



Escuela Superior  
de Ingeniería

ESCUELA SUPERIOR DE INGENIERÍA

ELECTRICAL ENGINEERING DEGREE

**DEVELOPMENT OF A ZERO-EMISSION  
PROPULSION SYSTEM BASED ON LI-ION  
BATTERIES FOR MARINE APPLICATIONS**

AUTHOR: DANIEL BENÍTEZ ARAGÓN

Cádiz, September 2015



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# **1. GENERAL INDEX**

Electrical Engineering Degree

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# General Index

|                                               |           |
|-----------------------------------------------|-----------|
| <b>1. GENERAL INDEX.....</b>                  | <b>3</b>  |
| <b>2. MEMORY.....</b>                         | <b>20</b> |
| 2.1. Purpose.....                             | 26        |
| 2.2. Scope.....                               | 26        |
| 2.3. Backgrounds.....                         | 26        |
| 2.4. Standards and benchmarks.....            | 28        |
| 2.4.1. Standards and regulations applied..... | 28        |
| 2.4.2. Software and design tools.....         | 30        |
| 2.4.3. Quality management plan.....           | 30        |
| 2.4.4. Bibliography.....                      | 30        |
| 2.4.5. Other references.....                  | 31        |
| 2.5. Definitions and abbreviations.....       | 31        |
| 2.5.1. Definitions .....                      | 31        |
| 2.5.2. Abbreviations.....                     | 36        |
| 2.6. Design requirements.....                 | 37        |
| 2.6.1. Vessel Type.....                       | 37        |
| 2.6.2. Main Features.....                     | 37        |
| 2.6.3. Ship plan.....                         | 38        |
| 2.6.4. Surface Areas.....                     | 39        |
| 2.6.5. Electrical system.....                 | 39        |
| 2.6.6. Electric current types.....            | 41        |
| 2.6.7. Operating conditions.....              | 42        |
| 2.6.7.1. Essential Services.....              | 42        |
| 2.6.7.2. Shore.....                           | 42        |
| 2.6.7.3. Function.....                        | 42        |
| 2.6.7.4. Top Speed.....                       | 42        |
| 2.6.8. Grounding.....                         | 43        |
| 2.6.9. Main power supply system.....          | 44        |
| 2.6.10. Emergency power supply system.....    | 45        |
| 2.6.11. Essential services.....               | 46        |
| 2.6.12. Starting batteries.....               | 47        |
| 2.6.13. Motors.....                           | 47        |



|                                                               |    |
|---------------------------------------------------------------|----|
| 2.6.14. Transformers.....                                     | 48 |
| 2.6.15. Power Converters.....                                 | 48 |
| 2.6.16. Rectifiers.....                                       | 48 |
| 2.6.17. Inverters.....                                        | 49 |
| 2.6.18. Lighting conditions.....                              | 49 |
| 2.6.19. Interior lighting .....                               | 50 |
| 2.6.20. Bridge lighting.....                                  | 51 |
| 2.6.21. Emergency lighting.....                               | 52 |
| 2.6.22. Ventilation.....                                      | 53 |
| 2.6.23. Switchboards.....                                     | 54 |
| 2.6.24. Cable selection.....                                  | 56 |
| 2.6.24.1. Conductors cross-section.....                       | 59 |
| 2.6.24.2. Voltage-drop of the conductors.....                 | 60 |
| 2.6.24.3. Short-circuit current.....                          | 60 |
| 2.6.25. Cable routing.....                                    | 63 |
| 2.6.25.1. Cable trays.....                                    | 64 |
| 2.6.25.2. Mounting.....                                       | 65 |
| 2.6.25.3. Lay-out and finishing.....                          | 67 |
| 2.6.25.4. Cable clamping.....                                 | 69 |
| 2.6.25.5. Connections and terminals.....                      | 69 |
| 2.6.26. Protections.....                                      | 70 |
| 2.6.26.1. Motor protection.....                               | 72 |
| 2.6.26.2. Battery protection.....                             | 72 |
| 2.6.26.3. Circuit protection.....                             | 73 |
| 2.6.26.4. Capacity of the circuit breakers.....               | 75 |
| 2.6.26.5. Short-circuit protection.....                       | 76 |
| 2.6.26.6. Over-current protection.....                        | 76 |
| 2.6.26.7. Insulation fault.....                               | 76 |
| 2.6.27. Penetrations of bulkheads and decks.....              | 77 |
| 2.6.27.1. Mounting instructions.....                          | 78 |
| 2.6.28. Designation and labelling of electrical material..... | 78 |
| 2.6.29. Equipment assembly.....                               | 79 |
| 2.7. Analysis of solutions.....                               | 80 |
| 2.7.1. Introduction.....                                      | 80 |
| 2.7.2. Electrical distribution types.....                     | 80 |

|                                                      |     |
|------------------------------------------------------|-----|
| 2.7.2.1. Permanently grounded neutral system.....    | 80  |
| 2.7.2.2. Isolated neutral systems.....               | 81  |
| 2.7.3. Main power supply system.....                 | 83  |
| 2.7.3.1. Genset.....                                 | 83  |
| 2.7.3.2. Pure Electrical.....                        | 84  |
| 2.7.3.3. Hybrid system.....                          | 84  |
| 2.7.3.4. Solution adopted.....                       | 86  |
| 2.7.4. Emergency power supply system.....            | 86  |
| 2.7.5. Motors.....                                   | 86  |
| 2.7.5.1. Induction motor.....                        | 87  |
| 2.7.5.2. Synchronous motor.....                      | 87  |
| 2.7.5.3. DC motor.....                               | 87  |
| 2.7.5.4. Solution adopted.....                       | 87  |
| 2.7.6. Rectifiers.....                               | 88  |
| 2.7.7. Inverters.....                                | 88  |
| 2.7.7.1. Solution adopted.....                       | 89  |
| 2.7.8. Interior lighting.....                        | 89  |
| 2.7.8.1. Solution adopted.....                       | 89  |
| 2.7.9. Ventilation.....                              | 90  |
| 2.7.9.1. Solution adopted.....                       | 90  |
| 2.7.10. Switchboards.....                            | 91  |
| 2.7.10.1. Environmental and thermic issues.....      | 91  |
| 2.7.10.2. Electrical issues.....                     | 91  |
| 2.7.10.3. Mechanical issues.....                     | 92  |
| 2.7.10.4. Solution adopted.....                      | 92  |
| 2.7.11. Conductors.....                              | 93  |
| 2.7.11.1. Constitution and selection .....           | 93  |
| 2.7.11.2. Electrical insulation.....                 | 94  |
| 2.7.11.3. Mechanical protection.....                 | 98  |
| 2.8. Final results.....                              | 100 |
| 2.8.1. Electric Power Load Analysis (EPLA).....      | 100 |
| 2.8.2. Electrical distribution type.....             | 101 |
| 2.8.3. Main power supply system.....                 | 102 |
| 2.8.3.1. Advantages of the battery banks system..... | 106 |
| 2.8.3.2. Battery system design.....                  | 107 |

|                                               |     |
|-----------------------------------------------|-----|
| 2.8.3.3. Li-ion battery cells.....            | 108 |
| 2.8.3.4. Battery Management System (BMS)..... | 109 |
| 2.8.3.5. Fabrication requirements.....        | 110 |
| 2.8.3.6. Cleanliness requirements.....        | 110 |
| 2.8.3.7. Certification.....                   | 110 |
| 2.8.3.8. Transportation.....                  | 110 |
| 2.8.3.9. Storage.....                         | 111 |
| 2.8.3.10. Testing.....                        | 111 |
| 2.8.3.11. Operating and maintenance.....      | 115 |
| 2.8.4. Motors.....                            | 115 |
| 2.8.5. Power rectifier.....                   | 116 |
| 2.8.6. Power Inverter.....                    | 117 |
| 2.8.7. Interior lighting.....                 | 118 |
| 2.8.8. Switchboards.....                      | 120 |
| 2.8.9. Conductors.....                        | 122 |
| 2.9. Planning.....                            | 123 |
| 2.10. Documents order.....                    | 123 |

### **3. ANNEXES.....125**

|                                                                |     |
|----------------------------------------------------------------|-----|
| 3.1. Introduction.....                                         | 131 |
| 3.2. EPLA (Electric Power Load Analysis).....                  | 131 |
| 3.2.1. 230 Vac power forecast.....                             | 133 |
| 3.2.1.1. Interior lighting.....                                | 133 |
| 3.2.1.2. Emergency lighting.....                               | 137 |
| 3.2.1.3. External lighting.....                                | 139 |
| 3.2.1.4. Ventilation .....                                     | 140 |
| 3.2.1.5. Electric plant and auxiliary systems consumption..... | 147 |
| 3.2.1.6. Outfit & furnishing consumption .....                 | 149 |
| 3.2.1.7. 230 Vac power forecast.....                           | 150 |
| 3.2.2. Direct current networks power forecast.....             | 150 |
| 3.2.2.1. 24 Vdc network power forecast.....                    | 151 |
| 3.2.2.2. 144 Vdc network power forecast.....                   | 152 |
| 3.2.3. Total power forecast.....                               | 153 |
| 3.3. Circuit distribution.....                                 | 154 |
| 3.3.1. Passengers Room.....                                    | 155 |

|                                                                        |     |
|------------------------------------------------------------------------|-----|
| 3.3.2. Entrance & Toilet.....                                          | 157 |
| 3.3.3. Anteroom.....                                                   | 159 |
| 3.3.4. Bridge.....                                                     | 161 |
| 3.3.5. Engine Room & Electrical Compartment.....                       | 163 |
| 3.4. Battery banks selection.....                                      | 165 |
| 3.4.1. Solution adopted.....                                           | 165 |
| 3.4.2. Battery banks connection.....                                   | 167 |
| 3.4.3. Connection with the quay.....                                   | 168 |
| 3.4.4. Connection with the motors.....                                 | 172 |
| 3.4.5. Connection with 230 Vac network.....                            | 174 |
| 3.5. Power inverter selection.....                                     | 177 |
| 3.6. Rectifier selection.....                                          | 177 |
| 3.7. Conductors & switches.....                                        | 179 |
| 3.7.1. Requirements.....                                               | 179 |
| 3.7.1.1. Maximum admissible current (or maximum heating) criteria..... | 179 |
| 3.7.1.2. Maximum voltage-drop criteria.....                            | 180 |
| 3.7.1.3. Temperature correction factors.....                           | 182 |
| 3.7.1.4. Cable grouping correction factors.....                        | 183 |
| 3.7.1.5. Calculation of the growth margin.....                         | 184 |
| 3.7.2. Cross-section calculation.....                                  | 185 |
| 3.7.2.1. 24 Vdc cross-section calculation.....                         | 185 |
| 3.7.2.2. 144 Vdc cross-section calculation.....                        | 193 |
| 3.7.2.3. 230 Vac cross-section calculation.....                        | 196 |
| 3.7.2.4. Switchboards cross-section calculation.....                   | 221 |
| 3.7.2.5. Power inverter cross-section.....                             | 226 |
| 3.7.3. Short-circuit currents calculation.....                         | 227 |
| 3.7.3.1. 24 Vdc short-circuit current calculation.....                 | 227 |
| 3.7.3.2. 230 Vac short-circuit current calculation.....                | 235 |
| 3.7.3.3. Switchboards short-circuit current calculation.....           | 247 |
| 3.7.3.4. Power inverter protection.....                                | 249 |
| 3.7.4. Protection of the motors.....                                   | 251 |
| 3.7.5. Interconnection .....                                           | 251 |
| 3.7.5.1. 144 Vdc interconnection (Motors).....                         | 252 |
| 3.7.5.2. 230 Vac interconnection.....                                  | 254 |
| 3.7.6. Bridge selector switch.....                                     | 256 |

|                                                                     |     |
|---------------------------------------------------------------------|-----|
| 3.7.7. Rating of earth conductors.....                              | 256 |
| 3.8. Basic Health and Safety Study.....                             | 257 |
| 3.8.1. Introduction.....                                            | 257 |
| 3.8.1.1. Justification of the Basic Health and Safety Study.....    | 257 |
| 3.8.1.2. Aim.....                                                   | 258 |
| 3.8.1.3. Works data.....                                            | 259 |
| 3.8.1.4. Electric power supply.....                                 | 259 |
| 3.8.1.5. Drinking water supply.....                                 | 259 |
| 3.8.1.6. Sanitary facilities.....                                   | 259 |
| 3.8.1.7. Servitude and conditions.....                              | 259 |
| 3.8.2. Safety standards to be applied in the works.....             | 260 |
| 3.8.2.1. Incompatibility between standards.....                     | 260 |
| 3.8.3. Validity.....                                                | 260 |
| 3.8.4. Changes in the Basic Health and Safety Study.....            | 260 |
| 3.8.5. Organization and responsibilities.....                       | 261 |
| 3.8.6. Works characteristics.....                                   | 262 |
| 3.8.6.1. Location.....                                              | 262 |
| 3.8.6.2. Works description.....                                     | 262 |
| 3.8.6.3. Implementation time.....                                   | 262 |
| 3.8.6.4. Amount of workers.....                                     | 262 |
| 3.8.6.5. Machinery.....                                             | 262 |
| 3.8.6.6. Electrical and instruments installation.....               | 262 |
| 3.8.6.7. Machines.....                                              | 262 |
| 3.8.6.8. Auxiliary sources.....                                     | 263 |
| 3.8.7. Protections.....                                             | 263 |
| 3.8.7.1. Collective protections.....                                | 263 |
| 3.8.7.2. Individual Protection Equipment.....                       | 264 |
| 3.8.8. Risk prevention.....                                         | 264 |
| 3.8.8.1. Training.....                                              | 264 |
| 3.8.9. Preventive medicine.....                                     | 265 |
| 3.8.10. Medical supervision.....                                    | 265 |
| 3.8.11. First aid at work .....                                     | 265 |
| 3.8.12. Intervention and first aid.....                             | 265 |
| 3.8.13. Medical care in temporary or permanent work disability..... | 266 |
| 3.8.14. Accident/incident information.....                          | 266 |

|                                                                  |     |
|------------------------------------------------------------------|-----|
| 3.8.15. Budget .....                                             | 266 |
| 3.8.16. Further works.....                                       | 267 |
| 3.8.17. Promoter's obligations.....                              | 267 |
| 3.8.18. Health and Security Coordinator.....                     | 267 |
| 3.8.19. Security and Health Plan.....                            | 268 |
| 3.8.20. Contractor and Subcontractor's responsibilities.....     | 269 |
| 3.8.21. Self-employed workers' responsibilities.....             | 270 |
| 3.8.22. Book of Incidents.....                                   | 271 |
| 3.8.23. Work stoppage.....                                       | 272 |
| 3.8.24. Worker's rights.....                                     | 272 |
| 3.8.25. Minimum safety and health requirements in the works..... | 272 |
| 3.9. DIALux results.....                                         | 273 |
| 3.9.1. Interior lighting.....                                    | 273 |
| 3.9.2. DIALux – Emergency lighting.....                          | 284 |
| 3.10. Catalogues.....                                            | 293 |
| 3.10.1. Battery bank catalogue.....                              | 293 |
| 3.10.1.1. SAFT SEANERGY Battery System.....                      | 293 |
| 3.10.1.2. SEANERGY Modules.....                                  | 295 |
| 3.10.2. Motor catalogue.....                                     | 297 |
| 3.10.2.1. ELCO EP-10000.....                                     | 297 |
| 3.10.3. Power inverter catalogue.....                            | 298 |
| 3.10.3.1. VICTRON ENERGY QUATTRO.....                            | 298 |
| 3.10.4. Ventilation fan catalogue.....                           | 300 |
| 3.10.4.1. NEOLINEO-100-Q.....                                    | 300 |
| 3.10.5. Luminarie catalogues.....                                | 304 |
| 3.10.5.1. GLAMOX CASA 16 13F SI.....                             | 304 |
| 3.10.5.2. GLAMOX I70 LED.....                                    | 306 |
| 3.10.5.3. GLAMOX E85-S.....                                      | 308 |
| 3.10.5.4. GLAMOX E80-S.....                                      | 310 |
| 3.10.5.5. GLAMOX JET 7.....                                      | 312 |
| 3.10.6. Conductor catalogues.....                                | 314 |
| 3.10.6.1. PROTOMONT NSSHÖU.....                                  | 314 |
| 3.10.6.2. EXZHELLENT – MAR RDt.....                              | 318 |
| 3.10.7. Switch catalogues.....                                   | 321 |
| 3.10.7.1. Schneider Electric iC60N.....                          | 321 |

|                                                                   |            |
|-------------------------------------------------------------------|------------|
| 3.10.7.2. Schneider Electric C120N.....                           | 322        |
| 3.10.7.3. Schneider Electric CM 18070.....                        | 324        |
| 3.10.7.4. Schneider Electric Interpact INS250.....                | 325        |
| 3.10.7.5. Schneider Electric Interpact INS80.....                 | 327        |
| 3.10.7.6. Schneider Electric NSX400N.....                         | 329        |
| 3.10.8. Battery Charger catalogue.....                            | 330        |
| 3.10.8.1. MASTERVOLT Mass 24/75.....                              | 330        |
| 3.10.9. Switchboard catalogue.....                                | 333        |
| 3.10.9.1. Legrand XL3 160.....                                    | 333        |
| 3.10.10. High-current socket.....                                 | 335        |
| 3.10.10.1. Marechal PFQ3.....                                     | 335        |
| <b>4. BLUEPRINTS.....</b>                                         | <b>337</b> |
| 4.1. General Blueprint.....                                       | 339        |
| 4.2. General Layout.....                                          | 339        |
| 4.3. General One-Line Diagram.....                                | 339        |
| 4.4. Passengers Room 230 Vac.....                                 | 339        |
| 4.5. Entrance & Toilet 230 Vac.....                               | 339        |
| 4.6. Anteroom 230 Vac.....                                        | 339        |
| 4.7. Bridge 230 Vac & 24 Vdc.....                                 | 339        |
| 4.8. Engine Rooms & Electrical Compartments 230.....              | 339        |
| <b>5. TERMS AND CONDITIONS.....</b>                               | <b>340</b> |
| 5.1. Aim.....                                                     | 345        |
| 5.1.1. Contract aim.....                                          | 345        |
| 5.1.2. Terms and Conditions aim.....                              | 345        |
| 5.2. General requirements.....                                    | 345        |
| 5.2.1. General terms.....                                         | 345        |
| 5.2.2. Blueprints.....                                            | 346        |
| 5.2.3. Energy sources quality.....                                | 347        |
| 5.2.4. Location and construction of the electrical equipment..... | 348        |
| 5.2.5. Ground connections.....                                    | 349        |
| 5.3. General terms.....                                           | 350        |
| 5.3.1. General terms aim.....                                     | 350        |
| 5.3.2. Range of application.....                                  | 350        |
| 5.3.3. Technical requirements.....                                | 351        |

|                                                                                 |     |
|---------------------------------------------------------------------------------|-----|
| 5.3.4. Legal provisions.....                                                    | 351 |
| 5.3.5. Director authority.....                                                  | 351 |
| 5.3.6. Contractor.....                                                          | 352 |
| 5.3.7. Work data.....                                                           | 352 |
| 5.3.8. Work rethinking.....                                                     | 353 |
| 5.3.9. Improvements and variations of the project.....                          | 353 |
| 5.3.10. Organization.....                                                       | 353 |
| 5.3.11. Work implementation.....                                                | 354 |
| 5.3.12. Monitoring of the work.....                                             | 354 |
| 5.3.13. Control book.....                                                       | 355 |
| 5.3.14. Inquiries request.....                                                  | 355 |
| 5.3.15. Proposal content.....                                                   | 355 |
| 5.3.16. Awarding.....                                                           | 356 |
| 5.3.17. Withholdings.....                                                       | 356 |
| 5.3.18. Delay penalization.....                                                 | 356 |
| 5.3.19. Permissions and licenses.....                                           | 356 |
| 5.3.20. Termination of the contract causes.....                                 | 356 |
| 5.3.21. Subcontracting.....                                                     | 357 |
| 5.3.22. Implementation period.....                                              | 358 |
| 5.3.23. Provisional review.....                                                 | 358 |
| 5.3.24. Warranty periods.....                                                   | 359 |
| 5.3.25. Final acceptance.....                                                   | 359 |
| 5.3.26. Work payment.....                                                       | 359 |
| 5.3.27. Materials payment.....                                                  | 360 |
| 5.3.28. Termination.....                                                        | 360 |
| 5.4. Economic terms.....                                                        | 361 |
| 5.4.1. Price composition.....                                                   | 361 |
| 5.4.2. Contract cost.....                                                       | 361 |
| 5.4.3. Contradictory prices .....                                               | 361 |
| 5.4.4. Price increases complaints due to different causes .....                 | 362 |
| 5.4.5. Review of the contracted prices.....                                     | 362 |
| 5.4.6. Material supply.....                                                     | 363 |
| 5.4.7. Constructor responsibilities with poor performance of the operators..... | 363 |
| 5.4.8. Unjustified work improvements .....                                      | 363 |
| 5.4.9. Payment of budgeted works.....                                           | 364 |



|                                                                                       |     |
|---------------------------------------------------------------------------------------|-----|
| 5.4.10. Payments.....                                                                 | 364 |
| 5.4.11. Compensation due to non-justified delays in the termination of the works..... | 364 |
| 5.4.12. Payment delays.....                                                           | 365 |
| 5.4.13. Work upgrades. Contrary cases.....                                            | 365 |
| 5.4.14. Defective but acceptable work units.....                                      | 365 |
| 5.4.15. Work insurance.....                                                           | 366 |
| 5.4.16. Works conservations.....                                                      | 366 |
| 5.4.17. Goods usage by the Contractor.....                                            | 366 |
| 5.5. Technical conditions of performance and assembly of the electrical system.....   | 367 |
| 5.5.1. General terms.....                                                             | 367 |
| 5.5.2. Main power supply system.....                                                  | 368 |
| 5.5.2.1. General terms.....                                                           | 368 |
| 5.5.2.2. Amount and power capacity of the main power supply system.....               | 368 |
| 5.5.2.3. Amount of power capacity of the converters.....                              | 368 |
| 5.5.3. Emergency power supply system.....                                             | 369 |
| 5.5.3.1. General terms.....                                                           | 369 |
| 5.5.4. External power supply system.....                                              | 370 |
| 5.5.4.1. General terms.....                                                           | 370 |
| 5.5.5. Power supply and distribution.....                                             | 370 |
| 5.5.5.1. Supply and distribution systems.....                                         | 370 |
| 5.5.6. Utilization factor.....                                                        | 372 |
| 5.5.7. Lighting circuits.....                                                         | 372 |
| 5.5.8. Motor circuits.....                                                            | 373 |
| 5.5.9. Motor control.....                                                             | 373 |
| 5.5.10. Protections.....                                                              | 374 |
| 5.5.10.1. General terms.....                                                          | 374 |
| 5.5.10.2. Short-circuit protection.....                                               | 375 |
| 5.5.10.3. Overload protection.....                                                    | 375 |
| 5.5.10.4. Motor protection.....                                                       | 375 |
| 5.5.10.5. Power converters protection.....                                            | 376 |
| 5.5.11. Switchboard implementation.....                                               | 376 |
| 5.5.11.1. General terms.....                                                          | 376 |
| 5.5.11.2. Location.....                                                               | 376 |
| 5.5.12. Cables.....                                                                   | 377 |
| 5.5.12.1. Voltages.....                                                               | 379 |

|                                                                                     |            |
|-------------------------------------------------------------------------------------|------------|
| 5.5.12.2. Operating temperature.....                                                | 379        |
| 5.5.12.3. Construction.....                                                         | 380        |
| 5.5.12.4. Size.....                                                                 | 381        |
| 5.5.12.5. Cable installation.....                                                   | 384        |
| 5.5.12.6. Mechanical protection of cables.....                                      | 385        |
| 5.5.12.7. Fixing of cables.....                                                     | 386        |
| 5.5.12.8. Penetration of bulkheads by cables.....                                   | 387        |
| 5.5.12.9. Installation of protective enclosures in cables.....                      | 387        |
| 5.5.12.10. One core cables for alternating current.....                             | 388        |
| 5.5.12.11. Ends of the cables.....                                                  | 388        |
| 5.5.12.12. Joints and circuits in cable systems.....                                | 389        |
| 5.5.12.13. Lighting. General terms.....                                             | 389        |
| 5.5.12.14. Incandescent and halogen lighting.....                                   | 389        |
| 5.5.12.15. Fluorescent lighting.....                                                | 390        |
| 5.5.12.16. Plugs and sockets.....                                                   | 390        |
| 5.6. Electrical equipment in flammable gas atmospheres or with pulverized fuel..... | 391        |
| 5.6.1. General terms.....                                                           | 391        |
| 5.7. Navigation and operation systems.....                                          | 391        |
| 5.7.1. Command devices.....                                                         | 391        |
| 5.8. Navigation lights.....                                                         | 392        |
| 5.8.1. General terms.....                                                           | 392        |
| 5.9. Fire-fighting system.....                                                      | 392        |
| 5.9.1. Fire detection and alarm systems.....                                        | 392        |
| 5.10. Emergency security systems.....                                               | 393        |
| 5.10.1. Emergency lighting.....                                                     | 393        |
| 5.10.2. Emergency alarm system.....                                                 | 394        |
| 5.10.3. Public address system.....                                                  | 394        |
| 5.11. Terms of use, maintenance and security.....                                   | 395        |
| 5.11.1. Work security.....                                                          | 395        |
| 5.11.2. Public security.....                                                        | 395        |
| <b>6. BILL OF MATERIAL.....</b>                                                     | <b>397</b> |
| 6.1. Introduction.....                                                              | 399        |
| 6.2. Batteries.....                                                                 | 399        |
| 6.3. Motors.....                                                                    | 400        |

|                                                  |            |
|--------------------------------------------------|------------|
| 6.4. Distribution.....                           | 400        |
| 6.4.1. Power inverters.....                      | 400        |
| 6.4.2. Interconnections.....                     | 400        |
| 6.4.3. Power rectifiers.....                     | 401        |
| 6.5. Passengers Room.....                        | 401        |
| 6.6. Entrance & Toilet.....                      | 402        |
| 6.7. Anteroom.....                               | 403        |
| 6.8. Bridge.....                                 | 404        |
| 6.9. Engine Rooms & Electrical Compartments..... | 405        |
| <b>7. BUDGET.....</b>                            | <b>407</b> |
| 7.1. Batteries.....                              | 409        |
| 7.2. Motors.....                                 | 409        |
| 7.3. Distribution.....                           | 410        |
| 7.3.1. Power inverters.....                      | 410        |
| 7.3.2. Interconnections.....                     | 410        |
| 7.3.3. Power rectifiers.....                     | 411        |
| 7.4. Passengers Room.....                        | 411        |
| 7.5. Entrance & Toilet.....                      | 413        |
| 7.6. Anteroom.....                               | 414        |
| 7.7. Bridge.....                                 | 416        |
| 7.8. Engine Rooms & Electrical Compartments..... | 418        |
| 7.9. Basic Health and Safety Study.....          | 419        |
| 7.10. Total Budget.....                          | 420        |

## Figures

|                                                                                         |     |
|-----------------------------------------------------------------------------------------|-----|
| Figure 1: Areas scheme.....                                                             | 38  |
| Figure 2: Power system.....                                                             | 40  |
| Figure 3: Simplified network diagram.....                                               | 62  |
| Figure 4: Permanently grounded neutral system.....                                      | 81  |
| Figure 5: Isolated neutral system.....                                                  | 83  |
| Figure 6: Test requirements for electrical characteristics of insulating compounds..... | 96  |
| Figure 7: Test requirements for mechanical characteristics of insulating compounds..... | 97  |
| Figure 8: Test requirements for particular characteristics of insulating compounds..... | 98  |
| Figure 9: First fault scheme.....                                                       | 102 |

|                                                                |     |
|----------------------------------------------------------------|-----|
| Figure 10: Second fault scheme.....                            | 102 |
| Figure 11: Block diagram of a generic battery bank system..... | 103 |
| Figure 12: Discharge at 25 °C at various rates.....            | 105 |
| Figure 13: C/5 discharge at various temperatures.....          | 105 |
| Figure 14: Cycle capability.....                               | 106 |
| Figure 15: Battery system performance tests.....               | 112 |
| Figure 16: Battery system electrical tests.....                | 112 |
| Figure 17: Battery system environmental tests.....             | 113 |
| Figure 18: Battery system safety tests.....                    | 114 |
| Figure 19: Rooms scheme.....                                   | 132 |
| Figure 20: Fan dimensions.....                                 | 144 |
| Figure 21: Fan dimensions 2.....                               | 144 |
| Figure 22: Characteristic and acoustic curve of the fan.....   | 146 |
| Figure 23: Example of connection with the quay.....            | 169 |
| Figure 24: Battery arrangement (motors).....                   | 173 |
| Figure 25: Battery arrangement (inverters).....                | 176 |
| Figure 26: Rating of cables with temperature class 90° C.....  | 180 |
| Figure 27: Rating of cables (24 Vdc).....                      | 187 |
| Figure 28: Rating of cables (144 Vdc).....                     | 195 |
| Figure 29: Example of a cross-section rating.....              | 199 |
| Figure 30: Passengers Room Port switchboard cross-section..... | 223 |
| Figure 31: Selectivity in 24 Vdc devices.....                  | 234 |
| Figure 32: Selectivity between C120N & iC60N.....              | 250 |
| Figure 33: Earthing connections and conductors.....            | 257 |
| Figure 34: Rating of cables with temperature class 70° C.....  | 382 |
| Figure 35: Rating of cables with temperature class 90° C.....  | 383 |

## Tables

|                                                                                 |    |
|---------------------------------------------------------------------------------|----|
| Table 1: Areas.....                                                             | 39 |
| Table 2: Services to be supplied by an emergency source.....                    | 46 |
| Table 3: Illumination levels at the Bridge.....                                 | 52 |
| Table 4: Temperature classes for insulating materials.....                      | 58 |
| Table 5: Minimum bending radius to 0,6/1 kV cables.....                         | 68 |
| Table 6: Insulation temperature during normal operation and short-circuit ..... | 95 |
| Table 7: Nominal diameter of braided wire.....                                  | 99 |

|                                                                                      |     |
|--------------------------------------------------------------------------------------|-----|
| Table 8: Type of protective sheaths.....                                             | 100 |
| Table 9: Amount of GLAMOX CASA 16 113F SL.....                                       | 119 |
| Table 10: Amount of GLAMOX i70-1200 LED 4500 DALI 840.....                           | 119 |
| Table 11: Planning.....                                                              | 123 |
| Table 12: Planning.....                                                              | 132 |
| Table 13: Illuminance requirements.....                                              | 135 |
| Table 14: Amount of GLAMOX CASA 16 113F SL.....                                      | 137 |
| Table 15: Amount of GLAMOX i70-1200 LED 4500 DALI 840.....                           | 137 |
| Table 16: Amount of GLAMOX E85-S.....                                                | 138 |
| Table 17: 230 V luminaires load factors.....                                         | 139 |
| Table 18: Volume and airflow calculation.....                                        | 141 |
| Table 19: Fan characteristics.....                                                   | 143 |
| Table 20: Characteristic and acoustic curve parameters.....                          | 145 |
| Table 21: Fan load factors.....                                                      | 146 |
| Table 22: Single-phase sockets.....                                                  | 147 |
| Table 23: Load factors of sockets.....                                               | 148 |
| Table 24: Battery rectifier load.....                                                | 148 |
| Table 25: Air conditioning system load.....                                          | 149 |
| Table 26: Leisure components and load factors.....                                   | 150 |
| Table 27: 24 V loads.....                                                            | 151 |
| Table 28: 24 V loads factors.....                                                    | 152 |
| Table 29: Motors load consumption and factors.....                                   | 153 |
| Table 30: Power forecast.....                                                        | 154 |
| Table 31: Passengers Room (Port Switchboard circuits).....                           | 155 |
| Table 32: Passengers Room (Starboard Switchboard circuits).....                      | 156 |
| Table 33: Entrance & Toilet (Port Switchboard circuits).....                         | 157 |
| Table 34: Entrance & Toilet (Starboard Switchboard circuits).....                    | 158 |
| Table 35: Anteroom (Port Switchboard circuits).....                                  | 159 |
| Table 36: Anteroom (Starboard Switchboard circuits).....                             | 160 |
| Table 37: Bridge (230 Vac Switchboard circuits).....                                 | 161 |
| Table 38: Bridge (24 Vdc Switchboard circuits).....                                  | 162 |
| Table 39: Engine Room & Electrical Compartment (Port Switchboard circuits).....      | 163 |
| Table 40: Engine Room & Electrical Compartment (Starboard Switchboard circuits)..... | 164 |
| Table 41: SEANERGY battery system main features.....                                 | 167 |
| Table 42: PROTOMONT NSSHÖU characteristics.....                                      | 171 |

|                                                                                             |     |
|---------------------------------------------------------------------------------------------|-----|
| Table 43: Correction factors for ambient temperature.....                                   | 183 |
| Table 44: Rate cross-section and voltage drop levels of 24 Vdc devices.....                 | 191 |
| Table 45: Conductors of 24 Vdc devices.....                                                 | 192 |
| Table 46: Passengers Room (Port Switchboard - Cross-section and voltage-drop).....          | 202 |
| Table 47: Passengers Room (Starboard Switchboard - Cross-section and voltage-drop).....     | 203 |
| Table 48: Entrance & Toilet (Port Switchboard - Cross-section and voltage-drop).....        | 204 |
| Table 49: Entrance & Toilet (Starboard Switchboard - Cross-section and voltage-drop).....   | 205 |
| Table 50: Anteroom (Port Switchboard - Cross-section and voltage-drop).....                 | 206 |
| Table 51: Anteroom (Starboard Switchboard - Cross-section and voltage-drop).....            | 207 |
| Table 52: Bridge (230 Vac Switchboard - Cross-section and voltage-drop).....                | 208 |
| Table 53: Engine Room & Electrical Compartment (Port - Cross-section and voltage-drop)..... | 209 |
| Table 54: Engine Room & Electrical Compartment (Starboard - Cross-section and voltage-drop) | 210 |
| Table 55: Passengers Room (Port Switchboard - Conductor).....                               | 212 |
| Table 56: Passengers Room (Starboard Switchboard - Conductor).....                          | 213 |
| Table 57: Entrance & Toilet (Port Switchboard - Conductor).....                             | 214 |
| Table 58: Entrance & Toilet (Starboard Switchboard - Conductor).....                        | 215 |
| Table 59: Anteroom (Port Switchboard - Conductor).....                                      | 216 |
| Table 60: Anteroom (Starboard Switchboard - Conductor).....                                 | 217 |
| Table 61: Bridge (230 Vac Switchboard - Conductor).....                                     | 218 |
| Table 62: Engine Room & Electrical Compartment (Port Switchboard - Conductor).....          | 219 |
| Table 63: Engine Room & Electrical Compartment (Starboard Switchboard - Conductor).....     | 220 |
| Table 64: Passengers Room Port switchboard currents.....                                    | 222 |
| Table 65: Secondary switchboards conductors.....                                            | 225 |
| Table 66: 24Vdc devices short-circuit currents.....                                         | 232 |
| Table 67: 24Vdc switches selection.....                                                     | 233 |
| Table 68: Amount of iC60N switches.....                                                     | 235 |
| Table 69: Passengers Room (Port Switchboard - Switches).....                                | 238 |
| Table 70: Passengers Room (Starboard Switchboard - Switches).....                           | 239 |
| Table 71: Entrance & Toilet (Port Switchboard - Switches).....                              | 240 |
| Table 72: Entrance & Toilet (Starboard Switchboard - Switches).....                         | 241 |
| Table 73: Anteroom (Port Switchboard - Switches).....                                       | 242 |
| Table 74: Anteroom (Starboard Switchboard - Switches).....                                  | 243 |
| Table 75: Bridge (230 Vac Switchboard - Switches).....                                      | 244 |
| Table 76: Engine Room & Electrical Compartment (Port Switchboard - Switches).....           | 245 |
| Table 77: Engine Room & Electrical Compartment (Starboard Switchboard - Switches).....      | 246 |

Table 78: Amount of iC60N switches.....247

Table 79: Secondary switchboards switches.....248

Table 80: Amount of switches for secondary switchboards.....249

Table 81: IEC Standards.....378

Table 82: Maximum temperatures for cables.....380

Table 83: Minimum internal bending radius.....384

Table 84: Maximum spacing of staples or clamps for fixing of cables.....387

Table 85: Lamps and caps.....390





## 2. MEMORY

Electrical Engineering Degree

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## Memory

|                                               |           |
|-----------------------------------------------|-----------|
| <b>2. MEMORY.....</b>                         | <b>20</b> |
| 2.1. Purpose.....                             | 26        |
| 2.2. Scope.....                               | 26        |
| 2.3. Backgrounds.....                         | 26        |
| 2.4. Standards and benchmarks.....            | 28        |
| 2.4.1. Standards and regulations applied..... | 28        |
| 2.4.2. Software and design tools.....         | 30        |
| 2.4.3. Quality management plan.....           | 30        |
| 2.4.4. Bibliography.....                      | 30        |
| 2.4.5. Other references.....                  | 31        |
| 2.5. Definitions and abbreviations.....       | 31        |
| 2.5.1. Definitions .....                      | 31        |
| 2.5.2. Abbreviations.....                     | 36        |
| 2.6. Design requirements.....                 | 37        |
| 2.6.1. Vessel Type.....                       | 37        |
| 2.6.2. Main Features.....                     | 37        |
| 2.6.3. Ship plan.....                         | 38        |
| 2.6.4. Surface Areas.....                     | 39        |
| 2.6.5. Electrical system.....                 | 39        |
| 2.6.6. Electric current types.....            | 41        |
| 2.6.7. Operating conditions.....              | 42        |
| 2.6.7.1. Essential Services.....              | 42        |
| 2.6.7.2. Shore.....                           | 42        |
| 2.6.7.3. Function.....                        | 42        |
| 2.6.7.4. Top Speed.....                       | 42        |
| 2.6.8. Grounding.....                         | 43        |
| 2.6.9. Main power supply system.....          | 44        |
| 2.6.10. Emergency power supply system.....    | 45        |
| 2.6.11. Essential services.....               | 46        |

|                                                  |    |
|--------------------------------------------------|----|
| 2.6.12. Starting batteries.....                  | 47 |
| 2.6.13. Motors.....                              | 47 |
| 2.6.14. Transformers.....                        | 48 |
| 2.6.15. Power Converters.....                    | 48 |
| 2.6.16. Rectifiers.....                          | 48 |
| 2.6.17. Inverters.....                           | 49 |
| 2.6.18. Lighting conditions.....                 | 49 |
| 2.6.19. Interior lighting .....                  | 50 |
| 2.6.20. Bridge lighting.....                     | 51 |
| 2.6.21. Emergency lighting.....                  | 52 |
| 2.6.22. Ventilation.....                         | 53 |
| 2.6.23. Switchboards.....                        | 54 |
| 2.6.24. Cable selection.....                     | 56 |
| 2.6.24.1. Conductors cross-section.....          | 59 |
| 2.6.24.2. Voltage-drop of the conductors.....    | 60 |
| 2.6.24.3. Short-circuit current.....             | 60 |
| 2.6.25. Cable routing.....                       | 63 |
| 2.6.25.1. Cable trays.....                       | 64 |
| 2.6.25.2. Mounting.....                          | 65 |
| 2.6.25.3. Lay-out and finishing.....             | 67 |
| 2.6.25.4. Cable clamping.....                    | 69 |
| 2.6.25.5. Connections and terminals.....         | 69 |
| 2.6.26. Protections.....                         | 70 |
| 2.6.26.1. Motor protection.....                  | 72 |
| 2.6.26.2. Battery protection.....                | 72 |
| 2.6.26.3. Circuit protection.....                | 73 |
| 2.6.26.4. Capacity of the circuit breakers.....  | 75 |
| 2.6.26.5. Short-circuit protection.....          | 76 |
| 2.6.26.6. Over-current protection.....           | 76 |
| 2.6.26.7. Insulation fault.....                  | 76 |
| 2.6.27. Penetrations of bulkheads and decks..... | 77 |

|                                                               |    |
|---------------------------------------------------------------|----|
| 2.6.27.1. Mounting instructions.....                          | 78 |
| 2.6.28. Designation and labelling of electrical material..... | 78 |
| 2.6.29. Equipment assembly.....                               | 79 |
| 2.7. Analysis of solutions.....                               | 80 |
| 2.7.1. Introduction.....                                      | 80 |
| 2.7.2. Electrical distribution types.....                     | 80 |
| 2.7.2.1. Permanently grounded neutral system.....             | 80 |
| 2.7.2.2. Isolated neutral systems.....                        | 81 |
| 2.7.3. Main power supply system.....                          | 83 |
| 2.7.3.1. Genset.....                                          | 83 |
| 2.7.3.2. Pure Electrical.....                                 | 84 |
| 2.7.3.3. Hybrid system.....                                   | 84 |
| 2.7.3.4. Solution adopted.....                                | 86 |
| 2.7.4. Emergency power supply system.....                     | 86 |
| 2.7.5. Motors.....                                            | 86 |
| 2.7.5.1. Induction motor.....                                 | 87 |
| 2.7.5.2. Synchronous motor.....                               | 87 |
| 2.7.5.3. DC motor.....                                        | 87 |
| 2.7.5.4. Solution adopted.....                                | 87 |
| 2.7.6. Rectifiers.....                                        | 88 |
| 2.7.7. Inverters.....                                         | 88 |
| 2.7.7.1. Solution adopted.....                                | 89 |
| 2.7.8. Interior lighting.....                                 | 89 |
| 2.7.8.1. Solution adopted.....                                | 89 |
| 2.7.9. Ventilation.....                                       | 90 |
| 2.7.9.1. Solution adopted.....                                | 90 |
| 2.7.10. Switchboards.....                                     | 91 |
| 2.7.10.1. Environmental and thermic issues.....               | 91 |
| 2.7.10.2. Electrical issues.....                              | 91 |
| 2.7.10.3. Mechanical issues.....                              | 92 |
| 2.7.10.4. Solution adopted.....                               | 92 |

|                                                      |     |
|------------------------------------------------------|-----|
| 2.7.11. Conductors.....                              | 93  |
| 2.7.11.1. Constitution and selection .....           | 93  |
| 2.7.11.2. Electrical insulation.....                 | 94  |
| 2.7.11.3. Mechanical protection.....                 | 98  |
| 2.8. Final results.....                              | 100 |
| 2.8.1. Electric Power Load Analysis (EPLA).....      | 100 |
| 2.8.2. Electrical distribution type.....             | 101 |
| 2.8.3. Main power supply system.....                 | 102 |
| 2.8.3.1. Advantages of the battery banks system..... | 106 |
| 2.8.3.2. Battery system design.....                  | 107 |
| 2.8.3.3. Li-ion battery cells.....                   | 108 |
| 2.8.3.4. Battery Management System (BMS).....        | 109 |
| 2.8.3.5. Fabrication requirements.....               | 110 |
| 2.8.3.6. Cleanliness requirements.....               | 110 |
| 2.8.3.7. Certification.....                          | 110 |
| 2.8.3.8. Transportation.....                         | 110 |
| 2.8.3.9. Storage.....                                | 111 |
| 2.8.3.10. Testing.....                               | 111 |
| 2.8.3.11. Operating and maintenance.....             | 115 |
| 2.8.4. Motors.....                                   | 115 |
| 2.8.5. Power rectifier.....                          | 116 |
| 2.8.6. Power Inverter.....                           | 117 |
| 2.8.7. Interior lighting.....                        | 118 |
| 2.8.8. Switchboards.....                             | 120 |
| 2.8.9. Conductors.....                               | 122 |
| 2.9. Planning.....                                   | 123 |
| 2.10. Documents order.....                           | 123 |

## MEMORY

### IDENTIFICATION SHEET

**Title of the document:**

DEVELOPMENT OF A ZERO-EMISSION PROPULSION SYSTEM BASED ON LI-ION BATTERIES FOR MARINE APPLICATIONS

**Location:**

Due to the fact that this project is focused on a transport ship, it will not have an static location.

**Petitioner:**

The project is ordered by the Electrical Engineering Department of the University of Cadiz, in order to give the university degree of Electrical Engineering Degree to Daniel Benítez Aragón. The director of the project is Mr. Juan Antonio Palacios García. The co-director is Mr. Germán Jiménez Ferrer.

**Author:**

This project has been written by the student of the Electrical Engineering Degree, Mr. Daniel Benítez Aragón, whose National ID (DNI) is 44053171-Y, and domiciled in Chiclana de la Frontera, La Tórtola Road, 4. Telephone number: 663929632. Email: dani.benitezaragon@alum.uca.es.

Cádiz, September 2015

Signature: Daniel Benítez Aragón

## 2.1. Purpose

The focus of this project is on the calculation and design of a pure electric propulsion system, which shall be used in a passenger vessel. To achieve this goal, it will be necessary a complete study of the whole electric system, from the lighting to the machinery, including ventilation, design of the blueprints, etc.

Within this project, several proposals regarding the final result will be taking into account, including the electrical system arrangement and machinery selection, eventually choosing the solution that assures the greatest performance and the lower polluting results.

It will be brought to the Competent Bodies that the study we are doing gathers the conditions and safeguards required, in order to obtain the Administrative Approval and Performance Approval, as well as to be used in the performance of the project.

## 2.2. Scope

The scope is based on the calculation and design of a pure electric propulsion system. Additional matters will be required in a lower level in order to obtain the final result. We can also find researches on the following areas:

- Electric power load calculations.
- Calculation and selection of energy efficient interior lighting.
- Sizing of the battery banks needed for supply the main propulsion.
- Calculation of the power conversion equipment, specially for the batteries and the supply of the 24 Vdc system at the Bridge.
- Calculation of the ventilation system at the Engine Room.
- Design of the one-line diagram of the electrical system.

## 2.3. Backgrounds

The development of technology based on battery and hybrid systems is helping the maritime industry overcome the challenges of emission regulations and efficiency maximization. But battery technology is also helping to address more stringent emissions regulations, with recent technological developments leading to an increasingly efficient alternative to traditional power sources. Nevertheless, battery systems are currently being used in shipping as an auxiliary or short term power source.

Electric and hybrid systems with energy storage in Li-ion batteries may provide significant reductions in costs of fuel, emissions and maintenance, as well as improved responsiveness, regularity and safety.

Thus, this document is focused on the operation of a light ship, double hull passenger ferry. The main characteristics of the vessel are: 24 m length and 7 m beam, having room for 100 people. Besides, it has two decks, the upper one for passengers and crew and the lower one for the machinery.

In order to achieve a free emission, energy efficient operation, the propulsion is designed to be completely electrical, using battery banks instead of diesel generators. Thus, it shall be necessary to calculate their performance in order to assure the required autonomy -operational time without recharging the batteries-. Once that the total power consumption of the vessel has been calculated, the battery banks will be sized according to a proper independence time of performance.

The vessel shall include shore connections, sized to charge the battery banks in the desired time to maintain the operational profile of the vessel.

The electrical system is composed of 230 Vac and 24 Vdc networks, fully compliant with the requirements of the IEC and classification society rules. Moreover, the motors shall need a specific voltage in order to make them work. This voltage will



be set once that the motors are selected. As it can be checked further, they will require a 144 Vdc connection. Besides, due to the use of battery banks, a couple (one for each hull) of power inverters must be sized for an adequate voltage level in order to implement a correct voltage transformation.

In order to reach these requirements, the vessel shall be composed of two independent electrical system, which shall be connected to one another in order to supply the other one during emergency situations. Each electrical system shall be composed of batteries, a motor, the necessary voltage converters and AC/DC switchboards to be placed on each hull. Both systems shall be interconnected so if a failure happens in one of them, the other one may be able to assure the supply in the emergency required by rules equipment. Moreover, the Bridge switchboards (230 Vac and 24 Vdc) will be supplied from an two position selector switch, which will allow us to choose which electrical system is the supplier.

In order to obtain some of the calculations required, several softwares shall be used. Referring to the lighting calculations, the Dialux software shall be used so as to obtain the number of lighting devices as well as the proper values of luminance. AutoCad will be used as well, in order to create all the required blueprints. Within the ventilation calculation, we will use the SODECA software in order to calculate the fans required.

In conclusion, advances in battery technology and energy management capability have rightly seen increasing interest in battery and hybrid power in the maritime industry. This project aims to help saving fuel and increasing efficiency, while reducing emissions. Moreover, battery installations also give significant reductions in noise and vibration compared to traditional fuel-based power systems.

## **2.4. Standards and benchmarks**

### 2.4.1. Standards and regulations applied

This project gathers the characteristics of the materials, the calculations that justifies their performance and the way of perform to do, complying the followings rules:

- Electrical Installation:
  - “Lighting of indoor workplaces” EN-12464-1 (June 2011)
  - “Lighting of outdoor workplaces” EN-12464-2 (October 2007)
  - “Electrical Installations” DNV – Rules for classification of Ships/High Speed, Light Craft and Naval Surface Craft, Part 4 Chapter 8 (July 2013)
  - “Electrical installations in ships Part 303: Equipment — Transformers for power and lighting” IEC 60092-303 (January 1980)
  - “Power transformers - Part 1: General” IEC 60076 (January 2011)
  - “Low-voltage switchgear and control-gear assemblies – Part 1: Type-tested and partially type-tested assemblies” UNE-EN 60439-1 (October 2001)
- Security and health:
  - “Nautical Safety” DNV – Rules for classification of Ships/High Speed, Light Craft and Naval Surface Craft, Part 6 Chapter 8 (July 2011)
- Other rules:
  - “General criteria for the drawing-up of the documents which make up a technical project” UNE 157001:2014 (June 2014)
  - OFFSHORE STANDARD DNV-OS-D101 “Marine and Machinery Systems and Equipment” DNV (October 2012)
  - “Shipbuilding. Engine-room ventilation in diesel-engined ships. Design requirements and basis of calculations” UNE-EN ISO 8861 (January 1999)
  - “Air-conditioning and ventilation of machinery control-rooms on board ships - Design conditions and basis of calculations” UNE-EN ISO 8862 (1987)

- “Rules for Classification and Construction. Ventilation.” DNV (July 2014)
- ISO/DIS 16315.3 – “Small craft — Electric propulsion system” (2014)

### 2.4.2. Software and design tools

The following softwares and design tools have been used in order to fulfil some of the tasks required during the project:

- **AutoCAD 2012**: Blueprint designs.
- **Open Office 3.3 Writer, Calc and Impress**: Drafting of the project and calculations, as well as the PowerPoint presentation.
- **Dialux 4.12**: Lighting calculations.
- **SODECA QuickFan 1.7**: Fan selector.
- **Adobe Photoshop CS6**: Figure editing.

### 2.4.3. Quality management plan

During the setting up of this project the rule UNE 157001 has been applied into the Elaboration Judgement of projects. Thus, the structure of every section has been based on the requirements set by this rule. The contents of every document have been checked in order to confirm that everything is found on the blueprints, measures and budgets.

A quality management plan will be applied in order to avoid mistakes during the setting up of this project. The method will use the contrast between data from beginning to end.

### 2.4.4. Bibliography

The following books and documents have been consulted:

- ZUMTOBEL – “The Lighting Handbook” 4th edition (October 2013)
- Naval Sea Systems Command – “Electric power load analysis (EPLA) for

surface ships” DDS 310-1 REV 1 (September 2012)

- Shipboard Propulsion, Power Electronics, and Ocean Energy – Mukund R. Patel, CRC Press – Taylor & Francis Group (2012)
- Shipboard Electrical Power Systems – Mukund R. Patel, CRC Press – Taylor & Francis Group (2012)
- Schneider Electric – “Calculation of short-circuit currents” (September 2005)
- ABB – “Circuit-breakers for direct current applications” (September 2007)
- DNV – “GL Guideline for Large Maritime Battery Systems” (March 2014)

#### **2.4.5. Other references**

- Modeling and Simulation of Electric Ships’ Power System Components and their Interaction - A. Ouroua, J.R. Jackson, J.H. Beno, R.C. Thompson, and E. Schroeder (Center for Electromechanics, The University of Texas at Austin)

## **2.5. Definitions and abbreviations**

In this section will be gathered every term and abbreviation that will appear within this project. In order to make them clear and understandable, they will be explained hereafter.

### **2.5.1. Definitions**

These are the terms that will be used on the develop of this project:<sup>1 2 3 4 5 6 7 8</sup>

- 
- 1 DNV Offshore Standard, Ch.1 Sec.1 – Page 12 (October 2012)
  - 2 DNV - Electrical Installations, Pt.4 Ch.8 Sec.13 – Page 121 (July 2013)
  - 3 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 32 (July 2013)
  - 4 DNV - Rules for Ships, Pt.4 Ch.1 Sec.1 – Page 7 (January 2013)
  - 5 ISO 8861 – “Shipbuilding — Engine-room ventilation in diesel-engined ships” (May 1998)
  - 6 ISO/DIS 16315.3 – “Small craft — Electric propulsion system” (2014)
  - 7 Naval Sea Systems Command “Electric power load analysis (EPLA) for surface ships” DDS 310-1 REV 1 (September 2012)
  - 8 DNV – “GL Guideline for Large Maritime Battery Systems” (March 2014)
-

- **Active components:** Are components for mechanical transfer of energy, e.g. pumps, fans, electric motors, generators, combustion engines and turbines. Heat exchangers, boilers, transformers, switchgear or cables are not considered to be active components.
- **Battery bank:** Mechanical assembly comprising battery cells and retaining frames or trays and possibly components for battery management.
  - **Cell:** Smallest electro chemical unit.
  - **Module:** Assembly of cells including some level of electronic control.
  - **Sub-pack:** Assembly of 1 or more modules. The smallest unit that can be electrically isolated.
  - **String:** Smallest unit in a battery system with same voltage level as the battery system (e.g. serial connected cells, modules or sub-packs).
  - **Battery pack:** One or more Sub-Packs that can work for the intended purpose as a standalone unit.
  - **Battery system:** One or more battery packs including all required systems for the intended purpose.
  - **Battery space:** Physical installation room including walls, floor, ceiling, and all functions and components which contribute to keep the battery system in the defined space at a specified set of environmental conditions (e.g. temperature or moisture level)
- **Conductor:** A conductor is a part of a construction or circuit designed for transmission of electric current.
- **Continuity of supply:** Is the condition for which during and after a fault in a circuit, the supply to the healthy circuits is permanently ensured.
- **Continuity of service:** Is the condition for which after a fault in a circuit has been cleared, the supply to the healthy circuits is re-established.
- **Emergency services:** Emergency services are those services that are essential for safety in an emergency condition.
- **Emergency source of electrical power:** An emergency source of electrical power is a source intended to supply the emergency switchboard and/or

equipment for emergency services in the event of failure of the supply from the main source of electrical power.

- **Emergency switchboard:** An emergency switchboard is a switchboard, which in the event of failure of the main electrical power supply system, is directly supplied by the emergency source of electrical power and/or the transitional source of emergency power and is intended to distribute electrical energy to the emergency power consumers.
- **Engine room:** This is the space containing propulsion machinery and machinery for generation of electrical power. Rooms within or adjacent to the engine room with visual contact with the machinery are considered to be part of the engine room.
- **Essential services:** Essential (primary essential) services are those services that need to be in continuous operation for maintaining the vessel's manoeuvrability in regard to propulsion and steering. Additional class notations may extend the term essential services. Such extensions, if any, can be found in the relevant rule chapters.
- **Hazardous area:** A hazardous area is an area (zones and spaces) containing a source of hazard and or in which explosive gas and air mixture exists, or may normally be expected to be present in quantities such as to require special precautions for the construction and use of electrical equipment and machinery.
  - **Zone 0:** It is an explosive atmosphere consisting of a mixture of air and flammable substances in state of gas, vapour or mist, that it is expected to be presented always or for long period of time.
  - **Zone 1:** It is an explosive atmosphere consisting of a mixture of air and flammable substances in state of gas, vapour or mist, that it is expected to be present periodically or occasionally during normal operation.
  - **Zone 2:** It is an explosive atmosphere consisting of a mixture of air and flammable substances in state it is present, vapour or mist, that it is not expected to be present during normal operation or for short periods of time.

- **Load factor:** For a given load, the ratio of the operating load to the connected load.
- **Machinery Room:** Room in which major items of equipment are installed. The term is used instead of Machinery Space on installations which are non-self propelled or fixed.
- **Machinery spaces:** All machinery spaces of category A and all other spaces containing propulsion machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.
- **Machinery spaces of category A:** Are those spaces and trunks to such spaces which contain:
  - Internal combustion machinery used for main propulsion; or
  - Internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
  - Any oil-fired boiler or oil fuel unit.
- **Main source of electrical power:** A main source of electrical power is a source intended to supply electrical power to the main switchboard(s) for distribution to all services necessary for maintaining the vessel in normal operational and habitable conditions.
- **Main switchboard:** A main switchboard is a switchboard directly supplied by the main source of electrical power or power transformer and intended to distribute electrical energy to the vessel's services.
- **Operating load:** For a given ambient condition and operating condition, the operating load represents a load's demand for power (kW). In 24-hour average load calculations, the operating load corresponds to the long-term average. For ship demand power calculations and zonal demand power calculations, the operating load may be somewhat greater than the average value to ensure equipment is sized properly to accommodate variance of the load around the

average value for extended periods of time. Operating load does not include instantaneous power surges which are caused by starting large motors or short duration peak loads.

- **Passenger ship:** A ship which carries more than 12 passengers. Passenger is every person other than:
  - The master and the members of the crew.
  - Other persons employed or engaged in any capacity on board a ship on the business of that ship.
  - Child under one year of age.
- **Peak load:** The maximum power a load will draw (not considering transients). The peak load should be less than or equal to a load's connected load.
- **Ship operating conditions:**
  - **Shore:** A shore condition is a ship operating condition in which the ship receives all electric power from a shore facility or a tender.
  - **Cruising:** A cruising condition is a ship operating condition corresponding to:
    - Condition III Wartime Cruising as defined by the ship's requirements documents, for combatants.
    - Cruising at a specified cruising speed; has self defence capability (if provided), but is not at general quarters for non-combatants.
  - **Functional:** A functional condition is a ship operating condition in which the ship is performing its designed function.
  - **Top Speed:** Top speed conditions applies when the motors are used at their maximum power capacity. The remaining loads shall require the same amount of power than in the functional condition.
  - **Emergency:** An emergency condition is a ship operating condition in which the ship is on emergency generator with ship service generators down.
    - **Essential Services:** During this condition, it must be assured that the essential services defined in **2.6.11. Essential services** (page 47) are supplied. Besides, the passengers' accommodation must be assured as far



as possible. The devices in the Bridge shall be supplied at all times.

- **State Of Health:** Reflects the general condition of the battery and the ability to deliver the specified performance compared to a new battery
- **Ventilation:** Provision of air to an enclosed space to meet the needs of the occupants and/or the requirements of the equipment therein.

### 2.5.2. Abbreviations

These are the abbreviations that will be used on the develop of this project:

- **AC:** Alternating current.
- **DC:** Direct current.
- **DIN:** Deutsches Institut für Normung e.V.
- **DNV:** Det Norske Veritas.
- **Em:** Average lighting level.
- **EMC:** Electromagnetic Compatibility.
- **EMS:** Energy Management System.
- **EPLA:** Electric Power Load Analysis.
- **ESB:** Emergerncy SwitchBoard.
- **HV:** High Voltage.
- **IEC:** International Electrotechnical Commission.
- **IP Code:** International Protection Marking.
- **ISO:** International Organization for Standardization .
- **LV:** Low Voltage.
- **LiFePo<sub>4</sub>:** Cell chemistry: Lithium Iron Phosphate.
- **MBMM:** Master Battery Management Module.
- **MSB:** Main SwitchBoard.
- **PE:** Protective Earth.
- **Ra:** Colour rendering index .
- **RFQ:** Request For Quotation (document).

- **RT:** Routine Test.
- **SB:** Switchboard.
- **SOH:** State Of Health.
- **SOLAS:** Safety Of Life At Sea.
- **TT:** Type Test.
- **UGR:** Unified Glare Rated.
- **UNE:** Una Norma Española.

## 2.6. Design requirements

The initial design requirements needed for the complete design of the electrical installations will be studied in this section. It gathers its main features, (length, beam,...), surface areas, electrical systems, etc.

### 2.6.1. Vessel Type

The vessel is a double hull passenger ferry. It aims to give touristic services and passengers transporting. The vessel has a pure electric propulsion system, i.e. fuel motors and fuel generators are not taken into account, which allows the vessel to perform its requirements independently and without polluting emissions.

### 2.6.2. Main Features

These are the main features that conforms the structure of the vessel:

- **Length Overall:** 23.95 m
- **Beam Maximum:** 6.74 m
- **Beam Moulded:** 6.50 m
- **Beam of WL Hull:** 1.40 m
- **HillDraft (Max):** 0.95 m
- **Vessel Draft (Max):** 1.25 m
- **Passenger Room:** 100 total

- **Black Water Tank:** 1 x 1000 Litres portside only
- **Fresh Water Tank:** 1 x 1500 Litres starboardside only

### 2.6.3. Ship plan

The ship is composed of two decks, each one with different rooms. There are subdivisions in both of the decks, in order to make the calculations and set the secondary electrical switchboards. The vessel has two hulls too, where the machinery rooms are placed, and have symmetrical distribution.

If we look at the blueprint from left to the right, we will see every zone. On the first deck, we will found first the Entrance, which has not walls, and at the same time the Toilet next to the Passengers Room. The Passengers Room is the largest room on the first floor. Later we will found the Anteroom of the bridge, and next to it, the Captain's Bridge.

On the second floor, every compartment shall be equal to the same compartment in the other hull. We will find, from left to the right, an Engine Room, a Tank Compartment, an Electrical Compartment and a Void Compartment.

The following screen provides all the information previously explained:

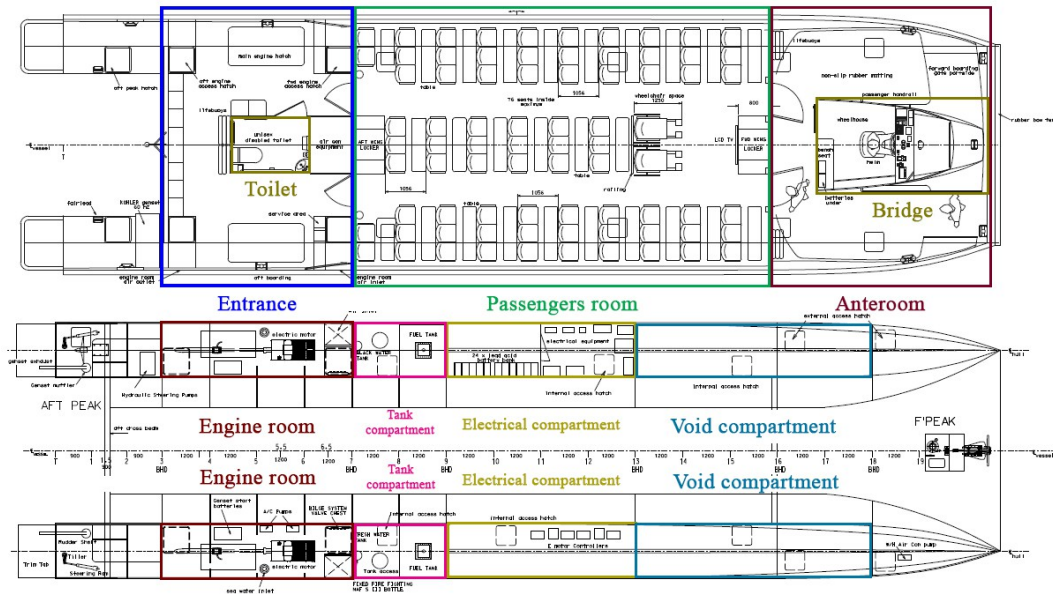


Figure 1: Areas scheme

#### 2.6.4. Surface Areas

The areas of all the surfaces within the ship are provided in the following table. It has been divided following the two decks structure:

| Floor        | Room                        | Area (m <sup>2</sup> ) |
|--------------|-----------------------------|------------------------|
| First floor  | Entrance                    | 23,60                  |
|              | Toilet                      | 2,59                   |
|              | Passengers room             | 60,27                  |
|              | Anteroom                    | 22,99                  |
|              | Captain's bridge            | 6,07                   |
| Second Floor | Engine room (x2)            | 5,88 (x2)              |
|              | Tank compartment (x2)       | 2,85 (x2)              |
|              | Electrical Compartment (x2) | 5,87 (x2)              |
|              | Void compartment (x2)       | 5,78 (x2)              |

Table 1: Areas

### 2.6.5. Electrical system

The electric ship power system may be organized in five main sections: prime power generation, power conversion and distribution, propulsion loads, ship service loads, and advanced system loads.

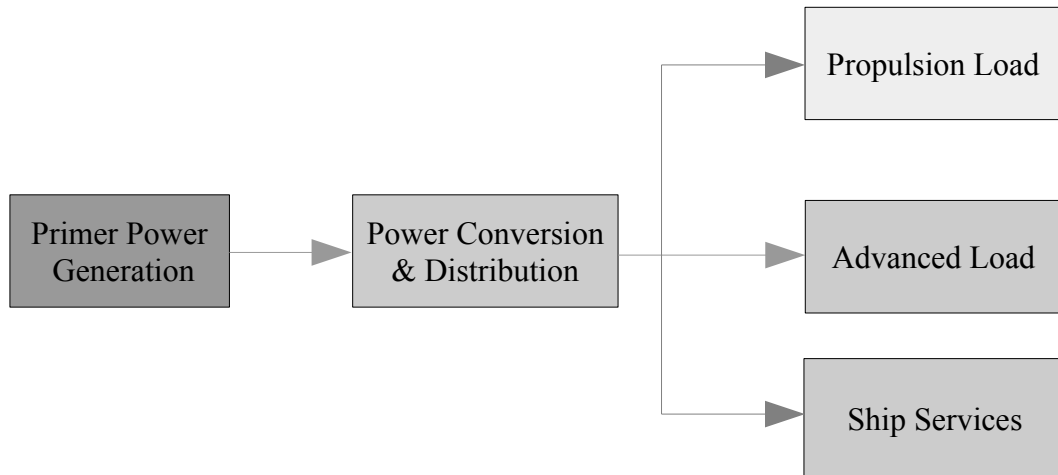


*Figure 2: Power system*

The ship shall count with two different electrical system, one for each hull. Thus, both blades shall count with a battery bank, an electric motor, a power conversion equipment, switchboards, etc. The reason for these two different electrical system is based on the necessity of an emergency system that provides power when there is a failure. Having two different systems placed each one in one hull give us the possibility to distribute the load consumption symmetrically and, in case of failure in one system, the other one may be able to supply the rest of the consumption during a fixed time.

There shall be component redundancy for main sources of power and power converters in the main power supply system so that with any source or power converter out of operation, the power supply system (i.e. the battery banks) shall be capable of supplying power to the following services:

- Those services necessary to provide normal operational conditions for propulsion and safety of the passengers.

- Starting the largest essential or important electric motor on board, (except auxiliary thrusters).
- Ensuring minimum comfortable conditions of habitability which shall include at least adequate services for cooking, heating, domestic refrigeration (except refrigerators for air conditioning), mechanical ventilation, sanitary and fresh water.
- For a duplicated essential or important auxiliary, one being supplied non-electrically and the other one electrically (e.g. lubricating oil pump No. 1 driven by the main engine, No. 2 by electric motor), it is not expected that the electrically driven auxiliary is used when one generator is out of service.<sup>9</sup>

The battery banks shall count with a power conversion system that allows to drop the voltage into the proper values. Thus, the 230 Vac system and the 24 Vdc may be both supplied from the battery banks.

The connection between 230 Vac and 24 Vdc is made by a rectifier which is supplied from both 230 Vac main switchboard through a two position selector switch. This allow us to supply the Bridge at any circumstance and avoid the use of emergency batteries at the bridge.

All this information can be checked at the blueprints. (Page 345 – **4. BLUEPRINTS**).

### **2.6.6. Electric current types**

There are three types of electric current working on the ship, depending on the task that are expected to perform.

- 24 Vdc Installation: Navigation devices, radiotelephony.
- 144 Vdc Installation: Battery banks and motors. These voltage is fixed by the

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<sup>9</sup> DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 18 (July 2013)

battery banks and motors selection which appears on the Annexes section.

- 230 Vac Installation: Lighting and one-phase loads, emergency lighting, navigation lights.

### **2.6.7. Operating conditions**

Depending on the task that the ship is performing, the total power consumption will reach a different value every time. As it was defined in **2.5.1. Definitions** (page 32), the ship may perform several conditions. Thus, the system shall not require the same amount of power while the ship is cruising than when it is in an emergency situation, for example. Therefore, it shall be necessary to define those situations.

#### **2.6.7.1. Essential Services**

Services defined in **2.6.11. Essential services** (page 47) must be supplied at all times during this condition. Besides, passengers' accommodation must be assured as far as possible. During this condition, 24 Vdc devices in the Bridge must be operational so as to be able to communicate if emergency appears. The total power consumption will be reduced up to 90% comparing to Function Condition.

#### **2.6.7.2. Shore**

During the Shore Condition, the vessel is supplied from a shore facility. Therefore, motors shall be stopped, as well as devices from the Bridge such as navigation & signal lights, searchlight or magnetic compass. Nevertheless, passengers accommodation shall remain assured. The total power consumption will be reduced up to 90% comparing to Function Condition.

#### **2.6.7.3. Function**

During Function Condition, the vessel is working at its designed function. Motors are used to keep the cruising speed, and general services are limited with the load factors depending of their function. The devices at the Bridge shall be available during this condition. Its total power consumption can be assumed as the basic value to

compare it with the remaining operating conditions.

#### **2.6.7.4. Top Speed**

During Top Speed Condition, motors are taken to their maximum power value, while the remaining devices and equipments stay at their level set on the Function Condition. The Top Speed Condition allow us to set the maximum power consumption within the vessel, and to size the elements required for its proper performance. The power consumption reaches a value that duplicates that one during Function Condition.

#### **2.6.8. Grounding**

The vessel main structure will be used as a low resistance grounding fault return. Copper interconnection between switchboards, or between several points of vessel grounding system will not be done. Besides, major electrical switchboards will be earthed directly to the structure, where more convenient. In order to take advantage of those connections, it shall be possible to group several earth connections to a common connection to the structure.

The earth cables, when required, shall be insulated with yellow/green cover. The cross section will be equal to the power cables or at least 50% of the power cables when they are bigger than or less.

All the cables shields shall be grounded at the power end. It can be used the following methods to comply with this requirement:

- Once the cable shield is undone, it must be interlaced without reducing section and the shield connected to the equipment grounding bar. Such connections shall have a green/yellow sleeve of PVC, or a yellow/green tape.
- Installing a grounding connector around the shield for easy connection by means of an isolated cable between the shield and the earth bar. The earth cable shall be at least the same section of the shield cable.



- The 3 phases medium voltage armour will be earthed at both end, except where otherwise specifically specified in the manufacture documentation.
- Instrument shield cables will be insulated from earth at the last equipment, and will be kept insulated along the cable route. The grounding will be done in the instrument grounding bar of the main equipment, except in generator control panel, where the manufacturer information will be taken into account.
- Pipes and ducts shall be earthed by mean of welding.
- All electrical equipment with a operating voltage above 48V must be directly earthed.

### **2.6.9. Main power supply system**

The main power supply system shall have the capacity to supply power to all services necessary for maintaining the ship in normal operation without recourse to the emergency source of power.

There shall be component redundancy for main sources of power, transformers and power converters in the main power supply system so that with any source, transformer or power converter out of operation, the power supply system shall be capable of supplying power to the electrical system.<sup>10</sup>

As it was stated previously, the vessel that is studied in this project must have a pure electric propulsion system. This means that the main power supply system shall not be conformed of diesel generators. This makes us focus on battery banks systems as the main power supply system. Being able to save energy and deliver it when it is required, makes it the best way of power supplying.

The battery banks must be interconnected with the rest of the vessel by using several power converters. Thus, the power will be able to flow from the quay to every load connected into the system.

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<sup>10</sup> DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 18 (July 2013)

Each battery powered system shall have a separate charging device, suitable for the actual service. Each charging device is, at least, to have sufficient rating for recharging to 80% capacity within 10 hours, while the system has normal load. The battery charger shall be suitable to keep the battery in full charged condition, (float charge), taking into account battery characteristics, temperature and load variations. If the battery requires special voltage regulation to obtain effective recharging, then this is to be automatic. If manual boost charge is provided, then the charger is to revert to normal charge automatically.<sup>11</sup>

On the following sections a study of the power forecast will be developed (page 133 – **3.2. EPLA (Electric Power Load Analysis)**), and with these results, we will be able to size the battery banks requirements and choose one that fits with those requirements.

#### **2.6.10. Emergency power supply system**

The emergency source of electrical power may be either a generator or an accumulator battery. The emergency source of power shall be automatically connected to the emergency switchboard in case of failure of the main source of electric power.<sup>12</sup>

The electrical power available shall be sufficient to supply all services essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously, also taking into account starting currents and transitory nature of certain loads.

Where the emergency source of electrical power is an accumulator battery it shall be capable of carrying the emergency electrical load without recharging while maintaining the voltage of the battery as required.

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<sup>11</sup> DNV – Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 26 (July 2013)

<sup>12</sup> DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 20 (July 2013)

The emergency source of electrical power shall be capable of supplying simultaneously at least the services listed in Table 2 for the periods specified, if they depend upon an electrical source for their operation.<sup>13</sup>

| Service                                            | Duration of emergency power (h) | Duration of transitional power (h) |
|----------------------------------------------------|---------------------------------|------------------------------------|
| Emergency lighting                                 | 18                              | 0.5                                |
| Navigation lights                                  | 18                              | 0.5                                |
| Fire pumps                                         | 18                              | -                                  |
| Fire fighting systems, e.g. total flooding systems | 0.5                             | -                                  |
| Steering gear                                      | 0.5                             | -                                  |
| Watertight doors and hatches                       | 18                              | 0.5                                |
| Communication                                      | 18                              | 0.5                                |
| Navigation                                         | 18                              | -                                  |
| Alarm systems                                      | 18                              | 0.5                                |

*Table 2: Services to be supplied by an emergency source*

Once again, in this project the emergency power supply system must be conformed by the power supply system of the hull that has not been damaged or disconnected. Thus, both power supply system must be interconnected in order to supply the other one during a failure, which makes mandatory that the two systems must have enough power to comply with the requirements stated on the previous table.

### 2.6.11. Essential services

As it was defined in **2.5.1. Definitions** (page 32), essential (primary essential) services are those services that need to be in continuous operation for maintaining the vessel's manoeuvrability in regard to propulsion and steering. Thus, these are the

<sup>13</sup> DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 21 (July 2013)

equipments and systems required for essential services:<sup>14</sup>

- Control, monitoring and safety devices or systems for equipment for essential services.
- Ventilation necessary to maintain propulsion.
- Steering gears.
- Cooling water pumps.
- Electrical equipment for electric propulsion plant - with lubricating oil pumps and cooling water pumps.
- Hydraulic pumps supplying the above equipment.
- Electric generators and associated power sources supplying the above equipment.

#### **2.6.12. Starting batteries**

According to the DNV, each starting battery shall have sufficient capacity for at least three start attempts of each of the engines being normally supplied. The duration of each starting shall be taken as minimum 10 s.<sup>15</sup>

Circuits connected to batteries above 12 V or above 1 Ah capacity shall have short-circuit and over-current protection. Short-circuit protection shall be located as close as is practical to the batteries, but not inside battery rooms, lockers, boxes or close to ventilation holes. The connection between the battery and the charger is also to have short-circuit protection.<sup>16</sup>

For this task, we will use the same batteries that conform the main power supply system, as they will be directly connected to the motors, being adjusted to the required voltage levels stated by the motors.

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14 DNV - Electrical Installations, Pt.4 Ch.8 Sec.13 – Page 121 (July 2013)

15 DNV - Rules for Classification of Ships, Pt.4 Ch.8 Sec.2 – Page 27 (July 2013)

16 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 36 (July 2013)

### 2.6.13. Motors

The DNV states that vessels having two or more propulsion motors and converters, or two electric motors on one propeller shaft, shall be arranged so that any unit may be taken out of service and electrically disconnected without affecting the operation of the others.<sup>17</sup>

In this project, the vessel shall count with two motors, one in each hull. The motors must be the same in order to make the interconnection suitable. Once again, the motors must be pure electrical, avoiding those which present a diesel component or an hybrid performance.

The motors which are about to be selected must comply with the torque requirements of the ship, i.e. they must be able to move the vessel within the proper speed.

The motors are selected on the following sections (**3.10.2. Motor catalogue** – page 302).

### 2.6.14. Transformers

Due to the fact that the vessel shall be supplied from battery banks which are in turn supplied from the quay, there will be no need of having transformers in the vessel. The batteries shall work with a direct current system which will be converter into an alternating current system by using power converters such as inverters or rectifiers.

### 2.6.15. Power Converters

This sections covers the following power electronics converters widely used in electrical power systems:

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<sup>17</sup> DNV - Electrical Installations, Pt.4 Ch.8 Sec.12 – Page 117 (July 2013)

- AC-DC converter - Rectifier
- DC-AC converter - Inverter

### **2.6.16. Rectifiers**

Rectifiers will be needed in this project to charge the batteries from the shore connection. As the power comes from the electrical system of the quay, it will be either 400 Vac or 230 Vac, so it must be changed first to a DC system.

The rectifier, due to the high values of power required, shall be out of the vessel, and will not be calculated in this project, assuming that the quay will have the devices required for this task.

### **2.6.17. Inverters**

The power electronics circuit used to convert DC into AC is known as the inverter, although the term converter is often used to mean either the rectifier or the inverter. The DC input to the inverter can be from a rectifier, battery, photovoltaic panel, or fuel cell.

In its simplest form, the single-phase, full-wave voltage source inverter (VSI) is made using four thyristor switches. The four thyristors are fired on and off sequentially in diagonal pairs for equal duration (i.e., each pair for a half cycle). This results in the load being alternatively connected to positive and negative polarities of the DC source, thus making the load voltage alternate between positive and negative polarities.<sup>18</sup>

In this project, there will be a need of two power inverters, i.e. one for each hull, in order to transform the DC network of the batteries into a 230 Vac system to supply loads as luminaries, air conditioning, etc.

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18 Shipboard Propulsion, Power Electronics, and Ocean Energy - Mukund R. Patel, CRC Press - Taylor & Francis Group – Page 64 (2012)

### **2.6.18. Lighting conditions**

The illumination of the workplaces where a task is performed must be suitable for the workers in order to allow them perform their activities. Also, it must fulfil the requirements needed for a comfortable stay of the passengers.

The lighting system shall be based on the following separation of the system:

- Main lighting system supplied from the main power supply system.
- Emergency lighting system supplied from the emergency power supply system, i.e. the power supply system of the hull which has not been disconnected.

The main electric lighting system shall provide illumination throughout those parts of the ship normally accessible to, and used by, passengers or crew, and shall be supplied from the main source of electrical power.

The following lighting shall be divided between at least two circuits from different parts of the main switchboard:

- Engine room lighting
- Switchboard room lighting
- Lighting in control room and of control positions
- Lighting in alleyways, stairways leading up to the boat deck and in saloons.<sup>19</sup>

On the other hand, the lighting conditions are well established on the related rules, fixing the necessary values in every parameter. Those parameters are explained on the following section.

### **2.6.19. Interior lighting**

An adequate level of lighting shall be provided, facilitating the performance of

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<sup>19</sup> DNV - Electrical Installations, Pt.4 Ch.8 Sec. 2 – Page 29 (July 2011)

all bridge tasks at sea and in port, during daytime and night-time. The lighting shall comprise both general lighting and task related lighting to ensure that illumination is compatible with individual operations and tasks.

There are several parameters that will depend on the activity that is being developed, as well as the place where it is taken. Those parameters are:

- **Average lighting level (Em):** Illuminance is the amount of luminous flux (lumen) that reaches vertically or horizontally a surface. To measure it we use the lux (lx). The lighting level depends on the task and its needs of visual acuity, the environmental conditions and the length of the activity. The lighting system must be designed in order obtain the required levels at the set height. It means that at the work places, the level will be measured at 80 cms above the floor. At toilets and walking places it will be measured from the floor. Furthermore, the lighting shall be as uniform as possible. It is recommended that the factor between the lowers values and the average have a value above 0.4.
- **Unified glare rated (UGR):** The glare can be produced when there are light sources whose luminance is higher than the average. Also, it can be due to the reflection on polished surfaces. The direct glare is avoid using sources that redistribute the flux. The daylight can produce glare too, and it can be avoid changing the furniture distribution and adding protections on the windows. The reflected glare depends on the colour and the shape of the walls, so they must have soft colours to avoid it. To represent the amount of glare is used the UGR, from the CIE (International Commission of Illumination).
- **Colour rendering index (Ra):** The chosen colour for a room with artificial lighting will depend on the chosen lamp. Specifically on two parameters: Colour rendering index (Ra) and its colour appearance due to its colour temperature. The colour rendering index represent the ability of the source to display standard colours, in contrast to a baseline pattern source. The higher is the value, the better is the colour display. On the other hand, the colour temperature defines the



colour tone of the light.

### 2.6.20. Bridge lighting

The lighting system shall enable the bridge personnel to adjust the illumination level as required in different areas of the bridge and by the needs of individual tasks. The illumination levels are shown in the following table.<sup>20</sup>

| Place                                    | Colour and illumination                                                                                   |
|------------------------------------------|-----------------------------------------------------------------------------------------------------------|
| Wheelhouse, general                      | White, at least 200 lux                                                                                   |
| Workstations (day)                       | White, at least 300 lux                                                                                   |
| Workstations (night)                     | Red, variable up to 20 lux                                                                                |
| Open staircase inside wheelhouse (day)   | White, at least 200 lux                                                                                   |
| Open staircase inside wheelhouse (night) | Red, variable up to 20 lux (Alt: fixed indirect red or filtered white light may be provided in the steps) |
| Chart table (day)                        | White, variable 100-1000 lux                                                                              |
| Chart table (night)                      | White filtered, variable up to 20 lux                                                                     |
| Toilet (day)                             | White, at least 200 lux                                                                                   |
| Toilet (night)                           | Red, variable up to 20 lux                                                                                |

*Table 3: Illumination levels at the Bridge*

### 2.6.21. Emergency lighting

The emergency lighting system shall be supplied from the emergency source of electrical power. Upon loss of main source of power, all required emergency lighting shall be automatically supplied from the emergency source of power. Emergency exterior lighting may however be controlled by switch on the Bridge.<sup>21</sup>

The arrangement of the emergency electric lighting system shall be such that fire, flood or other casualty, in spaces containing the emergency source of electrical

20 DNV Rules for Classification of Ships “Nautical Safety”, Pt.6 Ch.8 Sec.3 – Page 46 (July 2011)

21 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 29 (July 2013)

power, associated transforming equipment, if any, the emergency switchboard and the emergency lighting switchboard, will not render the main electric lighting system inoperative.<sup>22</sup>

In this project, the emergency lighting must be carried out by using the electrical system of the hull that has not been damaged or disconnected. Thus, each hull must have a connection supplying the lightings (or part of them) of the other hull in order to fulfil this requirement.

#### **2.6.22. Ventilation**

The ventilation system shall be designed to maintain acceptable working and living environment for the personnel and non-detrimental conditions for equipment and machinery.

There shall be independent ventilation systems for hazardous and non-hazardous areas.

The capacity of the ventilation plant should be such as to provide comfortable working condition in the engine room.

In order to meet these requirements, the air should be distributed to all parts of the engine room, so that pockets of stagnant hot air are avoided. Special considerations should be given to areas with large heat emission and to all normal working areas, where reasonably fresh and clean outdoor air should be provided through adjustable inlet devices.

The required air flow for combustion and evacuation of heat emission shall be calculated according to ISO 8861.

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22 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 41 (July 2013)

The air exhaust fans shall be designed to maintain a slight positive pressure in the engine room. The positive pressure should normally not exceed 50 Pa.

Fans serving hazardous spaces shall be designed with the least possible risk for spark generation. The parts of the rotating body and of the casing shall be made of materials which are recognised as being spark proof, and they are to have anti-static properties. Furthermore, the installation of the ventilation units shall be such as to ensure the safe bonding to the hull of the units themselves.<sup>23</sup>

Rooms where electrical equipment is located shall be sufficiently ventilated in order to keep the environmental conditions within the limits.

The air supply for internal cooling of electrical equipment (i.e. “ventilated equipment”) shall be as clean and dry as practicable. Cooling air shall not be drawn from below the floor plates in engine and boiler rooms.<sup>24</sup>

The rooms that are thought to have ventilation systems in this project are both Engine Rooms and Electrical Rooms because of the machinery that will be placed on them. Through the upcoming sections, the fan system will be calculated and a specific type of fan will be selected. A calculation of the airflow requirements can be checked at the Annexes section (3.2.1.4. Ventilation page – 142).

### **2.6.23. Switchboards**

One of the most important components in the electrical system are the switchboards. According to the rule UNE EN 60439-1, the switchboard is defined as the combination of one or more switch gears, with the associated components of command, measure, protection, etc, developed completely under the responsibility of the constructor, and with all the mechanical and electrical connections required.

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23 DNV - Offshore Standard DNV-OS-D101, Ch.2 Sec.4 – Pag. 65 October 2012

24 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 41 (July 2013)

The switchgear intended to assure the protection of the electrical equipment against external influences assures as well the primary function of protection to the direct contacts from people.

Switchboards shall be placed in easily accessible and well-ventilated locations, well clear of substantial heat sources such as boilers, heated oil tanks, and steam exhaust or other heated pipes. Ventilation and air conditioning systems shall be so arranged that possible water or condensation can not reach any switchboard parts.

Switchboards shall not be located immediately above spaces where high humidity or high concentrations of oil vapours can occur (e.g. bilge spaces), unless the switchboard has a tight bottom plate with tight cable penetrations.

The arrangement and installation of switchboards shall be such that operation and maintenance can be carried out in a safe and efficient way. When switchgear is located close to bulkheads or other obstructions, it shall be possible to perform all maintenance from the front.

Distribution switchboards shall be placed in accessible spaces with enclosures.

Alternatively switchboards may be placed in cupboards made of or lined with material that is at least flame-retardant, and with door, cable entrances and other openings (e.g. for ventilation) arranged so that the cupboard in itself complies with the protection required.

The front of the switchboard, inside such a cupboard, shall comply with enclosure type IP 20.<sup>25</sup>

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25 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 42 (July 2013)

The vessel that is studied in this document shall have several switchboards throughout it. The main ones shall be those that come from the battery banks and supply the motors and the inverters which in turn supply the 230 Vac loads. There will be some secondary switchboards, like those ones which supply every room. They will host several circuits conformed by the loads. There is a study of the circuit distribution in the Annexes section (**3.3. Circuit distribution** – page 156).

The placement of the switchboards shall be as follows:

**144 Vdc switchboard:**

- Main switchboard: Placed at the Electrical Room of each hull and supplied from the battery banks. It shall supply the DC motor.

**48 Vdc switchboard:**

- Main switchboard: Placed at the Electrical Room of each hull and supplied from the battery banks. It shall supply the 230 Vac main switchboard through the power inverter.

**230 Vac switchboard:**

- Main switchboard: It shall be placed at the Electrical Room. It shall supply all the secondary switchboards.
- Secondary switchboards: Placed on both sides and in opposite corners of the room that supplies. This will be useful in case of emergency situations, and will prevent from a total shut-down.

**24 Vdc switchboard:**

- Main switchboard: Placed at the Bridge, with the switches and fuses required. It will supply the navigation and the radio-electronic devices.

A blueprint representing the location of the switchboards can be checked at the

Blueprints section (**4. BLUEPRINTS** – page 345).

#### **2.6.24. Cable selection**

This section contains requirements for selection, construction and rating of fixed electrical cables for permanent installation based on the requirements of the Classification Society.<sup>26</sup>

##### Duty:

Unless otherwise clearly stated, the rating of electrical cables for power supply to equipment shall be for continuous full load duty.

##### Construction:

All switchboard wires, electrical cables and wiring external to equipment shall be at least of a flame-retardant type. (This requirement is intended to cover SOLAS Ch. II-1/45.5.2.)

All conductors shall consist of plain or metal-coated annealed copper according to IEC 60092-350 and shall be stranded according to IEC 60228 class 2 or class 5.

Class 1 (solid conductors) is accepted for Cat. cables (data communication cables) where the termination assembly provides sufficient mechanical integrity. Class 6 is accepted for flexible cables.

The use of other conductor metals may be considered in applications where copper cannot be used for chemical reasons.

##### Insulating materials:

General requirements for insulating materials for standard marine cables: The temperature classes and materials given in the Table 4 may be used.

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26 DNV - Electrical Installations, Pt.4 Ch.8 Sec.9 – Page 89 (July 2013)

| Material                                                    | Temperature °C |
|-------------------------------------------------------------|----------------|
| Polyvinyl chloride or (PVC)                                 | 70             |
| Ethylene propylene rubber (EPR)                             | 90             |
| Halogen free ethylene propylene rubber (HF EPR)             | 90             |
| Hard grade ethylene propylene rubber (HEPR)                 | 90             |
| Halogen free hard grade ethylene propylene rubber (HF HEPR) | 90             |
| Cross linked polyethylene (XLPE)                            | 90             |
| Halogen free cross linked polyethylene (HF XLPE)            | 90             |
| Halogen free cross linked polyolefin (HF 90)                | 90             |
| Silicone rubber, (S 95)                                     | 95             |
| Halogen free silicone rubber (HF S 95)                      | 95             |

*Table 4: Temperature classes for insulating materials*Wire braid and armour:

Cable braids shall be made of copper, copper alloy, or galvanised steel wire.

Braid and/or armour shall be separated from the core insulation by an inner non-metallic sheath, by tape or fibrous braid or roving.

Cable selection:<sup>27</sup>

These technical requirements for cables and cable installations are considered relevant for the system design phase. However, they apply as well to the final installation on the vessel.

Cables for services, required to be operable under fire conditions shall be of fire resistant type complying with the requirements of IEC 60331, where they pass through machinery spaces of category A (and other high fire risk areas other than those which they serve. For passenger vessels this requirement also applies for such cables passing through main vertical fire zones. (IACS UR E15).

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27 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 46 (July 2013)

The following electrical services are required to be operable under fire conditions:

- Fire and general alarm system.
- Fire extinguishing systems and fire extinguishing medium alarms.
- Control and power systems to power operated fire doors and status indication for all fire doors.
- Control and power systems to power operated watertight doors and their status indication.
- Emergency lighting.
- Public address system.
- Low location lighting.
- Emergency fire pump.
- Remote emergency stop/shutdown arrangements for systems which may support the propagation of fire and or explosion..

The rated voltage of a cable shall not be less than the nominal voltage of the circuits in which it is used.

#### **2.6.24.1. Conductors cross-section**

Conductor cross sections shall be based on the rating of the over current and short-circuit protection used. However the minimum cross section shall be:

- 0.5 mm<sup>2</sup> for 250 V for cables and switchboard wires for control and instrumentation
- 1.0 mm<sup>2</sup> for power circuit switchboard wires
- 1.0 mm<sup>2</sup> for 250 V and 0.6/1 kV power cables with the following exceptions:  
0.75 mm<sup>2</sup> may be used for flexible cables supplying portable consumers in accommodation spaces, and also for internal wiring of lighting fittings, provided



that the full load current is a maximum of 6 A and that the circuit's short-circuit protection is rated at a maximum of 10 A

- 10 mm<sup>2</sup> for 1.8/3 and 3.6/6 kV cables
- 16 mm<sup>2</sup> and upwards for cables above 6/10 kV.

#### **2.6.24.2. Voltage-drop of the conductors**

An AC distribution system shall be designed and installed so that the stationary voltage drop in supply to individual consumers, measured from the main switchboard to the consumer terminals, does not exceed 6% of system nominal voltage.

A DC distribution system shall be designed and installed so that the stationary voltage drop in supply to individual consumers, measured from the battery distribution to the consumer terminals, does not exceed 10% of system nominal voltage.

Specific requirements for transient voltages on consumer terminals during start or stop are not given. However, the system shall be designed so that all consumers function satisfactorily.<sup>28</sup>

Tests may be required to verify that the allowable voltage drop is not exceeded.

#### **2.6.24.3. Short-circuit current**

Characteristics of short-circuits:

The primary characteristics are:

- Duration (self-extinguishing, transient and steady-state).
- Origin.
- Mechanical (break in a conductor, accidental electrical contact between two conductors via a foreign conducting body such as a tool or an animal).
- Internal or atmospheric over-voltages.

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28 DNV – Electrical Installations, Pt. 4 Ch. 8 Sec. 2 – Page 17 (July 2013)

- Insulation breakdown due to heat, humidity or a corrosive environment.
- Location (inside or outside a machine or an electrical switchboard).

Consequences of short-circuits:

The consequences are variable depending on the type and the duration of the fault, the point in the installation where the fault occurs and the short-circuit power.

Consequences include:

- At the fault location, the presence of electrical arcs, resulting in:
  - Damage to insulation.
  - Welding of conductors.
  - Fire and danger to life.
- On the faulty circuit
  - Electrodynamic forces, resulting in:
    - Deformation of the busbars.
    - Disconnection of cables.
  - Excessive temperature rise due to an increase in Joule losses, with the risk of damage to insulation.
- On other circuits in the network or in near-by networks.
- Voltage dips during the time required to clear the fault, ranging from a few milliseconds to a few hundred milliseconds.
- Shutdown of a part of the network, the extent of that part depending on the design of the network and the discrimination levels offered by the protection devices.
- Dynamic instability and/or the loss of machine synchronisation.
- Disturbances in control/monitoring circuits.

Definition: <sup>29</sup>

A simplified network comprises a source of constant AC power, a switch, an impedance  $Z_{sc}$  that represents all the impedances upstream of the switch, and a load impedance  $Z_s$ .

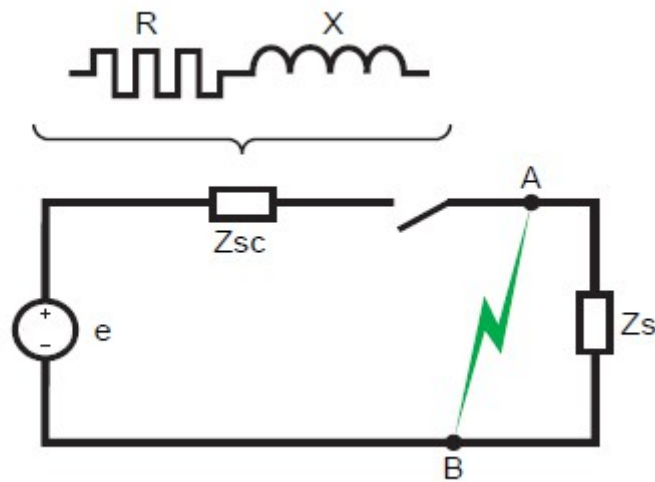


Figure 3: Simplified network diagram

In a real network, the source impedance is made up of everything upstream of the short-circuit including the various networks with different voltages (HV, LV) and the series-connected wiring systems with different cross-sectional areas (A) and lengths. In the previous figure, when the switch is closed and no fault is present, the design current  $I_s$  flows through the network.

When a fault occurs between A and B, the negligible impedance between these points results in a very high short-circuit current  $I_{sc}$  that is limited only by impedance  $Z_{sc}$ . The current  $I_{sc}$  develops under transient conditions depending on the reactances  $X$  and the resistances  $R$  that make up impedance  $Z_{sc}$ :

$$Z_{sc} = \sqrt{R^2 + X^2}$$

29 Schneider Electric - "Calculation of short-circuit currents" (September 2005)

However, the transient conditions prevailing while the short-circuit current develops differ depending on the distance between the fault location and the generator. This distance is not necessarily physical, but means that the generator impedances are less than the impedance of the elements between the generator and the fault location.

Aim:

It is necessary to calculate the short-circuit currents in each of the levels of the electrical system, in order to size the proper protection as well as the conductors. The cable cross section shall depend on the power consumed by the loads, in every voltage range. Therefore, knowing the current absorbed by the loads will be possible to size the cross section of the cable for every consumer.

Thus, this section will gather the calculations of every short-circuit current that may appear in the system, following several criteria in order to size the conductors. These criteria are:

- Maximum permissible current or maximum permissible heating, which shall be the most critical
- Maximum permissible voltage drop
- Higher permissibility in the conductor than the switch.

The calculation of the short-circuit currents can be checked at the Annexes section (**3.7.3. Short-circuit currents calculation** – page 230).

### **2.6.25. Cable routing**

Cable runs shall be installed well clear of substantial heat sources such as boilers, heated oil tanks, steam, exhaust or other heated pipes, unless it is ensured that the insulation type and current rating is adapted to the actual temperatures at such

spaces.<sup>30</sup>

The cables will be distributed among the circuits that conforms the electrical system, which can be checked at **3.3. Circuit distribution** – page 156.

#### 2.6.25.1. Cable trays

Regarding to cable trays, there are several options than may be adapted for the purpose of this project.

- **Ladder type trays:**
  - **A (width):** From 200 to 600 mm .
  - **B (distance between steps):** maximum 300 mm (Or less, according to cable diameter and the requirement of the Classification Society).
  - **C (group height):** 80 mm.
  - **L (length):** maximum 3 meters.
  - **Material:** Hot galvanized steel in accordance with EN ISO 1461.
  - **Thickness:** Manufacturer Standard.
  - **Use:** in all areas of the vessel.
  
- **Grating types trays:**
  - **A:** to 150 mm.
  - **C:** 30-105 mm
  - **L:** maximum of 3 meters.
  - **Thickness:** Manufacture Standard.
  - **Material:** Hot galvanized steel or steel primed and painted for indoor use and 316L stainless steel for outdoor use.
  - **Use:** Secondary trays and final branches in all areas of the vessel.

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30 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 45 (July 2013)

- **Secondary trays:**
  - Round steel rods of 8mm diameter, treated and painted according to the vessel structure where they are welded.
  - **L:** de 300 to 700 mm
  - **H:** 10- 200 mm
  - **Use:** in all areas of the vessel to approach the cables to the consumers. Only cables with an outer diameter less than 15 mm and for a maximum of four cables. For bigger cables, cables trays will be used.
  - **Comments:**
    - Welding must be performed to an structural element wherever possible, never to the shell plates.
- **Cable trays support:**
  - Distance between supports will not exceed 1600 mm
  - **Supports arrangement:**
    - “T” supports for trays 400mm width or bigger.
    - “L” supports for ladder trays and trays width less than 400mm
  - **Material:** Steel supports, L profile, dimensions: 30 x 30 x 3, 40 x 40 x 4 and 50 x 50 x 5.
  - Steel supports, U profiles, dimensions: 50 x 25.
  - The supports will be blasted and shop-primed.
  - **Comments:**
    - Compensations plates are needed depending on the thickness of the steel plate. No compensations plates are required when welded to reinforcements.
    - All cables exposed to the risk of mechanical damage shall be protected by suitable means to risk: flexible pipe, galvanized steel pipe or a tray with cover.
    - Trays are fixed to supports with screws.

### **2.6.25.2. Mounting**

Cable mounting shall comply with several requirements:

- When several layers of trays are required, the spacing between them will not be less than 175 mm.
- The trays shall have longitudinal continuity on its route, to ensure the maximum distance between two cables support, established by the Classification Society, according to the type of cable.
- When there is a bulkhead or deck isolation the tray shall be installed separated from the isolation to perform properly the cabling and clamping installation.
- In case of ceiling isolation the minimum separation between the tray and the insulation will be 175 mm. Cables trays will be installed above the decorated ceiling in the accommodation area.
- Derivations and crosses at different levels will be separated 175 mm.
- The maximum distance between horizontal and vertical derivations shall be 300 mm.
- Trays that pass near heat sources have to respect a minimum distance of 300 mm from heat source. In case of non-isolated pipes the minimum distance is 300. 150 mm from the outer isolation face when the pipe is isolated.
- Curved trays, shall have a bending radius of 6 times the biggest cable diameter passing through it. In any case it not be less than 300 mm. For special cables: flexible waveguide, coaxial fibre optic, the bending radius will be the maximum radius specified by the manufacturer to ensure a proper installation without deterioration.
- Switchboards foundations shall be painted according to the zone where they are located. When the bulkheads are isolated, the foundation shall provide a gap of 10 mm between the isolation and the switchboard.
- The edge of the tray shall be separated a maximum of 200 mm from the outer edge of the cable penetration, in order to ensure the last clamping 300 mm. The

Edge of the tray shall be vertically separated 10 mm above the base of the cable penetration.

- When there is a direction change between the tray and the penetration the tray will be separated 2/3 its width in both directions, longitudinally and vertically, in order to facilitate the cable bending. Alternatively the tray will follow the direction changes.
- The cables will be protected with covers or pipes in case of risk of mechanical damages.
- Pipe trays will be removable.
- Pipes used as trays shall have an inner diameter and a bending radius such as to allow easy installation of cables.
- When the cables pass through watertight bulkheads they will pass through multi-cables watertight transit system to maintain the bulkhead classification. Cables penetrations pass through duct cables shall be made according to the bulkhead classification.
- Drain holes will be made in pipes, diameter no less than 7mm, in order to facilitate ventilation and drainage to prevent the water inside.
- Compensation plates will be used when trays supports are welded directly to decks plates or to shell plates, with a thickness less than 10 mm.
- Compensation plates are not required when the trays supports are welded directly to the stiffeners.

#### **2.6.25.3. Lay-out and finishing**

Conductors shall comply with the following requirements related to their lay-out and finishing:

- Cables will be arranged directly on the trays and rods. Accessibility will be possible.
- The following situations shall be avoided during the cable laying:
  - Expansion parts of vessel structures.



- Excessive vibration in cable trays curves.
- Magnetic influenced areas.
- Excessive heat.
- The cables laying will be as straight as possible and avoiding disassembly of equipments.
- The minimum bending radius of cables up to 0,6/1 kV will be according to the cable type, and their minimum values are given in the following table as a guide:

| Insulation type                                                  | Outer covering                                             | Nominal outer diameter (D) | Minimum internal bending radius |
|------------------------------------------------------------------|------------------------------------------------------------|----------------------------|---------------------------------|
| Termoplastic or thermosetting circular copper conductors         | Unarmoured or unbraided                                    | $\leq 25$ mm               | 4·D                             |
|                                                                  |                                                            | $> 25$ mm                  | 6·D                             |
|                                                                  | Metal braid screened or armoured                           | Any                        | 6·D                             |
|                                                                  | Metal tape armoured or metal sheathed                      | Any                        | 6·D                             |
|                                                                  | Composite polyester/metal tape screen single or collective | Any                        | 8·D                             |
| Termoplastic or thermosetting with sector shaped copper conducts | Any                                                        | Any                        | 8·D                             |

*Table 5: Minimum bending radius to 0,6/1 kV cables*

- For cables of medium and high voltage the bending radius will be 15 times its external diameter and 20 times for single core cables.
- Segregations will be maintained as described in subsequent sections. Where instrumentation and power cables are crossed it will be performed in right angle.

- For redundant Systems (duplicated), the system “A” cables will be routed in separated trays from the main system “B” cables. System “A” instrumentation, control, F&G, PA/GA, will routed separated from the system “B”.
- In general, the cables entrance to the switchboards will be done from the bottom through cable glands that ensure its IP protection. Open areas and wet areas, the cables will be bent before entry to the switchboard.
- In general, direct joining of cables is forbidden, whether for constructive strategy or assembly were needed, connections boxes would be installed, EMC to maintain the degree of protection and insulation.
- Between converters and electric Motors shielded EMC cables and glands or multi-cables penetrations will be used.

#### **2.6.25.4. Cable clamping**

All the systems in interior zones shall comply the following requirements:

- In the horizontal trays, where the cables are laid above the tray, plastic clamps can be used, one metallic clamp will be installed approximately each 1,8 metres.
- In vertical trays, and horizontal trays where the cables are laid below the tray, one metallic clamp will be installed each 1,2 meters

As general rule, the separation between clamps in horizontal cable trays will be minimum 600 mm. The separation between clamps in verticals trays and horizontal trays where cables are laid below the tray will be 300 mm

Metallic clamps must be corrosion resistant.

#### **2.6.25.5. Connections and terminals**

- All wires will be marked with the cable identification and the number terminal block/plug according to the connections diagrams.
- The wire insulation will be cut closed to the terminal to reduce the length of the

bare wire and also clean input terminal.

- Terminal type will be appropriated for each section of the wire.
- A proper terminal will be used for cables and blocks, except where the manufacturer recommends entry directly with the wire f. e. bind blocks.
- In power circuits which require terminals will be closed type and bound with nut and lock washer or locknut.
- Cables will be fastened or secured before termination adequately convey so no efforts to terminals.
- Terminals will be used only in connected cables, others will remain identified with “spare” and cables tag in instrumentation cables.
- A tool will be used to tight the terminal blocks recommended by the manufacturer (or approved for this role) and respect the torque table.

### **2.6.26. Protections**

In this section are going to be studied protections systems that will be necessary on the different sections of the electrical system.

Overload protection may be arranged as load reduction or as the tripping of non-important consumers. Where more than one generator is necessary to cover normal load at sea, then important consumers may be tripped, if necessary.<sup>31</sup>

All circuits in the electric distribution systems shall have protection against accidental over-currents and short circuits as described in the next points.

- Each separate circuit shall be protected against short-circuit with the protection in the feeding end.
- Each circuit shall be protected against over-current.
- All consumers shall be separately protected, except as noted below.
- Loss of control voltage to protective functions shall either trip the corresponding

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31 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 31 (July 2013)

equipment or give an alarm on a manned control position, unless other specific requirements apply.

Exceptions:

- Circuit supplying multiple socket outlets, multiple lighting fittings or other multiple non-important consumers is accepted when rated maximum 16 A in 230 Vac systems.
- Separate short-circuit protection may be omitted for consumers serving non-important services. Each motor shall have separate over-current protection and control-gear.
- Common short-circuit protection for more than one consumer is acceptable for non-important consumers, and for important consumers constituting a functional service group (i.e. when the important function cannot be ensured by a single consumer of the group).
- Common overload or over-current protection for more than one consumer is acceptable when the protection system adequately detects over-load/over-current or other malfunction origin at individual consumer. Cables connected to individual consumer shall be sized to settings adjusted at the common protection.

The protective devices shall provide complete and co-ordinated protection through discriminative action in order to ensure:

- Continuity of supply to essential consumers and emergency consumers.
- Continuity of service to important consumers. Supply to healthy circuits shall be automatically re-established.
- Elimination of the fault to reduce damage to the system and hazard of fire.<sup>32</sup>

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32 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 32 (July 2013)

Regarding with the capacity of the protection, the DNV states some points that must be comply in the protection systems.<sup>33</sup>

- The breaking capacity of every protective device shall be not less than the maximum prospective short-circuit at the point where the protective device is installed.
- The making capacity of every circuit breaker or switch intended to be capable of being closed, if necessary, on short-circuit, shall not be less than the maximum value of the prospective short-circuit current at the point of installation.
- For non-important circuits, circuit breakers with insufficient breaking capacity can be used, provided that they are co-ordinated by upstream fuses, or by a common upstream circuit breaker or fuses with sufficient breaking capacity protecting the circuit breaker and connected equipment from damage.
- Circuit breakers in main switchboards are generally to be selected according to their rated service short-circuit breaking capacity.

#### **2.6.26.1. Motor protection**

According to DNV, the motors shall comply the following requirements to fulfil their protections. We recall that we will work with DC Motors.

- Over-current protection for motors may be disabled during a starting period.
- Over-current relays shall normally be interlocked, so that they must be manually reset after a release.
- Short-circuit and overload protection shall be provided in each insulated phase (pole) with the following exemptions:
  - For DC motors, over-current relay in one pole can be used, but this cannot then substitute over-current release at the switchboard<sup>34</sup>

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33 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 33 (July 2013)

34 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 35 (July 2013)

### **2.6.26.2. Battery protection**

Circuits connected to batteries above 12 V or above 1 Ah capacity shall have short-circuit and over-current protection. Protection may also be required for smaller batteries capable of creating a fire risk. short-circuit protection shall be located as close as is practical to the batteries, but not inside battery rooms, lockers, boxes or close to ventilation holes. The connection between the battery and the charger is also to have short-circuit protection.

Connections between cells and from poles to first short-circuit protection shall be short-circuit proof.

The main circuit from a battery to a starter motor may be carried out without protection. In such cases, the circuit shall be installed short-circuit proof, and with a switch for isolating purposes. Auxiliary circuits, which are branched off from the starter motor circuit, shall be protected as required in the first paragraph.<sup>35</sup>

Accumulator batteries shall be suitably housed, and compartments shall be properly constructed and efficiently ventilated.

- The batteries shall be so located that their ambient temperature remains within the manufacturer's specification at all times
- Battery cells shall be placed so that they are accessible for maintenance and replacement
- In battery boxes, the cells shall be placed at one height only
- The space above cells shall be sufficient for maintenance and cooling
- Normally, batteries shall not be located in sleeping quarters.<sup>36</sup>

### **2.6.26.3. Circuit protection**

The distribution of circuits that is developed in the Annexes section (**3.3. Circuit**

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35 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 36 (July 2013)

36 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 43 (July 2013)

**distribution** – page 156) must be protected too. DNV states some premises that must be comply:<sup>37</sup>

- Each separate circuit shall be protected against short-circuit with the protection in the feeding end.
- Each circuit shall be protected against over-current.
- All consumers shall be separately protected.
- Loss of control voltage to protective functions shall either trip the corresponding equipment or give an alarm on a manned control position, unless other specific requirements apply.
- No fuse, switch or breaker shall be inserted in earthing connections or conductors. Earthed neutrals may be disconnected provided the circuit is disconnected at the same time by means of multipole switch or breaker.
- The circuit breaker control shall be such that “pumping” (i.e. automatically repeated breaking and making) cannot occur.

This requirements count with several exceptions that are gathered on the following list:

- Circuit supplying multiple socket outlets, multiple lighting fittings or other multiple non-important consumers is accepted when rated maximum 16 A in 230 V systems, or 30 A in 110 V systems.
- Non-important motors rated less than 1 kW, and other non-important consumers, rated less than 16A, do not need separate protection.
- Separate short-circuit protection may be omitted for consumers serving non-important services. Each motor shall have separate over-current protection and control-gear.
- Common short-circuit protection for more than one consumer is acceptable for non-important consumers, and for important consumers constituting a functional

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37 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 33 (July 2013)

service group (i.e. when the important function cannot be ensured by a single consumer of the group).

- Common over-load or over-current protection for more than one consumer is acceptable when the protection system adequately detects over-load/over-current or other malfunction origin at individual consumer. Cables connected to individual consumer shall be sized to settings adjusted at the common protection.
- Separate short-circuit protection may be omitted at the battery or busbar end of short circuit proof installed cables.

This demands are applied in the calculation of the cross-section and switches required for each circuit, and it can be checked at **3.7. Conductors & switches** (page 181).

#### **2.6.26.4. Capacity of the circuit breakers**

- The breaking capacity of every protective device shall be not less than the maximum prospective short circuit at the point where the protective device is installed.
- The making capacity of every circuit breaker or switch intended to be capable of being closed, if necessary, on short-circuit, shall not be less than the maximum value of the prospective short circuit current at the point of installation.
- For non-important circuits, circuit breakers with insufficient breaking capacity can be used, provided that they are co-ordinated by upstream fuses, or by a common upstream circuit breaker or fuses with sufficient breaking capacity protecting the circuit breaker and connected equipment from damage.
- Circuit breakers in main switchboards are generally to be selected according to their rated service short-circuit breaking capacity.
- Every protective device or contactor not intended for short circuit interruption shall be co-ordinated with the upstream protection device.
- When a switchboard has two incoming feeders, necessary interlocks shall be



provided against simultaneously closing of both feeders when the parallel connected short circuit power exceeds the switchboards' short circuit strength. A short time parallel feeding as a “make before break” arrangement is accepted when arranged with automatic disconnection of one of the parallel feeders within 30 s.

#### **2.6.26.5. Short-circuit protection**

The general requirements for circuit protection in 201, 202 and 203 apply with the following exceptions

- Separate short circuit protection may be omitted for motors serving different functions of the same non-important equipment for example the engine room crane may include hoisting, slewing and luffing motors. Each motor should have separate over-load protection and control gear.
- Separate short circuit protection may be omitted at the battery or busbar end of short circuit proof installed cables. However, short circuit proof connections to busbars shall not be longer than 3 m.

#### **2.6.26.6. Over-current protection**

- Over-current protection shall not be rated higher or adjusted higher (if adjustable) than the cable's current-carrying capacity, or the consumers nominal current, whichever is less.
- The general requirements for circuit protection stated before apply with the following exceptions:
  - Over-current protection may be omitted for circuits supplying consumers having over-current protection in their control gear.
  - This also applies to a circuit supplying a distribution switchboard with consumers having over-current protection in their control gear, provided that the sum of the rated currents of the control gears does not exceed 100% of the supply cable's rating.<sup>38</sup>

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38 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 34 (July 2013)

#### 2.6.26.7. Insulation fault

Each insulated or high resistance earthed primary or secondary distribution system shall have a device or devices to continuously monitor electrical insulation to earth. For insulated distribution systems, the circulation current generated by each device for insulation monitoring shall not exceed 30 mA under the most unfavourable conditions. In case of abnormally low insulation values the following is required:

- **Low voltage systems:** An audible or visual indication
- **High voltage systems:** An alarm at a manned control station (i.e. both visual and audible signal).

#### 2.6.27. Penetrations of bulkheads and decks

Multi-blocks watertight transit system penetrations will be used. The transit system will be approved by the Classification Society. In special cases, non standard commercial transit system can be used, such as main switchboards, emergency switchboards entry. The manufacturer procedures shall be followed for the proper installation.

Blocks will be installed from down to up. Blind blocks will be installed in upper part of the penetration. 15% of free space will be left.

Referring to the DNV, penetrations of bulkheads and decks shall follow the following requirements:<sup>39</sup>

- Penetrations shall meet the fire and watertight integrity of the bulkhead or deck.
- The penetrations shall be carried out either with a separate gland for each cable, or with boxes or pipes filled with a suitable flame retardant packing or moulded material when those are put between areas or spaces with different fire or water

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<sup>39</sup> DNV - Electrical Installations, Pt.4 Ch.8 Sec.10 – Page 101 (July 2013)

integrity.

- The installation shall be in accordance with the manufacturers' installation instructions.

#### **2.6.27.1. Mounting instructions**

Penetrations of bulkheads and decks must follow a specific procedure plan. It is recommended to check installation of all cables before installing the blocks. To facilitate the assembly and to ensure correct operation of multi-cable transit system as watertight and fire resistant, the following precautions have to be taken:

- Sort the cables in the order in which they are going to be installed, avoiding crosses in the proximity of the penetrations.
- Avoid direction changes in the vicinity of the penetration. Cables have to enter perpendicular to the bulkhead or deck.
- Until it is fully assembled do not tauten the cables to the trays, supports or conduits, in a distance of 1,5 or 2 meters from each side.

Assembling must begin with bigger cables at the bottom, according to the sketch previously outlined. A light layer of silicone should be applied to frame surfaces and blocks in order to facilitate the placement of blocks. After finishing each row of blocks, it must be placed a stay plate. Stay plates are used to maintain the blocks in their position and distribute correctly the contact pressure on the frame.

A compression plate shall be placed in the last row of blocks before finishing the last row, pressing it against the top of the frame. The screws will be tightened once placed the last row (in case the frame has a compression screw). The compression plate have to be placed over the last row of blocks. The screws will be tightened sealing the enclosure. It must be tighted until slight sealing material goes around the metal pieces. This indicates that the blocks and the cables are tight enough to ensure the desired seal. Then, the screws must be loosed in order to terminate (about 1/8 turn) when the frame

allow it. Then, the multi-cable transit is complete.

### **2.6.28. Designation and labelling of electrical material**

This section aims to define the plates, labels, and tags that have to be fixed in all the elements of the electrical installation so that they remain identified in the whole vessel.

Every equipment will have a unique code according to its corresponding system, applicable functional identification, documents and diagrams. Whether one equipment or item modification required its cancellation, its code must not be reallocated to other equipment.

Power and lighting distribution switchboards will have identification and information labels. Distribution switchboards will have information labels next to each switch. Circuit number, consumer description and location have to be shown.

Individual identification labels can be omitted in multiple cable penetrations, bulkheads or decks, installing a label plate near, the penetration showing the cable trays in same order of installation in the penetration.

Cables will be marked with a laser head installed in the cable cutting machine. This mark will be done each 50 cm, by numbers. Colours marking will no be accepted. Marks height will be according to cable type and diameters. Height must be easily legible.

Labels and tags material must withstand environmental conditions. The text of the labels must withstand regular cleaning and remain legible after 30 years.

Identifications and information labels and tags will be sized according to the size of the equipment on which they are installed.

### **2.6.29. Equipment assembly**

Special care shall be taken in order to not place lighting fixtures, fire detectors, bells, horns, etc, interfering the areas where for equipment or machinery assembly or disassembly. Moreover, all junction boxes shall be labelled and identified, as well as all the emergency lighting, visible for easy inspection and location.

All the equipment shall be placed in order to facilitate its removal or access for maintenance. Wherever possible, equipment will not be placed in passageways or escape routes in case of difficulties. The assembly will have minimal interference, and will not difficult the movement of personnel.

## **2.7. Analysis of solutions**

### **2.7.1. Introduction**

There are several design alternatives in some of the aspects that conforms this project, and they will be evaluated on this section. One of them will be chosen in order to being developed. If there are more than one solution, some aspects will be taken in account, referring to the legal rules, facilities of installation, environmental issues, economic aspects and above all, security necessities.

### **2.7.2. Electrical distribution types**

#### **2.7.2.1. Permanently grounded neutral system**

An electrical connection with zero impedance between neutral and earth is fixed.

Since the neutral connection is grounded without limiting impedance, the fault current from phase to ground  $I_{k1}$  is basically a short-circuit from phase to neutral. Therefore, it reaches a high value.

The trigger happens when the first insulation fault appears.

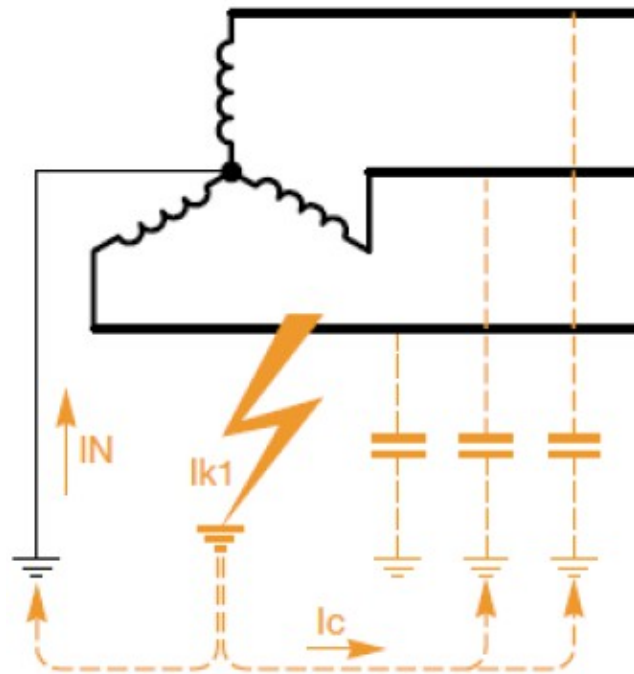


Figure 4: Permanently grounded neutral system

Advantages:

- This structure is perfect for the evacuation of over-voltages.
- It is possible to use devices with dimensioned isolation for phase to neutral voltage.
- No specific protection units are required: over-current protection units can be used for the permanent earth faults.

Disadvantages:

- This system has all the disadvantages and risks referred to the high fault current ground: maximum damage and disturbances.
- No continuity of service in the faulty feeder.
- Risks for operators is high

### 2.7.2.2. Isolated neutral systems

There is no grounding of the neutral point, except for measuring devices or protection.

In this type of electrical systems, a phase to earth fault only produces a low current through the phase-to-ground capabilities of fault-free phases.  $I_{k1}$  fault current can be maintained for a long time without causing any damage due to the fact that its value reaches no more than a few amps. It is not required to perform any action to eliminate this first fault, highlighting the advantages of this solution in terms of service continuity.

However, this entails the following consequences:

- Insulation must be continuously monitored and insulation monitoring must indicate the failure uncorrected.
- The subsequent bug tracking requires complex automatic equipment for quick identification of the faulty power output and also a qualified service operator to take care of the operation.
- If the first fault is not corrected, the second fault occurring on another phase will cause a two-phase short-circuit to ground that will clear the phase protection units.

#### Advantages:

- The main advantage is service continuity since the fault current is very low and does not cause automatic tripping in the first defect. It is the second fault that requires tripping.

#### Disadvantages:

- Not removing over-voltages can be a major drawback if the maximum voltage is high.
- Insulation costs are higher due to the phase voltage may remain between the

phase and earth for a long time with no automatic tripping.

- Insulation monitoring is compulsory, with indication of the first fault.
- It must have a maintenance department with equipment to quickly track the first insulation fault.
- There are risks of over-voltages caused by ferro-resonance.

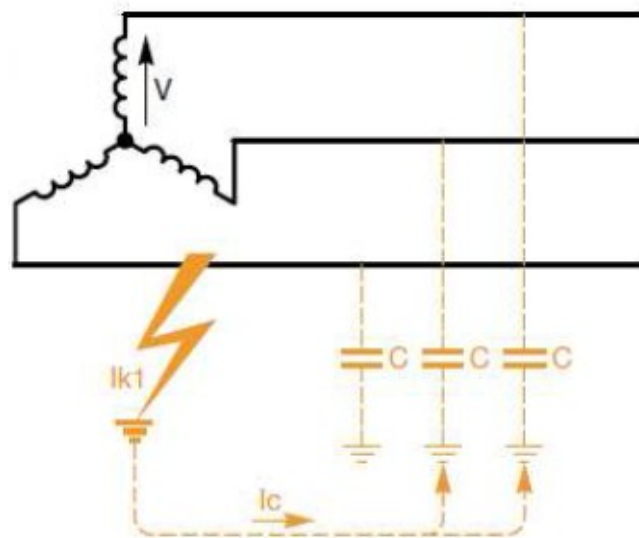


Figure 5: Isolated neutral system

### 2.7.3. Main power supply system

The main power supply system is what provides the ship with the amount of power required by every load in the system. It may be conformed by a Genset system (diesel generator), a Pure Electric system (battery banks) or a Hybrid system (both).

#### 2.7.3.1. Genset

A Genset or a Diesel Generator is the mixture of a diesel engine with an electric generator, which is usually an alternator, to generate electric power. A diesel compression-ignition engine often is designed to run on fuel oil, but some types are adapted for other liquid fuels or natural gas. Diesel generators are useful in systems that are not connected to a power grid, or as emergency power-supply if the grid fails.



Due to the fact that a Genset needs fuel supply to ensure its performance, it is not a pure electric system, and it makes it useless for the purpose of this document.

### **2.7.3.2. Pure Electrical**

Electric power, although a very convenient form of energy to distribute and use, cannot be easily stored on a large scale. Almost all electric power generated is consumed simultaneously in real time by the loads. However, various technologies are presently available to store energy on a relatively small scale. The electrochemical battery stores energy in the electromechanical form. Its energy conversion efficiency from electrical to chemical or vice versa is about 85%.<sup>40</sup>

Batteries used in shipping are big enough to fill a large compartment, because ultimately the physical size of a battery directly relates to the power it can produce. Batteries of this size use a variety of chemical processes, the two most common being lead-acid and lithium-ion. Both are robust, low cost, maintenance free and are considered safe with minimal risk of overheating. Lithium-ion batteries are favoured for their energy density, with lead-acid being too large for propelling a vessel requiring a significant electrical load.

A rechargeable battery is one whose electrochemical reaction is reversible. After a discharge, it can be recharged by injecting a direct current from an external source. In the charge mode, it converts the electrical energy into chemical energy. In the discharge mode, it is reversed. In both charge and discharge modes, about 15% of energy is converted into heat each way, which is dissipated to the surrounding medium. Therefore, the round trip energy conversion efficiency is about 70-75% of the rated power.

### **2.7.3.3. Hybrid system**

Hybrid propulsion refers to a combination of conventional propulsion and

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40 Shipboard Electrical Power Systems - Mukund R. Patel, CRC Press - Taylor & Francis Group – Page 297 (2012)

electric propulsion, with usually one or the other working at a time, but not simultaneously. It is used in a manner that optimizes the overall size, energy efficiency, and emission reduction of the power plant during one or more segments of ship operation. Hybrid propulsion is becoming more important in view of the environmental regulations being imposed on ships and ferries in busy ports and sea routes around the world in response to the rising public concern about emissions.

Advances in battery technology and energy management capability have rightly seen increasing interest in battery and hybrid power in the maritime industry, which has been reducing its fuel consumption in response to rising energy prices, even more so now to cut emissions as well.

Even with the most energy-efficient diesel engine, a large oil tanker emits more than 300,000 tons of CO<sub>2</sub> per year, equivalent to a medium-size coal power plant on land. And, there are more than 90,000 large ships in the world today. The industry has grown rapidly since industrial production has shifted away from the United States and Europe to China and south Asia, which means larger cargo travelling longer distances. Ships now carry more than 90% of the world's trade by volume, and have tripled the total tonnage capacity since the 1980s.<sup>41</sup>

Electric and hybrid vessels with energy storage in large Li-ion batteries and optimized power control provide significant reductions in fuel consumption and emissions. Such solutions also enable reduced maintenance and improved ship responsiveness, regularity, operational performance and safety in critical situations. However, a maritime battery might be 10 - 100 times (or more) larger than a traditional electric vehicle battery.<sup>42</sup>

The high energy content, combined with extreme charging and

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41 Shipboard Propulsion, Power Electronics, and Ocean Energy - Mukund R. Patel, CRC Press - Taylor & Francis Group – Page 261 (2012)

42 DNV GL Guideline for Large Maritime Battery Systems – Summary (2014)

operational patterns, represents new challenges in relation to safety, reliability and service life.

#### **2.7.3.4. Solution adopted**

Since this project aims to implement a pure electric propulsion system, the main power supply system shall be conformed of two battery banks, one for each hull, and they will need power converters to adjust the voltage levels. Because of the need of recharging the batteries, it will require a shore connection with an appropriate rectifier.

All-electric ships and hybrid ships with energy storage in large batteries and optimized power control can give significant reductions in fuel costs, maintenance and emissions, in addition to improved ship responsiveness, regularity, operational performance and safety in critical situations. Today hybridization of ships can provide fuel savings of 20 - 30% with a payback time of 2 to 4 years.<sup>43</sup>

Further advantages can be checked on page 107 (**2.8.3.1. Advantages of the battery banks system**).

A power consumption forecast will be studied in the Annexes section (page 133 – **3.2. EPLA (Electric Power Load Analysis)**). Using it as a reference, the battery banks may be sized (**3.4. Battery banks selection** – Page 167).

#### **2.7.4. Emergency power supply system**

As it was stated previously, the emergency power supply system lies in the double electrical system. As both systems are interconnected, whenever one of them is out of performance, the other one would be able to supply the whole vessel, or at least part of it, allowing it to supply the motors in the worst case scenario.

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43 DNV GL Guideline for Large Maritime Battery Systems – Page 2 (2014)

### **2.7.5. Motors**

As it has been stated before, the motors should be electrical. None of the diesel-engined motors must be selected, because it would put an end to the zero-emission goal. Thus, the selected motor should present an electrical structure in order to be coherent with the rest of the system.

Among the electric motors, it is possible to find several types of them. The most common ones are the induction motor, the synchronous motor and the DC motor.

#### **2.7.5.1. Induction motor**

The most used motor in the industry is the induction motor, also known as asynchronous motor, due to its simplicity and the brushless structure. It has a rugged construction and besides, it is relatively cheap comparing with other types of motors. It is a type of AC motor.

#### **2.7.5.2. Synchronous motor**

The synchronous motor and the synchronous generator share the same construction, with the difference that the conversion of current and energy is reversed. The currents flowing through the 3-phase stator produce a magnetic field which rotates, as happened in the induction motor. Besides, a rotor coil shall have a DC current injected from outside through slip rings and brushes. This is what makes the synchronous motor more expensive than the induction motor, giving it also more maintenance necessities.

#### **2.7.5.3. DC motor**

The DC motor has some features that differs from the induction motor and the synchronous motor. In the DC motor, the armature and the field coils placement is reversed from those in the AC motors. In this case, the field coil is on the stator and the rotor contains the armature coil. The commutator and the brushes are the suppliers of the injected current in the rotor (armature). This kind of construction characteristics makes the DC motor expensive in terms of costs and maintenance.

#### **2.7.5.4. Solution adopted**

Despite of the high capital and maintenance costs, the DC motor is the most suitable type to our project. This is because of the using battery banks as the main power supply system. Using an AC motor would suppose new power converters to make the current appropriate for those motors, with the associated losses of power.

Using a couple of DC motors, the required task would be summed up in adjust the output voltage produced by the batteries into the input voltage required by the motors. Thus, we would save not just power supplying, but also a significant amount of money. On the following section will be explained which DC motor has been selected (**2.8.4. Motors** – page 116).

#### **2.7.6. Rectifiers**

It was stated previously that the rectifier should be out of the vessel, and being installed at the quay, due to the high values of power that the batteries will require. It is because of this that it will be supposed that the rectifier comply with the requirements fixed by the electrical system of the vessel and it will not be calculated in this document.

Nevertheless, there shall be necessary a power rectifier to convert the 230 Vac voltage into the 24 Vdc required at the Bridge. This rectifier will be supplied by both of the electrical systems through a two position selector switch, and it will be placed at the Bridge in order to reduce the voltage-drop values.

This rectifier must comply the power demands of the 24 Vdc devices, and it shall be able to supply the adequate amount of direct current required. The selected model can be checked at **2.8.5. Power rectifier** – page 117.

### 2.7.7. Inverters

Regarding with the power inverters there are several options that could fit with our system, and it depends specially on the input voltage. This means that we may set up the battery banks to produce different voltage levels.

The standard inverters used in the industry usually present a power converter capacity of 12 Vdc, 24 Vdc or 48 Vdc. Besides, the total power amount that they can handle is a parameter that must be taken into account as well. It would be possible to size a custom inverter as well, but as it is explained on the next paragraph, it is an option that we don't consider useful to this project.

#### 2.7.7.1. Solution adopted

As it will be shown on the Final results section (**2.8.3. Main power supply system** – page 103), the chosen battery bank is conformed of modules with a voltage window of 37,79 Vdc to 53,21 Vdc. This means that the rated voltage can be set as 48 Vdc. This is what makes us choose a power inverter with a input voltage level of 48 Vdc.

It will be necessary as well to calculate the amount of power that these inverters shall convert, in order to choose the type that fits best with our requirements.

### 2.7.8. Interior lighting

There are several companies that offers a huge range of lighting systems to marine applications. But what is really important is set the type of lighting that the vessel would need for each room. There are several types, such as LEDs, downlights, floodlights, etc. We should, as well, take into account the exit emergency lights to guide the passengers through the vessel during an hypothetical dangerous scenario, as well as the exterior lighting and the “exit” signals.

#### 2.7.8.1. Solution adopted

For the rooms where the passengers are thought to stay (i.e. Entrance, Toilet, Passengers Room and Anteroom), the adequate lighting are the downlights type. This is because of the false ceiling that present those rooms. With this structure, the lightings would be easily installed, due to the space given by the false ceiling.

On the other hand, for those rooms where the crew is expected to be or work (i.e. the Bridge and the Engine Rooms & Electrical Compartments), the option that best fits with our requirements is the LED lightings. The Bridge shall count with a LED in a red colour that will be turn on just during night performances.

For the exterior lighting, we will use an outdoor lighting, and more specifically, a facade lighting that allows us to hang it at several points out of the rooms.

Regarding with the brands, the GLAMOX group is one of the most suitable possibilities that we could choose. It has a wide range of downlights depending on the characteristics that would be needed. Also, it works with LED types of lightings, as well as exit emergency lightings and outdoor facades lightings, which makes it very suitable for the requirements presented in this document.

### **2.7.9. Ventilation**

Ventilation system will be sized on the Annexes section based on the calculation of the airflow required for the adequate maintenance (**3.2.1.4. Ventilation** – page 142). To achieve this goal, there will be used two different methods (one using the reference of “Air-conditioning and ventilation of machinery control-rooms on board ships - Design conditions and basis of calculations” UNE-EN ISO 8862 (1987), and the other one using the “15 renovations per hour” method). That one that gives the higher value of airflow will be chosen.

Regarding to the fan system, it shall be chosen by using the amount of airflow requirements previously calculated in the SODECA software, which allows to select hundreds of models and upload bulk data into Excel.

#### **2.7.9.1. Solution adopted**

For the fan system, the industrial standards set systems of 230 Vac or 400 Vac. For the purpose of the document, the 400 Vac system has no value or usefulness, due to the structure of electrical system in the vessel (i.e. battery banks which work in DC regime and whose power is transformer into 230 Vac through power inverters). Thus, the 230 Vac fans are those which are more suitable within this matter. In the Annexes section is shown what type of ventilation system recommends the SODECA software.

#### **2.7.10. Switchboards**

The switchboards must comply with some characteristics. They must be highly versatile, allowing the performance of several configurations suited to different installation structures within harsh climatic, space and service conditions. Within the distribution field, they must present characteristics related to the distribution switchboards, specially suited to the industrial field.

The switchboards are a basic component in the electrical system. The selection of their characteristics and features requires a detailed analysis of the service conditions as well as the reliability that it must assure. In order to comply this chore, the significant mechanical and electrical requirements that take place in such a limited space must be taken into account. The various issues that must be considered and that condition in a decisive way the geometrical sized of the switchboard are varied: environmental, electrical, thermic and mechanical.

##### **2.7.10.1. Environmental and thermic issues**

Based on the rule UNE EN 60439-1, we can define the standard conditions of service by setting the boundary environmental values within which must be assure the proper performance. It must be taken into account the following parameters: location, disposal, room temperature, relative humidity, height above sea level and the degree of pollution.



#### **2.7.10.2. Electrical issues**

The electric scheme is decisive in the selection of the cabinet referring to its dimensions. Focusing just in the dimensional issues, the required space (i.e. the cabinet dimensions) can be easily calculated from its catalogue, which give us the dimensions of the switchgear.

Nevertheless, there are several features that can determine the structure of the cabinet. Some of them are:

- Location of the input supply (i.e. from the bottom or from the top. Using cables or busbars).
- The required spaces in order to assure the inspection, verification and maintenance.

The complete selection of the cabinet must take into account the electrical characteristics related to the section of the installation where it is going to be installed. These electrical characteristics are:

- Rated insulation voltage.
- Maximum rated current.
- Short-circuit current.
- Peak current.

#### **2.7.10.3. Mechanical issues**

The cabinet must be sized to deal with the mechanical requirements that produce short-circuit current. The cabinet must assure its electrical features up to their maximum values.

#### **2.7.10.4. Solution adopted**

Finally, the chosen switchboard must comply with all the requirements explained

before. There are several brands that offer suitable switchboard systems for marine applications. At the Final Results section will be shown the device selected (**2.8.8. Switchboards** – page 121).

### **2.7.11. Conductors**

The electrical energy provided by the battery banks shall be transported to the place where the loads which are going to use it are situated. Such transport is carried by conductors, making them a part with great importance in this project.

Depending on the place and the situation where the conductors are going to be installed the conductors must fulfil several conditions.

Regulations made by classification societies study extensively this issue. The chosen society for this document DNV shall be used for the selection, calculation, and installation of the cables.

#### **2.7.11.1. Constitution and selection**

As it is known, the conductor itself must be isolated and protected. The obtained set is called cable. Therefore, every cable shall be built by:

- One or more conductors.
- An electrical insulation.
- A mechanic protections.
- A cable core.

The cable core shall be responsible of the transport of electricity. It shall be constructed of a metal having the characteristics of high conductivity and ductility, as well as a reasonable cost.

None as copper meets those requirements. Moreover, both the regulation and

different standards specify the use of annealed pure copper. The conductivity must be at least 98% in the international annealed copper type, defined by the International Electrotechnical Commission (IEC). The maximum value of the resistivity is set at  $0.01759 \Omega \cdot \text{mm}^2 / \text{m}$ . at  $20^\circ \text{C}$ . The copper conductors shall be tinned where it has to be in contact with rubber, as this is the material used for insulation.

#### **2.7.11.2. Electrical insulation**

There are several types of electrical insulation used in the protection of conductors. Generally, it is possible to summarize the insulation of the conductors in two ideas:

- The nature of the insulating enclosures must be based on the maximum temperatures of the cable cores.
- Within the same type of insulation, the thickness, spacing between conductors in the same enclosure, etc. must be a function of the operating voltages.

Among the different names used to designate the different types of insulation, we have used the nomenclature provided by DNV in the following table.

For short-circuit conditions, the conductor cross-section of cables shall be sufficient to prevent the insulation from being damaged by high temperatures occurring by short-circuits at the cable end. The conductor temperature classes are given in IEC 60092-351.

| Type of insulating compound                                                                             | Abbreviated designation | Maximum rated conductor temperature °C |               |
|---------------------------------------------------------------------------------------------------------|-------------------------|----------------------------------------|---------------|
|                                                                                                         |                         | Normal operation                       | Short-circuit |
| a) Thermoplastic:<br>- Based upon polyvinyl chloride or copolymer of vinyl chloride and vinyl acetate   | PVC                     | 70                                     | 150           |
| b) Elastomeric or thermoset:<br>– based upon ethylene-propylene rubber or similar (EPM or EPDM)         | EPR                     | 90                                     | 250           |
| – based upon high modulus or hard grade ethylene propylene rubber                                       | HEPR                    | 90                                     | 250           |
| – based upon cross-linked polyethylene                                                                  | XLPE                    | 90                                     | 250           |
| – based upon silicone rubber                                                                            | S 95                    | 95                                     | 350*          |
| – based upon ethylene-propylene rubber or similar (EPM or EPDM) halogen-free                            | HF EPR                  | 90                                     | 250           |
| – based upon high modulus or hard grade halogen-free ethylene propylene rubber                          | HF HEPR                 | 90                                     | 250           |
| – based upon halogen-free cross-linked polyethylene                                                     | HF XLPE                 | 90                                     | 250           |
| – based upon halogen-free silicone rubber                                                               | HF S 95                 | 95                                     | 350*          |
| – based upon cross-linked polyolefin material for halogen-free cables                                   | HF 90                   | 90                                     | 250           |
| * This temperature is applicable only to power cables and not appropriate for tinned copper conductors. |                         |                                        |               |

Table 6: Insulation temperature during normal operation and short-circuit <sup>44</sup>

PVC-insulated conductors without further protection may be used for installation

in closed piping system in accommodation spaces, when the system voltage is maximum 250 V.

PVC-insulated conductors may be used for internal wiring of switchboards and other enclosures, and for control wiring installed in closed piping system. Other types of flame retardant switchboard wires may be accepted for the same purpose.

Due to brittleness at low temperatures, cables with PVC insulation and or inner/outer sheath, shall normally not be installed in refrigerated chambers, and holds for temperatures below -20°C, or across expansion joints on weather decks. Due to poor mechanical strength, the use of silicon-rubber-insulated cables is limited to applications where a high temperature resistant cable is necessary (where the ambient temperature can be above 70°C).<sup>45</sup>

Electrical and mechanical characteristics shall comply with the specifications of Table 2, 3 and 4, respectively of IEC 60092-351.<sup>46 47</sup>

| Designation of the insulating compound                                                  | EPR and HF EPR | HEPR and HF HEPR | XLPE and HF XLPE | S 95 and HF S 95 | HF 90 | PVC   |
|-----------------------------------------------------------------------------------------|----------------|------------------|------------------|------------------|-------|-------|
| <b>1</b> Insulation resistance constant $K_i$ (MΩ·km)<br>(see Clause 17 of IEC 60502-1) |                |                  |                  |                  |       |       |
| 1a – at 20 °C, minimum;                                                                 | 3 670          | 3 670            | 3 670            | 1 500            | 500   | 36,7  |
| 1b – at maximum operating temperature, minimum                                          | 3,67           | 3,67             | 3,67             | 2                | 0,5   | 0,037 |
| <b>2</b> Increase in a.c. capacity after immersion in water at 50 °C                    |                |                  |                  |                  |       |       |
| 2a – between the end of the 1st and the end of the 14th day, maximum (%)                | 15             | 15               | –                | 15               | 15    | 15    |
| 2b – between the end of the 7th and the end of the 14th day, maximum (%)                | 5              | 5                | –                | 5                | 5     | 5     |

Figure 6: Test requirements for electrical characteristics of insulating compounds

45 DNV – Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 48 (July 2013)

46 DNV – Electrical Installations, Pt.4 Ch.8 Sec.9 – Page 90 (July 2013)

47 IEC 60092-351 – Page 8 (April 2004)

| Designation of the insulating compound                                                                               | EPR<br>and<br>HF EPR | HEPR<br>and<br>HF HEPR | XLPE<br>and<br>HF XLPE | S 95<br>and<br>HF S 95 | HF 90 | PVC  |
|----------------------------------------------------------------------------------------------------------------------|----------------------|------------------------|------------------------|------------------------|-------|------|
| Mechanical characteristics without ageing<br>(see 8.1 of IEC 60811-1-1)                                              |                      |                        |                        |                        |       |      |
| Tensile strength, minimum (N/mm <sup>2</sup> )                                                                       | 4,2                  | 8,5                    | 12,5                   | 5,0                    | 9,0   | 12,5 |
| Elongation at break, minimum (%)                                                                                     | 200                  | 200                    | 200                    | 150                    | 120   | 150  |
| Mechanical characteristics after ageing<br>in air oven (see 8.1 of IEC 60811-1-2)                                    |                      |                        |                        |                        |       |      |
| After ageing without conductor                                                                                       |                      |                        |                        |                        |       |      |
| Treatment – temperature (°C)                                                                                         | 135                  | 135                    | 135                    | 200                    | 135   | 100  |
| – tolerance (°C)                                                                                                     | ±2                   | ±2                     | ±2                     | ±3                     | ±2    | ±2   |
| – duration (h)                                                                                                       | 168                  | 168                    | 168                    | 240                    | 168   | 168  |
| Tensile strength:                                                                                                    |                      |                        |                        |                        |       |      |
| a) minimum value (N/mm <sup>2</sup> )                                                                                | –                    | –                      | –                      | 4,0                    | –     | 12,5 |
| b) variation, maximum (%)                                                                                            | ±30                  | ±30                    | ±25                    | –                      | ±30   | ±25  |
| Elongation at break:                                                                                                 |                      |                        |                        |                        |       |      |
| a) minimum value (%)                                                                                                 | –                    | –                      | –                      | 120                    | 100   | 150  |
| b) variation, maximum (%)                                                                                            | ±30                  | ±30                    | ±25                    | –                      | ±30   | ±25  |
| After ageing with copper conductor                                                                                   |                      |                        |                        |                        |       |      |
| Treatment – temperature (°C)                                                                                         | –                    | 150                    | –                      | –                      | –     | –    |
| – tolerance (°C)                                                                                                     | –                    | ±3                     | –                      | –                      | –     | –    |
| – duration (h)                                                                                                       | –                    | 168                    | –                      | –                      | –     | –    |
| Tensile strength:                                                                                                    |                      |                        |                        |                        |       |      |
| variation, maximum (%)                                                                                               | –                    | ±30                    | –                      | –                      | –     | –    |
| Elongation at break:                                                                                                 |                      |                        |                        |                        |       |      |
| variation, maximum (%)                                                                                               | –                    | ±30                    | –                      | –                      | –     | –    |
| Mechanical characteristics after ageing<br>in air bomb at (0,55 ± 0,02) MPa<br>(see 8.2 of IEC 60811-1-2)            |                      |                        |                        |                        |       |      |
| Treatment – temperature (°C)                                                                                         | 127                  | 127                    | –                      | –                      | –     | –    |
| – tolerance (°C)                                                                                                     | ±1                   | ±1                     | –                      | –                      | –     | –    |
| – duration (h)                                                                                                       | 40                   | 40                     | –                      | –                      | –     | –    |
| Tensile strength:                                                                                                    |                      |                        |                        |                        |       |      |
| variation, maximum (%)                                                                                               | ±30                  | ±30                    | –                      | –                      | –     | –    |
| Elongation at break:                                                                                                 |                      |                        |                        |                        |       |      |
| variation, maximum (%)                                                                                               | ±30                  | ±30                    | –                      | –                      | –     | –    |
| <sup>a</sup> Test is only applicable to cables having bare copper conductors without any separator on the conductor. |                      |                        |                        |                        |       |      |

Figure 7: Test requirements for mechanical characteristics of insulating compounds

| Designation of the insulating compound                        | EPR | HEPR | XLPE | § 95 | HF EPR | HF HEPR | HF XLPE | HF § 95 | HF 90 | PVC |
|---------------------------------------------------------------|-----|------|------|------|--------|---------|---------|---------|-------|-----|
| Pressure test at high temperature (see 8.1 of IEC 60811-3-1)  |     |      |      |      |        |         |         |         |       |     |
| – Test temperature (°C)                                       | –   | –    | –    | –    | –      | –       | –       | –       | –     | 80  |
| – Tolerance (°C)                                              | –   | –    | –    | –    | –      | –       | –       | –       | –     | ±2  |
| – Time under load – 1st case (h)                              | –   | –    | –    | –    | –      | –       | –       | –       | –     | 4   |
| – 2nd case (h)                                                | –   | –    | –    | –    | –      | –       | –       | –       | –     | 6   |
| Maximum permissible depth of indentation (%)                  | –   | –    | –    | –    | –      | –       | –       | –       | –     | 50  |
| Hot set test (see Clause 9 of IEC 60811-2-1)                  |     |      |      |      |        |         |         |         |       |     |
| Treatment                                                     |     |      |      |      |        |         |         |         |       |     |
| – temperature (°C)                                            | 250 | 250  | 200  | 250  | 250    | 250     | 200     | 250     | 200   | –   |
| – tolerance (°C)                                              | ±3  | ±3   | ±3   | ±3   | ±3     | ±3      | ±3      | ±3      | ±3    | –   |
| – time under load (min)                                       | 15  | 15   | 15   | 15   | 15     | 15      | 15      | 15      | 15    | –   |
| – mechanical stress (N/cm <sup>2</sup> )                      | 20  | 20   | 20   | 20   | 20     | 20      | 20      | 20      | 20    | –   |
| Maximum elongation under load (%)                             | 175 | 175  | 175  | 175  | 175    | 175     | 175     | 175     | 175   | –   |
| Maximum permanent elongation (%)                              | 15  | 15   | 15   | 25   | 15     | 15      | 15      | 25      | 15    | –   |
| Heat shock test (see 9.1 of IEC 60811-3-1)                    |     |      |      |      |        |         |         |         |       |     |
| Treatment                                                     |     |      |      |      |        |         |         |         |       |     |
| – temperature (°C)                                            | –   | –    | –    | –    | –      | –       | –       | –       | –     | 150 |
| – tolerance (°C)                                              | –   | –    | –    | –    | –      | –       | –       | –       | –     | ±3  |
| – duration (h)                                                | –   | –    | –    | –    | –      | –       | –       | –       | –     | 1   |
| Loss of mass test (see 8.1 of IEC 60811-3-2)                  |     |      |      |      |        |         |         |         |       |     |
| Treatment                                                     |     |      |      |      |        |         |         |         |       |     |
| – temperature (°C)                                            | –   | –    | –    | –    | –      | –       | –       | –       | –     | 80  |
| – tolerance (°C)                                              | –   | –    | –    | –    | –      | –       | –       | –       | –     | ±2  |
| – duration (h)                                                | –   | –    | –    | –    | –      | –       | –       | –       | –     | 168 |
| Maximum permissible loss of mass (mg/cm <sup>2</sup> )        | –   | –    | –    | –    | –      | –       | –       | –       | –     | 2   |
| Behaviour at low temperature (see Clause 8 of IEC 60811-1-4)  |     |      |      |      |        |         |         |         |       |     |
| Tests to be carried out without previous ageing:              |     |      |      |      |        |         |         |         |       |     |
| Bending test (for core diameter ≤12,5 mm)                     |     |      |      |      |        |         |         |         |       |     |
| – Test temperature (°C)                                       | –   | –    | –    | –    | –      | –       | –       | –       | –     | –15 |
| – Tolerance (°C)                                              | –   | –    | –    | –    | –      | –       | –       | –       | –     | ±2  |
| Elongation test (for cores not subjected to the bending test) |     |      |      |      |        |         |         |         |       |     |
| – Test temperature (°C)                                       | –   | –    | –    | –    | –      | –       | –       | –       | –     | –15 |
| – Tolerance (°C)                                              | –   | –    | –    | –    | –      | –       | –       | –       | –     | ±2  |
| – Elongation at break, minimum (%)                            | –   | –    | –    | –    | –      | –       | –       | –       | –     | 30  |
| Impact test                                                   |     |      |      |      |        |         |         |         |       |     |
| – Test temperature (°C)                                       | –   | –    | –    | –    | –      | –       | –       | –       | –     | –15 |
| – Tolerance (°C)                                              | –   | –    | –    | –    | –      | –       | –       | –       | –     | ±2  |

Figure 8: Test requirements for particular characteristics of insulating compounds

### 2.7.11.3. Mechanical protection

The insulating enclosures of the conductors shall be coated with one or more protective linings and envelopes, with armour. Usually, dimensional characteristics are not set, but it must be such as to enable the successful implementation of the required tests.

There are metallic or non-metallic linings.

- Non-metallic:
  - Synthetic rubber (polychloroprene) G2 and G3.
  - Chlorosulfonated polythene H.
  - Thermoplastic materials G5, G6 and G7.
  - Textile materials.
- Metallic:
  - Lead or lead-based alloy lining.
  - Copper or copper-based alloy lining.
  - Braided armour.
  - Metal strips armour.
  - Metal wires armour.

Braid and/or armour shall be separated from the core insulation by an inner non-metallic sheath, by tape or fibrous braid or roving.

Irrespective of the metal used, the nominal diameter of the braid wire shall be in accordance with the following table:<sup>48</sup>

| Diameter of core assembly under braid<br>(mm)*                                     | Minimum diameter of threads in braid<br>(mm)** |
|------------------------------------------------------------------------------------|------------------------------------------------|
| $D \leq 10$                                                                        | 0.2                                            |
| $10 < D < 30$                                                                      | 0.3                                            |
| $D \geq 30$                                                                        | 0.4                                            |
| * Diameter under braid is fictitious and calculated by the method of IEC 60092-350 |                                                |
| ** The “coverage density” of the braid shall be in accordance with IEC 60092-350.  |                                                |

*Table 7: Nominal diameter of braided wire*

48 DNV – Electrical Installations, Pt.4 Ch.8 Sec.9 – Page 91 (July 2013)



Mechanical and particular characteristics of sheath materials shall comply with the specifications of Table II and III respectively of IEC 60092-359.

The temperature classes for the sheath material shall be at least 85 °C. Sheath materials shall be used in accordance with the following table. For cables intended for dynamic applications (flexible cables), other materials may be accepted.<sup>49</sup>

| Material                                                                                                                                                             | Abbreviated designation   |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
| Thermoplastic:<br>— Based on polyvinylchloride or copolymer of vinylchloride and vinylacetate<br>— Halogen free                                                      | ST2<br><br>SHF1           |
| Elastomeric or Thermosetting:<br>— Based on polychloroprene rubber<br>— Based on chlorosulphonated polyethylene or chlorinated polyethylene rubber<br>— Halogen free | SE1<br><br>SH<br><br>SHF2 |

*Table 8: Type of protective sheaths*

## 2.8. Final results

Results will be shown in this section. Procedures are expressed and developed at the calculation annex.

### 2.8.1. Electric Power Load Analysis (EPLA)

The power values that will be required are calculated in this section. Those values allow us to lay out the wire sections, the protection mechanisms and energy

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<sup>49</sup> DNV – Electrical Installations, Pt.4 Ch.8 Sec.9 – Page 91 (July 2013)

contracting. For a better overview check the calculation annex.

Every electric device that works on the ship is studied in order to calculate the power forecast. A total power value is calculated as a sum of every single device power. Later, this value is fixed according to the simultaneity and utilization factors. Therefore the calculated power is the highest expected load which determines the structure of the installation.

In this project, the resulting power reaches a value of 91788 W during the Top Speed condition and 44188 W during the Function condition.

### **2.8.2. Electrical distribution type**

The chosen type shall be the “isolated neutral” type described on the previous section. This type of distribution and protection system is commonly used in ships because its greater reliability, since the grounding fault of one driver did not produce a fault current to ground so that the service is interrupted or cause damage staff.

The ground faults must be detected and corrected as soon as possible to maintain this advantage. If a second ground fault occurs, there will be a selective disconnection of the affected part through over-current protection circuits maintaining the crew safety at all times.

The hull (ground) is only and exclusively connected to the protective ground of the devices, i.e. their housing and all parts that an operator may have access in the normal use of appliances.

This type of distribution and protection system is supported by the Classification Societies, civil organizations and military rules.

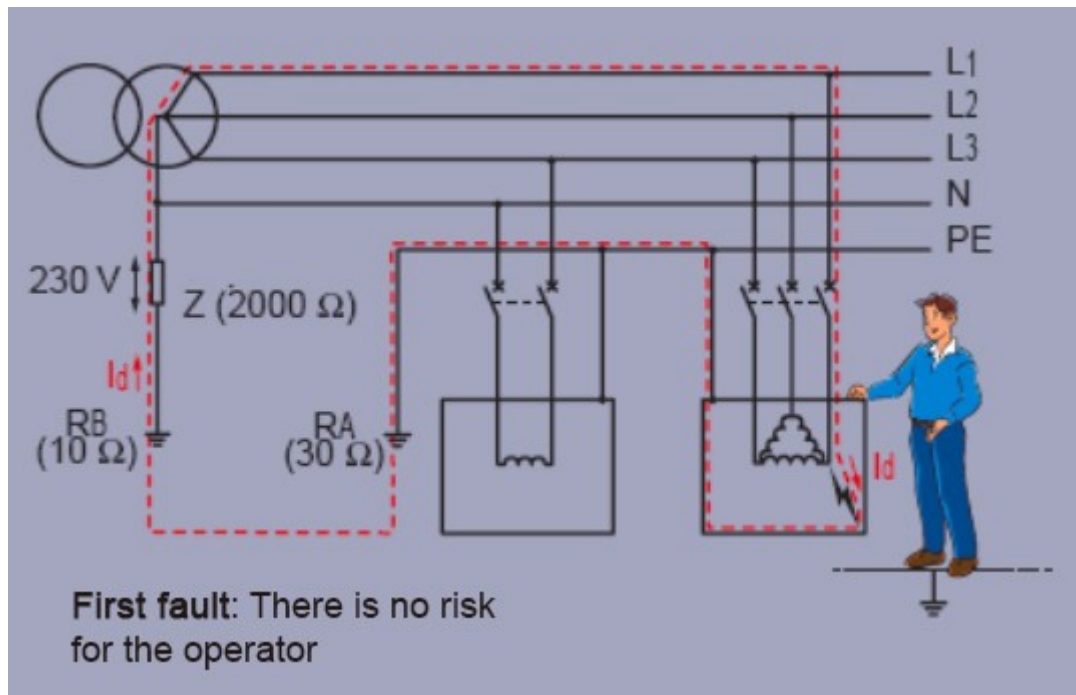


Figure 9: First fault scheme

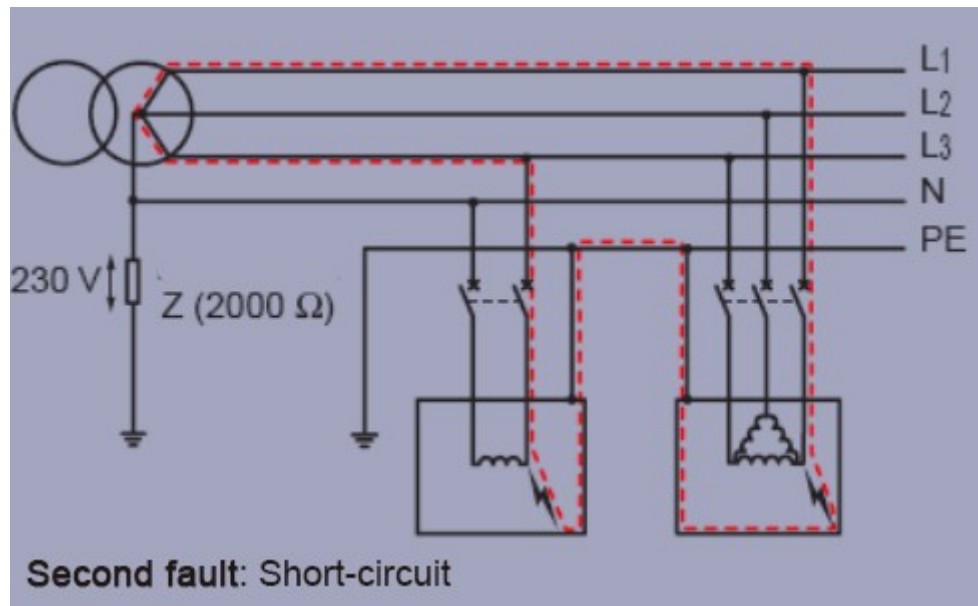


Figure 10: Second fault scheme

### 2.8.3. Main power supply system

As it shall be a pure electric vessel, the main power supply system shall be

conformed by battery banks, which shall be charged from the quay electrical installation through a battery charger. It will be necessary to size the banks in order to obtain enough time of electrical independence. Therefore, first will be necessary a power forecast so as to have knowledge of the amount of power required, and then, size the battery banks.

This battery charger must have potential enough to supply the battery banks, and that can lead us to place it out of the vessel. Besides, it is necessary to size a proper conductor to supply the batteries with this method.

Finally, the battery banks shall be connected in such a way that allow the motors work properly and be able at the same time to supply the rest of the loads. This means that the output voltage of the banks must fit with the required by the motors and at the same time with the power inverters that will supply the 230 Vac loads.

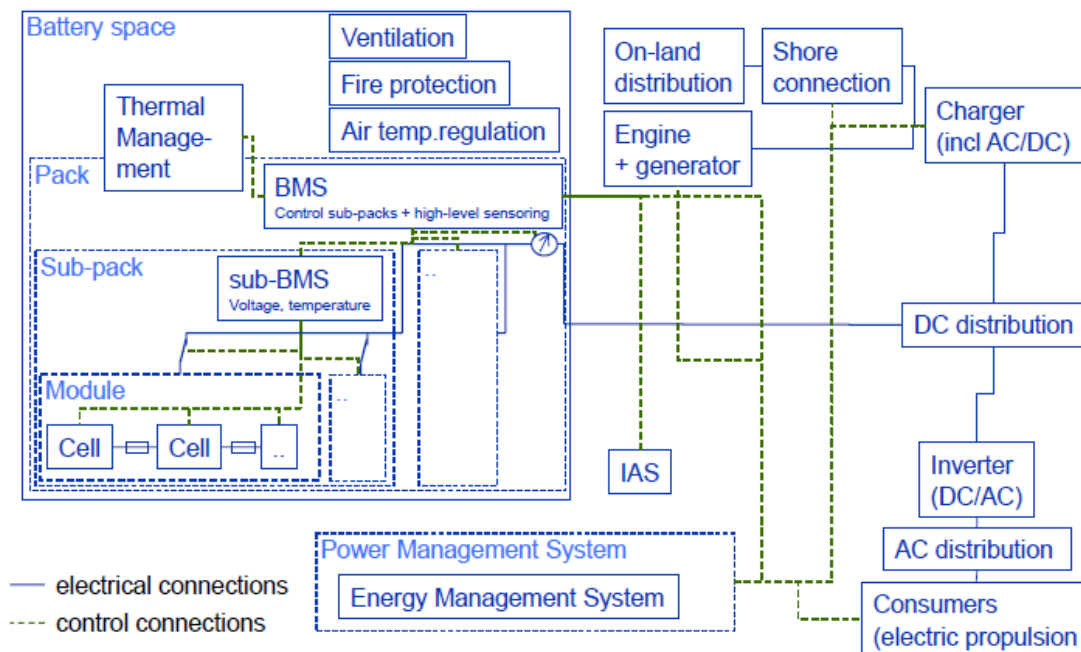


Figure 11: Block diagram of a generic battery bank system

As shown in Figure 11<sup>50</sup>, the main components of the generic battery system are the cells, the hardware needed for making battery modules and sub packs, the required components for thermal management, safety features as contactors and fuses, bus-bars and high voltage cabling, electronics, voltage and temperature sensors and low voltage cabling and connectors.

As it is shown in the Annexes section (**3.4. Battery banks selection**), the chosen battery bank shall be the SAFT SEANERGY model. Its main characteristics make it fit with the demands of the vessel. As a modular system, SEANERGY can be scaled to meet any requirements up to 750 V. The modules are based on SAFT's Li-ion Super Phosphate (SLFP) cell chemistry, which offers the advantage of improved high energy capability and optimized total cost of ownership when compared with standard Li-ion phosphate technologies.

Their main technical specifications, which can be checked in its catalogue at the end of the Annexes section (**3.10.1. Battery bank catalogue**), are as follows:

- **Nominal voltage (V):** 647
- **Capacity (Ah):** 82
- **Minimum energy (kWh):** 50
- **Nominal energy (kWh):** 53
- **Voltage window (V):** 529 to 745
- **Maximum charge voltage (V):** 750
- **Maximum discharge current (A):** 180
- **Nominal charge current (A):** 45
- **Recharge time (h):** 2

This battery bank presents several characteristic curves that are represented in its catalogue. This curves represents its discharge at various temperatures, at 25 °C at

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50 DNV – “GL Guideline for Large Maritime Battery Systems” (March 2014)

various rates and its cycle capability.

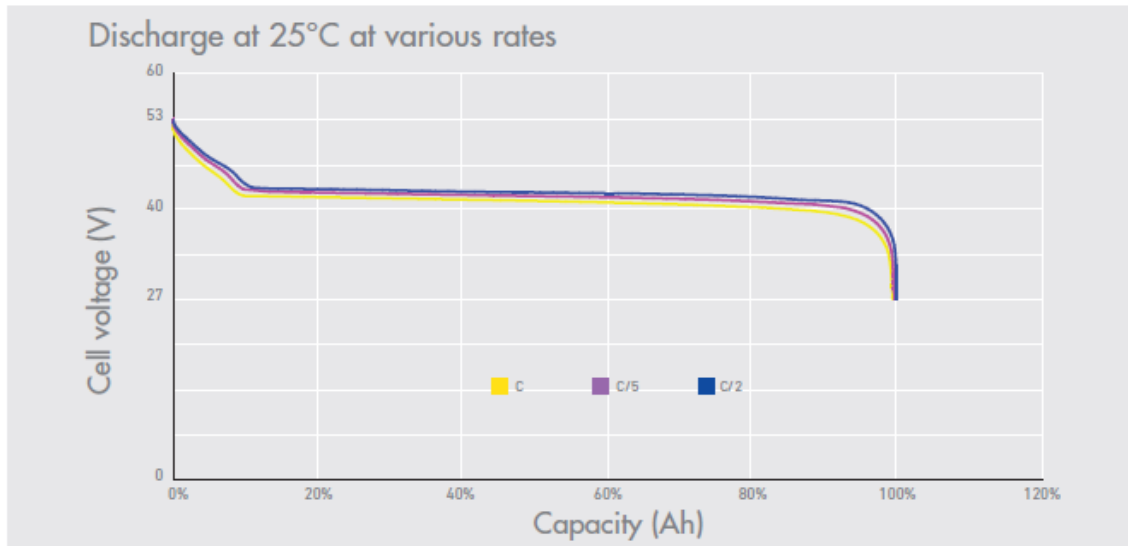


Figure 12: Discharge at 25 °C at various rates

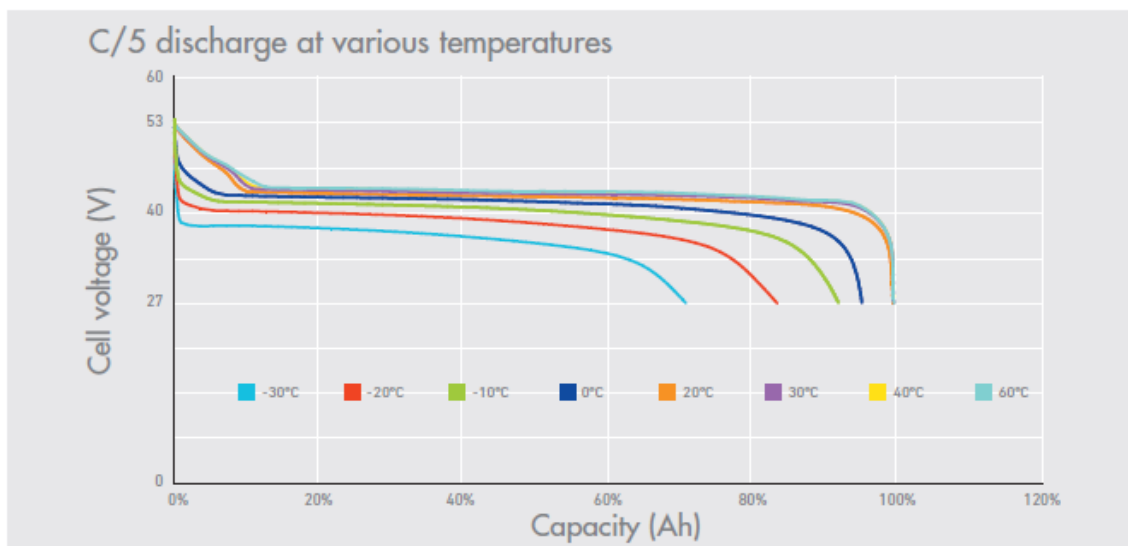


Figure 13: C/5 discharge at various temperatures

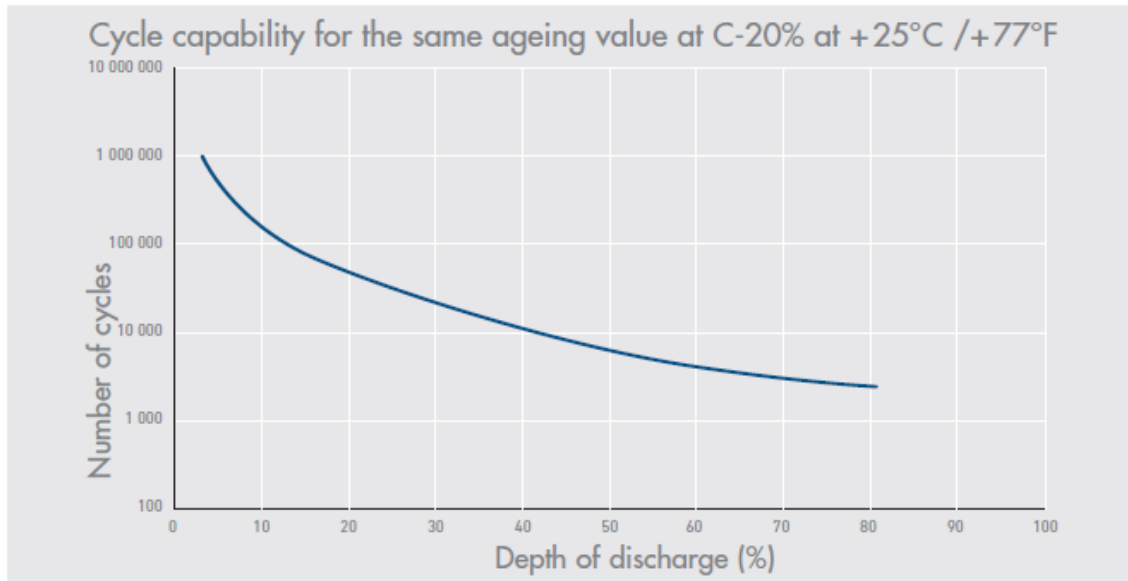


Figure 14: Cycle capability

#### 2.8.3.1. Advantages of the battery banks system

Implementing a battery bank in each hull of the vessel instead of any other option available to supply the electrical system gives us several advantages that must be taken into account, reinforcing this type of electrical arrangement and making it more suitable for future applications.

One of the most important advantages due to the use of battery banks is the space-saving of the Engine Rooms and the Electrical Compartments. There shall not be any need to use machinery meant to allow other devices to work, such as fuel pump or oil pump, with the consequent saving of room above named.

Also, the lack of use of diesel machinery reduces the risk of fire or explosion at the machinery rooms. Those risks shall not completely disappear, but their decrease will be meaningful.

By reducing the amount of machinery used another advantage may be taken into account, and that is that with less devices required to make the vessel work, there shall be less possibilities of lose one of them, with the consequently waste of money required

later on, and the wear of the machinery meant to restore the failure.

Space-saving due to the raw material required for the proper performance of the electrical system is another advantage that must be considered. There shall not be necessity of using fuel tanks, and thus less fire/explosion risks.

Noise reduction appears as an advantage as well, removing it from the diesel generators and fuel/oil supply systems. Battery banks are characteristic by their lack of noise production.

Compared to traditional batteries with water based electrolytes such as lead acid and nickel cadmium batteries, lithium ion batteries have two to eight times as much energy per weight unit. The high energy density as well as the use of a flammable electrolyte makes a safe design more challenging. Lithium based battery systems depend on a well designed and tested electronic control system for safe operations.<sup>51</sup>

Regarding to the SAFT SEANERGY battery bank, thanks to its modular construction, it is flexible to incoming changes or renovations, allowing the owner to adjust it according to the current demands.

#### **2.8.3.2. Battery system design**

When the ship building contract is signed, the responsibility and further design work is normally transferred to the yard. The yard prepares procurement packs for the various system components. It is recommended that potential battery providers are consulted at this phase.

Main priorities for a battery system for maritime applications are safety, reliability and sufficient life for the system to be economically feasible. All components in the battery systems must be of good quality to secure a safe and reliable system. The

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<sup>51</sup> DNV – “GL Guideline for Large Maritime Battery Systems” (March 2014)



integration and testing of the complete battery system is of similar importance as the quality of its single components. It is recommended that a safety assessment of the battery space is initiated in the design phase.

It is crucial to fully understand the duty cycles of the application as well as understanding the key requirements of the application for battery selection and optimum performance.

#### **2.8.3.3. Li-ion battery cells**

Li-ion based systems require that the voltage, current and temperature of each single cell in the system is monitored at all times. The voltage and current limits are temperature dependent. A proper system design requires that proper action can be taken if cell parameters are outside the manufacturer's recommendation. To decrease system complexity, temperature monitoring can include some predicted values based on measurements for a group of cells. We recommend redundancy in systems when predictive or correlated temperature measurements are used. Cells connected in parallel will have the same voltage and cells connected in series the same current.

There are a large number of manufacturers of different variants of Li-ion cells. Cell chemistries are optimized for different applications. In some applications the main focus is on high energy density and low cost. For other applications a very stable chemistry and long life is the main focus. Other applications can have a focus on power capabilities for charge or discharge or the ability to accept high current pulses for charge and discharge.

For maritime applications it is important to choose a cell with properties that can provide an optimum combination of safety, life, performance and cost for the application in question. A thorough understanding of all these aspects is required by the team doing the battery system design. To ensure this understanding, independent cell testing or advice from independent third parties who have done neutral testing may be required.

#### **2.8.3.4. Battery Management System (BMS)**

The electronic control system is frequently referred to as the Battery Management System (BMS). Voltage and temperature sensors are usually part of the module. It is recommended to consider some level of redundancy for these fundamental measurements, depending on the safety criticality of the system. The module may also include an electronic circuit board that controls the cells in the module via continuous checks and assessments. A key principle when locating sensors is to make the system in such a way that malfunctioning sensors may be detected. The module level BMS is part of the total battery electronic system.

The system may include additional sensor inputs such as current sensors and additional temperature sensors as well as other system specific sensors. It is recommended that each battery string has a separate current sensor in order to detect increased impedance that can lead to overheating. In addition, for systems containing a large number of strings, a group of strings can have a common current sensor. A “Master-BMS” usually controls the assembled battery system and communicates with the external power management system. It is crucial to ensure that the communication between the master BMS and the power management system for the actual application is properly specified for normal operation as well as for situations where a problem has occurred.

If a problem occurs in a battery system it may either be due to components or manufacturing failures. Software faults or inadequacies can also be a major source of problems. For problem solving and fault analyses it is important that all critical components in a battery system can be identified. All software and firmware version numbers and settings must be tracked. All critical components should have their unique number which should be traceable from the manufacturer of the component to final installation in a battery pack. The pack supplier should administer the database identifying the components used for the different modules and packs.

#### **2.8.3.5. Fabrication requirements**

Fabrication (manufacturing) requirements will vary substantially depending on the technology used. Some common requirements do however exist:<sup>52</sup>

- Product traceability.
- Cleanliness requirements.
- In-line and end-of-line (EOL) testing.
- Operator certification & training requirements.
- Health & safety regulations.

#### **2.8.3.6. Cleanliness requirements**

Battery systems are sensitive to contamination with materials that can initiate self-discharge, high impedance, loss of insulation or short-circuits. The cleanliness standards of the manufacturing facilities for each sub-assembly must address the risks associated with the sub-assembly in question. Sufficient internal separation of sub-assembly areas as well as separation of assembly areas, workshop, or packaging areas are usually necessary for both safety and performance reasons.

#### **2.8.3.7. Certification**

Construction and assembly of battery systems frequently involve operations that potentially introduce risk to operators. National regulations usually specify the required operator training for different voltage levels. In addition, the battery system manufacturer and power system supplier should have operator certification & training requirements and schedules to ensure necessary operator and product safety as well as product consistency and performance.

#### **2.8.3.8. Transportation**

In order to ensure safety during transport, nearly all lithium batteries are required

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52 DNV – “GL Guideline for Large Maritime Battery Systems” (March 2014)

to pass section 38.3 of the UN Manual of Tests and Criteria<sup>53</sup> (UN Transportation Testing) which is identical to IEC 62281. Note that this UN regulation is the only mandatory set of regulation for lithium-ion batteries today (12-2013).

Tests 1-8 of this specification are as follows:

- T1 – Altitude Simulation (Primary and Secondary Cells and Batteries).
- T2 – Thermal Test (Primary and Secondary Cells and Batteries).
- T3 – Vibration (Primary and Secondary Cells and Batteries).
- T4 – Shock (Primary and Secondary Cells and Batteries).
- T5 – External Short Circuit (Primary and Secondary Cells and Batteries).
- T6 – Impact (Primary and Secondary Cells).
- T7 – Overcharge (Secondary Batteries).
- T8 – Forced Discharge (Primary and Secondary Cells).

#### **2.8.3.9. Storage**

When storing battery cells a certain degree of self-discharge is inevitable. This could be both reversible and irreversible. The higher the storage temperature and the higher the state of charge of the cells, the higher the losses will be due to increased impedance. Most manufacturer ship battery cells and system at around 50% state of charge. It is important that cells and modules are not stored for longer period in hot climate. If the average storage temperature or temperature during transportation is above 30 - 35 °C, degradation due to calendar effects will accelerate. Considerations for storage prior to installation shall also include appropriate temperature and SOC safeguards.<sup>54</sup>

#### **2.8.3.10. Testing**

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<sup>53</sup> Recommendations on the Transport of Dangerous Goods. Manual of Tests and Criteria. 5th Revised Edition, December 2009. Section 38.3 refers to “Lithium Battery Testing Requirements

<sup>54</sup> DNV – “GL Guideline for Large Maritime Battery Systems” (March 2014)

The following tables<sup>55</sup> show examples for the range of test procedures which can be applied to a battery system for maritime applications by the battery system manufacturer. Some of these tests may be defined in the coming standard IEC62619 and will be applicable for testing. The tests are distinguished between TT (Type Test) and RT (Routine Test). The definitions are as follows:

- **Type Test (TT):** Conformity test made on one or more items representative of the production.
- **Routine Test (RT):** Conformity test made on each individual item during or after production.

The tests typically apply to either cell, module, sub pack or the complete battery system (column DUT – device under test).

| Test               | Comments                   | DUT            | TT/RT |
|--------------------|----------------------------|----------------|-------|
| Cell balancing     | According to specification | Battery system | RT    |
| SOC validation     | Validate the measured SOC  | Battery system | RT    |
| Charging behavior  | According to specification | Battery system | RT    |
| Discharge behavior | According to specification | Battery system | RT    |
| Capacity check     | According to specification | Battery system | RT    |

*Figure 15: Battery system performance tests*

| Test                  | Comments          | Component | TT/RT |
|-----------------------|-------------------|-----------|-------|
| Dielectrical strength | High Voltage test | Sub pack  | RT    |
| Insulation resistance |                   | Sub pack  | RT    |

*Figure 16: Battery system electrical tests*

<sup>55</sup> DNV – “GL Guideline for Large Maritime Battery Systems” (March 2014) (Pages 11 – 13)

| Test            | Comments                                 | Component      | TT/RT |
|-----------------|------------------------------------------|----------------|-------|
| Vibration       | IACS E10 /IEC 60092-504/ UN38.3/IEC62281 | Sub pack       | TT    |
| Drop            | UN38.3/IEC62281                          | Sub pack       | TT    |
| Heat            | IACS E10 /IEC 60092-504                  | Sub pack       | TT    |
| Cold            | IACS E10 /IEC 60092-504                  | Sub pack       | TT    |
| Corrosion       | IACS E10 /IEC 60092-504                  | Sub pack       | TT    |
| Flame retardant | IACS E10 /IEC 60092-504                  | Sub pack       | TT    |
| EMC             | IACS E10 /IEC 60092-504                  | Battery system | TT    |
| IP              | IEC 60529                                | Sub pack       | TT    |

*Figure 17: Battery system environmental tests*

| Test                               | Comments                                                                                                                                                                                                                                                                                                                                                                                           | Component        | TT/RT |
|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-------|
| External Short Circuit with no BMS | UN38.3/IEC62281                                                                                                                                                                                                                                                                                                                                                                                    | Module, Sub pack | TT    |
| External short with operable BMS   | Could also be performed with a complete string, requires a controller with breakers/relays                                                                                                                                                                                                                                                                                                         | Sub pack         | TT    |
| Internal Thermal Event             | Propagation on pack level. IEC62619 is assumed to cover relevant recommendations:<br>- unchanged module/pack structure (mechanical/electrical)<br>- SOC 100%, all cells balanced<br>- Normal temperature (alternative: max operation temperature)<br>- passive/charging/discharging status<br>- single cell set off on purpose (thermal element or other, cell location to be discussed)<br>- etc. | Sub pack         | TT    |
| Overcharge with no BMS             | UN38.3/IEC62281                                                                                                                                                                                                                                                                                                                                                                                    | Sub pack         | TT    |
| Emergency stop function            | -                                                                                                                                                                                                                                                                                                                                                                                                  | Battery system   | RT    |
| Alarms and shutdowns               | -                                                                                                                                                                                                                                                                                                                                                                                                  | Battery system   | RT    |
| HVIL                               | -                                                                                                                                                                                                                                                                                                                                                                                                  | Battery system   | RT    |
| Temperature protection BMS         | -                                                                                                                                                                                                                                                                                                                                                                                                  | Battery system   | RT    |
| Overvoltage protection BMS         | -                                                                                                                                                                                                                                                                                                                                                                                                  | Battery system   | RT    |
| Undervoltage protection BMS        | -                                                                                                                                                                                                                                                                                                                                                                                                  | Battery system   | RT    |
| Sensor failures                    | -                                                                                                                                                                                                                                                                                                                                                                                                  | Battery system   | TT    |
| Communication Failure              | -                                                                                                                                                                                                                                                                                                                                                                                                  | Battery system   | RT    |
| Reverse polarity protection        | -                                                                                                                                                                                                                                                                                                                                                                                                  | Battery system   | RT    |
| Nail Test                          | UL2580                                                                                                                                                                                                                                                                                                                                                                                             | Cell             | TT    |

Figure 18: Battery system safety tests

#### 2.8.3.11. Operating and maintenance

The normal use of the batteries should be fully automatic. There should be no need for manual interaction.

A plan for systematic maintenance and function testing shall be kept on-board showing in detail how components and systems shall be tested and what shall be observed during the tests. The plan shall include:

- Verification of the State Of Health (remaining lifetime of the batteries).
- Test of all instrumentation, automation and control systems affecting the battery system.
- Test intervals to reflect the consequences of failure involving a particular system. Functional testing of critical alarms should not exceed 3 month intervals. For non-critical alarms, the longest intervals are normally not to surpass 12 months.
- Acceptance criteria.
- Fault identification and repair.
- List of the supplier's service net.

Different battery systems will have different maintenance needs and maintenance recommendations. This should be included in the maintenance plan. Information about periodically testing should also be included in the vessels unmanned machinery space (E0) manual.

#### 2.8.4. Motors

The chosen motor is an Elco EP-10000. The vessel shall count with two units, one in each hull. Its main characteristics are as follow:

- **Boat size ranges:** 15 – 26 meters.
- **Horse power diesel equivalency:** 100 h.p.



- **Suggested horsepower replacement range:** 75 – 125 h.p.
- **Peak kW:** 73.5 kW.
- **Continuous kW:** 42.5 kW.
- **Miles per gallon equivalency:** 12 mpg.
- **Length:** 890 mm (35").
- **Width:** 480 mm (18.82").
- **Height:** 490 mm (19.25").
- **Weight:** 336 kg (740 lbs).
- **Cruising speed:** 7 – 9 knots.
- **Cruising time:** 6 – 2 hours.
- **Cruising range:** 34 – 18 nm.
- **Recharging time standard charger:** 3 – 4 hours.
- **Recharging time quick charger:** 2 – 3 hours.
- **Number of 12 volt 8-D batteries (245 Ah):** 12 batteries.
- **Battery bank voltage in total:** 144 Vdc.
- **Amps (maximum):** 295 A.

Its catalogue is added at the end of the Annexes section, on page 302 (**3.10.2. Motor catalogue**).

### **2.8.5. Power rectifier**

The battery charger chosen for this document is the MASTERVOLT Mass 24/75, whose specifications are listed as follows:

- **Nominal output voltage:** 24 V.
- **Total charge current:** 75 A.
- **Number of battery outlets:** 1
- **Battery capacity range:** 150-750 Ah.
- **Nominal input voltage:** 230 V (180-265 V), 50/60 Hz.

- **Supplies your system without battery:** Yes.
- **Display/read-out:** LED display.
- **Dimensions, h · w · d:** 420 x 318 x 130 mm.
- **Weight:** 7.7 kg.
- **Charge voltage Bulk:** 28.5 V.
- **Charge voltage Absorption:** 28.5 V.
- **Absorption time:** 4 hours.
- **Power consumption (DC side):** < 1 mA.
- **Full load consumption (230 V AC):** 2600 W.
- **Power factor control:** > 0.95
- **Temperature range (ambient temp.):** -25 °C to 80 °C, derating > 45 °C.
- **Protection degree:** IP23.

### 2.8.6. Power Inverter

The chosen inverter to convert the power from the battery banks for the 230 Vac network is the VICTRON ENERGY QUATTRO. Due to the structure of the electrical system, it must be used in both hulls. Its main characteristics, which can be checked in its catalogue (page 303 – 3.10.3.1. VICTRON ENERGY QUATTRO), are shown on the following list:

#### Output Specifications:

- **Continuous Output Power:** 8000 Watts.
- **Output Waveform:** Pure Sine 230Vac.
- **Nominal Efficiency:** 95% (Peak).
- **Output Frequency:** 50 Hz ± 1%.

#### Input Specifications:

- **Nominal Input Voltage:** 38 – 66 Vdc.

Dimensions:

- **Unit Weight:** 45 kg.
- **Unit Size L x W x H:** 470 x 350 x 280 mm.

### 2.8.7. Interior lighting

The vessel counts with a staves false ceiling, which is useful for covering cable trays and pipes, and for the set up of lightings inside the gaps of the ceiling. Thus, the downlight luminaires are the most suitable type of lightings within this project.

The GLAMOX group offers a wide range of downlights luminaires which are specially thought to perform in naval duties. Thus, the interior lighting of the vessel shall lie on this brand.

On the other hand, the Bridge, the Engine Rooms and the Electrical Rooms have requirements which make the LED type the most suitable. The GLAMOX group has also several luminaires which can do a proper performance.

For external lighting, GLAMOX offers also a variety of external facades luminaires that fits with the requirements of this project. They have a wide range of emergency lighting too that can be used.

For the Passengers room, as well as the Entrance, the Toilet and the Anteroom, the chosen lighting is a GLAMOX CASA 16 113F SI, which technical data are as follows:

- **Lamp power (W):** 13
- **Total consumption (W):** 19
- **Diameter (mm):** 160
- **Width (mm):** 176
- **Height (mm):** 100

- **Length (mm):** 419
- **Maximum ambient temperature (°C):** 25
- **IP classification:** 22

| Room         | Amount    | Power (W)  |
|--------------|-----------|------------|
| Entrance     | 9         | 171        |
| Toilet       | 2         | 19         |
| Passengers   | 24        | 456        |
| Anteroom     | 11        | 209        |
| <b>Total</b> | <b>46</b> | <b>874</b> |

*Table 9: Amount of GLAMOX CASA 16 113F SI*

At the Bridge, the Engine rooms and the Electrical rooms, the chosen lighting is a GLAMOX i70-1200 LED 4500 DALI 840, which technical data are as follows:

- **Total consumption (W):** 50
- **Diameter (mm):** 160
- **Width (mm):** 170
- **Height (mm):** 75
- **Length (mm):** 1194
- **Maximum ambient temperature (°C):** 45
- **IP classification:** 66/67

| Room                        | Amount   | Power (W)  |
|-----------------------------|----------|------------|
| Bridge                      | 1        | 50         |
| Engine Room (x2)            | 2        | 100        |
| Electrical compartment (x2) | 2        | 100        |
| <b>Total</b>                | <b>5</b> | <b>250</b> |

*Table 10: Amount of GLAMOX i70-1200 LED 4500 DALI 840*

The exterior lighting will be arranged using the GLAMOX JET 7 model, which is an outdoor facade lighting. Its main characteristics are as follows:

- **Total consumption (W):** 433
- **Width (mm):** 195
- **Height (mm):** 580
- **Length (mm):** 426
- **IP classification:** 65

For the emergency lighting, the chosen type is the GLAMOX E85-S as well as the GLAMOX E80-S for the “exit” indication.

All the catalogues are added at the end of the Annexes section (**3.10.5. Luminarie catalogues** – page 310).

### **2.8.8. Switchboards**

In this section will be explained the performance of each switchboards, recalling that it must have the same structure in both hulls.

#### Motor switchboard (144 Vdc):

This switchboard is responsible of supplying the motor from the 3x4 modules of the battery banks. As it was previously explained, the battery bank is sized to supply the 144 Vdc switchboard as well as the 48 Vdc. This switchboard shall count with the suitable protections. It must have an interconnection with the same switchboard placed in the other hull.

#### Main switchboard (48 Vdc):

This switchboard is responsible of receiving the energy coming from the 48 Vdc battery bank and deliver it to the 230 Vac switchboard through the power inverter. It

shall be placed close to the battery bank, in the Electrical Room. It shall comply with all the requirements set by the classification society, referring to location, position, tests and applicable regulations explained in the Terms and Conditions section.

Ship services switchboard (230 Vac):

This switchboard is responsible of receiving the energy coming from the power inverter and deliver it to the one-phase loads as well as to the rectifier converter responsible of supplying the 24 Vdc devices of the Bridge and also to its 230 Vac switchboard. The Bridge shall be supplied by both electrical systems through a two position selector switch.

Depending on the system that we are developing, the switchboard shall be placed at one of the corners of the room that it is supplying, and in the opposite side of the other one. For this purpose, the switchboards shall comply with all the demands stated at the Terms and Conditions section, referring to location, position, tests and applicable regulations.

The switchboard shall count with all the switch-gears required for the protection of the loads connected to it, as well as the voltage, current, frequency and power meters, complying as well with all the demands stated at the Terms and Conditions section.

It must have an interconnection with the same switchboard placed in the other hull.

Bridge devices switchboard (24 Vdc):

This switchboard is responsible of receiving the energy from both 230 Vac systems, through the above mentioned two position selector switch. It shall be placed at the Bridge, and it must comply with all the requirements set by the classification society, referring to location, position, tests and applicable regulations explained in the Terms and Conditions section.

The Bridge devices switchboard must deliver direct current to all the devices working at the Bridge, and shall count with all the switch-gears required for the protections of the loads, as well as voltage, current and power meters, complying with the regulations explained in the Terms and Conditions section.

Emergency switchboard:

As it has been explained previously, the vessel shall not have an specific emergency system, but a interconnection with the electrical system in the other hull. So when a failure happens, the interconnection must be able to supply the load of the whole system.

Solution adopted:

For this project, we have chose a LEGRAND XL<sup>3</sup> 160. Its characteristics can be checked at the Annexes section (**3.10.9. Switchboard catalogue** – page 340).

### 2.8.9. Conductors

In order to fulfil the requirements established by the Classification Society, the conductors that have been selected to this task are EXZHELLENT – MAR Rdt from GENERAL CABLE, whose catalogues are added at the end of the Annexes section (page 320 – **3.10.6. Conductor catalogues**). The main characteristics of those conductors are, as they are specified on the catalogue, the following ones:

- **Conductor:** annealed copper, stranded class 5.
- **Insulation:** halogen free cross linked polyethylene (hf xlpe) iec 60092-351.
- **Inner covering:** halogen free thermoplastic polyolefine (optional).
- **Outer sheath:** halogen free thermoplastic polyolefin.

These are flexible cables for marine applications with special performance of flame spread and low emission of smoke and fumes.

## 2.9. Planning

Using a table, it shall be arranged chronologically every activity thought to be performed referring to its length in days. All machines shall be tested onboard, after installation, so that acceptable starting and running performance are verified with full capacity of driven equipment, alternatively full generator load.<sup>56</sup>

| Activity     | Description                     | Length (days) |
|--------------|---------------------------------|---------------|
| 1            | Batteries installation          | 5             |
| 2            | Motors installation             | 3             |
| 3            | Power Inverters installation    | 3             |
| 4            | Power Rectifier installation    | 2             |
| 5            | Interior Lighting installation  | 5             |
| 6            | Emergency Lighting installation | 4             |
| 7            | External Lighting installation  | 3             |
| 8            | Extractor Fans installation     | 3             |
| 9            | Bilge Pump installation         | 3             |
| 10           | Wires installation              | 5             |
| 11           | Interconnections                | 3             |
| 12           | Final Test                      | 5             |
| <b>TOTAL</b> |                                 | <b>44</b>     |

*Table 11: Planning*

## 2.10. Documents order

The following list sets the priority order between the documents of the project, based on the UNE 157001 rule:

- Blueprints

<sup>56</sup> DNV – Electrical Installations, Pt.4 Ch.8 Sec.5 – Page 77 (July 2013)



- Terms of references
- Budget
- Memory



## 3. ANNEXES

Electrical Engineering Degree

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## Annexes

|                                                               |            |
|---------------------------------------------------------------|------------|
| <b>3.ANNEXES.....</b>                                         | <b>125</b> |
| 3.1.Introduction.....                                         | 131        |
| 3.2.EPLA (Electric Power Load Analysis).....                  | 131        |
| 3.2.1.230 Vac power forecast.....                             | 133        |
| 3.2.1.1.Interior lighting.....                                | 133        |
| 3.2.1.2.Emergency lighting.....                               | 137        |
| 3.2.1.3.External lighting.....                                | 139        |
| 3.2.1.4.Ventilation .....                                     | 140        |
| 3.2.1.5.Electric plant and auxiliary systems consumption..... | 147        |
| 3.2.1.6.Outfit & furnishing consumption .....                 | 149        |
| 3.2.1.7.230 Vac power forecast.....                           | 150        |
| 3.2.2.Direct current networks power forecast.....             | 150        |
| 3.2.2.1.24 Vdc network power forecast.....                    | 151        |
| 3.2.2.2.144 Vdc network power forecast.....                   | 152        |
| 3.2.3.Total power forecast.....                               | 153        |
| 3.3.Circuit distribution.....                                 | 154        |
| 3.3.1.Passengers Room.....                                    | 155        |
| 3.3.2.Entrance & Toilet.....                                  | 157        |
| 3.3.3.Anteroom.....                                           | 159        |
| 3.3.4.Bridge.....                                             | 161        |
| 3.3.5.Engine Room & Electrical Compartment.....               | 163        |
| 3.4.Battery banks selection.....                              | 165        |
| 3.4.1.Solution adopted.....                                   | 165        |
| 3.4.2.Battery banks connection.....                           | 167        |
| 3.4.3.Connection with the quay.....                           | 168        |
| 3.4.4.Connection with the motors.....                         | 172        |
| 3.4.5.Connection with 230 Vac network.....                    | 174        |
| 3.5.Power inverter selection.....                             | 177        |

---

|                                                                       |     |
|-----------------------------------------------------------------------|-----|
| 3.6.Rectifier selection.....                                          | 177 |
| 3.7.Conductors & switches.....                                        | 179 |
| 3.7.1.Requirements.....                                               | 179 |
| 3.7.1.1.Maximum admissible current (or maximum heating) criteria..... | 179 |
| 3.7.1.2.Maximum voltage-drop criteria.....                            | 180 |
| 3.7.1.3.Temperature correction factors.....                           | 182 |
| 3.7.1.4.Cable grouping correction factors.....                        | 183 |
| 3.7.1.5.Calculation of the growth margin.....                         | 184 |
| 3.7.2.Cross-section calculation.....                                  | 185 |
| 3.7.2.1.24 Vdc cross-section calculation.....                         | 185 |
| 3.7.2.2.144 Vdc cross-section calculation.....                        | 193 |
| 3.7.2.3.230 Vac cross-section calculation.....                        | 196 |
| 3.7.2.4.Switchboards cross-section calculation.....                   | 221 |
| 3.7.2.5.Power inverter cross-section.....                             | 226 |
| 3.7.3.Short-circuit currents calculation.....                         | 227 |
| 3.7.3.1.24 Vdc short-circuit current calculation.....                 | 227 |
| 3.7.3.2.230 Vac short-circuit current calculation.....                | 235 |
| 3.7.3.3.Switchboards short-circuit current calculation.....           | 247 |
| 3.7.3.4.Power inverter protection.....                                | 249 |
| 3.7.4.Protection of the motors.....                                   | 251 |
| 3.7.5.Interconnection .....                                           | 251 |
| 3.7.5.1.144 Vdc interconnection (Motors).....                         | 252 |
| 3.7.5.2.230 Vac interconnection.....                                  | 254 |
| 3.7.6.Bridge selector switch.....                                     | 256 |
| 3.7.7.Rating of earth conductors.....                                 | 256 |
| 3.8.Basic Health and Safety Study.....                                | 257 |
| 3.8.1.Introduction.....                                               | 257 |
| 3.8.1.1.Justification of the Basic Health and Safety Study.....       | 257 |
| 3.8.1.2.Aim.....                                                      | 258 |
| 3.8.1.3.Works data.....                                               | 259 |
| 3.8.1.4.Electric power supply.....                                    | 259 |

---

|                                                                    |     |
|--------------------------------------------------------------------|-----|
| 3.8.1.5.Drinking water supply.....                                 | 259 |
| 3.8.1.6.Sanitary facilities.....                                   | 259 |
| 3.8.1.7.Servitude and conditions.....                              | 259 |
| 3.8.2.Safety standards to be applied in the works.....             | 260 |
| 3.8.2.1.Incompatibility between standards.....                     | 260 |
| 3.8.3.Validity.....                                                | 260 |
| 3.8.4.Changes in the Basic Health and Safety Study.....            | 260 |
| 3.8.5.Organization and responsibilities.....                       | 261 |
| 3.8.6.Works characteristics.....                                   | 262 |
| 3.8.6.1.Location.....                                              | 262 |
| 3.8.6.2.Works description.....                                     | 262 |
| 3.8.6.3.Implementation time.....                                   | 262 |
| 3.8.6.4.Amount of workers.....                                     | 262 |
| 3.8.6.5.Machinery.....                                             | 262 |
| 3.8.6.6.Electrical and instruments installation.....               | 262 |
| 3.8.6.7.Machines.....                                              | 262 |
| 3.8.6.8.Auxiliary sources.....                                     | 263 |
| 3.8.7. Protections.....                                            | 263 |
| 3.8.7.1.Collective protections.....                                | 263 |
| 3.8.7.2.Individual Protection Equipment.....                       | 264 |
| 3.8.8.Risk prevention.....                                         | 264 |
| 3.8.8.1.Training.....                                              | 264 |
| 3.8.9.Preventive medicine.....                                     | 265 |
| 3.8.10.Medical supervision.....                                    | 265 |
| 3.8.11.First aid at work .....                                     | 265 |
| 3.8.12.Intervention and first aid.....                             | 265 |
| 3.8.13.Medical care in temporary or permanent work disability..... | 266 |
| 3.8.14.Accident/incident information.....                          | 266 |
| 3.8.15.Budget .....                                                | 266 |
| 3.8.16.Further works.....                                          | 267 |
| 3.8.17.Promoter's obligations.....                                 | 267 |

|                                                                  |     |
|------------------------------------------------------------------|-----|
| 3.8.18. Health and Security Coordinator.....                     | 267 |
| 3.8.19. Security and Health Plan.....                            | 268 |
| 3.8.20. Contractor and Subcontractor's responsibilities.....     | 269 |
| 3.8.21. Self-employed workers' responsibilities.....             | 270 |
| 3.8.22. Book of Incidents.....                                   | 271 |
| 3.8.23. Work stoppage.....                                       | 272 |
| 3.8.24. Worker's rights.....                                     | 272 |
| 3.8.25. Minimum safety and health requirements in the works..... | 272 |
| 3.9. DIALux results.....                                         | 273 |
| 3.9.1. Interior lighting.....                                    | 273 |
| 3.9.2. DIALux – Emergency lighting.....                          | 284 |
| 3.10. Catalogues.....                                            | 293 |
| 3.10.1. Battery bank catalogue.....                              | 293 |
| 3.10.1.1. SAFT SEANERGY Battery System.....                      | 293 |
| 3.10.1.2. SEANERGY Modules.....                                  | 295 |
| 3.10.2. Motor catalogue.....                                     | 297 |
| 3.10.2.1. ELCO EP-10000.....                                     | 297 |
| 3.10.3. Power inverter catalogue.....                            | 298 |
| 3.10.3.1. VICTRON ENERGY QUATTRO.....                            | 298 |
| 3.10.4. Ventilation fan catalogue.....                           | 300 |
| 3.10.4.1. NEOLINEO-100-Q.....                                    | 300 |
| 3.10.5. Luminarie catalogues.....                                | 304 |
| 3.10.5.1. GLAMOX CASA 16 13F SI.....                             | 304 |
| 3.10.5.2. GLAMOX I70 LED.....                                    | 306 |
| 3.10.5.3. GLAMOX E85-S.....                                      | 308 |
| 3.10.5.4. GLAMOX E80-S.....                                      | 310 |
| 3.10.5.5. GLAMOX JET 7.....                                      | 312 |
| 3.10.6. Conductor catalogues.....                                | 314 |
| 3.10.6.1. PROTOMONT NSSHÖU.....                                  | 314 |
| 3.10.6.2. EXZHELLENT – MAR RDt.....                              | 318 |
| 3.10.7. Switch catalogues.....                                   | 321 |

|                                                   |     |
|---------------------------------------------------|-----|
| 3.10.7.1.Schneider Electric iC60N.....            | 321 |
| 3.10.7.2.Schneider Electric C120N.....            | 322 |
| 3.10.7.3.Schneider Electric CM 18070.....         | 324 |
| 3.10.7.4.Schneider Electric Interpact INS250..... | 325 |
| 3.10.7.5.Schneider Electric Interpact INS80.....  | 327 |
| 3.10.7.6.Schneider Electric NSX400N.....          | 329 |
| 3.10.8.Battery Charger catalogue.....             | 330 |
| 3.10.8.1.MASTERVOLT Mass 24/75.....               | 330 |
| 3.10.9.Switchboard catalogue.....                 | 333 |
| 3.10.9.1.Legrand XL3 160.....                     | 333 |
| 3.10.10.High-current socket.....                  | 335 |
| 3.10.10.1.Marechal PFQ3.....                      | 335 |



### 3.1. Introduction

This document aims to study the development of a zero-emission propulsion system in a double hull vessel. Therefore, calculations must have to be made in order to size and fixed every requirement referred to the subject matter.

When we call it a zero-emission propulsion system, it is assumed that we are working with a pure electric propulsion system. This compels us to develop a complete study of the whole electric system that shall work in the vessel, in order to size it properly and adapted to the propulsion requirements.

It shall be necessary to calculate a detailed power forecast of all the loads and consumers of the system. Some of them, such as lighting or ventilation, shall require an independent study. Once that this power prevision has been calculated, we will be able to size the battery banks required for the electrical independence of the vessel.

### 3.2. EPLA (Electric Power Load Analysis)

In order to calculate the power forecast, it is necessary to know all the electrical devices installed, and with their rated powers obtain the total value. Once every device is determined, an Excel file will be created, and it shall contain the power balance with all the necessary data. The total value shall be the sum of every single power value. This sum shall be composed of different groups, laying on the several rooms. It is possible to distinguish between the following rooms:

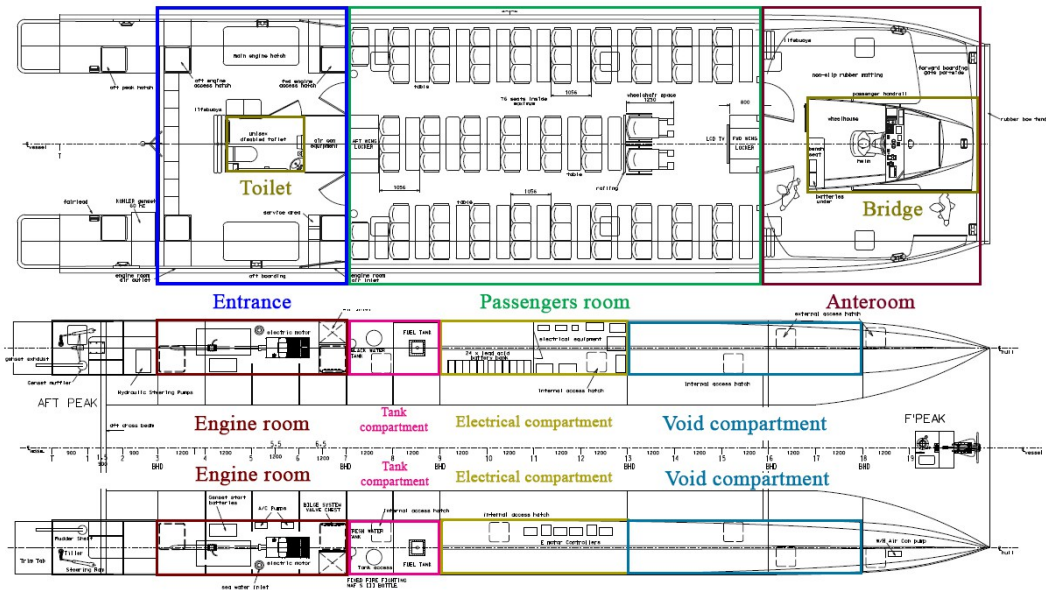


Figure 19: Rooms scheme

Those divisions are made following the criteria of a better understanding due to the structure of the ship. The area of every room is represented on the following table, which is divided in both decks:

| Floor        | Room                        | Area (m <sup>2</sup> ) |
|--------------|-----------------------------|------------------------|
| First floor  | Entrance                    | 23,6                   |
|              | Toilet                      | 2,59                   |
|              | Passengers room             | 60,27                  |
|              | Anteroom                    | 22,99                  |
|              | Captain's bridge            | 6,07                   |
| Second Floor | Engine room (x2)            | 5,88 (x2)              |
|              | Tank compartment (x2)       | 2,85 (x2)              |
|              | Electrical Compartment (x2) | 5,87 (x2)              |
|              | Void compartment (x2)       | 5,78 (x2)              |

Table 12: Planning

In order to select the battery bank that suits the most with the vessel structure

and its requirements within the power consumption, it will be necessary to gather the sum of the total power consumption, i.e. both 230 Vac and 24 Vdc networks, as well as the motors. Due to that, on the following sections will be calculated every consumer in both networks, and then the battery banks capacity shall be obtained. The load consumption shall differ depending on the condition in which the vessel is (i.e. Shore, Function, Top Speed...), and therefore load factors shall be used, referring to the situations described in **2.6.7. Operating conditions** (page 43).

### 3.2.1. 230 Vac power forecast

In this section, every load that is connected to the 230 Vac network will be studied, in order to know its consumption when the electric factors are applied.

#### 3.2.1.1. Interior lighting

In order to calculate the interior lighting that fits with the required parameters, the DIALux software shall be used. Within this software, every room that needs lightings shall be defined using its measures of surfaces. As a result, a new 3D simulation of the rooms is generated. We must comply with the requirements stated at **2.6.18. Lighting conditions** (page 51).

DIALux shall calculate the amount of lightings that every room needs, using as a reference the values of  $E_m$  (average illuminance) and UGR (upper limit for direct glare) given by the document “Lighting of indoor workplaces” EN-12464-1 (June 2011). Nevertheless, some rooms, like the Toilet and the Entrance, due to their own features, could not fulfil every requirement, because their size (Toilet) or the lack of walls (Entrance)

First of all, we will define the parameters which have a performance within this calculation.

- **Illuminance (E):** Describes the quantity of luminous flux falling on a surface. It

decreases by the square of the distance (inverse square law). Its unit is Lux (lx).

$$\text{Illuminance: } E(\text{lx}) = \frac{\text{luminous flux}(\text{lm})}{\text{area } (\text{m}^2)}$$

- **Unified Glare Rated (UGR):** Is the upper limit for direct glare. The UGR value calculated in the design process must lie below the following formula:

$$\text{UGR} = 8 \log \left[ \frac{0.25}{L_b} \sum \left( \frac{L^2 \omega}{p^2} \right) \right]$$

Where:

- **$L_b$ :** Background luminance
  - **$L^2$ :** Every luminance in the room squared
  - **$\omega$ :** The solid angle of the luminaire from the viewer's position
  - **$p^2$ :** Guth index, value which defines its phase-angle shift
- **$U_o$ :** Is the ratio between the lowest ( $E_{\min}$ ) and the main illuminance level ( $\bar{E}$ ) in the area that is evaluated. The result is a minimum level.

It is necessary to define what type of task or activity is supposed to be performed in every room, so as to know the values of illuminance and UGR required. Referring to “Lighting of indoor workplaces” EN-12464-1 (June 2011), the following table may be fulfilled.

| Room            | Task/Activity                                       | Illuminance (E) | UGR | U <sub>o</sub> |
|-----------------|-----------------------------------------------------|-----------------|-----|----------------|
| Entrance        | Places of public assembly / General areas / Lounges | 200             | 22  | 0.4            |
| Toilet          | Cloakrooms, washrooms, bathrooms, toilets           | 200             | 25  | 0.4            |
| Passengers Room | Places of public assembly / General areas / Lounges | 200             | 22  | 0.4            |
| Anteroom        | Places of public assembly / General areas / Lounges | 200             | 22  | 0.4            |
| Bridge          | -                                                   | -               | -   | -              |
| Engine Room     | -                                                   | -               | -   | -              |
| Electrical Room | -                                                   | -               | -   | -              |

Table 13: Illuminance requirements<sup>57</sup>

The Bridge, the Engine Rooms and the Electrical Rooms shall not follow specific requirements, due to its size and the necessity of facilitate the performances of the operators.

As it was defined previously at the Memory, the Bridge shall count with one white LED up to 300 lux during the day and one red LED up to 20 lux at night. The Engine Rooms and Electrical Rooms shall have at least two LEDs each one, placed at a low level, in order not to disturb the operators.

As it was stated previously at the Memory, the lightings of the Entrance, Toilet, Passengers Room and Anteroom shall be downlights, in order to take advantage of the

<sup>57</sup> "Lighting of indoor workplaces" EN-12464-1 (June 2011)

ceiling. On the other hand, the Bridge, the Engine Rooms and the Electrical Rooms shall count with LED luminaires placed at a low level in order not to glare the operators. The limited space of the machinery rooms makes a good reason as well to put the LEDs at a low level.

Thus, DIALux is able to calculate the conditions in every room. The UGR levels may be calculated only at the rooms that have an squared structure. Besides, in rooms like the Bridge, the Engine Rooms and the Electrical rooms it is not necessary to calculate it. The results obtained by DIALux shall be shown at the of this Annexes section (**3.9. DIALux results** – page 278).

A number of fundamental conclusions can be drawn from the pages previously referred:

- The luminaires of the Entrance have a characteristic structure which does not fit with the symmetrical arrangement. That is due to the fact that it is an outdoor room, so its luminaires shall be placed in a aesthetically way.
- The UGR levels of the Toilet (19 at its peak) do not fulfill the requirements (25). This can be ignored due to its size. There is no point in adding more luminaires in such a small room.
- The UGR levels of the Passengers Room are 22 at its peak, which does fulfill the requirements, as the Illuminance levels do as well (212 lx as average).
- The luminaires of the Passengers Room were modified from the original arrangement. The staggered pattern was used, in order to adjust the illuminance for the seats structure. Thus, the corridors shall count with a luminaires lines over them, as well as the seat lines.
- Although the Anteroom has a non-squared structure, its luminaires does follow a symmetrical arrangement. Nevertheless, this non-squared structure does not allow the software to calculate its UGR levels.
- The Bridge counts with a LED at its ceiling, which shall be used mainly at night

and preferably in a red colour.

- Both Engine Rooms have the same illuminaire arrangement: Two LEDs placed in a staggered way at the bottom. Thus, the operators would be able to work in a proper way.
- Both Electrical Compartments have the same illuminaire arrangement: Three LEDs placed at the ceiling, allowing a proper performance from the operators.

We can sum up the previous results in the tables below:

| Room            | Amount    | Power (W)  |
|-----------------|-----------|------------|
| Entrance        | 9         | 171        |
| Toilet          | 2         | 38         |
| Passengers Room | 24        | 456        |
| Anteroom        | 11        | 209        |
| <b>Total</b>    | <b>46</b> | <b>874</b> |

*Table 14: Amount of GLAMOX CASA 16 113F SI*

| Room                               | Amount    | Power (W)  |
|------------------------------------|-----------|------------|
| Bridge                             | 1         | 50         |
| Engine Room (Port)                 | 2         | 100        |
| Engine Room (Starboard)            | 2         | 100        |
| Electrical compartment (Port)      | 3         | 150        |
| Electrical compartment (Starboard) | 3         | 150        |
| <b>Total</b>                       | <b>11</b> | <b>550</b> |

*Table 15: Amount of GLAMOX i70-1200 LED 4500 DALI 840*

### 3.2.1.2. Emergency lighting

DIALux allows us to calculate the emergency lighting required too. For this task, we will use the GLAMOX E85-S. Their task shall be to indicate the exit way to the

passengers and the crew in case of emergency situation.

This luminaires should count with an independent circuit distribution in every switchboard, as it is state at **3.3. Circuit distribution** (page 156), and they may be grouped in the same one due to their low power demands. They must, as far as possible, do not disturb the installation of the interior lighting.

Every room in the vessel shall count with a emergency lighting network. Once again, their distribution can be checked at page 289, **3.9.2. DIALux – Emergency lighting**.

The amount of luminaries used to the emergency lighting are summed up in the following table:

| Room                               | Amount    | Power (W)  |
|------------------------------------|-----------|------------|
| Entrance                           | 5         | 25         |
| Toilet                             | 2         | 10         |
| Passengers Room                    | 8         | 40         |
| Anteroom                           | 7         | 35         |
| Bridge                             | 2         | 10         |
| Engine Room (Port)                 | 2         | 10         |
| Engine Room (Starboard)            | 2         | 10         |
| Electrical compartment (Port)      | 4         | 20         |
| Electrical compartment (Starboard) | 4         | 20         |
| <b>Total</b>                       | <b>36</b> | <b>180</b> |

*Table 16: Amount of GLAMOX E85-S*

Besides, the Bridge, Anteroom and the Passengers Room shall have emergency exit signals in some of their doors. For this task, we have choose the GLAMOX E80-S.



They work with their own batteries and are not essential for the power forecast of this document.

The catalogues of every lighting named here can be checked at the end of the Annexes section, from page 310 onwards (**3.10.5. Luminarie catalogues**).

### 3.2.1.3. External lighting

For this task, we will use the GLAMOX JET 7. The external lighting will be implemented as a single circuit connected to the Bridge 230 Vac switchboard, and it will use 7 luminaries distributed among the exterior of the vessel.

Once that every lighting has been calculated, we have to obtain the total power value. As it is shown in the tables, the total power values reaches values of 874 W, 550 W and 180 W. However, it is necessary to apply load factors in order to obtain the actual power value that shall be used. In order to obtain this, the document from Naval Sea Systems Command “Electric power load analysis (EPLA) for surface ships” DDS 310-1 REV 1 shall be checked by using the load factors recommended in each situation.<sup>58</sup>

| Device       | Load        | LF       | Essential     | LF       | Shore         | LF       | Function      | LF       | Top Speed     |
|--------------|-------------|----------|---------------|----------|---------------|----------|---------------|----------|---------------|
| Downlight    | 874         | 0,6      | 524,4         | 0,4      | 349,6         | 0,6      | 524,4         | 0,6      | 524,4         |
| LED          | 550         | 0,9      | 495           | 0,9      | 495           | 0,9      | 495           | 0,9      | 495           |
| Emergency    | 180         | 1        | 180           | 1        | 180           | 1        | 180           | 1        | 180           |
| External     | 3031        | 0,1      | 303,1         | 0,2      | 606,2         | 0,2      | 606,2         | 0,2      | 606,2         |
| <b>Total</b> | <b>4635</b> | <b>-</b> | <b>1502,5</b> | <b>-</b> | <b>1630,8</b> | <b>-</b> | <b>1805,6</b> | <b>-</b> | <b>1805,6</b> |

Table 17: 230 V luminaires load factors

Emergency lighting shall be used only during emergency situations. Nevertheless, it shall be constantly supplied in order to maintain their batteries charged

<sup>58</sup> Naval Sea Systems Command “Electric power load analysis (EPLA) for surface ships” DDS 310-1 REV 1 – Appendix A (September 2012)

and ready to work in any situation.

The most restrictive value is 1199,4 W, i.e. 1,20 kW. This value will be later necessary to calculate the power needed on the 230 Vac system.

$$P_L = 1805,6 \text{ W}$$

#### **3.2.1.4. Ventilation**

Some of the rooms that compose the vessel have electrical devices which may produce dangerous gases or significant heat emissions. Specifically, those rooms are the Engine Rooms and the Electrical Rooms.

Due to that, a ventilation system must be designed in order to maintain the proper values of temperature and pureness in the air.. To achieve this goal, an adequate amount of airflow shall be calculated, complying with the requirements stated on **2.6.22. Ventilation** (page 54).

There are several methods to understand and calculate the amount of airflow required in each room, depending on the heat produced by the devices and the number of air renovations per hour. Because of that, different values may be calculated. Nevertheless, we will implement the “15 renovations per hour” method due to its simplicity. Each room shall be studied separately (both Engine Rooms and Electrical Rooms have equal structures). Nevertheless the procedures shall be equal.

The “15 renovations per hour” method lays on the fact that a minimum times of air renovation shall take place inside the room. Once that the number of renovations per hour is known, the amount of air flow needed can be calculated.

If  $V$  represents the volume of the room, i.e. width · heigth · length, and  $N$  is the number of renovations per hour, the minimum air flow  $Q$  is:

$$\dot{Q} = V \cdot N$$

At this point, it is necessary to know the volume of every room under consideration. Once that all of them are known, we can proceed with the air flow calculation.

| Room                   | Width (m) | Length (m) | Height (m) | Volume (m <sup>3</sup> ) | Airflow (m <sup>3</sup> ·h <sup>-1</sup> ) |
|------------------------|-----------|------------|------------|--------------------------|--------------------------------------------|
| Engine Rooms           | 4,53      | 1,30       | 1,65       | 9,72                     | 145,8                                      |
| Electrical Compartment | 4,53      | 1,29       | 1,65       | 9,64                     | 144,6                                      |

*Table 18: Volume and airflow calculation*

Once that all the air flows required are calculated, it is time to calculate electric power of the fans. In order to achieve this, it is mandatory to obtain the effective power. The next formula is used to calculate it:

$$P_{ef} = \dot{Q} \cdot p$$

Where:

- **P<sub>ef</sub>**: Effective power (W)
- **p**: Pressure to overcome the friction of the fans (Pa)

The dimensional analysis of the previous formula is as follows:

$$W = \frac{m^3}{h} \cdot Pa$$

$$W = \frac{m^3}{h} \cdot \frac{h}{3600 \text{ s}} \cdot \frac{kg}{m \cdot s^2}$$

$$W = \frac{m^2 \cdot kg}{3600 \text{ s}^3}$$

The standard value to overcome the friction of the fans is 500 Pa. So it give us the following results for each pair of rooms:

- Engine Rooms:  $P_{efl} = \frac{145,8 \cdot 500}{3600} \rightarrow \mathbf{P_{efl} = 20,25 \text{ W}}$
- Electrical Rooms:  $P_{efl} = \frac{144,6 \cdot 500}{3600} \rightarrow \mathbf{P_{efl} = 20,08 \text{ W}}$

Finally, the electric power of the fans is calculated joining the previous value with the performances of the fans and the motors of the fans, using the following formula:

$$P_e = \frac{P_{ef}}{\eta_f \cdot \eta_m}$$

Where:

- $\mathbf{P_e}$ : Electric power (W)
- $\mathbf{\eta_f}$ : Fan performance
- $\mathbf{\eta_m}$ : Motor performance

The performance values may be, as a reference, 0,7 for the fan performance and 0,8 for the motor performance. Thus, the following results can be extracted from the previous formula.

- Engine Rooms:  $P_{el} = \frac{20,25}{0,7 \cdot 0,8} \rightarrow \mathbf{P_{el} = 36,16 \text{ W}}$

- Electrical Rooms:  $P_{e2} = \frac{20,08}{0,7 \cdot 0,8} \rightarrow P_{e2} = 35,86 \text{ W}$

Finally, in order to choose a suitable fan which fulfils every requirement previously calculated, we will use the SODECA QuickFan Selector software, which bring us a wide range of industrial fans.

Within this software, the selected fan for both pair of rooms is the NEOLINEO-100-Q, whose characteristics are represented on the following table:

| NEOLINEO-100-Q characteristics                     |               |
|----------------------------------------------------|---------------|
| Maximum airflow (m <sup>3</sup> ·h <sup>-1</sup> ) | 200,00/168,98 |
| Speed (rpm)                                        | 2450/2070     |
| Weight (kg)                                        | 1,20          |
| Peak Power (kW)                                    | 0,02/0,01     |
| Hz/phases                                          | 50/1          |
| Peak Current (A)                                   | 0,07/0,05     |

*Table 19: Fan characteristics*

Some of its features are as follows:

- Fan:**
  - Self-extinguishing plastic enveloping.
  - External terminal box with varying position.
- Motor:**
  - Ball bearing motors, IPX4 protection, with two adjustable speeds.
  - Single-phase 220-240 V 50/60 Hz.
  - Working temperature: -10°C → +60°C.
- Surface:**

- White self-extinguishing plastic.

Its dimensions and its blueprint are as follows:

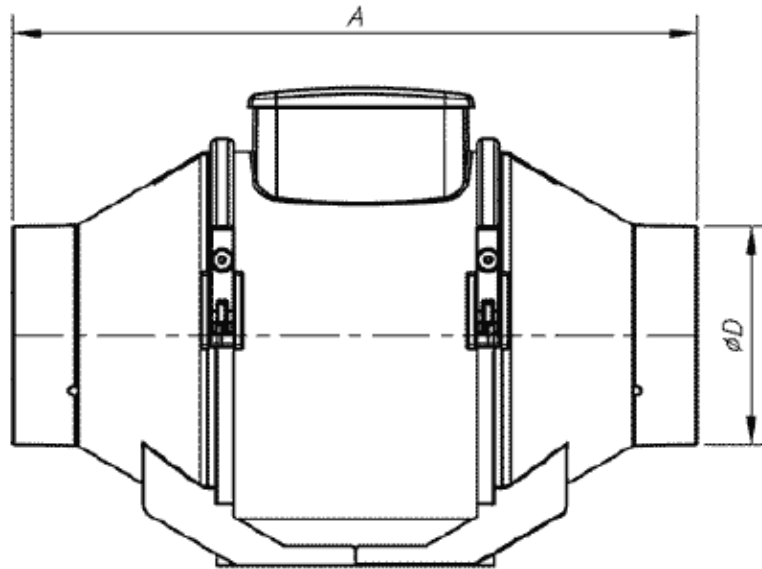


*Figure 20: Fan dimensions*

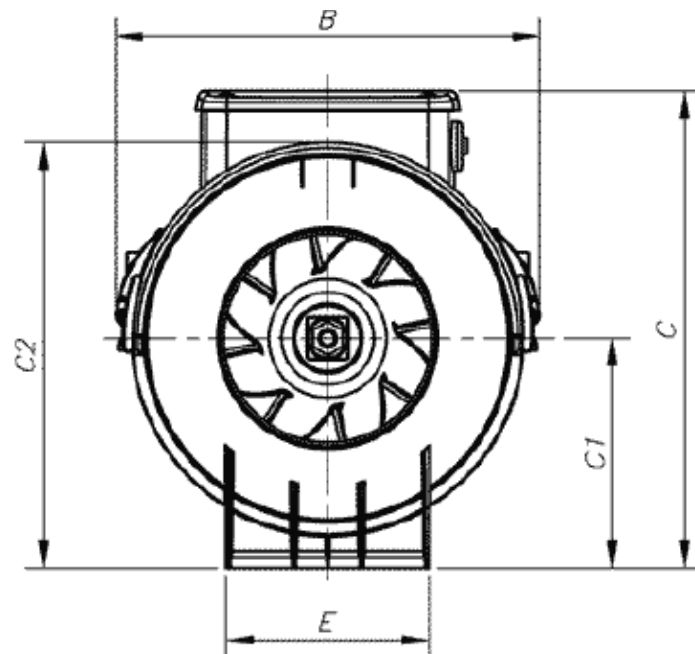


*Figure 21: Fan dimensions 2*

Where:

- **A:** 231 mm
- **B:** 156 mm
- **C:** 174 mm
- **C1:** 82 mm
- **C2:** 152 mm
- **ØD:** 96 mm
- **E:** 95 mm

The characteristic and acoustic curve for  $145 \text{ kg}\cdot\text{m}^{-3}$  is represented on the following graph, whose parameters are gathered as follows:

| Operating Point                            | 1      | PS     |
|--------------------------------------------|--------|--------|
| $\text{rpm}_{\text{max}}$                  | 2450   | 2450   |
| $Q \text{ (m}^3\cdot\text{h}^{-1}\text{)}$ | 178,03 | 150,42 |
| Pe (mmca)                                  | 1,5474 | 1,1046 |
| Pd (mmca)                                  | 2,4281 | 1,7333 |
| Pt (mmca)                                  | 3,9755 | 2,8379 |
| Speed (rpm)                                | 2450   | 2070   |
| Maximum Temperature (°C)                   | 60     | 60     |
| Air Speed ( $\text{m}\cdot\text{s}^{-1}$ ) | 6,30   | 5,32   |

Table 20: Characteristic and acoustic curve parameters

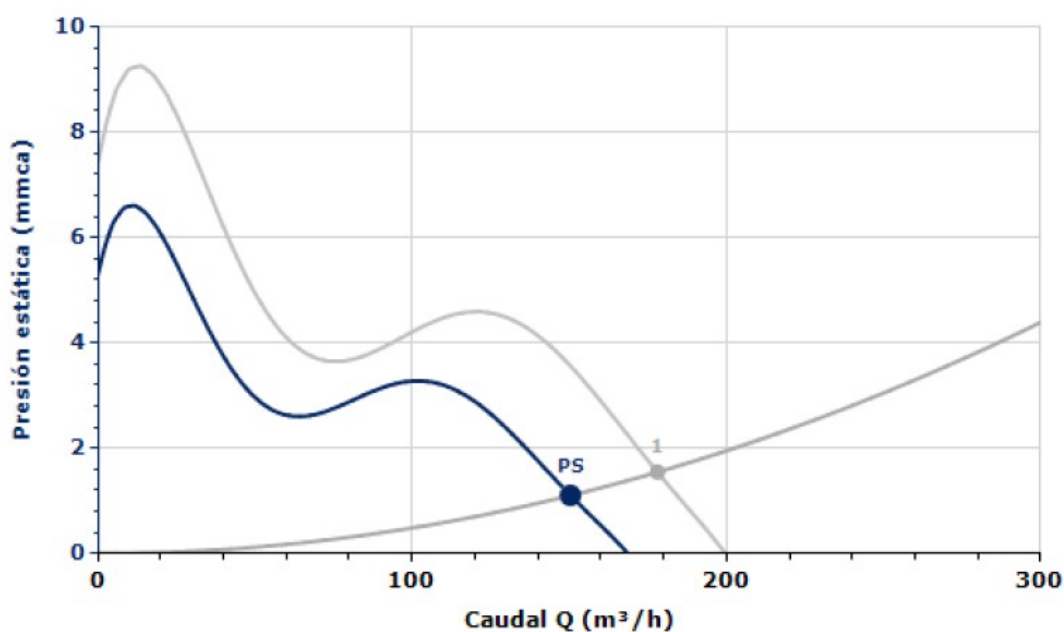


Figure 22: Characteristic and acoustic curve of the fan

Once that we have their peak values, we can adjust their values with the electrical factors, that are represented on the following table and that must be summed on the 230 Vac power forecast later.

| Device       | Load (W)  | LF       | Essential (W) | LF       | Shore (W) | LF       | Function (W) | LF       | Top Speed (W) |
|--------------|-----------|----------|---------------|----------|-----------|----------|--------------|----------|---------------|
| Fan 1        | 20        | 0,9      | 18            | 0,2      | 4         | 0,9      | 18           | 0,9      | 18            |
| Fan 2        | 20        | 0,9      | 18            | 0,2      | 4         | 0,9      | 18           | 0,9      | 18            |
| Fan 3        | 20        | 0,9      | 18            | 0,2      | 4         | 0,9      | 18           | 0,9      | 18            |
| Fan 4        | 20        | 0,9      | 18            | 0,2      | 4         | 0,9      | 18           | 0,9      | 18            |
| <b>Total</b> | <b>80</b> | <b>-</b> | <b>72</b>     | <b>-</b> | <b>16</b> | <b>-</b> | <b>72</b>    | <b>-</b> | <b>72</b>     |

Table 21: Fan load factors

As it is shown, 72 W is the value more restrictive, and it must be added to the 230 Vac power forecast.



$$P_F = 72 \text{ W}$$

### 3.2.1.5. Electric plant and auxiliary systems consumption

In this section we will encompass those devices which have an specific performance within the electric plant, and also, those whose operation is involve with the previous one.

Firstly, single-phase sockets which shall be used are listed on the following table. It is assumed that its rated power value is 100 W. It shall be distinguish between both floors.

|             | Room                             | Amount | Power (W) |
|-------------|----------------------------------|--------|-----------|
| Upper floor | Entrance                         | 4      | 400       |
|             | Toilet                           | 2      | 200       |
|             | Passengers                       | 26     | 2600      |
|             | Anteroom                         | 4      | 400       |
|             | Bridge                           | 2      | 200       |
| Lower floor | Engine Room Port                 | 2      | 200       |
|             | Engine Room Starboard            | 2      | 200       |
|             | Electrical Compartment Port      | 2      | 200       |
|             | Electrical Compartment Starboard | 2      | 200       |
| Sum         |                                  |        | 4600      |

Table 22: Single-phase sockets

Furthermore, sockets also needs their load factors in order to obtain a realistic power consumption.

| Load (W) | LF  | Essential (W) | LF  | Shore (W) | LF  | Function (W) | LF  | Top Speed (W) |
|----------|-----|---------------|-----|-----------|-----|--------------|-----|---------------|
| 4600     | 0,1 | 460           | 0,2 | 920       | 0,2 | 920          | 0,2 | 920           |

*Table 23: Load factors of sockets*

$$P_s = 920 \text{ W}$$

Besides, within the electric plant we can find the battery rectifier, which power consumption is shown on the following table:

| Load (W) | LF  | Essential (W) | LF  | Shore (W) | LF  | Function (W) | LF  | Top Speed (W) |
|----------|-----|---------------|-----|-----------|-----|--------------|-----|---------------|
| 2600     | 0,6 | 1560          | 0,4 | 1040      | 0,6 | 1560         | 0,6 | 1560          |

*Table 24: Battery rectifier load*

$$P_{BR} = 1560 \text{ W}$$

So, the electric plant shall have a consumption which will be the previous values summed up:

$$P_{EP} = P_s + P_{BR}$$

$$P_{EP} = 920 + 1560$$

$$\mathbf{P_{EP} = 2480 \text{ W}}$$

Within the auxiliary systems consumption we will find the fans previously calculated for ventilation as well as the air conditioning system, which has been used as a baseline date regarding to the surface of the Passengers Room (i.e. due to the fact that the Passengers Room has a surface of 60,27 m<sup>2</sup>, it will need an air conditioning system

that reaches approximately 2 kW of power consumption). Thus, the power consumption from the auxiliary systems shall be as follows:

| Load (W) | LF | Essential (W) | LF  | Shore (W) | LF  | Function (W) | LF  | Top Speed (W) |
|----------|----|---------------|-----|-----------|-----|--------------|-----|---------------|
| 2000     | 0  | 0             | 0,8 | 1600      | 0,8 | 1600         | 0,8 | 1600          |

*Table 25: Air conditioning system load*

$$P_{AC} = 1600 \text{ W}$$

This value, summed up with the fans load previously calculated, will show us the auxiliary systems total consumption:

$$P_{AS} = P_F + P_{AC}$$

$$P_{AS} = 72 + 1600$$

$$P_{AS} = 1672 \text{ W}$$

#### **3.2.1.6. Outfit & furnishing consumption**

Besides, it will be necessary to include other components, as a LCD TV, a sound amplifier, an air conditioning system, etc. for the enjoyment and comfort of the passengers. These elements have used as a baseline data, as well as their rated power consumption. They are gathered, together with their load factors, in the table below:

| Device       | Load (W) | LF  | Essential (W) | LF  | Shore (W) | LF  | Function (W) | LF  | Top Speed (W) |
|--------------|----------|-----|---------------|-----|-----------|-----|--------------|-----|---------------|
| LCD TV       | 52       | 0,1 | 5,2           | 0,1 | 5,2       | 0,5 | 26           | 0,5 | 26            |
| Amplifier    | 480      | 0,1 | 48            | 0,1 | 48        | 0,5 | 240          | 0,5 | 240           |
| Water heater | 750      | 0   | 0             | 0,2 | 150       | 0,2 | 150          | 0,2 | 150           |
| Total        | 1282     | -   | 53,2          | -   | 203,2     | -   | 416          | -   | 416           |

Table 26: Leisure components and load factors

$$P_{LC} = 416 \text{ W}$$

### 3.2.1.7. 230 Vac power forecast

To obtain the total power value that shall be required at the 230 Vac network, it is necessary to gather every consumer within this network. With the total value, it will be possible to determine how much power shall need this network system. This task may be fulfilled summing up every load calculated at the previous sections.

$$P_{230Vac} = P_L + P_{EP} + P_{AS} + P_{LC}$$

$$P_{230Vac} = 1805,6 + 2480 + 1672 + 416$$

$$P_{230Vac} = 6373,6W$$

As it has been calculated, the 230 Vac network system will require 6,3736 kW of power supply from the battery banks. This parameter will be important during the selection of the power inverters.

### 3.2.2. Direct current networks power forecast

Now it is time to calculate the required power supply in the Direct Current networks, which includes the devices in the Bridge as well as the propulsion machinery. The following sections will calculate those loads.

**3.2.2.1. 24 Vdc network power forecast**

To obtain the total power value that shall be required at the 24 Vdc network, it shall be necessary to gather every load within this system.

First of all, the following table shall define every 24 Vdc load.

| Device                     | Load (W)    |
|----------------------------|-------------|
| Magnetic compass           | 100         |
| Anemometer                 | 100         |
| Navigation & signal lights | 600         |
| Searchlight                | 900         |
| DGPS                       | 10          |
| Electromagnetic log        | 100         |
| Telephone system           | 100         |
| Exterior communications    | 400         |
| Radar                      | 300         |
| <b>Total</b>               | <b>2610</b> |

*Table 27: 24 V loads*

As it is shown, the total power value is 2610 W, i.e. 2,6 kW. However, it is necessary to apply load factors in order to obtain the real power value that shall be used. In order to obtain this, the document from Naval Sea Systems Command “Electric power load analysis (EPLA) for surface ships” DDS 310-1 REV 1 shall be checked in order to use the load factors recommended for each operating condition.

Therefore, the new power value will be determine by the use of the following power factors:

| Device                     | Load (W)    | LF       | Essential (W) | LF       | Shore (W) | LF       | Function (W) | LF       | Top Speed (W) |
|----------------------------|-------------|----------|---------------|----------|-----------|----------|--------------|----------|---------------|
| Magnetic compass           | 100         | 0,9      | 90            | 0        | 0         | 0,9      | 90           | 0,9      | 90            |
| Anemometer                 | 100         | 0,9      | 90            | 0        | 0         | 0,9      | 90           | 0,9      | 90            |
| Navigation & signal lights | 600         | 0,6      | 360           | 0        | 0         | 0,6      | 360          | 0,6      | 360           |
| Searchlight                | 900         | 0        | 0             | 0        | 0         | 0,2      | 180          | 0,2      | 180           |
| DGPS                       | 10          | 0,9      | 9             | 0        | 0         | 0,9      | 9            | 0,9      | 9             |
| Electromagnetic log        | 100         | 0,9      | 90            | 0        | 0         | 0,9      | 90           | 0,9      | 90            |
| Telephone system           | 100         | 1        | 100           | 0,2      | 20        | 0,7      | 70           | 0,7      | 70            |
| Exterior communications    | 400         | 0,4      | 160           | 0,1      | 40        | 0,7      | 280          | 0,7      | 280           |
| Radar                      | 300         | 0,8      | 240           | 0        | 0         | 0,8      | 240          | 0,8      | 240           |
| <b>Total</b>               | <b>2610</b> | <b>-</b> | <b>1139</b>   | <b>-</b> | <b>60</b> | <b>-</b> | <b>1409</b>  | <b>-</b> | <b>1409</b>   |

Table 28: 24 V loads factors

The greatest power required at the Bridge happens during the function situation. As it shown, this value is up to 1409 W.

$$P_{24Vdc} = 1409 \text{ W}$$

### 3.2.2.2. 144 Vdc network power forecast

The total power forecast referring to the propulsion machinery lies on both electric motors, which have been selected previously, and which rated value is 42,5 kW each one.

Now, applying the load factors in each situation, we will obtain the actual value during the different operating conditions

| Load (W)     | LF | Essential (W) | LF | Shore (W) | LF  | Function (W) | LF  | Top Speed (W) |
|--------------|----|---------------|----|-----------|-----|--------------|-----|---------------|
| 42500        | 0  | 0             | 0  | 0         | 0,4 | 18700        | 0,4 | 42500         |
| 42500        | 0  | 0             | 0  | 0         | 0,4 | 18700        | 0,4 | 42500         |
| <b>Total</b> | -  | 0             | -  | 0         | -   | 37400        | -   | 85000         |

*Table 29: Motors load consumption and factors*

As it is shown, the highest power requirement within the motors is 85 kW.

$$P_{144Vdc} = 85000 \text{ W}$$

### 3.2.3. Total power forecast

Finally, the total power forecast shall be the sum of the 230 Vac power consumption and the 24 Vdc power consumption.

$$P = P_{230Vac} + P_{24Vdc} + P_{144Vdc}$$

$$P = 6373,6 + 1409 + 85000$$

$$P = 92782,6 \text{ W}$$

We can sum it up on the following table:

| Group |                        | Connected Load (W) | Essential Services (W) | Shore (W) | Function (W) | Top Speed (W) |
|-------|------------------------|--------------------|------------------------|-----------|--------------|---------------|
| 2     | Propulsion             | 85,000             | 0,000                  | 0,000     | 37,400       | 85,000        |
| 3     | Electric Plant         | 11,835             | 3,523                  | 3,591     | 4,286        | 4,286         |
| 4     | Command & Surveillance | 2,610              | 1,139                  | 0,060     | 1,409        | 1,409         |
| 5     | Auxiliary Systems      | 2,080              | 0,872                  | 1,616     | 1,672        | 1,672         |
| 6     | Outfit & Furnishing    | 1,282              | 0,053                  | 0,203     | 0,416        | 0,416         |
| TOTAL |                        | 102,807            | 5,587                  | 5,470     | 45,183       | 92,783        |

Table 30: Power forecast

### 3.3. Circuit distribution

Now that every load has been defined, it is time to arrange the circuits that shall take place in the system. This distribution will help us to further calculations, like the type of conductor required or the selection of the switch in every circuit.

As it can be checked, we have grouped several units within the same circuit, whose voltage-drop and maximum current shall comply with the Classification Society demands. This parameters will be prove later.

Despite of the power factors applied during the power forecast of the ship, it shall be necessary to size the conductors as well as the protections for a full load consumption of the circuit. Socket circuits have a non-specified rated power consumption because of its dependence to the selected cross-section.



### 3.3.1. Passengers Room

| Passengers Room (Port Switchboard) |                |      |       |              |                |                |
|------------------------------------|----------------|------|-------|--------------|----------------|----------------|
| Description                        | Circuit Number | Name | Units | Power<br>(W) | Current<br>(A) | Voltage<br>(V) |
| Sockets                            | Circuit 1      | C1   | 6     | -            | -              | 230            |
| Sockets                            | Circuit 2      | C2   | 7     | -            | -              | 230            |
| Lighting                           | Circuit 3      | C3   | 6     | 114          | 0,5510         | 230            |
| Lighting                           | Circuit 4      | C4   | 6     | 114          | 0,5510         | 230            |
| Emergency<br>Lighting              | Circuit 5      | C5   | 4     | 20           | 0,0970         | 230            |

*Table 31: Passengers Room (Port Switchboard circuits)*

| Passengers Room (Starboard Switchboard) |                |      |       |              |                |                |
|-----------------------------------------|----------------|------|-------|--------------|----------------|----------------|
| Description                             | Circuit Number | Name | Units | Power<br>(W) | Current<br>(A) | Voltage<br>(V) |
| Sockets                                 | Circuit 6      | C6   | 6     | -            | -              | 230            |
| Sockets                                 | Circuit 7      | C7   | 7     | -            | -              | 230            |
| Lighting                                | Circuit 8      | C8   | 6     | 114          | 0,5510         | 230            |
| Lighting                                | Circuit 9      | C9   | 6     | 114          | 0,5510         | 230            |
| Emergency<br>Lighting                   | Circuit 10     | C10  | 4     | 20           | 0,0970         | 230            |

*Table 32: Passengers Room (Starboard Switchboard circuits)*

### 3.3.2. Entrance & Toilet

| Entrance & Toilet (Port Switchboard) |                |      |       |           |             |             |
|--------------------------------------|----------------|------|-------|-----------|-------------|-------------|
| Description                          | Circuit Number | Name | Units | Power (W) | Current (A) | Voltage (V) |
| Sockets (Entrance & Toilet)          | Circuit 11     | C11  | 3     | -         | -           | 230         |
| Lighting (Entrance)                  | Circuit 12     | C12  | 4     | 76        | 0,3670      | 230         |
| Lighting (Toilet)                    | Circuit 13     | C13  | 1     | 19        | 0,0920      | 230         |
| Emergency Lighting (Entrance)        | Circuit 14     | C14  | 3     | 15        | 0,0720      | 230         |
| Emergency Lighting (Toilet)          | Circuit 15     | C15  | 1     | 5         | 0,0240      | 230         |
| Extractor Fan                        | Circuit 16     | C16  | 1     | 110       | 0,6000      | 230         |
| Air Conditioning 1                   | Circuit 17     | C17  | 1     | 1000      | 5,4350      | 230         |

Table 33: Entrance & Toilet (Port Switchboard circuits)

| Entrance & Toilet (Starboard Switchboard) |                |      |       |           |             |             |
|-------------------------------------------|----------------|------|-------|-----------|-------------|-------------|
| Description                               | Circuit Number | Name | Units | Power (W) | Current (A) | Voltage (V) |
| Sockets (Entrance & Toilet)               | Circuit 18     | C18  | 3     | -         | -           | 230         |
| Lighting (Entrance)                       | Circuit 19     | C19  | 5     | 95        | 0,4590      | 230         |
| Lighting (Toilet)                         | Circuit 20     | C20  | 1     | 19        | 0,0920      | 230         |
| Emergency Lighting (Entrance)             | Circuit 21     | C21  | 2     | 10        | 0,0480      | 230         |
| Emergency Lighting (Toilet)               | Circuit 22     | C22  | 1     | 5         | 0,0240      | 230         |
| Air Conditioning 2                        | Circuit 23     | C23  | 1     | 1000      | 5,4350      | 230         |

Table 34: Entrance &amp; Toilet (Starboard Switchboard circuits)

### 3.3.3. Anteroom

| Anteroom (Port Switchboard)   |                |      |       |           |             |             |
|-------------------------------|----------------|------|-------|-----------|-------------|-------------|
| Description                   | Circuit Number | Name | Units | Power (W) | Current (A) | Voltage (V) |
| Sockets (Anteroom)            | Circuit 24     | C24  | 2     | -         | -           | 230         |
| Lighting (Anteroom)           | Circuit 25     | C25  | 5     | 95        | 0,4590      | 230         |
| Emergency Lighting (Anteroom) | Circuit 26     | C26  | 3     | 15        | 0,0720      | 230         |

Table 35: Anteroom (Port Switchboard circuits)

| Anteroom (Starboard Switchboard) |                |      |       |           |             |             |
|----------------------------------|----------------|------|-------|-----------|-------------|-------------|
| Description                      | Circuit Number | Name | Units | Power (W) | Current (A) | Voltage (V) |
| Sockets (Anteroom)               | Circuit 27     | C27  | 2     | -         | -           | 230         |
| Lighting (Anteroom)              | Circuit 28     | C28  | 6     | 114       | 0,5510      | 230         |
| Emergency Lighting (Anteroom)    | Circuit 29     | C29  | 2     | 10        | 0,0480      | 230         |

*Table 36: Anteroom (Starboard Switchboard circuits)*

### 3.3.4. Bridge

| Bridge (230 Vac Switchboard) |                |      |       |           |             |             |
|------------------------------|----------------|------|-------|-----------|-------------|-------------|
| Description                  | Circuit Number | Name | Units | Power (W) | Current (A) | Voltage (V) |
| Sockets                      | Circuit 30     | C30  | 2     | -         | -           | 230         |
| Lighting                     | Circuit 31     | C31  | 1     | 50        | 0,2420      | 230         |
| Emergency Lighting           | Circuit 32     | C32  | 2     | 10        | 0,0480      | 230         |
| External Lighting            | Circuit 33     | C33  | 7     | 606       | 2,9280      | 230         |
| Windlass Anchor              | Circuit 34     | C34  | 1     | 1000      | 4,8310      | 230         |

*Table 37: Bridge (230 Vac Switchboard circuits)*

| Bridge (24 Vdc Switchboard)   |                |      |       |              |                |                |
|-------------------------------|----------------|------|-------|--------------|----------------|----------------|
| Description                   | Circuit Number | Name | Units | Power<br>(W) | Current<br>(A) | Voltage<br>(V) |
| Magnetic compass              | Circuit 35     | C35  | 1     | 90           | 3,75           | 24             |
| Anemometer                    | Circuit 36     | C36  | 1     | 90           | 0,22           | 24             |
| Navigation & signal<br>lights | Circuit 37     | C37  | 1     | 360          | 15,00          | 24             |
| Searchlight                   | Circuit 38     | C38  | 1     | 180          | 7,50           | 24             |
| DGPS                          | Circuit 39     | C39  | 1     | 9            | 0,38           | 24             |
| Electromagnetic log           | Circuit 40     | C40  | 1     | 90           | 3,75           | 24             |
| Telephone system              | Circuit 41     | C41  | 1     | 70           | 2,92           | 24             |
| Exterior<br>communications    | Circuit 42     | C42  | 1     | 280          | 11,67          | 24             |
| Radar                         | Circuit 43     | C43  | 1     | 240          | 10,00          | 24             |

Table 38: Bridge (24 Vdc Switchboard circuits)



### 3.3.5. Engine Room & Electrical Compartment

| Engine Room & Electrical Compartment (Port Switchboard) |                |      |       |           |             |             |
|---------------------------------------------------------|----------------|------|-------|-----------|-------------|-------------|
| Description                                             | Circuit Number | Name | Units | Power (W) | Current (A) | Voltage (V) |
| Sockets                                                 | Circuit 44     | C44  | 4     | -         | -           | 230         |
| Lighting                                                | Circuit 45     | C45  | 5     | 250       | 1,1440      | 230         |
| Emergency Lighting (Opposite hull)                      | Circuit 46     | C46  | 6     | 30        | 0,1370      | 230         |
| Bilge Pump 1 (Opposite hull)                            | Circuit 47     | C47  | 1     | 600       | 2,8000      | 230         |
| Bilge Pump 2 (Opposite hull)                            | Circuit 48     | C48  | 1     | 600       | 2,8000      | 230         |
| Extractor Fans                                          | Circuit 49     | C49  | 2     | 40        | 0,1930      | 230         |

Table 39: Engine Room & Electrical Compartment (Port Switchboard circuits)

| Engine Room & Electrical Compartment (Starboard Switchboard) |                |      |       |           |             |             |
|--------------------------------------------------------------|----------------|------|-------|-----------|-------------|-------------|
| Description                                                  | Circuit Number | Name | Units | Power (W) | Current (A) | Voltage (V) |
| Sockets                                                      | Circuit 50     | C50  | 4     | -         | -           | 230         |
| Lighting                                                     | Circuit 51     | C51  | 5     | 250       | 1,1440      | 230         |
| Emergency Lighting (Opposite hull)                           | Circuit 52     | C52  | 6     | 30        | 0,1370      | 230         |
| Bilge Pump 3 (Opposite hull)                                 | Circuit 53     | C53  | 1     | 600       | 2,8000      | 230         |
| Bilge Pump 4 (Opposite hull)                                 | Circuit 54     | C54  | 1     | 600       | 2,8000      | 230         |
| Extractor Fans                                               | Circuit 55     | C55  | 2     | 40        | 0,1930      | 230         |

Table 40: Engine Room &amp; Electrical Compartment (Starboard Switchboard circuits)

### 3.4. Battery banks selection

Once that the total power consumption has been calculated, we can proceed sizing the battery banks required for the correct performance of the vessel.

It is already known that the total power forecast reaches a value of 92,783 W during the top speed. In order to make easier the calculations, it is possible to assume this value as 93 kW. Thus, a battery bank system with a value of 100 kW or higher would fit with the requirements of this vessel.

It is necessary to find a battery bank system which have enough power to supply not just the motors, but also the rest of the consumption in the vessel. Also, it must have a zero-emission performance in order to prevent polluting.

#### 3.4.1. Solution adopted

For this purpose, we have found that the “SEANERGY BATTERY SYSTEM” from the SAFT group fulfils the requirements prescribed in the previous sections.

The SAFT – SEANERGY BATTERY SYSTEM integrates power, safety, management and communication. It is a stand-alone rackable battery system, which offers the benefits of SAFT Li-ion Super Iron Phosphate technology in a qualified industrial design. The SEANERGY BATTERY SYSTEM provides maintenance-free energy storage in a reduced volume, combining safety and high operational reliability with outstanding lifetime under the most difficult environmental conditions.

Within its advantages, we can find some of them in the following list:

- Batteries enable zero-emissions operation.
- Significant savings on fuel.
- Estimated lifetime of 10+ years.
- Zero maintenance requirements.

- Batteries can achieve 95% charge status within two hours.
- Compact and lightweight battery leaves more space for passengers.

The system is designed for maritime energy storage and can deliver high-power and/or energy storage in a lightweight and compact package that is modular and can be scaled to meet the required duty.

In its catalogue, which is included at the end of this annexe on page 298 (**3.10.1. Battery bank catalogue**), we can find some of its applications. Some of them are:

- Passenger vessels (cruise liners, ferries, Ro-Pax, urban transports).
- Work-boats (tugs, offshore vessels, administration ships, fishing vessels).
- Inland shippings (river-sea shuttles, pushers/tugs, freight).
- Leisure vessels (mega yachts, medium size yachts).

Its main features are as follows:

| Nominal characteristics                                       |                      |
|---------------------------------------------------------------|----------------------|
| Nominal voltage (V) (with 14 modules max)                     | 647                  |
| Capacity (C/5) (Ah)                                           | 82                   |
| Minimum energy (C/5) (kWh)                                    | 50                   |
| Nominal energy (C/5) (kWh)                                    | 53                   |
| Mechanical characteristics (standard cabinet with 14 modules) |                      |
| Width max (mm)                                                | 600                  |
| Height max (mm)                                               | From 1200 up to 2300 |
| Depth (mm)                                                    | 800                  |
| Weight (without cabinet) (kg)                                 | 560                  |
| Maximum weight (with cabinet) (kg)                            | 750                  |
| Electrical characteristics                                    |                      |
| Voltage window (V)                                            | 529 to 745           |
| Maximum charge voltage (V)                                    | 750                  |
| Maximum discharge current (A)                                 | 180                  |
| Nominal charge current (A)                                    | 45                   |
| Recharge time (h) at nominal current (95% State of Charge)    | 2                    |

*Table 41: SEANERGY battery system main features*

These characteristics make the SEANERGY BATTERY SYSTEM very suitable for our requirements, not only because its technical features, but also because its zero-emission and fuel saving characteristics.

### 3.4.2. Battery banks connection

The battery banks shall be arranged into the electrical system in such a way that ensure the supply of the whole network as well as their own recharging. This means that the battery banks must be placed between several voltage converters, so as to be able to supply and get supplied.

### **3.4.3. Connection with the quay**

Firstly, the battery banks must be supplied from the shore connection, i.e. there must be a connection from the quay. This means that the recharging system shall work with a 230 Vac or 400 Vac, i.e. and alternating current system. Due to this, it will be necessary a rectifier between the batteries and the shore connection. This rectifier, as it was stated previously on the Memory, might be big enough to place it out of the vessel. Besides, it must have a cable whose characteristics make possible the connection.

The following scheme, provided by the SAFT catalogue, can be used as a guide of what was stated in this section.

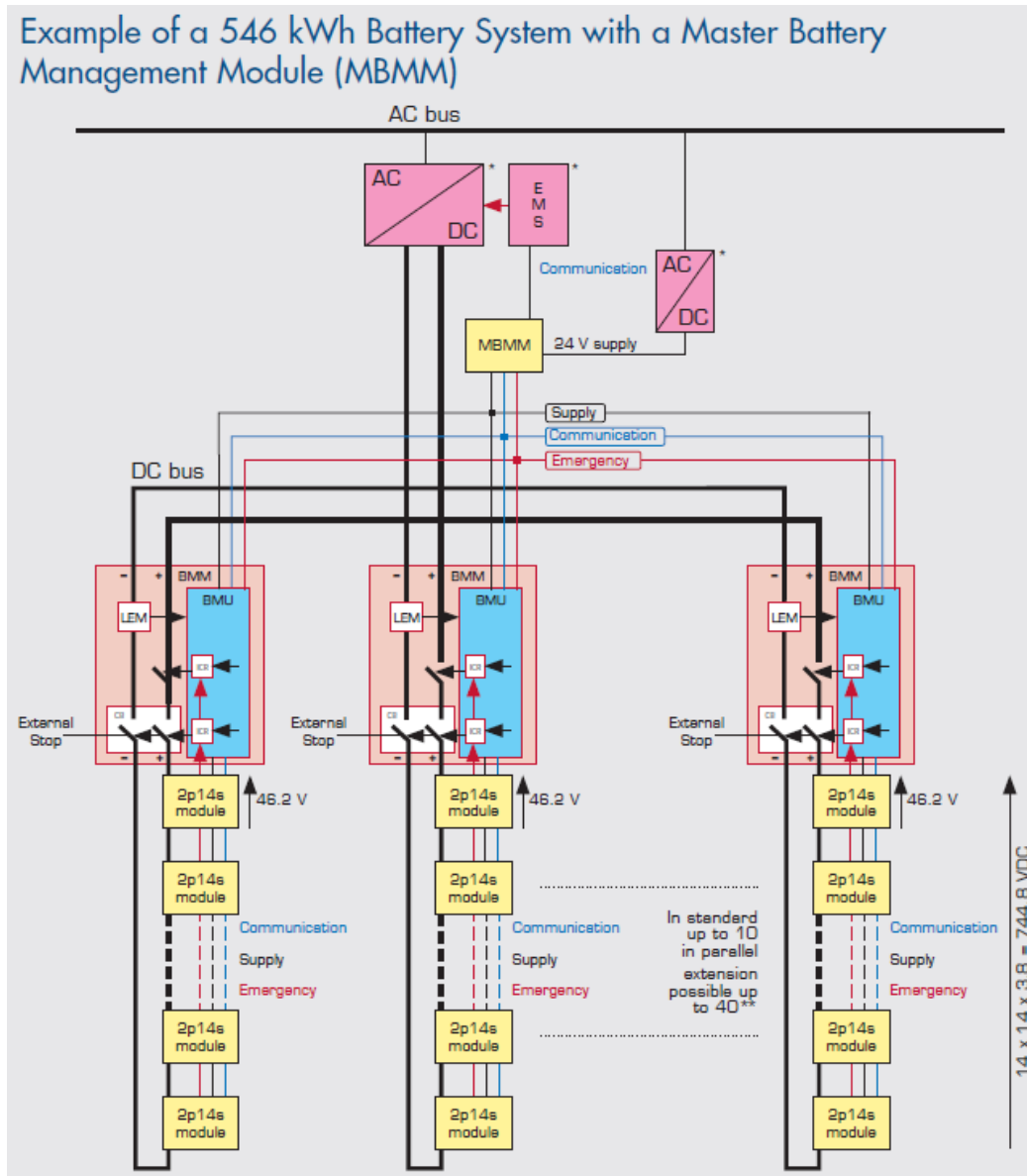


Figure 23: Example of connection with the quay

Once that the battery banks arrangement has been calculated, it is necessary to calculate the current required to their recharging.

The battery banks which shall supply the motors are 4 groups of 3 modules each one (i.e. 12 modules, see **Figure 24: Battery arrangement (motors)** – page 175), and referring to the catalogue, the nominal charge current reaches a value of 45 A, there will be necessary a current of 180 A per hull.

$$I = 4 \cdot I_C$$

$$I = 4 \cdot 45$$

$$I = 180 \text{ A}$$

Moreover, the battery banks which shall supply the 230 Vac network, as well as the 24 Vdc network of the Bridge are composed of 2 groups with 1 module each one (see **Figure 25: Battery arrangement (inverters)** – page 178). This will suppose a current of 90 A, according to the previous calculation.

#### Solution adopted

We have chosen the cable PROTOMONT NSSHÖU (DIN VDE 0250 part 812) for both task. For the motors, we have chose the model with number of cores and nominal cross-sectional area of 2x95 mm<sup>2</sup>, which is able to provide 301 A. For the inverters, we have chose the model with number of cores and nominal cross-sectional area of 2x16 mm<sup>2</sup>, which is able to provide 99 A. One pair of cable will be necessary for each hull of the vessel, as well as one conductor for the ground protection. Its catalogue is added at the end of the Annexes section, on page 320 (**3.10.6.1. PROTOMONT NSSHÖU**).

This cable have the following characteristics:



| Characteristic                                  | Unit            | Value |
|-------------------------------------------------|-----------------|-------|
| Number of cores and nominal crosssectional area | mm <sup>2</sup> | 4x95  |
| Conductor diameter                              | ca. mm          | 12,1  |
| Outer diameter of cable                         | Min mm          | 48,2  |
|                                                 | Max mm          | 52,2  |
| Fixed installed                                 | Min mm          | 209   |
| Free moving                                     | Min mm          | 261   |
| Weight of cable net 1000 m                      | ca. kg          | 5335  |
| Current-carrying capacity                       | 30° C A         | 301   |
| Permissible short-circuit current               | (1 s) kA        | 13,59 |
| Permissible pulling force                       | Max N           | 5700  |

Table 42: PROTOMONT NSSHÖU characteristics

To achieve this connection, it shall be necessary a high current plug that will allow the supply from the shore. In order to comply with this demand, we have chose a MARECHAL PFQ3, which main characteristics are:

- **Rated current:** 315 A
- **Maximum voltage:** 690 V
- **IP protection lid closed:** IP66/IP67
- **IP protection connected plug:** IP66/IP67
- **Shock resistance:** IK10
- **Ambient temperature:** -40 °C to +60 °C
- **Flexible wiring (min-max):** 95 - 185 mm<sup>2</sup>
- **Stranded wiring (min-max):** 95 - 185 mm<sup>2</sup>
- **Keying positions:** 10
- **Auxiliary contacts (10 A / 400 V):** 6
- **Pilot contacts (10 A / 400 V):** 2

Its catalogue can be checked at **3.10.10.1. Marechal PFQ3** – page 342.

### 3.4.4. Connection with the motors

The motors require 144 Vdc from the batteries, according to their catalogue. This means that the set up of the modules must be changed in order to fulfil this requirement.

Referring to the battery bank catalogue, the SAFT SEANERGY BATTERY SYSTEM has a voltage window from 529 Vdc to 745 Vdc when the 14 modules are connected in series.

$$529 \leq V_{dc} \leq 745$$

This means that every module have a voltage window from 37,79 Vdc to 53,21 Vdc.

$$\frac{529}{14} \leq V_{dc} \leq \frac{745}{14}$$

$$37,79 \leq V_{dc} \leq 53,21$$

Therefore, we must connect them in such a way that makes this range to a 144 Vdc size. This means connecting groups in parallel of 3 modules in series.

$$37,79 \cdot 3 \leq V_{dc} \leq 53,21 \cdot 3$$

$$113,36 \leq V_{dc} \leq 159,64$$

Due to the fact that this battery system is conformed of 14 modules, there must be 4 groups of 3 modules each, i.e. 12 modules altogether. The rest two shall be used to supply the 230 Vac loads by using a power inverter. This actions must be applied in both Electrical Rooms.

Thus, if the nominal energy with 14 modules reaches a value of 53 kWh, with 12 modules it will be 45,5 kWh per blade, i.e. 91 kWh for the whole propulsion system, which are the requirements that were necessary according to the previous calculations. It must be recalled that the propulsion system will reach 85 kW during its Top Speed operating condition, and 37,4 kW during the Function operating condition.

$$E_{Batteries} = E_B = 53000 \cdot \frac{12}{14}$$

$$E_B = 45429 \text{ Wh}$$

$$E_B \approx 45500 \text{ Wh}$$

$$E_{Total} = E_B \cdot 2 = 91 \text{ kWh}$$

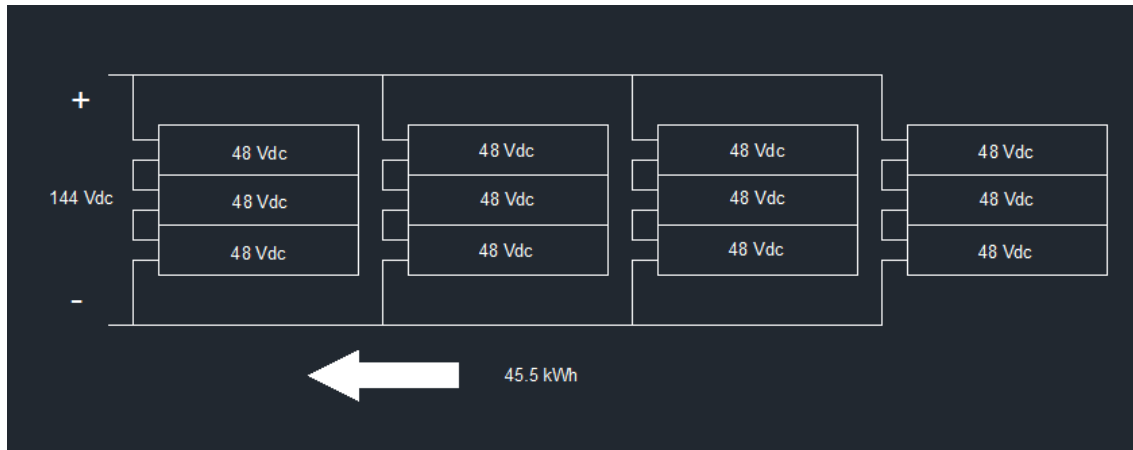


Figure 24: Battery arrangement (motors)

As mentioned above, during the Function operating condition, the propulsion system consume 37,4 kW. By a simple rule of three we can calculate that the SAFT – SEANERGY BATTERY SYSTEM will give us about two and a half hours of propulsion independence (independently of the consumption made by the remaining loads).

$$t = \frac{E}{P}$$

$$t = \frac{91000}{37400}$$

$$t = 2,4332 \text{ h} = 2 \text{ h } 26 \text{ min}$$

It is assumed that the top speed will never be actually reached, and that the vessel will run at its cruising speed almost always. Thus, the vessel would have 2 hours and 26 minutes of independence running in a Function regime. This values are enough for our requirements, taking into account that the actual independence time would be even greater, since the vessel will not be always working at a cruising speed.

In the case that the vessel would be moving at its Top Speed operating condition, this battery system would give us enough independence too. Using the same rule of three, we can check that the vessel would be independent for more than one hour:

$$t = \frac{91000}{85000}$$

$$t = 1,0706 \text{ h} = 1 \text{ h } 4 \text{ min}$$

Nevertheless it is important to remark that this kind of ship are not supposed to perform their routes in their Top Speed, due to their touristics conditions.

### **3.4.5. Connection with 230 Vac network**

In order to supply the remaining network, it shall be necessary to connect a power inverter between the batteries and the main switchboard. It shall be necessary a power inverter in both electrical systems.

As it was explained before, the battery bank counts with 14 modules, and 12 of them has been used to supply the motors.

Referring to the battery bank catalogue, the SEANERGY BATTERY SYSTEM have a voltage window from 529 Vdc to 745 Vdc when the 14 modules are connected in series.

$$529 \leq V_{dc} \leq 745$$

This means that every module have a voltage window from 37,79 Vdc to 53,21 Vdc.

$$\frac{529}{14} \leq V_{dc} \leq \frac{745}{14}$$

$$37,79 \leq V_{dc} \leq 53,21$$

Thus, the remaining two modules shall be connected in series, obtaining a voltage of 48 Vdc which is a standard value for the power inverters.

If the nominal energy with 14 modules reaches a value of 53 kWh, with 2 modules it will be 7,57 kWh per blade, i.e. 15,14 kWh for the whole vessel.

$$E_{Batteries} = E_B = 53000 \cdot \frac{2}{14}$$

$$E_B = 7571 \text{ Wh}$$

$$E_{Total} = E_B \cdot 2 = 15142 \text{ kWh}$$

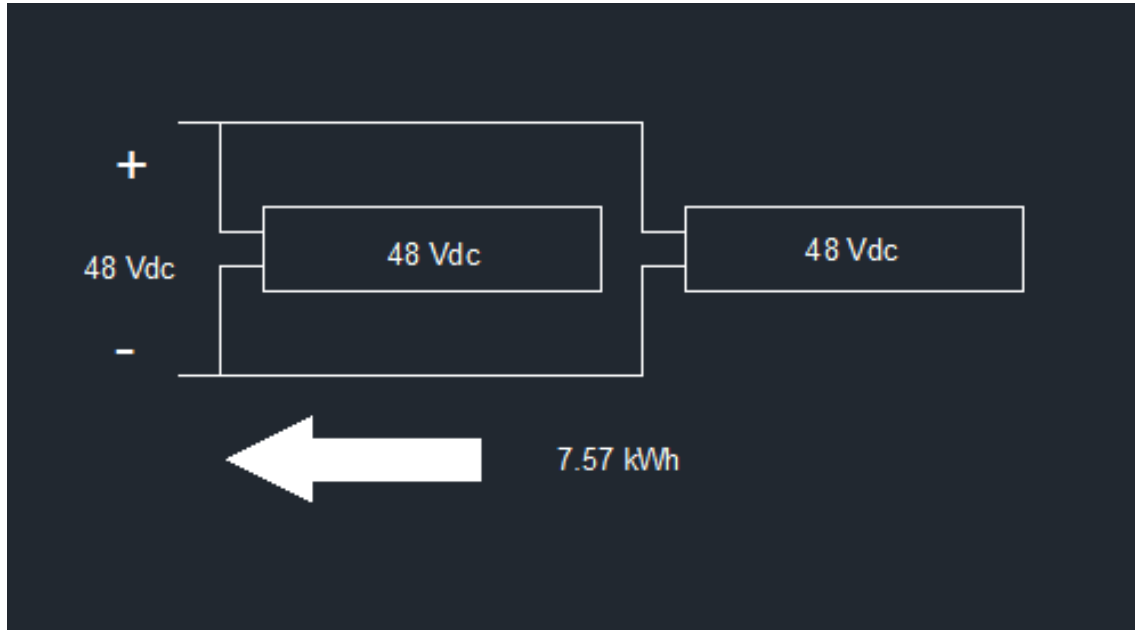


Figure 25: Battery arrangement (inverters)

According to the power forecast studied in the previous section (page 133 – **3.2. EPLA (Electric Power Load Analysis)**), the 230 Vac network demands 6373,6 kW, while the 24 Vdc network of the Bridge (which is supplied from both 230 Vac main switchboards, and have to be taken into account) demands 1409 W. This means that power inverters shall supply a total load of 7782,6 kW.

$$P_T = P_{230Vac} + P_{24Vdc}$$

$$P_T = 6373,6 + 1409$$

$$P_T = 7782,6 \text{ kW}$$

Thus, the battery banks ensures an independence of almost two hours for the accommodation of the passengers as well as for the communications of the Bridge.

$$t = \frac{E}{P}$$

$$t = \frac{15142}{7782,6}$$

$$t = 1,9456 \text{ h} = 1 \text{ h } 57 \text{ min}$$

### 3.5. Power inverter selection

As it has been calculated on the previous section, the 230 Vac and the 24 Vdc systems shall require 7782,6 kW in the Function and the Top Speed operating conditions, among luminaries, air conditioning, communications, etc.

The battery bank shall be able to supply 7,8 kWh at 48 Vdc. Thus, the chosen inverter shall deal with this values. As it was stated in the Memory, the power inverter that has been chosen is the VICTRON ENERGY QUATTRO.

Its main characteristics, which can be checked at the end of this Annexes section (page 303, **3.10.3.1. VICTRON ENERGY QUATTRO**), proves that it is suitable for our requirements:

#### Inverter Output Specifications:

- Continuous Output Power: 8000 Watts
- Output Waveform: Pure Sine 230 Vac

#### Input Specifications:

- Nominal Input Voltage: 38 – 66 Vdc

Each hull shall count with this power inverter connected to its battery bank.

### 3.6. Rectifier selection

The Bridge shall count with a rectifier which supplies the 24 Vdc devices. The

rectifier shall be connected to the 230 Vac network of both hulls through a two position selector switch, ensuring the supply during an emergency situation (i.e. if one of the systems is unable to supply the Bridge, through the two position switch we are able to connect it to the other electrical system, ensuring the supply at all times).

As it was calculated in the power forecast through the previous sections, the 24 Vdc network shall require a supply of 1409 W.

Thus, the amount of current that the rectifier shall deal with is:

$$I = \frac{P}{V}$$

$$I = \frac{1409}{24}$$

$$I = 58,7083 \text{ A}$$

Therefore, the rectifier shall be able to work with at least 58,71 A. The MASTERVOLT MASS 24/75 complies with those requirements, and its suitable for this task.

Its main characteristics are:

- Nominal output voltage: 24 V
- Total charge current: 75 A
- Nominal input voltage: 230 V (180-265 V), 50/60 Hz
- Full load consumption (230 V AC): 2600 W

Its characteristics fits with our requirements. Thus, one MASTERVOLT MASS 24/75 shall be placed at the Bridge, in order to avoid high voltage-drops.



## 3.7. Conductors & switches

Once that the type of insulation and the required protection is set, it is necessary to determine the section of the conductor.

Both heating of the conductor (due to the current flow) and the voltage-drop are a function of the current flowing through the conductor. Therefore, it shall be necessary to know the value of those currents before making any calculation.

In order to calculate the cross-section of the conductors, and according to the requirements set on **2.6.24. Cable selection** (page 58) and **2.6.26.3. Circuit protection** (page 74), as well as to the maximum level of dropped voltage, it shall be necessary to comply with the following requirements:

### 3.7.1. Requirements

#### 3.7.1.1. Maximum admissible current (or maximum heating) criteria

The maximum admissible current value that may flow through the cables shall not be higher than that one calculated using the following formula:

$$I = \frac{P}{V \cdot \cos \varphi}$$

In 230 Vac networks, the power factor ( $\cos \varphi$ ) shall depend on the load that we are studying. In DC networks, its value will be 1. Once that the currents have been calculated, it shall be necessary to look in the Classification Society (DNV) for a cross-section whose rate current is higher.<sup>59</sup>

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<sup>59</sup> DNV – Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 51 (July 2013)

| <b>Table J4 Rating of cables with temperature class 90°C</b> |                                                                   |     |               |     |                    |     |
|--------------------------------------------------------------|-------------------------------------------------------------------|-----|---------------|-----|--------------------|-----|
| <i>Nominal cross-section (mm<sup>2</sup>)</i>                | <i>Current rating (A)<br/>(Based on ambient temperature 45°C)</i> |     |               |     |                    |     |
|                                                              | <i>Single-core</i>                                                |     | <i>2-core</i> |     | <i>3 or 4-core</i> |     |
| 1                                                            | 18                                                                |     | 15            |     | 13                 |     |
| 1.5                                                          | 23                                                                |     | 20            |     | 16                 |     |
| 2.5                                                          | 30                                                                |     | 26            |     | 21                 |     |
| 4                                                            | 40                                                                |     | 34            |     | 28                 |     |
| 6                                                            | 52                                                                |     | 44            |     | 36                 |     |
| 10                                                           | 72                                                                |     | 61            |     | 50                 |     |
| 16                                                           | 96                                                                |     | 82            |     | 67                 |     |
| 25                                                           | 127                                                               |     | 108           |     | 89                 |     |
| 35                                                           | 157                                                               |     | 133           |     | 110                |     |
| 50                                                           | 196                                                               |     | 167           |     | 137                |     |
| 70                                                           | 242                                                               |     | 206           |     | 169                |     |
| 95                                                           | 293                                                               |     | 249           |     | 205                |     |
| 120                                                          | 339                                                               |     | 288           |     | 237                |     |
| 150                                                          | 389                                                               |     | 331           |     | 272                |     |
| 185                                                          | 444                                                               |     | 377           |     | 311                |     |
| 240                                                          | 522                                                               |     | 444           |     | 365                |     |
| 300                                                          | 601                                                               |     | 511           |     | 421                |     |
| 400<br>500<br>600                                            | DC                                                                | AC  | DC            | AC  | DC                 | AC  |
|                                                              | 690                                                               | 670 | 587           | 570 | 483                | 469 |
|                                                              | 780                                                               | 720 | 663           | 612 | 546                | 504 |
|                                                              | 890                                                               | 780 | 757           | 663 | 623                | 546 |

Figure 26: Rating of cables with temperature class 90°C

After this step, it shall be taken into account the maximum voltage-drop specified in the Classification Society, and it must ensure the minimum safety distance between conductors.

### 3.7.1.2. Maximum voltage-drop criteria

In order to calculate the voltage-drop according to the value of the cross-section, it shall be used the following formula:

$$\Delta V = I \cdot R$$

Where:

- $\Delta V$  (V): Is the maximum admissible value of the voltage drop.
- $I$  (A): Is the current when the load is at its greatest.
- $R$  ( $\Omega$ ): Is the resistance of the conductor.

Thus, taking into account that the resistance of a metallic conductor is based on the following formula:

| Three-phase system           | One-phase alternating current system | One-phase direct current system      |
|------------------------------|--------------------------------------|--------------------------------------|
| $R = \rho \cdot \frac{L}{S}$ | $R = \rho \cdot 2 \cdot \frac{L}{S}$ | $R = \rho \cdot 2 \cdot \frac{L}{S}$ |

Where:

- $\rho$  ( $\Omega \cdot \text{mm}^2/\text{m}$ ): Electrical resistivity of the conductor.
- $L$  (m): Length of the conductor.
- $S$  ( $\text{mm}^2$ ): Cross-section.

Applying this expression into the previous formula we obtain:

| Three-phase system                          | One-phase alternating current system                | One-phase direct current system                     |
|---------------------------------------------|-----------------------------------------------------|-----------------------------------------------------|
| $\Delta V = \frac{I \cdot \rho \cdot L}{S}$ | $\Delta V = \frac{I \cdot \rho \cdot L \cdot 2}{S}$ | $\Delta V = \frac{I \cdot \rho \cdot L \cdot 2}{S}$ |

And referring it to the cross-section value:

| Three-phase system                          | One-phase alternating current system                | One-phase direct current system                     |
|---------------------------------------------|-----------------------------------------------------|-----------------------------------------------------|
| $S = \frac{I \cdot \rho \cdot L}{\Delta V}$ | $S = \frac{I \cdot \rho \cdot L \cdot 2}{\Delta V}$ | $S = \frac{I \cdot \rho \cdot L \cdot 2}{\Delta V}$ |

Now, if we assume that the current depends on the voltage of the circuit and its required power, we obtain:

$$I = \frac{P}{V}$$

| Three-phase system                                  | One-phase alternating current system                        | One-phase direct current system                             |
|-----------------------------------------------------|-------------------------------------------------------------|-------------------------------------------------------------|
| $S = \frac{P \cdot \rho \cdot L}{\Delta V \cdot V}$ | $S = \frac{P \cdot \rho \cdot L \cdot 2}{\Delta V \cdot V}$ | $S = \frac{P \cdot \rho \cdot L \cdot 2}{\Delta V \cdot V}$ |

This formula shall be used on the following cross-section calculations, specifically the one-phase alternating current system and the one-phase direct current system, due to the lack of three-phase system in this project.

### 3.7.1.3. Temperature correction factors

Currents listed in the following table are valid for a room temperature of 45 °C and are applicable to electrical conditions of ships which navigate at high seas or in tropical climates.

Complying with the classification society, whenever it is expected that the room temperature can remain below 45 °C may be accepted higher admissible currents, but in

no case an ambient temperature below 35° C must be considered. When it is expected that the ambient temperature may exceed 45° C the permissible currents shall be reduced.

DNV provides a table in which indicates the coefficients to be applied in order to make these increases or decreases.<sup>60</sup>

| Cable temperature class                                                                                                                                                                                                                                                                       | Ambient temperature (°C) |      |      |      |      |      |      |      |      |      |      |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|------|------|------|------|------|------|------|------|------|------|
| °C                                                                                                                                                                                                                                                                                            | 35*                      | 40   | 45   | 50   | 55   | 60   | 65   | 70   | 75   | 80   | 85   |
| 60**                                                                                                                                                                                                                                                                                          | 1,29                     | 1,15 | 1,00 | 0,82 | -    | -    | -    | -    | -    | -    | -    |
| 70                                                                                                                                                                                                                                                                                            | 1,18                     | 1,10 | 1,00 | 0,89 | 0,77 | 0,63 |      |      |      |      |      |
| 85                                                                                                                                                                                                                                                                                            | 1,12                     | 1,06 | 1,00 | 0,94 | 0,87 | 0,79 | 0,71 | 0,61 | 0,50 | -    | -    |
| 90                                                                                                                                                                                                                                                                                            | 1,10                     | 1,05 | 1,00 | 0,94 | 0,88 | 0,82 | 0,74 | 0,67 | 0,58 | 0,47 | -    |
| 95                                                                                                                                                                                                                                                                                            | 1,10                     | 1,05 | 1,00 | 0,95 | 0,89 | 0,84 | 0,77 | 0,71 | 0,63 | 0,55 | 0,45 |
| * Correction factors for ambient temperature below 40°C will normally only be accepted for:<br>— cables in refrigerated chambers and holds, for circuits which only are used in refrigerated service<br>— cables on vessel with class notation restricting the service to non-tropical water. |                          |      |      |      |      |      |      |      |      |      |      |
| ** 60°C cables shall not be used in engine and boiler rooms.                                                                                                                                                                                                                                  |                          |      |      |      |      |      |      |      |      |      |      |

Table 43: Correction factors for ambient temperature

#### 3.7.1.4. Cable grouping correction factors

Cable rating and method of installation shall provide conditions preventing cables to operate above their design temperature.

When installed in a single layer without free air circulation between the cables, the current ratings specified in the previous tables can be used. However, these ratings are based on maximum 6 cables, which can be expected to be under full load simultaneously.

A correction factor of 0.85 shall be applied if more than 6 multi-core cables, are

60 DNV – Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 52 (July 2013)

installed without spacing for free air circulation.

The reduction factor for more than 6 single core cables should be as given in IEC 60092-352 Annex A. Free air circulation is achieved by a spacing equal the cable diameter when laid in a single layer. For three-foil formation, the distance shall be at least twice the cable diameter.<sup>61</sup>

Cables are attached in free air conditions in the following cases:

- With direct fixing on bulkheads or ceilings.
- With placement on cable trays, on wall brackets or opened trays.
- In gaps, provided that these section is much larger than the total cross-section of all installed cables.

The cables are installed in confined air conditions in the following cases:

- Located in narrow passages or ducts which do not allow the normal circulation of air around them. If the length of the conductor is less than 30 times smaller than the diameter of the wires it shall not be considered as a narrow passage.
- Under plastic or metallic tubes.
- Under closed trays.

#### **3.7.1.5. Calculation of the growth margin**

It shall be necessary the use of the following equation to determine the intensity that shall determine the section, after applying the correction factors that shall be needed.

$$I_z = \frac{I_{FL}}{F_T \cdot F_G} \cdot F_S$$

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61 DNV – Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 49 (July 2013)

Where:

- $I_z$  (A) is the adjusted current.
- $I_{FL}$  (A) is the current at a full load condition.
- $F_T$  is the correction factor based on the temperature.
- $F_G$  is the correction factor based on the grouping conditions.
- $F_S$  is a correction factor used to ensure a safety margin in case of any change in the conditions of the implementation and to extend the life of the cables. This factor increases the current 25%.

### 3.7.2. Cross-section calculation

The conductors that interconnect all the devices and machineries with each others must comply with several demands, and their cross-section must fulfil the Classification Society requirements. In order to achieve this task, the cross-sections of the cables which will have a performance in this document shall be calculated.

#### 3.7.2.1. 24 Vdc cross-section calculation

##### Rate current calculation

First of all, it is necessary to define the conditions within this system. The power forecast in the 24 Vdc installation has been calculated in previous sections (page 133 – **3.2. EPLA (Electric Power Load Analysis)**), and we estimated the total power required within this system. With this parameters (power and voltage), we are able to calculate the rate current value.

- $P_N = 1409$  W
- $V_N = 24$  V

$$I_N = \frac{P_N}{V_N}$$

$$I_N = \frac{1409}{24}$$

$$I_N = 58,7083 \text{ A}$$

This value must be adjusted according to the previous criteria:

$$I_Z = \frac{I_{FL}}{F_T \cdot F_G} \cdot F_S$$

Where:

- $I_Z$  (A) is the adjusted current
- $I_{FL}$  (A) is the current at a full load condition
- $F_T$  is the correction factor based on the temperature
- $F_G$  is the correction factor based on the grouping conditions
- $F_S$  is a correction factor used to ensure a safety margin in case of any change in the conditions of the implementation and to extend the life of the cables. This factor increases the current 25%.

Due to the conditions that this system presents, the only correction factor applied would be  $F_S$  in order to ensure the life of the cable and possible changes in the future.

$$I_Z = \frac{58,7083}{1 \cdot 1} \cdot 1,25$$

$$I_Z = 73,3854 \text{ A}$$

Thus, the maximum value of current that the 24 Vdc switchboard will deal with is 73,3854 A. Based on this value, the conductor can be now sized.



Referring to the DNV table that was previously shown, we must set a proper cross-section value for this current. Thus, the section should be 16 mm<sup>2</sup>, because it would ensure the adequate performance of the conductor.

| <b>Table J4 Rating of cables with temperature class 90°C</b> |                                                           |     |        |     |             |     |
|--------------------------------------------------------------|-----------------------------------------------------------|-----|--------|-----|-------------|-----|
| Nominal cross-section (mm <sup>2</sup> )                     | Current rating (A)<br>(Based on ambient temperature 45°C) |     |        |     |             |     |
|                                                              | Single-core                                               |     | 2-core |     | 3 or 4-core |     |
| 1                                                            | 18                                                        |     | 15     |     | 13          |     |
| 1.5                                                          | 23                                                        |     | 20     |     | 16          |     |
| 2.5                                                          | 30                                                        |     | 26     |     | 21          |     |
| 4                                                            | 40                                                        |     | 34     |     | 28          |     |
| 6                                                            | 52                                                        |     | 44     |     | 36          |     |
| 10                                                           | 72                                                        |     | 61     |     | 50          |     |
| 16                                                           | 96                                                        |     | 82     |     | 67          |     |
| 25                                                           | 127                                                       |     | 108    |     | 89          |     |
| 35                                                           | 157                                                       |     | 133    |     | 110         |     |
| 50                                                           | 196                                                       |     | 167    |     | 137         |     |
| 70                                                           | 242                                                       |     | 206    |     | 169         |     |
| 95                                                           | 293                                                       |     | 249    |     | 205         |     |
| 120                                                          | 339                                                       |     | 288    |     | 237         |     |
| 150                                                          | 389                                                       |     | 331    |     | 272         |     |
| 185                                                          | 444                                                       |     | 377    |     | 311         |     |
| 240                                                          | 522                                                       |     | 444    |     | 365         |     |
| 300                                                          | 601                                                       |     | 511    |     | 421         |     |
| 400<br>500<br>600                                            | DC                                                        | AC  | DC     | AC  | DC          | AC  |
|                                                              | 690                                                       | 670 | 587    | 570 | 483         | 469 |
|                                                              | 780                                                       | 720 | 663    | 612 | 546         | 504 |
|                                                              | 890                                                       | 780 | 757    | 663 | 623         | 546 |

Figure 27: Rating of cables (24 Vdc)

Now, this cross-section must comply with the voltage-drop criteria.

A DC distribution system shall be designed and installed so that the stationary voltage-drop in supply to individual consumers, measured from the battery distribution to the consumer terminals, does not exceed 10% of system nominal voltage.<sup>62</sup> However, due to the closeness between the rectifier, the switchboard and the devices, we will set the voltage drop as 5% at its peak. If the cross-section does not produce a voltage-drop higher than this value, then it will comply this criteria.

62 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 17 (July 2013)

As it was explained before, the section must fulfil the following formula:

$$\Delta V = \frac{I \cdot \rho \cdot L \cdot 2}{S}$$

Where:

- **I (A)**: Short-circuit current.
- **$\rho$  ( $\Omega \cdot \text{mm}^2/\text{m}$ )**: Electrical resistivity of the conductor. For copper conductors, this value is  $0,01759 \ \Omega \cdot \text{mm}^2/\text{m}$ .
- **L (m)**: Length of the conductor. Due to the dimensions of the Bridge, and assuming possible changes in the placement of the rectifier, the distance between the rectifier and the switchboard shall not exceed 10 m.
- **S ( $\text{mm}^2$ )**: Cross-section.

Thus:

$$\Delta V = \frac{73,39 \cdot 0,01759 \cdot 10 \cdot 2}{16}$$

$$\Delta V = 1,6137 \text{ V}$$

Once that this value is compared with the rate voltage of the system, i.e. 24 V, it is proved that it exceeds the set voltage drop value of 5%:

$$\Delta V (\%) = \frac{\Delta V}{V_N} \cdot 100$$

$$\Delta V (\%) = \frac{1,6137}{24} \cdot 100$$

$$\Delta V (\%) = 6,72 \% > 5 \%$$

This means that it shall be necessary to choose the following cross-section that is higher. According to the previous table, this value is 25 mm<sup>2</sup>, which does comply with the voltage-drop requirements.

$$\Delta V = \frac{73,39 \cdot 0,01759 \cdot 10 \cdot 2}{25}$$

$$\Delta V = 1,0327$$

$$\Delta V (\%) = \frac{1,0327}{24} \cdot 100$$

$$\Delta V (\%) = 4,3029 \% < 5 \%$$

With a voltage-drop lower than 5% of the nominal voltage, we can assure that this cross-section is suitable for our requirements.

Knowing this values, we can proceed to choose a proper conductor. For this matter, we have chosen the GENERAL CABLE EXZHELLENT – MAR RDT 2x25 mm<sup>2</sup> – model 7783212, annealed copper, stranded class 5, halogen free cross linked polyethylene (HF XLPE) insulation, outer sheath Halogen free thermoplastic polyolefin (SHF1), Rated voltage: 0,6/1 kV. Its catalogue is added at the end of the Annexes section, on page 324 (**3.10.6.2. EXZHELLENT – MAR RDt**) Its main features are gathered on the following list:

- Section (mm<sup>2</sup>): 2x25
- Outer diameter (mm): 18,8
- Weight (kg/km): 725

- Bending radius (mm): 75
- Current rating air 45 °C (A): 130
- Voltage drop ( $\cos \phi = 0,8$ ) (V/A·km): 1,458
- Inductance (mH/km): 0,246

Now that the main conductor of the 24 Vdc network has been calculated, it is time to calculate the conductors and protection to the rest of devices in this system. The procedure to calculate the cables and protections is the same as the previous one for the main cable. On the following tables are represented the calculation of those cables.

| Description                | Circuit Number | Name | Power (W) | Length (m) | Current (A) | 25% Growth Margin (A) | Minimum cross-section (mm <sup>2</sup> ) | Rate cross-section (mm <sup>2</sup> ) | Voltage drop (V) | Voltage Drop (%) | Rate Current (A) |
|----------------------------|----------------|------|-----------|------------|-------------|-----------------------|------------------------------------------|---------------------------------------|------------------|------------------|------------------|
| Magnetic compass           | Circuit 35     | C35  | 100       | 6          | 4,17        | 5,21                  | 0,9161                                   | 1,5                                   | 0,7329           | 3,0538           | 20               |
| Anemometer                 | Circuit 36     | C36  | 100       | 6          | 4,17        | 5,21                  | 0,0797                                   | 1,5                                   | 0,7329           | 3,0538           | 20               |
| Navigation & signal lights | Circuit 37     | C37  | 600       | 6          | 25          | 31,25                 | 0,4780                                   | 6                                     | 1,0994           | 4,5807           | 44               |
| Searchlight                | Circuit 38     | C38  | 900       | 7          | 37,5        | 46,88                 | 0,8365                                   | 10                                    | 1,1543           | 4,8098           | 61               |
| DGPS                       | Circuit 39     | C39  | 10        | 7          | 0,42        | 0,52                  | 0,0093                                   | 1,5                                   | 0,0855           | 0,3563           | 20               |
| Electromagnetic log        | Circuit 40     | C40  | 100       | 7          | 4,17        | 5,21                  | 0,0929                                   | 1,5                                   | 0,8551           | 3,5628           | 20               |
| Telephon sys.              | Circuit 41     | C41  | 100       | 8          | 4,17        | 5,21                  | 0,1062                                   | 1,5                                   | 0,9772           | 4,0718           | 20               |
| Exterior communications    | Circuit 42     | C42  | 400       | 8          | 16,67       | 20,83                 | 0,4249                                   | 6                                     | 0,9772           | 4,0718           | 44               |
| Radar                      | Circuit 43     | C43  | 300       | 8          | 12,5        | 15,63                 | 0,3187                                   | 6                                     | 0,7329           | 3,0538           | 44               |

Table 44: Rate cross-section and voltage drop levels of 24 Vdc devices

| Description                | Circuit Number | Name | Power (W) | Current (A) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Current (A) | Cable       | R (Ω/m) | L (H/m)   |
|----------------------------|----------------|------|-----------|-------------|------------|----------------------------------|------------------|-------------|---------|-----------|
| Magnetic compass           | Circuit 35     | C35  | 100       | 5,21        | 6          | 2x1,5 + 1,5                      | 20               | RDT 7783206 | 0,02361 | 3,31E-007 |
| Anemometer                 | Circuit 36     | C36  | 100       | 5,21        | 6          | 2x1,5 + 1,5                      | 20               | RDT 7783206 | 0,02361 | 3,31E-007 |
| Navigation & signal lights | Circuit 37     | C37  | 600       | 31,25       | 6          | 2x6 + 6                          | 44               | RDT 7783209 | 0,00592 | 2,72E-007 |
| Searchlight                | Circuit 38     | C38  | 900       | 46,88       | 7          | 2x10 + 10                        | 61               | RDT 7783210 | 0,00346 | 2,56E-007 |
| DGPS                       | Circuit 39     | C39  | 10        | 0,52        | 7          | 2x1,5 + 1,5                      | 20               | RDT 7783206 | 0,02361 | 3,31E-007 |
| Electromagnetic log        | Circuit 40     | C40  | 100       | 5,21        | 7          | 2x1,5 + 1,5                      | 20               | RDT 7783206 | 0,02361 | 3,31E-007 |
| Telephon sys.              | Circuit 41     | C41  | 100       | 5,21        | 8          | 2x1,5 + 1,5                      | 20               | RDT 7783206 | 0,02361 | 3,31E-007 |
| Exterior communications    | Circuit 42     | C42  | 400       | 20,83       | 8          | 2x6 + 6                          | 44               | RDT 7783209 | 0,00592 | 2,72E-007 |
| Radar                      | Circuit 43     | C43  | 300       | 15,63       | 8          | 2x6 + 6                          | 44               | RDT 7783209 | 0,00592 | 2,72E-007 |

Table 45: Conductors of 24 Vdc devices

### 3.7.2.2. 144 Vdc cross-section calculation

#### Rate current calculation

First of all, it is necessary to define the conditions within this system. The power forecast in the 144 Vdc installation has been previously calculated, and can be checked at page 154 (**3.2.2.2. 144 Vdc network power forecast**). With this parameters (power and voltage), we are able to calculate the rate current value.

The rate current that flow through the motors during the Top Speed operating condition (the more restrictive one) shall depend on their nominal power and the voltage level where they are working:

$$I_{sc} = \frac{S_N}{V_N}$$

Where:

- $S_N$ : Power required by the motors and supplied from the battery bank. This parameter can have two values. During the Function regime reaches a value of 18700 W for each motor, and during the Top Speed regime reaches a value of 42500 W for each motor.
- $V_N$ : Rate voltage of the batteries. In this case, this value is 144 Vdc

Thus, the short-circuit current shall reach the following value on both situations:

#### Cruising regime

$$I_{sc} = \frac{18700}{144}$$

$$I_{sc} = 129,86 \text{ A}$$

#### Top Speed regime

$$I_{sc} = \frac{42500}{144}$$

$$I_{sc} = 295,14 \text{ A}$$

Due to the fact that it must be selected the more restrictive value, the short-circuit current in this network would reach a value of 295,14 A. Thus, the maximum value of current that the 144 Vdc switchboard will deal with is 295,14 A. Based on this value, the conductors shall be sized. Using a method similar to the 24 Vdc calculation, and knowing that the power factor is equal to the unit, the cross-section of the conductors will be calculated.

The formula used to calculate the cross section of the conductors is:

$$S \geq \frac{\rho \cdot P \cdot L \cdot 2}{\Delta \cdot V \cdot V}$$

We assume that the maximum distance between the motor and the battery bank shall be of 10 m (according to the distribution of the Engine Rooms and the Electrical Compartments, and possible changes of their placement in the future).

$$S \geq \frac{0,01759 \cdot 42500 \cdot 10 \cdot 2}{14,4 \cdot 144}$$

$$S \geq 7,21 \text{ mm}^2$$

According to the calculation, a cross section equal or higher to 7,21 mm<sup>2</sup> would suit with our requirements. Referring to the Classification Society for a rate current of 295,14 A, two poles and 90° C, it is necessary to use a conductor with 150 mm<sup>2</sup> of cross section, which give us a maximum current of 331 A.<sup>63</sup>

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63 DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 51 (July 2013)



| <b>Table J4 Rating of cables with temperature class 90°C</b> |                                                                   |     |               |     |                    |     |
|--------------------------------------------------------------|-------------------------------------------------------------------|-----|---------------|-----|--------------------|-----|
| <i>Nominal cross-section (mm<sup>2</sup>)</i>                | <i>Current rating (A)<br/>(Based on ambient temperature 45°C)</i> |     |               |     |                    |     |
|                                                              | <i>Single-core</i>                                                |     | <i>2-core</i> |     | <i>3 or 4-core</i> |     |
| 1                                                            | 18                                                                |     | 15            |     | 13                 |     |
| 1.5                                                          | 23                                                                |     | 20            |     | 16                 |     |
| 2.5                                                          | 30                                                                |     | 26            |     | 21                 |     |
| 4                                                            | 40                                                                |     | 34            |     | 28                 |     |
| 6                                                            | 52                                                                |     | 44            |     | 36                 |     |
| 10                                                           | 72                                                                |     | 61            |     | 50                 |     |
| 16                                                           | 96                                                                |     | 82            |     | 67                 |     |
| 25                                                           | 127                                                               |     | 108           |     | 89                 |     |
| 35                                                           | 157                                                               |     | 133           |     | 110                |     |
| 50                                                           | 196                                                               |     | 167           |     | 137                |     |
| 70                                                           | 242                                                               |     | 206           |     | 169                |     |
| 95                                                           | 293                                                               |     | 249           |     | 205                |     |
| 120                                                          | 339                                                               |     | 288           |     | 237                |     |
| 150                                                          | 389                                                               |     | 331           |     | 272                |     |
| 185                                                          | 444                                                               |     | 377           |     | 311                |     |
| 240                                                          | 522                                                               |     | 444           |     | 365                |     |
| 300                                                          | 601                                                               |     | 511           |     | 421                |     |
| 400<br>500<br>600                                            | DC                                                                | AC  | DC            | AC  | DC                 | AC  |
|                                                              | 690                                                               | 670 | 587           | 570 | 483                | 469 |
|                                                              | 780                                                               | 720 | 663           | 612 | 546                | 504 |
|                                                              | 890                                                               | 780 | 757           | 663 | 623                | 546 |

Figure 28: Rating of cables (144 Vdc)

Nevertheless, due to the large size of this conductor, it is suitable to divide it into two or more conductors with a smaller cross-section. Thus, we will use two conductors of 50 mm<sup>2</sup> each one, whose maximum current value is 167 A according to the previous table (i.e. 334 A for the whole connection).

Knowing this values, we can proceed to choose a proper conductor. For this matter, we have chosen the General Cable EXZHELLENT – MAR Rdt 2x50 mm<sup>2</sup> model 7783218, annealed copper, stranded class 5, halogen free cross linked polyethylene (HF XLPE) insulation, outer sheath Halogen free thermoplastic polyolefin (SHF1), Rated voltage: 0,6/1 kV. Its catalogue is added at the end of the Annexes section (Page 324 – **3.10.6.2. EXZHELLENT – MAR RDT**). Its main features are

gathered on the following list:

- Section (mm<sup>2</sup>): 2x50
- Outer diameter (mm): 23,5
- Weight (kg/km): 1335
- Bending radius (mm): 95
- Current rating air 45 °C (A): 196
- Voltage drop (cos  $\phi$  = 0,8) (V/A·km): 0,766
- Inductance (mH/km): 0,250

### 3.7.2.3. 230 Vac cross-section calculation

This section will explain what method has been used for the selection of the section of each circuit in every switchboard of 230 Vac. In order to achieve this task, it shall be shown a concrete example (Circuit 3 from the Passengers Room Port Switchboard) in order to make sufficiently clear the procedure.

Two requirements are taken into account for the calculation of the section. It shall comply both of them.

#### Maximum admissible current:

The value of the nominal current that flows through the conductor shall be less than the maximum admissible value of the conductor.

Thus, the current that flows through the conductor reaches a value defined by the following formula:

$$I_n = \frac{P}{V \cdot \cos \varphi}$$

Where:

- $I_n$  (A) is the current value.
- $P$  (W) is the amount of power that requires the load.
- $V$  (V) is its voltage level.
- $\cos \varphi$  is the power factor of the load.

Circuits conformed by sockets can not be classified using the previous formula. It is because sockets can not be applied with an unitary power value, and their rate current shall be consider as the maximum admitted by the conductor, whose minimum cross-section is defined by the Classification Society. Thus, their voltage-drop values shall be calculated based on that rate current value.

The circuit that we are going to use as an example will be the Circuit 3 (C3), which groups 6 downlight luminaries (GLAMOX CASA 16 13F SI), and which is placed at the Passengers Room. It is connected to the Port switchboard of this room. In the circuit distribution (it can be checked at page 157 – **3.3.1. Passengers Room**), it was stated that its power demand would be of 114 W, producing a current of 0,5507 A:

$$I_n = \frac{114}{230 \cdot 0,9}$$

$$I_n = 0,5507 \text{ A}$$

This value must be adjusted according to the previous criteria:

$$I_z = \frac{I_{FL}}{F_T \cdot F_G} \cdot F_s$$

Where:

- $I_z$  (A) is the adjusted current

- $I_{FL}$  (A) is the current at a full load condition
- $F_T$  is the correction factor based on the temperature
- $F_G$  is the correction factor based on the grouping conditions
- $F_S$  is a correction factor used to ensure a safety margin in case of any change in the conditions of the implementation and to extend the life of the cables. This factor increases the current 25%.

Once again, the only correction factor that applies with this circuit is that one applied to ensure the life of the cables and possible changes in the future, by increasing the rate current in a 25%.

$$I_n = \frac{0,5507}{1 \cdot 1} \cdot 1,25$$

$$I_n = 0,6884 \text{ A}$$

According to the Classification Society rules<sup>64</sup>, conductor cross-sections shall be based on the rating of the over-current and short-circuit protection used. However the minimum cross section shall be:

- 0.5 mm<sup>2</sup> for 250 V for cables and switchboard wires for control and instrumentation.
- 1.0 mm<sup>2</sup> for power circuit switchboard wires.
- 1.0 mm<sup>2</sup> for 250 V and 0.6/1 kV power cables with the following exceptions: 0.75 mm<sup>2</sup> may be used for flexible cables supplying portable consumers in accommodation spaces, and also for internal wiring of lighting fittings, provided that the full load current is a maximum of 6 A and that the circuit's short-circuit protection is rated at a maximum of 10 A.
- 10 mm<sup>2</sup> for 1.8/3 and 3.6/6 kV cables.

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64 DNV – Electrical Installations, Pt.4 Ch.8 Sec.9 – Page 90 (July 2013)

- 16 mm<sup>2</sup> and upwards for cables above 6/10 kV.

Nevertheless, as a preventive measure, we will set 1.5 mm<sup>2</sup> for regular circuits up to its rate current (20 A) and 2.5 mm<sup>2</sup> for sockets circuits. If necessary, we will set higher cross-sections to circuits with higher current values. Then, it shall be needed a cable which cross-section has a value of 1,5 mm<sup>2</sup> for the circuit that we are studying. This value will allow us to have an admissible current of 20 A.

| <b>Table J4 Rating of cables with temperature class 90°C</b> |                                                           |     |        |     |             |     |
|--------------------------------------------------------------|-----------------------------------------------------------|-----|--------|-----|-------------|-----|
| Nominal cross-section (mm <sup>2</sup> )                     | Current rating (A)<br>(Based on ambient temperature 45°C) |     |        |     |             |     |
|                                                              | Single-core                                               |     | 2-core |     | 3 or 4-core |     |
| 1                                                            | 18                                                        |     | 15     |     | 13          |     |
| 1.5                                                          | 23                                                        |     | 20     |     | 16          |     |
| 2.5                                                          | 30                                                        |     | 26     |     | 21          |     |
| 4                                                            | 40                                                        |     | 34     |     | 28          |     |
| 6                                                            | 52                                                        |     | 44     |     | 36          |     |
| 10                                                           | 72                                                        |     | 61     |     | 50          |     |
| 16                                                           | 96                                                        |     | 82     |     | 67          |     |
| 25                                                           | 127                                                       |     | 108    |     | 89          |     |
| 35                                                           | 157                                                       |     | 133    |     | 110         |     |
| 50                                                           | 196                                                       |     | 167    |     | 137         |     |
| 70                                                           | 242                                                       |     | 206    |     | 169         |     |
| 95                                                           | 293                                                       |     | 249    |     | 205         |     |
| 120                                                          | 339                                                       |     | 288    |     | 237         |     |
| 150                                                          | 389                                                       |     | 331    |     | 272         |     |
| 185                                                          | 444                                                       |     | 377    |     | 311         |     |
| 240                                                          | 522                                                       |     | 444    |     | 365         |     |
| 300                                                          | 601                                                       |     | 511    |     | 421         |     |
| 400<br>500<br>600                                            | DC                                                        | AC  | DC     | AC  | DC          | AC  |
|                                                              | 690                                                       | 670 | 587    | 570 | 483         | 469 |
|                                                              | 780                                                       | 720 | 663    | 612 | 546         | 504 |
|                                                              | 890                                                       | 780 | 757    | 663 | 623         | 546 |

Figure 29: Example of a cross-section rating

In order to admit that the selected cross-section is suitable for our requirements, we should calculate the minimum cross-section that would hold that amount of amperes. For this task, we shall use the following formula:

$$S \geq \frac{I \cdot \rho \cdot L \cdot 2}{\Delta V}$$

Where:

- **S** (mm<sup>2</sup>) is the minimum cross-section admissible.
- **P** (W) is the power consumption of the load.
- **ρ** (Ω·mm<sup>2</sup>/m) is the electrical resistivity of the conductor. For copper conductors, this value is 0,01759 Ω·mm<sup>2</sup>/m.
- **L** (m) is the length of the conductor. It can be checked at the circuit distribution mentioned above.
- **ΔV** (V) is the maximum admissible value of the voltage drop.
- **V** (V) is the voltage level.

$$S \geq \frac{0,6884 \cdot 0,01759 \cdot 20 \cdot 2}{13,8}$$

$$S \geq 0,0351 \text{ mm}^2$$

This cross-section value is significantly lower than that one chose, making it suitable for our requirements. Thus, the voltage drop produced by the cross-section of 1,5 mm<sup>2</sup> shall be as follows:

#### Voltage drop:

An AC distribution system shall be designed and installed so that the stationary voltage-drop in supply to individual consumers, measured from the main switchboard to the consumer terminals, does not exceed 6% of system nominal voltage.<sup>65</sup>

Thus, the voltage-drop in every line shall be less than the 6%. In a network of

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<sup>65</sup> DNV – Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 17 (July 2013)

230 Vac, this value shall be 13,8 Vac.

$$\Delta V_{max} = 230 \cdot \frac{6}{100}$$

$$\Delta V_{max} = 13,8 \text{ A}$$

In order to assure that the section previously selected complies with the requirements referred to the voltage-drop, the following formula shall be used:

$$\Delta V = \frac{I \cdot \rho \cdot L \cdot 2}{S}$$

$$\Delta V = \frac{0,6884 \cdot 0,01759 \cdot 20 \cdot 2}{1,5}$$

$$\Delta V = 0,3229 \text{ V}$$

$$\Delta V (\%) = 0,1404 \%$$

This value is under the requirements by far. Then, both requirements are complied.

In the following tables shall be shown the cross-section values necessary for every circuit, as well as their voltage-drop produced. This values will be useful for future calculations of the required conductors.

| Passengers Room (Port Switchboard) |                |      |       |           |             |                       |             |            |                                  |                                       |                  |                  |              |
|------------------------------------|----------------|------|-------|-----------|-------------|-----------------------|-------------|------------|----------------------------------|---------------------------------------|------------------|------------------|--------------|
| Description                        | Circuit Number | Name | Units | Power (W) | Current (A) | 25% Growth Margin (A) | Voltage (V) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Cross-section (mm <sup>2</sup> ) | Voltage Drop (V) | Voltage Drop (%) | Rate Current |
| Sockets                            | Circuit 1      | C1   | 6     | -         | 26          | -                     | 230         | 29         | 1,9222                           | 2,5                                   | 10,6103          | 4,6132           | 26           |
| Sockets                            | Circuit 2      | C2   | 7     | -         | 26          | -                     | 230         | 32         | 2,1210                           | 2,5                                   | 11,7079          | 5,0904           | 26           |
| Lighting                           | Circuit 3      | C3   | 6     | 114       | 0,551       | 0,688                 | 230         | 20         | 0,0351                           | 1,5                                   | 0,3229           | 0,1404           | 20           |
| Lighting                           | Circuit 4      | C4   | 6     | 114       | 0,551       | 0,688                 | 230         | 24         | 0,0421                           | 1,5                                   | 0,3875           | 0,1685           | 20           |
| Emergency Lighting                 | Circuit 5      | C5   | 4     | 20        | 0,097       | 0,121                 | 230         | 14         | 0,0043                           | 1,5                                   | 0,0397           | 0,0172           | 20           |

Table 46: Passengers Room (Port Switchboard - Cross-section and voltage-drop)



| Passengers Room (Starboard Switchboard) |                |      |       |           |             |                       |             |            |                                  |                                       |                  |                  |              |
|-----------------------------------------|----------------|------|-------|-----------|-------------|-----------------------|-------------|------------|----------------------------------|---------------------------------------|------------------|------------------|--------------|
| Description                             | Circuit Number | Name | Units | Power (W) | Current (A) | 25% Growth Margin (A) | Voltage (V) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Cross-section (mm <sup>2</sup> ) | Voltage Drop (V) | Voltage Drop (%) | Rate Current |
| Sockets                                 | Circuit 6      | C6   | 6     | -         | 26          | -                     | 230         | 29         | 1,9222                           | 2,5                                   | 10,6103          | 4,6132           | 26           |
| Sockets                                 | Circuit 7      | C7   | 7     | -         | 26          | -                     | 230         | 32         | 2,1210                           | 2,5                                   | 11,7079          | 5,0904           | 26           |
| Lighting                                | Circuit 8      | C8   | 6     | 114       | 0,551       | 0,688                 | 230         | 20         | 0,0351                           | 1,5                                   | 0,3229           | 0,1404           | 20           |
| Lighting                                | Circuit 9      | C9   | 6     | 114       | 0,551       | 0,688                 | 230         | 24         | 0,0421                           | 1,5                                   | 0,3875           | 0,1685           | 20           |
| Emergency Lighting                      | Circuit 10     | C10  | 4     | 20        | 0,097       | 0,121                 | 230         | 14         | 0,0043                           | 1,5                                   | 0,0397           | 0,0172           | 20           |

Table 47: Passengers Room (Starboard Switchboard - Cross-section and voltage-drop)

| Entrance & Toilet (Port Switchboard) |                |      |       |           |             |                       |             |            |                                  |                                       |                  |                  |              |
|--------------------------------------|----------------|------|-------|-----------|-------------|-----------------------|-------------|------------|----------------------------------|---------------------------------------|------------------|------------------|--------------|
| Description                          | Circuit Number | Name | Units | Power (W) | Current (A) | 25% Growth Margin (A) | Voltage (V) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Cross-section (mm <sup>2</sup> ) | Voltage Drop (V) | Voltage Drop (%) | Rate Current |
| Sockets (Entrance & Toilet)          | Circuit 11     | C11  | 3     | -         | 26,000      | -                     | 230         | 12         | 0,7954                           | 2,5                                   | 4,3905           | 1,9089           | 26           |
| Lighting (Entrance)                  | Circuit 12     | C12  | 4     | 76        | 0,367       | 0,459                 | 230         | 11         | 0,0129                           | 1,5                                   | 0,1200           | 0,0500           | 20           |
| Lighting (Toilet)                    | Circuit 13     | C13  | 1     | 19        | 0,092       | 0,115                 | 230         | 4          | 0,0012                           | 1,5                                   | 0,0100           | 0,0000           | 20           |
| Emergency Lighting (Entrance)        | Circuit 14     | C14  | 3     | 15        | 0,072       | 0,091                 | 230         | 10         | 0,0023                           | 1,5                                   | 0,0200           | 0,0100           | 20           |
| Emergency Lighting (Toilet)          | Circuit 15     | C15  | 1     | 5         | 0,024       | 0,030                 | 230         | 4          | 0,0003                           | 1,5                                   | 0,0000           | 0,0000           | 20           |
| Extractor Fan                        | Circuit 16     | C16  | 1     | 110       | 0,600       | 0,750                 | 230         | 3          | 0,0057                           | 1,5                                   | 0,0500           | 0,0200           | 20           |
| Air Conditioning 1                   | Circuit 17     | C17  | 1     | 1000      | 5,435       | 6,793                 | 230         | 6          | 0,1039                           | 1,5                                   | 0,9600           | 0,4200           | 20           |

*Table 48: Entrance & Toilet (Port Switchboard - Cross-section and voltage-drop)*

| Entrance & Toilet (Starboard Switchboard) |                |      |       |           |             |                       |             |            |                                  |                                       |                  |                  |              |
|-------------------------------------------|----------------|------|-------|-----------|-------------|-----------------------|-------------|------------|----------------------------------|---------------------------------------|------------------|------------------|--------------|
| Description                               | Circuit Number | Name | Units | Power (W) | Current (A) | 25% Growth Margin (A) | Voltage (V) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Cross-section (mm <sup>2</sup> ) | Voltage Drop (V) | Voltage Drop (%) | Rate Current |
| Sockets (Entrance & Toilet)               | Circuit 18     | C18  | 3     | -         | 26,000      | -                     | 230         | 12         | 0,7954                           | 2,5                                   | 4,3905           | 1,9089           | 26           |
| Lighting (Entrance)                       | Circuit 19     | C19  | 5     | 95        | 0,459       | 0,574                 | 230         | 14         | 0,0205                           | 1,5                                   | 0,1884           | 0,0819           | 20           |
| Lighting (Toilet)                         | Circuit 20     | C20  | 1     | 19        | 0,092       | 0,115                 | 230         | 4          | 0,0012                           | 1,5                                   | 0,0108           | 0,0047           | 20           |
| Emergency Lighting (Entrance)             | Circuit 21     | C21  | 2     | 10        | 0,048       | 0,060                 | 230         | 7          | 0,0011                           | 1,5                                   | 0,0099           | 0,0043           | 20           |
| Emergency Lighting (Toilet)               | Circuit 22     | C22  | 1     | 5         | 0,024       | 0,030                 | 230         | 4          | 0,0003                           | 1,5                                   | 0,0028           | 0,0012           | 20           |
| Air Conditioning 2                        | Circuit 23     | C23  | 1     | 1000      | 5,435       | 6,793                 | 230         | 6          | 0,1039                           | 1,5                                   | 0,9560           | 0,4156           | 20           |

Table 49: Entrance &amp; Toilet (Starboard Switchboard - Cross-section and voltage-drop)

| Anteroom (Port Switchboard)   |                |      |       |           |             |                       |             |            |                                  |                                       |                  |                  |              |
|-------------------------------|----------------|------|-------|-----------|-------------|-----------------------|-------------|------------|----------------------------------|---------------------------------------|------------------|------------------|--------------|
| Description                   | Circuit Number | Name | Units | Power (W) | Current (A) | 25% Growth Margin (A) | Voltage (V) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Cross-section (mm <sup>2</sup> ) | Voltage Drop (V) | Voltage Drop (%) | Rate Current |
| Sockets (Anteroom)            | Circuit 24     | C24  | 2     | -         | 26,000      | -                     | 230         | 8          | 0,5302                           | 2,5                                   | 2,9270           | 1,2726           | 26           |
| Lighting (Anteroom)           | Circuit 25     | C25  | 5     | 95        | 0,459       | 0,574                 | 230         | 12         | 0,0175                           | 1,5                                   | 0,1615           | 0,0702           | 20           |
| Emergency Lighting (Anteroom) | Circuit 26     | C26  | 3     | 15        | 0,072       | 0,091                 | 230         | 12         | 0,0028                           | 1,5                                   | 0,0255           | 0,0111           | 20           |

Table 50: Anteroom (Port Switchboard - Cross-section and voltage-drop)

| Anteroom (Starboard Switchboard) |                |      |       |           |             |                       |             |            |                                  |                                       |                  |                  |              |
|----------------------------------|----------------|------|-------|-----------|-------------|-----------------------|-------------|------------|----------------------------------|---------------------------------------|------------------|------------------|--------------|
| Description                      | Circuit Number | Name | Units | Power (W) | Current (A) | 25% Growth Margin (A) | Voltage (V) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Cross-section (mm <sup>2</sup> ) | Voltage Drop (V) | Voltage Drop (%) | Rate Current |
| Sockets (Anteroom)               | Circuit 27     | C27  | 2     | -         | 26,000      | -                     | 230         | 8          | 0,5302                           | 2,5                                   | 2,9270           | 1,2726           | 26           |
| Lighting (Anteroom)              | Circuit 28     | C28  | 6     | 114       | 0,551       | 0,688                 | 230         | 18         | 0,0316                           | 1,5                                   | 0,2906           | 0,1264           | 20           |
| Emergency Lighting (Anteroom)    | Circuit 29     | C29  | 2     | 10        | 0,048       | 0,060                 | 230         | 7          | 0,0011                           | 1,5                                   | 0,0099           | 0,0043           | 20           |

Table 51: Anteroom (Starboard Switchboard - Cross-section and voltage-drop)

| Bridge (230 Vac Switchboard) |                |      |       |           |             |                       |             |            |                                  |                                       |                  |                  |              |
|------------------------------|----------------|------|-------|-----------|-------------|-----------------------|-------------|------------|----------------------------------|---------------------------------------|------------------|------------------|--------------|
| Description                  | Circuit Number | Name | Units | Power (W) | Current (A) | 25% Growth Margin (A) | Voltage (V) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Cross-section (mm <sup>2</sup> ) | Voltage Drop (V) | Voltage Drop (%) | Rate Current |
| Sockets                      | Circuit 30     | C30  | 2     | -         | 26,000      | -                     | 230         | 7          | 0,4640                           | 2,5                                   | 2,5611           | 1,1135           | 26           |
| Lighting                     | Circuit 31     | C31  | 1     | 50        | 0,242       | 0,302                 | 230         | 3          | 0,0023                           | 1,5                                   | 0,0212           | 0,0092           | 20           |
| Emergency Lighting           | Circuit 32     | C32  | 2     | 10        | 0,048       | 0,060                 | 230         | 4          | 0,0006                           | 1,5                                   | 0,0057           | 0,0025           | 20           |
| External Lighting            | Circuit 33     | C33  | 7     | 3031      | 14,643      | 18,303                | 230         | 50         | 2,3330                           | 2,5                                   | 12,8781          | 5,5992           | 26           |
| Windlass Anchor              | Circuit 34     | C34  | 1     | 1000      | 4,831       | 6,039                 | 230         | 10         | 0,1539                           | 1,5                                   | 1,4163           | 0,6158           | 20           |

Table 52: Bridge (230 Vac Switchboard - Cross-section and voltage-drop)

| Engine Room & Electrical Compartment (Port Switchboard) |                |      |       |           |             |                       |             |            |                                  |                                       |                  |                  |              |
|---------------------------------------------------------|----------------|------|-------|-----------|-------------|-----------------------|-------------|------------|----------------------------------|---------------------------------------|------------------|------------------|--------------|
| Description                                             | Circuit Number | Name | Units | Power (W) | Current (A) | 25% Growth Margin (A) | Voltage (V) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Cross-section (mm <sup>2</sup> ) | Voltage Drop (V) | Voltage Drop (%) | Rate Current |
| Sockets                                                 | Circuit 44     | C44  | 4     | -         | 26,000      | -                     | 230         | 21         | 1,3919                           | 2,5                                   | 7,6833           | 3,3406           | 26           |
| Lighting                                                | Circuit 45     | C45  | 5     | 250       | 1,144       | 1,430                 | 230         | 21         | 0,0766                           | 1,5                                   | 0,7044           | 0,3063           | 20           |
| Emergency Lighting (Opposite hull)                      | Circuit 46     | C46  | 6     | 30        | 0,137       | 0,172                 | 230         | 26         | 0,0114                           | 1,5                                   | 0,1047           | 0,0455           | 20           |
| Bilge Pump 1 (Opposite hull)                            | Circuit 47     | C47  | 1     | 600       | 2,800       | 3,500                 | 230         | 18         | 0,1606                           | 1,5                                   | 1,4776           | 0,6424           | 20           |
| Bilge Pump 2 (Opposite hull)                            | Circuit 48     | C48  | 1     | 600       | 2,800       | 3,500                 | 230         | 25         | 0,2231                           | 1,5                                   | 2,0522           | 0,8922           | 20           |
| Extractor Fans                                          | Circuit 49     | C49  | 2     | 40        | 0,193       | 0,242                 | 230         | 15         | 0,0092                           | 1,5                                   | 0,0850           | 0,0369           | 20           |

Table 53: Engine Room &amp; Electrical Compartment (Port - Cross-section and voltage-drop)



| Engine Room and Electrical Compartment (Starboard Switchboard) |                |      |       |           |             |                       |             |            |                                  |                                       |                  |                  |              |
|----------------------------------------------------------------|----------------|------|-------|-----------|-------------|-----------------------|-------------|------------|----------------------------------|---------------------------------------|------------------|------------------|--------------|
| Description                                                    | Circuit Number | Name | Units | Power (W) | Current (A) | 25% Growth Margin (A) | Voltage (V) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Cross-section (mm <sup>2</sup> ) | Voltage Drop (V) | Voltage Drop (%) | Rate Current |
| Sockets                                                        | Circuit 50     | C50  | 4     | -         | 26,000      | -                     | 230         | 21         | 1,3919                           | 2,5                                   | 7,6833           | 3,3406           | 26           |
| Lighting                                                       | Circuit 51     | C51  | 5     | 250       | 1,144       | 1,430                 | 230         | 21         | 0,0766                           | 1,5                                   | 0,7044           | 0,3063           | 20           |
| Emergency Lighting (Opposite hull)                             | Circuit 52     | C52  | 6     | 30        | 0,137       | 0,172                 | 230         | 26         | 0,0114                           | 1,5                                   | 0,1047           | 0,0455           | 20           |
| Bilge Pump 3 (Opposite hull)                                   | Circuit 53     | C53  | 1     | 600       | 2,800       | 3,500                 | 230         | 18         | 0,1606                           | 1,5                                   | 1,4776           | 0,6424           | 20           |
| Bilge Pump 4 (Opposite hull)                                   | Circuit 54     | C54  | 1     | 600       | 2,800       | 3,500                 | 230         | 25         | 0,2231                           | 1,5                                   | 2,0522           | 0,8922           | 20           |
| Extractor Fans                                                 | Circuit 55     | C55  | 2     | 40        | 0,193       | 0,242                 | 230         | 15         | 0,0092                           | 1,5                                   | 0,0850           | 0,0369           | 20           |

Table 54: Engine Room &amp; Electrical Compartment (Starboard - Cross-section and voltage-drop)

Thus, we can choose the proper cable for each circuit. For circuit 3, we have chose an EXZHELLENT – MAR RDT 0,6 / 1 kV 2 x 1,5 + 1,5 mm<sup>2</sup> – model 7783306.

Basically, the system shall count with two types of cables, and it shall depend on the load supplied. Due to the closeness between the switchboards and the circuits (the longest length is 50 m, while the shortest is 3 m), as well as the low amount of power required in each one, voltage-drops shall not reach high values. This means that almost every circuit may be equipped with the smallest section required.

Referring to the sockets, we have chose a greater cross-section (2 x 2,5 + 2,5 mm<sup>2</sup>) than the regular circuits (2 x 1,5 + 1,5 mm<sup>2</sup>). It is to ensure the proper performance of the sockets if they are connected to a unusually bigger load. The rest of the circuits shall count with a 1,5 mm<sup>2</sup> cross-section, which is enough to their task, due to the fact that the higher voltage-drop is 5,5992 % (i.e. external lighting placed out of the vessel and surrounding it) while the lower reaches a value of 0,0012 % (emergency lighting of the Toilet).

The following tables gathers the conductor chosen for every circuit, depending on their power, 25% growth margin current, their length and their voltage-drop. The tables tell us that **465 m** of EXZHELLENT – MAR RDT 0,6 / 1 kV 2 x 1,5 + 1,5 mm<sup>2</sup> – model 7783306 and **261 m** of EXZHELLENT – MAR RDT 0,6 / 1 kV 2 x 2,5 + 2,5 mm<sup>2</sup> – model 7783307 will be used.

| Passengers Room (Port Switchboard) |                |      |           |                       |            |                                  |              |                |         |         |
|------------------------------------|----------------|------|-----------|-----------------------|------------|----------------------------------|--------------|----------------|---------|---------|
| Description                        | Circuit Number | Name | Power (W) | 25% Growth Margin (A) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Current | Conductor      | R (Ω/m) | L (H/m) |
| Sockets                            | Circuit 1      | C1   | 600       | 3,432                 | 29         | 2x2,5+2,5                        | 26           | RDT<br>7783307 | 0,01420 | 3,07E-7 |
| Sockets                            | Circuit 2      | C2   | 700       | 4,005                 | 32         | 2x2,5+2,5                        | 26           | RDT<br>7783307 | 0,01420 | 3,07E-7 |
| Lighting                           | Circuit 3      | C3   | 114       | 0,688                 | 20         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| Lighting                           | Circuit 4      | C4   | 114       | 0,688                 | 24         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| Emergency Lighting                 | Circuit 5      | C5   | 20        | 0,121                 | 14         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |

Table 55: Passengers Room (Port Switchboard - Conductor)

| Passengers Room (Starboard Switchboard) |                |      |           |                       |            |                                  |              |                |         |         |
|-----------------------------------------|----------------|------|-----------|-----------------------|------------|----------------------------------|--------------|----------------|---------|---------|
| Description                             | Circuit Number | Name | Power (W) | 25% Growth Margin (A) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Current | Conductor      | R (Ω/m) | L (H/m) |
| Sockets                                 | Circuit 6      | C6   | 600       | 3,432                 | 29         | 2x2,5+2,5                        | 26           | RDT<br>7783307 | 0,01420 | 3,07E-7 |
| Sockets                                 | Circuit 7      | C7   | 700       | 4,005                 | 32         | 2x2,5+2,5                        | 26           | RDT<br>7783307 | 0,01420 | 3,07E-7 |
| Lighting                                | Circuit 8      | C8   | 114       | 0,688                 | 20         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| Lighting                                | Circuit 9      | C9   | 114       | 0,688                 | 24         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| Emergency Lighting                      | Circuit 10     | C10  | 20        | 0,121                 | 14         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |

Table 56: Passengers Room (Starboard Switchboard - Conductor)

| Entrance & Toilet (Port switchboard) |                |      |           |                       |            |                                  |              |             |         |         |
|--------------------------------------|----------------|------|-----------|-----------------------|------------|----------------------------------|--------------|-------------|---------|---------|
| Description                          | Circuit Number | Name | Power (W) | 25% Growth Margin (A) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Current | Conductor   | R (Ω/m) | L (H/m) |
| Sockets (Entrance & Toilet)          | Circuit 11     | C11  | 300       | 1,716                 | 12         | 2x2,5+2,5                        | 26           | RDT 7783307 | 0,01420 | 3,07E-7 |
| Lighting (Entrance)                  | Circuit 12     | C12  | 76        | 0,459                 | 11         | 2x1,5+1,5                        | 20           | RDT 7783306 | 0,02361 | 3,31E-7 |
| Lighting (Toilet)                    | Circuit 13     | C13  | 19        | 0,115                 | 4          | 2x1,5+1,5                        | 20           | RDT 7783306 | 0,02361 | 3,31E-7 |
| Emergency Lighting (Entrance)        | Circuit 14     | C14  | 15        | 0,091                 | 10         | 2x1,5+1,5                        | 20           | RDT 7783306 | 0,02361 | 3,31E-7 |
| Emergency Lighting (Toilet)          | Circuit 15     | C15  | 5         | 0,030                 | 4          | 2x1,5+1,5                        | 20           | RDT 7783306 | 0,02361 | 3,31E-7 |
| Extractor Fan                        | Circuit 16     | C16  | 110       | 0,750                 | 3          | 2x1,5+1,5                        | 20           | RDT 7783306 | 0,02361 | 3,31E-7 |
| Air Conditioning 1                   | Circuit 17     | C17  | 1000      | 6,793                 | 6          | 2x1,5+1,5                        | 20           | RDT 7783306 | 0,02361 | 3,31E-7 |

Table 57: Entrance &amp; Toilet (Port Switchboard - Conductor)

| Entrance & Toilet (Starboard switchboard) |                |      |           |                       |            |                                  |              |             |         |         |
|-------------------------------------------|----------------|------|-----------|-----------------------|------------|----------------------------------|--------------|-------------|---------|---------|
| Description                               | Circuit Number | Name | Power (W) | 25% Growth Margin (A) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Current | Conductor   | R (Ω/m) | L (H/m) |
| Sockets (Entrance & Toilet)               | Circuit 18     | C18  | 300       | 1,716                 | 12         | 2x2,5+2,5                        | 26           | RDT 7783307 | 0,01420 | 3,07E-7 |
| Lighting (Entrance)                       | Circuit 19     | C19  | 95        | 0,574                 | 14         | 2x1,5+1,5                        | 20           | RDT 7783306 | 0,02361 | 3,31E-7 |
| Lighting (Toilet)                         | Circuit 20     | C20  | 19        | 0,115                 | 4          | 2x1,5+1,5                        | 20           | RDT 7783306 | 0,02361 | 3,31E-7 |
| Emergency Lighting (Entrance)             | Circuit 21     | C21  | 10        | 0,060                 | 7          | 2x1,5+1,5                        | 20           | RDT 7783306 | 0,02361 | 3,31E-7 |
| Emergency Lighting (Toilet)               | Circuit 22     | C22  | 5         | 0,030                 | 4          | 2x1,5+1,5                        | 20           | RDT 7783306 | 0,02361 | 3,31E-7 |
| Air Conditioning 2                        | Circuit 23     | C23  | 1000      | 6,793                 | 6          | 2x1,5+1,5                        | 20           | RDT 7783306 | 0,02361 | 3,31E-7 |

Table 58: Entrance &amp; Toilet (Starboard Switchboard - Conductor)

| Anteroom (Port Switchboard)   |                |      |           |                       |            |                                  |              |                |         |         |
|-------------------------------|----------------|------|-----------|-----------------------|------------|----------------------------------|--------------|----------------|---------|---------|
| Description                   | Circuit Number | Name | Power (W) | 25% Growth Margin (A) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Current | Conductor      | R (Ω/m) | L (H/m) |
| Sockets (Anteroom)            | Circuit 24     | C24  | 200       | 1,144                 | 8          | 2x2,5+2,5                        | 26           | RDT<br>7783307 | 0,01420 | 3,07E-7 |
| Lighting (Anteroom)           | Circuit 25     | C25  | 114       | 0,574                 | 12         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| Emergency Lighting (Anteroom) | Circuit 26     | C26  | 15        | 0,091                 | 12         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |

Table 59: Anteroom (Port Switchboard - Conductor)

| Anteroom (Starboard Switchboard) |                |      |           |                       |            |                                  |              |                |         |         |
|----------------------------------|----------------|------|-----------|-----------------------|------------|----------------------------------|--------------|----------------|---------|---------|
| Description                      | Circuit Number | Name | Power (W) | 25% Growth Margin (A) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Current | Conductor      | R (Ω/m) | L (H/m) |
| Sockets (Anteroom)               | Circuit 27     | C27  | 200       | 1,144                 | 8          | 2x2,5+2,5                        | 26           | RDT<br>7783307 | 0,01420 | 3,07E-7 |
| Lighting (Anteroom)              | Circuit 28     | C28  | 95        | 0,688                 | 18         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| Emergency Lighting (Anteroom)    | Circuit 29     | C29  | 10        | 0,060                 | 7          | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |

Table 60: Anteroom (Starboard Switchboard - Conductor)



| Bridge (230 Vac Switchboard)  |                |      |           |                       |            |                                  |              |                |         |         |
|-------------------------------|----------------|------|-----------|-----------------------|------------|----------------------------------|--------------|----------------|---------|---------|
| Description                   | Circuit Number | Name | Power (W) | 25% Growth Margin (A) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Current | Conductor      | R (Ω/m) | L (H/m) |
| Sockets (Anteroom)            | Circuit 30     | C30  | 200       | 1,144                 | 7          | 2x2,5+2,5                        | 26           | RDT<br>7783307 | 0,01420 | 3,07E-7 |
| Lighting (Anteroom)           | Circuit 31     | C31  | 50        | 0,302                 | 3          | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| Emergency Lighting (Anteroom) | Circuit 32     | C32  | 10        | 0,060                 | 4          | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| External Lighting             | Circuit 33     | C33  | 3031      | 18,303                | 50         | 2x2,5+2,5                        | 26           | RDT<br>7783307 | 0,01420 | 3,07E-7 |
| Windlass Anchor               | Circuit 34     | C34  | 1000      | 6,039                 | 10         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |

Table 61: Bridge (230 Vac Switchboard - Conductor)

| Engine Room & Electrical Compartment (Port Switchboard) |                |      |           |                       |            |                                  |              |                |         |         |
|---------------------------------------------------------|----------------|------|-----------|-----------------------|------------|----------------------------------|--------------|----------------|---------|---------|
| Description                                             | Circuit Number | Name | Power (W) | 25% Growth Margin (A) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Current | Conductor      | R (Ω/m) | L (H/m) |
| Sockets                                                 | Circuit 44     | C44  | 400       | 2,288                 | 21         | 2x2,5+2,5                        | 26           | RDT<br>7783307 | 0,01420 | 3,07E-7 |
| Lighting                                                | Circuit 45     | C45  | 250       | 1,430                 | 21         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| Emergency Lighting<br>(Opposite hull)                   | Circuit 46     | C46  | 30        | 0,172                 | 26         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| Bilge Pump 1<br>(Opposite hull)                         | Circuit 47     | C47  | 60        | 3,500                 | 18         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| Bilge Pump 2<br>(Opposite hull)                         | Circuit 48     | C48  | 60        | 3,500                 | 25         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| Extractor Fan                                           | Circuit 49     | C49  | 40        | 0,242                 | 15         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |

Table 62: Engine Room &amp; Electrical Compartment (Port Switchboard - Conductor)

| Engine Room & Electrical Compartment (Starboard Switchboard) |                |      |           |                       |            |                                  |              |                |         |         |
|--------------------------------------------------------------|----------------|------|-----------|-----------------------|------------|----------------------------------|--------------|----------------|---------|---------|
| Description                                                  | Circuit Number | Name | Power (W) | 25% Growth Margin (A) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate Current | Conductor      | R (Ω/m) | L (H/m) |
| Sockets                                                      | Circuit 50     | C50  | 400       | 2,288                 | 21         | 2x2,5+2,5                        | 26           | RDT<br>7783307 | 0,01420 | 3,07E-7 |
| Lighting                                                     | Circuit 51     | C51  | 250       | 1,430                 | 21         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| Emergency Lighting<br>(Opposite hull)                        | Circuit 52     | C52  | 30        | 0,172                 | 26         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| Bilge Pump 3<br>(Opposite hull)                              | Circuit 53     | C53  | 60        | 3,500                 | 18         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| Bilge Pump 4<br>(Opposite hull)                              | Circuit 54     | C54  | 60        | 3,500                 | 25         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |
| Extractor Fan                                                | Circuit 55     | C55  | 40        | 0,242                 | 15         | 2x1,5+1,5                        | 20           | RDT<br>7783306 | 0,02361 | 3,31E-7 |

Table 63: Engine Room &amp; Electrical Compartment (Starboard Switchboard - Conductor)

#### **3.7.2.4. Switchboards cross-section calculation**

Once that the cross-sections of every circuit have been calculated, it is time to assigned the adequate cross-section to the secondary switchboards that hold those circuits. This means calculate the cross-section of the conductor that will reach the switchboards in every room.

The switchboards have been distributed among the rooms. As it is shown in the previous section, we will deal with two switchboards in the Passengers Room, the Entrance and the Toilet, the Anteroom and the Engine Rooms and Electrical Compartment. The Bridge will have one switchboard for the 230 Vac system and another one for the 24 Vdc system, both supplied through a interconnection from both electrical systems.

In order to calculate the required cross-section of every switchboard, as well as their circuit breaker, it is necessary to define the rate current of all of them. To achieve this, we have to sum up the currents of every load connected to the switchboard.

In order to clarify the procedure, we will take the Port switchboard of the Passengers Room as an example. Then, the rest of the cross-sections will be calculated through tables, as in the previous section.

The Port switchboard of the Passengers Room hosts five circuits (each of them with several loads), two of them for sockets, another two for lightings and the remaining one for the emergency lighting. As mentioned above, their current values, after all the adjustments, were as follows:

| Description        | Circuit Number | Name | Current (A) |
|--------------------|----------------|------|-------------|
| Sockets            | Circuit 1      | C1   | 26          |
| Sockets            | Circuit 2      | C2   | 26          |
| Lighting           | Circuit 3      | C3   | 0,6884      |
| Lighting           | Circuit 4      | C4   | 0,6884      |
| Emergency Lighting | Circuit 5      | C5   | 0,1208      |

Table 64: Passengers Room Port switchboard currents

Then, the total value that will flow through the switchboard shall be the sum of those values.

$$I_T = I_{C1} + I_{C2} + I_{C3} + I_{C4} + I_{C5}$$

$$I_T = 26 + 26 + 0,6884 + 0,6884 + 0,1208$$

$$I_T = 53,4976 \text{ A}$$

Once that we have the total value, we will need the length of the conductor in order to calculate its cross-section. Due to the fact that the Port switchboard of the Passengers Room is nearly above of the Port 230 Vac switchboard, its length will be of just 3 m. With this values, we are able to calculate its minimum cross-section, using the same formula as in the previous sections:

$$S \geq \frac{I \cdot \rho \cdot L \cdot 2}{\Delta V}$$

$$S \geq \frac{53,4976 \cdot 0,01759 \cdot 3 \cdot 2}{13,8}$$

$$S \geq 0,4091 \text{ mm}^2$$

This result tells us that any standard cross-section would be adequate to our requirements. Nevertheless, it will be the total current value which will set the proper cross-section. According to the table from the Classification Society quoted on the previous calculations, it would be necessary a 2x16 mm<sup>2</sup> conductor for this task, which would admit a 82 A current at its peak. We have chose this value instead of the 2x10 mm<sup>2</sup> as a way to facilitate the selection of a circuit breaker in the following sections.

| <b>Table J4 Rating of cables with temperature class 90°C</b> |                                                                   |     |               |     |                    |     |
|--------------------------------------------------------------|-------------------------------------------------------------------|-----|---------------|-----|--------------------|-----|
| <i>Nominal cross-section (mm<sup>2</sup>)</i>                | <i>Current rating (A)<br/>(Based on ambient temperature 45°C)</i> |     |               |     |                    |     |
|                                                              | <i>Single-core</i>                                                |     | <i>2-core</i> |     | <i>3 or 4-core</i> |     |
| 1                                                            | 18                                                                |     | 15            |     | 13                 |     |
| 1.5                                                          | 23                                                                |     | 20            |     | 16                 |     |
| 2.5                                                          | 30                                                                |     | 26            |     | 21                 |     |
| 4                                                            | 40                                                                |     | 34            |     | 28                 |     |
| 6                                                            | 52                                                                |     | 44            |     | 36                 |     |
| 10                                                           | 72                                                                |     | 61            |     | 50                 |     |
| 16                                                           | 96                                                                |     | 82            |     | 67                 |     |
| 25                                                           | 127                                                               |     | 108           |     | 89                 |     |
| 35                                                           | 157                                                               |     | 133           |     | 110                |     |
| 50                                                           | 196                                                               |     | 167           |     | 137                |     |
| 70                                                           | 242                                                               |     | 206           |     | 169                |     |
| 95                                                           | 293                                                               |     | 249           |     | 205                |     |
| 120                                                          | 339                                                               |     | 288           |     | 237                |     |
| 150                                                          | 389                                                               |     | 331           |     | 272                |     |
| 185                                                          | 444                                                               |     | 377           |     | 311                |     |
| 240                                                          | 522                                                               |     | 444           |     | 365                |     |
| 300                                                          | 601                                                               |     | 511           |     | 421                |     |
| 400<br>500<br>600                                            | DC                                                                | AC  | DC            | AC  | DC                 | AC  |
|                                                              | 690                                                               | 670 | 587           | 570 | 483                | 469 |
|                                                              | 780                                                               | 720 | 663           | 612 | 546                | 504 |
|                                                              | 890                                                               | 780 | 757           | 663 | 623                | 546 |

Figure 30: Passengers Room Port switchboard cross-section

With this value, we must calculate the expected voltage-drop and verify that it does not exceed the stated value of 6%.

$$\Delta V = \frac{I \cdot \rho \cdot L \cdot 2}{S}$$

$$\Delta V = \frac{53,4976 \cdot 0,01759 \cdot 3 \cdot 2}{16}$$

$$\Delta V = 0,3529 \text{ V}$$

$$\Delta V (\%) = 0,1534 \%$$

Thus, we can choose the proper cable for each switchboard. For the Passengers Room Port switchboard, we have chose an EXZHELLENT – MAR RDT 0,6 / 1 kV 2 x 16 + 16 mm<sup>2</sup> – model 7783311.

Applying this procedure to the remaining switchboards, we will obtain their required cross-section. The results are gathered on the following table:

| Switchboard                            | Side      | Total current (A) | Length (m) | Cross-section (mm <sup>2</sup> ) | Rate cross-section (mm <sup>2</sup> ) | Voltage-drop (V) | Voltage-drop (%) | Rate current (A) | Conductor   |
|----------------------------------------|-----------|-------------------|------------|----------------------------------|---------------------------------------|------------------|------------------|------------------|-------------|
| Passengers Room                        | Port      | 53,498            | 3          | 0,4091                           | 2x16+16                               | 0,3529           | 0,1534           | 82               | RDT 7783311 |
|                                        | Starboard | 53,498            | 7          | 0,9547                           | 2x16+16                               | 0,8234           | 0,3580           | 82               | RDT 7783311 |
| Entrance & Toilet                      | Port      | 34,238            | 11         | 0,9601                           | 2x10+10                               | 1,3249           | 0,5761           | 61               | RDT 7783310 |
|                                        | Starboard | 33,527            | 15         | 1,2838                           | 2x10+10                               | 1,7716           | 0,7703           | 61               | RDT 7783310 |
| Anteroom                               | Port      | 26,664            | 9          | 0,6118                           | 2x10+10                               | 0,8442           | 0,3671           | 61               | RDT 7783310 |
|                                        | Starboard | 26,749            | 5          | 0,3410                           | 2x10+10                               | 0,4705           | 0,2046           | 61               | RDT 7783310 |
| Bridge 230 Vac                         | -         | 50,704            | 10         | 1,2926                           | 2x16+16                               | 1,1149           | 0,4847           | 82               | RDT 7783311 |
| Bridge 24 Vdc                          | -         | 73,385            | 10         | 10,7232                          | 2x25+25                               | 0,9007           | 3,7531           | 108              | RDT 7783212 |
| Engine Rooms & Electrical Compartments | Port      | 34,843            | 3          | 0,2665                           | 2x10+10                               | 0,3677           | 0,1599           | 61               | RDT 7783310 |
|                                        | Starboard | 34,843            | 3          | 0,2665                           | 2x10+10                               | 0,3677           | 0,1599           | 61               | RDT 7783310 |

Table 65: Secondary switchboards conductors



### 3.7.2.5. Power inverter cross-section

Once that every circuit has been designed with a cross-section adequate to their consumption, as well as the switchboard that holds them, it is time to size the conductors that come from the power inverter.

It is reasonable to believe that this conductors shall be sized based on the amount of power that demands each 230 Vac main switchboard. Nevertheless, we have to remember the interconnection between both switchboards which would allow the continuity of the supply during an emergency situation. This means that the conductors from the power inverter should admit a current composed of every 230 Vac load, as well as the 24 Vdc loads from the Bridge.

Thus, and referring to the power forecast calculated on previous sections (which can be checked at page 155 – **3.2.3. Total power forecast**), we assume that the total power that will withstand the conductors shall be:

$$P_T = P_{230Vac} + P_{24Vdc}$$

$$P_T = 6373,6 + 1409$$

$$P_T = 7782,6 \text{ W}$$

Assuming a power factor ( $\cos \phi$ ) of 0.9 in the 230 Vac, and considering 1 in the 24 Vdc system, we will obtain the total current that this conductors shall support:

$$I_T = I_{230Vac} + I_{24Vdc}$$

$$I_T = \frac{P_{230Vac}}{V_{ac} \cdot 0.9} + \frac{P_{24Vdc}}{V_{dc}}$$

$$I_T = \frac{6373,6}{230 \cdot 0.9} + \frac{1409}{24}$$

$$I_T = 89,4987 \text{ A}$$

According to the Classification Society<sup>66</sup>, the required cross-section for this amount of current would be a 2x25 mm<sup>2</sup> conductor, which would withstand with 108 A. Thus, the chosen conductor will be an EXZHELLENT – MAR Rdt 2x25 + 25, reference 7783212, and it shall be used in both electrical system to supply the 230 Vac main switchboards from the power rectifiers.

The power rectifiers shall be in the same room as the 230 Vac main switchboards, i.e. the Electrical Compartment (check **4.2. General Layout** – page 347). Expecting changes in the layout of the components, we will demand 15 meters of this cable for each hull, in order to have enough conductor for future changes.

### 3.7.3. Short-circuit currents calculation

Every electrical installation must be protected against short-circuit currents. The intensity of the short-circuit current must be calculated for each of the different levels of the facility to determine the characteristics of the components that must withstand or cut the fault current. It shall be necessary to follow the requirements stated at **2.6.24.3.**

**Short-circuit current** (page 61).

#### 3.7.3.1. 24 Vdc short-circuit current calculation

The short-circuit current appears at the end of the line, therefore it will be required the value of the impedance in the conductor. Due to the fact that the conductors have been calculated in the previous section, we will be able to find those parameters in the catalogue of the product.

The cable that have been chosen is a General Cable EXZHELLENT – MAR Rdt

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66 DNV – Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 51 (July 2013)

2x25 mm<sup>2</sup> – model 7783212. The values of resistance and inductance of this model are as follows:

- Resistance (R): 1,458 V/A · km
- Inductance (X): 0,246 mH / km

Thus, the short-circuit current shall be calculated according to the following formula:

$$I_{SC} = \frac{C_V \cdot V}{Z_{SC}}$$

Where:

- **I<sub>SCmax</sub>**: Maximum short-circuit current.
- **C<sub>V</sub>**: Voltage coefficient. Due to the fact that the impedance lies only in the impedance of the line, its value shall be 0,8.<sup>67</sup>
- **U**: Network voltage.
- **Z<sub>SC</sub>**: Line impedance .

The line impedance value shall be composed of the resistance and inductance values of the cable:

$$Z_{SC} = \sqrt{R^2 + X^2}$$

$$Z_{SC} = \sqrt{(1,458 \cdot 0,010)^2 + \left(0,246 \cdot \frac{0,010}{1000}\right)^2}$$

$$Z_{SC} \approx 0,01458 \Omega$$

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<sup>67</sup> Notes from “Instalaciones Eléctricas” Chapter 4 – Juan Luis Beira Jiménez

Therefore:

$$I_{sc} = \frac{0,8 \cdot 24}{0,01458}$$

$$I_{sc} = 1317 \text{ A}$$

The maximum and the minimum short-circuit current are equal due to the fact that in both cases only the impedance of the line appears.

In order to protect this conductor, it is necessary to select a proper switch. This switch must comply as well with several requirements:

- The rate current of the switch must lie between the short-circuit current and the maximum admissible current to the cross section.

$$I_B \leq I_N \leq I_Z$$

$$73,39 \leq I_N \leq 108$$

- The breaking capacity of the switch must be higher than the maximum short-circuit current. This current is calculated on the following section.

$$I_{BC} \geq I_{SCmax}$$

$$I_{BC} \geq 1317 \text{ A}$$

- The magnetic current of the switch must be lower than the minimum short-circuit current.

$$I_{mag} \leq I_{CCmin}$$

$$I_{mag} \leq 1317 \text{ A}$$

- The specific let-through energy (i.e. the amount of energy that the switch allows to flow up to the breaking) must be lower than the maximum admissible of the conductor.

$$I^2 \cdot t < K^2 \cdot S^2$$

Where:

- $I^2 \cdot t$  is calculated from the catalogue of the switch
- $K$  is a factor that depends on the nature of the conductor and its final short-circuit temperatures. It has a value of 143 for a copper and XLPE conductor.
- $S$  is the section of the conductor

$$I^2 \cdot t < 143^2 \cdot 25^2$$

$$I^2 \cdot t < 12780625$$

Thus, the selected switch is a Schneider Electric c120N curve C – model A9N18361, which have the following characteristics:

- Rate current: 80 A

$$73,39 \leq 80 \leq 108$$

- Breaking capacity: 10 kA.

$$10 \text{ kA} \geq 1388 \text{ A}$$

- Magnetic current: 400 A

$$400 \leq 1388 \text{ A}$$

- Specific let-through energy: 11000 A<sup>2</sup> · s (approximately)

$$11000 < 12780625$$

Therefore, this switch complies with all the requirements. Its catalogue is attached at the end of this Annexes section on page 328 (**3.10.7.2. Schneider Electric C120N**). Once that the main switch has been calculated, it is necessary to calculate those required for every device. The following tables gathers this information.

| Description                | Circuit Number | Name | V<br>(V) | L<br>(km) | Cable   | R<br>( $\Omega$ /km) | X<br>(mH/km) | Z<br>( $\Omega$ ) | I <sub>sc</sub><br>(A) |
|----------------------------|----------------|------|----------|-----------|---------|----------------------|--------------|-------------------|------------------------|
| Magnetic compass           | Circuit 35     | C35  | 24       | 0,006     | 7783206 | 23,610               | 0,331        | 0,1417            | 135,5                  |
| Anemometer                 | Circuit 36     | C36  | 24       | 0,006     | 7783206 | 23,610               | 0,331        | 0,1417            | 135,5                  |
| Navigation & signal lights | Circuit 37     | C37  | 24       | 0,006     | 7783209 | 5,919                | 0,272        | 0,0355            | 540,6                  |
| Searchlight                | Circuit 38     | C38  | 24       | 0,007     | 7783210 | 3,458                | 0,256        | 0,0242            | 793,2                  |
| DGPS                       | Circuit 39     | C39  | 24       | 0,007     | 7783206 | 23,610               | 0,331        | 0,1653            | 116,2                  |
| Electromagnetic log        | Circuit 40     | C40  | 24       | 0,007     | 7783206 | 23,610               | 0,331        | 0,1653            | 116,2                  |
| Telephon sys.              | Circuit 41     | C41  | 24       | 0,008     | 7783206 | 23,610               | 0,331        | 0,1889            | 101,7                  |
| Exterior communications    | Circuit 42     | C42  | 24       | 0,008     | 7783209 | 5,919                | 0,272        | 0,0474            | 405,5                  |
| Radar                      | Circuit 43     | C43  | 24       | 0,009     | 7783209 | 5,919                | 0,272        | 0,0533            | 360,4                  |

Table 66: 24Vdc devices short-circuit currents

| Description                | Circuit Number | Name | Switch            | I <sub>B</sub><br>(A) | I <sub>N</sub><br>(A) | I <sub>Z</sub><br>(A) | I <sub>BC</sub><br>(kA) | I <sub>mag</sub><br>(A) | Selectivity |
|----------------------------|----------------|------|-------------------|-----------------------|-----------------------|-----------------------|-------------------------|-------------------------|-------------|
| Magnetic compass           | Circuit 35     | C35  | IC60 N – A9F76216 | 5,21                  | 16                    | 20                    | 6                       | 64                      | Yes         |
| Anemometer                 | Circuit 36     | C36  | IC60 N – A9F76216 | 5,21                  | 16                    | 20                    | 6                       | 64                      | Yes         |
| Navigation & signal lights | Circuit 37     | C37  | IC60 N – A9F76250 | 31,25                 | 50                    | 44                    | 6                       | 200                     | Yes         |
| Searchlight                | Circuit 38     | C38  | IC60 N – A9F76250 | 46,88                 | 50                    | 61                    | 6                       | 200                     | Partial     |
| DGPS                       | Circuit 39     | C39  | IC60 N – A9F76216 | 0,52                  | 16                    | 20                    | 6                       | 64                      | Yes         |
| Electromagnetic log        | Circuit 40     | C40  | IC60 N – A9F76216 | 5,21                  | 16                    | 20                    | 6                       | 64                      | Yes         |
| Telephon sys.              | Circuit 41     | C41  | IC60 N – A9F76216 | 5,21                  | 16                    | 20                    | 6                       | 64                      | Yes         |
| Exterior communications    | Circuit 42     | C42  | IC60 N – A9F76250 | 20,83                 | 50                    | 44                    | 6                       | 200                     | Yes         |
| Radar                      | Circuit 43     | C43  | IC60 N – A9F76250 | 15,63                 | 50                    | 44                    | 6                       | 200                     | Yes         |

Table 67: 24Vdc switches selection



## Selectividad

Aguas arriba: NG125N/H/L, C120N/H curva C

Aguas abajo: iC60N/H/L curvas B, C, D

Información técnica complementaria

2

220-240/380-415 V

| Aguas arriba                                                  |     |         |     |     |      |      |      |      |       |       |       |       |
|---------------------------------------------------------------|-----|---------|-----|-----|------|------|------|------|-------|-------|-------|-------|
| NG125N/H/L                                                    |     | C120N/H |     |     |      |      |      |      |       |       |       |       |
| Curva C                                                       |     |         |     |     |      |      |      |      |       |       |       |       |
| In (A)                                                        |     | 10      | 16  | 20  | 25   | 32   | 40   | 50   | 63    | 80    | 100   | 125   |
| Aguas abajo                                                   |     |         |     |     |      |      |      |      |       |       |       |       |
| 1P, 1P+N<br>2P (380-415 V)<br>red trifásica<br>3P, 3P+N<br>4P |     |         |     |     |      |      |      |      |       |       |       |       |
| Límite de selectividad (A)                                    |     |         |     |     |      |      |      |      |       |       |       |       |
| iC60N/H/L                                                     | 0,5 | T       | T   | T   | T    | T    | T    | T    | T     | T     | T     | T     |
| Curva B                                                       | 1   | 140     | 490 | 920 | 2300 | T    | T    | T    | T     | T     | T     | T     |
|                                                               | 2   | 80      | 250 | 380 | 550  | 1800 | 2400 | 8800 | 10000 | 13000 | T     | T     |
|                                                               | 3   | 80      | 190 | 280 | 380  | 1200 | 1400 | 4600 | 8000  | 8500  | 14000 | T     |
|                                                               | 4   | 80      | 130 | 240 | 300  | 870  | 820  | 2000 | 2300  | 3400  | 7000  | 13000 |
|                                                               | 6   |         | 130 | 160 | 200  | 630  | 620  | 1400 | 2300  | 2300  | 3600  | 6400  |
|                                                               | 10  |         |     | 160 | 200  | 510  | 480  | 1100 | 1300  | 1600  | 2200  | 3600  |
|                                                               | 13  |         |     |     | 200  | 450  | 320  | 930  | 1100  | 1400  | 2000  | 2600  |
|                                                               | 16  |         |     |     |      | 380  | 320  | 770  | 950   | 1200  | 1700  | 2300  |
|                                                               | 20  |         |     |     |      |      | 320  | 680  | 850   | 960   | 1500  | 2100  |
|                                                               | 25  |         |     |     |      |      |      | 600  | 760   | 960   | 1200  | 1800  |
|                                                               | 32  |         |     |     |      |      |      |      | 500   | 640   | 1200  | 1500  |
|                                                               | 40  |         |     |     |      |      |      |      |       | 640   | 800   | 1500  |
|                                                               | 50  |         |     |     |      |      |      |      |       | 840   | 800   | 1500  |
|                                                               | 63  |         |     |     |      |      |      |      |       |       | 800   | 1000  |
| Límite de selectividad (A)                                    |     |         |     |     |      |      |      |      |       |       |       |       |
| iC60N/H/L                                                     | 0,5 | T       | T   | T   | T    | T    | T    | T    | T     | T     | T     | T     |
| Curva C                                                       | 1   | 140     | 490 | 920 | 2300 | T    | T    | T    | T     | T     | T     | T     |
|                                                               | 2   | 80      | 250 | 380 | 550  | 2100 | 2400 | 8800 | 10000 | 13000 | T     | T     |
|                                                               | 3   |         | 190 | 280 | 380  | 1200 | 1400 | 4600 | 8000  | 8500  | 14000 | T     |
|                                                               | 4   |         | 130 | 160 | 300  | 780  | 820  | 2000 | 2300  | 3400  | 6000  | 13000 |
|                                                               | 6   |         | 130 | 160 | 200  | 630  | 620  | 1400 | 2300  | 2300  | 3600  | 5500  |
|                                                               | 10  |         |     |     | 200  | 510  | 480  | 930  | 1300  | 1400  | 2200  | 3100  |
|                                                               | 13  |         |     |     |      | 450  | 320  | 770  | 1100  | 1200  | 2000  | 2600  |
|                                                               | 16  |         |     |     |      |      | 320  | 770  | 950   | 1200  | 1700  | 2300  |
|                                                               | 20  |         |     |     |      |      |      | 680  | 850   | 960   | 1500  | 1800  |
|                                                               | 25  |         |     |     |      |      |      |      | 760   | 960   | 1200  | 1800  |
|                                                               | 32  |         |     |     |      |      |      |      |       | 640   | 1200  | 1500  |
|                                                               | 40  |         |     |     |      |      |      |      |       |       | 800   | 1500  |
|                                                               | 50  |         |     |     |      |      |      |      |       |       |       | 1000  |
|                                                               | 63  |         |     |     |      |      |      |      |       |       |       |       |
| Límite de selectividad (A)                                    |     |         |     |     |      |      |      |      |       |       |       |       |
| iC60N/H/L                                                     | 0,5 | T       | T   | T   | T    | T    | T    | T    | T     | T     | T     | T     |
| Curva D                                                       | 1   | 140     | 490 | 920 | 2300 | T    | T    | T    | T     | T     | T     | T     |
|                                                               | 2   | 80      | 250 | 380 | 550  | 1800 | 2400 | 8800 | 10000 | 13000 | T     | T     |
|                                                               | 3   |         | 190 | 280 | 380  | 1200 | 1200 | 4600 | 8000  | 8500  | 14000 | T     |
|                                                               | 4   |         |     | 160 | 300  | 780  | 820  | 2000 | 2300  | 3400  | 6000  | 13000 |
|                                                               | 6   |         |     | 160 | 200  | 510  | 620  | 1400 | 1900  | 1800  | 3600  | 5500  |
|                                                               | 10  |         |     |     |      | 450  | 480  | 930  | 1300  | 1400  | 2200  | 3100  |
|                                                               | 13  |         |     |     |      |      | 320  | 770  | 950   | 1200  | 1700  | 2600  |
|                                                               | 16  |         |     |     |      |      |      | 770  | 950   | 960   | 1500  | 2300  |
|                                                               | 20  |         |     |     |      |      |      |      | 760   | 960   | 1200  | 1800  |
|                                                               | 25  |         |     |     |      |      |      |      |       | 640   | 1200  | 1500  |
|                                                               | 32  |         |     |     |      |      |      |      |       |       | 800   | 1500  |
|                                                               | 40  |         |     |     |      |      |      |      |       |       |       | 1000  |
|                                                               | 50  |         |     |     |      |      |      |      |       |       |       |       |

Figure 31: Selectivity in 24 Vdc devices

From this tables, we can sum up that it shall be necessary the following amount of switches:

| Rating current (A) | Model             | Units    |
|--------------------|-------------------|----------|
| 16                 | IC60 N – A9F76216 | 5        |
| 50                 | IC60 N – A9F76250 | 4        |
| <b>TOTAL</b>       |                   | <b>9</b> |

Table 68: Amount of iC60N switches

### 3.7.3.2. 230 Vac short-circuit current calculation

As it was done during the calculation of the cross-section of the conductors, we will take the short-circuit current calculation of the Circuit 3 as an example.

This circuit shall count with the conductor EXZHELLENT – MAR RDT 0,6 / 1 kV 2 x 1,5 + 1,5 mm<sup>2</sup> – model 7783306. Referring to its catalogue, and as it was shown in the previous tables, this cable have a resistance of 0,02361 Ω/m, and an inductance of 3,31 · 10<sup>-7</sup> H/m. Knowing this values, it will be possible to calculate the impedance that has this circuit, as well as the short-circuit current value.

$$Z_{sc} = \sqrt{R^2 + X^2}$$

$$Z_{sc} = \sqrt{(2 \cdot L \cdot 0,02361)^2 + (2 \cdot L \cdot 3,31 \cdot 10^{-7})^2}$$

$$Z_{sc} = \sqrt{(2 \cdot 20 \cdot 0,02361)^2 + (2 \cdot 20 \cdot 3,31 \cdot 10^{-7})^2}$$

$$Z_{sc} \approx 0,9444 \Omega$$

As it is shown in the formula, the impedance shall take into account when the current is going to the load as well as when it is coming back. That is why it has been duplicated.

Now that we have the impedance value of the circuit, it is possible to calculate the short-circuit current value, which will be vital for the selection of the switch

required for protection.

$$I_{sc} = \frac{0,8 \cdot V_N}{Z_{sc}}$$

Where:

- $I_{sc}$ : Short-circuit current.
- $C_V$ : Voltage coefficient. Due to the fact that the impedance lies only in the impedance of the line, its value shall be 0,8.<sup>68</sup>
- $V_N$ : Voltage of the circuit.
- $Z_{sc}$ : Impedance of the circuit.

$$I_{sc} = \frac{0,8 \cdot 230}{0,9444}$$

$$I_{sc} = 194,83 \text{ A}$$

Once that this value is known, we can proceed to select the proper switch intended to protect the circuit from over-current and short-circuit situations. For this task, we will look for an adequate switch into the technical manual of Schneider Electric called Acti 9.

Thus, the chosen switch shall be an iC60N circuit breaker, with two poles, and a rating value from 0,5 to 63 A. From 0,5 to 4 A, its breaking capacity reaches a value of 50 kA, and from 6 to 63 A, the breaking capacity is 20 kA. Furthermore, the magnetic trip reaches a value of 4, 8 or 12 times its rating value, depending on the chosen curve. These parameters can be checked in its catalogue, which is added at the end of this annexe on page 327 (**3.10.7.1. Schneider Electric iC60N**).

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<sup>68</sup> Notes from “Instalaciones Eléctricas” Chapter 4 – Juan Luis Beira Jiménez

Referring to the circuit 3, we have chose an iC60N with a rating value of 1 A (curve B), which have a breaking capacity of 50 kA. This switch complies with the following requirements:

- Rate current: 1 A

$$0,688 \leq I \leq 20$$

- Breaking capacity: 50 kA.

$$50 \text{ kA} \geq 195 \text{ A}$$

- Magnetic current: 4 A

$$4 \leq 195 \text{ A}$$

The following tables gathers the switch selected for each circuit.

| Passengers Room (Port Switchboard) |                |      |            |                  |         |                |         |                  |        |       |          |          |
|------------------------------------|----------------|------|------------|------------------|---------|----------------|---------|------------------|--------|-------|----------|----------|
| Description                        | Circuit Number | Name | Length (m) | R ( $\Omega$ /m) | L (H/m) | Z ( $\Omega$ ) | Isc (A) | Switch           | In (A) | Curve | Imag (A) | Icu (kA) |
| Sockets                            | Circuit 1      | C1   | 6          | 0,01420          | 3,07E-7 | 0,82360        | 223     | IC60N – A9F73204 | 4      | B     | 16       | 50       |
| Sockets                            | Circuit 2      | C2   | 7          | 0,02361          | 3,31E-7 | 0,90880        | 202     | IC60N – A9F76206 | 6      | B     | 24       | 20       |
| Lighting                           | Circuit 3      | C3   | 6          | 0,02361          | 3,31E-7 | 0,94440        | 195     | IC60N – A9F73201 | 1      | B     | 4        | 50       |
| Lighting                           | Circuit 4      | C4   | 6          | 0,02361          | 3,31E-7 | 1,13328        | 162     | IC60N – A9F73201 | 1      | B     | 4        | 50       |
| Emergency Lighting                 | Circuit 5      | C5   | 4          | 0,02361          | 3,31E-7 | 0,66108        | 278     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |

Table 69: Passengers Room (Port Switchboard - Switches)

| Passengers Room (Starboard Switchboard) |                |      |            |                  |         |                |         |                  |        |       |          |          |
|-----------------------------------------|----------------|------|------------|------------------|---------|----------------|---------|------------------|--------|-------|----------|----------|
| Description                             | Circuit Number | Name | Length (m) | R ( $\Omega$ /m) | L (H/m) | Z ( $\Omega$ ) | Isc (A) | Switch           | In (A) | Curve | Imag (A) | Icu (kA) |
| Sockets                                 | Circuit 6      | C6   | 6          | 0,01420          | 3,07E-7 | 0,82360        | 223     | IC60N – A9F73204 | 4      | B     | 16       | 50       |
| Sockets                                 | Circuit 7      | C7   | 7          | 0,02361          | 3,31E-7 | 0,90880        | 202     | IC60N – A9F76206 | 6      | B     | 24       | 20       |
| Lighting                                | Circuit 8      | C8   | 6          | 0,02361          | 3,31E-7 | 0,94440        | 195     | IC60N – A9F73201 | 1      | B     | 4        | 50       |
| Lighting                                | Circuit 9      | C9   | 6          | 0,02361          | 3,31E-7 | 1,13328        | 162     | IC60N – A9F73201 | 1      | B     | 4        | 50       |
| Emergency Lighting                      | Circuit 10     | C10  | 4          | 0,02361          | 3,31E-7 | 0,66108        | 278     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |

Table 70: Passengers Room (Starboard Switchboard - Switches)

| Entrance & Toilet (Port Switchboard) |                |      |            |                  |         |                |         |                  |        |       |          |          |
|--------------------------------------|----------------|------|------------|------------------|---------|----------------|---------|------------------|--------|-------|----------|----------|
| Description                          | Circuit Number | Name | Length (m) | R ( $\Omega$ /m) | L (H/m) | Z ( $\Omega$ ) | Isc (A) | Switch           | In (A) | Curve | Imag (A) | Icu (kA) |
| Sockets (Entrance & Toilet)          | Circuit 11     | C11  | 12         | 0,0142           | 3,07E-7 | 0,34080        | 540     | IC60N – A9F73202 | 2      | B     | 8        | 50       |
| Lighting (Entrance)                  | Circuit 12     | C12  | 11         | 0,0236           | 3,31E-7 | 0,51942        | 354     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |
| Lighting (Toilet)                    | Circuit 13     | C13  | 4          | 0,0236           | 3,31E-7 | 0,18888        | 974     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |
| Emergency Lighting (Entrance)        | Circuit 14     | C14  | 10         | 0,0236           | 3,31E-7 | 0,47220        | 390     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |
| Emergency Lighting (Toilet)          | Circuit 15     | C15  | 4          | 0,0236           | 3,31E-7 | 0,18888        | 974     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |
| Extractor Fan                        | Circuit 16     | C16  | 3          | 0,0236           | 3,31E-7 | 0,14166        | 1299    | IC60N – A9F73201 | 1      | B     | 4        | 50       |
| Air Conditioning 1                   | Circuit 17     | C17  | 6          | 0,0236           | 3,31E-7 | 0,28332        | 649     | IC60N – A9F76210 | 10     | B     | 40       | 20       |

Table 71: Entrance &amp; Toilet (Port Switchboard - Switches)

| Entrance & Toilet (Starboard Switchboard) |                |      |            |                  |         |                |         |                  |        |       |          |          |
|-------------------------------------------|----------------|------|------------|------------------|---------|----------------|---------|------------------|--------|-------|----------|----------|
| Description                               | Circuit Number | Name | Length (m) | R ( $\Omega$ /m) | L (H/m) | Z ( $\Omega$ ) | Isc (A) | Switch           | In (A) | Curve | Imag (A) | Icu (kA) |
| Sockets (Entrance & Toilet)               | Circuit 18     | C18  | 12         | 0,0142           | 3,07E-7 | 0,34080        | 540     | IC60N – A9F73202 | 2      | B     | 8        | 50       |
| Lighting (Entrance)                       | Circuit 19     | C19  | 14         | 0,0236           | 3,31E-7 | 0,66108        | 278     | IC60N – A9F73201 | 1      | B     | 4        | 50       |
| Lighting (Toilet)                         | Circuit 20     | C20  | 4          | 0,0236           | 3,31E-7 | 0,18888        | 974     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |
| Emergency Lighting (Entrance)             | Circuit 21     | C21  | 7          | 0,0236           | 3,31E-7 | 0,33054        | 557     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |
| Emergency Lighting (Toilet)               | Circuit 22     | C22  | 4          | 0,0236           | 3,31E-7 | 0,18888        | 974     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |
| Air Conditioning 2                        | Circuit 23     | C23  | 6          | 0,0236           | 3,31E-7 | 0,28332        | 649     | IC60N – A9F76210 | 10     | B     | 40       | 20       |

Table 72: Entrance &amp; Toilet (Starboard Switchboard - Switches)



| Anteroom (Port Switchboard)   |                |      |            |                  |         |                |         |                  |        |       |          |          |
|-------------------------------|----------------|------|------------|------------------|---------|----------------|---------|------------------|--------|-------|----------|----------|
| Description                   | Circuit Number | Name | Length (m) | R ( $\Omega$ /m) | L (H/m) | Z ( $\Omega$ ) | Isc (A) | Switch           | In (A) | Curve | Imag (A) | Icu (kA) |
| Sockets (Anteroom)            | Circuit 24     | C24  | 8          | 0,01420          | 3,07E-7 | 0,2272         | 810     | IC60N – A9F73202 | 2      | B     | 8        | 50       |
| Lighting (Anteroom)           | Circuit 25     | C25  | 12         | 0,02361          | 3,31E-7 | 0,5666         | 325     | IC60N – A9F73201 | 1      | B     | 4        | 50       |
| Emergency Lighting (Anteroom) | Circuit 26     | C26  | 12         | 0,02361          | 3,31E-7 | 0,5666         | 325     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |

Table 73: Anteroom (Port Switchboard - Switches)

| Anteroom (Starboard Switchboard) |                |      |            |                  |         |                |         |                  |        |       |          |          |
|----------------------------------|----------------|------|------------|------------------|---------|----------------|---------|------------------|--------|-------|----------|----------|
| Description                      | Circuit Number | Name | Length (m) | R ( $\Omega$ /m) | L (H/m) | Z ( $\Omega$ ) | Isc (A) | Switch           | In (A) | Curve | Imag (A) | Icu (kA) |
| Sockets (Anteroom)               | Circuit 27     | C27  | 8          | 0,01420          | 3,07E-7 | 0,2272         | 810     | IC60N – A9F73202 | 2      | B     | 8        | 50       |
| Lighting (Anteroom)              | Circuit 28     | C28  | 18         | 0,02361          | 3,31E-7 | 0,8500         | 216     | IC60N – A9F73201 | 1      | B     | 4        | 50       |
| Emergency Lighting (Anteroom)    | Circuit 29     | C29  | 7          | 0,02361          | 3,31E-7 | 0,3305         | 557     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |

Table 74: Anteroom (Starboard Switchboard - Switches)

| Bridge (230 Vac Switchboard) |                |      |            |                  |         |                |         |                  |        |       |          |          |
|------------------------------|----------------|------|------------|------------------|---------|----------------|---------|------------------|--------|-------|----------|----------|
| Description                  | Circuit Number | Name | Length (m) | R ( $\Omega$ /m) | L (H/m) | Z ( $\Omega$ ) | Isc (A) | Switch           | In (A) | Curve | Imag (A) | Icu (kA) |
| Sockets                      | Circuit 30     | C30  | 7          | 0,01420          | 3,07E-7 | 0,1988         | 926     | IC60N – A9F73202 | 2      | B     | 8        | 50       |
| Lighting                     | Circuit 31     | C31  | 3          | 0,02361          | 3,31E-7 | 0,1417         | 1299    | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |
| Emergency Lighting           | Circuit 32     | C32  | 4          | 0,02361          | 3,31E-7 | 0,1889         | 974     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |
| External Lighting            | Circuit 33     | C33  | 50         | 0,01420          | 3,07E-7 | 1,4200         | 130     | IC60N – A9F73220 | 20     | B     | 80       | 20       |
| Windlass Anchor              | Circuit 34     | C34  | 10         | 0,02361          | 3,31E-7 | 0,4722         | 390     | IC60N – A9F76210 | 10     | B     | 40       | 20       |

Table 75: Bridge (230 Vac Switchboard - Switches)

| Engine Room & Electrical Compartment (Port Switchboard) |                |      |            |                  |         |                |         |                  |        |       |          |          |
|---------------------------------------------------------|----------------|------|------------|------------------|---------|----------------|---------|------------------|--------|-------|----------|----------|
| Description                                             | Circuit Number | Name | Length (m) | R ( $\Omega$ /m) | L (H/m) | Z ( $\Omega$ ) | Isc (A) | Switch           | In (A) | Curve | Imag (A) | Icu (kA) |
| Sockets                                                 | Circuit 44     | C44  | 21         | 0,01420          | 3,07E-7 | 0,5964         | 309     | IC60N – A9F73204 | 4      | B     | 16       | 50       |
| Lighting                                                | Circuit 45     | C45  | 21         | 0,02361          | 3,31E-7 | 0,9916         | 186     | IC60N – A9F73202 | 2      | B     | 8        | 50       |
| Emergency Lighting<br>(Opposite hull)                   | Circuit 46     | C46  | 26         | 0,02361          | 3,31E-7 | 1,2277         | 150     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |
| Bilge Pump 1<br>(Opposite hull)                         | Circuit 47     | C47  | 18         | 0,02361          | 3,31E-7 | 0,8500         | 216     | IC60N – A9F73204 | 4      | B     | 16       | 50       |
| Bilge Pump 2<br>(Opposite hull)                         | Circuit 48     | C48  | 25         | 0,02361          | 3,31E-7 | 1,1805         | 156     | IC60N – A9F73204 | 4      | B     | 16       | 50       |
| Extractor Fan                                           | Circuit 49     | C49  | 15         | 0,02361          | 3,31E-7 | 0,7083         | 260     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |

Table 76: Engine Room &amp; Electrical Compartment (Port Switchboard - Switches)

| Engine Room & Electrical Compartment (Starboard Switchboard) |                |      |            |                  |         |                |         |                  |        |       |          |          |
|--------------------------------------------------------------|----------------|------|------------|------------------|---------|----------------|---------|------------------|--------|-------|----------|----------|
| Description                                                  | Circuit Number | Name | Length (m) | R ( $\Omega$ /m) | L (H/m) | Z ( $\Omega$ ) | Isc (A) | Switch           | In (A) | Curve | Imag (A) | Icu (kA) |
| Sockets                                                      | Circuit 50     | C50  | 21         | 0,01420          | 3,07E-7 | 0,5964         | 309     | IC60N – A9F73204 | 4      | B     | 16       | 50       |
| Lighting                                                     | Circuit 51     | C51  | 21         | 0,02361          | 3,31E-7 | 0,9916         | 186     | IC60N – A9F73202 | 2      | B     | 8        | 50       |
| Emergency Lighting<br>(Opposite hull)                        | Circuit 52     | C52  | 26         | 0,02361          | 3,31E-7 | 1,2277         | 150     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |
| Bilge Pump 3<br>(Opposite hull)                              | Circuit 53     | C53  | 18         | 0,02361          | 3,31E-7 | 0,8500         | 216     | IC60N – A9F73204 | 4      | B     | 16       | 50       |
| Bilge Pump 4<br>(Opposite hull)                              | Circuit 54     | C54  | 25         | 0,02361          | 3,31E-7 | 1,1805         | 156     | IC60N – A9F73204 | 4      | B     | 16       | 50       |
| Extractor Fan                                                | Circuit 55     | C55  | 15         | 0,02361          | 3,31E-7 | 0,7083         | 260     | IC60N – A9F74270 | 0,5    | C     | 4        | 50       |

Table 77: Engine Room &amp; Electrical Compartment (Starboard Switchboard - Switches)

From the previous tables we can deduce that we shall need:

| Rating current (A) | Model            | Units     |
|--------------------|------------------|-----------|
| 0,5                | IC60N – A9F74270 | 17        |
| 1                  | IC60N – A9F73201 | 8         |
| 2                  | IC60N – A9F73202 | 7         |
| 4                  | IC60N – A9F73204 | 8         |
| 6                  | IC60N – A9F73206 | 2         |
| 10                 | IC60N – A9F73210 | 3         |
| 20                 | IC60N – A9F73220 | 1         |
| <b>TOTAL</b>       |                  | <b>46</b> |

*Table 78: Amount of iC60N switches*

It can be checked that every circuit fulfils the requirements of rate current, breaking capacity and magnetic current.

### **3.7.3.3. Switchboards short-circuit current calculation**

In the same way that it was calculated the proper conductors that shall supply the secondary switchboards, it is time to calculate the total short-circuit current of each of them, in order to select the adequate circuit breakers that will protect them.

Once again, it will be necessary to take the switchboards as the sum of every circuit hosted in them, obtaining a total power or total current value. We must chose circuit breakers that ensure all the requirements stated on the previous sections.

The following table gathers the result of this study.

| Switchboard                               | Side      | Length (m) | R ( $\Omega$ /m) | L (H/m) | Z ( $\Omega$ ) | Isc (A) | Switch              | In (A) | Curve | Imag (A) | Icu (kA) |
|-------------------------------------------|-----------|------------|------------------|---------|----------------|---------|---------------------|--------|-------|----------|----------|
| Passengers Room                           | Port      | 3          | 0,00222          | 2,45E-7 | 0,0133         | 13826   | IC60N – A9F75206    | 63     | C     | 504      | 20       |
|                                           | Starboard | 7          | 0,00222          | 2,45E-7 | 0,0311         | 5926    | IC60N – A9F75206    | 63     | C     | 504      | 20       |
| Entrance & Toilet                         | Port      | 11         | 0,00346          | 2,56E-7 | 0,0761         | 2419    | IC60N – A9F75204    | 40     | C     | 320      | 20       |
|                                           | Starboard | 15         | 0,00346          | 2,56E-7 | 0,1037         | 1774    | IC60N – A9F75204    | 40     | C     | 320      | 20       |
| Anteroom                                  | Port      | 9          | 0,00346          | 2,56E-7 | 0,0622         | 2956    | IC60N – A9F75204    | 32     | C     | 256      | 20       |
|                                           | Starboard | 5          | 0,00346          | 2,56E-7 | 0,0346         | 5321    | IC60N – A9F75204    | 32     | C     | 256      | 20       |
| Bridge 230 Vac                            | -         | 10         | 0,00346          | 2,56E-7 | 0,0692         | 2660    | IC60N – A9F75204    | 63     | C     | 504      | 20       |
| Bridge 24 Vdc                             | -         | 10         | 0,00146          | 2,46E-7 | 0,0146         | 1317    | C120N –<br>A9N18361 | 80     | C     | 400      | 10       |
| Engine Rooms & Electrical<br>Compartments | Port      | 3          | 0,00346          | 2,56E-7 | 0,0207         | 8868    | IC60N – A9F75204    | 40     | C     | 320      | 20       |
|                                           | Starboard | 3          | 0,00346          | 2,56E-7 | 0,0207         | 8868    | IC60N – A9F75204    | 40     | C     | 320      | 20       |

Table 79: Secondary switchboards switches

From the previous tables we can deduce that we shall need:

| Rating current (A) | Model            | Units     |
|--------------------|------------------|-----------|
| 32                 | IC60N – A9F77232 | 2         |
| 40                 | IC60N – A9F77240 | 4         |
| 63                 | IC60N – A9F77263 | 3         |
| 80                 | C120N – A9N18361 | 1         |
| <b>TOTAL</b>       |                  | <b>10</b> |

*Table 80: Amount of switches for secondary switchboards*

#### 3.7.3.4. Power inverter protection

Once that the conductors that supply the main 230 Vac switchboards have been sized (page 229 – **3.7.2.5. Power inverter cross-section**), it is time to calculate the general protection that will be installed in those switchboards. As it was stated in the section previously named, the conductors shall withstand the hypothetical current that would flow through the interconnection during an emergency situation. This means that the general switch shall withstand it too, in order to allow one battery bank to supply the whole electrical system (except from the motors).

The total current that will flow through those general switches was calculated earlier, and its value is 89,4987 A, and the conductor selected for this task was an EXZHELLENT – MAR Rdt 2x25 + 25, whose rate current is 108 A. Thus, we shall choose a general switch which rate current is between those values.

For this task, we have selected a SCHNEIDER ELECTRIC C120N Curve C – model A9N18362, whose rate current is 100 A, complying with the previous requirement. This switch will ensure the selectivity with the switches on the load side, except from the 63 A switches, which selectivity is not assured.

$$89,4987 < 100 < 108$$





## Selectividad

Aguas arriba: NG125N/H/L, C120N/H curva B

Aguas abajo: iC60N/H/L curvas B, C, D

Información técnica complementaria

2

220-240/380-415 V

| Aguas arriba                                                 |     |         |     |     |     |     |      |      |      |      |      |      |
|--------------------------------------------------------------|-----|---------|-----|-----|-----|-----|------|------|------|------|------|------|
| NG125N/H/L                                                   |     | C120N/H |     |     |     |     |      |      |      |      |      |      |
| Curva B                                                      |     |         |     |     |     |     |      |      |      |      |      |      |
| In (A)                                                       |     | 10      | 16  | 20  | 25  | 32  | 40   | 50   | 63   | 80   | 100  | 125  |
| Aguas abajo                                                  |     |         |     |     |     |     |      |      |      |      |      |      |
| 1P, 1P+N<br>2P (380-415 V)<br>red bifásica<br>3P, 3P+N<br>4P |     |         |     |     |     |     |      |      |      |      |      |      |
| Límite de selectividad (A)                                   |     |         |     |     |     |     |      |      |      |      |      |      |
| iC60N/H/L                                                    | 0,5 | T       | T   | T   | T   | T   | T    | T    | T    | T    | T    | T    |
| Curva B                                                      | 1   | 70      | 150 | 210 | 350 | 550 | 2000 | 2500 | T    | T    | T    | T    |
|                                                              | 2   | 60      | 110 | 140 | 230 | 310 | 590  | 630  | 1200 | 2100 | 3900 | 9700 |
|                                                              | 3   | 40      | 90  | 120 | 180 | 220 | 380  | 460  | 770  | 1400 | 2000 | 5300 |
|                                                              | 4   | 40      | 64  | 80  | 150 | 190 | 310  | 380  | 570  | 940  | 1400 | 2400 |
|                                                              | 6   |         | 64  | 80  | 100 | 130 | 290  | 300  | 440  | 620  | 930  | 1700 |
|                                                              | 10  |         |     | 80  | 100 | 130 | 240  | 200  | 380  | 550  | 770  | 1300 |
|                                                              | 13  |         |     |     | 100 | 130 | 160  | 200  | 380  | 480  | 680  | 1100 |
|                                                              | 16  |         |     |     |     | 130 | 160  | 200  | 250  | 320  | 600  | 940  |
|                                                              | 20  |         |     |     |     |     | 160  | 200  | 250  | 320  | 400  | 850  |
|                                                              | 25  |         |     |     |     |     |      | 200  | 250  | 320  | 400  | 750  |
|                                                              | 32  |         |     |     |     |     |      |      | 250  | 320  | 400  | 500  |
|                                                              | 40  |         |     |     |     |     |      |      |      | 320  | 400  | 500  |
|                                                              | 50  |         |     |     |     |     |      |      |      |      | 400  | 500  |
|                                                              | 63  |         |     |     |     |     |      |      |      |      |      | 500  |
| Límite de selectividad (A)                                   |     |         |     |     |     |     |      |      |      |      |      |      |
| iC60N/H/L                                                    | 0,5 | T       | T   | T   | T   | T   | T    | T    | T    | T    | T    | T    |
| Curva C                                                      | 1   | 70      | 150 | 210 | 350 | 550 | 2000 | 2500 | T    | T    | T    | T    |
|                                                              | 2   | 40      | 110 | 140 | 230 | 250 | 590  | 630  | 1200 | 2100 | 3900 | 9700 |
|                                                              | 3   |         | 64  | 120 | 180 | 220 | 380  | 460  | 770  | 1400 | 2000 | 5300 |
|                                                              | 4   |         | 64  | 80  | 150 | 190 | 310  | 340  | 570  | 940  | 1400 | 2400 |
|                                                              | 6   |         |     |     | 100 | 130 | 290  | 300  | 440  | 620  | 930  | 1700 |
|                                                              | 10  |         |     |     |     |     | 160  | 200  | 380  | 550  | 770  | 1100 |
|                                                              | 13  |         |     |     |     |     | 160  | 200  | 250  | 480  | 680  | 940  |
|                                                              | 16  |         |     |     |     |     |      |      | 250  | 320  | 600  | 940  |
|                                                              | 20  |         |     |     |     |     |      |      |      | 320  | 400  | 850  |
|                                                              | 25  |         |     |     |     |     |      |      |      |      | 400  | 750  |
|                                                              | 32  |         |     |     |     |     |      |      |      |      | 400  | 500  |
|                                                              | 40  |         |     |     |     |     |      |      |      |      |      | 500  |
| Límite de selectividad (A)                                   |     |         |     |     |     |     |      |      |      |      |      |      |
| iC60N/H/L                                                    | 0,5 | T       | T   | T   | T   | T   | T    | T    | T    | T    | T    | T    |
| Curva D                                                      | 1   | 60      | 150 | 210 | 350 | 550 | 2000 | 2500 | T    | T    | T    | T    |
|                                                              | 2   | 40      | 90  | 140 | 200 | 250 | 520  | 630  | 1200 | 2100 | 3900 | 9700 |
|                                                              | 3   |         | 64  | 80  | 180 | 220 | 380  | 380  | 770  | 1200 | 2000 | 5300 |
|                                                              | 4   |         |     | 80  | 150 | 190 | 310  | 340  | 570  | 820  | 1100 | 2400 |
|                                                              | 6   |         |     |     |     | 130 | 240  | 200  | 440  | 620  | 930  | 1700 |
|                                                              | 10  |         |     |     |     |     |      | 200  | 380  | 480  | 770  | 1100 |
|                                                              | 13  |         |     |     |     |     |      |      | 250  | 480  | 680  | 940  |
|                                                              | 16  |         |     |     |     |     |      |      |      | 320  | 600  | 940  |
|                                                              | 20  |         |     |     |     |     |      |      |      |      | 400  | 750  |
|                                                              | 25  |         |     |     |     |     |      |      |      |      |      | 500  |
|                                                              | 32  |         |     |     |     |     |      |      |      |      |      |      |

4000 Límite de selectividad = 4 kA.

T Selectividad total.

Sin selectividad.

2/22



Figure 32: Selectivity between C120N & iC60N

### 3.7.4. Protection of the motors

As it has been calculated in **3.7.2.2. 144 Vdc cross-section calculation** (page 195), the current that will appear in the motors during their peak function reaches a value of 295,14 A.

$$I_{sc} = \frac{S_N}{V_N}$$

Where:

- $S_N$ : Power required by the motors and supplied from the battery bank. This parameter can have two values. During the Function regime reaches a value of 18700 W for each motor, and during the Top Speed regime reaches a value of 42500 W for each motor.
- $V_N$ : Rate voltage of the batteries. In this case, this value is 144 Vdc.

$$I_{sc} = \frac{42500}{144}$$

$$I_{sc} = 295,14 \text{ A}$$

Thus, we shall select a proper circuit breaker in order to protect the motors during an over-current situation.

For this task, we have chose the SCHNEIDER ELECTRIC NSX400N 320 A, which have a rate current value of 320 A. Its catalogue is added at the end of the Annexes section (page 336 – 3.10.7.6. Schneider Electric NSX400N).

### 3.7.5. Interconnection

According to the aim of this project, both of the electrical systems placed in each

of the hulls must be interconnected so as to prevent the vessel from being without electrical supply in case of emergency. Thus, if one of the systems gets unable to perform its task, the other one should be capable to feed the loads.

It will be necessary to have an interconnection in two levels, one in the motors network (144 Vdc) and the other one in the 230 Vdc network. This is due to the use of two different battery banks for each task. It can be checked on the Blueprints section (page 345 – **4. BLUEPRINTS**)

The interconnection shall be made through the crossbar that connects both hulls, and its control may be placed on the Bridge in order to ease its function to the operators. For this task, it will necessary to use a pair of isolator switches. Those isolator switches must be rated according to the total current that may flow through them. This value can be calculated by adding every single value of the loads on the other side.

#### **3.7.5.1. 144 Vdc interconnection (Motors)**

The interruption of electric currents have more problems with DC networks than AC current. In the alternating current exists a natural step where the current reaches a zero-value in each half cycle. It is related to a spontaneous shutdown of the electric arc when the circuit is opened. In the DC system this does not happen and to extinguish the arc, it is necessary that the current decreases until it has disappeared. To achieve this, it shall be necessary that the interruption is performed gradually, without abrupt cancellations of the current that would lead in high voltages.

First of all, it is necessary to calculate the amount of current that may flow through the isolator switch. This value shall depend on the total power required. Due to the fact that the switch will interconnect both motors, it will be only necessary to divide its rate power value by the voltage level.

During the Function operating condition, which is the main condition where the vessel will be operating, the motors shall require 18,7 kW. Nevertheless, we should take

into account the Top Speed condition where the motor will be working at its top, i.e. 42,5 kW. However, this interconnection shall be used only during emergency situations. This means that the motors shall not be able to work at their Top Speed condition, but at a lower level than the Function condition. For this case, we suppose that the motors shall work with a 70% of their cruising capacity. Thus, with the values of power and voltage we can obtain the required current.

- **Motor rate power:** 13,1 kW
- **Voltage:** 144 Vdc

$$I_{IS} = \frac{P}{V}$$

$$I_{IS} = \frac{18700 \cdot 0,7}{144}$$

$$I_{IS} = 90,9028 \text{ A}$$

Thus, according to the Classification Society, for a rate current of 90,90 A, two poles and 90° C, it is necessary to use a conductor with 25 mm<sup>2</sup> of cross-section, which give us a maximum current of 108 A.<sup>69</sup> The chosen conductor shall be a EXZHELLENT MAR – Rdt 2x25 + 25 mm<sup>2</sup>, model 7783312.

For this task, we have chosen the SCHNEIDER ELECTRIC INTERPACT INS250, which have a rate current value of 100 A. Its catalogue is attached at the end of this Annexes section (page 331 – **3.10.7.4. Schneider Electric Interpact INS250**).

Thus, we ensure that the rate current of the isolator switch is between the actual current and the rate current of the conductor.

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<sup>69</sup> DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 51 (July 2013)

$$90,90 < 100 < 108$$

### 3.7.5.2. 230 Vac interconnection

For the 230 Vac interconnection, we must proceed in the same way as the 144 Vdc interconnection. In this case, we will have more loads, and it will necessary to add all their power requirements.

The interconnection shall supply the switchboards placed on the Passengers Room, the Entrance & Toilet, Anteroom, Bridge (230 Vac & 24 Vdc) and the Engine Rooms & Electrical Compartments.

Therefore, it is time to calculate the cross-section required in the interconnection. This conductor shall interconnect both 230 Vac main switchboards, and therefore it will support half of the 230 Vac loads previously calculated, and the whole 24 Vdc system of the Bridge. Although the two of the switchboards do not hold the same amount of loads, their values are virtually the same, because of the almost symmetrical distribution of the loads between both systems.

Thus, we will assume that this conductor will support half of the 230 Vac loads and the whole 24 Vdc system of the Bridge. Their values can be checked at the power forecast calculation (page 155 – **3.2.3. Total power forecast**).

$$P_T = \frac{P_{230Vac}}{2} + P_{24Vdc}$$

$$P_T = \frac{6373,6}{2} + 1409$$

$$P_T = 4595,8 \text{ W}$$

Assuming a power factor ( $\cos \varphi$ ) of 0.9 in the 230 Vac, and considering 1 in the

24 Vdc system, we will obtain the total current that this conductors shall support:

$$I_T = I_{230Vac} + I_{24Vdc}$$

$$I_T = \frac{\frac{P_{230Vac}}{2}}{V_{ac} \cdot 0.9} + \frac{P_{24Vdc}}{V_{dc}}$$

$$I_T = \frac{3186,8}{230 \cdot 0.9} + \frac{1409}{24}$$

$$I_T = 74,1035 \text{ A}$$

Referring to the Classification Society, it shall be necessary a 2x16 mm<sup>2</sup> conductor for this task, allowing a maximum current of 82 A. For this conductor, we have chosen a EXZHELLENT MAR – Rdt 2x16 + 16 mm<sup>2</sup>, model 7783311.

On the other hand, we have to establish a way to make this interconnection. For this task, we will install two isolator switches in each end of the conductor. This will allow us to let the current flow or not to flow, depending on the situation.

The isolator switch that we require must have a rate current value higher than 74,1035 A. Thus, we have chosen the SCHNEIDER ELECTRIC INTERPACT INS80, which have a rate current value of 80 A. Its catalogue is attached at the end of this Annexes section (page 334 – **3.10.7.5. Schneider Electric Interpact INS80**).

Thus, we ensure that the rate current of the isolator switch is between the actual current and the rate current of the conductor.

$$74,10 < 80 < 82$$

### 3.7.6. Bridge selector switch

Due to the structure of the electrical system, the Bridge is thought to be feed by both systems (one in each hull). Thus, both 230 Vac and 24 Vdc switchboards shall be supplied through a two position selector switch.

For this task, we have choose the SCHNEIDER ELECTRIC CM 18070 two position selector switch. Its main characteristics, as are shown in its catalogue (page 330 – **3.10.7.3. Schneider Electric CM 18070**), are as follows:

- **Rated operational current:** 20 A
- **Control type:** Toggle 2 positions.
- **Mounting mode:** Fixed
- **Height:** 82 mm
- **Width:** 18 mm
- **Depth :**75 mm
- **Electrical durability:** 30000 cycles AC-22.

This switch can be placed at the Bridge in order to ease the operator in case of necessity.

### 3.7.7. Rating of earth conductors

All earthing connections of copper shall have sufficient cross-section to prevent the current density exceeding 150 A/mm<sup>2</sup> at the maximum earth fault currents that can pass through them.

Minimum cross-section of earthing conductors shall be as listed in the following figure: <sup>70</sup>

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<sup>70</sup> DNV - Electrical Installations, Pt.4 Ch.8 Sec.2 – Page 48 (July 2013)



| Table J2 Earthing connections and conductors |                                                                                                                                                                                                                          |                                                                              |
|----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Arrangement of earth conductor               | Cross-section $Q$ of associated current carrying conductor (one phase or pole) ( $\text{mm}^2$ )                                                                                                                         | Minimum cross-section of earth conductor                                     |
| 1                                            | i) Insulated earth conductor in cable for fixed installation.                                                                                                                                                            | $Q \leq 16$                                                                  |
|                                              | ii) Copper braid of cable for fixed installation when the cable is provided with an insulating outer sheath. (For cables without insulating outer sheath, the braiding can not be used as a protective earth conductor). | $1/2$ of the current-carrying conductor, but not less than $16 \text{ mm}^2$ |
|                                              | iii) Separate, insulated earth conductor for fixed installation in pipes in dry accommodation spaces, when carried in the same pipe as the supply cable.                                                                 |                                                                              |
|                                              | iv) Separate, insulated earth conductor when installed inside enclosures or behind covers or panels, including earth conductor for hinged doors as specified in Sec.10 B.                                                |                                                                              |
| 2                                            | Uninsulated earth conductor in cable for fixed installation, being laid under the cable's lead sheath, armour or copper braid and in metal-to-metal contact with this.                                                   | $Q \leq 2.5$                                                                 |
|                                              |                                                                                                                                                                                                                          | $2.5 < Q \leq 6$                                                             |
|                                              |                                                                                                                                                                                                                          | $6 < Q$                                                                      |
| 3                                            | Separately installed earth conductor for fixed installation other than specified in 1 iii) and 1 iv).                                                                                                                    | $Q < 2.5$                                                                    |
|                                              |                                                                                                                                                                                                                          | $2.5 < Q$                                                                    |
| 4                                            | Insulated earth conductor in flexible cable.                                                                                                                                                                             | $Q \leq 16$                                                                  |
|                                              |                                                                                                                                                                                                                          | $16 < Q$                                                                     |

Figure 33: Earthing connections and conductors

According to this table, and referring to **2.6.8. Grounding** (page 44), we will chose a cross-section of  $16 \text{ mm}^2$  for each ground connection. Thus, we ensure that it complies with the requirements of the system.

## 3.8. Basic Health and Safety Study

### 3.8.1. Introduction

According to the UNE 157001 2014, the Basic Health and Safety Study must be included in the projects as part of the Annexes section. Thus, we will proceed to its development in the following sections.

#### 3.8.1.1. Justification of the Basic Health and Safety Study

Royal Decree 1627/1997 of 24 October, which sets the minimum health and

safety requirements during the implementation, states in paragraph 2 of Article 4 that works not included in the cases provided in the paragraph 1 of that Article, shall required a Basic Health and Safety Study by the Promoter.

Therefore, it must be checked that all the following circumstances applies:

- The Budget is less than € 450,759.
- b) The estimated duration of the work does not exceed 30 days, or more than 20 operators are not working simultaneously.
- c) The estimated amount of workers is less than 500 workers-day.
- d) There are no tunnels, galleries, dams or underground pipes.

Because of the compliance of the requirements of the Royal Decree 1627/1997 of 24 October, the following Basic Health and Safety Study is developed.

Also, this Basic Study complies with Law 31/1995, of November 8, (Law of occupational hazard prevention) in relation to the Employer's to inform and give adequate instructions in relation to the risks in the workplace and the protective measures and prevention.

Based on this Basic Study and Article 7 of the Royal Decree 1627/1997, each Contractor shall prepare a Safety and Health Plan based on their own system of implementation of the work, taking into account the particular circumstances of the work under.

#### **3.8.1.2. Aim**

As specified in paragraph 2 of Article 6 of the Royal Decree 1627/1997, the Basic Study shall specify:

- The safety and health standards applicable to the work.

- Identification of occupational hazards that can be avoided, indicating the necessary technical measures.
- List of workplace risks that can not be eliminated as stated above specifying the preventive measures to control and reduce risks assessing their effectiveness, especially when alternative measures are proposed. If any, it will take into account any task implemented. It shall contain specific measures according to the paragraphs of Annex II of the Royal Decree).
- Forecasts and information to implement in the future, under appropriate conditions of health and safety.

#### **3.8.1.3. Works data**

The status and the type of the works implemented are explained in the Memory of this project.

#### **3.8.1.4. Electric power supply**

The provisional electricity supply will be taken from the batteries, and in turn, from the shore connection, being provided the necessary attachment points on the location of the installation works.

#### **3.8.1.5. Drinking water supply**

The water supply will be through the regular supply lines in the region, area, etc. In the event that this is not possible, they have the necessary means to ensure their regular existence since the beginning of the work.

#### **3.8.1.6. Sanitary facilities**

It must have enough sanitary facilities. There must be means to facilitate the evacuation or relocation to specific places of faecal waters, so do not impact the environment.

#### **3.8.1.7. Servitude and conditions**

No interference in the work is expected, because if civil works and installation can be performed by different companies, there is no coincidence in time. However, according to Article 3 of the Royal Decree 1627/1997, if more than one company is involved in work implementations, the Promoter shall designate a coordinator specialized in safety and health matters during the implementation of the work. This designation should be subject to an express contract.

### **3.8.2. Safety standards to be applied in the works**

Safety standards to be applied in the work are described below:

- Law 31/1995 of 8 November, occupational hazard prevention.
- Royal Decree 485/1997 of 14 April about safety signs at work.
- Royal Decree 486/1997 of 14 April, about safety and health in the workplace.
- Royal Decree 487/1997 of 14 April, about handling of loads.
- Royal Decree 773/1997 of 30 May, about use of personal protective equipment.
- Royal Decree 39/1997 of 17 January, about regulation of prevention services.
- Royal Decree 1215/1997 of 18 July, about the use of work equipment.
- Royal Decree 1627/1997 of 24 October, about the minimum health and safety requirements set out in construction.
- Workers' Statute (Law 8/1980, Law 32/1984, Law 11/1994).

#### **3.8.2.1. Incompatibility between standards**

In case of contradiction between two rules or between specified herein and as indicated in a standard, it will prevail the criteria that provides greater security.

### **3.8.3. Validity**

Validity of this safety plan starts from the date of its approval by the health and safety coordinator appointed by the property.

#### **3.8.4. Changes in the Basic Health and Safety Study**

The Basic Health and Safety Study may be modified depending on the implementation process of the works, the progress of the works and any incidents or modifications that may arise throughout the works. Such amendments must also be approved by the Coordinator on health and safety.

The Basic Health and Safety Study, must be in the place permanently available to people involved in the implementation of the works, people with prevention responsibilities and the representatives of the workers, who may, in writing and in a reasoned manner, suggestions and alternatives as appropriate.

Also, the Basic Health and Safety Study will be permanently available for the Director.

#### **3.8.5. Organization and responsibilities**

According to the Royal Decree 1627/1997, there must be a coordinator for safety and health matters during the implementation of the works, which will develop the functions described in Article No. 9 and 10 of the Royal Decree. Both Contractor and Subcontractors, will apply as described in Article 11 of the Decree. Their application shall be binding to all staff of the Contractor.

The works implemented by the workers of the Contractor, will be only those relating to the organization and supervision of contracted work,. This task shall be done by the Project Manager and Technician on prevention.

Also, under this Basic Study of Safety and Health, each Subcontractor will prepare a Plan for Safety and Health at Work which will analyze, study, develop and complement the provisions contained in the Basic Study of Health and Safety , based on its own system of implementation of the work and/or it will be annexed to our study.

The implementation will be carried out by a subcontractor company for electrical installation activities.

### **3.8.6. Works characteristics**

#### **3.8.6.1. Location**

As it was stated in the Memory, this project is focused on a two hull vessel, and it will not have a defined location.

#### **3.8.6.2. Works description**

The scope of this document will include the whole electrical system of a two hull vessel, including its propulsion as well as the luminaries, ventilation, etc. It is thought to perform as a pure electric system, ensuring a zero-emission performance.

#### **3.8.6.3. Implementation time**

The implementation time of the works shall be four months.

#### **3.8.6.4. Amount of workers**

The estimated amount of workers shall be of five workers per working day.

#### **3.8.6.5. Machinery**

Machines, tools and auxiliary sources that are going to be used in the work in this study they are as follows.

#### **3.8.6.6. Electrical and instruments installation**

It is expected to use the following tools for the implementation of the works:

- Drills
- Welders
- Burners

- Hand tools

#### **3.8.6.7. Machines**

It is expected to use the following machinery for the implementation of the works:

- Backhoe
- Electrical cement mixer
- Lifting crane
- Material transport truck

#### **3.8.6.8. Auxiliary sources**

It is expected to use the following sources for the implementation of the works:

- Hand metal ladders, or failing this, small scaffolds, to work in short heights, or to access a high place on the ground. No metal ladders shall be used in the vicinity of unprotected electrical installations.

### **3.8.7. Protections**

#### **3.8.7.1. Collective protections**

Necessary collective protection will be study according to the project blueprints and considering the types of risks listed above and the needs of the workers. The following list gathers the planned protections:

- Several warning of danger signs.
  - Mandatory use of safety boots.
  - Mandatory use of gloves.
  - Mandatory use of safety glasses.
  - Danger: contact with electric current.

- It will be checked that all machinery and tools have their collective protections under current regulations.
- Work fence demarcating and protecting the work area.
- Marking tapes.
- Ground connection.
- RCDs.
- Presence of fire extinguishers nearby.

#### **3.8.7.2. Individual Protection Equipment**

The protections necessary to perform the works of this project are:

- Overalls.
- Safety boots
- Tool Belt.
- Safety glasses
- Dielectric gloves.
- Reflective vest.

### **3.8.8. Risk prevention**

#### **3.8.8.1. Training**

The Contractors must provide their workers with training and safety information necessary for the implementation of the works. To this end talks about starting activities will be given, as well as single lectures. All of them shall inform the workers about the risks that they are exposed, as well as preventive and protective measures that they count with to avoid them. It must keep a record justifying the talks and the assistance given.

Besides, they shall be notified with the use of different security features mentioned herein.



In the operations of maintenance, implementation, etc. it shall count with proper staff and the right to development various activities. Breaks between shifts must be set as well.

In the case that the works are performed by anyone other than the operators of the project, operators will be duly approved according to the safety standards of the property.

### **3.8.9. Preventive medicine**

This section gathers the measures to reduce the consequences of accidents that the workers are inevitably exposed to. This will be implemented through four measures:

- Medical surveillance of the workers.
- First-aid kits.
- Swift action in the first support of injured workers.
- Healthcare medicine in case of accident or illness.

### **3.8.10. Medical supervision**

As it is stated in the current legislation, all workers of the main Contractor and Subcontractors working on this project must have been declared suitable in a medical examination by specialists in occupational medicine of the corresponding Employment Mutual, with which the main Contractor and Subcontractors have hired all healthcare services.

### **3.8.11. First aid at work**

First-aid kits are not allow for small cures work. The first aid support should be done in the Medical Services of the property.

### **3.8.12. Intervention and first aid**

The Contractor must hire the services of an employment mutual (External Prevention Service).

It shall be provided in a visible place a list of telephone numbers and addresses of the employment mutual, ambulances, firemen, taxis, etc., as well as a map of the closest medical centres to the work and the access roads that allows the faster way to ensure transport of injured people to assistance centres.

### **3.8.13. Medical care in temporary or permanent work disability**

This service is covered by the Employment Mutual, which has contracted coverage policy for permanent or temporary disability, as well as death by accident or occupational disease. Each Subcontractor will set the corresponding equivalent insurance.

### **3.8.14. Accident/incident information**

It shall be necessary to follow the procedures of the property. Also, when an accident occurs, with or without time-off work, Contractors/Subcontractors will fill the report of standardized accident, sending it to the Security Coordinator of the work within less than 24 hours . Under no circumstances the injured worker will be taken out from the facilities without prior notification.

Subsequently, the research report of standardized accidents will take place following the protocol stated in it, requesting the cooperation of witnesses if any and describing with the utmost rigor and detail the conclusions reached after the investigation at the place of the facts, which will be presented to the Security Coordinator.

### **3.8.15. Budget**

In the Execution Material Budget (EMB) of this project has been reserved a

section with a budget of 2079,61€euros for the Basic Health and Safety Study.

Royal Decree 1627/1997 sets minimum requirements and there is no requirement of an estimate to quantify the total expenditure planned for the implementation of this study.

Although not mandatory we recommend booking in the project budget an amount for the Basic Health and Safety Study., which can vary between 1% and 2% of the EMB, depending on the type of work.

### **3.8.16. Further works**

Paragraph 3 of Article 6 of Royal Decree 1627/1997 provides that in the Basic Health and Safety Study will take place forecasts and information for carrying out further works, under proper conditions of health and safety.

### **3.8.17. Promoter's obligations**

Before the start of works, the Promoter shall appoint a coordinator for safety and health, every time that during the implementation of the works it requires more than a company, or a company and various self-employed or self-employed.

The introduction of Royal Decree 1627/1997 and Paragraph 2 of Article 2 states that the Contractor and the Subcontractor shall be as an employer for the purposes specified in the regulations on prevention of occupational hazards. As during the building work is common the existence of numerous subcontractors, it will be possible the existence of a Coordinator in the implementation phase.

The appointment of the Coordinator for Safety and Health matters shall not relieve the Promoter from responsibilities. The Promoter must make a notification to the labor authority before the start of works, and it must be drafted in accordance with the provisions in Annex III of Royal Decree 1627/1997 . It must be exposed visibly in the

work and updated if necessary.

### **3.8.18. Health and Security Coordinator**

The appointment of the Coordinator in the drafting and implementation of the work will fall on the same person.

Health and Security Coordinator shall perform the following functions during the execution of the work,:

- Coordinate the application of general principles of prevention and safety.
- Coordinate the activities of the work to ensure that businesses and active personnel applied consistently and responsibly the principles of preventive action as reflected in Article 15 of the Law on Prevention of Occupational Risks in the implementation of the work, and particularly in the activities referred to in Article 10 of Royal Decree 1627/1997.
- Approve the Health and Safety Plan prepared by the Contractor and, where appropriate, the changes applied.
- Organize the coordination of business activities provided in Article 24 of the Law on Prevention of Occupational Risks.
- Coordinate activities and control functions for the correct application of the methods of work.
- Take the necessary measures to ensure that only authorized persons may access to the work.

The Director will assume these functions when the appointment of the coordinator is not necessary.

### **3.8.19. Security and Health Plan**

Under the Basic Health and Safety Study, the Contractor shall prepare a Safety and Health Plan before starting the works, in which will analyse, study, develop and

complement the provisions contained in the Basic Study and depending on his own system of work implementation. The Plan shall include, where appropriate, proposals of alternative prevention measures, made by the Contractor and with the corresponding technical justification. These measures must not involve decreased levels of protection under the Basic Study.

The Health and Safety Plan must be approved before the start of the work by the Safety and Health Coordinator. This may be modified by the Contractor according to the process of implementation of the works, the progress of the works and any incidents or modifications that may arise throughout the works, but always with the express approval of the Coordinator. When the appointment of the Coordinator is not required, the functions attributed to it will be assumed by the Director.

Staff involved in the implementation of the work, as well as people or companies with prevention responsibilities may submit suggestions and alternatives that might improve the Plan. The Plan shall be available at the work.

### **3.8.20. Contractor and Subcontractor's responsibilities**

Contractor and Subcontractor must comply with the following requirements:

- 1. Apply the principles of preventive action as reflected in Article 15 of the Law on Prevention of Occupational Risks, in particular:
  - Maintaining the work in a clean state.
  - Selection of jobs and work areas, taking into account their access and determining routes or areas of displacement or movement.
  - Manipulation of different materials and use of auxiliary resources.
  - Maintenance, prior check and regular monitoring of facilities and devices necessary for the implementation of works, in order to correct the defects that may affect the safety and health of the workers.
  - Delimitation and conditioning of storage areas, particularly if it's hazardous

materials.

- The storage and disposal of wastes.
- The collection of hazardous materials.
- The adaptation of the time period of the stages of the works.
- The cooperation between all those involved in the work.
- The interactions or incompatibilities with any other work or activity.
- 2. Comply with the Health and Safety Plan and make his staff to comply with it.
- 3. Comply with the rules on the prevention of occupational risks, taking into account the obligations on the coordination of business activities provided in Article 24 of the Law on Prevention of Occupational Risks and meet the minimum requirements set out in Annex IV Royal Decree 1627/1997.
- 4. Inform and provide the self-employed workers with the Health and Safety measures required.
- 5. Address the instructions and comply with the instructions of the Coordinator for safety and health during the implementation of the work.

Contractor and Subcontractor will be responsible for the proper implementation of preventive measures stated in the Plan. Also, they will be responsible for the obligations that apply directly to them or, where appropriate, to workers hired by them. They will also be responsible for the consequences caused by the failure of the measures stated in the Plan.

The responsibilities of the Coordinator, Director and the Promoter shall not exempt the Contractors and Subcontractor from theirs.

### **3.8.21. Self-employed workers' responsibilities**

The self-employed workers are required to:

- 1. Apply the principles of preventive implementation stated in Article 15 of the Law on Prevention of Occupational Risks, and in specially:
  - Maintaining the work place in good order and cleanliness.

- The storage and disposal of wastes.
- The collection of hazardous materials.
- The adaptation of the time period of the stages of the works.
- The cooperation between all workers involved in the work.
- The interactions or incompatibilities with any other work or activity.
- 2. Comply with the requirements stated in Annex IV of Royal Decree 1627/1997.
- 3. Adjust their work to the duties on the coordination of business activities provided in Article 24 of the Law on Prevention of Occupational Risks.
- 4. Comply with the obligations established for workers in Article 29, paragraphs 1 and 2 of the Law on Prevention of Occupational Risks.
- 5. Using work equipment complying with the provisions of Royal Decree 1215/1997.
- 6. Choose and use protective equipment in the terms established in Royal Decree 773/1997.
- 7. Address the instructions and comply with the instructions of the Coordinator for safety and health.

The self-employed must meet the provisions of the Health and Safety Plan.

### **3.8.22. Book of Incidents**

In every workplace there will be, for the purposes of controlling and monitoring the Safety and Health Plan, a Book of Incidents consisting of sheets in duplicate and will be given by the Technician who has approved the Safety Plan and Health. It should always be kept in the workplace by the Coordinator. The Director, Contractors and Subcontractors, self-employed workers, people with responsibilities in the prevention of the companies involved, representatives of workers and technicians will have access to the book, who can make notes in it.

They may only make entries in the Book of Incidents related to compliance with

the Plan.

Every time an entry is made in the Book, the Coordinator must return within twenty-four hours a copy to the Labour and Social Security Inspectorate of the province in which the work is being implemented. The Coordinator shall notify the Contractor and workers' representatives such endorsements.

### **3.8.23. Work stoppage**

During the execution of the works, if the Coordinator notices a non-compliance with health and safety measures, he must inform the Contractor and shall record such infringement in the Book of Incidents, being authorized to, in circumstances of serious and imminent risk to safety and health of workers, have the paralysis of pits or, where appropriate, the whole work.

The Coordinator will report this fact to be relevant, to the Labour and Social Security Inspectorate of the province in which the work is being implemented. The Coordinator shall also notify the Contractor, and if any, the Subcontractors and/or self-employed workers.

### **3.8.24. Worker's rights**

Contractors and Subcontractors must ensure that workers receive adequate and understandable information about all measures required to be taken in regard to their safety and health at work.

A copy of the Health and Safety Plan and any of its amendments will be provided by the Contractor to the representatives of workers in the workplace.

### **3.8.25. Minimum safety and health requirements in the works**

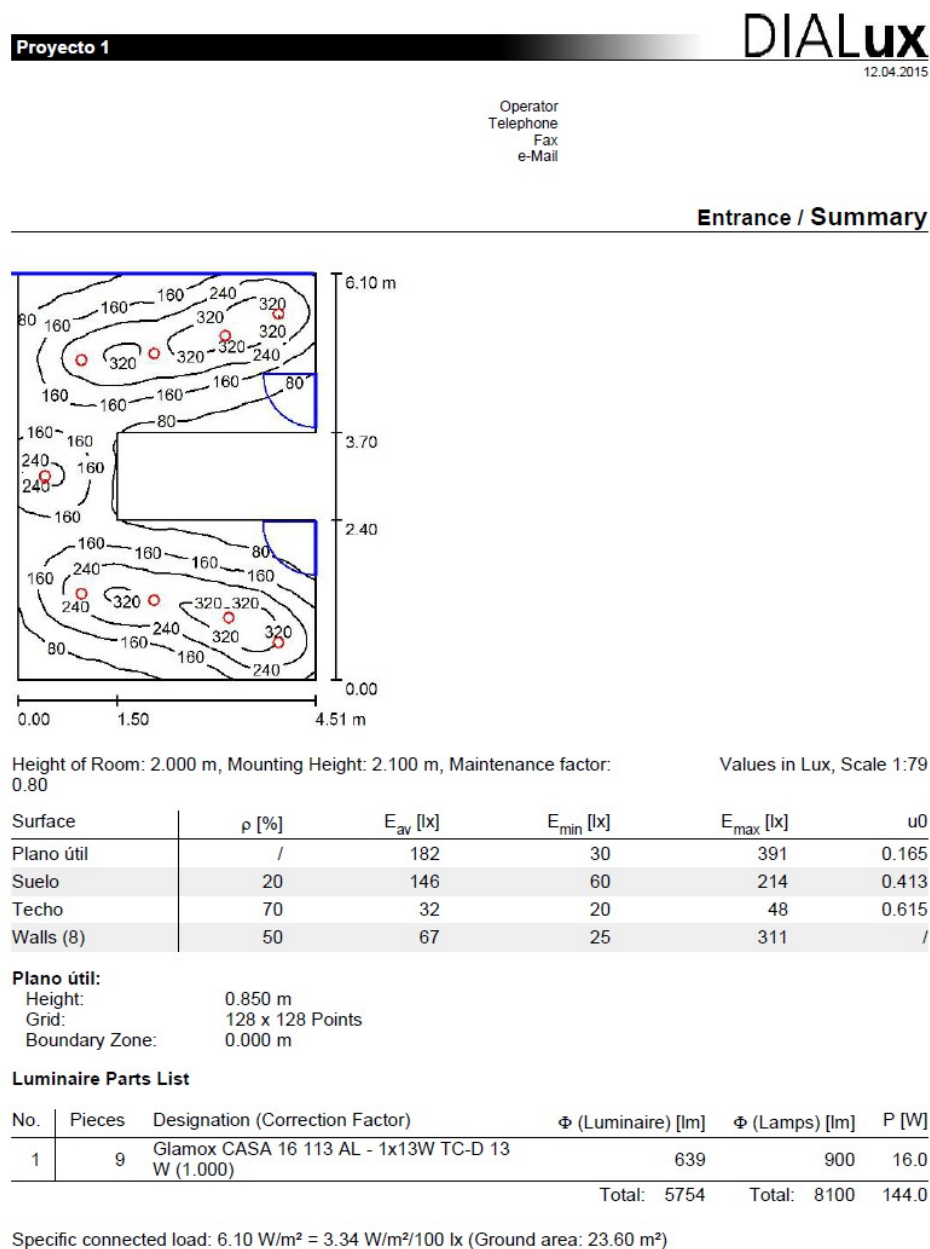
The expected duties in the three parts of Annex IV of Royal Decree 1627/1997, that sets minimum requirements of safety and health in the construction shall be applied



whenever required by the features of the work or activity, the circumstances or a hazard.

## 3.9. DIALux results

### 3.9.1. Interior lighting



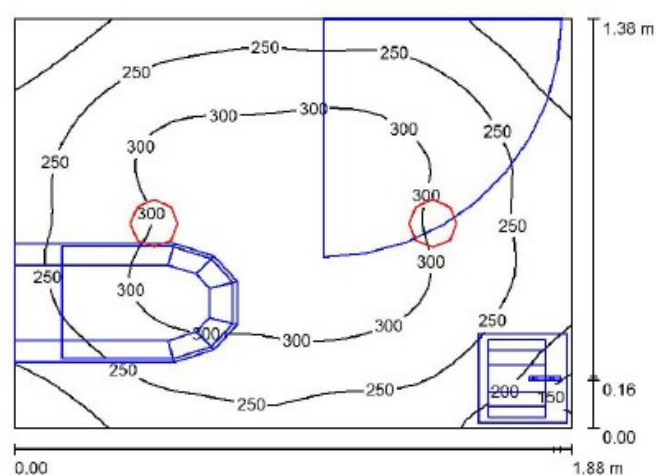
## Proyecto 1

DIALux

13.04.2015

Operator  
Telephone  
Fax  
e-Mail

## Toilet / Summary



Height of Room: 2.000 m, Mounting Height: 2.100 m, Maintenance factor: 0.80

Values in Lux, Scale 1:18

| Surface    | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0    |
|------------|------------|---------------|----------------|----------------|-------|
| Plano útil | /          | 265           | 95             | 338            | 0.358 |
| Suelo      | 20         | 133           | 23             | 172            | 0.172 |
| Techo      | 70         | 53            | 39             | 62             | 0.728 |
| Walls (4)  | 50         | 107           | 13             | 237            | /     |

## Plano útil:

Height: 0.850 m  
Grid: 32 x 32 Points  
Boundary Zone: 0.000 m

## Luminaire Parts List

| No.    | Pieces | Designation (Correction Factor)                 | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|-------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 2      | Glamox CASA 16 113 AL - 1x13W TC-D 13 W (1.000) | 639                     | 900                 | 16.0  |
| Total: |        |                                                 | 1279                    | 1800                | 32.0  |

Specific connected load:  $12.36 \text{ W/m}^2 = 4.66 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $2.59 \text{ m}^2$ )

Proyecto 1

DIALux

13.04.2015

Operator  
Telephone  
Fax  
e-Mail

Toilet / UGR Calculation Area 3 / Table (UGR)



|       |       |       |
|-------|-------|-------|
| 1.039 | 19    | /     |
| 0.346 | 19    | /     |
| m     | 0.470 | 1.410 |

Attention: The coordinates refer to the image above.

Grid: 2 x 2 Points

Position of surface in room:  
Marked point:  
(5.682 m, 20.779 m, 1.200 m)



Min  
/

Max  
19

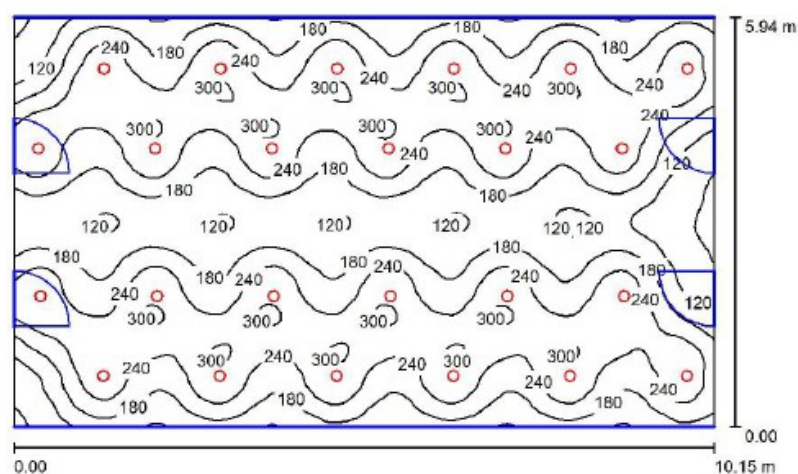
Proyecto 1

**DIALux**

12.04.2015

Operator  
Telephone  
Fax  
e-Mail

### Passengers Room / Summary



Height of Room: 2.000 m, Maintenance factor: 0.80

Values in Lux, Scale 1:77

| Surface    | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | $u0$  |
|------------|------------|---------------|----------------|----------------|-------|
| Plano útil | /          | 212           | 50             | 311            | 0.237 |
| Suelo      | 20         | 191           | 92             | 234            | 0.480 |
| Techo      | 80         | 41            | 30             | 70             | 0.726 |
| Walls (4)  | 50         | 84            | 39             | 302            | /     |

#### Plano útil:

Height: 0.850 m  
Grid: 128 x 128 Points  
Boundary Zone: 0.000 m

#### Luminaire Parts List

| No.    | Pieces | Designation (Correction Factor)                 | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|-------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 24     | Glamox CASA 16 113 AL - 1x13W TC-D 13 W (1.000) | 639                     | 900                 | 16.0  |
| Total: |        |                                                 | 15345                   | 21600               | 384.0 |

Specific connected load:  $6.37 \text{ W/m}^2 = 3.01 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $60.27 \text{ m}^2$ )

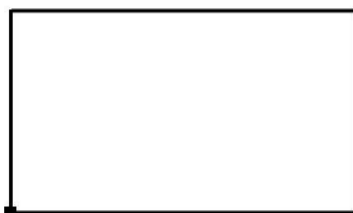
Proyecto 1

DIALux

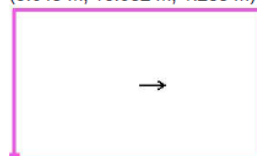
12.04.2015

Operator  
Telephone  
Fax  
e-Mail

Passengers Room / Superficie de cálculo UGR 1 / Table (UGR)



Position of surface in room:  
Marked point:  
(8.640 m, 18.502 m, 1.200 m)



|       |           |           |       |       |       |       |           |       |       |       |
|-------|-----------|-----------|-------|-------|-------|-------|-----------|-------|-------|-------|
| 5.342 | <u>22</u> | 18        | 21    | 20    | 15    | 21    | 16        | 11    | 19    | /     |
| 4.155 | 18        | <u>22</u> | 19    | 17    | 21    | 17    | 21        | 19    | 13    | /     |
| 2.968 | 17        | 17        | 17    | 15    | 16    | 14    | 14        | 15    | <10   | /     |
| 1.781 | 18        | <u>22</u> | 19    | 16    | 21    | 17    | <u>22</u> | 19    | 13    | /     |
| 0.594 | <u>22</u> | 17        | 15    | 20    | 14    | 21    | 16        | 11    | 19    | /     |
| m     | 0.509     | 1.528     | 2.546 | 3.564 | 4.583 | 5.601 | 6.619     | 7.638 | 8.656 | 9.674 |

Attention: The coordinates refer to the image above.

Grid: 10 x 5 Points

Min  
/

Max  
22

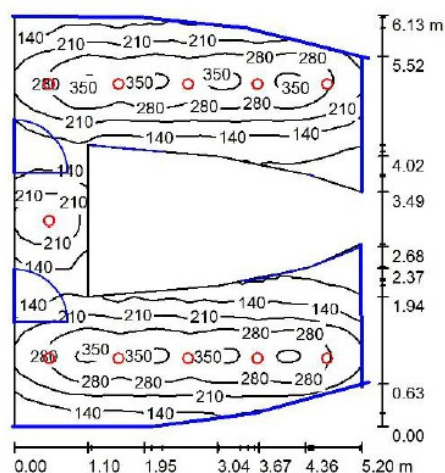
## Proyecto 1

DIALux

12.04.2015

Operator  
Telephone  
Fax  
e-Mail

## Anteroom / Summary



Height of Room: 2.000 m, Maintenance factor: 0.80

Values in Lux, Scale 1:79

| Surface    | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | $u0$  |
|------------|------------|---------------|----------------|----------------|-------|
| Plano útil | /          | 214           | 29             | 364            | 0.133 |
| Suelo      | 20         | 162           | 16             | 217            | 0.097 |
| Techo      | 70         | 37            | 15             | 55             | 0.418 |
| Walls (16) | 50         | 74            | 2.47           | 214            | /     |

## Plano útil:

Height: 0.850 m  
Grid: 128 x 128 Points  
Boundary Zone: 0.000 m

## Luminaire Parts List

| No.    | Pieces | Designation (Correction Factor)                 | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|-------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 11     | Glamox CASA 16 113 AL - 1x13W TC-D 13 W (1.000) | 639                     | 900                 | 16.0  |
| Total: |        |                                                 | 7033                    | 9900                | 176.0 |

Specific connected load:  $7.66 \text{ W/m}^2 = 3.58 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $22.99 \text{ m}^2$ )

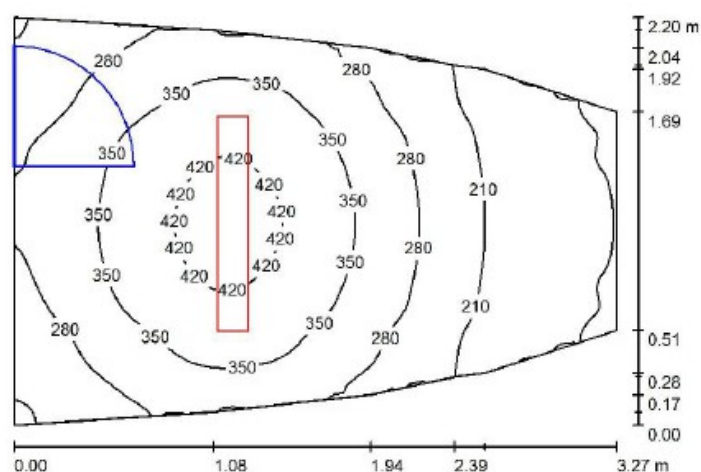
Proyecto 1

DIALux

14.04.2015

Operator  
Telephone  
Fax  
e-Mail

## Bridge / Summary



Height of Room: 2.800 m, Mounting Height: 2.800 m, Maintenance factor: 0.80

Values in Lux, Scale 1:29

| Surface    | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0    |
|------------|------------|---------------|----------------|----------------|-------|
| Plano útil | /          | 295           | 130            | 442            | 0.440 |
| Suelo      | 20         | 201           | 130            | 250            | 0.647 |
| Techo      | 70         | 95            | 57             | 209            | 0.596 |
| Walls (12) | 50         | 175           | 83             | 480            | /     |

## Plano útil:

Height: 0.850 m  
Grid: 64 x 64 Points  
Boundary Zone: 0.000 m

## Luminaire Parts List

| No.    | Pieces | Designation (Correction Factor)                                  | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|------------------------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 1      | Glamox i70-1200 LED 4500 840 - 1x50W<br>LED i70 4500 840 (1.000) | 4521                    | 4517                | 50.0  |
| Total: |        |                                                                  | 4521                    | 4517                | 50.0  |

Specific connected load:  $8.23 \text{ W/m}^2 = 2.79 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $6.07 \text{ m}^2$ )



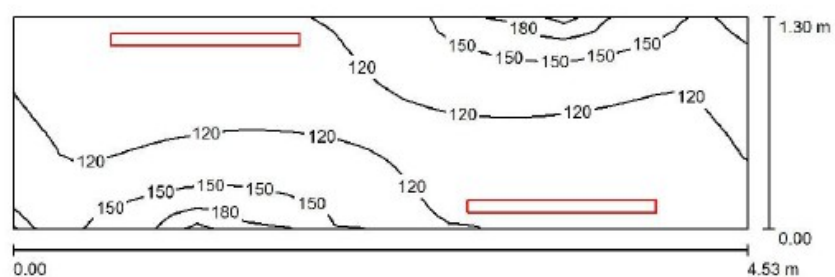
## Proyecto 1

DIALux

14.04.2015

Operator  
Telephone  
Fax  
e-Mail

## Engine Room Port / Summary



Height of Room: 2.800 m, Mounting Height: 0.500 m, Maintenance factor: 0.80

Values in Lux, Scale 1:33

| Surface    | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | $u0$  |
|------------|------------|---------------|----------------|----------------|-------|
| Plano útil | /          | 123           | 89             | 228            | 0.723 |
| Suelo      | 20         | 514           | 127            | 1082           | 0.247 |
| Techo      | 70         | 151           | 110            | 177            | 0.725 |
| Walls (4)  | 50         | 276           | 90             | 985            | /     |

## Plano útil:

Height: 0.850 m  
Grid: 32 x 16 Points  
Boundary Zone: 0.000 m

## Luminaire Parts List

| No.    | Pieces | Designation (Correction Factor)                                  | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|------------------------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 2      | Glamox i70-1200 LED 4500 840 - 1x50W<br>LED i70 4500 840 (1.000) | 4521                    | 4517                | 50.0  |
| Total: |        |                                                                  | 9043                    | 9034                | 100.0 |

Specific connected load:  $16.99 \text{ W/m}^2 = 13.80 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $5.88 \text{ m}^2$ )

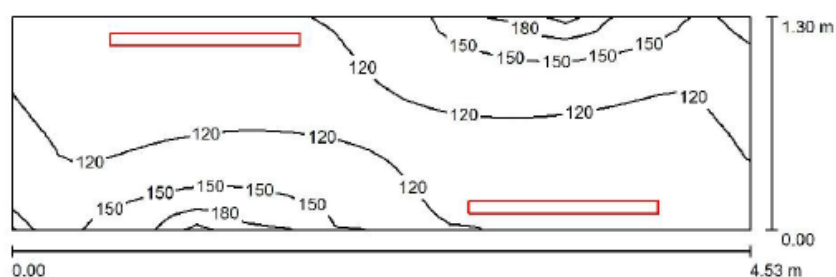
Proyecto 1

DIALux

14.04.2015

Operator  
Telephone  
Fax  
e-Mail

## Engine Room Starboard / Summary



Height of Room: 2.800 m, Mounting Height: 0.500 m, Maintenance factor: 0.80

Values in Lux, Scale 1:33

| Surface    | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0    |
|------------|------------|---------------|----------------|----------------|-------|
| Plano útil | /          | 123           | 89             | 228            | 0.723 |
| Suelo      | 20         | 514           | 127            | 1082           | 0.247 |
| Techo      | 70         | 151           | 110            | 177            | 0.725 |
| Walls (4)  | 50         | 276           | 90             | 985            | /     |

## Plano útil:

Height: 0.850 m  
Grid: 32 x 16 Points  
Boundary Zone: 0.000 m

## Luminaire Parts List

| No.    | Pieces | Designation (Correction Factor)                                  | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|------------------------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 2      | Glamox i70-1200 LED 4500 840 - 1x50W<br>LED i70 4500 840 (1.000) | 4521                    | 4517                | 50.0  |
| Total: |        |                                                                  | 9043                    | 9034                | 100.0 |

Specific connected load:  $16.99 \text{ W/m}^2 = 13.80 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $5.88 \text{ m}^2$ )

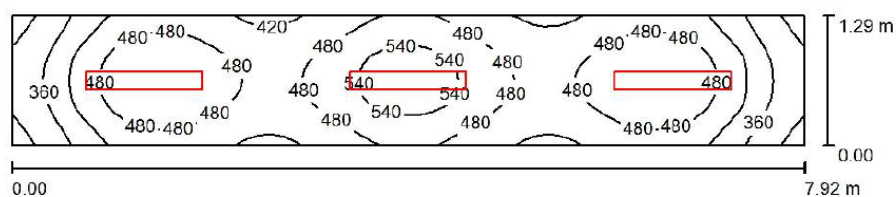
## Proyecto 1

DIALux

18.08.2015

Operator  
Telephone  
Fax  
e-Mail

## Electrical Compartment Port / Summary



Height of Room: 2.800 m, Mounting Height: 2.800 m, Maintenance factor: 0.80

Values in Lux, Scale 1:57

| Surface   | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | $u0$  |
|-----------|------------|---------------|----------------|----------------|-------|
| Workplane | /          | 460           | 280            | 573            | 0.609 |
| Floor     | 20         | 320           | 229            | 371            | 0.715 |
| Ceiling   | 70         | 177           | 100            | 317            | 0.566 |
| Walls (4) | 50         | 295           | 113            | 797            | /     |

## Workplane:

Height: 0.850 m  
Grid: 64 x 16 Points  
Boundary Zone: 0.000 m

## Luminaire Parts List

| No.    | Pieces | Designation (Correction Factor)                                  | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|------------------------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 3      | Glamox i70-1200 LED 4500 840 - 1x50W<br>LED i70 4500 840 (1.000) | 4521                    | 4517                | 50.0  |
| Total: |        |                                                                  | 13564                   | 13551               | 150.0 |

Specific connected load:  $14.62 \text{ W/m}^2 = 3.18 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $10.26 \text{ m}^2$ )

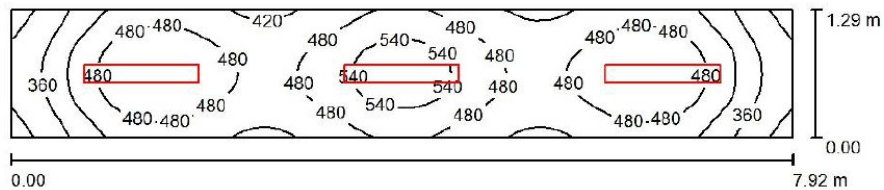
## Proyecto 1

DIALux

18.08.2015

Operator  
Telephone  
Fax  
e-Mail

## Electrical Compartment Starboard / Summary



Height of Room: 2.800 m, Mounting Height: 2.800 m, Maintenance factor: 0.80

Values in Lux, Scale 1:57

| Surface   | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | $u0$  |
|-----------|------------|---------------|----------------|----------------|-------|
| Workplane | /          | 460           | 280            | 573            | 0.609 |
| Floor     | 20         | 320           | 229            | 371            | 0.715 |
| Ceiling   | 70         | 177           | 100            | 317            | 0.566 |
| Walls (4) | 50         | 295           | 113            | 797            | /     |

## Workplane:

Height: 0.850 m  
Grid: 64 x 16 Points  
Boundary Zone: 0.000 m

## Luminaire Parts List

| No.    | Pieces | Designation (Correction Factor)                                  | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|------------------------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 3      | Glamox i70-1200 LED 4500 840 - 1x50W<br>LED i70 4500 840 (1.000) | 4521                    | 4517                | 50.0  |
| Total: |        |                                                                  | 13564                   | 13551               | 150.0 |

Specific connected load:  $14.62 \text{ W/m}^2 = 3.18 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $10.26 \text{ m}^2$ )

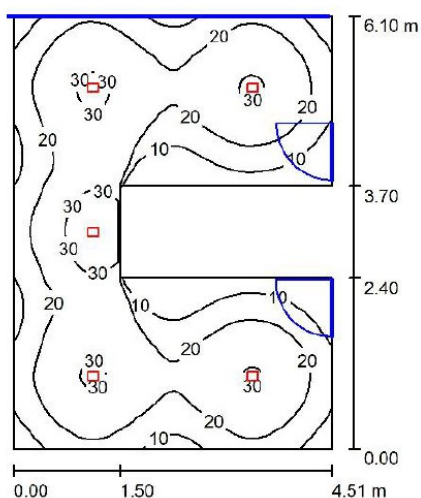
### 3.9.2. DIALux – Emergency lighting

Proyecto 1

**DIALux**  
18.08.2015

 Operator  
Telephone  
Fax  
e-Mail

Entrance / Summary



Height of Room: 2.000 m, Mounting Height: 2.000 m, Maintenance factor: 0.80

Values in Lux, Scale 1:79

| Surface    | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0    |
|------------|------------|---------------|----------------|----------------|-------|
| Plano útil | /          | 20            | 2.28           | 35             | 0.114 |
| Suelo      | 20         | 15            | 8.13           | 21             | 0.542 |
| Techo      | 70         | 3.12          | 1.84           | 5.98           | 0.590 |
| Walls (8)  | 50         | 6.93          | 1.93           | 90             | /     |

**Plano útil:**
 Height: 0.850 m  
Grid: 128 x 128 Points  
Boundary Zone: 0.000 m
**Luminaire Parts List**

| No.    | Pieces | Designation (Correction Factor)                     | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|-----------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 5      | Glamox E85-S WB LED E1/E3 - 1x2W LED E85 WB (1.000) | 120                     | 120                 | 5.0   |
| Total: |        |                                                     | 600                     | 600                 | 25.0  |

Specific connected load:  $1.06 \text{ W/m}^2 = 5.30 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $23.60 \text{ m}^2$ )

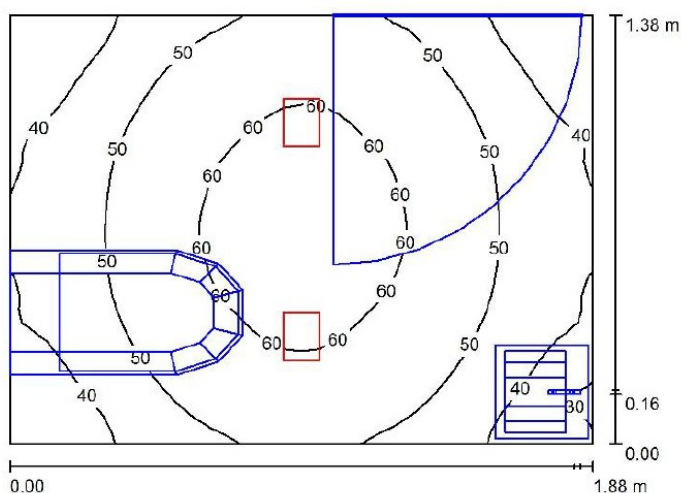
## Proyecto 1

DIALux

18.08.2015

Operator  
Telephone  
Fax  
e-Mail

## Toilet / Summary



Height of Room: 2.000 m, Mounting Height: 2.000 m, Maintenance factor: 0.80

Values in Lux, Scale 1:18

| Surface    | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | $u0$  |
|------------|------------|---------------|----------------|----------------|-------|
| Plano útil | /          | 50            | 18             | 64             | 0.365 |
| Suelo      | 20         | 23            | 4.61           | 28             | 0.200 |
| Techo      | 70         | 9.56          | 6.82           | 12             | 0.713 |
| Walls (4)  | 50         | 21            | 2.56           | 116            | /     |

## Plano útil:

Height: 0.850 m  
Grid: 32 x 32 Points  
Boundary Zone: 0.000 m

## Luminaire Parts List

| No.    | Pieces | Designation (Correction Factor)                     | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|-----------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 2      | Glamox E85-S WB LED E1/E3 - 1x2W LED E85 WB (1.000) | 120                     | 120                 | 5.0   |
| Total: |        |                                                     | 240                     | 240                 | 10.0  |

Specific connected load:  $3.86 \text{ W/m}^2 = 7.67 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $2.59 \text{ m}^2$ )

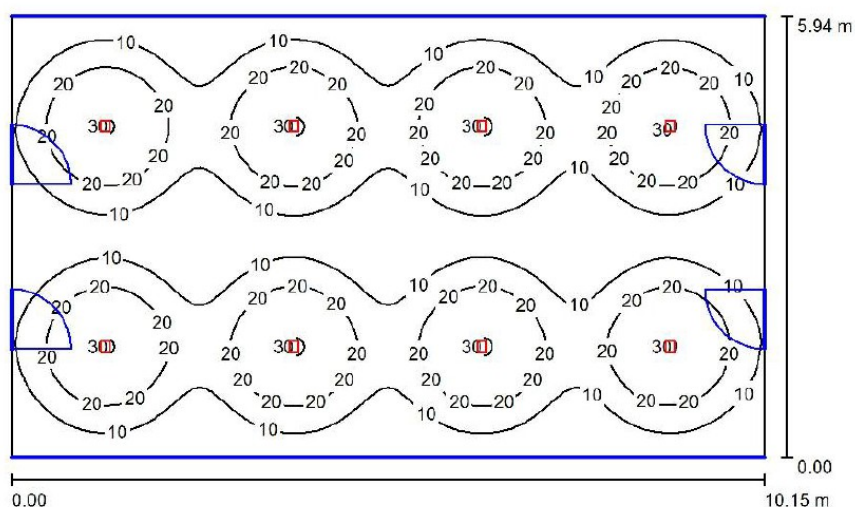
## Proyecto 1

DIALux

18.08.2015

Operator  
Telephone  
Fax  
e-Mail

## Passengers Room / Summary



Height of Room: 2.000 m, Mounting Height: 2.000 m, Maintenance factor: 0.80

Values in Lux, Scale 1:77

| Surface    | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | $u0$  |
|------------|------------|---------------|----------------|----------------|-------|
| Plano útil | /          | 14            | 1.48           | 31             | 0.104 |
| Suelo      | 20         | 13            | 6.57           | 15             | 0.518 |
| Techo      | 80         | 2.32          | 1.54           | 2.70           | 0.665 |
| Walls (4)  | 50         | 3.99          | 1.65           | 9.98           | /     |

## Plano útil:

Height: 0.850 m  
Grid: 128 x 128 Points  
Boundary Zone: 0.000 m

## Luminaire Parts List

| No.    | Pieces | Designation (Correction Factor)                     | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|-----------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 8      | Glamox E85-S WB LED E1/E3 - 1x2W LED E85 WB (1.000) | 120                     | 120                 | 5.0   |
| Total: |        |                                                     | 960                     | 960                 | 40.0  |

Specific connected load:  $0.66 \text{ W/m}^2 = 4.65 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $60.27 \text{ m}^2$ )



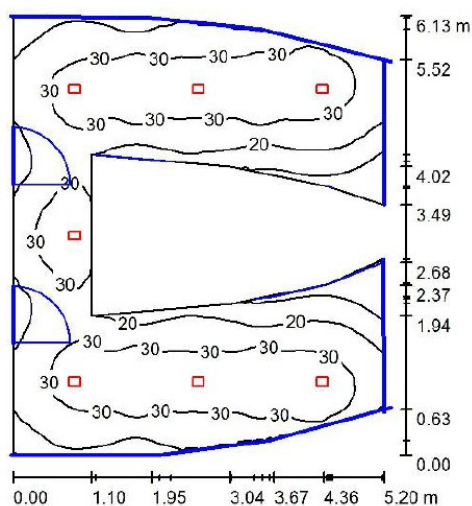
## Proyecto 1

DIALux

18.08.2015

Operator  
Telephone  
Fax  
e-Mail

## Anteroom / Summary



Height of Room: 2.000 m, Mounting Height: 2.000 m, Maintenance factor: 0.80

Values in Lux, Scale 1:79

| Surface    | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | $u0$  |
|------------|------------|---------------|----------------|----------------|-------|
| Plano útil | /          | 26            | 2.12           | 37             | 0.081 |
| Suelo      | 20         | 19            | 1.80           | 24             | 0.097 |
| Techo      | 70         | 4.18          | 1.75           | 8.84           | 0.420 |
| Walls (16) | 50         | 9.05          | 0.25           | 232            | /     |

## Plano útil:

Height: 0.850 m  
Grid: 128 x 128 Points  
Boundary Zone: 0.000 m

## Luminaire Parts List

| No.    | Pieces | Designation (Correction Factor)                     | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|-----------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 7      | Glamox E85-S WB LED E1/E3 - 1x2W LED E85 WB (1.000) | 120                     | 120                 | 5.0   |
| Total: |        |                                                     | 840                     | 840                 | 35.0  |

Specific connected load:  $1.52 \text{ W/m}^2 = 5.82 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $22.99 \text{ m}^2$ )



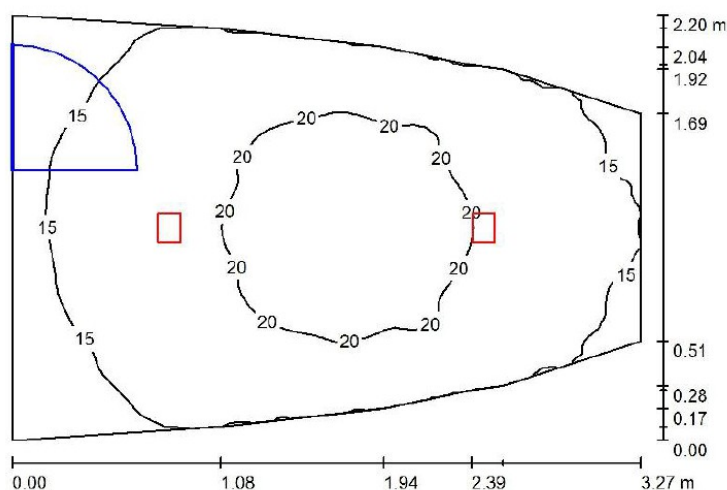
## Proyecto 1

DIALux

18.08.2015

Operator  
Telephone  
Fax  
e-Mail

## Bridge / Summary



Height of Room: 2.800 m, Mounting Height: 2.800 m, Maintenance factor: 0.80

Values in Lux, Scale 1:29

| Surface    | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | $u0$  |
|------------|------------|---------------|----------------|----------------|-------|
| Plano útil | /          | 18            | 11             | 21             | 0.629 |
| Suelo      | 20         | 12            | 9.83           | 13             | 0.829 |
| Techo      | 70         | 3.70          | 2.63           | 4.84           | 0.711 |
| Walls (12) | 50         | 9.03          | 2.51           | 24             | /     |

## Plano útil:

Height: 0.850 m  
Grid: 64 x 64 Points  
Boundary Zone: 0.000 m

## Luminaire Parts List

| No.    | Pieces | Designation (Correction Factor)                        | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|--------------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 2      | Glamox E85-S WB LED E1/E3 - 1x2W LED<br>E85 WB (1.000) | 120                     | 120                 | 5.0   |
| Total: |        |                                                        | 240                     | 240                 | 10.0  |

Specific connected load:  $1.65 \text{ W/m}^2 = 9.28 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $6.07 \text{ m}^2$ )

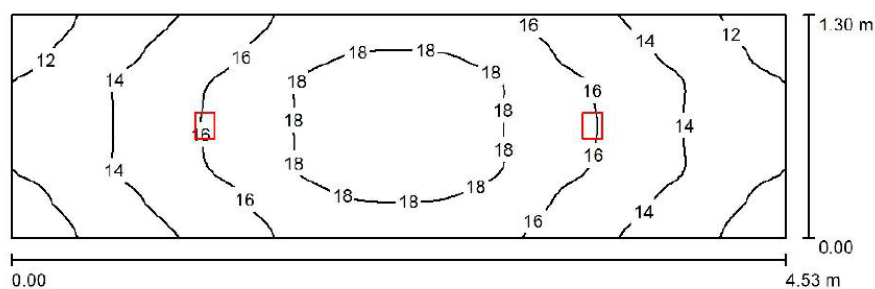
## Proyecto 1

DIALux

18.08.2015

Operator  
Telephone  
Fax  
e-Mail

## Engine Room Port / Summary



Height of Room: 2.800 m, Mounting Height: 2.800 m, Maintenance factor: 0.80

Values in Lux, Scale 1:33

| Surface    | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0    |
|------------|------------|---------------|----------------|----------------|-------|
| Plano útil | /          | 15            | 11             | 19             | 0.700 |
| Suelo      | 20         | 10            | 7.90           | 12             | 0.775 |
| Techo      | 70         | 3.70          | 2.61           | 4.68           | 0.704 |
| Walls (4)  | 50         | 8.39          | 2.63           | 34             | /     |

## Plano útil:

Height: 0.850 m  
Grid: 64 x 32 Points  
Boundary Zone: 0.000 m

## Luminaire Parts List

| No.    | Pieces | Designation (Correction Factor)                     | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|-----------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 2      | Glamox E85-S WB LED E1/E3 - 1x2W LED E85 WB (1.000) | 120                     | 120                 | 5.0   |
| Total: |        |                                                     | 240                     | 240                 | 10.0  |

Specific connected load:  $1.70 \text{ W/m}^2 = 11.03 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $5.88 \text{ m}^2$ )

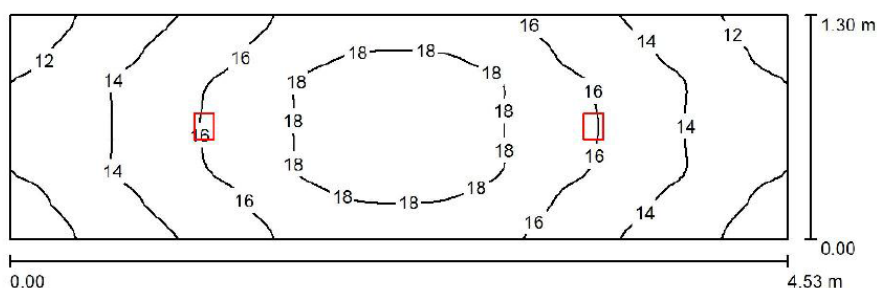
## Proyecto 1

DIALux

18.08.2015

Operator  
Telephone  
Fax  
e-Mail

## Engine Room Starboard / Summary



Height of Room: 2.800 m, Mounting Height: 2.800 m, Maintenance factor: 0.80

Values in Lux, Scale 1:33

| Surface    | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0    |
|------------|------------|---------------|----------------|----------------|-------|
| Plano útil | /          | 15            | 11             | 19             | 0.700 |
| Suelo      | 20         | 10            | 7.90           | 12             | 0.775 |
| Techo      | 70         | 3.70          | 2.61           | 4.68           | 0.704 |
| Walls (4)  | 50         | 8.39          | 2.63           | 34             | /     |

## Plano útil:

Height: 0.850 m  
Grid: 64 x 32 Points  
Boundary Zone: 0.000 m

## Luminaire Parts List

| No.    | Pieces | Designation (Correction Factor)                     | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|-----------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 2      | Glamox E85-S WB LED E1/E3 - 1x2W LED E85 WB (1.000) | 120                     | 120                 | 5.0   |
| Total: |        |                                                     | 240                     | 240                 | 10.0  |

Specific connected load:  $1.70 \text{ W/m}^2 = 11.03 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $5.88 \text{ m}^2$ )

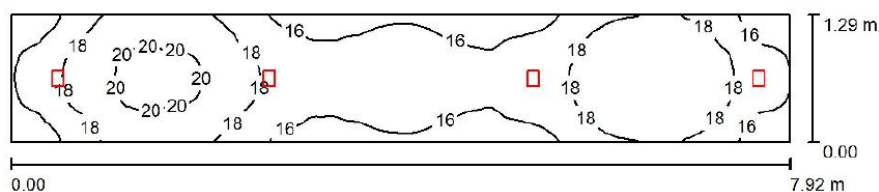
## Proyecto 1

DIALux

18.08.2015

Operator  
Telephone  
Fax  
e-Mail

## Electrical Compartment Port / Summary



Height of Room: 2.800 m, Mounting Height: 2.800 m, Maintenance factor: 0.80

Values in Lux, Scale 1:57

| Surface   | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0    |
|-----------|------------|---------------|----------------|----------------|-------|
| Workplane | /          | 17            | 14             | 21             | 0.828 |
| Floor     | 20         | 12            | 10             | 13             | 0.836 |
| Ceiling   | 70         | 4.71          | 3.12           | 8.61           | 0.663 |
| Walls (4) | 50         | 10            | 3.40           | 130            | /     |

## Workplane:

Height: 0.850 m  
Grid: 128 x 32 Points  
Boundary Zone: 0.000 m

## Luminaire Parts List

| No.    | Pieces | Designation (Correction Factor)                        | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|--------------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 4      | Glamox E85-S WB LED E1/E3 - 1x2W LED<br>E85 WB (1.000) | 120                     | 120                 | 5.0   |
| Total: |        |                                                        | 480                     | 480                 | 20.0  |

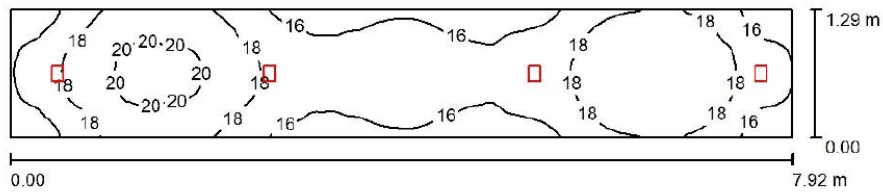
Specific connected load:  $1.95 \text{ W/m}^2 = 11.14 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $10.26 \text{ m}^2$ )

Proyecto 1

**DIALux**  
18.08.2015

Operator  
Telephone  
Fax  
e-Mail

**Electrical Compartment Starboard / Summary**



Height of Room: 2.800 m, Mounting Height: 2.800 m, Maintenance factor: 0.80

Values in Lux, Scale 1:57

| Surface   | $\rho$ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0    |
|-----------|------------|---------------|----------------|----------------|-------|
| Workplane | /          | 17            | 14             | 21             | 0.828 |
| Floor     | 20         | 12            | 10             | 13             | 0.836 |
| Ceiling   | 70         | 4.71          | 3.12           | 8.61           | 0.663 |
| Walls (4) | 50         | 10            | 3.40           | 130            | /     |

**Workplane:**

Height: 0.850 m  
Grid: 128 x 32 Points  
Boundary Zone: 0.000 m

**Luminaire Parts List**

| No.    | Pieces | Designation (Correction Factor)                        | $\Phi$ (Luminaire) [lm] | $\Phi$ (Lamps) [lm] | P [W] |
|--------|--------|--------------------------------------------------------|-------------------------|---------------------|-------|
| 1      | 4      | Glamox E85-S WB LED E1/E3 - 1x2W LED<br>E85 WB (1.000) | 120                     | 120                 | 5.0   |
| Total: |        |                                                        | 480                     | 480                 | 20.0  |

Specific connected load:  $1.95 \text{ W/m}^2 = 11.14 \text{ W/m}^2/100 \text{ lx}$  (Ground area:  $10.26 \text{ m}^2$ )

### 3.10. Catalogues

In this section will be shown the catalogues of the devices used in this document.

#### 3.10.1. Battery bank catalogue

##### 3.10.1.1. SAFT SEANERGY Battery System

## Seanergy® battery system

### High energy and high power Li-ion battery system

The Seanergy® battery system has been designed to suit the various power and energy requirements of a large variety of marine applications.

Its modular design allows to adapt the battery configuration:

- to any system voltage from 48 V to 750 V,
- for floating or cycling applications,
- to any discharge pattern from high energy: energy requirements (hours or days of discharge) to very high power demands of seconds or minutes

#### Applications

- Passenger vessels (cruise liners, ferries, Ro-Pax, urban transports)
- Workboats (tugs, offshore vessels, administration ships, fishing vessels)
- Inland shippings (river-sea shuttles, pushers/tugs, freight)
- Leisure vessels (mega yachts, medium size yachts)

#### Seanergy® battery system

The Seanergy® battery system integrates power, safety, management and communication. It is a stand-alone rackable battery system, which offers the benefits of Saft Li-ion Super Iron Phosphate® technology in a qualified industrial design.

The Seanergy® battery system provides maintenance-free energy storage in a reduced volume, combining safety and high operational reliability with outstanding lifetime under the most difficult environmental conditions.

#### Features

Unprecedented design flexibility through:

- Series connection of base modules to suit system voltages of up to 750 V maximum
- One unique control module per string, containing battery management and communication
- Parallel operation

#### Highest energy/power density

- Seanergy® modules use battery cells LiFePO<sub>4</sub> VL 41M Fe 265 Wh/liter, or VL 30P Fe 200 Wh/liter high power cell

#### Stand-alone system

- Integrating power, controls, communication and safety into a standard rack-assembly



| Nominal characteristics                                       |                           |
|---------------------------------------------------------------|---------------------------|
| Nominal voltage (V) (with 14 modules max)                     | 647                       |
| Capacity (C/5) (Ah)                                           | 82                        |
| Minimum energy (C/5) (kWh)                                    | 50                        |
| Nominal energy (C/5) (kWh)                                    | 53                        |
| Mechanical characteristics (standard cabinet with 14 modules) |                           |
| Width max (mm)                                                | 600                       |
| Height max (mm)                                               | From 24U to 47U           |
| Depth (mm)                                                    | 800                       |
| Weight (without cabinet) (kg)                                 | 560                       |
| Maximum weight (with cabinet) (kg)                            | 750                       |
| Electrical characteristics                                    |                           |
| Voltage window (V)                                            | 529 to 745                |
| Maximum charge voltage (V)                                    | 750                       |
| Maximum discharge current (A)                                 | 180                       |
| Maximum charge current (A)                                    | 180 (Power) - 80 (Energy) |
| Maximum time (h) at nominal current (95% State of Charge)     | 0.5 (Power) - 2 (Energy)  |



## Smart operation

- State of charge and state of health indication
- Built-in battery control for efficient operation
- Redundant safety
- Comprehensive communication
- Compatible with standard rectifiers

## Benefits

- Optimized battery configuration whatever application requirements, due to modular architecture with standardized base elements
- No development cost and time due to configure customized battery solutions
- Reduced battery space and weight
- Easy installation and upscaling
- High operational reliability
- Optimized supervision strategy through remote control/diagnostic
- Very long lifetime
- Preventive but not premature replacement at end of life

## Safety

Redundant safety design to cope with component failure or abusive conditions:

- At cell level: no reaction in an abuse event with inert iron phosphate positive material, shutdown-effect separator, mechanical vent
- At module level: electronic board, individual cell voltage monitoring, module temperature monitoring, balancing, fuse
- At battery system level: electronic board, power switch, current sensor



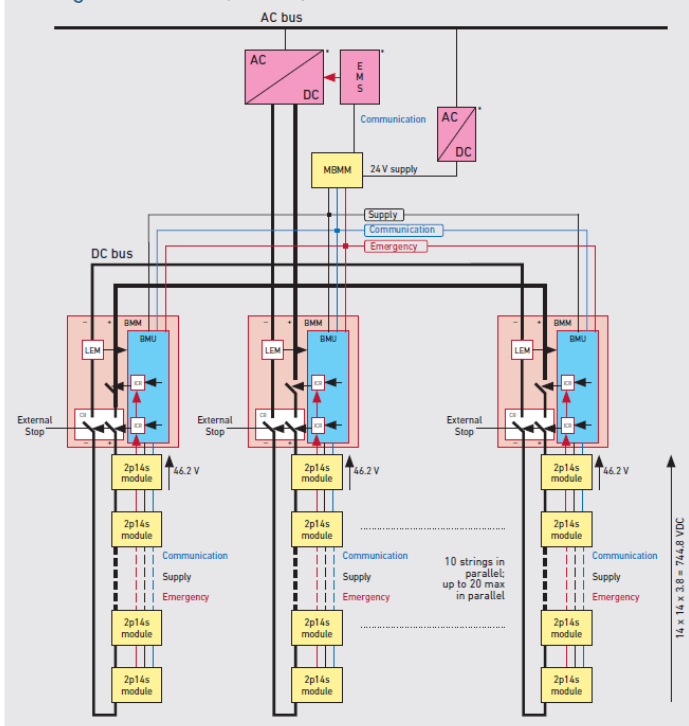
## Operating conditions

|                                                   |                               |
|---------------------------------------------------|-------------------------------|
| Lifetime at +20°C perm (+68°F)                    | 20 years                      |
| Lifetime at +40°C (+104°F)                        | >10 years                     |
| Cycle life (depending on delta DoD%; +20°C/+68°F) | from 3000 to 1 million cycles |
| Operating temperature                             | -25°C/+55°C (-13°F/+131°F)    |
| Storage temperature                               | -40°C/+55°C (-40°F/+131°F)    |

## Compliance to standards

|                                      |                                                                                                             |
|--------------------------------------|-------------------------------------------------------------------------------------------------------------|
| Module safety                        | EN 50178, cCSAus 60950, IEC 60950                                                                           |
| United Nation Class                  | UN 3480                                                                                                     |
| Hazard classification                | Class 9                                                                                                     |
| Transportation regulation compliance | UN recommendations for dangerous goods transportation, model regulations and manual tests and criteria 38.3 |
| EMC                                  | EN 61000-4-2 Class B / EN 61000-4-3 Class A / EN 55022 Class B                                              |
| Protection class                     | IP 22                                                                                                       |

## Example of a 500 kWh Battery System with a Master Battery Management Module (MBMM)



\* Not supplied by Saft  
\*\* Consult Saft



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Doc No.: 35002-2-0515

Edition: May 2015

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Société par Actions Simplifiée au capital de 31 944 000 €

RCS Bobigny B 383 703 873

Produced in the UK by Arthur Associates Limited



## 3.10.1.2. SEANERGY Modules

# Seanergy® modules

## High energy and high power Li-ion Super-Iron Phosphate

Saft's Seanergy® modules are the ideal choice for local energy management, particularly in conjunction with hybrid propulsion, photovoltaic and other renewable energy generators.

Built with proven Saft Li-ion Super-Iron Phosphate® (LiFePO<sub>4</sub>) technology, the Seanergy® module provides maintenance-free energy storage in a reduced volume, combining high operational reliability over thousands of cycles with outstanding energy efficiency. Its modular design allows adaptation of the battery configuration to various energy and voltage levels.

Saft always supplies Li-ion 3U module with an associated Battery Management System (BMS).



### Applications

- Hybrid-electric and/or full electric propulsion
- Auxiliary systems, hotel load
- Emergency back-up
- Actuators

### Benefits of the Li-ion technology

- Reduced mass and volume
- Very long calendar, storage and cycling life
- Faster charging time
- Maintenance-free
- Operates in any orientation
- No memory effect
- High power (continuous and pulses)

### Operational benefits

- Enable full electric propulsion with a compact volume (entering and exiting harbours and restricted areas)
- Load-levelling function to keep high level of fuel efficiency and reduced number of generating sets
- Standby power at shore
- Design flexibility (improved scalability and modularity)

|                                                            | Seanergy® 48P<br>(Power)           | Seanergy® 48M<br>(Energy) |
|------------------------------------------------------------|------------------------------------|---------------------------|
| Nominal characteristics                                    |                                    |                           |
| Nominal voltage (V)                                        | 46.2                               | 46.2                      |
| Minimum capacity (C/5) (Ah)                                | 56                                 | 78                        |
| Nominal capacity (C/5) (Ah)                                | 60                                 | 82                        |
| Minimum energy (C/5) (Wh)                                  | 2500                               | 3600                      |
| Nominal energy (C/5) (Wh)                                  | 2600                               | 3800                      |
| Nominal energy density (Wh/l)                              | 76                                 | 106                       |
| Nominal specific energy (Wh/kg)                            | 69                                 | 96                        |
| Mechanical characteristics                                 |                                    |                           |
| Standard                                                   | 19" - 3U - Double depth            |                           |
| Width (mm)                                                 | 448                                |                           |
| Height (mm)                                                | 133                                |                           |
| Depth (mm)                                                 | 602.5                              |                           |
| Weight (kg)                                                | 39.5                               |                           |
| Electrical characteristics at + 25°C / + 77°F              |                                    |                           |
| Voltage window (V)                                         | 37.8 to 53.2                       |                           |
| Maximum discharge current (A)                              | 180                                | 180                       |
| Peak discharge current (10 s) (A)                          | 250                                | 250                       |
| Maximum charge current (A)                                 | 180                                | 80                        |
| Peak charge current (10 s) (A)                             | 250                                | 180                       |
| Recharge time (h) at nominal current (95% State of Charge) | 0.5                                | 2                         |
| Operating and storage conditions                           |                                    |                           |
| Lifetime at + 20°C perm (+ 68°F)                           | >20                                |                           |
| Lifetime at + 30°C (+ 86°F)                                | > 10                               |                           |
| Cycle life (60% dod; + 20°C / + 68°F)                      | > 6000 cycles                      |                           |
| Operating temperature                                      |                                    |                           |
| - discharge                                                | - 25°C / + 55°C (- 13°F / + 131°F) |                           |
| - charge                                                   | 0°C / + 55°C (+ 32°F / + 131°F)    |                           |
| Storage temperature                                        | - 40°C / + 55°C (- 40°F / + 131°F) |                           |
| Storage time                                               | 1 year                             |                           |





## Features

- Compact modules integrating VLM Fe Li-ion cells, module supervision and cell balancing
- Advanced industrial design offering highest reliability and robustness
- 20 years design life with high daily energy throughput
- Multiple cycling patterns from daily deep discharge to dynamic multiple charge/discharge profiles from any state of charge
- Best energy efficiency of all available energy storage systems
- State of charge and state of health indication (through BMM)
- 2-level redundant safety

## System capability

- Series connection of up to 750 V
- Battery string management and interfacing through separate BMM module
- Multi-string paralleling through MBMM to upscale battery energy

## Functional characteristics

Saft Seanergy® module technology contains VLM Fe cells with advanced nickel-based lithium-ion Super-Iron Phosphate® technology:

- Best safety among Li-ion chemistries
- Outstanding calendar and cycle life and reliability
- Stable internal resistance over entire life
- High capacity cell

## Mechanical & electrical interface

- Vertical or horizontal implementation
- Systems for 19" rack-mount in 3U height
- Stackable
- Optional 3U rack-mount brackets
- 2 screw terminals

## Safety

Redundant safety design to cope with component failure or abusive conditions:

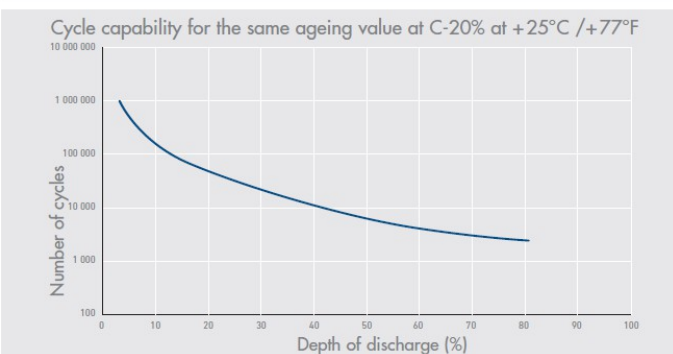
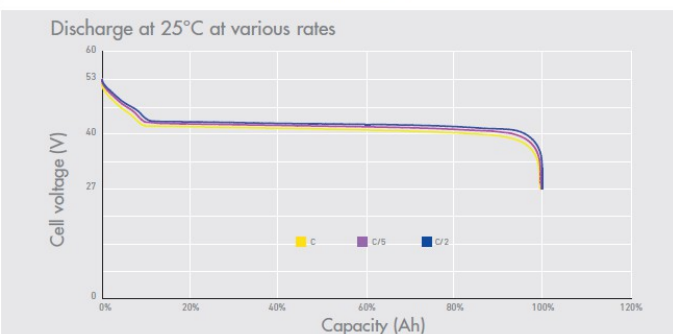
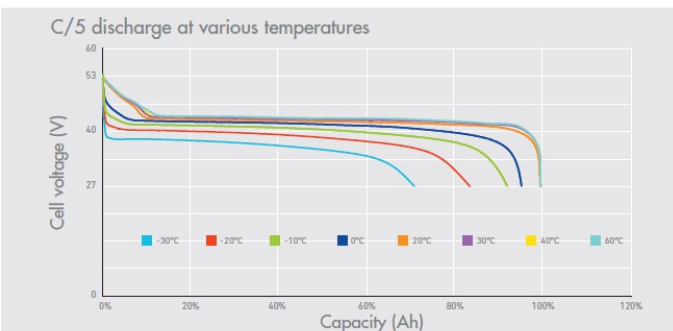
- At cell level: no reaction in an abuse event with inert iron phosphate positive material, shutdown-effect separator, mechanical vent
- At module level: electronic board, individual cell voltage monitoring, module temperature monitoring, balancing, fuse
- At battery system level: electronic board, power switch, current sensor



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Fax : +33 1 49 93 19 69  
[www.saftbatteries.com](http://www.saftbatteries.com)

## Compliance to standards

|                                 |                                                                                                                |
|---------------------------------|----------------------------------------------------------------------------------------------------------------|
| Module safety                   | EN 50178, cCSAus 60950, IEC 60950                                                                              |
| United Nation Class             | UN 3480                                                                                                        |
| Hazard classification           | Class 9                                                                                                        |
| Transport regulation compliance | UN recommendations for dangerous goods transportation, model regulations and manual tests and criteria 38.3    |
| EMC                             | EN 61000-4-2 Class B / EN 61000-4-3 Class A / EN 614000-4-4 Class B / EN 614000-4-6 Class A / EN 55022 Class B |
| Protection class                | IP 20                                                                                                          |



Doc No.: 35016-2-0515

Edition: May 2015

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Société par Actions Simplifiée au capital de 31 944 000 €  
RCS Bobigny B 383 703 873

Produced in the UK by Arthur Associates Limited

### 3.10.2. Motor catalogue

#### 3.10.2.1. ELCO EP-10000



## Electric Inboard

motor performance

# Elco EP-10000

U.S. Patent Number 8,012,608

|                                        |               |
|----------------------------------------|---------------|
| Boat size ranges                       | 50' - 85'     |
| Horse power diesel equivalency         | 100 h.p.      |
| Suggested horsepower replacement range | 75 - 125 h.p. |
| Peak kW                                | 73.5 kW       |
| Continuous kW                          | 42.5 kW       |
| Miles per gallon equivalency           | 12 mpg        |
| Length                                 | 35"           |
| Width                                  | 18.82"        |
| Height                                 | 19.25"        |
| Weight                                 | 740 lbs       |

ELECTRIC

**E-POWER ELECTRIC PERFORMANCE**

|                                          |               |
|------------------------------------------|---------------|
| Cruising speed*                          | 7 - 9 knots   |
| Cruising time*                           | 6 - 2 hours   |
| Cruising range*                          | 34 - 18 nm    |
| Recharging time standard charger*        | 3 - 4 hours   |
| Recharging time quick charger*           | 2 - 3 hours   |
| Number of 12 volt 8-D batteries (245 Ah) | 12 batteries  |
| Battery bank voltage in total            | 144 vdc       |
| Amps (maximum)                           | 295 amps      |
| Kilowatts (peak output kW rating)        | 73.5 kW       |
| Kilowatts (continuous output kW rating)  | 42.5 kW       |
| Charger                                  | Elcon PFC5000 |
| Quick charger (optional)                 | Elcon PFC8000 |

HYBRID

**E-POWER HYBRID ELECTRIC PERFORMANCE: OPTIONAL GENERATOR**

|                                                 |                                                                                                  |
|-------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Genset kilowatt size (AC or DC)*                | 12 - 25 kW                                                                                       |
| Typical fuel tank capacity for genset (gallons) | 125 gal                                                                                          |
| Cruising speed*                                 | 7 - 9 knots                                                                                      |
| Cruising time*                                  | 81 - 49 hours                                                                                    |
| Cruising range*                                 | 583 - 437 nm                                                                                     |
| Number of 12 volt 8-D batteries (245 Ah)        | 12 batteries                                                                                     |
| Battery bank voltage                            | 144 vdc                                                                                          |
| Charger(s) required                             | 2 - 3 chargers                                                                                   |
| Charger                                         | Elcon PFC8000                                                                                    |
| Genset (continuous output rating)               | Northern Lights M844LW3 (20kW)    Northern Lights M844W3 (30kW) or Northern Lights M864W3 (25kW) |

\*Actual performance may vary based on operating conditions, figures above when traveling between 60-80% of hull speed. \*\*Shore power-50% depth of discharge  
To convert from nautical miles (nm) to statute miles multiply nm by 1.15. With Electric Hybrid system additional kilowatts should be added depending on house loads (1,000 watts equals 1kW)

### 3.10.3. Power inverter catalogue

#### 3.10.3.1. VICTRON ENERGY QUATTRO



Quattro  
48/5000/70-100/100



Quattro  
24/3000/70-50/50

##### Dos entradas CA con conmutador de transferencia integrado

El Quattro puede conectarse a dos fuentes de alimentación CA independientes, por ejemplo a la red del pantalán o a un generador, o a dos generadores. Se conectará automáticamente a la fuente de alimentación activa.

##### Dos salidas CA

La salida principal dispone de la función "no-break" (sin interrupción). El Quattro se encarga del suministro a las cargas conectadas en caso de apagón o de desconexión de la red eléctrica/generador. Esto ocurre tan rápido (menos de 20 milisegundos) que los ordenadores y demás equipos electrónicos continúan funcionando sin interrupción. La segunda salida sólo está activa cuando a una de las entradas del Quattro le llega alimentación CA. A esta salida se pueden conectar aparatos que no deberían descargar la batería, como un calentador de agua, por ejemplo.

##### Potencia prácticamente ilimitada gracias al funcionamiento en paralelo

Hasta 10 unidades Quattro pueden funcionar en paralelo. Diez unidades 48/10000/140, por ejemplo, darán una potencia de salida de 90 kW/100 kVA y una capacidad de carga de 1400 amperios.

##### Capacidad de funcionamiento trifásico

Se pueden configurar tres unidades para salida trifásica. Pero eso no es todo: hasta 10 grupos de tres unidades pueden conectarse en paralelo para proporcionar una potencia del inversor de 270 kW/300kVA y más de 4.000A de capacidad de carga.

##### PowerControl – En casos de potencia limitada del generador, del pantalán o de la red

El Quattro es un cargador de baterías muy potente. Por lo tanto, usará mucha corriente del generador o de la red del pantalán (16A por cada Quattro 5kVA a 230 VCA). Se puede establecer un límite de corriente para cada una de las entradas CA. Entonces, el Quattro tendrá en cuenta las demás cargas CA y utilizará la corriente sobrante para la carga de baterías, evitando así sobrecargar el generador o la red del pantalán.

##### PowerAssist – Refuerzo de la potencia del generador o de la red del pantalán

Esta función lleva el principio de PowerControl a otra dimensión, permitiendo que el Quattro complemente la capacidad de la fuente alternativa. Cuando se requiera un pico de potencia durante un corto espacio de tiempo, como pasa a menudo, Quattro compensará inmediatamente la posible falta de potencia de la corriente del pantalán o del generador con potencia de la batería. Cuando se reduce la carga, la potencia sobrante se utiliza para recargar la batería.

##### Energía solar: Potencia CA disponible incluso durante un apagón

El Quattro puede utilizarse en sistemas FV, conectados a la red eléctrica o no, y en otros sistemas eléctricos alternativos.

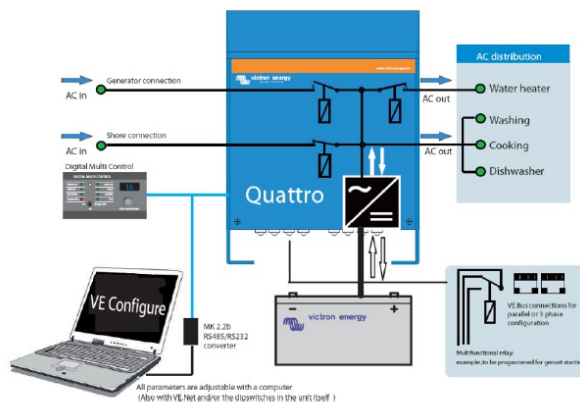
##### La configuración del sistema no puede ser más sencilla

Una vez instalado, el Quattro está listo para funcionar.

Si ha de cambiarse la configuración, se puede hacer en cuestión de minutos mediante un nuevo procedimiento de configuración del conmutador DIP. Con los conmutadores DIP se puede incluso programar el funcionamiento en paralelo y en trifásico; ¡sin necesidad de ordenador!

Además, también se puede utilizar un VE.Net en vez de los conmutadores DIP.

Y hay sofisticados programas disponibles (VE.Bus Quick Configure y VE.Bus System Configurator) para configurar varias nuevas y avanzadas características.







# Development of a zero-emission propulsion system based on Li-ion batteries for marine applications

Daniel Benítez Aragón | University of Cádiz

|                                                       |                                                                                                                      |                                                                  |                                            |                      |
|-------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|--------------------------------------------|----------------------|
| Quattro                                               | 12/3000/120-50/50<br>24/3000/70-50/50                                                                                | 12/5000/220-100/100<br>24/5000/120-100/100<br>48/5000/70-100/100 | 24/8000/200-100/100<br>48/8000/110-100/100 | 48/10000/140-100/100 |
| PowerControl / PowerAssist                            | SI                                                                                                                   |                                                                  |                                            |                      |
| Conmutador de transferencia Integrado                 | SI                                                                                                                   |                                                                  |                                            |                      |
| 2 entradas CA                                         | Rango de tensión de entrada: 187-265 V CA Frecuencia de entrada: 45 – 65 Hz Factor de potencia: 1                    |                                                                  |                                            |                      |
| Corriente máxima (A)                                  | 50 / 50                                                                                                              | 2x100                                                            | 2x100                                      | 2x100                |
| INVERSOR                                              |                                                                                                                      |                                                                  |                                            |                      |
| Rango de tensión de entrada (V CC)                    | 9,5 – 17V 19 – 33V 38 – 66V                                                                                          |                                                                  |                                            |                      |
| Salida (1)                                            | Tensión de salida: 230 VAC ± 2% Frecuencia: 50 Hz ± 0,1%                                                             |                                                                  |                                            |                      |
| Potencia cont. de salida a 25 °C (VA) (3)             | 3000                                                                                                                 | 5000                                                             | 8000                                       | 10000                |
| Potencia cont. de salida a 25°C (W)                   | 2500                                                                                                                 | 4500                                                             | 7000                                       | 9000                 |
| Potencia cont. de salida a 40°C (W)                   | 2200                                                                                                                 | 4000                                                             | 6300                                       | 8000                 |
| Pico de potencia (W)                                  | 6000                                                                                                                 | 10000                                                            | 16000                                      | 20000                |
| Eficacia máxima (%)                                   | 93 / 94                                                                                                              | 94 / 94 / 95                                                     | 94 / 96                                    | 96                   |
| Consumo en vacío (W)                                  | 15 / 15                                                                                                              | 25 / 25 / 25                                                     | 30 / 35                                    | 35                   |
| Consumo en vacío en modo de ahorro (W)                | 10 / 10                                                                                                              | 20 / 20 / 20                                                     | 25 / 30                                    | 30                   |
| Consumo en vacío en modo búsqueda (W)                 | 4 / 5                                                                                                                | 5 / 5 / 6                                                        | 8 / 10                                     | 10                   |
| CARGADOR                                              |                                                                                                                      |                                                                  |                                            |                      |
| Tensión de carga de 'absorción' (V CC)                | 14,4 / 28,8                                                                                                          | 14,4 / 28,8 / 57,6                                               | 28,8 / 57,6                                | 57,6                 |
| Tensión de carga de "flotación" (V CC)                | 13,8 / 27,6                                                                                                          | 13,8 / 27,6 / 55,2                                               | 27,6 / 55,2                                | 55,2                 |
| Modo de "almacenamiento" (V CC)                       | 13,2 / 26,4                                                                                                          | 13,2 / 26,4 / 52,8                                               | 26,4 / 52,8                                | 52,8                 |
| Corriente de carga batería casa (A) (4)               | 120 / 70                                                                                                             | 220 / 120 / 70                                                   | 200 / 110                                  | 140                  |
| Corriente de carga batería de arranque (A)            | 4 (sólo modelos de 12 y 24V)                                                                                         |                                                                  |                                            |                      |
| Sensor de temperatura de la batería                   | SI                                                                                                                   |                                                                  |                                            |                      |
| GENERAL                                               |                                                                                                                      |                                                                  |                                            |                      |
| Salida auxiliar (A) (5)                               | 25                                                                                                                   | 50                                                               | 50                                         | 50                   |
| Relé programable (6)                                  | 1x                                                                                                                   | 3x                                                               | 3x                                         | 3x                   |
| Protección (2)                                        | a - g                                                                                                                |                                                                  |                                            |                      |
| Puerto de comunicación VE.Bus                         | Para funcionamiento paralelo y trifásico, supervisión remota e integración del sistema                               |                                                                  |                                            |                      |
| Puerto com. de uso general (7)                        | 1x                                                                                                                   | 2x                                                               | 2x                                         | 2x                   |
| Características comunes                               | Temperatura de funcionamiento: -20 a +50 °C Humedad (sin condensación): máx. 95%                                     |                                                                  |                                            |                      |
| CARCASA                                               |                                                                                                                      |                                                                  |                                            |                      |
| Características comunes                               | Material y color: aluminio (azul RAL 5012) Categoría de protección: IP 21                                            |                                                                  |                                            |                      |
| Conexiones de la batería                              | Cuatro pernos M8 (2 conexiones positivas y 2 negativas)                                                              |                                                                  |                                            |                      |
| Conexión 230 V CA                                     | Bornes de tornillo de 13 mm. <sup>2</sup> (6 AWG)                                                                    | Pernos M6                                                        | Pernos M6                                  | Pernos M6            |
| Peso (kg)                                             | 19                                                                                                                   | 34 / 30 / 30                                                     | 45/41                                      | 45                   |
| Dimensiones (al x an x p en mm.)                      | 362 x 258 x 218                                                                                                      | 470 x 350 x 280<br>444 x 328 x 240<br>444 x 328 x 240            | 470 x 350 x 280                            | 470 x 350 x 280      |
| NORMATIVAS                                            |                                                                                                                      |                                                                  |                                            |                      |
| Seguridad                                             | EN 60335-1, EN 60335-2-29                                                                                            |                                                                  |                                            |                      |
| Emisiones / Inmunidad                                 | EN55014-1, EN 55014-2, EN 61000-3-3, EN 61000-6-3, EN 61000-6-2, EN 61000-6-1                                        |                                                                  |                                            |                      |
| Directiva de automoción                               | 2004/104/EC                                                                                                          |                                                                  |                                            |                      |
| 1) Puede ajustarse a 60 Hz 120 V 60 Hz si se solicita | 3) Carga no lineal, factor de cresta 3:1                                                                             |                                                                  |                                            |                      |
| 2) Claves de protección:                              | 4) a 25 °C de temperatura ambiente                                                                                   |                                                                  |                                            |                      |
| a) cortocircuito de salida                            | 5) Se desconecta si no hay fuente CA externa disponible                                                              |                                                                  |                                            |                      |
| b) sobrecarga                                         | 6) Relé programable que puede configurarse como alarma general, subtercción CC o señal de arranque para el generador |                                                                  |                                            |                      |
| c) tensión de la batería demasiado alta               | Capacidad nominal CA: 230V/4A                                                                                        |                                                                  |                                            |                      |
| d) tensión de la batería demasiado baja               | Capacidad nominal CC: 4A hasta 35VDC, 1A hasta 60VDC                                                                 |                                                                  |                                            |                      |
| e) temperatura demasiado alta                         | 7) Entre otras funciones, para comunicarse con una batería BMS de Litio-Ion                                          |                                                                  |                                            |                      |
| f) 230 V CA en la salida del inversor                 |                                                                                                                      |                                                                  |                                            |                      |
| g) ondulación de la tensión de entrada demasiado alta |                                                                                                                      |                                                                  |                                            |                      |



## Panel Multi Control Digital

Una solución práctica y de bajo coste de seguimiento remoto, con un selector rotatorio con el que se pueden configurar los niveles de Power Control y Power Assist.



## Panel Blue Power

Se conecta a un Multi o a un Quattro y a todos los dispositivos VE.Net, en particular al controlador de baterías VE.Net. Representación gráfica de corrientes y tensiones.



## Funcionamiento y supervisión controlados por ordenador

Hay varias interfaces disponibles:

- **Convertidor MK2.2 VE.Bus a RS232**  
Se conecta al puerto RS232 de un ordenador (ver "Guía para el VEConfigure")
- **Convertidor MK2-USB VE.Bus a USB**  
Se conecta a un puerto USB (ver Guía para el VEConfigure)
- **Convertidor VE.Net a VE.Bus**  
Interfaz del VE.Net (ver la documentación VE.Net)
- **Victron Global Remote**  
El Global Remote es un módem que envía alarmas, avisos e informes sobre el estado del sistema a teléfonos móviles mediante mensajes de texto (SMS). También puede registrar datos de monitores de baterías Victron, Multi, Quattro e inversores en una página web mediante una conexión GPRS. El acceso a esta web es gratuito.
- **Victron Ethernet Remote**  
Para conectar a Ethernet.



## Monitor de baterías BMW

El monitor de baterías BMW dispone de un avanzado sistema de control por microprocesador combinado con un sistema de medición de alta resolución de la tensión de la batería y de la carga/descarga de corriente. Aparte de esto, el software incluye unos complejos algoritmos de cálculo, como la fórmula Peukert, para determinar exactamente el estado de la carga de la batería. El BMV muestra de manera selectiva la tensión, corriente, Ah consumidos o tiempo restante de carga de la batería. El monitor también almacena una multitud de datos relacionados con el rendimiento y uso de la batería. Hay varios modelos disponibles (ver la documentación del monitor de baterías).

### 3.10.4. Ventilation fan catalogue

#### 3.10.4.1. NEOLINEO-100-Q

NEOLINEO



## NEOLINEO

*Extractores en línea para conductos con cuerpo extraíble y tamaño reducido con rodamientos a bolas de Larga Duración*





**Ventilador:**

- Envoltente en material plástico autoextinguible V0
- Caja de bornes externa, con posición variable
- Instalación rápida y sencilla
- Los modelos T están equipados con temporizador

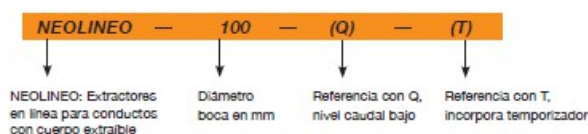
**Motor:**

- Motores con rodamientos a bolas de Larga Duración, protección IPX4, de dos velocidades y regulables
- Monofásicos 220-240V 50/60 Hz
- Temperatura de trabajo: -10°C +80°C

**Acabado:**

- En material plástico, de color blanco, autoextinguible al fuego V0

#### Código de pedido



#### Características técnicas

| Modelo           | Velocidad max / min (r/min) | Intensidad máxima admisible 230V (A) | Potencia instalada (W) | Caudal máximo (m³/h) | Nivel sonoro irradiado* dB(A) | Peso aprox. (Kg) |
|------------------|-----------------------------|--------------------------------------|------------------------|----------------------|-------------------------------|------------------|
| NEOLINEO-100-Q   | 2450/2070                   | 0,07/0,05                            | 15/12                  | 200/155              | 29/25                         | 1,2              |
| NEOLINEO-100-Q T | 2450/2070                   | 0,07/0,05                            | 15/12                  | 200/155              | 29/25                         | 1,2              |
| NEOLINEO-100     | 2170/1590                   | 0,11/0,09                            | 23/20                  | 255/180              | 30/25                         | 1,8              |
| NEOLINEO-100 T   | 2170/1590                   | 0,11/0,09                            | 23/20                  | 255/180              | 30/25                         | 1,8              |
| NEOLINEO-125     | 2300/1600                   | 0,15/0,11                            | 33/25                  | 365/250              | 33/27                         | 1,8              |
| NEOLINEO-125 T   | 2300/1600                   | 0,15/0,11                            | 33/25                  | 365/250              | 33/27                         | 1,8              |
| NEOLINEO-150     | 2290/1520                   | 0,26/0,18                            | 58/40                  | 550/385              | 33/28                         | 2,4              |
| NEOLINEO-150 T   | 2290/1520                   | 0,26/0,18                            | 58/40                  | 550/385              | 33/28                         | 2,4              |
| NEOLINEO-160     | 2290/1520                   | 0,26/0,18                            | 58/40                  | 550/385              | 34/28                         | 2,4              |
| NEOLINEO-160 T   | 2290/1520                   | 0,26/0,18                            | 58/40                  | 550/385              | 34/28                         | 2,4              |
| NEOLINEO-200-Q   | 2720/1780                   | 0,37/0,22                            | 75/45                  | 950/700              | 36/30                         | 3,7              |
| NEOLINEO-200     | 3120/1990                   | 0,63/0,21                            | 74/22                  | 1060/790             | 38/32                         | 3,7              |
| NEOLINEO-200-Q T | 2720/1780                   | 0,37/0,22                            | 75/45                  | 950/700              | 36/30                         | 3,7              |
| NEOLINEO-250-Q   | 2520/1740                   | 0,50/0,40                            | 110/85                 | 990/720              | 39/37                         | 7,1              |
| NEOLINEO-250     | 3010/1720                   | 1,06/0,26                            | 124/27                 | 1250/650             | 57/43                         | 5,3              |
| NEOLINEO-315     | 2350/1800                   | 1,60/0,83                            | 240/119                | 1900/1400            | 60/53                         | 9,5              |

\*Los niveles de presión sonora irradiados, están obtenidos a 3 metros en campo libre, con tubos rígidos en aspiración y descarga.



#### Erp. Características del punto de máxima eficiencia (BEP)

| Modelo       | MC | EC | VSD | SR   | $\eta_e$ [%] | N    | (kW)  | (m³/h) | (mmH₂O) | (RPM) |
|--------------|----|----|-----|------|--------------|------|-------|--------|---------|-------|
| NEOLINEO-315 | C  | S  | NO  | 1,00 | 33,5%        | 50,1 | 0,261 | 1061   | 30,27   | 2350  |

## NEOLINEO

Dimensiones mm

| Modelo           | A     | B     | C     | C1    | C2  | øD  | E     |
|------------------|-------|-------|-------|-------|-----|-----|-------|
| NEOLINEO-100-Q   | 231   | 156   | 174   | 82    | 152 | 96  | 95    |
| NEOLINEO-100-Q T | 231   | 156   | 174   | 82    | 152 | 96  | 95    |
| NEOLINEO-100     | 303   | 188,5 | 211   | 101,5 | 189 | 96  | 90    |
| NEOLINEO-100 T   | 303   | 188,5 | 211   | 101,5 | 189 | 96  | 90    |
| NEOLINEO-125     | 258   | 188,5 | 211   | 101,5 | 189 | 122 | 90    |
| NEOLINEO-125 T   | 258   | 188,5 | 211   | 101,5 | 189 | 122 | 90    |
| NEOLINEO-150     | 294   | 214,5 | 234   | 112,5 | 212 | 148 | 110   |
| NEOLINEO-150 T   | 294   | 214,5 | 234   | 112,5 | 212 | 148 | 110   |
| NEOLINEO-160     | 272,5 | 214,5 | 234   | 112,5 | 212 | 158 | 110   |
| NEOLINEO-160 T   | 272,5 | 214,5 | 234   | 112,5 | 212 | 158 | 110   |
| NEOLINEO-200-Q   | 300   | 234,5 | 260,5 | 125,5 | 235 | 196 | 140   |
| NEOLINEO-200     | 300   | 234,5 | 260,5 | 125,5 | 235 | 196 | 140   |
| NEOLINEO-200 T   | 300   | 234,5 | 260,5 | 125,5 | 235 | 196 | 140   |
| NEOLINEO-250-Q   | 385   | 300   | 317   | 152,5 | 292 | 247 | 176,5 |
| NEOLINEO-250     | 385   | 300   | 317   | 152,5 | 292 | 247 | 176,5 |
| NEOLINEO-315     | 448   | 361,5 | 392,5 | 188,5 | 359 | 312 | 220,5 |

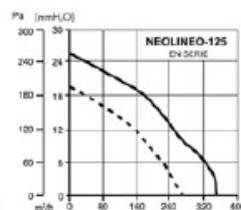
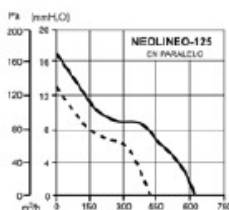
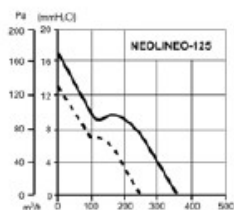
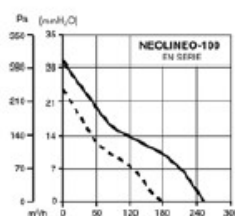
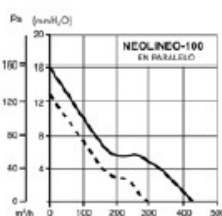
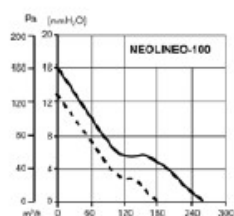
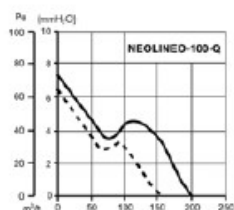
Curvas Características

Q= Caudal en m<sup>3</sup>/h

Pe= Presión estática en mm.c.a., Pa

— Velocidad Máxima

- - - - - Velocidad Mínima



SODECA

23

NEOLINEO



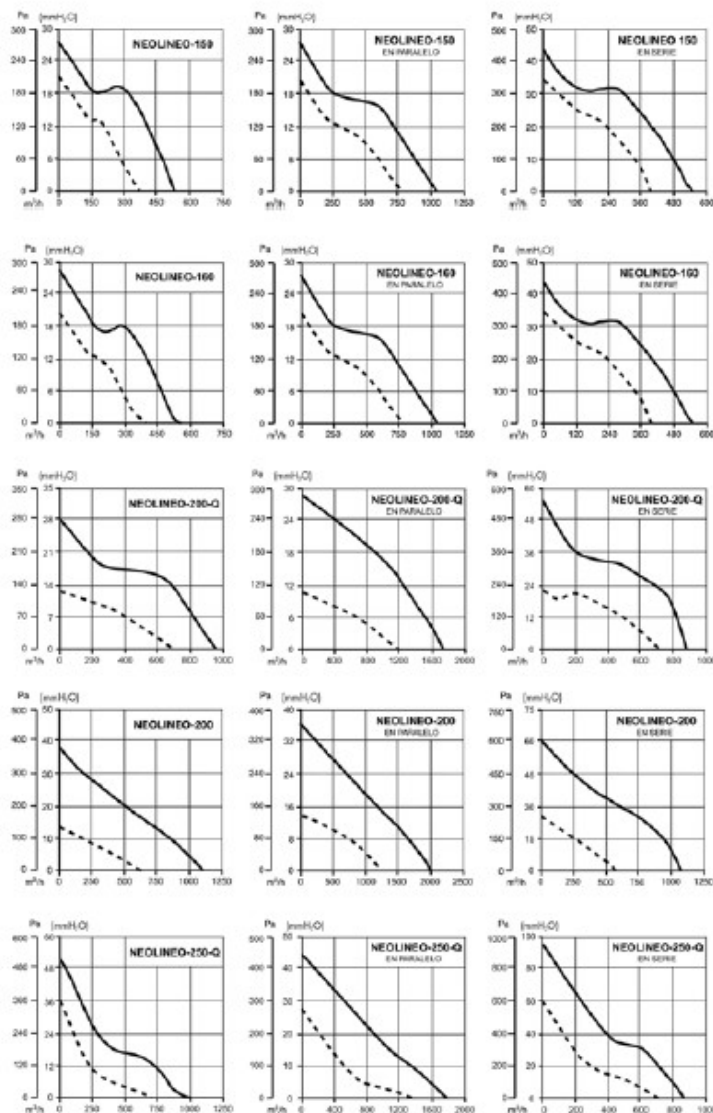
### Curvas Características

Q= Caudal en m<sup>3</sup>/h

Pe= Presión estática en mm.c.a., Pa

— Velocidad Máxima

--- Velocidad Mínima



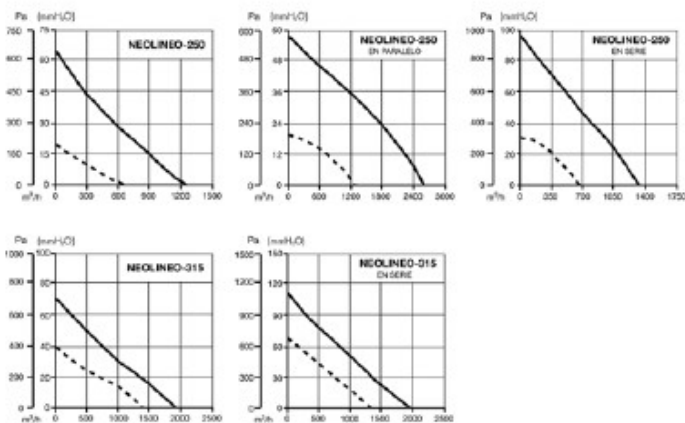


## NEOLINEO

### Curvas Características

Q= Caudal en m<sup>3</sup>/h  
Pe= Presión estática en mm.c.a., Pa

— Velocidad Máxima  
- - - - - Velocidad Mínima



### Accesorios

Ver apartado accesorios.



SODECA

25

### 3.10.5. Luminarie catalogues

#### 3.10.5.1. GLAMOX CASA 16 13F SI



Downlight indoor fluorescent  
**230109**

CASA 16 113F SI

The indoor fluorescent downlights come with a wide range of decors. The décor elements are made in painted, chromed or brushed steel, brass, aluminium, glass and acrylic.



| Light source           |                              |
|------------------------|------------------------------|
| Lamp power (W)         | 13                           |
| Number of lamps        | 1                            |
| Lamp base              | G24d-1                       |
| Light source           | TC-D                         |
| Electrical data        |                              |
| Voltage from (V)       | 230                          |
| Minimum frequency (Hz) | 50                           |
| Total consumption (W)  | 19                           |
| Body                   |                              |
| Colour of body         | White                        |
| Body material          | Galv Steel                   |
| Ballast                |                              |
| Type of Ballast        | High power factor correction |

| Dimensions                       |                                         |
|----------------------------------|-----------------------------------------|
| Diameter (mm)                    | 160                                     |
| Width (mm)                       | 176                                     |
| Height (mm)                      | 100                                     |
| Length (mm)                      | 419                                     |
| Technical data                   |                                         |
| Maximum ambient temperature (°C) | 25                                      |
| IP classification                | 22                                      |
| Termination                      |                                         |
| Termination                      | 5x2x2.5mm <sup>2</sup> Push In terminal |
| Mounting Accessories             | PRE-R                                   |
| Optic                            |                                         |
| Light distribution Up/Down       | 0/100                                   |



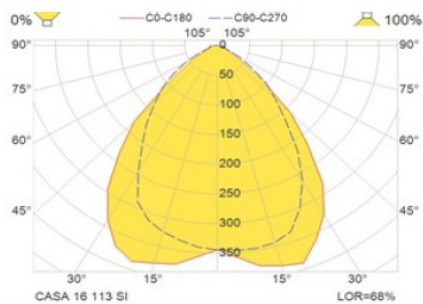
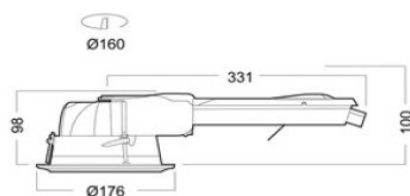
## Downlight indoor fluorescent 230109

### CASA 16 113F SI

The indoor fluorescent downlights come with a wide range of decors. The décor elements are made in painted, chromed or brushed steel, brass, aluminium, glass and acrylic.



## Drawings



## 3.10.5.2. GLAMOX I70 LED



i70 LED

I700644000



i70-1200 LED 4500 DALI 840 TW PC QW25

Glamox i70 is a slim IP66/67 LED luminaire for surface mounting through fixed end brackets. Supplied with integrated IP68 quick connectors for easy installation. The luminaire is designed for optimal heat management and is approved for ambient temperatures (Ta) from 55°C down to -35°C.



## Light source

|                                         |               |
|-----------------------------------------|---------------|
| Light source                            | LED           |
| Colour rendering and colour temperature | CRI>80, 4000K |
| Lumen/Watt                              | 90            |
| Lumen value supplied light source (lm)  | 4500          |
| Lumen Out                               | 4515          |
| Rated lifetime L70 Ta25                 | 108000        |
| Rated lifetime L70 maximum Ta           | 50000         |
| MacAdam step                            | 3             |

## Termination

|                        |                  |
|------------------------|------------------|
| Type of through wiring | 5-pole           |
| Number of blind plugs  | 2                |
| Blind-plug             | M25-Polyamide    |
| Ready for mounting     | Glamox-holder    |
| Plug type              | Wieland RST 2013 |

## Optic

|                       |               |
|-----------------------|---------------|
| Optic                 | Opal          |
| Material of reflector | Aluminium     |
| Colour of reflector   | White         |
| Material of diffuser  | Polycarbonate |

## Body

|                  |           |
|------------------|-----------|
| Body material    | Aluminium |
| Colour of body   | Silver    |
| Body colour code | RAL 9016  |
| MaterialEndCap   | Polyamide |

## Electrical data

|                                          |     |
|------------------------------------------|-----|
| Voltage from (V)                         | 230 |
| Maximum frequency (Hz)                   | 60  |
| Maximum voltage (V)                      | 230 |
| Minimum frequency (Hz)                   | 50  |
| Number of ballast on a MCB16 type B fuse | 8   |
| Number of ballast on a MCB16 type C fuse | 13  |
| Total consumption (W)                    | 50  |

## Technical data

|                                  |       |
|----------------------------------|-------|
| Maximum ambient temperature (°C) | 45    |
| IK Classification                | 10    |
| Minimum ambient temperature (°C) | -25   |
| IP classification                | 66/67 |

## Dimensions

|                   |      |
|-------------------|------|
| Height (mm)       | 75   |
| Width (mm)        | 170  |
| Gross weight (kg) | 6,4  |
| Length (mm)       | 1194 |

## Ballast

|                   |                |
|-------------------|----------------|
| Type of Ballast   | High frequency |
| Number of ballast | 2              |

## Remarks

|         |                                                                                         |
|---------|-----------------------------------------------------------------------------------------|
| Remarks | Blind plugs: 2xM25x1.5 polyamide With end caps necessary to complete Quick Connect plug |
|---------|-----------------------------------------------------------------------------------------|



i70 LED  
I700644000

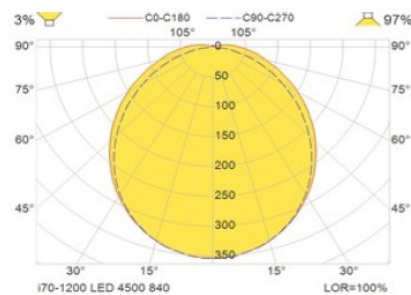
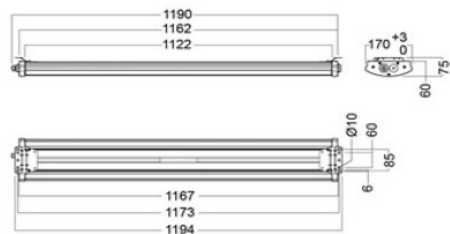


i70-1200 LED 4500 DALI 840 TW PC QW25

Glamox i70 is a slim IP66/67 LED luminaire for surface mounting through fixed end brackets. Supplied with integrated IP68 quick connectors for easy installation. The luminaire is designed for optimal heat management and is approved for ambient temperatures (Ta) from 55°C down to -35°C.



## Drawings



### 3.10.5.3. GLAMOX E85-S

E85-S

E85111200



E85-S WB LED E1/ST

A surface mounted escape route light or anti panic emergency light system based on LED. Using a environment friendly NiMh battery.



#### Electrical data

|                        |     |
|------------------------|-----|
| Maximum voltage (V)    | 240 |
| Maximum frequency (Hz) | 60  |
| Minimum frequency (Hz) | 50  |
| Voltage from (V)       | 220 |
| Total consumption (W)  | 5   |

#### Dimensions

|                   |      |
|-------------------|------|
| Height (mm)       | 54   |
| Width (mm)        | 153  |
| Gross weight (kg) | 0,71 |
| Length (mm)       | 118  |

#### Technical data

|                                  |    |
|----------------------------------|----|
| Maximum ambient temperature (°C) | 45 |
| IP classification                | 20 |
| Minimum ambient temperature (°C) | 0  |

#### Emergency

|                                |                |
|--------------------------------|----------------|
| Duration in battery mode (hrs) | 1 hour         |
| Type of emergency              | ST = Self test |



#### Light source

|                 |     |
|-----------------|-----|
| Number of lamps | 1   |
| Light source    | LED |
| Lumen/Watt      | 24  |
| Lumen Out       | 120 |

#### Optic

|                           |                          |
|---------------------------|--------------------------|
| Optic                     | WB = Wide Beam Reflector |
| Colour of reflector       | Silver                   |
| Material of reflector     | PC = polycarbonate       |
| Lightdistribution Up/Down | 0/100                    |

#### Ballast

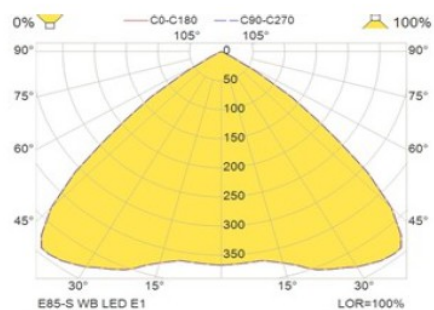
|                    |                                   |
|--------------------|-----------------------------------|
| Number of ballast  | 1                                 |
| Type of Ballast    | Non maintained                    |
| Wiring Accessories | E3L = Integrated LED<br>Emergency |

#### Body

|                |                 |
|----------------|-----------------|
| Colour of body | White (RAL9016) |
| Body material  | Aluminium       |

#### Termination

|             |                                            |
|-------------|--------------------------------------------|
| Termination | 5x2x2.5mm <sup>2</sup> Push In<br>terminal |
|-------------|--------------------------------------------|



### 3.10.5.4. GLAMOX E80-S



E80-S is a surface mounted exit sign based on LED.

E80-S is recognized by the use of high quality material and components.

Signs for both 20 and 30 metre reading distance are available. Can be supplied for manual, selftest and central controlled testing and monitoring. Using an environment friendly NiMH battery. Are also available for centralized battery. Signs are included.

Special mounting brackets are ordered separately.





E80-S



E80-S



E80-S

TECHNICAL DESCRIPTION

BODY MATERIAL & COLOUR

White painted aluminium with component plate in polycarbonate.

MOUNTING

For surface ceiling mounting. Flag, wall and suspended possible by using a kit. The kit must be ordered separately.

ACCESSORIES

Wall bracket, flag bracket and suspension must be ordered separately.

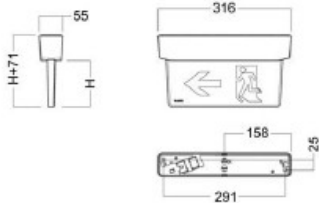
CONNECTION

Cable entry on top and knock-out in each side. 3 or 5 pole terminal block.

EMERGENCY SYSTEM

Supplied in standard (S), selftest (ST) or addressable (DALI) system for 1 or 3 hours duration.

MEASUREMENT DRAWINGS



E80-S

## 3.10.5.5. GLAMOX JET 7

514252782



JET 7 BODY SYM HAMMERED REFLECTOR BLACK



| Optic                     |                 |
|---------------------------|-----------------|
| Optic                     | SYM = Symmetric |
| Material of diffuser      | Glass           |
| Material of reflector     | Aluminium       |
| Lightdistribution Up/Down | 0/100           |

| Technical data    |     |
|-------------------|-----|
| IP classification | 6 5 |
| IK Classification | 8   |

| Light source |       |
|--------------|-------|
| Lamp base    | E 4 0 |



| Dimensions      |       |
|-----------------|-------|
| Height (mm)     | 5 8 0 |
| Width (mm)      | 1 9 5 |
| Net weight (kg) | 8,56  |
| Length (mm)     | 4 2 6 |

| Body           |           |
|----------------|-----------|
| Colour of body | Black     |
| Body material  | Aluminium |

| Termination |        |
|-------------|--------|
| Termination | 5x6-SC |

| Remarks               |             |
|-----------------------|-------------|
| necessary to complete | Ballast-kit |



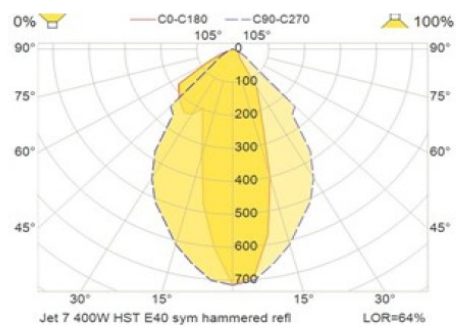
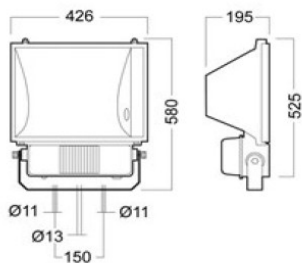
514252782



JET 7 BODY SYM HAMMERED REFLECTOR BLACK



## Drawings



### 3.10.6. Conductor catalogues

#### 3.10.6.1. PROTOMONT NSSHÖU

| GUMMISCHLAUCHLEITUNGEN – RUBBER FLEXIBLE CABLES |              |
|-------------------------------------------------|--------------|
| Energieleitungen<br>Power cables                | DIN VDE 0250 |

Gummischlauchleitungen  
für die Verwendung im Bergbau und in der Industrie

HD Rubber Flexible Cables  
for use in Mining and Industries

#### PROTOMONT NSSHÖU 0,6/1 kV



##### Technische Angaben

|                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Markenname        | PROTOMONT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Bauartkürzzeichen | NSSHÖU                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Norm              | DIN VDE 0250 Teil 812                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Approbationen     | VDE, MSHA P-189-3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Verwendung        | <p>Für den beweglichen Einsatz und für feste Verlegung im Bergbau unter Tage, im Tunnelbau, im Bergbau über Tage, in Steinbrüchen, auf Baustellen und ähnlichen Betrieben, bei hohen mechanischen Beanspruchungen.</p> <p>Die Leitungen sind verwendbar in Innenräumen, im Freien, in explosionsgefährdeten Bereichen, in der Industrie und in landwirtschaftlichen Betrieben.</p> <p>Sie sind auch für die ständige Verwendung im Schmutzwasser bis höchstens 40 °C geeignet. Wegen der unterschiedlichen und auch häufig wechselnden Zusammensetzung des Schmutzwassers dürfen die Leitungen nur in leicht zugänglichen und kontrollierbaren Bereichen eingesetzt werden (Einbautiefen von ca. 10 m, wie sie üblicherweise in Schmutzwasserbecken anzutreffen sind). Diese Leitungen sind auch im Betriebs-, Kühl-, Oberflächen-, Regen- und Mischwasser einsetzbar, ebenso in Grund- und Meerwasser, wobei die Anforderungen an die Zugänglichkeit und Kontrollierbarkeit verringert werden können. In diesem Fall bestehen keine Bedenken, die Leitungen in größeren Wassertiefen bis 500 m einzusetzen.</p> <p>Bei aggressivem Wasser oder Wasser mit besonderer Zusammensetzung ist die Beständigkeit der Leitung im Einzelfall zu überprüfen.</p> <p>Darüber hinaus gelten die allgemeinen Festlegungen in DIN VDE 0298-3</p> |

##### Technical Details

|                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Trademark        | PROTOMONT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Type Designation | NSSHÖU                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Standard         | DIN VDE 0250 part 812                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Approval         | VDE, MSHA P-189-3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Application      | <p>For flexible use and fixed installation in underground mining applications, tunnel building applications, open-cast mining applications, in quarries, on construction sites and similar applications, with heavy mechanical stresses.</p> <p>The cables can be used indoors as well as outdoors, in explosion-hazard areas, in industry and in agriculture.</p> <p>They can be used permanently in waste water up to 40 °C. Owing to the various (and frequently changing) substances of which the contaminated water is made up, the cables may be used only in easily accessible areas that can be inspected (installation depth of approximately 10 m, as customarily encountered in sewage water tanks).</p> <p>The cables can also be used in industrial water, cooling water, surface water, rainwater and mixed water - and in groundwater and seawater to a more limited extent. The requirements for accessibility and inspection are less stringent in such cases at depths greater than 10 m up to 500 m.</p> <p>If the water concerned is aggressive or composed of special substances, the cable's resistance properties should be examined.</p> <p>In other respects the specifications of DIN VDE 0298 part 3 apply.</p> |



Änderungen vorbehalten  
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PRYSMIAN Kabel und Systeme GmbH  
Alt-Moabit 91D  
D-10559 Berlin

Seite / page 1/4

PKS OEM / SL  
Dokument: 07DS401\_31.doc  
Ausgabe: 3.1 / 03.2010

**GUMMISCHLAUCHLEITUNGEN – RUBBER FLEXIBLE CABLES****Energieleitungen  
Power cables****DIN VDE 0250**

|                                          |                                                                                                                             |                                                                                                                         |
|------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| Leiter<br>Conductor                      | Kupfer, verzinkt, feindrähtig Klasse 5<br>nach DIN VDE 0295 / IEC 60228                                                     | Copper, tinned, finely stranded class 5<br>in accordance with DIN VDE 0295 / IEC 60228                                  |
| Isolierung<br>Insulation                 | PROTOLON, Werkstoffbasis EPR, Mischungstyp 3GI3<br>nach DIN VDE 0207                                                        | PROTOLON, basis EPR, compound 3GI3 in accordance with<br>DIN VDE 0207                                                   |
| Aderkennzeichnung<br>Core identification | bis 5 Adern: farbig nach DIN VDE 0293-308<br>ab 6 Adern: hell mit schwarzen Ziffern                                         | up to 5 cores: colored in accordance with DIN VDE 0293-308<br>from 6 cores: light with black numbers                    |
| Innenmantel<br>Inner sheath              | Vulkanisierte Gummimischung, Werkstoffbasis EPR,<br>Mischungstyp GM1b nach DIN VDE 0207<br>(nicht bei einadrigen Leitungen) | Vulcanized rubber compound, basis EPR, compound GM1b in<br>accordance with DIN VDE 0207<br>(not for single-core cables) |
| Außenmantel<br>Outer sheath              | Vulkanisierte Gummimischung, Werkstoffbasis CPE,<br>Mischungstyp 5GM5 nach DIN VDE 0207                                     | Vulcanized rubber compound, basis CPE, compound 5GM5 in<br>accordance with DIN VDE 0207                                 |
| Kennzeichnung<br>Marking                 | (JJ) <VDE> PROTOMONT NSSHÖU 4x25<br>(JJ) = Herstellungsjahr (JJ) = Year of manufacturing                                    |                                                                                                                         |

|                                                               |                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                         |         |                          |
|---------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|--------------------------|
| Elektrische<br>Eigenschaften<br>Electrical<br>characteristics | Nennspannung (Wechselspannung)                                                                                                                                                                                                                                                   | Rated AC voltage                                                                                                                                                                                                                        | $U_0/U$ | 0,6/1 kV                 |
|                                                               | Höchste, dauernd zulässige Betriebs-<br>spannung der Anlagen oder Netze bei<br>- Wechselstrom bzw. Drehstrom<br>Leiter-Erde / Leiter-Leiter<br>- Gleichstrom<br>Leiter-Erde / Leiter-Leiter                                                                                      | Maximum permissible operation voltage<br>of plant and power system<br>- Single-phase and three-phase AC operation<br>Line-Earth / Line-Line<br>- DC operation<br>Line-Earth / Line-Line                                                 |         | 0,7/1,2 kV<br>0,9/1,8 kV |
|                                                               | Prüfwechselspannung (Prüfdauer)                                                                                                                                                                                                                                                  | AC test voltage (test duration)                                                                                                                                                                                                         |         | 3 kV<br>(5 min)          |
|                                                               | Strombelastbarkeit<br>Die Angaben gelten bei Dauerbetrieb mit<br>Gleichstrom bzw. mit Wechsel- oder Dreh-<br>strom mit 50 bis 60 Hz bei 30 °C Umge-<br>bungstemperatur, an Flächen liegend,<br>zwei oder drei Adern belastet, bei viel-<br>adrigen Leitungen alle Adern belastet | Current-carrying capacity<br>The values are valid for permanent operation<br>with DC or AC with 50 up to 60 Hz at 30 °C<br>ambient temperature, touching a surface,<br>two or three cores loaded, multi-core cables all<br>cores loaded |         |                          |
|                                                               |                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                         |         |                          |

|                                                           |                                                              |                                                                           |  |                      |
|-----------------------------------------------------------|--------------------------------------------------------------|---------------------------------------------------------------------------|--|----------------------|
| Thermische<br>Eigenschaften<br>Thermal<br>characteristics | Höchste zulässige Betriebstemperatur<br>am Leiter            | Maximum permissible operating temperature<br>at conductor                 |  | 90 °C                |
|                                                           | Höchste zulässige Kurzschlußtemperatur<br>am Leiter          | Maximum permissible short circuit temperature at<br>conductor             |  | 250 °C<br>(max. 5 s) |
|                                                           | Tiefste zulässige Temperaturen<br>- bewegt<br>- nicht bewegt | Minimum permissible temperatures<br>- when in motion<br>- when stationary |  | -25 °C<br>-40 °C     |
|                                                           | Höchste zulässige Wassertemperatur                           | Maximum permissible water temperature                                     |  | 40 °C                |

|                                                               |                                          |                                                         |      |                      |
|---------------------------------------------------------------|------------------------------------------|---------------------------------------------------------|------|----------------------|
| Mechanische<br>Eigenschaften<br>Mechanical<br>characteristics | Zugbelastbarkeit                         | Permissible pulling force                               | max. | 15 N/mm <sup>2</sup> |
|                                                               | Mindestbiegeradien<br>siehe Auswahldaten | Minimum permissible bending radii<br>see selection data |      |                      |

|                                                                                        |                                       |                                         |  |                                   |
|----------------------------------------------------------------------------------------|---------------------------------------|-----------------------------------------|--|-----------------------------------|
| Beständigkeit<br>gegen äußere<br>Einflüsse<br>Stability against<br>external influences | Ölbeständigkeit                       | Oil resistance                          |  | DIN EN 60811-2-1<br>IEC 60811-2-1 |
|                                                                                        | Flammausbreitung, einzelne Leitung    | Flame propagation, single cable         |  | DIN EN 60332-1-2<br>IEC 60332-1-2 |
|                                                                                        | Wasserbeständigkeit, Prüfung nach ... | Water resistance, test according to ... |  | DIN VDE 0282-16                   |



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D-10559 Berlin

Seite / page 2/4

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Ausgabe 3.1 / 03.2010

**GUMMISCHLAUCHLEITUNGEN – RUBBER FLEXIBLE CABLES****Energieleitungen  
Power cables****DIN VDE 0250****Auswahldaten - Selection data**

| Aderanzahl und<br>Leiternenn-<br>querschnitt                                                           | Bestell-Nr.<br>Order no. | Leiter-<br>durch-<br>messer     | Leitungsaußen-<br>durchmesser |            | Biegeradius<br>Bending radius |                                        | Gewicht<br>netto                    | Strom-<br>belast-<br>barkeit     | Zuläs-<br>siger<br>Kurz-<br>schluß-<br>strom              | Zuläs-<br>sige<br>Zug-<br>kraft      |
|--------------------------------------------------------------------------------------------------------|--------------------------|---------------------------------|-------------------------------|------------|-------------------------------|----------------------------------------|-------------------------------------|----------------------------------|-----------------------------------------------------------|--------------------------------------|
| Number of cores<br>and<br>nominal cross-<br>sectional area                                             |                          | Con-<br>ductor<br>dia-<br>meter | Outer diameter of<br>cable    |            | fixed<br>installed            | bei<br>Beweg-<br>ung<br>free<br>moving | Weight of<br>cable<br>net<br>1000 m | Current-<br>carrying<br>capacity | Permis-<br>sible<br>short-<br>circuit<br>current<br>(1 s) | Permis-<br>sible<br>pulling<br>force |
| mm²                                                                                                    |                          | ca.<br>mm                       | min.<br>mm                    | max.<br>mm | min.<br>mm                    | min.<br>mm                             | ca.<br>kg                           | 30°C<br>A                        | kA                                                        | max.<br>N                            |
| <b>PROTOMONT NSSHÖU-O 1x... 0,6/1 kV mit schwarzer Aderisolierung / with black core insulation</b>     |                          |                                 |                               |            |                               |                                        |                                     |                                  |                                                           |                                      |
| 1 x 16                                                                                                 | 5DL1 112                 | 5,4                             | 10,6                          | 11,8       | 35                            | 47                                     | 231                                 | 103                              | 2,29                                                      | 240                                  |
| 1 x 25                                                                                                 | 5DL1 113                 | 6,3                             | 12,8                          | 14,0       | 56                            | 70                                     | 349                                 | 137                              | 3,58                                                      | 375                                  |
| 1 x 35                                                                                                 | 5DL1 114                 | 7,4                             | 13,9                          | 15,1       | 60                            | 76                                     | 443                                 | 169                              | 5,01                                                      | 525                                  |
| 1 x 50                                                                                                 | 5DL1 115                 | 8,8                             | 15,6                          | 17,1       | 68                            | 86                                     | 601                                 | 211                              | 7,15                                                      | 750                                  |
| 1 x 70                                                                                                 | 5DL1 116                 | 10,6                            | 17,7                          | 19,2       | 77                            | 96                                     | 814                                 | 261                              | 10,01                                                     | 1050                                 |
| 1 x 95                                                                                                 | 5DL1 117                 | 12,1                            | 19,7                          | 21,2       | 85                            | 106                                    | 1041                                | 314                              | 13,59                                                     | 1425                                 |
| 1 x 120                                                                                                | 5DL1 118                 | 14,3                            | 22,4                          | 23,9       | 96                            | 120                                    | 1325                                | 367                              | 17,16                                                     | 1800                                 |
| 1 x 150                                                                                                | 5DL1 120                 | 15,9                            | 24,4                          | 25,9       | 104                           | 130                                    | 1615                                | 422                              | 21,45                                                     | 2250                                 |
| 1 x 185                                                                                                | 5DL1 121                 | 17,5                            | 27,2                          | 29,4       | 118                           | 147                                    | 1997                                | 481                              | 26,46                                                     | 2775                                 |
| 1 x 240                                                                                                | 5DL1 122                 | 20,3                            | 30,4                          | 32,6       | 130                           | 163                                    | 2575                                | 571                              | 34,32                                                     | 3600                                 |
| 1 x 300                                                                                                | 5DL1 123                 | 23,1                            | 34,6                          | 36,8       | 147                           | 184                                    | 3244                                | 681                              | 42,90                                                     | 4500                                 |
| <b>PROTOMONT NSSHÖU-O 2x... 0,6/1 kV Aderfarben / Color of cores: blue, brown</b>                      |                          |                                 |                               |            |                               |                                        |                                     |                                  |                                                           |                                      |
| 2 x 1,5                                                                                                | 5DL1 204                 | 1,6                             | 10,6                          | 12,2       | 49                            | 61                                     | 165                                 | 23                               | 0,21                                                      | 45                                   |
| 2 x 2,5                                                                                                | 5DL1 205                 | 1,9                             | 11,7                          | 13,3       | 53                            | 67                                     | 205                                 | 30                               | 0,36                                                      | 75                                   |
| 2 x 4                                                                                                  | 5DL1 206                 | 2,4                             | 14,5                          | 16,5       | 66                            | 83                                     | 330                                 | 41                               | 0,57                                                      | 120                                  |
| <b>PROTOMONT NSSHÖU-O 3x... 0,6/1 kV Aderfarben / Color of cores: brown, black, grey</b>               |                          |                                 |                               |            |                               |                                        |                                     |                                  |                                                           |                                      |
| 3 x 1,5                                                                                                | 5DL1 756                 | 1,6                             | 11,1                          | 12,7       | 51                            | 64                                     | 195                                 | 23                               | 0,21                                                      | 68                                   |
| 3 x 2,5                                                                                                | 5DL1 751                 | 1,9                             | 12,2                          | 13,8       | 55                            | 69                                     | 235                                 | 30                               | 0,36                                                      | 113                                  |
| 3 x 4                                                                                                  | 5DL1 760                 | 2,4                             | 14,7                          | 16,7       | 67                            | 84                                     | 345                                 | 41                               | 0,57                                                      | 180                                  |
| 3 x 6                                                                                                  | 5DL1 946                 | 2,9                             | 15,7                          | 17,7       | 71                            | 89                                     | 420                                 | 53                               | 0,86                                                      | 270                                  |
| 3 x 10                                                                                                 | 5DL1 944                 | 3,9                             | 20,3                          | 22,3       | 89                            | 112                                    | 690                                 | 74                               | 1,43                                                      | 450                                  |
| 3 x 16                                                                                                 | 5DL1 311                 | 5,4                             | 23,1                          | 25,1       | 100                           | 126                                    | 917                                 | 99                               | 2,29                                                      | 720                                  |
| 3 x 25                                                                                                 | 5DL1 964                 | 6,3                             | 26,1                          | 29,1       | 116                           | 146                                    | 1309                                | 131                              | 3,58                                                      | 1125                                 |
| 3 x 35                                                                                                 | 5DL1 391                 | 7,5                             | 29,9                          | 32,9       | 132                           | 165                                    | 1751                                | 162                              | 5,01                                                      | 1575                                 |
| 3 x 185                                                                                                | 5DL1 320                 | 17,9                            | 59,8                          | 63,8       | 255                           | 319                                    | 7570                                | 461                              | 26,46                                                     | 8325                                 |
| <b>PROTOMONT NSSHÖU-J 3x... 0,6/1 kV Aderfarben / Color of cores: green-yellow, blue, brown</b>        |                          |                                 |                               |            |                               |                                        |                                     |                                  |                                                           |                                      |
| 3 x 1,5                                                                                                | 5DL1 304                 | 1,6                             | 11,1                          | 12,7       | 51                            | 64                                     | 185                                 | 23                               | 0,21                                                      | 68                                   |
| 3 x 2,5                                                                                                | 5DL1 305                 | 1,9                             | 12,2                          | 13,8       | 55                            | 69                                     | 235                                 | 30                               | 0,36                                                      | 113                                  |
| 3 x 4                                                                                                  | 5DL1 306                 | 2,4                             | 15,2                          | 17,2       | 69                            | 86                                     | 380                                 | 41                               | 0,57                                                      | 180                                  |
| 3 x 6                                                                                                  | 5DL1 914                 | 2,9                             | 16,6                          | 18,6       | 74                            | 93                                     | 447                                 | 53                               | 0,86                                                      | 270                                  |
| <b>PROTOMONT NSSHÖU-J 4x... 0,6/1 kV Aderfarben / Color of cores: green-yellow, brown, black, grey</b> |                          |                                 |                               |            |                               |                                        |                                     |                                  |                                                           |                                      |
| 4 x 1,5                                                                                                | 5DL1 404                 | 1,6                             | 11,8                          | 13,4       | 54                            | 67                                     | 215                                 | 23                               | 0,21                                                      | 90                                   |
| 4 x 2,5                                                                                                | 5DL1 405                 | 1,9                             | 14,1                          | 16,1       | 64                            | 81                                     | 319                                 | 30                               | 0,36                                                      | 150                                  |
| 4 x 4                                                                                                  | 5DL1 406                 | 2,4                             | 15,7                          | 17,7       | 71                            | 89                                     | 411                                 | 41                               | 0,57                                                      | 240                                  |
| 4 x 6                                                                                                  | 5DL1 407                 | 2,9                             | 16,9                          | 18,9       | 76                            | 95                                     | 508                                 | 53                               | 0,86                                                      | 360                                  |
| 4 x 10                                                                                                 | 5DL1 410                 | 3,9                             | 21,1                          | 23,1       | 92                            | 116                                    | 803                                 | 74                               | 1,43                                                      | 600                                  |
| 4 x 16                                                                                                 | 5DL1 412                 | 5,4                             | 25,2                          | 28,2       | 113                           | 141                                    | 1181                                | 99                               | 2,29                                                      | 960                                  |
| 4 x 25                                                                                                 | 5DL1 413                 | 6,3                             | 29,8                          | 32,8       | 131                           | 164                                    | 1721                                | 131                              | 3,58                                                      | 1500                                 |
| 4 x 35                                                                                                 | 5DL1 414                 | 7,5                             | 32,7                          | 35,7       | 143                           | 179                                    | 2176                                | 162                              | 5,01                                                      | 2100                                 |
| 4 x 50                                                                                                 | 5DL1 415                 | 8,8                             | 38,1                          | 41,1       | 164                           | 206                                    | 3022                                | 202                              | 7,15                                                      | 3000                                 |
| 4 x 70                                                                                                 | 5DL1 416                 | 10,6                            | 42,1                          | 45,1       | 180                           | 226                                    | 3939                                | 250                              | 10,01                                                     | 4200                                 |
| 4 x 95                                                                                                 | 5DL1 417                 | 12,1                            | 48,2                          | 52,2       | 209                           | 261                                    | 5335                                | 301                              | 13,59                                                     | 5700                                 |
| 4 x 120                                                                                                | 5DL1 418                 | 14,2                            | 54,6                          | 58,6       | 234                           | 293                                    | 6758                                | 352                              | 17,16                                                     | 7200                                 |
| 4 x 150                                                                                                | 5DL1 420                 | 16,1                            | 60,8                          | 64,8       | 259                           | 324                                    | 8021                                | 404                              | 21,45                                                     | 9000                                 |
| 4 x 185                                                                                                | 5DL1 421                 | 17,9                            | 67,3                          | 71,3       | 285                           | 357                                    | 10154                               | 461                              | 26,46                                                     | 11100                                |
| 4 x 240                                                                                                | 5DL1 422                 | 20,3                            | 73,7                          | 77,7       | 311                           | 389                                    | 10621                               | 547                              | 34,32                                                     | 14400                                |



Änderungen vorbehalten  
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PRYSMIAN Kabel und Systeme GmbH  
Alt-Moabit 91D  
D-10559 Berlin

Seite / page 3/4

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Dokument: 07DS401\_31.doc  
Ausgabe 3.1 / 03.2010



## GUMMISCHLAUCHLEITUNGEN – RUBBER FLEXIBLE CABLES

Energieleitungen  
Power cables

DIN VDE 0250

## Auswahldaten - Selection data

| Aderanzahl und<br>Leitern-<br>querschnitt<br><br>Number of cores<br>and<br>nominal cross-<br>sectional area<br><br>mm <sup>2</sup> | Bestell-Nr.<br>Order no. | Leiter-<br>durch-<br>messer<br><br>Con-<br>ductor<br>dia-<br>meter<br><br>ca.<br>mm | Leitungsaußen-<br>durchmesser<br><br>Outer diameter of<br>cable<br><br>min. max.<br>mm mm | Biegeradius<br>Bending radius<br><br>fest<br>verlegt<br>fixed<br>installed<br>bei<br>Beweg-<br>ung<br>free<br>moving<br><br>min. max.<br>mm mm | Gewicht<br>netto<br><br>Weight of<br>cable<br>net<br><br>1000 m<br><br>ca.<br>kg | Strom-<br>belast-<br>barkeit<br><br>Current-<br>carrying<br>capacity<br><br>30°C<br>A | Zuläs-<br>siger<br>Kurz-<br>schluß-<br>strom<br>Permis-<br>sible<br>short-<br>circuit<br>current<br>(1 s)<br>kA | Zuläs-<br>sige<br>Zug-<br>kraft<br>Permis-<br>sible<br>pulling<br>force<br><br>max.<br>N |
|------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
|                                                                                                                                    |                          |                                                                                     |                                                                                           |                                                                                                                                                |                                                                                  |                                                                                       |                                                                                                                 |                                                                                          |

## PROTOMONT NSSHÖU-J 3x.../... 0,6/1 kV mit reduziertem Schutzleiter / with reduced PEN-conductor

Aderfarben / Color of cores: green-yellow, brown, black, grey

|             |          |      |      |      |     |     |      |     |       |      |
|-------------|----------|------|------|------|-----|-----|------|-----|-------|------|
| 3 x 50/25   | 5DL1 715 | 8,8  | 38,4 | 41,4 | 166 | 207 | 2874 | 202 | 7,15  | 2250 |
| 3 x 70/35   | 5DL1 716 | 10,6 | 42,3 | 45,3 | 181 | 227 | 3714 | 250 | 10,01 | 3150 |
| 3 x 95/50   | 5DL1 717 | 12,1 | 48,1 | 52,1 | 208 | 261 | 4899 | 301 | 13,59 | 4275 |
| 3 x 120/70  | 5DL1 718 | 14,2 | 54,6 | 58,6 | 234 | 293 | 6482 | 352 | 17,16 | 5400 |
| 3 x 150/95  | 5DL1 722 | 16,1 | 60,0 | 64,0 | 256 | 320 | 7568 | 404 | 21,45 | 6750 |
| 3 x 185/120 | 5DL1 721 | 17,9 | 67,3 | 71,3 | 285 | 357 | 9328 | 461 | 26,46 | 8325 |

## PROTOMONT NSSHÖU-J 3x...+3x.../3 0,6/1 kV mit aufgeteiltem Schutzleiter / with splitted PEN-conductor

Aderfarben / Color of cores: green-yellow, brown, black, grey

|                  |          |      |      |      |     |     |      |     |       |      |
|------------------|----------|------|------|------|-----|-----|------|-----|-------|------|
| 3 x 185+3 x 95/3 | 5DL1 973 | 17,9 | 60,7 | 64,7 | 259 | 324 | 8690 | 461 | 26,46 | 8325 |
|------------------|----------|------|------|------|-----|-----|------|-----|-------|------|

## PROTOMONT NSSHÖU-J 5x... 0,6/1 kV

Aderfarben / Color of cores: green-yellow, blue, brown, black, grey

|         |          |     |      |      |     |     |      |     |      |      |
|---------|----------|-----|------|------|-----|-----|------|-----|------|------|
| 5 x 1,5 | 5DL1 504 | 1,6 | 12,7 | 14,3 | 57  | 72  | 250  | 23  | 0,21 | 113  |
| 5 x 2,5 | 5DL1 505 | 1,9 | 15,2 | 17,2 | 69  | 86  | 363  | 30  | 0,36 | 188  |
| 5 x 4   | 5DL1 506 | 2,4 | 17,0 | 19,0 | 78  | 95  | 482  | 41  | 0,57 | 300  |
| 5 x 6   | 5DL1 507 | 2,9 | 19,1 | 21,1 | 84  | 106 | 633  | 53  | 0,86 | 450  |
| 5 x 10  | 5DL1 510 | 3,9 | 23,0 | 25,0 | 100 | 125 | 956  | 74  | 1,43 | 750  |
| 5 x 16  | 5DL1 512 | 5,4 | 27,4 | 30,4 | 122 | 152 | 1396 | 99  | 2,29 | 1200 |
| 5 x 25  | 5DL1 513 | 6,3 | 32,4 | 35,4 | 142 | 177 | 2051 | 131 | 3,58 | 1875 |
| 5 x 35  | 5DL1 514 | 7,5 | 36,9 | 39,9 | 160 | 200 | 2743 | 162 | 5,01 | 2625 |

## PROTOMONT NSSHÖU-J ...x1,5 0,6/1 kV

Aderfarben / Color of cores: light, with black numbers

|          |          |     |      |      |     |     |     |      |      |     |
|----------|----------|-----|------|------|-----|-----|-----|------|------|-----|
| 7 x 1,5  | 5DL1 933 | 1,6 | 15,2 | 17,2 | 69  | 86  | 364 | 15,0 | 0,21 | 158 |
| 8 x 1,5  | 5DL1 931 | 1,6 | 16,6 | 18,6 | 74  | 93  | 419 | 13,8 | 0,21 | 180 |
| 10 x 1,5 | 5DL1 879 | 1,6 | 17,7 | 19,7 | 79  | 99  | 476 | 12,7 | 0,21 | 225 |
| 24 x 1,5 | 5DL1 907 | 1,6 | 24,3 | 27,3 | 109 | 137 | 910 | 9,4  | 0,21 | 540 |

## PROTOMONT NSSHÖU-J ...x2,5 0,6/1 kV

Aderfarben / Color of cores: light, with black numbers

|          |          |     |      |      |     |     |      |      |      |     |
|----------|----------|-----|------|------|-----|-----|------|------|------|-----|
| 7 x 2,5  | 5DL1 911 | 1,9 | 17,4 | 19,4 | 78  | 97  | 497  | 19,5 | 0,36 | 263 |
| 10 x 2,5 | 5DL1 748 | 1,9 | 21,0 | 23,0 | 92  | 115 | 671  | 16,5 | 0,36 | 375 |
| 12 x 2,5 | 5DL1 755 | 1,9 | 21,2 | 23,2 | 93  | 116 | 735  | 15,6 | 0,36 | 450 |
| 14 x 2,5 | 5DL1 893 | 1,9 | 22,6 | 24,6 | 98  | 123 | 810  | 15,0 | 0,36 | 525 |
| 18 x 2,5 | 5DL1 937 | 1,9 | 24,5 | 27,5 | 110 | 138 | 1034 | 13,5 | 0,36 | 675 |
| 24 x 2,5 | 5DL1 842 | 1,9 | 28,3 | 31,3 | 125 | 157 | 1300 | 12,3 | 0,36 | 900 |

## PROTOMONT NSSHÖU-J ...x4 0,6/1 kV

Aderfarben / Color of cores: light, with black numbers

|        |          |     |      |      |     |     |      |      |      |     |
|--------|----------|-----|------|------|-----|-----|------|------|------|-----|
| 7 x 4  | 5DL1 750 | 2,4 | 20,5 | 22,5 | 90  | 113 | 698  | 26,7 | 0,57 | 420 |
| 12 x 4 | 5DL1 957 | 2,4 | 25,6 | 28,6 | 114 | 143 | 1070 | 21,3 | 0,57 | 720 |
| 14 x 4 | 5DL1 892 | 2,4 | 25,7 | 28,7 | 115 | 144 | 1130 | 20,5 | 0,57 | 840 |

Bei abweichender Umgebungstemperatur sind die Belastbarkeitwerte mit folgenden Faktoren umzurechnen:

For other ambient temperatures, the current-carrying capacities must be converted with the following factors:

| °C | 10   | 15   | 20   | 25   | 30   | 35   | 40   | 45   | 50   | 55   | 60   | 65   | 70   | 75   | 80   |
|----|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| f  | 1,15 | 1,12 | 1,08 | 1,04 | 1,00 | 0,96 | 0,91 | 0,87 | 0,82 | 0,76 | 0,71 | 0,65 | 0,58 | 0,50 | 0,41 |

Zulässige Kurzschlußströme  $I_{kz}$  für andere Ausschaltzeiten  $t_k$  bis zu 5 s erhält man mitPermissible short-circuit currents  $I_{kz}$  for other break times  $t_k$  up to 5 s are calculated using the formula

$$I_{kz} = I_{kz} \sqrt{\frac{t_k}{t_k}}$$



Seite / page 4/4

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### 3.10.6.2. EXZHELLENT – MAR RDt

#### EXZHELLENT – MAR RDt



##### ENERGÍA / POWER

Tensión asignada / Rated voltage: 0,6/1 kV



Sin armadura / Non armoured

##### NORMAS / STANDARDS:

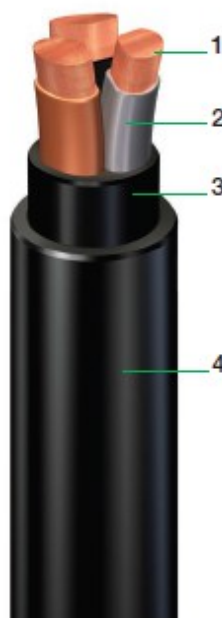
IEC 60092-350  
IEC 60092-351  
IEC 60092-353  
IEC 60092-359

IEC 60754-1  
IEC 60754-2  
IEC 61034-2

IEC 60332-1-2  
IEC 60332-3-22

##### CONSTRUCCIÓN:

- 1.- **CONDUCTOR:**  
Cobre recocido clase 5.
- 2.- **AISLAMIENTO:**  
Poliétileno reticulado libre de halógenos (HF XLPE).  
IEC 60092-351.  
Identificación de conductores:  
ver página 30.
- 3.- **RECUBRIMIENTO INTERNO:**  
Poliolefina termoplástica, libre de halógenos (Opcional).
- 4.- **CUBIERTA EXTERIOR:**  
Poliolefina termoplástica, libre de halógenos (SHF1).  
IEC 60092-359.



##### CONSTRUCTION:

- 1.- **CONDUCTOR:**  
Annealed copper, stranded class 5.
- 2.- **INSULATION:**  
Halogen free cross linked polyethylene (HF XLPE).  
IEC 60092-351.  
Core identification: see page 30.
- 3.- **INNER COVERING:**  
Halogen free thermoplastic polyolefine (Optional).
- 4.- **OUTER SHEATH:**  
Halogen free thermoplastic polyolefin (SHF1).  
IEC 60092-359.

##### APLICACIONES Y CARACTERÍSTICAS PRINCIPALES:

Cables flexibles para instalación en buques con especiales características de no propagación del incendio y reducida emisión de humos opacos, gases ácidos y corrosivos.

##### MAIN USES AND FEATURES:

Flexible cables for marine applications with special performance of flame spread and low emission of smoke and fumes.

##### CARACTERÍSTICAS DE DISEÑO:

Temperatura máxima del conductor en servicio permanente: 90°C  
Temperatura mínima de instalación y tendido: -15 °C.  
Temperatura mínima de operación: -40 °C.

##### DESIGN CHARACTERISTICS:

Max. rated conductor temperature in normal operation: 90°C  
Minimum handling & laying temperature: -15 °C.  
Minimum operational temperature: -40 °C.



## EXZHELLENT – MAR RDt



### ENERGÍA / POWER

Tensión asignada / Rated voltage: 0,6/1 kV

| CÓDIGO  | SECCIÓN<br>NOMINAL | DIÁMETRO<br>EXTERIOR | PESO   | RADIO<br>CURVATURA | INTENSIDAD<br>ADMISIBLE<br>AIRE 45 °C | CAÍDA TENSIÓN<br>(COS $\varphi=0,8$ ) | INDUCTANCIA |
|---------|--------------------|----------------------|--------|--------------------|---------------------------------------|---------------------------------------|-------------|
| CODE    | CROSS<br>SECTION   | OUTER<br>DIAMETER    | WEIGHT | BENDING<br>RADIUS  | CURRENT<br>RATING AIR 45 °C           | VOLTAGE DROP<br>(COS $\varphi=0,8$ )  | INDUCTANCE  |
|         | mm <sup>2</sup>    | mm                   | kg/km  | mm                 | A                                     | V/A. km                               | mH/km       |
| 7783105 | 1x1                | 4,7                  | 35     | 20                 | 16                                    | 34,60                                 | 0,455       |
| 7783106 | 1x1,5              | 4,9                  | 40     | 20                 | 21                                    | 23,64                                 | 0,430       |
| 7783107 | 1x2,5              | 5,3                  | 50     | 25                 | 28                                    | 14,23                                 | 0,395       |
| 7783108 | 1x4                | 5,9                  | 65     | 25                 | 38                                    | 8,865                                 | 0,365       |
| 7783109 | 1x6                | 6,4                  | 85     | 30                 | 49                                    | 5,942                                 | 0,342       |
| 7783110 | 1x10               | 7,4                  | 125    | 30                 | 67                                    | 3,477                                 | 0,314       |
| 7783111 | 1x16               | 8,4                  | 180    | 35                 | 91                                    | 2,234                                 | 0,295       |
| 7783112 | 1x25               | 10,2                 | 275    | 45                 | 117                                   | 1,473                                 | 0,290       |
| 7783113 | 1x35               | 11,3                 | 365    | 45                 | 147                                   | 1,069                                 | 0,277       |
| 7783114 | 1x50               | 13,1                 | 510    | 55                 | 180                                   | 0,771                                 | 0,272       |
| 7783115 | 1x70               | 15,4                 | 715    | 65                 | 233                                   | 0,567                                 | 0,265       |
| 7783116 | 1x95               | 17,0                 | 920    | 70                 | 285                                   | 0,448                                 | 0,257       |
| 7783117 | 1x120              | 19,2                 | 1.170  | 80                 | 333                                   | 0,367                                 | 0,253       |
| 7783118 | 1x150              | 21,2                 | 1.450  | 85                 | 386                                   | 0,311                                 | 0,254       |
| 7783119 | 1x185              | 23,1                 | 1.740  | 95                 | 444                                   | 0,270                                 | 0,253       |
| 7783120 | 1x240              | 26,4                 | 2.310  | 160                | 528                                   | 0,222                                 | 0,248       |
| 7783121 | 1x300              | 30,0                 | 2.890  | 180                | 612                                   | 0,193                                 | 0,243       |
| 7783205 | 2x1                | 7,3                  | 60     | 30                 | 13                                    | 34,57                                 | 0,349       |
| 7783206 | 2x1,5              | 7,8                  | 70     | 35                 | 23                                    | 23,61                                 | 0,331       |
| 7783207 | 2x2,5              | 8,8                  | 105    | 35                 | 31                                    | 14,20                                 | 0,307       |
| 7783208 | 2x4                | 9,9                  | 150    | 40                 | 43                                    | 8,839                                 | 0,287       |
| 7783209 | 2x6                | 11,0                 | 215    | 45                 | 55                                    | 5,919                                 | 0,272       |
| 7783210 | 2x10               | 13,1                 | 330    | 55                 | 75                                    | 3,458                                 | 0,256       |
| 7783211 | 2x16               | 15,3                 | 480    | 65                 | 100                                   | 2,218                                 | 0,245       |
| 7783212 | 2x25               | 18,8                 | 725    | 75                 | 130                                   | 1,458                                 | 0,246       |
| 7783213 | 2x35               | 21,2                 | 970    | 85                 | 161                                   | 1,057                                 | 0,239       |
| 7783214 | 2x50               | 23,5                 | 1.335  | 95                 | 196                                   | 0,766                                 | 0,250       |
| 7783215 | 2x70               | 25,1                 | 1.645  | 150                | 251                                   | 0,556                                 | 0,232       |
| 7783216 | 2x95               | 27,8                 | 2.110  | 170                | 306                                   | 0,438                                 | 0,227       |
| 7783217 | 2x120              | 31,3                 | 2.675  | 190                | 357                                   | 0,358                                 | 0,226       |
| 7783218 | 2x150              | 34,6                 | 3.315  | 210                | 412                                   | 0,302                                 | 0,228       |
| 7783219 | 2x185              | 38,0                 | 4.005  | 230                | 472                                   | 0,262                                 | 0,229       |
| 7783220 | 2x240              | 43,5                 | 5.315  | 265                | 558                                   | 0,215                                 | 0,226       |

## EXZHELLENT – MAR RDt



### ENERGÍA / POWER

Tensión asignada / Rated voltage: 0,6/1 kV

| CÓDIGO   | SECCIÓN NOMINAL | DIÁMETRO EXTERIOR | PESO   | RADIO CURVATURA | INTENSIDAD ADMISIBLE AIRE 45 °C | CAÍDA TENSIÓN (COS $\varphi=0,8$ ) | INDUCTANCIA |
|----------|-----------------|-------------------|--------|-----------------|---------------------------------|------------------------------------|-------------|
| CODE     | CROSS SECTION   | OUTER DIAMETER    | WEIGHT | BENDING RADIUS  | CURRENT RATING AIR 45 °C        | VOLTAGE DROP (COS $\varphi=0,8$ )  | INDUCTANCE  |
|          | mm <sup>2</sup> | mm                | kg/km  | mm              | A                               | V/A. km                            | mH/km       |
| 7783305  | 3x1             | 7,7               | 75     | 35              | 11                              | 34,57                              | 0,349       |
| 7783305* | 2x1+1           | 7,7               | 75     | 35              | 11                              | 34,57                              | 0,349       |
| 7783306  | 3x1,5           | 8,3               | 90     | 35              | 20                              | 23,61                              | 0,331       |
| 7783306* | 2x1,5+1,5       | 8,3               | 90     | 35              | 20                              | 23,61                              | 0,331       |
| 7783307  | 3x2,5           | 9,4               | 130    | 40              | 28                              | 14,20                              | 0,307       |
| 7783307* | 2x2,5+2,5       | 9,4               | 130    | 40              | 28                              | 14,20                              | 0,307       |
| 7783308  | 3x4             | 10,5              | 170    | 45              | 37                              | 8,839                              | 0,287       |
| 7783308* | 2x4+4           | 10,5              | 170    | 45              | 37                              | 8,839                              | 0,287       |
| 7783309  | 3x6             | 11,9              | 275    | 50              | 47                              | 5,919                              | 0,272       |
| 7783309* | 2x6+6           | 11,9              | 275    | 50              | 47                              | 5,919                              | 0,272       |
| 7783310  | 3x10            | 14,0              | 415    | 60              | 65                              | 3,458                              | 0,256       |
| 7783310* | 2x10+10         | 14,0              | 415    | 60              | 65                              | 3,458                              | 0,256       |
| 7783311  | 3x16            | 16,3              | 610    | 65              | 87                              | 2,218                              | 0,245       |
| 7783311* | 2x16+16         | 16,3              | 610    | 65              | 87                              | 2,218                              | 0,245       |
| 7783312  | 3x25            | 20,1              | 930    | 80              | 110                             | 1,458                              | 0,246       |
| 7783313  | 3x35            | 22,7              | 1.255  | 95              | 137                             | 1,057                              | 0,239       |
| 7783314  | 3x50            | 25,3              | 1.595  | 155             | 167                             | 0,759                              | 0,235       |
| 7783315  | 3x70            | 29,4              | 2.205  | 180             | 214                             | 0,556                              | 0,232       |
| 7783316  | 3x95            | 32,6              | 2.840  | 195             | 259                             | 0,438                              | 0,227       |
| 7783317  | 3x120           | 36,9              | 3.625  | 225             | 301                             | 0,358                              | 0,226       |
| 7783318  | 3x150           | 40,6              | 4.475  | 245             | 347                             | 0,302                              | 0,228       |
| 7783319  | 3x185           | 44,5              | 5.410  | 270             | 397                             | 0,262                              | 0,229       |
| 7783320  | 3x240           | 51,0              | 7.185  | 310             | 468                             | 0,215                              | 0,226       |
| 7783321  | 3x300           | 58,1              | 9.015  | 350             | 540                             | 0,186                              | 0,223       |
| 7783405  | 4x1             | 8,4               | 90     | 35              | 10                              | 34,57                              | 0,349       |
| 7783405* | 3x1+1           | 8,4               | 90     | 35              | 10                              | 34,57                              | 0,349       |
| 7783406  | 4x1,5           | 9,2               | 115    | 40              | 20                              | 23,61                              | 0,331       |
| 7783406* | 3x1,5+1,5       | 9,2               | 115    | 40              | 20                              | 23,61                              | 0,331       |
| 7783407  | 4x2,5           | 10,2              | 165    | 45              | 28                              | 14,20                              | 0,307       |

\* Estos códigos tienen conductor de protección "Amarillo/Verde". Rogamos especifique la composición de la columna "SECCIÓN NOMINAL" cuando solicite este tipo de cable.

\* These codes contain "Green/Yellow" earthing conductor. Please state the construction under "CROSS SECTION" column when ordering this type of cable.

### 3.10.7. Switch catalogues

#### 3.10.7.1. Schneider Electric iC60N

Interruptores  
automáticos  
termomagnéticos

**iC60N**

IEC 60898: **6000** A / IEC 60947-2: 10 kA  
curvas B, C y D

Nuevo

| Tipo               | In (A) | Referencias Curvas B | C        | D        | Ancho en pasos 8mm |
|--------------------|--------|----------------------|----------|----------|--------------------|
| 1P                 | 0,5    | -                    | A9F74170 | A9F75170 | 2                  |
|                    | 1      | A9F73101             | A9F74101 | A9F75101 |                    |
|                    | 2      | A9F73102             | A9F74102 | A9F75102 |                    |
|                    | 3      | A9F73103             | A9F74103 | A9F75103 |                    |
|                    | 4      | A9F73104             | A9F74104 | A9F75104 |                    |
|                    | 6      | A9F76106             | A9F77106 | A9F75106 |                    |
|                    | 10     | A9F76110             | A9F77110 | A9F75110 |                    |
|                    | 16     | A9F76116             | A9F77116 | A9F75116 |                    |
|                    | 20     | A9F76120             | A9F77120 | A9F75120 |                    |
|                    | 25     | A9F76125             | A9F77125 | A9F75125 |                    |
|                    | 32     | A9F76132             | A9F77132 | A9F75132 |                    |
|                    | 40     | A9F76140             | A9F77140 | A9F75140 |                    |
|                    | 50     | A9F76150             | A9F77150 | A9F75150 |                    |
|                    | 63     | A9F76163             | A9F77163 | A9F75163 |                    |
| 1 polo protegido   | 0,5    | -                    | A9F74270 | -        | 4                  |
|                    | 1      | A9F73201             | A9F74201 | A9F75201 |                    |
|                    | 2      | A9F73202             | A9F74202 | A9F75202 |                    |
|                    | 3      | A9F73203             | A9F74203 | A9F75203 |                    |
|                    | 4      | A9F73204             | A9F74204 | A9F75204 |                    |
|                    | 6      | A9F76206             | A9F77206 | A9F75206 |                    |
|                    | 10     | A9F76210             | A9F77210 | A9F75210 |                    |
|                    | 16     | A9F76216             | A9F77216 | A9F75216 |                    |
|                    | 20     | A9F76220             | A9F77220 | A9F75220 |                    |
|                    | 25     | A9F76225             | A9F77225 | A9F75225 |                    |
|                    | 32     | A9F76232             | A9F77232 | A9F75232 |                    |
|                    | 40     | A9F76240             | A9F77240 | A9F75240 |                    |
|                    | 50     | A9F76250             | A9F77250 | A9F75250 |                    |
|                    | 63     | A9F76263             | A9F77263 | A9F75263 |                    |
| 2 polos protegidos | 0,5    | -                    | A9F74370 | -        | 6                  |
|                    | 1      | A9F73301             | A9F74301 | A9F75301 |                    |
|                    | 2      | A9F73302             | A9F74302 | A9F75302 |                    |
|                    | 3      | A9F73303             | A9F74303 | A9F75303 |                    |
|                    | 4      | A9F73304             | A9F74304 | A9F75304 |                    |
|                    | 6      | A9F76306             | A9F77306 | A9F75306 |                    |
|                    | 10     | A9F76310             | A9F77310 | A9F75310 |                    |
|                    | 16     | A9F76316             | A9F77316 | A9F75316 |                    |
|                    | 20     | A9F76320             | A9F77320 | A9F75320 |                    |
|                    | 25     | A9F76325             | A9F77325 | A9F75325 |                    |
|                    | 32     | A9F76332             | A9F77332 | A9F75332 |                    |
|                    | 40     | A9F76340             | A9F77340 | A9F75340 |                    |
|                    | 50     | A9F76350             | A9F77350 | A9F75350 |                    |
|                    | 63     | A9F76363             | A9F77363 | A9F75363 |                    |
| 3 polos protegidos | 0,5    | -                    | A9F74470 | -        | 8                  |
|                    | 1      | A9F73401             | A9F74401 | A9F75401 |                    |
|                    | 2      | A9F73402             | A9F74402 | A9F75402 |                    |
|                    | 3      | A9F73403             | A9F74403 | A9F75403 |                    |
|                    | 4      | A9F73404             | A9F74404 | A9F75404 |                    |
|                    | 6      | A9F76406             | A9F77406 | A9F75406 |                    |
|                    | 10     | A9F76410             | A9F77410 | A9F75410 |                    |
|                    | 16     | A9F76416             | A9F77416 | A9F75416 |                    |
|                    | 20     | A9F76420             | A9F77420 | A9F75420 |                    |
|                    | 25     | A9F76425             | A9F77425 | A9F75425 |                    |
|                    | 32     | A9F76432             | A9F77432 | A9F75432 |                    |
|                    | 40     | A9F76440             | A9F77440 | A9F75440 |                    |
|                    | 50     | A9F76450             | A9F77450 | A9F75450 |                    |
|                    | 63     | A9F76463             | A9F77463 | A9F75463 |                    |
| 4 polos protegidos | 0,5    | -                    | A9F74470 | -        | 8                  |
|                    | 1      | A9F73401             | A9F74401 | A9F75401 |                    |
|                    | 2      | A9F73402             | A9F74402 | A9F75402 |                    |
|                    | 3      | A9F73403             | A9F74403 | A9F75403 |                    |
|                    | 4      | A9F73404             | A9F74404 | A9F75404 |                    |
|                    | 6      | A9F76406             | A9F77406 | A9F75406 |                    |
|                    | 10     | A9F76410             | A9F77410 | A9F75410 |                    |
|                    | 16     | A9F76416             | A9F77416 | A9F75416 |                    |
|                    | 20     | A9F76420             | A9F77420 | A9F75420 |                    |
|                    | 25     | A9F76425             | A9F77425 | A9F75425 |                    |
|                    | 32     | A9F76432             | A9F77432 | A9F75432 |                    |
|                    | 40     | A9F76440             | A9F77440 | A9F75440 |                    |
|                    | 50     | A9F76450             | A9F77450 | A9F75450 |                    |
|                    | 63     | A9F76463             | A9F77463 | A9F75463 |                    |

• Los iC60N son interruptores automáticos que combinan las siguientes funciones:  
• Protección de circuitos contra corrientes de cortocircuito.  
• Protección de circuitos contra corrientes de sobrecarga.  
• Adecuados para aislamiento industrial según la norma IEC 60947-2.  
• Señalización de defecto mediante un indicador mecánico situado en la parte frontal del interruptor automático.  
• Distribución terminal terciario e industrial.

| Corriente alterna (CA) 50/60 Hz                 |            |             |             |              |
|-------------------------------------------------|------------|-------------|-------------|--------------|
| Poder de corte (Icu) según la norma IEC 60947-2 |            |             |             |              |
| Tensión (Ue)                                    |            |             |             |              |
| F/F (2P, 3P, 4P)                                | 12 a 133 V | 220 a 240 V | 380 a 415 V | 440 V        |
| FIN (1P, 1P+N)                                  | 12 a 80 V  | 100 a 133 V | 220 a 240 V | -            |
| Calibre (In)                                    | 0,5 a 4 A  | 50 kA       | 50 kA       | 25 kA        |
|                                                 | 6 a 63 A   | 36 kA       | 20 kA       | 10 kA        |
|                                                 |            |             |             | 6 kA         |
|                                                 |            |             |             | 100 % de Icu |
|                                                 |            |             |             | 75 % de Icu  |

| Poder de corte (Icn) según la norma IEC 60898-1 |            |         |  |  |
|-------------------------------------------------|------------|---------|--|--|
| Tensión (Ue)                                    |            |         |  |  |
| F/F                                             | 400 V      |         |  |  |
| FIN                                             | 230 V      |         |  |  |
| Calibre (In)                                    | 0,5 a 63 A | 6 000 A |  |  |

| Corriente continua (CC)                         |            |               |               |               |
|-------------------------------------------------|------------|---------------|---------------|---------------|
| Poder de corte (Icu) según la norma IEC 60947-2 |            |               |               |               |
| Tensión (Ue)                                    |            |               |               |               |
| Entre +/–                                       | 12 a 72 V  | 100 a 133 V   | 220 a 240 V   |               |
| Número de polos                                 | 1P         | 2P (en serie) | 3P (en serie) | 4P (en serie) |
| Calibre (In)                                    | 0,5 a 63 A | 6 kA          | 6 kA          | 6 kA          |
|                                                 |            |               |               | 100 % de Icu  |

• Aumento de la vida útil del producto gracias a las características siguientes:  
• Alta resistencia a sobretensiones gracias a un diseño industrial de alto nivel (grado de contaminación, tensión asignada impulsional y tensión asignada de aislamiento).  
• Alto poder de limitación (ver curvas de limitación).  
• Cierre brusco independientemente de la velocidad de actuación de la maneta.  
• Indicación, apertura, cierre y disparo remotos mediante contactos auxiliares opcionales.  
• Alimentación eléctrica superior o inferior.

#### Datos técnicos

| Características principales                                    |                                              |
|----------------------------------------------------------------|----------------------------------------------|
| Según la norma IEC 60947-2                                     |                                              |
| Tensión asignada de aislamiento (Ui)                           | 500 V CA                                     |
| Grado de contaminación                                         | 3                                            |
| Tensión asignada impulsional (Uimp)                            | 6 kV                                         |
| Disparo térmico                                                | Temperatura de referencia 50 °C              |
| Degradación por temperatura                                    | Ver capítulo 10                              |
| Disparo magnético                                              | Curva B 4 In ± 20%                           |
|                                                                | Curva C 8 In ± 20%                           |
|                                                                | Curva D 12 In ± 20%                          |
| Categoría de utilización                                       | A                                            |
| Según la norma IEC 60898-1                                     |                                              |
| Clase de limitación                                            | 3                                            |
| Poder de corte y conexión nominal de un polo individual (Icn1) | Icn1 = Icn                                   |
| Características adicionales                                    |                                              |
| Grado de protección (IEC 60529)                                | Dispositivo únicamente IP20                  |
|                                                                | Dispositivo en cofre modular IP40            |
| Endurecimiento (apertura-cierre)                               | Eléctrico 10.000 ciclos                      |
|                                                                | Mecánico 20.000 ciclos                       |
| Categoría de sobretensión (IEC 60364)                          | IV                                           |
| Temperatura de funcionamiento                                  | –35 °C a +75 °C                              |
| Temperatura de almacenamiento                                  | –40 °C a +95 °C                              |
| Tropicalización (IEC 60068-1)                                  | Tratamiento 2 (humedad relativa 95% a 55 °C) |

#### Peso (g)

| Interruptor automático |       |
|------------------------|-------|
| Tipo                   | iC60N |
| 1P                     | 126   |
| 2P                     | 260   |
| 3P                     | 376   |
| 4P                     | 600   |

Dimensiones: CAP 12  
Complementos técnicos: CAP 10



### 3.10.7.2. Schneider Electric C120N

# Multi 9

## C120N circuit-breaker



The C120N circuit-breaker is a miniature device adapted to final distribution in the industry and tertiary sectors:

- > Outgoer in medium power switchboard.
- > Enclosure supply end.

#### Operation

- > Protection of cables against overloads and short-circuits:
  - C curve: standard networks,
  - D curve: for circuits with a strong inrush current (motors, transformers).
- > Manual control and isolation.

#### Advantages

- > Compliance with standards: AS/NZS 60898.
- > Ratings from 63 to 125 A (1 to 4-pole).
- > Breaking capacity of 10 000 A.
- > Characteristics adapted to the industrial environment:
  - insulation voltage  $U_i$ : 500 V,
  - impulse voltage  $U_{imp}$ : 6 kV.
- > Service breaking capacity:  $I_{cs} = 75\% I_{cu}$ .
- > Positive break indication.
- > Installation on rail using bistable DIN clip.
- > Total compatibility with Prisma Plus switchboards.
- > Design, performances and range coherent with C60 circuit-breakers.
- > Remote tripping and indication by adding clip-on electrical auxiliaries, which are common with C60 circuit-breakers.
- > Earth leakage protection when combined with a Vigi C120 module.



### The range

**TmC120  
Remote Control**

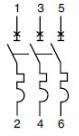
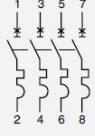
**C120N  
Circuit-Breaker**

**Vigi C120  
Module**

**Auxiliaries**

**Accessories**

## Choice table

| Type                                                                                     | Width in mod. of 9 mm | Rating (A) | Cat. no. curve C | D     |
|------------------------------------------------------------------------------------------|-----------------------|------------|------------------|-------|
| 1P<br>  | 3                     | 63         | 18356            | 18378 |
|                                                                                          |                       | 80         | 18357            | 18379 |
|                                                                                          |                       | 100        | 18358            | 18380 |
|                                                                                          |                       | 125        | 18359            | 18381 |
| 2P<br>  | 6                     | 63         | 18360            | 18382 |
|                                                                                          |                       | 80         | 18361            | 18383 |
|                                                                                          |                       | 100        | 18362            | 18384 |
|                                                                                          |                       | 125        | 18363            | 18385 |
| 3P<br>  | 9                     | 63         | 18364            | 18386 |
|                                                                                          |                       | 80         | 18365            | 18387 |
|                                                                                          |                       | 100        | 18367            | 18388 |
|                                                                                          |                       | 125        | 18369            | 18389 |
| 4P<br> | 12                    | 63         | 18371            | 18390 |
|                                                                                          |                       | 80         | 18372            | 18391 |
|                                                                                          |                       | 100        | 18374            | 18392 |
|                                                                                          |                       | 125        | 18376            | 18393 |

## Implementation

- > Designed for installation in modular enclosures and cubicles.
- > Easy assembly and disassembly: on symmetrical rail with bistable lock (immediate fixing).
- > Simplified combination of circuit-breaker with auxiliaries: using clip-ons.
- > Combination of circuit-breaker with Vigi C120 module using rigid cables: quick with no risk of error (rating, order of phases, etc.).

## Technical data

### Common electrical data

- > Power circuit:
  - ratings from 63 to 125 A,
  - max. voltage rating: 440 V AC,
  - insulation voltage 500 V,
  - breaking capacity as in AS/NZS 60898:

| Type        | Voltage (V AC) | Breaking capacity (A) |
|-------------|----------------|-----------------------|
| 1, 2, 3, 4P | 230...415      | 10 000                |

- fast closing,
- positive break indication: opening is indicated by a green strip on the device's control toggle. This indicator shows that all poles are open with a safety distance allowing downstream interventions.

- > Electrical durability:
  - 10 000 cycles at  $I_n \leq 63$  A,
  - 5 000 cycles at  $I_n = 80...125$  A.

### Tripping curves

The magnetic trip units operate:

- > C curve: between 5 and 10 In.
- > D curve: between 10 and 14 In.

### Mechanical data

- > Connection by:
  - tunnel terminals with insulated guard (tightened using a screwdriver) for copper cable:
    - flexible from 1.5 to 35 mm<sup>2</sup>,
    - rigid from 1.5 to 50 mm<sup>2</sup>,
  - aluminium cable terminals: from 16 to 50 mm<sup>2</sup>,
  - insulated sub-distribution terminals, 3 copper cables:
    - flexible from 1.5 to 10 mm<sup>2</sup>,
    - rigid from 1.5 to 16 mm<sup>2</sup>,
  - comb busbars.
- > Durability: 20 000 cycles (O-C).
- > Dimensions (w x h x d mm): 27 x N (number of poles) x 81 x 70.
- > Weight (g): 1P: 205, 2P: 410, 3P: 615, 4P: 820.

## Environment

- > Tropicalisation: treatment 2 (relative humidity 95% at 55°C).
- > Degree of protection:
  - of case: IP 40D,
  - of terminals: IP 20B.
- > Operating temperature: -30°C to +60°C.
- > Storage temperature: -40°C to +70°C.

Owing to changes in standards and equipment, the characteristics given in the text and images in this document are not binding until they have been confirmed with us.

Schneider Electric New Zealand Ltd

Customer Care Freecall 0800 652 999

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Approval No: N22673

3.10.7.3. Schneider Electric CM 18070

Product data sheet  
Characteristics

18070  
2 positions selector switch CM - modular - 1  
OC - 20 A - 250 V



|                          |                            |
|--------------------------|----------------------------|
| Main                     |                            |
| Switch application       | Electrical circuit control |
| Range of product         | Clario                     |
| Device short name        | CM                         |
| Pole contact composition | 1 C/O                      |

|                                              |                                                                                                                                                                                                                                                                  |
|----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Complementary                                |                                                                                                                                                                                                                                                                  |
| [Ie] rated operational current               | 20 A                                                                                                                                                                                                                                                             |
| [Ue] rated operational voltage               | 250 V AC                                                                                                                                                                                                                                                         |
| Control type                                 | Toggle 2 positions                                                                                                                                                                                                                                               |
| Mounting mode                                | Fixed                                                                                                                                                                                                                                                            |
| Mounting support                             | 35 mm symmetrical DIN rail                                                                                                                                                                                                                                       |
| Comb busbar distribution block compatibility | ProDis upside                                                                                                                                                                                                                                                    |
| 9 mm pitches                                 | 2                                                                                                                                                                                                                                                                |
| Height                                       | 82 mm                                                                                                                                                                                                                                                            |
| Width                                        | 18 mm                                                                                                                                                                                                                                                            |
| Depth                                        | 75 mm                                                                                                                                                                                                                                                            |
| Electrical durability                        | 30000 cycles AC-22                                                                                                                                                                                                                                               |
| Connections - terminals                      | Staggered tunnel terminal ≤ 2,5 mm² flexible without cable end 2<br>Staggered tunnel terminal ≤ 2,5 mm² rigid without cable end 2<br>Staggered tunnel terminal ≤ 2,5 mm² flexible with cable end 2<br>Staggered tunnel terminal ≤ 2,5 mm² rigid with cable end 2 |

|                                       |                              |
|---------------------------------------|------------------------------|
| Environment                           |                              |
| Standards                             | IEC 60669-1<br>IEC 60947-5-1 |
| Quality labels                        | NF                           |
| Tropicalisation                       | 2                            |
| Relative humidity                     | 95 % 55 °C                   |
| Ambient air temperature for operation | -20...50 °C                  |
| Ambient air temperature for storage   | -40...80 °C                  |
| RoHS EUR conformity date              | 0721                         |
| RoHS EUR status                       | Compliant                    |

The information provided in this documentation contains general descriptions and/or technical characteristics of the products contained herein. The documentation is not intended as a substitute for and is not to be used for determining suitability or reliability of these products for specific user applications. It is the duty of any such user or integrator to perform the appropriate and complete risk analysis, evaluation and testing of the products with respect to the relevant specific application or use thereof. Neither Schneider Electric Industries SAS nor any of its affiliates or subsidiaries shall be responsible or liable for misuse of the information contained herein.

#### **3.10.7.4. Schneider Electric Interpact INS250**

## Product data sheet

### Characteristics

31100

switch-disconnector Compact INS250 - 100 A - 3 poles



#### Main

|                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|---------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Commercial Status                           | Commercialised                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Range                                       | Compact                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Product name                                | INS250                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Poles description                           | 3P                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Network type                                | AC<br>DC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Network frequency                           | 50/60 Hz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| [Ie] rated operational current              | DC-23A: 100 A DC 125 V 2 poles in series<br>DC-22A: 100 A DC 125 V 2 poles in series<br>AC-23A: 100 A AC 50/60 Hz 660/690 V<br>AC-23A: 100 A AC 50/60 Hz 500/525 V<br>AC-23A: 100 A AC 50/60 Hz 480 V NEMA<br>AC-23A: 100 A AC 50/60 Hz 440/480 V<br>AC-23A: 100 A AC 50/60 Hz 380/415 V<br>AC-23A: 100 A AC 50/60 Hz 220/240 V<br>AC-22A: 100 A AC 50/60 Hz 660/690 V<br>AC-22A: 100 A AC 50/60 Hz 500/525 V<br>AC-22A: 100 A AC 50/60 Hz 480 V NEMA<br>AC-22A: 100 A AC 50/60 Hz 440/480 V<br>AC-22A: 100 A AC 50/60 Hz 380/415 V<br>AC-22A: 100 A AC 50/60 Hz 220/240 V |
| [Ui] rated insulation voltage               | 750 V AC 50/60 Hz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| [Ith] conventional free air thermal current | 100 A ( 60 °C )                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| [Icm] rated short-circuit making capacity   | 330 kA 690 V AC 50/60 Hz with upstream protection circuit breaker<br>30 kA 690 V AC 50/60 Hz switch-disconnector alone                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| [Ue] rated operational voltage              | 690 V AC 50/60 Hz<br>125 V DC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Suitability for isolation                   | Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| Contact position indicator                  | Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| Visible break                               | No                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Pollution degree                            | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

#### Complementary

|                                          |                                                                                                                                                                                                                                                                      |
|------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Control type                             | Direct front rotary handle                                                                                                                                                                                                                                           |
| Handle colour                            | Black                                                                                                                                                                                                                                                                |
| Mounting mode                            | Fixed                                                                                                                                                                                                                                                                |
| Mounting support                         | Plate<br>Rail                                                                                                                                                                                                                                                        |
| Upside connection                        | Front                                                                                                                                                                                                                                                                |
| Downside connection                      | Front                                                                                                                                                                                                                                                                |
| Maximum power                            | AC-23: 55 kW 660/690 V AC 50/60 Hz<br>AC-23: 55 kW 500/525 V AC 50/60 Hz<br>AC-23: 55 kW 480 V NEMA AC 50/60 Hz<br>AC-23: 55 kW 440 V AC 50/60 Hz<br>AC-23: 45 kW 380/415 V AC 50/60 Hz<br>AC-23: 22 kW 230 V NEMA AC 50/60 Hz<br>AC-23: 22 kW 220/240 V AC 50/60 Hz |
| Rated duty                               | Uninterrupted                                                                                                                                                                                                                                                        |
| [Icw] rated short-time withstand current | 8.5 kA ( 1 s ) conforming to IEC 60947-3<br>4.9 kA ( 3 s ) conforming to IEC 60947-3<br>2.2 kA ( 20 s ) conforming to IEC 60947-3<br>1.8 kA ( 30 s ) conforming to IEC 60947-3                                                                                       |

Sep 1, 2015

1

The information provided in this documentation contains general descriptions and/or technical characteristics of the products contained herein. It is not intended as a substitute for and is not to be used for determining suitability or reliability of these products for specific user applications. It is the duty of any such user or integrator to perform the appropriate and complete risk analysis, evaluation and testing of the products with respect to the relevant specific application or use thereof. Neither Schneider Electric Industries SAS nor any of its affiliates or subsidiaries shall be responsible or liable for misuse of the information contained herein.



|                       |                                                                                                                                                                                                                                                                                                                                                        |
|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Mechanical durability | 15000 cycles                                                                                                                                                                                                                                                                                                                                           |
| Electrical durability | DC-23A: 1500 cycles 125 V DC 2 poles in series<br>DC-22A: 1500 cycles 125 V DC 2 poles in series<br>AC-23A: 1500 cycles 690 V AC 50/60 Hz<br>AC-23A: 1500 cycles 500 V AC 50/60 Hz<br>AC-23A: 1500 cycles 440 V AC 50/60 Hz<br>AC-22A: 1500 cycles 690 V AC 50/60 Hz<br>AC-22A: 1500 cycles 500 V AC 50/60 Hz<br>AC-22A: 1500 cycles 440 V AC 50/60 Hz |
| Connection pitch      | 35 mm                                                                                                                                                                                                                                                                                                                                                  |
| Height                | 136 mm                                                                                                                                                                                                                                                                                                                                                 |
| Width                 | 140 mm                                                                                                                                                                                                                                                                                                                                                 |
| Depth                 | 96 mm                                                                                                                                                                                                                                                                                                                                                  |
| Product weight        | 2 kg                                                                                                                                                                                                                                                                                                                                                   |

#### Environment

|                                       |                              |
|---------------------------------------|------------------------------|
| Standards                             | IEC 60947-1<br>IEC 60947-3   |
| Product certifications                | CCC<br>KEMA-KEUR             |
| IP degree of protection               | IP40 conforming to IEC 60529 |
| IK degree of protection               | IK07 conforming to EN 50102  |
| Ambient air temperature for operation | -25...70 °C                  |
| Ambient air temperature for storage   | -50...85 °C                  |

### 3.10.7.5. Schneider Electric Interpact INS80

#### Product data sheet Characteristics

28904

switch-disconnector Interpact INS80 - 3 poles - 80 A

#### Main

|                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|---------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Device short name                           | Interpact INS80                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Switch-disconnector name                    | Interpact INS80                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Poles description                           | 3P                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Network type                                | AC<br>DC                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Network frequency                           | 50/60 Hz                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| [Ie] rated operational current              | 80 A AC-22A: AC 50/60 Hz 220/240 V<br>80 A AC-22A: AC 50/60 Hz 380/415 V<br>80 A AC-22A: AC 50/60 Hz 440/480 V<br>80 A AC-22A: AC 50/60 Hz 480 V NEMA<br>80 A AC-22A: AC 50/60 Hz 500 V<br>40 A AC-23A: AC 50/60 Hz 500 V<br>63 A AC-23A: 440/480 V AC 50/60 Hz<br>63 A AC-23A: AC 50/60 Hz 480 V NEMA<br>72 A AC-23A: AC 50/60 Hz 380/415 V<br>80 A AC-23A: AC 50/60 Hz 220/240 V<br>80 A DC-22A: DC 125 V 2 poles in series<br>80 A DC-23A: DC 125 V 2 poles in series |
| [Ui] rated insulation voltage               | 690 V AC 50/60 Hz                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| [Uimp] rated impulse withstand voltage      | 8 kV                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| [Ith] conventional free air thermal current | 80 A ( 60 °C )                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| [Icm] rated short-circuit making capacity   | 15 kA switch-disconnector alone 500 V AC 50/60 Hz<br>75 kA with upstream protection circuit breaker 500 V AC 50/60 Hz                                                                                                                                                                                                                                                                                                                                                    |
| [Ue] rated operational voltage              | 125 V DC<br>500 V AC 50/60 Hz                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Suitability for isolation                   | Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Contact position indicator                  | Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Visible break                               | No                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Pollution degree                            | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

#### Complementary

|                               |                                                                                                                                                                                                                                |
|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Control type                  | Rotary handle                                                                                                                                                                                                                  |
| Mounting mode                 | Fixed                                                                                                                                                                                                                          |
| Mounting support              | DIN rail<br>Plate                                                                                                                                                                                                              |
| Upside connection             | Front                                                                                                                                                                                                                          |
| Downside connection           | Front                                                                                                                                                                                                                          |
| Cable cross section           | 1.5...50 mm²                                                                                                                                                                                                                   |
| Maximum power                 | 15 kW AC-23: 230 V NEMA AC 50/60 Hz<br>22 kW AC-23: 220/240 V AC 50/60 Hz<br>22 kW AC-23: 500/525 V AC 50/60 Hz<br>30 kW AC-23: 480 V NEMA AC 50/60 Hz<br>37 kW AC-23: 380/415 V AC 50/60 Hz<br>37 kW AC-23: 440 V AC 50/60 Hz |
| Rated duty                    | Uninterrupted                                                                                                                                                                                                                  |
| Intermittent duty class       | Class 120 - 60 %                                                                                                                                                                                                               |
| Enclosure dimensions for Ithe | 190 mm x 115 mm x 55 mm                                                                                                                                                                                                        |

The information provided in this document contains general descriptions and/or technical characteristics of the products of the Schneider Electric group. It is not intended to be used for determining suitability or reliability of these products for specific user applications. It is the duty of any such user or integrator to perform the appropriate and complete risk analysis, evaluation and testing of the products with respect to the relevant specific application or use thereof. Neither Schneider Electric Industries SAS nor any of its affiliates or subsidiaries shall be responsible or liable for misuse of the information contained herein.

|                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| [Icw] rated short-time withstand current | 0.067 kA ( 20 s ) conforming to IEC 60947-3<br>1.73 kA ( 3 s ) conforming to IEC 60947-3<br>3 kA ( 1 s ) conforming to IEC 60947-3<br>5.5 kA ( 30 s ) conforming to IEC 60947-3                                                                                                                                                                                                                                                                          |
| Mechanical durability                    | 20000 cycles                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Electrical durability                    | 1500 cycles 220/240 V AC 50/60 Hz AC-22A:<br>1500 cycles 380/415 V AC 50/60 Hz AC-22A:<br>1500 cycles 440 V AC 50/60 Hz AC-22A:<br>1500 cycles 500 V AC 50/60 Hz AC-22A:<br>1500 cycles 220/240 V AC 50/60 Hz AC-23A:<br>1500 cycles 380/415 V AC 50/60 Hz AC-23A:<br>1500 cycles 440 V AC 50/60 Hz AC-23A:<br>1500 cycles 500 V AC 50/60 Hz AC-23A:<br>1500 cycles 125 V 2 poles in series DC DC-22A:<br>1500 cycles 125 V 2 poles in series DC DC-23A: |
| Connection pitch                         | 18 mm                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Height                                   | 85 mm                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Width                                    | 90 mm                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Depth                                    | 62.5 mm                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Product weight                           | 0.5 kg                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

#### Environment

|                                       |                              |
|---------------------------------------|------------------------------|
| Standards                             | IEC 60947-1<br>IEC 60947-3   |
| Product certifications                | CCC<br>KEMA-KEUR             |
| IP degree of protection               | IP40 conforming to IEC 60529 |
| IK degree of protection               | IK07 conforming to EN 50102  |
| Ambient air temperature for operation | -25...70 °C                  |
| Ambient air temperature for storage   | -50...85 °C                  |

## 3.10.7.6. Schneider Electric NSX400N

PVR\*: 2855.22 EUR

**Principal**

|                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Estatus comercial                            | Comercializado                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Gama                                         | Compact                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Tipo de producto o componente                | Disyuntor                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Nombre del dispositivo                       | Compact NSX400N                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Aplicación dispositivo                       | Motor                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Número de polos                              | 3P                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Descripción polos protegidos                 | 3t                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Tipo de red                                  | CA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Frecuencia asignada de empleo                | 50/60 Hz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| [In] corriente nominal                       | 400 A ( 40 °C )<br>320 A ( 65 °C )                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| [Ui] Tensión asignada de aislamiento         | 800 V CA 50/60 Hz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| [Uimp] Tensión asignada de choque            | 8 kV                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| [Ue] Tensión asignada de empleo              | 690 V CA 50/60 Hz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Tipo de poder de corte                       | N                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Poder de corte                               | Icu 42 kA en 440 V CA 50/60 Hz de acuerdo con IEC 60947-2<br>En 480 V CA 50/60 Hz de acuerdo con NEMA AB1<br>Icu 50 kA en 380/415 V CA 50/60 Hz de acuerdo con IEC 60947-2<br>50 kA en 480 V CA 50/60 Hz de acuerdo con UL 508<br>20 kA en 600 V CA 50/60 Hz de acuerdo con UL 508<br>Icu 30 kA en 500 V CA 50/60 Hz de acuerdo con IEC 60947-2<br>En 600 V CA 50/60 Hz de acuerdo con NEMA AB1<br>Icu 10 kA en 660/690 V CA 50/60 Hz de acuerdo con IEC 60947-2<br>Icu 85 kA en 220/240 V CA 50/60 Hz de acuerdo con IEC 60947-2<br>Icu 22 kA en 525 V CA 50/60 Hz de acuerdo con IEC 60947-2<br>85 kA en 240 V CA 50/60 Hz de acuerdo con UL 508<br>En 240 V CA 50/60 Hz de acuerdo con NEMA AB1 |
| [Ics] poder de corte en servicio             | Ics 42 kA 440 V CA 50/60 Hz de acuerdo con IEC 60947-2<br>Ics 30 kA 500 V CA 50/60 Hz de acuerdo con IEC 60947-2<br>Ics 50 kA 380/415 V CA 50/60 Hz de acuerdo con IEC 60947-2<br>Ics 10 kA 660/690 V CA 50/60 Hz de acuerdo con IEC 60947-2<br>Ics 85 kA 220/240 V CA 50/60 Hz de acuerdo con IEC 60947-2<br>Ics 11 kA 525 V CA 50/60 Hz de acuerdo con IEC 60947-2                                                                                                                                                                                                                                                                                                                               |
| Aptitud al seccionamiento                    | Sí de acuerdo con IEC 60947-2<br>Sí de acuerdo con EN 60947-2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Categoría de empleo                          | A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Unidad de control                            | Micrologic 1.3 M                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Tipo de unidad de control                    | Electrónico                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| Funciones de protección de unidad de control | I                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Corriente de rearme                          | 320 A ( 65 °C )                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

### 3.10.8. Battery Charger catalogue

#### 3.10.8.1. MASTERVOLT Mass 24/75

## Mass 24/75



Product code: 40020756

**MASTERVOLT**  
THE POWER TO BE INDEPENDENT

## For the toughest tasks

Mass battery chargers are designed for the toughest conditions for professional, semi-professional and recreational purposes. Even under the most extreme conditions the products from the Mass series operate faultlessly, giving you round-the-clock output when necessary. The sustainability and technologies that underpin the Mass concept have long been proven in practice. With an MTBF of 280,000 hours at full capacity and 24/7 use, the Mass products are ideal for the toughest tasks and any situation that requires a reliable power supply.

### Making the best even better

The reliability and long lifespan of Mastervolt's battery chargers have been established beyond doubt over the past 20 years. While the Mass products have evolved with the latest technological developments, the dimensions and connections have remained the same. As a result it is exceptionally easy to replace one unit with another with only negligible downtime.

### Mastervolt Green by Heart

As part of our constant search for eco-friendly and long-lasting solutions, Mastervolt has developed the Green by Heart programme. Its impact on the Mass battery chargers include:

- An exceptionally effective use of the consumed input current ( $\cos \phi$ ) > 0.98!
- Faster charging of batteries, even when the input current is limited.
- Use of top quality components with a long lifespan.
- Savings in weight and space.
- Fewer installation materials.



## Specifications

### General specifications

|                                      |                                              |
|--------------------------------------|----------------------------------------------|
| Nom. output voltage                  | 24 V                                         |
| Total charge current                 | 75 A                                         |
| Number of battery outlets            | 1                                            |
| Battery capacity range               | 150-750 Ah                                   |
| Nominal input voltage                | 230 V (180-265 V), 50/60 Hz                  |
| Supplies your system without battery | yes                                          |
| Display/read-out                     | LED display                                  |
| Dimensions, hwxwd                    | 420 x 318 x 130 mm<br>16.5 x 12.5 x 5.1 inch |
| Weight                               | 7.7 kg<br>17.0 lb                            |
| Approvals                            | CE, ABYC A-31, RRR, RS, Lloyds, DNV, GL      |

### Technical specifications

|                                          |                                                                      |
|------------------------------------------|----------------------------------------------------------------------|
| Charge characteristic                    | IUoUo, automatic 3-step+ for gel/AGM/wet/Lithium Ion                 |
| Charge voltage Bulk                      | 28.5 V                                                               |
| Charge voltage Absorption                | 28.5 V                                                               |
| Absorption time                          | 4 hours                                                              |
| Charge voltage Float (wet batteries)     | 26.5 V                                                               |
| Charge voltage Float (gel/AGM batteries) | 27.6 V                                                               |
| Temperature compensation                 | -60 mV/ °C<br>-33 mV/ °F                                             |
| Voltage compensation                     | voltage drop compensation in DC cables up to 3 V                     |
| Power consumption (DC side)              | < 1 mA                                                               |
| Full load consumption (230 V AC)         | 2600 W                                                               |
| Power factor control                     | > 0.95                                                               |
| Temperature range (ambient temp.)        | -25 °C to 80 °C, derating > 45 °C<br>-13 to 176 °F                   |
| Cooling                                  | vario fan                                                            |
| Sound level                              | < 48 dBA at 1 mtr                                                    |
| Protection degree                        | IP23                                                                 |
| Protections                              | over temperature, over load, short circuit, high/low battery voltage |
| MasterBus compatible                     | yes                                                                  |
| CSI/DC alarm                             | integrated in the battery charger as standard                        |

**MASTERVOLT**  
THE POWER TO BE INDEPENDENT

### 3.10.9. Switchboard catalogue

#### 3.10.9.1. Legrand XL<sup>3</sup> 160

XL<sup>3</sup> 160 ENCLOSURES

## Class II insulated enclosures

2

XL<sup>3</sup> 160 insulated enclosures with dimensions optimised for distribution up to 160 A.

These enclosures are divided into:

- "Fully modular" enclosures with 2 to 6 rows. These can take the DPX 125 and the Vistop 160 with no need for any accessories
- Enclosures with dedicated space and 3 or 4 modular rows, for integrating French tariff kits or the DPX 160.

XL<sup>3</sup> 160 insulated enclosures have been designed to simplify wiring and connection:

- Side panels can be removed separately
- Removable chassis
- Frame can be dismantled

XL<sup>3</sup> 160 also offers original solutions for holding and running the wiring, a large working area and a high-quality finish.

### CHARACTERISTICS

Class II @ insulated enclosure

Short-circuit resistance Ipk: 20 kA

IP 30, IP 40 with door and IP 43 with door and seal

IK 04, IK 07 with door

Conforming to standards IEC 60439-1 and 60439-3

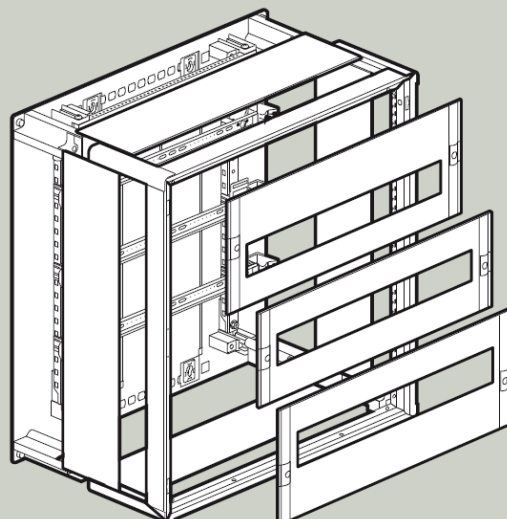
Fireproof according to IEC 60695-2-1-750°C/5s

Suitable for installations in public buildings

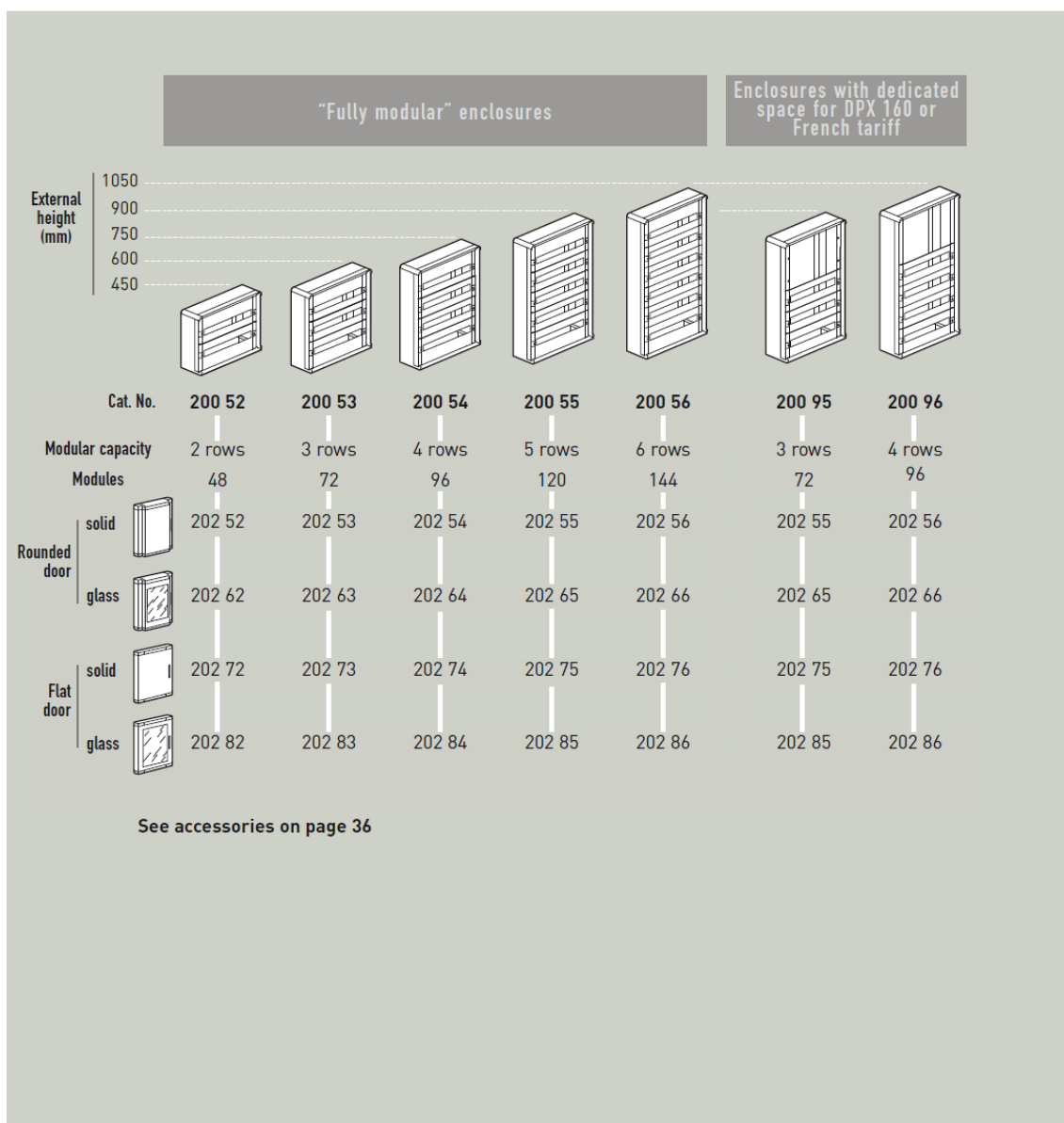
Can take devices up to 160 A

Colour RAL 7035

Supplied complete with rails and faceplates, wire guide rings for vertical wiring and brass bar for protective conductors.







### 3.10.10. High-current socket

#### 3.10.10.1. Marechal PFQ3

## PFQ3 & Q4

HIGH-CURRENT PLUGS &amp; SOCKETS

315 A and 400 A  
IP66/IP67

#### MAIN FEATURES

|                              |                             |                                   |                          |
|------------------------------|-----------------------------|-----------------------------------|--------------------------|
| Rated current                | 315 A (PFQ3) / 400 A (PFQ4) | Flexible wiring (min-max)         | 95 - 185 mm <sup>2</sup> |
| Maximum voltage              | 690 V                       | Stranded wiring (min-max)         | 95 - 185 mm <sup>2</sup> |
| IP protection lid closed     | IP66/IP67                   | Wiring for single or multi entry  |                          |
| IP protection connected plug | IP66/IP67                   | Keying positions                  | 10                       |
| Shock resistance             | IK10                        | Auxiliary contacts (10 A / 400 V) | 6                        |
| Ambient temperature          | -40 °C to +60 °C            | Pilot contacts (10 A / 400 V)     | 2                        |



| Voltage 50 Hz | Polarity | Part no. | Part no. |
|---------------|----------|----------|----------|
| 380 - 440 V   | 3P+E     | 4734013  | 4738013  |
| 380 - 440 V   | 3P+N+E   | 4734017  | 4738017  |
| 660 - 690 V   | 3P+E     | 4734193  | 4738193  |
| 660 - 690 V   | 3P+N+E   | 4734197  | 4738197  |

► Other voltages, frequencies and contact configurations are available (see page 10).



| Voltage 50 Hz | Polarity | Part no. | Part no. |
|---------------|----------|----------|----------|
| 380 - 440 V   | 3P+E     | 4744013  | 4748013  |
| 380 - 440 V   | 3P+N+E   | 4744017  | 4748017  |
| 660 - 690 V   | 3P+E     | 4744193  | 4748193  |
| 660 - 690 V   | 3P+N+E   | 4744197  | 4748197  |

► Other voltages, frequencies and contact configurations are available (see page 10).

## BOXES

Cable gland included



Wiring from 95 to 150 mm<sup>2</sup>

Wiring from 150 to 185 mm<sup>2</sup>

|            | Wiring from 95 to 150 mm <sup>2</sup> | Wiring from 150 to 185 mm <sup>2</sup> |
|------------|---------------------------------------|----------------------------------------|
| 46 - 50 mm | 474A023951                            | 474A023241                             |
| 51 - 55 mm | 474A023952                            | 474A023242                             |
| 56 - 60 mm | 474A023953                            | 474A023243                             |
| 61 - 65 mm | 474A023954                            | 474A023244                             |
| 66 - 70 mm | 474A023955                            | 474A023245                             |
| 71 - 75 mm | 474A023956                            | 474A023246                             |
| 76 - 80 mm | 474A023957                            | 474A023247                             |
| 81 - 85 mm | 474A023958                            | 474A023248                             |
| 86 - 90 mm | 474A023959                            | 474A023249                             |

On request: boxes for installation in ducts, boxes equipped with circuit breaker, earth-leakage switch, contactor,...

## HANDLES



Straight \*

Angled 90°

|            | Straight * | Angled 90° |
|------------|------------|------------|
| 46 - 50 mm | 474A013-50 | 474A913-50 |
| 51 - 55 mm | 474A013-55 | 474A913-55 |
| 56 - 60 mm | 474A013-60 | 474A913-60 |
| 61 - 65 mm | 474A013-65 | 474A913-65 |
| 66 - 70 mm | 474A013-70 | 474A913-70 |
| 71 - 75 mm | 474A013-75 | 474A913-75 |
| 76 - 80 mm | 474A013-80 | 474A913-80 |
| 81 - 85 mm | 474A013-85 | 474A913-85 |
| 86 - 90 mm | 474A013-90 | 474A913-90 |

\* Trumpet gland available on request

### INFO +

#### Electrical interlocking

PFC/PFQ devices are not intended for connection or disconnection under load. Electrical interlocking with a switch or a pilot controlled contactor is required. Boxes with the following

equipment are available upon request:

- circuit breaker or differential switch,
- contactor,
- fuses,
- loop-out enclosures,
- terminals for single pole cables...

See next page: « how to wire a PF »

#### ACCESSORIES & OPTIONS

Key for locking and operating pilot contacts  
473A824



Inlet lid  
474A126





## 4. BLUEPRINTS

Electrical Engineering Degree

**Author:** Daniel Benítez Aragón

**Director:** Juan Antonio Palacios García

**Co-Director:** Germán Jiménez Ferrer

**Blueprints**

**4. BLUEPRINTS.....337**

4.1. General Blueprint.....339

4.2. General Layout.....339

4.3. General One-Line Diagram.....339

4.4. Passengers Room 230 Vac.....339

4.5. Entrance & Toilet 230 Vac.....339

4.6. Anteroom 230 Vac.....339

4.7. Bridge 230 Vac & 24 Vdc.....339

4.8. Engine Rooms & Electrical Compartments 230.....339

**4.1. General Blueprint**

**4.2. General Layout**

**4.3. General One-Line Diagram**

**4.4. Passengers Room 230 Vac**

**4.5. Entrance & Toilet 230 Vac**

**4.6. Anteroom 230 Vac**

**4.7. Bridge 230 Vac & 24 Vdc**

**4.8. Engine Rooms & Electrical Compartments 230**





## 5. TERMS AND CONDITIONS

Electrical Engineering Degree

**Author:** Daniel Benítez Aragón

**Director:** Juan Antonio Palacios García

**Co-Director:** Germán Jiménez Ferrer

## Terms and Conditions

|                                                                  |            |
|------------------------------------------------------------------|------------|
| <b>5.TERMS AND CONDITIONS.....</b>                               | <b>340</b> |
| 5.1.Aim.....                                                     | 345        |
| 5.1.1.Contract aim.....                                          | 345        |
| 5.1.2.Terms and Conditions aim.....                              | 345        |
| 5.2.General requirements.....                                    | 345        |
| 5.2.1.General terms.....                                         | 345        |
| 5.2.2.Blueprints.....                                            | 346        |
| 5.2.3.Energy sources quality.....                                | 347        |
| 5.2.4.Location and construction of the electrical equipment..... | 348        |
| 5.2.5.Ground connections.....                                    | 349        |
| 5.3.General terms.....                                           | 350        |
| 5.3.1.General terms aim.....                                     | 350        |
| 5.3.2.Range of application.....                                  | 350        |
| 5.3.3.Technical requirements.....                                | 351        |
| 5.3.4.Legal provisions.....                                      | 351        |
| 5.3.5.Director authority.....                                    | 351        |
| 5.3.6.Contractor.....                                            | 352        |
| 5.3.7.Work data.....                                             | 352        |
| 5.3.8.Work rethinking.....                                       | 353        |
| 5.3.9.Improvements and variations of the project.....            | 353        |
| 5.3.10.Organization.....                                         | 353        |
| 5.3.11.Work implementation.....                                  | 354        |
| 5.3.12.Monitoring of the work.....                               | 354        |
| 5.3.13.Control book.....                                         | 355        |
| 5.3.14.Inquiries request.....                                    | 355        |
| 5.3.15.Proposal content.....                                     | 355        |
| 5.3.16.Awarding.....                                             | 356        |
| 5.3.17.Withholdings.....                                         | 356        |

|                                                                                          |     |
|------------------------------------------------------------------------------------------|-----|
| 5.3.18.Delay penalization.....                                                           | 356 |
| 5.3.19.Permissions and licenses.....                                                     | 356 |
| 5.3.20.Termination of the contract causes.....                                           | 356 |
| 5.3.21.Subcontracting.....                                                               | 357 |
| 5.3.22.Implementation period.....                                                        | 358 |
| 5.3.23.Provisional review.....                                                           | 358 |
| 5.3.24.Warranty periods.....                                                             | 359 |
| 5.3.25.Final acceptance.....                                                             | 359 |
| 5.3.26.Work payment.....                                                                 | 359 |
| 5.3.27.Materials payment.....                                                            | 360 |
| 5.3.28.Termination.....                                                                  | 360 |
| 5.4.Economic terms.....                                                                  | 361 |
| 5.4.1.Price composition.....                                                             | 361 |
| 5.4.2.Contract cost.....                                                                 | 361 |
| 5.4.3.Contradictory prices .....                                                         | 361 |
| 5.4.4.Price increases complaints due to different causes .....                           | 362 |
| 5.4.5.Review of the contracted prices.....                                               | 362 |
| 5.4.6.Material supply.....                                                               | 363 |
| 5.4.7.Constructor responsibilities with poor performance of the operators.....           | 363 |
| 5.4.8.Unjustified work improvements .....                                                | 363 |
| 5.4.9.Payment of budgeted works.....                                                     | 364 |
| 5.4.10.Payments.....                                                                     | 364 |
| 5.4.11.Compensation due to non-justified delays in the termination of the works<br>..... | 364 |
| 5.4.12.Payment delays.....                                                               | 365 |
| 5.4.13.Work upgrades. Contrary cases.....                                                | 365 |
| 5.4.14.Defective but acceptable work units.....                                          | 365 |
| 5.4.15.Work insurance.....                                                               | 366 |
| 5.4.16.Works conservations.....                                                          | 366 |
| 5.4.17.Goods usage by the Contractor.....                                                | 366 |
| 5.5.Technical conditions of performance and assembly of the electrical system.....       | 367 |

|                                                                        |     |
|------------------------------------------------------------------------|-----|
| 5.5.1.General terms.....                                               | 367 |
| 5.5.2.Main power supply system.....                                    | 368 |
| 5.5.2.1.General terms.....                                             | 368 |
| 5.5.2.2.Amount and power capacity of the main power supply system..... | 368 |
| 5.5.2.3.Amount of power capacity of the converters.....                | 368 |
| 5.5.3.Emergency power supply system.....                               | 369 |
| 5.5.3.1.General terms.....                                             | 369 |
| 5.5.4.External power supply system.....                                | 370 |
| 5.5.4.1.General terms.....                                             | 370 |
| 5.5.5.Power supply and distribution.....                               | 370 |
| 5.5.5.1.Supply and distribution systems.....                           | 370 |
| 5.5.6.Utilization factor.....                                          | 372 |
| 5.5.7.Lighting circuits.....                                           | 372 |
| 5.5.8.Motor circuits.....                                              | 373 |
| 5.5.9.Motor control.....                                               | 373 |
| 5.5.10.Protections.....                                                | 374 |
| 5.5.10.1.General terms.....                                            | 374 |
| 5.5.10.2.Short-circuit protection.....                                 | 375 |
| 5.5.10.3.Overload protection.....                                      | 375 |
| 5.5.10.4.Motor protection.....                                         | 375 |
| 5.5.10.5.Power converters protection.....                              | 376 |
| 5.5.11.Switchboard implementation.....                                 | 376 |
| 5.5.11.1.General terms.....                                            | 376 |
| 5.5.11.2.Location.....                                                 | 376 |
| 5.5.12.Cables.....                                                     | 377 |
| 5.5.12.1.Voltages.....                                                 | 379 |
| 5.5.12.2.Operating temperature.....                                    | 379 |
| 5.5.12.3.Construction.....                                             | 380 |
| 5.5.12.4.Size.....                                                     | 381 |
| 5.5.12.5.Cable installation.....                                       | 384 |
| 5.5.12.6.Mechanical protection of cables.....                          | 385 |

|                                                                                   |     |
|-----------------------------------------------------------------------------------|-----|
| 5.5.12.7.Fixing of cables.....                                                    | 386 |
| 5.5.12.8.Penetration of bulkheads by cables.....                                  | 387 |
| 5.5.12.9.Installation of protective enclosures in cables.....                     | 387 |
| 5.5.12.10.One core cables for alternating current.....                            | 388 |
| 5.5.12.11.Ends of the cables.....                                                 | 388 |
| 5.5.12.12.Joints and circuits in cable systems.....                               | 389 |
| 5.5.12.13.Lighting. General terms.....                                            | 389 |
| 5.5.12.14.Incandescent and halogen lighting.....                                  | 389 |
| 5.5.12.15.Fluorescent lighting.....                                               | 390 |
| 5.5.12.16.Plugs and sockets.....                                                  | 390 |
| 5.6.Electrical equipment in flammable gas atmospheres or with pulverized fuel.... | 391 |
| 5.6.1.General terms.....                                                          | 391 |
| 5.7.Navigation and operation systems.....                                         | 391 |
| 5.7.1.Command devices.....                                                        | 391 |
| 5.8.Navigation lights.....                                                        | 392 |
| 5.8.1.General terms.....                                                          | 392 |
| 5.9.Fire-fighting system.....                                                     | 392 |
| 5.9.1.Fire detection and alarm systems.....                                       | 392 |
| 5.10.Emergency security systems.....                                              | 393 |
| 5.10.1.Emergency lighting.....                                                    | 393 |
| 5.10.2.Emergency alarm system.....                                                | 394 |
| 5.10.3.Public address system.....                                                 | 394 |
| 5.11.Terms of use, maintenance and security.....                                  | 395 |
| 5.11.1.Work security.....                                                         | 395 |
| 5.11.2.Public security.....                                                       | 395 |

## **5.1. Aim**

### **5.1.1. Contract aim**

The aim of this document is the implementation of the whole electrical system in a double-hull vessel, specially its propulsion system.

Due to this, the RFQ document must be presented, in order to start the works previously mentioned. Those works must comply the requirements explained on this section.

The provision of services shall follow the requirements fixed at the Terms and Conditions section.

### **5.1.2. Terms and Conditions aim**

The main purpose of this Terms and Conditions section lays in setting rules for the work offer requests and set the rights and duties of the requesting companies, due to the fact of being it from the very first moment of the request, as well as set all those that may be produced after the first offer, if any.

## **5.2. General requirements**

### **5.2.1. General terms**

The requirements of this chapter apply to passenger ships and cargo ships, except where it is otherwise stated.

While these requirements are considered appropriate by the International Convention for the Safety of Life at Sea (SOLAS), 1974, and their amendments applicable, they may also be given by a Regulatory Statute Authority of the country in which the vessel must be registered. Compliance with Regulatory Statute Authority, may be accepted, meeting on the requirements of the International Convention for the Safety of

Life at Sea, 1974, and their applicable amends.

Electrical services required to keep the ship sailing, whiting operating and liability conditions must be able to keep it without making use of the emergency power supply.

Basic services for security, should be kept under several emergency conditions.

Passengers, crew and ship security must be prevented from the electrical hazardous situations.

Compliance with the International Electrotechnical Commission (IEC), publication 92 "Electrical Installations in Ships", or with an accepted National Charter may be accepted as appropriate to the requirements of this chapter, subject to inspection and test in the presence of the inspector.

### **5.2.2. Blueprints**

At least three copies of the blueprints should be provided for study. Additional copies must be provided when requested.

A single-line diagram of the main and emergency power and lighting system shall include:

- Characteristics of the machines, converters, batteries and semiconductors
- All suppliers connected to the main and emergency switchboards
- Distribution switchboards
- Insulation type, size and load current of the cables
- Closures, types and power of the circuit breakers and fuses.

Blueprints shall count with calculations of short-circuit currents in the main and emergency switchboards.

For ships which explosive atmospheres due to gas and / or pulverized fuel may appear, it must be supplied a blueprint with a general layout of the ship showing the hazardous areas.

A list of the electrical equipment located in hazardous areas, give details of:

- Equipment type
- Type of protection (for example: Ex "d")
- Temperature class(for example: T3)
- Access protection of switchboards (for example: IP55)
- Authority certification
- Certificate number
- Location of the equipment

A top-view of the layout of the ship, representing the location of most of the items of electrical system, for example: main and emergency power suppliers, main and emergency switchboards, etc.

### **5.2.3. Energy sources quality**

Every equipment fed from the main or emergency source of energy must be designed and constructed to be able to work satisfactorily under normal variations of voltage and frequency.

Every equipment shall operate satisfactorily with the following variations of their parameters when they are measured at the entrance of the terminal.

- Voltage:



- Permanent changes: + 6%, -10%.
- Transients: + 20%, -15%.
- Recovery time: 1.5 seconds.
- Frequency:
  - Permanent changes: + 5%.
  - Transient variations:  $\pm 10\%$ .
  - Recovery time: 5 seconds.

#### **5.2.4. Location and construction of the electrical equipment**

Electrical equipment, as far as possible, should be located in an accessible place, free of flammable materials, well ventilated areas, where flammable gases may not be stored and where they are not exposed to the risk of mechanical damage or water, steam or oil. If they are necessarily exposed to such risks, the equipment must be properly constructed or isolated. Current carrying parts must be insulated, where necessary.

All appliances must be constructed, and installed so as not to cause injury when handled or touched during normal operation.

The insulation material and the isolated winding must be fire retardant and resistant to shock, water, sea air and oil mist, unless special precautions are taken to protect them.

The control circuits and / or pilot lamps shall not have current flowing through them when they are disconnected from the control switch. This shall not be applied to synchronism switches and / or sockets.

Operation of all electrical equipment and lubrication devices must be efficient under vibration and shock conditions that may occur during normal operation.

All nuts and screws used in with connection meanings must be tight.

Conductors and equipment must be located at enough distance from magnetic compasses, or should be arranged so that the interference of the magnetic field are negligible when circuits are connected or disconnected.

Where electric power is used for propulsion, equipment must be located to work satisfactorily in the case of a partial flooding bilge water over the top of the tank, above the floor level.

#### **5.2.5. Ground connections**

All metal parts of electrical equipment not exposed to current and cables must be grounded.

The metal covers of cables must be effectively grounded at both ends of the cables. In the final sub-circuits, rather than installed in hazardous areas or spaces, it shall only be considered adequate grounding at the end of the supply. Simple sockets may be accepted for instrumentation cables if considered for technical reasons.

Electrical continuity in metal covers of the cables must be assured along the entire length of the cable, specifically at the joints and sockets.

The metal parts of portable instruments must be grounded by a continuous flexible cable.

Grounding conductors must be made of copper or other corrosion-resistant material and be securely installed and protected, where necessary, against damage and against electrolytic corrosion. Connections must be secured so they can not work loosely under vibration situations.

The cross section of the copper cables is generally equal to the cross section of the conductors carrying current higher than 16 mm<sup>2</sup>. Above that value, they must be

equal to the section of the current carrying cable with a minimum of 16 mm<sup>2</sup>. All other grounding cables must have a conductance no less than that specified for an equivalent grounding cable.

The connection of the grounding conductor in the hull, must be made in an accessible place, and must be secured by a screw or pin with a diameter greater than 6 mm, which should only be used for this purpose. Shiny metal surfaces in contact areas must be secured immediately before the nut or screw is tightened, and where necessary, the union must be protected against electrolytic corrosion. The connection shall be unpainted.

### **5.3. General terms**

#### **5.3.1. General terms aim**

This section aims to set those terms on which must lay the contracting and performance of every work that conforms this project.

#### **5.3.2. Range of application**

The terms that have been set on this section are thought to supply enough guarantees of proper performance in every device that conforms the calculated installation. Besides, security rules and length must be set to physical elements as well as the performance and set up procedures. All of this shall be based on the regular and responsible use of the said elements.

The official certificates needed before the supply and the placing of the materials are named on these general terms, as well as the tests that are thought to be required by the direction, in order to check if the quality fulfils the specifications stated by the supplier.

### **5.3.3. Technical requirements**

All the materials used must comply the quality specified by the technical documents.

The contractor shall be responsible in the case of an improper final assembly. Once that the work is definitely awarded, and before it begins, the contractor must present, at the request of the work director, all information and material samples that are related to the budget and the tender submitted.

Materials that have not been admitted by the director will not be certified. This previous control shall not constitute their final acceptance, due to the fact that they may be rejected if, even after their placement, they fail to comply the required conditions, which means that they must be replaced by material which does comply those requirements.

### **5.3.4. Legal provisions**

The Contractor is obliged to comply with the regulations of their job, the hiring of compulsory insurance, family and old age allowances, and of sickness insurance and all the social regulations applicable or which may hereafter be issued.

The Contractor shall be classified, according to Order of the Ministry of Finance, in the group, subgroup and category related to the project and to be set in the Terms and Conditions documents, if appropriate.

### **5.3.5. Director authority**

The Director will be responsible for solving, in general, all problems arising during the implementation of the works of this project, according to the powers granted by the legislation.

Specially, the Contractor shall follow their instructions referring to the quality

and storage of materials, implementation of construction units, interpretation of blueprints and specifications, modifications of the project, implementation program of work and precautions to be taken while developing them as well as matters related to the conservation of landscape aesthetics that may be affected by the installations.

#### **5.3.6. Contractor**

The contractor may be every natural or legal person who has legal or technical right to perform it. The rights of the contractor, according to the Spanish law rules, must exist and be credited at the moment of the first offer or contract.

Offers may be presented only by manufacturers or sellers of the installations implemented in this project, through themselves or their legal representatives. Any of them may credit the document given by bidding company, according to the requirements demanded by law.

The offers presented by the contractors verify the acceptance of each and every clause of this Articles and Condition section and those clauses established on the offer.

#### **5.3.7. Work data**

A copy of the blueprints and specifications of the project will be delivered to the Contractor, as well as those blueprints or data necessary for the full execution of the work.

The Contractor can make a copy, at their expense, Memory, Annexes and second copies of all documents. The Contractor is responsible for the preservation of the original from which gets copies, which will be returned to the Director after its use.

Moreover, within a period of two months after the completion of the work, the Contractor must update the various existing blueprints and documents, according to the characteristics of the finished work, delivering the Director two full dossiers of the work

actually executed.

The Contractor will not make alterations, corrections, omissions, additions or substantial changes in the data set in the project without prior written approval of the Director.

#### **5.3.8. Work rethinking**

When the Contractor has the project and before starting the works, the Director will be able to perform a rethinking of works paying special attention to the singular points, delivering to the Contractor those references and data needed to set their location . It will be necessary a duplicated record, which must reflect clearly the data provided, signed by the Director and the representative of the Contractor.

Rethinking costs shall be paid by the Contractor.

#### **5.3.9. Improvements and variations of the project**

They shall be considered as improvements or changes in the project those that have been expressly ordered in writing by the Director, with a fixed price prior to their execution.

Accessory or delicate works not included in the award prices, may be implemented with separate personnel of the Contractor.

#### **5.3.10. Organization**

The Contractor shall act as the legal representative, accepting all the responsibilities and being forced to pay wages and charges that are legally established, and generally everything that is legislated before or during the execution of the work. Within the terms of the Terms and Conditions documents, the organization of the work as well as and the determination of the origin of the used materials, shall be done by the Contractor who is responsible of the security against accidents.

However, the Contractor shall inform the Director of all arrangements of technical organization of the work, as well as the source of the materials and comply with the orders given by the Director concerning extreme data.

In the administration works, the Contractor shall provide daily report to the Director of admission of personnel, purchase of materials, rental of aids and all costs required. For employment contracts, material purchase or aid rentals, whose wages, prices or quotas exceed by more than 5% of the normal price in market, the Contractor shall seek the prior approval of the Director, who must respond within the following eight days the request, except in cases of urgency.

#### **5.3.11. Work implementation**

Works will be implemented according to the Project and the conditions contained in these Terms and Conditions and the special Terms and Conditions, if any.

Unless by a Director approval in writing, the Contractor shall not make any alteration or modification of any kind in the implementation of the work according to the project or in the technical conditions.

The Contractor shall be responsible for the external staff which may be required for the administrative monitoring.

The Contractor shall choose a specialized technician for conducting the works, and he must be accepted by the Director.

#### **5.3.12. Monitoring of the work**

The Director will establish the monitoring of works that he considers as necessary. For all expenses related to surveillance, including wages, displacements, materials testing (mechanical and chemical), etc, the Contractor will pay each month for

the corresponding amount.

#### **5.3.13. Control book**

In order to reach a proper coordination of the work and to avoid doubts and misunderstandings, the Contractor shall have available a control book in which shall be recorded in a diary form the executions and variations that may happen. Each work visit must count with a signing of the project management and the person responsible of the work in the Contractor's name.

This book shall have numbered and signed pages and will be on the work location during the its duration. When modifications or variations are stated in drawings or plans, they shall be dated and signed by both parties.

#### **5.3.14. Inquiries request**

Companies with interest in presenting offers may visit the installations explained in this Terms and Conditions section. Also, they may make any explanatory inquiry that they consider as appropriate.

#### **5.3.15. Proposal content**

Offers must be presented in a closed envelope and signed by the contractor, representative person or the company concerned. In this offer, its content and tenderer name shall be declared. The closed envelope must have these documentations:

- Documents that credit the legal condition of the tenderer.
- Terms and Conditions observations: The bidding company may submit any observation that they want in this section, both administrative conditions and technical conditions. Those observations must be referred to the different sections on those Terms and Conditions documents that the bidding company may consider appropriate.
- Economic proposal. They must show the performance budget, (in unitary costs),



the whole budget of material implementation, the percentage of industrial profit applied, and 1% of the corresponding IVA tax, in order to obtain the performance budget.

- Works plan: The bidding company must present a work plan which shall contain the conclusion dates of the implementation phases.

#### **5.3.16. Awarding**

The work plan may be awarded to one or two bidding companies. Once that the offer or offers that are more favourable have been approved (or rejected), every tenderer must be informed with the final decision.

#### **5.3.17. Withholdings**

From the total amount paid to the contractor, a 5% of guarantee withholding shall be discount, which must be paid before one year of the period provided.

#### **5.3.18. Delay penalization**

If the period of time set by the tenderer in his proposal has been exceeded, a delay penalization of 1% shall be required for each day of delay from the original date of the works conclusion. This may be avoided only by any reason beyond their control.

#### **5.3.19. Permissions and licenses**

The contractor must paid all the permissions and licenses required for the works implementation. The contractor must pay as well the making of all documents and paperworks required for the legalization of every installation at the industrial delegation. Instances of application fro approval and launching must be managed by the contractor too. The installations are not considered as finished until those documents are fully completed.

#### **5.3.20. Termination of the contract causes**

Whenever recidivism has done to any of the faults listed, there may appear

causes to the termination of the contract, without any economic compensation to the contractor company.

- If the contractor company was not complying with the offers requirements.
- If the contractor company did not maintain their commitments with the works implementation.
- If the contractor company was not complying any of the rest fixed requirements.
- The lack of observance in the work security measures.
- Produce damage actions to the installations or services of the property.
- Non-compliance with the current labour laws, specially the non-payment taxes and social security.

#### **5.3.21. Subcontracting**

The contractor company may not contract services from other company to implement some property committed duties without a previous report to the property, which must give its explicit unconditional written agreement before the subcontracting, reserving the right to reject it.

The contractor company shall assume in any case the whole responsibility of the work implementation, according to fixed requirements, as well as the total amount of the penalizations derived from the lack of compliance of the fixed economic agreements.

Related rules must complete the prescriptions of this Terms and Conditions section referring to those materials and work units which have not been mentioned in it specifically, depending on the judgement of the director engineer whether study the contradictions.

Subcontracts shall comply with the following requirements:

- The Director must know in writing the subcontract work, showing parts of work to be done and their economic conditions, in order to obtain previously the Director's agreement.
- Units of work shall not exceed 50% of the total budget of the main work.

In any case, the Contractor shall not be linked at all nor recognize any contractual obligation between him and any subcontractor. Moreover, any subcontracting of works shall not relieve the Contractor of any of its obligations to the Employer.

#### **5.3.22. Implementation period**

Complete and partial deadlines indicated in the contract, shall start from the rethinking date.

The Contractor shall comply with the deadlines that are indicated in the contract for the implementation of the works and they shall not be extended.

Nevertheless, deadlines may be modified when it is to be determined by the Director due to requirements of the completion of the work

If for any reason, completely unrelated to the Contractor , it is not possible to start the works on schedule or had to be stopped once started, the extension strictly necessary will be granted by the Director.

#### **5.3.23. Provisional review**

Once construction is completed, on the following 15 days from the request of the Contractor, a provisional reception of them shall occur by the Employer. The presence of the Director and Contractor's representative shall be necessary, with its corresponding record, in which shall state conformity with the work, if this is the case. The record shall be signed by the Director and the representative of the Contractor. The work would

considered as received if its implementation is correct, according to the requirements of the Terms and Conditions documents.

In the case that the work has not been received, it must be reflected on the record and the Contractor will be given the required instructions in order to repair the observed defects, setting a deadline. Once that period has expired, there will be a new examination. The repair shall be borne by the Contractor. If the Contractor fails to meet these requirements, it will be possible to declare the contract as terminated with consequential loss of the deposit.

#### **5.3.24. Warranty periods**

The warranty period shall be that one stated in the contract and shall start from the date of approval of the record, until final acceptance takes place. The Contractor is responsible for the conservation of the work, being their responsibility defect reparations due to bad execution or poor quality materials.

During this period, the Contractor shall afford the Employer against all third party claims.

#### **5.3.25. Final acceptance**

Once the warranty period specified in the contract is over, or after six months of provisional acceptance, final acceptance of the works shall start, with the presence of the Director and the representative of the Contractor, being necessary its proper record in a duplicate form (if the works are in conformity), which shall be signed by the Director and Contractor's representative and ratified by the Employer and the Contractor.

#### **5.3.26. Work payment**

Work payment shall be done in a monthly basis. Certificates containing only units completely finished shall be needed. Those certificates shall follow the established

prices, reduced by 10%. Scaling, plans and references needed to check them shall be included as well.

The Director shall issue the certificates of the executed works that will be provisional documents. They may be rectifiable by the final settlement or any of the following certifications. Moreover, they will not suppose any approval or acceptance of the work performed.

#### **5.3.27. Materials payment**

Whenever there is no danger of disappearing or deteriorating collected and useful materials, according to the Director's judgement, they will be paid related to the decomposed prices. Such materials will be indicated by the Director, who must reflect it on the work reception work, noting the deadline periods. The Contractor shall be responsible for any damage occurring in the loading, transport and unloading of the material.

Restitution of empty bobbins shall be made within a month, once the cable contained is installed. In case of delay in their return, damage or loss, the Contractor shall also bear the extra costs that may result.

#### **5.3.28. Termination**

If the implementation of the works was not adequate or of installed material does not gather the required conditions, then it would be possible to lead to the termination of the contract with the loss of the bond, if any, by the Contractor.

In this case a deadline must be fixed in order to complete the units whose stoppage could damage the works. During this period new jobs shall not be started. Supplies of materials that may have been made after the date of termination shall not be certified.

## **5.4. Economic terms**

### **5.4.1. Price composition**

The following items are considered as direct costs:

- Those materials, with the price referring to the work, that stay integrated into the specific unit or that are necessary to their performance.
- Equipment and technical systems to security and sanitation in order to prevent and protect from accidents and professional diseases.
- Overhead costs are conformed of overhead costs of the company, financial costs, burdens and administrative fees, legally established. They shall be expressed as a percentage of the sum of direct costs.
- Industrial profit: The industrial profit of the contractor is established on 4% from the sum of the previous costs.
- Material implementation cost: The material implementation cost is based on the result obtained from the sum of the direct cost.
- Contract cost: The cost of the contract is the sum of the direct costs, overhead costs and the industrial profit.
- The IVA tax is based on that sum but does not integrate the price.

### **5.4.2. Contract cost**

The contract cost is understood as the total cost of the unity of the work, i.e., the material implementation price, added to the percentage (%) of general costs and industrial profit of the contractor. General costs are normally set as 13% and the industrial profit as a 6%, unless the special conditions establish other percentages.

### **5.4.3. Contradictory prices**

Contradictory prices may appear only when the Property, through the director, decide to introduce items or quality changes, or when may be necessary to deal with an unforeseen circumstance. The contractor will be required to implementing the necessary

changes.

With absence of an agreement, the price must be set contradictorily between the technician and the contractor before the work has started and within the period established by the special Terms and Conditions. If the difference remains, the most similar concept within the prices must be used firstly, and as an alternative, the most used bank price in the city may be used as well.

The contradictory prices that may appear must always refer to unitary prices of the contract date.

#### **5.4.4. Price increases complaints due to different causes**

If before the contract signing, the contractor would not have done the complaint or observation required, he or she will not be able to claim an increase in the fixed price of the corresponding budget as a basis for the work performance, under any pretext of mistake or omission.

#### **5.4.5. Review of the contracted prices**

Due to the fact that the works are contracted at their own risk and peril, it will not be admitted the price review as long as the increase of the missing items does not reach an amount higher than 5% of the total budget of the contract.

In case of variations higher than this percentage, a proper review must be carried out, according to the procedure established on the special Terms and Conditions. Thus, the contractor shall receive an allowance corresponding to the difference resulting from a variation of the IPC higher than 5%.

There shall not be a review of the prices of those units that may be out of the provided deadlines in the timetable of the work.

#### **5.4.6. Material supply**

The contractor must give the material supply and machinery required by the property.

Once that are given by the owner, the supplied materials are of his property. Their preservation and caring are managed by the contractor.

#### **5.4.7. Constructor responsibilities with poor performance of the operators**

If in the monthly summary that the constructor must give to the director about the implemented works, the director notices that, in every work or in one of them, the performance of the operators are significantly lower than the regular ones generally admitted for similar operators, the constructor must be warned, in order to make him manage the necessary arrangements to increase the production related to the requirements of the director.

If the constructor has been informed, and in the following months the performance has not experienced an increase, the owner may claim for the difference, lowering the amount of money of the constructor up to 15%. If there is no agreement with the operators performance, this matter shall be attended by law.

#### **5.4.8. Unjustified work improvements**

If the Contractor, even with the authorization of the Director, uses better made materials, or materials with a greater size than those one specified on the project documents, or if he replace them with a more expensive material, or in general, if he makes without authorization any change in the works that is beneficial under the judgement of the director, he will not have rights to additional charges, but the amount of money previously set on the project.



#### **5.4.9. Payment of budgeted works**

Except for what is established about economic matters at the special Terms and Conditions, the payment of the budgeted works must be done according to the procedure required within those explained below:

- If there are fixed prices for similar items, those items without an specific amount units shall be calculated based on the application of the established price.
- Contradictory prices must be set to those items without an specific amount of units if there are fixed prices for similar items
- If there are no fixed prices for similar items, the items without an specific amount of units shall be paid completely to the Contractor, unless the work budget stablish that this payment must be justified. In this case, the Director shall report the Contractor the procedure that must be followed in order to comply that payment. Wages and items shall be refer to the accepted budget prices, or to those which, before the implementation of the work, have been accepted by both parts. Its total cost may be increased with the percentage fixed on the special Terms and Conditions section, referring to general costs and the industrial profit of the contractor.

#### **5.4.10. Payments**

Payments shall be effected by the owner within the periods previously established, and their amount shall correspond to those on the work certifications made by the Director.

#### **5.4.11. Compensation due to non-justified delays in the termination of the works**

Compensation due to non-justified delays must be set in a per thousand rate (‰) of the total cost of the contracted operations. This will be applied for every delay day, starting from the termination date fixed on the work timetable.

The resulting amount shall be discount to the deposit.

#### **5.4.12. Payment delays**

Any application of ruling of the contract based on the delay of payments shall be rejected when the contractor does not justify the budget related to the implementation period within the date specified in the contract.

#### **5.4.13. Work upgrades. Contrary cases**

No work improvements shall be admitted, only in the case where the Director in writing ordered the execution of new works or works that improve the quality of the contract ones, and the materials and equipment under the contract. Work increases in the contracted units shall not be admitted neither, except in case of error in the measurements of the project, unless expanding is ordered by the Director, in writing as well.

In all these cases it is an indispensable condition that both contracting parties, before his execution or implementation, agree in writing the total cost of the improved units, prices of new materials or equipment for using matters and all the increases that these improvements or increases may result on the amount of contracted units.

The same criteria and procedure shall be followed when the Director enter innovations involving a substantial reduction in the amount of contracted work units.

#### **5.4.14. Defective but acceptable work units**

Whenever defective but acceptable work (according to the Technical Director's judgement) is needed to be evaluated, the Technical Director of the works will determine the price after knowing the Contractor's opinion, who must comply with this resolution, except in the case where, being within the implementation period, he prefers to remake the work without exceeding that period.

#### **5.4.15. Work insurance**

The Contractor must insure the contracted work throughout the duration of its implementation, up to the final acceptance. The insurance price shall match with the price of the insured items. In the event of a loss, the amount paid by the Insurance Company shall be paid to the Owner.

The Contractor's refund shall be made by certifications, like the rest of the work. In any case the Owner may not have different necessities than the reconstruction of the damaged parts, unless the Contractor express his consent in a public document. Infringement of this clause shall be sufficient reason to allow the Contractor to terminate the contract with the return of the deposit, full payment of fees, collected materials, etc. as well as a compensation to the Contractor equal to the amount of damages caused, but only equivalent to the compensation paid by the Insurance Company, according to those damages caused by the loss. Those damages shall be assessed by the Technical Director.

Conditions stated in the policy or policies of insurance, shall be informed to the Owner by the Contractor, in order to know if he agrees.

#### **5.4.16. Works conservations**

If the Contractor does not address the conservation of the works during the warranty period (which is his duty), the Technical Director, as the Owner representative, will find anything he needs to take care of the cleaning and all that was necessary for the preservation of the work, being paid by the Contractor.

#### **5.4.17. Goods usage by the Contractor**

During the implementation of the works, if the Contractor uses materials or supplies belonging to the same, under authorization of the Owner, he shall be obliged to repair them and take care of them in order to return them at the contract termination. They must be in perfect condition, and must be necessary a replacement of those which

have been disabled, without compensation for the improvements made to them.

If at the termination of the contract the Contractor has not comply with those requirements, then the Owner shall take responsibilities, paying in the Contractor's name and with fees charged to the deposit.

## **5.5. Technical conditions of performance and assembly of the electrical system**

### **5.5.1. General terms**

All materials used in the electrical system shall be high quality and shall meet the conditions required by the regulations and other existing legal provisions concerning materials.

All materials may be subject to analysis or testing, which are necessary to prove their quality, on behalf of the Contractor. Any other analysis or test that has been specified as necessary must be approved by the Technical Direction. They may be rejected if they do not comply with the conditions of the installation.

Those materials not mentioned in the project that may produce conflicting prices shall meet the conditions required, according to the Director. The Contractor shall not have any rights to ask for a compensation due to those conditions.

All works in this project will be implemented carefully in accordance with the best practices of electrical installations, in accordance with the required regulations as well as a strict compliance with the instructions given by the Director. Therefore, the Contractor shall not use the price reduction as an excuse for those carefully implementations nor those best quality installations.

## **5.5.2. Main power supply system**

### **5.5.2.1. General terms**

The main power supply system shall comply with the requirements of this section, without using to the emergency power supply system

### **5.5.2.2. Amount and power capacity of the main power supply system**

In normal operation, the amount and power of generators and inverters groups shall:

- Be enough to ensure the operation of electrical services for essential equipment, ensuring the living conditions and the machinery.
- Have enough capacity to allow starting the motors without causing any failure. Moreover, the release of a motor or any device due to excessive voltage drop in the system shall be avoided.
- Be capable of providing the electrical services needed to start the main propulsion machinery from a non-current condition. The source of emergency power can be used to help, if they can supply power for the required devices.

The arrangement of the main energy sources must be such that the operation of electrical equipment essential services, living conditions and the machinery is maintained.

### **5.5.2.3. Amount of power capacity of the converters**

The number and power capacity of power converters should be enough to ensure the operation of electrical equipment for essential functions, living conditions and machinery, even when one of the power converters is out of service.

### **5.5.3. Emergency power supply system**

#### **5.5.3.1. General terms**

It must be provided an independent power supply system for emergency situations.

The location of the emergency power supply system, their associated power converters, emergency switchboards and emergency lighting switchboard in relation to the main power supply system, must be such as to ensure that a fire or other casualty in spaces containing the main power supply system, shall not interfere with the supply, control, and distribution of emergency power. Spaces containing the emergency power supply system shall not be next to the boundaries of Category A machinery. If this is not possible, it must provided the details of the proposed provision.

It must be provided appropriate measures to protect in an independently way the emergency operation under all circumstances.

Emergency source of power may be used exceptionally and for short periods to feed circuits that are not an emergency.

The power available should be sufficient to feed all the essential services that ensure safety in an emergency situation. During a reparation of these services, both systems may be operated simultaneously.

During normal operation of the main switchboard, the emergency switchboard must be fed by an interconnection, which must be adequately protected at the main switchboard against overload and short-circuit situations, and must automatically disconnected from the emergency switchboard if there is a fault the main source of electrical energy.

In order to ensure quick accessibility to the emergency power supply system,

provision should be made, where necessary, to automatically disconnect the circuits that are not about emergency devices from the emergency switchboard to ensure that power is available to emergency circuits.

#### **5.5.4. External power supply system**

##### **5.5.4.1. General terms**

If there is a supply of electricity from a source in stowage or elsewhere, there must be installed a switchboard in a suitable location for the convenient reception of flexible cables from the external source. The switchboard shall have circuit breakers and fuses.

Suitable cables must be provided, and they must be permanently fixed, connecting terminals of the switchboard to a switch and / or a circuit breaker in the main switchboard. It must be provided with an indicator in the main switchboard to show when they have current flowing through them.

In the connection box must be provided a note with full information of the power system, the voltage and frequency of the system, and the procedure to connect it to the vessel.

#### **5.5.5. Power supply and distribution**

##### **5.5.5.1. Supply and distribution systems**

The following supply and distribution systems are accepted:

- DC system: One phase, two wires.
- AC system: One phase, two wires.
- AC system: Three phases, three wires. (Four phases with neutral grounded)

In general, the voltage systems for alternating current and direct current shall not exceed the following values:

- 15000 V for power generation and distribution.
- 500 V for cooking and heating equipment, permanently connected to fixed cables.
- 250 V for lighting, heating and other applications not listed previously.

Voltages above those previously defined shall be subject to special consideration.

The arrangement of the main power system shall be such that a fire or other casualty in any space containing the main source of electrical energy, its power converters, the main switchboard and the main lighting switchboard, do not leave inoperable emergency services.

The main switchboard should be located relatively far away from the main source of energy as possible, so that the integrity of the main power system may be affected only by a fire or other casualty in only one space.

The arrangement of the emergency power system shall be such that a fire or other accident in a space containing a source of emergency power, its power converters, the emergency switchboard and the emergency lighting switchboard, do not leave inoperable essential services.

The distribution system required for an emergency must be arranged in such a way that a fire in a main area, defined in SOLAS Chapter II-2 / A - 3.4.9, does not interfere with the emergency distribution in some other area.

Where the total electrical power of the main suppliers exceed 3 kW or it is



supplied with a high voltage, the devices should make possible to divide the switchboard at least in two independent sections, each one powered by at list a supplier, by using fuses or other measures.

Where the previous clause can be applied, and in addition, the essential services are duplicated, they shall be fed from a section switchboard. They must arranged in such a way that makes possible to divide the section switchboard in at least two independent sections, each fed by a separate section from the main switchboard and directly from a power converter.

#### **5.5.6. Utilization factor**

Circuits supplying two or more sub-circuits must be classified in accordance with the total connected load, and where justified, the use of utilization factor. Where spare parts are provided on a section switchboard or distribution switchboard, tolerances shall be implemented for future increases in load.

Utilization factors can be applied to the size of cables and breakers and fuses power calculations, related to the loads duty cycle calculations and the frequency and length of loads of motors.

For winches and lift motors utilization factor must be calculated and provided when required.

#### **5.5.7. Lighting circuits**

A final sub-circuit with an intensity exceeding 16A shall not feed more than one light point.

In final sub-circuit which a current value of 16 A or less, the number of light points fed by it shall not exceed the following values.

- 10 light points for circuits of 24 - 55 V
- 14 light points for circuits of 110 - 127 V
- 18 light points for circuits of 220 - 250 V

The number of points shall not be restricted for final sub-circuits for information panel and electrical signals lighting, where the light points are closely grouped. However, the maximum operating current for the sub-circuit shall not exceed 10 A.

Lighting circuits must be supplied by a final sub-circuit different from the heating and power.

The lighting of the Engine Rooms, control stations and work spaces should be supplied from at least two final sub-circuits, so that a failure of any of the circuits will not leave the space in darkness.

Lighting for hazardous enclosed spaces must be fed from at least two final sub-circuits to allow the lighting from a circuit, and let the other one for maintenance matters.

The lighting in unoccupied spaces, such as cargo, must be controlled by multi-pole switches, out of those areas. Complete isolation of these circuits and control measures for the blocking in the off position must be provided.

#### **5.5.8. Motor circuits**

For each motor, it must be provided a final sub-circuit, separated from essential services.

#### **5.5.9. Motor control**

Every electric motor should be provided with efficient measures to be started and stopped, placed to be easily handled by the operators of the motor. Each motor with

more than 0.5 kW must be provided with control devices as explained below.

Measures must be provided to prevent unwanted startings after a stop due to low voltage or complete loss of voltage. This does not apply to engines where a hazardous condition may result from the breakdown of the automatic start.

Measures shall be provided to automatically disconnections in an over-current situation due to mechanical overloading of the motor.

The control unit of the motor must be suitable for the starting current and the entire load current of the motor.

## **5.5.10. Protections**

### **5.5.10.1. General terms**

Installations

against over-current, including short-circuits and other electrical faults. Release time / fault tolerance of the devices must be provided. Moreover, the coordinated protection must ensure the following statements.

- Performance of essential and emergency services under failure situations by an erroneous action of protective devices. As far as possible, the devices must also ensure the performance of other services.
- The elimination of faults to reduce damage to the system and fire situations.

Protection against short circuits and overloads should be provided on each line not grounded in the power and distribution systems.

Protection against short circuits must be provided for each energy source and at every point where there is a subdivision in the distribution circuit.

Where protection circuits for power suppliers are provided, wiring between the generator and the switchboard must be installed in a way that minimizes the risk of short-circuit situations.

Short-circuit protection may be omitted from the wiring connections or equipment elements which are internally protected against short-circuits. Moreover, where short-circuits situations are inconsistent or where wiring is installed in such a way that minimizes the risk of short-circuit, protection may be omitted as well.

Overload protection may be omitted in a isolated type circuit line or in circuits supplying equipment incapable of being normally overloaded.

#### **5.5.10.2. Short-circuit protection**

Protection against short-circuit current must be provided with circuit breakers or fuses.

Manufacturing characteristics and breaking strength of each device must be adequate protection for potential levels of failures in its implementation point.

#### **5.5.10.3. Overload protection**

Fuse, circuit breakers and other protective devices, provided for overload protection, shall melt / trip, ensuring the protection of the wiring and electrical equipment against overheating resulting from mechanical or electrical overload.

Fuses proposed for short-circuit protection must not be used for overload protection.

#### **5.5.10.4. Motor protection**

Engines whose power exceeds 0.5 kW shall be individually protected against overloads and short circuits. For motors that are duplicated for essential services,

overload protection can be replaced by an overload alarm.

Protection for motors and their supplying cables may be equipped with the same device. Allowance shall be given taking into account the differences between the power of the motor and the cable.

#### **5.5.10.5. Power converters protection**

Protection against short circuits and overloads in power converters must be equipped with circuit breakers or fuses in the primary circuit.

### **5.5.11. Switchboard implementation**

#### **5.5.11.1. General terms**

Where the assembly of distribution switchboards is necessary, their components shall comply with one of the following standard amendments:

- IEC Publication 439: Implementation of switchboards and control devices for low voltage.
- IEC Publication 298: AC switchboards in metal boxes and control devices for voltages from 1 kV up to 38 kV.
- IEC Publication 466: AC switchboards in isolated boxes for voltages from 1 kV Up to 38 kV.
- Approved and relevant National Standardization .
- In addition, it shall comply with the following requirements.

#### **5.5.11.2. Location**

An unobstructed space of not less than 1 meter wide shall be provided at the front of main switchboards.

Where necessary, the space at the back of the main switchboards shall allow

their maintenance and, in general, it shall not be less than 0.6 meters, except if it can be reduced to 0.5 meters due to reinforcements or frames.

Locations defined above shall have non-slip surfaces. In addition, the surface shall be electrically isolated where the access to parts with current flowing through them is normally possible.

#### **5.5.12. Cables**

Electric cables for fixed wiring shall be designed, manufactured and tested in accordance with an IEC Publication, set out in the following table, or with an approved National Standard.

| Application                                                   | IEC Standard | Title                                                                                                                    |
|---------------------------------------------------------------|--------------|--------------------------------------------------------------------------------------------------------------------------|
| General construction and test requirements                    | 92-350       | Shipboard power cables – General construction and test requirements                                                      |
| Fixed energy and control circuits                             | 92-353       | Power cables for rated voltages 1 kV and 3 kV                                                                            |
| Over 60 V instrumentation, control and communication circuits | 92-375       | Shipboard telecommunication cables and radio-frequency cables. General instrumentation, control and communication cables |
| Over 250 V control circuits.                                  | 92-376       | Shipboard multicore cables for control circuits                                                                          |
| Fixed high voltage circuits.                                  | 502          | Power cables with extruded insulation and their accessories for rated voltages from 1 kV up to 30 kV                     |
| Mineral insulation                                            | 702          | Mineral insulated cables for a voltage not exceeding 750 V                                                               |

Table 81: IEC Standards

Electrical cables complying with IEC Publication 502 have stranded conductors. Electric cables for non fixed wiring applications shall comply with approved standards. For the implementation of this section, tubes, pipes, boxes and any other systems for mechanical protection of cables will be hereafter referred with the generic name of "protective coating".

Routine tests shall cover at least:

- Measure of the electrical resistance of conductors
- High-voltage tests
- Measure of the insulation resistance
- For high voltage cables partial discharge tests shall be made according to the requirements of the relevant publication or the national standardization

Evidences of the successful completion of the routine testing will be provided by the manufacturer. Particular and special tests shall be made, when required, in accordance with the requirements of the relevant publication or the national Standards. The manufacturer will issue a test report.

#### **5.5.12.1. Voltages**

The normal voltage of a cable shall not be less than the nominal voltage for which it is used. The maximum voltage which appear in the cables shall not exceed the maximum voltage for which it was designed.

The cables used in ungrounded systems shall be suitable to withstand the additional stresses that may appear in the isolation during a ground fault.

#### **5.5.12.2. Operating temperature**

For normal operation, the maximum temperature in the insulating material shall be at least 10 ° C higher than the maximum room temperature which is expected to appear in the space where the cable is installed.

For normal operation and short-circuit operation, the maximum conductor in the insulating materials shall not exceed the values listed in the following table.



| Insulating material                                                 | Maximum temperature (°C) |                   |
|---------------------------------------------------------------------|--------------------------|-------------------|
|                                                                     | Normal operation         | Short-circuit     |
| Polyvinyl chloride or copolymer of vinyl chloride and vinyl acetate | 60                       | 150               |
| Polyethylene                                                        | 60                       | 130               |
| Polyethylene (based on ethylene propylene rubber or similar)        | 85                       | 250               |
| Based on polyethylene chemically crossed                            | 85                       | 250               |
| Silicon rubber                                                      | 95                       | Shall be supplied |
| Mineral                                                             | 95                       | Shall be supplied |

Table 82: Maximum temperatures for cables

Cables constructed of an insulating material not included in the previous table shall comply with the national standardization.

#### 5.5.12.3. Construction

Electrical cables should be at least of a flame-retardant type. It shall be accepted the compliance with IEC Publication 332-1 (Tests on electric and optical fibre cables under fire conditions).

Exceptions to the above requirements will be subject to a special study (applications such as radio frequency systems and digital communications, which require the use of particular types of cables).

Where fire resistant cables are required, they shall meet the performance requirements of IEC Publication 331: Tests for Electric Cables under Fire Conditions.

Where electric cables are installed in locations exposed to water, damp places or

with steam, in machinery rooms, refrigerated spaces or exposed to noxious fumes including petrol vapor, shall have the insulated conductor with closed material in a coated cover material appropriate to the environment.

Electrical cables whose construction requires metal coating, armor or braided shall be provided with a complete coating or other measures to protect the metallic element from corrosion.

Circuits with a rate current above 20 A shall need cables whose shield is of a non-magnetic material.

Electrical cables shall be able to withstand the mechanical and thermal effects of the maximum short-circuit current that can flow in any part of the circuit in which they are installed, taking into account not only the time/current characteristics of the circuit protection devices, but also the maximum short-circuit current that may appear. Where maximum short-circuit current exceeds 70 kA, evidences shall be supplied for its analysis, when required, showing that the cable construction can withstand the effects of short-circuit current.

#### **5.5.12.4. Size**

The maximum continuous load carried by a cable shall not exceed its continuous regime current. Cables shall be chosen so that the normal maximum temperature of the cable during normal operation, is not exceeded in the isolation. When required, correction coefficients may be applied.

The cross-sectional area of the conductors shall be enough to ensure that, under short-circuit conditions, the normal maximum operating temperature of the conductor during short-circuit regime is not exceeded, taking into account the time/current characteristics of the protection devices and the maximum values of likely short-circuit current.

Regime current of the cables given in the following tables are based on the maximum conductor temperature of the cable. Whenever the cross-section is chosen based on maximum current values, their characteristics shall be given for their analysis. Alternative short-circuit temperature limits other than those given in the tables can be used according to the method of IEC 724 (Guide To the Short-Circuit Temperature Limits of Electric Cables) or national standardization.

| <b>Table J3 Rating of cables with temperature class 70°C</b> |                                                           |     |        |     |             |     |
|--------------------------------------------------------------|-----------------------------------------------------------|-----|--------|-----|-------------|-----|
| Nominal<br>cross-section (mm <sup>2</sup> )                  | Current rating (A)<br>(Based on ambient temperature 45°C) |     |        |     |             |     |
|                                                              | Single-core                                               |     | 2-core |     | 3 or 4-core |     |
| 1.5                                                          | 15                                                        |     | 13     |     | 11          |     |
| 2.5                                                          | 21                                                        |     | 18     |     | 15          |     |
| 4                                                            | 29                                                        |     | 25     |     | 20          |     |
| 6                                                            | 37                                                        |     | 31     |     | 26          |     |
| 10                                                           | 51                                                        |     | 43     |     | 36          |     |
| 16                                                           | 68                                                        |     | 58     |     | 48          |     |
| 25                                                           | 90                                                        |     | 77     |     | 63          |     |
| 35                                                           | 111                                                       |     | 94     |     | 78          |     |
| 50                                                           | 138                                                       |     | 117    |     | 97          |     |
| 70                                                           | 171                                                       |     | 145    |     | 120         |     |
| 95                                                           | 207                                                       |     | 176    |     | 145         |     |
| 120                                                          | 239                                                       |     | 203    |     | 167         |     |
| 150                                                          | 275                                                       |     | 234    |     | 193         |     |
| 185                                                          | 313                                                       |     | 266    |     | 219         |     |
| 240                                                          | 369                                                       |     | 314    |     | 258         |     |
| 300                                                          | 424                                                       |     | 360    |     | 297         |     |
|                                                              | DC                                                        | AC  | DC     | AC  | DC          | AC  |
| 400                                                          | 500                                                       | 490 | 425    | 417 | 350         | 343 |
| 500                                                          | 580                                                       | 550 | 493    | 468 | 406         | 385 |
| 630                                                          | 670                                                       | 610 | 570    | 519 | 469         | 427 |

*Figure 34: Rating of cables with temperature class 70° C*

| <b>Table J4 Rating of cables with temperature class 90°C</b> |                                                                         |     |               |     |                    |     |
|--------------------------------------------------------------|-------------------------------------------------------------------------|-----|---------------|-----|--------------------|-----|
| <i>Nominal cross-section (mm<sup>2</sup>)</i>                | <i>Current rating (A)</i><br><i>(Based on ambient temperature 45°C)</i> |     |               |     |                    |     |
|                                                              | <i>Single-core</i>                                                      |     | <i>2-core</i> |     | <i>3 or 4-core</i> |     |
| 1                                                            | 18                                                                      |     | 15            |     | 13                 |     |
| 1.5                                                          | 23                                                                      |     | 20            |     | 16                 |     |
| 2.5                                                          | 30                                                                      |     | 26            |     | 21                 |     |
| 4                                                            | 40                                                                      |     | 34            |     | 28                 |     |
| 6                                                            | 52                                                                      |     | 44            |     | 36                 |     |
| 10                                                           | 72                                                                      |     | 61            |     | 50                 |     |
| 16                                                           | 96                                                                      |     | 82            |     | 67                 |     |
| 25                                                           | 127                                                                     |     | 108           |     | 89                 |     |
| 35                                                           | 157                                                                     |     | 133           |     | 110                |     |
| 50                                                           | 196                                                                     |     | 167           |     | 137                |     |
| 70                                                           | 242                                                                     |     | 206           |     | 169                |     |
| 95                                                           | 293                                                                     |     | 249           |     | 205                |     |
| 120                                                          | 339                                                                     |     | 288           |     | 237                |     |
| 150                                                          | 389                                                                     |     | 331           |     | 272                |     |
| 185                                                          | 444                                                                     |     | 377           |     | 311                |     |
| 240                                                          | 522                                                                     |     | 444           |     | 365                |     |
| 300                                                          | 601                                                                     |     | 511           |     | 421                |     |
|                                                              | DC                                                                      | AC  | DC            | AC  | DC                 | AC  |
| 400                                                          | 690                                                                     | 670 | 587           | 570 | 483                | 469 |
| 500                                                          | 780                                                                     | 720 | 663           | 612 | 546                | 504 |
| 600                                                          | 890                                                                     | 780 | 757           | 663 | 623                | 546 |

Figure 35: Rating of cables with temperature class 90° C

The cross-sectional area of the conductors shall be enough to ensure that voltage variations does not happen in when the cable takes the maximum current under normal operating conditions. Those variations are:

- Voltage:
  - Permanent changes: + 6%, -10%.
  - Transients: + 20%, -15%.
  - Recovery time: 1.5 seconds.

Size of the ground conductors shall comply with the following requirement: The cross section of the copper cables is generally equal to the cross section of the conductors carrying current higher than 16 mm<sup>2</sup>. Above that value, they must be equal to the section of the current carrying cable with a minimum of 16 mm<sup>2</sup>. All other grounding cables must have a conductance no less than that specified for an equivalent grounding cable.

The cross sectional area of the conductors used in circuits with cyclic or discontinuous loads shall be enough to ensure that the normal maximum temperature of the conductor does not exceeded the limits when the cable is operating under normal operating conditions.

#### 5.5.12.5. Cable installation

The routing of the cables shall be fixed, as far as possible, in a straight line and in accessible locations.

The minimum inside bending radius for the installation of fixed cables shall be given in accordance with the construction and size of cables and shall not be less than the value given in the following table.

| Cable construction                                           |                                         | Total diameter     | Minimum internal bending radius<br>(times the total cable diameter) |
|--------------------------------------------------------------|-----------------------------------------|--------------------|---------------------------------------------------------------------|
| Isolation                                                    | Surface coating                         |                    |                                                                     |
| Thermoplastic elastomer;<br>600/1000 V and less              | Covered metal.<br>Shielded and braided. | Anyone             | 6D                                                                  |
|                                                              | Others                                  | < 25 mm<br>> 25 mm | 4D<br>6D                                                            |
| Mineral                                                      | Covered by carbide                      | Anyone             | 6D                                                                  |
| Thermoplastic elastomer; for over<br>600/1000<br>Multi-core. | Anyone                                  | Anyone             | 20D                                                                 |
|                                                              | Anyone                                  | Anyone             | 15D                                                                 |

Table 83: Minimum internal bending radius

Electrical cables for essential and emergency services shall be arranged, as far as possible, to avoid galleys, engine rooms and other enclosed spaces with high risk of fire, unless when it is necessary. Those cables shall be, wherever possible, taken at a convenient distance of the bulkheads to prevent them from being useless due to the heat of the bulkheads that may be caused by a fire in an adjacent space.

Electrical cables shall have different maximum temperature than the insulation materials with. Thus, they must be installed so that the maximum permissible conductor temperature for normal operation of each cable is not exceeded.

Electrical cables shall have a protective coating, which must not damage the coating of other cables when grouped with them.

Electrical cables will be installed as far from heat sources as possible. If it cannot be avoided installing electric cables close to heat sources, and where consequently there is a risk of damage to cables by heat, they will be installed with suitable protection, insulation or other precautions.

If electrical cables are installed in groups, provision shall be made to limit the spread of fire, which can be performed by the use of suitable fire stops markers. They can be considered alternative devices.

Electrical cables will not be covered or painted with materials that could adversely affect its function or its fire protection features.

Electrical cables should be arranged, if possible, at an enough distance from sources of mechanical danger. Where necessary, the cables will be protected according to the requirements of the following section.

#### **5.5.12.6. Mechanical protection of cables**

Electrical cables exposed to risks from mechanical damage shall be protected by

suitable protective enclosures, unless protective coatings (i.e. shield or cover) are sufficient to withstand the possible cause of damage.

Electrical cables in areas where there is exceptional risk of mechanical damage, such as warehouses, stowage spaces, cargo, etc., shall be adequately protected by metal protective enclosures, unless the ship's structure provides adequate protection.

Non-metallic and fixed, protective enclosures must be flame retardant, according to the requirements of IEC 92-101 (Definitions and general requirements). The metal protective enclosures shall be effectively protected from corrosion.

#### **5.5.12.7. Fixing of cables**

Electrical cables shall be effectively supported and secured, without being damaged. It shall be necessary the use of systems which are difficult to ignite as clamps or collars.

Distances between supports will be given according to the type of cable and the likelihood of vibrations, and shall not exceed 400 mm. For a horizontal cable, fixing must be provided to contain the movement of the cable. Spacing between the fixed points can be more than 900 mm, if it is scheduled to have holders with maximum spacing, as specified in the following table.

This relationship shall not be applied to cables going in open areas or which may be subject of seawater forces.

| Cable external diameter |                 | Shielded cables<br>(mm) | Unshielded cables<br>(mm) |
|-------------------------|-----------------|-------------------------|---------------------------|
| Greater than (mm)       | Lower than (mm) |                         |                           |
| -                       | 8               | 200                     | 250                       |
| 8                       | 13              | 250                     | 300                       |
| 13                      | 20              | 300                     | 350                       |
| 20                      | 30              | 350                     | 400                       |
| 30                      | -               | 400                     | 450                       |

*Table 84: Maximum spacing of staples or clamps for fixing of cables*

Holders and accessories shall have robust and resistant to corrosion materials or adequately insulated from corrosion before its implementation.

Where electric cables are fixed with clamps made of a material other than metal, the material must be flame resistant, and suitable fixings will be supplemented by metal clamps, spaced at a regular distance that does not exceed 2 meters.

One core cables shall be secured using holders with adequate resistance in order to withstand the maximum values corresponding to the expected short-circuit current forces.

#### **5.5.12.8. Penetration of bulkheads by cables**

Where electrical cables pass through bulkheads, isolated from fire, that separate areas or dangerous spaces non-hazardous from hazardous, the arrangement shall ensure the integrity of bulkheads and decks so that they are not damaged. The arrangement shall ensure that the cables are not adversely affected.

Electrical cables that pass through decks shall be protected by covering them with passing-decks tubes. Where cables pass through heat insulation, they will be made at right angle in tubes sealed at both ends.



#### **5.5.12.9. Installation of protective enclosures in cables**

Protective enclosures shall be mechanically continuous through joints, and effectively supported and secured to prevent damage to electrical cables.

The inner radius of bending protective enclosures shall not be less than that required for the largest cable installed.

#### **5.5.12.10. One core cables for alternating current**

When installed in protective enclosures, electrical cables belonging to the same circuit shall be installed in the same protective covers, unless the protective casing is made of non-magnetic material.

The staples shall include electrical cables of all phases of a circuit, unless the clamps are made of non-magnetic material.

#### **5.5.12.11. Ends of the cables**

The ends of all conductors with a cross section larger than 4 mm<sup>2</sup>, shall be fixed with compression sleeves or mechanical clamps. Welded sleeves can be used in conjunction with non-corrosive flux, which provide during short-circuit regime a maximum temperature of conductor in the union not greater than 160 ° C.

Electrical cables with hygroscopic insulation (for example, mineral insulation) shall have their ends sealed against moisture penetration.

Sleeves and terminal connections shall have design and dimensions such that the maximum current flowing through them shall not produce heat that could damage the insulation. Temperatures produced shall not exceed those permitted for the insulation of the wires.

The fixing solutions shall be able to withstand the thermal and mechanical effects of short-circuit currents.

#### **5.5.12.12. Joints and circuits in cable systems**

If joints are necessary, it shall be implemented so that all the cables are properly fixed, isolated and protected from the air. The flame-proofing and fire resistant properties of the cable shall be saved. The continuity of the metal covers, braided or armored, shall be maintained and current carrying capacity of the cables shall not be affected.

Sockets shall be made in proper boxes, with a design which keeps the drivers adequately insulated, protected from the air and installed in terminals or main busbars with appropriate dimensions for the current regime.

#### **5.5.12.13. Lighting. General terms**

The lamp holder shall be constructed of fire retardant and non-hygroscopic materials.

Lighting fixtures shall be arranged to prevent temperature increases, which overheat or damage surrounding materials. They must not damage the integrity of the fire divisions.

#### **5.5.12.14. Incandescent and halogen lighting**

The tungsten filament lamps and caps shall comply with the following table.

| Designation       | Maximum performance |           | Maximum current through the cap (A) |
|-------------------|---------------------|-----------|-------------------------------------|
|                   | Voltage (V)         | Power (W) |                                     |
| Screw cap lamps   |                     |           |                                     |
| E40               | 250                 | 3000      | 16                                  |
| E27               | 250                 | 200       | 16                                  |
| E14               | 250                 | 15        | 2                                   |
| E10               | 24                  | -         | 2                                   |
| Bayonet cap lamps |                     |           |                                     |
| B22               | 250                 | 200       | 4                                   |
| B15d              | 250                 | 15        | 2                                   |
| B15s              | 55                  | 15        | 2                                   |
| Fluorescent lamps |                     |           |                                     |
| G13               | 250                 | 80        | -                                   |
| G5                | 250                 | 13        | -                                   |

Table 85: Lamps and caps

Caps of E40 type shall be provided with measures for holding the lamp in the socket.

#### 5.5.12.15. Fluorescent lighting

Fluorescent lighting and their caps shall comply with the previous tables.

Accessories, capacitors and other devices shall not be mounted on surfaces that may be subject to high temperatures. If they are separately implemented, they shall be enclosed in a grounded conductive housing.

If there are installed capacitors of 0.5 microfarads or more measures shall be provided for download them when the power is turned off.

#### 5.5.12.16. Plugs and sockets

The rise of temperature in the active parts of the plug and the socket shall not exceed 30 ° C. The plug and the socket shall be constructed so that they can not easily be short-circuited if the plug is in or out, and the pins of the plug can not be made in such a way that each pole of the plug may be grounded.

Every socket with a rated current of 16 A or more shall be fitted with a switch, and shall be closed so that the plug can not be inserted or taken out when the switch is in the “On” position.

Where it is necessary to ground the parts which do not carry current of portable or transportable equipment, some effective measures in order to ground the sockets shall be applied.

On exposed weather decks, kitchens, laundries, machinery spaces and all wet locations, plugs and sockets must be protected against rain and spray, and shall be provided with measures to maintain quality after moving the pin.

## **5.6. Electrical equipment in flammable gas atmospheres or with pulverized fuel**

### **5.6.1. General terms**

The installation of electrical equipment in areas containing flammable gas or stem and / or pulverized fuel shall be minimized as far as possible, through the necessary implementations and supply of lighting, indicators, alarms and controls that enhance the security of the vessel.

## **5.7. Navigation and operation systems**

### **5.7.1. Command devices**

Two exclusive circuits supplied from the main source of electrical power shall be

provided for each electric or electro-hydraulic command device. Moreover, each circuit shall have adequate capacity for supplying all motors which can be connected simultaneously, One of these circuits may work through the main emergency switchboard.

## **5.8. Navigation lights**

### **5.8.1. General terms**

Navigation lights shall be connected separately to a distribution switchboard which must be implemented only for this task. This switchboard must be connected directly or through power converters, to the main switchboard. The distribution switchboard shall be accessible to the operator.

Each navigation light shall be controlled and protected in each insulated pole by a switch and a fuse or circuit breaker implemented on the switchboard.

Each navigation light shall count with an automatic indicator which must give acoustic and / or optical indications of the breakdown of the light. If only one sound device is installed, it shall be connected to an independent power source, for example a battery, provided with devices to prove their performance. If an optical signal is used, connected in series with navigation light, measures shall be provided in order to prevent the extinction of the navigation light at the failure of the signal. The requirements of this paragraph shall not apply to tugs vessels, fishing vessels or other small vessels. On the navigation bridge It shall be provided that the navigation lights are transferred to an alternative circuit supplied from the main source of power.

## **5.9. Fire-fighting system**

### **5.9.1. Fire detection and alarm systems**

Systems of fire detection and alarm system shall be supplied from exclusive

circuits from two sources of power, one of them shall be an emergency source, with automatic switch located on or adjacent to the main display panel of fire detection.

The control panel of fire detection shall be placed on the Bridge.

Detectors and manual call points shall be grouped into sections. With the activation of the detectors or manual call points, a visual and audible signal shall start at the control panel and the indicator devices. If the signal has not been handled in the space of two minutes, an audible alarm will sound automatically throughout the crew accommodation and service spaces, control stations and machinery space of Category A. This sound system alarm is not needed to be an part of the detection system.

The indicator devices shall point out at least the section where the detector or manual call has been activated. At least one unit shall be located in an easily accessible place to the members of the crew. If the control panel is located in the central control station then a display unit shall be located on the Bridge.

The information shall be clearly indicated in each display unit about the spaces covered and the location of the section.

## **5.10. Emergency security systems**

### **5.10.1. Emergency lighting**

Emergency lights shall be arranged in such a way that a fire or other casualty in spaces containing the emergency source of electrical power, power converters and the emergency lighting switchboards does not let inoperative the main lighting system.

The level of illumination provided by the emergency lighting shall be adequate to allow evacuation in an emergency situation, taking care of the possible presence of smoke.

Exists of each main room occupied by passengers or crew shall be continuously lighted by an emergency lighting.

Switches shall not be installed at the final sub-circuit of the accessories of the emergency lights, unless the implemented lightings are working in unmanned spaces, for example stowage rooms, refrigeration rooms, etc. Switches shall only be accessible to the crew, ensuring that emergency lightings are powered when such spaces are occupied.

Where emergency lightings accessories are connected to dimmers, its regular level of lighting shall be automatically restored when the main lighting is lost.

Accessories shall be specially marked to indicate that they are part of the emergency lighting system.

### **5.10.2. Emergency alarm system**

An electrically operating bell or horn or other warning system installed in addition to the ship's whistle or siren to warn about the general emergency alarm, shall meet the requirements of this section.

The alarm system shall be powered by exclusive circuits, one from the main source of power and the other one from the emergency source of power, with automatic switching located at or adjacent to the distribution panel of the main alarm signal.

### **5.10.3. Public address system**

Where the public address system is within internal communication equipment required in an emergency, it shall be supply by exclusive circuits, one from the main power supply system and the other one from the emergency power supply system. It shall use automatic switching located adjacent to the public address system.

## **5.11. Terms of use, maintenance and security**

### **5.11.1. Work security**

The Contractor shall provide what were necessary for the maintenance of machines, tools, materials and working equipment in a safe condition.

While operators are working in voltage circuits or equipment with voltage or close to them, they shall wear clothing without metal accessories and avoid unnecessary use of metal objects; meters, rulers, handles of oilers, cleaners, etc. used should not be of conductive material. Tools or equipment shall be carried in bags. Insulated footwear shall be used, or at least without bindings nor soles with steel spikes.

The staff of the Contractor must use all devices and personal protective equipment, safety clothing and tools required to eliminate or reduce hazards during their performance. Those equipments may be helmet, goggles, insulated stool, etc. The Director may suspend the work if he considers that the Contractor's staff is exposed to dangers that are correctable.

The Director may require the Contractor, ordering it in writing, termination of the work of any employee or worker who, by recklessly, was able to cause accidents that did endanger the physical integrity of the worker or his partners.

The Director may require at any time before or after the commencement of the work that the Contractor presents the documents that prove the social security systems of all types (affiliation, accident, illness, etc.) in the way legally established.

### **5.11.2. Public security**

The Contractor shall take all the maximum precautions in all operations and use of equipment to protect people, animals and things of hazards from work. The



Contractor shall be responsible of those accidents.

The Contractor shall maintain enough insurance policy to protect him and his employees or workers against liability for damages, public liability, etc. that may be incurred either by the Contractor or others as a result of the implementation of the work.



## 6. BILL OF MATERIAL

Electrical Engineering Degree

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## Bill of Material

|                                                 |            |
|-------------------------------------------------|------------|
| <b>6.BILL OF MATERIAL.....</b>                  | <b>397</b> |
| 6.1.Introduction.....                           | 399        |
| 6.2.Batteries.....                              | 399        |
| 6.3.Motors.....                                 | 400        |
| 6.4.Distribution.....                           | 400        |
| 6.4.1.Power inverters.....                      | 400        |
| 6.4.2.Interconnections.....                     | 400        |
| 6.4.3.Power rectifiers.....                     | 401        |
| 6.5.Passengers Room.....                        | 401        |
| 6.6.Entrance & Toilet.....                      | 402        |
| 6.7.Anteroom.....                               | 403        |
| 6.8.Bridge.....                                 | 404        |
| 6.9.Engine Rooms & Electrical Compartments..... | 405        |

## 6.1. Introduction

It shall be necessary to create a list of the materials that are going to be used in this project in order to carry out the Budget . The following list will detail some characteristics of these materials which have been chosen by using catalogues extracted from the internet.

The list must indicate the amount of units that are going to be used. When it comes to conductors, the units will express the amount of meters that we are going to use.

Once that the Bill of Material is completed, we can proceed to calculate the Budget of this project.

## 6.2. Batteries

| Code | Description                                                                                                                 | Units |
|------|-----------------------------------------------------------------------------------------------------------------------------|-------|
| BA01 | SAFT Seanergy Module<br><i>Compact modules integrating VLM Fe Li-ion cells, module supervision and cell balancing</i>       | 28,00 |
| BA02 | SAFT Seanergy Battery Management System (BMS)<br><i>Monitors, calculates and reports data from the SAFT Seanergy Module</i> | 2,00  |
| BA03 | SAFT Seanergy Case<br><i>SAFT Seanergy Modules storage</i>                                                                  | 2,00  |
| BA04 | Conductor PROTOMONT NSSHÖU-J 2x95 mm <sup>2</sup> 0,6/1 kV<br><i>Connection with the quay</i>                               | 20,00 |
| BA05 | Conductor PROTOMONT NSSHÖU-J 2x16 mm <sup>2</sup> 0,6/1 kV<br><i>Connection with the quay</i>                               | 20,00 |
| BA06 | High-current socket MARECHAL PFQ3<br><i>Connection with the quay</i>                                                        | 2,00  |

### 6.3. Motors

| Code | Description                                                                   | Units |
|------|-------------------------------------------------------------------------------|-------|
| MO01 | 144 Vdc Switchboard LEGRAND XL <sup>3</sup> 160                               | 2,00  |
| MO02 | Electric DC Motor ELCO EP-1000                                                | 2,00  |
| MO03 | General Automatic Switch SCHNEIDER ELECTRIC<br>NSX400N 320 A                  | 2,00  |
| MO04 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x50 mm <sup>2</sup> | 40,00 |

### 6.4. Distribution

#### 6.4.1. Power inverters

| Code | Description                                                                        | Units |
|------|------------------------------------------------------------------------------------|-------|
| PI01 | 48 Vdc Switchboard LEGRAND XL <sup>3</sup> 160                                     | 2,00  |
| PI02 | Power Inverter/Charger VICTRON ENERGY MULTIPLUS 5<br>kVA 48 Vdc/230 Vac            | 2,00  |
| PI03 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x25 + 25 mm <sup>2</sup> | 30,00 |
| PI04 | General Automatic Switch SCHNEIDER ELECTRIC C120N<br>2x100A                        | 2,00  |
| PI05 | 230 Vac Main Switchboard LEGRAND XL <sup>3</sup> 160                               | 2,00  |

#### 6.4.2. Interconnections

| Code | Description                                                                        | Units |
|------|------------------------------------------------------------------------------------|-------|
| IN01 | Isolator switch SCHNEIDER ELECTRIC INTERPACT<br>INS250, 100 A                      | 2,00  |
| IN02 | Isolator switch SCHNEIDER ELECTRIC INTERPACT INS80,<br>80 A                        | 2,00  |
| IN03 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x16 + 16 mm <sup>2</sup> | 30,00 |
| IN04 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT                                       | 30,00 |

0,6/1 kV 2x25 + 25 mm<sup>2</sup>

### 6.4.3. Power rectifiers

| Code | Description                                                     | Units |
|------|-----------------------------------------------------------------|-------|
| PR01 | Rectifier/Battery Charger MASTERVOLT MASS 24/75                 | 1,00  |
| PR02 | 2 positions selector switch SCHNEIDER ELECTRIC CM<br>18070 20 A | 1,00  |
|      | <i>Connection with one of the electrical systems</i>            |       |

### 6.5. Passengers Room

| Code | Description                                                                                                                                                                                                                                         | Units  |
|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|
| PR01 | Passengers Room Switchboard LEGRAND XL <sup>3</sup> 160                                                                                                                                                                                             | 2,00   |
| PR02 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x63 A                                                                                                                                                                                                     | 2,00   |
| PR03 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x4 A                                                                                                                                                                                                      | 2,00   |
| PR04 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x6 A                                                                                                                                                                                                      | 2,00   |
| PR05 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x1 A                                                                                                                                                                                                      | 4,00   |
| PR06 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x0,5 A                                                                                                                                                                                                    | 2,00   |
| PR07 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x16 + 16 mm <sup>2</sup>                                                                                                                                                                  | 10,00  |
| PR08 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x2,5 + 2,5 mm <sup>2</sup>                                                                                                                                                                | 122,00 |
| PR09 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x1,5 + 1,5 mm <sup>2</sup>                                                                                                                                                                | 116,00 |
| PR10 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 1x16 mm <sup>2</sup><br><i>Ground and protection</i>                                                                                                                                       | 10,00  |
| PR11 | Schuko sockets<br><i>Sockets holder with ground connection on the side. In one-phase systems, with ground connection (phase, neutral and ground), including gang box, universal instrument box with screws, socket holder type Schuko 10 – 16 A</i> | 26,00  |

|      |                                                                                                                                                                                 |       |
|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| PR12 | GLAMOX CASA 16 113F SI<br><i>Downlight 1x19 W. Downlight, in Galv Steel. White trimring.<br/>IP22 . Light source TC-D 1x13W. Ballast type High power<br/>factor correction.</i> | 24,00 |
| PR13 | GLAMOX E85-S<br><i>Surface mounted escape rout light or anti panic emergency light<br/>system based on LED</i>                                                                  | 8,00  |
| PR14 | GLAMOX E80-S<br><i>Exit sign based on LED. White painted aluminium with<br/>component plate in polycarbonate.</i>                                                               | 2,00  |

## 6.6. Entrance & Toilet

| Code | Description                                                                                                                                       | Units |
|------|---------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| EA01 | Entrance & Toilet Switchboard LEGRAND XL <sup>3</sup> 160                                                                                         | 2,00  |
| EA02 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x40 A                                                                                                   | 2,00  |
| EA03 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x2 A                                                                                                    | 2,00  |
| EA04 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x1 A                                                                                                    | 2,00  |
| EA05 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x0,5 A                                                                                                  | 7,00  |
| EA06 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x10 A                                                                                                   | 2,00  |
| EA07 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x10 + 10 mm <sup>2</sup>                                                                | 26,00 |
| EA08 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x2,5 + 2,5 mm <sup>2</sup>                                                              | 24,00 |
| EA09 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x1,5 + 1,5 mm <sup>2</sup>                                                              | 73,00 |
| EA10 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 1x16 mm <sup>2</sup><br><i>Ground and protection</i>                                     | 10,00 |
| EA11 | Schuko sockets<br><i>Sockets holder with ground connection on the side. In one-<br/>phase systems, with ground connection (phase, neutral and</i> | 6,00  |



|      |                                                                                                                                                                         |       |
|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
|      | <i>ground), including gang box, universal instrument box with screws, socket holder type Schuko 10 – 16 A</i>                                                           |       |
| EA12 | GLAMOX CASA 16 113F SI<br><i>Downlight 1x19 W. Downlight, in Galv Steel. White trimring. IP22 . Light source TC-D 1x13W. Ballast type High power factor correction.</i> | 11,00 |
| EA13 | GLAMOX E85-S<br><i>Surface mounted escape rout light or anti panic emergency light system based on LED</i>                                                              | 7,00  |
| EA14 | GLAMOX E80-S<br><i>Exit sign based on LED. White painted aluminium with component plate in polycarbonate.</i>                                                           | 1,00  |
| EA15 | Extractor Fan (Toilet) FANTECH EN31                                                                                                                                     | 1,00  |

## 6.7. Anteroom

| Code | Description                                                                                                   | Units |
|------|---------------------------------------------------------------------------------------------------------------|-------|
| AR01 | Anteroom Switchboard LEGRAND XL <sup>3</sup> 160                                                              | 2,00  |
| AR02 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x32 A                                                               | 2,00  |
| AR03 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x2 A                                                                | 2,00  |
| AR04 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x1 A                                                                | 2,00  |
| AR05 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x0,5 A                                                              | 2,00  |
| AR06 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x10 + 10 mm <sup>2</sup>                            | 14,00 |
| AR07 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x2,5 + 2,5 mm <sup>2</sup>                          | 16,00 |
| AR08 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x1,5 + 1,5 mm <sup>2</sup>                          | 49,00 |
| AR09 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 1x16 mm <sup>2</sup><br><i>Ground and protection</i> | 10,00 |
| AR10 | Schuko sockets                                                                                                | 4,00  |

*Sockets holder with ground connection on the side. In one-phase systems, with ground connection (phase, neutral and ground), including gang box, universal instrument box with screws, socket holder type Schuko 10 – 16 A*

AR11 GLAMOX CASA 16 113F SI 11,00

*Downlight 1x19 W. Downlight, in Galv Steel. White trimring. IP22 . Light source TC-D 1x13W. Ballast type High power factor correction.*

AR12 GLAMOX E85-S 5,00

*Surface mounted escape rout light or anti panic emergency light system based on LED*

AR13 GLAMOX E80-S 2,00

*Exit sign based on LED. White painted aluminium with component plate in polycarbonate.*

## 6.8. Bridge

| Code | Description                                                                        | Units |
|------|------------------------------------------------------------------------------------|-------|
| BR01 | Bridge Switchboard LEGRAND XL <sup>3</sup> 160                                     | 2,00  |
| BR02 | Circuit breaker SCHNEIDER ELECTRIC c120N 2x80A                                     | 1,00  |
| BR03 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x63 A                                    | 1,00  |
| BR04 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x2 A                                     | 1,00  |
| BR05 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x0,5 A                                   | 2,00  |
| BR06 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x20 A                                    | 1,00  |
| BR07 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x10 A                                    | 1,00  |
| BR08 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x16 A                                    | 5,00  |
| BR09 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x50 A                                    | 4,00  |
| BR10 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x16 + 16 mm <sup>2</sup> | 10,00 |
| BR11 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x25 + 25 mm <sup>2</sup> | 10,00 |
| BR12 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT                                       | 57,00 |

|      |                                                                                                                                                                                                                                   |       |
|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
|      | 0,6/1 kV 2x2,5 + 2,5 mm <sup>2</sup>                                                                                                                                                                                              |       |
| BR13 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT                                                                                                                                                                                      | 51,00 |
|      | 0,6/1 kV 2x1,5 + 1,5 mm <sup>2</sup>                                                                                                                                                                                              |       |
| BR14 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT                                                                                                                                                                                      | 22,00 |
|      | 0,6/1 kV 2x6 + 6 mm <sup>2</sup>                                                                                                                                                                                                  |       |
| BR15 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT                                                                                                                                                                                      | 7,00  |
|      | 0,6/1 kV 2x10 + 10 mm <sup>2</sup>                                                                                                                                                                                                |       |
| BR16 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT                                                                                                                                                                                      | 10,00 |
|      | 0,6/1 kV 1x16 mm <sup>2</sup>                                                                                                                                                                                                     |       |
|      | <i>Ground and protection</i>                                                                                                                                                                                                      |       |
| BR17 | Schuko sockets                                                                                                                                                                                                                    | 2,00  |
|      | <i>Sockets holder with ground connection on the side. In one-phase systems, with ground connection (phase, neutral and ground), including gang box, universal instrument box with screws, socket holder type Schuko 10 – 16 A</i> |       |
| BR18 | GLAMOX i70-1200 LED 4500 DALI 840                                                                                                                                                                                                 | 1,00  |
|      | <i>LED 1x50 W</i>                                                                                                                                                                                                                 |       |
| BR19 | GLAMOX E85-S                                                                                                                                                                                                                      | 2,00  |
|      | <i>Surface mounted escape rout light or anti panic emergency light system based on LED</i>                                                                                                                                        |       |
| BR20 | GLAMOX E80-S                                                                                                                                                                                                                      | 1,00  |
|      | <i>Exit sign based on LED. White painted aluminium with component plate in polycarbonate.</i>                                                                                                                                     |       |
| BR21 | GLAMOX JET 7                                                                                                                                                                                                                      | 7,00  |
|      | <i>Exterior lighting. Jet 7 body sym hammered reflector black</i>                                                                                                                                                                 |       |
| BR22 | Windlass anchor MAXWELL MARINE RC10                                                                                                                                                                                               | 1,00  |

## 6.9. Engine Rooms & Electrical Compartments

| Code | Description                                     | Units |
|------|-------------------------------------------------|-------|
| EE01 | Anteroom Bridge LEGRAND XL <sup>3</sup> 160     | 2,00  |
| EE02 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x40 A | 2,00  |

---

|      |                                                                                                                                                                                                                                                     |        |
|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|
| EE03 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x4 A                                                                                                                                                                                                      | 6,00   |
| EE04 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x2A                                                                                                                                                                                                       | 2,00   |
| EE05 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x0,5 A                                                                                                                                                                                                    | 4,00   |
| EE06 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x10 + 10 mm <sup>2</sup>                                                                                                                                                                  | 6,00   |
| EE07 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x2,5 + 2,5 mm <sup>2</sup>                                                                                                                                                                | 42,00  |
| EE08 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 2x1,5 + 1,5 mm <sup>2</sup>                                                                                                                                                                | 210,00 |
| EE09 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT<br>0,6/1 kV 1x16 mm <sup>2</sup><br><i>Ground and protection</i>                                                                                                                                       | 10,00  |
| EE10 | Schuko sockets<br><i>Sockets holder with ground connection on the side. In one-phase systems, with ground connection (phase, neutral and ground), including gang box, universal instrument box with screws, socket holder type Schuko 10 – 16 A</i> | 8,00   |
| EE11 | GLAMOX i70-1200 LED 4500 DALI 840<br><i>LED 1x50 W</i>                                                                                                                                                                                              | 10,00  |
| EE12 | GLAMOX E85-S<br><i>Surface mounted escape rout light or anti panic emergency light system based on LED</i>                                                                                                                                          | 12,00  |
| EE13 | Bilge pump VIGILEX SS                                                                                                                                                                                                                               | 4,00   |
| EE14 | Extractor Fan NEOLINEO-100-Q                                                                                                                                                                                                                        | 4,00   |

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## 7. BUDGET

Electrical Engineering Degree

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## Budget

|                                                 |            |
|-------------------------------------------------|------------|
| <b>7.BUDGET.....</b>                            | <b>407</b> |
| 7.1.Batteries.....                              | 409        |
| 7.2.Motors.....                                 | 409        |
| 7.3.Distribution.....                           | 410        |
| 7.3.1.Power inverters.....                      | 410        |
| 7.3.2.Interconnections.....                     | 410        |
| 7.3.3.Power rectifiers.....                     | 411        |
| 7.4.Passengers Room.....                        | 411        |
| 7.5.Entrance & Toilet.....                      | 413        |
| 7.6.Anteroom.....                               | 414        |
| 7.7.Bridge.....                                 | 416        |
| 7.8.Engine Rooms & Electrical Compartments..... | 418        |
| 7.9.Basic Health and Safety Study.....          | 419        |
| 7.10.Total Budget.....                          | 420        |

## 7.1. Batteries

| Code                    | Description                                                                                                                 | Units | Unit/Price | Price              |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------------|-------|------------|--------------------|
| BA01                    | SAFT Seanergy Module<br><i>Compact modules integrating VLM Fe Li-ion cells, module supervision and cell balancing</i>       | 28,00 | 2.559,00 € | 71.652,00 €        |
| BA02                    | SAFT Seanergy Battery Management System (BMS)<br><i>Monitors, calculates and reports data from the SAFT Seanergy Module</i> | 2,00  | 1.031,00 € | 2.062,00 €         |
| BA03                    | SAFT Seanergy Case<br><i>SAFT Seanergy Modules storage</i>                                                                  | 2,00  | 468,95 €   | 937,90 €           |
| BA04                    | Conductor PROTOMONT NSSHÖU-J<br>2x95 mm <sup>2</sup> 0,6/1 kV<br><i>Connection with the quay</i>                            | 20,00 | 161,21 €   | 3.224,20 €         |
| BA05                    | Conductor PROTOMONT NSSHÖU-J<br>2x16 mm <sup>2</sup> 0,6/1 kV<br><i>Connection with the quay</i>                            | 20,00 | 27,15 €    | 543,00 €           |
| BA06                    | High-current socket MARECHAL PFQ3<br><i>Connection with the quay</i>                                                        | 2,00  | 2.575,00 € | 5.150,00 €         |
| <b>Total Batteries:</b> |                                                                                                                             |       |            | <b>83.569,10 €</b> |

## 7.2. Motors

| Code | Description                                                  | Units | Unit/Price  | Price       |
|------|--------------------------------------------------------------|-------|-------------|-------------|
| MO01 | 144 Vdc (Motors) Switchboard<br>LEGRAND XL3 160              | 2,00  | 365,78 €    | 731,56 €    |
| MO02 | Electric DC Motor ELCO EP-1000                               | 2,00  | 20.256,58 € | 40.513,16 € |
| MO03 | General Automatic Switch SCHNEIDER<br>ELECTRIC NSX400N 320 A | 2,00  | 2.855,22 €  | 5.710,44 €  |
| MO04 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV     | 40,00 | 201,10 €    | 8.044,00 €  |

2x50 mm<sup>2</sup>**Total Motors:****54.999,16 €**

## 7.3. Distribution

### 7.3.1. Power inverters

| Code                         | Description                                                                           | Units | Unit/Price | Price             |
|------------------------------|---------------------------------------------------------------------------------------|-------|------------|-------------------|
| PI01                         | 48 Vdc Switchboard LEGRAND XL3 160                                                    | 2,00  | 365,78 €   | 731,56 €          |
| PI02                         | Power Inverter/Charger VICTRON<br>ENERGY MULTIPLUS 5 kVA 48<br>Vdc/230 Vac            | 2,00  | 2.989,00 € | 5.978,00 €        |
| PI03                         | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>2x25 + 25 mm <sup>2</sup> | 30,00 | 22,40 €    | 672,00 €          |
| PI04                         | General Automatic Switch SCHNEIDER<br>ELECTRIC C120N 2x100A                           | 2,00  | 217,25 €   | 434,50 €          |
| PI05                         | 230 Vac Main Switchboard LEGRAND<br>XL3 160                                           | 2,00  | 365,78 €   | 731,56 €          |
| <b>Total Power Inverters</b> |                                                                                       |       |            | <b>8.547,62 €</b> |

### 7.3.2. Interconnections

| Code | Description                                                                           | Units | Unit/Price | Price    |
|------|---------------------------------------------------------------------------------------|-------|------------|----------|
| IN01 | Isolator switch SCHNEIDER ELECTRIC<br>INTERPACT INS250, 100 A                         | 2,00  | 133,22 €   | 266,44 € |
| IN02 | Isolator switch SCHNEIDER ELECTRIC<br>INTERPACT INS80, 80 A                           | 2,00  | 79,25 €    | 158,50 € |
| IN03 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>2x16 + 16 mm <sup>2</sup> | 30,00 | 16,75 €    | 502,62 € |
| IN04 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>2x25 + 25 mm <sup>2</sup> | 30,00 | 22,40 €    | 672,00 € |



**Total Interconnections****1.599,56 €****7.3.3. Power rectifiers**

| Code                          | Description                                                                                                                 | Units | Unit/Price | Price             |
|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------|-------|------------|-------------------|
| PR01                          | Rectifier/Battery Charger MASTERVOLT<br>MASS 24/75                                                                          | 1,00  | 1.875,00 € | 1.875,00 €        |
| PR02                          | 2 positions selector switch SCHNEIDER<br>ELECTRIC CM 18070 20 A<br><i>Connection with one of the electrical<br/>systems</i> | 1,00  | 15,92 €    | 15,92 €           |
| <b>Total Power Rectifiers</b> |                                                                                                                             |       |            | <b>1.890,92 €</b> |

**7.4. Passengers Room**

| Code | Description                                                                           | Units  | Price/Unit | Price    |
|------|---------------------------------------------------------------------------------------|--------|------------|----------|
| PR01 | Passengers Room Switchboard<br>LEGRAND XL <sup>3</sup> 160                            | 2,00   | 365,78 €   | 731,56 € |
| PR02 | Circuit breaker SCHNEIDER ELECTRIC<br>iC60N 2x63 A                                    | 2,00   | 187,00 €   | 374,00 € |
| PR03 | Circuit breaker SCHNEIDER ELECTRIC<br>iC60N 2x4 A                                     | 2,00   | 135,69 €   | 271,38 € |
| PR04 | Circuit breaker SCHNEIDER ELECTRIC<br>iC60N 2x6 A                                     | 2,00   | 80,67 €    | 161,34 € |
| PR05 | Circuit breaker SCHNEIDER ELECTRIC<br>iC60N 2x1 A                                     | 4,00   | 135,69 €   | 542,76 € |
| PR06 | Circuit breaker SCHNEIDER ELECTRIC<br>iC60N 2x0,5 A                                   | 2,00   | 151,84 €   | 303,68 € |
| PR07 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>2x16 + 16 mm <sup>2</sup> | 10,00  | 16,75 €    | 167,54 € |
| PR08 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV                              | 122,00 | 3,43 €     | 418,95 € |

|                               |                                                                                                                                                                                                                                   |        |            |                    |
|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------------|--------------------|
|                               | 2x2,5 + 2,5 mm <sup>2</sup>                                                                                                                                                                                                       |        |            |                    |
| PR09                          | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV                                                                                                                                                                          | 116,00 | 2,48 €     | 287,45 €           |
|                               | 2x1,5 + 1,5 mm <sup>2</sup>                                                                                                                                                                                                       |        |            |                    |
| PR10                          | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV                                                                                                                                                                          | 10,00  | 7,33 €     | 73,26 €            |
|                               | 1x16 mm <sup>2</sup>                                                                                                                                                                                                              |        |            |                    |
|                               | <i>Ground and protection</i>                                                                                                                                                                                                      |        |            |                    |
| PR11                          | Schuko sockets                                                                                                                                                                                                                    | 26,00  | 5,00 €     | 130,00 €           |
|                               | <i>Sockets holder with ground connection on the side. In one-phase systems, with ground connection (phase, neutral and ground), including gang box, universal instrument box with screws, socket holder type Schuko 10 – 16 A</i> |        |            |                    |
| PR12                          | GLAMOX CASA 16 113F SI                                                                                                                                                                                                            | 24,00  | 497,00 €   | 11.928,00 €        |
|                               | <i>Downlight 1x19 W, in Galv Steel. White trimring. IP22 . Light source TC-D 1x13W. Ballast type High power factor correction.</i>                                                                                                |        |            |                    |
| PR13                          | GLAMOX E85-S                                                                                                                                                                                                                      | 8,00   | 55,00 €    | 440,00 €           |
|                               | <i>Surface mounted escape rout light or anti panic emergency light system based on LED. White painted aluminium with component plate in polycarbonate.</i>                                                                        |        |            |                    |
| PR14                          | GLAMOX E80-S                                                                                                                                                                                                                      | 2,00   | 1.193,00 € | 2.386,00 €         |
|                               | <i>Exit sign based on LED. White painted aluminium with component plate in polycarbonate.</i>                                                                                                                                     |        |            |                    |
| <b>Total Passengers Room:</b> |                                                                                                                                                                                                                                   |        |            | <b>18.215,92 €</b> |

## 7.5. Entrance & Toilet

| Code | Description                                                                                                                                  | Units | Unit/Price | Price      |
|------|----------------------------------------------------------------------------------------------------------------------------------------------|-------|------------|------------|
| ET01 | Entrance & Toilet Switchboard<br>LEGRAND XL <sup>3</sup> 160                                                                                 | 2,00  | 365,78 €   | 731,56 €   |
| ET02 | Circuit breaker SCHNEIDER ELECTRIC<br>iC60N 2x40 A                                                                                           | 2,00  | 91,12 €    | 182,24 €   |
| ET03 | Circuit breaker SCHNEIDER ELECTRIC<br>iC60N 2x2 A                                                                                            | 2,00  | 135,69 €   | 271,38 €   |
| ET04 | Circuit breaker SCHNEIDER ELECTRIC<br>iC60N 2x1 A                                                                                            | 2,00  | 135,69 €   | 271,38 €   |
| ET05 | Circuit breaker SCHNEIDER ELECTRIC<br>iC60N 2x0,5 A                                                                                          | 7,00  | 151,84 €   | 1.062,88 € |
| ET06 | Circuit breaker SCHNEIDER ELECTRIC<br>iC60N 2x10 A                                                                                           | 2,00  | 75,87 €    | 151,74 €   |
| ET07 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>2x10 + 10 mm <sup>2</sup>                                                        | 26,00 | 10,90 €    | 283,35 €   |
| ET08 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>2x2,5 + 2,5 mm <sup>2</sup>                                                      | 24,00 | 3,43 €     | 82,42 €    |
| ET09 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>2x1,5 + 1,5 mm <sup>2</sup>                                                      | 73,00 | 2,48 €     | 180,89 €   |
| ET10 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>1x16 mm <sup>2</sup><br><i>Ground and protection</i>                             | 10,00 | 7,33 €     | 73,26 €    |
| ET11 | Schuko sockets<br><i>Sockets holder with ground connection on the side. In one-phase systems, with ground connection (phase, neutral and</i> | 6,00  | 5,00 €     | 30,00 €    |

|                                     |                                                                                                                                                                     |       |            |                    |
|-------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|------------|--------------------|
|                                     | ground), including gang box, universal instrument box with screws, socket holder type Schuko 10 – 16 A                                                              |       |            |                    |
| ET12                                | GLAMOX CASA 16 113F SI<br>Downlight 1x19 W, in Galv Steel. White trimring. IP22 . Light source TC-D 1x13W. Ballast type High power factor correction.               | 11,00 | 497,00 €   | 5.467,00 €         |
| ET13                                | GLAMOX E85-S<br>Surface mounted escape rout light or anti panic emergency light system based on LED. White painted aluminium with component plate in polycarbonate. | 7,00  | 55,00 €    | 385,00 €           |
| ET14                                | GLAMOX E80-S<br>Exit sign based on LED. White painted aluminium with component plate in polycarbonate.                                                              | 1,00  | 1.193,00 € | 1.193,00 €         |
| ET15                                | Extractor Fan (Toilet) FANTECH EN31                                                                                                                                 | 1,00  | 50,00 €    | 50,00 €            |
| <b>Total Entrance &amp; Toilet:</b> |                                                                                                                                                                     |       |            | <b>10.416,10 €</b> |

## 7.6. Anteroom

| Code | Description                                      | Units | 0,00 €   | Price    |
|------|--------------------------------------------------|-------|----------|----------|
| AR01 | Anteroom Switchboard LEGRAND XL <sup>3</sup> 160 | 2,00  | 365,78 € | 731,56 € |
| AR02 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x32 A  | 2,00  | 72,77 €  | 145,54 € |
| AR03 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x2 A   | 2,00  | 135,69 € | 271,38 € |
| AR04 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x1 A   | 2,00  | 135,69 € | 271,38 € |
| AR05 | Circuit breaker SCHNEIDER ELECTRIC               | 2,00  | 151,84 € | 303,68 € |

|      |                                                                                                                                                                                                                                                     |       |          |            |
|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|----------|------------|
|      | iC60N 2x0,5 A                                                                                                                                                                                                                                       |       |          |            |
| AR06 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>2x10 + 10 mm <sup>2</sup>                                                                                                                                                               | 14,00 | 10,90 €  | 152,57 €   |
| AR07 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>2x2,5 + 2,5 mm <sup>2</sup>                                                                                                                                                             | 16,00 | 3,43 €   | 54,94 €    |
| AR08 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>2x1,5 + 1,5 mm <sup>2</sup>                                                                                                                                                             | 49,00 | 2,48 €   | 121,42 €   |
| AR09 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>1x16 mm <sup>2</sup>                                                                                                                                                                    | 10,00 | 7,33 €   | 73,26 €    |
|      | <i>Ground and protection</i>                                                                                                                                                                                                                        |       |          |            |
| AR10 | Schuko sockets<br><i>Sockets holder with ground connection on the side. In one-phase systems, with ground connection (phase, neutral and ground), including gang box, universal instrument box with screws, socket holder type Schuko 10 – 16 A</i> | 4,00  | 5,00 €   | 20,00 €    |
| AR11 | GLAMOX CASA 16 113F SI<br><i>Downlight 1x19 W, in Galv Steel. White trimring. IP22 . Light source TC-D 1x13W. Ballast type High power factor correction.</i>                                                                                        | 11,00 | 497,00 € | 5.467,00 € |
| AR12 | GLAMOX E85-S<br><i>Surface mounted escape rout light or anti panic emergency light system based on LED. White painted aluminium with component plate in polycarbonate.</i>                                                                          | 5,00  | 55,00 €  | 275,00 €   |

|                        |                                                                                               |      |            |                    |
|------------------------|-----------------------------------------------------------------------------------------------|------|------------|--------------------|
| AR13                   | GLAMOX E80-S                                                                                  | 2,00 | 1.193,00 € | 2.386,00 €         |
|                        | <i>Exit sign based on LED. White painted aluminium with component plate in polycarbonate.</i> |      |            |                    |
| <b>Total Anteroom:</b> |                                                                                               |      |            | <b>10.273,74 €</b> |

## 7.7. Bridge

| Code | Description                                                                     | Units | 0,00 €   | Price    |
|------|---------------------------------------------------------------------------------|-------|----------|----------|
| BR01 | Bridge Switchboard LEGRAND XL <sup>3</sup> 160                                  | 2,00  | 365,78 € | 731,56 € |
| BR02 | Circuit breaker SCHNEIDER ELECTRIC c120N 2x80A                                  | 1,00  | 196,42 € | 196,42 € |
| BR03 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x63 A                                 | 1,00  | 187,00 € | 187,00 € |
| BR04 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x2 A                                  | 1,00  | 135,69 € | 135,69 € |
| BR05 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x0,5 A                                | 2,00  | 151,84 € | 303,68 € |
| BR06 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x20 A                                 | 1,00  | 79,67 €  | 79,67 €  |
| BR07 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x10 A                                 | 1,00  | 75,87 €  | 75,87 €  |
| BR08 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x16 A                                 | 5,00  | 77,37 €  | 386,85 € |
| BR09 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x50 A                                 | 4,00  | 201,10 € | 804,40 € |
| BR10 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT 0,6/1 kV 2x16 + 16 mm <sup>2</sup> | 10,00 | 16,75 €  | 167,54 € |
| BR11 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT 0,6/1 kV 2x25 + 25 mm <sup>2</sup> | 10,00 | 22,40 €  | 224,00 € |

|      |                                                                                                                                                                                                                                                     |       |            |            |
|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|------------|------------|
| BR12 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>2x2,5 + 2,5 mm <sup>2</sup>                                                                                                                                                             | 57,00 | 3,43 €     | 195,74 €   |
| BR13 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>2x1,5 + 1,5 mm <sup>2</sup>                                                                                                                                                             | 51,00 | 2,48 €     | 126,38 €   |
| BR14 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>2x6 + 6 mm <sup>2</sup>                                                                                                                                                                 | 22,00 | 6,98 €     | 153,60 €   |
| BR15 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>2x10 + 10 mm <sup>2</sup>                                                                                                                                                               | 7,00  | 10,90 €    | 76,29 €    |
| BR16 | Conductor GENERAL CABLE<br>EXZHELLENT – MAR RDT 0,6/1 kV<br>1x16 mm <sup>2</sup><br><i>Ground and protection</i>                                                                                                                                    | 10,00 | 7,33 €     | 73,26 €    |
| BR17 | Schuko sockets<br><i>Sockets holder with ground connection on the side. In one-phase systems, with ground connection (phase, neutral and ground), including gang box, universal instrument box with screws, socket holder type Schuko 10 – 16 A</i> | 2,00  | 5,00 €     | 10,00 €    |
| BR18 | GLAMOX i70-1200 LED 4500 DALI 840<br><i>LED 1x50 W</i>                                                                                                                                                                                              | 1,00  | 300,00 €   | 300,00 €   |
| BR19 | GLAMOX E85-S<br><i>Surface mounted escape rout light or anti panic emergency light system based on LED. White painted aluminium with component plate in polycarbonate.</i>                                                                          | 2,00  | 55,00 €    | 110,00 €   |
| BR20 | GLAMOX E80-S                                                                                                                                                                                                                                        | 1,00  | 1.193,00 € | 1.193,00 € |

*Exit sign based on LED. White painted aluminium with component plate in polycarbonate.*

|                      |                                                                   |      |            |                    |
|----------------------|-------------------------------------------------------------------|------|------------|--------------------|
| BR21                 | GLAMOX JET 7                                                      | 7,00 | 2.012,00 € | 14.084,00 €        |
|                      | <i>Exterior lighting. Jet 7 body sym hammered reflector black</i> |      |            |                    |
| BR22                 | Windlass anchor MAXWELL MARINE RC10                               | 1,00 | 2.058,71 € | 2.058,71 €         |
| <b>Total Bridge:</b> |                                                                   |      |            | <b>21.673,66 €</b> |

## 7.8. Engine Rooms & Electrical Compartments

| Code | Description                                                                       | Units  | 0,00 €   | Price    |
|------|-----------------------------------------------------------------------------------|--------|----------|----------|
| EE01 | Anteroom Bridge LEGRAND XL <sup>3</sup> 160                                       | 2,00   | 365,78 € | 731,56 € |
| EE02 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x40 A                                   | 2,00   | 91,12 €  | 182,24 € |
| EE03 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x4 A                                    | 6,00   | 135,69 € | 814,14 € |
| EE04 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x2A                                     | 2,00   | 135,69 € | 271,38 € |
| EE05 | Circuit breaker SCHNEIDER ELECTRIC iC60N 2x0,5 A                                  | 4,00   | 151,84 € | 607,36 € |
| EE06 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT 0,6/1 kV 2x10 + 10 mm <sup>2</sup>   | 6,00   | 10,90 €  | 65,39 €  |
| EE07 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT 0,6/1 kV 2x2,5 + 2,5 mm <sup>2</sup> | 42,00  | 3,43 €   | 144,23 € |
| EE08 | Conductor GENERAL CABLE EXZHELLENT – MAR RDT 0,6/1 kV 2x1,5 + 1,5 mm <sup>2</sup> | 210,00 | 2,48 €   | 520,38 € |
| EE09 | Conductor GENERAL CABLE                                                           | 10,00  | 7,33 €   | 73,26 €  |



|                                                         |                                                                                                                                                                                                                                                     |       |          |                   |
|---------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|----------|-------------------|
|                                                         | EXZHELLENT – MAR RDT 0,6/1 kV<br>1x16 mm <sup>2</sup><br><i>Ground and protection</i>                                                                                                                                                               |       |          |                   |
| EE10                                                    | Schuko sockets<br><i>Sockets holder with ground connection on the side. In one-phase systems, with ground connection (phase, neutral and ground), including gang box, universal instrument box with screws, socket holder type Schuko 10 – 16 A</i> | 8,00  | 5,00 €   | 40,00 €           |
| EE11                                                    | GLAMOX i70-1200 LED 4500 DALI 840<br><i>LED 1x50 W</i>                                                                                                                                                                                              | 10,00 | 300,00 € | 3.000,00 €        |
| EE12                                                    | GLAMOX E85-S<br><i>Surface mounted escape rout light or anti panic emergency light system based on LED. White painted aluminium with component plate in polycarbonate.</i>                                                                          | 12,00 | 55,00 €  | 660,00 €          |
| EE13                                                    | Bilge pump VIGILEX SS                                                                                                                                                                                                                               | 4,00  | 200,00 € | 800,00 €          |
| EE14                                                    | Extractor Fan NEOLINEO-100-Q                                                                                                                                                                                                                        | 4,00  | 100,00 € | 400,00 €          |
| <b>Total Engine Rooms &amp; Electrical Compartments</b> |                                                                                                                                                                                                                                                     |       |          | <b>8.309,94 €</b> |

## 7.9. Basic Health and Safety Study

| Code | Description                                                                                                              | Units | 0,00 €     | Price      |
|------|--------------------------------------------------------------------------------------------------------------------------|-------|------------|------------|
| HS01 | Basic Health and Safety Study<br><i>The Basic Health and Safety Study will have 1% of the total costs of the project</i> | 1,00  | 2.079,61 € | 2.079,61 € |

## 7.10. Total Budget

| Section      | Description                               | Price               | Percentage |
|--------------|-------------------------------------------|---------------------|------------|
| 7.1          | Batteries                                 | 83.569,10 €         | 37,69%     |
| 7.2          | Motors                                    | 54.999,16 €         | 24,81%     |
| 7.3.1        | Distribution: Power inverters             | 8.547,62 €          | 3,86%      |
| 7.3.2        | Distribution: Interconnections            | 1.599,96 €          | 0,72%      |
| 7.3.3        | Distribution: Power rectifiers            | 1.890,92 €          | 0,85%      |
| 7.4          | Passengers Room                           | 18.215,92 €         | 8,22%      |
| 7.5          | Entrance & Toilet                         | 10.416,10 €         | 4,70%      |
| 7.6          | Anteroom                                  | 10.273,74 €         | 4,63%      |
| 7.7          | Bridge                                    | 21.673,66 €         | 9,78%      |
| 7.8          | Engine Rooms & Electrical<br>Compartments | 8.309,94 €          | 3,75%      |
| 7.9          | Basic Health and Safety Study             | 2.216,55 €          | 1,00%      |
| <b>Total</b> |                                           | <b>221.712,67 €</b> |            |

### Material implementation budget

|                         |                     |
|-------------------------|---------------------|
| 13,00% Material costs   | 28.822,59 €         |
| 6,00% Industrial profit | 13.302,74 €         |
| 30% Labour              | 66.513,68 €         |
| <b>Total</b>            | <b>330.351,68 €</b> |

### Bidding budget

|                              |                     |
|------------------------------|---------------------|
| 21,00% Value-added tax (VAT) | 69.373,76 €         |
| <b>TOTAL</b>                 | <b>399.725,44 €</b> |

The total Budget reaches a value of 399725,44 € (THREE HUNDRED NINETY NINE THOUSAND SEVEN HUNDRED TWENTY FIVE point FORTY FOUR euros).



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PROPULSION SYSTEM BASED ON LI-ION  
BATTERIES FOR MARINE APPLICATIONS**

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Cádiz, September 2015