

4. Environmental conditions

All electrical component/equipment is to be designed for continuous operation in the condition in the following ambient conditions.

If stainless steel is used for items foreseen to be installed in outer areas, only AISI316 (not to be welded) or AISI316L (to be welded) steel is to be used.

4.1. Angular motion (Inclination of Ship)

In compliance with LRs Part 6 Chapter 2 Para 1.9:

Type of machinery, equipment or component	Angles of inclination, in degrees ⁽²⁾			
	Athwartship		Fore-and-aft	
	static	dynamic	static	dynamic
Essential electrical equipment	15	22.5	5 ⁽³⁾	7,5
Safety systems, e.g., emergency power installations, crew and passenger safety systems	22.5	22.5	10	10
Switchgear, electrical and electronic appliances ⁽¹⁾				

NOTES

(1) Up to an angle of 45° no undesired switching operations or operational changes may occur.

(2) Athwartships and fore-and-aft inclinations may occur simultaneously.

(3) Where the length of the ship exceeds 100 m, the fore-and-aft static angle of inclination may be taken as: 500/L Degrees where L=Rule length, in metres, see LRs Pt 3, Ch 1,6.1.

4.2. Environmental Class (related to 721-3-6 IEC publication)

In general Environmental Class for Electrical Equipment to be fitted on board is to be:

- 6K 3 climatic
- 6B 2 biological
- 6M 2 mechanical
- 6C 1 chemical
- 6S 1 mechanical active

4.3. Noise Level and Vibration

Electrical equipment and machinery if not otherwise indicated will be capable to operate without any malfunction in presence of vibrations up to the values indicated in the IEC 60092-101 standard.

Rotating electrical machines vibration to have maximum amplitude values corresponding to those indicated in IEC 60034-14. Rotor must be dynamically balanced complete with shaft half key in place, as foreseen by the Rules.

Rotating electrical machines noise level must be in accordance with 60034 - 9 IEC Recommendation.

Airborne noise level of low voltage transformers is to be maximum 60 dBa at 1 m, without enclosure (any direction).

With the exception of low voltage transformers, the expected airborne noise level for each type of equipment, presented as average A-weighted sound pressure level (around the machinery), measured at a distance of one-meter front the surface in dB with ref. $2 \cdot 10^{-5}$ Pa, must not exceed the value of 85 dB(A).

4.3.1. Test Procedure

When required by the Builder all measurements in workshop have to be performed with machinery / equipment running at its nominal load or its normal operating condition by the Contractor.

Where on board limits have to be fulfilled as per Ship Specification, measurements will be performed to check the respect of the limits.

4.3.2. Quality Control

The noise behaviour shall be checked during design, fabrication and installation of equipment and machinery to ensure that the final noise/vibration limits will be complied with.

Should any measured values overtake the a.m. relevant limits, the Contractor has to undertake all actions needed to fulfil the requirements on his account.

During the vessel's construction, inspection should be carried out to ensure that the actions taken to reduce the noise in accordance with the agreed predictions shall be effective.

5. Hazardous areas

The vessel is equipped with liquefied natural gas (LNG) dual fuel engines. Here below the different hazardous areas and the prescription of electrical equipment expected to be installed in them. If special category spaces and hazardous areas are overlapping, electrical equipment selection and installation shall be for the most severe requirements herein mentioned.

The classification of Hazardous areas shall be shown on Builder drawing:

- Dangerous Goods Hazardous Classified Spaces Functional Arrangement

5.1. Electrical equipment installed beside LNG system

Liquefied Natural Gas system comprises hazardous areas (e.g. bunker station) classified according Lloyd Register, IEC 60079-10 and resolution MSC 1/Circ.1591, MSC 95/22/Add.1 and MSC.1/Circ.1558.

Electrical equipment installed in zone 1 relevant to LNG hazardous areas shall be:

- Safe type Exd, Exe, Ex (ia or ib)
- Gas group IIA
- Temperature class T2
- Minimum degree of protection:

Electrical equipment installed in zone 2 relevant to LNG hazardous areas, shall be tested specifically for zone 2, for example:

- Exn protection
- Minimum class of protection:
 - IP56 in open decks,
 - IP55 elsewhere.

5.2. Electrical portable ship equipment hazardous areas

Electrical portable equipment usable in above mentioned hazardous areas shall be suitable for usage in them.

Apparatus which could be interested to above mentioned requirements, but not limited to, are:

- Portable radios
- Wireless phones
- Cellular phones
- Pagers
- Portable lamps
- Electric tools (e.g. drills, etc.)
- Electrical portable instrumentation (e.g. multi-meter, etc.)

Since dangerous areas and LNG spaces follows different classification regulation and prescription, ever refer to above mentioned Rules as well as to Builder drawing:

- Dangerous Goods Hazardous Classified Spaces Functional Arrangement

for proper selection of the electrical equipment to be used or installed in different hazardous zones.

6. General technical prescriptions

Main technical prescriptions for electrical equipment are provided in the following paragraphs.

6.1. Available electric supply

Electrical power is distributed to users with the below listed distribution systems:

Item	Voltage	Freq.	Phase	Cond.
Generators	11000/690	60	3	3
MV motors	11000	60	3	3
LV Motors in general	690	60	3	3
Cooking and heating equipment over 3 kW	440/220	60	3	3
Fractional kW motors (see also 7.10.1.2.1)	220	60	3/1	3/2
Navigation aids	690/220	60	3/1	3/2
Radio plant	220/127	60	3/1	3/2
	24	DC	2	2
Automation plant	690	60	3	3
Galley, pantry, washing machinery up to 3 kW incl.	220/120	60	3/1	3/2+T
Lighting:				
• normal lined spaces	220	60	3/1	3/2+T
• not lined spaces	220	60	3/1	3/2+T
• portable	24	60	3/1	3/2
• emergency/transitional	220	60	2	2+T
• low location lighting	24	DC	2	2+T
Internal communications	220	60	1	2+T
	24/48	DC	2	2+T
Alarms and signals	24	DC	2	2+T
11 kV MSWB aux. Circuits	110	DC	2	2+T

Item	Voltage	Freq.	Phase	Cond.
Sockets in general	440/220/127	60	3/1	3/2+T 1+N+T
Shaver sockets in bathroom with isolating transformer.	220/120	60	2	2
Cabin sockets for American fittings	127	60	3/1	1+N+T
High risk areas sockets	220/127*	60	3/1	1+N+T
Rigging equipment	440	60	3	3

“T” means “earth” conductor.

“N” means “neutral” conductor

(*) 220VAC sockets in ER areas, 127 VAC sockets in outer areas.

Main electrical power is generated and distributed at 11000V, 3 phase, 60Hz via a 3 wire. HV network is earthed through earthing resistors connected at the star point of HV generators.

All other LV distribution network are system with neutral point unearthed.

Earth insulated distribution systems will be provided with permanent insulation level monitoring in accordance with Classification Society requirements.

6.2. Network voltage waveform

Total voltage harmonic distortion in voltage waveform (THDv) is not to exceed the following limits:

On High Voltage Network:

- $THDv \leq 5\%$ with all four half motors configuration
- $THDv \leq 8\%$ in degraded condition

On Low Voltage Network:

- THDv according Lloyd Register Rules.

The supplied electrical equipment installed and connected on board is to be capable of operating within its design parameters and providing rated performance with a THDv up to 12%.

6.3. Short circuit withstand of electrical equipment

Components of electrical system are to be designed and constructed so as to withstand for the admissible duration the thermal and electrodynamic stresses caused by possible over-currents, including short-circuit.

The rated short-circuit making and breaking capacity of every protective device is to be adequate for the prospective fault level at its point of installation.

According to above, the Manufacturer have to require the relevant short-circuit value in the point of installation in due time and anyway not later than basic design stage.

The Manufacturer must provide all the power rated values and any additional information in order to calculate the relevant short-circuit current in the point of installation.

Protection relay coordination between various boards shall be documented and considered as included in the scope of supply.

The Manufacturer must provide, for each point of installation a table as containing at least the information

6.4. Ingress Protection (IP) degree

The IP rating for electrical equipment shall be in accordance with IEC standards and Lloyd Register Rules requirements.

The following IP ratings are to apply for electrical equipment enclosures:

- IP44 for engine spaces and open deck areas
- IP56 for bilge areas where is to be provided
- IP44 for galleys, pantries and laundries
- IP22 for accommodation spaces

In particular, for following equipment minimum protection (IP) ratings are to be as follows:

- | | |
|---------------------------------|---------------------------|
| • Low voltage main switchboards | IP22 in switchboard rooms |
| • Air conditioning boards | IP44 in AC-rooms |

- Medium Voltage (MV) switchboards IP32
- Group Starter panels (GSPs) IP22 in switchboard rooms
- Cabin distribution units IP44
- UPS cabinets IP22 in switchboard rooms

The IP rating for enclosures of distribution boards to be as follows:

- Engine room and A/C Stations: IP 44
- Control rooms and accommodation dry spaces: IP 23
- Galley, laundries etc.: IP 44
- Open decks: IP 56

The IP rating for enclosures of junction boxes to be as follows:

- IP44 for enclosed spaces
- IP56 for weather decks
- IP68 or highest if liable to be submerged

Specific requirements for equipment in hazardous areas are detailed in section 5 of this document.

6.5. Labelling

Marking of all switchboards, distribution panels, control boards, junction boxes and all other electrical components included in scope of supply shall be provided.

Flame retardant materials are to be used for name plates, labels and mimic diagrams. Brass nameplates are to be used on exposed decks.

The name and identification shall correspond with references used in the system drawings and documentation.

Intelligible, permanent identification on external controls, instrumentation and circuit breakers as well as on internal components of electrical equipment shall be provided. Engraved "screwed on" (or, where not feasible, fixed by other suitable means) nameplates, with black letters on white background, are to be fitted to identify all switchboards, distributions boards and other electrical cubicles. Circuit breakers on switchboards and distribution panelboards, instruments, controls, etc are to be identified in accordance with Builder's standards with engraved or printed text and fixed with screws, rivets or other alternative method that ensures easy replacement in case of need.

All circuit breakers and miniature circuit breakers are to be labelled – close to the breaker – to indicate supplied consumer.

Labelling of the internal components of the electrical equipment shall be according Manufacturer's standards.

For labelling requirements, refer also to separate documents.

6.6. Painting schedule and colours

The painting schedule to be detailed in the offer and to include at least:

- Surface preparation (elimination of metal defects, weld asperities, weld droplets; sharp angles rounding, cleaning, degreasing pickling, phosphatising).
- Paint type description (epoxy with solvent, powder type, others).
- Method and condition of application:
- Product preparation, environment,
- Oven temperature, curing. etc.
- Dry film thickness to be specified with tolerance.

External surfaces of electrical switchboards, transformers and rotating machines shall be RAL 7019 colour with sheen finish.

6.7. Indicating Lights and Push Buttons

The colour code to be used throughout the installation is to be as follows:

Type	Description
Green pushbuttons	Start for single speed motors
	High speed for two speed motors
Green lamps	Motor running (single speed)
	Motor running (high on two speed)
	Circuit breaker closed
	Contactor closed
Amber pushbuttons	Low speed for two speed motors
Amber lamps	Low speed for two speed motors
Red pushbuttons	Stop
	Emergency stop

Type	Description
Red lamps	Stop
	Alarm
	Circuit breaker open
	Contactors open
	Warning
Blue lamps	Anti-condensation heaters
White pushbuttons	All other duties
White lamps	Supply available
	All other duties

All indicating lamps to be LED type.

Indicator lamps for communication apparatus, navigation aids and LES equipment are to be as per Mfr's standard.

7. Electrical machinery and components

7.1. Rotating machines

Rotating MV electrical machines (alternators, thruster motors, HVAC compressor motors and propulsion motors), are to be subject to the insulation qualification and acceptance tests described within IEC/TS 60034-18-42. An estimation of life expectancy, nominally 30 years under the specific network conditions onboard, is to be determined.

All the above machines are to be subject to a partial discharge test in the factory and again between six months and one year after the delivery of the Vessel to establish a reference level for future trend analysis.

Low voltage rotating electrical machines with a power rating of 500KW and above (LV alternators and LV motors for fans and pumps), are to be subject to the qualification and acceptance tests described within IEC/TS 60034-18-41.

Rotating machinery i.e. generators and electric motors are to be installed in accordance with the required arrangements for the prime mover or the driven machine.

7.2. Electric motors

Motors integrated into machines or supplied in integrated units for galley, pantry, accommodation ladders and laundry appliances are to be in accordance with the Manufacturer's standard.

Motors are to be of the squirrel cage asynchronous type and are to comply with IEC standards.

Main characteristics of all motors are to meet those required by the driven machine, such as pumps, compressors, fans, and as described in other Sections of this document.

Auxiliary motors are to be rated about 10% higher than the maximum driven machine duty (pump, compressor or fan).

Motors are to have class F insulation and class F temperature rise.

Where variable speed drive (VFD) is installed, appropriate motor construction (in accordance with IEC 60034-25) is to be used according to motor Mfr. Prescriptions.

7.2.1. Enclosure and Installation

Motors installed on weather decks and those used for grinders, pulpers and axial flow fans are to be completely enclosed (IP 56 protection).

The six ends of the windings are to be led into the terminal box.

The terminal box is to be built in accordance with the Manufacturer's standard and is to have the same protection degree as the motor. The terminal block for the motor supply cables is to have studs, nuts washers and copper links or bars in accordance with the current rating of the motors.

Motors are to be installed in such a way that the terminal box has direct unobstructed access.

7.2.2. Revolutions

All motors up to and including 350 kW are to be rated at 1800 rev/min. Motors over 350 kW are not to exceed 900 rev/min unless otherwise specified in this Specification. Changes to these limitations are to be subject to Buyer's approval.

7.2.3. Standstill Heaters

Standstill heaters without thermostat are to be provided for motors fitted on weather decks with IP 56 protection, for essential motors over 20 kW, and for motors with water coolers, IP 44 protection.

Thruster motors heaters are to be provided with thermostats.

Heaters are to be supplied at 220 V via the auxiliary transformers included in their starters.

The power supply for heaters is to be separately protected from the motor control circuit.

If, in exceptional cases, it is necessary to supply the heater from a separate external supply, the heater circuit supply is to pass through the main starter isolating switch so that the heater supply can be isolated.

Heaters are to be controlled via an auxiliary contact of the main contactor or associated relay.

The "heater on" pilot lamp is to be fitted on the starter front door.

Heater terminals on the motor are to be separately protected, shrouded and labelled.

7.2.4. HV motors

For motors with a rated power higher than 500 kW, the supply voltage is to be 11000 V, three phase, 60 Hz.

11000 V motors are to have a fabricated steel frame with cross members.

11 kV motors air conditioning compressors, are to be IP 44 protection.

Fresh water coolers for the 11000 V thruster motors are to be provided.

Heat exchangers construction reference as follows:

Inner tubes (water side)	Cu/Ni 70/30
Fined outer tubes (air side)	Cu
Tube plates (water side)	Naval brass
Tube plates (air side)	Galvanized steel
Water boxes and flanges	Steel (with Rilsan protection)
Anodes	no anodes

Cooling of A/C compressor motors to be in accordance with the standard approved during Manufacturer's selection.

Each 11000 V thruster motor is to be provided with:

- three Pt 100 thermo-resistances plus one as spare on each winding (total twelve)
- one Pt 100 thermo-resistance on DE bearing and one Pt 100 thermo-resistance on NDE bearing.
- one Pt 100 thermo-resistance at cooling air outlet.
- one water leakage detector with local indication and SPDT electric contact.

Interface with IAMCS will be provided.

Each air conditioning compressor motor is to be provided with the same monitoring as the thruster motors if fresh water cooled or, if alternative design for cooling is provided,

monitoring for that is to be in accordance with the standard approved during Manufacturer's selection

7.2.5. LV motors

For motors up to and including 500 kW, the supply voltage is to be 690 V (or 440 V), 60 Hz. Fractional motors below 1 kW for various services may be supplied with 690/440/230/220/127 V A.C. single or three phase, 60 Hz, in accordance with the Manufacturer's standard.

690 V and 440 V motors are to be rated for an ambient air temperature of 50°C and to be capable of operating continuously with the maximum total harmonic distortion in voltage waveform (THDv) foreseen for all supplied electrical equipment, as detailed in 6.2.

690 V and 440 V motors are to have frame and end shield materials in cast iron, except for motors rated below 1 kW.

690 V and 440 V motors are to be totally enclosed of IP 55 protection externally fan cooled.

The LV motors bearings are to be of the end-shielded radial ball bearing type with preloaded axial spring suitable for grease lubrication and equipped with grease nipples. Small motors with bearings "grease packed for life" in accordance with the Manufacturer's standards may be proposed, subject to Owners approval.

The grease used for the bearings is to be in accordance to the operating conditions and the Manufacturer's requirements.

LV motors efficiency is to be in compliance with IEC 60034-30-1 with the implementation time schedule according to EU Minimum Energy Performance Standards. Motors will be rated to work also up to 50°C but IE3 performance will not be guaranteed above 40°C.

Motors designed exclusively for converter operation or fully integrated into machines are exempted from the above requirement.

Rigging motors, motors foreseen to run only for short intervals (with duty type outside those specified by IEC 60034-30 standard) and motors foreseen to function only in emergency conditions (e.g. EDDG radiator fan, Hi-Fog pumps) are exempted from complying IE3 standard, and are to be rated to the Mfr standard .

7.3. Transformers

Transformers are to be treated to resist moisture, oil vapour and salt air.

Electrostatic screens between the windings are to be provided for medium and low voltage transformers.

Maximum voltage drops are to be according to classification requirements.

Dismantling and removal of cast resin transformer coils is to be achievable minimising interference from the main vessel's structure, including piping and cable trays.

Thermal inspection windows are to be provided to enable monitoring of cable connections.

Resilient mountings are to be provided to prevent iron core vibration transmission to the structure.

7.3.1. LV transformers

Low Voltage transformers are to be single phase, 3-phase or three times single phase grouped with one or two secondary windings.

Each low voltage transformer will have the following characteristics:

- Technology: Dry type, resin coated
- Cooling: Natural air cooling
- Windings: Copper
- Insul./temp. rise class: F/B
- Protection: IP23
- Service: Continuous

Together with rated voltage terminals, the primary winding is to be equipped with taps ($\pm 2.5\%$ and $\pm 5\%$ of rated voltage) for output voltage regulation.

LV/LV transformers of 400kVA and above to be provided with

- two PT100 sensors for each secondary winding phase, one connected to local display and one spare;
- anti-condensation heaters.

LV/LV transformers to have resin impregnated windings designed in order to allow disassembling. To make the disassembly possible, the magnetic core shall not be resin impregnated but coated with a corrosion resistant sealant.

Low Voltage Transformers shall be provided with a base-frame that can be directly welded on the bridge. Resilient mountings shall be installed between the base frame and the bottom plates of transformer enclosures to prevent iron core vibration transmission to the structure.

The cable connections are to be done on a dedicated terminal board suitable for cable connection with lugs, nuts and bolts. Internal connection between windings and terminal board are to be done by cables or bars.

The terminal box is to be mounted externally of the transformer in general on one of the shortest sides.

7.4. Cables

Before the order, the Supplier/Manufacturer of the system is to clearly inform of all special requirements for cable installation (separate cable trays, special EMI level, steel pipe protection, subject to be damaged from painting, others) and type (armoured cable, screened cable, others). Where recommended by Supplier, special cables may be used.

Cables included in scope of supply are to be either of the Type Approved type or according to the applicable standards among those listed below. Relevant certificates and data sheets to be provided.

Where recommended by Supplier, special cables may be used.

As far as possible, the equipment/machinery must be delivered to the Shipyard with cables fitted on it already installed and connected, i.e. all cables fitted on machinery and that are not to be connected with other plants, are to be already installed and connected.

The cables are to be in accordance with:

- IEC Publication 60092 series
- IEC 60332-1 (single cable) and 60332-3 (bunched cables) for flame retardant characteristics
- IEC 60331 for fire resisting characteristics
- IEC 60754-1 & 2 for halogen free properties of low voltage cables
- IEC 61034-1 & 2 for smoke density measurement of low voltage cables
- IEC 60228 class 2 for standard conductors and class 5 for flexible conductors limited to largest cross sections of low voltage power cables (16 mm² and over).

Main power (greater than 80 amps) cables are to be in one length and joints or sharp bends are not permitted.

The maximum working current for all cables is to be in compliance with the Classification Society or IEC Rules.

Electric cables are to be of the "halogen free" low toxicity type except special cables where a halogen free version is not available, in which case they are to be of a flame retardant type with low emission of smoke, toxic and corrosive gases. These non-halogen free cables are subject to the Buyer's approval on a case by case basis.

Fire resistant cables are to be used for Safety Systems, in accordance with Classification Society, and Safe Return to Port (SRtP) requirements.

Fire resistant cables are required where the ambient temperature exceeds 70°C.

Fire resistant cables to be used for SRtP essential system are to comply with interpretation 13 of the IMO MSC.1/Circ. 1369 and are to fulfil following prescriptions:

- All cables that need to remain in operation after a fire casualty are to be in compliance with IEC 60331-1 and IEC 60331-2, and are to be installed according to Builder's standards.
- Cables of rated voltage up to and including 0.6/1.0 kV with an overall diameter not exceeding 20 mm are to be in accordance with IEC 60331-2 and CEI EN 50200 Annex E for water spray withstand.
- Cables of rated voltage up to and including 0.6/1.0 kV with an overall diameter exceeding 20 mm are to be in accordance with IEC 60331-1 with an additional water jet test. The additional test consists in the application of five bursts of water (5s duration) repeated every minute during the last five minutes of IEC test, as indicated in the BS 8491. The water jet device to be in accordance with BS 8491. The flame and shock application devices are to be according to IEC 60331-1.

7.4.1. MV cables

Medium voltage (M.V.) cables complying with IEC 60332-3-22, category A, are to have:

- Conductor: Tinned copper stranded conductors -IEC 60228;
- Conductor screen: Extruded semi-conductive layer around the conductors
- Insulation: Extruded Ethylene Propylene Rubber HEPR or XLPE according to IEC 60092-360.
- Insulation screen: Extruded semi-conductive layer around the insulated conductor
- Metallic screen: Copper tape screen or semi-conducting tape with copper spinning around each insulated conductor
- Inner covering: Extruded thermoplastic halogen free compound. In three core cables, halogen free inner covering to include triple semi compressive insulating round halogen free fillers.
- Armour: Tinned copper wire or galvanized steel wire braid armour;
- Outer sheath: Red color halogen free compound SHF1 according to IEC60092- 360 to be stamped with Maker's name, cross section, type of cable, Rules in compliance with.

MV cables are to be armoured.

The cable construction of the high voltage generation and distribution system to be suitable for the operating voltage of 11kV, i.e 8.7/15(17.5) kV, with conductor screen, core screen and overall armour.

Medium voltage cable between propulsion transformers and converters, including the cables to the actual motors are to be rated according to the voltage of the selected propulsion system.

Cable terminations to be such that there is satisfactory stress grade at the cable ends.

Cable connections are to be carefully prepared and sealed to prevent ingress of moisture.

If single core cables are used, precautions must be taken against circulating currents in the sheaths or screens.

7.4.2. LV cables

Low voltage (L.V.) cables complying with IEC 60332-3, category A, up to and including 10 mm² with the following construction standard:

- Conductor: Red copper stranded conductors -IEC 60228;
- Insulation: Extruded Ethylene Propylene Rubber EPR or XLPE according to IEC 60092- 360
- Inner covering: Fire retardant tape (if armoured)
- Armour (if any): Galvanized steel or red copper wire braid;
- Outer sheath: Halogen free compound SHF1 according to IEC60092-360 to be stamped with Maker's name, cross section, type of cable, Rules in compliance with. For not armoured cables, outer sheath to be of the extruded-penetrating type.

Low voltage (L.V.) cables complying with IEC 60332-3, category A, above 10 mm² with the following construction standard:

- Conductor: Red copper stranded conductors -IEC 60228;
- Insulation: Extruded Ethylene Propylene Rubber EPR or XLPE according to IEC 60092- 360
- Inner covering: Halogen free fillers and flame retardant tape
- Armour (if any): Galvanized steel or red copper wire braid;
- Outer sheath: Halogen free compound SHF1 according to IEC60092- 360 to be stamped with Maker's name, cross section, type of cable, Rules in compliance with.

The external sheaths of the low voltage cables are to be of the following colours:

RAL description	Type of cable
9004 Signal Black	Power
6018 Yellow Green	Small power and lighting (with incorporated Yellow/Green protection conductor)
2003 Pastel Orange	Multicore and twisted pair

The external sheaths of SDCN data cables are to be subject to a unique colour scheme. Power and lighting cables, unless otherwise stated, are to be 0.6/1 kV grade with a maximum operating temperature of 90 deg. C.

Multicore cables with cross section above 1 mm² are to be 0.6/1 kV.

Twisted pair cables with cross section above 0.75 mm² are to be 150/250 V grade.

Cables sensitive to interference are to be provided with additional screens made of aluminium polyester tape ensuring 100% screening capacity.

Cable screening may consist of overall collective screening, individual pair screening or overall plus individual pair screening dependent on system requirements and sensitivity to interference, according to system manufacturer's recommendation.

Multi-core and twisted pair cables are to be marked at regular intervals with a number separately identifying each core or each pair.

Motor supply cables to have at least 10% spare capacity, above the motor rated current.

The cables supplying all section board and distribution board are to have at least 10% spare capacity, taking into account the load factor.

Where "fire resistant cables" are required by the Rules (e.g. emergency circuits), or where the ambient temperature exceeds 70°C, the cables are to have in addition to the above:

- Mica-glass tape over the conductor/s or equivalent solution to meet the requirements of IEC 60331.

Cables feeding the propulsion excitation cubicles are to be armoured.

Cables for internal connection of electric equipment are to be in accordance with the Mfr. standard if accepted by the Classification Societies.

The minimum size allowable for fixed wiring for power and lighting cables is 1.5 mm². Cables of smaller cross-sectional area may be used for specific purposes such as terminal wiring of decorative lighting in cabins or public areas, subject to Buyer's approval.

Cables for the secondary side of the lighting distribution (downstream the electronic ballast) can be 1mm², flexible type.

Minimum size of standard multi-core twisted pair cables for communication and instrumentation systems is to be 0.75 mm².

However for communication data and instrumentation, multi-core cables with smaller cross section may be used to satisfy system specification, for example CAT6 or other international data cable standards. Please refer to SDCN description for additional information regarding data cables.

Cables for portable lamps are to be oil resistant, and not less than 1.5 mm².

Where recommended by subcontractors and approved by Buyer, special cables may be used.

Cable size for low voltage AC and DC equipment to be calculated according to voltage drop which is not to exceed 6%, and 3% for navigation light circuits.

7.4.3. Installation of cables

The cable installation is to be in accordance with the IEC Publications 60092-401, 60533 and the requirements of SOLAS and of the Classification Society Rules requirements.

Where cable installation is included in scope of supply, refer to separate document.

The following groups of cables are to be routed separately:

Group J	High voltage cables	EMI generating NOT EMI susceptible
Group K	Power cables and lighting feeders	EMI generating NOT EMI susceptible
Group N	Remote control and signal (relays, mechanical contacts and coils)	EMI generating (transient voltages/currents) Slightly EMI susceptible
	Low voltage/current signals (sensors, communication, audio equipment, data communication bus, etc.)	Slightly EMI generating EMI susceptible
Group S	Thyristor controls, high frequency signals (antennas, radar scanners, log, Echo-sounder, etc.)	Highly EMI generating or Highly EMI susceptible

The separation of cables carrying various voltages and used for various services is to meet the Classification Society Rules requirements.

All cables are to be routed on metal trays, conduits, pipes and individual supports according to Builder's standards.

Galvanized steel trays are not to be provided with further primer and painting.

External cable trays and supports to be made of stainless steel.

Bare steel trays or supports for them, are to be provided with surface preparation, priming and painting according to Builder's standards.

Spare capacity on cable trays is to be provided, although it is accepted that the Builder may use some of the spare capacity for late additional cables.

Cables shall be effectively supported and secured without outer sheath damage, respecting their minimum bend radii.

All cables are to be secured to withstand the effects of system fault currents.

Where flame retardant plastic fasteners are used, metal clips must be installed in accordance with Yard's installation procedures and Classification Society requirements.

Approved flame retardant plastic straps are to be used to secure coaxial cables to avoid signal attenuation.

The distance between supports is to be in accordance with Classification Society requirements.

Medium voltage cables are to be fitted over their full length in galvanized steel duct with holes.

Soft packing is to be installed between cables and clips on 11 kV system

11 kV cable trays are to be marked, at regular intervals, as follows:

DANGER-HIGH VOLTAGE- 11.000 VOLTS.

Single core cables are to be interposed at intervals of approximately 15 m or installed in trefoil formation.

Vertical cable runs in machinery spaces shall have steel fastening clips.

Cable runs shall be accessible and kept away from excessive heat sources and from steam and exhaust gas pipes, and shall be avoided in spaces exposed to drip or accumulation of water or oily vapour.

Where cables are exposed to any mechanical damage in baggage handling, store handling and other exposed spaces, they shall be protected by steel plate or steel conduit in accordance with the Builder's practice. As an alternative galvanized steel flexible hose may be used in some circumstances where approved by the Buyer.

The cover plates for these cables to be of the type which does not allow water to collect from condensation or the sprinkler/water fog system.

Cables seriously damaged during the installation and therefore not capable of carrying the relevant voltage and current, or not capable of supporting specified data or communication standards are to be renewed over the entire length.

Cable runs are not to pass through refrigeration spaces.

Cables are to be laid above and not under water and steam pipes. Exceptions may be made for crossing where unavoidable.

Installation of main cable ways in accommodation areas to be on galvanized steel cable trays.

The minimum distances from the bulkhead to cable supports in unlined spaces are to be as follows:

- Cable trays below 300 mm: 100 mm
- Cable trays above 300 mm : 150 mm

Cable trays fitted in machinery spaces are to be steel plate protected where they are 1.5 meters or less above the floor plates.

Cables supplying appliances in exposed locations are to be to run inside the superstructure.

Cables on masts or posts are to be routed inside

Cable runs are to be kept clear of open decks in passenger areas.

No electrical cable run is to be installed below the lower engine room platform.

If cables are to be fitted in bilges for sensors or lights, they are to be led in tubes under the floor. The tubes are to be fitted with drain holes and securely attached to the ship's structure, and are to be provided with plastic anti chafing inserts at both ends for cable protection.

In living quarters, offices and public rooms, cables are to be located either behind or within the lining and secured to iron rods by means of approved plastic straps or are to be run in steel conduits.

In unlined public spaces, cable trays are to be covered.

Cables to plug sockets, switches and lamps, are to be installed and concealed. If concealing is not possible in specific cases, the wiring to be covered by special mouldings in plastic or light alloy. Decorative mouldings to be arranged so that an easily removable section of duct is fitted next to the outlet being served.

Single cables may be fixed with clips on existing frames.

Cable ends and conductors are to be marked at each connection point in accordance with drawings and international standards.

Cables are to have their ends marked with plastic numbers type cable markers to identify them with their respective numbers shown on the circuit diagrams.

Power cables ends are to be marked with the phase indication.

Each end of sensor cables are to be tagged with the address number corresponding to that listed in the register of alarm and measurement monitoring points.

Cables under 6 mm² are to have a free loop of wire for later convenience.

Conductors of 1.5 mm² and above are to terminate in pressure crimped cable terminals. Exception may be made for pressure-type or equivalent terminal blocks.

Connections are to have washers, nuts and locknuts.

No more than two cable cores are to be terminated at one point.

Where flame-proof, intrinsically safe or high operating temperature equipment is provided, the electrical cables and passages are to meet the requirements for such equipment.

Cables are not to be painted. Prior to painting in an area, all cables are to be covered / masked.

All electrical cables in DDGG and EDDG rooms, oil fired boiler areas, fuel oil and lubricating oil separator rooms, and external fan rooms on the upper decks are to be coated with the FIRE SECURITY coating system.

Electrical connectors of an approved type may be used in lined areas for lighting, PA and fire detection terminal equipment.

7.4.4. Earthling

Except where exempted as mentioned hereafter, all non-current carrying exposed metal parts of electrical equipment and cables are to be earthed for personal protection against electric shock.

The following parts are to be exempted from the requirements

- spare cables, and spare cores in used cables
- lamp-caps, where suitably shrouded;
- shades, reflectors and guards supported on lamp-holders or light fittings constructed of, or shrouded in, non-conducting material;
- metal parts on, or screws in or through, non-conducting materials, which are separated by such material from current-carrying parts and from earthed non-current carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
- apparatus which is constructed in accordance with the principle of double insulation;
- bearing housings which are insulated in order to prevent circulation of current in the bearings;
- clips for fluorescent lamps;

- cable clips and pipes for cable protection;
- apparatus supplied at a safety voltage not exceeding 50 V DC or 50 V AC, between conductors, or between any conductor and earth in a circuit isolated from the supply. Autotransformers are not to be used for the purpose of achieving the alternating current voltage;
- apparatus or parts of apparatus which although not shrouded in insulating material is nevertheless otherwise so guarded that it cannot be touched and cannot come in contact with exposed metal.

Electrical consumers are to be bonded to earth and between removable / hinged parts of their structures by means of earth bonding straps. Consumers fed via cables up to 2.5mm² may be connected to their distribution point's earthing bar via the earth core of the feeder cable. Consumers fed with cables of greater cross-sectional area are to be bonded locally direct to the hull. Standard cabinets and racks may utilise their Manufacturer's approved bonding method for connection of all non-current carrying parts with one dedicated bonding strap to hull.

- Armouring, braiding and other metal coverings of cables are to be effectively earthed. Where the armouring, braiding and other metal coverings are earthed at one end only, they are to be adequately protected and insulated at the unearthed end with the insulation being suitable for the maximum voltage that may be induced. The cables earthing / bonding to prevent excessive circulating currents and overheating of the cables
- The electrical continuity of all metal coverings of cables throughout the length of the cable, particularly at joints and tapings is to be ensured.
- Metal parts of portable appliances, other than current-carrying parts and parts exempted are to be earthed by means of an earth-continuity conductor in the flexible cable or cord through the associated plug and socket-outlet.
- Earthing conductors are to be of copper or other corrosion-resistant material and be securely installed and protected where necessary against damage and also, where necessary, against electrolytic corrosion. Connections are to be so secured that they cannot work loose under vibration.
- The nominal cross-section areas of earthing conductors for electrical equipment are, in general to be equal to the cross-section of the current-carrying conductor up to 16 mm², with a minimum of 1.5 mm². Above this figure they are to be equal to at least half the cross-section of the current-carrying conductor with a minimum of 16 mm².
- The nominal cross-section areas of copper earthing conductors for armouring, braiding and other metal coverings of cables are, in general, to be equal to the equivalent cross-section of the armouring, braiding and other metal coverings with a minimum of 1.5 mm².
- Earthing conductors of materials other than copper are to have a conductance not less than that specified for an equivalent copper earthing conductor.

The connection of the earthing conductor to the hull of the ship is to be made in an accessible position, and is to be secured by a screw or stud of diameter not less than 6 mm which is to be used for this purpose only. Bright metallic surfaces at the contact areas are to be ensured immediately before the nut or screw is tightened and, where necessary, the joint is to be protected against electrolytic corrosion.

Earthing of cable braiding, cable supports and metallic cable protections are to meet the requirements of the system supplier and to be verified by Classification Society.

Signal cable screens are to be earthed in accordance with the requirements of the Manufacturer of the equipment.

Earthing is to be continued through junction boxes and other fittings such as conduits.

Power cable armour and screens are to be earthed at both ends of the cable, unless required at one end only for operational reasons.

All exposed continuous metal work in bathrooms is to be bonded together (equipotential bonding) and earthed to the hull at an accessible location in the cabin technical space.

7.4.6. Bus-Bar Marking

Bus bar marking is to be:

AC system	D.C. system
Phase R marked L1	Positive (+) L +, Red
Phase S marked L2	Negative (-) L -, Blue
Phase T marked L3	
Neutral marked N	

Where distributed, the neutral conductor shall be of the distinctive colour blue. The colour of the earthing conductor is always to be green and yellow.

7.4.7. Cable types allowed

Enclosures C1 and C2 of this document include the standard/special cable types that can be used to design/implement the systems on board.

In any case, the cables not included into the Enclosure C1 and C2:

- shall be provided by an Type Approval certificate from a Classification Society and
- shall respect the relevant cables typology regulations and contractual obligations included into this document (in particular into paragraphs 0, 7.4.1, 7.4.2 and 7.5).

May one of the a.m. conditions not be satisfied by a cable typology strictly required by the system design, the supplier shall issue the detailed documentations, including relevant tests, in order to get a “by-case” approval.

The supplier shall implement the system design in order to minimize the use of cables not included into the Enclosure C1 and C2 lists.

The cables not included into the Enclosure C1 and C2 but approved for the system design shall be part of the supplier scope, if no specific request of de-scoping is issued . These cables shall be clearly identified in the system offer and shall have a dedicated quotation value.

Relevant costs for test and/or approval required for the use of a cable not included into the Enclosure C1 and C2 shall be at suppliers charge.

If the supplier wish to use a specific manufacturer/model for a cable type included into Enclosure C1 and C2 list, this cable type shall follow the same approval process as it would have been necessary for a cable type not included into the a.m. lists.

Cables inside panels (i.e. not running in the ship) or included in the scope of supply of the Supplier can be freely chosen, within the limits of this document.

7.4.9. Cable penetrations

Cable penetration shall be in accordance with Builder’s standard installation procedure.

Cable penetrations to be as follows:

Location	Details	Type of penetration
Below the bulkhead deck	Watertight	Compression type MCT
	Fire Proof	Compression type MCT
Above the bulkhead deck	Inside the flooding area for Watertight and Fire-Proof	Compression type MCT
	Outside the flooding area	Compression type MCT

Spare capacity on cable penetrations is to be provided, although it is accepted that the Builder may use some of the spare capacity for late additional cables.

For cables passing through beams, non-watertight bulkheads and openings, plastic flame retardant bushing are to be provided.

Where cables enter motors, starters and other power and lighting electrical appliances, glands or heat-shrinkable sleeves are to be installed. Heat-shrinkable sleeves are to be used only where cables enter from the bottom.

On external decks, or where cable penetrations are exposed in pantries, Galleys, garbage areas, or they are at the lowest level of machinery spaces, cable glands (not heat-shrinkable sleeves) are to be fitted.

Cable penetrations for generators, medium voltage and propulsion electric motors, medium voltage transformers and propulsion converters are to be of the modular compression type MCT .

Where cables enter electrical enclosure from the top, compression type MCTs or an equivalent solution maintaining the IP rating of the equipment are to be installed subject to Buyer's approval.

7.5. Fiber Optic Cables

Fiber optic cables shall be in accordance, as far as applicable, to the relevant requirements of Electrical cables (see paragraph 7.4)

7.6. Switchboards and distribution boards

7.6.1. General

All switchboards shall comply with IEC 60092-302 (LV) and 60092-503 (MV).

The construction of LV substation switchboards is to conform to form 4b construction as defined in IEC60439.

The construction of LV GSP starters is to conform to form 4b construction as defined in IEC60439.

Incoming and outgoing cables are to penetrate from the top or bottom. Modular multiple cable transits are to be foreseen on the top.

Control and instrumentation voltages shall not exceed 230 volts.

7.6.2. LV Switchgears

Each switchgear is to be provided with switchboard (SWB) units of dead-front type, mounted on a common steel base.

Construction is to be arranged to allow safe and clear access to all parts and components for maintenance, service, replacement, monitoring, adjustment and inspection in service. Live parts are to be provided with protection against inadvertent contact.

Units are to have side and top cover plates, hinged front and rear doors(where construction is designed for rear access), the bottom plates are to be provided with suitable cable passages.

The switchgears are to have a drip proof enclosure with IP protection in accordance with the requirements of 6.4.

In general cooling shall be provided through natural ventilation. Forced ventilation to be discussed case-by-case .

The base is to be made of rugged steel profiles, the supporting frame for the units are to be made of profiled steel plates, minimum 2 mm thick; doors and covers are to be minimum 1,5 mm thick steel plate (thicker plates required for structural elements). The construction is to be suitable for shipboard installation and is to be fitted on resilient mountings.

Resilient mountings are to be fitted between switchgears' bed plates and counter-base plates to be welded on the deck.

It is to be possible to open front doors without removal of CB handles.

Insulated handrails or insulated handles suitably fitted on the front of the switchgear shall be provided in accordance with Rules Requirements. Where access to the rear is required, insulated handrail or handles are to be suitably fitted on the rear of the switchgear.

The doors are to automatically secured when in the open position and divided in two parts in height.

Hinged panels doors which carry equipment and devices operating at 24 volts or more, are to be fitted with a flexible earth connection to the main frame.

Control devices and instruments having metal handles or cases are to be earthed.

All metalwork shall be bonded together and to earth; an earth bar shall be provided.

Cable screens, transformer earth screens, and current transformer secondary shall be connected to the earth bar.

220 V plastic material fluorescent/LED lighting fixtures are to be provided for switchboard with rear access for internal illumination together with 220 V sockets.

All wiring, protective devices and terminal boards to be indelibly marked in accordance with the wiring diagrams.

Location of internally mounted operators controls is to be indicated by external labels.

Outgoing circuits are to be provided with labels on the outside of panels which indicate circuit number and name of consumer.

A prominent and permanent warning notice giving the maximum voltage to be fitted at the ends of the switchboard for caution.

7.6.3. LV Distribution boards

The power, small power and lighting distribution boards are to consist of a painted steel cabinet with hinged doors, a bus bar system and appropriate protection circuit breakers.

The distribution boards are to have a drip proof enclosure with IP protection in accordance with the requirements of 6.4.

The live parts are to be protected by steel covers with insulated handles for removal.

The doors are to have a self-locking latch to keep them in the open position.

Labelling of the circuits is to be provided inside, on the protection plate. A list of all circuits is to be provided and fitted inside of each distribution board.

7.6.4. Internal wiring

Internal wiring shall be of multi stranded heat-resistant type with numbered ferrules and crimped terminals at each end.

Wiring is to be run in looms, securely cleated, protected and supported, or routed in synthetic flame retardant cable trunking with covers. Where internal wiring passes between sections which may be split for shipping or installation, terminal blocks are to be provided. Connections to components on hinged panels are to be flexible, taped or loomed and arranged so as not to chafe on metal edges or impede access when the panel is open. All wiring is to be arranged so that there is no stress on terminals.

Wires for control circuits are to be arranged in approved synthetic flame retardant cable trays with covers.

7.6.5. Connection cables and bus-bars

Power cables will be connected in input and output to the electrical equipment as foreseen by the supplier (e.g. connection on busbars, on terminals of circuit breakers/switch disconnectors, on threaded studs, on terminal blocks, etc).

Terminal blocks for power and control wiring shall be of the screw type.

In particular, for power cables with cross section greater than 2,5 mm², terminals shall be of the bolt type for cable connection with lug.

The connection of the power cables will be carried out following the specific instructions of the equipment supplier and the Builder's installation standards.

Cables for communication, data and instrumentation systems will be connected the electrical equipment as foreseen by the supplier.

Adequate provision to be made for main and control cable access and installation, cable supports to be provided if necessary.

Suitable cable entrance to be provided in all cases and there shall be provision of earthing cable screens when required.

Cable terminations are to be suitable for the circuit current and voltage, the connected cables and system fault level.

The bus bar systems are to be designed on the basis of the maximum rated current of the upstream dedicated transformer/feeding line and are to be supported to withstand the electrodynamics stresses of prospective short circuit currents.

Bus bars connections shall be made so as to inhibit corrosion and maintain joint integrity.

Connections between bus bars and circuit breakers, switches etc. are to be mainly in copper bars. Other solutions (e.g. flexible bars, double insulated connections) can be used according to Manufacturer's standard.

The bus bars are to be identified with coding markers.

The temperature rise for bus bar compartments is to be in accordance with Classification Society requirements. The temperature rise of other compartments is not to exceed 20 °C. Local increases may be accepted, provided that these are not in the vicinity of electronic components.

7.6.6. Auxiliary circuits

Switchboards are to be complete with all necessary supplies.

The interlock circuits for the 11 kV MSWB CBs and contactors, ER-SUB main, CBs, for incoming supply lines of distribution transformers and associated relays are to be supplied at 110 V DC.

All other auxiliary circuits are to be supplied with at max. 220 V - 60 Hz through auxiliary transformers which are to be protected by automatic circuit breakers of plug-in type directly connected to the bus bars, or at max 110VDC.

7.7. Junction Boxes

Junction boxes are to have a drip proof enclosure with IP protection in accordance with the requirements of 6.4.

All terminals in junction boxes are to be of the compression type.

The junction boxes used for splicing are to be marked with voltage level(s) and box identification.

Junction boxes are to be installed for each lighting fixture with heat resistant wires to lighting fixture.

Junction boxes above deck head linings are to be indelibly marked, and indication of their locations is to be given on panels.

Junction boxes are not to be fitted under windows, scupper pipes or water/fuel/oil/steam pipes.

7.8. Terminal boards

Where the equipment is provided with terminal boards, these must be suitably marked.

Polyamide, or equivalent, insulated terminal blocks to be approved by Classification Societies and to be fitted inside metal terminal boxes.

Terminal boards for power and control wiring shall be of the screw type.

In particular, for power cables with cross section greater than 2,5 mm², terminals shall be of the bolt type for cable connection with lug.

The installation of plastic material terminal boxes is allowed only if demonstrated to be of:

- best available quality
- flame retardant type
- not releasing incandescent molten plastic drops during burning (class V0 according to UL 94 flammability testing) or toxic/harmful gasses

The terminal boxes and the cubicles are to be sized in order to have adequate free space to contain all conductors (spares included) to be connected to the terminal boards.

The terminal box of all equipment are to be designed considering a max temperature of the bus bars cable connection of 90°C at nominal power

7.9. Automatic CBs and switch disconnectors

Circuit protection is to be by circuit breakers and not fuses.

Fuses may be used for:

- 11kV contactors
- 11 kV measuring voltage transformers,
- Motor short-circuit protection; only if approved, for starters part of system packages
- Auxiliary circuits protection, only if approved, as part of system packages
- Protection of electronic equipment

The CBs, switch disconnectors and HV contactors with fuses shall:

- be suitable for installation on board
- have adequate current carrying capacity for the normal rated current,
- have adequate breaking and/or making capacity to withstand short circuit currents in accordance with IEC 61363-1 procedures for calculating short circuit currents in three phase A.C

7.9.1. HV Switchboards' automatic CBs and contactors with fuses

The main circuit breakers are to be vacuum type and contactors are to be vacuum type with digital protection devices.

The CBs and contactors with fuses are to be of the withdraw-able type with test position, electric and emergency manual control and are to be equipped with the necessary interlocks to avoid unsafe operation.

The CBs of generators and transformers are to be controlled by time delayed relays for selective protection.

The CBs equipped with shunt opening coils are to have coil open circuit monitoring .

7.9.2. LV switchgears automatic CBs and switch disconnectors

All outgoing circuits from LV switchboards and distribution boards to be by automatic circuit breakers (fuses cannot be used).

Automatic CBs installed in LV switchboards are to be of the same Manufacturer.

All circuit breaker to have open/closed indicators.

Switch disconnectors are to be of the on-load switching type

Switch disconnectors at transformer secondary may be replaced with automatic CBs when necessary for the purpose of overload protection.

CBs up to 630 A rated current are to be of moulded case (MCCB) plug-in or air withdrawable type; automatic CBs over the above rated current are to be of the air (ACB) withdrawable type.

Withdrawable ACBs are to be fitted with solid-state microprocessor based protection system. All necessary displays are shown on indication panel. Local programming to be provided. The control unit is to give a display of the electrical quantities relevant to the protected circuit, i.e. current in each phase, voltage phase and line, power, power factor and frequency.

Open type CBs are to be provided with interlocks to prevent withdrawal from the cubicle when the circuit breakers are closed and to prevent closure if not correctly secured in the cubicles; circuit breakers are to be provided with test facilities which can be operated in the withdrawn position.

Selective protection against short circuits is to be provided but limited to CBs of incoming supply lines and to CBs of outgoing supply lines of distribution boards.

Automatic CBs types and characteristics are to be submitted to the Buyer for approval (through the selectivity study).

In each LV switchgear, about 10% spare distribution circuit breakers as well as spare spaces to be provided.

7.9.3. LV distribution boards' automatic CBs and switch disconnectors

Outgoing circuits of each LV distribution board shall be protected as follows:

- 1) 690 V and 440 V circuits are to be equipped with three-pole molded case automatic circuit breakers of the plug-in type, with overload and short circuit protection.
- 2) 230 V, 220 V and 120 V circuits are to be equipped with 2-pole, 3-pole or 4-pole moulded case circuit breakers of miniature type circuit breakers (MCB), with overload and short circuit protection.
- 3) Residual current protection devices are to be provided for:
 - passengers and crew cabins sockets and lighting circuits
 - free sockets in public areas
 - table and free standing lamps (if any) in public areas

- E.R. spaces

Residual current protection device (30 mA) is to be fitted to the CB furthest downstream the circuit

- 4) Only miniature circuit breakers to be used.
- 5) 24 V circuits are to be equipped with 2-pole MCBs, with overload and short circuit protection.
- 6) The external lighting distribution boards are to be provided with contactors to remotely control the external lighting circuits from the Wheelhouse.

In each LV distribution panel to be provided with an incoming bus bar isolating switch or one CB is to be provided in case the automatic circuit breakers are of the miniature type; where plug-in type molded case CBs are provided, the bus bar isolating switch is not to be fitted.

The CB type and characteristics are to be submitted to the Buyer for approval (through the selectivity study).

In each LV distribution board, about 10% spare circuit breakers as well as spare spaces to be provided.

7.10. Interface with the IAMCS

If the equipment is to be interfaced with the IAMCS, the remote functions requested (alarms, controls, indications, etc.) are to be agreed before the order (see 7.10.3) and are to be carried out via hardwired or serial line interfaces as described hereafter (see 7.10.1 and 7.10.2).

In general, hardwired interfaces are to be used, while serial line interface is to be expressly requested and is foreseen by the Ship Specification, as agreed with the Buyer, for the following systems:

The following systems – but not limited to – are to be integrated or interfaced with the IAMCS:

- Power management system including mode selection system
- Main engines
- Thruster system
- Emergency diesel engine
- Medium voltage switchboards
- Low voltage switchboards
- Pumps and fans
- Remote control valves

- Temperature controllers
- Viscosity controllers
- Tank monitoring and remote level gauging
- Interface to the “Dynamic Trim Support System”
- Management of all auxiliary and electrical systems as listed within the ship specification
- Propulsion electric motors, propulsion converters, propulsion transformers and propulsion remote control system
- HVAC chillers
- Emergency switchboard
- Water mist and CO2 system
- Incinerators
- Stabilizers and steering
- UPS and battery charger
- Shell and watertight / splash tight door
- Lifts
- Life boat
- Internal IAMCS
- HVAC system
- Refrigerated rooms
- Safety Systems
- Navigation system
- Fire, watertight and shell doors
- Fire detection system
- Swimming pools
- Mooring
- LNG system.

The following systems are to be interfaced with the IAMCS via serial lines (the serial lines are to be provided with back-up by hard-wired common alarm):

- Diesel Engines Safety and Control System (redundant serial link from each engine) for monitoring functions only, while Hardwired I/Os are to be used for control function and key monitoring functions.
- Main electric propulsion system (two redundant serial lines port, two redundant serial lines stbd) for monitoring functions only, while Hardwired I/Os are to be used for control functions and key monitoring functions

- Medium voltage switchboard protection devices (redundant serial link from each MSWB) for monitoring functions only, while Hardwired I/Os are to be used for control functions and key monitoring functions
- Low voltage ER switchboards, for monitoring functions only (failure of the line is not to cause the failure of the circuit breakers' relays), while Hardwired I/Os are to be used for control functions and key monitoring functions
- Valve remote control system (two redundant links to be provided, total four)
- Group Starter Panels and Individual Starter Panels (quantity of redundant serial lines as needed to comply with SRtP)
- Level gauging system (1 redundant serial line)
- Flooding detection system (1 redundant serial line, may be shared with Level gauging system)
- HVAC system (one redundant serial line per each MVZ – total 12)
- AC chillers (both centrifugal and absorption - 1 serial line per each plant, total 2)
- Provision compressors system and Refrigerated rooms system (1 serial line)
- Cabin Fan Coil Control System (CFCCS) (1 serial line per MVZ)
- Safety Management Control System (SMCS) (1 redundant serial line – total two)
- Advance Waste Water Treatment System (AWWTS) (1 serial line)
- Reverse Osmosis Plant (one line for each plant, total 2)
- Fuel booster modules (one link for each module, total 2)
- Stability computers (one redundant line for two computers, total two)
- Voyage data recorder (1 redundant serial line)
- GPS (1 serial line for IAMCS time synchronization)
- Master clock system (1 serial line for HVAC time based control programs)
- Integrated Navigation System (1 serial line)
- Dynamic Trim Support tool (DTS) (1 serial line)
- Shore connection control system (1 serial line)
- LNG package automation system (1 redundant serial link per each plant)

Serial lines are to have a refresh time at least consistent with the time constants of the controlled/monitored processes.

7.10.1. Hardwired

The hardwired interface is to be foreseen according to the specification described hereafter:

- Outputs for monitoring by IAMCS (signals from the plant control system):
 - Digital alarm: potential free normally closed (NC) contact;
 - Digital indication: potential free normally open (NO) contact;
 - Analogue indication: analogue output signal 4-20mA “passive” from the plant control system (powered at 24V DC by IAMCS)
- Inputs for control by IAMCS (signals to the plant control system):
 - Digital start/stop, open/close and other command inputs: 24V DC relay triggered by the IAMCS with a 24V DC voltage pulse (24V DC powered by IAMCS) or in alternative with a voltage free pulse contact (24V DC powered by the plant control system) (see Note)
 - Analogue control input: analogue input signal 4-20mA “passive” from IAMCS (powered at 24V DC by the plant control system)

All hardwired interface signals are to be isolated from earth. For such purpose the analogue output signals are to be galvanic isolated inside the plant control system cabinet.

For shutdown signals, cable monitoring (detection both open loop and short circuit) with only 2-wire connections is to be provided. Cable failure is not to activate the safety function.

Note: in case the plant is to be controlled by IAMCS, a digital output signal “available for control” is to be foreseen by the plant control system for such control.

7.10.2. Serial line signals

Signals via serial line (RS232, RS485 or others) or Ethernet with standard protocol (Modbus RTU or TCP, Profibus DP, NMEA0183).

Each serial line from the connected systems must have an hardwired common alarm as a back-up (activated by any of the alarms included in the serial line)

7.10.3. List of interface signals

The Supplier is to provide his equipment with the input/output signals as required in the “List of interface signals with IAMCS” that is part of the Technical Specification of the plant. The a.m. lists must be agreed before the official purchase order of the plant, with the target to define the definitive list of the input/output signals.

7.11. Interface between Supplier system and other external starters

When the supplied plant is to be interfaced with an external starter in order to control the relevant auxiliary (pump, fan, etc.), the following interface is to be foreseen:

- Outputs by the plant control system to the external starter:
 - Take control digital output: potential free normally open (NO) contact
 - Start signal digital output: potential free normally open (NO) pulse contact
 - Stop signal digital output: potential free normally open (NO) pulse contact
 - Speed control analogue output (if fitted): analogue output signal 4-20mA “active” to the starter (powered at 24V DC by the starter)
- Inputs to the plant control system from the external starter:
 - Running signal digital input: potential free normally open (NO) contact
 - Speed feedback analogue input (if fitted): analogue input signal 4-20mA “passive” from the starter (powered at 24V DC by the plant control system)

7.12. Transducers, sensors and transmitters

Controllers, control valves, transmitters, solenoid valves, limit switches and proximity switches, pilot lamps, instruments, etc. within the IAMCS scope of supply are to be of a standard type and range of sizes.

7.12.1. Temperature switches, temperature sensors and thermometers

For temperatures up to 200°C analogue temperature sensors are to be of the three wire platinum thermo-resistance type (Pt 100) and are to be connected to instruments and monitoring equipment via suitable interfaces.

For temperatures above 200°C analogue temperature sensors are to be of the thermocouple type (Ni-Cr-Ni type). Also, they are to be connected to instruments and monitoring equipment via suitable interfaces and their signal is to be proportionally linearized in the remote local process station.

Temperature sensors signals to be transmitted with screened cables.

The accuracy of platinum thermo-resistance and thermocouples is to be within $\pm 1\%$ and $\pm 3\%$, respectively.

For all sensing elements, suitable wells and pockets are to be provided which are of a type, which permits removal of the sensors with the systems full and under pressure.

All wells and pockets are to be welded into suitable bosses and are to be filled with heat conducting compound.

Junction boxes for sensors are always to be fitted above the floor plates.

Sensors and wiring are to be located above the level of the bottom floor plates. Where location below the floor is unavoidable, the sensors heads and terminal boxes are to be watertight (IP 67).

Sensors are to be inserted so that the total length of the sensor is immersed in the pocket or well.

Location of sensor well is to be such that it is adequately covered by the medium.

The use of thermo-switches is to be confined to safety functions only; exceptions to this are only after written approval by the Buyer, on a case-by-case basis.

Local thermometers are to be of the glass liquid filled type, mounted in a protective sleeve and fitted in a thermometer pocket. The construction and material of the pocket is to be compatible with the temperature/pressure rating and material of the piping system in which the pocket is fitted.

7.12.2. Pressure switches and sensors

Pressure transmitters are to be of one of the following types: (LVDT) Differential transformer, Membrane Bellows or Bourdon tube.

The output from the sensors is to be a linear milliamp signal, with a normal range of 4-20 mA, exceptions are subject to written approval by the Buyer.

The sensor body and diaphragm materials are to be compatible with the process fluid and pressure.

Pressure transmitters and pressure switches are to be provided with test pump connections and test cocks.

Differential pressure switches or flow switches are to be used where normal pressure switches may be unreliable due to static pressure fluctuations.

Differential pressure sensors are to be capable of withstanding full system pressure without loss of accuracy.

Pressure sensors are to be capable of withstanding 50% overload without subsequent loss of accuracy.

All pressure transmitters, temperature switches, pressure gauges, etc. are to be fitted in groups on the ship's structure (bulkhead mounting plates), with the exception of those that have to be fitted on the machinery itself.

Main system pressures such as, lubricating oil, cooling water, fuel oil etc. is to be monitored by analogue pressure transducers connected to IAMCS.

7.12.3. Level switches and sensors

In general, all level switches except those fitted to the boilers are to be of the float type with magnetic switches. Consideration is to be given to the use of “tuning fork” type level switches for use in difficult applications.

Level switches for the boilers are to be according to the boiler Supplier's standards.

Where the level switches are to be mounted on the top or the side of a tank they are to be equipped with testing facilities using a level or test rod.

Where the level switches are to be fitted on the top of a tank, then the support pipe or bracket is to be about 200mm above the tank top to permit the removal of the floating element when the tank is partially full.

7.12.4. Tachometers

Generally, the transmitters for tachometers are to be of the magnetic type, using a frequency to voltage converter to send a linearly proportional voltage signal to indicators etc.

7.12.5. Flow meters

Flow meters must be installed on the equipment / plant where required in the relevant supply specification.

7.12.6. Accuracy of measurement

The measurement stability and accuracy of all the instrumentation is to be guaranteed to within about $\pm 1.5\%$ of full scale value if not specified otherwise in the relevant supply specification. In both cases, the transducer errors are to be excluded and they are for an ambient temperature between 0°C and 45°C.

The range of the gauges and transducers will be selected so that normal operating area does not exceed 67% of full scale reading. By pulsating pressure the normal operating pressure not to exceed 60% of full scale.

7.12.7. Controllers

The temperature, pressure and level automatic control functions is to be performed by process control stations integrated in the IAMCS, with the exception of packages with stand-alone control systems. The functions are to include proportional, integral and derivative actions (PID).

All controllers shall enable manual/automatic operation of the control valves from any IAMCS operation station and it shall also be possible to operate the controlled valves manually locally on the valve (manual control hand-wheel).

The controlling data and status of control loops including measured value, output value and set point value are to be displayed on IAMCS. Set points and control parameters can be changed via IAMCS. A change-over function for auto/manual control is to be provided.

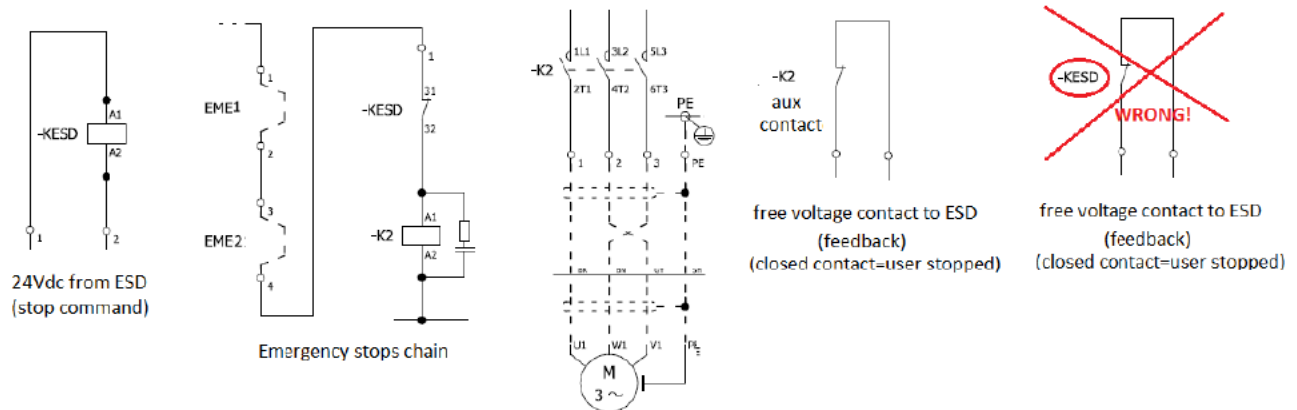
Control loops are to maintain the actual pressure temperature, flow or level to within $\pm 2\%$ of set point during steady conditions and to within $\pm 5\%$ of set point under changing conditions.

7.13. Interface with Emergency Shut Down (ESD) System

The Supplier equipment/machinery to be interfaced with the ESD system is to provide the following remote functions:

- Dedicated 24 Vdc relay for emergency shutdown activation (energized relay = shut down) is to be provided. A contact of the a.m. relay is to be used to shut down the equipment (e.g. contact may be connected to the emergency stops daisy chain of the system).
- Since ESD performs the relay coil monitoring, in order to avoid that the line monitoring current provided by the ESD 24Vdc output could energize the relay coil or could keep the relay pulled in, the relay is to be chosen taking into consideration the release voltage (must drop-out voltage) and coil impedance values. Relay type is therefore to be agreed.
- A free voltage contact for indication of shut down completed (status feedback) is to be provided to the ESD system (closed contact = equipment stopped). The a.m. contact is to provide the "real" status of the equipment (stopped) and therefore it cannot be a contact of the same relay used for the shutdown activation (e.g. it may be an auxiliary contact of the line contactor or an output from a PLC of the equipment).
- Option: a resistor (value to be defined) may be required to be connected in parallel to the status feedback contact, in order to allow to ESD system to perform the wire break monitoring. Available terminals are to be taken into consideration for resistor connection. The manufacturer must contact SY in due time (and anyway not later than the basic design stage) to check if the monitoring resistance is to be installed

Below picture shows the described principles.



The equipment/machinery that, in principle, are to be connected to the ESD system with the above mentioned interface are the following:

- Scrubbers
- Vacuum sewage system;
- Grey water system;
- Evaporators system;
- Reverse Osmosis
- Bilge water separators system;
- Boilers;
- Incinerators system;
- Sludge purifier;
- FO/LO purifiers and pumps;
- Booster fuel module;
- Sea water pumps (overboard discharge in way of lifeboats);
- Emergency diesel generators.

In principle, following systems have their own specific interface with ESD system, which shall be described case-by-case in their own Technical Specification:

- Hinged Fire door
- Sliding door
- Side door
- Watertight Doors
- Lift
- GSP/ISP

- Low Location Lighting
- Galley Hood Control Cabinet
- Hood Dampers
- Rolling Shutter

7.13.1. ESD Interface with fire and shut-off dampers

The status of fire and shut-off damper shall be taken by the ESD system (status taken from internal limit switch).

The ESD shall be connected to the damper panel (or GSP or ISP if outside ACS).

7.14. Electrical instruments

All instruments shall be of the same standard design, exceptions to be agreed with SY. All meters are to be to DIN Standard.

The analogue meters fitted on switchboards, instrument boards and control boards are to be of the moving coil type, flush mounted, square flange white dials and black numerals.

The analogue Instruments fitted on switchboards, instrument boards and control boards are to be of flush type with 96 x 96 mm flange.

In case of installation constraints, the installation of 72x72 analogue instruments to be discussed case-by-case

Analogue instruments indicating through 270 degrees are preferred, i.e. long scale. Each instrument is to be clearly identified in accordance with the requirements of 6.5.

The upper limit of the scale of the voltmeters to be approximately 120% of the rated voltage. On analogue voltmeters, rated voltage to be indicated by a red line.

The upper limit of the scale of the ammeters to be approximately 130% of the rated current. On analogue ammeters, red marks are to be provided at rated values for transformer and users, and at the value corresponding to the feeder cable carrying capacity for power and lighting panel boards.

Watt meters and ammeters for use with alternators must be able to indicate 15% of full load reverse power, as well as 130% full load with red line at full load.

Scale deflection on other analogue meters to be according to Classification Society Rules requirements.

The accuracy of the analogue instruments is to be 1.5% at full scale deflection.

Current transformers shall be Class 1 for instrumentation duty and 5P for protection duty; voltage transformers for instrumentation shall be Class index 1.5 and 1 for protection duty

7.15. PLC Program and Documentation

PLCs of main systems (where provided) are to be delivered with program back-ups and documentation of software, diagnostics, interface descriptions, set-points and parameters and to include interface devices (laptop/programming devices) according to manufacturer recommendations.

7.16. Standardization of components

The Suppliers are to supply the various components following the principle of limiting the spare parts holding, services and maintenance.

7.17. Spare parts

Detailed spare parts list is to be provided as follows:

- Recommended by Classification Societies (spare parts included in the Scope of Supply)
- Recommended by Manufacturer. for two years operation.
- Recommended by Manufacturer. for five years operation.
- Special tools, where necessary, to be included in the scope of supply

7.18. Supervision and tests

Test Inspections and Certificates are to be as specified on document:

- General Requirements for Supply

8. Cybersecurity risk mitigation measures

The supplier is to support the Builder and the Owner in implementing the Cyber security prevention strategies and risk mitigation measures for its scope of supply

The supplier is also to support the Builder and the Owner in all the analysis required by the interaction of the system to the other connected systems.

Cybersecurity risk mitigation measures shall be identified, implemented and verified for any system or subsystem that:

- Involves safety and/or security
- Require or provide ship-to-shore/shore-to-ship communication
- Is interfaced to ship digital communication network (SDCN)
- Require periodical external data updates
- Is subject to periodical software/firmware updates

The design and system architecture of the systems is to respect and support the requirements of Cyber Security prevention.

The IEC62443 is to be used as a guideline for assessment, implementation and verification.

The supplier is to provide an asset inventory of all involved components as a basis for the cyber security assessment.

The supplier is also to support the Builder and the Owner for what concerns the activities of verification and penetration test of the final configuration (executed by the Owner after delivery of the vessel) and is to provide the countermeasures to any findings related to its scope.

Hereinafter a set of basic guidelines are described to minimize the cyber security risk.

However, the compliance to these guidelines does not exempt the supplier from supporting the Builder and Owner in the above described activities.

All external interfaces, direct or via SDCN, are to be protected by dedicated hardware or virtualized software firewalls provided in the scope of the system supplier; alternative solutions to firewalls providing same security level can be proposed at Builder's and Owner's approval. System and network architecture is to be designed with special attention to network segregation and network partition to prevent any unintended network communication between security boundaries. Where reasonable the preference for interfaces to external plants connected to the systems is for point-to-point serial interfaces.

At the end of sea trials, all system servers, clients and other components are to be provided with the latest released operating systems and related security patches; systems which need type approval are to be provided with the latest type-approved

version. No obsolete operating systems are to be used. Builder to document the used software versions, operating systems and application software.

Unused ports on any network components are to be blocked and unintentional use is to be prevented.

Specific dedicated user accounts shall be defined for all the systems with the proper authorization and user levels; generic/admin users shall be removed. Document and file transfer in and out of the systems is to be provided with a dedicated and protected web server or similar.

The system access via removable storage devices (like USB stick or others) is to be prevented on all computers and only available for maintenance purposes.

Either antivirus prevention or “executable white listing” is to be provided throughout all the systems.

User access rights to the systems are to be based on different individual accounts with dedicated user rights for monitoring, operating and system administration.

Servers and client workstations are to be provided with customized operating system setups excluding and preventing any not required OS functionality and adapted to the specific requirements of the related system and cyber security.

9. Drawings and documents

The documentation is to be supplied in accordance to the requirement of the SY document:

- General Requirements for Supply

In addition to what above, the scope of supply includes at least the documents indicated in the following table within the indicated time schedule. All other drawings necessary for the complete definition and understanding of the system/equipment are included in the scope of supply. One single drawing can contain more drawings of the table, anyway all the information required must be clearly indicated. All the documents are to fulfil the following requirements:

- to be developed using IEC electrical design standard symbols;
- to be in compliance with ISO 9000 quality management standards;
- written and organised in order to be easily readable;
- to have a summary;
- all revisions are to have modifications clearly indicated (e.g. with clouding);
- as far as practicable, ISO A4 and A3 format are to be used.

Notes:

- E-Mail limit is 1,5 MB for each e-mail
- columns “with offer”, “for working” and “as built” contains the number of copies to be submitted
- “for working” documents is not a preliminary document
- preliminary documents will be not officially considered
- an “as built” document is a document describing the system as installed onboard at the delivery of the ship.

14.5. Enclosure "C1" – Allowed cable types

Colour and level	Rated voltage	Type	Cabin singlecore cables			
			not fire resistant		fire resistant	
			not armoured	armoured	not armoured	armoured
not defined	250 V	SINGLE CORE	1x1,5			
			1x2,5			

Colour and level	Rated voltage	Type	Power cables HF-			
			not fire resistant		fire resistant	
			not armoured	armoured	not armoured	armoured
			P	PA	P-FR-WSR	PA-FR-WSR
black K	0,6/1 kV	SINGLE phase	2x1,5	2x1,5	2x1,5	2x1,5
green K or N						
			2x4 (*)			
			2x6 (*)			
black K		THREE phases	3x1,5		3x1,5	3x1,5
			3x2,5	3x2,5	3x2,5	3x2,5
			3x6	3x6	3x6	3x6
			3x10		3X10	3X10
			3x16	3x16	3x16	3x16
			3x25		3x25	3x25
			3x50	3x50	3x50	3x50
			3x70	3x70	3x70	3x70
			3x95		3x95	3x95
			3x127	3x127	3x127	3x127
		THREE phases with NEUTRAL	4x6	4x6	4x6	
			4x16			
			4x50	4x50	4x50	
			4x70	4x70	4x70	
			4x95	4x95	4x95	
4x127			4x127	4x127		
green K or N		SINGLE phase with EARTH	3G1,5	3G1,5	3G1,5	3G1,5
			3G2,5	3G2,5	3G2,5	3G2,5
black K			3G6	3G6	3G6	3G6
green K or N		THREE phases with EARTH	4G1,5	4G1,5		
black K			4G2,5	4G2,5		
	4G6		4G6			
	4G16		4G16			

(*) dedicated for power-line communication

Colour	Rated voltage	Type	Multicore cables HF			
			not fire resistant		fire resistant	
			not armoured	armoured	not armoured	armoured
			M	MA	M-FR-WSR	MA-FR-WSR
orange N	0.6/1 kV	1 mm ²	4x1	4x1	4x1	4x1
			7x1	7x1	7x1	7x1
			10x1	10x1	10x1	10x1
					14x1	
			19x1	19x1	19x1	19x1
			30x1	30x1	30x1	30x1
		1,5 mm ²	4x1,5	4x1,5	4x1,5	4x1,5
			7x1,5	7x1,5	7x1,5	
			10x1,5	10x1,5	10x1,5	
			19x1,5	19x1,5	19x1,5	
			24x1,5	24x1,5		
					30x1,5	
		2,5 mm ²	4x2,5	4x2,5	4x2,5	4x2,5

Colour	Rated voltage	Type	Twisted cables HF- not fire resistant			
			collective screen		individual & collective screen	
			not armoured	armoured	not armoured	armoured
			TXCS	TXCSA	TXISCS	TXISCSA
orange N	60 V	0,5 mm ²	1x2x0,5	1x2x0,5		
			2x2x0,5			
			4x2x0,5	4x2x0,5		
			7x2x0,5			
			14x2x0,5	14x2x0,5		
			30x2x0,5			
	250 V	0,75 mm ²	1x2x0,75	1x2x0,75		
			2x2x0,75	2x2x0,75	2x2x0,75	2x2x0,75
			4x2x0,75	4x2x0,75	4x2x0,75	4x2x0,75
			7x2x0,75	7x2x0,75		
			10x2x0,75	10x2x0,75	10x2x0,75	10x2x0,75
			14x2x0,75		14x2x0,75	14x2x0,75
			19x2x0,75	19x2x0,75	19x2x0,75	19x2x0,75
			30x2x0,75	30x2x0,75	30x2x0,75	
		1,5 mm ²	1x2x1,5	1x2x1,5		
			2x2x1,5	2x2x1,5	2x2x1,5	2x2x1,5
			4x2x1,5	4x2x1,5	4x2x1,5	4x2x1,5
			10x2x1,5	10x2x1,5	10x2x1,5	10x2x1,5
			14x2x1,5		14x2x1,5	14x2x1,5
			19x2x1,5	19x2x1,5		
			30x2x1,5		30x2x1,5	30x2x1,5

Colour	Rated voltage	Type	Twisted cables HF- fire resistant WSR			
			collective screen		individual & collective screen	
			not armoured	armoured	not armoured	armoured
			TXCS	TXCSA	TXISCS	TXISCSA
orange N	250 V	0,75 mm ²	1x2x0,75	1x2x0,75		
			2x2x0,75		2x2x0,75	
			4x2x0,75	4x2x0,75	4x2x0,75	
			10x2x0,75		10x2x0,75	
			14x2x0,75		14x2x0,75	
			19x2x0,75	19x2x0,75	19x2x0,75	
			30x2x0,75			
		1,5 mm ²	1x2x1,5	1x2x1,5		
			4x2x1,5	4x2x1,5	4x2x1,5	4x2x1,5
			10x2x1,5			
			19x2x1,5	19x2x1,5	19x2x1,5	19x2x1,5
					30x2x1,5	30x2x1,5

14.6. Enclosure "C2" – Special cables

Application	Group	Type
Fiber optic	OM2	12-core
	OM3	12-core
	OM4	12-core
	OM5	12-core
	OS2	12-core
Network	Cat6	U/UTP
		F/UTP
		U/UTP Duplex
		F/UTP Duplex
	Cat6A	U/FTP
		F/FTP
		S/FTP
		U/FTP Duplex
		F/FTP Duplex
Industrial	Profibus	1x2xAWG22 foiled with drain wire 150ohm
		1x2xAWG22 foiled 150ohm
	CAN-Bus	1x2x0.50mm ² copper braided 127ohm
		2x2x0.75mm ² copper braided 127ohm
"SRTP"	OM2	8-core Fire Resistant
	OS2	8-core Fire Resistant
	Cat5E	FTP Fire/Water Spray Resistant