TECHNICAL SPECIFICATION

No. I-ET-3010.00-5147-711-P4X-001

CLIENT:

AREA:

TITLE: MAIN GENERATOR FOR OFFSHORE UNITS

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DATE AUG/30/18
DESIGN ESUP
EXECUTION CAVALIERE
CHECK MARCELO BP
APPROVAL MATTOSO

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1. OBJECTIVE

This specification establishes the minimum conditions required for the design, manufacture, inspection, commissioning, testing and delivery of main synchronous generators, excitation equipment, grounding resistor, set of accessories, auxiliary equipment, protection and instruments assembled in generator frame intended to be part of Main Turbogenerator or Main Motogenerator PACKAGES for PETROBRAS UNITS.

This specification does not define requirements for Turbogenerator Control Panels (TGCP), Motogenerator Control Panels (MGCP), turbines, engines, couplers, speed reducers, machinery protection system or any other accessories or auxiliary equipment out of generator frame. For requirements about these equipment, see specific technical specifications.

2. GENERAL

2.1. DEFINITION OF TERMS

Within the contents of this Specification:

“UNIT” means the FPSO (Floating Production Storage and Offloading), FSO (Floating Storage and Offloading), SS (Semi-Submersible) or Fixed Offshore Unit.

“PACKAGE” means an assembly of equipment supplied interconnected and operating, requiring only the available utilities from the UNIT for the PACKAGE operation.

“MANUFACTURER” means the responsible by fabrication of equipment or components internal to the PACKAGE.

"CONTRACTOR" means the Supplier, Manufacturer or Vendor of the goods and/or services described in the Equipment/Material Specifications.

“CLASSIFICATION SOCIETY” means such authority or organisation appointed to ensure conformity with all requirements necessary to obtain certification or classification of the goods and/or services described herein.

“FIELD FORCING” means a feature of reinforcing the generator field applied before starting of a large motor to assist in reducing voltage drop.

2.2. ABBREVIATIONS

PMS Power Management System.
AVR Automatic Voltage Regulation.
TGCP Turbo Generator Control Panel.
CS Classification Society.
CT Current Transformer.
VT Voltage Transformer.
EPL Equipment protection level.
Level of protection provided by an "Ex" equipment, certificate for installation in classified areas, such as Ga, Gb, Gc, Da, Db or Dc, according to IEC 60079-0 and IEC 60079-14.

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<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tr>
<td>RT</td>
<td>Routine Test - Test carried out on all units supplied.</td>
</tr>
<tr>
<td>TT</td>
<td>Type Test - Test carried out on an equipment representing the other equipment, aiming to demonstrate that they meet the specified conditions not covered by routine tests.</td>
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NOTE: A generator is considered to be representative of the others, if it is completely identical in relation to rated values and construction. Type tests may be considered equally valid, if carried out in an equipment that presents some deviations of rated values or other characteristics. These deviations shall be subject to agreement between MANUFACTURER and PETROBRAS.

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<tr>
<th>Code</th>
<th>Description</th>
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<tr>
<td>ST</td>
<td>Special Test – Tests other than type or routine tests, performed by agreement between MANUFACTURER and PETROBRAS.</td>
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<tr>
<td>TDPF</td>
<td>Tests During Manufacturing Process - Are the tests carried out during the manufacturing process of the equipment. (Teste Durante o Processo de Fabricação)</td>
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<tr>
<td>TCAG</td>
<td>Tests of complete driver-generator set, carried out at location defined by PACKAGER, or String Tests. (Teste do Conjunto Acionador e Gerador)</td>
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<tr>
<td>TAF</td>
<td>Factory Acceptance Tests - Tests are carried out at the equipment manufacturing site. (Teste de Aceitação de Fábrica)</td>
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<tr>
<td>TAC</td>
<td>Field Acceptance tests - Tests are carried out at the final place of operation of the equipment. (Teste de Aceitação de Campo)</td>
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<tr>
<td>THD</td>
<td>Total Harmonic Distortion.</td>
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<tr>
<td>PIT</td>
<td>Inspection and testing plan.</td>
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<tr>
<td>PMG</td>
<td>Permanent Magnet Generator.</td>
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3. **CODES, STANDARDS & REFERENCE DOCUMENTS**

The equipment shall comply with all rules and regulations stated by Brazilian Authorities, Classification Society and International Standards. Following these mandatory requirements, the equipment shall comply with requirements of this technical specification and the documents listed in 3.2 (second priority in case of conflict).

The set shall be submitted to CS approval, according to project documentation.

Any deviation from this specification or the standards and reference documents shall be clearly identified by the CONTRACTOR and agreed by the PETROBRAS.

3.1. **CODES, STANDARDS AND RECOMMENDED PRACTICES**

3.1.1 **IEC – INTERNATIONAL ELECTROTECHNICAL COMMISSION**

IEC 60034-1 Rotating Electrical Machine - Ratings and Performance;
TECHNICAL SPECIFICATION

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ESUP

IEC 60034-2-1 Rotating Electrical Machines - Part 2-1: Standard Methods for Determining Losses and Efficiency from Tests (Excluding Machines for Traction Vehicles);

IEC 60034-3 Rotating Electrical Machines - Part 3: Specific Requirements for Synchronous Generators Driven by Steam Turbines or Combustion Gas Turbines;

IEC 60034-4-1 Rotating Electrical Machines - Part 4-1: Methods for Determining Electrically Excited Synchronous Machine Quantities from Tests;

IEC 60034-5 Rotating Electrical Machines - Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code);

IEC 60034-6 Rotating Electrical Machines - Part 6: Methods of Cooling (IC Code);

IEC 60034-7 Rotating Electrical Machines - Part 7: Classification of Types of Construction, Mounting Arrangements and Terminal Box Position (IM Code);

IEC 60034-8 Rotating Electrical Machines - Part 8: Terminal Markings and Direction of Rotation;

IEC 60034-9 Rotating Electrical Machines - Part 9: Noise Limits;

IEC 60034-15 Rotating Electrical Machines - Part 15: Impulse Voltage Withstand Levels of Form-Wound Stator Coils for Rotating a.c. Machines;

IEC 60034-16-1 Rotating Electrical Machines – Part 16-1: Excitation Systems for Synchronous Machines – Definitions;

IEC 60034-18-1 Rotating Electrical Machines - Part 18-1: Functional Evaluation of Insulation Systems - General Guidelines;

IEC 60034-22 Rotating Electrical Machines - Part 22: AC generators for reciprocating internal combustion (RIC) engine driven generating sets;

IEC TS 60034-27-2 Rotating Electrical Machines – Part 27-2: On-line partial discharge measurements on the stator winding insulation of rotating electrical machines;

IEC 60034-27-3 Rotating electrical machines - Part 27-3: Dielectric dissipation factor measurement on stator winding insulation of rotating electrical machines;

IEC 60034-29 Rotating Electrical Machines - Part 29: Equivalent Loading and Superposition Techniques - Indirect Testing to Determine Temperature Rise;

IEC 60050-411 International Electrotechnical Vocabulary - Chapter 411: Rotating Machinery;

IEC 60079 Explosive atmospheres – All Parts;

IEC 60085 Electrical insulation – Thermal evaluation and designation;

IEC 60092 Electrical Installations in Ships - All Parts;

IEC 60255-149 Measuring relays and protection equipment – Part 149: Functional requirements for thermal electrical relays;

IEC 60270 High-Voltage Test Techniques - Partial Discharge Measurements;

IEC 60364-4-41 Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock;
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IEC 60533 Electrical and Electronic Installations in Ships - Electromagnetic Compatibility (EMC) – Ships with a Metallic Hull;
IEC 60751 Industrial Platinum Resistance Thermometers and Platinum Temperature Sensors;
IEC 61000-4-7 Electromagnetic Compatibility (EMC) – Part 4-7: Testing and Measurement Techniques – General Guide on Harmonics and Interharmonics Measurements and Instrumentation, for Power Supply Systems and Equipment Connected Thereunto;
IEC 61869 Instrument transformers – All Parts;
IEC 61892 Mobile and Fixed Offshore Units - Electrical Installations - All parts.

3.1.2 API – AMERICAN PETROLEUM INSTITUTE
API STD. 546 Brushless Synchronous Machines - 500 kVA and Larger;
API STD. 670 Machinery Protection Systems.

3.1.3 IEEE – INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERING
IEEE C57.32 Requirements, Terminology, and Test Procedure for Neutral Grounding Devices;
IEEE 43 Recommended Practice for Testing Insulation Resistance of Rotating Machinery;
IEEE 115 Guide for Test Procedures for Synchronous Machines - Part I / Part II;
IEEE 286 Recommended Practice for Measurement of Power Factor Tip-Up of Electric Machinery Stator Coil Insulation;

3.1.4 IMO - INTERNATIONAL MARITIME ORGANIZATION
IMO I810E Code for the Construction and Equipment of Mobile Offshore Drilling Units (MODU CODE).

3.1.5 ISO - INTERNATIONAL ORGANIZATION FOR STANDARDIZATION
ISO 281 Rolling Bearings – Dynamic Load Ratings and Rating Life;
ISO 7919-3 Mechanical vibration – Evaluation of machine vibration by measurements on rotating shafts - Part 3: Coupled industrial machines;
ISO 10816-3 Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts – Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15000 r/min when measured in situ;
ISO 12944-2 Paints and varnishes – Corrosion protection of steel structures by protective paint systems - Part 2: Classification of environments.

3.1.6 BRAZILIAN LABOUR AND EMPLOYMENT MINISTRY
NR-10 Segurança em Instalações e Serviços em Eletricidade;
NR-12 Segurança no Trabalho em Máquinas e Equipamentos;
NR-17 Ergonomia;
NR-26  Sinalização de Segurança;
NR-30  Segurança e Saúde no Trabalho Aquaviário - ANEXO II – Plataformas e Instalações de Apoio.

3.1.7  **ASME**

ASME B1.20.1  Pipe Threads, General Purpose (Inch);
ASME B16.5  Pipe Flanges and Flanged Fittings NPS 1/2 through NPS 24 Metric/Inch Standard;
ASME BPVC VIII-1 Rules for Construction of Pressure Vessels.

3.1.8  **NEMA - NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION**

NEMA MG 1  Motors and Generators;

### 3.2. REFERENCE DOCUMENTS

[1] PACKAGE TECHNICAL SPECIFICATION
[2] NOISE CONTROL REQUIREMENTS SPECIFICATION
[3] I-ET-3010.00-5140-700-P4X-001 – SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS
[4] I-ET-3010.00-5140-700-P4X-002 – SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS
[5] I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS
[6] I-ET-3010.00-5140-700-P4X-005 – REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS
[7] I-ET-3010.00-1200-956-P4X-001 – QUALIFICATION TESTS FOR PAINT SYSTEMS
[8] I-LI-3010.00-5140-700-P4X-001 – ELECTRICAL EQUIPMENT DATA-SHEET MODELS
[9] SPECIFICATION OF AVAILABLE UTILITIES
[10] I-ET-3010.00-5400-947-P4X-002 – SAFETY SIGNALLING

**Note:** Documents without code in the list are documents with variations according to project characteristics. Verify in project documentation list the reference for codes of these documents.
4. GENERAL REQUIREMENTS

4.1. GENERAL

4.1.1 Unless otherwise specified in the project documentation, the generator and its auxiliary systems shall be designed and manufactured taking into account a minimum life period of 25 years.

4.1.2 The sizing of equipment shall consider periods of continuous operation in rated conditions with minimum duration of 10,000 hours without interventions for preventive or corrective maintenance requiring the equipment to stop.

4.1.3 Requirements for shaft coupling, base skid and safety grounding connections will be defined in PACKAGE TECHNICAL SPECIFICATION.

4.1.4 The equipment and installation shall comply with requirements of I-ET-3010.00-5140-700-P4X-005 – REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS.

4.2. HAZARDOUS AREAS

4.2.1 Generators for installation in classified areas of flammable gases shall have an "Ex" protection type certification in accordance with applicable legislation in force in Brazil and IEC 60079 and IEC 61892-7.

4.2.2 Electrical equipment installed in external safe areas, that shall be kept operating during emergency shutdown ESD-3P or ESD-3T shall be certified with the type of protection and EPL suitable for installation in hazardous areas Zone 1 Group IIA temperature T3, according to IEC 61892-7.

4.2.3 Certificates shall comply with requirements of I-ET-3010.00-5140-700-P4X-002 – SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

4.3. ENVIRONMENTAL CONDITIONS

4.3.1 Generators and all accessories and auxiliary equipment shall operate properly at the following temperatures and conditions:

a) Annual average temperature: 45°C;

b) Monthly average temperature of the hottest month: 45°C;

c) Maximum temperature: 45°C;

d) Minimum temperature: 10°C;

e) Relative humidity of the air: 15% to 95%;

f) Maximum altitude: 1000m.

4.3.2 The generators and all accessories and auxiliary equipment shall comply with environmental requirements of I-ET-3010.00-5140-700-P4X-002 – SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.
4.4. INCLINATION REQUIREMENTS

4.4.1 The generator employed in a floating maritime UNIT shall be able to operate under slope variations (static and dynamic) and acceleration conditions specified by the IMO MODU CODE, IEC 61892-5 and Classification Society.

5. MECHANICAL REQUIREMENTS

5.1. LIFTING CHARACTERISTICS

5.1.1 The housing of the generator shall have devices which allow the hoisting of the equipment assembled with all its integral parts.

Note: Parts with mass of more than 25 kg, shall have its own hoist devices (e.g.: detachable exciter, heat exchanger, terminal box caps, panels, etc.).

5.1.2 The generator shall be designed and manufactured in such a way as to allow the rotor to be extracted horizontally, at operational site, without need of removal of the stator.

Note: The tools necessary for the rotor extraction at the operating site shall be provided.

5.2. SPEED LIMITS

5.2.1 The generator shall be supplied with devices to prevent the transmission of dynamic mechanical stresses to the set’s base up to 120 % of rated speed.

5.2.2 The generator and its exciter shall support an overspeed of 20 % above the rated value for 2 minutes.

5.3. CORROSION PROTECTION AND PAINTING SYSTEM

5.3.1 The generator and its control and protection panels shall be corrosion-resistant due to environmental characteristics and/or service conditions as indicated in the data-sheet.

5.3.2 Unless otherwise specified in the data-sheet, the anticorrosive treatment shall conform to the requirements of the specification I-ET-3010.00-1200-956-P4X-001 – QUALIFICATION TESTS FOR PAINT SYSTEMS and the last coat colour for the equipment shall be Light Green Munsell 5G8/4.

5.3.3 Inner components mounting plate, internal doors faces shall be Safety Orange Munsell 2.5YR6/14.

Note: Colours shall comply with NR-30 Annex II.

5.3.4 The mounting and fastening elements shall be manufactured in AISI 316L stainless steel.

5.4. DEGREE OF PROTECTION (IP CODES)

5.4.1 Unless otherwise specified in the data-sheet, the generator shall have minimum IP56 protection degree in the housing, exciter, power, auxiliary terminal boxes and accessories, when installed in an external environment of floating UNITS, according to IEC 60034-5. When installed in fixed UNITS the minimum protection degree shall be IP55. When installed in utilities rooms or machinery rooms the minimum protection degree shall be IP-54.
5.4.2 For accessories and auxiliary electrical equipment see requirements in I-ET-3010.00-5140-700-P4X-002 – SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

5.5. NOISE

5.5.1 Generators shall comply with requirements of IEC 60034-9, PACKAGE TECHNICAL SPECIFICATION and NOISE CONTROL REQUIREMENTS SPECIFICATION. The strictest requirement shall prevail.

Note: For generators installed inside "hood", the acceptance criterion refers to the level of audible noise measured externally to the "hood".

5.6. VIBRATION AND BALANCE

5.6.1 The generator shall be designed, manufactured and tested in factory to be approved in the assembly tests (when required) and field for vibration levels established by IEC 61892, CS and PACKAGE TECHNICAL SPECIFICATION.

5.6.2 If the PACKAGE TECHNICAL SPECIFICATION does not define limits, the limits of Zone A/B of ISO 7919-3 or ISO 10816-3 shall be considered.

5.7. BEARINGS

5.7.1 Bearing shall be calculated for a minimum uninterrupted operation L10 (ISO 281) of 50000 h.

5.7.2 Generator shall be supplied with magnetic centre location indicator and acceptable axial displacement limit.

5.7.3 For grease lubricated bearings, they shall be provided with nipples-pin re-lubrication system, with fitting antechamber or natural drainage device for excess grease output.

5.7.4 Oil lubricated bearings shall be provided with level viewfinders for ring, speckle or similar ring lubrication cases, and flow display for each bearing in the case of forced lubrication.

5.7.5 Sleeve bearings shall be provided with sealing devices in order to avoid contamination of the internal components of the generator and to ensure the required protection degree.

5.7.6 Means shall be provided to avoid the circulation of currents between the shaft and the bearings (see IEC 60034-25 as reference).

5.8. COOLING METHODS (IC CODES) AND VENTILATION

5.8.1 The generator shall have cooling method (IC code) according to the data-sheet indicated and in accordance with the requirements of IEC 60034-6.

5.8.2 Unless otherwise indicated in data-sheet, cooling method shall be IC8A1W, using fresh water according to definitions of SPECIFICATION OF AVAILABLE UTILITIES of the project.

5.8.3 Unless otherwise specified in data-sheet, the specific cooling water flow shall not exceed 2 m³/h/MVA.
5.9. TUBULAR AIR/WATER HEAT EXCHANGER

5.9.1 Unless otherwise specified in the data-sheet, the heat exchanger shall be manufactured and tested according to ASME BPVC VIII-1 and CS.

5.9.2 Unless otherwise specified in the data-sheet, the generator shall contain two heat exchangers with individual capacity of at least 80% of the rated power of the generator.

5.9.3 Unless otherwise stated in data-sheet, air-water heat exchangers shall comply with the following requirements:

a) Heat exchanger material of all parts in contact with cooling water (pipes, flanges, header, etc.) shall be in corrosion resistant alloy, for example, 9010 copper-nickel alloy. The fins shall be of copper. It shall not be permitted use of carbon steel, even with internal organic coating;

b) Galvanic corrosion between dissimilar metals shall be avoided;

c) Load losses shall not exceed 0.7kgf/cm²;

d) Heat exchanger shall be built into or mounted on the machine casing, always on a position to allow easy access for maintenance;

e) The tubing shall be double tube type so that any leakage from the internal tube will be collected by the external one. The internal tube shall be according to item a). The external tube shall be of copper, with fins of the same material. It shall be avoided galvanic corrosion between dissimilar metals.

f) It shall be provided protection to avoid the water to be in contact with the windings, in case of leakage, crack in pipes or condensation in exchanger;

g) The length of the tube beam of the heat exchanger shall be greater than the width of the generator housing, so that the heads, mirrors and joints are located externally to the housing and that if leakage occurs in those items, there is no water intake for the Interior of the housing

h) It shall be provided means for draining off the water in case of leakage;

i) An alarm system shall be provided for signalling of leakage of water between the internal and the external tube;

j) Installation of auxiliary fans shall be not be acceptable;

k) Thermometers shall be installed at the exchanger water inlet and outlet;

l) Manometers shall be installed at the exchanger water inlet and outlet;

m) Differential pressure detectors shall be installed at exchanger water inlet and outlet;

n) It shall be provided two inspection windows at opposite sides each other;

o) It shall be provided facilities to perform hydrostatic test for heat exchangers and blocking valves on site, as well as for testing the water leakage alarm unit.

5.9.4 The water speed limit of 2.5 m/s shall not be exceeded to avoid erosion.

5.9.5 The external leak collector shall be equipped with two level sensors (redundancy), for indication of leakage in the generator. There shall be a drain (above the level sensor adjustment point) to be kept open, to prevent unsigned or high-flow leaks from causing system filling and overflowing into the generator housing.
5.9.6 There shall be a drain to be kept closed, for exhaustion of the collector.

5.9.7 A warning plate shall be installed on the collector, in AISI 316L stainless steel, with a yellow background and black letters, informing which drain shall be kept open and which drain shall be kept closed. Entries shall start with the word 'attention' and shall use letters with a minimum of 15 mm in height.

5.9.8 The heat exchanger shall be built with features and position that facilitate access and maintenance. The heads (caps) and beam shall be removable. All tubes shall be accessible for cleaning and pipes presenting leaks shall allow plugs or seal stoppers to be blocked.

5.9.9 There shall have connections to vent and drain.

5.9.10 All threaded connections shall be supplied with metallic plugs suitable for temperature and operating pressure.

5.9.11 The screws subjected to pressure shall conform to the applicable pressure and specified operating temperature standards. Unless otherwise specified in the data-sheet the screws shall be manufactured in stainless steel type A193-B8M (AISI 316).

5.9.12 The connecting flanges of the external water inlet and outlet tubes shall meet the technical, dimensional, pressure class and flange requirements according to ASME B16.5.

5.10. NAMEPLATE BOARDS, IDENTIFICATION AND SAFETY WARNINGS

5.10.1 The nameplate shall be stainless steel AISI 316 containing, in addition to the information indicated by IEC 60034-1, the following data:

a) total mass;

b) mass of the rotor;

c) Mass of the heat exchanger;

d) Date of manufacture;

e) Petróleo Brasileiro S.A.- PETROBRAS;

f) Name of the PETROBRAS Operations Unit (UO);

g) "TAG" of the generator;

h) Material Requisition number (RM);

i) Purchase order number (PC) or purchase order of goods and Services (PCS) in cases of purchase processes directly carried out by PETROBRAS.

5.10.2 The data, identification and warning plates of the generator, both major and additional, as well as its fastening screws, shall be manufactured from AISI 316 stainless steel.

5.10.3 The data plates, identification and warning of the generator shall be fixed in non-detachable locations of the frame so that, no changes can occur during maintenance work.

5.10.4 The generator shall have a specific plate, containing an arrow indicating the direction of rotation, installed on the side attached to the drive. The requirements of this plate shall meet the requirements indicated in this standard on data boards, identification and warning. They shall be accessible for reading.
5.10.5 The data boards, identification and warning of the generator shall have their data embossed in bas-relief. These plates and the system of recording or marking of the data or figures used shall withstand chemical attacks, the specified environmental characteristics and shall remain legible for the entire predicted time of life of the generator.

5.10.6 Generators terminals and neutral boxes shall have a warning plate according to the following: "PERIGO: ALTA TENSÃO. NÃO ABRA QUANDO ENERGIZADO".

5.10.7 Complementary warnings, as required by NR-10 and NR-12, shall be verified in I-ET-3010.00-5400-947-P4X-002 – SAFETY SIGNALLING and I-ET-3010.00-5140-700-P4X-002 – SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

5.11. POWER, NEUTRAL AND AUXILIARY TERMINAL BOXES

5.11.1 The generator shall be provided with independent boxes for line terminals, neutral terminals, exciter and auxiliary closures, sized for wrapping the terminations of the power cords and the control cables and signals.

5.11.2 The power terminal box shall be able to withstand the overpressure resulting from a three-phase short circuit within it, according to the value reported on the data-sheet, with duration of 0.1s. If a rupture device is used for the relief of the pressure, it shall not compromise the degree of protection (IP) of the housing and the discharge of the resulting gases shall not be directed to places where the staff is normally present.

5.11.3 Power terminal box shall have insulating barriers between phases.

5.11.4 The terminal boxes shall have sufficient space to accommodate the cable terminations, cable curves, surge capacitors, lightning arrestors, protection and measurement and transformers, heating resistors and grounding equipment.

5.11.5 Terminal boxes shall be scaled so that the internal temperature is adequate to the operational limits of these components without compromising their useful life.

5.11.6 Terminal boxes shall have cable inputs by means of cable glands, in quantities and dimensions according to the data-sheet. In cases of conical threaded inputs of the NPT type, these shall conform to the ANSI/ASME B1.20.1 requirements. For power terminals, cable input holes shall be on a removable non-magnetic plate so as to allow cable disconnection without damaging the terminations.

5.11.7 Unless otherwise indicated in data-sheet, the power terminal box shall be attached to the casing on the left hand side, when facing the generator at the coupling end. The constructive, assembly and position form of the terminal boxes shall be according to IEC 60034-7 (IM code).

Note: For non-sheltered installations, exits from the boxes by the top are not accepted.

5.11.8 Power terminal boxes shall be supplied with insulators made of non-hygroscopic materials.

5.11.9 Unless otherwise defined in data-sheet, terminal boxes spacing and design, shall consider the following equipment:

a) Three surge capacitors (line side);

b) Three lightning arrestors (line side);
c) Three-phases VTs with respective fuses for AVR (line side);
d) Three-phases double secondary VTs with respective fuses for protection and measurement (line side);
e) Two-phases CTs for AVR (line side);
f) Three bus-type CTs for measurement (line side) (line side);
g) Three partial discharge couplers (line side).
h) Three bus-type CTs for differential protection 87. CT's for differential (neutral side);
i) Three bus-type CT's with two secondary windings (one suitable for measurement and one for protection) (neutral side);
j) Grounding transformer and grounding resistor (neutral side);

Note 1: 1) Three identical CTs for differential protection 87 shall be supplied loose, to be installed in main switchgear.

2) CTs and VTs burdens shall have extra capacity of 50VA to external (PMS) connection.

5.11.10 Undrilled extended tinned copper bars, with support, shall be provided on lower portion of terminal box, with a minimum vertical distance of 700 mm between bus bars and cable entry plate.

5.12. INSPECTION WINDOWS
5.12.1 Generator shall have openings with removable caps (coupled and uncoupled sides) and suitable pathways to allow inspection by borescope.

5.12.2 These openings shall give access to rotor core ends, coil heads and groove conductor outputs.

5.12.3 Inspection access shall be provided, allowing a visual inspection of the bearings, exciter and replacement of the rotating diodes.

5.12.4 Machine design shall allow inspection of the air gap between stator and rotor. Inspection shall be possible at both ends.

6. ELECTRICAL REQUIREMENTS
6.1. ELECTRICAL CHARACTERISTICS
6.1.1 The generator shall be synchronous.

6.1.2 The generator and the excitation system shall comply with requirements of voltage regulation defined by IEC 61892-1.

6.1.3 The generator shall operate in such a way as to meet its primary function, under rated load operating condition, without reducing the life of the electrical insulation system, continuously within the voltage and frequency variation ranges for the Zone (A) indicated in IEC 60034-1. The generator shall also be able to operate satisfactorily within the limits of Zone B according to IEC 60034-1.
6.1.4 The generator shall be able to operate continuously under unbalanced system conditions, provided that:
   a) The current in none of the phases exceeds the rated value;
   b) The relationship between the negative sequence component and the rated current does not exceed the values determined in IEC 60034-1.

6.1.5 The generator shall be able to operate continuously in the grounding conditions of the electrical system in which it shall be installed, with the maximum zero-sequence harmonic currents.

Note: The maximum zero-sequence harmonic currents shall take into account the zero sequence voltage generated by the generator/system and the grounding resistor capacity.

6.1.6 The generator shall be provided with damper windings to allow parallel operation.

6.1.7 Unless otherwise specified in the data-sheet, the generator shall be designed considering the rated power factor equal to 0.8 inductive.

6.1.8 The minimum rated efficiency to be serviced for rated operating conditions (apparent power, power factor, voltage and frequency) shall be 98% at 100% load.

Note: The efficiency values are subject to the tolerances indicated in IEC 60034-1.

6.1.9 The generators shall meet the THD and individual harmonic limits, according to IEC 61892-3.

6.1.10 The minimum acceptable efficiency at full load, with rated voltage and power factor is 97.5%.

6.1.11 Synchronization criteria will be defined in PACKAGE TECHNICAL SPECIFICATION.

6.2. THERMAL CHARACTERISTICS

6.2.1 The stator, rotor and complete excitation system of the generators shall withstand the following conditions of overcurrent:
   - 300% of stator rated current, with zero power factor, during 2 s;
   - 150% of stator rated current, with rated power factor, for 30 s.

6.2.2 The generator shall comply with negative sequence currents and harmonic currents requirements of IEC 60034-1.

6.2.3 The values of the heating and cooling thermal time constants (τ in minutes) shall be informed by the MANUFACTURER in the respective fields of the data-sheet, in order to allow the proper parameterization of the thermal protection (function 49), according to The requirements indicated in IEC 60255-149.

6.3. WINDINGS INSULATION SYSTEMS

6.3.1 The insulation of the stator, exciter and rotor windings shall be of class F or higher, according to the requirements of IEC 60085 and IEC 60034-18-1. However, the temperature of the hottest point of each of the generator windings shall not exceed the temperature limit of class B insulation (IEC 60034-1), considering the operation of the generator at rated voltage, current, frequency, power factor and ambient temperature conditions.
6.3.2 Alternatively, for the rotor, it is acceptable the insulation temperature class H and the temperature of the hottest point of the rotor winding shall not exceed the temperature limit of class F insulation (IEC 60034-1).

6.3.3 The temperature rise shall be considered related to the inlet water temperature and the rules of IEC 60034-1 are applicable.

6.3.4 The vacuum impregnation method shall be used for winding insulation construction.

6.3.5 All coils shall have anti-corona protection, achieved using a semi-conduction tape, in the slot part of the coil. For generators with rated voltage equal to, or higher than 6kV in addition to anti-corona protection, windings shall have stress grading.

6.3.6 Generators with rated voltage equal to, or higher than 6kV shall be designed and manufactured in such a way as to be approved in sealed winding spray-test, in accordance with the procedures indicated on NEMA MG 1.

6.4. EXCITATION SYSTEMS

6.4.1 The excitation system shall comply with necessities of electrical system, considering among others: operation in parallel, isolated operation, starting of large motors, field forcing application, disturbances of the electrical system, etc.

6.4.2 Unless otherwise specified in the data-sheet, the exciter of the generator shall be "brushless" type (rotating, brushless) with PMG ("Permanent Magnet Generator").

6.4.3 The excitation system shall be "self excitation" type and shall be equipped with a pre-excitation circuit (priming).

6.4.4 The complete excitation system shall be sized to provide a positive ceiling voltage of exciter equal to or greater than 200% of the rated field voltage with the generator at full load for at least 2 seconds.

6.4.5 The excitation system shall have a speed response ("Excitation system nominal response", according to IEEE 421-1) equal to or greater than 0.5 pu per second.

6.4.6 The complete excitation system shall be sized so that the voltage at the generator terminals is equal to or greater than 85% of the rated voltage during the start of the largest motor, taking into account the initial load, starting time and the number of generators in operation, as defined in the data-sheet. For this transient, the recovered voltage ("recovery voltage") shall reach and maintain the rated voltage, with a deviation of ± 3%, in less than 1.5 seconds.

6.4.7 The excitation system shall be sized to provide a continuous current value not less than 110% of the excitation current required by the generator, when operating the maximum load, with 105% of the voltage and with a rated power factor.

6.4.8 The precision of the voltage regulator (as defined by IEEE 421-1) shall be indicated by the MANUFACTURER on the data-sheet.

6.4.9 The excitation system control panel shall comply with requirements of I-ET-3010.00-5140-700-P4X-002 – SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS and I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS.

6.4.10 The excitation system control shall contain at least the following features:
a) Dual redundant microprocessed controllers, both with capacity to be master controller;
b) Automatic control of generator voltage;
c) Manual control of generator voltage;
d) Smooth transition from automatic control to manual control and vice-versa;
e) Smooth transition between controllers;
f) Automatic ratio Volt/Hertz limitation;
g) Automatic excitation limitation at maximum and minimum values ($E_{fd_{max}}$ and $E_{fd_{min}}$);
h) Reactive load sharing control;
i) Field forcing control;
j) Remote control (control of mode Automatic/Manual, operation mode Local/Remote, set point Increase/Decrease, reactive load sharing and field forcing start/stop) from external equipment.

6.4.11 It shall be possible to select the master controller. In case of failure of master controller, the redundant controller shall take the control without voltage variation.

6.4.12 Switching between control modes (Automatic/Manual), between operation modes (Local/Remote) and between controllers shall be possible under any operating condition, without voltage variation.

6.4.13 Power supply for redundant equipment shall be independent, in order to avoid common mode failures.

6.4.14 Field forcing, shall be adjustable allowing the setup of voltage rise values, time for step up and step down ramps or steps, and field forcing maximum time.

6.4.15 The exciter identification plate shall be stainless steel AISI 316 containing at least the following data:
   a) Name of the MANUFACTURER;
   b) Serial number and type;
   c) Type of excitation;
   d) Rated exciter power;
   e) Rated excitation voltage;
   f) Rated excitation current;
   g) Isolation class;
   h) Year of manufacture;
   i) Mass.

6.4.16 The excitation system control shall have port and communication protocol according to the required in PACKAGE TECHNICAL SPECIFICATION and in the data-sheet, for remote control and monitoring of internal variables.

6.4.17 It shall be possible to remotely monitor at least:
   a) Exciter and field winding insulation resistance.
   b) Rotating rectifier diodes (alarms for open and short-circuited diodes).
6.4.18 The excitation system control shall have additional port dedicated to local configuration using portable computer connection.

6.4.19 The "Automatic/Manual", "Local/remote" selection commands shall be available for remote control through wiring.

6.4.20 All operation functions of the excitation system control shall be carried with the doors of the panel closed.

6.4.21 The excitation system control shall store the set-point data, configuration parameters, readings, and measurements in non-volatile memory.

6.4.22 All system adjustments shall be accessible to the user. In the event of the adjustments being made through proprietary software, there shall be no blockage requiring PETROBRAS to pay the transfer of the license for the use of the software. Configuration software shall be part of the scope of supply, be active in the delivery process, and have valid licenses for an indefinite period.

6.4.23 The control system shall allow continuous operation, with no dead zone, compensated and stabilized, with sufficient gain to maintain the terminal voltage of the generator within the range of 0.5% of the reference voltage on a permanent basis. Continuous cyclical variation of the rated voltage is permitted, within limits of IEC 61892-1.

6.4.24 The excitation system control shall include at least the following functions of monitoring, alarm, control and protection:
   a) Overheating or overcurrent field limiter;
   b) Sub-excitation limiting;
   c) Volt/Hertz Limiter;
   d) AVR failure or fault;
   e) Ground fault at "brushless" system.

6.4.25 Unless otherwise specified in the data-sheet, the circuits and components of protection, control and automation of the excitation system shall be fed at 220 Vdc isolated (IT system), from external continuous current power supply system, as defined in I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS.

6.4.26 In case of static excitation systems, the pre-excitation and de-excitation shall comply with:
   a) De-excitation system shall ensure the discharge of the whole stored energy when the field circuit-breaker or contactor opens is in the most critical condition. Over voltages occurring shall not cause damage to any part of the equipment;
   b) The field circuit-breaker or contactor shall be able to interrupt the field current during transient abnormalities, supporting the maximum voltage and energy values arising from the resulting arc;
   c) The field circuit-breaker or contactor shall have auxiliary contacts available for interlocking with the protection and control system.

6.5. PROTECTION

6.5.1 For protection and control panel and for driver protection requirements, see PACKAGE TECHNICAL SPECIFICATION.
6.5.2 Unless otherwise specified in the data-sheet, the generator and auxiliary components shall be supplied with necessary sensors and devices to comply with at least the protective functions shown in Table 1:

Table 1 — Synchronous Generator Protection Functions.

<table>
<thead>
<tr>
<th>PROTECTION FUNCTION</th>
<th>ALARM</th>
<th>MAIN CIRCUIT-BREAKER</th>
<th>TRIP</th>
<th>DISABLE</th>
<th>CLOSE</th>
<th>TRIP FIELD</th>
<th>TRIP PRIME MOVER</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 – Over-excitation V/Hz</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 – Synchronism Check</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27 – Undervoltage</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32 – Reverse Power</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38 – High Temperature – bearings (1)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39 – High Vibration</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40 – Field Loss</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>46 – Current Unbalance</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>49T – Stator – High Temperature (RTD) (1)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51V – Overcurrent With Voltage Restraint</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>58 – Rotating Diode Bridge Failure</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>59 – Overvoltage</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>59G – Ground Fault (Neutral overvoltage)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 – Voltage Unbalance – VT fuse supervision (2)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63Q – Lube Oil Underpressure, or Lube Oil System Failure</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>64F – Field Ground Fault (1)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>64G – Stator Winding Ground Fault</td>
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<td></td>
</tr>
<tr>
<td>67G – Directional ground fault overcurrent</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>81 – Underfrequency (3)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>81 – Overfrequency</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>87 – Differential current</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>AVR failure (4)</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Water Leakage</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Air High Temperature</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>High Humidity Inside Generator (5)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1) First stage alarms. Second stage trips.
2) Inhibit actuation of functions 32, 40 and 51V.
3) Coordinated with load shedding control.
4) Shall be included in AVR.
5) Inhibit start.
7. AUXILIARY AND CONTROL EQUIPMENT

7.1. GENERAL
7.1.1 Auxiliary equipment design criteria are defined in I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS, I-ET-3010.00-5140-700-P4X-002 – SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS and PACKAGE TECHNICAL SPECIFICATION.

7.2. PROTECTION, CONTROL AND MONITORING PANEL
7.2.1 Protection, control and monitoring panel requirements are defined in PACKAGE TECHNICAL SPECIFICATION.

7.3. SYNCHRONIZING SYSTEM
7.3.1 See PACKAGE TECHNICAL SPECIFICATION.

7.4. INSTRUMENT TRANSFORMERS
7.4.1 Generators shall be supplied with voltage transformers (VT) and current transformers (CT) for protection and measurement, as specified in the data-sheet.
7.4.2 Instrument transformers shall comply with I-ET-3010.00-5140-700-P4X-002 – SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

7.5. ANTI-CONDENSING HEATING RESISTORS
7.5.1 The generators and terminal boxes shall have heating resistors operating so that the internal temperature is above the condensation temperature and, at least 30°C below the insulation system temperature class, when the generator is off.
7.5.2 Unless otherwise specified in the data-sheet, the power supply voltage of the heating resistors shall be 220 Vac isolated (IT system).

7.6. MONITORING AND MEASURING INSTRUMENTS AND SENSORS
7.6.1 The instruments and sensors for monitoring and measuring the generator and auxiliary systems shall meet the requirements of the API STD. 670.
7.6.2 Unless otherwise specified in the data-sheet the connections of the instruments, sensors, vents and drains shall use conical NPT type threads, with a diameter of 3/4 of an inch.
7.6.3 The sensor circuits’ cables shall be shielded to avoid the effects of electromagnetic interference.
7.6.4 The sensor circuits’ cables shall be installed allowing replacement without the need of opening the generator housing (except the circuits of the winding temperature sensors).
7.6.5 The temperature sensors shall be of type RTD Pt-100 (Platinum 100 ohms @ 0 °C) 3 wires and shall meet the requirements of IEC 60751.
7.6.6 The stator winding temperature shall be monitored using nine (three per phase) embedded Pt-100 detectors.
7.6.7 Each bearing shall be monitored using two sensors (double-bearing sensor is acceptable). The position of RTDs shall be in accordance with IEC 60034-1.

7.6.8 If required on the data-sheet, bearing thermometers for temperature indication shall be supplied.

7.6.9 The reading instruments provided shall have their scale in unity of the international system of units.

7.6.10 Unless otherwise specified in the data-sheet, the air/water exchanger shall be supplied with 4 RTD-type sensors for remote indication of the temperature of inlet and outlet of water or air and cooling air.

7.6.11 If required in the data-sheet, the air/water heat exchanger shall be supplied with a pressure transmitter, standard 4 to 20 MA, in order to monitor the pressure difference between the inlet and the water outlet of the heat exchanger.

7.6.12 Generators with hydrodynamic bearings shall have two radial vibration sensors per bearing ("proximitors").

7.7. PARTIAL DISCHARGE MONITORING

7.7.1 Unless otherwise specified in the data-sheet, generators with rated voltage equal to or greater than 6kV and rated power equal to or greater than 5MVA shall have an 80 pF coupling capacitor unit per phase suitable for on-line monitoring of partial discharges as well as the corresponding auxiliary terminal box, including all devices (e.g. BNC connectors) required to allow the connection of portable monitoring equipment. The coupling capacitors shall be installed inside the power terminal box of the generator.

Notes 1) The coupling capacitors shall be positioned according to the IEC TS 60034-27-2 recommendations.

2) The coupling capacitors for partial discharge measurement shall comply with minimum performance according to IEC TS 60034-27-2.

7.8. TERMINALS AND CONNECTORS FOR POWER, CONTROL AND GROUNDING CABLES

7.8.1 The generator shall be supplied with two grounding terminal(s) placed on the outer side of the housing at opposite sides and indelibly marked with grounding symbol. Terminals shall be proper for copper cables with the cross section defined in data-sheet.

7.8.2 The generator shall have an additional grounding terminal inside the power terminal and neutral terminal boxes.

7.8.3 The generator’s shaft shall have a grounding brush.

7.8.4 The generator shall be supplied with power terminals, in quantity and dimensions according to the data-sheet.

7.8.5 All connectors shall be supplied and secured (so that they are not lost in transport) inside the power and neutral terminal boxes.

7.8.6 For cable construction requirements and colours follow requirements in I-ET-3010.00-5140-700-P4X-002 – SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.
7.8.7 Cable sizing and tagging shall follow requirements of I-ET-3010.00-5140-700-P4X-001 – SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS.

7.9. GROUNDING RESISTORS AND TRANSFORMERS

7.9.1 Each main generator neutral point shall be grounded by high resistance with transformer. Grounding transformer, grounding resistance and respective sensors and relays shall be located inside generator neutral terminal box.

7.9.2 The grounding transformer and resistor shall comply with requirements of I-ET-3010.00-5140-700-P4X-002 – SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

7.9.3 Unless otherwise defined in project documentation, grounding transformer and grounding resistor rated values shall be defined in respective data-sheets.

8. INSPECTIONS AND TESTS

8.1.1 Unless otherwise specified in data-sheet, the tests listed in Table 2, Table 3 and Table 4 shall be carried out. Tests required by CS, if not listed, are mandatory and shall be included.

8.1.2 The MANUFACTURER shall submit, after placing the purchase order (PC), together with the approval documentation, the inspection and testing plan (PIT), meeting the requirements indicated in this specification and in data-sheet. PIT shall list:
   a) Routine, type and special tests that will be carried out during manufacturing process (TDPF);
   b) Routine, type and special tests to be carried out in factory (TAF);
   c) If required, the complete driver-generator set tests (TCAG or String Tests), to be carried out at location defined by PACKAGER, and;
   d) Field acceptance tests (TAC).

Note: PIT shall indicate for each test, the applicable standards and the acceptance criteria for each measurement and test to be carried.

8.1.3 Certificate reports, approved by CS shall be accepted by PETROBRAS for type tests of identical equipment.

8.1.4 Manufacturer shall permit PETROBRAS witnessing the tests.

Table 2 — Testing During Manufacturing Process (TDPF).

<table>
<thead>
<tr>
<th>(TDPF) Test List description</th>
<th>RT</th>
<th>TT</th>
<th>ST</th>
<th>Procedure and acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verification of the technical documentation</td>
<td>X</td>
<td></td>
<td></td>
<td>Project documents</td>
</tr>
<tr>
<td>Visual Inspection</td>
<td>X</td>
<td></td>
<td></td>
<td>Project documents</td>
</tr>
<tr>
<td>Verification of the calibration certificates of the instruments used in the tests</td>
<td>X</td>
<td></td>
<td></td>
<td>PIT</td>
</tr>
<tr>
<td>Rotor balancing ( ^{(1)} )</td>
<td>X</td>
<td></td>
<td></td>
<td>[1] or ISO 7919-3 or ISO 10816-3</td>
</tr>
</tbody>
</table>
## TECHNICAL SPECIFICATION

No. I-ET-3010.00-5147-711-P4X-001

Rev. 0

Area: \( \text{SHEET: 24 of 30} \)

Title: MAIN GENERATOR FOR OFFSHORE UNITS

### (TDPF) Test List description

<table>
<thead>
<tr>
<th>Procedure and acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 60034-27-3 or IEEE 286</td>
</tr>
<tr>
<td>IEC 60034-15</td>
</tr>
<tr>
<td>IEC 60034-15</td>
</tr>
<tr>
<td>ASME BPVC VIII-1</td>
</tr>
<tr>
<td>IEEE 115</td>
</tr>
<tr>
<td>IEEE 115</td>
</tr>
<tr>
<td>NEMA MG 1</td>
</tr>
<tr>
<td>IEEE 1434</td>
</tr>
<tr>
<td>API-546</td>
</tr>
<tr>
<td>IEC 60034-32</td>
</tr>
<tr>
<td>IEC 61000-4-7 or IEC 61800-3</td>
</tr>
</tbody>
</table>

### (TAF) Test List description

<table>
<thead>
<tr>
<th>Procedure and acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project documents</td>
</tr>
<tr>
<td>IEC 60079 and applicable legislation</td>
</tr>
<tr>
<td>PIT and Project documents</td>
</tr>
<tr>
<td>Project documents</td>
</tr>
<tr>
<td>Project documents</td>
</tr>
</tbody>
</table>

### Notes:

1) Complete set, including fan, exciter, PMG etc.
2) Applicable to generators with preformed winding with rated voltage greater than or equal to 6 kV. Consider two additional coils (sample coils) identical to those manufactured for the generator, selected randomly and tested outside the stator. If at least one reel fails, the total set of coils shall be rejected and the manufacturing process shall be evaluated.
3) Applicable to generators with rated voltage equal to or greater than 6kV.
4) Applicable to generators with rated power equal to or greater than 25 MVA.

### Table 3 — Factory Acceptance Tests (TAF).

<table>
<thead>
<tr>
<th>Procedure and acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project documents</td>
</tr>
<tr>
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</tr>
<tr>
<td>PIT and Project documents</td>
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<td>Project documents</td>
</tr>
<tr>
<td>Project documents</td>
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</tbody>
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<thead>
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<tbody>
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<td>Project documents</td>
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<tr>
<td>IEC 60079 and applicable legislation</td>
</tr>
<tr>
<td>PIT and Project documents</td>
</tr>
<tr>
<td>Project documents</td>
</tr>
<tr>
<td>Project documents</td>
</tr>
</tbody>
</table>
### TECHNICAL SPECIFICATION

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<table>
<thead>
<tr>
<th>(TAF) Test List description</th>
<th>RT</th>
<th>TT</th>
<th>ST</th>
<th>Procedure and acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement of winding resistance</td>
<td>X</td>
<td></td>
<td></td>
<td>IEC 60034-4-1</td>
</tr>
<tr>
<td>Checking the location of the magnetic center</td>
<td>X</td>
<td></td>
<td></td>
<td>API 546, data-sheet and this specification</td>
</tr>
<tr>
<td>Air gap and eccentricity measurement</td>
<td>X</td>
<td></td>
<td></td>
<td>API 546, data-sheet and this specification</td>
</tr>
<tr>
<td>Checking and marking the direction of rotation</td>
<td>X</td>
<td></td>
<td></td>
<td>Driver documents and data-sheet</td>
</tr>
<tr>
<td>Phase sequence verification and terminals marking (motor-generator)</td>
<td>X</td>
<td></td>
<td></td>
<td>IEC 60034-1, IEC 60034-8 and ISO 8528</td>
</tr>
<tr>
<td>Phase sequence verification and terminals marking (turbo-generator)</td>
<td>X</td>
<td></td>
<td></td>
<td>IEC 60034-1, IEC 60034-8 and IEC 60034-3</td>
</tr>
<tr>
<td>Unbalanced phase check (motor-generator)</td>
<td>X</td>
<td></td>
<td></td>
<td>IEC 60034-22</td>
</tr>
<tr>
<td>Unbalanced phase check (turbo-generator)</td>
<td>X</td>
<td></td>
<td></td>
<td>≤ 0,5%</td>
</tr>
<tr>
<td>Measurement and analysis of waveform and THD</td>
<td>X</td>
<td></td>
<td></td>
<td>IEC 60034-1</td>
</tr>
<tr>
<td>Test and determination of the sustained short-circuit curve</td>
<td>X</td>
<td></td>
<td></td>
<td>IEC 60034-4-1 and CS</td>
</tr>
<tr>
<td>Test and determination of the no-load saturation curve</td>
<td>X</td>
<td></td>
<td></td>
<td>IEC 60034-4-1</td>
</tr>
<tr>
<td>Efficiency measurement</td>
<td>X</td>
<td></td>
<td></td>
<td>IEC 60034-2-1</td>
</tr>
<tr>
<td>Winding temperature rise</td>
<td></td>
<td>X</td>
<td></td>
<td>IEC 60034-1, IEC 61892-3, or IEEE 15 Method 4 (1)</td>
</tr>
<tr>
<td>Cooling system check (leakage, flow, pressure and coolant speed)</td>
<td>X</td>
<td></td>
<td></td>
<td>This specification</td>
</tr>
<tr>
<td>Bearing temperature rise</td>
<td></td>
<td>X</td>
<td></td>
<td>IEC 60034-1</td>
</tr>
<tr>
<td>Vibration tests (run out, vibration on the shaft, vibration on bearings and operation of the lubrication system)</td>
<td>X</td>
<td></td>
<td></td>
<td>This specification</td>
</tr>
<tr>
<td>Overspeed test</td>
<td>X</td>
<td></td>
<td></td>
<td>IEC 60034-1</td>
</tr>
<tr>
<td>Voltage and current on shaft</td>
<td>X</td>
<td></td>
<td></td>
<td>IEEE 115</td>
</tr>
<tr>
<td>Measurement of audible noise level</td>
<td>X</td>
<td></td>
<td></td>
<td>This specification</td>
</tr>
<tr>
<td>Voltage withstand test</td>
<td>X</td>
<td></td>
<td></td>
<td>IEC 60034-1</td>
</tr>
<tr>
<td>Measurement of insulation resistance</td>
<td>X</td>
<td></td>
<td></td>
<td>IEEE 43</td>
</tr>
<tr>
<td>Measurement of polarization index</td>
<td>X</td>
<td></td>
<td></td>
<td>IEEE 43</td>
</tr>
<tr>
<td>Measurement of bearing insulation</td>
<td>X</td>
<td></td>
<td></td>
<td>API 546</td>
</tr>
<tr>
<td>Occasional overcurrent test</td>
<td></td>
<td>X</td>
<td></td>
<td>IEC 60034-1</td>
</tr>
<tr>
<td>Partial discharge measurement (2)</td>
<td>X</td>
<td></td>
<td></td>
<td>IEC TS 60034-27-2 and IEC 60270</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>(TAF) Test List description</th>
<th>RT</th>
<th>TT</th>
<th>ST</th>
<th>Procedure and acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power factor tip-up test</td>
<td>X</td>
<td></td>
<td></td>
<td>IEC 60034-27-3, or IEEE 286</td>
</tr>
<tr>
<td>Sudden three-phase short circuit (parameter calculation) (3)</td>
<td>X</td>
<td></td>
<td></td>
<td>IEC 60034-4-1</td>
</tr>
<tr>
<td>Verification of the protection degree (IP)</td>
<td>X</td>
<td></td>
<td></td>
<td>IEC 60034-5</td>
</tr>
<tr>
<td>Bearings inspection</td>
<td></td>
<td>X</td>
<td></td>
<td>API 546</td>
</tr>
<tr>
<td>Check of lubrication oil ingress inside the generator</td>
<td></td>
<td>X</td>
<td></td>
<td>Visual inspection</td>
</tr>
<tr>
<td>Measurement of excitation current at rated load</td>
<td></td>
<td>X</td>
<td></td>
<td>IEC 60034-4-1 and this specification</td>
</tr>
<tr>
<td>Painting verification (colour, grip and thickness)</td>
<td></td>
<td>X</td>
<td></td>
<td>[7]</td>
</tr>
<tr>
<td>Short-circuit withstand test (3)</td>
<td></td>
<td>X</td>
<td></td>
<td>IEC 60034-1</td>
</tr>
<tr>
<td>Functional and performance test of excitation system, including AVR (including Field Forcing, when required)</td>
<td></td>
<td>X</td>
<td></td>
<td>This specification</td>
</tr>
</tbody>
</table>

Notes
1) In case of use of or IEEE 115 Method 4, consider all criteria for open-circuit and short-circuit loading:
   a) specified voltage with terminals open;
   b) specified armature current with the terminals short-circuited;
   c) zero excitation.
2) Applicable for generators with rated voltage equal to or greater than 6kV.
3) By agreement with the MANUFACTURER.

Table 4 — String tests (TCAG).

<table>
<thead>
<tr>
<th>Test List description</th>
<th>Test procedure and acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Checking the PIT technical documentation</td>
<td>Project documents</td>
</tr>
<tr>
<td>Verification of the calibration certificates of the instruments used in the tests</td>
<td>PIT</td>
</tr>
<tr>
<td>Visual inspection and verification of assembly and identification, data and safety plates</td>
<td>Project documents</td>
</tr>
<tr>
<td>Vibration tests (run out, vibration on the shaft, vibration on bearings and operation of the lubrication system)</td>
<td>Project documents</td>
</tr>
<tr>
<td>Continuous operation tests (including full load temperature rise)</td>
<td>PIT</td>
</tr>
<tr>
<td>Measurement of insulation resistance and polarization index</td>
<td>IEEE 43</td>
</tr>
<tr>
<td>Heat exchanger leakage verification</td>
<td>PIT</td>
</tr>
<tr>
<td>Measurement of voltage and frequency regulation at transient and continuous load conditions (including &quot;Field Forcing&quot; when required)</td>
<td>IEC 61892-1 (frequency), IEC 61892-3 (voltage) and CS</td>
</tr>
<tr>
<td>Functional test of alarms, measuring devices, control, signalling, keys and relays for the control panels.</td>
<td>Project documents</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Test List description</th>
<th>Test procedure and acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check of lubrication oil ingress inside the generator</td>
<td>Visual inspection</td>
</tr>
<tr>
<td>Checking the protection functions</td>
<td>Project documents</td>
</tr>
</tbody>
</table>

Notes 1) Complete requirements for TCAG are defined in PACKAGE TECHNICAL SPECIFICATION.

8.1.5 The certificates presented shall be with valid dates.
8.1.6 Unless otherwise defined in data-sheet or in other PACKAGE documents, the tolerances defined by standards shall be applicable.

9. SPARE PARTS AND TOOLS

9.1. SPARE PARTS

9.1.1 CONTRACTOR shall include in the scope of supply all spare parts required for start-up and commissioning.

9.1.2 CONTRACTOR shall supply spare parts required by CS, if any.

9.2. UNUSUAL TOOLS

9.2.1 CONTRACTOR shall supply all unusual tools required for installing, commissioning, operation and maintenance of the equipment specified.

10. TECHNICAL DOCUMENTS

10.1. GENERAL REQUIREMENTS

10.1.1 Data filled in data-sheet issued by PETROBRAS are mandatory. In case of divergence between the data-sheet issued by PETROBRAS and this specification, data-sheet data prevails.

10.1.2 If there is no generator data-sheet issued by PETROBRAS, the template of I-LI-3010.00-5140-700-P4X-001 – ELECTRICAL EQUIPMENT DATA-SHEET MODELS shall be used.

10.1.3 MANUFACTURER shall list, in the data-sheet, the technical standards applied to the manufacturing and testing of the generator, which complement the ones presented in section 3.

10.1.4 The data-sheet fields, filled by the MANUFACTURER for BID may consider tolerances according to project requirements. As built data-sheet shall be filled in with final measured and tested data.

10.1.5 MANUFACTURER shall provide all certification required by CS.

10.1.6 It shall be issued Brazilian Portuguese versions for all documents required by NR-12, besides the English version.
10.2. DOCUMENTS TO PROPOSAL

At least the following technical documents and information shall be included to the proposal:

a) Documents List;

b) List of standards applicable to the design, fabrication and tests;

c) Country of origin of the equipment;

d) Data-sheets of generator and accessories completely filled out with technical data and all tests to be applied;

e) Generator characteristic curves;

f) Drawing indicating the main dimensions, the weight of the generator and all its subsystems (panels, heat exchangers, filter, excitation system, lubrication, etc.);

g) Drawing with main information on the generator’s heat exchanger;

h) Specification or description of generator protections;

i) Specification or description of generator lubrication system;

j) Specification of excitation system, with modules architecture, protection, communication e performance data;

k) Specification of painting system for generator and all accessories;

l) Technical catalogues of all generator components containing all information and technical characteristics;

m) List of sensors and instruments, with respective data;

n) List of unusual tools required for maintenance of the generator;

o) List of recommended spare parts for two (2) years operation with separate prices for each item;

p) List of spare parts for commissioning and tests;

q) List of similar previous supplies consistent with the specification requirements defined by PETROBRAS;

r) List of deviations from project documentation;

s) Utility consumption list;

t) Description service capabilities, price schedule and service support during testing, installation, commissioning, and maintenance.

10.3. DOCUMENTS TO BE SUBMITTED FOR APPROVAL

At least the following documents and information shall be submitted to PETROBRAS approval, besides updated revisions of documents listed in item 10.2:

a) Documents list;

b) Dimensional drawings of all (generator, terminal boxes, auxiliary boxes, heat exchanger, exciter, panels, lubrications auxiliaries, etc.) and each component, with at least:
   - all dimensions;
   - static and dynamic weights;
   - center of gravity;
   - minimum free space for maintenance, assembly and disassembly;
lifting devices;
electrical power, control and instruments inlets, outlets and connections positions and data;
utilities connections positions and data;
internal components layout, dimensions and details;
instrument positions and connections;
fixing and coupling devices details;
rotating direction.

c) One-line, multi-line diagrams, functional and block diagrams for generator, excitation system, panels and auxiliary components;
d) Block diagrams of generator’s excitation system with adjustment of parameters;
e) Excitation system’s mathematical models, including all adjustment of parameters;
f) Protection adjustment parameters data;
g) Power, control and instruments wiring and interconnection diagrams;
h) Generator characteristic curves;
   - Capability curves for at least 80% of rated temperature in cooling water, rated temperature in cooling water and 120% of rated temperature in cooling water;
   - Capability curves for at least 95% of rated voltage, rated voltage and 105% of rated voltage;
   - Stator thermal limits (stator current x time);
   - Rotor thermal limits (field current x time);
   - Magnetic package damage curve due to ground fault (current through stator core lamination x time);
   - Efficiency curves (efficiency x power) for at least power factors of 0.8, 0.85, 0.9 and 1.0;
   - Short-circuit characteristic curve (Stator current x Field current), for at least 95% of rated voltage, rated voltage and 105% of rated voltage;
   - Saturation curve (stator voltage x field current), for at least no load, rated load and zero power factor, at least 95% of rated voltage, rated voltage and 105% of rated voltage;
   - No load characteristic curve;
   - Exciter saturation curve (main rotor voltage x field current);
   - Efficiency curve (efficiency x load), for at least 0.8, 0.85, 0.9 and 1.0 power factor;
   - Efficiency curve (efficiency x cooling water temperature);
   - Negative sequence curve (I₂ x time);
   - Overflux limit curve (V/Hz x time);
   - V curves for at least 95% of rated voltage, rated voltage and 105% of rated voltage;
   - Stator current decrement curves – field response (stator current x field current), including symmetrical three-phase short-circuit, DC component of three-phase short-circuit and field current;
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- Stator current decrement curves – field response (stator current x field current), including symmetrical three-phase short-circuit, DC component of three-phase short-circuit and constant field current;
- Stator current decrement curves – field response (stator current x field current), including symmetrical line-line short-circuit, DC component of line-line short-circuit and field current;
- Stator current decrement curves – field response (stator current x field current), including symmetrical line-line short-circuit, DC component of line-line short-circuit and constant field current;
- Stator current decrement curves – field response (stator current x field current), including symmetrical line-ground short-circuit, DC component of line-ground short-circuit and field current;
- Voltage and frequency variations as a function of time for sudden application of 30 %, 50 %, 80 % and 100 % of the generator’s rated load;
- Voltage and frequency variation limits curve, showing allowable zones;
- Output power curve (output power x cooling water temperature), for at least temperature rise class B and temperature rise class F.

i) Base forces and stress data;
j) Operation manuals, including controls procedures;
k) Troubleshooting manuals;
l) Repair and maintenance procedure manuals;
m) Assembly and disassembly procedure manuals;
n) Attachment and coupling procedure manuals;
o) Lifting procedure manuals;
p) Packing and transportation procedures manuals;
q) List of all equipment, components, materials, parts, pieces, accessories and devices, with identification of manufacturer, part number and model;
r) Generator data-sheet duly filled out;
s) Generator’s mathematical models, including all parameters;
t) Electrical auxiliary equipment and components data-sheet filled out, according to templates of I-LI-3010.00-5140-700-P4X-001 – ELECTRICAL EQUIPMENT DATA-SHEET MODELS;
u) Lubrication oil system diagrams and details;
v) Inspection and testing plan (PIT);
w) Current transformer saturation curves;
x) Grounding transformer saturation curves;
y) Tests reports;
z) Certificates of equipment for hazardous areas.