INDEX OF REVISIONS

REV.	DESCRIPTION AND/OR AFFECTED SHEETS
0	Original Emission

Note 1: Revised by CLW4, U3FL, DVLY, RHCG, ES24, U4KI, C5D0, BTLL

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	08/05/2023								
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, qualification, manufacturing, routine testing and acceptance of SUBSEA HIGH-VOLTAGE POWER CONNECTION SYSTEM from 3.6/6.0(7.2)kV up to 18/30(36)kV and its elements, accessories and tools that shall be part of the Subsea Processing & Boosting Systems (SP&BS).

1.1.1 For sake of simplicity each SUBSEA HIGH-VOLTAGE POWER CONNECTION SYSTEM WM connectors, penetrators, cable termination, jumpers and pigtail assemblies, accessories and tools will be referred herein as “Subsea HV-PCS Element” 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 and interfaces with other SP&BS equipment.

2 TERMS, DEFINITIONS, ACRONYMS AND ABREVIATIONS

2.1 For the purposes of this TS, the following Terms and Definitions apply.

Dataroom: One or several meetings when SUPPLIER presents paper copies of the documents not available for PETROBRAS in electronic format for PETROBRAS verification and comments.

Field Proven: A field proven Subsea HV-PCS Element is one that have been successfully qualified with temperature, pressure, voltage, and currents ratings equal or superior to SP&BS requirements stated in this TS, successfully installed in water depth equal or greater than 1,500 meters and in operation without failures for at least 3 years.

In situ ambient condition: temperature, pressure, and all fluids that equipment is in contact with, internally and externally, when in subsea operation.

I_r: Rated ampacity used in all Type tests. I_r shall be at least 20% higher than HV-PCS maximum operational current at SP&BS rated point of operation in *in situ* ambient condition.

U_0: Phase-to-earth voltage used as reference in all Type tests. U_0 shall be at least 10% higher than HV-PCS maximum operational phase-to-earth voltage at SP&BS rated point of operation.

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

FAT: Factory Acceptance Tests

HV: High-Voltage (voltages equal or greater than 1kV)

HV-PCS: High-Voltage Power Connection System

IR: Insulation Resistance

PN: Part Number

QA: Quality Assurance

QC: Quality Control

RIM: Reliability and Integrity Management

SEPS: Subsea Electrical Power System

TMA: Technology Maturity Assessment

TRC: Technical Risk Categorization

TRL: Technological Readiness Level

TS: Technical Specification

UTA: Umbilical Termination Assembly

WM: Wet-mateable

3 REFERENCE DOCUMENTS

3.1 PETROBRAS' Documents

Doc. Nr.	Title
[1] SEPS Technical Specification NOTE 01	Subsea Electrical Power System
[2] ET-3000.00-1500-600-PEK-006	Requisitos Gerais de Equipamentos Submarinos
[3] SP&BS Technical Specification NOTE 01	Subsea Processing & Boosting System

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 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/IEEE 61886-1	Subsea equipment – Part 1: Power connectors, penetrators and jumper assemblies with rated voltage from 3kV (U_{max}=3,6kV) to 30kV (U_{max}=36kV)

4 SUBSEA HV-PCS SCOPE OF SUPPLY

4.1 SUPPLIER SEPS´ topology shall be according to [1].

4.2 In addition to the HV-PCS main elements described in [1], SUPPLIER shall supply all HV-PCS accessories needed to perform tests at surface and subsea, for protection and for intervention support, consisting, as a minimum, of:

4.2.1 Surface test connectors to perform IR test and electrical continuity check in all equipment and HV jumpers individually and prior to system integration.

4.2.2 Subsea HV dummy connectors to perform IR and electrical continuity test in all equipment and HV jumpers as part of troubleshooting activities to effectively locate the point of failure in the SEPS.

4.2.3 Subsea parking places to allow parking of HV jumpers and subsea HV dummy connectors in adequate number to minimize subsea operations.

4.2.4 Surface protection caps.

4.2.5 Subsea protection caps.

4.2.6 HV jumpers' deployment frame to install HV jumpers separately and independently of other equipment installation, as per section 10 of this TS.

4.3 Subsea HV-PCS system spares in SUPPLIER´s scope of supply shall include all elements described in [1] and all elements described in item 4.2 of this TS.

4.4 SUPPLIER shall provide all special tools and tools´ related accessories as part of its scope of work to perform HV-PCS foreseen activities to assembly, test, install, connect, and disconnect, troubleshoot, retrieve, and repair any "Subsea HV-PCS Element" in the scope of supply.

4.4.1 SUPPLIER shall present a list of these special tools as part of the scope of supply.

5 SUBSEA HV-PCS TECHNOLOGY MATURITY ASSESSMENT

5.1 SUPPLIER shall perform a TMA, as per [4] and [5], of each selected Subsea HV-PCS Element to evaluate each element technical risk and maturity in line with the SP&BS application characteristics and safety and performance goals.

5.1.1 TRL shall be assessed using the design requirements stated in this TS and the Type Tests stated in [6]. Each element gap to assure TRL 4 shall be identified, and the qualification activities and Type tests needed to assure TRL 4 shall be clearly identified and performed as part of detailed engineering phase, as stated in [1] and [3].

5.1.2 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 [3].

5.1.3 SUPPLIER shall present the Subsea HV-PCS TMA Report in the first SEPS technical meeting, together with the action plan with detailed scope and schedule to be performed during Detail Design stage to assure TRL4 achievement before element manufacture starts and to assure TRC C achievement during all project life cycle stages, from Detail Design to Operation.

5.2 SUPPLIER shall provide a Qualification Assurance Report, as per [5], for each element assured TRL 4 reporting, as a minimum, the following:

5.2.1 Design documentation as per section 4.1 of [6] including the complete list of design documents with document number, title, revision, emission date and summary.

5.2.2 Type Test documentation as per section 4.2 of [6] including the complete list of procedures and test reports with document number, title, revision, emission date and summary.

5.2.3 Design Analysis documentation as per section 4.5 of [6] including the complete list of analysis reports with document number, title, revision, emission date and summary.

5.2.4 Subsea HV-PCS Element datasheet as per section 4.6 of [6].

5.2.5 Improvements arising from Subsea HV-PCS Element manufacture and assembly procedures, tools, and facilities.

5.2.6 Improvements arising from qualification testing and assessment.

5.2.7 Improvements in QC/QA procedures.

5.2.8 List of manufacturing, assembly, testing, and QC/QA documents validated through Subsea HV-PCS Element qualification test program to achieve TRL 4 and TRC C with document number, title, revision, and emission date.

5.2.9 Potential Subsea HV-PCS Element and component´s weaknesses, residual risks, and uncertainties.

5.3 SUPPLIER shall provide a Track Record Report for each element assured Field Proven reporting, as a minimum, the following:

5.3.1 List of previous installed elements informing operator, project name and operation conditions (water depth, ambient temperature, voltage, current, frequency, differential pressure for penetrators, jumper length and configuration, i.e., single-phase or arranged in a three-phase bundle, cable interfaced).

5.3.2 Design documentation as per section 4.1 of [6] including the complete list of design documents with document number, title, revision, emission date and summary.

5.3.3 Type Test documentation as per section 4.2 of [6] including the complete list of procedures and test reports with document number, title, revision, emission date and summary.

5.3.4 Design Analysis documentation as per section 4.5 of [6] including the complete list of analysis reports with document number, title, revision, emission date and summary.

5.3.5 Subsea HV-PCS Element datasheet as per section 4.6 of [6].

5.3.6 Improvements arising from Subsea HV-PCS Element manufacture and assembly procedures, tools, and facilities.

5.3.7 Improvements arising from system integration, installation, and subsea operations.

5.3.8 Improvements in QC/QA procedures.

5.3.9 List of manufacturing, assembly, testing, and QC/QA documents to assure TRC C with document number, title, revision, and emission date.

5.3.10 Potential Subsea HV-PCS Element and component´s weaknesses, residual risks, and uncertainties.

5.4 PETROBRAS, as its own discretion and during all project phases, may ask for a *dataroom* to verify any document listed in the TMA Report, Qualification Assurance Report and/or Track Record Report.

6 SUBSEA HV-PCS ELEMENTS GENERAL DESIGN REQUIREMENT

6.1 Only single-phase WM connectors and penetrators shall be used.

6.2 Test current (I_r) used in Type tests shall be at least 20% higher than HV-PCS Elements maximum operational current at the SP&BS *in situ* ambient condition.

6.3 Test voltage-to-earth voltage (U_0) used as reference in Type tests shall be at least 10% higher than HV-PCS Elements maximum operational phase-to-earth voltage of the SP&BS.

6.4 Design requirements shall be according to section 5 of [6].

SUPPLIER shall produce a Design Final Report as per section 4.1 of [6] as part of the Subsea HV-PCS Databook to be delivered to PETROBRAS.

7 QUALIFICATION TESTS

7.1 As stated in item 5.1 of this TS, SUPPLIER shall perform all qualification activities and Type tests not already successfully executed prior to project award to assure TRL 4 according to the design requirements stated in this TS and according to the Type testing stated in [6].

7.1.1 A detailed qualification scope, as per sections 10 and 11 of [6], and qualification schedule for each Subsea HV-PCS Element shall be presented in the first SEPS technical meeting, as stated in [1].

7.1.2 Each Subsea HV-PCS Element shall have its qualification program started immediately after the first SEPS technical meeting, as stated in [1].

7.1.3 The Subsea HV-PCS Element manufacturing shall begin only after all element qualification program is completed, with the element successfully qualified and the

Qualification Assurance Final Report, as per item 7.3 of this TS, approved by PETROBRAS.

7.2 SUPPLIER shall perform, as a minimum, the Type tests for new interface cable in section 11.3 of [6] for each new interface cable not previously qualified. However, if there has been a change to the cable interface to suit a new type of cable, the new interface cable qualification tests in section 11.3 of [6] shall be repeated unless reasonable justification for not doing so is provided by SUPPLIER supported by previously performed tests procedures and test results reports.

7.3 SUPPLIER shall produce a Qualification Assurance Final Report, with detailed test procedures and reports as per section 4.2 of [6] and section 7 of this TS, as part of the Subsea HV-PCS Databook to be delivered to PETROBRAS.

8 FACTORY ACCEPTANCE TESTING

8.1 Subsea HV-PCS Element shall be assembly and tested by trained personnel.

8.2 FAT shall be according to Routine tests in sections 7, 8 and 9 of [6].

8.3 At the end of FAT, SUPPLIER shall measure the IR of each surface test connector in the scope of supply separately and perform the IR measurements of dummy connectors and HV jumpers (WM terminated and penetrator terminated jumpers) with these surface test connectors.

8.3.1 IR shall be measured applying 5kV and registered at 30 seconds, 1 minute, 5 minutes and 10 minutes. IR measurements shall be stable or slightly increasing over time.

8.3.2 Date, connector, or jumper assembly PN, ambient temperature and humidity shall be registered.

8.3.3 All information shall be organized in a spreadsheet and future IR measurements up to system integration and installation shall be registered in this spreadsheet and the document updated for comparison and IR trend.

8.4 FAT documentation shall be according to section 4.3 of [6].

8.5 As built documentation shall be according to section 4.4 of [6].

8.6 SUPPLIER shall produce a FAT Final Report, with detailed test procedures and reports as

per section 4.3 of [6] and section 8 of this TS, as part of the Subsea HV-PCS Databook to be delivered to PETROBRAS.

9 SUBSEA HV-PCS PACKAGING AND SHIPPING REQUIREMENTS

9.1 Connectors´ storage and transportation shall comply with item 5.11 of [6].

9.2 Connectors shall be shipped with protection caps and inside plastic or similar material protection to avoid contact with dust and humidity.

9.3 All Subsea HV-PCS Elements shall be shipped inside storage cases adequate for offshore transport.

9.3.1 The storage cases shall be resistant, stable and with handling fixtures for onshore and offshore handling with crane.

9.3.2 The storage cases shall provide ingress protection against dust and humidity. Storage cases shall not be made of wood.

9.4 The storage cases shall have internal fixtures to maintain the component stable and protected from shock, vibrations and displacements during handling, storage, and transportation.

9.5 For long components like jumpers and connectors terminated with long pigtails, the storage case internal fixture shall respect the cable minimum bending radius and prevent any bending or torsion to occur on cable or cable termination during handling, storage, and transportation.

9.6 Cable pigtail not terminated in connector or penetrator shall be adequately protected to avoid ingress of dust and humidity.

9.7 The integrity of the storage case shall be maintained, and component shall remain inside its storage case up to its integration with subsea equipment.

10 SUBSEA HV-PCS SUBSEA INSTALLATION AND OPERATION REQUIREMENTS

10.1 After UTA and subsea pump module installation, all HV subsea connections shall be made by means of HV flying jumpers terminated in WM connectors adequate for ROV operation.

10.1.1 In order to facilitate subsea operations (launching, handling and connections by

ROV), the jumpers shall have lifting points and handling accessories to allow cable operations with hoist.

10.1.2 HV jumper hose shall be designed with intermediate handles to facilitate ROV operation. The number and placement points shall be validated on subsea installation and operations studies.

10.2 SUPPLIER shall perform a subsea installation and operations study to support all HV jumper procedures to guarantee they can be performed by a single ROV without auxiliary tools or systems.

10.2.1 The analysis shall consider, at least, hose stiffness, jumper length and weight, ROV flying conditions, ROV positioning for connections / disconnections / parkings, locking and unlocking mechanism, ROV load capability, HV connection positions at ROV interface panel at UTA and at Pump Module, HV jumper arrangement at the deployment frame and all other relevant information that may impact ROV operations.

10.2.2 All connection and disconnection scenarios shall be analyzed and tested.

10.3 A HV jumpers´ deployment frame shall comply with [2] and be designed:

10.3.1 To install the 3 (three) single-phase or the 1 (one) three-phase HV jumpers separately and independently of other subsea equipment installation.

10.3.2 To protect the HV jumpers during installation and retrievable operations.

10.3.3 To respect jumpers minimum bending radius.

10.3.4 To be installed by cable.

10.3.5 With only one hoisting point for offshore installation. More hoisting points may be considered for transportation.

10.4 SUPPLIER shall perform the HV jumpers´ deployment frame installation and retrieval studies.

10.4.1 Slings shall be design shall consider hoisting loads and maximum installation and retrieval loads indicated in the installation and retrieval studies.

10.5 HV jumper connectors shall be easily connected and disconnect by ROV.

10.5.1 A connection mechanism shall provide a mechanical alignment system with visual indication prior to any electrical contact and that facilitate ROV operation.

10.5.2 A connection mechanism with visual indication shall guarantee that both male and female (plug and receptacle) WM connectors are fully connected and locked in the connected position and to avoid accidental or not intentional disconnection.

10.5.3 Connection mechanism shall be tolerant to marine growth, sand deposition and/or calcium-magnesium layer deposition. Deposition of such material shall not affect locking and unlocking the connector.

10.5.4 Connection mechanism shall be designed for subsea cleaning and spillage in connected position.

10.5.5 External connection mechanism shall be avoided.

10.6 HV jumper connectors shall have adequate handle bars for ROV interface.

10.6.1 Handle type (D-handle, T-bar, O-bar, Fishtail etc.) shall be defined for direct operation of ROV manipulator considering load, distance and position precision criteria at each ROV operation.

10.7 Interface between HV connectors and cable shall be protected with bend stiffeners.

10.8 All subsea connectors shall be installed with subsea protective caps.

10.9 SUPPLIER shall guarantee that any forces, flexions, and torsions the HV-PCS elements are subjected during assembly, testing, storage, installation, and operation, including cable loads and accidental loads during element transposition, do not surpass design loads.

10.9.1 Those loads shall be clearly specified in all HV-PCS procedures.

10.9.2 Installation and retrieval HV jumper procedures shall clearly specify limits of bending radius, flexion, torsion etc.

11 SUBSEA HV-PCS DATABOOK

11.1 SUPPLIER shall provide the Subsea HV-PCS Databook before HV-PCS installation including, as a minimum:

11.1.1 Design Report as per item 6.4

11.1.2 Each element Qualification Assurance Report as per item 5.2 of this TS.

11.1.3 Each element Track Record Report as per item 5.3 of this TS.

11.1.4 Transportation, receipt transportation, lifting, storage, installation, final inspection, deployment, and retrieval detailed procedures.

11.1.5 As Built documentation as per section 4.4 of [6].

11.1.6 Qualification Assurance Final Report as per item 7.3.

11.1.7 IR measurements timeline and trend as per item 8.3.3.

11.1.8 FAT Final Report as per item 8.6.