	<b>TECHNICAL SPECIFICATION</b>		No. <b>I-ET-3010.00-5140-775-P4X-001</b>
	CLIENT:		SHEET: <b>1</b> of <b>20</b>
	JOB:		--
	AREA:		
TITLE:		<b>REQUIREMENTS FOR ELECTRICAL GENERATION EXCITATION SYSTEM FOR OFFSHORE UNITS</b>	INTERNAL ESUP

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AREA:

SHEET: **2** of **20**

TITLE: **REQUIREMENTS FOR ELECTRICAL GENERATION  
EXCITATION SYSTEM FOR OFFSHORE UNITS**

**INTERNAL**  
**ESUP**

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## 1. OBJECTIVE

This specification establishes the minimum conditions required for the design, manufacture, inspection, commissioning, testing and delivery of excitation systems for Turbogenerators and Engine-Driven Hull Generators used in PETROBRAS OFFSHORE UNITS.

This specification does not define requirements for the electrical excitation systems of Emergency and Auxiliary Generators. Such requirements are established in the respective equipment technical specification.

This specification also does not define requirements for the following components: Turbogenerator Control Panels (TGCP), Hull Generator Control Panels (HGCP), Emergency Generator Control Panels (EGCP), Auxiliary Generator Control Panels (AGCP), turbines, engines, couplers, speed reducers, machinery protection system, and any other accessories or auxiliary equipment out of generator excitation system. Such requirements can be found in technical specifications related to the mentioned components.

## 2. GENERAL

### 2.1. DEFINITION OF TERMS

For information about general terminology meaning, see I-ET-3010.00-1200-940-P4X-002 – GENERAL TECHNICAL TERMS.

Within the contents of this Specification:

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

“LOCAL” means excitation control is performed by excitation panel (GEP) or generator control panel (TGCP or HGCP).

“REMOTE” means excitation control is performed by external equipment outside excitation panel (PMS).

“AUTOMATIC” means the excitation control is automatic when the switch is in LOCAL position in the excitation panel.

“MANUAL” means the excitation control is performed manually by operator in front of excitation panel when the switch is in LOCAL position in the excitation panel.

### 2.2. ABBREVIATIONS

A&C	Automation and Control System.
AVR	Automatic Voltage Regulation.
CS	Classification Society.
CT	Current Transformer.
ESA	Electrical System Automation.
FCR	Field Current Regulation.
GEP	Generator Excitation Panel.
HGCP	Hull Generator Control Panel.
ITP	Inspection and Testing Plan.

PMG	Permanent Magnet Generator.
PMS	Power Management System.
R	Routine Test - Test carried out on all units supplied.
S	Special Test – Tests other than type or routine tests, performed by agreement between MANUFACTURER and PETROBRAS.
TAC	Field Acceptance Tests - Tests carried out at the final place of operation of the equipment. (Teste de Aceitação de Campo).
TAF	Factory Acceptance Tests – Tests carried out at the equipment manufacturing site. (Teste de Aceitação de Fábrica).
TCAG	Tests of complete driver-generator set, carried out at a location defined by PACKAGER, or String Tests. (Teste do Conjunto Acionador e Gerador).
TDPF	Tests During Manufacturing Process - Tests carried out during the manufacturing process of the equipment. (Teste Durante o Processo de Fabricação).
THD	Total Harmonic Distortion.
TGCP	Turbo Generator Control Panel for Gas and Steam Turbines, when applicable.
T	Type Test - Test carried out on a piece of equipment representing the other equipment, aiming to demonstrate that they meet the specified conditions not covered by routine tests.  Type tests may be considered equally valid, if carried out in equipment that presents some deviations of rated values or other characteristics. These deviations shall be subject to agreement between MANUFACTURER and PETROBRAS.
VT	Voltage Transformer.

### 3. CODES, STANDARDS & REFERENCE DOCUMENTS


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

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

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

##### 3.1.1. IEC – INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC 60034-1	Rotating Electrical Machine - Ratings and Performance
IEC 60034-2-1	Rotating Electrical Machines - Part 2-1: Standard Methods for Determining Losses and Efficiency from Tests (Excluding Machines for Traction Vehicles)
IEC 60034-3	Rotating Electrical Machines - Part 3: Specific Requirements for Synchronous Generators Driven by Steam Turbines or Combustion Gas Turbines

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IEC 60034-4-1	Rotating Electrical Machines - Part 4-1: Methods for Determining Electrically Excited Synchronous Machine Quantities from Tests		
IEC 60034-5	Rotating electrical machines – Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) – Classification		
IEC 60034-16-1	Rotating Electrical Machines – Part 16-1: Excitation Systems for Synchronous Machines – Definitions		
IEC 60034-16-2	Rotating electrical machines Part 16: Excitation systems for synchronous machines Chapter 2: Models for power system studies		
IEC 60034-16-3	Rotating Electrical Machines - Part 16: Excitation Systems for Synchronous Machines - Section 3: Dynamic Performance		
IEC 60034-18-21	Rotating electrical machines – Part 18-21: Functional evaluation of insulation systems – Test procedures for wire-wound windings – Thermal evaluation and classification		
ISO 8528	Reciprocating Internal Combustion Engine Driven Alternating Current Generating Sets		
IEC 60079	Explosive atmospheres – All Parts		
IEC 60092	Electrical Installations in Ships - All Parts		
IEC 60255-149	Measuring relays and protection equipment – Part 149: Functional requirements for thermal electrical relays		
IEC 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 (EMC) – Ships with a Metallic Hull		
IEC 61439	Low-voltage switchgear and controlgear – All Parts		
IEC 61869	Instrument transformers – All Parts		
IEC 61892	Mobile and Fixed Offshore Units - Electrical Installations - All parts		
IEC 60255-24	Measuring relays and protection equipment – Part 24: Common format for transient data exchange (COMTRADE) for power systems		
<b>3.1.2. API – AMERICAN PETROLEUM INSTITUTE</b>			
API STD. 546	Brushless Synchronous Machines - 500 kVA and Larger		
API STD. 670	Machinery Protection Systems		
<b>3.1.3. IEEE – INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERING</b>			
IEEE 43	Recommended Practice for Testing Insulation Resistance of Rotating Machinery		
IEEE 115	Guide for Test Procedures for Synchronous Machines - Part I / Part II		
IEEE C37.111	Measuring relays and protection equipment – Part 24: Common format for transient data exchange (COMTRADE) for power systems		
IEEE C37.118	Synchrophasors for Power Systems		
IEEE 421.1	Standard Definitions for Excitation Systems for Synchronous Machines		
IEEE 421.2	Guide for Identification, Testing, and Evaluation of the Dynamic Performance of Excitation Control Systems		

- IEEE 421.3 High-Potential Test Requirements for Excitation Systems for Synchronous Machines
- IEEE 421.4 IEEE Guide for the Preparation of Excitation System Specification
- IEEE 421.6 Recommended Practice for the Specification and Design of Field Discharge Equipment for Synchronous Machines

### 3.1.4. IMO - INTERNATIONAL MARITIME ORGANIZATION

- IMO I810E Code for the Construction and Equipment of Mobile Offshore Drilling Units (MODU CODE)

### 3.1.5. SECRETARIA DO TRABALHO

- NR-10 Segurança em Instalações e Serviços em Eletricidade
- NR-12 Segurança no Trabalho em Máquinas e Equipamentos
- NR-17 Ergonomia
- NR-26 Sinalização de Segurança
- NR-37 Segurança e Saúde em Plataformas de Petróleo

### 3.1.6. NEMA - NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

- NEMA MG 1 Motors and Generators

## 3.2. REFERENCE DOCUMENTS

- [1] GENERATOR PACKAGE TECHNICAL SPECIFICATION
- [2] I-ET-3010.00-5147-711-P4X-001 – MAIN GENERATOR FOR OFFSHORE UNITS
- [3] I-ET-3010.00-5262-700-P4X-002 – HULL GENERATOR PACKAGE FOR OFFSHORE UNITS
- [4] I-ET-3010.00-5140-700-P4X-004 – PN-5140001 - POWER MANAGEMENT SYSTEM (PMS) FOR OFFSHORE UNITS
- [5] I-ET-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE
- [6] I-DE-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION DIAGRAM
- [7] I-LI-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST
- [8] I-ET-3010.00-5140-700-P4X-001 – SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS
- [9] I-ET-3010.00-5140-700-P4X-002 – SPECIFICATION FOR ELECTRICAL MATERIAL FOR OFFSHORE UNITS
- [10] I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS
- [11] I-ET-3010.00-5140-741-P4X-004 – SPECIFICATION FOR LOW-VOLTAGE GENERIC ELECTRICAL PANELS FOR OFFSHORE UNITS

- [12] I-ET-3010.00-5140-700-P4X-005 – REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS
- [13] I-ET-3010.00-5140-700-P4X-009 – GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS
- [14] I-ET-3010.00-1200-956-P4X-002 – GENERAL PAINTING
- [15] I-LI-3010.00-5140-700-P4X-001 – ELECTRICAL EQUIPMENT DATA-SHEET MODELS
- [16] I-ET-3010.00-5400-947-P4X-002 – SAFETY SIGNALLING
- [17] I-ET-3010.00-5143-700-P4X-001 – ELECTRICAL SYSTEM PROTECTION CRITERIA
- [18] I-DE-3010.00-5143-946-P4X-001 – MEDIUM-VOLTAGE SYSTEMS PROTECTION DIAGRAM
- [19] DR-ENGP-I-1.15 – COLOR CODING
- [20] I-ET-3010.00-1200-940-P4X-002 – GENERAL TECHNICAL TERMS

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

## 4. GENERAL REQUIREMENTS

### 4.1. GENERAL

- 4.1.1 The Generation Excitation System comprises exciter and excitation system panel, including all their accessories, at least, but not limited to, exciter and field windings, AVR, PMG, excitation protection system, junction boxes, synchronism equipment, etc.
- 4.1.2 Unless otherwise specified in the project documentation, excitation system and its auxiliary systems shall be designed and manufactured to foresee a minimum life period of 30 years.
- 4.1.3 The sizing of equipment shall consider periods of continuous operation in rated conditions with minimum duration of 24000 hours without interventions for preventive or corrective maintenance requiring the equipment to stop.
- 4.1.4 CANCELLED.
- 4.1.5 The equipment and installation shall comply with requirements of I-ET-3010.00-5140-700-P4X-005 – REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS, 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-001 – SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS.
- 4.1.6 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.
- 4.1.7 PETROBRAS shall have full access to the whole documentation and data related to the Package, including (but not limited to) diagrams, source codes of software, licenses, passwords, configurations, parameterizations, controls, PLC files, AVR file settings, alarms, event records, firmware updates, etc.

4.1.8 Unless otherwise specified in the project documentation, excitation system panel shall be part of the TGCP/HGCP and shall be installed contiguous to these panels.

#### 4.2. HAZARDOUS AREAS

4.2.1 Electrical and instrumentation circuits passing through hazardous areas shall comply with Brazilian regulations, IEC 60079 and IEC 61892-7.

4.2.2 Equipment and material to be installed in hazardous areas, as well as the corresponding certificates, shall comply with the requirements of I-ET-3010.00-5140-700-P4X-009 – GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

#### 4.3. ENVIRONMENTAL CONDITIONS

4.3.1 CANCELLED.

4.3.2 The excitation system and all its accessories and auxiliary equipment shall comply with environmental requirements of I-ET-3010.00-5140-700-P4X-009 – GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

#### 4.4. INCLINATION REQUIREMENT

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

### 5. MECHANICAL REQUIREMENTS

#### 5.1. CONSTRUCTION, FIXATION AND LIFTING CHARACTERISTICS

5.1.1 Unless otherwise specified in the project documentation, the excitation system panel fixation and lifting shall follow the requirements of I-ET-3010.00-5140-741-P4X-004 – SPECIFICATION FOR LOW-VOLTAGE GENERIC ELECTRICAL PANELS FOR OFFSHORE UNITS.

5.1.2 Unless otherwise specified in the project documentation, the exciter fixation and lifting shall follow the requirements of GENERATOR PACKAGE TECHNICAL SPECIFICATION.

5.1.3 The generator shall be designed and manufactured in such a way as to allow the exciter to be extracted horizontally, at operational site. The tools necessary for the exciter extraction at the operating site shall be provided by MANUFACTURER.

5.1.4 The housing of the exciter shall have devices which allow the hoisting of the equipment assembled with all its integral parts. Parts with mass of more than 25 kg, shall have its own hoist devices.

5.1.5 MANUFACTURER shall design the excitation system equipment providing minimum free space for assembly, disassembly, maintenance and inspection of exciter and excitation panel components, according to I-ET-3010.00-5140-700-P4X-001 – SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS.

#### 5.2. SPEED LIMITS

5.2.1 The exciter shall support an overspeed of 20 % above the rated value for 2 minutes.

#### 5.3. CORROSION PROTECTION AND PAINTING SYSTEM

5.3.1 The excitation system and all its accessories and auxiliary equipment shall be corrosion-resistant due to environmental characteristics and/or service conditions as indicated in the generator datasheet.

5.3.2 CANCELLED.

5.3.3 Painting shall be in accordance with requirements of I-ET-3010.00-5140-700-P4X-009 – GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

#### 5.4. DEGREE OF PROTECTION (IP CODES)

5.4.1 The excitation system panel shall have minimum IP42 protection degree and shall be installed inside electrical panels rooms.

5.4.2 The exciter shall have minimum protection degree according to the generator protection degree.

5.4.3 For accessories and auxiliary electrical equipment see requirements in I-ET-3010.00-5140-700-P4X-009 – GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

#### 5.5. VIBRATION AND BALANCE

5.5.1 The exciter shall be designed, manufactured and tested to confirm compliance to vibration limits requirements of the GENERATOR PACKAGE TECHNICAL SPECIFICATION.

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

5.5.3 The excitation system panel shall comply with vibration requirements defined in I-ET-3010.00-5140-700-P4X-009 – GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS and Classification Society rules.

#### 5.6. COOLING METHODS (IC CODES) AND VENTILATION

5.6.1 The exciter shall have the same cooling method (IC code) specified for the generator and in accordance with the requirements of IEC 60034-6.

#### 5.7. NAMEPLATE BOARDS, IDENTIFICATION AND SAFETY WARNINGS

5.7.1 The excitation system panel nameplate shall be stainless steel AISI 316 containing, in addition to the information indicated by IEC 61439-1, at least the following data:

- a) Total mass;
- b) Date of manufacture;
- c) Petróleo Brasileiro S.A.- PETROBRAS;
- d) Name of the PETROBRAS Business Unit (UN);
- e) "TAG" of the panel;
- f) Material Requisition number (RM);
- g) Purchase order number (PC) or purchase order of goods and Services (PCS) in cases of purchase processes directly carried out by PETROBRAS.

5.7.2 The exciter identification plate shall be stainless steel AISI 316 containing, in addition to the information indicated by IEC 60034-1, at least the following data:

- a) Name of the MANUFACTURER;
- b) Serial number and type;
- c) Type of excitation;
- d) Rated exciter power;
- e) Rated excitation voltage;
- f) Rated excitation current;
- g) Isolation class;
- h) Year of manufacture;
- i) Mass.

5.7.3 The data, identification and warning plates of the excitation system, as well as its fastening screws, shall be manufactured from AISI 316 stainless steel.

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

5.7.5 Information included in warning plates shall be in Portuguese language and shall be submitted to PETROBRAS approval.

5.7.6 Warning labels in electrical equipment shall be in accordance with requirements of I-ET-3010.00-5140-700-P4X-009 – GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

## 6. ELECTRICAL REQUIREMENTS

### 6.1. ELECTRICAL CHARACTERISTICS

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

6.1.2 The generator and its excitation system shall comply with the synchronization criteria defined in GENERATOR PACKAGE TECHNICAL SPECIFICATION, I-ET-3010.00-5140-700-P4X-004 – PN-5140001 - POWER MANAGEMENT SYSTEM (PMS) FOR OFFSHORE UNITS and Project documentation.

6.1.3 Exciter winding insulation system shall follow the requirements specified in 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.

### 6.2. EXCITATION SYSTEMS

6.2.1 The excitation system shall comply with the requirements of electrical system, considering among others: operation in parallel, isolated operation, starting of large motors, energization of large transformers, field forcing application, disturbances of the electrical system, load shedding, etc.

6.2.2 The exciter of the generator shall be brushless type (rotating, brushless) with PMG (Permanent Magnet Generator).

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

- 6.2.4 The complete excitation system shall be sized to provide a positive ceiling voltage of exciter equal to or greater than 200% of the rated field voltage with the generator at full load for at least 2 seconds.
- 6.2.5 The complete excitation system shall be able to sustain and, therefore, withstand the following generator overcurrent conditions:
- 300% of stator rated current for 2 s under a three-phase short-circuit at the generator terminals;
  - 150% of stator rated current, with rated power factor, for 30 s.
- 6.2.6 The excitation system shall have a speed response (Excitation system nominal response, according to IEEE 421.1) equal to or greater than 0.5 p.u. per second.
- 6.2.7 The complete excitation system shall be sized so that the voltage at the generator terminals is equal to or greater than 85% of the rated voltage during the start of the largest motor, taking into account the initial load, starting time and the number of generators in operation, as defined in the datasheet. For this transient, the recovered voltage (recovery voltage) shall reach and maintain the rated voltage, with a deviation according to the requirements of IEC 61892-1.
- 6.2.8 The excitation system shall be sized to provide a continuous current value not less than 110% of the excitation current required by the generator, when operating under full load, with 105% of rated voltage and a rated power factor.
- 6.2.9 The precision of the voltage regulator (as defined by IEEE 421.1) shall be indicated by the MANUFACTURER on the datasheet.
- 6.2.10 The excitation system panel shall comply with requirements of I-ET-3010.00-5140-700-P4X-009 – GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS, I-ET-3010.00-5140-741-P4X-004 – SPECIFICATION FOR LOW-VOLTAGE GENERIC ELECTRICAL PANELS FOR OFFSHORE UNITS, and I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS.
- 6.2.11 The excitation system panel shall house at least the following components:
- a) Automatic Voltage Regulators (AVR);
  - b) Generator Protection Relay;
  - c) Synchroscope;
  - d) Sync-check relay;
  - e) Double Voltmeter;
  - f) Double Frequency meter;
  - g) Rotor Ground Fault Relay;
  - h) Lockout Relays;
  - i) Auto-synchronizer relay;
  - j) Power Quality Meter;
  - k) Generator circuit-breaker Open/Close switch and lamps;
  - l) Voltage Lower/Raise switch;

- m) Frequency Lower/Raise switch;
- n) Synchronization Mode (Off/Manual/Automatic) selector switch;
- o) Automatic/Manual Excitation Mode (Isochronous/Droop or Island/Parallel) selector switch and lamps;
- p) Local/Remote selector switch;
- q) Regulation Mode (FCR/AVR) selector switch and lamps;
- r) Excitation System On/Off selector switch and lamps;
- s) AVR A/B selector switch and lamps;
- t) AVR A/B failure lamps;
- u) Excitation Voltmeter;
- v) Excitation Ammeter;

6.2.12 The excitation system control shall contain at least the following features:

- a) Dual redundant microprocessed controllers, both with capacity to be master controller;
- b) Automatic control of generator voltage;
- c) Manual control of generator voltage;
- d) Droop Voltage Control Model (Parallel Mode);
- e) **Constant Voltage Control Mode (Island Mode);**
- f) Smooth transition from automatic to manual control and vice-versa;
- g) **Smooth transition from local to remote control and vice-versa;**
- h) Smooth transition between controllers;
- i) Automatic Volt/Hertz **limiter;**
- j) Automatic **overexcitation and underexcitation limiters** ( $E_{fdmax}$  and  $E_{fdmin}$ );
- k) **Automatic Stator Current limiter;**
- l) Reactive load sharing control;
- m) Field forcing control;
- n) Remote control (control of mode Automatic/Manual, operation mode Local/Remote, set point Increase/Decrease, reactive load sharing and field forcing start/stop) from external equipment.

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

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

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

- 6.2.16 Field forcing, shall be adjustable in the PMS, allowing the setup of voltage rise values, time for step-up and step-down ramps or steps, and field forcing maximum time, according to the requirements of I-ET-3010.00-5140-700-P4X-004 – PN-5140001 - POWER MANAGEMENT SYSTEM (PMS) FOR OFFSHORE UNITS.
- 6.2.17 The excitation system control shall have ports and communication protocols according to the required in GENERATOR PACKAGE TECHNICAL SPECIFICATION and I-ET-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE, for remote control and monitoring of internal variables.
- 6.2.18 It shall be possible to perform at least the following functions, from ESA maintenance computer workstations connected to the excitation system communication ports: download/upload and change of settings, monitoring of all variables, access to alarms and events logs, download oscillography records, manually trigger oscillography records and excitation system tests.
- 6.2.19 The excitation system control shall have time synchronization according to I-ET-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE.
- 6.2.20 It shall be possible to remotely monitor at least:
- a) Exciter and field winding insulation resistance.
  - b) Rotating rectifier diodes (alarms for open and short-circuited diodes).
- 6.2.21 The excitation system control shall have additional port dedicated to local configuration using portable computer connection.
- 6.2.22 The "Automatic/Manual", "Local/remote" selection commands shall be available for remote control through wiring.
- 6.2.23 All operation functions of the excitation system control shall be carried out with the doors of the panel closed.
- 6.2.24 The excitation system control shall store the set-point data, configuration parameters, readings, and measurements in non-volatile memory.
- 6.2.25 All system adjustments shall be accessible to the user. In the event of the adjustments being made through proprietary software, there shall be no blockage requiring PETROBRAS to pay the transfer of the license for the use of the software. Configuration software shall be part of the scope of supply, be active in the delivery process, and have valid licenses for an indefinite period.
- 6.2.26 The excitation control system shall allow continuous operation, with no dead zone, compensated and stabilized, with sufficient gain to maintain the terminal voltage of the generator within the range of 0.5% of the reference voltage on a permanent basis. Continuous cyclical variation of the rated voltage is permitted, within limits of IEC 61892-1.
- 6.2.27 The AVR shall be provided with internal register of events, variables and protection functions.
- 6.2.28 The AVR shall be capable of trigger oscillography records manually and automatically. Oscillography records format shall be IEEE Standard Common Format for Transient Data Exchange (COMTRADE).

- 6.2.29 The excitation system control shall include at least the following functions of monitoring, alarm, control and protection:
- a) Overheating or overcurrent field limiter;
  - b) Field overvoltage limiter;
  - c) Rotating diodes monitoring;
  - d) AVR failure or fault;
  - e) Ground fault at "brushless" system;
  - f) Field Overvoltage;
  - g) Field Overcurrent;
  - h) Generator Undervoltage;
  - i) Generator Overvoltage;
  - j) Loss of Sensing Voltage;
  - k) Loss of Field;
  - l) Exciter Diode Monitoring;
  - m) Crowbar Circuit;
  - n) Soft Start Function;
  - o) Underfrequency Limiter;
  - p) Volts per Hertz Ratio Limiter;
  - q) Overexcitation Limiter;
  - r) Underexcitation Limiter;
  - s) Stator Current Limiter;
  - t) Automatic Synchronizer;
  - u) Exciter and field winding insulation resistance monitoring;
  - v) Rotating rectifier diodes (alarms for open and short-circuited diodes).
- 6.2.30 Unless otherwise specified in the data-sheet, the circuits and components of protection, control and automation of the excitation system shall be fed at 220 Vdc isolated (IT system), from external continuous current power supply system, as defined in I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS.
- 6.2.31 Exciter enclosure shall have heating resistors operating so that the internal temperature is above the condensation temperature and, at least 30 °C below the insulation system temperature class, when the generator is off.
- 6.2.32 Unless otherwise specified in the data-sheet, the circuits and components of lighting and heating of the excitation system shall be fed at 220Vac isolated (IT system), from external power supply system, as defined in I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS.
- 6.2.33 The excitation system shall withstand, without damage, any faults or abnormal operation of the synchronous machine.

- 6.2.34 The rectifier bridge shall be sized with a voltage rating equal to three times the rated root mean square (rms) input voltage.
- 6.2.35 The excitation system shall be able to operate during fault conditions at generator terminals.
- 6.2.36 All components that employ firmware shall be supplied with firmware latest version and procedures to maintain firmware updated.
- 6.2.37 AVRs human-machine interfaces (HMIs) shall display AVR data and allow variables parameterization.

### 6.3. INTERFACE SIGNALS

- 6.3.1 For interface signals with Turbo Generator and TGCP, please refer to GENERATOR PACKAGE TECHNICAL SPECIFICATION and I-ET-3010.00-5147-711-P4X-001 – MAIN GENERATOR FOR OFFSHORE UNITS.
- 6.3.2 For interface signals with Hull Generator and HGCP, please refer to I-ET-3010.00-5262-700-P4X-002 – HULL GENERATOR PACKAGE FOR OFFSHORE UNITS.
- 6.3.3 For interface signals with PMS, please refer to I-ET-3010.00-5140-700-P4X-004 – PN-5140001 - POWER MANAGEMENT SYSTEM (PMS) FOR OFFSHORE UNITS.
- 6.3.4 For interface signals with ESA, please refer to I-ET-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE, I-DE-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION DIAGRAM and I-LI-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.

## 7. AUXILIARY AND CONTROL EQUIPMENT

### 7.1. GENERAL

- 7.1.1 Auxiliary equipment design criteria, including exciter junction boxes, are defined in the following documentation:
- I-ET-3010.00-5140-700-P4X-002 – SPECIFICATION FOR ELECTRICAL MATERIAL FOR OFFSHORE UNITS;
  - I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS;
  - I-ET-3010.00-5140-700-P4X-009 – GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS;
  - GENERATOR PACKAGE TECHNICAL SPECIFICATION;
  - I-ET-3010.00-5147-711-P4X-001 – MAIN GENERATOR FOR OFFSHORE UNITS;
  - I-ET-3010.00-5262-700-P4X-002 – HULL GENERATOR PACKAGE FOR OFFSHORE UNITS.

### 7.2. PROTECTION, CONTROL AND MONITORING PANEL

- 7.2.1 Protection, control and monitoring panel requirements are defined in GENERATOR PACKAGE TECHNICAL SPECIFICATION.

### 7.3. SYNCHRONIZING SYSTEM

7.3.1 See GENERATOR PACKAGE TECHNICAL SPECIFICATION, I-ET-3010.00-5140-700-P4X-004 – PN-5140001 - POWER MANAGEMENT SYSTEM (PMS) FOR OFFSHORE UNITS and Project documentation.

### 7.4. INSTRUMENT TRANSFORMERS

7.4.1 Instrument transformers connection shall comply with I-DE-3010.00-5143-946-P4X-001 – MEDIUM-VOLTAGE SYSTEMS PROTECTION DIAGRAM.

### 7.5. MONITORING AND MEASURING INSTRUMENTS AND SENSORS

7.5.1 The sensor circuits' cables shall be shielded to avoid the effects of electromagnetic interference according to IEC 60533.

7.5.2 Cables, instruments and sensors grounding shall follow the requirements of I-ET-3010.00-5140-700-P4X-001 – SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS.

### 7.6. TERMINALS AND CONNECTORS FOR POWER, CONTROL AND GROUNDING CABLES

7.6.1 All connectors shall be supplied and secured (so that they are not lost in transport) inside the exciter, junction boxes and excitation panel.

7.6.2 Cable construction and colour shall comply with the requirements established in I-ET-3010.00-5140-700-P4X-002 – SPECIFICATION FOR ELECTRICAL MATERIAL FOR OFFSHORE UNITS.

7.6.3 Cable sizing and tagging shall follow requirements of:

- I-ET-3010.00-5140-700-P4X-004 – PN-5140001 - POWER MANAGEMENT SYSTEM (PMS) FOR OFFSHORE UNITS;
- I-ET-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE;
- I-DE-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION DIAGRAM;
- I-LI-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST;
- I-ET-3010.00-5140-700-P4X-001 – SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS.

7.6.4 Unless otherwise defined in the project documentation, cable entrance shall be from the bottom of the excitation system panel.

7.6.5 Cable entrance shall be from the bottom for exciter junction boxes.

## 8. INSPECTIONS AND TESTS

8.1.1 Tests required for the generator control panel are indicated in Table 1. Any other test required by CS shall be also performed.

8.1.2 Other tests related to the excitation system are indicated in 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.

Table 1 – Tests to be performed in Generator Excitation Panel.

Test	T	R	S	Test Procedure and Acceptance Criteria
Visual and Dimensional Verification		X		Project Documentation
Painting Check		X		[13]
Insulation resistance		X		IEC 61439-1
Voltage Withstand Test		X		IEC 61439-1
Functional Tests <sup>(1)</sup>		X		Project Documentation

**Notes:** 1) Functional Tests include check of AVRs and Generator Protection Relay functionalities.

## 9. SPARE PARTS

### 9.1. GENERAL

- 9.1.1 PACKAGER shall include in the scope of supply all spare parts required for start-up and commissioning.
- 9.1.2 PACKAGER shall supply spare parts required by CS, if any.

### 9.2. UNUSUAL TOOLS

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

## 10. TECHNICAL DOCUMENTS

### 10.1. GENERAL REQUIREMENTS

- 10.1.1 Data regarding excitation system filled in datasheet issued by PETROBRAS are mandatory. In case of divergence between the datasheet issued by PETROBRAS and this specification, the **datasheet shall** prevail.
- 10.1.2 If there is no generator datasheet issued by PETROBRAS, the template of I-LI-3010.00-5140-700-P4X-001 – ELECTRICAL EQUIPMENT DATA-SHEET MODELS shall be used.
- 10.1.3 MANUFACTURER shall list, in the datasheet, the technical standards applied to the manufacturing and testing of the generator, which complement **those** presented in section 3.
- 10.1.4 The data-sheet fields, filled by the MANUFACTURER for BID may consider tolerances according to project requirements. As built datasheet shall be filled in with final measured and tested data.
- 10.1.5 MANUFACTURER shall provide all certification required by CS.

### 10.1.6 CANCELLED.

### 10.2. DOCUMENTS TO PROPOSAL

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

- Documents List;
- List of standards applicable to the design, fabrication and tests;
- Country of origin of the equipment;

- d) Datasheets of excitation system and accessories completely filled out with technical data and all tests to be applied;
- e) Drawing indicating the main dimensions, the weight of the excitation system panel and all its subsystems (relays, AVR, controllers, HMI, etc);
- f) Specification of excitation system, with modules architecture, protection, communication and performance data;
- g) Specification of painting system for excitation system panel;
- h) Technical catalogues of all excitation system components containing all information and technical characteristics;
- i) List of sensors and instruments, with respective data;
- j) List of unusual tools required for maintenance of the excitation system;
- k) List of recommended spare parts for two (2) years operation with separate prices for each item;
- l) List of spare parts for commissioning and tests;
- m) List of similar previous supplies consistent with the specification requirements defined by PETROBRAS;
- n) List of deviations from project documentation;
- o) Utility consumption list;
- p) Description service capabilities, price schedule and service support during testing, installation, commissioning, and maintenance.

### 10.3. DOCUMENTS TO BE SUBMITTED FOR APPROVAL

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

- a) Documents list;
- b) Dimensional drawings of all excitation system equipment (relays, AVR, controllers, HMI, etc) and each component, with at least:
  - all dimensions;
  - static and dynamic weights;
  - centre of gravity;
  - minimum free space for maintenance, assembly and disassembly;
  - lifting devices;
  - electrical power, control and instruments inlets, outlets and connections positions and data;
  - utilities connections positions and data;
  - internal components layout, dimensions and details;
  - instruments positions and connections;
  - fixing and coupling devices details.
- c) One-line, multi-line diagrams, functional and block diagrams for excitation system, panels and auxiliary components;
- d) Block diagrams of excitation system with adjustment of parameters;
- e) Excitation system's mathematical models, including all adjustment of parameters;

- f) Protection adjustment parameters data (Relays and AVR);
- g) AVR parameters setting data;
- h) Power, control and instruments wiring and interconnection diagrams;
- i) Base forces and stress data;
- j) Operation manuals, including control procedures;
- k) Troubleshooting manuals;
- l) Repair and maintenance procedure manuals;
- m) Assembly and disassembly procedure manuals;
- n) Lifting procedure manuals;
- o) Packing and transportation procedures manuals;
- p) List of all equipment, components, materials, parts, pieces, accessories and devices, with identification of manufacturer, part number and model;
- q) Excitation system panel datasheet duly filled out;
- r) Electrical auxiliary equipment and components datasheet filled out, according to templates of I-LI-3010.00-5140-700-P4X-001 – ELECTRICAL EQUIPMENT DATA-SHEET MODELS;
- s) Inspection and testing plan (ITP);
- t) Tests Procedure;
- u) Test reports;
- v) Certificates of equipment for hazardous areas, if applicable;
- w) List of recommended spare parts for two (2) years operation with separate prices for each item;
- x) List of spare parts for commissioning and tests.

## 11. TRAINING

- 10.1 Manufacturer shall provide training to qualify PETROBRAS personnel to start-up, operate, use HMI applications, use configuration software and perform maintenance (install, test, disassemble, replace parts, make adjustments, etc) on each equipment of excitation system. The training shall encompass all items to its understanding. Vendor shall provide an excitation system simulator during training.
- 10.2 The maintenance training shall be performed at construction yard and/or onboard the UNIT, after completion of the Performance Acceptance Tests and prior to PETROBRAS approval of the system acceptance.
- 10.3 The operation training shall be performed onshore in a proper training facility provided by MANUFACTURER during the Detailed Engineering phase, with minimum duration of 40 hours. There shall be an additional operation training after equipment assembly and commissioning, in order to cover possible modifications.
- 10.4 The maintenance training shall be provided by MANUFACTURER for 15 (fifteen) maintenance personnel and the operation training for 15 (fifteen) operation personnel, both in Brazilian Portuguese language and shall be performed using equipment identical to the supplied.



- 10.5 Manufacturer shall take full responsibility over the professionals teaching the training course, including their transportation and lodging.
- 10.6 Manufacturer shall submit for approval the detailed training programs.

**12. SERVICES**

- 11.1 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.
- 11.2 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.
- 11.3 MANUFACTURER shall carry out tests to confirm the performance requirements of the Excitation System, including external interfaces, stability limits and actuation times defined by Electrical System Studies requirements and recommendations.