PETROBRAS	**TECHNICAL SPECIFICATION**	Nº: I-ET-3000.00-1500-700-PEK-006	
	CLIENT: PETROBRAS		FOLHA: 1 de 25
	JOB: Subsea Processing and Boosting Systems		
	AREA: Subsea Electrical Power System		
SUB/ES/EECE	TITLE: **TOPSIDE HIGH-VOLTAGE VARIABLE FREQUENCY DRIVE**		SUB/ES/EECE/ECE

INDEX OF REVISIONS

REV.	DESCRIPTION AND/OR AFFECTED SHEETS
0	Original Emission

Note 1: Revised by CLW4, U3FL, DVLY, RHCG

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	15/05/2023								
DESIGN	SP&BS								
EXECUTION	CXS2								
CHECK	Note 1								
APROVAL	UR6A								

SUMMARY

1 PURPOSE

1.1 This Technical Specification (TS) defines the minimum requirements for design, manufacturing, testing, and acceptance of TOPSIDE HIGH-VOLTAGE VARIABLE FREQUENCY DRIVE and all its accessories that shall be part of the Subsea Processing and Boosting System (SP&BS).

1.1.1 The TOPSIDE HV VFD consists of the complete integrated equipment which main parts are the input transformer, the voltage source converter (rectifier + DC link + inverter), the output filter, the cooling systems, and all related accessories.

1.1.2 For sake of simplicity the TOPSIDE HV VFD input transformer and its accessories will be referred herein as “Input Transformer” except when otherwise specified.

1.1.3 For sake of simplicity the TOPSIDE HV VFD Voltage Source Converter (VSC) and its accessories will be referred herein as “Topside Converter” except when otherwise specified.

1.1.4 For sake of simplicity the TOPSIDE HV VFD output filter and its accessories will be referred herein as “Output Filter” except when otherwise specified.

1.2 This TS is part of a document package for SP&BS bid and product development purposes.

1.2.1 This TS shall be referred in full for Subsea Electrical Power System (SEPS) detailed design, interfaces with other SP&BS equipment, and interfaces with FPSO.

2 TERMS, DEFINITIONS, ACRONYMS AND ABREVIATIONS

2.1 For the purposes of this TS, the following Acronyms and Abbreviations apply.

AF: Air-forced (cooled)
EMC: Electromagnetic Compatibility
FAT: Factory Acceptance Testing
FPSO: Floating Production Storage Offload
IP: Enclosure degree of protection according to [16]
LV: Low-Voltage (voltages less than 1kV)
HV: High-Voltage (voltages equal or greater than 1kV)
RIM: Reliability and Integrity Management
RMS: Root Mean Square
SEPS: Subsea Electrical Power System

SIT: System Integration Test

SP&BS: Subsea Processing and Boosting System

TMA: Technology Maturity Assessment

TRC: Technology Risk Categorization

TRL: Technology Readiness Level

TS: Technical Specification

VFD: Variable Frequency Drive

VSC: Voltage Source Converter

3 REFERENCE DOCUMENTS

3.1 PETROBRAS' Documents

Doc. Nr.	Title
[1] SEPS Technical Specification NOTE 01	Subsea Electrical Power System
[2] SP&BS Technical Specification NOTE 01	Subsea Processing & Boosting System
[3] Interface with FPSO Technical Specification NOTE 01	Interface of the SP&BS with the FPSO facilities

NOTE 01: Technical Specification specific of the bidding process.

3.2 Industry Codes, Standards, Rules and Regulations

The latest issue of the reference standards shall be used unless it is specified in the table below or otherwise agreed. Other recognized standards may be used, provided it can be shown that they meet or exceed the requirements of the standards referenced below. Variations or alternatives, if proposed, shall be submitted to PETROBRAS for approval before SP&BS detailed design starts.

Doc. Nr. or Author	Title
[4] API RP 17N, 2nd Ed., Addendum 1 – May 2018	Recommended Practice on Subsea Production System Reliability, Technical Risk, and Integrity Management
[5] API RP 17Q, 2nd Ed. May 2018	Recommended Practice on Subsea Equipment Qualification
[6] IEC 60076-1	Power Transformers – Part 1: General
[7] IEC 60076-3	Power Transformers – Part 3: Insulation levels, dielectric tests and external clearances in air
[8] IEC 60076-5	Power Transformers – Part 5: Ability to withstand short circuit
[9] IEC 60076-6	Power Transformers – Part 6: Reactors
[10] IEC 60076-10	Power Transformers – Part 10: Determination of sound levels

[11] IEC 60076-11	Power Transformers – Part 11: Dry-type Transformers
[12] IEC 60076-18	Power Transformers – Part 18: Measurement of frequency response
[13] IEC TS 60076-20	Power Transformers – Part 20: Energy Efficiency
[14] IEC 60146-1-1	Semiconductor Converters – General Requirements and Line Commutated Converters – Part 1-1: Specification of Basic Requirements
[15] IEC 60270	High-voltage test techniques – Partial discharge measurements
[16] IEC 60529	Degrees of protection provided by enclosures (IP Code)
[17] IEC 61378-1	Converter Transformers – Part 1: Transformers for industrial applications
[18] IEC 61378-3	Converter Transformers – Part 3: Application Guide
[19] IEC 61800-3	Adjustable Speed Electrical Power Drive Systems – Part 3: EMC Requirements and Specific Test Methods
[20] IEC 61800-4	Adjustable Speed Electrical Power Drive Systems – Part 4: General Requirements – Rating Specifications for A.C. Power Drive Systems above 1,000Vac and not Exceeding 35kV
[21] IEC 61800-5-1	Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy
[22] IEC 61800-5-2	Adjustable Speed Electrical Power Drive Systems – Part 5-2: Safety Requirements - Functional
[23] ISO 12944-2	Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 2: Classification of environments

4 TOPSIDE HV VFD SCOPE OF SUPPLY

4.1 The Topside HV VFD shall be supplied with, at least, the following items:

4.1.1 Input Transformer, Topside Converter, Output Filter in a protection enclosure and with an adequate structure to be suitable to operate under inclination variations (static and dynamic) and acceleration conditions specified by FPSO movement stated in [3] without any degradation of its mechanical, thermal and electrical characteristics and to be installed as presented in [3].

4.1.2 Complete monitoring system.

4.1.3 Complete cooling system.

4.1.4 All instrumentation, electrical and mechanical terminations, HV and LV cable glands.

4.1.5 All accessories, tools, and spare parts to execute foreseen inspections and structural,

mechanical, and electrical maintenance during a period of 5 (five) years of operation to assure the integrity of the Topside HV VFD and its auxiliaries.

4.1.6 A service computer shall be provided with all necessary software to perform configuration, parameterization, setpoint adjustment, analysis, troubleshoot, etc., including communication cables, in any of its components.

4.1.7 Topside HV VFD Databook.

4.1.8 SUPPLIER shall provide the auxiliary tool over wheels to remove / install the power cells from / into the panel and move it to / from another location as part of Topside HV-VFD scope of supply.

5 TOPSIDE HV VFD TECHNOLOGY MATURITY ASSESSMENT

5.1 SUPPLIER shall select a Topside HV VFD manufacturer with previous experience in design of HV VFD for application with long cable length (some kilometers) between converter output terminals and motor terminals and with experience in design of HV VFD for installation in offshore floating units.

5.2 SUPPLIER´s designed Topside HV VFD shall be capable of carrying, in continuous service, the rated power and the power levels in all operational range defined by SUPPLIER to comply with all operational conditions detailed by SUPPLIER to fully fulfill SP&BS safety and performance requirements within equipment operational temperature, current, and voltage limits and respective operational safety margins.

5.3 SUPPLIER shall perform a TMA, as per [4] and [5], of the Topside HV VFD and its components to evaluate the Topside HV VFD and each of its component´s technical risk and maturity in line with SP&BS application characteristics and safety and performance goals.

5.3.1 TRL shall be assessed using the design requirements stated in this TS and SP&BS application characteristics. Each element gap to assure TRL 4 shall be identified and the design and/or tests activities needed to assure TRL 4 shall be clearly identified and performed as part of SP&BS detailed engineering phase, as stated in [1] and [2].

5.3.2 TRC shall be assessed using, at least, the change risk factors stated in [4] for equipment and for procedures. SUPPLIER shall implement actions in its RIM for each change risk factor classified as ‘A – Very High’ or ‘B – High’ to reduce it, at least, to

'C – Medium', as stated in [1] and [2].

5.3.3 SUPPLIER shall present the Topside HV VFD TMA Report in the first SEPS technical meeting, together with the action plan with detailed scope and schedule to assure TRL 4 and TRC C achievement during all project life cycle stages, from Detail Design to Operation.

5.4 SUPPLIER shall provide a Track Record Report of the selected Topside HV VFD Manufacturer providing evidence that Topside HV VFD Manufacturer has previous experience as per item 5.1 of this TS. SUPPLIER shall present the Topside HV VFD Track Record Report in the first SEPS technical meeting. The Topside HV VFD Track Record Report shall report, as a minimum, a list of previous installed HV VFD informing:

5.4.1 Operator, platform name, floating unit type and water depth.

5.4.2 Company name, application with long cables length and cable total length.

5.4.3 Input Transformer type and main characteristics: insulation material, number of windings, windings current and voltage, connection diagram, operational frequency range, losses, power, monitoring system, cooling method, ambient condition (open, ventilated room, acclimatized room) and equipment IP.

5.4.4 Topside Converter type and main characteristics: input current, voltage, power factor and number of pulses; output current, voltage, control modes, switching levels and modulation method; monitoring system; efficiency; cooling method and equipment IP.

5.4.5 Output Filter type and main characteristics.

6 TOPSIDE HV VFD MAIN REQUIREMENTS

6.1 Total Harmonic Distortion at Topside HV VFD feeder shall comply with [22] not exceeding 5%. Individual components shall be limited to 3% distortion at worst operational condition regarding harmonic distortion.

6.1.1 No input filters are allowed.

6.2 The Topside HV VFD shall be capable of carrying, in continuous service, the rated power and the power levels in all operational range defined by SUPPLIER to comply with all operational conditions detailed by SUPPLIER to fully fulfill SP&BS safety and performance

requirements without exceeding any material temperature limit and safety margin.

6.2.1 The temperature rise and the cooling requirements of the Topside HV VFD in any of its components shall be verified at rated point of operation and in all operational range defined by SUPPLIER to comply with all operational conditions detailed by SUPPLIER to fully fulfill SP&BS safety and performance requirements.

6.3 The Topside HV VFD efficiency shall be defined considering the limit of total power demand per SEPS feeder according to [3].

6.3.1 Efficiency determination shall consider the included losses as per [14].

6.4 The Topside HV VFD input total power factor shall be greater than 0.94 inductive and the fundamental power factor shall be greater than 0.95 inductive.

6.5 The Topside HV VFD shall comply with EMC Requirements and Type Tests stated in [19].

6.5.1 SUPPLIER shall follow the EMC recommendations of the Topside HV VFD manufacturer.

6.6 The Topside HV VFD shall comply with Safety Requirements stated in [21] and [22].

6.6.1 SUPPLIER shall evaluate all Safety Requirements as per [21] and [22] and shall present in the first SEPS technical meeting a Safety Evaluation Report describing how each requirement will be assured in the selected Topside HV VFD design.

6.6.2 SUPPLIER shall perform all Routine and Sample Test as per [21] as part of the Topside HV VFD FAT.

6.6.3 SUPPLIER shall present the Test Report of the tests already successfully performed as per [22].

6.6.4 SUPPLIER shall repeat the tests stated in [22] if actual design modifications of the Topside HV VFD compromises the functional safety of the equipment and to reassure functional safety is maintained. The analysis of impact of design modification on functional safety shall be according to [22].

6.7 As a general directive, SUPPLIER shall present the Type Test Report of each type test already successfully performed and not impacted for any change in the Topside HV VFD design to comply with SP&BS safety and performance requirements.

6.7.1 Each Type Test Report and related manufacturer Assurance Letter shall be provided to PETROBRAS in the first SEPS technical meeting.

6.7.2 In the lack of the documents stated in 6.7.1, SUPPLIER shall perform the Type Test as part of SP&BS detailed engineering phase, as stated in [1] and [2]. The list of tests and test schedule shall be presented in the first SEPS technical meeting.

6.8 The Topside HV VFD shall be submitted to FAT after all main components have successfully concluded their respective type, routine, and special tests and the Topside HV VFD is fully integrated.

6.9 In addition to SUPPLIER´s own inspection and testing requirements, SUPPLIER shall perform the tests presented in Table 6.9 of this TS.

6.9.1 SP&BS motor shall be used as the driven equipment in the Topside HV VFD FAT tests on Table 6.9.

Table 6.9 – Topside HV VFD FAT

Test	Test procedure reference
Light load test	[20]
Load characteristic test (Load envelope test)	[20]
Load duty test (Intermittent load test)	[20]
Allowable full load current versus speed test	[20]
Temperature rise tests	[20]
Efficiency	[20]
Line-side current distortion content	[20]
Power factor	[20]
Checking of auxiliary devices	[20]
Checking co-ordination of protective devices	[20]
Checking properties under unusual service conditions	[20]
Shaft current/bearing insulation	[20]
Audible noise	[20]
Torque pulsation	[20]
Motor vibration	[20]
Dynamic performance	[20]
Current limit and current loop test	[20]
Speed loop test	[20]
Automatic restart/re-acceleration	[20]

6.9.2 Topside HV VFD FAT may be performed loaded by a motor similar of the subsea motor, with same mechanical (torque / speed curve) and electrical (motor type, rated power and

voltage) characteristics.

6.9.3 Motor vibration test shall be performed during SEPS SIT.

6.9.4 SUPPLIER shall produce a Topside HV VFD Inspections and Tests Final Report, with detailed inspection evidence of the Topside HV VFD assembly and integration, the detailed test procedures, and test reports of each FAT, as part of the TOPSIDE HV VFD Databook to be delivered to PETROBRAS.

7 INPUT TRANSFORMER REQUIREMENTS

7.1 Input Transformer shall be dry-type molded in epoxy resin or encapsulated with glass fiber epoxy resin under vacuum.

7.2 Input Transformer shall comply with [3].

7.3 Input Transformer shall be installed sized for continuous duty and shall comply with [6], [17] and [18].

7.4 The permissible temperature rise referred to environmental conditions shall be as a maximum average, equal to 80ºC for the outer winding(s) and 100ºC for the inner winding(s), according to [11].

7.5 Input Transformer shall comply with Climatic Class C1, according to [11].

7.6 Input Transformer shall comply with Environmental Class E1, according to [11].

7.7 Input Transformer shall comply with Fire Behavior Class F1, according to [11].

7.8 Input Transformer protective paint system shall be suitable to category C5-M – very high corrosivity (offshore environments) according to [23].

7.9 Input Transformer shall withstand the dynamic and thermal effects of short-circuit current at the secondary and all other terminals according to [11] and [8].

7.9.1 Input Transformer shall be suitable for a short-circuit level, next to the primary terminals, equal to that of the supply panel busbar according to [3].

7.10 Input Transformer windings shall comply with the following requirements:

7.10.1 All windings shall have F Class (155ºC) insulation.

7.10.2 The insulation resin shall be non-fire propagating and self-extinguishing and, in case of fire, shall not release toxic gases.

7.10.3 Their construction shall permit the removal of each winding separately, for maintenance in site.

7.10.4 Both windings shall have uniform insulation to permit their operation, indifferently, with earthed or insulated neutral systems.

7.10.5 Lifetime shall be at least 25 years.

7.10.6 Maximum temperature after short-circuit shall be under limits of [8].

7.10.7 SUPPLIER shall evaluate the need of an earthed shield between the primary and the secondary windings.

7.11 Input Transformer shall be installed inside a ventilated room part of the SP&BS VFD´s Topside Module, as per [3].

7.11.1 SUPPLIER shall supply a latticed protection enclosure, with suitable ventilation, for each transformer to protect against accidental contacts, with minimum protection degree IP 21 according to [16].

7.11.2 The enclosure grating shall enable thermographic inspection of transformer windings and connections with no necessity to open the enclosure.

7.11.3 Facilities for lifting of the complete transformer and for their horizontal displacements shall be supplied and comply with SUPPLIER rigging plan stated in [3].

7.12 Input Transformer cables shall comply with the following requirements:

7.12.1 All conducting parts shall be insulated with resin.

7.12.2 No stress shall be applied to bushings or terminations. These fixing devices shall be built of non-magnetic material.

7.12.3 When copper/aluminum connections exist, these shall be encapsulated.

7.12.4 Galvanic insulation shall be provided to avoid electrolytic corrosion in case of dissimilar metallic material.

7.13 It shall be designed and constructed in way that, at full load, the noise level shall not exceed 80dBA at a distance equal to 1.5 meters and calculated by [10]. The most restrictive criteria shall be considered.

7.14 Input Transformer design shall provide facilities to allow earthing, through screwed connectors, separately, to the transformer frame to the terminal block box and to the enclosure.

7.14.1 Facilities shall be provided to allow temporary earthing by means of ground cables, through screwed connectors, separately, to the transformer frame to the terminal block box and to the enclosure.

7.15 Efficiency values shall be informed in the Topside HV VFD Databook as defined in [13].

7.16 The short-circuit impedance of all windings shall be informed in the Topside HV VFD Databook.

7.17 The initial magnetizing inrush current peak value resulting from transformer primary winding to secondary winding(s) energization shall be informed in the Topside HV VFD Databook.

7.18 Input Transformer shall be air-cooled. It shall provide fully redundant air forced circulation.

7.19 Input Transformer shall have the following instrumentation and monitoring functions, as a minimum, during operation:

7.19.1 Winding’s voltage, current and redundant temperature measurement.

7.19.2 Cooling system monitoring: temperatures and condition monitoring system of motors and fans of the forced air circulation system.

7.19.3 All input transformer variables shall be monitored by SEPS Workstations according to [1].

7.20 The Input Transformer shall be subject to a design analysis covering, as a minimum:

7.20.1 Electrostatic, magnetic, thermal, and mechanical finite element analysis, covering type tests and intended operational conditions. The analysis shall verify that the worst-case design electrical loads, including fault scenarios, do not exceed electrical, magnetic, thermal, or mechanical limitations for any material. The analysis shall include all modelling assumptions for the FEA and the design.

7.20.2 Worst case mechanical design loads (test, storage, handling, maintenance, installation/retrieval, and operation). All handling conditions foreseen in the rigging plan shall be verified.

7.20.3 The thermal analysis shall be performed both at the rated power, and at the actual load power (if different) and cover as a minimum:

7.20.3.1 Load-losses due to RMS and harmonic currents. The calculation principle of additional losses shall be performed as presented in [17].

7.20.3.2 Maximum continuous temperatures of insulating materials and winding temperature rises.

7.20.3.3 Maximum continuous hot spot temperature.

7.20.3.4 Start-up conditions shall be addressed separately.

7.20.4 Possible nonlinear material properties.

7.20.5 The parameters used in the thermal analysis shall be based on measured data for example for viscosity, thermal resistance etc.

7.21 Ability to withstand short circuits. The calculations shall be performed in accordance with [8].

7.22 The material selection, material properties and limitations used in the analysis shall be identified and documented based on qualified, recognized, and repeatable fabrication processes. This is also applicable for bonding between materials.

7.23 Description of welding, painting, and corrosion protection, including surface treatment solutions.

7.24 SUPPLIER shall provide adequate monitoring points during testing to determine the performance, capacity, and efficiency at selected operating conditions of the transformer and its components to enable a comparison of the results with the values and conditions that have been guaranteed by SUPPLIER.

7.24.1 Monitored points during test shall also provide evidence that transformer is inside its operational envelope, e.g., hot spot temperatures, saturation, voltage, and current distortions that supports its reliability target.

7.24.2 Testing shall verify the thermal and cooling characteristics at the most critical operating points of the transformer loading.

7.24.3 Testing shall verify the thermal and cooling characteristics at the most critical transformer load distortion.

7.25 Unless specified otherwise, the acceptance criteria for the tests in this TS shall be those given in the reference standards.

7.26 In addition to SUPPLIER´s own inspection and testing requirements, SUPPLIER shall perform the inspections and tests presented in Table 7.28, Table 7.29 and Table 7.30 of this TS.

7.27 Inspection shall verify, as a minimum, the following:

7.27.1 Design documentation according to this TS.

7.27.2 Calibration certificate issued by an accredited laboratory of all instruments used during testing valid at the date of the test execution.

7.27.3 Cooling system detailed inspection.

7.27.4 Visual and dimensional inspection, including internal spaces and components.

7.28 At least, the Type Tests in Table 7.28 shall be performed.

7.28.1 As a general directive, SUPPLIER shall present the Type Test Report of each type test already successfully performed and not impacted for any change in the Topside Transformer design to comply with SP&BS safety and performance requirements.

7.28.2 Each Type Test Report and related manufacturer Assurance Letter shall be provided to PETROBRAS in the first SEPS technical meeting.

7.28.3 In the lack of the documents stated in 7.28.1 or if identified in 5.3.1, SUPPLIER shall perform the Type Test as part of SP&BS detailed engineering phase, as stated in [1] and [2]. The list of tests and test schedule shall be presented in the first SEPS technical meeting.

Table 7.28 – Input Transformer Type Tests

Test	Test procedure reference
Lightning impulse test	[7] and [11]
Temperature rise test	[11]
Dielectric type tests	[7]
Determination of sound level	[10]
Measurement of no-load loss and current at 90% and 110% of rated voltage	[6]
Short-circuit withstand test	[8] and [11]
Environmental tests	[11]
Climatic tests	[11]
Fire behavior test	[11]
Degree of protection of enclosure	[16]

7.29 At least, the Routine Tests in Table 7.29 shall be performed.

Table 7.29 – Input Transformer Routine Tests

Test	Test procedure reference
Measurement of winding resistance	[6]
Measurement on voltage ratio	[6]
Check of phase displacement	[6]
Measurement of short-circuit impedance	[6] and [11]
Measurement of load loss	[6] and [11]
Measurement of no-load loss and current	[6]
Dielectric routine tests	[7]
Separate-source AC withstand voltage test	[7] and [11]
Induced AC withstand voltage test	[7] and [11]
Partial discharge measurement	[15], [7] and [11]
Measurement of harmonics of the load current	[6], [17] and [18]

7.30 At least, the Special Test in Table 7.30 shall be performed.

Table 7.30 – Input Transformer Special Tests

Test	Test procedure reference
Determination of capacitance windings-to-earth, and between windings	[6]
Measurement of the dissipation factor (tan δ) of the insulation system capacitances.	[6]
Measurement of zero-sequence impedances on three-phase transformers	[6]
Measurement of DC insulation resistance each windings to earth and between windings.	[6]
SFRA (sweep frequency response analysis) test	[12]

7.31 SUPPLIER shall produce an Input Transformer Inspections and Tests Final Report, with detailed inspection evidence of Input Transformer manufacture and final assembly, detailed test procedures and detailed reports of each Input Transformer Type, Routine and Special Test, as part of the TOPSIDE HV VFD Databook to be delivered to PETROBRAS.

8 TOPSIDE CONVERTER REQUIREMENTS

8.1 Topside Converter shall be designed according to [14], [20], [21] and [22].

8.2 Topside Converter cooling system:

8.2.1 If Topside Converter is water-cooled, it shall be cooled by a dedicated closed-loop water cooling system with air-to-water heat exchangers.

8.2.2 Fully redundant air forced circulation shall be provided.

8.2.3 The cooler shall be so designed as to avoid wetting transformer windings, whether by leakage or condensation in the heat-exchanger.

8.2.4 The water / air heat exchangers assembly shall be provided with leakage detector.

8.2.5 A collecting tray shall be provided under the exchanger/inner flanges for drainage of any leakage, which shall be piped to leakage detector and to a visible drain.

8.2.6 The heat exchangers shall be provided with direct local reading of inlet/outlet temperatures and differential pressure monitoring to be alarmed at SEPS Workstations.

8.3 If Topside Converter is air-cooled, it shall provide fully redundant air forced circulation.

8.4 Topside Converter protective paint system shall be suitable to category C5-M – very high

corrosivity (offshore environments) according to [23].

8.5 Lifetime shall be at least 25 years.

8.6 Topside Converter shall be installed inside an acclimatized room part of the SP&BS VFD´s Topside Module, as per [3].

8.6.1 Power, and control shall be segregated, installed inside different panel columns.

8.6.2 The protection enclosure shall have suitable ventilation for each panel column with minimum protection degree IP 22 according to [16].

8.6.3 The enclosure grating shall enable thermographic inspection of cable connections with no necessity to open the enclosure.

8.6.4 Panel doors shall have an electromechanical door lock mechanism to guarantee that the door can only be opened with Topside Converter de-energized.

8.6.5 An earthing switch shall be installed in the Topside Converter output terminals to assure no voltage condition during operations within Topside Converter or in the system equipment in its output.

8.6.6 Facilities for lifting of the complete transformer and for their horizontal displacements shall be supplied and comply with SUPPLIER rigging plan stated in [3].

8.7 Topside Converter shall comply with performance criteria F, T and D according to [14].

8.8 Topside Converter shall comply with environmental conditions according to [14].

8.8.1 Additionally, the Topside Converter shall comply with offshore environment and mechanical stress due to FPSO movements as stated in [3].

8.9 Topside Converter shall have the following protection functions (alarm and trip), as a minimum, during operation.

8.9.1 Line-side supply:

8.9.1.1 Outage, phase loss.

8.9.1.2 Line overvoltage.

8.9.1.3 Line under-voltages.

8.9.1.4 Line voltage unbalance.

8.9.2 Line feeder:

8.9.2.1 Over-current.

8.9.2.2 Overload.

8.9.3 Converter:

8.9.3.1 CPU failure.

8.9.3.2 Overcurrent.

8.9.3.3 Overload.

8.9.3.4 Short-circuit (three-phase, phase-to-phase and phase-to-ground).

8.9.3.5 Overvoltage.

8.9.3.6 Undervoltage.

8.9.3.7 Ground fault.

8.9.3.8 Loss of cooling.

8.9.3.9 Over-temperature.

8.9.3.10 Loss of auxiliary supply.

8.9.3.11 Loss of communication to process control.

8.9.4 Motor:

8.9.4.1 Motor over / under-voltage.

8.9.4.2 Reverse phase voltage protection (27/47 functions)

8.9.4.3 Motor overcurrent (50/51 functions).

8.9.4.4 Long starting time / incomplete sequence (48 function).

8.9.4.5 Negative sequence unbalance protection (46 function).

8.9.4.6 Ground detection protection (50GS function).

8.9.4.7 Overload.

8.9.4.8 Over-speed.

8.9.4.9 High vibrations (signal from subsea vibration monitoring system).

8.9.4.10 Motor over-temperature (signal from subsea temperature measurement of barrier fluid).

8.9.4.11 Barrier fluid system failure.

8.9.5 Cooling system monitoring:

8.9.5.1 If water-cooled, closed-loop water cooling system monitoring system comprising, at least, of temperatures and pressures measurements and leak detectors.

8.9.5.2 If air cooled, temperatures and condition monitoring system of motors and fans of the forced air circulation system.

8.9.6 All alarm and trip functions, and additional monitoring variables shall be confirmed during SP&BS risk analysis stated in [1] and [2].

8.9.7 All protection functions and additional monitoring variables shall be monitored and shall alarm at SEPS Workstations.

8.10 SUPPLIER shall provide adequate monitoring points during testing to determine the performance, capacity, and efficiency at selected operating conditions of the Topside Converter and its components to enable a comparison of the results with the values and tolerances, as per [14], and conditions that have been guaranteed by SUPPLIER.

8.10.1 Monitored points during test shall also provide evidence that Topside Converter is inside its operational envelope, e.g., hot spot temperatures, efficiency, power factor, voltage and current distortions, voltage and current capability that supports its reliability target.

8.10.2 Testing shall verify the thermal and cooling characteristics at the most critical

operating points of loading magnitude.

8.10.3 Testing shall verify the thermal and cooling characteristics at the most critical load distortion.

8.11 Unless specified otherwise, the acceptance criteria for the tests in this TS shall be those given in the reference standards.

8.12 In addition to SUPPLIER´s own inspection and testing requirements, SUPPLIER shall perform the inspections and tests presented in Table 7.28, Table 7.29 and Table 7.30 of this TS.

8.13 Inspection shall verify, as a minimum, the following:

8.13.1 Design documentation according to this TS.

8.13.2 Calibration certificate issued by an accredited laboratory of all instruments used during testing valid at the date of the test execution.

8.13.3 Cooling system detailed inspection.

8.13.4 Visual and dimensional inspection, including internal spaces and components.

8.14 At least, the Type Tests in Table 8.14 shall be performed.

8.14.1 As a general directive, SUPPLIER shall present the Type Test Report of each type test already successfully performed and not impacted for any change in the Topside Converter design to comply with SP&BS safety and performance requirements.

8.14.2 Each Type Test Report and related manufacturer Assurance Letter shall be provided to PETROBRAS in the first SEPS technical meeting.

8.14.3 In the lack of the documents stated in 8.14.1 or if identified in 5.3.1, SUPPLIER shall perform the Type Test as part of SP&BS detailed engineering phase, as stated in [1] and [2]. The list of tests and test schedule shall be presented in the first SEPS technical meeting.

Table 8.14 – Topside Converter Type Tests

Test	Test procedure reference
Insulation	[14]
Light load and operation	[14]
Rated current / output	[14]
Current sharing, if parallel connected semiconductors	[20]
Voltage division, if series connected semiconductors	[20]
Power loss determination	[14]
Temperature rise	[14]
Checking of auxiliary devices	[14]
Checking the properties of the control equipment	[20]
Checking of protective devices	[14]

8.15 At least, the Routine Tests in Table 8.15 shall be performed.

Table 8.15 – Topside Converter Routine Tests

Test	Test procedure reference
Insulation	[14]
Light load and operation	[14]
Checking of auxiliary devices	[14]
Checking the properties of the control equipment	[20]
Checking of protective devices	[14]

8.16 At least, the Special Test in Table 8.16 shall be performed.

Table 8.16 – Topside Converter Special Tests

Test	Test procedure reference
Overcurrent capacity	[14]
Interphase ripple voltage and ripple current	[14]
Measurement of inherent voltage regulation	[14]
Power factor	[14]

8.17 SUPPLIER shall produce a Topside Converter Inspections and Tests Final Report, with detailed inspection evidence of Topside Converter manufacture and assembly, detailed test procedures and test reports of each Topside Converter Type, Routine and Special Test, as part of the TOPSIDE HV VFD Databook to be delivered to PETROBRAS.

9 OUTPUT FILTER REQUIREMENTS

9.1 SUPPLIER shall perform electrical analysis to identify the need of an Output Filter to reduce

harmonic content, dv/dt and/or avoid overvoltage due to resonance with umbilical power cables.

9.1.1 No active filters are allowed.

9.2 Output Filter shall be air-forced cooled (AF).

9.2.1 Fully redundant air forced circulation shall be provided.

9.3 Lifetime shall be at least 25 years.

9.4 Output Filter reactor shall fully comply with [9].

9.5 Output Filter shall have the following instrumentation and monitoring functions, as a minimum, during operation:

9.5.1 Output voltage and current and redundant temperature measurement in each of its elements.

9.5.2 All Output Filter variables shall be monitored by SEPS Workstations according to [1].

9.6 SUPPLIER shall provide adequate monitoring points during testing to determine the performance, capacity, and efficiency at selected operating conditions of the Output Filter and its components to enable a comparison of the results with the values and conditions that have been guaranteed by SUPPLIER.

9.6.1 Monitored points during test shall also provide evidence that the Output Filter is inside its operational envelope, e.g., hot spot temperatures, saturation, electrical and mechanical resonance, voltage, and current distortions that supports its reliability target.

9.6.2 Testing shall verify the thermal and cooling characteristics at the most critical operating points of loading magnitude.

9.6.3 Testing shall verify the thermal and cooling characteristics at the most critical operating points of load distortion.

9.7 In addition to SUPPLIER´s own inspection and testing requirements, SUPPLIER shall perform the tests in the Output Filter reactor presented in 9.8, Table 9.9, Table 9.10 and Table 9.11.

9.8 Inspection shall verify, as a minimum, the following:

9.8.1 Design documentation according to [9].

9.8.2 Calibration certificate issued by an accredited laboratory of all instruments used during testing valid at the date of the test execution.

9.8.3 Visual and dimensional inspection, including internal spaces and components.

9.9 At least, the Reactor Type Tests in Table 9.9 shall be performed.

9.9.1 As a general directive, SUPPLIER shall present the Type Test Report of each type test already successfully performed and not impacted for any change in the Reactor design to comply with SP&BS safety and performance requirements.

9.9.2 Each Type Test Report and related manufacturer Assurance Letter shall be provided to PETROBRAS in the first SEPS technical meeting.

9.9.3 In the lack of the documents stated in 9.9.1 or if identified in 5.3.1, SUPPLIER shall perform the Type Test as part of SP&BS detailed engineering phase, as stated in [1] and [2]. The list of tests and test schedule shall be presented in the first SEPS technical meeting.

Table 9.9 – Output Filter Reactor Type Tests

Test	Test procedure reference
Measurement of inductance	[9]
Measurement of loss and quality factor	[9]
Lightning impulse test	[9]
Temperature rise test	[9]

9.10 At least, the Reactor Routine Tests in Table 9.10 shall be performed.

Table 9.10 – Output Filter Reactor Routine Tests

Test	Test procedure reference
Measurement of winding resistance	[6]
Measurement of inductance	[9]
Measurement of loss and quality factor	[9]
Winding overvoltage test	[9]

9.11 At least, the Reactor Special Test in Table 9.11 shall be performed.

Table 9.11 – Output Filter Reactor Special Tests

Test	Test procedure reference
Short-circuit current test	[9]
Measurement of acoustic sound level at rated continuous current	[9]
Separate source A.C. withstand voltage test	[9]
Inrush current withstand test for filter and damping reactors	[9]

9.12 SUPPLIER shall produce an Output Filter Inspections and Tests Final Report, with detailed inspection evidence of Output Filter Reactor manufacture and assembly, detailed test procedures and test reports of each Output Filter Reactor Type, Routine and Special Test, as part of the TOPSIDE HV VFD Databook to be delivered to PETROBRAS.

10 TOPSIDE HV VFD DATABOOK

10.1 SUPPLIER shall provide the TOPSIDE HIGH-VOLTAGE VARIABLE FREQUENCY DRIVE Databook before SP&BS installation including, as a minimum:

10.1.1 Topside HV VFD TMA Report as per item 5.3 of this TS.

10.1.2 Topside HV VFD Track Record Report as per item 5.4 of this TS.

10.1.3 Topside HV VFD EMC Type Test Reports as per item 6.5 of this TS.

10.1.4 Topside HV VFD Safety Evaluation Report as per item 6.6.1 of this TS.

10.1.5 Topside HV VFD electrical, thermal and energy safety requirements Type Test Reports, Routine Test Reports and Sample Test Reports as per [21].

10.1.6 Topside HV VFD functional safety requirements Test Reports as per [22].

10.1.7 Topside HV VFD Inspections and Tests Final Report as per item 6.9.2 of this TS.

10.1.8 Topside HV VFD As Built documentation.

10.1.9 Input Transformer Inspection and Tests Final Reports as per item 7.31 of this TS.

10.1.10 Input Transformer detailed procedure for each activity foreseen during equipment lifetime, e.g., transportation, lifting, storage, installation, commissioning, start-up, inspection, troubleshoot, repair, maintenance etc.

10.1.11 Input Transformer As Built documentation.

10.1.12 Topside Converter Inspection and Tests Final Report as per item 8.17 of this TS.

10.1.13 Topside Converter detailed procedure for each activity foreseen during equipment lifetime, e.g., transportation, lifting, storage, installation, commissioning, start-up, inspection, troubleshoot, repair, maintenance etc.

10.1.14 Topside Converter As Built documentation.

10.1.15 Output Filter Inspections and Tests Final Report as per item 9.12 of this TS.

10.1.16 Output Filter detailed procedure for each activity foreseen during equipment lifetime, e.g., transportation, lifting, storage, installation, commissioning, start-up, inspection, troubleshoot, repair, maintenance etc.

10.1.17 Output Filter As Built documentation.