

NORSOK STANDARD

ELECTRICAL SYSTEMS

E -001

Rev. 3, December 1997

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FOREWORD

NORSOK (The competitive standing of the Norwegian offshore sector) is the industry initiative to add value, reduce cost and lead time and eliminate unnecessary activities in offshore field developments and operations.

The NORSOK standards are developed by the Norwegian petroleum industry as a part of the NORSOK initiative and supported by OLF (The Norwegian Oil Industry Association) and TBL (Federation of Norwegian Engineering Industries). NORSOK standards are administered and issued by NTS (Norwegian Technology Standards Institution).

The purpose of NORSOK standards is to contribute to meet the NORSOK goals, e.g. by replacing individual oil company specifications and other industry guidelines and documents for use in existing and future petroleum industry developments.

The NORSOK standards make extensive references to international standards. Where relevant, the contents of a NORSOK standard will be used to provide input to the international standardisation process. Subject to implementation into international standards, the NORSOK standard will be withdrawn.

INTRODUCTION

This issue of NORSOK standard E-001 replaces E-CR-001, rev. 2, January 1996.

1 SCOPE

This standard contains provisions for electrical installations at all voltages and is intended to enable safety in the design of electrical systems, selection, and use of electrical equipment for generation, storage, distribution and utilization of electrical energy for all purposes in offshore units which are being used for the purpose of exploration or exploitation of petroleum resources.

This standard is based on equipment and practices which are in current use but it is not intended in any way to hamper development of new or improved techniques.

This standard does not apply for the electrical installations in rooms used for medical purposes or in tankers.

2 NORMATIVE REFERENCES

The following standards include provisions which, through reference in this text, constitute provisions of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet or exceed the requirements of the standards referenced below.

IEC 34-5	Rotating electrical machines, Part 5: Classification of degree of protection provided by enclosures of rotating electrical machines (IP code).
IEC 76-1	Power transformers, Part 1: General.
IEC 146-4	Semiconductor convertors, Part 4: Method of specifying the performance and test requirements of uninterruptible power systems.
IEC 298	AC metal-enclosed switchgear and controlgear for rated voltages above 1kV and up to and including 52kV. (1990-12)
IEC 439-1	Low-voltage switchgear and controlgear assemblies - Part 1: Type-tested and partially type-tested assemblies
IEC 947-4-1	Low voltage switchgear and control gear, Part 4: Contactors and motor-starters. Section one - Electromechanical contactors and motor-starters.
IEEA	Guidelines for the documentation of selectivity (discrimination) in a.c. systems.
IEEA	Veiledning for varmekabelanlegg i industri og offshore.
EN 50091-1	Uninterruptable power systems (UPS), Part 1: General and safety requirements.
NEK 606	Cables for offshore installations Halogen-free, or mud resistant
NORSOK I-CR-002	Safety and automation systems (SAS) (will be renumbered I-002).
NORSOK S-DP-001	Technical safety (will be renumbered S-001).
NORSOK S-002	Working environment.
NORSOK T-CR-001	Telecommunication systems. (will be renumbered T-001)
PE	Elektrisitetestilsynet; Retningslinjer for jording i maritime anlegg

3 DEFINITIONS and ABBREVIATIONS

3.1 Definitions

Can	Can requirements are conditional and indicates a possibility open to the user of the standard.
Informative references	Shall mean informative in the application of NORSOK standards.
May	May indicates a course of action that is permissible within the limits of the standard (a permission).
Normative references	Shall mean normative in the application of NORSOK standards.
Shall	Shall is an absolute requirement which shall be followed strictly in order to conform with the standard.
Should	Should is a recommendation. Alternative solutions having the same functionality and quality are acceptable.

3.2 Abbreviations

AVR	Automatic Voltage Regulator.
CENELEC	European Committee for Electrotechnical Standardization.
EPS	Emergency Power Supply.
ESD	Emergency Shut Down.
FCR	Field Current Regulator.
HVAC	Heating, Ventilation and Air Conditioning.
IFEA	Industriens Forening for Elektroteknikk og Automatisering
ISO	International Organization for Standardization.
LED	Light Emitting Diode
MCC	Motor Control Center.
NEK	Norsk Elektroteknisk Komite
NPD	Norwegian Petroleum Directorate
PABX	Private Automatic Branch Exchanger Panel (telephone panel).
PCS	Process Control System.
PDCS	Power Distribution Control System.
PE	Produkt- og Elektrisitetstilsynet former ET - Elektrisitetstilsynet.
PLC	Programmable Logic Controller.
RTD	Resistor Temperature Detector.
SAS	Safety and Automation Systems.
THD	Total Harmonic voltage Distorsion
UPS	Uninterruptible Power Supply.
VDU	Visual Display Unit.

4 DESIGN CRITERIA

The electrical system shall fulfill the requirement of the EU directive 89/3367EEC (EMC).

4.1 Studies and calculations

4.1.1 Electrical load study

Electrical load lists shall be prepared to establish the electrical power requirements throughout the installation. Load estimates shall be carried out for all operational states, e.g.:

- Drilling.
- Maximum power consumption for all systems.
- Life support.
- Emergency.
- Minimum load for full production with low priority loads disconnected.

An electrical load profile shall be prepared for normal operations over the entire lifetime of the installation.

Separate load studies shall be carried out to establish the temporary load requirements during pre production phases, e.g.:

- Onshore commissioning and testing.
- Float out.
- Deck mating.
- Inshore hookup and commissioning.
- Tow out.
- Offshore hookup and commissioning.

An allowance and contingency multiplication factor shall be applied to the estimated load to select the rating of generators and transformers.

The following factors should be used:

- Feasibility study : 1.5
- Conceptual study: 1.35 - 1.4
- Pre-engineering : 1.25
- Detail : 1.10
engineering

Note: If the electrical load data at different stages are well defined, lower factors may be used.

4.1.2 Load flow calculations

Steady state load flow calculations shall be carried out for the operational states giving maximum peak load and minimum load based on 4.1.1.

The following data should be computed:

- Magnitude and phase angle of the busbar voltages.
- Active and reactive power production and load at the busbars.
- Active and reactive power flow in cables and transformers.
- Power losses.
- Recommended setting of the transformers tapplings.
- Voltage rise in long runs of high voltage cables.

4.1.3 Short circuit calculations

Short circuit calculation shall be carried out for the following fault conditions, with maximum and minimum fault contribution.

- 3-phase symmetrical fault.
- Single-phase to earth fault.
- Phase to phase fault.
- Phase to phase to earth fault.

The maximum symmetrical rms value of the sub transient fault current should not exceed the following values:

11 / 6.6kV	:	40kA rms
690V	:	50kA rms
400/230V	:	30kA rms - Main distribution board
400/230V	:	10kA rms - Sub distribution board

4.1.4 Power system dynamic calculations

A stability analysis of the electrical power system shall be carried out and shall comprise simulations of the system transient behaviour following disturbances during relevant operational modes of the installation.

The simulations shall include:

- Direct on line starting of the largest motors.
- Short-circuited feeders with clearance of the fault after set time delay of the protective relays or clearing time of the fuses.
- Generator short circuit with clearance of the fault and generator trip after the set time delay of the protective relays. Based on the analysis, load shedding shall be applied when required.
- Generator trip. Based on analysis, load shedding shall be applied when required.

The analysis shall be carried out for the worst case conditions with respect to system stability, which shall be determined separately by each project.

The analysis shall prove that the system will restabilize following the specified disturbances, and that the transient voltage and frequency variations, motor slip, reacceleration and start up times are within acceptable limits.

4.1.5 Protective relay coordination and discrimination study

A relay coordination study shall be carried out to determine the setting of the protective relays and direct acting circuit breakers.

Series connected overcurrent relays, direct acting circuit breakers and fuses shall be coordinated to achieve correct discrimination during fault conditions. Correct discrimination shall be maintained for the minimum and maximum prospective fault currents, while the thermal effect of the fault current shall not exceed the thermal withstand capability of any circuit component.

The relay coordination study shall be carried out according to the requirements of the IFEA "Guidelines for the documentation of selectivity (discrimination) in a.c. systems."

4.1.6 Calculation of harmonic currents and voltages

A harmonic study shall be carried out when Power Drive System(s) is a part of the electrical network. The magnitude of the harmonics and the total voltage distortion shall be computed for all main busbars.

On high voltage busbars ($U_n > 1000V$), the Total Harmonic voltage Distorsion (THD) should not exceed 8% and no single harmonic should exceed 6%, corresponding to IEC 1000-2-4, class 2.

On low voltage busbars ($U_n < 1000V$) the Total Harmonic voltage Distorsion (THD) should not exceed 10%, and no single harmonic should exceed 8% corresponding to IEC 1000-2-4, class 3.

The detailed harmonic voltage acceptance limits shall correspond to IEC 1000-2-4, class 2 for high voltage, and class 3 for low voltage.

Note: It may be necessary to feed equipment sensitive to harmonics from an UPS system.

4.1.7 Cable selection and sizing criteria

An electrical cable sizing study shall be performed in order to establish cable sizing criteria. The following general criteria shall be incorporated:

- Nominal current.
- Voltage drop, stationary and transient, according to Table 1.
- Short circuit withstand capability, mechanical and thermal.
- Type of cable to be used for which purpose and area, ie mud/oil resistant, fire resistant etc.

Electrical cables shall comply with NEK 606.

The voltage drop in cables should not exceed the following values, measured from the last distribution board with regulating facilities, ie supplied by a transformer with tappings or a generator.

Table 1 - Voltage drop in cables

System voltage	Circuit type	Voltage drop	Typical power factor
400/230V	Feeder	2%	0,9
	Branch	4%	
	Total	6%	
	Lighting, at last fixture	10%	
11/6,6/0,69kV	Feeder	2%	0,8
	Branch	4%	
	Motor feeder	4%	
	Total	6%	
	Motor feeder at starting	20%	0,3

5 SYSTEM requirements

5.1 System voltage and frequency

The following voltage levels and frequency shall be used:

11kV, 3-phase	Generation and distribution voltage. Should be used when total installed generator capacity exceeds 20MW. Should be used for motors from 400kW and above.
6.6kV, 3-phase	Generation and distribution voltage. Should be used when total installed generator capacity is between 4-20MW. Should be used for motors from 300kW and above.
690V, 3-phase	Generation and distribution voltage. Should be used when total installed generator capacity is below 4MW. Should be used for consumers below 400kW and as primary voltage for converters for drilling motors.
400/230V 3-phase + N	TN-C-S / TN-S system shall be used as distribution voltage for lighting and small power, and for heaters below 3kW, including heat tracing. For living quarter, kitchen and laundry 400V 3-phase may be used as supply voltage to consumers. The system shall be symmetrically loaded.
UPS 230V	IT system shall be used as distribution voltages for instrumentation, single phase: control, telecommunication and safety systems.
230V IT	May be used for emergency power supply system.
750V d.c.	Shall be used for d.c. drilling motors. Note: Other power supply systems may be used for drilling equipment.
UPS 48V d.c.	Shall only be used as distribution voltage for telecommunication systems.
Frequency	50Hz.

Only one high voltage level should be employed.

5.2 Power supply

Necessary redundancy to obtain the required availability shall be provided to maintain the power supply during normal maintenance operations and service interruption of critical power distribution equipment.

5.2.1 Main power supply

The main power supply shall serve all electrical functions during normal operation.

The main power supply may be arranged with subsea cables from a neighbouring unit, from shore, or with local power generation, or with a combination of the alternatives.

When local power generation is provided, the generators shall be grouped in a central power plant. The unit rating and number of generating sets shall be adapted to the load profile of the systems served over the entire lifetime of the unit.

The main power generator auxiliary consumers shall be supplied from two sources , the main and the emergency system. A change-over system shall be provided.

5.2.2 Emergency power supply

The emergency power supply system shall serve emergency power consumers as defined by NPD. Reference is also made to NORSOK standard S-DP-001, Technical safety.

The emergency power supply systems shall comprise a combination of UPS systems, and if necessary an engine generation system.

The emergency generator(s) shall be arranged for parallel operation with the main power grid for regular testing and maintenance of the set(s).

The emergency power supply system shall be independent of the main supply systems. Main and emergency distribution equipment shall be located in separate rooms. Sub distribution boards may be located in the same room as main supply systems.

The generator(s) shall start automatically and operate directly on the emergency busbar in case of failure of main system. The normal starting time until the emergency switchboard is energized shall not exceed 45 seconds.

5.2.3 Uninterruptible power supply (UPS) system

UPS systems shall be provided for emergency services and non emergency services requiring continuous a.c. or d.c. power supply in case of failure of the main power supply, and for services that will malfunction upon occurrence of normally expected voltage transients.

UPS power shall be provided for the following services:

- Safety systems (emergency consumers).
- Control systems required for operation and monitoring of safety auxiliary systems.
- Vital telecommunication systems.
- Control systems required for restarting of the drilling and production systems.
- Control equipment liable to fail or malfunction upon occurrence of normally expected voltage transients, e.g., on starting of large induction motors.
- Obstruction lights.
- Circuit breaker control voltage.

Reference is also made to NORSOK standard S-DP-001, Technical safety.

Each battery charger should be provided with facilities for battery load test including recording of test values.

Analysis shall be carried out to demonstrate the availability and reliability of the UPS system.

Backup time for public address systems and PABX/radio systems shall be according to NORSOK T-CR-001 Telecommunication systems.

Redundant UPS units shall not contain common mode failure elements.

5.2.4 Drilling backup power supply

The backup power supply for drilling shall secure well and equipment in case of main power failure. The back-up power supply should be part of the permanent power supply system. For removable drilling facilities the backup power supply should be part of the drilling package.

5.2.5 Subsea power supply

The platform power system shall provide electrical power to the topside part of the Subsea production control system, which in turn shall generate the necessary hydraulic and electrical power and control signals to the subsea installation.

Equipment which is required for shutting down the subsea installation in a controlled manner, shall be powered from the UPS system.

Where the subsea control system requires dual redundancy this requirement shall also apply to the UPS.

5.3 Power distribution system

5.3.1 Main power distribution system

The electrical power distribution system should be provided with duplicate incomers and a bus-section circuit breaker for all major switchboards. The bus-section circuit breaker shall be normally open, the incoming circuit breakers normally closed. Duplicate equipment shall be supplied from different busbar sections.

For switchboards fed directly from generators, the bus-tie breaker shall be normally closed.

The configuration of the main power distribution system shall depend on the regularity requirements of the production process.

5.3.2 Emergency distribution system

In normal operation the emergency switchboard shall be fed from the main power system. After loss of main power the switchboard shall be fed from the emergency generator(s).

The busbar sectionalizing arrangement shall be adapted to the emergency generator configuration.

Electrical equipment classified as emergency equipment shall be connected to the emergency switchboard. Equipment requiring continuous operation according to statutory regulations shall be connected to UPS systems, fed from the emergency switchboard. Self-contained emergency equipment with battery units shall be fed from the emergency switchboard.

5.3.3 Power distribution control system (PDCS)

A Power distribution control system (PDCS) shall be established and include as a minimum the following functions, available on a VDU in the central control room:

- Mimic diagram(s) of the electrical network with circuit breaker and isolator status.
- Control of all main breakers in the electrical network.
- Status and alarm monitoring of all main breakers.
- Alarm from all relevant sub distribution boards and UPS systems.
- Event recording of all alarms and status changes.

In addition the following functions may be included where required:

- Load shedding system.
- Power management system.
- Change over using "make-before-break" between incomer and busbar breakers.
- Power reading of main generators, high voltage motors, feeders, and other analogue values according to table 3, clause 6.4.2.
- Trend recording.
- Motor starter interface if not directly to the PCS.

The PDCS shall be an independent functional unit with interface to the PCS, either as a part of the SAS hardware or as an independent unit with data communication to the PCS.

Alarm and control signals shall be collected from each switchboard to the PDCS by use of local control units, distributed I/O units or intelligent units with communication.

Data communication with standard protocols and electrical interface should be used.

The event recording function shall enable printing of all events sequentially with the proper identification, time and date tagging. The time resolution for the Main distribution system shall be maximum 20 ms while I/O units for motors and sub-systems shall be maximum 1s. Time tagging shall preferably take place on the lowest level (I/O-unit). All time tagging shall be time synchronised with the SAS or corresponding time reference.

The total response time from operation of main breaker from VDU to reached status change, shall not exceed 3s. Ref. NORSOK I-CR-002, Annex 2 - Guidelines for time response.

Where implemented, the load shedding system shall be an independent software module within the PDCS. Care must be taken to ensure that the response time is sufficient to enable the load shedding system to perform its function and maintain a stable electrical system.

5.4 Earthing

Earthing systems shall comply with ET "Elektrisitetstilsynet" "Retningslinjer for jording i maritime anlegg".

Exception: Field equipment shall be earthed through the supply cable.

5.4.1 System earthing

The system earthing methods for the different voltage levels are shown in Table 2. For high voltage levels, the system earthing shall be performed as "High resistance earthing" according to definition in FEAM para. 2813.1.5 (Norwegian text only): "Høyohmig jordet nøytralspunkt: Et system hvor nøytralspunktet er jordet over en motstand med størrelse lik eller litt mindre enn 1/3 av den kapasitive reaktans av en fase mot jord."

The resistive current shall for all voltage levels be limited to the maximum values given in table 2.

Table 2 - System earthing methods

Voltage	Power source	Transformer
11kV	Generator neutral shall be high resistance earthed. Maximum earth fault current shall be limited to 20A per generator.	Transformer neutral shall be high resistance earthed. Maximum earth fault current shall be limited to 20A per transformer.
6.6kV	Generator neutral shall be high resistance earthed. Maximum earth fault current shall be limited to 20A per generator	Transformer neutral shall be high resistance earthed. Maximum earth fault shall be limited to 20A per transformer.
690V	Generator neutral shall be high resistance earthed. Maximum earth fault current shall be limited to 100A per generator.	Transformer neutral shall be high resistance earthed. Maximum earth fault current shall be limited to 100A per transformer.
400/230V TN systems		Transformer neutrals shall be solidly earthed.
230V IT UPS, Emergency	Isolated.	Isolated
D.C.	Both poles isolated. (1)	

Notes:

1. D.C. voltages for telecommunication system may have one pole earthed.
2. Emergency generator neutral(s) shall be isolated.

5.4.2 Lightning protection

No additional installations will be required for the lightning protection, provided the unit consist of bolted and welded steelwork that will provide a continuous current path from the highest point of the unit to the main earth.

5.5 Lighting system

5.5.1 General

The following clauses govern the design and functional requirements of the general lighting system.

Other lighting systems such as navigation aids, helideck lighting, marking systems and aviation obstruction lighting shall be designed according to the requirements of statutory regulations.

Lighting calculations shall be performed, and a maintenance factor shall be applied, reflecting the environmental conditions and maintenance intervals.

It should be noted that lighting equipment with electronic starter may cause interference with radio communication. A study shall be performed to investigate the extent of the problem and propose solution.

5.5.2 Lighting equipment

The general lighting system shall be designed with fluorescent luminaries. The fluorescent tubes shall be of the two pins, slim long life type.

Floodlights, with high pressure sodium lamp, shall be used for general lighting of open deck areas, inside big open modules where an acceptable mounting height is achievable, on cranes, flare booms, sea surface below boat and raft stations.

Incandescent luminaries shall not be used. For comfort lighting within the living quarter and office areas, low energy lighting sources like compact/mini tubes should be used.

It shall be possible to vary the lighting level within control rooms and common recreation areas.

Battery operated handlamps with battery chargers shall be provided. The handlamps shall be certified for use in zone 1.

Emergency luminaries shall be of the instant start type.

Electrically powered lighting or photoluminescent indicators, low level lighting, shall be placed at points of the escape to readily identify all escape routes when the normal emergency lights are less efficient due to smoke. What type to be used depend upon the type of area. These luminaries shall meet zone 1 requirements.

For emergency distribution boards, Ex-certification shall be evaluated in each case depending on the location.

Illuminated level gauges should be of the Light Emitting Diode (LED) type with long life time.

5.5.3 Lighting system design

The lighting system should consist of four categories of lighting:

- Normal lighting:
Covering approximately 70% of the lighting requirements. The normal lighting shall be fed from the main distribution system.
- Emergency standby lighting:
Covering approximately 30% of the platform lighting requirements. In normal operation the emergency stand by lighting shall form part of the normal lighting system.
- Emergency escape lighting:
A part of the emergency luminaries, shall be supplied from a battery source, and sited according to prEN1838. Other emergency luminaries e.g. floodlights, shall be supplied from a UPS system.
- Portable emergency lighting:
The battery charger for battery operated handlamps shall be fed from the emergency distribution system.

Local subdistribution boards shall be provided for power distribution to the lighting system within each functional area. The distribution boards shall to the extent possible be located in non-hazardous dry areas.

Distribution boards for emergency lighting shall be equipped for common remote alarming of tripped circuit.

5.5.4 Normal lighting illuminance levels

The illumination levels shall comply with the NORSOK standard S-002, Working environment.

5.5.5 Emergency lighting illuminance levels

The illumination levels shall comply with the relevant parts of prEN1838.

5.6 Power outlets

5.6.1 Small power outlets

A small power convenience socket outlet system shall be designed such that any area can be reached with a 25m flexible cord without passing through doors.

In control rooms, local equipment rooms and offices approximately 20% of the convenience outlets shall be fed from the local emergency subdistribution board limited to essential equipment which has to be available during a shutdown situation.

Convenience socket outlets shall be rated 16A. Circuits dedicated for socket outlets shall have no other consumers connected.

Ex certified equipment shall be used in naturally ventilated areas.

5.6.2 Power outlets

A power socket outlet system shall be designed such that any working area can be reached with a 40m flexible cable without passing through doors or different decks.

The sockets shall be rated 63A, 400/230V, 3 phases + neutral. Ex certified equipment shall be used in naturally ventilated areas.

5.7 Temporary work station

Socket outlets or junction boxes for connection of 125A, 400/230V, 3 phase + neutral, temporary work station for turnarounds and major modification work, should be located close to container lay down areas.

Ex certified equipment shall be used in naturally ventilated areas.

5.8 Electrical heat tracing

5.8.1 General

Heat tracing shall be applied for frost protection, condensation prevention and process temperature maintenance.

Design, material and installation should be according to the guidelines issued by IFEA "Veiledning for varmekabelanlegg i industri og offshore".

5.8.2 Design

The heat tracing cables should be of the self limiting type.

Temperature control devices like resistor temperature devices (RTD), thermostats etc. should not be used. For specific applications, however, where the self limiting characteristic of the heating cable is unsuitable regarding response or temperature limitations, temperature control device control shall be used. Temperature control devices shall be installed if excessive temperature will cause corrosion on pipes and tubing.

5.8.3 Power supply

One heat tracing circuit should only supply one process system.

Each of the circuits shall be equipped with an automatic trip, 30mA earth fault relay. Trip indication shall be provided for each circuit. Common alarm shall be given to a central alarm system for each subdistribution board.

Subdistribution boards shall be provided for local power distribution to the heat tracing system in each functional area. The distribution boards should not be located in hazardous areas or in exposed environments.

5.9 Navigational aid system

All power supply and control equipment for fog horn and navigational lights shall be located indoors, at a location suitable for maintenance activities.

The integrated power supplies shall be galvanically isolated from the mains.

5.10 Thermographic inspection

Possibilities for thermographic on load inspection or use of thermostrips for equipment like power transformer, UPS, switchgear and motor control center, should be arranged where possible.

5.11 Separate electrical rooms

Separate electrical equipment rooms shall be used when required by statutory regulations.

5.12 Location of major electrical equipment

In order to avoid installation of major electrical equipment in hazardous areas or in exposed environments, all major electrical equipment shall be installed inside equipment rooms with a controlled atmosphere.

5.13 Ignition source control

Equipment left live in an ESD situation shall be explosion protected and suitable for installation in zone 1 area. Excepted is emergency equipment in living quarter and other areas subject to special considerations. Reference is also made to NORSOK standard S-DP-001, Technical safety.

Depending on the location, small power outlets, power outlets and temporary work stations shall be automatically isolated upon detection of gas.

6 EQUIPMENT REQUIREMENTS

Equipment with identical functions should be directly interchangeable.

High voltage equipment shall be equipped for earthing by a portable apparatus. The terminals and the earthed frame shall be provided with earth lug or ball suitable for connection of standardised portable mobile earthing apparatus. A standard type of earthing arrangement shall be selected for all equipment.

For air insulated switchgears isolation of circuits shall be by use of withdrawable breakers and starters.

Circuit breakers shall be equipped with mechanically acting push buttons for local testing and emergency operations, and be provided with "service" and "test" positions.

Safety thermostats in heaters shall be wired directly into the control circuit of the feeding circuit.

Earth bars shall normally be located in front of the cable entries to allow easy access for inspection and maintenance.

Space shall be provided for entry, strapping and termination of all cables as specified in the data sheet plus 10% spare.

6.1 High voltage switchboard

6.1.1 General

The switchboard and cubicles shall be metal enclosed according to IEC 298-3.102. In addition the cubicles shall be of type metal clad according to IEC 298-3.102.1. Separate low voltage compartments shall be located in the front of the switchboard.

The switchboard shall be of either air or SF6 insulated type.

All circuitbreakers and contactors shall be of either vacuum or SF6 type. For SF6 insulated switchboards, circuitbreakers should be used throughout the switchboard.

The circuit breakers and contactors shall have test possibilities when disconnected from the mains. The control voltage shall be supplied from an UPS system of 230V AC.

For air insulated switchgears the high voltage compartments shall be provided with pressure relief facilities possible for connection to ducting leading out of the room.

Surge arrestors or other protection devices shall be used in connection with vacuum contactors/circuitbreakers where switching voltage escalation may exceed the insulation level.

The switchgear room shall allow for extension of the switchgear in at least one end.

All circuitbreakers and contactors shall be withdrawable for air insulated switchboards. Circuitbreakers, contactors, and earthing switches shall be provided with padlocking facilities.

Mechanical interlock between circuitbreaker, contactor, and earthing switch in the same cubicle shall be provided. Where mechanical interlock is not possible (i.e. closing of earth switch on live main busbar), other interlock system shall be provided.

6.1.2 Testing

Routine tests shall be performed according to IEC 298 Section 7. High voltage switchboards shall be tested according to IEC 298 for arcing due to internal faults. The duration of the arc shall be 1 second.

6.2 Low voltage switchboard

6.2.1 General

Spare space of approximately 10% at the time of delivery of the equipment should be provided. Spare panels and compartments shall facilitate future installation without shutting down the switchboard.

The control voltage shall be supplied from an UPS system at 230V a.c. for air circuit breakers and other critical consumers.

Status for main circuit breakers shall be shown on the breaker front. (On, off, trip.)

Starters shall be designed for direct on-line starting of type AC3 according to IEC 947-4-1.

The control voltage shall be supplied from a common control voltage transformer for each motor starter cubicle or each busbar section. A separate control voltage busbar should be provided. Protection shall be provided individually for each motor starter circuit.

The starters shall have a test possibility when disconnected from the main circuit.

Starters should be grouped into motor control centers located in switchboard rooms. Pad locking facilities shall be provided for all incoming and outgoing circuits. This shall apply for all voltage levels including 230V.

6.2.2 Testing

Routine tests shall be performed according to IEC 439-1.

6.3 Uninterruptible power supply (UPS)

6.3.1 General

The UPS unit shall meet the requirement in EN 50091-1.

Each main distribution board section shall be equipped with earth fault detection and common alarm. The earthfault detection system shall as a minimum be of a type that enables manual fault finding of each outgoing circuit. Space shall be provided for fault finding of the outgoing circuits with a portable apparatus.

The UPS unit shall have internal test facilities to verify all operational features for the system including battery discharge test without closing down the supply to the consumers. The UPS shall have a separate battery discharge alarm.

To obtain isolation from all power sources at ESD, all battery breakers shall have a remote trip function. Means shall be provided to enable closure of the battery breaker after a trip without utilising external auxiliary voltage or temporary links.

Upon detection of a sustained overload, the UPS shall switch over to the by-pass supply.

Selection and coordination of protection devices shall ensure selectivity in all modes.

All UPS systems shall be equipped with a manual by-pass circuit for maintenance purpose and a static switch for automatic and uninterrupted transfer of load from the inverter to the by-pass supply. Retransfer of the load from the manual bypass switch to the inverter shall be manually operated.

The main supply and the bypass supply, or the supply to the A and B unit for redundant UPS units, should be fed from different switchboards, or from different bus sections of the same switchboard.

The UPS unit shall have a mimic diagram on front showing operational modes and voltage/amps/frequency.

The UPS shall resume normal operation after return of a.c. input supply.

Air circulation gaps around the battery cells shall be provided according to the manufacturer recommendation.

6.3.2 Testing

Routine tests shall be performed according to IEC 146-4.7.

6.4 Electrical indicating instruments

6.4.1 General

Panel instruments should be of class 1.5.

Current transformers for measuring purposes shall have 5A or 1A secondary current.

Voltage transformers shall have 110V secondary voltage. Shunts used on d.c. current metering shall be 60mV.

Where synchronizing can take place, the following instruments shall be provided for manual synchronizing:

- Synchronoscope.
- Double voltmeter.
- Double frequency meter.
- Check sync. relay

6.4.2 Requirements

Electrical indicating instruments shall be according to Table 3, Electrical indicating instruments.

Table 3 - Electrical indicating instruments

	Generators		Motor feeders	Transf. feeders/ outgoing circuit br. feeders	Incomers	D.C. systems	Busbar metering
Indicating instruments	Incomers	Control panel					
Voltmeter + selector switch	X	X			X		X (2)
1 voltmeter						X	
Ammeter + selector switch (1)	X	X		X	X		
1 ammeter						X	
Wattmeter		X (2)	(3)X	(3)X			
VAr meter		X					
Frequency meter		X					
Synchroscope		X					
Ammeter for field current AVR		X					
Temperature measurement		X	X HV motors only	X HV transformers only			
Hours run meter		X	X (2)				
kWh meter		X					

Notes:

1. Ammeters may be used.
2. The values shall be registered in the PDCS if available.
3. Optional, may be implemented in the PDCS or local.

6.5 Motors

6.5.1 General

A.C. motors should be of the squirrel cage, direct on-line start type. Where variable speed/torque regulation is required, converter fed a.c. motors shall be used. D.C. motors may be used for certain applications.

The terminals and the earthed frame of high voltage motors shall be provided with contact bolts for application of mobile earthing apparatus.

High voltage motors shall have pre formed windings.

High voltage motors windings shall be vacuum impregnated.

6.5.2 Motor rating, Ex protection and enclosure

Motor rating and protection shall be according to Table 4.

Table 4 - Motor rating and degree of protection (IP)

Motor type	Nominal voltage	Rated output	Ex protection (4)	Insulation class	Enclosure
LV	400V a.c. (3)	< 200kW	e, n, d/e (1)	F	IP55 (2)
LV	690V a.c.	< 400kW	e, n, d/e (1)	F	IP55 (2)
HV	6.6kV a.c. 11kV a.c.	> 300kW > 400kW	p, d/e (1)	F	IP55 (2)

Notes:

- Shall be used with Ex e termination.
- IP56 shall be used where equipment may be exposed to powerful water jets.
- For special applications only.
- Non-ex type motors may be used in non-hazardous mechanically ventilated areas.

Motors in zone 1 or 2 rated above 6,6kV shall be Ex p or Ex d with Ex e termination.

Totally Enclosed Fan Cooled (TEFC) motors may be used on open deck provided the motor is protected by embedded temperature detectors for trip upon blocking of fan blades.

6.5.3 Local control stations

Local emergency stop adjacent to the motor shall be connected directly to the motor starter circuit.

Control stations shall be standardized according to IEC with respect to symbols, colours and lettering on pushbuttons, indication lights, selector switches, etc. throughout the unit.

6.5.4 Testing

Routine tests shall be performed according to IEC 34.

6.6 Generators

6.6.1 General

The generator shall be designed for operation in parallel with units of equal and unequal ratings.

The stator winding shall be star connected and star point and main terminals brought out to terminal boxes on the outside of the generator hood.

The generator should be delivered with a neutral resistor as an integral part of the generator. The resistor shall be rated in accordance with the data sheet.

Minimum two temperature resistance sensors shall be embedded in each phase of the stator winding.

The rotor shall be dynamically balanced according to relevant international standards and be able to withstand an overspeed of 120% of the nominal speed for two minutes.

The exciter shall be of the brush less type and directly connected to the main shaft. The rated output of the exciter and rectifier assembly shall be minimum 110% of the nominal value required when the generator is running at rated load and power factor.

Facilities shall be provided for continuous monitoring of exciter and field winding insulation resistance. Facilities shall be provided for monitoring of the rectifier diodes. Alarms shall be given for failed open as well as failed shorted diodes.

The electronic automatic voltage regulator (AVR) shall have adequate protection against voltage surges, shall be free of voltage drift, be insensitive to temperature changes and shall maintain regulation accuracy for frequency variations of $\pm 10\%$ of rated value.

The AVR system shall consist of dual independent channels:

- either a double AVR system
- or with one AVR channel and one FCR (manual field current regulator) channel.

For a double AVR system, one channel shall be main while the other shall be in stand-by. It shall be possible to manually choose which channel shall be in main.

For a system with one AVR and one FCR, the AVR shall be main and the FCR shall be stand-by.

For both systems, a follow-up regulation shall be provided. This shall ensure voltage stability upon transfer between the main and stand-by channel.

Automatic transfer from main to stand-by channel shall take place for faults influencing the regulation. For the AVR/FCR system such automatic change-over shall only take place when two or more generators are running in parallel.

Each bearing shall be provided with temperature detectors (one spare) for alarm and shutdown purposes.

The lubrication oil system shall operate during spin-down of the generator in a black out situation, preferably by gravity fed lube oil supply.

6.6.2 Testing

Routine tests shall be performed according to IEC 34.

6.7 Power transformers

6.7.1 General

High voltage power transformers shall be prepared for forced cooling rated 140% of AN rated load. The transformer shall normally be of the cast resin dry type. Low voltage (LV/LV) transformers may be dry type without cast resin insulation.

Neutral resistor may be an integrated part of the transformer, including current transformer.

6.7.2 Testing

Routine tests shall be performed according to IEC 76-1.

7 RELAYS AND PROTECTION

7.1 General

Solid state, microprocessorbased multifunction protective relays with programmable release characteristics should be employed for protection of the electrical power generation and distribution system and electric motors.

Relays with data communication features should be employed in large, centrally controlled systems.

7.2 Main generator protection

Main generator protection shall be according to Table 5.

Table 5 - Generator protection

Protective function	Trip generator breaker	Generator de-excitation	PDCS and generator control alarms
Differential protection (2)	X	X	X
Overload and shortcircuit	X	X	X
Earth fault	X	X	X
AVR fault (3)	X	X	X
Stator RTD, temp. high			X
Stator RTD, temp. hi/hi	X		X
Rotor earth fault	X		X
Directional earth fault (1)	X	X	X
Overvoltage	X	X	X
Undervoltage	X		X
Reverse active power (1)	X		X
Reverse reactive power (1)	X		X
Negative phase sequence	X		X

Notes:

1. For generators in parallel operation only.
2. For generators above 4MVA.
3. May be an integral part of the AVR

7.3 Emergency generator protection

Emergency generator protection shall be according to Table 6.

Table 6 - Emergency generator protection

Protective Function	Emergency mode		Test mode	
	Trip generator breaker	PDCS and generator control alarms	Trip generator breaker	PDCS and generator control alarms
Short circuit	X	X	X	X
Overcurrent		X	X	X
Earth fault		X	X	X
Stator RTD, temp.high		X		X
Stator RTD, temp. hi/hi		X	X	X
Reverse active power (1)	X	X	X	X

Note 1) For generators in parallel operation only.

7.4 Electric motor and power transformer protection

Electric motor and power transformer protection shall be according to Table 7.

Table 7 - Motor and power transformer protection

Protective function to disconnect supply	Low voltage motor	High voltage motor	Power transformer	PDCS alarms
Overload	X	X	X	X
Shortcircuit	X	X	X (5)	X
Earth fault	X	X	X (4)	X
Differential protection			X (6)	X (6)
RTD, temp. high		X (1)	X (1)	X
RTD, temp. high high		X (2)	X	X
Stalled rotor	X (3)	X		X
No. of start attempts/thermal state		X		X
Negative sequence		X		X

Notes:

1. Alarm only.
2. Should the RTD detect overtemperature in motors driving fire water pumps, an alarm only shall be annunciated while the operation shall be continued in emergency mode.
3. Stalled rotor protection shall be provided for submerged pump motors and other critical motors when specified in the datasheet.
4. Earth fault protection shall be provided:
 - For protection of the primary winding against internal faults.
 - For protection of the switchboard connected to the secondary winding, and internal faults when the neutral point is earthed across a neutral resistor.
5. Shall protect the primary and secondary windings, and the busbar of the switchboard connected to the secondary winding.
6. Differential protection not required for dry type transformers.

7.5 11kV / 6.6kV busbar relays

The following relays shall be installed in each busbar section of 11kV / 6.6kV switchboard:

- Undervoltage relay.
A stationary undervoltage situation shall initiate tripping of the connected motors.
- Frequency relay.
Input to Load Shedding System.
- Arc detection relay.
An arc detection system shall be installed either alone or in combination with a current relay. Detection shall sectionalise the busbar and trip incomer(s). This does not apply for single phase air or SF6 insulated switchboards.

7.6 Other circuits

Other circuits shall be equipped as follows:

Lighting and small power transformers:

- Circuit breakers with primary overcurrent/shortcircuit relay, moulded case circuit breaker or fuse.
- Earth fault protection.

690V Sub-distribution feeders:

- Circuit breakers with overcurrent/short circuit relay.
- Earth fault protection.

Feeders to 230V sub-distribution boards:

- Moulded case circuit breakers with overcurrent/shortcircuit relay.
- Earth fault protection.

Lighting and small power circuits:

- Miniature circuit breakers.
- Earth fault protection.

Trace heating circuits:

- Miniature circuit breakers.
- Earth fault protection.

Outgoing feeders below 400A may be provided with load breaker and fuses.

8 INFORMATIVE REFERENCES

- IEC 364-4-41: Electrical installations of buildings, Part 4: Protection for safety, Chapter 41: Protection against electric shock.
- IEC 533: Electromagnetic compatibility of electrical and electronic installations in ships.
- IEC 1000-2-4 Electromagnetic Compatibility (EMC) - Part 2:Environment - Section 4: Compatibility levels in industrial plants for low-frequency conducted disturbances.
- prEN 1838: 1995 Lighting applications - Emergency lighting.

ANNEX A EQUIPMENT DATA SHEETS (NORMATIVE)

- EDS-001 UNINTERRUPTIBLE POWER SUPPLY (UPS) Rev. 3, Dec.1997
- EDS-002 EG, AC GENERATOR Rev. 3, Dec.1997
- EDS-003 EH, HIGH VOLTAGE SWITCHBOARD (>1kV) Rev. 2, Jan. 1996
- EDS-004 EM, INDUCTION MOTOR Rev. 2, Jan. 1996
- EDS-005 EN, LOW VOLTAGE SWITCHBOARD (<1kV) Rev. 2, Jan. 1996
- EDS-007 ET, POWER TRANSFORMER Rev. 3, Dec. 1997