PETROBRAS	TECHNICAL SPECIFICATION	Nº: I-ET-3010.00-5147-332-P4X-001	
	CLIENT: SRGE		SHEET: 1 of 39
	JOB: -		
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SRGE	TITLE: TECHNICAL SPECIFICATION - GAS TURBINE DRIVER FOR GAS TURBOGENERATOR SET		INTERNAL
			ESUP

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FORM OWNED TO PETROBRAS N-0381 REV.L.

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1. DEFINITIONS AND ABBREVIATIONS

1.1 DEFINITIONS:

PETROBRAS	FPSO contracting and operating company.
PACKAGER	Company responsible for project, assembly, construction, fabrication and test of main equipment, and project, assembly, integration, tests and furnishing of all other equipment in the skid, including the auxiliaries systems.
PURCHASER	EPC company responsible for project, assembly, erection, construction, fabrication, test and furnishing, lift, hook up, installation and integration of all Modules of FPSO, with complete and fully operative systems in accordance with the requirements of this specification, codes and standards referenced therein. PURCHASER matches Module Supplier, Bidder, Integrator and Automation Integrator from I-ET-3010.00-1200-940-P4X-002.
VENDOR	Company hired by the purchaser or packager to supply of equipment, components of equipment, instruments, control systems, etc. that will be part of the main system to be supplied.

1.2 ABBREVIATIONS:

AEPR	Automation & Electrical Panels Room
AMS	Asset Management System
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASV	Antisurge Valve
AVM	Anti-Vibration Mounting.
BDV	Blow Down Valve
CCR	Central Control Room (located in the Hull Accommodation)
CCR-ATR	Central Control Room – Automation and Turbomachinery Room
CGS	Compressor Governor System
CGS_HMI	Human Machine Interface for Compressor Governor System
CSS	Control and Safety System
Cv	Coefficient flow valve
DGS	Dry Gas Seal
DIO	Optical Internal Distributor
ESD	Emergency shutdown
FAT	Factory Acceptance Test
FGS	Fire and Gas System
FIT	Factory Integrated Test
FPSO	Floating Production Storage and Off-loading
FPU	Floating Production Unit

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FST	Factory Stability Test
GCPR	Generator Control Panels Room
HMI	Human Machine Interface
HVSD	Hydraulic Variable Speed Drive
IGCR	Inert Gas Compressor Running
I/O	Input/Output
LAN	Local Area Network
MCC	Motor Control Center
MMS	Machinery Monitoring System
MPA	Automatized Procedures Module (Portuguese: Módulo de Procedimentos Automatizados)
MPS	Machinery Protection System
MRT	Mechanical Running Test
OPC UA	Open Platform Communications Unified Architecture
PAS	Package Automation System
PCP	Package Control Panel
PCS	Process Control System
PLC	Programmable Logic Controller
PMS	Power Management System
PSD	Process Shutdown System
PSV	Pressure Safety Valves
PCV	Pressure Control Valves
PDCV	Pressure Differential Control Valve
P&ID	Piping and Instrument Diagram
RESD	Emergency Shutdown Relay
RFI	Radio Frequency Interference
RIO	Remote I/O Panel
SAT	Site Acceptance Test
SDV	Shut Down Valve
SGCS	Seal Gas Conditioning System
SGP	Seal Gas Panel
SLT	Sound Level Test
SIT	Site Integration Test
SOS	Supervision and Operation System
SYAT	Shipyard Acceptance Test
TAP	Performance Acceptance Test
TCP/IP	Transmission Control Protocol/Internet Protocol
TGCP	Turbogenerator Control Panel
TGCP_HMI	Human Machine Interface for Unit Control Panel
UCP	Unit Control Panel

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UCP_HMI	Human Machine Interface for Unit Control Panel
WHRU	Waste Heat Recovery Unit

2. GENERAL

2.1. Gas turbine for Turbogenerator package units shall be in accordance with API std 616, last edition.

2.2. The complete Turbogenerator package shall be designed for minimum 30 years of operation installed on a fixed platform or on the FPSO (Floating Production Storage and Off-loading).

2.3. All documents listed in Material Requisition and specific project's "TURBOGENERATOR PACKAGE SPECIFICATION", as stated in the DOCUMENT LIST, are mandatory. All requirements for Turbogenerator package are described in these documents.

2.4. All components of the system shall be suitable for offshore environment, throughout the whole platform service life, under all operational conditions and submitted to Unit motions and accelerations described in PETROBRAS specifications.

2.5. PACKAGER and PURCHASER shall be entirely responsible for material selection on 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 applicable ASTM standard.

2.6. All shop punch lists shall be cleared before shipment.

2.7. Equipment shall be prepared for outdoor storage according to PURCHASER specifications.

2.8. PACKAGER and PURCHASER shall specify the products to be used for preservation of the equipment components and spare parts, 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.

2.9. Hazardous and toxic materials with associated adverse health effects shall be avoided or minimized. PACKAGER, PURCHASER and VENDOR 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, PURCHASER and VENDOR 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.

2.10. 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;
- Specific data;
- Tag number;

- Client area;
- Supplier name;
- Series number and model;
- Year of manufacturing;
- Main design and test data: pressure, temperature, voltage, rotation, etc;
- Purchaser's requisition number (RM);
- Purchaser's request for quotation number (RFQ);
- Purchaser's order number (PO);
- Empty weight;
- Design code.

2.11. All safety signals shall be in Portuguese language.

3. CONSTRUCTION FEATURES

3.1 The gas turbine shall be standard combustor aero-derivative type and gas/liquid fuel configuration. The gas turbine shall be supplied complete with protective bag and transportation stand.

3.2 For continuous running duty basis, the gas turbine shall be capable of driving electrical generator at site rated conditions, including typical losses (mechanical, auxiliaries, inlet and exhaust losses, ageing and fouling) at the end of the life cycle. Site rated conditions for the gas turbine performance design shall be considered as 30°C ambient temperature, sea level and offshore tropical environment (80% relative humidity).

3.3 Turbogenerator to be installed in a safe area. If not indicated in other specific project document, fresh cooling water temperature available is 35 ºC, maximum outlet temperature 55 ºC and ambient temperature: 14 ºC minimum/25 ºC mean/35 ºC maximum.

3.4 The Mean Time Between Overhauls (MTBO) shall be, at least, 24000 equivalent operating hours (EHO) on gas fuel. No major parts disassembly will be accepted for inspection or replacement before the referred period of continuous operation. No components with service life lower than 24000 EHO will be accepted.

3.5 Gas Turbine ignition system shall not have radioactive components.

3.6 Gas turbine design shall enable borescope inspection of hot gas path and blading, fitted with dedicated plugged holes at the combustion chambers, transition pieces, first and last stage of air compressor, gas generator and power turbine

3.7 The gas turbine shall be able to restart at any time after an indeterminate period of time with no auxiliary AC power. PACKAGER shall provide all auxiliary systems located within PACKAGER limits, to comply with this requirement and submit them to the PURCHASER in clarification phase, before proposal phase. PURCHASER will not guarantee any facility during time without AC power. See also 4.6.13, 4.6.14 and 4.10.9.

3.8 Devices to sample collection shall be foreseen for analysis of exhaust gases emissions from the gas turbine.

3.9 All bearings shall be designed to minimize oil foaming and prevent whirl at any operating speed.

3.10 The turbogenerator centerline shall be oriented in the fore/aft direction in case of installed on a FPSO (Floating Production Storage and Off-loading).

3.11 The highest bearing (hydrodynamic tilting pads type) surface metal temperature shall not exceed 100 ºC (212 ºF) at any operating condition.

3.12 PACKAGER and PURCHASER shall guarantee air for seal and cooling systems to gas turbine during black shutdown. Complete high pressure air or nitrogen storage system including intensifier is acceptable by means to be defined by PURCHASER (air or nitrogen bottles or pressure vessel.

4. ACCESSORIES AND AUXILIARIES

4.1 Piping

4.1.1 Except where indicated, all piping and accessories within equipment package limit shall be in accordance with PACKAGER piping specification and international standards.

4.1.2 All auxiliary piping requiring field connections shall be brought to the skid edge and shall be flanged.

4.1.3 Manual block valves and spectacle/blind flanges shall be provided at all battery limits such as inlet and outlet nozzles, drain lines, etc. PACKAGER and PURCHASER consider piping standards per each specific project's "PIPING SPECIFICATION FOR TOPSIDES" as stated in the DOCUMENT LIST. Manual valves shall be installed at the skid edge to be operated. Access to all manual valves shall be free.

4.1.4 All equipment shall have sufficient flexibility in all pipe and duct connections.

4.1.5 The interconnecting pipework between auxiliary skid and the main baseplate shall be provided by PURCHASER. The interconnections between the gas lines shall be routed above the skids. Drainage shall occur in all lower parts of the piping regardless of FPSO motion under all operational conditions and submitted to Unit motions and accelerations described in PETROBRAS specifications

4.1.6 Systems/equipment isolation shall comply with Isolation Guidelines requirements from specific project's document "DESCRIPTIVE MEMORANDUM – PROCESS".

4.2 Couplings and coupling guards

4.2.1 PACKAGER is responsible for all couplings within the package, including those for auxiliary equipment.

4.2.2 Coupling for main equipment shall be a stainless-steel flexible-element, non-lubricated type.

4.2.3 Couplings and coupling guards shall be according to API 671 latest edition. PACKAGER shall submit to PETROBRAS main equipment coupling data sheet according to API 671 last edition.

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4.2.4 All coupling guards (including those for auxiliary equipment) shall be rigid, fully enclosed, in non-sparking material and solely fitted to equipment baseplates, not fastened. Safety coupling guards (without feet) are also acceptable. In case of failure, guards shall be able to retain broken parts, for personnel protection (OHSA 1910.219 shall be complied). 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.

4.2.5 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.

4.3 Baseplate

4.3.1 Main baseplate shall be capable of supporting the stresses arising from platform motions and shall be provided with three (3) point supports and Anti-Vibration Mounting (AVM).

4.3.2 Baseplate shall be rigid enough to avoid permanent distortion during lifting, shipment and operation. When the baseplate is lifted, with all equipment mounted, beam deflection shall not exceed L/400 (L is the total baseplate length).

4.3.3 Driver, driven machine, transmission, oil system and local panel shall be mounted on a single baseplate including auxiliaries. PACKAGER and PURCHASER shall submit layout to PETROBRAS comments and approval.

4.3.4 Baseplate shall be provided with nonskid covering all walking and work area. Solid decking plate shall be removable where required for maintenance.

4.3.5 All furnished skids shall be sufficiently stiff to withstand all vibration loads induced by the equipment and transfer them to the deck beams.

4.3.6 Skid mounted assemblies shall be constructed in order to avoid equipment or parts dismounting during lifting.

4.3.7 No equipment / component shall protrude beyond the skid limits. In cases where it cannot be avoided, required protection against mechanical damage shall be provided.

4.3.8 Each skid shall be provided with facilities (pad-eyes, lugs, bollards and spreader bar) for lifting, having suitable access for rigging. The estimated lifting load and safety factor for each point shall be informed in PURCHASER proposal. Main lifting points shall not be welded to the beam flange, unless the strength level is low enough or if the beam flange has a suitable thickness.

4.3.9 All equipment to be mounted on skids shall allow on-field leveling and alignment using jacking screws (in both plane directions) and precision type shims. Total shim thickness shall not exceed 6.35mm and the number of shims shall be kept to a minimum. Any additional height shall be made up of solid stainless-steel plate.

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4.3.10 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 motion.

4.3.11 Fasteners (including washers) and shims shall be constructed in stainless steel AISI 316L.

4.4 Support system

4.4.1 All required supporting 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 PACKAGER and PUCHASER.

4.5 Insulation

4.5.1 All required insulation for personnel protection or machine thermal efficiency shall be applied and provided by PACKAGER.

4.5.2 Insulating shall ensure a temperature below 60˚C over the external surface for personnel protection.

4.5.3 To prevent corrosion under insulation, only non-hygroscopic insulation material shall be used.

4.5.4 In order to avoid damages during transportation and erection, insulation shall be carried out after final installation before sail away.

4.6 Oil system

4.6.1 The synthetic lube oil system shall be designed per API 614 for special purpose applications (latest edition) to supply lube oil and control oil to gas generator and power turbine (if applicable).

4.6.2 The mineral lube oil system shall be designed per API 614 for special purpose applications (latest edition) to supply lubricating oil to the power turbine (if applicable), gearbox and driven equipment.

4.6.3 Each turbogenerator train shall have its oil systems and shall be installed on the main baseplate. Special considerations shall be given to the FPSO motion in order to guarantee bearing lube and its oil drainage during normal operation and post-lube.

4.6.4 Special consideration shall be given to the presence of dirt, debris and any foreign matter in sensitive parts (bearings, for instance). Provisions shall be made for by-pass of sensitive parts while system flushing operations are performed.

4.6.5 PACKAGER shall propose its standard oil system configuration, but the configuration of the coolers and filters shall be as Oil System Data Sheet.

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4.6.6 PACKAGER shall provide sampling points for oil analysis at reservoir, 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 enable samples taken during operation.

4.6.7 Except for oil pumps, all piping, tubing, wetted metallic parts and appurtenance including lube oil and control oil systems shall be in stainless steel AISI 316L.

4.6.8 Socket welds for piping and tubing is prohibited.

4.6.9 Reservoirs:

- Reservoir shall be provided with filling connections (with filter), level indicator sight glass, antifoaming devices, accessible manholes, valve drain at skid edge and include provisions for nitrogen purges;
- All return lines shall be top entry type, extending inlet duct inside the reservoir to below minimum operating level in order to avoid foaming;
- Reservoir shall be designed to facilitate air separation between the bearing return and pump supply;
- Vents shall be fitted with oil vapor separator in order to recover oil due to evaporation losses and environmental protection (PACKAGER shall guarantee maximal oil losses of five (5) ppm). Vents shall be dimensioned with the same size as the oil return header, at least;
- 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.

4.6.10 The expected configuration pumps are:

- Main oil pump: Shaft-driven (preferable) or electric motor driven (AC power);
- Stand-by pump: Electric motor driven (AC power);
- Main and stand-by pumps shall have the same capacity;
- If the main pump is electrically driven, then main and stand-by pumps shall be identical.

4.6.11 Oil coolers shall be multi-plate duplex with changeover valve. Cooler shall have provision for future increase of the number of plates. The cooling water pressure shall be lower than oil pressure at heat exchanger interior.

- Stainless steel AISI 316L, if closed loop cooling water system;
- Titaniun, if open loop cooling water system.

4.6.12 Oil filters shall be duplex (twin) with changeover valve. The canisters, transfer valves and piping for oil filter system shall be stainless steel AISI 316L construction. Filter element material shall be corrosion and water resistant. There shall be no by-pass around any filter.

4.6.13 Lube oil system shall have rundown tank for emergency conditions. The rundown tank shall have enough capacity for bearing cooling during cost-down time and cool-down time and shall be monitored with PACKAGER specifications and international standards for this system.

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4.6.14 DC pump (125Vdc), different voltage shall be approved by PETROBRAS, is acceptable only for cool-down time, since all accessories and auxiliaries (including accumulator batteries and batteries chargers) are provided. Accumulators batteries and batteries chargers shall be optimized for entire system and shall have full redundancy (for more information, refer to specific project's "TOPSIDES UPS AND DC SYSTEMS ONE-LINE DIAGRAM" as stated in the DOCUMENT LIST). Batteries voltage (analog signal 4-20mA) and battery bank undervoltage alarm (hardwired signal) shall be available on TGCP_HMI. In addition to the DC pump test during the starting sequence, the PAS shall perform a daily DC pump test while the TG is running, initiating an alarm in case of low discharge pressure.

4.6.15 PACKAGER shall inform all data and characteristics of electric load (as power, source, etc.) for each pump driver, heater, etc. in proposal phase. PURCHASER will furnish electrical utilities required by PACKAGER, considering platform available voltages as stated in I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS.

4.6.16 API datasheets for pumps and heat exchangers shall be included in proposal.

4.6.17 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.

4.6.18 Vent line shall be designed considering FPSO motion under all operational conditions and submitted to Unit motions and accelerations described in PETROBRAS specifications in order to avoid liquid seal.

4.6.19 PACKAGER shall provide all data of oil system equipment and fluid as oil consumption, oil complete specification and filter elements life.

4.7 Gearbox

4.7.1 If required, the speed reducing gearbox shall be double helical, single stage designed in accordance with API 613, Latest Edition to 1800 RPM nominal output speed with API 1.1 SF. It shall be included a device to allow manually rotation of the shafts for maintenance purpose (such as shaft mechanical alignment or borescope inspection).

4.7.2 Gearbox shall be designed as a "stand-alone" unit, whereby no external thrust loads shall be imposed upon the gearbox by other equipment.

4.7.3 Shaft oil seal shall be easily accessible for removal and re-installation without removing couplings.

4.7.4 All bearings shall be pressure lubricated and fully replaceable at field.

4.8 Pressure vessels

4.8.1 For nozzles less than 2" in nominal diameter, forged steel couplings may be used. Couplings shall be at least class 6000#, for socket weld.

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4.8.2 All nozzles having a nominal diameter of 2” or greater, shall be flanged, except when specified for butt weld in the piping.

4.8.3 The minimum nominal diameter of nozzles intended for any purpose shall be 3/4”.

4.8.4 Only full penetration welds are permitted.

4.8.5 All shell reinforcements, integral or not, shall always have the same shell P-number.

4.8.6 The minimum degree of radiographic examination for weld inspections according table UW-12 shall be full or spot.

4.9 Enclosure

4.9.1 Each gas turbine shall have its own enclosure and shall be stainless steel AISI 316L.

4.9.2 Enclosures shall consist of removable panels and doors supported on a heavy duty frame. The enclosure shall be fabricated and bolted so that it can be completely disassembled. Roof sections shall also be removable.

4.9.3 Enclosure shall be weather-tight.

4.9.4 Joints between panels, skid, floor, piping, ducts, cabling and shaft penetrations shall be properly sealed to prevent noise propagation, ventilation problems and for safety according to PETROBRAS requirements.

4.9.5 Enclosure shall be provided with wide full-opening side doors to allow adequate maintenance access, assembly and disassembly of all parts of the equipment, including the replacement of the complete gas generator and/or power turbine. Hinges shall be strong enough to withstand constant use and wear.

4.9.6 Enclosure doors shall be fitted with lockable handles and, in service, these doors shall be kept locked. Enclosures shall be fitted with open door alarm devices. PACKAGER shall provide anti-panic catch in order to open the doors anytime from inside. Door locations shall be clearly marked, both inside and outside the enclosure.

4.9.7 Access doors shall be fitted with viewing windows.

4.9.8 Enclosure shall be provided with inspection and internal lighting, adequate for inspection and maintenance in any area into the enclosure.

4.9.9 PACKAGER shall provide electrically driven lifting / handling devices and internal structure components enabling assembly, disassembly and removal all components inside the enclosure with adequate and certified capacity to handle maximum maintenance weight and/or dimensions.

4.9.10 Ventilation system

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- PACKAGER shall propose your standard ventilation system configuration and inform all data and characteristics of electric load (as power, source, etc.) for each fan driver. PURCHASER will furnish all electrical utilities required by PACKAGER, considering platform available voltages as in I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS;
- PACKAGER shall be responsible to furnish complete enclosure ventilation system, proper for area specification, including all ducts, inertial type vane separator (inlets), coalescent filter (inlets), fire dampers (inlets and outlets), fans, drivers and actuators;
- The enclosure ventilation shall be negative pressure type;
- At least two full-capacity (2x100%) ventilation fans shall be provided for the gas turbine enclosure. DC motors shall not be used;
- During ESD event, the ventilation fan and auxiliaries electrical loads shall be supplied by essential AC power;
- The rated electrical power of the ventilation fans shall not exceed: (a) 90 kW for 33,000 kW (site rated) gas turbine models; (b) 55 kW for other gas turbine models below 33,000 kW (site rated) capacity;
- Fan must be sized to prevent the inside enclosure temperature from exceeding 60°C;
- The air shall be filtered before reaching the fans and the enclosure. The filter of the ventilation air system shall be independent of the filter of the combustion air system. The ventilation air must not be bleed from the combustion air system filter;
- The necessary airflow rate shall be calculated and informed by PACKAGER according international standards;
- The control of the ventilation system shall be included at unit control panel.

4.9.11 Fire and gas detection and high pressure water mist fire extinguishing systems (mandatory) shall be designed in accordance with NFPA 750, IMO-SOLAS and I-ET-3010.00-5420-300-P4X-001 – FIRE PROTECTION FOR MACHINERY HOODS. The systems shall be provided complete with audible and visual warning indicators. Fire extinguishing skid may be provided loose for mounting by others. Water make-up provision and back-up nitrogen bottles shall be applied. The selection of main or back up nitrogen bottles can be carried out by manual valves.

4.9.12 No enclosure is required for gearbox and generator if the required noise level is achieved.

4.9.13 Enclosure material, bolts, fasteners, nuts, door hinges, locks, latches and ventilation system shall be stainless steel AISI 316L.

4.9.14 Fire extinguishing system shall be water mist type.

4.10 Starting system

4.10.1 The starting system shall be capable of three starts within a one hour period, at least. PACKAGER shall inform the maximum allowable number of starts per hour and the minimum interval between two consecutive starts.

4.10.2 Gas turbine starting system shall be carried out by means of an electric or electric-hydraulic motor.

4.10.3 Driver torque, power, inertia, maximum speed and all starting system requirements and control methods (including acceleration curves, temperature limits, etc.) shall be submitted to PURCHASER during proposal phase.

4.10.4 For electro-hydraulic system, hydraulic part may be mounted on a small skid immediately adjacent to the baseplate. For electric motor, all system shall be placed inside main baseplate. For electric motor and electro-hydraulic system, PACKAGER shall supply variable speed drive (VSD) to control of voltage drop and shall comply with I-ET-3010.00-5140-772-P4X-002 - SPECIFICATION FOR LOW-VOLTAGE FREQUENCY CONVERTERS, SOFTSTARTERS AND INVERTERS FOR OFFSHORE UNITS.

4.10.5 The starting system shall be semiautomatic and controlled from the unit control panel.

4.10.6 The starting system design shall allow occasional rotation of turbine after shutdown or when not in operation for sustained periods.

4.10.7 The starting sequence shall include sufficient cranking time to purge the exhaust duct system with WHRU according to API 616.

4.10.8 The starting system shall be able to support off-line cleaning procedure.

4.10.9 The gas turbine shall be capable to immediate restart at any time after a shutdown event. Forced lockout time is not acceptable. If necessary to adopt an electrical motoring motor to the gas generator, it shall be in 125 Vdc, different voltage shall be approved by PETROBRAS. All accessories and auxiliaries (including accumulator batteries and batteries chargers) shall be provided by PACKAGER. Accumulator batteries and batteries chargers shall be optimized for entire system and shall have full redundancy (for more information, refer to specific project's "TOPSIDES UPS AND DC SYSTEMS ONE-LINE DIAGRAM" as stated in the DOCUMENT LIST). Alternative solutions to the dc motor (e.g. AC motor fed by inverter systems) shall be submitted to PETROBRAS approval. All necessary means to change from DC to AC motor (including but not limited to arrangement in the electrical room, inverters, bypass switches, accessories, auxiliaries etc.) are included in the PACKAGER´s scope.

4.10.10 In case of an ignitor transformer be necessary, it shall comply with I-ET-3010.00-5140-713-P4X-001 - SPECIFICATION FOR TRANSFORMERS FOR OFFSHORE UNITS, and PACKAGER shall provide this equipment.

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4.11 Fuel system

4.11.1 The dual fuel system shall include all necessary equipment, instruments and controls for a complete, safe and operable system. Gas fuel shall be considered as default operation fuel.

4.11.2 The gas turbine shall be capable to operate continuously with high CO2 content fuel gas (25% mol) during upset conditions without hardware modification. Packager shall consider all fuel gas compositions informed in the Turbogenerator datasheet.

4.11.3 For all fuel gas range compositions lower than 25% CO2 mol content, PACKAGER shall design a fuel system capable to operate subjected to high CO2 rate change (high rate of LHV and Wobbe Index change) in order to guarantee a safe, stable and operable system.

4.11.4 PACKAGER shall confirm acceptance of fuel specified by PETROBRAS and clearly state any deviation from specifications and its consequences during the proposal phase, indicating the maximum and minimum variation in each characteristic and/or component.

4.11.5 Gas to liquid changeover shall be both manual and automatic. Liquid to gas changeover shall be manual. The system shall be capable of fuel changeover at any load condition, while maintaining constant frequency electrical output. PACKAGER shall inform, during the proposal phase, the required fuel consumption to assure the complete fuel changeover of each and all gas turbine.

4.11.6 Control system shall automatically purge trapped fuel gas in order to assure minimum allowable temperature and free-moisture before start-up.

4.11.7 Fire safe block and drain / vent valves outside the enclosure shall isolate the skid from liquid and gas fuel supply during fire shutdown. The respective valve assemblies shall be shipped loose.

4.11.8 All fuel system equipment shall be located near the turbine enclosure.

4.11.9 Gas fuel system:

- SDV (Shut Down Valve) and BDV (Blow Down Valve) outside the enclosure shall isolate the skid from gas fuel supply during fire shutdown;
- A fuel strainer upstream the connection point at enclosure. Gas filter shall be selected for maximum service life;
- Inside enclosure, a warm up vent valve, two shutoff valves, a inter shutoffs vent valve, a fuel control valve and all piping and appurtenances required by international standards, PACKAGER experience and for compliance with Classification Society's requirements;
- All piping and components for gas fuel shall be stainless steel 316L;
- In case of BDV or inter shutoffs vent valve opening during fuel gas operation, the system shall changeover to liquid fuel type.

4.11.10 Liquid fuel system:

- Inside enclosure, a three way valve, two shutoff valves, a inter shutoffs vent valve, a liquid fuel control valve and all piping and appurtenances required by international standards, PACKAGER experience and for compliance with Classification Society's requirements;
- Provisions shall be made to prevent coke formation in the liquid fuel nozzles while the engine is operating with gas fuel (demineralized water is not acceptable). PACKAGER shall submit proposed details to PETROBRAS for review and approval;
- All piping and components for liquid fuel shall be stainless steel 316L.

4.12 Gas turbine cleaning system

4.12.1 PACKAGER shall provide one combined on-line/off-line gas turbine cleaning system with mobile wash water trolley provided with lifting facilities, wheels and brakes. The cart wheels shall have proper locking device to prevent motion.

4.12.2 Equipment shall include a pressurized reservoir with filling, venting and drain connections.

4.12.3 Requirements for detergent, demineralized water and other utilities (if applicable) shall be specified by PACKAGER and submitted to PETROBRAS.

4.12.4 PACKAGER shall inform which parameters are used to define the interval (fired hours) between cleaning operations.

4.12.5 All necessary instrumentation and equipment for a complete, safe and operable cleaning system shall be provided as PACKAGER standard.

4.12.6 PACKAGER shall furnish hoses shipped loose, in accordance with PURCHASER information about distances. PURCHASER shall provide demineralized water and other utilities (if applicable) inside of module. No cart wheel outside of module is acceptable for demineralized water supply.

4.12.7 All parts in contact with water shall be in stainless steel AISI 316L, including hose assemblies.

4.12.8 One carts for each turbogenerator module shall be provided. Each cart shall have two tanks, one for the water/detergent mixture and one for pure water.

4.13 Combustion air inlet system

4.13.1 The Air Intake System shall be a kind of Low Velocity Combustion Air Inlet System (equal or less than 3.0 m/s) with steps of filtration arranged in a proper sequence of static filter elements. High velocity air filter is not acceptable

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4.13.2 Combustion air inlet system shall include, at least: rain protection with trash screen, weather protection louvers, inertial separator, coalescer/pre-filter Class M6, filter elements Class F9 and higher efficiency filter elements Class E12, air intake silencer, acoustic insulation, all duct sections, support structure, all required mounting parts, plenum chamber and expansion joint and internal AC lighting, complete with lighting switch certified for hazardous. Total pressure drop of combustion air inlet system shall not exceed 680 Pa (@ gas turbine inlet) considering filter elements clean. Differential pressure monitoring on each and overall stages on control panel.

4.13.3 The air filter system must have high efficiency to remove inlet salt water droplets and filtering dry particles from the air stream. Its shall be designed to cover all operating conditions.

4.13.4 The configuration of air filter system shall be at least:

- The zero stage shall be a rain protection with trash screen;
- The first stage is a weather protection louver shall be a kind of wall or inertial separator like vertical vanes, with salt water drainage collector and to sloped rainwater. It shall be stage-vane separator type in stainless steel AISI 316L;
- The second stage filter shall be a coalescer and pre-filter Class M6 which is pocket type prefilter. The pockets shall be self-supporting, welded and foam-sealed to frame complete with welded in spacers for mechanical strength or sewn. Class M6 according to ISO 16890/PM1 (EN 779:2012), dimensions 592 x 592 x 640 mm. The filter support racks shall be in stainless steel AISI 316L and shall be fitted with the fixing pieces and the anti-leaks gasket, moisture-resistant up to 100% relative humidity;
- The third stage shall be a fine dust high efficiency filter element, Class F9 according to ISO 16890/PM1 (EN 779:2012), dimensions 592 x 592 x 292 mm, The filter support racks shall in stainless steel AISI 316L and shall be fitted with the fixing pieces and the anti-leaks gasket, moisture-resistant up to 100% relative humidity;
- The fourth stage shall be a kind of EPA - High-Efficiency Air Filters (Class E12) according to EN 1822:2009, dimensions 592 x 592 x 292 mm. The filter support racks shall be in stainless steel, AISI 316L and shall be fitted with the fixing pieces and the anti-leaks gasket, moisture-resistant up to 100% relative humidity, larger filter surface based on construction feature vertical pleating and separators, filter media in a rigid and moulded V-CELL frame and made of Glass Fiber Paper.

4.13.5 Threaded fastenings shall be wired locked. All components downstream of the last filter shall be constructed with continuous welding and designed to withstand all forces generated at the maximum allowable air intake shutdown differential pressure.

4.13.6 All inlet air system components shall be in stainless steel AISI 316L steel. Hard points to be provided on the house for mounting to module and/or FPSO structure.

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4.13.7 Inlet plenum orientation vertical upwards. A door and internal ladders shall be provided for easy and safe personnel access to the gas turbine inlet plenum for maintenance procedures, visual inspection and cleaning.

4.14 Combustion gas exhaust system

4.14.1 All trains shall comply with requirements in order to receive a Waste Heat Recovery Unit (WHRU). PURCHASER shall submit all specification for these parts to PETROBRAS and shall comment complete exhaust system design.

4.14.2 Exhaust system shall be oriented vertically upwards including, exhaust diffuser, transition piece, expansion joint and silencer. Hard points are provided on the silencer for mounting to the module and/or FPSO structure.

4.14.3 Exhaust system vertical stack height shall be confirmed/updated later by Detail Design. However, its height cannot be less than the highest height of the adjacent modules

4.14.4 Exhaust system shall be fitted with all necessary pressure safety valve, pressure and temperature transmitters, vent and drain valves as required by PETROBRAS and according to PACKAGER and PURCHASER experience.

4.14.5 Exhaust system shall be designed for the full back pressure of the WHRU.

4.14.6 The exhaust silencer shall also incorporate lifting provisions.

4.14.7 Construction materials: stainless steel AISI 409 or 321L for silencer hot gas path; casing/ducting per manufacturer standard depending upon hot or cold casing construction. All expansion joint supports shall be in stainless steel AISI 316L.

4.14.8 Diffuser shall not use material that allow intragranular corrosion, e.g. ASTM S40910 and S40920 shall not be used.

5. AUTOMATION

5.1 General requirements

5.1.1. Package Automation System (PAS) shall supervise and control the main generation service that include turbogenerator and auxiliaries as well as its Waste Heat Recovery Unit (WHRU).

5.1.2. PACKAGER will be responsible for all required control, interlocking interface and communications architecture with the systems/process plant outside its scope of supply, in order to guarantee the proper start-up, crank/purge, warm-up, loading, automatic or manual synchronization and load sharing, normal stop and emergency shutdown sequences.

5.1.3. 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 part of Package Automation System (PAS).

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5.1.4. 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.

5.1.5. 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.

5.1.6. The PAS shall be designed according to the requirements described in these specifications I-ET-3010.00-5147-332-P4X-001 – TECHNICAL SPECIFICATION FOR TURBOGENERATOR and I-ET-3010.00-1200-800-P4X-002 - AUTOMATION, CONTROL AND INSTRUMENTATION ON PACKAGE UNITS and specifications required by international standards and Classification Society's requirements, as well as 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.

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- 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-3010.00-5420-300-P4X-001 – FIRE PROTECTION FOR MACHINERY HOODS;
- I-ET-3010.00-5500-854-P4X-001 - MACHINERY MONITORING SYSTEM;
- 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 D.C. UPS FOR OFFSHORE UNITS

5.1.7. 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

5.1.8. All instrumentation and alarms/trips mentioned in the data sheets 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.

5.1.9. PACKAGER shall supply Turbogenerator Control Panel (TGCP) and Remote I/O (RIO) panels (if any). TGCP will be installed at the Generator Control Panels Room (GCPR) and RIO (if any) will be installed in the field by PURCHASER.

5.1.10. 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.

5.1.11. 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".

5.1.12. 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.

5.1.13. 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.

5.1.14. 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.

5.1.15. 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.

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5.1.16. PAS shall not be restarted without manual acknowledgement of the shutdown conditions.

5.1.17. 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.

5.1.18. 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.).

- Note: The 30 minutes autonomy may vary in each project due to necessary autonomy to complety safe depressurizing. See project documentation for actual autonomy time.

5.1.19. 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.

5.1.20. PURCHASER and PACKAGER shall not supply any components (including hardware, firmware, software etc.) for PAS that are obsolete or that has Declaration of Obsolescence.

5.1.21. Instruments used to monitor thrust load on gas turbines shall be transmitters and not local gauges.

5.2 TGCP hardware

5.2.1 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 bellow 30 ºC. 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);
- HMI hardware (TGCP_HMI);
- Ventilation exit at the top;
- Network switchs 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;

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- 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);
- Auxiliaries devices start-up and stop push-buttons and switches (to define main and stand-by) in the HMI. Auxiliaries devices start-up and stop push-buttons and switches can also be by hardware on the panel front door;
- Sound alarm;
- Start counter and hourmeter in the panel front door. Three start counters and three hourmeters shall also be in the TGCP_HMI, one total, one for gas fuel and one for liquid fuel;
- Fire and Gas Safety System;
- Machinery Protection System (MPS);
- Interface for Machinery Monitoring System (MMS);
- Start and stop lamp status;
- TGCP and all its components shall be designed considering that GCPR temperature can reach 40ºC.

5.2.2 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.

5.2.3 Networks for control, safety and monitoring shall be segregated from each other and redundant.

5.2.4 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.

5.3 PAS software

5.3.1 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.

5.3.2 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.

5.3.3 HMI software (with runtime and development licenses) shall be provided.

5.3.4 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.

5.3.5 The control system programming shall be in accordance with PETROBRAS specification. PURCHASER proposal shall inform the programming language used in the system.

5.3.6 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).

5.4. PAS system

5.4.1. The PAS shall be capable of carrying out control, interlock, process, start-up, normal stop, emergency shutdown, normal operation and safety procedures for main machinery and auxiliary equipment (including WHRU). And also including all the necessary interfaces to connect with remote I/O (if any), 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.

5.4.2. Emergency Shutdown Relay (RESD) shall be provided to actuate directly on the fuel shutoff valves.

5.4.3. The Emergency shutdown retentive push buttons, signal form PSD (Process Shutdown System), over speed and MPS, shall actuate the RESD and be used as input for TGCP safety PLC.

5.4.4. PAS shall include, at least, the following functions:

- Start-up, crank/purge, 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;

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- Gas fuel specific consumption flow in Nm^3/h (corrected to PETROBRAS standard conditions at 1atm and 20ºC);
- Liquid fuel consumption in liters per hour;
- Fuel gas and liquid consumption totalizers;
- Monitoring and control of variable geometry system position;
- Ignition and fuel monitoring and control (including fuel control valve position);
- Enclosure ventilation and fire & gas system monitoring and control;
- Automatic on-line and off-line turbine cleaning system;
- 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.

5.4.5. All the instruments and auxiliary equipment needed in order to guarantee synchronizing operation shall be installed in each 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 TG).

5.4.6. 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.

5.4.7. 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.

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5.4.8. PAS shall have high reliability, integrity and availability for operation in fail safe mode in order to avoid, whenever possible, an unnecessary shutdown or loss any process variable with safety function.

5.4.9. PAS shall include on-line testing and self-diagnosis facilities, in order to allow the maintenance technician, identify failures, enabling corrective maintenance without causing unit shutdown and avoiding operation without any safety function.

5.4.10. 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.

5.4.11. There shall be assured the synchronism between all TGCP's of the system. Generators protection relays also must 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.

5.4.12. 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 for PETROBRAS.

5.4.13. Apart from the driver controls and monitoring devices, it houses flush mounted panel meters for generator current, frequency, voltage, kW, kVAr, power factor and AVR voltage and current.

5.4.14. The philosophy for integrating of 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 ARCHICTETURE 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.

5.4.15. With the platform in emergency mode (ESD), essential ventilation Hood motors shall be turned on by TGCP only if it is confirmed gas presence in the gas turbine hood.

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5.4.16. 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.

5.4.17. 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.

5.4.18. Cooling water temperature signal shall be send from TGCP to PMS (to permit calculation of available generation budget).

5.4.19. 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).

5.4.20. 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.

5.4.21. TGCP also houses 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.

5.4.22. In case of UAS signal from PMS, TGCP shall commutate to LOCAL mode operation. These signals shall be send to TGCP by electrical system controllers.

5.4.23. 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.

5.4.24. The TGCP shall be provided with a LOCAL/PMS enable selector switch, in local position the generator’s TGCP control the speed and voltage, in PMS position the PMS (REMOTE) shall control the speed and voltage.

5.4.25. AVR and fuel controls of each generator shall be located at TGCP.

5.4.26. 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.

5.4.27. 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.

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5.4.28. 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.

5.4.29. 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.

5.4.30. 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.

5.4.31. 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.

5.5. Waste Heat Recovery Unit (WHRU)

5.5.1. PAS shall be responsible for Waste Heat Recovery Unit (WHRU) control and safety interlocking, receiving water temperature and pressure signals from CSS, and actuating on dampers according a temperature set point, also received from CSS.

5.5.2. PAS shall also receive a digital signal from CSS commanding dampers to bypass position.

5.5.3. During TG startup, WHRU control shall sequence dampers opening in order to purge both WHRU bundle and bypass ducts, prior to enabling water temperature control.

5.5.4. If WHRU is not available, PAS shall allow startup of the TGs, through the bypass operation, purging only the bypass duct. In this case, the dampers shall remain in bypass position until a next startup with WHRU available and purged.

5.5.5. PAS shall provide WHRU operation status, malfunction, and shutdown signals to CSS.

5.6 Human Machine Interface of TGCP (TGCP_HMI)

5.6.1. 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.

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5.6.2. 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.

5.6.3. TGCP_HMI shall comply, at least, with the following requirements:

- Industrial microcomputer installed inside the panel housing;
- 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) must be programmable to start storage. ESD or Normal Stop are events that 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 miliseconds time resolution. The messenge of first trip of SD sequence shall be emphasized;
- Auxiliares PI&Ds with all variables;
- Display of equipment schematic layout with all variables from Machinery Protection System.

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5.6.4. 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.

5.6.5. 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.

5.6.6. 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.

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

5.6.8. Each TGCP_HMI must also be able to allow operation of any further turbo generator set, including remote TGCP_HMI.

5.6.9. 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.

5.6.10. TGCP_HMI software must be compatible with OSI "Plant Information-PI" software;

5.6.11. One remote TGCP_HMI for shall be provided, with the same functionalities of the TGCP_HMI, to be installed at Central Control Room (CCR). This TGCP_HMI shall be a 19" rack-mounted PC, shipped loose . The PC shall have four ethernet ports, each port must be connected to the PAS system switch of each turbogenerator packager.

5.7. Machinery Protection System

5.7.1. Machinery Protection System (MPS) shall be according to the API 670 latest revision.

5.7.2. 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;

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- 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); two (2) accelerometers for gas turbine (one (1) for GG and one (1) for PT at least).

5.7.3. Probes shall allow gap adjustment.

5.7.4. All bearings must have metal temperature monitoring (two sensors installed, one spare). Only where metal bearing temperature measure is not feasible, PACKAGER shall propose a bearing oil outlet temperature sensor with the same alarm and shutdown signals as indicated for metal bearing temperature in data sheets. Shall be provided for thrust bearings two temperature sensors at active side, and two temperature sensors at inactive side. All bearing temperatures shall be directly connected to MPS rack.

5.7.5. All vibration and temperature protection systems shall be according Original Equipment Manufacturer (OEM) standards and API 670 compliant.

5.7.6. 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).

5.7.7. 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.

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

5.7.9. 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.

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

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

5.7.12. Paired channels (XY) from the two transducers mounted at each bearing for radial shaft vibration monitoring shall be allocated at the same MPS IO card.

5.7.13. 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.

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

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

5.8. Machinery Monitoring System (MMS)

5.8.1. 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.

5.8.2. 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.

5.8.3. For a basic description, the primary function of this system is to perform analysis of the following parameters:

- Aerothermodynamic (gas turbine): at least the following real-time performance maps (in SI units) including actual operating point: PT speed, GG speed, ambient temperature, specific fuel consumption and heat rate versus shaft power; Air flow, axial compressor outlet pressure and temperature, HP turbine outlet pressure and temperature, PT exhaust pressure and temperature, specific fuel consumption, heat rate, combustion chamber temperature and PT speed versus GG speed; Exhaust pressure and temperature versus PT speed; Axial compressor outlet pressure and temperature, HP turbine outlet pressure and temperature, PT exhaust pressure and temperature, GG and PT speeds, IGV and CGV positions and control signals, fuel consumption (corrected to 20ºC and 1 atm) versus time. PACKAGER shall also furnish an algorithm for evaluate the total remaning life considering fuel consumption and number of starts;
- Mechanical: all machinery protection system signals (with possibility to make analysis like FFT, full spectrum, Bode plot, waterfall diagram, shaft average center line, orbit, X-Y plot and experience-based vibration analysis) and auxiliary system signals (as mineral and synthetic lube system).

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

5.8.5. 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.

5.8.6. 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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6.1. 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.

6.2. 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

6.3. 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.

6.4. 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.

6.5. 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.

6.6. 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.

6.7. 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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6.8. The accumulator battery and battery charger, when requested by the package, and unless otherwise indicated, shall be supplied in accordance with I-ET-3010.00-5140-714-P4X-001 - SPECIFICATION FOR ELECTRICAL BATTERIES FOR OFFSHORE UNITS and I-ET-3010.00-5140-773-P4X-002 - SPECIFICATION FOR GENERIC D.C. UPS FOR OFFSHORE UNITS. Accumulator batteries shall be vented lead-acid.

6.9. The excitation system shall comply with I-ET-3010.00-5140-775-P4X-001 - REQUIREMENTS FOR ELECTRICAL GENERATION EXCITATION SYSTEM FOR OFFSHORE UNITS.

7. OPERATION AND MAINTENANCE REQUIREMENTS

7.1. PACKAGER and PURCHASER shall make the applicable recommendations to optimize operation and maintenance, taking into account the remote location and platform general conditions. Any changes to equipment design, materials or specific spares that may improve the equipment operability, availability or reliability shall be submitted to PETROBRAS for review and approval. But PACKAGER and PURCHASER shall always comply with PETROBRAS requirements before suggest any modification.

7.2. The packages shall be designed so that all maintenance can be carried out with standard tools as much as possible.

7.3. 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.

7.4. 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.

7.5. 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.

7.6. 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.

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7.7. PACKAGER and PURCHASER shall provide special tools for all maintenance activities including tools for gas turbine and generator rotor assembly disassembly and removal.

7.8. PACKAGER and PURCHASER shall include in proposal a schedule stating the expected time between major overhauls.

7.9. PACKAGER and PURCHASER shall provide a gearbox shaft end with an adaptor in order to allow manual turning for maintenance purposes.

7.10. Noise control requirements

7.10.1. Noise control analysis is a mandatory item to be carried out. PACKAGER and PURCHASER shall present noise data regarding items included in scope of supply.

7.10.2. The GT acoustic enclosure shall be designed to reduce the pressure noise level emitted by the GT skid to less than 85 dB(A) at 1.0 m distance, 1.5 m height in the free field conditions. The overall GTG train noise pressure level shall be less than 90 dB(A) at 1.0 m distance and up to 2.0 m height from the floor.

7.10.3. The noise control system for the package shall consider the noise radiated by inlet/outlet piping, equipment enclosure including ventilation system, (if specified) and equipment casings.

7.10.4. Whenever electric motor drivers are used, it shall be verified if motor fan design can be modified (e.g., use of unidirectional blades, etc.) before any apparatus are applied for noise attenuation.

7.10.5. In case of expected noise are higher than allowable limits, the equipment must be furnished with some noise control reduction measure. PACKAGER and PURCHASER may consider the best solution, which may include or not the supply of an acoustic and thermal enclosure with ventilation and safety system requirements. The use of device to comply with noise requirement must be proved to be efficient and submit to PETROBRAS approval.

7.10.6. For all equipment installed without acoustical enclosure, the following data will be required during proposal phase:

- Sound power level of the equipment;
- Sound pressure level, in each of the four main directions and in one point of the top.

7.10.7. For all equipment installed inside acoustic enclosure, the following data will be required during proposal phase:

- Sound power level of the equipment without enclosure;
- Sound pressure level, in each of the four main directions and in one point of the top, for the equipment plus enclosure;
- Acoustical data of enclosure and silencers (when applicable).

8. INSPECTION AND TESTING

8.1. General requirements

8.1.1. PETROBRAS is entitled to inspect the package anytime during fabrication to ensure that material and workmanship are in accordance with the specifications.

8.1.2. Inspection of materials and / or equipment will be made by PETROBRAS or its authorized representatives.

8.1.3. Unless otherwise specified, all witnessed tests shall be informed, at least, 90 days before the scheduled dates.

8.1.4. Unless otherwise established by PETROBRAS inspector, all equipment shall be available for inspection in an unpainted state.

8.1.5. All PAS shall be functionally tested at supplier facilities. All control sequences and shutdown logics shall be simulated and tested against the requirements. Details of supplier standard functional test procedures shall be submitted to PETROBRAS approval.

8.1.6. PETROBRAS inspector shall have the right to request inspections to ensure that the equipment complies with the relevant Classification Society requirements.

8.1.7. 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 previously be approved by PETROBRAS. The subsequent inspection necessary to confirm the satisfactory results will be at PACKAGER and PURCHASER cost.

8.1.8. After factory acceptance tests, a borescope inspection shall be carried out, recorded and send to PETROBRAS.

8.1.9. All fuel system welds shall be 100% radiographically inspected and submitted to magnetic particle examination.

8.2. Hydrostatic test (HT)

8.2.1. For all trains, parts being tested shall be externally coated with a layer of white lead carbonate or any other suitable powder to help leakage detection.

8.2.2. No vises or clamping devices shall be used for pressing of nozzle flanges.

8.2.3. PTFE tape or thread compounds shall not be used to prevent leakage of threaded plugs and connections.

8.3. Performance Test (PT)

8.3.1. Performance Test shall be performed on each unit (gas generator and power turbine) and spare (gas generator and power turbine) according to ASME PTC 22.

8.3.2. The performance test procedure shall be agreed with PETROBRAS.

8.4. Mechanical Running Test (MRT)

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8.4.1. MRT shall be performed on each unit (gas generator and power turbine) and spare (gas generator and power turbine) according to API STD 616.

8.4.2. 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, starting / stopping ramp, equipment vibration signature, diagram for all bearing signals and phase angle versus speed.

8.4.3. The MRT procedures shall be agreed with PETROBRAS.

8.5. Sound Level Test (SLT)

8.5.1. 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.

8.5.2. 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.

8.5.3. 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.

8.5.4. If the normal operating condition cannot be reached in the test facilities, PACKAGER, PETROBRAS and PURCHASER shall agree with measurements methods and values.

8.5.5. 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 to reach this limit, if required by PETROBRAS.

8.6. Factory Integrated Test (FIT)

8.6.1. PACKAGER shall execute one turbogenerator FIT in their installations, FIT shall be a functional test including the following contract parts, at least: gas generator, power turbine, gearbox, electric generator, PAS, starting system, oil system (synthetic and mineral), liquid and gas fuel system.

8.6.2. The FIT procedure, with the steps and duration, shall be similar to the MRT, and shall have, at least, three starts and three stops.

8.6.3. Vibration requirements (limits, acceptance, etc.) shall be the same used for MRT.

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8.6.4. Generators will be tested according to electrical standards references according I-ET-3010.00-5147-711-P4X-001 – MAIN GENERATORS FOR OFFSHORE UNITS.

8.6.5. Control check shall be done during FIT, as part of functional test.

8.6.6. FIT shall include a load step test (0% to 25%, 25% to 50%, 50% to 75%, 75% to 100% and 40% to 90%) and rejection charge test (100% to 0%, 75% to 0%, 50% to 0%, 25% to 0%).

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

8.6.7. Fuel changeover shall be tested both from diesel to gas and gas to diesel, at full load, 50% and no load.

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

8.6.9. A hot restart sequence shall be performed during FIT, including a check of the slow turning system. Automatic lock verification through the turbine start command on the HMI shall be performed, stating which parameters will be monitored.

8.6.10. The FIT procedure shall be agreed with PETROBRAS.

8.7. Shipyard Acceptance Test (SYAT)

8.7.1. Shipyard Acceptance Test (SYAT) is a functional test onshore, performed on each unit.

8.7.2. Shipyard Acceptance Test (SYAT) shall be performed in the shipyard facilities after turbogenerator with WHRU is fully pre-commissioned and completely integrated with all systems of FPSO that support the operation of main generation system.

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

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8.7.4. PURCHASER and PACKAGER shall perform a SLT during SYAT.

8.7.5. The Gas Turbogenerator SYAT shall be performed according to the requirements of COMMISSIONING DESCRIPTIVE MEMORANDUM.

8.8. Site Acceptance Test (SAT)

8.8.1. Site Acceptance Test (SAT) is an offshore acceptance test to be performed when the turbogenerator is able to operate with gas fuel after all commissioning is complete and not pending.

8.8.2. SAT shall be performed according to Annex A (Rotating Equipment Reliability Test).

8.8.3. PURCHASER and PACKAGER will provide all facilities, support and technical assistance procedures (mounting procedures, MCC, lube oil, load bank, fuel, etc.) for SAT. PURCHASER is responsible for any repairs required during the SAT that are not caused by factors external to the turbogenerator system.

8.8.4. Procedures and results shall be submitted for Classification Society and PETROBRAS final approval.

8.8.5. PURCHASER will perform a SLT during SAT.

8.9. Post Inspection Test (PIT)

8.9.1. A gas turbine borescope test inspection shall be performed on every unit immediately after the last run prior to delivery and a report recorded in CD/DVD (movie or photo files). Dismantling, inspection and reassembling will be only required in case of unsatisfactory Mechanical Running Test (MRT), as defined in API 616, Section 6.

9. ANNEXES

9.1 Annex A: Rotating Equipment Reliability Test.

ANNEX A – ROTATING EQUIPMEN