
 PETROBRAS	TECHNICAL SPECIFICATION		N°: I-ET-3010.2Q-5147-332-P4X-002				
	CLIENT:	MARLIM LESTE E SUL				SHEET:	1 of 31
	JOB:	BASIC DESIGN – REVIT I					
	AREA:	MARLIM LESTE E SUL					
	TITLE:	STEAM TURBINE DRIVER FOR STEAM TURBOGENERATOR SET				ESUP	
						INTERNAL	
INDEX OF REVISION							
REV.	DESCRIPTION AND/OR REVISED SHEETS						
0	ORIGINAL.						
A	REVISED WHERE INDICATED.						
B	REVISED WHERE INDICATED.						
C	REVISED WHERE INDICATED.						
D	REVISED WHERE INDICATED.						
	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	
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1. PURPOSE

The purpose of this document is to set minimum technical requirements for the following equipment:

TB-TG-5147002 - Steam Turbine Driver for Steam Turbogenerator Set

to be provided as an integral part of the Combined Cycle Power Plant to be installed in FPSO REVIT MARLIM LESTE E SUL.



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2. DEFINITIONS AND ABBREVIATIONS**2.1 Definitions:**

For the purposes of this document, the following definitions shall apply:


PETROBRAS	FPSO owner and operator company (end-user).
PURCHASER	The EPC Contractor company, responsible for the detail design, supply of materials, fabrication, erection, construction, commissioning, and startup of the entire FPSO vessel, including the lifting, hook-up, installation, and integration of all Modules in the FPSO topside, with complete and fully operative systems in accordance with the requirements of this specification, and other technical documents, codes and standards referenced herein.
PACKAGER	The equipment Main Vendor company with unit responsibility for the whole steam turbogenerator set (in this case, the steam turbine vendor as per section 4 of Annex B), and responsible for providing the complete the turbogenerator set to the PURCHASER as a single and integrated package.

2.2 Abbreviations:

AEPR	Automation & Electrical Panels Room
AMS	Asset Management System
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
AVM	Anti-Vibration Mounting
CCR	Central Control Room (located in the Hull Accommodation)
CCR-ATR	Central Control Room – Automation and Turbomachinery Room
CSS	Control and Safety System
DIO	Optical Internal Distributor
ESD	Emergency shutdown
FAT	Factory Acceptance Test
FIT	Factory Integrated Test
FPSO	Floating Production Storage and Off-loading
FST	Factory Stability Test
GCPR	Generator Control Panels Room
HMI	Human Machine Interface
I/O	Input/Output
LAN	Local Area Network
MCC	Motor Control Center
MMS	Machinery Monitoring System
MPS	Machinery Protection System
MRT	Mechanical Running Test
OPC UA	Open Platform Communications Unified Architecture
PAS	Package Automation System
PLC	Programmable Logic Controller
PMS	Power Management System
PSD	Process Shutdown System


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P&ID	Piping and Instrument Diagram
RESD	Emergency Shutdown Relay
RIO	Remote I/O Panel
SAT	Site Acceptance Test
SLT	Sound Level Test
SIT	Site Integration Test
STG	Steam Turbogenerator
SYAT	Shipyards Acceptance Test
TGCP	Turbogenerator Control Panel
TGCP_HMI	Human Machine Interface for Unit Control Panel


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3. GENERAL

- 3.1 Steam turbine for the Steam Turbogenerator set shall be provided in accordance with the latest edition of API Std 612 and the respective PETROBRAS overlay specification for offshore applications (Annex B of this document).
- 3.2 Whenever applicable, the requirements stated in document *I-ET-3010.2Q-5100-940-P4X-001 - COMBINED CYCLE POWER PLANT PACKAGE* are mandatory, as well as those requirements from other documents, codes and standards referenced therein.
- 3.3 The complete Steam Turbogenerator set shall be designed for a minimum of 30 years of operation installed in the FPSO.
- 3.4 The PACKAGER's scope of supply shall comprise, at least, but not limited to, the following items:
 - 3.4.1 Steam turbine, electric generator, and gear unit.
 - 3.4.2 Couplings and coupling guards.
 - 3.4.3 Main equipment baseplate/skid.
 - 3.4.4 Trip and throttle valve(s), pressure and thermal relief valves, shutoff valves and other protection devices and components, as required.
 - 3.4.5 Insulation and jacketing.
 - 3.4.6 Steam turbine governing system.
 - 3.4.7 Complete lube and control oil system, including oil purifier and mist eliminator system.
 - 3.4.8 Turning gear device.
 - 3.4.9 Jack oil system.
 - 3.4.10 Surface condenser.
 - 3.4.11 Steam turbine gland condensing system.
 - 3.4.12 Complete vacuum system.
 - 3.4.13 Turning gear device.
 - 3.4.14 Auxiliary piping and appurtenances (within STG package limits).
 - 3.4.15 Instrumentation and controls for machinery monitoring, controlling, interlocking and protection.
 - 3.4.16 Junction boxes.
 - 3.4.17 Control panels and connection to the FPSO control system.
 - 3.4.18 Batteries, battery chargers and other electrical equipment and protection, as required in *I-ET-3010.2Q-5100-940-P4X-001 – Combined Cycle Power Plant Package*.
 - 3.4.19 Shop inspections and tests.
 - 3.4.20 Special tools (if any).
 - 3.4.21 Spare parts (as per applicable Contract Exhibits).
 - 3.4.22 Complete technical documentation (including IOM manuals in Brazilian Portuguese language).
 - 3.4.23 Assembly, commissioning, and start-up supervision (including supervision during functional tests at shipyard and performance tests at FPSO final location).
 - 3.4.24 Operation and Maintenance training.

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- 3.5 All components of the STG package shall be suitable for offshore environment, throughout the whole platform service life, under all operational conditions and submitted to the FPSO motions and accelerations described in PETROBRAS specifications.
- 3.6 The PACKAGER shall be entirely responsible for the material selection of items not specified by PETROBRAS and shall inform material of all main parts according to ASTM code. All bolts and nuts shall be supplied with PACKAGER certificates and fully marked according to the applicable ASTM standard.
- 3.7 All pending items from the shop punch lists shall be resolved and closed before shipment.
- 3.8 PACKAGER shall specify the products to be used for preservation of the equipment components and spare parts (as per applicable Contract Exhibits), their removal and reapplication methods and the application date. Such data shall be summarized on two tags to be securely fastened on all equipment and outside of each crate. If rust preventives are required, volatile products shall not be applied.
- 3.9 Hazardous and toxic materials with associated adverse health effects shall be avoided or minimized. PACKAGER and PURCHASER are encouraged to promote their replacement. Asbestos, hazardous, and toxic components shall not be used in the materials and equipment supplied for this project or for this plant or facility. As the use of such materials will not be tolerated, PETROBRAS strongly recommends PACKAGER and PURCHASER to take all necessary measures to ensure their use is fully avoided throughout this project. Material safety datasheets may be required by PETROBRAS any time, to demonstrate that a particular material has not been, is not and will not be used throughout all stages of this project.
- 3.10 All equipment, components and panels shall have a nameplate easy to access, to view and read. Nameplate shall be made in stainless steel AISI 316L and bolted (with stainless steel elements) to the equipment. Layout drawings shall be submitted to PURCHASER approval. Nameplates shall contain the following information, in Brazilian Portuguese language:
- Client name
 - Client job
 - Client area
 - Supplier name
 - Series number and model
 - Year of manufacturing
 - Main design and test data: pressure, temperature, voltage, rotation, etc.
 - Specific data
 - Tag number
 - PURCHASER's Material Requisition number (RM)
 - PURCHASER's Request for Quotation number (RFQ)
 - PURCHASER's Order number (PO)
 - Empty weight
 - Design code
- 3.11 All safety signals shall be in Portuguese language.

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4. CONSTRUCTION FEATURES

- 4.1 The steam turbine shall be a reaction-type, special-purpose condensing turbine, with one controlled extraction.
- 4.2 The steam flow extracted from the steam turbine shall be used as a heating source to the FPSO Hot Water closed circuit (Heating Medium) for further use by the process heat consumers.
- 4.3 Besides normal and rated steam mass flowrates and power, PACKAGER shall inform the steam mass flowrate and power under the worst steam conditions.
- 4.4 The steam turbogenerator shall be installed in a safe area.
- 4.5 The steam turbine shall be capable to restart at any time after an indeterminate period with no auxiliary AC power supply. PACKAGER shall provide all auxiliary systems required to meet this requirement and the PURCHASER shall submit them to PETROBRAS before proposal.
- 4.6 Steam turbine bearings shall be designed to minimize oil foaming and prevent whirl at any operating speed.
- 4.7 The steam turbogenerator centerline shall be oriented in the fore/aft direction of the FPSO (Floating Production Storage and Off-loading).



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5. ACCESSORIES AND AUXILIARIES**5.1 Piping**

- 5.1.1 Unless otherwise specified, all piping and accessories within the equipment baseplate/skid limits shall be provided by the PACKAGER, in accordance with PACKAGER's piping specifications and international standards.
- 5.1.2 All auxiliary piping requiring field connections shall be brought by the PACKAGER to the equipment baseplate/skid edge and shall be flanged.
- 5.1.3 Manual block valves and spectacle/blind flanges shall be provided at drain lines, oil system lines, gland sealing lines and other battery limits of the Steam Turbogenerator package, whenever applicable. PACKAGER and PURCHASER shall follow the requirements of the specific project's document "PIPING SPECIFICATION FOR TOPSIDES", as stated in the DOCUMENT LIST. Manual valves shall be installed at the equipment baseplate/skid edge to be operated. Free access to all manual valves shall be provided.
- 5.1.4 All piping and ducting shall be designed and provided with sufficient flexibility.
- 5.1.5 The interconnecting pipework between auxiliary skids and the main baseplate/skid shall be provided by the PURCHASER. Drainage shall occur in all lower parts of the piping.
- 5.1.6 Systems/equipment isolation shall comply with Isolation Guidelines requirements from specific project's document "DESCRIPTIVE MEMORANDUM – PROCESS".

5.2 Couplings and coupling guards

- 5.2.1 PACKAGER is responsible for all couplings and coupling guards within the steam turbogenerator package, including those for auxiliary equipment.
- 5.2.2 All couplings (including those for auxiliary equipment) shall be non-lubricated, metallic flexible-element type. Flexible elements shall be in stainless steel.
- 5.2.3 Turbine main-drive couplings and coupling guards shall be in accordance with API Std 671 latest edition. PACKAGER shall submit to PETROBRAS datasheets for the turbine main-drive couplings in accordance with API Std 671 last edition.
- 5.2.4 Turbine main-drive couplings shall incorporate a feature that allows the transmission of load for a limited period in the event of a complete flexible element failure to allow safe shutdown of equipment.
- 5.2.5 All coupling guards (including those for auxiliary equipment) shall be rigid, fully enclosed, in spark-resistant material, and solely fitted to equipment baseplates, not fastened. Safety coupling guards (without feet) are also acceptable.
- 5.2.6 In case of failure, guards shall be able to retain broken parts, for personnel protection (OHS 1910.219 shall be complied).
- 5.2.7 Coupling guards shall be designed to allow removal without disassembling the coupling and shall be constructed so that routine inspections are performed by means of strobe light, with the equipment running.
- 5.2.8 Coupling guard drains shall have sight glasses in horizontal drain lines. The coupling guard shall not be used as a normal operating lube oil drain path.



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5.3 Baseplate


- 5.3.1 The steam turbine, electrical generator, gear unit, oil system and local panel shall be mounted on a single baseplate, including auxiliaries. The PACKAGER and the PURCHASER shall submit layout for PETROBRAS review and approval.
- 5.3.2 Main equipment baseplate shall be capable of withstanding the stresses arising from the FPSO motions and accelerations and shall be provided with three (3) point supports and Anti-Vibration Mounting (AVM).
- 5.3.3 Baseplate shall be rigid enough to avoid permanent distortion during lifting, shipment, and operation. When baseplate is lifted with all equipment mounted on it, beam deflection shall not exceed $L/400$ (L is the total baseplate length).
- 5.3.4 Baseplate shall be provided with nonskid decking covering all walking and work area. Solid decking plate shall be removable where required for maintenance.
- 5.3.5 All furnished skids shall be sufficiently rigid to withstand vibration loads induced by the equipment and transfer them to the deck beams.
- 5.3.6 Skid mounted assemblies shall be constructed to avoid equipment or parts dismounting during lifting.
- 5.3.7 No equipment / component shall protrude beyond the baseplate/skid limits. In cases where it cannot be avoided, required protection against mechanical damage shall be provided.
- 5.3.8 Each baseplate/skid shall be provided with lifting facilities (pad-eyes, lugs, bollards, and spreader beams), having suitable access for rigging. The estimated lifting load and safety factor for each point shall be informed in PACKAGER's proposal.
- 5.3.9 All equipment to be mounted on skids shall allow on-field leveling and alignment using jackscrews (in both plane directions) and precision type shims. Total shim thickness shall not exceed 6.35 mm and the number of shims shall be kept to a minimum. Shims shall be made of solid 316L stainless steel plate.
- 5.3.10 All skid mounted equipment containing liquids that shall be drained onto the skid area, shall be fitted with drip pan underneath the equipment and provided with flanged nozzle with sufficient slope. Drip pans draining system shall be designed considering the total deluge flow over the skid. Drain nozzles arrangements shall be provided at the skid edge with appropriate piping, blocking valve, strainer, and water seal, in order to perform drainage regardless of FPSO motions.
- 5.3.11 Fastening elements (including washers) shall be constructed in stainless steel AISI 316L.

5.4 Support system

- 5.4.1 All required support system (including spring supports, structure, etc.) shall be supplied (for on-skid elements) or specified with all design requirements (such as loads, position, forces, etc.) by the PACKAGER.

5.5 Insulation and Jacketing

- 5.5.1 All required thermal insulation and jacketing for proper operation and personnel protection shall be provided by the PACKAGER.
- 5.5.2 Insulation and jacketing shall ensure a temperature below 60°C at external surfaces for personnel protection.

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<p>5.5.3 To prevent corrosion under insulation, only non-hygroscopic insulation material shall be used.</p> <p>5.5.4 To avoid damages during transportation and erection, insulation shall be carried out after final installation, before FPSO sail away.</p> <p>5.6 Oil system</p> <p>5.6.1 The PACKAGER shall provide a complete pressurized lube and control oil system in accordance with the latest edition of API Std 614, to serve as a common oil system for the entire machinery train (i.e., steam turbine, gear unit, and electric generator).</p> <p>5.6.2 The oil system shall be designed with all system components and related valves and manifolds mounted on the main equipment baseplate.</p> <p>5.6.3 The PACKAGER shall ensure bearing lubrication and oil drainage during equipment startups/shutdowns, normal operation, and post-lube conditions when subjected to the FPSO motions and accelerations, as specified.</p> <p>5.6.4 Special consideration shall be given to the presence of dirt, debris, and any foreign matter in bearings and other sensitive parts (bearings, for instance). Provisions shall be made for bypassing sensitive parts while oil system flushing is performed.</p> <p>5.6.5 PACKAGER shall provide sampling points at the oil reservoir, oil supply manifold and oil return line of each equipment. Sampling facilities shall be permanent, fitted with valves installed in T-type connections, oil spill and drip collectors and spillback lines to be routed back to oil reservoir. Sampling arrangement shall allow for the collection of oil samples during operation.</p> <p>5.6.6 Except for oil pump casings, all piping and appurtenances, tubing, filters, heat-exchangers, accumulators, valves, oil reservoir, rundown tank, and other wetted metallic parts of the oil system shall be in AISI 316L stainless steel material.</p> <p>5.6.7 Socket welds for piping and tubing are prohibited.</p> <p>5.6.8 Oil Reservoir:</p> <p>5.6.8.1 Reservoir shall be provided with filling connections (with filter), level indicator sight glass, antifoaming devices, accessible manholes, valve drain at skid edge and provisions for nitrogen purging.</p> <p>5.6.8.2 All return lines shall be of top-entry type, extending the inlet duct inside the reservoir to below minimum operating level to avoid foaming.</p> <p>5.6.8.3 Reservoir shall be designed to facilitate air separation between the bearing return and oil pump supply.</p> <p>5.6.8.4 An electric lube oil heater shall be provided, interlocked with a low-level and oil temperature control. This device shall be designed to facilitate removal without having to drain the reservoir or stop the equipment.</p> <p>5.6.9 Oil pumps:</p> <p>5.6.9.1 Oil pumps shall be rotary type.</p> <p>Note: If the total oil flow exceeds the limits for application of rotary-type oil pumps, centrifugal oil pumps can be proposed as alternative, provided they are prior approved by PETROBRAS.</p> <p>5.6.9.2 Main oil pump shall be shaft-driven type.</p> <p>5.6.9.3 Stand-by oil pump shall be electric motor driven (AC power).</p> <p>5.6.9.4 Main and stand-by oil pumps shall have the same capacity (2 x 100%).</p>			



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- 5.6.9.5 <Deleted.>
- 5.6.9.6 Emergency oil pump (125Vdc - different voltage shall be approved by PETROBRAS) is acceptable only for cooling down purposes. In addition to the emergency oil pump test during the starting sequence, the PAS shall perform a daily emergency oil pump test while the STG is running, initiating an alarm in case of low discharge pressure.
- 5.6.9.7 If hydraulically lifting of the rotor(s) is required prior to startup, two identical jacking oil pumps shall be provided (2 x 100%). By default, all jack up operations shall be automatic, controlled by train PLC. Whenever feasible, manual operation shall only be applied for maintenance purposes.
- 5.6.10 Oil coolers shall be multi-plate duplex with changeover valve (2 x 100%). Coolers shall have provision for future increase of the number of plates. The cooling water pressure shall be lower than oil pressure. Coolers shall be in full AISI 316L stainless steel.
- 5.6.11 Oil filters shall be duplex (twin) with changeover valve (2 x 100%). The canisters, transfer valves and piping for oil filter system shall be in AISI 316L. Filtering elements shall be made of corrosion-resistant and water-proof material. There shall be no by-pass around any filter.
- 5.6.12 Oil system shall be provided with an atmospheric overhead rundown tank for bearings lubrication during coastdown time.
- 5.6.13 An extraction oil mist eliminator system fitted with electric motor-driven fans (2 x 100%) and a vacuum relief device shall be provided to recover oil due to evaporation losses and for environmental protection. The PACKAGER shall guarantee a maximum oil loss of 5 (five) ppm. Vents shall be at least of the same size as the oil return header.
- 5.6.14 PACKAGER shall inform all data and characteristics of electric load (as power, source, etc.) for each pump driver, heater, etc. in his technical proposal. PURCHASER will furnish electrical utilities required by the PACKAGER, considering FPSO available voltages as stated in I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS.
- 5.6.15 API datasheets for oil pumps and heat exchangers shall be included in PACKAGER's technical proposal.
- 5.6.16 All oil vents shall be interconnected, fitted with flame arrestors, and routed to a safe area. All oil drains shall also be interconnected and routed to oil reservoir. Flame arrestor material shall be compatible with vent line material.
- 5.6.17 Vent lines shall be designed considering the FPSO motions and accelerations (as described in PETROBRAS specifications) under all operational conditions, in order to avoid air or liquid pockets.
- 5.6.18 PACKAGER shall provide all data of oil system equipment and fluid as oil consumption, oil complete specification and filter elements life.

5.7 Gear Unit

- 5.7.1 The gear unit shall be provided by the PACKAGER as a double-helical, single-stage speed reducer in accordance with the latest edition of API Std 613.
- 5.7.2 The nominal output speed of the gear unit shall be 1800 RPM.
- 5.7.3 It shall be included a device to allow manually rotation of the shafts for maintenance purpose (such as shaft mechanical alignment or borescope inspection).



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- 5.7.4 Gear unit shall be designed as a "stand-alone" unit, whereby no external thrust loads shall be imposed upon the gearbox by other equipment.
- 5.7.5 Shaft oil seal shall be easily accessible for removal and re-installation without removing couplings.
- 5.7.6 All bearings shall be pressure lubricated and fully replaceable at field.

5.8 Pressure vessels

- 5.8.1 Pressure vessels shall comply with I-ET-3010.00-1200-540-P4X-001 - REQUIREMENTS FOR PRESSURE VESSELS DESIGN AND FABRICATION.



6. AUTOMATION

6.1 General requirements


- 6.1.1 The Package Automation System (PAS) shall supervise and control the main generation service that includes the steam turbogenerator set and auxiliaries.
- 6.1.2 PACKAGER shall be responsible for all required controls, interlocking interfaces and communications architecture with the systems/process plant outside its scope of supply, in order to guarantee the proper start-up, warm-up, loading, automatic or manual synchronization, load sharing, normal stop and emergency shutdown sequences.
- 6.1.3 Turbogenerator Control Panel (TGCP), Remote I/O Panels (RIO), Machinery Protection System (MPS), Machinery Monitoring System (MMS) interface, Asset Management System (AMS) interface and Device and Field Instrumentation are parts of the Package Automation System (PAS).
- 6.1.4 Package Automation System (PAS) shall be designed to ensure safe and reliable operation, performing sequencing, interlocking, protection, control and monitoring during starting, operation, normal stop and emergency shutdown. The PAS shall not allow undesirable nor unsafe operations. PAS shall be furnished functionally assembled and tested.
- 6.1.5 Each turbogenerator package shall have its own PAS. Each PAS shall operate independently, so a failure of any component in the turbogenerator package does not affect the availability of any other turbogenerator package.
- 6.1.6 Besides the requirements stated herein, the PAS shall be provided in accordance with the requirements of I-ET-3010.00-1200-800-P4X-002 - AUTOMATION, CONTROL AND INSTRUMENTATION ON PACKAGE UNITS, international standards, Classification Society, as well as with the following specifications:
 - I-DE-3010.00-5140-700-P4X-003 - GROUNDING INSTALLATION TYPICAL DETAILS
 - I-DE-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE DIAGRAM
 - I-ET-3010.00-1200-800-P4X-010 - CRITERIA FOR ESTABLISHING CABLE CODES AND CABLE GLAND CODES
 - I-ET-3010.00-1200-800-P4X-013 - GENERAL CRITERIA FOR INSTRUMENTATION PROJECTS
 - I-ET-3010.00-1200-850-P4X-002 - ASSET MANAGEMENT SYSTEM (AMS)
 - I-ET-3010.00-5140-775-P4X-001- REQUIREMENTS FOR ELECTRICAL GENERATION EXCITATION SYSTEM FOR OFFSHORE UNITS
 - I-ET-3010.00-5140-700-P4X-001 - SPECIFICATION FOR ELECTRIC DESIGN FOR OFFSHORE UNITS
 - I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL FOR OFFSHORE UNITS
 - I-ET-3010.00-5140-700-P4X-003 - ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS
 - I-ET-3010.00-5140-700-P4X-004 - PN-5140001 - POWER MANAGEMENT SYSTEM (PMS) FOR OFFSHORE UNITS
 - I-ET-3010.00-5140-700-P4X-005 - REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS
 - I-ET-3010.00-5140-712-P4X-001 - LOW-VOLTAGE INDUCTION MOTORS FOR OFFSHORE UNITS

- I-ET-3010.00-5140-713-P4X-001 - SPECIFICATION FOR TRANSFORMERS FOR OFFSHORE UNITS
- I-ET-3010.00-5140-772-P4X-002 - SPECIFICATION FOR LOW-VOLTAGE FREQUENCY CONVERTERS, SOFTSTARTERS AND INVERTERS FOR OFFSHORE UNITS
- I-ET-3010.00-5140-741-P4X-001 - LOW-VOLTAGE MOTOR CONTROL CENTER AND SWITCHGEAR FOR OFFSHORE UNITS
- I-ET-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE
- I-ET-3010.00-5143-700-P4X-001 - ELECTRICAL SYSTEM PROTECTION CRITERIA
- I-ET-3010.00-5147-711-P4X-001 - MAIN GENERATOR FOR OFFSHORE UNITS
- I-ET-3010.00-5520-800-P4X-004 - AUTOMATION NETWORK REQUIREMENTS
- I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST
- I-DE-3010.00-5140-797-P4X-002 - ELECTRICAL SYSTEM AUTOMATION TYPICAL ACTUATION DIAGRAMS
- I-DE-3010.00-5143-946-P4X-001 - MEDIUM-VOLTAGE SYSTEMS PROTECTION DIAGRAM
- I-ET-3010.00-5140-741-P4X-002 - MEDIUM-VOLTAGE MOTOR CONTROL CENTER AND SWITCHGEAR FOR OFFSHORE UNITS
- I-ET-3010.00-5140-700-P4X-007 - SPECIFICATION FOR GENERIC ELECTRICAL EQUIPMENT FOR OFFSHORE UNITS
- I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS
- I-ET-3010.00-5140-741-P4X-004 - SPECIFICATION FOR LOW-VOLTAGE GENERIC ELECTRICAL PANELS FOR OFFSHORE UNITS
- I-ET-3010.00-5140-714-P4X-001 - SPECIFICATION FOR ELECTRICAL BATTERIES FOR OFFSHORE UNITS
- I-ET-3010.00-5140-773-P4X-002 - SPECIFICATION FOR GENERIC DC UPS FOR OFFSHORE UNITS

6.1.7 Additionally, the PAS shall also be designed according to the requirements described in each specific project's documents stated in the DOCUMENT LIST:

- AUTOMATION INTERFACE OF PACKAGED UNITS
- AUTOMATION AND CONTROL ARCHITECTURE
- INSTRUMENTATION ADDITIONAL TECHNICAL REQUIREMENTS
- FIELD INSTRUMENTATION
- EQUIPMENT LIST
- AUTOMATION AND CONTROL SYSTEM FUNCTIONS - TOPSIDES
- AUTOMATION NETWORK DESCRIPTION

6.1.8 All instrumentation and alarms/trips mentioned in the datasheets and P&IDs are the minimum required by PETROBRAS, as well as required by international standards. PACKAGER and PURCHASER may indicate other instrumentation and alarms/trip for general protection and monitoring according to their experience and for compliance with Classification Society's requirements and submit them to PETROBRAS for approval.

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<p>6.1.9 PACKAGER shall supply Turbogenerator Control Panel (TGCP) and Remote I/O (RIO) panels. TGCP will be installed at the Generator Control Panels Room (GCPR) and RIO will be installed in the field by PURCHASER.</p> <p>6.1.10 All requirements for PAS shall be checked during Factory Acceptance Test (FAT), Factory Integration Test (FIT) and Site Acceptance Test (SAT) according to IEC 62381 and Classification Society rules.</p> <p>6.1.11 PAS shall be considered as P2S type, according to Technical Specification I-ET-3010.00-1200-800-P4X-002 - AUTOMATION, CONTROL AND INSTRUMENTATION ON PACKAGE UNITS, and per each specific project, the following documents stated in the DOCUMENT LIST: "AUTOMATION INTERFACE OF PACKAGE UNITS" and "AUTOMATION AND CONTROL SYSTEM FUNCTIONS – TOPSIDES".</p> <p>6.1.12 PACKAGER and PURCHASER shall provide to PETROBRAS all keys, drivers, manuals, installation media and licenses of all software inside package, including all development tools and comply with requirements from specific project's document "DESCRIPTIVE MEMORANDUM – AUTOMATION AND CONTROL SYSTEM - SCOPE DEFINITION". No software access restrictions will be accepted by PETROBRAS.</p> <p>6.1.13 All proper means of electrical and environmental protection shall be applied to all instruments and electrical equipment, particularly those located in hazardous areas and/or an aggressive saline air environment. Instruments and electrical equipment shall comply with IEC-60079 and they shall be at least IP-56.</p> <p>6.1.14 In order to guarantee adequacy to IEC-61892-7, all instruments, electrical equipment and panels installed in field open areas shall be certified to operate in Zone 2 Group IIA temperature T3, including certified enclosures against explosive atmosphere are mandatory.</p> <p>6.1.15 PACKAGER shall provide a local instrumentation board (rack) installed on the equipment baseplate, as mentioned on data sheets. Oil filled gauges shall be provided for analogical instruments subject to high vibration levels.</p> <p>6.1.16 PAS shall not be restarted without manual acknowledgement of the shutdown conditions.</p> <p>6.1.17 The FPSO electrical system will supply electric power according to the I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS.</p> <p>6.1.18 PAS shall be fed during emergency shutdown according to the I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS. All accessories and auxiliaries (including UPS, accumulator batteries and batteries chargers) shall be provided by others.</p> <p>6.1.19 The 220 Vdc power to the PAS will be guaranteed for 30 minutes in the black shutdown event. If the PAS needs to be kept powered for more than 30 minutes, the PACKAGER shall provide its own UPS and battery bank and PURCHASER shall be responsible for all additional impacts related to installation of these additional UPS and battery bank (structure, architecture, HVAC, gas detectors, safety, etc.).</p> <p>6.1.20 PURCHASER and PACKAGER shall not supply any components (including hardware, firmware, software etc.) for PAS that are obsolete or that has Declaration of Obsolescence.</p>			

6.2 TGCP hardware

- 6.2.1 The Turbogenerator Control Panels (TGCPs), to be located in the Generator Control Panels Room (GCPR), shall have front and rear access doors, IP22 protection level and cable entry from the bottom of the panel. The internal temperature shall be kept below 30 °C. Each TGCP shall include, at least:
- One dedicated safety system and one dedicated control system, each system shall be implemented using Programmable Logic Controllers (PLC) with redundant CPUs
 - HMI hardware (TGCP_HMI)
 - Ventilation exit at the top
 - Network switches and DIO optical fiber
 - One individual redundant communication network system with the electrical system controllers
 - One individual redundant communication network system with the automation and control system
 - Redundant communication network system with PMS. The TGCPs and PMS panels shall communicate among each other through a redundant proprietary high speed deterministic network (HSDN). In case of communication failure between PMS and TGCP panels, the turbogenerators shall continue to operate
 - Acknowledgment and reset push-buttons
 - Turbogenerator start and stop push-buttons in the HMI. Turbogenerator start and stop and lamp status push-buttons can also be by hardware on the panel front door
 - Emergency shutdown retentive push-button in the HMI. Emergency shutdown retentive push-button shall also be by hardware on the panel front door;
 - Emergency Shutdown Relay (RESD)
 - Start/stop pushbuttons and switches (to define main and stand-by) for auxiliary equipment and devices in the HMI. Start/stop pushbuttons and switches for auxiliary equipment can also be performed by hardware on the panel front door
 - Sound alarm
 - Start counter and hour meter in the panel front door and in the TGCP_HMI
 - Machinery Protection System (MPS)
 - Interface for Machinery Monitoring System (MMS)
 - Start and stop lamp status
 - TGCP and all its components shall be designed considering environmental and operating conditions defined in I-ET-3010.00-1200-800-P4X-002
- 6.2.2 The network switches shall be industrial manageable type. A package entry switch shall be supplied and installed complying with requirements shown in AUTOMATION NETWORK DESCRIPTION.
- 6.2.3 Networks for control, safety and monitoring shall be segregated from each other and redundant.
- 6.2.4 Safety System PLC shall receive all process variables related to emergency shutdown logics, execute these logics and perform hardwired actuation on final elements in abnormal situation. Control System PLC is responsible for control and monitoring functions of the process variables.

6.3 PAS software

- 6.3.1 PAS shall enable changes of set points, timer presets and control parameters, input by-passing and output override with the system in operation, without damage to the process.
- 6.3.2 The control system programming and configuration shall be carried out by the TGCP_HMI or additionally through a laptop computer (not provided by PACKAGER or PURCHASER) with software editor. The software editor shall be provided by PACKAGER or PURCHASER.
- 6.3.3 HMI software (with runtime and development licenses) shall be provided.
- 6.3.4 Access to configuration and programming shall be protected by change management tools, including specific passwords with several levels, such as: general, operation, maintenance, and engineering. All passwords shall be delivered to PETROBRAS with NO access restrictions.
- 6.3.5 The control system programming shall be in accordance with PETROBRAS specification. PURCHASER proposal shall inform the programming language used in the system.
- 6.3.6 HMI alarm annunciation shall comply with ISA-18.1, according to the sequence F2M-1 (manual reset first out with no subsequent alarm flashing and silence pushbutton. Alarm Management Systems shall comply with ISA -18.2).

6.4 PAS system

- 6.4.1 PAS shall be capable of performing control, interlocking, process, start-up, normal stop, emergency shutdown, normal operation and safety procedures for main machinery and auxiliary equipment. PAS shall also include all necessary interfaces to connect with remote I/O, Machinery Protection System (MPS), Motor Control Center (MCC) and other controls and security systems, such as: Control and Safety System (CSS), Power Management System (PMS), Asset Management System (AMS) and Machinery Monitoring System (MMS). PAS shall not allow undesirable nor unsafe operations.
- 6.4.2 Emergency Shutdown Relay (RESD) shall be provided to actuate directly on the steam shutoff valves.
- 6.4.3 The Emergency shutdown retentive push buttons, signal from PSD (Process Shutdown System), overspeed and MPS, shall actuate the RESD and be used as input for TGCP safety PLC.
- 6.4.4 PAS shall include, at least, the following functions:
- Start-up, warm-up, loading, automatic or manual synchronization and load sharing, normal stop and emergency shutdown sequences without causing any damage to equipment or process instability
 - Indication and recording of unit malfunction / shutdown, event signals and all machinery sequences (such as start-up, normal stop, etc.)
 - Monitoring and control of all variables, alarms and shutdowns signals, with TGCP_HMI indication, as described in PETROBRAS specifications (such as temperature, pressures, etc. indicated in P&IDs and data sheets), as well as PACKAGER specification and P&IDs, required by international standards, and for compliance with Classification Society's requirements
 - Steam mass flow and steam conditions at the turbine inlet, extraction and exhaust
 - Generator voltage, current and frequency monitoring and control

- Droop/isochronous mode switching monitoring and control with bumpless transfer over the entire load range
 - Synchronization monitoring and control (with indication for synchronization attended). Automatic start and synchronizing of the main generator to respective main switchgear (PN-5143001) bus bar under a PMS request (discrete signal)
 - Automatic stop the main generator under a PMS request (discrete signal)
 - Synchronization mode selector switch shall have the following positions: Manual, Automatic and Off
 - Indication for active/reactive power output
 - The Field Forcing Process, triggered by PMS signal, shall actuate over AVR inside TGCP, increasing the voltage set point to a pre-selected adjustable value, during a pre-selected adjustable time, in order to mitigate voltage drop problems during starting of high power motors.
- 6.4.5 All instruments and auxiliary equipment required to ensure synchronizing operation shall be installed in PAS, including the following facilities:
- Double voltmeter
 - Double frequency meter
 - Synchronoscope
 - Indicative lamp of permission by relay 25 for circuit-breaker closing
 - Closing push button to the circuit breaker
 - Frequency control switch
 - Voltage control switch (one dial for each STG)
- 6.4.6 PAS shall send and receive hardwired signals to/from Control and Safety System (CSS) according to the specific project's "AUTOMATION INTERFACE OF PACKAGED UNITS" as stated in the DOCUMENT LIST.
- 6.4.7 PAS shall send and receive hardwired signals to/from Electrical System according to I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.
- 6.4.8 PAS shall have high reliability, integrity, and availability for operation in fail safe mode to avoid, whenever possible, unnecessary shutdowns or loss of any process variable with safety function.
- 6.4.9 PAS shall include on-line testing and self-diagnosis facilities so as to allow the maintenance technician to identify failures, enabling corrective maintenance without causing unit shutdown and avoiding operation without any safety function.
- 6.4.10 In case of power failure, system shall retain all programs and data as well as interface software for a minimum of six months, not being necessary to reconfigure the system after power restore. During a power failure, all outputs shall be automatically changed to their safe position.
- 6.4.11 There shall be assured the synchronism between all TGCP's of the system. Generators protection relays also shall be synchronized together with TGCP's according to and I-ET-3010.00-5140-797-P4X-001 ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE and I-DE-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE DIAGRAM. The synchronism must be integrated to CSS (Control and Safety System) clock.



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- 6.4.12 Connectivity to external system through open communication protocols shall be MODBUS and OPC UA by Ethernet TPC/IP Protocol. All I/O digital/analogic variables, alarms and trips, controllers' signals and parameters and events including first out shall be available. A full list of available signals, parameters and events shall be provided to PETROBRAS.
- 6.4.13 Apart from the driver controls and monitoring devices, PAS shall house flush mounted panel meters for generator current, frequency, voltage, kW, kVAr, power factor and AVR voltage and current.
- 6.4.14 The philosophy for integrating this panel into the control and operation systems of its installation site is defined at the specific project's documents stated in the DOCUMENT LIST: "AUTOMATION INTERFACE OF PACKAGE UNITS" and "AUTOMATION AND CONTROL ARCHITECTURE", as well as at I-ET-3010.00-1200-800-P4X-002 - AUTOMATION, CONTROL AND INSTRUMENTATION ON PACKAGED UNITS, I-DE-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE DIAGRAM, I-ET-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE, I-ET-3010.00-5140-700-P4X-004 - PN-5140001 - POWER MANAGEMENT SYSTEM (PMS) FOR OFFSHORE UNITS, I-DE-3010.00-5140-797-P4X-002 - ELECTRICAL SYSTEM AUTOMATION TYPICAL ACTUATION DIAGRAMS AND I-LI-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.
- 6.4.15 The closing of circuit-breaker shall be supervised by synchronism check relay, which shall verify if suitable synchronizing conditions are satisfied, and shall permit the circuit-breaker closing either by the operator, via TGCPs or via PMS.
- 6.4.16 TGCP shall receive a resumed signal "13.8KV not in fault" to allow the turbogenerator starting. This interface signal shall be listed in I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.
- 6.4.17 Synchronization to the respective bus of main switchgear panel (PN-5143001) shall be controlled from TGCP; an auto-synchronizing device shall match the speed/phase angle of the oncoming generator with the bus of PN-5143001 (which can be a dead bus).
- 6.4.18 At synchronization of speed, phase angle and with voltage difference within tolerances, the generator shall be connected to the bus automatically. Manual synchronization of a generator shall be possible; speed and phase angle shall be monitored at the package generator control panel synchronous scope.
- 6.4.19 TGCP shall house generator electrical protection relay (including differential protection) and others dedicated protections such as diode failure protection, loss of excitation protection, rotor earth fault protection, generator winding and bearing temperature monitoring, CACW heat exchanger cooling water leakage detection, cooling air temperature monitoring and generator bearing vibration monitoring. Generator protection shall comply with I-ET-3010.00-5143-700-P4X-001 – ELECTRICAL SYSTEM PROTECTION CRITERIA.
- 6.4.20 In case of UAS signal from PMS, TGCP shall commutate to LOCAL mode operation. These signals shall be sent to TGCP by electrical system controllers.
- 6.4.21 TGCP shall be an autonomous control and only be submitted to PMS control in PMS mode (REMOTE). In LOCAL mode, TGCP shall be able to function autonomous fulfilling its designed operational functions allowing turbogenerator stop, start and adjustments.
- 6.4.22 The TGCP shall be provided with a LOCAL/PMS enable selector switch. In local position, the generator's TGCP shall control the speed and voltage. In PMS position, the PMS (REMOTE) shall control the speed and voltage.



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- 6.4.23 AVR and fuel controls of each generator shall be located at TGCP.
- 6.4.24 For a generator set, the PAS shall enable the turbine generator set to operate in isolated, base load, isochronous mode (which shall establish 60 cycle power), or in load following, load sharing droop mode, synchronized to the base load unit.
- 6.4.25 The PAS shall be suitable for controlling during automatic and manual synchronization of the generator, and automatic load sharing during parallel operation with other turbine driven equipment.
- 6.4.26 The metering voltage and current for the PAS and AVR are provided via the Main Switchgear PN-5143001 metering VT's and CT's. The AVR parallel operation CT, earth fault VT and differential CT's are located in the generator terminal box.
- 6.4.27 External supply for power, control, lighting and heating of PAS shall comply with I-ET-3010.00-5140-700-P4X-003 - ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS, including autonomy time, in case of systems supplied from UPS. Manufacture shall include any necessary voltage converters in case of necessity of different values. Deviations shall be submitted to PETROBRAS approval.
- 6.4.28 Optical converters shall be provided for external network communications for each TGCP panel. Optical fiber communications cables shall be also provide for communicating the different control modules.
- 6.4.29 The PAS interface with AMS shall be as described in the specific project's "AUTOMATION INTERFACE OF PACKAGE UNITS" as stated in the DOCUMENT LIST.

6.5 Human Machine Interface of TGCP (TGCP_HMI)

- 6.5.1 TGCP_HMI shall allow the operator to view and acknowledge alarms and trips, protections reset, status of each I/O and intermediate variables, software monitoring/modification, system configuring, first-out of alarms and shutdowns, list of set points and parameters, analog variables, variables performance and trend, recording of all relevant data and periodic reports, events, number of starts and operation hours, I/O forcing, by-pass of inputs and override of outputs.
- 6.5.2 Generator data shall be displayed on the TGCP_HMI (Human Machine Interface of TGCP), as both numeric and bar graph data. A selected part of the available data shall be available for monitoring at the CCR, via a data link connected to the Unit CSS (via Package Ethernet Switches) – as shown in I-DE-3010.00-5140-797-P4X-001 ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE DIAGRAM.
- 6.5.3 TGCP_HMI shall comply, at least, with the following requirements:
- Industrial microcomputer installed inside the panel housing
 - Remote access to HMI shall be provided for onshore access, in accordance with AUTOMATION NETWORK DESCRIPTION. Additional Ethernet network card shall be available for package LAN, if necessary (remote access shall be password protected)
 - Read and write access to removable data storage devices shall be disabled (enabling this access shall be possible with password protection)
 - HMI screen shall be on front door of the panel. Minimum 20-inch widescreen LCD color touch screen display
 - The CPU of HMI shall be independent from the display screen of HMI
 - Historical log:



- a. Daily files - Recording and storing of all digital and analog variables, alarms and events of PAS system with 1 second sample time. Storage shall be at least 72 files (24 days x 3 months)
- b. Hourly files - Recording and storing, in high speed (minimum sample time shall be less than 40 milliseconds), of all analog and digital variables, alarms and events of PAS system. Storage shall be at least 72 files (24 hours x 3 days)
- Event and trigger log:
 - a. Storing all variables in the minimum sample time (less than 40 milliseconds) during 15 minutes, 10 minutes before and 05 minutos after the programmable event/trigger. Storing at least 150 files per programmable event/trigger
 - b. All events and all analog/digital variables (trigger is reaching a preset value) shall be programmable to start storage. ESD or Normal Stop events shall already be programmable in TGCP_HMI to start storage
- Trend with capable of playback any stored variables and showing a set of minimum 12 variables at the same time
- Capable of export of stored variables logs in the CSV standard (data separated by semicolon)
- Listing in chronological order of all alarms, trips and events user-defined actions with PLC timestamps with milliseconds time resolution. The message of first trip of SD sequence shall be emphasized
- PI&Ds of auxiliary systems with all variables
- Display of equipment schematic layout with all variables from Machinery Protection System

6.5.4 PACKAGER shall provide TGCP_HMI supervisory software (runtime and development tool) running on Windows environment, compatible with the size of the application and in its latest version (preferably at 64 bits). Software shall be supplied, installed, configured in the TGCP_HMI and provided with complete manuals / electronic media. Software licenses shall also be provided.

6.5.5 Access to configuration and programming shall be protected by change management tools, including specific passwords with several levels, such as: general, operation, maintenance and engineering. All passwords shall be delivered to PETROBRAS with NO access restrictions.

6.5.6 If, for any reason, TGCP_HMI have some malfunction, the control system shall continue with all its function normally. PACKAGER shall provide a hardware interface (such as a laptop computer connection) in order to establish an external communication with PLC.

6.5.7 English and Brazilian Portuguese languages shall be used on all HMI screens installed on TGCP.

6.5.8 All Data (historical trend, event and trigger and alarm and trip logs) shall be synchronized among all HMIs. All PLCs, HMIs, MPS shall be synchronized. Time synchronism shall be sent from Time Servers, see the specific project's "AUTOMATION NETWORK DESCRIPTION" as stated in the DOCUMENT LIST.

6.5.9 TGCP_HMI software shall be compatible with OSI "Plant Information-PI" software.

6.6 Machinery Protection System

6.6.1 Machinery Protection System (MPS) shall be in accordance with the API Std 670 latest revision.

6.6.2 Probe arrangement for driven equipment, gearbox and driver:

- Radial vibration: Two (2) non-contact probes for each radial bearing (X-Y signal);
- Axial position: Two (2) non-contact probes for each axial bearing. For gearbox an arrangement with two (2) probes on low speed shaft;
- Phase: One (1) phase reference transducer for every different shaft speed;
- Casing vibration: Two (2) accelerometers for gearbox casing (one (1) over the input and one (1) over the output shaft centerline, near radial bearings); two (2) accelerometers for electric generator (one (1) for each bearing housing).

6.6.3 Probes shall allow gap adjustment.

6.6.4 All hydrodynamic radial bearings shall be fitted with two embedded bearing metal temperature sensors. All hydrodynamic thrust bearings shall be fitted with two temperature sensors at the active side and two temperature sensors at inactive side. All bearing temperatures shall be directly connected to MPS rack.

6.6.5 Each monitor channel shall be capable of continuously comparing the input signal to warning set points. The warning system shall comprise at least two (2) levels: alarm and shutdown. The exception is axial position monitor, for which shall be supplied with four (4) independent alarms and shutdown adjustable limits (two (2) for each direction).

6.6.6 The vibration signals (including displacement and accelerometers) of the whole train shall have an unfiltered output at the TGCP (one per channel) for recording and maintenance purposes.

6.6.7 Each channel shall be supplied with an electronic configurable time delay to avoid activation of alarm during transient signals.

6.6.8 All wiring shall be protected by flexible conduits to a stainless steel AISI 316L junction box (at skid edge), neatly routed to allow machine maintenance without damaging probes and wire leads.

6.6.9 Extension cables shall be armored and installed on cable trays.

6.6.10 Oscillator-demodulators shall be mounted in an intrinsically safe junction box, if applicable.

6.6.11 A controlled access set point multiplier function shall be provided with actuation by an external contact closure with causes the alarm (alert) and shut down (danger) set points to be increase by integer multiple.

6.6.12 All vibration signals channels shall be allocated at the same MPS monitor of the corresponding phase reference signal channel.


6.6.13 MPS x MMS interface shall not use internal control panel switches. MPS shall be connected directly to MMS panel.

6.7 Machinery Monitoring System (MMS)

6.7.1 The MMS (provided by PURCHASER) shall be designed in according to the requirements described in the items below and in the specification I-ET-3010.00-5500-854-P4X-001 – MACHINERY MONITORING SYSTEM.

6.7.2 Besides the control and supervisory TGCP system, Machinery Protection System shall be integrated in the Machinery Monitoring System (MMS) of the FPSO, provided by PURSHASER, for maintenance purposes. PACKAGER shall provide interface cards installed in the Machinery Protection System to allow the interconnection with the MMS (software and hardware). All vibration signals (including displacement and accelerometers) shall be available with buffer signal output.

6.7.3 All signals from MPS monitoring cards shall be available to send data to MMS.

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- 6.7.4 In addition to the signal available through the MPS Communication Card, PACKAGER shall make available the required process variable signals presented in the I-ET-3010.00-5500.854-P4X-001 – MACHINERY MONITORING SYSTEM (MMS), through the Package Fast Ethernet Network to perform the functions above in the Machinery Monitoring System.
- 6.7.5 Packager shall provide all documentation of vibration signals and configuration files of the Machinery Protection System to be implemented by the MMS Supplier for Monitoring System configuration.



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- 7.1 Electrical synchronous generator and its auxiliary systems that compose this package shall comply with requirements of I-ET-3010.00-5147-711-P4X-001 - MAIN GENERATOR FOR OFFSHORE UNITS.
- 7.2 Excitation system for electrical generator shall comply with I-ET-3010.00-5140-775-P4X-001-REQUIREMENTS FOR ELECTRICAL GENERATION EXCITATION SYSTEM FOR OFFSHORE UNITS.
- 7.3 Panels, Electrical equipment and materials shall comply with requirements of:
- I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL FOR OFFSHORE UNITS.
 - I-ET-3010.00-5140-700-P4X-007 - SPECIFICATION FOR GENERIC ELECTRICAL EQUIPMENT FOR OFFSHORE UNITS
 - I-ET-3010.00-5140-700-P4X-008 - SPECIFICATION FOR LIGHTING AND ELECTRICAL SIGNALLING FOR OFFSHORE UNITS
 - I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS
 - I-ET-3010.00-5140-713-P4X-001 - SPECIFICATION FOR TRANSFORMERS FOR OFFSHORE UNITS
 - I-ET-3010.00-5140-741-P4X-004 - SPECIFICATION FOR LOW-VOLTAGE GENERIC ELECTRICAL PANELS FOR OFFSHORE UNITS
 - I-ET-3010.00-5140-772-P4X-002 - SPECIFICATION FOR LOW-VOLTAGE FREQUENCY CONVERTERS, SOFTSTARTERS AND INVERTERS FOR OFFSHORE UNITS
 - I-ET-3010.00-5140-714-P4X-001 - SPECIFICATION FOR ELECTRICAL BATTERIES FOR OFFSHORE UNITS
 - I-ET-3010.00-5140-773-P4X-002 - SPECIFICATION FOR GENERIC D.C. UPS FOR OFFSHORE UNITS
- 7.4 Electrical installations inside the package and the voltages to be supplied for electrical loads (motors, heaters, control panels, etc.) shall comply with requirements of I-ET-3010.00-5140-700-P4X-003 - ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS.
- 7.5 Electrical motors shall comply with requirements of I-ET-3010.00-5140-712-P4X-001 - LOW-VOLTAGE INDUCTION MOTORS FOR OFFSHORE UNITS. The electrical motors shall be fed from platform panels.
- 7.6 The electrical communications interfaces of the package shall comply with requirements of I-DE-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE DIAGRAM, I-ET-3010.00-5140-797-P4X-001 –ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE, I-DE-3010.00-5140-797-P4X-002 - ELECTRICAL SYSTEM AUTOMATION TYPICAL ACTUATION DIAGRAMS and I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.
- 7.7 Equipment, accessories, piping and structures shall be grounded according to requirements of I-DE-3010.00-5140-700-P4X-003 - GROUNDING INSTALLATION TYPICAL DETAILS, I-ET-3010.00-5140-700-P4X-001 – SPECIFICATION FOR ELECYTRICAL DESIGN FOR OFFSHORE UNITS, IEC 61892-6 and IEC-60092-502. Besides these standards, for installations in hazardous area, the grounding requirements of IEC 61892-7 shall be complied with.
- 7.8 All electrical panel shall comply with I-ET-3010.00-5140-700-P4X-005 - REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS.


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- 7.9 The PACKAGER shall provide accumulator batteries and battery chargers for all continuous and intermittent loads (e.g. emergency oil pump, jacking oil pump and turning gear) that shall be fed during STG coastdown and cooldown periods in case of blackouts due to emergency shutdown. For further details, refer to the requirements stated in *I-ET-3010.2Q-5100-940-P4X-001 – Combined Cycle Power Plant Package*.
- 7.10 The excitation system shall comply with I-ET-3010.00-5140-775-P4X-001 - REQUIREMENTS FOR ELECTRICAL GENERATION EXCITATION SYSTEM FOR OFFSHORE UNITS.

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8. OPERATION AND MAINTENANCE REQUIREMENTS

- 8.1 PACKAGER and PURCHASER shall make the applicable recommendations to optimize operation and maintenance, considering the remote location and platform general conditions. Any changes to equipment design, materials or specific spares (as per applicable Contract Exhibits) that may improve the equipment operability, availability or reliability shall be prior submitted to PETROBRAS for review and approval. PACKAGER and PURCHASER shall always comply with PETROBRAS requirements before suggesting any modification.
- 8.2 The steam turbogenerator set shall be designed so that all maintenance tasks can be performed with standard tools as much as possible. If required, special tools and devices shall be provided by the PACKAGER in accordance with the following requirements:
- 8.2.1 Spreader beams or other special lifting devices required for installation or maintenance shall be provided by the PACKAGER.
- 8.2.2 Borescope, strobe light and camera required for visual inspection of turbomachinery internals shall be considered as special tools, whenever they are of special design and are not commercially available catalog items.
- 8.2.3 Special tools shall be packaged in separate storage containers, rugged metal boxes, and shall be marked "special tools for (tag/item number)". Each tool and respective container / toolbox shall be stamped or tagged to indicate the contents and use.
- 8.3 Equipment layout shall enable easy and safe access for maintenance to all components and parts. PACKAGER and PURCHASER shall provide suitable lighting, walkways, ladders and handrails inside the skids and inside the module, for all packages, including auxiliaries. All equipment and peripherals, especially oil reservoirs, shall have full access and inspection doors / hatches.
- 8.4 Instruments and piping accessories shall be arranged in proper location in order to allow easy access by maintenance and operation personnel. Installation of piping and cable supports next to couplings, bearings and seals shall be avoided, for instance.
- 8.5 PACKAGER and PURCHASER shall prepare detailed assembly, disassembly and maintenance procedures, describing the use of all involved lifting apparatus and including all required preventive and corrective maintenance tasks. PACKAGER and PURCHASER shall inform the need for disassembling any component or equipment in order to facilitate access for maintenance. Suitable maintenance routes shall be provided to remove the main components and auxiliaries, avoiding interference with structures, piping, cabling, electric conduits and supports, equipment, etc. This plan shall be submitted to PETROBRAS for approval.
- 8.6 PACKAGER and PURCHASER shall provide lifting / handling devices and external structure components enabling assembly, disassembly and removal all components inside the package (gas turbine, gearbox, electric generator rotor, generator exciter, WHRU's heat recovery coil, etc.) with adequate and certified capacity to handle maximum maintenance weight and / or dimensions. Lifting and handling devices shall be according to the specific project's "TOPSIDE'S MECHANICAL HANDLING PROCEDURES" as stated in the DOCUMENT LIST.
- 8.7 PACKAGER and PURCHASER shall provide special tools for all maintenance activities including tools for gas turbine and generator rotor assembly disassembly and removal.
- 8.8 PACKAGER and PURCHASER shall include in proposal a schedule stating the expected time between major overhauls.
- 8.9 PACKAGER and PURCHASER shall provide a gearbox shaft end with an adaptor in order to allow manual turning for maintenance purposes.

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8.10 Noise control requirements

- 8.10.1 Noise control analysis is a mandatory item to be carried out for the steam turbogenerator set and shall be a joint effort of the PACKAGER and the PURCHASER.
- 8.10.2 The steam turbogenerator set furnished by the PACKAGER shall conform to the maximum allowable sound pressure level of 85 dBA, measured at 1 (one) meter away from the equipment surfaces, including piping and auxiliary systems.
- NOTE: the SPL limit stated above refers to all operating conditions, considering that 100% load may not necessarily be the noisiest one.
- 8.10.3 The following data shall be included by the PACKAGER in the technical proposal:
- Expected values for maximum SPL per octave band for the steam turbogenerator set;
 - Sound pressure levels for each of the four main directions and at one point of the top.
- 8.10.4 If the expected SPL of the steam turbogenerator set is higher than the maximum allowable SPL above, the PACKAGER shall consider the use of removable acoustic blankets (or another suitable noise control design countermeasure), which shall be prior submitted for PETROBRAS approval.



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9. INSPECTION AND TESTING**9.1 General requirements**


- 9.1.1 The steam turbogenerator set (including auxiliary equipment and components) shall be factory inspected and tested in accordance with the applicable codes, specifications, and standards, as specified.
- 9.1.2 PETROBRAS is entitled to inspect the steam turbogenerator set at the facilities of PACKAGER or its sub-suppliers anytime during fabrication, to ensure that materials, procedures, and workmanship are in accordance with the specifications and other contractual requirements.
- 9.1.3 Inspections of materials, procedures, and equipment will be carried out by PETROBRAS or by PETROBRAS authorized representatives.
- 9.1.4 Unless otherwise specified, all witnessed tests shall be informed, at least, 90 days before the scheduled dates.
- 9.1.5 Factory acceptance tests (Mechanical Running, Performance Tests, etc.) shall be performed only after all required documents (rotordynamic analyses, test procedures, etc.) are approved by PETROBRAS.
- 9.1.6 All reports of static tests, inspections, balancing, runout, calibration of shop instruments, and any other contracted examinations, shall be made available for PETROBRAS review before factory acceptance tests are allowed to start.
- 9.1.7 Factory acceptance tests shall not be initiated without PETROBRAS' inspector be granted to visually inspect the equipment to be tested, test bed arrangement and instrumentation or any other aspect of the test bench.
- 9.1.8 Unless otherwise established by PETROBRAS inspector, all equipment shall be available for inspection in an unpainted state.
- 9.1.9 All PAS shall be functionally tested at PAS Supplier's facilities. All control sequences and shutdown logics shall be simulated and tested against the requirements. Details of PAS Supplier standard functional test procedures shall be prior submitted for PETROBRAS approval.
- 9.1.10 PETROBRAS' inspector is entitled to request inspections to ensure that the equipment complies with the relevant Classification Society requirements.
- 9.1.11 In case any defects and / or shortcomings are found, PACKAGER and PURCHASER shall bear the full cost of such inspection and replacement, as necessary. Any repair shall be prior approved by PETROBRAS. The subsequent inspection necessary to confirm the satisfactory results will be at PACKAGER and PURCHASER expenses.

9.2 Hydrostatic test (HT)

- 9.2.1 Parts being hydrottested shall be externally coated with a layer of white lead carbonate or any other suitable powder to help leakage detection.

9.3 Performance Test (PT)

- 9.3.1 The Steam Turbine shall be shop performance tested in accordance with ASME PTC-6 at full load or, if not possible due to shop facility constraints, at part load, considering in this latter case all applicable similarity conditions.
- 9.3.2 The shop performance test procedure shall be prior agreed with PETROBRAS.

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9.4 Mechanical Running Test (MRT)

- 9.4.1 A MRT shall be performed for the steam turbine in accordance with API Std 612 and Annex B. A MRT for the spare rotor, if any (as per applicable Contract Exhibits), shall also be performed.
- 9.4.2 PACKAGER shall submit to PETROBRAS digital files (storage type to be mutually agreed during detailed design) with vibration data recorded during MRT and all test information, including, at least: failed tests, with sweeping, start/stop ramps, equipment vibration signature, diagram for all bearing signals and phase angle versus speed.
- 9.4.3 MRT procedure shall be prior agreed with PETROBRAS.
- 9.4.4 Actuation / response time of shutdown systems shall be verified to prevent rotor from exceeding the required trip speed (overshooting).
- 9.4.5 Hand trip device and manual exerciser of trip mechanism shall be checked during testing. Slow running speeds are acceptable.

9.5 Sound Level Test (SLT)

- 9.5.1 The sound pressure meter shall be class I, according to IEC 61672. The characteristics of the octave filter shall be in accordance with IEC 61260. The sound pressure reading shall be made as equivalent continuous level, for 60 seconds sampling time. The recorded values shall be corrected to the nearest entire value within 1dB. A maximum deviation of 2dB will be allowed, both for the A scale weighted value and for the octave bands between 31.5 Hz and 8000 Hz.
- 9.5.2 The procedures for sound measurement assume a condition of free field over reflecting floor. This implies that the tests will be preferably performed in an outside area, with a smooth floor made of concrete, asphalt, etc. If this condition is not satisfied, then the correction for measurements in rooms shall be applied.
- 9.5.3 If the difference between the background noise level and the equipment sound level plus the background is less than 10dB, the measurements shall be corrected.
- 9.5.4 If normal operating condition cannot be reached at test bench, PACKAGER, PETROBRAS and PURCHASER shall agree with measurements, procedure and values to be used during the test.
- 9.5.5 If the values measured and reported during the shop test are higher than the limits submitted by PACKAGER and approved by PETROBRAS in proposal, PACKAGER and PURCHASER shall provide, without extra cost, sound attenuation methods in order to reach this limit, if required by PETROBRAS.
- 9.5.6 SLT procedure shall be prior agreed with PETROBRAS.

9.6 Factory Integrated Test (FIT)

- 9.6.1 PACKAGER shall perform a shop Factory Integrated Test (FIT) for the steam turbogenerator set. FIT shall be a functional test including the following contract parts, at least: steam turbine, gearbox, electric generator, PAS, lube and control oil system, and gland sealing system.
- 9.6.2 The FIT procedure, with the steps and duration, shall be similar to MRT. Vibration requirements (limits, acceptance, etc.) shall be the same used for MRT.
- 9.6.3 Generators shall be tested according to electrical standards references as described in I-ET-3010.00-5147-711-P4X-001 – MAIN GENERATORS FOR OFFSHORE UNITS.
- 9.6.4 Control check shall be done during FIT as part of functional test.



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9.6.5 FIT shall include a load step test and rejection charge test. Steps shall be prior agreed with PETROBRAS.

- The Voltage Regulation limits, in continuous and transitory test conditions shall comply with:
 - Steady-state: $\pm 2.5\%$ ⁽¹⁾ ⁽²⁾
 - Transient: -15% to $+20\%$ ⁽¹⁾ ⁽³⁾
 - Transient recovered voltage: $\pm 2.5\%$ ⁽¹⁾ ⁽³⁾
 - Maximum transient recovery time: 1.5s ⁽¹⁾ ⁽³⁾
- The Frequency Regulation limits, in continuous and transient test conditions shall comply with:
 - Steady-state: $\pm 2.5\%$ ⁽⁴⁾ ⁽²⁾
 - Transient: $\pm 10\%$ ⁽⁴⁾ ⁽³⁾
 - Transient recovery frequency: $\pm 2.5\%$ ⁽⁴⁾ ⁽³⁾
 - Transient maximum recovery time: 3s ⁽¹⁾ ⁽³⁾

Notes:

- (1) related to rated voltage (IEC 61892-3);
- (2) for all loads from zero to rated load at rated power factor (IEC 61892-3);
- (3) for transient load with the following steps;
- (4) related to rated frequency (IEC 61892-3).

9.6.6 PACKAGER shall indicate any problem to perform testing with nominal frequency or voltage.

9.6.7 FIT procedure shall be prior agreed with PETROBRAS.

9.7 Shipyard Acceptance Test (SYAT)

9.7.1 Shipyard Acceptance Test (SYAT) is a functional test of the complete steam turbogenerator set to be performed on the shipyard.

9.7.2 Shipyard Acceptance Test (SYAT) shall be performed after the steam turbogenerator set is fully commissioned and completely integrated with all systems of FPSO that support the operation of the main generation system.

9.7.3 PURCHASER shall provide all facilities, support, and technical procedures to execute a SYAT. PACKAGER shall provide technical assistance for all SYAT.

9.7.4 SYAT shall be performed as an integral part of the Combined Cycle Integrated Test specified in I-MD-3010.2Q-1200-970-P4X-001 – COMMISSIONING DESCRIPTIVE MEMORANDUM.

9.7.5 SYAT procedure shall be prior agreed with PETROBRAS.

9.8 Site Acceptance Test (SAT)

9.8.1 Site Acceptance Test (SAT) is an offshore acceptance test of the steam turbogenerator set to be performed at FPSO final location.

9.8.2 SAT shall be performed in accordance with ASME PTC 6 and Annex A (Rotating Equipment Reliability Test), as an integral part of the Offshore Combined Cycle Integrated Test specified in I-MD-3010.2Q-1200-970-P4X-001 – COMMISSIONING DESCRIPTIVE MEMORANDUM.

9.8.3 SAT procedure shall be prior agreed with PETROBRAS. Results shall be submitted for Classification Society and PETROBRAS final approval.



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10. ANNEXES

10.1 Annex A: Rotating Equipment Reliability Test



10.2 Annex B: PETROBRAS Overlay Specification for API Std 612 - Offshore Applications

