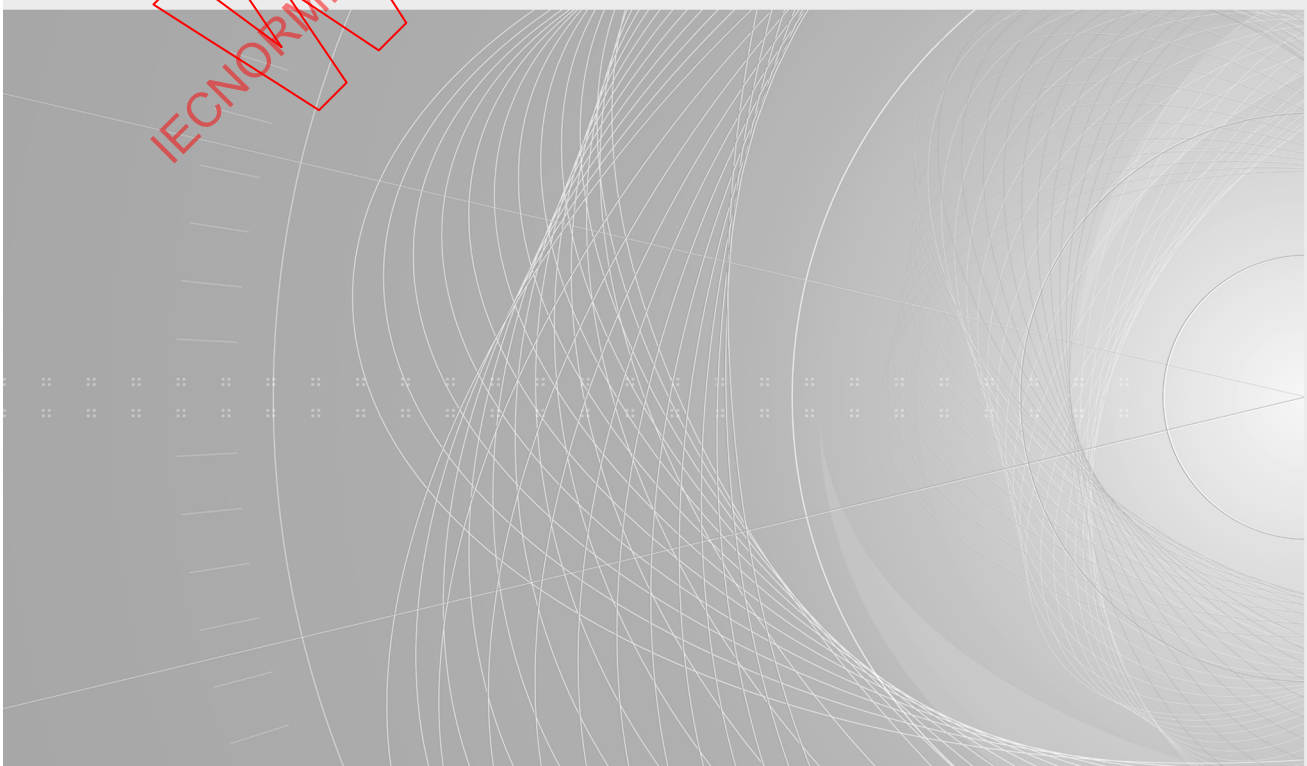
IEC 60092-501

Edition 4.0 2007-08

INTERNATIONAL STANDARD

Electrical installations in ships –
Part 501: Special features – Electric propulsion plant



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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

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Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRICAL INSTALLATIONS IN SHIPS –

Part 501: Special features – Electric propulsion plant

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60092-501 has been prepared by IEC technical committee 18: Electrical installations of ships and of mobile and fixed offshore units.

This fourth edition cancels and replaces the third edition published in 1984. It constitutes a technical revision.

This edition included the following significant technical changes with respect to the previous edition:

a) requirements regarding system responsibility, electromagnetic compatibility (EMC), harmonic distorsion and filtering, special requirements for ships with propulsion motor(s) and podded drives, and power management system (PMS);
b) overall technical review to update the standard according to general requirements and referenced equipment standards.

The text of this standard is based on the following documents:

FDIS	Report on voting
18/1057/FDIS	18/1063/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 60092 series, under the general title *Electrical installations in ships*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

IEC 60092 forms a series of international standards for electrical installations in sea-going ships, incorporating good practice and coordinating, as far as possible, existing rules. These standards form a code of practical interpretation and amplification of the requirements of the International Convention on Safety of Life at Sea, a guide for future regulations which may be prepared and a statement of practice for use by shipowners, shipbuilders and appropriate organizations.

ELECTRICAL INSTALLATIONS IN SHIPS –

Part 501: Special features – Electric propulsion plant

1 Scope

This part of IEC 60092 specifies requirements for all electric propulsion plant and gives the specifications, system design, installation and testing of at least

- generators and their prime movers;
- switchboards;
- transformers/reactors;
- semiconductor convertors;
- propulsion motors;
- excitation systems;
- control, monitoring and safety systems;
- wires, cables, busbars, trunking systems.

Bow and stern thrusters intended as auxiliary steering devices, booster and take-home devices, all auxiliary generating plants, and accumulator battery powered propulsion machinery and equipment are excluded.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034 (all parts), *Rotating electrical machines*

IEC 60034-1:2004, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60076 (all parts), *Power transformators*

IEC 60092 (all parts), *Electrical installations in ships*

IEC 60092-101, *Electrical installations in ships – Part 101: Definitions and general requirements*

IEC 60092-202, *Electrical installations in ships – Partie 202: System design – Protection*

IEC 60092-204, *Electrical installations in ships – Part 204: System design – Electric and electrohydraulic steering gear*

IEC 60092-301, *Electrical installations in ships – Part 301: Equipment – Generators and motors*

IEC 60092-302, *Electrical installations in ships* –Part 302: *Low-voltage switchgear and controlgear assemblies*

IEC 60092-303, *Electrical installations in ships – Part 303: Equipment - Transformers for power and lighting*

IEC 60092-504:2001, *Electrical installations in ships – Part 504: Special features – Control and instrumentation*

IEC 60146 (all parts), *Semiconductor convertors*

IEC 60146-2, *Semiconductor convertors – Part 2:Self-commutated semiconductor converters including direct d.c.converters*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

IEC 61378-1, *Convertor transformers – Part 1: Transformers for industrial applications*

IEC 62271-200:2003, *High-voltage switchgear and controlgear – Part 200: A.C. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

International Maritime Organization, *International convention of the safety of life at sea* (SOLAS):2004, *Chapter II-I/ Regulations 27, 29 and 30*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply:

3.1
azimuth drive
system which moves the propulsion unit around the vertical axis

3.2
double sensor
two sensor elements in one housing

3.3
local control station
place of control where a system is installed which creates a reference value for the convertors independent from the remote control system and any external limitations

3.4
locked electrical spaces
spaces constructed as dry spaces which are provided with lockable doors and are intended solely for installation of electrical equipment

3.5
main control station
place of control of the main propulsion system which is manned under seagoing conditions

3.6
nominated body

installer or manufacturer that has been given direct responsibility for the complete propulsion system.

3.7
one failure principle
during and after a fault in a circuit, the supply to the healthy circuits is permanently ensured (continuity of supply) and after a fault in a circuit has been cleared, the supply to the healthy circuits is re-established (continuity of service)

3.8
podded drive
propulsion system in which the motor is located in a dedicated, submerged unit (pod housing) of the ship

3.9
power management system (PMS)
control and safety system which provides the load depending starts and stops of the prime movers, the load sharing, etc.

3.10
propulsion generator
generator mainly used for power supply of the propulsion system

3.11
propulsion motor
electrical motor intended to provide propulsion power

3.12
propulsion switchboard
switchboard mainly used for power distribution to the propulsion systems

3.13
redundant sensor
two single sensors in separate housings

3.14
remote control system
system which comprises all equipment necessary to operate units from a control position where the operator cannot directly observe the effect of his actions

4 System

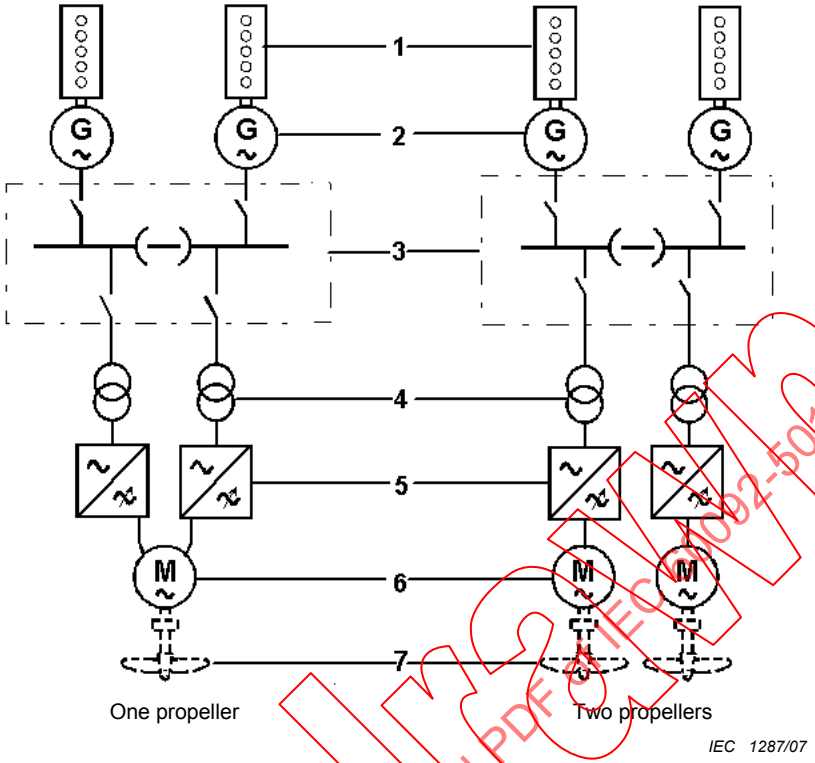
4.1 System design

4.1.1 General

A typical electrical propulsion system consists of the following hardware components:

- propulsion generators;
- switchboard;
- transformers to convert the ships voltage to the convertor voltage;
- convertor to supply the electric motor;
- control system;
- propulsion motor

A typical configuration of the hardware components is shown in Figure 1.



Key

1 Main engine
2 Propulsion generator
3 Switchboard
4 Propulsion transformer
5 Propulsion convertor
6 Propulsion motor
7 Propeller

Figure 1 – Typical equipment (configuration) for ships with one or two propellers

4.1.2 Design requirements

The one failure principle shall be the basis of the design.

NOTE Recognizable failures should not injure the one failure principle. Undetected failures should be avoided. However, it may be unavoidable that some undetected failures may injure the one failure principle.

It shall be possible for all machinery essential for the safe operation of the ship to be controlled from a local position, even in the case of failure in any part of the automatic remote control system, see Clause 14.

4.1.3 Special requirements for ships with only one propulsion motor

Synchronous and induction motors shall be equipped with two stator winding systems which can be disconnected from the respective convertor. Each convertor shall be designed for at least 50 % nominal power of the propulsion drive.

DC motors shall have two separate rectifiers, each for 50 % nominal motor current, with means for disconnecting each rectifier. The convertors shall be mutually independent. Any single failure in one convertor shall not result in complete loss of propulsion power.

Motors with permanent excitation shall be equipped with two stator winding systems which can be disconnected from the respective convertor. Additionally, there shall be a braking or

blocking system which can fix the shaft under all weather and normal towing conditions. Alternatively, a decoupling system may be used which ensures standstill of motor shaft.

4.1.4 Special requirements for ships with more than one propulsion motor

Any electrical failure in a propulsion convertor or propulsion motor shall not make all shafts unavailable.

For all types of propulsion, there shall be a braking or blocking system which can fix the shaft under all weather conditions, propulsion by the remaining shafts and normal towing conditions.

4.2 System responsibility

There shall be one nominated body responsible for the integration of the complete propulsion system.

This body shall have the necessary expertise and resources enabling a controlled integration process.

4.3 Torsional stress and torsional vibrations

In order to prevent excessive torsional stresses and torsional vibrations of excessive magnitude, careful consideration shall be given to co-ordination of the moments of inertia and the elasticity constants of the entire propulsion system, and electrical characteristics in the system.

The entire oscillating system may include prime movers, generators, transformers, convertors, exciters, motors, slip-couplings, gears, shafts and propellers.

The manufacturers of the components shall provide all necessary information to the system responsible body, see 4.2.

The highest oscillating torque can be expected in case of two-phase short circuit of the motor. The highest steady state torque can be expected in case of three-phase short circuit of the motor.

NOTE It is assumed that torque during short circuit conditions will be less than the torque during the crash stop manoeuvre

These possible load situations shall be managed by the propulsion plant. Evidence shall be made by torsional vibration calculation.

4.4 Operational stability

The control system shall be able to control the propulsion system under all weather and manoeuvring conditions.

Other onboard systems shall not influence the propulsion or manoeuvrability of the ship, for example no common communication links, no common hardware. Special consideration shall be given to electromagnetic interference.

All means for normal operation of the propulsion system, including necessary power generation, shall have interlocks in order to prevent incorrect operation and damages.

4.5 Protection against moisture and condensate

Effective means, for example space heaters or air dryers, shall be provided in motors, generators, convertors, transformers and switchboards to prevent accumulation of moisture and condensate, even if they are idle for appreciable periods.

Propulsion motors shall be equipped with an electric heating designed to maintain the temperature inside the machine at about 3 K above ambient temperature.

4.6 Excitation systems

4.6.1 General requirements

Every excitation system shall be supplied by a separate feeder.

The obtainable current and voltage of excitation systems and their supply shall be suitable for the output required during manoeuvring, overcurrent and short circuit or stalling conditions.

Excitation power circuits may be protected against short circuits only, and tripping shall be alarmed.

If the built-in short-circuit monitoring device of the excitation system trips, the respective circuit breaker of the generator or motor shall also trip.

If the excitation system is fitted with independent safety devices, for example against under-frequency and over-voltage or voltage/frequency-functions, they shall be adjusted in such a way that the system protection reacts first.

Excitation circuits shall be provided with means for suppressing voltage rise when an excitation switch is opened.

Special consideration shall be given to the total harmonic distortion and power factor.

4.6.2 Generators

The steady and transient regulation conditions of the excitation system including the automatic voltage regulator shall be in accordance with IEC 60092-301.

Excitation systems shall be supplied from the generator side and the generator shall be self-excited. In general, the voltage built up shall be done without the aid of an external electric power source.

External power supply may be used for exciter control circuits provided that redundancy for this external source is arranged, even for the voltage built up. The external source of power shall be supplied from the corresponding main switchboard section and emergency source of electrical power with battery back up. At least two external power supplies for all generators are required. Every generator excitation system shall be supplied by independent power supply.

4.6.3 Propulsion motors

It shall be possible to supply the exciter circuits from the same switchboard section supplying the stator windings.

4.7 Wires, cables, busbars, trunking systems

Cables and insulated conductors used for internal wiring shall be at least of a flame retardant type. In case of wiring adjacent to equipment containing hydraulic or other oils, the insulation

shall be resistant to that oil, or be properly shielded from it. The cables and insulated conductors shall also be resistant to sea air containing moisture and salt and seawater and they shall be not hygroscopic. They shall also be able to withstand the vibration levels and the temperatures at the location installed and they shall be able to withstand internal and external short-circuits. This also applies to singles wires of cables within terminal boxes.

For all electrical components and installations, materials shall be used that minimize the emission of smoke, soot and toxic gases in case of fire.

Bus-bar systems for power transport shall be either certified for lifelong operation without service, or all joints shall be accessible for inspection and maintenance.

In locations where cables may be subjected to mechanical damage, they shall be protected with special reliable covers or shall be installed in metallic pipes.

5 Electromagnetic compatibility (EMC) and harmonic distortion

5.1 General

Propulsion systems shall comply with performance criterion A of IEC 61000-6-2. This means no degradation of performance or loss of function is allowed during normal operation.

5.2 Total harmonic distortion, THD

Equipment producing transient voltage, frequency and current variations is not to cause malfunction of other equipment on board, neither by conduction, induction or radiation.

The design shall take in account that propulsion convertors create interferences within the propulsion network.

For the propulsion network the total harmonic distortion (THD) value of the voltage shall not exceed 10 %. If a THD-value of 10 % is exceeded, the person responsible for the propulsion system, see 4.2, shall ensure interference-free operation of all connected equipment. If the propulsion network and the ship's network are directly connected the THD value of the voltage shall not exceed the values stated in IEC 60092-101.

The design of cabling and cables, transformers, protection devices etc. shall take into account the high level of harmonic currents caused by the convertor system.

5.3 Radio frequency interferences

If convertors for propulsion plants are placed in separate rooms or cabinets, the maximum values for emissions are valid only outside these rooms or cabinets. The immunity requirements of the propulsion convertor shall comply with at least the requirements for all other equipment on board.

Conducted and radiated emissions leaving the convertor cabinet or room shall be reduced to a system-compatible level.

6 Prime movers

6.1 General requirements

The engines driving the propulsion generators are the main engines.

Main engines shall comply with the specifications of the relevant authorities.

6.2 Speed deviations

If the propulsion generators are also used for supplying the ship network, static and dynamic frequency deviations shall meet the requirements of the ship network.

Where the speed control of the propeller requires speed variation of the prime mover, the governor shall be provided with means for local control as well as for remote control.

The prime mover rated power in conjunction with its overloading and load build-up capabilities shall be adequate to supply the power needed during transitional changes in operating conditions of the electrical equipment due to manoeuvring and sea and weather conditions.

6.3 Parallel operation

In case of parallel operation of generators, the governing system used shall permit stable operation to be maintained over the entire operational load range of the prime-movers.

The speed governor characteristics of prime movers shall be such that in parallel operation the load on individual generators is shared, as far as possible, in proportion to the output of each generator.

6.4 Reverse power

When manoeuvring, for example from full propeller speed ahead to full propeller speed astern with the ship making full way ahead, the prime-mover shall be capable of absorbing a proportion of the regenerated power without tripping due to overspeed or reverse power.

Means external to the mechanical and electrical rotating machinery may be provided in the form of for example braking resistors to absorb excess amounts of regenerated energy and to reduce the speed of the propulsion motor.

The amount of regenerated power shall be limited by the control system.

7 Generators

7.1 General requirements

Generators shall be designed in accordance with the IEC 60034 series and IEC 60092-301.

Generators shall have a protection degree of at least IP 23. Medium voltage generators shall have a protection degree of at least IP 44.

Generators operating with semiconductor convertors shall be designed for the expected harmonics of the system. A sufficient reserve shall be considered for the temperature rise, compared with sinusoidal load.

Stator windings of generators rated above 500 kVA shall be provided with temperature sensors.

Generators above 1 500 kVA shall be equipped with differential current protection.

7.2 Bearing and lubrication

7.2.1 General

All bearings shall be equipped with temperature indicators. The measuring point shall be as specified in IEC 60034-1.

Adequate lubrication shall be ensured even in inclined positions. Provision shall be made for checking the bearing lubrication.

Generators shall be equipped with devices which, in the event of a failure of the normal lubricating oil supply, provide adequate lubrication until the machine has come to standstill.

No lubricating liquid shall flow out of the bearings and penetrate into the machine.

In case of bearings with forced lubrication, failure of the oil supply (loss of oil pump, loss of pressure in the bearing supply pipe) and the attainment of excessive bearing temperatures, an alarm shall be given. If the temperature rises further, the generator shall be stopped.

To avoid damage to bearings, it is essential to ensure that no harmful currents can flow between bearings and shaft.

7.2.2 Sleeve bearings

Sleeve bearings shall be easily replaceable.

Two-part bearings shall be fitted with thermometers indicating, wherever possible, the temperature of the lower bearing shell.

7.2.3 Roller bearings

Roller bearings shall be sufficiently preloaded, where applicable.

7.3 Cooling

The temperature of the cooling air of machines provided with forced air ventilation, air ducts, air filters or water coolers shall be continuously monitored by means of thermometers which are readable from outside the machine. Temperature sensors shall be provided to trigger an alarm.

For machines with a closed circuit cooling method with a heat exchanger, the flow of primary and secondary coolants shall be monitored.

Leakage-water and condensed moisture shall be kept away from the windings. Leakage monitoring is required.

7.4 Protection

The protection shall be in accordance with IEC 60092-202.

7.5 Test

Propulsion generators shall be individually tested at the manufacturer's works. The scope of the tests is stated in the IEC 60034 series.

The additional heating caused by total harmonic distortion shall be taken into account during the temperature rise test.

8 Propulsion switchboards

The propulsion switchboard shall be in accordance with IEC 62271-200 (high voltage) adapted to shipbuilding requirements or IEC 60092-302 (low voltage) and shall be designed like a main switchboard. The longitudinal segregation of the bus bar shall be done by a load switch disconnector or equivalent equipment.

Special consideration shall be given to the total harmonic distortion, see 5.2, and power factor.

9 Propulsion transformers

9.1 General requirements

9.1.1 General

Transformers and reactors shall be in accordance with IEC 60092-303 and power transformers in accordance with IEC 61378-1 and the IEC 60076 series.

Special consideration shall be given to the total harmonic distortion, see 5.2, and power factor.

At least two independent propulsion transformers shall be installed.

Only transformers with separate windings shall be used. Auto transformers are permitted for motor starting.

Transformers producing low voltage from medium voltage shall be equipped with an earthed shield winding between the low-voltage and medium-voltage coil.

The winding temperatures of propulsion transformers shall be monitored.

9.1.2 Degree of protection

Transformers located in engine rooms shall have a protection degree of at least IP 23. Medium voltage transformers, located in engine rooms, shall have a protection degree of at least IP 44.

All transformers located in dedicated locked electrical spaces may have any degree of protection of at least IP 20.

9.2 Cooling

9.2.1 Liquid cooled transformers

Measures shall be taken to ensure that the windings are completely covered by liquid, even for inclinations up to and including 22,5°.

They shall be provided with a collecting arrangement which permits the proper disposal of the liquid.

A fire detector and a suitable fire extinguishing system shall be installed in the vicinity of the transformer. The fire fighting system may be manually operated.

Liquid cooled transformers shall be provided with gas-actuated protection devices.

The liquid temperature shall be monitored. A prealarm shall be actuated before the maximum permissible temperature is attained. When the maximum permissible temperature limit is reached, the transformer shall be switched off.

The liquid filling level shall be monitored by means of two separate sensors. The monitoring system shall actuate an alarm at the first stage and shall trigger a shutdown at the second stage, when the permissible limit is exceeded.

9.2.2 Air cooled transformers

Ventilators and temperatures of the cooling air for forced-ventilated transformers shall be monitored.

9.2.3 Air forced/water forced cooled transformers

For transformers with a closed circuit cooling method with a heat exchanger, the flow of primary and secondary coolants shall be monitored. Leakage-water and condensed moisture shall be kept away from the windings. Leakage monitoring is required.

9.3 Instrumentation

Propulsion transformers shall be equipped with a three-phase ammeter on primary side.

9.4 Protection

Each propulsion transformer shall be protected against overcurrent and short-circuit at the primary and secondary side.

Protection on secondary side may be achieved by the convertor.

9.5 Test

Propulsion transformers shall be individually tested at the manufacturer's works. The scope of the tests including the vector-group test is stated in IEC 61378-1.

The additional heating caused by total harmonic distortion, see 5.2, shall be taken into account during the temperature rise test.

10 Convertors

10.1 General

Convertors shall be designed in accordance with the IEC 60146 series.

Two entirely separate convertors shall be installed.

Common control of the convertors is not permitted. This means, for example, that two single tachometer generators or one doubled tachometer generator shall be installed if a tachometer generator is needed for ship's operation.

Two galvanically isolated actual speed sensors shall be provided for each control system. Common housing of both sensors is permitted.

If the convertor feeds a permanently excited synchronous motor, a switch disconnector shall be fitted in the motor-convertor line which opens automatically in case of an inverter fault. Devices which support fault diagnosis shall be installed.

10.2 Design of semiconductor convertors

Propulsion convertors shall be designed for the nominal torque of the drive. Short-term overload and speed variations resulting from overloads shall not lead to a shutdown of the system.

The cabinets for semiconductor convertors shall meet the standards of the main switchboard.

High voltage convertors shall be treated like high voltage switchgear and control gear in accordance with IEC 62271-200 adapted to shipbuilding requirements. The enclosures shall be manufactured to withstand accidental arcs in accordance with Annex A of IEC 62271-200, or shall be located that personnel safety is ensured.

The power components for semiconductor convertors shall be easy replaceable.

10.3 Cooling of semiconductor convertors

If semiconductor convertors are fitted with forced-cooling, means for monitoring the cooling system shall be provided.

In case of a failure of the cooling system, measures shall be taken to prevent damage to the convertor. An alarm shall be given. The alarm signal can be generated by the flow of the coolant, or by the temperature of the semiconductors.

Single failures in convertor cooling systems shall not lead to the tripping of all convertors of the ship's propulsion.

10.4 Protection

The following protection of convertors shall be provided:

Operational overvoltages in a supply system to which convertors are connected shall be limited by suitable devices to prevent damage. Protective fuses for these devices shall be monitored.

A suitable control shall ensure that the permissible current of semiconductor elements cannot be exceeded during normal operation.

Semiconductors shall not be damaged by direct short circuit at the terminals. Protection by fuses is permitted. The convertor shall control the current in such a way that no components are damaged when the convertor is switched on to a blocked motor.

10.5 Test

Convertors shall be individually tested at the manufacturer's works. The scope of the tests, for example functional test, adjustments, limitations, failure handling, is stated in IEC 60146-2.

11 Harmonic filtering

Line filters can be used to ensure the required harmonic distortion in the mains at any step of propulsion.

Each individual filter circuit shall be protected against overcurrents and short-circuit currents. The fuses in filter circuits shall be monitored.

Using line filters, the filter layout shall be designed for any conceivable line configuration. In particular, self-resonance shall be excluded under any load condition and all generator combinations.

In the case of several parallel filter circuits, the current symmetry shall be monitored. An asymmetrical current distribution in the individual filter circuits and the failure of one filter shall be alarmed.

The additional heating caused by total harmonic distortion shall be taken into account during the temperature rise test.

12 Propulsion motors

12.1 General requirements

For motors, the requirements of the IEC 60034 series and IEC 60092-301 shall apply.

Motors shall have a protection degree of at least IP 23. Medium voltage motors shall have a protection degree of at least IP 44.

Stator windings of a.c. motors and interpole, mainpole and compensation windings of d.c. motors, all rated above 500 kVA, shall be provided with temperature sensors.

Motors operating with semiconductor convertors shall be designed for the expected harmonics of the system. A sufficient reserve shall be considered for the temperature rise, compared with sinusoidal load.

12.2 Bearing and lubrication

12.2.1 General

The requirements of generator bearing and lubrication apply, see 7.2, with the following additional requirements.

In case of bearings with forced lubrication, redundant pumps shall be provided.

12.3 Cooling of propulsion motors

The requirements of generator cooling apply, see 7.3, with the following additional requirements.

Sufficient cooling shall be ensured under all load and speed conditions.

Suitable temperature detectors shall trigger an alarm.

If the cooling of the propulsion motors fails, restricted service (manoeuvrability) shall be possible. Interventions by the operator, for example opening of emergency air flaps are permitted.

12.4 Protection

12.4.1 Overcurrent

Overcurrent protective devices in the main and excitation circuits shall be set sufficiently high so that there is no possibility of their operating due to the overcurrents caused by manoeuvring or normal operation in heavy seas or in floating broken ice.

The control system shall ensure that manoeuvring, normal operation in heavy seas or rough weather or operation in broken ice will not overload any part of the system.

Short-circuit and overcurrent protection may be provided by the convertor.

Annex A gives an alarm-matrix of the different motor designs such as permanent-excited motors, synchronous motors, asynchronous motors and DC motors.

12.4.2 Overspeed of propulsion motors

An independent overspeed protection device is required[1)].

Propulsion motors shall be capable of withstanding overspeed up to the limit reached in accordance with the characteristics of the overspeed protection device at its normal operational setting.

12.5 Test

Propulsion motors shall be individually tested at the manufacturer's works. The scope of the tests is stated in the IEC 60034 series.

The additional heating caused by total harmonic distortion shall be taken into account during the temperature rise test.

After the first temperature-rise test and after each repeated inspection, an insulation resistance measurement shall be carried out.

If the neutral point is not accessible, the stipulated phase-against-phase insulation test is not possible. The manufacturer shall offer an equivalent test.

12.6 Short-circuit withstand capability

Motors shall be capable of withstanding a sudden short circuit at their terminals under rated conditions without suffering damage.

Steady state short circuit current of permanent excited motors shall not cause thermal damages of the motor and the current carrying components (for example cables, feeders, slip rings).

12.7 Accessibility and facilities for repairs *in situ*

For purposes of inspection and repair, provision shall be made for access to the stator and rotor coils, and for the withdrawal and replacement of field coils.

Facilities shall be provided for supporting the shaft to permit inspection and withdrawal replacement of bearings.

Adequate access shall be provided to permit resurfacing of commutators and slip-rings, as well as the renewal and bedding of brushes, rotating rectifiers and protection equipment, if any.

Slip-couplings shall be designed to permit removal as a unit without axial displacement of the driving and driven shaft, and without removing the poles.

13 Special requirements for podded drives

13.1 General requirements

The manufacturer shall take into account that during operation, inaccessible spaces and special environmental conditions require sufficient measures, for example highly reliable materials and components, adequate amount of sensors, special mechanical precautions.

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1) International Maritime Organization, IMO, SOLAS Chapter II-1, Regulation 27, 1st paragraph.

The components, for example controls, sensors, slip rings, cable connections and auxiliary drives, shall withstand the strength of vibration, of at least 4 g from 3 Hz to 100 Hz.

13.2 Sensors

13.2.1 General requirements

The manufacturer shall prepare a list of all sensors with type, location of their installation, task and values (range, set points and action caused).

Important operational values for maintaining the drive and control ability in inaccessible areas shall be recorded, evaluated and shown redundantly.

The recorded results shall be checked for plausibility. Implausible input signals shall trigger an alarm. It shall be possible to differentiate extreme measure values from sensor faults.

Sensors which can only be changed during dry docking shall at least be constructed as double sensors.

13.2.2 Bearings

Oil filling levels shall be monitored. This also applies during operation. Oil leakage shall be alarmed. A control of the oil filling level shall be possible, independent from the alarm and monitoring system.

This applies to circulated lubrication systems as well. These systems shall additionally be equipped with flow monitoring.

Shaft bearings shall be monitored to observe changes during operation, for example by analysis of temperatures, vibrations and oil quality.

The temperature of the shaft bearings shall be monitored. The alarm shall be carried out in two steps (action 1: alarm, action 2: stop). The temperature indication for shaft bearings shall be provided independently from the alarm and monitoring system. Redundant sensors are required.

The measurement of the motor bearing temperature shall be carried out in accordance with subclause 8.9 of IEC 60034-1, Measurement of bearing temperature.

13.2.3 Bilges

The bilge level shall be monitored.

In addition to the conventional bilge sensors (high level, HL), independent sensors (high high level, HHL) shall be provided which stop the propulsion automatically and protect it from consequential damages. In the case where the connecting component between the pod housing and the hull is a separated room and not connected to the engine bilge, a level monitoring shall be provided there.

The shaft sealing system shall be monitored in a way that ingress of sea water is ascertained before consequential damages appear. An emergency sealing system shall be provided. The function of the activation system shall be controllable, for example with compressed air up to the last valve. In combination with the emergency sealing system there shall be a braking or blocking system which can fix the shaft under all weather and normal towing conditions. The activation of sealing and breaking system shall be indicated at each control station.

13.2.4 Fire alarm

An effective fire monitoring shall be provided.

13.2.5 Accessible areas

Sufficient illumination and temporary ventilation shall be provided for accessible areas where regular maintenance work needs to be carried out. Entries to these areas shall be locked in such a way that access is only possible, if the personnel cannot be endangered by the drives.

13.3 Protection of the propulsion motor

13.3.1 Protection against internal faults

Motors of more than 1 MW and all permanent excited motors shall be provided with protection against internal faults that also monitors the connections between the convertor and motor. In the case of a fault, the power supply to the defective equipment shall be interrupted within an appropriate period of time.

13.4 Air humidity

Humidity shall be monitored for motors with closed air systems.

13.5 Motor supply lines

Cables operated at high temperature limits shall be installed separate from other cables. If required, a protection against contact shall be provided.

Test reports of temperature rise tests of bus bars with increased current density or cables operated at high conductor temperature values shall be submitted to the nominated body, see 4.2.

During the temperature rise test on the sea trial, it shall be proven that the permitted maximum temperature values in the area of the terminals are not exceeded.

IP protection for all terminals, cable glands and busbar connections shall be at least IP 44.

These requirements are also valid for control cables.

13.6 Slip rings

It shall be taken into account that the mechanical and electrical characteristics of the slip rings can be degraded by contamination with oil, carbon dust and salt-mist air, or by oxidation.

A temperature-rise test of the slip ring shall be carried out as a type test.

The suitability of used materials at maximum permitted temperature values shall be proven. The permitted conductor temperature values of the connected cables shall not be exceeded. During the temperature rise test at the sea trial, it shall be proven that the permitted temperature limits are not exceeded.

In case of data transmission carried out via a bus system, two redundant transmission paths shall be provided. Failure of each single system shall be alarmed.

External or forced cooled slip rings shall be dimensioned sufficiently for restricted operation without the cooling system. The cooling system failure shall be alarmed.

13.7 Azimuth drive

13.7.1 General requirements

Azimuth drives shall meet the requirements of steering gear in accordance with IEC 60092-204. One failure principle shall be ensured for all electrical and hydraulic components. For these purposes, a failure mode effect analysis (FMEA) shall be provided and practically proven, as far as possible, by the nominated body, see 4.2. Safe operation of the ship shall be ensured independently of the angular position of the pod and ship's speed in the event of any failure. The position of the azimuth drive shall be mechanically indicated on site.

At least two independent azimuth drives shall be provided for each podded drive, whereby one drive shall be supplied from the emergency switchboard and the other from main switchboard.

Azimuth drives shall be protected against overcurrent (for example by convertor, if applicable) and short circuit. They shall be able to supply 160 % of the torque necessary for the rated speed of movement in accordance with the International Maritime Organization, IMO, SOLAS Ed. 2004, Chapter II-1/ Regulations 29 and 30 for 60 s. Azimuth systems with different design, for example hydraulic systems, shall also be able to fulfil these requirements.

13.7.2 Thrust azimuth angle

Generally, the thrust azimuth angle shall be limited to ±35° [2]. At low propulsion power rating, low ship speed or crash-stop manoeuvre these limits may be exceeded.

The thrust azimuth angle shall be limited related to the propulsion shaft power and/or selected operation mode so that the safety of the ship is not endangered. The propulsion power shall be limited related to the actual azimuth angle so that the safety of the ship is not endangered.

Reaching or exceeding the limitations shall be alarmed.

After triggering the limitation, it shall be possible to move the azimuth drive back to the allowed range without manual reset.

13.7.3 Control

The operation and indication equipment shall be arranged in a way that the moving direction or the propulsion direction of the ship is clearly discernible. It shall be clearly discernible for the operator whether the moving direction or the propulsion direction was chosen.

13.7.4 Local control station for azimuth drives

For local control for propulsion, see 14.5.2.2. The local control station for azimuth drives shall be equipped accordingly:

- ammeter for each supply side current of each load component;
- azimuth angle indicator for each podded drive;
- plant ready for operation for each drive;
- plant disturbed for each drive;
- power limited (from convertor);
- control from engine control room;
- control from the bridge and

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2) International Maritime Organization, IMO, SOLAS Edition 2004 Chapter II-1 Regulation 29 and 30.

- running indication for the associated propulsion drive.

The local control station can be activated locally and shall have the highest priority.

14 Control

Computer based systems shall be designed and tested in accordance with IEC 60092-504.

14.1 Power management system (PMS)

Additional to the requirements described in IEC 60092-504, the following requirements shall apply:

For power supply with generators operating in parallel, there shall be a device/computer program for automatic power management, which will ensure adequate power generation, even in transit/manoeuvre. Automatic load based disconnection of diesel generators in manoeuvre mode is forbidden.

In case of under-frequency of the supplying mains, overcurrent or overload and reverse power the propulsion power has to be limited.

If generators are running in parallel and one of them is tripping, the power supply system shall be provided with suitable means of load reductions to protect the remaining generators against unacceptable load steps. The same requirement applies to bus tie breakers.

Tripping of the bus tie breaker may not lead to any malfunction of the system. It is not necessary that the system remains in the automatic mode if the supply system is split.

Any loss of automatic function shall be alarmed.

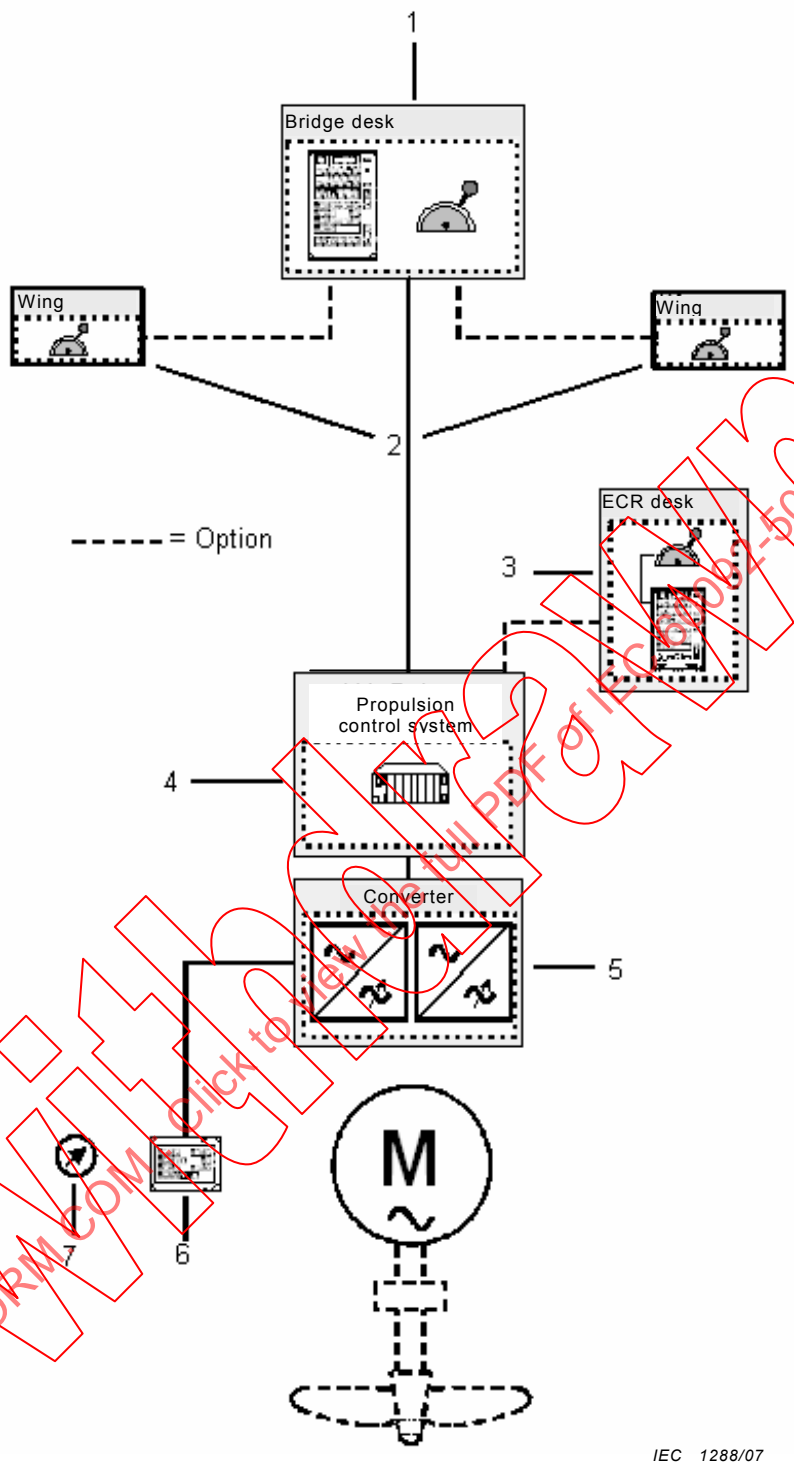
14.2 Typical control configuration

The control configuration shall comply with IEC 60092-504.

In Figure 2, the signal lines of an electric propulsion system are shown.

The minimal system configuration consists of one control stand, one central processing unit, two convertors, one motor (two winding systems), one local control panel (two independent reference inputs) and one telegraph receiver. Optionally, the wing control and the engine control room (ECR) control are described.

Control shall be possible if the control system failed, therefore the local control panel shall be directly connected to the convertors.



Key

1 Bridge desk
2 Wing
3 Engine control room (ECR) desk
4 Propulsion control system
5 Convertors
6 Local control panel
7 Telegraph receiver

Figure 2 – Typical control configuration

14.3 Location of manoeuvring controls

The main propulsion manoeuvring controls may be located at any convenient place.

Whenever control outside the engine room is applied, an arrangement shall be provided whereby the propulsion plant can also be controlled from the engine room or control room.

The local control station shall be located in the vicinity of the drives or convertors so that changes in the control of propulsion can be recognized.

Each control station shall have an emergency stop device which is independent of the drive's control and the active control place. The emergency stop device shall ensure the tripping of the feeder breaker for the propulsion convertor.

14.4 Main and local control station

Additional to the requirements of 9.5 of IEC 60092-504 (2001), the following requirements shall apply.

At least mutually independent main and local control stations shall be provided. In the case of breakdown, malfunctioning or loss of power supply of the propulsion control system, the control of the convertors shall remain possible at the local control panel, see Figure 2.

The bridge shall be fitted with a system which ensures that the steering, the monitoring and the control of the steering gear can be operated independently of the propulsion system. Communication to all local control stations in parallel shall be possible.

All alarms shall be acknowledgeable at the local control stations. Alarms which do not require any further intervention can be acknowledged at the main control station. Restart of the propulsion plant shall be possible from both control stations, depending on which one has been preselected. After a blackout, it shall be possible to restart the propulsion plant at the main control station.

14.5 Measuring-, indicating- and monitoring equipment

14.5.1 General requirements

Failures in measuring, monitoring and indicating equipment shall not cause a failure of the drives control, for example, failure of the actual value or of the reference value shall not cause an excessive increase of propeller speed and/or direction.

14.5.2 Measuring equipment and indicators

14.5.2.1 General

Main propulsion plants shall be provided with at least the following measuring equipment and indicators at control stations.

14.5.2.2 At local control station

At the local control station the measuring equipment and indicators shall include:

- ammeter for each supply side current of each load component;
- revolution indicator for each shaft;
- plant ready for operation;
- plant disturbed;
- power limited (from convertor);

- control from engine control room; and
- control from the bridge.

14.5.2.3 At (main) control station on the bridge

At the (main) control station on the bridge, the measuring equipment and indicators shall include:

- revolution indicator per shaft;
- shaft power meter;
- plant ready for switching on;
- plant ready for operation;
- plant disturbed;
- power limitation;
- request to reduce the power if not automatically controlled or equipped with override push button;
- control from engine control room;
- control from the local control station; and
- indication of the generators used for propulsion.

NOTE An indicator for remaining power is recommended.

When two or more control stations are provided for variable speed and pitch propellers, a propeller speed and pitch indicator shall be provided at each control station.

14.5.2.4 At (main) control station in the engine control room

At the (main) control station in the engine control room, the measuring equipment and indicators shall include:

- revolution indicator for each shaft;
- shaft power meter;
- plant ready for switching on;
- plant ready for operation;
- plant disturbed;
- power limitation;
- request to reduce the power if not automatically controlled or equipped with override push button;
- control from the local control station;
- control from the bridge; and
- indication of the generators used for propulsion.

For fault monitoring of the equipment, see Annex A.

14.6 Availability

In general, the loss of power of any other control and monitoring system or the malfunctioning of these systems shall not result in loss of propulsion, steering or azimuth drives.

Propulsion and azimuth drives and controls shall have self-acting routines to detect failure.

The most probable failures, for example loss of power, wire failure etc., shall result in the least critical of all possible new conditions (fail to safety).

15 Tests

15.1 General

In addition to the standard tests described in other parts of the IEC 60092 series, the following special tests shall be carried out.

All tests of components or subsystems or systems carried out during manufacturing, factory acceptance test and dock and sea trials shall be documented. The test results shall be documented in such a way that single components can be identified and traced.

The current, voltage and temperature capabilities of cables, bus-bar systems and slip-rings shall be verified by type-tests or routine tests.

15.2 In-process-tests

A plan shall be generated before production which indicates all tests carried out by the manufacturer and sub-suppliers.

15.3 Factory acceptance test

Before the factory acceptance test, the test procedure shall be documented.

As far as practicable, all normal acceptance tests of equipment shall be carried out at the manufacturer's works to show that they meet the requirements of this standard and the ordering specification.

In addition to the standard tests described in other clauses of the IEC 60092 series, all protective devices shall be tested to show that they are electrically and mechanically satisfactory.

15.4 Dock and sea trials

Before the dock and sea trials, the test procedure shall be documented.

Complete tests shall be carried out including heat run and manoeuvring tests which shall include a crash stop of the ship from full speed to zero speed.

All tests necessary to demonstrate that each item of the plant and the system as a whole is satisfactory for duty shall be performed.

The test program shall include tests of the propulsion plant in normal and abnormal conditions.

Start-up and stop sequences shall be tested, also as controlled by the power management system, when relevant.

Safety functions, alarms and indicators shall be tested. A physical check of all sensors shall be performed.

All control modes shall be tested from all control locations.

Immediately prior to and after trials, the insulation resistance of power circuits shall be measured and recorded.

As far as possible, the tests shall be executed during dock trials.

16 Documentation

The nominated body, see 4.2, shall be responsible for ensuring that complete documentation is available for all relevant components and systems.

Each manufacturer shall give documented evidence of conformity that his plant fulfils the requirements of this part of IEC 60092.

Annex A
(normative)

Alarm-matrix

This annex provides alarm-matrixes for different motor designs such as permanent-excited motors (Table A.1), synchronous motors (Table A.2), asynchronous motors (Table A.3) and DC motors (Table A.4).

Table A.1 – Alarm matrix for permanent excited motors

Monitored value	Limiting value	Display in ECR[a] (local) or MCR[b]	Local diagnostic tool[c]	Action alarm	Action reduce[d]	Action stop	Indication on main control station
Motor							
External lubrication	Failure	X	Inspection glass	X	If applicable	If applicable	C
Bearing temperature	Max	X	Thermometer	X	X	-	C
Stator winding temp	Max	X	-	X	X	-	C
External cooling, water and/or air	Failure	X		X			C
Cooling air temperature, engine inlet at closed loop cooling system	Max	X	Thermometer	X	-	-	C
Coolant	Leakage	X	-	X	-	-	C
Speed	Max	X		X		X	C
Earth fault monitoring at stator with transformer feeding	Min	X	-	X	-	-	C
Transformer/reactor							
Transformer, winding temperature	Max	X	-	X	X	-	C
Coolant	Leakage	X	-	X	-	-	C
External cooling	Failure	X	-	X	-	-	C
Convertor							
Mains	Failure	X	-	X	-	Restart possible from main control station	C
External cooling	Failure	X	-	X	X	-	C
Power section-temperature	Max	X	-	X	-	X	C
Coolant quality (only at direct cooling)	Min	X	-	X	-	-	C
Coolant	Leakage	X	-	X	-	-	C
Warning	-	-	-	-	-	-	C
Breakdown	-	X		X		X	C
Speed-/ rotor position sensor detection	Failure	X	-	X	-	-	C