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	JOB:		--
	AREA:		
SRGE	TITLE: MEDIUM-VOLTAGE FREQUENCY CONVERTER FOR OFFSHORE UNITS		INTERNAL
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C	REVISED WHERE INDICATED DUE TO CONSISTENCY ANALYSIS
D	REVISED WHERE INDICATED DUE TO RFI INPUTS AND P71-GRM
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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.

This specification also comprises Medium-Voltage Soft-Starters and other equipment covered by IEC 61800-2 and IEC 61800-4.

2. CODES, STANDARDS & REFERENCE DOCUMENTS

2.1 GENERAL


2.1.1. 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.


2.1.2. Any deviation from this specification or the standards and reference documents shall be informed by Supplier/Manufacturer and approved by PETROBRAS.

2.2 CODES AND STANDARDS

2.2.1 IEC - INTERNATIONAL ELECTROTECHNICAL COMMISSION

- | | | |
|------|----------------|---|
| [1] | IEC 60068-2-2 | Environmental testing – Part 2-2: Tests – Test B: Dry heat - Edition 5.0 |
| [2] | IEC 60068-2-30 | Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle) |
| [3] | IEC 60079-14 | Explosive atmospheres – Part 14: Electrical installations design, selection and erection. |
| [4] | IEC 60417-DS | Graphical Symbols for Use on Equipment – Database Snapshot |
| [5] | IEC 60721-3-1 | Classification of environmental conditions - Part 3-1 Classification of groups of environmental parameters and their severities – Storage |
| [6] | IEC 60721-3-2 | Classification of environmental conditions - Part 3-2: Classification of groups of environmental parameters and their severities - transportation and handling. |
| [7] | IEC 60721-3-3 | Classification of environmental conditions – Part 3-3: Classification of groups of environmental parameters and their severities – Stationary use at weather protected locations. |
| [8] | IEC 61188-5-1 | Printed Boards and Printed Boards Assemblies – Design and Use – Part 5-1: Attachment (Land/Joint) Considerations – Generic Requirements. |
| [9] | IEC 61378-1 | Converter Transformers - Part 1: Transformers for Industrial Applications. |
| [10] | IEC 61800-2 | Adjustable Speed Electrical Power Drive Systems – Part 2: General requirements –Rating specifications for adjustable speed |

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		AC power drive systems	
[11]	IEC 61800-3	Adjustable Speed Electrical Power Drive Systems - Part 3: EMC Requirements and Specific Test Methods.	
[12]	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.	
[13]	IEC 61800-5-1	Adjustable speed electrical power drive systems – Part 5-1: Safety requirements – Electrical, thermal and energy	
[14]	IEC 62271-1	High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and Controlgear.	
[15]	IEC 62271-200	High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV.	
[16]	IEC 62326-1	Printed Boards - Part 1: Generic Specification	
[17]	IEC 62326-4	Printed Boards - Part 4: Rigid Multilayer Printed Boards with Interlayer Connections - Sectional Specification	
[18]	IEC 62477-2	Safety requirements for power electronic converter systems and equipment – Part 2: Power electronic converters from 1 000 V AC or 1 500 V DC up to 36 kV AC or 54 kV DC.	
[19]	IEC TS 60034-25	Rotating Electrical Machines - Part 25: AC Electrical Machines Used in Power Drive Systems – Application Guide	
[20]	IEC 60533	Electrical and electronic installations in ships – Electromagnetic compatibility (EMC) – Ships with a metallic hull.	
[21]	IEC 60146-1-1	Semiconductor Convertors - General Requirements and Line Commutated Convertors – Part 1-1: Specification of basic requirements.	
[22]	IEC/TR 60146-1-2	Semiconductor Convertors - General Requirements and Line Commutated Convertors – Part 1-2: Application Guide.	
[23]	IEC 60146-1-3	Semiconductor Convertors - General Requirements and Line Commutated Convertors – Part 1-3: Transformers and Reactors	
[24]	IEC 60146-2	Semiconductor converters – Part 2: Self-commutated semiconductor converters including direct d.c. converters.	
[25]	IEC 61892	Mobile and fixed offshore units – Electrical installations	
	Note: 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 for PETROBRAS approval.		

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2.2.2 ASTM - AMERICAN SOCIETY FOR TESTING AND MATERIALS (WHERE SPECIFIED)

[26] ASTM F1166 Standard Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities

2.2.3 IEEE - INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

[27] IEEE 1566 IEEE Standard for Performance of Adjustable-Speed AC Drives Rated 375 kW and Larger.

[28] IEEE 1580 Recommended Practice for Marine Cable for Use on Shipboard and Fixed or Floating Facilities

[29] IEEE C57.18.10 Standard Practices and Requirements for Semiconductor Power Rectifier Transformers.

[30] IEEE 519 Recommended Practice and Requirements for Harmonic Control in Electrical Power Systems.

[31] IEEE 1584 Guide for Performing Arc-Flash Hazard Calculations

2.2.4 LABOUR SECRETARY - MINISTRY OF ECONOMY - REGULATORY STANDARDS FOR OCCUPATIONAL SAFETY AND HEALTH

[32] NR-10 Segurança em Instalações e Serviços em Eletricidade

[33] NR-12 Segurança no Trabalho em Máquinas e Equipamentos

[34] NR-37 Segurança e Saúde em Plataformas de Petróleo

2.2.5 INMETRO – INSTITUTO NACIONAL DE METROLOGIA NORMALIZAÇÃO E QUALIDADE INDUSTRIAL


[35] Portaria nº 115 March, 21st 2022

2.2.6 IPC- ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

[36] IPC 6012 Qualification and Performance Specification for Rigid Printed Boards

2.2.7 ABNT – ASSOCIAÇÃO BRASILEIRA DE NORMALIZAÇÃO TÉCNICA

[37] ABNT NBR 16820 Sistemas de sinalização de emergência — Projeto, requisitos e métodos de ensaio.

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2.3 REFERENCE DOCUMENTS

- [38] I-ET-3010.00-5140-712-P4X-002 - MEDIUM-VOLTAGE INDUCTION MOTORS FOR OFFSHORE UNITS
- [39] I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS
- [40] I-ET-3010.00-1200-300-P4X-001 - NOISE AND VIBRATION CONTROL REQUIREMENTS
- [41] I-ET-3010.00-1200-956-P4X-002 - GENERAL PAINTING
- [42] I-ET-3010.00-5140-700-P4X-005 - REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS
- [43] I-ET-3010.00-5140-713-P4X-001 - SPECIFICATION FOR TRANSFORMERS FOR OFFSHORE UNITS
- [44] I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL FOR OFFSHORE UNITS
- [45] I-ET-3010.00-5143-700-P4X-001 - ELECTRICAL SYSTEM PROTECTION CRITERIA
- [46] I-ET-3010.00-5140-700-P4X-001 - SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS
- [47] I-ET-3010.00-5140-700-P4X-007 - SPECIFICATION FOR GENERIC ELECTRICAL EQUIPMENT FOR OFFSHORE UNITS
- [48] I-ET-3010.00-5400-947-P4X-002 - SAFETY SIGNALLING
- [49] I-ET-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE
- [50] I-DE-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE DIAGRAM
- [51] I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST
- [52] I-LI-3010.00-5140-700-P4X-001 - ELECTRICAL EQUIPMENT DATA-SHEET MODEL

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 VSD-FC CHARACTERISTICS

3.1 GENERAL

- 3.1.1** All material and equipment supplied to the VSD-FC shall meet applicable standards, Classification Society rules and NR-10.
- 3.1.2** VSD-FC shall be designed, manufactured, and tested according to standards listed on item 2.2 and according to reference documents listed on item 2.3.
- 3.1.3** It shall not be acceptable out of date or obsolete equipment or components. Technical support and supply of spare parts shall be guaranteed for ten (10) years.
- 3.1.4** In the scope of MOTOR manufacturing, VSD-FC Supplier/Manufacturer acknowledge only:
- 1) 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, they shall be certified as a unit association (motor-VSD-protective device) as required by IEC 60079-14.
 - 2) Alternatives foreseen in IEC 60079-14 for this certification (as a unit association) are acceptable. See I-ET-3010.00-5140-712-P4X-002 - MEDIUM-VOLTAGE INDUCTION MOTORS FOR OFFSHORE UNITS.

3.2 ENVIRONMENTAL CONDITIONS, INCLINATION AND VIBRATION REQUIREMENTS

3.2.1 LIFE OPERATION CONDITIONS

- 3.2.1.1** The VSD-FC shall be designed for indoor areas operation as per I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.
- 3.2.1.2** VSD-FC shall be tropicalized, according to I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.
- 3.2.1.3** VSD-FC shall be suitable to operate under vibration and acceleration requirements defined by I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.
- 3.2.1.4** VSD-FC 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-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.
- 3.2.1.5** When installed in mobile units and ships (FPSO and FSO), the VSD-FC shall be suitable to operate normally under motion and inclination limits (static and dynamic) specified by I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.
- 3.2.1.6** The installation locations of the VSD-FC and its accessories shall be classified in accordance with IEC 60721-3-3, as shown in Table 1. Requirements of I-ET-3010.00-

5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS listed above apply.

Table 1 – VSD-FC – Environmental Climatic Conditions by IEC 60721-3-3.

Definition	Minimum Class	Observations
Climatic conditions (K)	3K20 ⁽¹⁾	Enclosed locations. Fully air-conditioned enclosed locations. Air temperature and humidity control is used continuously to maintain the required conditions. (Similar to 3K2 by IEC 60721-3-3 of 1994)
Special climatic conditions (Z)	3Z1	Negligible
Biological conditions (B)	3B1	Negligible (Similar to 3B1 by IEC 60721-3-3 of 1994)
Chemically active substances (C)	-	No Chemically active substances (Similar to 3C1 by IEC 60721-3-3 of 1994)
Mechanically active substances (S)	3S5	No. Precautions have been taken to minimize the presence of dust and sand. (Similar to 3S1 by IEC 60721-3-3 of 1994)
Mechanical conditions (M)	3M11	Locations experiencing low levels of vibration and insignificant levels of shock, such as those transmitted from air conditioning, machines or passing vehicles in the vicinity (Similar to 3M1 by IEC 60721-3-3 of 1994)
Notes: 1) Drive equipment may operate in indicated conditions; however, it shall be designed to operate in temperatures indicated in I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS. 2) Deviations to conditions above shall be informed to PETROBRAS for acknowledge and approval.		

3.2.2 TRANSPORT AND HANDLING CONDITIONS

3.2.2.1 Unless otherwise defined in Project Documentation, the frequency converter shall be designed and manufactured considering transport and handling temperatures between -25 and 55 °C.

3.2.2.2 The frequency converter transport shall be according with IEC 60721-3-2, considering the following requirements in Table 2.

Table 2 – VSD-FC Transport and Handling Conditions by IEC 60721-3-2.

Definition	Minimum Class	Observations
Climatic conditions (K)	2K11	Weather-protected transportation without temperature and humidity controls in unventilated enclosures in arid, temperate, tropical, and cold climates. Polar climate is excluded. The product may be transported in heated, pressurized aircraft holds. Shipping and packing for a period longer than 6 months (Similar to 2K4 in old version of IEC 60721-3-2.)
Biological conditions (B)	2B1	Negligible (Similar to 2B1 in old version of IEC 60721-3-2.)
Chemically active substances (C)	2C2	Transportation and handling in areas with normal levels of contaminants as experienced in urban areas with industrial activity scattered over the whole area, or with heavy traffic. This includes transportation in areas where salt mist is present including maritime transport of containers but not transport on open decks of ships. (Similar to 2C2 in old version of IEC 60721-3-2.)
Mechanically active substances (S)	2S5	Applies to transportation and handling with limited precautions to minimize the presence of dust and sand such as enclosed transport. (Similar to 2S2 in old version of IEC 60721-3-2.)
Mechanical conditions (M)	2M5	Handling, transport by rail, river, sea, air (jet aircraft only) and road transport using good vehicles on good roads. This category includes transport of goods within ISO containers, plus road transport using poor vehicles and/or on poor roads as well as handling using trolleys with no suspension. (Similar to 2M3 in old version of IEC 60721-3-2.)
Notes: 1) Deviations to conditions above shall be informed to PETROBRAS for acknowledge and approval. 2) IEC 61800-2 climactic conditions for storage and transport conditions for “in shipping packaging for more than 6 months” apply when specific condition is not indicated above.		

3.2.2.3 Inclination, shock, humidity and temperature sensors shall be available and shall record the maximum values that the VSD-FC was subjected during transportation.

3.2.2.4 Inclination, shock, humidity and temperature sensors initial values shall be recorded in a report at final packing in factory before shipping to site. This values shall be compared at site, during delivery inspection, see section 12.5. At delivery, the sensors inspection shall be witnessed by PETROBRAS.

3.2.3 STORAGE CONDITIONS


3.2.3.1 Unless otherwise defined in Project Documentation, the frequency converter shall be designed and manufactured considering storage temperatures between -25 and 55 °C.

3.2.3.2 Unless otherwise defined in project documentation, the frequency converter storage shall be according with IEC 60721-3-1, considering the following requirements of Table 3.

Table 3 – VSD-FC Storage Conditions by IEC 60721-3-1.

Definition	Minimum Class	Observations
Climatic conditions (K)	1K25	Applies to open-air storage in the tropical climatic classification. Some constructions sites may require 1K27, that applies to open-air storage in the cold and polar climatic classifications. (Similar to 1K10 in old version of IEC 60721-3-1.)
Special climatic conditions (Z)	1Z1	Negligible (Similar to 1Z1 in old version of IEC 60721-3-1.)
Biological conditions (B)	1B1	Applies to storage locations with environmental controls in place to prevent the growth of mould and physical controls to prevent attack by animals. (Similar to 1B1 in old version of IEC 60721-3-1.)
Chemically active substances (C)	1C2	Applies to locations with normal levels of contaminants as experienced in urban areas with industrial activity scattered over the whole area, or with heavy traffic. Salt mist is present in coastal areas. (Similar to 1C2 in old version of IEC 60721-3-1.)
Mechanically active substances (S)	1S11	Applies to enclosed storage locations not situated in proximity to dust or sand sources and with no precautions to minimize the ingress of dust or sand. Such enclosed storage locations could include shipping containers (Similar to 1S2 in old version of IEC 60721-3-1.)
Mechanical conditions (M)	1M12	Applies to storage locations experiencing significant levels vibration and shock, such as those close to heavy machines. (Similar to 1M1 in old version of IEC 60721-3-1.)
Notes: 1) Deviations to conditions above shall be informed to PETROBRAS for acknowledge and approval. 2) IEC 61800-2 climactic conditions for storage and transport conditions for “in shipping packaging for more than 6 months” apply when specific condition is not indicated above. 3) Construction site location shall define condition to be agreed with Supplier/Manufacturer.		

3.2.3.3 Supplier/Manufacturer shall inform PETROBRAS at delivery and in databook documentation, see section 12.5, all necessary requirements and auxiliary systems for equipment storage beyond 6 months, if needed.

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3.3 SYSTEM INPUT VOLTAGE AND FREQUENCY

3.3.1 VSD-FC shall be suitable for operation with system voltage and frequency variations according to I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

3.3.2 VSD-FC design shall provide protection against voltage surge and means to mitigate accumulation of electrostatic charges.

3.4 NOISE LEVEL

3.4.1 VSD-FC equipment noise level requirements shall comply with I-ET-3010.00-1200-300-P4X-001 - NOISE AND VIBRATION CONTROL REQUIREMENTS.

3.5 MATERIAL REQUIREMENTS

3.5.1 All materials used shall be non-hygroscopic, flame retardant and resistant to corrosion caused by maritime environment and contact with hydrocarbons.

3.5.2 To avoid galvanic corrosion, contact between different metallic materials shall be prevented. A mean to prevent this form of corrosion shall be implemented if the contact between different metallic materials is necessary.

3.5.3 Internal bar voltage insulation and junction supports shall be of non-hygroscopic and non-flammable material and shall insulate against the expected voltage levels during normal operation.

3.6 MECHANICAL STRUCTURE CONSTRUCTION REQUIREMENTS

3.6.1 VSD-FC shall have minimum mechanical protection degree IP as defined I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS for panels and transformers (if not incorporated).


3.6.2 The maximum height, including the plinth, shall not exceed 2400 mm (excluding VSD-FC cooling fans, cooling exhaust ducts, and the exhaust ducts gas expansion from short-circuits).

3.6.3 VSD-FC shall comprise metallic compartments arranged in vertical sections, with the purpose to retard the fire propagation from one functional unit to another.

3.6.4 The base of the VSD-FC shall be drilled, and the panel shall be fixed to one metallic base (skid) using screws through the holes.

3.6.5 The skid shall be dimensioned just like a bi-supported beam along the longitudinal direction, to support the whole panel weight. The skid shall have sides covered with plates to avoid access of humidity to the VSD-FC's lower section. The skid shall be drilled and fixed directly to the floor. Supplier/Manufacturer shall supply the skid and all necessary hardware to fix the skid to the floor.

3.6.6 To avoid dangerous inclination of VSD-FC when manoeuvring it during construction and installation, the two point supported beam on the longitudinal direction fixing base shall also have transversal directional beams. These transversal beams shall not interfere with cable access and any other installation requirements. Other solution may be accepted if previously submitted for PETROBRAS approval.

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3.6.7 VSD-FC shall be designed and constructed so that all services, including operation, installation, maintenance, configuration, etc. can be done from the front side, so that Power Panel could be installed with the rear side close to walls. Rear access to VSD-FC is not acceptable. If specific access is necessary, PETROBRAS shall be informed for approval.

3.6.8 For floating units, the floor-mounted panels shall be provided with an insulating handrail in the fixed frontal side.

3.6.9 Vertical sections shall have hinged doors on their front sides.

Note: Hinged doors shall have an open position lock device.

3.6.10 The equipment that requires either set or calibration shall be installed in such a way that it shall not be necessary to open the door to proceed with the calibration.

3.6.11 If indicated in the Datasheet, the VSD-FC shall have removable plates on the back.

3.6.12 Power and control modules shall be assembled in segregated compartments, cabinets, or columns.

3.7 MECHANICAL HANDLING REQUIREMENTS

3.7.1 VSD-FC shall be properly packed (see section 3.2.2), so that no damage occurs during transport, storage and handling operations.

3.7.2 The panels shall be designed to minimize the number of connected columns during handling. Mechanical handling partition shall be informed to PETROBRAS in documentation for approval (section 12.4).

3.7.3 VSD-FC shall be provided with lifting eyelets. Other solutions for handling shall be sent to PETROBRAS for acknowledge and approval.

3.7.4 In case of VSD-FC with a segregated power transformer installed in an independent cubicle, the transformer and its cubicle shall be separated from power cells during handling.

Note: If different approach is necessary, Supplier/Manufacturer shall inform topology and necessary equipment handling and assembly to PETROBRAS (as required in section 12.4).

3.8 PAINTING


3.8.1 Painting shall be appropriate for offshore installation and shall comply with the requirements of I-ET-3010.00-1200-956-P4X-002 - GENERAL PAINTING.

3.8.2 The last colour coat 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).

3.8.3 For VSD-FCs associated with firefighting equipment, the last colour coat shall be Safety Red Munsell 5R4/14.

3.9 INPUT TRANSFORMER INSTALLATION REQUIREMENTS

3.9.1 Unless otherwise defined in Project Documentation, the VSD-FC input transformer shall be integrated with VSD-FC cabinets. The input power transformer shall be included as a continuation, besides, the VSD-FC power electronics and control cabinets.

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- 3.9.2** When approved by PETROBRAS, it shall be acceptable VSD-FC with separate input transformers. This transformer may be installed in a transformer room separated of the converter (electronic power and control).
- 3.9.3** VSD-FC power transformer shall comply with room installation requirements. VSD-FC installation room temperature is controlled, and the transformer room is ventilated only.
- 3.9.4** Supplier/Manufacturer shall comply with the space and lift weight restriction of Module and shall be responsible for all impacts caused by the choice (area, weight, heat dissipation, HVAC system, cables, etc.).
- 3.9.5** Selection by Supplier/Manufacturer of bigger, less efficient, and heavier VSDs shall not be used as motivation to change orders, shall not be considered as change in project and is not acceptable as motivation for claims.

3.10 ELECTRICAL STRUCTURE CONSTRUCTION REQUIREMENTS

- 3.10.1** VSD-FC power and control circuits shall be designed considering that a failure in one component or printed circuit board shall not cascade or induce another failure in other components or printed boards.
- 3.10.2** All metallic parts that make up the VSD-FC and are not intended to conduct electricity shall have electrical continuity and be connected to the panel's ground bus. The ground bus shall be located at the bottom of each section of the VSD-FC and it shall have a compression connector, suitable for connecting grounding copper cable with nominal section as indicated in the I-ET-3010.00-5140-700-P4X-001 - SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS. The doors shall have electrical continuity with the metal structure of the VSD-FC through flexible copper strip.
- 3.10.3** Internal VSD-FC 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.
- 3.10.4** VSD-FC shall comply with the requirements of IEC 61800-5-1.
- 3.10.5** Control circuits, including microprocessor and digital inputs and outputs shall be galvanically isolated from the power circuits.
- 3.10.6** Galvanic insulation of VSD-FC control, input and output circuits shall be in accordance with IEC 61800-5-1.
- 3.10.7** All VSD-FC shall have galvanic isolators for analogic interfaces with A&C or Package Control Panels.

3.11 POWER AND CONTROL VOLTAGES

- 3.11.1** The auxiliary power or control required for internal circuits of VSD-FC shall come from a normal panel, low-voltage, external power source, unless otherwise indicated in the Project Documentation.

Note: control voltages are defined in section 6.2.1 b).

- 3.11.2** Unless otherwise defined in Project Documentation, power for auxiliary control voltages is not supplied from either UPS A.C. or UPS D.C. source.

3.12 INTERNAL ELECTRIC ARC PROTECTION

3.12.1 Medium-Voltage VSD-FC shall be supplied with internal electric arc monitor device, or it shall have an arc withstand capability.

3.12.1.1 In case of internal electric arc monitor device, it shall be able to send a signal for instantaneous opening of the feeding panel circuit-breaker to shut down the converter.

3.12.1.2 In case of VSD-FC with arc withstand capability, it shall comply with IEC 62271-200.

3.12.2 Safety requirements for VSD-FC shall comply with IEC 62477-2.

3.12.3 The incident energy level of electric arc shall be calculated according to IEEE 1584.

3.13 INSTRUMENTS

3.13.1 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.

3.13.2 Maximum height for installation of pushbuttons and instruments shall be in accordance with I-ET-3010.00-5140-700-P4X-005 - REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS.

3.14 HEATING RESISTORS

3.14.1 VSD-FC shall be provided with 1 (one) heating resistor for each vertical section, fed by external 220 Vac 2ph ungrounded. See 6.2.1.c).

Note: In case of external transformers, see requirements in I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS and I-ET-3010.00-5140-713-P4X-001 - SPECIFICATION FOR TRANSFORMERS FOR OFFSHORE UNITS.

3.14.2 These resistors shall be protected by thermomagnetic circuit-breakers and be automatically controlled by means of adjustable thermostats. The maximum adjustable temperature shall be 60°C.

3.15 PRINTED CIRCUIT BOARDS

3.15.1 Printed circuit boards shall be manufactured in accordance with standards IEC 62326-1, IEC 62326-4, and IEC 61188-5-1. Alternative standard IPC 6012 is also acceptable.

3.15.2 Plates, circuits, and their components shall be tropicalized, have treatment specific conformal coating, as defined in I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL FOR OFFSHORE UNITS to work for the expected lifetime according to environmental conditions informed in I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

3.15.3 Printed circuit boards components shall be suitable for operation at temperatures up to 70 °C according to environmental conditions informed in I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

3.15.4 Printed circuit boards shall have undergone accelerated aging tests ("burn-in tests"), and thermal fatigue cycles ("stress").

- As defined in IEC 60068-2-2 and IEC 60068-2-30:
 - These tests shall be executed for a minimum period of 16 hours at 65 °C or 72 hours at 60 °C to stabilize the components and detect signs of premature failures.
 - During these tests, printed circuit boards shall execute energizing cycles and de-energization routines. After testing, the plates shall remain functional without fault or degradation.
- Test report or test certificate from printed circuit boards Supplier/Manufacturer is acceptable to fulfil requirement.
- Similar or more restrictive alternative tests and its respective certificates can be sent to PETROBRAS for acknowledge and approval.

3.15.5 The components of the printed circuit boards shall have an industrial grade quality, specified to operate within modules, and be air convection cooled.

3.15.6 Electronic circuits shall be mounted on printed circuit boards, which must be connected to the control system through bolted connectors or the "plug in" type. The process shall have resources that prevent loosening of connections.

3.15.7 PCB shall be removable and provided with guides that make it easier their extraction and prevent their wrong assembly.

3.15.8 PCB shall not be connected directly to the main power circuit without a short circuit current protection device (fuses, transducer, etc).

3.16 MAINTENANCE AND RELIABILITY

3.16.1 Manufacturer shall supply all devices and specific tools, which are necessary for the operation and maintenance of the VSD-FC.

3.16.2 The VSD-FC shall be built to facilitate maintenance and minimize the time of repair. Internal components must be grouped by function (module) and provide interchangeability between any module that has the same function.


3.16.3 The VSD-FC shall be designed to achieve a MTTR of 1 h or less for parts replacement. The maximum time to repair shall not exceed 3 h at the 95% confidence level. The above times assume that spare parts, required tools and competent personnel are on hand and preferentially without the need of specialized tools, as defined in IEEE 1566.

3.16.4 The layout of the components, test points, rulers and posts terminals shall be done allowing access for circuit testing, adjustments, repairs, and maintenance through the front of the VSD-FC, without the need to remove any module printed circuit board or other component.

3.16.5 The VSD-FC and its auxiliary systems shall be designed and manufactured to operate continuously serving the primary function in the operation of the motor for a period of at least 2 years (17520 h) in the environmental conditions specified in section 3.2 or in Project Documentation, with no maintenance after the commissioning period.

3.16.6 VSD-FC components shall NOT require preventive or routine maintenance that compromises safety or requires shutdown during the indicated period of 2 years of initial operation (MTBF \geq 17520 h).

3.16.7 The VSD-FC and its auxiliary systems shall be designed and manufactured considering a minimum operation life of 20 years (175200 h). In this operational period, it is considered

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the execution of the maintenance procedures recommended in the maintenance plan supplied by the **Supplier/Manufacturer**. Note that unit lifetime is defined in 30 years.

3.16.8 VSD-FC Capacitors shall be specified for a minimum service life of, at least, 10 years (87600 h) unless otherwise defined in Project Documentation. The capacitors lifetime shall consider the temperature within the VSD-FC enclosure and the worst voltage and current conditions.

3.16.9 It shall be informed in documentation proposal and approval phases, see 12.1 and 12.4, the MTTF defined by technology/topology and MTTR – segregated by mode of failure. In the later phase, see 12.5, the list of failures (with their MTTR) and replaceable parts per failure shall be included.

3.17 CABLES AND ACCESSORIES

3.17.1 The VSD-FC **power** cables and accessories shall comply with I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL FOR OFFSHORE UNITS and it shall be supplied in the package.

Note: In case of external transformers, all power, control and monitoring connection cables between VSD-FC and transformer are in the scope of the VSD-FC package.

3.17.2 VSD-FC Manufacturer shall approve the output power cables between VSD-FC and the motor.

3.17.3 All points of wiring for internal and external connection (input and output circuits) shall be functionally identified within the VSD-FC on each terminal block or power connection, including power cables, grounding, controls, signals, and alarms.

3.17.4 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.

3.17.5 Input and output power cables terminal lugs shall be **crimped**, pin or screwed type, adequate to cable cross section.


3.17.6 **Cable crimped** terminals, if used, shall be furnished together with VSD-FC, and installed within the converter.

3.17.7 To avoid electromagnetic interference, the control wiring shall be segregated from the **power cables**. Also, the A.C. voltages shall be segregated from all D.C. voltage. It shall be done by different channels, adequate distances, or using shielded cables.

3.17.8 **All VSD-FC input and output wiring connections** must be located on the bottom of the converter, unless otherwise indicated in the Project Documentation.

3.17.9 VSD-FC electrical cable armature shall have a grounding from the power panel to the VSD-FC and from the VSD-FC to driven motor. The shielding/armature of the grounding cables installation shall be in accordance with IEC TS 60034-25.

3.17.10 Power cables used in VSD-FC shall comply with IEEE 1580 recommended guidelines, where it is applicable.

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3.18 VSD-FC COOLING SYSTEMS

3.18.1 Unless otherwise indicated in the Project Documentation, VSD-FC power electronic switching cells and transformer shall be air cooled.

3.18.2 When approved by PETROBRAS, it shall be acceptable water cooled VSD-FC for power output equal to, or above, 5 MW.

3.18.3 VSD-FC cooling system shall be fully redundant and independent. In case of failure, automatic transfer with alarm shall be provided.

3.18.4 In case of air cooled VSD-FC, the exhausted hot air shall be direct to electrical room. If required in the Project Documentation, the air exhaust system shall consider a duct from the VSD-FC cabinet to outside of the electrical room.

Note: VSD-FC Transformer shall be considered if it is in the same room as panel.

3.18.5 VSD-FC control module shall be air cooled, fully redundant, including at least two independent fans. Automatic transfer with alarm shall be provided in case of failure.

3.18.6 The influence of adjacent compartments (power and control assemblies, separated compartments, cabinets, or columns) shall be considered to keep the temperature of the individual compartments within the limits of their components.

3.18.7 The cooling system to maintain semiconductors within their permissible operating temperature limits, shall be designed for a lifetime of least 10 years (87600 h), and intermediate stops for scheduled maintenance are acceptable for each 5 years (43800 h).

4. VSD-FC PERIPHERAL EQUIPMENT

4.1 POWER TRANSFORMER CHARACTERISTICS

4.1.1 The input power transformer shall comply with I-ET-3010.00-5140-713-P4X-001 - SPECIFICATION FOR TRANSFORMERS FOR OFFSHORE UNITS. Any deviation shall be submitted for PETROBRAS approval.

4.1.2 Environmental conditions, inclination, vibrations, and other conditions for the input transformers are defined in 3.2. Any deviation shall be submitted for PETROBRAS approval.

4.1.3 The input power transformer shall present the characteristics listed below. Any deviation shall be submitted for PETROBRAS approval.

a) Rated power:

- Shall be compatible with the rectifier requirements, including power factor and harmonics, and lifetime.
- Shall be derated depending on the level of the harmonic content in the current demanded 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.
- Supplier/Manufacturer shall present rating calculation report for PETROBRAS acknowledge.

- 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).
 Note: In case of Class H insulation, the report of test certification of insulation material, shall be provided to PETROBRAS.
- d) Type: Dry, with winding construction technologies defined I-ET-3010.00-5140-713-P4X-001 - SPECIFICATION FOR TRANSFORMERS FOR OFFSHORE UNITS.
- e) Minimum external degree of protection (if not built-in): IP-22. See I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS;
- f) Taps: 0 %, \pm 2.5% and \pm 5% (if external).
- g) Windings: Compatible with the VSD-FC topology (rectifier pulse number).
- h) Two RTD, platinum resistance temperature detectors type (PT100 Ω @ 0°C) per winding or thermostats (see 4.3); 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.

4.1.4 VSC-FC Input Transformer shall have the same lifetime indicated in section 3.16.7.

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

4.1.6 For forced-air cooled VSC-FC Input Transformer, Supplier/Manufacturer shall provide means for proper individual equipment cooling. No room requirements shall be considered as auxiliary aiding for cooling. Temperatures informed in section 4.1.1 shall be considered. Cooling definitions are stated in section 3.18.

4.1.7 In case of VSD-FC independent transformers, it shall have all necessary hatches, provisions, and accessories for forced air ventilation.

4.1.8 For all VSC-FC Input Transformer above 5 MW, it shall evaluate the need of a pre-magnetization device. If the pre-magnetization device is necessary, it shall follow requirements defined in I-ET-3010.00-5140-713-P4X-001 - SPECIFICATION FOR TRANSFORMERS FOR OFFSHORE UNITS.

4.1.9 VSD-FC TRANSFORMER GROUNDING

4.1.9.1 Manufacturer shall define grounding type (high-value resistance, neutral isolated, etc.) of secondary windings of the input transformer to avoid unwanted: ground system interactions, harmonic flows and common mode voltages.

4.1.9.2 This grounding type shall be suitable to Medium-Voltage power system grounding type.

4.1.9.3 VSD-FC grounding type shall allow protective functions defined in I-ET-3010.00-5143-700-P4X-001 - ELECTRICAL SYSTEM PROTECTION CRITERIA and I-ET-3010.00-

5140-700-P4X-001 - SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS.

4.2 FEEDER PROTECTION

4.2.1 Feeder Protection is in the scope of switchgear manufacturing, VSD-FC Supplier/Manufacturer acknowledge for interface only:

4.2.1.1 Electrical system protection requirements shall follow I-ET-3010.00-5143-700-P4X-001 - ELECTRICAL SYSTEM PROTECTION CRITERIA.

4.2.1.2 INPUT FEEDER PROTECTION

- The feeder protection is in the scope of I-ET-3010.00-5143-700-P4X-001 - ELECTRICAL SYSTEM PROTECTION CRITERIA.
- The feeder protection shall be approved by VSD-FC Manufacturer.

4.2.1.3 VSD-FC FEEDER PROTECTION COMMANDS

- There shall be two outputs for VSD-FC shutdown commands:
 - one to alarm the VSD-FC switching shutdown and
 - other to open main feeder switching device.
- In case of failures in the driven motor (except short circuit to ground and between phases) or over temperature, VSD-FC shall only alarm and either turn off the switching or reduce load. These types of failures shall not trip the circuit-breaker or open contactor.

4.3 INPUT TRANSFORMER PROTECTION

4.3.1 For VSD-FC input power transformer, incorporated or not in VSD-FC topology, its temperature protection shall be performed by VSD-FC control.

4.3.2 VSD-FC input power transformer alarms shall be sent to Electrical System Automation.

4.3.3 VSD-FC input power transformer trip signals shall be sent to feeder protection MMR.

4.3.4 Over-temperature in VSD-FC transformer, the VSD-FC shall:

- First stage: alarm and reduce the load.
- Second stage: alarm, turn off the VSD-FC, and trip feeder.

Note: It shall be possible to adjust these parameters.

4.3.5 The I-ET-3010.00-5143-700-P4X-001 - ELECTRICAL SYSTEM PROTECTION CRITERIA, shall be verified.

4.4 OUTPUT REACTOR

4.4.1 The VSD-FC output reactor, if available, shall comply with IEC 61800-4 and I-ET-3010.00-5140-700-P4X-007 - SPECIFICATION FOR GENERIC ELECTRICAL EQUIPMENT FOR OFFSHORE UNITS. Any divergence shall be submitted to PETROBRAS for approval.

4.4.2 Output reactor shall be included inside the VSD-FC cabinet. Any different installation shall be submitted to PETROBRAS for approval.

4.4.3 The VSD-FC output reactor shall present the characteristics listed below. Any discrepancy shall be submitted for PETROBRAS approval.

- a) Rated power shall be compatible with the VSD-FC necessities, including power factor and harmonics, and lifetime.
- b) Rated Frequency: 60Hz \pm 5%.
- c) Insulation: class F with temperature rise plus ambient temperature under the limits of class B or class H with temperature rise plus ambient temperature under the limits of class F.
- d) Type: Dry, epoxy encapsulated or moulded.
- e) Minimum external degree of protection (if not built-in): IP-22. See I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.
- f) The reactor overtemperature protection shall make use of a platinum element type Resistance Temperature Detector (RTD) (PT100 Ω @ 0°C).

Note: Output reactor coils shall be designed to operate with high dV/dt generated by the inverter switching.

5. NAMEPLATES, LABELS AND MARKINGS

5.1 NAMEPLATES


5.1.1 The VSD-FC panel nameplates shall be in accordance with I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

5.1.2 The VSD-FC panel nameplates shall be outfitted with a main identification plate containing, at least, the following data:

- a) **Supplier/Manufacturer** name or manufacturer brand
- b) **Input** voltage, number of phases, nominal **input** frequency.
- c) Maximum supply current in continuous operation or power in kVA.
- d) Maximum supported symmetric short-circuit current and test time.
- e) Maximum output voltage.
- f) Nominal output current in continuous operation.
- g) Momentary current (overload) for 60 seconds.
- h) Output frequency-controlled range.

5.1.3 The VSD-FC panel shall be outfitted with plate of supplemental identification containing, at least, the following data:

- a) PETRÓLEO BRASILEIRO S.A. – PETROBRAS.
- b) name of the department of PETROBRAS.
- c) name of the enterprise (platform).
- d) TAG number of the Panel.

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- e) number of the RM.
- f) number of the Order of Purchase of Material (PC).
- g) in alternative to paragraph f), the number of the contract, in the cases of acquisition built-in in contract of the type of lump sum ("Turnkey ", "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.

5.1.4 The VSD-FC panel shall have identification frontal plates indicating components of that compartment, i.e.: rectifier, inverter, power cells, cable input, cable output, control, etc.

5.1.5 The VSD-FC panel back doors, if any existent, shall have identification plates identical to the plates identifying the front sections.

5.1.6 The VSD-FC 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-DS.

Note: See component markings and labels requirements in section 5.2.

5.1.7 If VSD-FC input transformer is segregated and located in a different cabinet, this cabinet shall contain an additional nameplate containing at least the following information:

- a) current,
- b) input voltage and voltage ratio,
- c) nominal power,
- d) taps
- e) Connection schematics
- f) Phase displacement angles
- g) Class of insulation.
- h) Temperature elevation class,
- i) Environmental supporting ambient conditions and fire conditions, etc.

5.2 COMPONENTS MARKINGS – LABELS

5.2.1 Internally to VSD-FC 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.).

5.2.2 No adhesives shall be used to fix the labels.

Note: for small internal components (i.e.: small circuit-breakers, contactors, auxiliary relays) where acrylic labels are not feasible due to constrict sizes and small spaces, adhesive labels are allowed.

5.2.3 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 warnings as required by NR-10 and NR-12. These warnings shall follow section A-5 of ABNT NBR 16820 (Cuidado, risco de choque elétrico/Warning, risk of electrical shock).

5.2.4 Warnings shall follow the standard labels as required in ABNT NBR 16820 for electrical panels risk of shock also informed in I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS and I-ET-3010.00-5400-947-P4X-002 - SAFETY SIGNALLING.

6. VSD-FC POWER AND CONTROL

6.1 CIRCUIT CONFIGURATION

6.1.1 The VSD-FC shall be matched and selected according to the requirements of load, output harmonics, supply system and ambient conditions.

6.1.2 The optimum system configuration shall consider:

- a) load power over the operational speed range.
- b) torque/speed load characteristics over the operational speed 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 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: Cyclo-converters, super-synchronous and sub-synchronous converter cascades shall not be accepted for motor speed control.

6.2 ELECTRICAL CHARACTERISTICS

6.2.1 The main electrical characteristics are:

- a) Rated input main voltage: in accordance with Project Documentation.
- b) Rated input auxiliary control voltage: voltage value shall be in accordance with Project Documentation, three phases, from normal panel; as defined in 3.11.1.
- c) Rated input auxiliary voltage for heating resistors: 1 x 220 Vac, 2ph ungrounded, from normal panel.
- d) Input frequency: 60 Hz.
- 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 variation of $\pm 10\%$, as defined in IEC 61800-4. This reduced torque and power shall be proportional to the ratio between input voltage and 90%.

- h) **Supplier/Manufacturer** shall indicate drive capability to keep rated output power at rated output speed during transient event of input voltage dip of 20% up to 5 s, 300 cycles, as defined in IEC 61800-4. 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: 1 to 75 Hz, unless otherwise defined in Project Documentation.
- k) Minimum rectifier pulse number shall be: 18 (eighteen).

Notes:

- a. For drives with high frequency rectifiers (able to minimize harmonic contents and control power factor using high frequency switching) this limit is not applicable.
- b. The number of pulses (18 pulses minimum) 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 519) and makes the harmonic filters unnecessary.
- c. This THD shall be calculated considering the characteristic and non-characteristic harmonics, including those due to the DC Link filter necessary to avoid dc current/voltage modulation due to switching of the inverter.
- d. The individual current and voltage harmonics shall comply with the IEEE 519, too.

6.2.2 VSD-FC shall be non-regenerative, unless otherwise defined in Project Documentation. It shall not give current contribution to a short-circuit that occurs upstream the VSD-FC.

6.2.3 Inverter output voltage and drive performance shall be designed to comply with allowed torque ripple (torque pulsation) in the electric motor.

6.2.4 Inverter output voltage and drive performance shall be designed to avoid overvoltage at cable and motor's terminals.

6.2.5 **Complementing 6.2.1.h) with IEC 61892 requirements**, VSD-FC shall be designed to operate, without shutdown, during system transient voltage variations, up to 1.5 seconds, in the range of 80% to 120% of the voltage indicated in the Project Documentation, admitting frequency variation for 5 seconds in the range 54 Hz to 66 Hz. These are input variation conditions defined in I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

6.2.6 **Ride through Capability**: Unless otherwise indicated in Project Documentation, VSD-FC shall be able to withstand voltage dips one or more phases of the input voltage between 10% and 100% for 500 ms, 30 cycles, without occurrence of shutdown as defined in IEC 61800-4. It may use motor kinetic energy to auxiliary this recovery.

6.2.7 **Voltage Spike, Overvoltage Transitory Capability**: VSD-FC shall be able to operate without shutdown when subjected to transient overvoltage of 2.8 times the nominal voltage phase-feeding phase (system voltage and transient voltage, as defined in IEEE 1566, with rise time of 0.1 μ s and base time of 70 μ s).

6.2.8 VSD-FC shall be **capable of supply a three phase electric motor as described in** the Project Documentation.

6.2.9 If automatic reacceleration is specified in the Project Documentation, VSD-FC shall be capable to identify the rotational shaft speed and synchronize the three-phase voltage

properly, taking the machine to the desired operating condition (motor re-start while still running, coasting).

6.3 EFFICIENCY AND INPUT POWER FACTOR

6.3.1 The minimum efficiency for the VSD-FC system including 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.

6.3.2 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.

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

6.3.4 The efficiency and power factor presented by the Supplier/Manufacturer at the proposal shall be verified during the factory and string tests.

6.4 VOLTAGE AND CURRENT DISTORTION - THD


6.4.1 At the input side, VSD-FC shall comply with IEEE 519 for harmonics measured at the PCC (point of common coupling), as defined in section 6.2.1 k).

6.4.2 The use of input filters or network reactance is not allowed for VSD-FC to comply with 6.4.1.

6.4.3 At the output side, the maximum acceptable voltage THD in normal operation shall be 5% as defined in IEEE 519. All frequencies shall be considered in the calculation, i.e., not only the integer multiples of fundamental frequency.

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

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

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6.5 INPUT CURRENT FILTERS

6.5.1 At the input side of the VSD-FC, it shall not be allowed the use of harmonic filters to achieve input harmonics limits (see 6.4.1 and 6.4.2).

6.5.2 In any situation the harmonic distortion of the frequency converter input current shall be less than 15%, see maximum values defined in IEC 61800-3.

Note: Solutions with the use of passive filter are only accepted upon specific PETROBRAS approval.

6.6 OUTPUT VOLTAGE DISTORTION AND OUTPUT FILTERS

6.6.1 It is acceptable to use output filters to reduce output voltage harmonic distortion and to avoid overvoltage due to resonance and to limit voltage change rate or dV/dt.

6.6.2 VSD-FC shall always be supplied with one of the following output filters:

- a) Output reactor.
- b) Sine filter.
- c) dV/dt filter.

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

6.6.4 For output power cables equal to or longer 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.

Note: If VSD-FC Supplier/Manufacturer has the technology to provide the controlled voltage output with necessary quality and not requiring output filters, it shall inform PETROBRAS and ask for technology solution approval.

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

6.7 ELECTROMAGNETIC INTERFERENCE (EMI) AND COMPATIBILITY (EMC)

6.7.1 The VSD-FC control circuit shall be designed and built to be insensitive to electromagnetic interference (EMI), generated by itself or other equipment in the production unit, as well as other telecommunication systems, including phones and radios. VSD-FC EMC shall comply with IEC 61800-3 and IEC 61800-4.

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

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

6.7.4 Supplier/Manufacturer shall deliver documentation with detailed assembling and installation procedures and instructions to avoid electromagnetic interference between package and other unit equipment.

6.7.5 VSD-FC EMC test reports shall be presented at proposal.

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

6.8 RIPPLE TORQUE

6.8.1 The maximum ripple torque shall be in accordance with motor/driven equipment set Supplier/Manufacturer specification for the whole speed range and shall not lead to torsional oscillation.

6.9 PROTECTION DEVICES

6.9.1 VSD-FC shall have the protection functions listed in Table 4, as defined in IEC 61800-4.

Table 4 – VSD-FC protection functions.

VSD-FC protection functions	Alarm	Trip	Remark
Line-side supply (internal to VSD-FC)			
Outage, phase loss	X	X	
Line overvoltage	X	X	
Line under-voltage	X	X	
Line voltage unbalance	X	X	
Line feeder			
Scope of I-ET-3010.00-5143-700-P4X-001 - ELECTRICAL SYSTEM PROTECTION CRITERIA.			
Transformer			
Over-temperature	X	X	
Loss of cooling media	X	X	
Converter			
Overcurrent	X	X	commutation failure, short circuit, etc.
Overload	X	X	thermal
Overvoltage	X	X	See 6.9.4.
Ground fault	X	X	
Loss of cooling	X	X	
Over-temperature	X	X	
Loss of auxiliary supply	X	X	
Loss of communication to process control	X	X	
Loss of speed feedback	X		
Short-circuit ("Three phases" and "phase to phase", with and without ground and phase to ground).	X	X	may be done by overcurrent and ground-fault
Undervoltage	X	X	
Underload	X	X	both current and power protection with time adjustment
Motor (See also I-ET-3010.00-5143-700-P4X-001 - ELECTRICAL SYSTEM PROTECTION CRITERIA)			
Motor over/under-voltage	X	X	
Motor overcurrent	X	X	
Overload	X	X	Thermal, protection by electronic thermal relay
Over-speed	X	X	
Winding over-temperature	X	X	

6.9.2 Additionally, to the protection functions in Table 4, VSD-FC shall have the following alarms, listed in Table 5.

Table 5 – VSD-FC complementary functions.

VSD-FC protection functions	Alarm	Trip	Remark
Converter			
CPU failure	X		
UAM (Unit Alarm Malfunction)	X		May be done by VSD-FC CPU
UAS (Unit Alarm Shutdown)	X	X	May be done by VSD-FC CPU
Cooling failure or Cooling system changeover	X	X	
Missing run or start permissive	X		

6.9.3 VSD-FC shall have internal protection against voltage surges and accumulation of electrostatic charges.

6.9.4 VSD-FC overvoltage protection shall trigger the following actions:

- a) Connect the braking resistor **if available**.
- b) Send alarm signal to Automation and Control Systems
- c) **Block or disable** semiconductor inverter devices firing pulses.
- d) Disconnect the VSD-FC feeder.

6.9.5 Protection functions can be done internally or by an additional digital relay supplied with the VSD-FC.

Note: In case of additional digital relay, it shall be installed in VSD-FC.

6.9.6 VSD-FC input transformer and reactors RTD PT100Ω @ 0°C shall be monitored by VSD-FC internal **thermal** protection.

6.9.7 Out of range values from RTD PT100Ω @ 0°C shall be recognized by VSD-FC protection control as a **detection system failure**.

6.9.8 RTD PT100Ω @ 0°C open circuit or short-circuit condition shall be identified **and** an alarm shall be sent to control system.

6.9.9 For Medium-Voltage motor driven by VSD-FC, the motor RTD PT100Ω @ 0°C shall be **monitored** by upstream MMR protection.

6.9.10 Motor PTC thermistors shall be **monitored** by VSD-FC internal protection.

6.9.11 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.

Note: Details of motor PTC thermistor are defined in I-ET-3010.00-5140-712-P4X-002 - MEDIUM-VOLTAGE INDUCTION MOTORS FOR OFFSHORE UNITS.

6.9.12 A mechanical protection, like mechanical interlocking shall be provided to avoid personnel injury due to improper access to the Medium-Voltage VSD-FC interior. The Medium-Voltage VSD-FC shall not operate with doors open. If the drive is running, the opening of its doors shall cause a VSD-FC trip.

6.9.13 Two warning plates shall be provided in Brazilian Portuguese, one with indication of life risk due to the presence of High/Medium-Voltage and the other informing electrical hazard

due to capacitors that keeps voltage for some time (the safe time shall be indicated). See section 5.2.

6.10 VSD-FC CONTROL

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

6.10.2 VSD-FC shall have an auto supervisory and auto diagnose system. The self-monitoring routine should check the availability of the circuit's components and their programming and continuously and automatically perform the failure sequence routine.

6.10.3 VSD-FC shall have a resident non-volatile memory: the self-diagnosis, adjustment and configuration parameters, input and output addressing, records of the last failure events, passwords, and lock codes to the parameters to avoid access to unauthorized person.

6.10.4 VSD-FCs shall have the following adjustable parameters available:

- a) acceleration and braking ramps, separately programmable, capable of being remotely started.
- b) minimum and maximum operation frequencies.
- c) output frequency set point.
- d) inhibition of critical resonance frequency ranges of the mechanical system.
- e) programming of automatic re-start function, after a voltage dip or undervoltage event.
- f) torque limit.
- g) "ride through" function, see 6.2.6 if applicable.

6.10.5 The auxiliary or control voltage needed for internal circuits of the VSD-FC shall be obtained from external power source, according to 6.2.1 b).

6.10.6 An internal UPS Power Module shall be provided to feed local memory and auxiliary control circuits during a short-term power loss, allowing either a ride-through (up to 500 ms, see 6.2.6) and/or a controlled equipment shutdown.

6.10.7 If the VSD-FC is a VSI (Voltage Source Inverter) type, it shall be able to be energized and to be operated with the driven motor disconnected, without the occurrence of internal failures.

6.10.8 When specified in Project Documentation, the VSD-FC shall have an induction motor slip compensation, to maintain the adjustment of engine rotation, without fluctuation, from the condition of "no load" up to the condition "nominal load".

6.10.9 VSD-FC output frequency control range shall be as indicated in the Project Documentation.

Note: Minimum range is defined in 6.2.1.j).

6.10.10 VSD-FC shall provide both acceleration and deceleration times compatible to the mechanical load being driven and the ramp up starting current shall have a value close to the motor nominal current.

6.10.11 VSD-FC shall be able to drive the motor in both directions, clockwise and counter-clockwise, by setting up a single parameter. It also shall be capable to block direction of rotation inversion through parameterization.

6.10.12 The VSD-FC shall be able to control the driven motor rotational speed in an open loop system, within output frequency resolution limit informed in the Project Documentation, and without need to install a tachometer in motor axis to feedback of the rotation signal.

6.10.13 ADDITIONAL VSD-FC CONTROL MODULES

6.10.13.1 The following special controls shall be required in Project Documentation for specific applications. The VSD-FC Datasheet or Project Documentation shall clearly indicate the additional requirement.

6.10.13.2 ZI COMPENSATION

For VSD-FC feeding either very long cables (greater than 1000 m) or ESPs (Electrical Submersible Pumps):

- a) VSD-FC shall have an internal and automatic ZI compensation routine due to voltage drop in the power cable connecting the driver output to the electric motor.
- b) This ZI compensation algorithm shall compensate the power cable voltage drop in order to have the voltage at the electric motor terminals equal to the respective set point.

6.10.13.3 PID FUNCTION PROCESS CONTROL

If required in the Project Documentation, the VSD-FC shall have a continuous process control (control block) module, for the execution of PID function regulation. The module for continuous process control shall have the following characteristics:

- a) It shall be microprocessor based, with digital processing of the control algorithm and shall have the programming capacity of proportional gain parameters, integral action, and derivative action.
- b) It shall be able to receive a 4 -20 mA remote signal from the process variable, acquired by a primary control element (sensor), to be negative feedback.
- c) It shall be able to receive a remote a 4 -20 mA "set-point", as indicated in the Project Documentation, coming from the supervisory system of automation and control, to define the adjustment, point or the reference value of the control variable.

6.10.13.4 BRAKING MODULE

If specified in the Project Documentation, the VSD-FC shall have an additional braking module. This additional braking module shall have the following characteristics:

- a) It shall be connected to the D.C. intermediate stage bus.
- b) It shall have resistors with characteristics and energy dissipation capacity.
- c) The braking module shall be supplied together with the VSD-FC, installed internally in VSD-FC casing or in a package with a degree of protection suitable for the installation site.

6.11 VSD-FC AUTOMATION

6.11.1 All VSD-FCs shall include network interfaces and shall follow 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 regarding architecture and Ethernet communication protocols. The VSD-FC network interface shall be used for control and monitoring signals, parameterization, and programming.

6.11.2 VSD-FCs shall have at least input, and output signals listed in I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST and I-DE-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE DIAGRAM.

6.11.3 For the VSD-FC, it shall be supplied:

- a) back-up copies of the initial VSD-FC parameters configuration in digital format that allows its upload to the converter control module.
- b) the memory map for the communication between equipment and Electrical System Automation considering, at least, signals listed in I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST and protocols 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.

6.11.4 All VSD-FC expected to receive ESD or other wet signals from A&C or Package Control Panels shall have interposing relays with enough quantity to convert discrete 24 VDC signal in discrete voltage-free signal.

6.11.5 Remote START and STOP controls shall initiate pre-programmed acceleration and deceleration ramps, respectively.

6.11.6 Remote TRIP (ESD) command shall immediately de-energize the motor and disconnect VSD-FC feeder.

6.11.7 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).
Note: LOCAL option shall be locked, and available only by password.
- b) START switch (for test and operation), 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

Note: **During normal operation**, the alphanumeric digital indicator, shall, at least, allow simultaneous visualization of the VSD-FC output frequency and current values to the driven machine.

6.11.8 Programming, control, and adjustment keys should be identified in such a way that the continuous use does not remove their identifications.

6.11.9 The VSD-FC shall **allow parameters values upload/download**.

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

- a) Analog 4-20 mA reference signal, for remote motor speed control, with the selector switch LOCAL/REMOTE on the REMOTE position.

Note: LOCAL option shall be locked, and available only by password.

- b) Discrete signal for remote START.
- c) Discrete signal for remote STOP.
- d) Discrete signal for TRIP (ESD).

For complementary signals information, see 6.11.2 referenced documents.

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

- a) Summary of defects alarms, resulting from the performance of internal protections.
- b) "trip" by internal defect.
- c) Operation mode "local" or "remote".
- d) Motor heating resistor internal control.
- e) Converter tripped to open main feeder switching device.
- f) Alarm the VSD-FC switching shutdown.
- g) VSD-FC running/stopped.

6.11.12 VSD-FCs shall have at least the following analogue 4-20 mA output signals:

- a) Output current.
- b) Output speed or frequency.

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

- a) Selectors.

- b) Alarm functions.
- c) Network communication (see 6.11.3 b)).
- d) Monitoring and diagnostics.
- e) Input and Output functions.
- f) Logical functions.
- g) Timing and comparison
- h) Event registration.

6.11.14 VSD-FC shall have an internal log report where all events shall be recorded for later analysis. This log of events shall:

- a) be synchronized with system GPS clock through SNTP.
- b) be accessible through the existing ethernet network connection.
- c) shall have sufficient available memory to record at least 100 last events, or equivalent memory to record the last 7 days of operation.

Alternative solutions are accepted if previously submitted and approved by PETROBRAS.

6.11.15 The VSD-FC shall have its internal clock synchronized with Electrical System Automation Time Server through the time protocol according to I-ET-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE.

6.11.16 All devices with logging or communication capabilities internal to the VSD-FC shall have its internal clock synchronized with Electrical System Automation. Supplier/Manufacturer is responsible to provide means of synchronization among internal components which are not connected to Electrical System Automation networks. All other internal devices connected to Electrical System Automation networks shall be synchronized with the Electrical System Automation Time Server through the time protocol according to I-ET-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE.

6.11.17 All events and alarms shall be logged in the equipment with the time stamp synchronized with the internal clock, which shall be synchronized with the Electrical System Automation Time Server.

6.11.18 VSD-FC HMI screens shall be available for onshore operation and supervision. Networked smart devices in the electrical system shall be accessible onshore for adjustment and parameterization. If this function is available, PETROBRAS shall be consulted for location available telecommunication resources and policy and network security protocols.

7. TESTS

7.1 GENERAL REQUIREMENTS

7.1.1 The Power Drive System for the VSD-FC shall comply with the reference indicated in Table 6.

Table 6 – VSD-FC Components Test List Reference.

VSD-FC Component	IEC standard and References
Transformer	IEC 60146-1-3 clause 5, IEC 61378-1, this Specification and I-ET-3010.00-5140-713-P4X-001 - SPECIFICATION FOR TRANSFORMERS FOR OFFSHORE UNITS
Motor	See I-ET-3010.00-5140-712-P4X-002 - MEDIUM-VOLTAGE INDUCTION MOTORS FOR OFFSHORE UNITS
Converter (VSD-FC)	See Table 7

7.1.2 VSD-FC tests shall be according to IEC 61800-3, IEC 61800-4, IEC 60146-1-1, and this specification.

7.1.3 All type test (TT), routine tests (RT), special tests (ST) indicated in this section, are mandatory, unless otherwise defined in Project Documentation, or later agreed with PETROBRAS.

7.1.4 For VSD-FC Converter, VSD-FC Control and Protection, the tests list, test references, and test acceptance criteria references shall follow Table 7.

7.1.5 All special tests (ST) in Table 7 shall be agreed upon Supplier/Manufacturer and PETROBRAS.

Table 7 – VSD-FC Standard Tests and References.

VSD-FC MINIMUM TEST LIST	TT	RT	ST	REFERENCE, METHOD, ACCEPTANCE CRITERIA
Insulation ⁽¹⁾	X	X		IEC 61800-4 and IEC 60146-1-1
Measurements of light load and rated load/functional test ⁽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 ⁽³⁾			X	IEC 61800-4, IEC 60146-1-1, IEC 60146-2
Current sharing ⁽⁵⁾	X			IEC 61800-4 Applicable for drives with parallel devices.
Voltage division ⁽⁵⁾	X			IEC 61800-4 Applicable for drives with series devices
Interphase ripple voltage and ripple current ⁽⁵⁾			X	IEC 61800-4 and IEC 60146-1-1 (ripple measurement)



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VSD-FC MINIMUM TEST LIST	TT	RT	ST	REFERENCE, METHOD, ACCEPTANCE CRITERIA
Power loss determination for assembly and equipment (see IEC 61800-4)	X			IEC 61800-4, IEC 60146-1-1, IEC 60146-2
Temperature rise ⁽⁴⁾	X	X		IEC 61800-4 and IEC 60146-1-1
Measurement of inherent voltage regulation ⁽⁵⁾			X	IEC 61800-4 and 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 LOCAL CONTROL, monitoring, and signalling	X	X		Project Documentation
Checking REMOTE CONTROL, monitoring, and signalling	X	X		Project Documentation
Checking the protective devices	X	X		Project Documentation IEC 61800-4 and IEC 60146-1-1
Audible noise (commissioning test)			X	Project Documentation IEC 61800-4 and IEC 60146-1-1
Power factor			X	Project Documentation IEC 61800-4 and IEC 60146-1-1
Visual inspection ⁽⁶⁾	X	X		Project Documentation IEC 60146-1-1
Measurement of harmonic currents			X	IEC 60146-1-1
EMC - Electromagnetic immunity	X			IEC 61800-3, IEC 61800-4, IEC 60146-1-1
EMI - Electromagnetic emissions (Radio frequency radiated and conducted disturbances)	X			IEC 61800-3, IEC 60146-1-1 IEC 60533
Verification of transformer rating calculation	X			IEC 61378-1 or IEEE C57.18.10 and This specification.
Load characteristic test (Load envelope test) ^{(7) (9)}			X	IEC 61800-4
Load duty test (Intermittent load test) ^{(7) (9)}			X	IEC 61800-4
Allowable full load current versus speed test ^{(7) (9)}			X	IEC 61800-4
Input transformer temperature rise ^{(8) (9)}			X	Project Documentation
Efficiency ⁽⁷⁾			X	IEC 61800-4, IEC 60146-1-1, IEC/TR 60146-1-2.
TT - Type Test, RT - Routine Test, ST - Special Test, X – Test requested in indicated reference.				



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VSD-FC MINIMUM TEST LIST	TT	RT	ST	REFERENCE, METHOD, ACCEPTANCE CRITERIA
<p>Note (1) Insulation tests may be done with the power semiconductor devices short-circuited. The Supplier/Manufacturer of the component shall have separately checked the insulation level of these devices.</p> <p>Note (2) A light load test might be performed with a choke or motor of smaller power than the assigned one. However, the voltage and speed/frequency ranges shall be relevant.</p> <p>Note (3) The overcurrent of the converter reflects the overload capability of the VSD-FC. Specified values of short time over current or starting up sequences of actual load shall 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 shall prior to the tests produce theoretical calculations of the junction temperature.</p> <p>Note (5) Topology defined tests, not applicable to all topologies – Supplier/Manufacturer to inform.</p> <p>Note (6) During Routine tests, verify Internal bar insulation and junctions supports have adequate insulation levels.</p> <p>Note (7) Test procedures alternatives can be presented to PETROBRAS for acknowledge, and approval.</p> <p>Note (8) Input transformer temperature rise test can be covered by “temperature rise test” if transformer is part of the cabinet drive or if it is tested together. Transformer temperature monitoring shall be part of the test. This test shall be repeated during Commissioning or String test.</p> <p>Note (9) To be executed during commissioning or String test.</p>				

7.1.6 All tests show in Table 8 are special tests, based in IEC 61800-4, IEC 60146-1-1 or this specification. The tests show in Table 8 will be required when specified for String Test and/or Commissioning Tests, or if specifically defined in datasheet or project documentation. When required, these tests shall be contractually agreed upon.

Table 8 – Special VSD-FC Drive Systems Tests.

VSD-FC MINIMUM TEST LIST	METHOD / ACCEPTANCE CRITERIA	COMMENTS
Additional tests - Insulation resistance	IEC 60146-1-1	
Check of operation with rated power during voltage drop and overvoltage	Project Documentation, This specification, section 6.2	
Line-side current distortion content	IEC 61800-4	
Measurement of harmonic currents	IEC 61800-4, IEC 60146-1-1	During commissioning or String test
Checking properties under unusual service conditions	IEC 61800-4	
Shaft current/bearing insulation	IEC 61800-4	Motor test. String Test
Torque pulsation	IEC 61800-4	Motor test. String Test
Motor vibration	IEC 61800-4	Motor test. String test
Dynamic performance test - Current limit and current loop test	IEC 61800-4	During commissioning or String test

VSD-FC MINIMUM TEST LIST	METHOD / ACCEPTANCE CRITERIA	COMMENTS
Dynamic performance test - Speed loop test	IEC 61800-4	During commissioning or String test
Dynamic performance test - Automatic restart/re-acceleration	IEC 61800-4	During commissioning or String test
Checking of properties of incorporated stabilization of control system ⁽³⁾	Project Documentation This specification (Section 6.10.13.3)	Only if indicated in Project Documentation or in Datasheet
Zi compensation module test ⁽³⁾	Project Documentation, This specification (Section 6.10.13.2)	
Withstand ability to 3-phase short-circuit ⁽³⁾	Project Documentation	Complied with type test report or certificate
Ground fault test (with current limiting) ⁽³⁾	Project Documentation	Complied with type test report or certificate
Specific internal damage test	Project Documentation and This specification (Sections 3.10.1 and 7.2.6)	Complied with type test report or certificate. Mandatory for drives above 5 MW.

7.1.7 A procedure for downloading VSD-FC parameters and event logs shall be established. This routine shall be done after factory acceptance, commissioning, and start-up tests. This data shall be attached to the test report.

Note: The parameterization file shall be provided in VSD-FC software format.

7.2 FACTORY TESTS

7.2.1 PETROBRAS personnel shall witness all factory acceptance tests that PETROBRAS understands to be necessary. These witnessed tests are indicated in purchase contract.

7.2.2 Factory acceptance tests report shall be presented for PETROBRAS approval.

7.2.3 FACTORY ROUTINE AND SPECIAL TESTS

7.2.3.1 Factory Tests shall follow the Project Documentation indicated VSD-FC test list (Routine and Special tests); these tests shall cover the test lists indicated in section 7.1.

7.2.3.2 VSD-FC shall be tested at the factory:

- a) with load (measurements of light load and rated load/functional test (see Table 7))
- b) including starting, stopping, all circuits' tests (Checking properties (see Table 7))
- c) measurements of efficiency (see Table 8)
- d) voltage and current distortion (see Table 7),
- e) power factor (see Table 7),
- f) audible noise (see Table 7).

7.2.3.3 During Routine Test of Measurements of light load and rated load and functional test (see Table 7) VSD-FC shall be tested at main power input (transformer input, if transformer exists) the operational conditions defined in sections 6.2:

a) **input voltage dip**

- a. Continuous, reduction of 10% in input voltage (6.2.1 g)
- b. Transient, reduction of 20% in input voltage up to 5 s, 300 cycles (6.2.1 h)

b) **input overvoltage**

- a. Continuous, increase of 10% in input voltage (6.2.1 g)
- b. Transient, increase of 20% in input voltage up to 1,5 s, 90 cycles (6.2.5).

c) **Ride though Capability:** voltage dips one or more phases of the input voltage between 10% and 100% for 500 ms, 30 cycles (6.2.6).

d) **Voltage Spike, Overvoltage Transitory Capability:** transient overvoltage of 2.8 times the nominal voltage phase-feeding phase (6.2.7).

Note: Type test certificate or test report is acceptable as evidence.

7.2.3.4 The measurements of efficiency (see Table 8 and section 6.3.1) and power factor (see Table 7 and section 6.3.2) shall be made at 25%, 50%, 75%, 90% and 100% of the rated power of the drive.

Note: For low power ratings – alternative solutions for measurement shall be sent to PETROBRAS for acknowledge and approval.

7.2.3.5 Voltage and current distortion measurements (see section 6.4) and acceleration time of the set, shall also be made at 25%, 50%, 75%, 90% and 100% of the rated power of the drive.

7.2.3.6 The drive package shall operate continuously for 24 hours (Duty Class IV as defined by IEC 60146-1-1) without any fail or alarm.

Note: As defined in IEC 60146-1-1, the rated currents for converters and test conditions for assemblies: 1,00 p.u. continuously, 1,25 p.u. for 2 hours, and 2,00 p.u. for 10 s.

7.2.3.7 The VSD-FC rated current/Load test shall be carried out after completion of the assembly. The test shall be carried out at full load current for a period of at least 4 hours on a permanent basis after the VSD-FC has reached the balance of thermal temperature of 40°C. If this temperature value is not possible, use of appropriate correction factor shall be done. During this test, the VSD-FC shall be operated within the short-term permissible overload range, during shorter interval cycles, as defined in IEC 60146-1-1 and IEC 60146-2.

7.2.3.8 The following points/environments shall be temperature monitored:

- a) power transformer, power semiconductors, power capacitors, reactors, filters.
- b) control cubicle and control cards.

Note: 1) The values found shall be lower than the values informed in the proposal in the documentation submitted together with the proposal for the useful life of the specified.

2) Alternative solutions for temperature measurement shall be sent to PETROBRAS for acknowledge and approval.

7.2.3.9 Tests shall be made with adequate and calibrated equipment and recorded by an oscillography recorder.

7.2.3.10 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 and expected results or acceptance criteria.

7.2.4 LONG CABLES VSD-FC ZI COMPENSATION TEST REQUIREMENTS

7.2.4.1 Only if required in project documentation, see 6.10.13.2.

7.2.4.2 Check of the automatic ZI compensation, when required (see section 6.10.13.2), shall include output filters.

7.2.4.3 It shall be accepted the use of a controlled impedance to simulate the cable influence.

7.2.4.4 It shall be checked the VSD-FC behaviour regarding voltage control at motor terminals and regarding calculation of motor current for protection purpose.

Note: The voltage in motor terminals shall be confirmed.

7.2.5 ESP VSD-FC SPECIFIC TEST REQUIREMENTS

7.2.5.1 For VSD-FC feeding ESP, measurement of intake pressure, discharge pressure, intake temperature, motor winding temperature, motor vibration and current leakage by ESP multifunction meter shall be carried-out.

Note: All these requirements are in the scope of the ESP Supplier/Manufacturer, so the requirements may change according to the ESP downhole sensor supplier or other monitoring technologies used.

7.2.5.2 For VSD-FC feeding ESP, three separate digital inputs shall be provided in VSD-FC, two for connecting ESD system (ESP turn off with and without speed breaking ramp) and one for connection of ESP PLC (turn off without speed breaking ramp).

7.2.5.3 For VSD-FC feeding ESP, VSD-FC PLC shall be slave to ESP PLC master. Communication network, protocols, and exchanged information shall be defined by ESP.

7.2.5.4 Tests report with multifunction meters of the same manufacturer, and same part number shall be accepted for this test.

7.2.6 POWER SEMICONDUCTORS VSD-FC SPECIFIC TEST REQUIREMENTS

7.2.6.1 According to section 3.10.1, all VSD-FC power and control circuits shall be designed considering that a failure in one component or printed circuit board shall not cascade or induce another failure in other components or printed boards.

1) This test shall consider, i.e.:

- a) short circuit on internal semiconductors power feeding bus,
- b) a power semiconductor short circuit,

c) and a power capacitor explosion.

- 2) The acceptance criterion is that corrective maintenance is carried out in less than two hours, considering the spare parts recommended by the Supplier/Manufacturer are available.
- 3) Power semiconductors should be tested at full voltage and maximum current.
- 4) Tests of power semiconductor blocks shall be carried out in equivalent to those of actual operation.

7.2.6.2 Type test reports or breakdown tests reports executed in equipment prototype shall be accepted as proof that any failure in the power module does not spread causing failures in other parts of the frequency converter. Type Test reports or test certificates shall be provided to PETROBRAS for approval.

7.2.7 INPUT TRANSFORMER SPECIFIC TEST REQUIREMENTS

7.2.7.1 The Input Power Transformer as component shall be subject to the following, as per Supplier/Manufacturer:

- Inspection Requirements,
- Factory Acceptance Test (FAT),
- Field Acceptance Test, and,
- Inspection and Testing Plan, as follows.

7.2.7.2 For VSD-FC input transformers, the required tests by the respective Classification Society and by I-ET-3010.00-5140-713-P4X-001 - SPECIFICATION FOR TRANSFORMERS FOR OFFSHORE UNITS shall be carried out.

7.2.7.3 The Supplier/Manufacturer of the VSD-FC transformer shall submit together with the documentation for approval, after placing the Purchase Order (PC), the inspection test plan (PIT), relating all tests, type, routine and special at factory (TAF) and the tests to be carried out in field (TAC). All tests shall meet the requirements indicated in this Standard and Project Documentation.

7.2.7.4 The inspection test plan (PIT) shall indicate, together with each routine test, of type or special, the respective applicable Technical Standards, as well as their criteria and maximum and minimum ranges of acceptance of each measurement to be performed during testing.


7.2.7.5 Prior to inspection, the inspection test plan (PIT) shall be approved by PETROBRAS.

7.2.8 OUTPUT FILTERS TESTS:

7.2.8.1 Insulation test shall be performed as per Supplier/Manufacturer procedure.

7.2.8.2 Passive filters shall be tested (energized), as per Supplier/Manufacturer procedure, with full voltage and current at maximum frequency without failure.

7.2.8.3 Current, voltage, active and reactive power and filter's components temperatures shall be measured and recorded as per Supplier/Manufacturer procedure.

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7.3 STRING TESTS


- 7.3.1 String test shall be performed according with driven machine documentation.
- 7.3.2 During String tests, **Supplier/Manufacturer** of VSD-FC shall execute or repeat all tests foreseen in section Table 7 and Table 8.
- 7.3.3 The VSD-FC String Test List shall be presented for PETROBRAS approval.

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 VSD-FC **Supplier/Manufacturer** shall provide technical assistance for the start-up test.
- 7.4.3 VSD-FC **Supplier/Manufacturer** shall **assist in verifying** any necessary measurements and field adjustment corrections that shall be done to comply at site with motor and driven equipment system performance and electrical system requirements.
- 7.4.4 VSD-FC **Supplier/Manufacturer** shall issue a report with all field control and protection adjustments (e.g., ground failure, overload, current imbalance, under voltage, etc.). The reports shall be sent to PETROBRAS.

8. SOFTWARES AND SPECIFIC APPLICATION TOOLS

- 8.1 **Supplier/Manufacturer** shall supply all electrical devices and specific or unusual tools necessary for operation, installation, and maintenance. They shall be delivered with each drive.
- 8.2 It shall be included, if applicable to VSD-FC drive, at least:
 - a) Grounding tools.
 - b) Specific semiconductor device exchange tool package (if applicable).
 - c) Specific cables and pins for signal measurement.
 - d) Complete software package (programs, operational system, manuals, diagnosis software, etc.) for uploading and downloading programs/firmware, and event logs.
 - Note: When PLC is included in VSD-FC package, it shall include PLC files for parametrization, programming, and logic, etc. Software Program Licenses shall not have expiration dates. PLC files and backup files shall be organized and self-explained through text commentaries.
 - e) Auxiliary trolley or special car for cell extraction and substitution **if available**.
- 8.3 When PLC is included in VSD-FC package, it shall be available to PETROBRAS the minimum access permissions to PLCs and IHMs software packages that allow maintenance analysis and troubleshooting, **with no need for** vendor mobilization, and exposure to risks of loss of production and outgoing profit.
- 8.4 It shall be provided to PETROBRAS back-ups of solutions/changes implemented in software. Delivery of solutions/changes shall be informed, documented, and delivered to PETROBRAS after all phases of foreseen tests.

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9. VSD-FC WARRANTY

- 9.1 After the commissioning period, the drive shall have the capability to run continuously for a period of at least 2 years (17520 h), as defined in 3.16.5, under the specified site conditions without any scheduled shutdown.
- 9.2 No component of the drive system shall require any routine or preventive maintenance that needs a shutdown of the system over any consecutive 2 years period following initial operation (MTBF \geq 17520 h), see 3.16.6.
- 9.3 The **Supplier/Manufacturer** shall submit a document that contains a routine of maintenance for the reserve power cells, ensuring the availability of **these cells** during the lifetime of the equipment.
- 9.4 The **Supplier/Manufacturer** shall provide a warranty of 24 (twenty-four) months after the start-up or 10,000 hours of operation, what occurs later.
- 9.5 This item covers the whole package (including power transformer, protection devices, etc.).
- 9.6 Before VSD-FC start-up, the **Supplier/Manufacturer** shall inform to PETROBRAS any deviation at the installation location, ambient conditions, and equipment itself.

10. TECHNICAL ASSISTANCE

- 10.1 VSD-FC **Supplier/Manufacturer** shall inform PETROBRAS in documentation at proposal, section 12.3, if they comply with the following requirements:
 - 10.1.1 **Supplier/Manufacturer** shall provide and guarantee Technical Assistance at Rio de Janeiro, Brazil.
 - 10.1.2 The assistance time shall be in a period shorter or equal to 2 (two) days for the location defined above.
 - 10.1.3 Technical assistance shall cover the whole package (including power transformer, protection devices, etc.).
 - 10.1.4 The replacement parts shall be available at Production Unit in a period shorter than 10 days.
 - 10.1.5 Remote monitoring technical assistance package option shall be informed if existent.
 - 10.1.5.1 The minimum foreseen monitoring values shall be:
 - a) Internal temperature at power modules.
 - b) Internal/External transformer hottest points temperatures.
 - c) Capacitor cubicle temperature.
 - d) Motor hottest points temperature.
 - e) Input and output currents.

11. SPARE PARTS

- 11.1 **Supplier/Manufacturer** shall furnish a list of spare parts for two years of continuous operation, to be approved by PETROBRAS.
- 11.2 A list with quotation of all VSD-FC spare parts, including part number, original **Supplier/Manufacturer**, and individual prices, shall be presented at proposal.
- 11.3 **Supplier/Manufacturer** shall provide the necessary spare parts for the commissioning and pre operation periods.

12. DOCUMENTATION

- 12.1 All **required** documentation shall be delivered in digital media.
- 12.2 All digital media shall be Microsoft Windows™ compatible. Other cases shall have specific PETROBRAS approval.
- 12.3 At proposal,

Technical documentation to be presented together with the proposal:

- Equipment datasheet and accessories with estimative of harmonics and power dissipation.
- Equipment layout with views, dimensional drawings, dimensions, cables entrances, fixation details and weights.
- Codes, standards, and recommended practices adopted.
- Reference list of same model manufactured drives.
- System component efficiency, for 25%, 50%, 75%, 90% and 100% of the rated power.
- Efficiency measurement method adopted.
- Thermal load of both VSD-FC cabinet and power transformer (if integrated or separated), with indication of air and water (if water cooled) distribution for heat transfer.
- Diagrams, control diagrams, auxiliary loads power requirement, heat loss, etc.
- List of recommended spare parts see 11.2.
- 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.
- MTTF shall be defined by technology/topology proposed, see 3.16.5.
- MTTR – segregated by mode of failure, see 3.16.3.
- DC Link and other power capacitor expected lifetime in hours, 3.16.8.
- Technical assistance conditions informed in section 10.

12.4 For approval:

Documentation to be provided after purchase order placement for construction approval:

- Equipment Datasheets fulfilled.
- Equipment layout drawings with views, dimensions, cables entrances, fixation, weights, sections, and details.
- Mechanical handling partition for delivery.
- Functional, logical and connection diagrams.
- Components list, with at least: item, description, MTBF (Mean Time Between Failure), quantity and part number.

Note: MTTF shall be defined by technology/topology proposed and MTTR – segregated by mode of failure. The list of failures (with their MTTR) and replaceable parts per failure shall be included.

- Spare parts list as above.
- Harmonics study and spectrum.
- Tests plan as defined in section 7 and test report.
- Tests' certification, by motor Supplier/Manufacturer, if driving Ex equipment, according to 3.1.4;
- A list of protection functions and equipment parameters and all its adjustments and configurations for the proposed converter service and feeding motor.

Note: The parameterization file shall be provided in VSD-FC software format.

- Lifting drawings with weights and gravity centre.


12.5 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.

Note: MTTF shall be defined by technology/topology proposed and MTTR – segregated by mode of failure. The list of failures (with their MTTR) and replaceable parts per failure shall be included.

- Tests reports as defined in section 7 and agreed with PETROBRAS.
- Storage requirements, as defined in 0, for periods longer than 6 months, if necessary.
- Report of inclination, shock, and temperature sensors at factory packaging before transportation to site, as defined in 3.2.2.3.
- Equipment mathematical models (with parameters values) for system computational simulation.

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

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- 12.7 All other documents shall be presented in English or in Brazilian Portuguese. All technical documentation delivered in Brazilian Portuguese shall have a copy delivered in English.
- 12.8 All reference manuals and reports shall be provided, in English and in Brazilian Portuguese languages (Brazilian Portuguese to comply with NR-12 requirements).
- 12.9 Tests and studies reports shall be delivered with the package too.
- 12.10 All studies and computational simulation files shall be delivered in digital media with indication of the software used and its version. The parameterization file shall be provided in VSD-FC software format.

13. TRAINING

- 13.1 Supplier/Manufacturer shall provide training for at least 10 (ten) PETROBRAS personnel, about VSD-FC technology, operation, and maintenance.
- 13.2 Training shall be provided in Brazil, during commissioning period, in Portuguese language.
- 13.3 Training shall be done in two different periods to be agreed with PETROBRAS.
- 13.4 Training program (content, duration, dates, etc.) shall be approved by PETROBRAS.
- 13.5 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 software, configuration, parameterization and adjustment of VSD-FC and its components.

14. ABBREVIATIONS

DC	Direct Current
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESP	Electrical Submersible Pump
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
MMR	Microprocessor-based multifunction protection relays
MTTR	Mean Time To Repair
NEMA	National Electrical Manufacturers Association
PCB	Printed Circuit Board
PCC	Point of Common Coupling (panel where VSD-FC is feed)
PLC	Programmable Logic Controller
PTC	Positive Temperature Coefficient
RFI	Radio Frequency Interference
RTD	Resistance Temperature Detector
THD	Total Harmonic Distortion
UAM	Unit Alarm Malfunction
UAS	Unit Alarm Shutdown
UHF	Ultra-High Frequency
UPS	Uninterruptible Power System
VHF	Very High Frequency
VSD	Variable Speed Drive
VSD-FC	Variable Speed Drive – Frequency Converter

15. ANNEX I – DATASHEET REFERENCE

- 15.1 The Datasheets are templates and do not refer to any equipment. The Supplier/Manufacturer shall fill in a Datasheet for each equipment.
- 15.2 For equipment without Datasheet templates in annexes, Supplier/Manufacturer shall fill in Datasheets according to its own standard and submit to PETROBRAS approval.
- 15.3 All existing Datasheet templates are available at I-LI-3010.00-5140-700-P4X-001 - ELECTRICAL EQUIPMENT DATA-SHEET MODEL.