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1. OBJECTIVE

1.1. This document defines the minimum requirements for design, engineering, manufacture, inspection, installation, integration, commissioning, assistance for programming and delivery of PN-5140001 - Power Management System (PMS) for offshore Units.

1.2. PMS shall be designed for offshore installation and shall be field-proven, not a prototype device. It is necessary that PMS supplier detains experience in generator control and offshore platform electrical systems by evidencing its track record containing at least two years of previous successful application in the field.

1.3. The PMS is responsible for the management of the medium voltage generators: Main Turbogenerators and Hull Generators (when foreseen in the project).

1.4. The Hull Generators (when foreseen in the project) can be classified as Type I or Type II, according to I-ET-3010.00-5262-700-P4X-002 - HULL GENERATOR PACKAGE FOR OFFSHORE UNITS. The Type I generators shall be controlled by the PMS and Type II generators shall not be controlled by PMS (no interfaces with HGCP and 6.6kV Medium Voltage Hull MCC). See the ELECTRICAL SYSTEM DESCRIPTIVE MEMORANDUM for the applicable type in the project.

1.5. The voltage levels in this Technical Specification (13.8kV and 6.6kV) may vary according with the specificity of the project.

1.6. The main functions of PMS are:

- To guarantee the stable operation of the electrical system, increasing its reliability;
- To automatically control the electrical system frequency;
- To automatically control the voltage at main busbar of 13.8kV Main Switchgear;
- To provide, besides the Main Turbogenerator Control Panels (TGCP) and Hull Generator Control Panels (HGCP), a second station to operation (on/off/synchronize) of Main Turbogenerator Units and Hull Generators. Refer to item 3.2.5. The HGCP and Hull Generators requirements are only applicable for Type I Hull Generators;
- To control the synchronization process through tie circuit-breakers and busbars interconnection circuit-breakers of 13.8kV Main Switchgear;
- To control the synchronization process of the tie circuit-breaker and transformers incoming circuit-breakers of the 6.6kV Hull MCC (when foreseen the Type I Hull Generator in the project);
- To automatically control the active load sharing among generators that are running in parallel, according to Parallel Mode 1 and Parallel Mode 3 (refer to 3.1.1);
- To automatically control the reactive load sharing (and power factor) among generators that are running in parallel;
- To enable or inhibit starting of loads according to available generation capacity;
- To automatically control load shedding according to the available generation capacity;
- To automatically transfer load from a running generator to the remaining running units during the procedure of stoppage of one unit;
- To control the “Field Forcing” process in all medium voltage generators (Main Turbogenerator Units and Type I Hull Generators) in order to minimize voltage drop during starting of high power motors;

- To generate trend graphics of main variables (active power for each unit, reactive power for each unit, current for each unit, frequency, voltage, etc) of at least 10 days, with minimum sample rate of 1 seconds.

2. CODES, STANDARDS & REFERENCE DOCUMENTS

2.1. General

2.1.1. The PMS shall comply with the requirements of Classification Society, Brazilian Legislation, applicable regulatory rules and the codes and standards listed below.

2.1.2. Any deviation from this specification or the standards and reference documents shall be clearly defined by Manufacturer and approved by PETROBRAS.

2.2. Codes, Standards and Recommended Practices

2.2.1. IEC – International Electrotechnical Commission

IEC 61869	Instrument Transformers (all relevant parts)
IEC 60092	Electrical Installations in Ships
IEC 61439-2	Low-voltage switchgear and controlgear assemblies – Part 2: Power switchgear and controlgear assemblies
IEC 60364-4-41	Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock
IEC 60533	Electrical and Electronic Installations in Ships - Electromagnetic Compatibility
IEC 60947	Low-voltage Switchgear and Controlgear - All parts
IEC 61086	Coatings for Loaded Printed Wire Boards (conformal Coatings) - All parts
IEC 61892	Mobile and Fixed Offshore Units - Electrical Installations - All parts
IEC 62381	Automation Systems in the Process Industry - Factory Acceptance Test (FAT), Site Acceptance Test (SAT), and Site Integration Test (SIT)

2.2.2. Brazilian Labour and Employment Ministry

NR-10	Segurança em Instalações e Serviços em Eletricidade
NR-37	Segurança e Saúde em Plataformas de Petróleo

2.2.3. Brazilian Environment Ministry

Resolução Conama nº 382

Resolução Conama/MMA nº 501

2.3. Reference Documents

[1] I-ET-3010.00-5140-741-P4X-004 – SPECIFICATION FOR LOW-VOLTAGE GENERIC ELECTRICAL PANELS FOR OFFSHORE UNITS

[2] I-ET-3010.00-5140-700-P4X-005 - REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS

[3] I-DE-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE DIAGRAM

[4] I-ET-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE

[5] I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST

[6] DR-ENGP-I-1.15 - COLOR CODING

[7] I-ET-3010.00-5147-711-P4X-001 - MAIN GENERATOR FOR OFFSHORE UNITS

[8] TECHNICAL SPECIFICATION FOR TURBOGENERATOR PACKAGE

[9] ELECTRICAL SYSTEM DESCRIPTIVE MEMORANDUM

[10] I-ET-3010.00-5262-700-P4X-002 - HULL GENERATOR PACKAGE FOR OFFSHORE UNITS

[11] I-ET-3010.00-5140-700-P4X-003 - ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS

[12] I-ET-3010.00-5140-775-P4X-001 - REQUIREMENTS FOR ELECTRICAL GENERATION EXCITATION SYSTEM FOR OFFSHORE UNITS

[13] ELECTRICAL SYSTEM DESCRIPTIVE MEMORANDUM

[14] I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS

3. FUNCTIONAL CHARACTERISTICS

3.1. Definitions

3.1.1. The following definitions shall be considered for this document:

- Droop: speed control mode, related to prime movers of generators, performed by speed controller installed in TGCP or HGCP, which allows generators in parallel operation to share loads in proportion to their active power ratings. This definition refers to a single machine. The speed (frequency) and the load (active power) of each prime mover follow a percentage curve defined by:

$$Droop[\%] = \frac{No\ Load\ Speed - Full\ Load\ Speed}{No\ Load\ Speed}$$

- Isochronous: speed control mode, related to prime movers of generators, performed by speed controller installed in TGCP or HGCP, which keeps the speed (frequency) at a defined set point, despite the active power demand. This definition refers to a single machine.
- Parallel Mode 1: electrical system active power control mode, performed by PMS as secondary speed controller of prime movers of generators, sharing the total active power demand evenly (with the same percentage related to rated active power) amongst all Main Turbogenerators and Type I Hull Generators in parallel and remote/automatic position. This definition refers to electrical system (multiple machines in parallel).

- Parallel Mode 2: electrical system active power control mode, performed by PMS as secondary speed controller of prime movers of generators, so that 1 to (N-1) Main Turbogenerators and Type I Hull Generators keep fixed the active power and the remaining generators produce variable active power to balance generation and demand dividing the remaining active power evenly (with the same percentage related to rated active power). "N" is the quantity of generators in parallel. This definition refers to electrical system (multiple machines in parallel).
- Parallel Mode 3: electrical system active power control mode, performed by PMS as secondary speed controller of prime movers of generators, sharing the total active power demand evenly (with the same percentage related to rated active power) amongst all Main Turbogenerators and Type I Hull Generators in parallel and remote/automatic position. During a transient event (N-1) generators respond according to its speed versus load curve and 1 (one) Main Turbogenerator produces variable active power to balance generation and demand. "N" is the quantity of generators in parallel. The Main Turbogenerator with variable active power controls the frequency of the system. After the transient event the secondary controller of the prime movers acts on the speed versus load curve (N-1) generators sharing the total active power demand evenly (with the same percentage related to rated active power). This definition refers to electrical system (multiple machines in parallel).

- Field Forcing Process: actuate over AVRs inside TGCPs and HGCPs (HGCP requirement only applicable to Type I Hull Generators), 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.
  - UAM (Unit Alarm Malfunction): Alarm of the PMS that means that something is wrong with the equipment but it is still operating.
  - UAS (Unit Alarm Shutdown): Alarm of the PMS that means that something is wrong with the equipment and it is not operating.
  - Maximum Active Power (P_{MAX}): maximum active power that the generator can supply according to actual gas turbine conditions.
  - Individual Spinning Reserve (SR) or individual Power Budget: Maximum Active Power (P_{MAX}) for each generator minus Instantaneous Active Power (P_{INST}) produced by each generator

$$(SR) = P_{MAX} - P_{INST}$$

  - Global Spinning Reserve (GSR) = Σ SR for all generators in parallel operation.

NOTE 1: The PMS shall not permit a specific generator individual configuration when it results in a non-foreseen parallel mode operation.
NOTE 2: Vendor definitions (if are different from defined above) shall be adapted according to this Technical Specification or shall be submitted for PETROBRAS approval.

3.1.2. Depending on Main Turbogenerator or Hull Generator manufacturers, the individual control mode (droop, isochronous, etc.) of each Turbogenerator to achieve the Parallel Mode 1, Parallel Mode 2 and Parallel Mode 3 may vary.

3.1.3. Some Main Turbogenerator or Hull Generators manufacturers use the names droop and isochronous for control modes different from the descriptions above. There are also particular control modes and nominations for different manufacturers (isochronous-load-sharing, smart isochronous, etc.). This is valid also for reactive (voltage) control. PMS manufacturer shall analyse and understand the control modes (frequency, voltage, active power, reactive power, power factor) used by Turbogenerator and Type I Hull Generators manufacturer and shall adapt its (PMS) internal control to fully comply with functions required in this document. This kind of adaptation shall not be acceptable as motivation for change-orders or claims.

3.1.4. PMS manufacturer shall adapt the nomination of control modes according to Turbogenerator and Type I Hull Generator manufacturers standard, in order to avoid misunderstand and conflict in the whole documentation (PMS, Main Turbogenerators and Hull Generators). The new nomination shall be submitted to PETROBRAS, for approval. This kind of adaptation shall not be acceptable as motivation for change-orders or claims.

3.1.5. PETROBRAS reserves the right to exclude any Parallel Control Mode during the Detailed Design. This kind of adaptation shall not be acceptable as motivation for change-orders or claims.

3.2. General Requirements

3.2.1. PMS shall be manufactured, tested and installed according to functions described in 1.3.

3.2.2. PMS shall be a microprocessor based control system with interface modules specifically designed for the required functions.

3.2.3. PMS control functions shall not depend of software routines on the supervisory system installed in the HMI.

3.2.4. With PMS out of operation, the operation and control of each generator from its respective TGCP or HGCP and the operation of any other package or equipment shall not be impaired.

3.2.5. The UAM and the UAS conditions and the reset actions in PMS shall not turn off loads or generators, shall not carry out black-out and shall not impair the operability of electrical system of the platform.

3.2.6. Since different Turbogenerators and Hull Generators manufacturers have different control equipment and different control strategies, PMS Manufacturer shall adapt PMS control, logical, HMI, hardware and software to the interface and control characteristics of the equipment to which it will be connected, assuring the stability of electrical system operation and assuring full operability of functions defined in 1.3. This kind of adaptation shall not be acceptable as motivation for change-orders or claims.

3.2.7. The main 13.8 kV switchgear may be consisted of 2 (two) or more busbars. These busbars may be interconnected by tie circuit-breakers or busbars interconnection circuit-breakers. The status (closed/open) of these circuit-breakers may lead to multiple separated systems, one for each resulting island (subset of interconnected or isolated busbars) of the 13.8kV Main Switchgear. PMS shall be capable of identifying and controlling each system/island independently as required by each functionality.

3.3. Generators Control

3.3.1. Each generator will have a TGCP/PMS and HGCP/PMS switch (Local/Remote) and an Off/Automatic/Manual Synchronization switch, located in each TGCP and HGCP. Refer to I-ET-3010.00-5147-711-P4X-001 - MAIN GENERATOR FOR OFFSHORE UNITS and I-ET-3010.00-5262-700-P4X-002 - HULL GENERATOR PACKAGE FOR OFFSHORE UNITS. The HGCP and Hull Generators requirements are only applicable for Type I Hull Generators.

3.3.2. The operation of start and synchronization of Main Turbogenerators/Type I Hull Generators from PMS shall be possible only for TGCPs/HGCPs with the first switch in PMS (Remote) position and the second switch in Automatic Synchronization position.

3.3.3. Each TGCP/HGCP shall send a status signal of these switches (TGCP/PMS, HGCP/PMS and Off/Automatic/Manual Synchronization) to PMS. Refer to I-ET-3010.00-5147-711-P4X-001 - MAIN GENERATOR FOR OFFSHORE UNITS and I-ET-3010.00-5262-700-P4X-002 - HULL GENERATOR PACKAGE FOR OFFSHORE UNITS. The HGCP and Hull Generators requirements are only applicable for Type I Hull Generators

3.3.4. The start and stop control of generators from PMS shall be executed through TGCPs or HGCPs, including commands to open and close the incoming circuit-breaker in 13.8kV Main Switchgear and 6.6kV Medium Voltage Hull MCC. PMS shall send signals to start and stop operation to each TGCP/HGCP. The HGCP, Hull Generators and 6.6kV Medium Voltage Hull MCC requirements are only applicable for Type I Hull Generators.

3.3.5. In case of start command, each TGCP/HGCP will start its respective generator. When ready to synchronize, a signal shall be sent to PMS. PMS shall send an additional command to synchronize the generator with the busbar and close its circuit-breaker. In case of synchronization or breaker closing failure, TGCP/HGCP shall receive a reset signal from PMS in order to reset the sequence failure alarm and allow to restart the synchronization and circuit-breaker closing sequence upon receiving a new command. Signals shall be exchanged according to I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST. The Hull Generator start command is only applicable for Type I Hull Generators.

3.3.6. As soon as the generator is connected to the busbar, if the switch TGCP/PMS or HGCP/PMS (Type I Hull Generators) is in PMS (Remote) position, the PMS shall take over the controls of the generator set to a mode (nomination according to Turbogenerator manufacturer) that allows full control of frequency and voltage from PMS, in order to establish the active and reactive load sharing among generators in parallel and in order to keep the frequency and the voltage following set points, according to the electrical system control mode at PMS (Parallel Mode 1, Parallel Mode 2 or Parallel Mode 3 – refer to 3.1.1).

3.3.7. In case of the controlled stop command by PMS HMI, the PMS shall verify if available power generation remaining is able to keep the loads in operation after the stoppage of the selected generator. If the remaining generation is enough to keep the loads in operation, PMS shall transfer the load to the remaining generators and send the stop signal to TGCP/HGCP (Type I Hull Generators), which will open the main circuit-breaker and control the cool-down process of the generator. During the transfer load, the generator in stoppage process shall not continue in the load sharing. If the remaining generation is not enough to keep the loads in operation, the stoppage process shall be interrupted and an alarm shall be sent to operator.

3.3.8. The status (Open/Closed/Available/Not Available/Inserted/Extracted) of the generators incoming circuit-breakers of 13.8kV Main Switchgear and 6.6kV Medium Voltage Hull MCC shall be sent to PMS from TGCPs and HGCPs. The 6.6kV Medium Voltage Hull MCC requirements are only applicable for Type I Hull Generators.

3.3.9. The generators have capacity to run in parallel or in stand-alone operation depending on the status of the tie circuit-breakers, busbars interconnection circuit-breakers or the circuit-breakers connected to 6.6kV Medium Voltage Hull MCC and depending on the quantity of generators on in each busbar. The PMS shall monitor the status of the circuit-breakers and the quantity of generators in each busbar, to determine which generators run in parallel and in stand-alone operation. All PMS control functions shall be automatically adapted to the operation mode as per this status. The 6.6kV Medium Voltage Hull MCC requirements are only applicable for Type I Hull Generators.

3.3.10. For information about synchronization process, refer to item 3.9.

3.3.11. In case of the PMS receive the information that the Main Tubogenerator is in “Step to Idle”, the PMS shall not consider this Turbogenerator in the Global Spinning Reserve.

3.4. Active Power Generation Load Sharing

3.4.1. PMS shall carry out active power load sharing among Generators in remote position in TGCP and HGCP (HGCP shall be considered when foreseen the Type I Hull Generator in the project), according to Parallel Mode 1, Parallel Mode 2 and Parallel Mode 3 (defined in 3.1.1). It shall be possible to select in PMS HMI which Turbogenerator will be with variable active power, in case of Parallel Mode 3.

3.4.2. To carry out this function, PMS shall calculate and send active power load share set point or shall send increase or decrease frequency signals to TGCPs and HGCP (HGCP shall be considered when foreseen the Type I Hull Generator in the project), according to generator manufacturer control strategy. PMS shall carry out the Load Sharing function and shall simultaneously control the frequency of the system. The PMS calculation of the load sharing set point shall only consider the active power of parallel generators in remote position on TGCP and HGCP (only applicable for Type I Hull Generators).

3.4.3. Generation capacities are pending on the fuel selection and cooling water temperature. The PMS shall determine the capacity of each generator based on fuel selection and on Maximum Active Power (P_{MAX}) signals (from TGCPs or HGCPs). TGCPs/HGCPs shall send signals to PMS, informing the fuel selection. Generation capacities are pending on other variables, but these relations shall be considered by manufacturer in Maximum Active Power (P_{MAX}) signals sent from TGCPs/HGCPs to PMS. PMS manufacturer shall analyse the formation of Maximum Active Power (P_{MAX}) signals (from Main Turbogenerator and Hull Generator manufacturers), in order to correctly consider this signal and the fuel selection signal. The PMS shall permit use the Maximum Active Power (P_{MAX}) signal from TGCP/HGCP or a value defined in HMI for each generator, being used the lowest value among them. Signals shall be exchanged according to I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST. The HGCP and Hull Generators requirements are only applicable for Type I Hull Generators.

3.4.4. The PMS shall perform the load sharing among the main generators respecting the maximum active power limit of each Turbogenerator and Type I Hull Generator, according to the Maximum Active Power (P_{MAX}) signal from TGCP/HGCP or value defined in HMI. Additionally, the Main Turbogenerators shall not participate of the load sharing if NPT (Power Turbine Rotation) fuel control mode of the turbine is not activated.

3.4.5. PMS shall monitor the control modes and the position of control switches of each TGCP/HGCP (HGCP shall be considered when foreseen the Type I Hull Generator in the project), analysing the compatibility of these modes and positions with the requirements to Active Power Generation Load Sharing Control.

3.4.6. In case of wrong control mode (droop, isochronous or other nomination, according to generator manufacturer) selected in TGCPs/HGCPs, if the TGCP/PMS or HGCP/PMS (Local/Remote) switch of this TGCP/HGCP is in PMS (Remote) position, PMS shall send a control signal to TGCP/HGCP, to commutate to the correct control mode. The HGCP and PMS interfaces are only applicable for Type I generators.

3.4.7. In case of switches of TGCPs/HGCPs (HGCP shall be considered when foreseen the Type I Hull Generator in the project) in wrong positions, impeding the control, PMS shall generate one local alarm signal and one remote network alarm signal to be sent to ESA, indicating the wrong position and the TGCP/HGCP (HGCP shall be considered when foreseen the Type I Hull Generator in the project) which control is impeded. Signals shall be exchanged according to I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.

3.4.8. It shall be possible to set in PMS screen a safety factor in order to reduce the generation active power. This safety factor is set according to possible uncertainties about generation measurements in order to avoid a generation overload during load starting.

3.4.9. PMS shall keep the stability of the system in case of any tie circuit-breaker or busbar interconnection circuit-breaker opening in 13.8kV Main Switchgear, tie circuit-breaker opening in the 6.6kV Medium Voltage Hull MCC or opening of the transformers incoming circuit-breakers connected to 6.6kV Hull Generator MCC. In this operational condition, PMS shall be capable to manage separate active power generation load sharings, for each busbar of the 13.8kV Main Switchgear and the 6.6kV Medium Voltage Hull MCC panel of the Hull Generator. For loads in 6.6kV MCCs, PMS shall be capable to detect in which feeder of the 13,8kV Panel the load is connected, according to the status of the incoming and tie circuit-breakers. Manufacturer shall submit the solution for PETROBRAS approval. The 6.6kV Medium Voltage Hull MCC requirements are only applicable for Type I generators.

3.4.10. The acceptable dead band in the active power generation load sharing shall be a maximum of 0.5MW. Differences in active power load sharing greater than dead band setting shall be automatically corrected by PMS. The dead band can be adjustable in the HMI, controlled by password.

3.5. Reactive Power Generation Load Sharing

3.5.1. PMS shall calculate a target reactive power value for each generator and shall maintain this value by adjusting the AVRs' set points in TGCPs/HGCPs (HGCP shall be considered when foreseen the Type I Hull Generator in the project) using increase or decrease pulses issued via voltage-free contacts. Refer also to 3.1.3, 3.1.4 e 3.2.6.

3.5.2. The target reactive power value shall be calculated to share reactive load evenly among interconnected generators in remote position on TGCP/Type I HGCP (PMS control), in proportion to the generators capacity (similar to Parallel Mode 1, but considering reactive power control).

3.5.3. The acceptable dead band in the reactive power generation load sharing shall be a maximum of 0.5MVAr. Differences in reactive power load sharing greater than dead band setting shall be automatically corrected by PMS. The dead band can be adjustable in the HMI, controlled by password.

3.5.4. Reactive power control is closely linked to voltage control, so increase or decrease signals for voltage and reactive power shall be combined in PMS to produce a single increase or decrease output signals for each TGCP/Type I HGCP. The PMS shall automatically share the reactive power and control the voltage at main busbar as secondary control. Refer to I-ET-3010.00-5147-711-P4X-001 - MAIN GENERATOR FOR OFFSHORE UNITS and I-ET-3010.00-5262-700-P4X-002 - HULL GENERATOR PACKAGE FOR OFFSHORE UNITS.

3.5.5. Alternative control strategies may be required, according to generators manufacturers. PMS manufacturer shall comply with items 3.1.3, 3.1.4 e 3.2.6, adapting its (PMS) internal control, in order to provide full and reliable reactive power, power factor and voltage control of Main Generation and Type I Hull Generator.

3.5.6. The PMS shall be fully compatible with AVR and all interfaces with the acquired generators. Refer to I-ET-3010.00-5140-775-P4X-001 - REQUIREMENTS FOR ELECTRICAL GENERATION EXCITATION SYSTEM FOR OFFSHORE UNITS.

3.5.7. PMS shall keep the stability of the system in case of any tie circuit-breaker or busbar interconnection circuit-breaker opening in 13.8kV Main Switchgear, tie circuit-breaker opening in the 6.6kV Medium Voltage Hull MCC panel or opening of the transformers incoming circuit-breakers connected to Hull Generator panel. In this operational condition, PMS shall be capable to manage separate reactive power generation load sharings, for each semibar of the 13.8kV Main Switchgear and the 6.6kV MCC panel of the Hull Generator. For loads in 6.6kV MCCs, PMS shall be capable to detect in which feeder of the 13,8kV Panel the load is connected, according to the status of the incoming and tie circuit-breakers. Manufacturer shall submit the solution for PETROBRAS approval. The 6.6kV Medium Voltage Hull MCC requirements are only applicable for Type I Hull Generators.

3.6. Load Shedding

3.6.1. PMS shall be able to trip all motors in 13.8kV or transformers in 13.8kV for resistive loads of 13.8kV Main Switchgear (include the spare loads) to avoid cascade failure of the generation system. The amount of load to be shed shall considerer de real active power demand of each load. Load shedding shall be activated in the following situations:

- Sudden loss of generators leading to an overload of the remaining generators on line;
- Gradual generator overload;
- Gradual and Instantaneous system underfrequency;
- Sudden opening of any tie circuit-breaker or busbars interconnection circuit-breaker of the 13.8kV Main Switchgear leading to an overload of the remaining generators on line in each resulting island (subset of interconnected busbars);
- Main Turbogenerators total demand exceeding 100MW, when UNIT is not an "All-Electric" type, to comply with Resolução Conama nº 382 (This requirement shall not be applied to All-Electric units as per Resolução Conama/MMA nº 501. All-Electric Units are those in which turbines are only used for electric power generation).

3.6.2. The performance shall be reached by a selective load disconnection (for the situations above) according to a priority table. This table shall aggregate the instantaneous load demand of some selected loads achieved according to I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST. To each load, a priority shall be allocated, thus defining the shedding sequence to be adopted. The operator shall have access, controlled by password, to change priorities in this table by HMI. The priority table shall be the same for all load shedding situations.

3.6.3. The instantaneous load demand of the loads listed in 3.6.1 shall be achieved according to I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST. For communication interfaces, refer to 3.10. This interface cannot imply in time delay to load shedding functions.

3.6.4. The selection of loads for shedding and their corresponding priorities shall be defined during Detailed Design, based in the Transient Stability Study. A preliminary table of minimum loads that shall be considered for reference is described in ELECTRICAL SYSTEM DESCRIPTIVE MEMORANDUM.

3.6.5. PMS shall have an internal table with the operational active power values of all loads included in load shedding process. The operator shall have access to change values in this table and priorities to shed. It shall be possible to block the load shedding for any load, including many loads simultaneously, defined by the operator, controlled by password. This block may be implemented as a priority to be selected which will never be shed in load priority list.

3.6.6. The PMS shall calculate the generation capacity, taking into consideration item 3.4.3.

3.6.7. The PMS shall be able to distinguish a large generation deficit from a gradual generation overload, so as to properly active either the fast or the gradual action load shedding.

3.6.8. Fast action load shedding shall be performed in case of severe incidents resulting in a large generation deficit (such as a generator circuit-breaker opening or tie circuit breaker opening). In this case, the PMS shall immediately detect the power deficiency and then trip sufficient loads to keep the system stability up to 100 ms (one hundred miliseconds) or during time limit based in the Transient Stability Study.

3.6.9. The trip time shall consider the time between circuit-breaker opening (generator or TIE) and the time to close the load trip relay (normally open contact).

3.6.10. Gradual generation overload (active power demand higher than Maximum Active Power sent by TGCP) or trend of overload of any generator shall be detected. A preset gradual generation overload limit shall be possible to be set.

3.6.11. At the moment that a gradual generation overload is detected, the system shall check the generator time-dependent capability. If the overload is maintained for a time such that the generator overload limit is reached, then PMS shall perform disconnection of loads as fast as possible (one control program scan). The amount of load to be shed shall consider the total load demand and the number of parallel generators available.

3.6.12. Underfrequency load shedding shall have two ways of operation: one related to a non-severe underfrequency (gradual underfrequecy load shedding) and another related to a sudden underfrequency (instantaneous underfrequency load shedding). The process shall be initiated when the frequency of the system falls below the preset value for the duration of a preset time or instantaneously in case the frequency reaches the instantaneous underfrequency load shedding setpoint. The trip shall be recursive beginning by the top priority loads to be shed and shedding consecutively the lower priorities in steps. Each underfrequency setpoint shall shed one or more priorities at once according to the underfrequency severity.

3.6.13. Gradual underfrequency load shedding shall use an integrator frequency *versus* time. The fastness to start the gradual underfrequency load shedding and the amount of load to be shed shall be directly proportional to the system frequency reduction, i.e. the greater the underfrequency, the faster to start the load shedding and the greater the active power to be shed. The Gradual underfrequency load shedding shall be divided in steps and the PMS screen shall allow adjustments of frequency, time and amount of load to be shed. PMS manufacturer shall present for PETROBRAS approval, the method (equation) used to define the power to be turned off as function of frequency.

3.6.14. For instantaneous underfrequency load shedding, PMS shall perform the load shedding in a maximum time of 100ms (one hundred miliseconds) or during time limit based in the Transient Stability Study. In this function, PMS shall allow adjustments in the screen of the load active power that will be shed.

3.6.15. If the frequency of the system is not recovered after the first load shedding cycle, PMS shall be capable to recognize subsequent scenarios and perform new frequency check routines and new underfrequency load sheddings until the system frequency recovery.

3.6.16. PMS load shedding functions shall have independent algorithms for each function (instantaneous underfrequency, gradual underfrequency, fast load shedding, gradual generator overload) in order to allow parallel operation of this functions. There is no priority between algorithms. All algorithms works at same time and shedding loads in accordance with events (generator trip, underfrequency, etc). PMS load shedding shall be able to shed loads during simultaneous events.

3.6.17. The operator shall have access to inhibit any of the load shedding functions (instantaneous underfrequency, gradual underfrequency, fast load shedding, gradual generator overload), controlled by password in PMS HMI.

3.6.18. The PMS shall be able to allow short-time generation overload such as motor starting and transformers in-rush.

3.6.19. PMS shall keep the stability of the system in case of any tie circuit-breaker or busbar interconnection circuit-breaker opening in 13.8kV Main Switchgear, tie circuit-breaker opening in the 6.6kV Medium Voltage Hull MCC or opening of the transformers incoming circuit-breakers connected to 6.6kV Medium Voltage Hull MCC. In this operational condition, PMS shall be capable to manage separate load shedding control tables, one for each resulting island (subset of interconnected busbars) of the 13.8kV Main Switchgear. For loads in 6.6kV MCCs, PMS shall be capable to detect in which feeder of the 13,8kV Panel the load is connected, according to the status of the incoming and tie circuit-breakers. Manufacturer shall submit the solution for PETROBRAS approval. The 6.6kV Medium Voltage Hull MCC requirements are only applicable for Type I Hull Generators.

3.6.20. The load shedding outputs shall use voltage-free contacts, which relays shall be energized to trip the loads. The output contacts for loads in 13.8kV panel shall be N.O. (normally opened - to turn on trip coil of circuit-breakers). PMS cannot shed power transformers (electrical distribution system 13.8 kV / 6.6 kV and 13.8 kV / 480 V).

3.6.21. The PMS shall have provisions to prevent spurious load shedding due to a single hardware failure or I/O failure.

3.6.22. To comply with the Resolution Conama 382/06, the total electric power demand supplied by Main Turbogenerators shall not surpass 100MW for non All-Electric UNIT. PMS shall control this limit in Main Turbogenerators, transferring load to the Hull Generators, or shedding loads when Hull Generators rated power is achieved (only applicable for Type I Hull Generators). It's acceptable transitory power demand greater than 100MW in Main Turbogenerators during motor starting, or other transitory events. Manufacturer shall submit the solution to Petrobras approval. (This requirement shall not be applied to All-Electric units as per Resolução Conama/MMA nº 501. All-Electric Units are those in which turbines are only used for electric power generation).

3.7. Load Starting Inhibition

3.7.1. PMS shall carry out starting load inhibition routine, started by external "Starting Request" signals. Prior to the closing command of any motor load circuit-breaker in 13.8kV Main Switchgear, PMS shall be able to check its databank for the expected load to be added (according to 3.6.5), sending a "Starting Permission" signal, if there is generation capacity. PMS shall check if the total active power demand in Main Turbogenerators not exceed 100MW.

3.7.2. The loads to be inhibited through the starting load inhibition system shall be defined from the stability study to be performed during Detailed Design.

3.7.3. For the loads that will be inhibited, the closing of respective circuit-breakers or contactors shall be inhibited to avoid a permanent overload in generation system or exceeding the limits of voltage drop (e.g.: when trying to start one main gas compressor with only one main generator). In such a case, the PMS shall indicate the necessity of starting the next available generator and shall block the motor starting (not sending the "Starting Permission" signal).

3.7.4. PMS shall be capable to carry out starting load inhibition considering the status of any tie circuit-breaker or busbar interconnection circuit-breaker of the 13.8kV Main Switchgear open or closed. For any tie circuit-breaker or busbar interconnection circuit-breaker of the 13.8kV Main Switchgear open, PMS shall be capable to manage multiple separated systems for starting load inhibition: one for each resulting island (subset of interconnected or isolated busbars) of the 13.8kV Main Switchgear. For each system, the functions defined in 3.7.3 shall be performed. Manufacturer shall submit the solution for PETROBRAS approval.

3.7.5. The "Starting Request" and "Starting Permission" signals shall be exchanged according to I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.

3.7.6. For loads classified as EA01 in I-ET-3010.00-5140-700-P4X-003 - ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS, the starting process is as follows:

1) a load starting is requested from:
   a) Supervisory and Operating System (SOS) HMI or;
   b) field push-button;
2) the starting request is sent to PMS, through ESA, that verifies its data bank according to generation available power;
3) a starting permission[1] can be sent or not by PMS to A&C, through ESA, that verifies the permissive logic built up for the load;
4) according to permissive logic, a starting signal from A&C is sent to MCC/CDC, through ESA.

Note 1: For loads that need field forcing control, refer to 3.8.

3.7.7. For loads classified as EA02 and EA03 in I-ET-3010.00-5140-700-P4X-003 - ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS, the starting process is as follows:

1) a load starting can be requested from:
   a) VSD or soft-starter or;

b) field push-button;
c) Electrical System HMI

2) the starting request is sent to PMS, through ESA, and PMS verifies its data bank according to generation available power;

3) a starting permission[1] can be sent or not by PMS to VSD or soft-starter, through ESA.

Note 1: For loads that need field forcing control, refer to 3.8.

3.7.8. For loads classified as EA04 in I-ET-3010.00-5140-700-P4X-003 - ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS, the starting process is as follows:

1) a load starting is requested from:
   a) the Package Control Panel (via workstation or push-button, according to package documentation) or;
   b) field push-button (if required in package standards);

2) the starting request is sent to PMS, that verifies its data bank according to generation available power;

3) a starting permission[1] can be sent or not by PMS to Package Control Panel, according to main generation available power.

Note 1: For loads that need field forcing control, refer to 3.8.

3.7.9. It shall be possible to set in PMS screen safety factors in order to reduce both generation available active and reactive power. These safety factors are set according to possible uncertainties of the generation measurements in order to avoid a generation overload during load starting.

3.8. Field Forcing Control

3.8.1. Before the starting of some high power motors, defined by Detailed Design according to Electrical System studies, PMS shall actuate over all AVRs in the TGCPs and HGCPs (HGCP requirement only applicable to Type I Hull Generators) and control the Field Forcing Process (refer to 3.1.1), in order to minimize voltage drop at main busbar. The start of Field Forcing process shall be synchronized with the “Starting Permission” signal. The operator shall have access to change the values and time duration of Field Forcing in HMI.

3.8.2. PMS shall send “Starting Permission” signal to the loads after the voltage at busbar that feeds the load reach the pre-selected adjustable value, according to Electrical Studies. Refer to I-ET-3010.00-5147-711-P4X-001 - MAIN GENERATOR FOR OFFSHORE UNITS and I-ET-3010.00-5262-700-P4X-002 - HULL GENERATOR PACKAGE FOR OFFSHORE UNITS.

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

3.8.4. The time requirements for this process shall be defined during Detailed Design, by Electrical System studies. PMS shall comply with these requirements.

3.8.5. PMS manufacturer shall analyse and fully understand the AVRs used by Main Turbogenerator and Type I Hull Generator manufacturers and shall adapt it in the PMS internal control to fully comply with it during the Field Forcing process. Since different Main Turbogenerator and Hull Generators manufacturers have different AVR control equipment and different control strategies, PMS Manufacturer shall adapt PMS control, logical, interfaces, HMI, hardware and software to the interface and control characteristics of generators manufacturers, assuring the stability of electrical system operation and assuring full operability of this function. This kind of adaptation shall not be acceptable as motivation for change-orders or claims.

3.8.6. During the Field Forcing process the PMS shall share the total active and reactive power demand evenly amongst all generators in parallel and remote/automatic position.

3.8.7. For interface with AVR, refer to I-ET-3010.00-5140-775-P4X-001 - REQUIREMENTS FOR ELECTRICAL GENERATION EXCITATION SYSTEM FOR OFFSHORE UNITS.

3.9. Circuit-Breakers Control

3.9.1. PMS shall control (open / close) of any tie circuit-breaker or busbar interconnection circuit-breaker of 13.8KV Main Switchgear, tie circuit-breaker of 6.6kV Medium Voltage Hull MCC and Power Transformers incoming circuit-breakers connected to 6.6kV Hull MCC. The parallelism among generators through the circuit-breakers shall be controlled by the PMS, which shall send signals to TGCPs and HGCPs of generators in operation to control the voltage and frequency and shall send a closing command to these circuit-breakers when the parallelism requirements are guaranteed. The closing command shall be inhibited on unsynchronized conditions. The 6.6kV Medium Voltage Hull MCC requirements are only applicable for Type I Hull Generators.

3.9.2. PMS shall monitor the control modes and the position of control switches of each TGCP/HGCP (HGCP shall be considered when foreseen the Type I Hull Generator in the project), analysing the compatibility of these modes and positions with the requirements to control the synchronization process through tie circuit-breaker.

3.9.3. In case of switches in wrong positions, impeding this actuation, alarms shall be generated, according to item 3.4.7.

3.9.4. In case of wrong control mode selected in TGCPs/HGCPs, if the Local/Remote switch of this TGCP/HGCP is in PMS (Remote) position, PMS shall send a control signal to TGCP/HGCP, to commutate to the correct control mode. If the switch is in TGCP/HGCP (Local) position, PMS shall send one local alarm signal and one remote network alarm signal to ESA, indicating the wrong switch in the TGCP/HGCP. Signal shall be exchanged according to I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST. The HGCP, Hull Generators and 6.6kV Medium Voltage Hull MCC requirements are only applicable for Type I Hull Generators.

3.9.5. PMS shall monitor the dead-bus condition in every busbar of 13.8KV Main Switchgear, in order to allow safe closing of tie circuit-breakers or busbar interconnection circuit-breakers in case of dead-bar in any busbar. The dead-bar monitoring shall consider the following hardwired signals: positions of circuit-breakers (open / closed), voltages at busbars and power produced by Turbogenerators. Signal shall be exchanged according to I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.

3.9.6. The overall dead-bus condition signal of 13.8 kV Main Switchgear, when all busbars are in dead-bus condition, shall be used to generate the dead-bus signal to be exchanged according to I-LI-3010.00-5140-797-P4X-001 - Electrical System Automation Interface Signal List.

3.9.7. PMS shall monitor the dead-bus condition in both busbars of Hull 6.6 KV MCC (which Hull generators are connected), in order to allow safe closing of tie circuit-breaker in case of dead-bar in one or in both busbars. The dead-bar monitoring shall consider the following hardwired signals: positions of circuit-breakers (open / closed), voltages at busbars and power produced by Hull Generator. The dead-bus requirements for 6.6kV Medium Voltage Hull MCC are only applicable for Type I Hull Generators.

3.9.8. The overall dead-bus condition signal of Hull 6.6 kV MCC, when both busbars are in dead-bus condition, shall be used to generate the dead-bus signal to be exchanged according to I-LI-3010.00-5140-797-P4X-001 - Electrical System Automation Interface Signal List. The dead-bus requirements for 6.6kV Medium Voltage Hull MCC are only applicable for Type I Hull Generators.

3.9.9. It shall be possible to carry out the synchronization process automatically, through PMS control actuating on TGCPs/HGCPs or manually, using manual increase and decrease selector switches for voltage and frequency. There shall be one selector switch to select the controlled busbar (the control signals shall actuate on Main Turbogenerators/Hull Generators of the selected busbar), in case of manual control. The HGCP, Hull Generators and 6.6kV Medium Voltage Hull MCC requirements are only applicable for Type I Hull Generators.

3.9.10. All necessary instruments, indicators and switches shall be installed on front door of PMS. It shall be possible to carry out this operation with the doors closed.

3.10. Communication Interfaces

3.10.1. The main interfaces among PMS, A&C, ESA, TGCPs, HGCPs and Electrical Panels are defined in I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.

3.10.2. The PMS shall be connected to ESA through Fast Ethernet Networks according to 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. PMS shall not interconnect any Electrical System Automation Network internally, maintaining the physical network segregation of Electrical System Automation Networks.

3.10.3. The PMS controllers shall communicate with ESA using a communication protocol based on Ethernet defined by PMS manufacturer. Other network interfaces (for example IEC 61850, OPC UA, etc.) shall follow Electrical System Automation specifications. For details, refer to 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.

3.10.4. The PMS base time requirements with ESA are defined in I-ET-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE.

3.10.5. PMS Controller shall be capable to communicate using IEC61850 protocol in order to provide communication with IEDs (MMRs).

3.10.6. All input signals not defined as hardwired connection shall be received by these network connections.

3.10.7. All internal data of PMS shall be available at ESA through these network connections, for remote monitoring.

3.10.8. PMS shall include an OPC UA (Open Platform Communications Unified Architecture) client and server software in the PMS server computer compatible with Electrical System Automation OPC UA Client and server Software to be connected to the topside fast Ethernet HMI/OPC UA network according to I-DE-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE DIAGRAM.

3.10.9. PMS OPC UA Client and Server shall allow the topside Electrical System Automation RTDSs to read and write all data from the PMS database in order to allow supervision and control integration from Topside Electrical System Automation.

3.10.10. PMS OPC UA client and server shall be capable of reading data from Electrical System Automation OPC UA Client and Server in order to obtain general supervision data, which are not related to PMS control functions, from Electrical System Automation to PMS.

3.10.11. The PMS server computer shall have one dedicated network interface card to provide connection to the topside fast Ethernet HMI/OPC UA network using the IP address range from the topside fast Ethernet HMI/OPC UA network.

3.10.12. PMS HMI shall include a dedicated Ethernet network interface card to provide remote desktop connection through the Electrical System Automation A&C Interface Fast Ethernet network using A&C IP range.

3.10.13. All output contacts shall be sized for the making and breaking capacity required by the respective loads.

3.10.14. The use of fast action interposing relays shall be limited to multiplication of contacts and for cases where there is no output contact with necessary capacity to switch the load. These cases shall be submitted to PETROBRAS approval.

3.10.15. Interface relays (when approved) power consumption shall be 1VA maximum.

3.10.16. PMS shall access the printers installed in Central Control Room (CCR) by means of the network communication.

3.11. Alarms

3.11.1. At least the following alarms shall be included to indicate possible problems with the power system controlled by PMS. The alarms shall be active for the duration of the problem and shall be resettable from its HMI. The list below is not intended to define all alarms and shall be complemented by Detailed Design. The alarm texts shall be revised, complemented and submitted to PETROBRAS approval, in order to clearly define each condition.

- Gradual overload;
- Load shedding actuated (it shall be informed if the actuation was triggered by fast load shedding control, gradual load shedding control, gradual underfrequency control, sudden underfrequency control or total demand exceeding 100MW in the Main Turbogenerators with values to shed and system frequency);
- Total active power demand of the Turbogenerators greater than 95MW, load shedding will occur if load demand reaches more than 100 MW (only considering the Main Turbogenerators power demand), applicable to non All-Electric UNITs;
- Low spinning reserve;
- High spinning reserve;
- Active power sharing mismatch (> 0.5MW);
- Reactive power sharing mismatch (> 0.5 Mvar);
  - Generator target (active power and reactive power) cannot be achieved;
- Generator operation outside capability curve region (the exceeded limit shall be informed);
- TGCP/HGCP control switch or control mode in wrong position to allow synchronization through circuit-breakers (the TGCP/HGCP, the switch and the control mode shall be informed);
- TGCP/HGCP control switch or control mode in wrong position to allow Active Power Load Sharing (the TGCP/HGCP, the switch and the control mode shall be informed);
- TGCP/HGCP control switch or control mode in wrong position to allow Reactive Power Load Sharing (the TGCP/HGCP, the switch and the control mode shall be informed);
- Remaining generators available power not enough to supply power demand - Stoppage sequence aborted (in case of stop request from PMS HMI for one turbogenerator - turbogenerator to be stopped shall be informed);
- Motorical load starting request denied - insufficient generation capacity (the motor load and the generation deficit shall be informed);
- Motorical load starting request denied - excessive voltage drop expected (the motor load and the generation deficit shall be informed);
- Parallel operation in isochronous mode inhibited (see item 3.14.2).

3.12. Diagnostics

3.12.1. PMS shall include comprehensive self-diagnostic. All diagnostic shall be performed automatically on-line, identified and alarmed.

3.12.2. The diagnostic shall include, at least:

- I/O status check

- Busbar voltage measurement fault (when the foreseen voltage, based on circuit-breakers status, is different from the actual measured value. Dead band shall be defined in detailed design)
- Busbar frequency measurement fault (when the foreseen frequency, based on circuit-breakers status, is different from the actual measured value. Dead band shall be defined in detailed design)
- Software check
- PMS power supply check (both feeders shall be checked)
- Processor(s) check
- System memory check
- All networks Communication status check
- Failure in control voltage
- Ground fault summary

3.12.3. All failures shall be individually indicated at PMS HMI. The texts shall be revised, complemented and submitted to PETROBRAS approval, in order to clearly define each condition.

3.12.4. Failures that not impair PMS operation shall be combined in a network and a hardwired (voltage-free contact) common alarm output signal of UAM. The alarm signal shall be exchanged according to I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.

3.12.5. Failures that impair PMS operation shall inhibit PMS external actuation and shall be combined in a network and a hardwired (voltage-free contact) common alarm output signal of UAS. The alarm signal shall be exchanged according to I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.

3.13. Event Logging

3.13.1. PMS shall use a Windows application for sequentially logging and time stamping of events. The events shall be displayed as and when they occur. Events shall be able to be sorted, filtered and exported to a standard windows database file.

3.13.2. PMS base time shall be synchronized and use the same time tagging format used by Electrical System automation devices. Refer to I-ET-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE.

3.13.3. PMS shall have a portable flash drive with security mechanisms to prevent unauthorized data access (size shall be defined during Detailed Design). The minimum capacity of store shall be 6 months of historical data collection and register.

3.13.4. PMS shall logging all important events, at least:

- Loading shedding events
- Load sharing commands
- All alarms listed in 3.11
- Diagnostics fail alarms
- Medium voltage circuit-breakers status
- Turbogenerator trips and circuit-breaker status
- Control mode of each generator
- Local/remote switch position
- Automatic/manual switch position

- Field Forcing Process
- Change of load shedding priority table
- UAM and UAS alarms

3.14. Interlockings

3.14.1. The PMS shall control and shall monitor the interlockings foreseen for the electrical system.

3.14.2. PMS shall inhibit the closing of generator circuit-breaker of any Generator in isochronous mode to operate in parallel with other generators in isochronous mode if the incoming generator TGCP/PMS (or HGCP/PMS if applicable) switch is at Local option. This requirement may need adaptations, according to 3.1.3 and 3.1.4. Network alarm signal shall be sent to ESA.

4. CONSTRUCTIVE CHARACTERISTICS

4.1. PMS shall be manufactured, tested and installed according to all standards listed on item 2.

4.2. For installation in ships (FPSO and FSO), the standards IEC 60092-201 and IEC 60092-302 shall have priority over others standards.

4.3. PMS Manufacturer shall provide all instructions, tools, accessories (connection cables, connectors, calibration boxes, etc.), softwares and software licenses that are necessary for assembly, start-up, operation, maintenance and disassembly of PMS.

4.4. PMS shall be rack-mounted in a floor-mounted panel provided with a Human Machine Interface (HMI) which displays the operational screens and all data and operational presets.

4.5. PMS shall have internal separation so that redundant items or elements shall be installed in different compartments.

4.6. PMS shall comply with all requirements about environmental, motion, inclination, vibration, voltage, frequency, electromagnetic compatibility (EMC) and constructive characteristics for panels, defined by I-ET-3010.00-5140-741-P4X-004 – SPECIFICATION FOR LOW-VOLTAGE GENERIC ELECTRICAL PANELS FOR OFFSHORE UNITS and I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

4.7. The last coat color shall be Light Green Munsell 5G8/4. Inner components mounting plate, internal doors faces shall be Safety Orange Munsell 2.5YR6/14, according to DR-ENGP-I-1.15 - COLOR CODING

4.8. PMS shall be proper for indoor installation.

4.9. PMS control circuits shall be fed by two 220VDC feeders, isolated from ground, supplied by external UPS. PMS shall remain functioning during failure of one (anyone) of the power supplies, without momentary blackout. There shall be selector switches to turn on/off these UPS supplies.

4.10. If Manufacturer uses other internal control voltages, galvanically isolated from external power source, this internal control voltage shall be isolated from ground and one ground fault detector shall be supplied and installed (because the ground fault detectors installed

in UPS distribution panels will not be effective for ground faults in this system) inside PMS.

4.11. PMS shall have a label identifying the grounding system for the power and control systems.

4.12. Circuits and terminals with different voltages shall be properly separated, signalized and protected against accidental contacts.

4.13. For the main distribution busbar of PMS it shall be foreseen a Surge Protective Device (SPD) according to requirements of NFPA 70 for insulated systems. SPD shall have a maximum discharge current of 10 kA in 8/20 microseconds, as required by NFPA 780 section 4.20.3.2.2.

4.14. PMS heating circuits shall be fed by one 220VAC, 2 phases, isolated neutral, 60Hz external normal supply.

4.15. The PMS, shall have indication of the NAME and the FUNCTION of the equipment, in addition to the alphanumeric TAG. Each component for manoeuvrings and monitoring, selector switches, pilot lamps, status indication etc. shall have individual identification, in Portuguese language.

4.16. PMS controllers shall be constituted of redundant, hot-standby system without any common mode fault and with facilities for hot-swap.

4.17. The devices related to operation installed inside the panel shall have an indication label with a clear identification of the TAG.

4.18. The PMS shall have at least the following quantity of reserve I/O points:

- 20% for discrete input I/O, related to the total discrete input I/O points;
- 20% for discrete output I/O, related to the total discrete output I/O points;
- 20% for analog input I/O, related to the total analog input I/O points;
- 20% for analog output I/O, related to the total analog output I/O points.
- 20% for auxiliary relays to load shedding.

4.19. In order to make the communication among the PMS and each TG, MC, 13.8kV Main Switchgear and 6.6kV MCCs (6.6kV MCCs requirements are applicable when foreseen the Type I Hull Generator in the project) possible and in order to comply with all function required in 1.3, the PMS Manufacturer shall provide at least 30 (thirty) additional spare hardwired input or output discrete points and 6 (six) additional spare hardwired input or output analog points, to be used, if necessary, during Detailed Design without additional cost. This quantity is additional to requirement of item 4.18.

4.20. The PMS software and hardware requirements shall be the same as the requirements for Electrical System Automation Equipment defined in I-ET-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE.

4.21. It shall be installed inside PMS panel the galvanic isolators for analog signals received.

5. PMS INTERFACE (HMI)

5.1. HMI Screens

5.1.1. HMI shall be a Manufacturer standard display installed on the panel door, “windows” style and hierarchically organized.

5.1.2. HMI shall have at least 21”.

5.1.3. The PMS control software and the HMI shall run on separate microprocessor systems, with an ethernet network link using vendor standard communication protocol providing communications between them. The HMI shall use the operating system “Windows”.

5.1.4. A maintenance interface shall be provided for connection of a PC laptop.

5.1.5. At least the following display screens shall be available:

- Main One-Line Diagram screen with status (on and off) of all medium-voltage circuit-breakers (include spare loads), contactors and generators, all low-voltage generators, system total demand and voltages, frequency and power available at each bus-bar;
- Detailed screens and tables;
- Trend screens;
- Detailed screens of each Main Turbogenerator Unit, including all monitored variables and settings;
- Detailed screens of each Hull Generator Unit, including all monitored variables and settings (only applicable for Type I Hull Generators);
- Capability curves (showing operation point) and vector graphics;
- Generation capacity screen;
- Generation duty settings screens;
- Load Shedding priority screen and configuration screen;
- Alarms screen;
- Events Screen;
- Operator adjustment settings screen;
- Synchronization screens;
- Medium-voltage tie circuit-breakers and busbars interconnection circuit-breakers operation screens;
- Diagnostics screens;
- Communication integrity screen.

5.1.6. HMI screens shall comply with I-ET-3010.00-5140-700-P4X-005 - REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS.

5.1.7. The screens shall be submitted to PETROBRAS for comments and approval.

5.1.8. Screens shall be printable.

5.1.9. Screens language shall be Portuguese.

5.1.10. HMI display shall not be fitted with active screen saver applications.

5.1.11. HMI shall be promptly ready after return of power.

5.2. Signalling and Indication Instruments

5.2.1. PMS shall have minimum signalling and indication instruments, as required in I-ET-3010.00-5140-700-P4X-005 - REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS.

5.2.2. Any other signalling and indication instruments necessary to fully comply with function requirements of item 1.3 shall be included in PMS.

5.2.3. The minimum signalling LEDs to be included are listed in the following table.

Table 1 - Minimum Signalling LEDs

Colour	English Label	Portuguese Label
Red	UPS SUPPLY “A” ON	ALIMENTADOR DA UPS “A” LIGADO
Red	UPS SUPPLY “B” ON	ALIMENTADOR DA UPS “B” LIGADO
Red	CONTROL SUPPLY OK	TENSÃO DE CONTROLE OK
Red	PMS HEALTHY	PMS OPERACIONAL
Flashing Red	PMS MALFUNCTION (UAM)	PMS EM MAU FUNCIONAMENTO (UAM)
Yellow	PMS FAULT (UAS)	PMS NÃO OPERACIONAL (UAS)
White	BUSBARS “A” AND “B” SYNCHRONIZED	BARRAS “A” E “B” SINCRONIZADAS

5.3. Access Levels

5.3.1. All processor configurations, parameters, logic functions, timing data, operating programs, diagnostic programs and human machine interface programs shall be stored in non-volatile memory and protected from unauthorized or accidental access. The protection shall be by password access with different levels, to be defined in detailed design and approved by PETROBRAS.

5.3.2. Operator and maintenance presets shall be protected by a password access.

5.3.3. The access to USB (Universal Serial Bus) ports and to all other ports shall be controlled by password, in order to provide information security and to avoid external unexpected interventions (virus, etc.).

6. DOCUMENTATION

6.1.1. The following documents shall be provided at proposal:

a) Documents list;
b) Dimensional drawings including frontal and upper views and estimated weight;
c) Technical Specification, comprising system, equipment, accessories, cables, materials, softwares and all functions carried-out by PMS;
d) Deviations list related to this Technical Specification, including reasons for deviation, alternative proposals and impacts in performance and cost;
e) Technical catalogues with information about all components;
f) Spare parts list for two years of operation, including prices for each part;
g) Technical assistance prices and representative address;
h) Complete description of services and training courses;
i) List of applicable standards;
j) Inspection and test schedule, including acceptance criteria for each test;
k) Type tests certificates;
l) List of sites (oil and gas platform or industrial installation) where PMS similar made by vendor stay in operation. PMS shall be design to offshore installation and cannot be prototype device;
m) Other documents required in project documentation.

6.1.2. The following documents shall be provided for approval:

a) Documents list;
b) Dimensional drawings including frontal, internal and upper views, details, location of lifting eyelets and area for incoming cables;
c) Technical Specification details of all functions carried-out by PMS;
d) Weight and volume for transportation;
e) Rated power and power consumption (W and VA);
f) Total weight and operational thermal dissipation;
g) Electrical drawings, including detailed logic blocks (including all functions), one-line, three-lines and functional diagrams;
h) Connection diagrams, including all terminal blocks;
i) Cables list;
j) Instruments schedule, data sheets and calculation sheets related to the performance of PMS;
k) I/O list;
l) Components and materials list;
m) Detailed test procedures for FAT, SAT and SIT, including tests plan, assembly diagram, instruments to be used (including accuracy) in accordance with item 11. These documents shall be submitted to be approved prior to tests;
n) Training course program and services schedule;
o) Technical reports with performance requirements;
p) Programming tools, system reports, system diagnosis, etc.;
q) Complete source codes of all softwares (with comments explanation for all routines and description of all variables);
r) Complete documentation of network addresses and protocols;
s) Package and transportation instructions;
t) HMI screens schemes;
u) Warranty certificate and declaration of availability of spare parts for 10 (ten) years.

6.1.3. The following documents and softwares shall be provided with PMS:

a) “As built” revisions of all documents listed in items 6.1.1 and 6.1.2 above;
b) Storage, lifting and unpacking instructions;
c) Installation and assembly instructions;
d) Operation instructions shall have a clear description of the function devices in Portuguese language;
e) Maintenance instructions manual, including MTBF and MTTR, and list of tools and auxiliary devices required for maintenance in Portuguese language;
f) Spare parts list;
g) "As built" technical catalogue for all components;
h) Complete training course documentation in Portuguese;
i) Complete test report;
j) Complete version of configuration, parameterisation and monitoring softwares for all equipment that could be configured or monitored by software;
k) Complete list of “as built” adjustment settings;
l) All softwares used by PMS with your licences to use.

7. TRAINING

7.1.1. Manufacturer shall provide training to qualify PETROBRAS technicians to operate, use HMI applications and maintain (install, disassemble, replace parts, make adjustments, etc) each equipment. The training shall encompass all items to its understanding. Vendor shall provide a PMS simulator during training.

7.1.2. The maintenance training shall be performed at construction yard and/or aboard the platform, after completion of the Performance Acceptance Tests and prior to PETROBRAS approval of the Systems Acceptance.

7.1.3. The operation training shall be performed onshore, in a proper training ambience provided by Manufacturer, during the Detailed Engineering phase (at least 40h). There shall be a recycling operation training after commission and installation, in order to cover possible modifications.

7.1.4. The maintenance training shall be delivered for 15 (fifteen) maintenance technicians and the operation training for 15 (fifteen) operators, both in Brazilian Portuguese language and shall be performed using equipment identical to the supplied.

7.1.5. Manufacturer shall take full responsibility over the professionals teaching the training course, including their transportation and lodging.

7.1.6. Manufacturer shall submit for approval the detailed training programs.

8. SERVICES

8.1.1. Manufacturer shall be responsible for the comprehensive system covering design, engineering, manufacturing, equipment supply, installation, integration, commissioning, testing, training and all documentation according to this specification.

8.1.2. All services related to software and equipment programming and configuration shall allow future modification. Manufacturer shall supply all source codes to allow this, with complete documentation.

8.1.3. Manufacturer shall carry out tests to confirm the performance requirements of PMS, including external interfaces, stability limits and actuation times defined by Electrical System stability study and electromagnetic compatibility requirements.

8.1.4. Manufacturer shall provide the necessary spare parts for the commissioning and pre operation periods.

9. GUARANTEE

9.1.1. Manufacturer shall guarantee all components (hardware & software) included in its scope of supply, for at least 24 (twenty four) months from delivery and for at least 12 (twelve) months in operation.

9.1.2. Manufacturer shall guarantee the performance requirements for PMS, including stability limits and actuation times defined by Electrical System stability study.

9.1.3. This warranty shall cover fabrication and installation problems, as well as any service included in the scope of supply.

9.1.4. Manufacturer shall guarantee the supply of spare parts during at least 10 years after the acceptance tests date, and technical assistance at installation site performed by qualified and certified maintenance staff, when requested.

9.1.5. It shall not be acceptable out of date or obsolete equipment or components. Technical support and supply of replacement parts shall be guaranteed for ten (10) years.

10. SYSTEM LIFE TIME

10.1.1. The version of the equipment hardware shall be available at the board and at the device enclosure.

10.1.2. Manufacturer shall inform the product discontinuation in time for PETROBRAS have the option of order spare products or prepare extensions.

10.1.3. Manufacturer shall guarantee the supply of the same or compatible network components (cards, switches, etc.), from the pointing of view of functionality, mounting and wiring, during platform life time.

11. ACCEPTANCE TESTS

11.1.1. Manufacturer shall be responsible for performing all the relevant acceptance tests (FAT, SAT and SIT) as defined at IEC 62381 standard.

11.1.2. Manufacturer shall be responsible for providing personnel, material, necessary equipment and instruments for all the tests, including an IHM simulator with all PMS functions, independent of the place where they are carried out, until the final commissioning and acceptance of the unit by PETROBRAS.

11.1.3. Manufacturer shall provide detailed technical information about the equipment in specific design review meetings with PETROBRAS. The objective of these specific design review meetings is to solve technical issues, avoiding future failures or problems in the equipment or during integration with other equipment.

11.1.4. These design review meetings shall occur before fabrication, during fabrication, before Factory Acceptance Test, before Site Acceptance Test or at any additional moment required by PETROBRAS.

11.1.5. Manufacturers shall present in these meetings detailed technical information explaining how they solved specific technical issues related to equipment, asked by PETROBRAS.

11.1.6. The following tests shall be carried-out at Manufacturer installations (Factory Acceptance Tests - FAT), prior to delivery:

- Documentation check;
- Mechanical inspection;
- Hardware and software inventory check;
- Check of requirements for environmental condition;
- Check of motion, inclination and vibration requirements;
- Wiring and termination inspection;
- Start-up test;

- Visualization and operation (including password accessibility to all screens and adjustment settings);
- Check of consistency between capability curve screen and data from turbogenerator manufacturer;
- Current and power consumption measurement (A, W and VA);
- General system functions including hardware and diagnostic check;
- Interruption of one power supply (220V) and check if the system keeps running without failure. Return of this power supply and interruption of the second power supply and check if the system keeps running without failure;
- Functional tests according to all the functional characteristics indicated on item 3 (Functional Characteristics);
- I/O check performance, including:
  - Verification of calibration of analogue signals;
  - Verification of alarm and fault signals;
  - Verification of shutdown and fault-causing-shutdown signals;
  - Simulation of hardwired interface signals to/from other equipment;
  - Verification of network communication with other equipment using simulator tool, to verify correct data communication by means of transmission of randomly chosen signal;
- All PMS functions and operation modes shall be tested;
- Simulation of lost of the voltage and frequency signals;
- Test of the Field Forcing;
- Test of the performance of load shedding of all specified loads (included the spare loads), with oscilloscope register of the trip time and comparing with Electrical System Studies requirement or up to 100ms (one hundred miliseconds);
- Test of performance of simultaneous loss of generators and tie circuit-breaker or busbars interconnection circuit-breaker opening;
- Check of load shedding outputs contacts for 13.8kV loads (N.O.);
- Check of proper operation of ground fault detection system, when required, according to 4.10;
- Check of proper operation of external connection for heating resistors powering;
- Test of dead-bus condition and signal generation at 13.8kV Main Switchgear;
- Test of dead-bus condition and signal generation at 6.6kV Hull MCC. Only applicable for projects with Type I Hull Generators.

11.1.7. After the installation at site, at least the following tests (Site Acceptance Tests - SAT) shall be carried-out in order to assure that the equipment are correctly installed:

- Documentation check;

- Mechanical inspection (grounding system, power supply, network connections, etc.);
- Hardware and software inventory check;
- Wiring and termination inspection;
- Start-up and diagnostic check;
- Test of suitable operability turning off each incoming power supply and keeping the other one on;
- Check of all adjustment settings;
- Current and power consumption measurement (A, W and VA);
- Check of actions during outage of input voltage and frequency signals;
- Check of remote (from PMS) change of control mode of TGCPs (Droop / Isochronous or other nomination according to generator manufacturer – refer to 3.1.4);
- Check of load shedding (including sudden overload, gradual overload and system gradual and underfrequency events), including oscillographic register to verify total time of trip actuation;
- Check of proper operation of load starting inhibition system, with tie circuit-breakers or busbars interconnection circuit-breakers open and closed;
- Test of the Field Forcing;
- Visualization and operation (including password accessibility to all screens and adjustment settings);
- Check of consistency between capability curve screen and data from generator manufacturer;
- Check of proper operation of ground fault detection system, when required, according to 4.10;
- Check of base time synchronism with external signal;
- Download of softwares.

11.1.8. After integration at site, at least the following tests (Site Integration Tests - SIT) shall be carried-out:

- Documentation check;
- Mechanical inspection (communication link among systems);
- Diagnostic check (inspect communication between systems, baud rate, etc.);
- Download softwares;
- Check of all adjustment settings;
- Current and power consumption measurement (A, W and VA);
- Check of base time synchronism with external signal;
- Complete functional test integrated with other equipment, including at least:

- Control of voltage of Main Generators and Type I Hull Generators with tie circuit-breakers or busbars interconnection circuit-breakers closed (Parallel Mode 1, Parallel Mode 2 and Parallel Mode 3);
- Control of voltage of Main Generators and Type I Hull Generators alternating tie circuit-breakers or busbars interconnection circuit-breakers to open status, controlling simultaneously every resulting system/island (Parallel Mode 1, Parallel Mode 2 and Parallel Mode 3);
- Control the frequency of the Main Generators and Type I Hull Generators with tie circuit-breakers or busbars interconnection circuit-breakers closed (Parallel Mode 1, Parallel Mode 2 and Parallel Mode 3);
- Control the frequency of the Main Generators and Type I Hull Generators alternating tie circuit-breakers or busbars interconnection circuit-breakers to open status, controlling simultaneously every resulting system/island (Parallel Mode 1, Parallel Mode 2 and Parallel Mode 3);
- Operation (on/off/synchronization) of Main Generators and Type I Hull Generators;
- Check of proper calculation of generation capacity according to external information of fuel, including change in capability curve screen;
- Load transference from a running generator to the remaining running generators during procedure of stoppage;
- Control (synchronization) of circuit-breakers of Main Switchgear and Type I Hull Generators;
- Actuation of active and reactive load sharing among Generators in parallel operation with tie circuit-breakers or busbars interconnection circuit-breakers closed (Parallel Mode 1, Parallel Mode 2 and Parallel Mode 3);
- Actuation of active and reactive load sharing among Generators in parallel operation alternating tie circuit-breakers or busbars interconnection circuit-breakers to open status, controlling simultaneously every resulting system/island (Parallel Mode 1, Parallel Mode 2 and Parallel Mode 3);
- Check of proper operation of load starting inhibition system with tie circuit-breakers or busbars interconnection circuit-breakers closed;
- Check of proper operation of load starting inhibition system alternating tie circuit-breakers or busbars interconnection circuit-breakers to open status;
- Check of proper operation of load shedding system (including sudden overload, gradual overload and gradual and sudden underfrequency events) with tie circuit-breakers or busbars interconnection circuit-breakers closed, including oscillographic register to verify total time of trip actuation, comparing with Electrical System Studies requirement;
- Check of proper operation of load shedding system (including sudden overload, gradual overload, gradual and sudden underfrequency events) alternating tie circuit-breakers or busbars interconnection circuit-breakers to open status, including oscillographic register to verify total time of trip actuation, comparing with Electrical System Studies requirement;

- Check of proper operation of load shedding, changing the priority table;
- Check of proper operation of field forcing control process with tie circuit-breakers or busbars interconnection circuit-breakers closed;
- Check of proper operation of field forcing control process alternating tie circuit-breakers or busbars interconnection circuit-breakers to open status;
- Check of proper operation of alarms;
- Check of proper operation of interlocks;
- Check of automatic charge of software and screens after return of power;
- Check of password accessibility to screens, adjustment settings, and communication ports.

- Remote access and data downloads;
- Test of dead-bus condition and signal generation at 13.8kV Main Switchgear;
- Test of dead-bus condition and signal generation at 6.6kV Hull MCC. Only applicable for projects with Type I Hull Generators.

11.1.9. The following points shall be tested for EMC:

- Power supply inputs to each device;
- Alarm and auxiliary I/O connections;
- Permanently connected substation computers;
- All metallic connections to any Ethernet hub, including power supply inputs, alarms, and ports utilizing balanced twisted pair inputs.

11.1.10. The equipment shall be considered to have passed the EMC tests if, during and until completed the tests, all of the following are met for the equipment and the connected devices (requirements of reference standards shall be included):

- No hardware damage occurs;
- No change in calibration beyond normal tolerance is caused by the test;
- No loss or corruption of stored memory or data occurs, including active or stored settings;
- System resets do not occur, and manual resetting is no required;
- Established communications are not permanently lost;
- If disrupted, established communications automatically recover within an acceptable time period;
- Communication errors, if they occur, do not jeopardize the protect or control functions;
- No changes in the states of the electrical, mechanical, or communication signal outputs occur. This includes alarms and status outputs;
- No erroneous, permanent change of state of the visual, audible or message outputs occurs. Momentary changes in these outputs during the tests are permitted;
- No error outside the normal tolerances for data communication signals occurs.

11.1.11. Manufacturer shall supply any item necessary to be added or replaced during tests and commissioning of PMS.

12. ABBREVIATIONS AND ACRONYMS

A&C	Automation and Control System
AVR	Automatic Voltage Regulation
CCR	Central Control Room
CDC	Switchgear
ESA	Electrical System Automation
EMC	Electromagnetic Compatibility
ESD	Emergency Shutdown
FAT	Factory Acceptance Test
FPSO	Floating Production Storage and Offloading Unit
FSO	Floating Storage and Offloading Unit
HMI	Human Machine Interface
I/O	Input / Output
IEC	International Electrotechnical Commission
MC	Motocompressor
MCC	Motor Control Center
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
MV	Medium Voltage
N.C.	Normally Closed
N.O.	Normally Open
PMS	Power Management System
SAT	Site Acceptance Test
SIT	Site Integration Test
TCP/IP	Transmission Control Protocol / Internet Protocol
TGCP	Turbogenerator Control Panel
UAM	Unit Alarm Malfunction
UAS	Unit Alarm Shutdown
UPS	Uninterruptible Power Supply
VSD	Variable Speed Driver
VT	Voltage Transformer
HGCP	Hull Generator Control Panel