PETROBRAS	**TECHNICAL SPECIFICATION**	**Nº:** I-ET-3010.1M-5147-332-P4X-001	
	CLIENT: SRGE		**SHEET:** 1 of 33
	JOB: REFERENCE BASIC DESIGN		1001056398 0010
	AREA: BÚZIOS		
DP&T-SRGE	**TITLE:** **TECHNICAL SPECIFICATION FOR TURBOGENERATOR PACKAGE**		**NP-1**
			ESUP

MICROSOFT WORD / V. 2010 / I-ET-3010.1M-5147-332-P4X-001_A

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1. GENERAL

1.1. The gas turbine shall be dual fuel standard combustor aero-derivative or light industrial type. The package shall be designed for minimum 25 years of operation installed on a fixed platform or on a FPU (Floating Production Unit).

1.2. The electric power capacity shall be 29.6 MW base-load, for continuous running duty basis, at site rated conditions after all the mechanical losses for the complete set and the inlet and exhaust losses including air inlet filter and WHRU (Waste Heat Recovery Unit) and degradation losses for ageing and fouling. Site rated conditions for the gas turbine performance design shall be considered as 30ºC ambient temperature, sea level and off-shore tropical environment (80% relative humidity, 1 atm).

1.3. The drive train center line is oriented in the fore/aft direction on the FPSO. 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.

1.4. Turbo-generator to be installed in a safe area.

1.5. Outdoor electrical equipment to be at least IP56 and outdoor instrumentation to be at least IPW-65, where W means saline atmosphere.

1.6. PACKAGER shall consider all documents listed in Material Requisition as mandatory. Electrical, automation and safety requirements for Turbogenerator (package unit) are described in this document.

1.7. 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 PURCHASER specifications.

1.8. PACKAGER shall be entirely responsible for material selection on items not specified by PURCHASER 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.

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

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

1.11. PACKAGER 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.

1.12. Hazardous and toxic materials with associated adverse health effects shall be avoided or minimized. PACKAGER and sub-suppliers are encouraged to promote their replacement. Asbestos has been identified as detrimental to human health, especially regarding serious and often fatal diseases such as lung cancer, asbestosis and mesothelioma. Therefore, it 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, PURCHASER strongly recommends PACKAGER and sub-suppliers to take all necessary measures to ensure their use is fully avoided throughout this project. Material safety data-sheets may be required by PURCHASER any time, to demonstrate that a particular material has not been, is not and will not be used throughout all stages of this project.

1.13. Gas Turbine ignition system shall not have radioactive components.

1.14. All equipment, components and panels shall have a nameplate easy to access, to view and read. Nameplate shall be made in AISI 316 stainless steel 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 requisition number (RM);
- Purchaser's request for quotation number (RFQ);
- Purchaser's order number (PO);
- Empty weight;
- Design code.

1.15. All safety signals shall be in Portuguese language.

2. CONSTRUCTION FEATURES

2.1 Aero-derivative or light industrial per API 616, latest edition (with agreed deviations), manufacturer's standard combustor, gas/liquid fuel configuration, complete with protective bag and transportation stand. Power turbine, if applicable, may be industrial or aero-derivative type. Minimum ISO shaft power rate for the gas turbine (GG+PT) shall be 33000 kW on standard natural gas fuel.

2.2 Gas turbine design shall enable boroscope 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

2.3 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.

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

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

3. ACCESSORIES AND AUXILIARIES

3.1 Piping

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

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

3.1.3 Manual block valves and spectacle / blind flanges shall be provided at all battery limits such as inlet and outlet nozzles, drain lines, etc. PACKAGER considering piping standards as in I-ET-3010.1M-1200-200-P4X-001 – PIPING SPECIFICATION FOR TOPSIDE.

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

3.1.5 The interconnecting pipework between auxiliary skid and the main baseplate shall be provided by PURCHASER.

3.2 Couplings and coupling guards

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

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

3.2.3 PACKAGER shall submit to PURCHASER main equipment coupling data sheet according to API 671.

3.2.4 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. 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.

3.2.5 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.

3.3 Baseplate

3.3.1 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).

3.3.2 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).

3.3.3 Driver, driven machine and transmission shall be mounted on a single baseplate. Other auxiliaries shall be mounted on the same baseplate (preferable) or provided with their own skid. PACKAGER shall submit layout to PURCHASER comments and approval.

3.3.4 The baseplate shall have a removable solid checkered plate or open grating top floor where required for maintenance.

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

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

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

3.3.8 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 PACKAGER 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.

3.3.9 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.

3.3.10 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. A single drain nozzle shall be located at the skid edge with appropriate piping, blocking valve, strainer and water seal.

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

3.4 Support system

3.4.1 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.

3.5 Insulation

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

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

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

3.5.4 In order to avoid damages during transportation and erection, insulation shall be carried out after final installation in place.

3.6 Oil system

3.6.1 An independent synthetic oil (lube and control) console shall be designed per API 614 latest edition (with agreed deviations) to supply lubricating oil to gas generator. Control system, shall includes twin filters with changeover valve, duplex plate type heat exchanger and temperature control valve, 316L stainless steel reservoir and piping, vent mist eliminator and all necessary on-skid instrumentation, valves, piping, wiring, controls and transmitter rack preferably installed on main equipment baseplate.

3.6.2 An independent mineral oil (lube) package shall designed per API 614 latest edition (with agreed deviations) to supply lubricating oil to the power turbine (if applicable), gearbox and driven equipment under all FPU vessel motions for continuous satisfactory operation, preferably installed near main equipment baseplate, and shall includes twin filters with changeover valve. Other oil system configuration shall be submitted to PURCHASER approval, but shall follow the philosophy described on project documents concerning dual auxiliaries, instrumentation, alarms, etc.

3.6.3 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.

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

3.6.5 Emergency system shall have rundown tank or shaft driven pump. Proposed system shall have enough capacity for bearing cooling during cost-down time and shall be monitored with PACKAGER specifications and international standards. DC pumps (125Vdc) are acceptable as on option to the shaft driven pump, 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.

3.6.6 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.

3.6.7 All piping and appurtenances downstream oil filters shall be made of AISI 316L stainless steel.

3.6.8 Socket welds for piping and tubing is prohibited.

3.6.9 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.

3.6.10 Oil coolers shall be multi-plate duplex type oil/fresh water or oil/air heat exchanger with temperature control valve. The material shall be AISI 316L stainless steel, if closed loop cooling water system is provided by PURCHASER. Cooler shall have provision for future increase of the number of plates. The cooling water pressure shall always be lower than oil pressure at heat exchanger interior.

3.6.11 The canisters, transfer valves and piping for oil filter system shall be 316L stainless steel construction. Filter element material shall be corrosion and water resistant. There shall be no by-pass around any filter.

3.6.12 The expected configuration for pumps are:

- Main oil pump: Shaft-driven (preferable) or electric motor driven (AC power);
- Stand-by pump: Electric motor driven (~~essential~~ AC power).

3.6.13 For non shaft-driven pumps, the main and stand-by pumps shall be identical. In all cases, stand-by pumps shall have the same capacity as the main pump.

3.6.14 API data sheets for pumps and heat exchangers shall be included in proposal.

3.6.15 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.

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

3.7 Gearbox

3.7.1 If required, the speed reducing gearbox shall be double helical, single stage designed in accordance with API 613, Latest Edition (with agreed deviations) 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 boroscope inspection).

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

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

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

3.8 Pressure vessels

3.8.1 In order to avoid categorizing of any pressure vessel (and heat exchanger, where applicable) according the requirements of the Brazilian Labor Ministry regulation NR-13, when possible, the product of pressure (in mega Pascal) multiplied by the volume (in cubic meters) of any equipment shall be lower than 8. Where applicable, NR-13 calculation sheets and specific nameplates shall be provided.

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

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

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

3.8.5 Only full penetration welds are permitted.

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

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

3.9 Enclosure

3.9.1 Each gas turbine shall have its own enclosure.

3.9.2 Enclosures shall consist of a series 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.

3.9.3 Enclosure shall be weather-tight.

3.9.4 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 PURCHASER requirements.

3.9.5 Enclosure shall be provided with wide full-opening side doors to allow adequate maintenance access, assembly and disassembly of all parts of the equipment. Hinges shall be strong enough to withstand constant use and wear.

3.9.6 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.

3.9.7 Access doors shall be fitted with viewing windows.

3.9.8 Enclosure shall be provided with inspection and internal lighting, adequate for each maintenance service area.

3.9.9 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.

3.9.10 Ventilation system

- 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 all auxiliaries electrical loads shall be supplied by essential AC power;
- The electrical power of the ventilation fans shall not exceed 55 kW;
- Fan must be sized to prevent the inside enclosure temperature from exceeding 60°C. Higher temperature may be accepted, if PACKAGER guarantees safety conditions for all equipment functionality;
- The air shall be filtered before reaching the fans and the enclosure;
- 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 pane;.

3.9.11 Fire and gas detection and high pressure water mist fire extinguishing systems 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. Back up nitrogen bottles shall be applied. The selection of main or back up nitrogen bottles can be carried out by manual valves.

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

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

3.10 Starting system

3.10.1 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.

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

3.10.3 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.

3.10.4 For electro-hydraulic system, hydraulic part shall be mounted on a small skid immediately adjacent to the baseplate. For electric motor, all system shall be placed inside baseplate. For electric motor and electro-hydraulic system, PACKAGER shall supply electronic soft starter or variable speed drive (VSD) to control of voltage drop and shall comply with I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

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

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

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

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

3.10.9 The main generator shall be capable to immediate restart at any time after a shutdown event. Electrical motor to crank the gas generator rotor, if applicable, shall be in 125 Vdc. 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.

3.10.10 In case of an ignitor transformer be necessary, it shall comply with I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS, and PACKAGER shall provide these equipment.

3.11 Fuel system

3.11.1 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.

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

3.11.3 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 change over of each and all gas turbine.

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

3.11.5 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.

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

3.11.7 Gas fuel system:

- System shall include shutoff valve, vent, bleed and all piping and appurtenances required by international standards, PACKAGER experience and for compliance with Classification Society's requirements.
- PACKAGER shall furnish a single fuel strainer upstream the fuel package connection point. Gas filter shall be selected for maximum service life (PACKAGER shall indicate this data in proposal).
- Fuel gas coalescer unit is to be installed immediately upstream of the skid fuel gas blocking valve and shall be fitted with a PSV (if required), a continuous flow transfer valve, pressure transmitter, automatic liquid dunp facility and level gauge.

3.11.8 Liquid fuel system:

- System shall be provided with pump, twin filters (2x100%), with continuous flow transfer valves, vent, drains, charge facilities, shutoff valve, relief valve, throttle valve, and all additional required components.
- Provisions shall be made to prevent coke formation in the liquid fuel manifolds while the engine is operating with gas fuel. PACKAGER shall submit proposed details to PURCHASER for review and approval. Please find Petrobras' liquid fuel specification in the I-RL-3010.1M-1200-940-P4X-001 - GENERAL SPECIFICATION FOR AVAILABLE UTILITIES.

3.11.9 All on-skid fuel piping components and tubing for gas and liquid fuel shall be 316L stainless steel.

3.12 Gas turbine cleaning system

3.12.1 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.

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

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

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

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

3.12.6 PACKAGER shall furnish hoses shipped loose, in accordance with PURCHASER information about distances.

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

3.12.8 Two tanks shall be provided, one for the water/detergent mixture and one for pure water. Two single tank carts are acceptable instead of one cart with two tanks per FPU.

3.13 Combustion air inlet system

3.13.1 Combustion air inlet system shall include, at least: rain protection with trash screen, weather protection louvers, filter housing, four-stage filter, air intake silencer, 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 area (Ex de).

3.13.2 The air filter system shall be assembled in four-stage and 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.

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

- The first stage shall be filter wall or inertial separator 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 coalescers or prefilter range shall pockets type. The pockets shall be self-supporting, welded and foam-sealed to frame complete with welded in spacers for mechanical strength. Class G – 4 according to EN 779. The filter elements standard sized shall be 595 x 595 mm wide. The filter support racks shall in stainless steel, AISI 316L;
- The third stage shall be identical to the first stage*;*
- The fourth or the final stage high efficiency filters shall be a high-efficiency filter. The filter elements standard sizes shall be 595 x 595 mm wide, double flanged class F - 9 according to EN 779 classification, moisture-resistant up to 100% relative humidity. The filter support racks shall in stainless steel, AISI 316L;
- Differential pressure monitoring on each and overall stages on control panel.

3.13.4 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.

3.13.5 All inlet air system components shall be in unpainted AISI 316L stainless steel. Hard points to be provided on the house for mounting to the FPU structure.

3.13.6 Air Inlet Module, shall include, inlet ducting, inlet silencer and acoustic insulation. Inlet plenum orientation vertical upwards. Material unpainted 316L stainless steel. 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).

3.14 Combustion gas exhaust system

3.14.1 All trains shall comply with requirements in order to receive a Waste Heat Recovery Unit (WHRU) system, main and by-pass stack, which shall be provided by others. PACKAGER shall submit all specification for these parts to PURCHASER and shall comment complete exhaust system design.

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

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

3.14.4 The exhaust silencer shall also incorporate lifting provisions.

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

4. AUTOMATION

4.1 General requirements

4.1.1 Package Automation System (PAS) shall be designed to ensure safe and reliable operation, performing protection, control and monitoring during start-up, operation, normal and emergency shutdown. PAS shall be furnished functionally tested, assembled and ready for connection.

4.1.2 All instrumentation and alarms mentioned in the data sheets are the minimum required by PURCHASER. PACKAGER shall indicate other instrumentation and alarms for general protection and monitoring according to their experience and submit them to PURCHASER for approval.

4.1.3 PACKAGER shall provide a local gauge board (rack) installed on the equipment baseplate, if feasible, as mentioned on data sheets. Oil filled gauges shall be provided for analogical instruments subject to high vibration levels.

4.1.4 PAS shall include all required components to ensure continuous monitoring, functionally tested, assembled and ready for connection.

4.1.5 PACKAGER shall supply Turbo Generator Control Panel (TGCP) shipped loose TGCP shall have IP-42 protection level and will be installed at the Generator Control Panels Room (GCPR) by others.

4.1.6 The unit shall have a specific feature so that the equipment cannot be restarted without manual acknowledgement of the shutdown conditions.

4.1.7 All requirements for PAS shall be checked during Site Acceptance Test, according to IEC 62381.

4.1.8 Package 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 to I-MD-3010.1M-5520-800-P4X-001 – AUTOMATION AND CONTROL SYSTEM FUNCTIONS - TOPSIDE.

4.1.9 PACKAGER shall provide to PURCHASER all keys, drivers, manuals and licenses of all software inside package. No software access restrictions will be accepted by PURCHASER.

4.1.10 PACKAGER shall make the necessary provisions for interconnection to be installed by others, if necessary for main equipment operation and safety, including instrument signals, alarms, controls and interlocking, etc.

4.1.11 PACKAGER will be responsible for all required control and interlocking interface with the process plant outside its scope of supply, in order to guarantee the proper start-up, operation, pressurized and depressurized shutdown.

4.1.12 Proper means of electrical and environmental protection shall be applied to instruments and instrumentation-related electrical/electronic installations located in hazardous areas and/or an aggressive saline air environment. In order to guarantee adequacy to IEC-61892-7, all field instruments and other electrical instrumentation equipment installed in open areas shall be certified to operate in Zone 1. Certified enclosures against explosive atmosphere are mandatory. Remote I/O panels shall be made of AISI 316 stainless steel and installed in shelters protected from rain and wind in the respective ~~compression~~ modules. The panels shall have IP56 protective level and the panels internal temperature shall be kept bellow 30 degrees centigrade.

4.2 TGCP hardware

4.2.1 Each equipment package shall have its own TGCP, with monitoring and control functions for all equipment (generator, driver, transmission and auxiliaries). Each TGCP shall operate independently, so a failure of any component within a TGCP does not affect the availability of any other TGCP.

4.2.2 Each TGCPs located at the GCPR shall have:

- IP42 protection level;
- Frontal HMI;
- Cable entry from the bottom of the panel;
- Front access doors.

4.2.3 Each TGCP shall include, at least:

- One dedicated safety system and one dedicated control system, which shall be implemented using Programmable Logic Controllers (PLC);
- HMI hardware;
- First-out and reset devices;
- Main equipment and auxiliaries start-up and stop devices;
- Sound alarm;
- Start counter and independent hourmeter (for each type of fuel);
- Machinery Protection System;
- Fire and gas and HVAC control and Safety System;
- 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.

4.2.4 The network switches shall be industrial manageable type.

4.2.5 Control and supervisory networks must be redundant.

4.2.6 TGCP and all its components shall be designed considering that GCPR room temperature can reach 40º C.

4.3 TGCP software

4.3.1 PAS shall enable changes of set points, timer presets and control parameters, forcing I/O via software, input by-passing, output override with the system in operation, without damage to the process.

4.3.2 The control system programming and configuration shall be carried out by the TGCP or additionally through a laptop computer (not provided by PACKAGER) with software editor. The software editor shall be provided by PACKAGER.

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

4.3.4 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 whit NO access restrictions.

4.3.5 The control system programming shall be in accordance with PACKAGER specification. PACKAGER proposal shall inform the programming language used in the system.

4.3.6 The alarm annunciator units 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 IEC 62682).

4.4 TGCP system

4.4.1 The ~~equipment~~ TGCP shall be capable of carrying out control, interlock, process, start-up, 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, machine Protection System (MPS), Motor Control Center (MCC) and other controls and PETROBRAS security systems, such as: Control and Safety System (CSS), Power Management System (PMS), Asset Management System (AMS) and Machine Monitoring System (MMS).

4.4.2 Emergency shutdown relay shall be provided to actuate directly on the fuel gas shutoff valve.

4.4.3 The ESD from push buttons, PSD (Process Shutdown System), over speed and MPS, shall actuate the emergency shutdown relay and be used as input for TGCP safety PLC.

4.4.4 Control system shall not allow undesirable nor unsafe operations.

4.4.5 TGCP shall include, at least, the following functions:

- Automatic and manual start-up, loading, normal / emergency stop, purge and 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 indication as described in PURCHASER specifications (such as temperature, pressures, etc. indicated in P&IDs and data sheets);
- Indication of independent fuel consumption totalizer;
- Independent hourmeter (for diesel and gas) and starts counter;
- Speed monitoring and control system (all shafts, excluding gear);
- Gas fuel specific consumption flow in Nm^3/h (corrected to PURCHASER standard conditions at 1atm and 20ºC);
- Liquid fuel consumption in liters per hour;
- 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;
- Field-force control, triggered by external (PMS) signal, in order to apply temporary booster in output voltage during start-up of large motors to avoid excessive voltage drop.

4.4.6 All the instruments and auxiliary equipment needed in order to guarantee synchronizing operation shall be installed in each TGCP, 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).

4.4.7 TGCP shall be capable to send and receive signals to / from PAS according to PURCHASER specifications.

4.4.8 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.

4.4.9 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.

4.4.10 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.

4.4.11 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.

4.4.12 Connectivity to external system through open communication protocols shall be MODBUS and OPC (Open Platform Communications) by Ethernet TPC/IP Protocol. All I/O variables, controllers (including performance, load sharing and surge) and first out events shall be available.

4.4.13 TGCP panels shall comply with:

- I-ET-3010.00-5140-700-P4X-003 - ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS;
- I-ET-3010.00-5140-700-P4X-005 – REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS;
- I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS and shall be located at a temperature controlled panels' room.

4.4.14 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.

4.4.15 The philosophy for integrating of this panel into the control and operation systems of its installation site is defined 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 AND I-LI-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.

4.4.16 The interfaces signals related to electrical equipment are defined in I-ET-3010.00-5140-700-P4X-004 – PN-514001 - POWER MANAGEMENT SYSTEM (PMS) FOR OFFSHORE UNITS and listed at I-LI-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.

4.4.17 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.

4.4.18 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.

4.4.19 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.

4.4.20 All TGCP digital signals shall be available for external network communications, even those who already are available hardwired shall be considered. A full list of available digital signals shall be provided for PETROBRAS.

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

4.4.22 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).

4.4.23 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.

4.4.24 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.

4.4.25 In case of UAS or UAM signals from PMS, TGCP shall commutate to LOCAL mode operation. These signals shall be send to TGCP by electrical system controllers. This interface signal are listed in I-LI-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNAL LIST.

4.4.26 TGCP shall be an autonomous control and only be submitted to PMS control in REMOTE mode. In LOCAL mode, TGCP shall be able to function autonomous fulfilling its designed operational functions allowing turbogenerator stop, start and adjustments.

4.4.27 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 REMOTE shall control the speed and voltage.

4.4.28 AVR and governor controls of each generator shall be located at TGCP.

4.4.29 For a generator set, the governor 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.

4.4.30 The governor 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.

4.4.31 The maximum amount of load the generator unit can share shall be full load without flameout.

4.4.32 The metering voltage and current for the governor 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.

4.4.33 External supply for power, control, lighting and heating of TGCP 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.

4.4.34 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.

4.4.35 The TGCP interface with AMS shall be as described in I-ET-3010.1M-1200-800-P4X-014 - AUTOMATION INTERFACE OF PACKAGE.

4.5 Waste Heat Recovery Unit (WHRU)

4.5.1 TGCP 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.

4.5.2 TGCP shall also receive a digital signal from CSS commanding dampers to bypass position.

4.5.3 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.

4.5.4 If WHRU is not available, TGCP 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.

4.5.5 TGCP shall provide WHRU operation status, malfunction, and shutdown signals to CSS.

4.6 Human Machine Interface (HMI)

4.6.1 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.

4.6.2 Generator data shall be displayed on the HMI (Human Machine Interface) display 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.

4.6.3 The logs shall be CSV (comma separated values) standard in three (3) different report types:

- Daily files of digital and analog variables with 1 second sample time and three months storage;
- Hourly files of digital and analog variables with 40 milliseconds sample time and last five days storage;
- Individual ESD files of digital and analog variables with 40 milliseconds sample time and ten minutes storage time (six minutes before and four minutes after the occurrence of ESD or normal stop). The HMI shall maintain the last 200 individual files at least;

4.6.4 HMI shall comply, at least, with the following requirements:

- Industrial microcomputer installed inside the panel housing;
- One aditional Ethernet network card available for PURCHASER use purpose (remote monitoring connection);
- Panel-mounted LCD color screen display. The CPU shall be independent from the display screen;
- Data logging and event/variable recording and storing, including any event, alarms, trips and digital/analog variables values historic for at least two months with sample time not greater than 1 second and dead band not greather than 1%;
- Listing of all incoming alarms chronologically in a directory and a user-defined actions with PLC timestamps up to miliseconds time resolution;
- Historical and predictive trending (all variables);
- Real-time measurements;
- Display of equipment schematic layout;
- Display all analog and digital variables from sharing controllers, machinery protection and machinery monitoring systems.

4.6.5 PACKAGER shall provide HMI supervisory software (runtime and development tool) running on Windows environment, compatible with the size of the application and in its latest version. Software shall be supplied, installed, configured in the HMI and provided with complete manuals / electronic media.

4.6.6 If, for any reason, 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.

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

4.6.8 Each HMI must be capable to allow operation of any turbo generator system.

4.6.9 HMI software must be compatible with OSI "Plant Information-PI" software;

4.6.10 Two (2) remotes HMI (19'' PC), one (1) installed at central control room (CCR) with the same TGCP functionalities and another to be installed onshore with only viewing functionalities. These two HMI shall be provided for the turbogeneration service, allowing operation of any turbogenerator.

4.7 Machinery Protection System

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

4.7.2 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;
- Keyphasor: 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); two (2) accelerometers for gas turbine (one (1) for GG and one (1) for PT at least).

4.7.3 Probes shall allow gap adjustment.

4.7.4 PACKAGER shall identify which temperature sensor is used for each variable (bearing temperature, oil temperature, etc.).

4.7.5 Only where metal bearing temperature measure is not feasible, PACKAGER shall propose a bearing oil outlet temperature gauge with the same alarm and shutdown signals as indicated for metal bearing temperature in data sheets.

4.7.6 Monitors shall be mounted on Turbo Generator Control Panel (TGCP).

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

4.7.8 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).

4.7.9 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.

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

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

4.7.12 Extension cables shall be armored and installed through tray channel.

4.7.13 Oscillator-demodulators shall be mounted in an intrinsically safe junction box.

4.7.14 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.

4.7.15 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.

4.8 Machine Monitoring System (MMS)

4.8.1 Besides the control and supervisory TGCP system, Machinery Protection System shall be integrated in the Machinery Monitoring System (MMS) of the FPSO, provided by others, 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.

4.8.2 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)

4.8.3 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.

4.8.4 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.

4.8.5 MPS radial vibration monitoring cards shall have all available variables enabled to send data to MMS.

5. ELECTRICAL

5.1 General

5.1.1 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.

5.1.2 Electrical equipment and materials shall comply with requirements of I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

5.1.3 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.

5.1.4 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.

5.1.5 The electrical communications interfaces of the package shall comply with requirements of I-DE-3010.00-5140-797-P4X-00 – ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE DIAGRAM, I-ET-3010.00-5140-797-P4X-001 –ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE and I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.

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

5.1.7 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.

5.1.8 The accumulator battery and battery charger, when requested by the package, and unless otherwise indicated, shall be supplied in accordance with I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS. Accumulator batteries shall be vented lead-acid.

5.1.9 Electrical equipment installed in external safe areas or hazardous areas that shall be kept operating during emergency shutdown ESD-3P and ESD-3T shall be certified for installation in hazardous areas Zone 1 Group IIA temperature T3.

~~**5.2TGCP (Turbo Generator Control Panel)**~~

~~5.2.1 Each Turbogenerator unit shall have its own control and protection panel (TGCP) for the complete package.~~

~~5.2.2 Each control panel shall have its dedicated interlocking and control systems which shall be implemented using Programmable Logic Controllers (PLC), to be installed in air conditioned safe common local control room. Control Room to be supplied by others.~~

~~5.2.3 There must be assured the synchronism between all TGCP's of the system. Generators protection relays also must be synchronized together with TGCP's using IRIG-B network protocol. The synchronism must be integrated to CSS (Control and Safety System) clock.~~

~~5.2.4 TGCP must be designed considering the fail safe logic concept.~~

~~5.2.5 TGCP shall be capable to have a remote client station in order to allow remote control and monitoring based on TCP/IP connection.~~

~~5.2.6 TGCP shall include one Ethernet network card available for Petrobras use purpose (remote monitoring connection).~~

~~5.2.7 Each Turbogenerator Package TGCP shall have:~~

- ~~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.~~

~~5.2.8 TGCP panels shall comply with:~~

- ~~I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS;~~
- ~~I-ET-3010.00-5140-700-P4X-005 – REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS;~~

- I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS and shall be located at a temperature controlled panels' room.

TGCP Functions

5.3.1 TGCP PLC shall be responsible for:

- Running generator's turbines;
- Manual start and stop of turbogenerators;
- 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);
- Start and stop signals to generator package auxiliary motors starters at external motor control centers.

5.3.2 The TGCPs and PMS panels shall communicate among each other through a redundant proprietary high speed deterministic network (HSDN).

5.3.3 In case of communication failure between PMS and TGCP panels, the turbogenerators shall continue to operate in stand alone mode, and shall not be tripped off.

5.3.4 The Turbogenerator Control Panel (TGCP) shall control and monitor the electrical power output of each generator.

5.3.5 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.

5.3.6 The generator's control and monitoring panel shall contain the devices related to the protection, synchronism, alarm and command systems comprising the local operation interface of the equipment.

5.3.7 The philosophy for integrating of this panel into the control and operation systems of its installation site is defined 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 AUTOMATIONARCHICTETURE DIAGRAM, I-ET-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEMAUTOMATION ARCHITECTURE AND I-LI-30310.00-5140-797-P4X-001 – ELECTRICAL SYSTEMAUTOMATION INTERFACE SIGNALS LIST.

5.3.8 The interfaces signals related to electrical equipment are defined in I-ET-3010.00-5140-700-P4X-004 – PN-514001 - POWER MANAGEMENT SYSTEM (PMS) FOR OFFSHORE UNITS and listed at I-LI-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.

5.3.9 Generator data shall be displayed on the HMI (Human Machine Interface) display 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-3010.1M-5140-797-P4X-002 TOPSIDE ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE DIAGRAM and I-ET-3010.1M-5140-797-P4X-001 TOPSIDE ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE documents.

5.3.10 Hood essential ventilation motors shall be turn on by TGCP only when platform is in emergency mode (ESD) and only if it is confirmed gas presence in the gas turbine hood.

5.3.11 At parallel operation of two or more generators, voltage level and reactive (kVAr) and active (kW) power sharing shall be controlled by the Power Management System (PMS) via the generator AVR's and the electronic gas turbine governor. PMS shall control the electrical power system and the main generator sets on voltage, frequency, active power sharing, reactive power sharing and load shedding, as required by I-ET-3010.00-5140-700-P4X-004 – PN-514001 - POWER MANAGEMENT SYSTEM (PMS) FOR OFFSHORE UNITS.

5.3.12 The parallelism from TGCP shall be possible through Main Generators circuit-breakers.

5.3.13 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.

5.3.14 Turbogenerator is defined as "P2S" package and shall comply with I-ET-3010.00-1200-800-P4X-002 – AUTOMATION, CONTROL AND INSTRUMENTATION ON PACKAGED UNITS.

5.3.15 In case of UAS or UAM signals from PMS, TGCP shall commutate to LOCAL mode operation. These signals shall be send to TGCP by electrical system controllers. This interface signal are listed in I-LI-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNAL LIST.

5.3.16 TGCP shall be an autonomous control and only be submitted to PMS control in REMOTE mode. In LOCAL mode, TGCP shall be able to function autonomous fulfilling its designed operational functions allowing turbogenerator stop, start and adjustments.

5.3.17 Synchronization mode selector switche shall have the following positions: MANUAL, AUTOMATIC and OFF.

5.3.18 All the instruments and auxiliary equipment needed in order to guarantee synchronizing operation shall be installed in each TGCP, including the following facilities:

- MANUAL / AUTOMATIC / OFF synchronization swicth;
- 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).

5.3.19 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.

5.3.20 All TGCP digital signals shall be available for external network communications, even those who already are available hardwired shall be considered. A full list of available digital signals shall be provided for PETROBRAS.

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

5.3.22 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).

5.3.23 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.

5.3.24 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.

5.3.25 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 shall control the speed and voltage.

5.3.26 AVR and governor controls of each generator are located at TGCP.

5.3.27 For a generator set, the governor 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.

5.3.28 The governor 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.

5.3.29 The maximum amount of load the generator unit can share shall be full load without flameout.

5.3.30 The metering voltage and current for the governor 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.

5.3.31 External supply for power, control, lighting and heating of TGCP 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.

5.3.32 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.

5.3.33 External time synchronization signal shall be provided according to and I-ET-3010.1M-5140-797-P4X-001 TOPSIDE ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE and I-DE-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE DIAGRAM.

6. OPERATION AND MAINTENANCE REQUIREMENTS

6.1 PACKAGER 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 PURCHASER for review and approval. But PACKAGER shall always comply with PURCHASER requirements before suggest any modification.

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

6.3 Equipment layout shall enable easy and safe access for maintenance to all components and parts. PACKAGER shall provide suitable lighting, walkways, ladders and handrails for all packages, including auxiliaries. All equipment and peripherals, especially oil reservoirs, shall have full access and inspection doors / hatches.

6.4 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.

6.5 PACKAGER 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 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 PURCHASER for approval.

6.6 PACKAGER shall provide electrically driven 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 I-ET-3010.1M-5266-630-P4X-001 – TOPSIDE´S MECHANICAL HANDLING PROCEDURES.

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

6.8 PACKAGER shall include in proposal a schedule stating the expected time between major overhauls.

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

6.10 Noise control requirements

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

6.10.2 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.

6.10.3 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.

6.10.4 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.

6.10.5 In case of expected noise are higher than allowable limits, the equipment must be furnished with some noise control reduction measure. PACKAGER 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 PURCHASER approval.

6.10.6 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.

6.10.7 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).

7. INSPECTION AND TESTING

7.1 General requirements

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

7.1.2 Inspection of materials and / or equipment will be made by PURCHASER or its authorized representatives.

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

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

7.1.5 All TGCP 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 PURCHASER approval.

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

7.1.7 In case any defects and / or shortcomings are found, PACKAGER shall bear the full cost of such inspection and replacement as necessary. Any repair shall previously be approved by PURCHASER. The subsequent inspection necessary to confirm the satisfactory results will be at PACKAGER cost.

7.1.8 After factory acceptance tests, a boroscope inspection shall be carried out, recorded and send to PURCHASER.

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

7.2 Hydrostatic test (HT)

7.2.1 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.

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

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

7.3 Performance Test (PT)

7.3.1 PT shall be performed on each unit (gas generator and power turbine) according to ASME PTC 22.

7.4 Mechanical Running Test (MRT)

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

7.4.2 PACKAGER shall submit to PURCHASER a CD 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.

7.5 Sound Level Test (SLT)

7.5.1 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.

7.5.2 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.

7.5.3 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.

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

7.5.5 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 shall provide, without extra cost, sound attenuation methods in order to reach this limit, if required by PURCHASER.

7.6 **Complete Unit Test (CUT)**

7.6.1 PACKAGER shall execute a CUT, including the following contract parts, at least: gas generator, power turbine, gearbox, electric generator, TGCP, starting system, oil system, liquid and gas fuel system.

7.6.2 CUT shall be a full load functional test and may be combined with others (MRT, PT or/and CUT) for test procedures optimization according PACKAGER schedule.

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

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

7.6.5 Control check shall be done during CUT, as part of functional test.

7.6.6 CUT shall include a load step test (0 to 25%, 25% to 50%, 50% to 75% and 75% to 100%) and total rejection charge test (100% to 0). Frequency fluctuation shall not be sufficient to sensitize the intended electrical protections and trigger loads.

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

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

7.7 **Site Acceptance Test (SAT)**

7.7.1 PURCHASER will provide all facilities and technical procedures (mounting procedures, MCC, lube oil, load bank, fuel, etc.) to execute a full load test onshore for each set with oil fuel. PACKAGER shall provide technical supervision for all onshore SAT. Procedures and results shall be submitted for Classification Society and PURCHASER final approval.

7.7.2 Besides onshore SAT, an offshore functional test with gas fuel shall be performed during 72 hours, for each set.

7.7.3 Probes and monitors shall be tested and calibrated before SAT, during commissioning. Calibration curves shall be plotted and checked according to probes standards tolerances.

7.7.4 PURCHASER will perform a SLT during SAT.

7.8 **Post Inspection Test (PIT)**

7.8.1 A gas turbine boroscope 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.