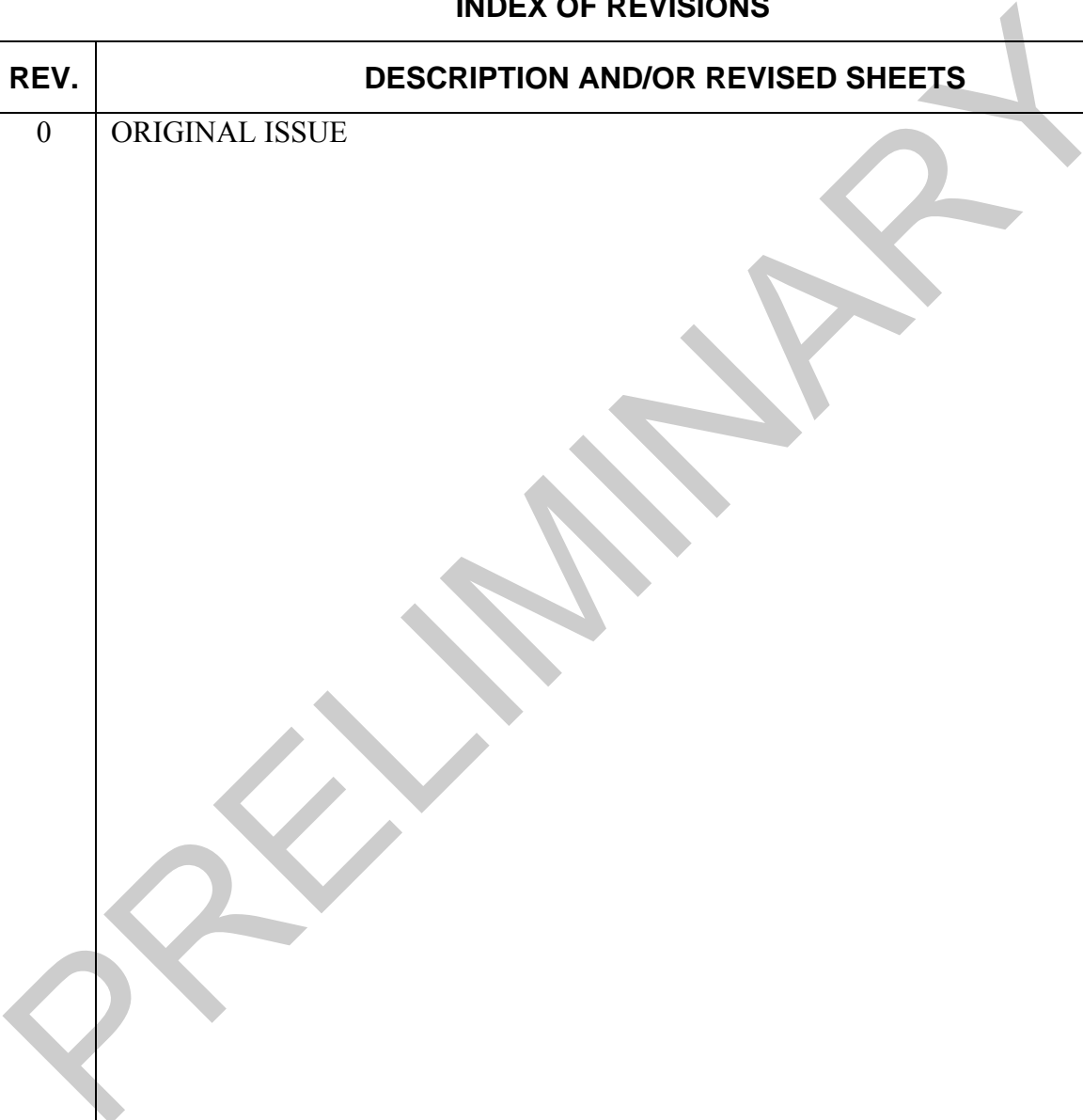
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1. OBJECTIVE

This document defines the minimum requirements for design, construction, installation and test of medium-voltage frequency converters (VSD-FCs) for offshore units.

2. CODES, STANDARDS & REFERENCE DOCUMENTS

The medium-voltage frequency converter shall comply with the requirements of Classification Society, Brazilian Legislation, applicable regulatory rules and the codes and standards listed below, all on their latest revisions.

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

2.1 IEC - International Electrotechnical Commission

- IEC 60076 Power Transformers - Parts: 1, 3, 4, 5, 10, 11, 12;
- IEC 60146-1-1 Semiconductor converters – General requirements and line commutated converters – Part 1-1: Specification of basic requirements;
- IEC 60146-2 Semiconductor converters – Part 2: Self-commutated semiconductor converters including direct d.c. converters
- IEC 60529 Degrees of Protection Provided by Enclosures (IP Code);
- IEC 60533 Electrical and Electronic Installations in Ships - Electromagnetic Compatibility;
- IEC 61000 Electromagnetic compatibility (EMC);
- IEC 61188-5-1 Printed Boards and Printed Boards Assemblies – Design and Use – Part 5-1: Attachment (Land/Joint) Considerations – Generic Requirements;
- IEC 61378-1 Converter Transformers - Part 1: Transformers for Industrial Applications;
- IEC 61800-3 Adjustable Speed Electrical Power Drive Systems - Part 3: EMC Requirements and Specific Test Methods;
- IEC 61800-4 Adjustable Speed Electrical Power Drive Systems - Part 4: General Requirements - Rating Specifications for A.C. Power Drive Systems above 1000Vac and not exceeding 35kV;
- IEC 61892 Mobile and Fixed Offshore Units - Electrical Installations.
- IEC 62271-1 High-voltage switchgear and controlgear – Part 1: Common specifications
- IEC 60417-SN 5 Graphical Symbols for Use on Equipment

Notes: (1) The IEC standards may be replaced by their equivalent NEMA, ANSI, IEEE or MIL standards, when applicable. The replacement of these standards shall be submitted to PETROBRAS approval.

- (2) The NEMA standards can be replaced by their equivalent IEC standards, when applicable. The replacement of these standards shall be submitted to PETROBRAS approval.

2.2 ASTM - American Society for Testing and Materials (Where Specified)

F1166 Standard Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities

2.3 IEEE - Institute of Electrical and Electronics Engineers, Inc.

Std 519 Recommended Practice and Requirements for Harmonic Control in Electrical Power Systems;

Std C57.18.10 Standard Practices and Requirements for Semiconductor Power Rectifier Transformers.

2.4 Brazilian Labour and Employment Ministry

NR-10 Segurança em Instalações e Serviços em Eletricidade

NR-12 Segurança no Trabalho em Máquinas e Equipamentos

2.5 INMETRO – Instituto Nacional de Metrologia Normalização e Qualidade Industrial

Portaria 179 May 18th 2010

Portaria 89 Feb 23rd 2012

2.6 PETROBRAS Documents

- [1] I-ET-3010.00-5140-700-P4X-001 - SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS
- [2] I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS
- [3] I-ET-3010.00-5140-700-P4X-005 - REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS
- [4] ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE SPECIFICATION
- [5] TOPSIDE ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE DIAGRAM
- [6] I-ET-3000.00.-1200-956-P4X-001 - QUALIFICATION TESTS FOR PAINT SYSTEMS
- [7] ELECTRICAL SYSTEM DESCRIPTIVE MEMORANDUM
- [8] I-ET-3010.00-5400-947-P4X-021 - SAFETY SIGNALLING
- [9] I-LI-3010.00-5140-700-P4X-001 - ELETRICAL EQUIPMENT DATA SHEET TEMPLATES

**TECHNICAL SPECIFICATION**

No. I-ET-3010.00-5140-772-P4X-001

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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.


3. GENERAL CONDITIONS

3.1 General

- 3.1.1 The components and systems of VSD-FCs shall be designed for continuous operation under rated output power conditions, considering the allowable overload cycles, and under continuous speed control conditions in the full output frequency range of the VSD-FC, without reduction of system capability.
- 3.1.2 Manufacturer is responsible for detailed electrical design and engineering within the VSD-FC and shall perform all functions required to interface with the design of electrical system, as well as guarantee the control and monitoring from Control Panel.
- 3.1.3 All material and equipment supplied to the VSD-FC shall meet applicable standards, Classification Society rules and NR-10.
- 3.1.4 VSD-FC shall be installed inside an electrical panels' room in a safe area.
- 3.1.5 VSD-FC shall be provided with 1 (one) heating resistor for each vertical section, fed by external 220VAC. These resistors shall be protected by thermomagnetic circuit-breakers and be automatically controlled by means of adjustable thermostats.
- 3.1.6 Power Panel shall have minimum mechanical protection degree IP 22, according to IEC 60529.
- 3.1.7 VSD-FC shall be packed properly for transportation, so that no damage occurs during transport, storage and lifting operations.
- 3.1.8 Instruments sizes, deflection, type (analogue or digital), position orientation and quantity shall be according to I-ET-3010.00-5140-700-P4X-005 - REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS.
- 3.1.9 Printed circuit boards shall be manufactured in accordance with standard IEC 61188-5-1. Semiconductor components shall be suitable for operation at temperatures up to 70°C and shall have undergone burn-in tests.
- 3.1.10 For VSD-FCs feeding motors installed in hazardous areas Zone 1 or Zone 2 or installed in safe external area but kept in operation during ESD-3P or ESD-3T conditions, the entire set (motor and drive) shall be certified to this location taking into consideration the VSD type and the frequency variation range, according to INMETRO Portaria 89, Feb 23rd 2012 and Portaria 179, May 18th 2010.
- 3.1.11 Internal bar insulation and junctions supports shall be of non-hygroscopic and not flammable. All these equipment shall be at the adequate insulation levels.

3.2 Environmental Conditions, Inclination Requirements and Vibration Requirements

- 3.2.1 The temperature design for the Panels shall be 45°C, as stated in IEC 61892-1.
- 3.2.2 The design humidity, as a function of temperature, shall be 90% up to 45°C and 70% above 45°C, as stated in IEC 61892-1.

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<p>3.2.3 Panels and internal equipment and materials shall be suitable for storage, service and installation on marine and petrochemical environment, complying with requirements related to these conditions defined in I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.</p> <p>3.2.4 Panels shall comply with inclination, motion and vibrations requirements defined in I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.</p> <p>3.3 Installation</p> <p>3.3.1 The VSD-FC shall be installed in a conditioned room (24°C), but the VSD-FC shall be able to operate continually at full load with ambient temperature according to item 3.2.1.</p> <p>3.3.2 The input power transformer shall be included inside the VSD-FC cabinet. However, if approved by PETROBRAS, this transformer may be installed in a transformer room, separated of the converter (electronic power and control). The transformer room is ventilated only.</p> <p>3.3.3 For floating units, the floor-mounted panels shall be provided with an insulating handrail in the fixed frontal side.</p> <p>3.3.4 Internal VSD auxiliary and control circuits that are installed on the VSD-FC cabinet shall be suitably protected from the main circuit as required by IEC 62271-1, and NR-10.</p> <p>3.4 Painting</p> <p>3.4.1 Painting process shall be proper for offshore installations, and shall comply with the requirements of I-ET-3000.00.-1200-956-P4X-001 - QUALIFICATION TESTS FOR PAINT SYSTEMS.</p> <p>3.4.2 The last coat colour shall be Light Green (MUNSELL notation 5 G 8/4). Inner components mounting plates, internal faces of doors and safety barriers shall be Safety Orange (MUNSELL notation 2.5 Y R 6/14). For VSD-FCs associated to firefighting equipment, the last coat colour shall be Safety Red Munsell 5R4/14.</p> <p>3.5 Cables and Accessories</p> <p>3.5.1 The electric cables shall comply with I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS and it shall be supplied in the package.</p> <p>3.5.2 VSD-FC Manufacturer shall approve the output power cables between VSD-FC and the motor.</p> <p>3.5.3 All points of wiring for external connection (input and output circuits) shall be functionally identified within the converter on each terminal block or power connection, including power cables, grounding, controls, signals and alarms.</p> <p>3.5.4 Control conductors shall be grouped in terminal blocks exclusively used for this purpose. Cables and terminal blocks shall be properly identified according to the wiring diagrams.</p> <p>3.6 Noise Level</p> <p>3.6.1 The maximum noise level at the VSD-FC room due to the package operation shall be lower than 80 dBA, at a distance equal to 1.50 m.</p>						

3.7 Nameplates and Markings

- 3.7.1 The VSD panel nameplates shall be in accordance with IEC 62271-1 and made with AISI-316 stainless steel.
- 3.7.2 The VSD panel nameplates shall be outfitted with a main identification plate containing, at least, the following data:
- Manufacturer name or manufacturer brand
 - Supply voltage, number of phases, nominal supply frequency;
 - Maximum supply current in continuous operation or power in kVA;
 - Maximum supported symmetric short-circuit current and test time;
 - Maximum output voltage;
 - Nominal output current in continuous operation;
 - Momentary current (overload) during 60 seconds;
 - Output frequency controlled range;
- 3.7.3 The VSD panel shall be outfitted with plate of supplemental identification containing, at least, the following data:
- PETRÓLEO BRASILEIRO S.A. - PETROBRAS;
 - name of the department of PETROBRAS;
 - name of the enterprise (platform);
 - TAG number of the Panel;
 - number of the RM;
 - number of the Order of Purchase of Material (PCM);
 - number of the Authorization of Material Supply (AFM);
 - in alternative to paragraph f) and g), the number of the contract, in the cases of acquisition built-in in contract of the type lump sum ("Turn Key ", "Lump Sum", etc.).
- Note 1 - The supplemental data nameplate may be included in the main nameplate.
- Note 2 - The supplemental data nameplate shall be manufactured in the same material of the main nameplate.
- 3.7.4 The VSD panel back doors, if any existent, shall have identification plates identical to the plates identifying the front sections.
- 3.7.5 The VSD panels shall have their compartments signalled with literal and graphical labels of instructions, cares, warnings and alert of dangers according to the requirements for identification plates listed in ASTM F1166 and IEC 60417-SN.
- 3.7.6 Components Markings – Labels
- 3.7.6.1 Internally to Panels all equipment and components shall be identified with black acrylic labels, with white letters, containing the codification compatible with design documents (list of materials, diagram, etc.).
- 3.7.6.2 No adhesives shall be used to fix the labels.
- 3.7.6.3 All electrical equipment, floor mounted, panel like, panel type, or similar in construction to a panel, regardless of the area where it is installed, shall have the following warnings as required by NR-10 and NR-12.
- 3.7.6.4 Warnings shall follow the standard labels as required in ABNT 13434-2 for electrical panels risk of shock also informed in I-ET-3010.00-5140-700-P4X-002 -

SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS and I-ET-3010.00-5400-947-P4X-021 - SAFETY SIGNALLING.

4. VSD-FC - INPUT POWER TRANSFORMER

4.1 General Characteristics

4.1.1 The input power transformer shall comply with I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS. Any discrepancy shall be submitted to PETROBRAS approval.

4.1.2 The input power transformer shall present the characteristics listed below. Any discrepancy shall be submitted to PETROBRAS approval.

a) Rated power:

- Shall be compatible with the rectifier necessities, including power factor and harmonics.
- Transformer rating shall be accordingly derated depending on the level of the harmonic content in the current generated by the rectifier that will flow through it (for this calculation the operating range of speed shall be considered).
- Transformer rating shall follow IEC 61378-1 or IEEE C57.18.10.
- Manufacturer shall present rating calculation report for PETROBRAS approval.

b) Rated Frequency: 60Hz \pm 5%;

c) Insulation: class F with temperature rise plus ambient temperature under the limits of class B (all windings) or class H with temperature rise plus ambient temperature under the limits of class F (all windings);

d) Type: Dry, epoxy encapsulated or moulded;

e) Minimum external degree of protection (if not built-in): IP-22.

f) Taps: 0 %, \pm 2.5% and \pm 5%;

g) Windings: Compatible with the VSD-FC rectifier pulse number;

h) Two RTD, platinum resistance temperature detectors type (PT100 Ω @ 0oC) per winding or thermostats (see also item 4.2, and 4.2.4); These RTDs shall be in contact with the hottest temperature parts of the windings.

i) Metallic shield layer, with proper connection for grounding, between primary and each secondary winding.

Note: Input power transformer windings shall be suitably designed to operate with the high dV/dt generated by the rectifier switching.

4.1.3 Unless otherwise defined in datasheet VSC-FC Input Transformer Temperature Rise Tests shall be repeated during String Tests.

4.1.4 For VSC-FC Input Transformer secondary series connected, individual transformers shall comply with phase-to-ground insulation values. Manufacturer shall provide individual transformer insulation data.

4.1.5 For VSC-FC Input Transformer air cooling ventilation manufacturer shall provide all means for proper individual transformer cooling. No room requirements shall be considered as auxiliary aiding for cooling. Temperatures informed in section 4.1.1 shall be considered.

4.2 Feeder Protection

4.2.1 The feeder protection is PETROBRAS scope. The basic will be:

- a) Undervoltage (27 function);
- b) Instantaneous/Time overcurrent (50/51 functions), in case of circuit-breakers or fuses, in case of contactors;
- c) Instantaneous ground fault overcurrent (50GS function).

4.2.2 The protection shall be made by contactor and fuses when primary voltage is 4.16 kV, or circuit-breaker when primary voltage is 13.8 kV.

4.2.3 The feeder protection shall be approved by VSD-FC Manufacturer.

4.2.4 In case of VSD input transformer incorporated or not in VSD topology structure, input transformer temperature protection shall be made by VSD control, and alarm and trip signals shall be send to feeder protection.

5. VSD-FC - ELECTRONIC POWER AND CONTROL

5.1 Circuit Configuration

5.1.1 The VSD-FC shall be matched and selected according to the requirements of load, output harmonics, supply system and ambient conditions. The optimum system configuration shall consider:

- a) load power over the full speed operation range;
- b) torque/speed load characteristics over the full speed variation range;
- c) starting and stoppage's load requirements;
- d) dynamic response requirements;
- e) speed control range;
- f) overvoltage at cable or motor terminals due to resonance or harmonic presence;
- g) requirements regarding to power factor as well as to voltage and current distortion factors, individual harmonics and notches at the Point of Common Coupling (PCC) with the supplying MCC or Switchgear;
- h) cooling requirements;
- i) necessity of output filters.

Note: Cycloconverters, supersynchronous and subsynchronous converter cascades shall not be accepted for motor speed control.

5.2 Electrical Characteristics

5.2.1 The main electrical characteristics are:

- a) Rated input main voltage: in accordance with data sheet;
- b) Rated input auxiliary control voltage: 1 x 480Vac, three phase, from normal panel;
- c) Rated input auxiliary voltage for heating resistors: 1 x 220Vac, two phases, from normal panel.
- d) Input frequency: 60Hz;
- e) Rated power: in accordance with load requirements;
- f) VSD-FC shall be able to operate at motor rated torque and power.

- g) VSD-FC shall be able to operate at reduced proportional torque and power with momentary input bus voltage of 80% to 90%. This reduced torque and power shall be proportional to the ratio between input voltage and 90%.
- h) Manufacturer shall indicate drive capability to keep rated output power at rated output speed during transient event of input voltage drop of 20% for 10 s. It shall be indicated the allowable frequency of this event.
- i) Output Frequency Range: In accordance with load requirements;
- j) Minimum Output Operation Frequency Range: 35 to 72 Hz;
- k) Minimum rectifier pulse number: 18 (eighteen). For drives with high frequency rectifiers (able to minimise harmonic contents and control power factor using high frequency switching) this limit is not applicable.

Note: The number of pulses of the rectifier shall be chosen in such way that the voltage at the feeding MCC or Switchgear presents a maximum THD of 5 % (IEEE Std 519) and makes the harmonic filters unnecessary. This THD shall be calculated considering the characteristics and non-characteristics harmonics, including those due to the DC Link filter necessary to avoid dc current/voltage modulation due to switching of the inverter. The individual current and voltage harmonics shall comply with the IEEE Std 519, too.

- 5.2.2 Inverter output voltage and drive performance shall be designed to comply with allowed torque ripple (torque pulsation) in the electrical motor. Inverter output voltage and drive performance shall be designed to avoid overvoltages at cable and motor's terminals.
- 5.2.3 If required in Data-Sheet, VSD-FC shall have a ZI compensation internal automatic routine due to voltage drop between drive and motor at power cable. This algorithm shall permit to control voltage at motor's terminal taking into account cable's voltage drop. This requirement is mandatory for VSD-FC feeding ESP (Electrical Submersible Pump).
- 5.2.4 Cooling system shall be air-air, fully redundant and independent, including at least two fans. Automatic transfer with alarm shall be provided in case of failure.
- 5.2.5 It shall be connected a duct at the VSD-FC panel exhaust fan discharge (for room air conditioning).
- 5.2.6 VSD-FC shall be non regenerative, so it shall not give current contribution to a short-circuit that occurs upstream the VSD-FC.
- 5.2.7 Power and control shall be assembled in separated compartments, cabinets or columns.
- 5.2.8 VSD-FC shall be fitted with RFI/EMI output filters.
- 5.2.9 VSD-FC shall be fitted with dV/dt limit filters if required by the associated motor insulation limitations.

5.3 VSD-FC Efficiency and Input Power Factor

- 5.3.1 The minimum efficiency for the VSD-FC system, i.e., VSD-FC, power transformers, cooling auxiliary devices, control and protection devices and accessories shall be:
 - a) 96.0% efficiency, with tolerance -0.0%, at 100% rated load;
 - b) 95.5% efficiency, with tolerance -0.0%, at 75% rated load;
 - c) 95.0% efficiency, with tolerance -0.0%, at 50% rated load;
 - d) 94.0% efficiency, with tolerance -0.0%, at 25% rated load.

5.3.1 The minimum power factor at the VSD-FC set input with rated voltage and frequency shall be:

- a) 0.95 lag, with tolerance -0%, at 100% rated load;
- b) 0.95 lag, with tolerance -0%, at 75% rated load;
- c) 0.92 lag, with tolerance -0%, at 50% rated load;
- d) 0.92 lag, with tolerance -0%, at 25% rated load.

5.3.2 It shall not be allowed power factor correction devices or equipment (capacitor banks or others).

5.3.3 The efficiency and power factor presented by the supplier at the proposal shall be proven during the factory and string tests.

5.4 VSD-FC's Output Voltage Distortion and Output Filters

5.4.1 Unless otherwise agreed with motor Manufacturer, maximum acceptable output voltage Total Harmonic Distortion (THD) shall be 5% (IEEE Std 519) in normal operation. All frequencies shall be considered in the calculation, i.e., not only the integer multiples of fundamental frequency.

5.4.2 Unless otherwise agreed with motor Manufacturer, maximum acceptable output voltage individual harmonic shall be 3% (IEEE Std 519) in normal operation.

5.4.3 It is acceptable to use output filters to reduce output voltage harmonic distortion and to avoid overvoltage due to resonance.

5.4.4 An EMI/RFI filter shall ever be provided.

5.4.5 A dV/dt filter shall be provided whenever required by the motor insulation limits, considering the effects of the connection cables.

5.4.6 Current and voltage measurements for motor protection and control shall be done after the filters.

5.4.7 For long cables, lengths bigger than 100 m, output filters to reduce output voltage harmonic distortion and to avoid overvoltage due to resonance and dV/dt required by the motor insulation limits are mandatory.

5.5 Protection Devices

5.5.1 The following minimum protection functions shall be included in the VSD-FC:

- a) CPU failure;
- b) Overcurrent (VSD-FC, motor);
- c) Overload (VSD-FC, motor);
- d) Short-circuit, for VSD-FC's internal and output (Three phases and phase to phase, with and without ground and phase to ground);
- e) Overvoltage (internal and output);
- f) Undervoltage (internal and output);
- g) Overtemperature (VSD-FC);
- h) Motor overload thermal protection by electronic thermal relay;
- i) Internal protection against voltage surges and accumulation of electrostatic charges;
- j) External failure alarm;
- k) Low control voltage;

- l) Loss of speed reference;
- m) Overspeed;
- n) Cooling failure or Cooling system changeover;
- o) Missing run or start permissive;
- p) Motor torque limit;
- q) Lack of phase (input and output);
- r) Negative sequence (input and output);
- s) Underload (both current and power protection with time adjustment);
- t) Reverse phase voltage;
- u) Ground fault in motor;
- v) UAM (Unit Alarm Malfunction);
- w) UAS (Unit Alarm Shutdown).

5.5.2 Protection functions can be done by an external additional relay supplied with the VSD-FC.

5.5.3 Out of range values from RTD PT100Ω @ 0oC shall be recognized as a failure of detection system. PT100Ω @ 0oC open circuit or short-circuit condition shall be identified. This item is applicable for all RTDs of the package, including VSD-FC, transformer and motor protection.

5.5.4 VSD-FCs shall provide electronic protection to the motor, which shall be capable of estimating the temperature of its windings based on programmed parameters referring to the motor. This protection shall cause the motor to be turned off when its thermal capacity is exceeded.

5.5.5 A mechanical protection, like mechanical interlocking shall be provided in order to avoid personnel injury due to improper access to medium-voltage at interior of VSD-FC. The drive shall not run with doors opened or access to medium-voltage. If the drive is running, its door opening shall cause VSD-FC trip.

5.5.6 It shall be provided an advertising (Warning Plate) in Brazilian Portuguese with indication of risk to life due to high/medium voltage. Additional advertising (Warning Plate) in Brazilian Portuguese shall be provided with indication of risk due to existence of capacitors that keeps voltage for some minutes (the safe time shall be indicated).

5.6 Control

5.6.1 The VSD-FC control shall be microprocessor-based and have auto-diagnose system.

5.6.2 VSD-FCs shall permit in its programming and configuration at least the following basic adjustments:

- a) acceleration and braking ramps, separately programmable, capable of being started from the external reference command;
- b) minimum and maximum operation frequencies;
- c) output frequency during operation;
- d) inhibition of critical resonance frequency ranges of the mechanical system;
- e) programming of automatic re-start function, after a trip or undervoltage event;
- f) torque limit.

5.6.3 The auxiliary or control voltage needed for internal circuits of the VSD-FC shall be obtained from external power source, according to 5.2.1b).

5.6.4 If required by Manufacturer, internal UPS shall be provided to feed local memory and control circuits.

5.7 Automation

5.7.1 VSD-FC shall be capable to communicate via network, according to ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE SPECIFICATION.

5.7.2 The VSD-FC shall be fully monitored, operated and parameterized through network communication.

5.7.3 For the minimum signals to be sent to and received from VSD-FC see ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE SPECIFICATION.

5.7.4 VSD-FCs shall have a local digital HMI (human machine interface) on its front side to allow man/machine interface and user friendly dialog. This HMI shall contain at least the following devices for operation and monitoring:

- a) selector switch or parameter settable option for selection of mode of operation (LOCAL/REMOTE);
- b) START switch for test, enabled by password;
- c) STOP switch;
- d) parameter selection switches;
- e) parameter and adjustment programming switches;
- f) key for increment of functions or control values;
- g) key for decrement of functions or control values;
- h) signalling LED indicating energized equipment;
- i) digital alphanumeric display to indicate:
 - ready to start;
 - speed;
 - current;
 - fault diagnosis;
 - alarms;
 - self-supervision system messages;
 - adjustment parameter values;
 - indication of remote communication failure

5.7.5 VSD-FCs shall have at least the following input signals for remote control:

- a) analog 4-20mA reference signal, for remote motor speed control, with the selector switch LOCAL/REMOTE on the REMOTE position;
- b) discrete signal for remote START;
- c) discrete signal for remote STOP;
- d) discrete signal for remote TRIP.

5.7.6 Remote START and STOP controls shall initiate pre-programmed acceleration and deceleration ramps, respectively. Remote TRIP command shall immediately de-energize the motor.

5.7.7 VSD-FCs shall have at least the following digital output signals:

- a) motor heater internal control;

b) converter tripped to open main feeder switching device.

5.7.8 VSD-FCs shall have at least the following analog 4-20mA output signals:

- a) output current;
- b) output speed or frequency.

5.7.9 VSD-FCs control shall be microprocessor-based and contain at least the following functions:

- a) selectors;
- b) alarm functions;
- c) network communication;
- d) monitoring and diagnostics;
- e) input and output functions.

5.8 Electromagnetic Interference

5.8.1 The VSD-FC control circuit shall be designed and built in such a way as to be insensitive to electromagnetic interference (EMI), generated by its converter or other equipment in the production unit, as well as other communication systems, including phones and radios.

5.8.2 The VSD-FC control circuit and the converter shall be designed and built taking into account that they shall not produce induced or conducted electromagnetic interference in others electronic equipment in the Unit.

5.8.3 All the VSD-FC control signals cables and power cables shall be suitably designed and allocated not to produce induced or conducted interference in instrumentation and communication systems.

5.8.4 Manufacturer shall deliver documents with detailed procedures and instructions of assembling and installation in order to avoid electromagnetic interference between package and other unit equipment.

5.8.5 Test procedures for factory, string (or load) and start-up tests shall be presented at proposal. They shall include standards, rules and recommended limits.

5.8.6 VSD-FC shall comply with emission and immunity EMC (Electromagnetic Compatibility) and RFI (Radio Frequency Interference) requirements according to IEC 61000 and IEC 60533, presenting Performance Criterion A.

5.9 Ripple Torque

5.9.1 The maximum ripple torque shall be in accordance with motor/pump set manufacturer specification for the whole speed variation range and shall not lead to torsional oscillation.

6. VOLTAGE AND CURRENT DISTORTION - THD

6.1 General

6.1.1 The voltage THD at the common coupling point (PCC) shall be limited to 5%, and the relative amplitude of each individual harmonic shall not be greater than 3% of the fundamental component (in accordance with IEEE-519).

6.1.2 The notches in voltage waveforms shall be limited in accordance with IEEE Std 519 standard.

6.1.3 The non-characteristic current harmonics like the even multiples or the non-integer multiples of the line frequency shall be limited according to IEEE Std. 519.

6.1.4 Maximum current THD in common coupling point (PCC) shall be limited to 5%.

6.2 Harmonic Filters

6.2.1 It shall not be allowed to use harmonic filters to achieve VSD-FC input harmonics limits.

7. TESTS

7.1 General Requirements

7.1.1 The list of minimum tests that shall be performed in VSD-FC is in datasheet, see ANNEX i – *DATASHEET REFERENCE*.


7.1.2 It shall be established a download routine of the VSD's parameters and event logs. At least, this procedure shall be done after the factory, commissioning and start-up tests. This data shall be incorporated in annex format at the test report.


7.1.3 When required in Data-Sheet, tests shall follow the detail below.

7.1.4 VSD tests in shall follow indicated references of Table 1 according to IEC 61800-4 and this specification.

Table 1 – VSD Tests and References

Test Description	Type Test	Routine Test	Special Test	Reference for Test and verification
Insulation (NOTE 1)	X	X		IEC 61800-4 and IEC 60146-1-1
Light load and operation (NOTE 2)	X	X		IEC 61800-4, IEC 60146-1-1, IEC 60146-2
Rated current/output	X	X		IEC 61800-4, IEC 60146-1-1, IEC 60146-2
Overcurrent capability (NOTE 3)			X	IEC 61800-4, IEC 60146-1-1, IEC 60146-2
Current sharing	X			IEC 61800-4
Voltage division	X			IEC 61800-4
Interphase ripple voltage and ripple current			X	IEC 61800-4 and IEC 60146-1-1
Power loss determination	X			IEC 61800-4, IEC 60146-1-1, IEC 60146-2
Temperature rise (NOTE 4)	X			IEC 61800-4 and IEC 60146-1-1
Measurement of inherent voltage regulation			X	IEC 61800-4 and

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Test Description	Type Test	Routine Test	Special Test	Reference for Test and verification
				IEC 60146-1-1
Checking of auxiliary devices	X	X		IEC 61800-4 and IEC 60146-1-1
Checking the properties of the control equipment	X	X		IEC 61800-4
Checking the protective devices	X	X		This Specification sections 4.2 and 5.5; IEC 61800-4 and IEC 60146-1-1
Audible Noise			X	This Specification sections 7.2 and 7.5; IEC 61800-4 and IEC 60146-1-1
Power factor		X		This Specification
Addition Tests			X	IEC 61800-4 and IEC 60146-1-1
Electromagnetic Immunity			X	This Specification sections 7.2 and 7.5; IEC 61800-3 and IEC 60533
Electromagnetic Emissions			X	This Specification sections 7.2 and 7.5; IEC 61800-3 and IEC 60533
Internal bar insulation and junctions supports adequate insulation levels.		X		This Specification, sections 3.1, 4.1, 5.1 and 5.2.
<p>Note 1 Insulation tests may be done with the power semiconductor devices short-circuited. The manufacturer of the component should have separately checked the insulation level of these devices.</p> <p>Note 2 A light load test might be performed with a motor of smaller power than the assigned one. However the voltage and speed/frequency ranges should be relevant.</p> <p>Note 3 The overcurrent of the converter reflects the overload capability of the VSD. Specified values of short time over current or starting up sequences of actual load should be applied for the time interval specified.</p> <p>Note 4 The temperature tests should verify adequate margins for the power semiconductors as well as other critical devices, for example capacitors and printed wiring boards (PWB). To document semiconductor margins, the converter manufacturer should prior to the tests produce theoretical calculations of the junction temperature.</p>				

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7.2 Factory Tests

- 7.2.1 VSD-FC shall be tested at the factory with load, including starting, stopping, all circuits tests, measurements of efficiency, voltage and current distortion, power factor, audible noise, EMI etc. Voltage drop at transformer input of 10% (continuous) and 20% (transient) and rated power and overvoltage at transformer input of 10% (continuous) and 20% (transient) and rated power.
- 7.2.2 The measurements of efficiency, voltage and current distortion, power factor, vibration, acceleration time of the set, audible noise shall be made at 25%, 50%, 75%, 90% and 100% of the rated power of the drive.
- 7.2.3 The drive package shall operate continuously during 24 hours without any fail or alarm.
- 7.2.4 Tests shall be made with adequate and calibrated equipment and recorded by an oscillographic recorder.
- 7.2.5 Detailed test procedures and associated codes, standards and recommended practices shall be presented at proposal for PETROBRAS approval. Test procedures shall include diagrams with all test equipment specifications.
- 7.2.6 Check of the automatic ZI compensation, when required, shall include output filters. It shall be accepted the use of a controlled impedance to simulate the cable influence. It shall be checked the VSD-FC behaviour regarding control of voltage at motor terminals and regarding calculation of motor current to protection.
- 7.2.7 For VSD-FC feeding ESP, measurement of intake pressure, discharge pressure, intake temperature, motor winding temperature, vibration and current leakage by ESP multifunction meter shall be carried-out.
- 7.2.8 For VSD-FC feeding ESP, three separate digital inputs shall be provided in VSDs, two for connecting ESD system (ESP turn off with and without speed breaking ramp) and one for connection of ESP CLP (turn off without speed breaking ramp).
- 7.2.9 For VSD-FC feeding ESP, VSD CLP shall be slave to ESP CLP master. Communication network, protocols, and exchanged information shall be defined by ESP.
- 7.2.10 Tests report with multifunction meters of the same manufacturer, same model and same type shall be accepted for this test.
- 7.2.11 PETROBRAS personnel shall witness all factory tests that PETROBRAS understands to be necessary. These witnessed tests are indicated in purchase contract.
- 7.2.12 Factory tests report shall be presented for PETROBRAS approval.
- 7.2.13 Output Filters Tests:
- a) Insulation test shall be performed.
 - b) Passive filters shall be tested (energised) with full voltage and current at maximum frequency without failure.
 - c) Current, voltage, active and reactive power and filter's components temperatures shall be measured and recorded.

7.3 String Tests

- 7.3.1 When required in driven machine documentation, string test shall be performed.

7.4 Commissioning and Start-up Tests

7.4.1 VSD-FC shall be pre-commissioned at the shipyard with no-load.

7.4.2 In the beginning of start-up, harmonic, EMI and others measurement shall be provided and, if necessary, the minor field adjustment shall be done by Manufacturer, in order to comply with motor and pump system performance and electrical system requirements.

7.5 RFI & EMI Immunity Tests

7.5.1 The entire systems (including control boards, communication boards, measurement boards, power systems, etc.) shall be fully operative during these tests.

7.5.2 All the sections of the VSD-FC shall be interconnected and energized, being the whole system in conditions of normal operation.

7.5.3 Additionally to the EMC tests defined in IEC 61800-3 and IEC 60533, the following test procedure shall be performed:

- a) For the purpose of radiation generation, two transceivers (VHF and UHF) shall be triggered simultaneously;
- b) In the course of the test, the transceivers shall be kept in the vertical position, horizontally aligned, 5m apart from each other, at 1.5 m above the floor:
 - 1st position: the transceivers shall be 1m apart from the panel front wall;
 - 2nd position: the transceivers shall be 1m apart from the panel rear wall.
- c) The tests in the 1st and 2nd positions shall be carried out, at least, in three frequency ranges of the transceivers, namely the lower, the intermediate and the upper range.
- d) The transceivers shall be triggered, in each frequency range and position for at least during 02 minutes.
- e) The output variables shall not suffer distortion or variation compared to the input variables, in the course of the test.

7.5.4 The results of the tests shall be recorded on certified reports.

7.5.5 All the deviations, exceptions and comments about the tests shall be reported in appendices.

7.5.6 The certified reports shall be sent to PETROBRAS for approval.

7.5.7 The transceivers shall be compliant with the following specifications:

- a) VHF transceiver:
 - Manufacturer: Motorola;
 - Model: MX-360;
 - Frequency ranges: from 130 MHz to 174 MHz;
 - Power: 1 W
- b) UHF transceiver:
 - Manufacturer: Motorola;
 - Model: MT-340;
 - Frequency ranges: from 430 MHz to 520 MHz;
 - Power: 5 W.

8. SOFTWARES AND UNUSUAL TOOLS

8.1.1 Manufacturer shall supply all electrical devices and unusual tools necessary for operation, installation and maintenance. They shall be delivered with each drive.

8.1.2 It shall be included, at least:

- a) Grounding tools;
- b) Unusual semiconductor device exchange tool package (if applicable);
- c) Unusual cables and pins for signal measurement;
- d) Complete software package (programs, operational system, manuals, diagnosis software etc) for uploading and downloading programs/firmware;

9. WARRANTY AND TECHNICAL ASSISTANCE

9.1 After the commissioning period, the drive shall have the capability to run continuously for a period of at least 24 months, under the specified site conditions without any scheduled shutdown. No component of the drive system shall require any routine or preventive maintenance that needs a shutdown of the system over any consecutive 24 months period following initial operation.

9.2 The manufacturer shall submit a document that contains a routine of maintenance for the reserve cells, ensuring the availability of this cells during the lifetime of the equipment

9.3 The manufacturer shall provide a warranty of 24 (Twenty four) months after the start-up or 10,000 hours of operation, what occurs later.

9.4 Manufacturer shall provide and guarantee Technical Assistance at Rio de Janeiro - Brazil in a period shorter than 2 (two) days. The replacement parts shall be stored in Brazil and when required, they shall be available at Production Unit in a period shorter than 10 days.

9.5 This item covers the whole package (including power transformer, protection devices etc).

10. SPARE PARTS

10.1 Manufacturer shall furnish a list of spare parts for two years of continuous operation, to be approved by PETROBRAS.

10.2 A list with quotation of all VSD-FC spare parts, including part number, original manufacturer and individual prices, shall be presented at proposal.

11. DOCUMENTATION

11.1 At proposal:

- Equipment data sheet and accessories with estimative of harmonics and power dissipation;
- Equipment layout with views, cables entrances, fixation details and weights;
- Codes, standards and recommended practices adopted;
- Reference list;
- System component efficiency, for 35%, 50%, 75%, 90% and 100% of the rated power;
- Efficiency measurement method adopted;

- Equipment mathematical models (with parameters values) for system computational simulation;
- Thermal load of VSD-FC and rectifier power transformer, with indication of air and water distribution for heat transfer;
- Diagrams, control diagrams, dimensional drawings, auxiliary loads power requirement, heat loss, etc;
- List of recommended spare parts.
- List with quotation of all VSD-FC Spare Parts;
- Detailed specification and quotation of all package power cables. If length data is not defined or available the quotation shall be per unity of length.

11.2 For approval:

- Equipment data sheets fulfilled;
- Equipment layout drawings with views, cables entrances, fixation, weights, sections and details;
- Functional and connection diagrams;
- Components list, with at least: item, description, MTBF (Mean Time Between Failure), quantity and part number;
- Spare parts list as above;
- Harmonics study and spectrum;
- Tests plan;
- Tests certification, according to 3.1.10;
- A list of protection functions and equipment parameters and all its adjustments and configurations for the proposed converter service and feeding motor;
- Lifting drawings with weights and gravity center.

11.3 At delivery:

- Technical manuals of transportation, storage, start-up, commissioning, operation, maintenance and other necessities shall be delivered with the package. They shall cover the whole package and its components. The MTTR of VSD-FCs shall be informed in documentation.
- Tests reports.

11.4 Operation and maintenance manuals shall be delivered in Brazilian Portuguese and English.

11.5 All other documents shall be presented in English or in Brazilian Portuguese. When technical document is delivered in Brazilian Portuguese, the same one shall also be delivered in English.

11.6 All reference manuals and reports, shall be provide, in at least, two copies in English language and two copies in Brazilian Portuguese language and comply with NR-12 requirements.

11.7 Tests and studies reports shall be delivered with the package too. There shall be supplied three copies of each report and they shall be delivered in paper and digital media.

11.8 All studies and computational simulation files shall be delivered in digital media with indication of the software used and its version.



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11.9 All digital media shall be Microsoft Windows™ compatible. Other cases shall have specific PETROBRAS approval.

12. TRAINING

12.1 Manufacturer shall provide training for at least 10 (ten) PETROBRAS personnel, about VSD-FC technology, operation and maintenance.

12.2 Training shall be provided in Brazil, during commissioning period, in Portuguese language.

12.3 Training plan shall include at least control diagram analysis, storage, transportation, installation, operation, corrective maintenance, preventive maintenance, disassembly, assembly, use of tools and accessories, interface with automation, use of softwares, configuration, parameterization and adjustment of VSD-FC and its components.

13. ABBREVIATIONS

DC	Direct Current
EMI	Electromagnetic Interference
EMC	Electromagnetic Compatibility
ESP	Electrical Submersible Pump
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
MTTR	Mean Time To Repair
NEMA	National Electrical Manufacturers Association
PCC	Point of Common Coupling (panel where VSD-FC is feed)
RFI	Radio Frequency Interference
RTD	Resistance Temperature Detector
PTC	Positive Temperature Coefficient
THD	Total Harmonic Distortion
UHF	Ultra High Frequency
UPS	Uninterruptible Power System
VHF	Very High Frequency
VSD	Variable Speed Drive
VSD-FC	Variable Speed Drive – Frequency Converter

14. ANNEX I – DATASHEET REFERENCE

14.1 The datasheets shown in annexes are models and do not refer to any equipment. The manufacturer shall fill in a datasheet for each equipment.

14.2 For equipment without datasheet model in annexes, Manufacturer shall fill in data-sheets according to its own standard and submit to PETROBRAS approval.

14.3 All existing data sheet templates are available at I-LI-3010.00-5140-700-P4X-001 - ELETRICAL EQUIPMENT DATA SHEET TEMPLATES.