ELEKTROINŠTITUT MILAN VIDMAR

TECHNICAL SPECIFICATIONS FOR PHASE SHIFTING TRANSFORMER DIVAČA SUBSTATION 400 KV, 600 MVA, ± 40 °

Study No.: 2735, Rev. 2

Ljubljana, November 2026

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ABSTRACT

This Technical Specification defines the minimum technical, functional, design, manufacturing, testing, documentation, transport, installation, commissioning and performance requirements for the supply of one three-phase 400 kV, 600 MVA, Phase-Shifting Transformer (PST) with associated auxiliary equipment for installation at the 400/220/110 kV Divača Substation in Slovenia.

The new PST forms part of the long-term development of the Divača substation and shall be fully compatible with the two existing phase-shifting transformers already in service. The supplied equipment shall enable secure and reliable parallel operation of all three PST units while maintaining full interoperability of protection, control, monitoring, communication and automation systems under all specified operating conditions and tap positions. The design shall also ensure operational flexibility, allowing any single transformer to be removed from service without compromising the required functionality of the installation, subject to applicable operational limitations.

The specification establishes the technical requirements for all major PST components, including the active part, magnetic core, windings, bushings, cooling system, on-load tap changer (OLTC), advance-retard switch (ARS), monitoring equipment, current and voltage transformers, protection devices, control cubicles, communication interfaces and auxiliary systems. Particular emphasis shall be placed on long-term operational reliability, maintainability, environmental performance, operational safety and compliance with the IEC 60076-57-1202, IEC 60076 series, IEC 60214, IEC 61869 and other applicable international standards.

The scope of supply includes factory design, manufacturing, routine and type testing, transport, supervision of installation, commissioning, site acceptance testing, personnel training, spare parts, documentation and integration of the PST monitoring system into the existing ELES central monitoring platform. In addition, the Contractor shall provide a BIM

model developed to Level of Development (LOD 350, 400 and 500) to support installation, construction coordination and future asset management.

The objective of this specification is to ensure that the supplied Phase-Shifting Transformer provides high operational availability throughout its service life, achieves full compatibility with the existing installation at Divača Substation, and satisfies the technical, operational and reliability requirements of the Slovenian Transmission System Operator (ELES) for secure operation of both the Slovenian and interconnected ENTSO-E transmission networks.

Keywords: Phase-Shifting Transformer (PST), 400 kV, Divača Substation, Parallel Operation, On-Load Tap Changer (OLTC), Advance-Retard Switch (ARS), Transformer Monitoring System, Protection and Control, IEC 60076, BIM (LOD 350, 400 and 500).

LIST OF ABBREVIATIONS

COLM	Central On-line Monitoring
OLM	On-line Monitoring
DGA	Dissolved Gas Analysis
EMC	Electromagnetic Compatibility
FAT	Factory Acceptance Tests
SAT	Site Acceptance Tests
FRNC	Flame-Retardant Non-Corrosive Halogen Free
OLTC	On-load Tap Changer
ARS	Advance-Retard Switch
S/S	Substation
TS	Technical Specification
PST	Phase Shifting Transformer
JO and SOLO	Contractor-specific terminal designations used for the common and separate neutral connections of the exciting transformer winding. The designations are retained throughout this specification for consistency with the existing PST units
Purchaser	ELES, d. o. o.
Contractor	Company awarded the Contract and responsible for the complete supply of the PST
Manufacturer	The entity responsible for the design and manufacture of the equipment or its components.

TABLE OF CONTENTS

1 GENERAL INTRODUCTORY INFORMATION 6

1.1 Scope of Tender documents 6

1.2 Subject, scope and limits of supply 8

1.3 On-site Conditions 9

2 GENERAL REQUIREMENTS 11

2.1 Measuring units 11

2.2 Standards and codes 11

2.3 Materials and workmanship 11

2.4 Review of the suitability of production processes 12

2.5 Final assembly 12

2.6 Standard voltages 13

2.7 Components identification, Inscriptions and Displays 13

2.8 Colour Code 14

2.9 PST Design 14

2.10 Manufacturing requirements 15

2.11 Cabinets and Marshalling Racks 16

2.12 LV cables of the PST 18

2.13 Instrumentation and control equipment 18

2.14 Low voltage switchgear and protective elements 18

2.15 Wiring and connection elements 19

2.16 Auxiliary equipment 20

3 ACCEPTANCE TESTS 21

3.1 Interphase control and measurements in the manufacturing process 21

3.2 Factory acceptance test 21

3.3 Site acceptance test 22

4 TECHNICAL ENVIRONMENTAL AND SAFETY REGULATIONS 23

5 MATERIALS AND WORKMANSHIP 24

6 PACKAGING 25

7 TRANSPORT, LOADING AND UNLOADING 26

8 DOCUMENTATION 28

9 WARRANTY PERIOD 30

10 ERECTION SUPERVISION AND OPERATION START 31

11 SPARE PARTS 32

12 TRAINING 33

13 MAIN TECHNICAL CHARACTERISTICS 34

13.1 General and ratings 34

13.2 Operating conditions 43

13.3 Continuous output rating 43

13.4 Losses 43

14 SCOPE AND LIMITS OF SUPPLY 45

14.1 Scope of supply 45

14.2 Erection tools 45

14.3 Limits of supply 45

14.4 Scope of erection and supervision 46

15 CONSTRUCTION, MATERIALS, WORKMANSHIP 47

15.1 Standards 47

15.2 General requirements 49

15.3 Magnetic circuit 49

15.4 Windings 51

15.5 PST Insulation oil and paper 54

15.6 On-Load Tap Changer (OLTC), Advance-Retard Switch (ARS) and Parallel Operation 55

15.7 Cooling system 60

15.8 Bushings 63

15.9 Current transformers 66

15.10 Measuring, monitoring and protection equipment 70

15.11 On-line monitoring system 73

15.12 Measuring equipment and sensors 74

15.13 Erection works 78

15.14 Winding and core temperature optical sensors 78

15.15 PST tanks, Conservators and Oil Preservation System 80
15.16 Dehydrating breather 84
15.17 Piping, valves, joints, stainless steel flange and gaskets 85
15.18 PST pressure relief valves / devices 88
15.19 Identification plates 89
15.20 Grounding terminals 90
15.21 Anticorrosion protection 91
15.22 Support Reactions 95
15.23 PST Foundation and layout drawings 95

16 ERECTION REQUIREMENTS 97
16.1 Erection works at site 97
16.2 Erection supervision 98
16.3 Other requirements 98

17 INSPECTION AND TESTS 100
17.1 Factory tests 101
17.2 On site tests 105

18 QUALITY CONTROL DOCUMENTATION 109
18.1 QA certificates 109
18.2 Test reports 109
18.3 Functional test and QA certificates 109
18.4 Interphase inspection report 110

19 CONTRACTOR DOCUMENTATION 111
19.1 General project documentation 112
19.2 Active part and electrical design documentation 112
19.3 OLTC/ARS documentation 114
19.4 Bushings and current transformers 114
19.5 Tank, cooling system and oil system documentation 115
19.6 Measuring, monitoring, protection and auxiliary systems 116
19.7 Foundation, transport and erection documentation 117
19.8 Quality, inspection and test documentation 117
19.9 Operation and maintenance documentation 118
19.10 Dynamic thermal model of the PST 118
19.11 Carbon footprint of PST manufacturing 119

20 TENDERER DOCUMENTATION 120

21 SCHEDULES OF TECHNICAL DATA 122

LIST OF FIGURES

Figure 1: Name Plate of Divča PST-441 36
Figure 2: Name plate of Divča PST-442 37
Figure 3: Technical data OLTC 1a 38
Figure 4: Techical data OLTC 1b 39
Figure 5: Technical data on the existing PST 40
Figure 6: Inteconection Between the Two On-Load Tape Changers (OLTCs) 41
Figure 7: PST Protection Scheme 42
Figure 8: Current transformers in series unit of PST 67
Figure 9: Current transformers in Exciting unit of PST 67
Figure 10: Isometric View of the Third PST Layout at Divača Substation 128
Figure 11: Electrical Drawing – Third PST Installation at Divača Substation 129
Figure 12: Plan View of the Third PST Layout at Divača Substation 130

LIST OF TABLES

Table 1: Standard voltages 13
Table 2: Colour code 14
Table 3: Required Level of Development (LOD) of Delivered BIM Models 28
Table 4: General data 34
Table 5: Test voltages/Insulation Levels 53
Table 6: Bushing’s insulation levels 66
Table 7: Technical Schedule-Current Transformers 69
Table 8: Anticorrosion protection of PST radiators 91
Table 9: Anticorrosion protection of PST tank 92

Table 10: Protective coating specification 92

Table 11: Inspections 93

Table 12: Schedules of Technical Data 122

1 GENERAL INTRODUCTORY INFORMATION

1.1 Scope of Tender documents

The Slovenian transmission network forms an integral part of the ENTSO-E interconnected European electricity system, within the Continental Europe synchronous area. Due to Slovenia's geographical position between Central Europe, South-Eastern Europe and the Northern Italian electricity system, the Slovenian electric power system is strongly exposed to cross-border exchanges, transit flows and regional market-driven power flows. The Slovenian transmission system is connected with the neighbouring transmission systems of Austria, Croatia, Italy and Hungary, and therefore plays an important role in the secure operation of the wider interconnected European power system and in the functioning of the internal European electricity market. ELES states that the Slovenian transmission network is well connected to the Austrian, Italian, Croatian and Hungarian systems and that Slovenia participates in the development of the single European electricity market.

In the period since the original project documentation was prepared, the operating environment of the European power system has changed significantly. The former UCTE framework has been incorporated into ENTSO-E, while market integration, coordinated capacity calculation, regional security coordination and the implementation of European network codes have substantially increased the need for coordinated and controllable cross-border operation. Capacity calculation is now organised through capacity calculation regions, which define the bidding-zone borders where coordinated capacity calculation is applied. Slovenia is part of the Core capacity calculation region, which includes, among others, Austria, Croatia, Hungary and Slovenia, while the Slovenian–Italian border is closely linked with the Italy North / Central European coordination framework.

At the same time, the European transmission network is increasingly affected by decarbonisation, large-scale integration of renewable energy sources, changes in generation dispatch, electrification of demand, and higher variability of commercial exchanges. These developments lead to more frequent changes in the magnitude and direction of physical power flows. As ENTSO-E emphasises, European transmission systems have become more interconnected, while variability of power flows has increased, requiring stronger regional coordination among transmission system operators.

Because of its relatively small size, limited domestic controllable generation portfolio and unfavourable transit position, the Slovenian transmission system cannot independently and fully influence the resulting physical power flows caused by regional market transactions. Commercial exchanges between different European market areas may therefore create substantial physical flows through Slovenia, especially on the westward and south-westward corridors towards Italy. These flows may change rapidly depending on the regional generation-load balance, renewable production, hydrological conditions, outages, market schedules and available cross-border capacities.

The 400 kV interconnection between Slovenia and Italy, in particular the Divača – Redipuglia/Divača–Redipuglia corridor, remains a strategically important element

for the integration of the Slovenian and Italian electricity markets, for secure cross-border transmission and for regional adequacy. ELES and Terna have recently agreed on a joint upgrade of the cross-border connection between Slovenia and Italy, with the objective of increasing transmission capacity, strengthening market integration and improving the adequacy of the interconnected power system. The project includes the upgrade of the phase-shifting transformer arrangement in the Divača substation by adding a new third unit, enabling the full utilisation of the 400 kV Divača–Redipuglia line capacity. The present transmission capacity of this corridor is 1,200 MVA, while after the upgrade it is expected to increase to 1,800 MVA.

The existing phase-shifting transformer installation in the Divača substation, with a total nominal through power of 2 × 600 MVA, has occasionally been operated close to or above its desirable loading level. In addition to the need for higher controllability of active power flows on the Slovenian–Italian border, operational experience has shown the importance of redundancy and maintainability of this key cross-border control asset. The installation of a third 400 kV phase-shifting transformer unit with a nominal through power of 600 MVA and the same regulation range of ± 40 ° (electrical degrees) will increase the available controllable transfer capability and improve the operational flexibility of the Divača substation.

The third PST unit will enable the three-unit arrangement to achieve a total nominal through power of 1,800 MVA under normal operating conditions. It will also provide an important maintenance advantage: during scheduled maintenance or outage of one PST unit, the remaining two units will still be available for operation, thereby preserving a significant part of the controllable cross-border capacity and reducing the operational risk associated with maintenance of a single unit. This is particularly important because the PST in Divača is a critical device for controlling physical flows on the Slovenian–Italian 400 kV corridor and for maintaining secure operation of the Slovenian transmission network under both normal and disturbed operating conditions.

Based on present and expected future power system conditions, the installation of the third 400 kV PST unit in the Divača substation is therefore justified by the following main requirements: increased controllability of active power flows on the Slovenian–Italian border; mitigation of overloads and loop flows caused by regional market exchanges; improved utilisation of the 400 kV Divača–Redipuglia interconnection; higher operational security under N-1 and maintenance conditions; increased flexibility for coordinated ENTSO-E system operation; and improved support for the continued integration of the Slovenian transmission system into the European internal electricity market.

Consequently, in order to ensure secure, reliable and flexible operation of the Slovenian electric power system, and to maintain adequate controllability of power flows under present and future European transmission system conditions, the installation of a third 400 kV phase-shifting transformer unit in the Divača substation is foreseen.

1.2 Subject, scope and limits of supply

The subject of supply includes:

- one three-phase 400 kV phase-shifting transformer unit for installation in the Divača substation,
- all associated equipment, accessories, control and protection interfaces,
- documentation,
- factory tests,
- transport,
- erection with supervision,
- site testing and commissioning services required for safe and reliable integration with the existing PST installation,
- supply shall also include spare bushings for the phase-shifting transformer installation, namely one spare 400 kV bushing (BIL 1550 kV), one spare JO (SOLO). The JO and SOLO spare bushings shall each have a basic insulation level (BIL 550 kV). All spare bushings shall be fully compatible with the supplied transformer unit and suitable for long-term storage and future replacement under the applicable service conditions,
- one additional vacuum-type DSI On-Load Tap Changer (OLTC).

The new PST unit shall be designed for parallel operation with the two existing PST units in the Divača substation. Its design, ratings, phase-shifting range, control philosophy and operational characteristics shall be compatible with the existing installation, so that the complete three-unit arrangement can be operated as an integrated PST system for active power flow regulation on the 400 kV Slovenian–Italian interconnection.

The upgraded PST installation shall enable operation with all three units in service, as well as operation with any two units in service and one unit out of service for maintenance or outage conditions, subject to the applicable operational limits, protection settings and network security criteria.

The scope of supply shall also include participation in the coordination of wiring works and connection at interface points, including support during testing of protection, control, monitoring and automation system functions. The Contractor shall provide supervision of installation works and commissioning of the phase-shifting transformer, remove all packing material and any other material used during transport and installation, and provide training for the Purchaser’s personnel. The Contractor shall also perform parameterisation of the on-line PST monitoring system, implement all required communication links and integrate the system into the existing ELES Diagnostic-Analytical Centre.. In addition, the Contractor shall supply 20 pieces of a 3D scale model of the phase-shifting transformer in scale 1:40.

The Contractor shall deliver a BIM model of the Phase-Shifting Transformer (PST) developed to Level of Development LOD (for more information, refer to Chapter 8). The

model shall be suitable for fabrication, installation, construction coordination and interface management, and shall include accurate geometry, dimensions, location, connection points, access and clearance requirements, anchoring/foundation interfaces, cable and auxiliary system interfaces, and all other information necessary for coordinated installation and integration into the Purchaser's BIM environment.

All installation works on the phase-shifting transformer and on the equipment included in the scope of supply shall be performed by the Contractor in accordance with the defined limits of supply.

The Contractor shall provide supervision of transport and unloading at the installation site. The Contractor shall prepare an installation and supervision programme, including a cost estimate for installation and supervision activities, and these costs shall be included in the offered price.

In performing the works, the Contractor shall comply with the restrictions, requirements and guidelines arising from the ISO 14001 and ISO 45001 standards, according to which the Purchaser is certified.

The scope of supply shall not include civil works. The Contractor shall provide, in due time, all documentation necessary for the continuation and completion of the project.

1.3 On-site Conditions

The Contractor shall take into account the following on-site conditions:

- The site altitude is below 1,000 m above sea level.
- The equipment shall be designed for the following ambient temperature ranges:
  - indoor equipment: from - 5 °C to + 40 °C, with an average relative humidity of up to 95 % over 24 hours;
  - outdoor equipment: from - 25 °C to + 40 °C (without solar irradiation).
- The equipment shall be designed to withstand seismic conditions. The design ground acceleration shall be ag = 0.25 g, for medium ground conditions, Tb = 0.15 s, and importance class IV in accordance with SIST EN 1998-1.
- The pollution level shall correspond to pollution degree b, in accordance with IEC/TS 60815-1.
- Ice conditions shall correspond to Class 10, in accordance with the applicable IEC standards.
- The equipment shall be designed for wind loading corresponding to a wind speed of 42 m/s or a wind pressure of 1.1 kN/m².
- The equipment shall comply with the maximum permissible audible noise level of 70 dB sound pressure level at rated voltage, rated frequency, no load operation and

without fans, and 72 dB sound pressure level at short circuit and 100 % with fans in operation.

- The equipment shall comply with the electromagnetic compatibility requirements applicable to similar high-voltage power substations.

2 GENERAL REQUIREMENTS

2.1 Measuring units

All measurements units shall be indicated in SI system (Système International d'Unités).

2.2 Standards and codes

Unless specified elsewhere in the below Special Technical Specifications, the design, used materials, manufacture and testing procedures of all products specified in this Tender document shall comply with the approved standard(s).

Approved standards are:

- SIST - Industrial standards valid in Republic Slovenia,
- EN (European standards),
- ISO (International Standardisation Organization),
- IEC (International Electrotechnical Commission).

Approved standard publications issued by the following organizations of standardisation are considered being approved standards for the execution of works:

- SIST - Industrial standards valid in the Republic of Slovenia,
- EN, CEN, CENELEC - European standards,
- ISO - International Standardisation Organization,
- IEC - International Electrotechnical Commission,
- DIN - Deutsche Industrie Norm (German industrial standards),
- ASTM - American Society for Testing and Materials,
- VDE - German Electrotechnical Commission.

If no SIST, EN, IEC, DIN, ASTM, VDE or ISO standards exist for any special case, then the Contractor can submit a national standard to the Purchaser. Any other standard as proposed by the Contractor will be accepted on the approval of the Purchaser and applications in the Contract, and provided the Standards are written or translated into Contract Language and the equivalent standards as listed under the following Article are indicated.

2.3 Materials and workmanship

Material's physical properties shall comply with the below tender requirements and be selected to fit best the basic target of the Purchaser to achieve good reliability, low maintenance cost and a long lifespan of the product. Materials shall be conforming to the latest technical achievements and in accordance with latest issue of the respective Standards. Material specifications, including grade or class, shall be shown on the

appropriate detailed drawings to be later submitted for review in course of setting of Contract. The Contractor shall demonstrate its experience by providing relevant references.

If during manufacturing of the equipment, deviations from the documentation and/or instructions occur, the Contractor must immediately inform the Purchaser about them.

2.4 Review of the suitability of production processes

To ensure a long service life of the transformer, the manufacturer must have a production process that ensures the cleanliness of the production premises and prevents the introduction of impurities into the production areas used for magnetic core assembly, winding manufacturing, winding assembly, assembly of the active part and final assembly.

The manufacturer must have internal standards aligned with ISO 9001, ISO 14001 and ISO 45001. The manufacturer must have procedures in place to ensure cleanliness during production as part of its QA/QC system.

ELES reserves the right to carry out a suitability check at the manufacturer's premises in the form of an assessment of the production premises and processes before concluding the contract (an audit). ELES also agrees to obtain the opinion of an independent institution.

The suitability check will also be carried out during the manufacture of the transformer itself in the form of intermediate inspections.

2.5 Final assembly

The final assembly process of the transformer, from the completion of the drying process of the active part (opening of the furnace) to the hermetic sealing of the transformer tank, must be carried out under controlled conditions of humidity and air temperature.

As part of the tender documentation, the manufacturer must submit a description of the process for performing the final assembly of the transformer at the factory under ambient conditions, together with supporting evidence.

ELES reserves the right to verify the adequacy of the conditions for final assembly at the manufacturer's premises during the tender phase, before concluding the contract, through an audit. ELES also reserves the right to obtain the opinion of an independent institution.

ELES reserves the right to verify the management of the conditions for final assembly of the transformer at the manufacturer's factory.

In the event of prolonged exposure of the active part to air with a higher moisture content, an extended final assembly process or poor ambient conditions, as determined by QC, ELES reserves the right to impose a contractual penalty and/or request re-drying of the active part once during assembly.

Re-drying shall be performed no more than once. The Tenderer must plan the activities to ensure that re-drying is not required more than once.

2.6 Standard voltages

The following standard voltages listed in Table 1 are applied on site:

Table 1: Standard voltages

Transmission System	
Network rated voltage	400 kV
Highest system voltage = Highest voltage for equipment	420 kV
Grounding	Effective
Low voltage System	
Three phase AC voltage	400/230 V, ± 5 %, five wire, grounded (TN-C-S)
Single phase AC voltage	230 V, ± 5 %, three-wire, grounded (TN-C-S)
DC control and protection voltage	220 V, -15 %, +10 %, not grounded
Inverter AC Supply	230 V, ± 1 %, three-wire, grounded (TN-S)

The voltages are maximum nominal operating voltages according to IEC 60038. AC system frequency is 50 Hz. The required nominal currents for the equipment and devices are stated in technical specifications.

2.7 Components identification, Inscriptions and Displays

In readably visible locations the identifications plates made of non-corroding or otherwise disintegrating material should be applied. Identification plate shall contain at least the Manufacturer's name, serial number, date of production and main technical data. All safety related (warning) plates, necessary for safe operation, and safety at work, shall have the standardized attributes in force on site and put in visible place. All identification plates shall be in Slovene language.

Each cable or wiring connection shall be on both sides suitably marked according to the designation from the cable list and the pertaining drawings.

2.8 Colour Code

In general, the colour coding of wiring in control panels, electrical connections, etc., shall be in accordance with the respective recommendations stated in IEC Standards (Table 2). Live parts of electrical connections shall respect the colour coding according to IEC 60445.

Table 2: Colour code

CONDUCTORS		Alpha-numeric Designation	Symbol	Colour
AC System	Phase 1	L1		Brown
	Phase 2	L2		Black
	Phase 3	L3		Grey
	Neutral	N		Light blue
DC System	Positive	L+	+	Red
	Negative	L-	-	Blue
	Neutral	M		Light blue
Common Grounding and Neutral in TN-C Systems		PEN		Green/yellow
Protection Grounding		PE		Green/yellow
Grounding		E		Black/light blue

Colour code on control panels and displays shall be marked to distinguish between the following voltage levels:

- 400 kV red
- 220 kV green
- 110 kV black
- 10.5 kV violet
- 400/230 V violet
- 220 V DC orange.

2.9 PST Design

The design of the unit shall enable installation on a flat surface and shall ensure compliance with all technical tender requirements, easy maintenance, and reliable and safe operation. During the design stage, the Contractor shall take into account the latest good engineering practice, as well as the latest applicable international and national recommendations, standards, and regulations. All site-specific requirements, including compatibility with the existing equipment and installations, shall also be considered.

Wherever possible, individual components and parts shall be standardised. This shall reduce the required number of spare parts and thereby simplify maintenance, exchange, and/or replacement. For this purpose, the Purchaser may require the use of certain types of small mechanical and electrical materials for the supplied equipment.

The equipment, including all auxiliary parts necessary for normal operation, shall be free from defects. During the design, manufacturing, and erection stages, the Contractor shall comply with all protection measures required by applicable codes and standards, with particular attention to grounding/earthing.

All LV electrical parts, which can be energised must be mechanically protected against accidental touching or additionally insulated. Mechanical protection could be disassembled with a special tool only.

2.10 Manufacturing requirements

The PST equipment (motor drive and marshaling cabinet etc.) shall be manufactured according to the latest good engineering practice having a mechanical protection level IP 55 at least according to SIST EN 60529.

Equipment must be provided with the required grounding connections.

LV connecting terminals, relays and instruments shall be placed in the protected part, being easily accessible during operation, and at the same time protected against accidental touch. Connection identification designations shall be clear and mounted on visible places.

Easy access shall be ensured to the terminals or connections and for the equipment and elements maintenance. Elements for manual operation control and monitoring shall be installed 80 to 180 cm above the final floor.

All equipment shall be suitable for the cable connections from the lower side; connection terminals shall be placed to allow for an easy access and assembling.

Control, signalling and power supply cables shall have cable shield grounded through EMC cable glands. EMC cable glands shall be supplied together with the PST.

Each cubicle or box shall have on the side, where the cables are grounded, an adequately shaped (one or more) plates, allowing reliable connection of cable shields to the ground (according to EMC guidelines and at least fulfilling the SIST EN 61936-1, IEC TR 61000-5-2 and IEC TR 61000-5-6 requirements).

All equipment shall be designed to prevent short circuiting caused by animals. On the lower side of the cubicles and boxes, metal plate with cable glands shall be installed.

All devices, connections and incoming cables shall be designed in a way to be prevented from the fire arise, fire expanding or any damage caused by the fire.

All cubicles and other equipment shall be equipped with connection terminals of adequate quality and numbered with durable numbers and designations, produced by a renown Contractor with positive references in this field. Terminals shall be harmonized with the

site and its choice can be requested by the Purchaser. Requested terminal are Weidmueller, Phoenix or similar of equal quality. All wiring connections shall be equipped with element/terminal designation.

All switching and protection equipment (circuit breakers, switches, MCBs, fuses, ...) must be of the adequate quality, produced by a company with positive references on the market and can be matter of the on-site harmonizing on Purchaser request. Components produced by Möller, Siemens, Schneider or ABB are preferred. Elements shall be installed into the cubicle in a logical order.

In any case, cubicle disconnection from the power supply using in-cubicle mounted hand-controlled switching elements shall be possible. For easier equipment operation monitoring, doors shall be equipped with adequate signalization.

Devices shall be of modular type, composed from units, suitable for easy transport and erection. Composing parts shall be fast exchangeable with no special tool required.

All conductors' connections shall be adequately handled (silvered or tinned) according to valid standards.

Supplied and erected equipment shall withstand all electrical, mechanical and thermal loading, which can arise during normal operation of the unit and in eventual short-circuit or ground-fault conditions.

Distances between conductors and grounded parts shall be according to valid technical codes and standards.

All cubicles and boxes shall be made from stainless steel.

Control and connection boxes shall be equipped with an anti-condensation heater. Operation of heaters shall be automatic with adjustable thermostatic relay. Cubicles shall be equipped with the light, switched on and off with a door mounted micro-switch.

Each component shall be equipped with Manufacturer's name and type designation and with nameplates for use designation in Slovene language.

Equipment parts, which are constantly or temporary on high voltage potential, must be protected against accidental touch and visible designated according to safety codes.

2.11 Cabinets and Marshalling Racks

Cabinets and marshalling racks shall be made from folded stainless-steel sheet having minimum thickness of 1.5 mm to ensure rigid mechanical support to the control and monitoring equipment. They must be supplied completed with all frames, doors (hinges and locks).

The cubicles, panels and marshalling racks shall be workshop completed and tested with all elements, labels, internal wiring, with all cable terminal connections and designations.

All cubicles must be suitable for continuous operation under the climatic conditions prevailing at Site. An adequate corrosion protection is also requested.

A proper natural ventilation of cubicles with dust-protected vent openings shall ensure keeping the temperature inside the cubicle below 55 °C in any conditions, supposing the maximum ambient temperature of 40 °C and equipment in normal operation.

It shall be designed according to IEC 60529, protection class IP 55.

All equipment inside cubicles must be installed in such a way to enable cable entry as needed due to implemented cable trays. Cable connections to cubicles must be provided with suitable seals as to prevent the ingress of dust, water, vermin, or the propagation of an eventual fire.

Each panels/cubicle must be provided with grounding devices for grounding of incoming cables as requested by EMC regulations. A Cu grounding bar having a minimum cross-section of 30 x 5 mm shall run the full length of the cubicles, panels or boards. Each grounding bar shall be directly connected to the PST tank by using NYYJ Cu 70 mm^2 conductor. All metallic cable shields of external cables (entering this cubicle) shall be directly connected using screws to the grounding bar. All metallic cable shields of internal cables (entering this cubicle) shall be connected to the grounding system using EMC cable glands.

All metallic parts of cubicle/panel/rack must be directly connected in order to form a unique galvanic unit due to operational safety and EMC. Doors and other not fixed parts must be grounded together with the cubicle/panel/rack housing applying Cu braided flexible connection having minimum cross-section of 16 mm^2.

All elements intended for operational interactions (instruments, control and selector switches, indicating lamps, pushbuttons, displays and others) shall be flush-mounted at conveniently accessible heights on the front of the cubicle or cubicle door. These elements must be installed higher than 80 cm, but not more than 180 cm above the ground in a logical and clear manner. The layouts of all the front views are subject of the Purchaser approval.

An adequate vibration and shock-absorbers must be installed wherever required for the correct operation of installed elements.

After accomplishment of the final commissioning, all panels/cubicles must have at least 20 % spare space for installing of additional elements.

Clearances between live parts and to earth shall be in accordance with the latest relevant technical and safety regulations. Equipment live parts must be protected against accidental human touch and adequately labelled.

Anti-condensation heaters, with AC single phase power supply, shall maintain the inside temperature of cubicles or compartments by about 5 °C above the ambient temperature to prevent internal condensation. Heaters in switchgear cubicles, control cubicles, panels, desks, etc., shall be temperature controlled automatically by adjustable thermostats.

2.12 LV cables of the PST

All cables of voltages 230/400 V AC and 220 V DC shall be made for temperature range from -25 °C to 120 °C and shall be suitable for outdoor installation. Copper cord shall be flexible, finely wired (IEC 60228, cl. 5); insulation shall be flame retardant and non combustible (FRNC), marked/numbered, with screen of tinned copper shield (at least 80 % of the area around the circumference), sheath shall be FRNC. All material shall be halogen free and UV resistant.

2.13 Instrumentation and control equipment

Measuring ranges of delivered sensors and other elements of all measuring devices, particularly of the OLM, must be adapted to the ranges where the measuring values are to be normally expected.

An adequate length of cables supplied as integral part of the measuring/control devices must be provided to strictly avoid any additional couplings between the sensor and the destined terminal box. Prefabricated field proven connectors must be provided for such integrated sensor-cable components.

The following general requirements shall be respected:

- Equipment shall be suitable (e.g. IP protections level) for the ambient in which the instrument will be located.
- All analogue transmitters shall have a current output of 4-20 mA. DC isolated output is strictly requested. Two wire connections are preferred. If this is not applicable, a power supply is requested.
- Current capacity and electric resistance of contacts must enable reliable direct connection to the control system (220 V DC).
- All supplied equipment must enable satisfactory terminating and grounding of cables.
- All transmitters shall have internals and fittings of a corrosion resistant material suitable to the medium being measured.
- All components shall be suitable for continuous operation under site conditions.
- All instrumentation and control circuits shall be designed for 220 V DC.
- Measuring points selected for protection purposes shall be separated and shall not be combined with the control system.
- All protection devices must enable two separated, normally open, free contacts (trip contacts) for protection system.

2.14 Low voltage switchgear and protective elements

All auxiliary system elements shall be dimensioned in a way to assure continuous operation of the entire cooling system at nominal PST loading (MCBs, cables, wiring and other).

MCBs shall be of single or three phase type, adequately current dimensioned, with sealed doors/opening mechanism. If required they must be equipped with auxiliary contacts.

Contactors must be air type with enclosure class AC 3 acc. to IEC standards. Switched on, they shall withstand fault currents until breaking executed by the selective over-current protection element. Thermal overcurrent trigger shall be of the adjustable type, suitable to the drive requirements and temperature compensated to the temperature 70 °C.

Fuses shall be selective type; they shall suitably break short circuit currents in the circuit. No special tools for fuse replacement should be required for up to 63 A rated current.

Switches shall enable hand control from the front side. They shall be equipped with a control handle and self-cleaning contacts in hard enclosure, with mechanism for fast on and off operation, capable of switching of the rated current. They may be equipped with HRC fuses in parallel if necessary.

2.15 Wiring and connection elements

All wiring inside panels, racks, boards, etc. shall be made of stranded copper wires with a minimum cross-section of 1.5 mm^2. The insulation material shall be of fire-resistant and UV - resistant polyvinyl chloride (PVC), or of other approved type. The wiring shall be capable to withstand without deterioration under conditions prevailing at the individual place of installation. All control and power cables must be shielded.

Every wiring connection must be completed with wiring terminations, dimensioned according to the wiring cross-section. All connections to the outer devices must be arranged on one or more terminal strips.

Terminal strips shall be numbered beginning from left to right and from top to bottom.

Terminals shall be of the adequate quality and shall be harmonized to the substation where they have been mounted on the terminal strip. Terminals shall be self-supported, non-inflammable consisting of two separate pressure clamping plates suitable for connection of incoming or outgoing stranded or solid conductors respectively. All internal wiring shall enter the terminal block at one side only. All terminal blocks shall contain 20 % spare terminals of category C. Insulation barriers shall be provided between each pair of power circuits and between the terminal categories, their shape shall be such as to give adequate protection to the terminals whilst allowing easy access to the same.

All connections shall be efficiently protected against oxidation and electrolysis damage. All connections shall be designated with non-ageing identification ferrules. The ferrules shall be clamped in such a way that they cannot become loose after removing the wire from the terminal.

2.16 Auxiliary equipment

Where appropriate, each constitutive part of the PST unit shall be equipped with all necessary auxiliary switches, contactors and mechanisms of indication/signalling, protection, metering, control, interlocking and other function/services. All auxiliary switches shall be wired up to a terminal board, assembled in an accessible position clear of the operating mechanism and are to be protected in a suitable way to obtain a strong long lasting contact system.

All equipment, whether fitted with a heating device or not, shall be provided with suitable drainage and be free from pockets in which moisture can collect.

The protection relays shall be adequately selected for the system elements protection. The protection relays shall be equipped with all necessary auxiliaries such as tripping unit, time relay, external resetting device (hand reset flag with seal-in operation). The relays shall provide easy access for testing and setting purposes. Tripping of a protection system shall be indicated as an alarm.

3 ACCEPTANCE TESTS

Acceptance tests comprise equipment testing intended to formally verify design, construction and functional ability of a device and system. Complying with specifications is assessed by verification of analytical data, element testing and operation demonstrations. Final acceptance shall include also verification of the supply completeness and approval of the relevant documentation.

Beside type tests and special measurements and tests, required in Special technical specifications, the most important tests are:

- interphase control and measurements in the manufacturing process,
- factory acceptance tests and
- site acceptance tests.

3.1 Interphase control and measurements in the manufacturing process

Inter-phase measurements on the active part of the PST will be performed to verify the electrical condition and insulation integrity between phases. Samples of the paper insulation will be taken and included in the drying process of the windings and the active part for subsequent DP analysis, to assess the condition and ageing level of the cellulose insulation. A visual inspection of the PST active part will also be carried out to identify any visible mechanical damage, contamination, deformation, displacement of components, loosened connections, or other abnormalities before further assembly or continuation of the refurbishment process. The inspection hold points will be defined during the design review.

3.2 Factory acceptance test

Factory acceptance test (FAT) shall be executed in the Manufacturer's works applying suitable testing equipment and supervised/certified by the factory QA/QC services. Contractor shall prepare written procedures for factory testing, according to valid technical codes and latest standards. Factory testing procedures proposal shall be submitted to the Purchaser for approval. Factory tests shall be executed by the Manufacturer according to by Purchaser approved procedures under witnessing by the Purchaser or/and Purchaser's authorized personnel. The order of the tests must be carried out in accordance with the applicable standards. Regardless of FAT results, the Contractor remains responsible for correct equipment operation after transport and erection/assembling at site. Responsibility is not depending on the Purchaser FAT approval. Factory tests shall be carried out according to approved procedures, all pertaining activities shall be done by the Manufacturer. Independently from the Purchaser test approval, also after erection, the Contractor remains still responsible for the correct operation of the equipment. It is the Contractor's duty to plan and organize the test procedures execution. Factory acceptance test shall verify all in related documents specified attributes/functionality of the equipment in the factory environment. Contractor shall prepare in advance the testing timetable with

a list of testing procedures to be done and inform Purchaser before testing according to the time schedule, approved by Purchaser. Contractor duty is to submit measurement procedures, certificates and other evidence about calibration status and suitableness of the testing and measuring equipment. All deviations from the expected and required results, characteristics and magnitudes/values shall be documented in the Contractor's diary. Necessary repair and/or any corrective actions shall be enlisted, described, examined and commented by Purchaser and Contractor representatives. In case of any deviations, the project manager can demand in name of the Purchaser a stop-works and repeating testing and/or examination of unsuitable equipment or auxiliary modules. The PST shall be energised at rated frequency under test conditions corresponding, as far as practicable, to the rated operating conditions. For a three-phase unit, three-phase excitation shall be applied where required by IEC 60076-57-1202 and by the approved test programme.

3.3 Site acceptance test

Site tests on equipment shall be performed by the Contractor after erection on the site and before technical commissioning. Before start, the Contractor shall submit to Purchaser all proposed procedures to approve.

Site acceptance tests shall be executed by the Contractor according to by Purchaser approved procedures under witnessing by the Purchaser or/and Purchaser's authorized personnel. The order of the tests must be carried out in accordance with the applicable standards.

All equipment Contractor's instructions and guidance, generally valid codes, standards and Purchaser requirements shall be considered.

The Purchaser and Contractor shall be agreed in written about consequences, if the equipment will not fulfil required acceptance conditions in the agreed time.

4 TECHNICAL ENVIRONMENTAL AND SAFETY REGULATIONS

Contractor's obligation and responsibility is to consider Slovene branch official acts, based on the Slovene SIST standards, European EN and international IEC standards, to fulfil all requirements of the EU guidelines. In case, that above mentioned standards for certain equipment does not exist, Contractor can propose the application of other acceptable national standards, subject to prior approval by the Purchaser.

Contractor must consider at least the following (Slovenian Laws are listed in Slovenian original Titles):

- Gradbeni zakon (GZ-1) (Uradni list RS, št. 199/21, 105/22 – ZZNŠPP, 133/23, 85/24 - ZAID-A, 47/25 – odl. US in 75/25), with corresponding changes and amendments,
- Zakon o meroslovju ZMer-1-UPB1 (Ur. list RS 26/05),
- Zakon o standardizaciji (ZSta-1) (Ur. list RS 59/99),
- Zakon o varnosti in zdravju pri delu (ZVZD-1) (Ur. list RS 43/11),
- Zakon o varstvu pred požarom ZVPoz (Ur. list RS 3/07 – uradno prečiščeno besedilo, 9/11, 83/12, 61/17 – GZ, 189/20 – ZFRO in 43/22) with corresponding legislation,
- Zakon o varstvu okolja ZVO-1 (Ur. list RS, št. 39/06, 49/06 – ZMetD, 66/06 – odl. US, 33/07 – ZPNačrt, 57/08 – ZFO-1A, 70/08, 108/09, 108/09 – ZPNačrt-A, 48/12, 57/12, 92/13, 56/15, 102/15, 30/16, 61/17 – GZ, 21/18 – ZNOrg, 84/18 – ZIURKOE, 158/20 in 44/22 – ZVO-2).

Contractor shall consider required guidelines for EMC (by IEC and EN standards).

Contractor shall indicate all recommendations, codes and standards, which will be used for the equipment production and testing.

5 MATERIALS AND WORKMANSHIP

Materials used in the manufacture of the specified equipment shall be of the kind, composition and physical properties best adapted to their various purposes in accordance with the best up-to-date engineering practice.

The materials used for the manufacture of the equipment shall be new, first quality, suitable for use, with no defects or imperfections and appropriate according to above mentioned standards.

All surfaces shall be precisely and smoothly treated. Painted surfaces shall be rounded on the corners with minimum radius of 2 mm. Drills and openings shall be designed not to weaken the basic construction or material.

Welding shall be performed only by qualified personnel with approved certificates. Welding shall conform to the welding standards valid in Republic of Slovenia.

In general, allowed designed material and steel structures loading shall not exceed required values from standards DIN EN 1993 (Eurocode 3).

Material and work procedures for the supplied equipment shall be carefully selected respecting the purpose of the equipment but taking into consideration all site and operation conditions too. Incoming material and manufacturing stage inspection procedures, inspection of the finalized product shall be verified by the documented (written) QA/QC Contractor procedure.

6 PACKAGING

The Contractor shall prepare/preserve/secure, pack and load all materials and equipment in such a manner that they are protected from damage during the shipment and will be responsible for all damage resulting from improper packing. Each part of the package shall be plainly marked with basic information (content, weight, correct handling) on two opposite sides. All parts exceeding 50 kg gross weight shall be prepared for shipment so, that handling by machines is possible. All electrical parts and delicate mechanical parts subject to damage from moisture shall be packed in hermetically sealed containers. Oil shipping requirements are described in Chapter 15.5.

7 TRANSPORT, LOADING AND UNLOADING

The Contractor shall be fully responsible for the organisation and execution of the transport of the phase-shifting transformer and all associated equipment to the Divača substation site.

The transport shall be carried out as an abnormal/heavy-load transport by rail and/or by road, in accordance with the approved transport study, applicable legislation and regulations, the requirements of the relevant transport infrastructure operators, and the conditions imposed by the competent authorities. The Contractor shall obtain, in due time and at its own responsibility, all permits, approvals, consents, escorts and any other authorisations required for the safe and lawful transport of the equipment to the installation site.

The Contractor shall also be explicitly responsible for unloading, on-site transport within the Divača substation area, handling, positioning, installation and final placement of the PST on its foundation. All such activities shall be carried out using suitable equipment, qualified personnel and approved working methods, and shall comply with the Contractor's instructions, the approved method statement, the applicable health and safety requirements, and all relevant technical standards and regulations.

All costs, risks, permits, approvals, organisational measures, traffic restrictions or road closures, escorts, insurance, unloading, handling, on-site transport and placement of the PST on its foundation shall be deemed to be included in the scope of supply and shall remain the sole duty and responsibility of the Contractor.

The Contractor shall ensure that the selected transport route, whether by rail, by road, or by a combination of both, is technically suitable for the dimensions, mass, axle loads and other transport characteristics of the PST and associated equipment. Where required, the Contractor shall prepare or arrange for the preparation of all necessary route surveys, transport feasibility assessments, lifting and handling plans, risk assessments and method statements.

Prior to the commencement of transport, the Contractor shall submit the relevant transport documentation to the Purchaser for information and, where required, for approval. Such documentation shall include, as applicable, the proposed transport route, transport schedule, permits, special transport conditions, unloading and handling procedures, lifting plans, risk assessments, insurance documentation and details of the specialised transport and lifting contractors.

The Contractor shall be responsible for ensuring that the transport, unloading and installation activities do not cause damage to public infrastructure, railway infrastructure, roads, bridges, access roads, substation roads, foundations, buildings, equipment or any other existing facilities. Any damage caused during transport, unloading, handling or installation shall be repaired at the Contractor's expense and without delay.

The responsibility of the Contractor shall extend up to and include the final positioning of the PST on its designated foundation, ready for subsequent assembly, connection, testing and commissioning activities, unless otherwise explicitly stated in the Contract.

During transport to the final site, the PST shall be equipped with two (2) mechanical stress measuring device (Shock recorder (x, y and z direction)) which shall be placed diagonally each other on the tank. After transport the device shall be opened and records analyzed by a commission, in presence of the Contractor and Purchaser. The Contractor shall submit to the Purchaser a written report about the transport stresses.

The Contractor shall bear full responsibility for all transport, transhipment, unloading, on-site movement and positioning of the equipment up to its final installation location.

8 DOCUMENTATION

The Contractor shall submit to the Purchaser a list of all planned documents, detailed descriptions, calculations, curves, graphs, studies and similar documented information, necessary and/or important for the quality assessment and evaluation of each equipment and device to be produced or supplied. The list of documents must also indicate the dates of submission of documents to the Purchaser and the original formats of documents already approved. From the submitted list, the Purchaser will determine the documents that he will check and approve.

Before equipment and device production, documentation shall be submitted to the Purchaser for approval according to the time schedule for submitting of documentation. Documentation review shall be executed in the commonly agreed term, (3) weeks are foreseen. In case of remarks, dealing with tender requirements, the Contractor shall make corrections to his documentation in appropriate time and return the revised documentation to the Purchaser. Any disagreement or misunderstanding shall be solved in a meeting of both parties.

The Contractor shall provide a BIM model. The Contractor shall deliver BIM models of all equipment and devices. BIM model files shall be exchanged using the standardized open Industry Foundation Classes (IFC) format. The IFC 2x3 (Coordination View 2.0) or IFC 4 (Reference View) schema shall be used.

Table 3: Required Level of Development (LOD) of Delivered BIM Models

Design Phase	**Required LOD**
Detailed Design (PZI)	LOD 350–400
As-Built Documentation (PID)	LOD 500

BIM models delivered as part of the As-Built Documentation (PID) at **LOD 500** shall accurately represent the equipment and devices as actually installed. In addition to the BIM models (IFC files), the Supplier shall also deliver 3D models in **STEP (.STP)** format. The 3D models shall be structured as individual components (i.e. they shall not be combined into a single component) and shall enable subsequent separation into individual files for use during the operation and maintenance phase.

The minimum level of model decomposition shall correspond to individual items of equipment, including, but not limited to:

- bushing;
- current transformer;
- on-load tap changer, including the motor drive and control system;
- transformer monitoring system;
- transformer active part, including the tank and cooling system;
- and other equivalent major equipment components.

Technical data for all equipment shall be provided in digital format.

In case, that during the project certain document part or document as a whole is not clear or is insufficient, the Purchaser can request completion or additional documentation.

The review shall not relieve the Contractor of the responsibility for guaranteed conformity to the operation requirements.

All documentation shall fulfil in form, content and language Slovene legislation requirements and the international standards.

9 WARRANTY PERIOD

The general Defects Liability Period (warranty period) for the tendered equipment is defined in contract. The guarantee period for anti-corrosion protection is also defined in contract.

At reclamation in case of failure or other irregularity of the equipment during warranty period, the Contractor shall send his representative to the site in time not later then 2 (two) days after receiving the written announcement. If he does not reply according to the requirement, Purchaser has right to require a new equipment on Contractor costs.

Failures or deficiencies of the supplied equipment after the reclamation shall be stated by common commission, consisted of Contractor and Purchaser representatives.

If during the erection or in the warranty period failures are indicated, which affect the required reliability, the Contractor shall repair or replace all unsuitable equipment at his own costs.

All repairs performed during the warranty period must comply with the same technical requirements (as defined in the technical tender documentation) and contractual provisions (including warranty coverage and contractual penalties) as those applicable to the manufacture of a new PST.

For replaced equipment or device, warranty conditions are also defined in contract, except for software failures, which shall be repaired at Contractor cost also after that period. Dismantling, erection, testing, transport, insurance and all other costs connected with the new part shall be covered by the Contractor. The Contractor shall dismount and takeover failed parts on his own expense.

If the Contractor and Purchaser representative can not agree, decision from the accredited institution / accredited laboratory for questionable device testing is obligated for both.

10 ERECTION SUPERVISION AND OPERATION START

Erection conditions shall be assured by the Contractor.

The Contractor shall provide:

- erection with expert supervision personnel for erection, preoperational testing and start-up,
- special tools and erection devices,
- PST erection and
- all the start-up and other functional tests.

Contractor shall recommend the erection executing company. The proposal must be approved by the Purchaser.

11 SPARE PARTS

The Contractor shall provide service activities and functionality identical spare parts of the PST during the overall lifetime of the equipment (min. period of 40 years).

The supply of spare parts includes:

- 1 piece of HV phase bushing,
- 1 piece of JO (SOLO) bushing
- 1 piece of vacuum-type DSI On-Load Tap Changer (OLTC).

Bushings should be stored in containers for permanent storage (more than 10 years).

12 TRAINING

The Contractor shall offer a suitable program of expert training of the Purchaser's personnel.

Training shall be organized as:

- training at erection site after erection and before operation start-up under the Contractor expert leadership and

- training for shall be intended to the operation and maintenance personnel (10 people at site for 1 day for PST and 10 people at site for 1 day for monitoring system), from this remaining time is left for additional information, explanations, etc. in the warranty period.

Training shall be based on the equipment applications for S/S Divača.

Training plan shall be defined in amount, personnel, site and expense in the offer. Training costs shall be covered by the Contractor and shall be added to the Tender price.

13 MAIN TECHNICAL CHARACTERISTICS

13.1 General and ratings

The main data listed in Table 4 include technical specification for PST to serve as basis in the process of bidding. The backbone to formulate its content were in references cited standards and other publications. More detailed technical data on the PST are provided in Chapter 21, which contains the table of Technical specifications.

Table 4: General data

Type designation of the PST	
Application:	Outdoor from - 25 °C to + 40 °C without direct solar radiation in accordance with IEC 60076-2
Standard:	IEC 60076-57-1202
Rated system voltage/nominal system voltage:	400 [kV]
Highest system voltage U_m:	420 [kV]
Continuous throughput power rating:	600 [MVA]
PST type throughput power rating	410 [MVA]
Number of phases:	3
Rated voltage S and L side:	400 [kV]
Highest voltage S and L side:	420 [kV]
No load phase angle shift:	± 40 [°] ± 1 % (± 0,4 °)
On load tap changer range:	± 32 [steps]
Insulation level winding (line): Insulation level winding (JO, SOLO):	AC 630, LI 1425/CW 1550, SI 1050 [kV] LI 450, AC 185 [kV]
Noise level (method sound pressure) at rated voltage, rated frequency, no load operation, at max. positon of OLTC and without fans acc. to IEC 60076-10 Noise level (method sound pressure) at short circuit and 100 % with fans in operation acc. to IEC 60076-10	70 [dB] 72 [dB]
Type of cooling series and exciting unit: – ONAN	 80 [%]

– ONAF	100 [%]
Temperature rise limits: Average winding: Top oil: Winding hot spot:	 60 [K] 55 [K] 73 [K]
PST oil:	Type A (fully inhibited high-grade oil), TVAI, acc. to IEC 60296:2020
No load losses at 0° phase shift: No load losses at max. phase shift: Short circuit losses at 0° phase shift: Short circuit losses at max. phase shift:	≤ 115 [kW] ≤ 225 [kW] ≤ 970 [kW] ≤ 1840 [kW]

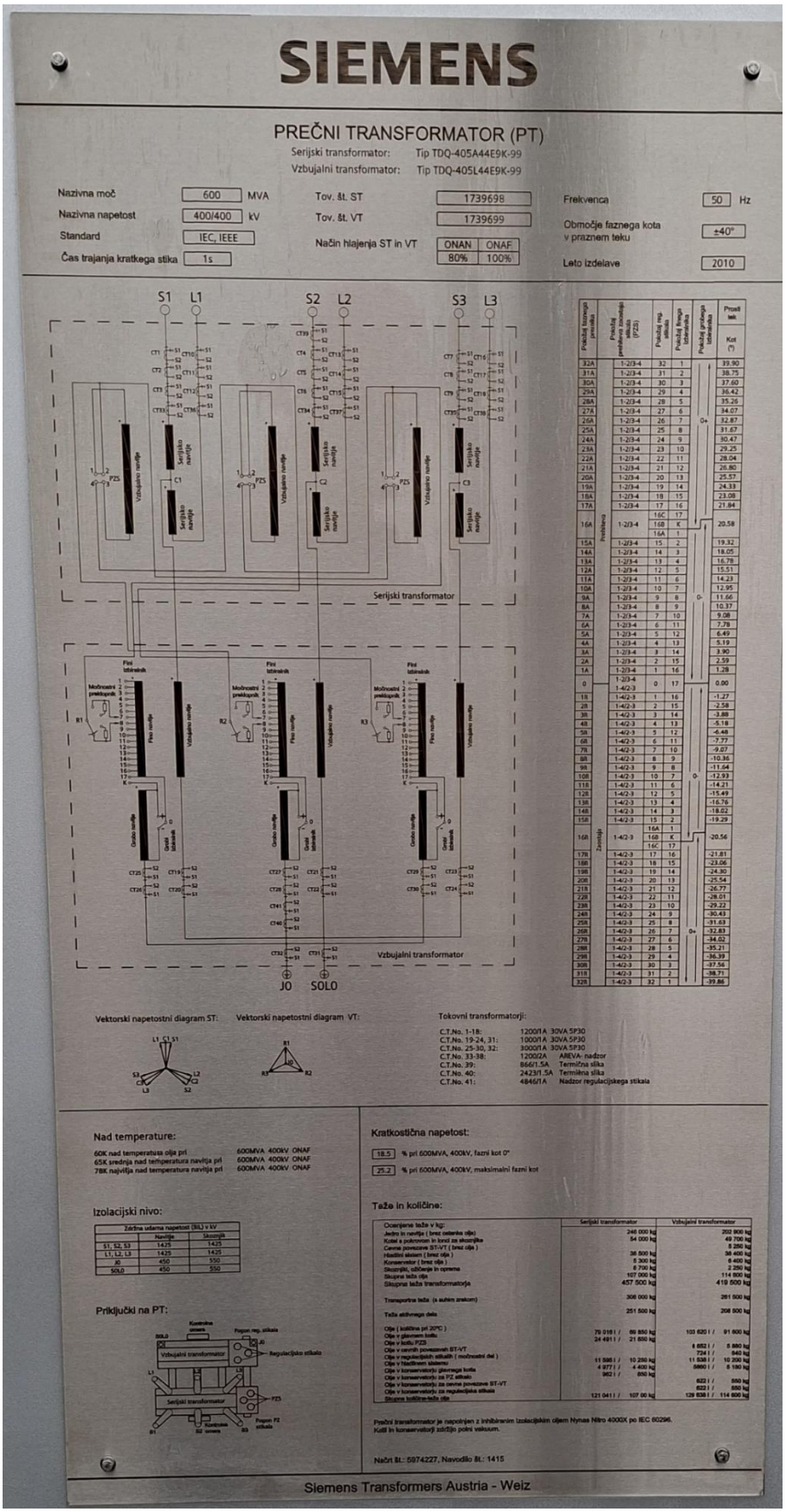


Figure 1: Name Plate of Divča PST-441

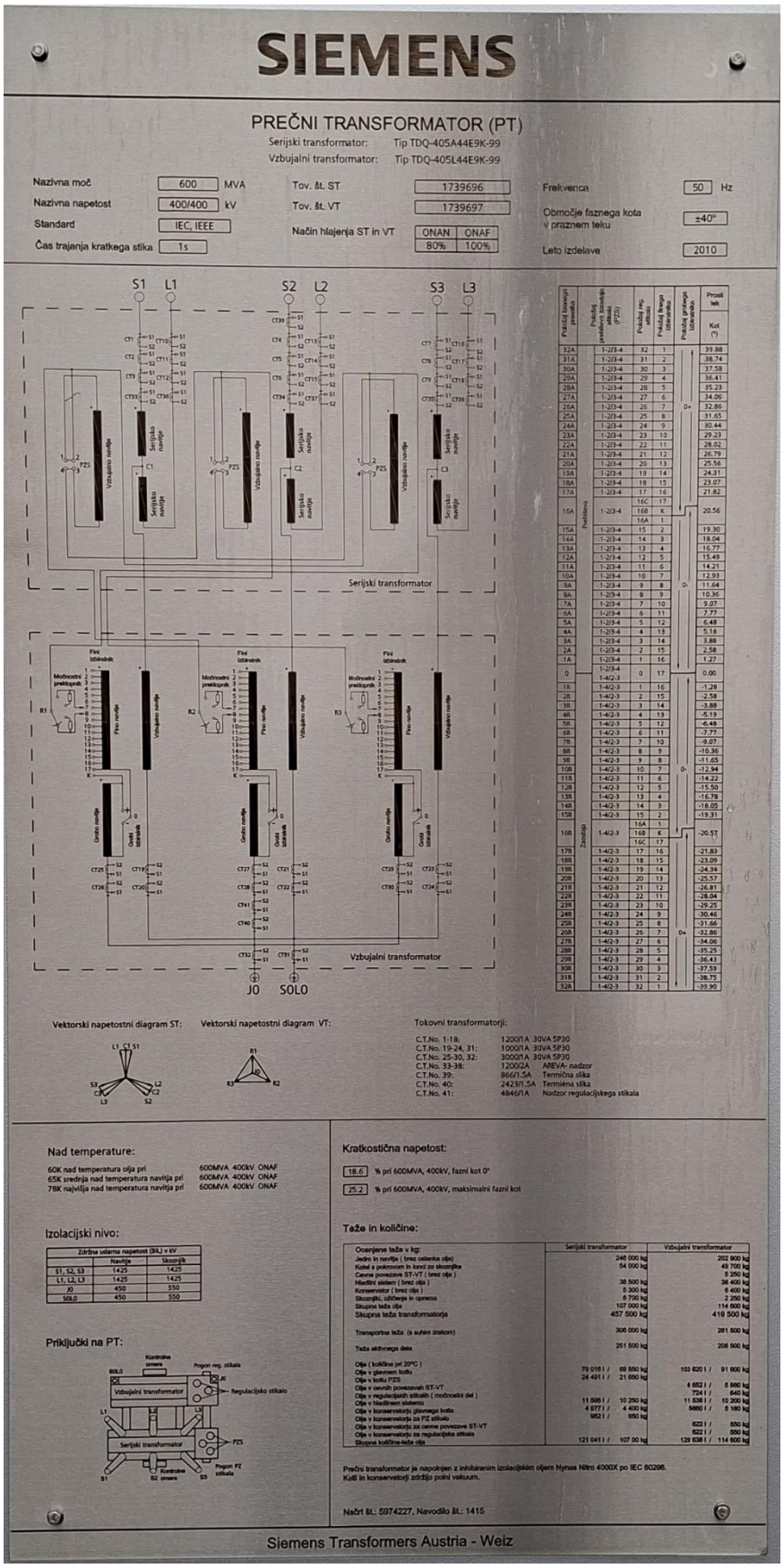


Figure 2: Name plate of Divča PST-442

ON-LOAD TAP CHANGER DATA

Manufacturer: Maschinenfabrik Reinhausen GmbH
Product Line: OILTAP R
Type: 3 x RI 3003-123/D-18 35 3G
Year of Manufacture: 2010

1 General

1.1 Summary of the technical data

On-load tap-changer	R III 1200 Y	R I 1201	R I 2002	R I 2402[3]	R I 3003
Number of poles and application	3 (neutral point)	1	1	1	1
Max. rated through-current I_{um} (in A)	1200	1200	2000	2400	3000
Rated short-time withstand current (in kA)	15	15	24	24	30
Rated short-circuit duration (in s)	3	3	3	3	3
Rated peak withstand current (in kA)	37.5	37.5	60	60	75
Max. rated step voltage U_{im} (in V)[1]	4000	4000	4000	4000	3000
Step capacity (P_{StN}) (in kVA)	3000	3000[3]	4400[2]	6000[3]	6000
Rated frequency (in Hz)	50 to 60				
Operating positions	Without change-over selector: max. of 18 With change-over selector: max. of 35				
Rated insulation level					
Highest voltage for equipment U_m (in kV)[5]	72.5	123	170	245[3]	300	362[7]
Highest operating voltage U_b (phase-phase) on diverter switch (in kV)	55	79	145	170	245	300[8]
Rated lightning impulse withstand voltage (in kV, 1.2|50)	350	550	750	950	1050	1175
Rated switching impulse withstand voltage (in kV)					850	950
AC withstand voltage (in kV, 50 Hz, 1 min.)	140	230	325	395	460	510
Rated withstand voltages of internal insulation	see table 3					
Oil compartment	Pressure-proof up to 0.3 bar continuous difference pressure (test pressure 0.6 bar), head and cover of the on-load tap-changer are vacuum-proof.					
Oil suction pipe	Installed as standard (for details, see BA 18)					
Temperature range	The on-load tap-changer OILTAP® R can be operated in the rated load range with oil temperatures of -25 °C to +105 °C.					

Table 1 a

4 TD 115/02 115/02/01/0

Figure 3: Technical data OLTC 1a

On-load tap-changer		R III 1200 Y	R I 1201	R I 2002	R I 2402	R I 3003
Weight (in kg) ca.	without change-over selector	525	360	445[4]	445	525
	with change-over selector	595 (770[4])	410 (500[4])	505 (640[4])	505 (640[4])	595 (780[4])
Displacement volume (in dm^3) ca.	72.5 kV	289 (367[4])	274 (353[4])	280 (360[4])	280 (360[4])	286 (367[4])
	123 kV	314 (392[4])	299 (376[4])	305 (384[4])	305 (384[4])	311 (392[4])
	170 kV	334 (412[4])	319 (396[4])	325 (404[4])	325 (404[4])	331 (412[4])
	245 kV	354 (432[4])	339 (416[4])	345 (424[4])	345 (424[4])	351 (432[4])
	300 kV		369 (446[4])	374 (453[4])	374 (453[4])	380 (461[4])
Oil filling quantity V_s and minimum volume DV[6] of the diverter switch oil compartment	72.5 kV			168		
	123 kV			188		
	170 kV			203		
	245 kV			218		
	300 kV			240		

Figure 4: Techical data OLTC 1b

ADVANCE-RETARD SWITCH (ARS) DATA

Manufacturer: Maschinenfabrik Reinhausen GmbH
Product Line: ARS
Type: 3 x AR I 1622 123 18020S
Operating Instructions: BA 274/01
Year of Manufacture: 2010

8. TEHNIČNI PODATKI PST

Ime	napetost stran *L*	napetost stran *S*	S_{th}	število odcepov	nevtralni odcep	fazni zamik	reg. napetosti
T441 T442	400 kV	400 kV	1200 MVA*	65 (+/- 0+32)	0	+/- 40⁰	0

*2 enoti po 600 MVA (Pri $I_{th}=I_{stat}$ in $U=U_n$ je $S_{th}=600$ MVA)

Trajni termični tok (I_{th}):	**I_{stat} = 866 A** (po projektu za TR) ali **I_{din} = vrednost izračunana z DTR** **Opomba:** Če je aplikacija za DTR izklopljena je trajni termični tok (I_{th}) enak I_{stat} O vklopu/izklopu aplikacije za DTR odloča operater RCV

Skupna impedanca	**A = +/-40⁰**	**α = 0⁰**
	R= 0,371 ohm, X= 32,7 ohm	R= 0,196 ohm, X= 26,3 ohm

Odcep PST je predstavljen kot relativna vrednost na nevtralni odcep, enako kot v SVEES.

PST režim	odcep	alfa /°	Ztr / Ω
RETARD	-32	-40,0	66,3
	-31	-38,8	65,3
	-30	-37,6	64,3
	-29	-36,5	63,3
	-28	-35,3	62,3
	-27	-34,1	61,4
	-26	-32,9	60,6
	-25	-31,7	59,7
	-24	-30,5	59,0
	-23	-29,3	58,2
	-22	-28,1	57,5
	-21	-26,8	56,8
	-20	-25,6	56,2
	-19	-24,4	55,6
	-18	-23,1	55,1
	-17	-21,9	54,6
	-16B	-20,6	54,2
	-16A	-20,6	55,8
	-15	-19,3	55,0
	-14	-18,1	54,3
	-13	-16,8	53,6
	-12	-15,5	52,9
	-11	-14,2	52,3
	-10	-13,0	51,7
	-9	-11,7	51,2
	-8	-10,4	50,7
	-7	-9,1	50,3
	-6	-7,8	50,0
	-5	-6,5	49,7
	-4	-5,2	49,4
	-3	-3,9	49,3
	-2	-2,6	49,1
	-1	-1,3	49,0
	neutral	0,0	49,0

PST režim	odcep	alfa /°	Ztr / Ω
ADVANCE	neutral	0	49,0
	1	1,3	49,0
	2	2,6	49,1
	3	3,9	49,3
	4	5,2	49,4
	5	6,5	49,7
	6	7,8	50,0
	7	9,1	50,3
	8	10,4	50,7
	9	11,7	51,2
	10	13,0	51,7
	11	14,2	52,3
	12	15,5	52,9
	13	16,8	53,6
	14	18,1	54,3
	15	19,3	55,0
	16A	20,6	55,8
	16B	20,6	54,2
	17	21,9	54,6
	18	23,1	55,1
	19	24,4	55,6
	20	25,6	56,2
	21	26,8	56,8
	22	28,1	57,5
	23	29,3	58,2
	24	30,5	59,0
	25	31,7	59,7
	26	32,9	60,6
	27	34,1	61,4
	28	35,3	62,3
	29	36,5	63,3
	30	37,6	64,3
	31	38,8	65,3
	32	40,0	66,3

Figure 5: Technical data on the existing PST

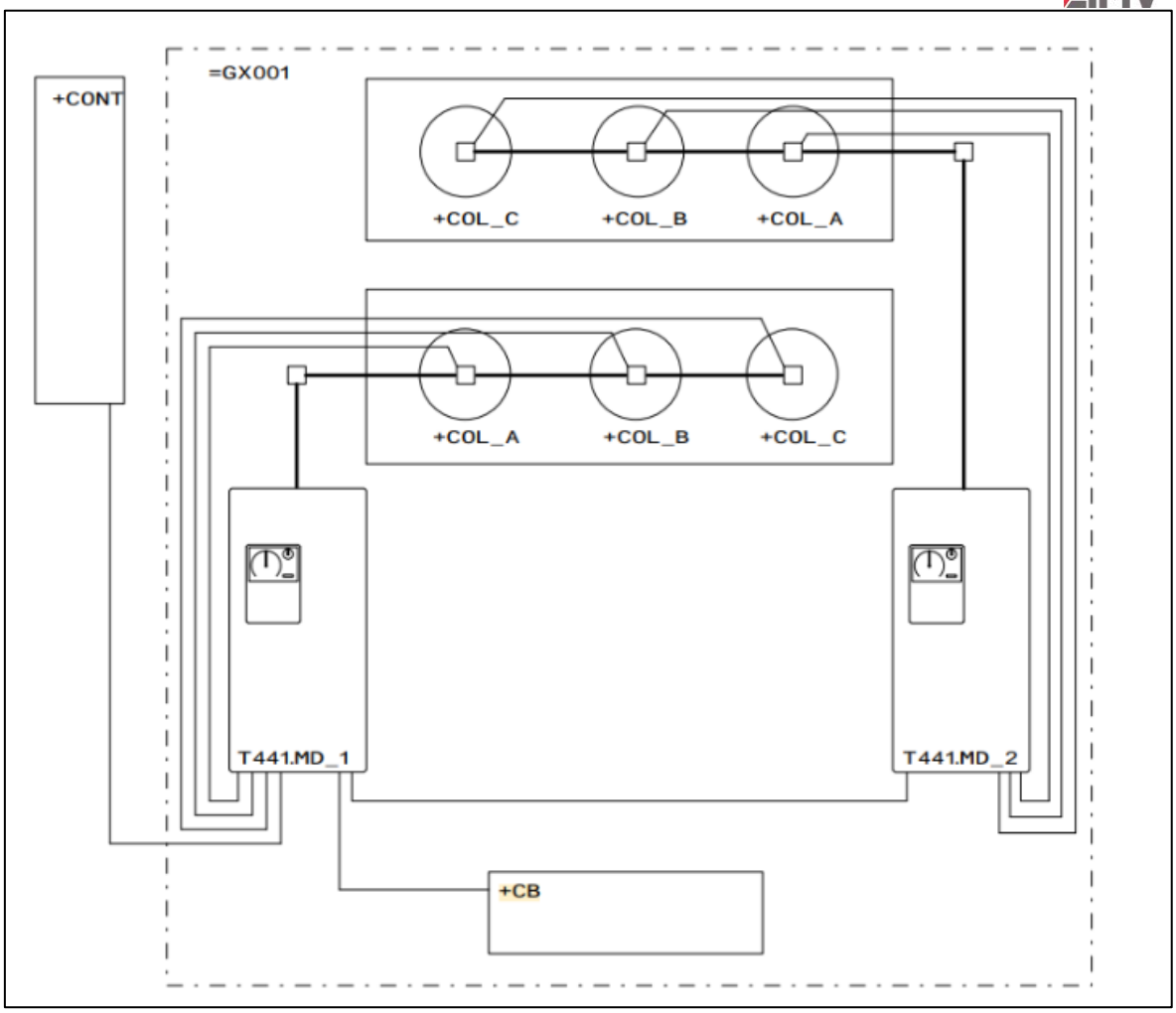


Figure 6: Interconection Between the Two On-Load Tape Changers (OLTCs)

9.5. Zaščitna shema PST

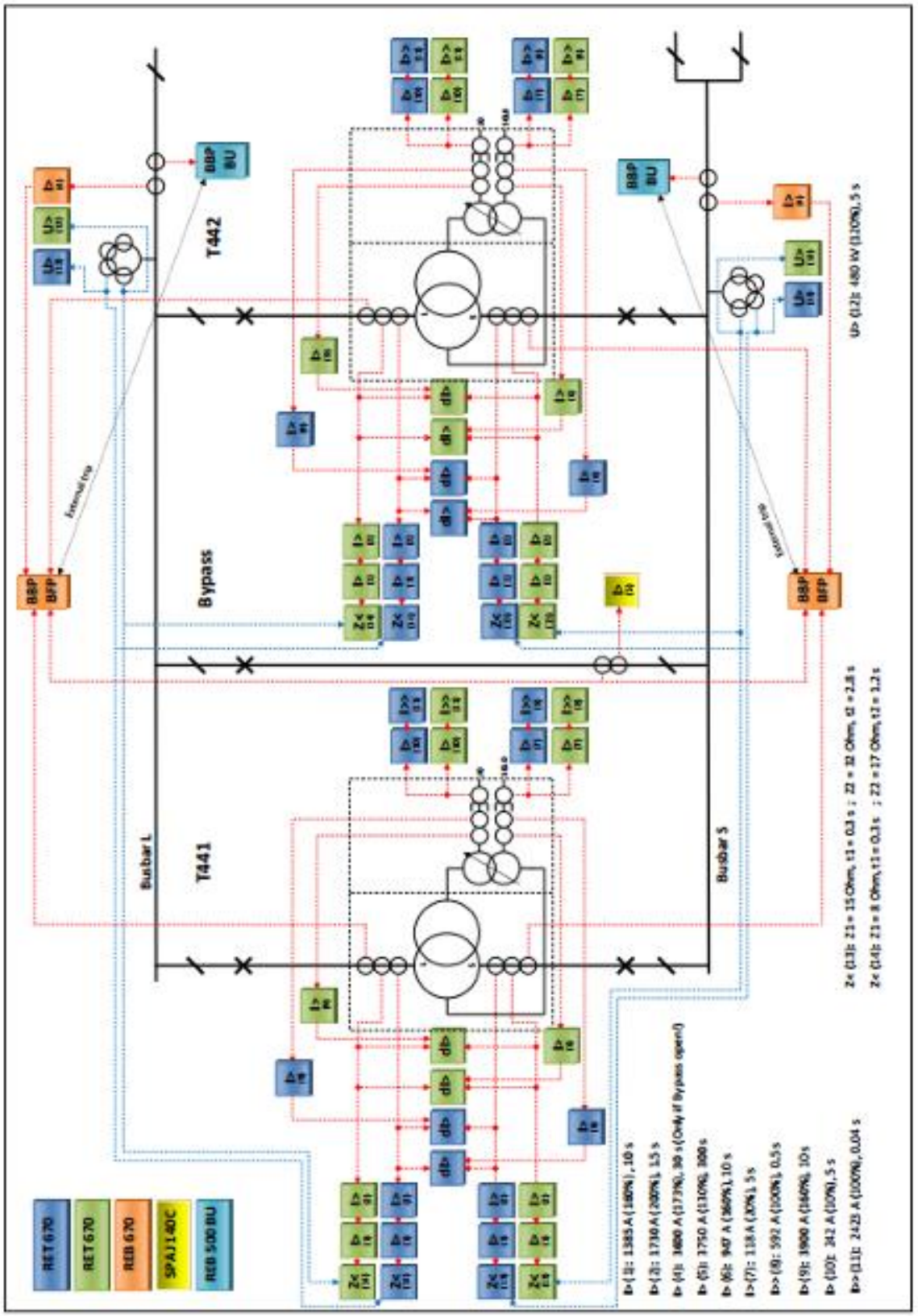


Figure 7: PST Protection Scheme

13.2 Operating conditions

Operating conditions in S/S Divača depend on the operating requirements of the national transmission network power demand. The Slovenian national transmission system is at the highest voltage level interconnected with ENTSO-E 400 kV network.

Normal operating conditions are met when the S/S is operating at:

- rated voltage ± 5 %,
- rated frequency ± 2 %,

Abnormal operating conditions assume:

- rated voltage ± 10 %,
- rated frequency ± 5 %,

The highest values of three phase short circuit current on the busbars in S/S Divača:

- 400 kV busbars I''_{k3} = 32.3 kA
- Short circuit duration t_k = 1 s.

The design shall meet also all other site requirements listed in General Technical Specifications.

400 kV transmission network has effectively grounded neutral point (grounding factor 1.1), 110 kV network has effectively grounded neutral point (grounding factor 1.1).

13.3 Continuous output rating

Continuous output rating of the PST as specified in Tables of technical data shall be guaranteed within the limits of winding temperature rises and hot spots specified in the table of rated data.

If the PST fails to meet the requirements, then the Contractor shall be bound to modify the PST or the equipment causing the deficiency within six months to bring the output to the Purchaser's requirements.

13.4 Losses

The guaranteed losses of the PST shall not exceed the maximum values specified in Table 4 (see Clause 13.1). For contractual purposes, the guaranteed loss values shall be subject to a positive tolerance of 0%.

The tolerances specified in IEC 60076-1 for the assessment of technical conformity shall not be interpreted as an increase in the contractually guaranteed loss values or as an allowance applicable to contractual financial consequences.

The no-load losses at the middle and extreme OLTC tap positions, as well as the load losses at the middle and extreme OLTC tap positions, shall be taken as the basis for verification of the guaranteed losses during Factory Acceptance Tests (FAT).

If the measured losses exceed the guaranteed values, the corresponding price reductions or liquidated damages shall be determined and applied in accordance with the Contract, irrespective of the tolerances permitted under IEC 60076-1.

The Contractor shall declare the guaranteed no-load and short-circuit losses at 0° phase shift and at maximum phase shift, in accordance with Table 4 (see Clause 13.1).

14 SCOPE AND LIMITS OF SUPPLY

14.1 Scope of supply

Specifications and requirements stated in the Tender Documents are not to be considered as a limitation. The Contractor is to supply all other parts of equipment and render all those services free of charge that from whatsoever reasons or faults have not been specifically stated in the Tender, if they are of essential importance for continuous, reliable and safe operation of the Works.

The scope of the supply and the Works to be carried out include but is not limited to:

- PST 600 MVA acc. to technical data from clause 13.1, acc. to General technical specifications and Special technical specifications, all together with required documentation,
- packaging and transport, placing PST to the foundations including transport insurance,
- PST erection (bushing insulators, cooling system, conservator, oil filling, etc.),
- erection supervision, site tests and site acceptance tests, commissioning, all acc. to General technical specifications and Special technical specifications,
- training of Purchaser's personnel,
- used packaging material removal from the site and clearing away parts of the equipment,
- 20 pieces of 3D-printed PST models at a 1:40 scale and
- spare parts delivery.

No civil works are included in the scope of supply. Contractor shall provide and carry out collecting and sending on time to the Purchaser of all necessary documentation for timely continuation of all works on the project.

Time limits equipment supply shall be defined in Contract to be signed by both the Contractor and the Purchaser.

14.2 Erection tools

All tools, necessary for the PST erection works in accordance with detailed description and instructions, shall be assured by the Contractor or by its electrical erection subsupplier.

14.3 Limits of supply

The following interfacing points concerning the PST equipment unloaded and placed to its foundation, and to other equipment shall be considered as the limit of supply:

- To the civil structure: foundations of the PST

- To other primary electrical equipment:
  - HV terminals (S1, S2, S3, L1, L2, L3),
  - HV neutral terminal (JO and SOLO).
- To the secondary electrical devices:
  - 400/230 V AC terminals to the substation auxiliary power supply system,
  - terminal strips and optical connectors for connections to the control and monitoring equipment system,
  - terminal for PST grounding.

14.4 Scope of erection and supervision

All erection works on the PST and on the cooling equipment shall be performed and achieved by Contractor in accordance with limits of supply.

Contractor shall unload PST and provide on site transport supervision, up to the final place.

Contractor shall present erection and supervision works program and estimation of pertaining costs, which shall be included in the offered price.

All works must be performed in compliance with the applicable environmental and occupational health and safety standards. In particular, the Contractor must observe the requirements and guidelines of ISO 14001 and ISO 45001, under which the Purchaser is certified.

15 CONSTRUCTION, MATERIALS, WORKMANSHIP

15.1 Standards

As stated in General Technical Specifications, the latest edition of IEC and other standards shall be binding the Contractor for the manufacture, erection and testing of the PST.

The list of applicable standards and clauses shall be proposed by the Contractor and agreed with the Purchaser before signing the Contract.

Here below, some of important IEC Standards were selected and listed for reference:

– IEC 60076-57-1202	Liquid immersed phase-shifting transformers
– IEC 62032	Guide for the Application, Specification and Testing of Phase-Shifting Transformers
– IEC 60076	Power transformers
– IEC 60076-1	General
– IEC 60076-2	Temperature rise for liquid-immersed transformers
– IEC 60076-3	Insulation level & dielectric tests external clearances in air
– IEC 60076-4	Guide to the lightning impulse and switching impulse testing Power transformers and reactors
– IEC 60076-5	Ability to withstand short circuit
– IEC 60076-7	Loading guide for oil-immersed power transformers
– IEC 60076-10	Determination of noise levels
– IEC 60296	Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment
– IEC 60214 (-1, -2)	Tap-changers
– IEC 60450	Measurement of the average viscometric degree of polymerization of new and aged cellulosic electrically insulating materials
– IEC 60567	Oil-filled electrical equipment - Sampling of free gases and analysis of free and dissolved gases in mineral oils and other insulating liquids - Guidance

– IEC 60599	Mineral oil-impregnated electrical equipment in service – Guidance on the interpretation of dissolved and free gases analysis
– IEC 60616	Terminal and tapping markings for power transformers
– IEC 60617	Graphical symbols for diagrams Part 6: Production and conversion of electrical
– IEC 61125	Insulating liquids – Test methods for oxidation stability – Test method for evaluating the oxidation stability of insulating liquids in the delivered state
– IEC 61181	Mineral oil-filled electrical equipment - Application of dissolved gas analysis (DGA) to factory tests on electrical equipment
– IEC 61198	Mineral insulating oils – Methods for the determination of 2 furfural and related compounds
– SIST EN 61869-1	Instrument transformers - Part 1: General requirements
– SIST EN 61869-2	Instrument transformers - Part 2: Additional requirements for current transformers
– IEC 60422	Mineral insulating oils in electrical equipment – Supervision and maintenance guidance
– SIST EN ISO 4624	Paints and varnishes - Pull-off test for adhesion
– SIST EN ISO 8501-1	Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings
– SIST EN ISO 12944-1, 2	Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Part 2: Classification of environments
– SIST EN ISO 12944-5	Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Part 5: Protective paint systems
– DIN EN 312266-1	Industrial valves – Testing valves-Part 1: Pressure tests, test procedures and acceptacne criteria

– DIN EN 312266-2	Industrial valves – Testing valves-Part 2: Tests, test procedures and acceptacne criteria
– EN 1993 (Eurocode 3)	Steel structures shall be designed in accordance with the applicable parts of EN 1993 (Eurocode 3) and executed in accordance with EN 1090-2.
– SIST EN ISO 14713-1,2	General Design Principles and Corrosion Protection Requirements
– SIST EN ISO 1461	Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods

15.2 General requirements

The PST shall meet the latest stage of achievements in the design and construction of PST and power transformers. Equipment and materials shall be designed to conform to the imposed climatic and operating conditions. The mechanical and electrical design of the PST shall be based on the following conditions and requirements:

a) The main dimensions must consider all requirements and limitations from the site and from the attached drawings.
b) The maximum permissible temperature rise of the PST oil (top oil) shall not exceed 55 K and the average temperature rise of the winding is to be limited to 60 K (hot spot 73 K). The PST, completely assembled with bushings and connections, shall be designed and constructed to withstand without damage the effects of inrush currents and transient phenomena which may arise during system faults in service, such as line-to-line, double line-to-earth and three-phase faults associated with the relevant system and grounding conditions.
c) The PST shall be designed with particular attention to the suppression of harmonic voltages to eliminate wave form distortion and from any eventual high frequency disturbances reaching such a magnitude to cause interference with communication circuits.

15.3 Magnetic circuit

The magnetic flux density in the limbs and yokes of the PST shall be designed taking into account the increased excitation resulting from the specified PST overload conditions.

The magnetic circuit shall be designed to prevent partial discharges, internal short-circuit paths, and flashovers to the earthed clamping structure. The core shall be manufactured from high-grade, non-ageing, low-loss, high-permeability, cold-rolled, grain-oriented silicon steel laminations. The steel quality shall be uniform over the complete surface. The laminations shall be thin, properly processed after cutting, and shall have smooth edges. Both sides of each lamination shall be insulated with material resistant to pressure and hot transformer oil.

The core shall be clamped and braced by suitable clamps and supporting elements so as to withstand, without damage or permanent deformation, the mechanical forces caused by short-circuit stresses, transport and handling, and to prevent displacement of the core laminations. The limb clamping structure shall be of non-magnetic material.

Suitable vertical oil ducts shall be provided to ensure free oil circulation and efficient cooling of the core. The core hot-spot temperature shall not exceed the specified design limit under rated and specified overload conditions. Any part of the core supporting structure in contact with cellulose insulation shall comply with the temperature limits applicable to Class A insulation.

Core lamination pressing by through-bolts passing through the laminations shall not be used, unless specifically justified and approved. Holes required for core assembly may be used only where they do not adversely affect the magnetic, mechanical or dielectric performance of the core.

Adequate metallic bonding shall be provided between core lamination packets to maintain all parts of the core assembly at the same electrical potential.

To prevent a closed magnetic circuit through the tank, the upper main core clamping structure shall not form an unintended magnetic or conductive path through the tank cover. The magnetic circuit shall be insulated from structural parts and shall withstand a test voltage of 2 kV RMS for one minute between the core, core bolts and frame.

The main core earthing connection shall have a cross-sectional area of not less than 80 mm^2. Connections inserted between laminations may have a reduced cross-sectional area, but not less than 20 mm^2.

The magnetic core shall be earthed through insulated conductors and terminals mounted on the outside of the transformer tank. The core jointing structure shall also be insulated from the core and the tank and shall be earthed externally. The design shall provide accessible test terminals to enable insulation resistance measurements of the magnetic core and, where applicable, its individual subassemblies, allowing periodic testing and early detection of insulation faults or unintended earth connections.

The maximum magnetic flux density in any part of the magnetic core shall not exceed 1.85 T under the most unfavourable continuous voltage-to-frequency (U/f) operating conditions specified in Clause 13.2, considering all relevant tap positions and internal winding voltage conditions.

For normal operating conditions, the maximum external U/f ratio corresponds to a system voltage of 420 kV and a frequency of 49 Hz.

The Contractor shall demonstrate compliance with this requirement by submitting appropriate magnetic design calculations.

Abnormal operating conditions specified in Clause 13.2 shall be assessed separately, taking into account the duration of such conditions, possible core saturation and the resulting thermal and operational limitations.

15.4 Windings

The PST windings shall be designed and manufactured to ensure reliable operation throughout the specified service life under all operating conditions, including rated load, continuous overload, emergency loading, through-fault conditions, transport and seismic conditions where applicable.

All windings shall be manufactured from high-conductivity copper conductors. The insulation system shall consist of high-quality cellulose insulation suitable for operation in transformer insulating liquid and designed in accordance with the IEC 60076 series of standards.

The winding design shall take into account all electrical, mechanical, thermal and dielectric stresses that may occur during factory testing, transport, installation and service, including:

- rated operating conditions;
- specified overload conditions;
- external short-circuit currents;
- switching overvoltages;
- lightning impulse and chopped-wave impulse voltages;
- transient recovery voltages;
- transport and handling forces.

The windings shall successfully withstand all dielectric tests specified in IEC 60076-3, including lightning impulse tests with chopped waves where applicable, without damage or deterioration of insulation.

The winding mechanical design shall comply with IEC 60076-5 and shall be capable of withstanding the mechanical forces resulting from external short circuits without permanent deformation or reduction of dielectric withstand capability.

The Contractor shall demonstrate the short-circuit withstand capability by one of the following:

- a valid type-test report for a PST of similar design and rating;
- documented design verification demonstrating compliance with IEC 60076-5;
- or other evidence acceptable to the Purchaser.

The windings shall be rigidly clamped and adequately braced to prevent movement caused by electromagnetic forces, transport, vibration or other service conditions. The clamping system shall maintain adequate compression throughout the PST's expected service life without requiring readjustment.

The active part shall be thoroughly dried using an approved vacuum drying process before final assembly. The drying process shall ensure the moisture content required for the guaranteed dielectric performance and long-term insulation reliability.

The winding arrangement shall provide unobstructed circulation of insulating liquid through all cooling ducts to ensure uniform cooling under all specified operating conditions.

Connections between windings, bushings, tap changer and internal leads shall be mechanically supported to withstand vibration and short-circuit forces. Internal conductors shall be arranged to minimize electrodynamic stresses and local overheating.

All winding insulation levels shall comply with IEC 60076-3 and with the insulation coordination requirements specified in this Technical Specification.

The winding design shall minimize electric field concentrations and partial discharge activity throughout the expected operating range.

The guaranteed winding hot-spot temperature rise shall comply with IEC 60076-2 under rated operating conditions. During the specified overload conditions, the hot-spot temperature shall remain within the limits corresponding to the selected insulation system and the specified transformer loading capability.

The transformer shall be equipped with fibre-optic winding temperature monitoring. The fibre-optic monitoring system shall include:

- fibre-optic temperature sensors permanently installed within the windings;
- an optical signal converter;
- local temperature indication;
- alarm and trip outputs;
- communication interface for integration into the transformer monitoring system.

The number and locations of the fibre-optic temperature sensors shall be determined by the Manufacturer based on the thermal design of the PST and submitted to the Purchaser for approval. At least twelve fibre-optic temperature sensors shall be installed in the series unit and at least twelve fibre-optic temperature sensors shall be installed in the exciting/regulating unit. The calculated hot-spot location(s) in each winding shall be equipped with two independent fibre-optic sensors to provide measurement redundancy. The proposed sensor arrangement shall be supported by the Manufacturer's thermal and hot-spot calculations. Temperature measurements shall represent the actual winding hot-spot locations.

The complete fibre-optic monitoring system, including sensors, converters, accessories, power supply, communication interfaces and all necessary installation materials, shall be included in the scope of supply. The fibre-optic temperature measurement system shall be suitable for continuous operation in hot transformer oil and under the specified electromagnetic, thermal, mechanical and dielectric conditions. Sensors and measuring equipment shall be of proven type, such as FISO, LumaSense/Luxtron, Neoptix or

technically equivalent, subject to Purchaser approval. Sensor locations, routing, fixing method, feedthroughs, connection details and channel identification shall be documented in the relevant drawings.

The PST design shall permit the performance of Sweep Frequency Response Analysis (SFRA) measurements in accordance with IEC 60076-18 for future condition assessment of the windings. Any auxiliary or test windings required for factory testing, site testing or condition monitoring shall be provided by the Contractor where necessary. Their design and purpose shall be documented in the final design documentation.

The Contractor shall provide detailed drawings showing the winding arrangement, conductor types, insulation system, cooling ducts, mechanical supports and winding connections.

The PST shall be designed and manufactured to withstand the test voltage levels specified in IEC/EN 60076 and in this specification. The required insulation levels are given in Table 5.

Table 5: Test voltages/Insulation Levels

Terminal	U_m (kV_{rms})	Test voltages/Insulation Levels			
		Power Frequency (kV_{rms})	Lightning Impulse Full wave (kV_{crest})	Lightning Impulse Chopped wave (kV_{crest})	Switching Impulse 250/2500ms (kV_{crest})
Line S1, S2, S3 L1, L2, L3	420	630	1425	1550	1050
Neutral JO SOLO	123	185	450	--	--

The use of metal-oxide arresters across the regulation winding to limit overvoltages shall not be permitted. The winding insulation, voltage distribution and regulation winding arrangement shall therefore be designed to withstand the specified operating voltages, test voltages and transient overvoltages without reliance on such arresters.

The inrush current shall be kept as low as practicable to avoid unacceptable disturbances in the power system during energisation of the PST and to avoid neutral-current peak values and durations that could initiate unwanted operation of earth-fault protection.

The degree of polymerisation of the cellulose insulation after treatment shall be certified. Where epoxy-bonded or resin-bonded insulation materials are used, the degree of bonding or curing shall also be certified.

15.5 PST Insulation oil and paper

Only new oil of Type A, TVAI quality shall be used. The oil shall be fully inhibited, high-grade insulating oil complying with the requirements of IEC 60296:2020, Table 4 - General Specifications. The oil properties must comply with all the requirements cited in the Schedule of technical data and acc. to standard IEC 60296:2020 and should be tested according to IEC, DIN, ISO, ASTM standard methods and comply with the requirements given in the Table of technical data.

In case that an antioxidant is added to oil, it shall not contain sulphur components. Oil shall not contain corrosive sulphur or potentially corrosive sulphur and shall be tested acc. to DIN 51353 and IEC 62535 standards to be considered non-corrosive.

The initial filling of the PST shall be carried out using the same type of insulating liquid as used during the Factory Acceptance Tests (FAT), either TVAI fully inhibited high grade naphthenic oil or fully inhibited high grade insulating oil produced from GTL (Gas-to-Liquid) base oils.

The oil used during the Factory Acceptance Tests (FAT) must be of the same origin as used for on-site filling. If a different type of oil is used then the miscibility and compatibility of the oils shall be verified by an accredited laboratory in accordance with IEC 60296:2020, Clause 5.3 – Miscibility and compatibility.

Before the initial oil filling of the PST on site, an examination shall be carried out to verify that the PST insulating liquid complies with the requirements specified in the technical specification of this document. In addition, the oxidation stability of the batch of insulating liquid intended for filling the PST shall be verified in accordance with IEC 61125.

The Contractor will be requested to submit to the Purchaser before the factory release the test report of the applied oil. It should be emphasized that the Purchaser will release the oil shipment to the site exclusively after obtaining the certification of PCB absence (below 2 ppm) in the oil sample taken from the delivery tank. This certification shall be sent to Purchaser in acreditable report.

The PST shall be supplied and shipped without initial oil filling. The tank should be filled with dry air or nitrogen and kept under over-pressure above ambient air pressure. Oil shall be delivered in tank, under the nutrition pressure, in sufficient quantity to refill the PST oil volume and to compensate for losses during subsequent processing at site. Oil type Shell Diala S4 ZX-I or Nynas Nytro 4000X must be used.

The sampling of transformer oil shall be carried out before the first filling, after the dielectric tests have been performed, after the factory tests have been completed and before the first start-up.

Concerning the quality of the applied paper insulation, the Purchaser will impose on the bidder to respect the following.

Before the manufacturing process is initiated, the degree of polymerization (DP) of the paper insulation to be used shall be verified in accordance with IEC 60450.

Thermally upgraded insulating paper from the Weidmann production shall be used. The reduction of Nitrogen content of thermally upgraded paper, after exposed to the sealed tube test in accordance with ASTM D-982, should not be higher than 50 %.

All samples of paper insulation to be used for winding manufacturing (one representative sample for each winding) shall be properly sampled and traceably labeled prior to manufacturing (paper type, winding type, identification marking indicating that the paper is intended for pre-manufacturing testing). Testing of the average degree of paper polymerization shall be done before manufacturing release.

- DP - average degree of polymerization must not be lower than 1100.

Further on, the testing of paper polymerization degree shall be done after drying in each of manufacturing phases. Paper samples taken and tested after drying process (windings and active part of PST) shall fulfil the following requirements:

- average degree of polymerization of all paper samples must not be lower than 1100,
- average degree of polymerization of any from all tested samples must be higher than 1050,
- Humidity (moisture) must not exceed 0.5 %.

These pilot samples shall follow the same path of drying process as the active part of PST itself and will be subjected to inspection and testing after each phase during drying process.

The Contractor will be requested to submit to the Purchaser before the factory release the paper insulation test report.

Sample taking and testing shall be performed by an authorized and accredited independent body selected and assigned by the Purchaser.

The Supplier shall submit to the Purchaser all paper and oil test results performed on its behalf.

15.6 On-Load Tap Changer (OLTC), Advance-Retard Switch (ARS) and Parallel Operation

The On-Load Tap Changer (OLTC), Advance-Retard Switch (ARS) and Parallel Operation shall be manufactured by Reinhausen GmbH, Germany.

Compatibility with existing PST units: The new PST will operate together with two existing Phase Shifting Transformers installed in the same substation. The new PST shall therefore be fully compatible with the existing PST units regarding:

- regulating characteristics;

- phase-angle regulation;
- tap-changing philosophy;
- electrical characteristics;
- operating sequences;
- parallel operation.

The existing PST units are planned to be upgraded in the future by replacement of the existing OLTC control cubicles, protection equipment and associated control systems with MR ETOS® equipement This upgrade will be carried out under a separate procurement contract and is not included in the scope of this Tender.

Nevertheless, the new PST shall be designed to ensure full compatibility with the future upgraded control system. The Contractor shall provide all information required for successful integration of the new transformer into the future common parallel control system.

The Contractor shall clearly identify any interface requirements, communication requirements or engineering constraints necessary to ensure future interoperability of all three PST units.

The OLTC diverter switch shall be installed in a separate oil compartment isolated from the main transformer tank. The design shall permit inspection, maintenance and overhaul of the OLTC without contamination of the main transformer oil or disturbance of the transformer active part.

The OLTC shall be capable of continuous operation under all specified operating conditions and at every tap position. The switched current capability shall be at least 120 % of the transformer's rated current. The OLTC shall be designed for frequent operation throughout the complete service life of the transformer with minimum maintenance requirements. The complete switching mechanism shall withstand all mechanical and electrical stresses occurring during normal operation, overload operation and external short circuits.

The OLTC shall be capable of performing at least 300,000 switching operations before first maintenance requiring intervention such as greasing or mechanical servicing of the drive mechanism. Replacement of vacuum interrupter cells shall not be required before at least 600,000 switching operations. The Contractor shall confirm the applicable maintenance intervals for the selected VACUTAP type and PST duty.

The OLTC oil expansion tank, where applicable for the selected design, shall be connected to the OLTC switching compartment by a dedicated pipe. The connecting pipe shall be provided with a separate OLTC protection relay. The closing valve shall be installed on the conservator side of the oil-flow relay. The OLTC conservator compartment shall be equipped with its own magnetic oil-level indicator, low-oil-level alarm contact, filling valve, drain valve, air breather installed at accessible eye level and overpressure protection device.

ETOS system shall provide OLTC and ARS control, monitoring, diagnostic and communication functions. The motor drive shall be suitable for a 400/230 V AC, 50 Hz auxiliary supply. The motor drive cabinet shall include at least:

- Local/Remote selector switch;
- Raise/Lower pushbuttons;
- emergency stop;
- mechanical operation counter;
- electrical operation counter;
- tap position indication;
- anti-condensation heater;
- thermostat;
- interior lighting;
- motor protection;
- torque protection;
- limit switches;
- terminal blocks for all external wiring.

Phase-angle and short-circuit impedance compatibility

The new PST shall be designed to ensure compatibility with the two existing PST units throughout the complete regulation range of 65 tap positions (32A–0–32R).

The Contractor shall provide calculated no-load phase-angle characteristics and short-circuit impedance characteristics for all 65 tap positions. The short-circuit impedances shall be expressed as percentages on a common base of 600 MVA and 400 kV.

The Purchaser has provided the available reference characteristics of the two existing PST units.The Contractor shall take these reference characteristics into account when designing the new PST and shall demonstrate compatibility with the existing units by appropriate engineering calculations and simulations.

The compatibility assessment shall include, as a minimum:

- comparison of the no-load phase-angle characteristics and short-circuit impedances over the complete regulation range;
- calculation of circulating currents resulting from differences in phase angles and impedances;

- verification of load sharing and loading limits during parallel operation of two and three PST units;
- assessment of relevant combinations of tap positions, including temporary tap-position differences during coordinated regulation;
- assessment of the operating conditions at and near the zero phase-shift position, where circulating currents may be particularly significant;
- verification that the proposed design and control philosophy do not result in unacceptable circulating currents, overloading or operational restrictions under the specified operating conditions.

The general tolerances for no-load phase angle and short-circuit impedance specified in IEC/IEEE 60076-57-1202, Clause 14.2, shall not, by themselves, be considered sufficient evidence of compatibility for parallel operation.

The maximum permissible differences between the characteristics of the new PST and those of the existing units shall be assessed against the compatibility and acceptance criteria specified by the Purchaser in the Tender Documents.

Any restrictions on permissible tap-position combinations, load sharing, switching sequences or parallel operation identified by the Contractor shall be explicitly stated in the Tender and supported by appropriate technical justification.

The final compatibility assessment, updated on the basis of the measured FAT characteristics of the new PST, shall be submitted to the Purchaser for approval before delivery.

Manual emergency operation shall be provided and mechanically interlocked to prevent simultaneous manual and motor operation. Each tap-changing operation shall be initiated by a single control pulse and shall be completed automatically. Continuous control signals shall not result in repeated switching operations.

The Advance-Retard Switch (ARS) shall be specifically designed for Phase Shifting Transformer duty. Mechanical and electrical interlocking shall prevent incorrect switching sequences. The ARS shall be fully coordinated with the OLTC and shall operate only according to the approved switching sequence. Complete documentation describing the switching sequence and interlocking philosophy shall be included in the Tender.

The regulating system shall be designed for reliable automatic parallel operation of three Phase Shifting Transformers. The control philosophy shall also support operation of any combination of two PST while the remaining PST is out of service due to maintenance, inspection, failure or operational requirements. Operation of a single PST shall also be fully supported. Automatic transition between three-PST, two-PST and single-PST operation shall not require modification of regulator settings.

The regulating system shall ensure:

- stable phase-angle regulation;
- equal load sharing;

- prevention of circulating currents;
- prevention of unnecessary tap operations (tap hunting);
- coordinated tap-changing sequences;
- stable operation following restoration of communication after temporary communication loss.

Failure or isolation of one PST shall not impair automatic regulation of the remaining PST.

The Contractor shall demonstrate, by calculation, simulation or documented engineering analysis, that the proposed PST is suitable for parallel operation with the existing PST units under all specified operating configurations.

The regulating equipment shall provide all interfaces necessary for integration into the substation control and monitoring system.

The ETOS system shall be suitable for integration into the station control and monitoring system and shall support, as a minimum:

- hardwired control signals;
- hardwired status indications;
- binary alarms;
- BCD tap position output for compatibility with the existing installation;
- IEC 61850 communication;
- Modbus TCP communication, if required by the Purchaser.

The regulating equipment shall continuously monitor its operating condition. The following information shall be available locally and remotely:

- tap position;
- ARS position;
- switching operation counter;
- motor operating time;
- switching time monitoring;
- motor current monitoring;
- OLTC alarms;
- maintenance indication;
- diagnostic status.

The Contractor shall submit with the Tender:

- complete technical description of the OLTC and ARS;
- switching diagrams and operating sequences;

- maintenance schedule;
- diagnostic functions;
- communication interfaces;
- recommended spare parts list;
- reference list of comparable installations;
- documentation demonstrating compatibility with parallel operation of multiple PST units.

Note: The future replacement of the OLTC control cubicles, protection systems and associated control equipment of the two existing PST units is outside the scope of this Tender and will be procured under a separate contract. However, the new PST shall be designed and documented to ensure seamless integration into the future common parallel control system.

15.7 Cooling system

The PST shall be provided with a cooling system designed in accordance with IEC 60076-2 and the applicable parts of the IEC 60076 series. The transformer shall be designed for ONAN/ONAF cooling. Under ONAN cooling, the transformer shall be capable of continuously carrying at least 80 % of its rated power. Automatic transition to ONAF cooling shall provide continuous operation at 100 % rated power under the specified site conditions. The cooling system shall be designed for continuous operation at the specified maximum ambient temperature of +40 °C (shade air temperature).

The number, size and arrangement of radiators shall be determined by the Manufacturer on the basis of the guaranteed PST losses and thermal performance. The arrangement of radiators shall take into account the available installation space within S/S Divača and shall permit safe operation, inspection and maintenance.

Failure of any single fan, fan motor or cooling controller shall not lead to immediate PST overload or forced outage under rated operating conditions.

The cooling system shall maintain PST temperatures within the limits specified by IEC 60076-2 under all specified operating conditions. The guaranteed temperature rises shall comply with the Technical Data Schedule.

The thermal design shall ensure adequate cooling of:

- top oil;
- average winding temperature;
- winding hot-spot temperature;
- OLTC compartment (where applicable).

The cooling system shall provide uniform oil circulation and avoid local hot spots.

The design shall permit isolation and removal of an individual radiator without draining the main PST tank. Removal during PST operation is desirable but not mandatory unless explicitly approved by the Purchaser. Each radiator shall be equipped with isolating butterfly valves on both oil connections. Each radiator shall be provided with:

- oil drain valve;
- oil sampling point where appropriate;
- air vent at the highest point.

Removal or isolation of one radiator or one fan shall not result in damage to the PST. The Manufacturer shall clearly specify any operational limitations associated with such conditions. Cooling equipment shall be designed to minimise maintenance requirements throughout the service life of the transformer. The radiators shall be detachable and connected to the tank or radiator headers by flanged connections with oil-resistant O-ring gaskets or other approved sealing arrangements. Each radiator group shall be equipped with lifting lugs. Radiators and radiator headers shall withstand full vacuum, oil pressure, thermal expansion, transport loads and operational vibration. The radiators shall be of robust pressed-steel construction and shall be securely fastened to the tank or to an approved independent framework. The design shall minimise vibration and prevent unacceptable vibration levels during all operating conditions and oil-tightness under all specified service conditions, including wind, ambient temperature variations and transformer vibration.

Cooling fans shall be directly mounted under the radiators. The fans shall:

- be designed for direct start and continuous operation, and connected to a three-phase supply of 400/230 V, 50 Hz,
- be dynamically balanced;
- operate with low vibration;
- be suitable for continuous outdoor service;
- be protected against accidental contact by galvanized steel guards;
- have totally enclosed squirrel-cage induction motors or equivalent maintenance-free motors.

Each fan shall be individually replaceable without dismantling the radiator structure.

The cooling pipework shall withstand the same internal pressure and vacuum conditions as the PST tank. If expansion joints are required, shall be provided on top and bottom cooler pipe connection.

The cooling system shall be automatically controlled based on the measured top-oil temperature (OTI) and winding temperature (WTI). The cooling control shall provide automatic sequential switching of cooling stages in accordance with adjustable temperature set-points and hysteresis.

The cooling equipment shall also be capable of manual operation by means of local and remote controls. Failure of the monitoring or control system shall not prevent manual operation of the cooling equipment.

The cooling system shall minimise unnecessary switching operations by means of adjustable temperature differentials (hysteresis) and minimum fan operating times. Following restoration of the auxiliary power supply after an interruption, the cooling system shall automatically return to the selected operating mode prior to the interruption.

The PST monitoring system shall monitor and record the operating status of the cooling equipment, the measured top-oil and winding temperatures, and generate alarms in the event of cooling equipment malfunction. Failure of one fan group shall not prevent operation of the remaining fan groups.

The cooling control equipment shall be installed in a weatherproof cabinet mounted on the transformer. The enclosure shall provide a minimum degree of protection IP55 according to IEC 60529. Fans shall be dynamically balanced in accordance with ISO 21940. All auxiliary equipment shall be rated for continuous operation. Auxiliary motors shall be supplied from a 400/230 V AC, 50 Hz auxiliary supply. Control and signalling circuits shall operate from the station 220 V DC supply unless otherwise specified.

The cooling system shall continuously monitor the operating condition of all cooling equipment. The following information shall be available locally and remotely:

- cooling mode (ONAN/ONAF);
- running status of each fan group;
- fan failure;
- cooling system alarm;
- cooling system trip;
- operating hours of each fan group;
- cooling equipment maintenance indication;
- inlet and outlet temperature measurement of the cooling system.

All alarms and status signals shall be transmitted to the substation control system. The cooling control system shall be also integrated with the transformer monitoring system.

The cooling system shall ensure reliable PST operation independently of the operating status of the other Phase Shifting Transformers installed in Divača substation.

The cooling philosophy shall support all anticipated operating scenarios, including:

- three PST units operating in parallel;
- any two PSTs operating in parallel while one transformer is out of service;
- operation of a single PST.

The cooling system shall not impose operational restrictions on the parallel operation philosophy of the three PST units.

The Contractor shall submit together with the Tender:

- thermal design description;
- cooling calculations;
- cooling equipment data sheets;
- fan characteristics;
- cooling control philosophy;
- control logic diagrams;
- alarm list;
- maintenance schedule;
- recommended spare parts list.

The cooling system shall be designed so that no scheduled maintenance requiring PST outage is necessary for a minimum period of ten (10) years under normal operating conditions, except for routine inspections and functional testing.

15.8 Bushings

Bushings for voltage levels U_m = 420 kV and U_m = 123 kV shall be of the resin-impregnated condenser type, RIP, oil-free, with silicone composite insulators. The bushings shall be manufactured in the European Union or in Switzerland, unless otherwise explicitly approved by the purchaser. The same requirements shall also apply to the neutral bushing, where applicable.

The bushings shall comply with IEC 60137 and with all applicable requirements of this specification. The insulation withstand levels of the bushings shall be at least equal to the specific basic insulation level, switching impulse withstand level where applicable, lightning impulse withstand level and power-frequency withstand voltage of the corresponding windings. The bushing insulation levels and creepage distances are given in Table 6.

For each combination of highest voltage for equipment and insulation level, only one bushing type shall be used. The use of different bushing types for the same voltage and insulation level combination shall not be permitted, to ensure interchange ability, uniform maintenance practice and standardisation of spare parts.

The rated current of each bushing shall be selected considering the rated current of the PST, rated frequency, operating conditions, overload requirements and thermal limits. The rated current of the bushing shall not be lower than the maximum current occurring in the corresponding PST terminal under the specified operating conditions.

Where the rated current of the bushing is selected from the standardised rated-current values specified in IEC/EN 60137, the selected value shall be the nearest standard value equal to or higher than the required PST current.

The shed material shall be a polymeric material based on silicone. The final polymer compound, after the addition of functional fillers, shall contain at least one-third pure silicone rubber. It shall not contain ethylene-vinyl acetate, ethylene-propylene rubber, ethylene-propylene-diene monomer or other UV-sensitive material. Only high-temperature vulcanised silicone rubber or liquid silicone rubber shall be used. Room-temperature vulcanised silicone rubber shall not be used for high-voltage applications.

The silicone housing shall have a tracking resistance of at least 4.5 kV, class 1A, in accordance with IEC 60587. The hydrophobicity recovery shall be WC 1–3 within 48 hours after complete loss of hydrophobicity, assessed in accordance with IEC TS 62073 or an equivalent approved method.

All hollow silicone composite insulators shall comply with IEC 61462 and the relevant parts of IEC 62217. The design of the composite insulators shall be verified by design tests and type tests in accordance with IEC 61462 and IEC 62217. Each composite insulator shall be subjected to the applicable routine tests in accordance with IEC 61462.

The bushings shall be completely oil-tight and shall be provided with capacitance and dielectric dissipation factor, tan δ, measuring terminals or capacitive taps, as applicable. Bushings shall be equipped with capacitive taps for measurement and diagnostic purposes. The measuring terminals and capacitive taps shall allow capacitance and tan δ measurements without disconnection of the primary connections. They shall be accessible, protected against moisture ingress and suitable for safe testing during commissioning and maintenance.

The bushings shall be designed and installed so that replacement is possible with minimum lowering of the PST oil level. The Manufacturer shall describe the required procedure for bushing replacement, including oil-level requirements, lifting arrangement, sealing arrangement and precautions for maintaining cleanliness and dielectric integrity.

Each bushing shall be provided with a rating plate in accordance with IEC 60137. The rating plate shall include at least the Manufacturer’s identification, type designation, catalogue number, year of manufacture, serial number, rated voltage, highest voltage for equipment, rated current, insulation levels, capacitance, dielectric dissipation factor reference value, mechanical characteristics and mounting angle where applicable. If the mounting angle exceeds 30°, it shall be clearly indicated on the rating plate.

Terminal dimensions, connection details and permissible mechanical terminal loads shall be stated in the technical documentation.

The high-voltage terminals shall be suitable for direct connection to aluminium-alloy clamping material. The terminal design shall prevent galvanic corrosion, excessive contact resistance, local overheating and mechanical overstressing. Contact surfaces, fastening

details, permissible terminal loads and required tightening torques shall be stated in the technical documentation. The 400 kV terminals shall be of bolted type with a 60 mm diameter and neutral (JO and SOLO) 40 mm unless otherwise specified in the approved design documentation. The terminal shape, dimensions, drilling pattern and connection arrangement shall be submitted for Purchaser approval.
The location of the bushings on the PST tank, as well as the phase sequence and terminal arrangement, shall comply with the layout shown in the attached drawings. Any deviation from the specified bushing location, terminal sequence or connection arrangement shall be subject to prior written approval by the Purchaser.

The high-voltage bushings of all three phases and the neutral bushing shall be selected, and the PST tank or cover shall be designed, so as to allow the installation of instrument current transformers on source (S), load (L) and at the neutral point for protection and monitoring purposes, where required by the protection concept. The instrument current transformers shall comply with IEC 61869-2 and with the accuracy, burden, rated current, short-time current and insulation requirements specified in this specification.
The bushing arrangement shall be designed to withstand all mechanical, thermal, electrical and environmental stresses occurring during transport, installation, testing, operation, switching transients, short-circuit conditions, wind loading, seismic loading where applicable and maintenance. Adequate clearances, creepage distances, corona shielding and electric-field grading shall be provided.

The Contractor shall submit complete bushing documentation, including at least:

- bushing Manufacturer and type designation;
- confirmation of resin-impregnated condenser, oil-free design;
- confirmation that the bushings are manufactured in the European Union or in Switzerland, unless otherwise approved by the purchaser;
- rated voltage, rated current and highest voltage for equipment;
- insulation levels and test voltages;
- creepage distance and pollution class;
- silicone material data and hydrophobicity performance;
- IEC 60137 type-test and routine-test certificates;
- IEC 61462 and IEC 62217 compliance evidence for composite insulators;
- capacitance and tan δ reference values;
- terminal dimensions and mechanical terminal-load limits;
- bushing arrangement drawings;
- replacement procedure;
- current-transformer accommodation details HV and HV neutral bushings;
- maintenance and testing instructions.

Bushing insulation levels and creepage distances are given in Table 6.

Table 6: Bushing's insulation levels

Terminal	No.	U_m (kV_{rms})	Insulation Levels			Min. creepage distance (mm)
			Power Frequency, under rain (kV_{rms})	Basic Insulation Level (Equal to dry lightning impulse withstand voltage.) (kV_{crest})	Dry switching impulse (kV_{crest})	
Line S1, S2, S3 L1, L2, L3	6	420	≥ 650	1550	1050	≥ 11500
Neutral JO, SOLO*	2	123	230	550	--	≥ 3625

***JO and SOLO are Manufacturer-specific terminal designations used for the common and separate neutral connections of the exciting PST.**

Cylindrical terminals are accepted in those cases where the terminal is a natural termination of the internal conductor arrangement.

Terminals of copper or a copper alloy shall be tin coated to layer thickness of at least 50 µm. Copper alloy sensitive to stress corrosion must not be used.

15.9 Current transformers

The PST shall be equipped with current transformers (CTs) for protection, control, monitoring and metering purposes. The number, location and functional arrangement of the CTs shall be equivalent to those applied on the existing PST at Divača Substation (Figure 8 and Figure 9) and shall be agreed with the Purchaser.

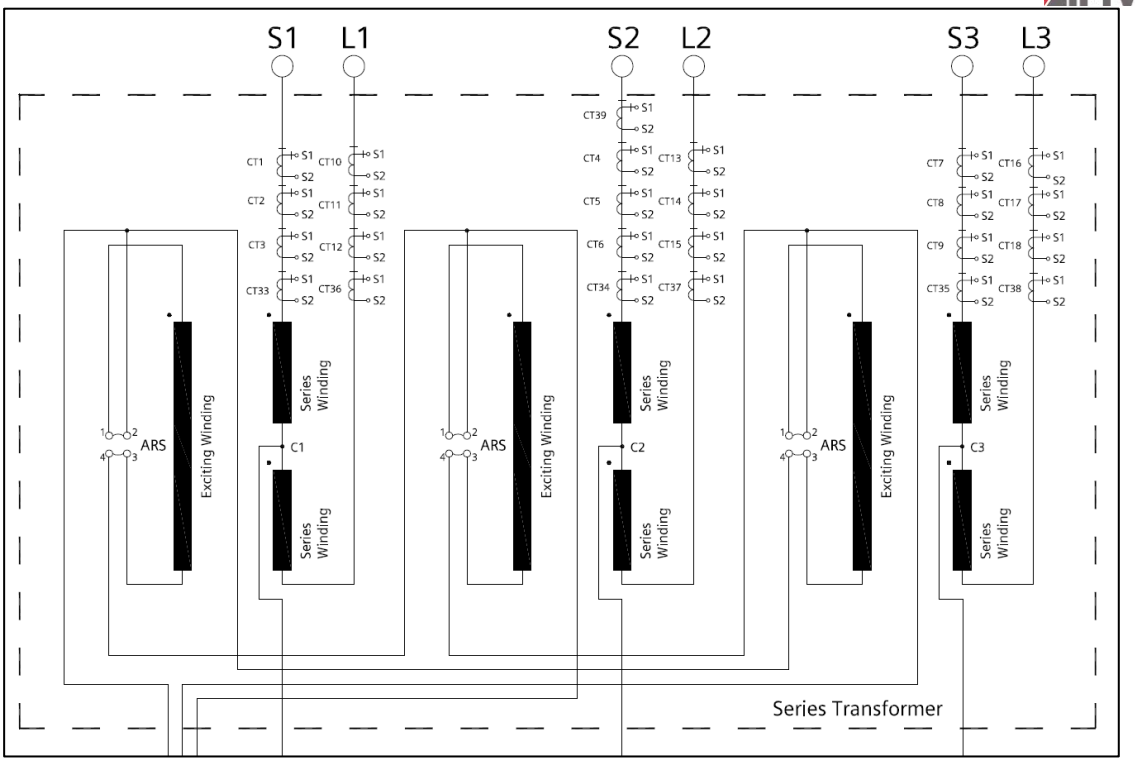


Figure 8: Current transformers in series unit of PST

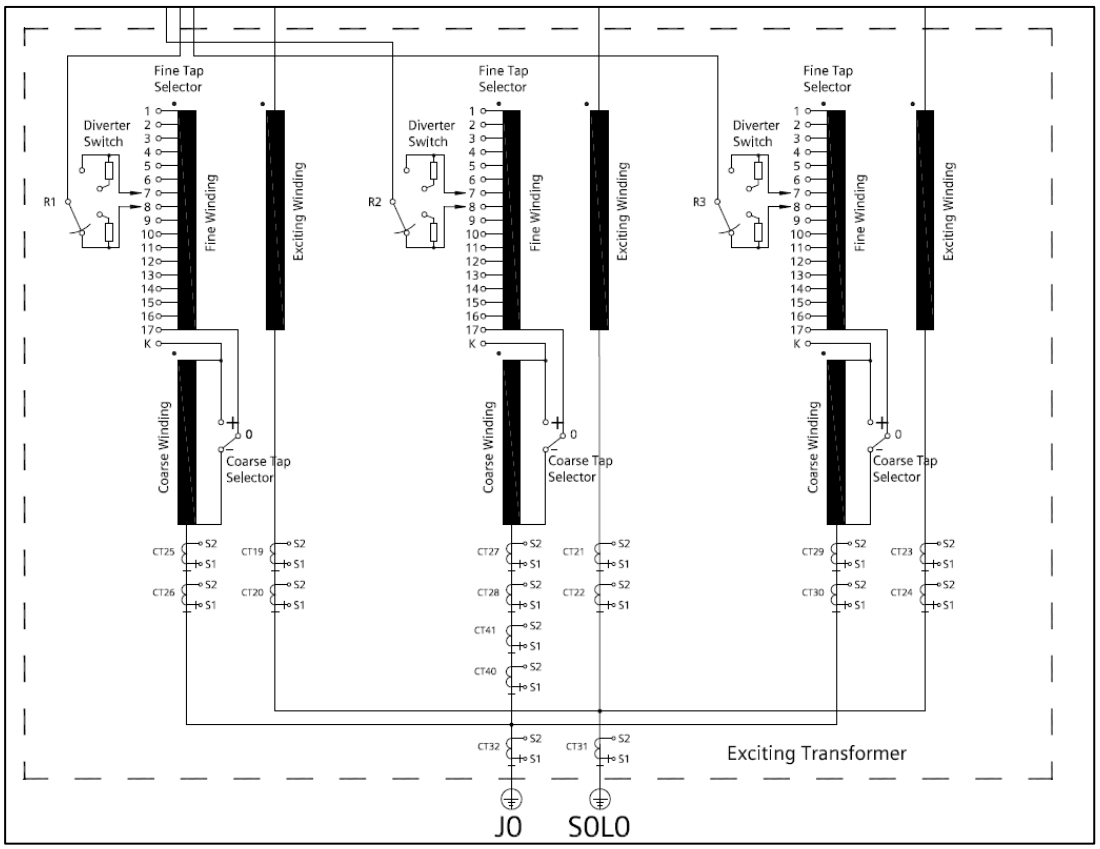


Figure 9: Current transformers in Exciting unit of PST

The current transformers shall fulfil the requirements of IEC 61869-1 and IEC 61869-2. Current transformers shall be installed at all locations necessary to ensure proper operation of the protection, control and monitoring systems, including the series transformer terminals, exciting transformer terminals and internal connections where required by the transformer design.

Each CT location shall be provided with an adequate number of independent cores for:

- transformer differential protection;
- restricted earth fault protection, where applicable;
- backup protection;
- control and automation;
- disturbance recording;
- monitoring;
- metering, where required;
- future spare cores.

The Manufacturer shall determine the CT ratios according to the final PST design and the maximum continuous current, overload capability and short-circuit current requirements. Protection CTs shall comply with IEC 61869-2 and shall be of Class PX or an equivalent protection class capable of meeting the protection system requirements. The CTs shall be designed to avoid saturation under the maximum through-fault currents and shall provide reliable operation of all protection functions.
The knee-point voltage, secondary winding resistance and excitation characteristics shall be selected by the Manufacturer based on the protection calculations. The selected characteristics shall not be inferior to those of the existing PST units installed at Divača Substation.

Each CT shall be factory tested in accordance with IEC 61869-2. Individual test reports shall be supplied for every CT core and shall include, as a minimum:

- transformation ratio;
- ratio error;
- phase displacement;
- polarity;
- secondary winding resistance;
- excitation (magnetisation) characteristic;
- knee-point voltage;
- excitation current at knee point;
- insulation tests.

The Manufacturer shall submit complete CT calculations demonstrating that the selected CT characteristics satisfy all protection requirements.

Table 7: Technical Schedule-Current Transformers

Item	Requirement
Applicable standard	IEC 61869-2
Secondary rated current	1 A
Installation	Integrated within the PST
Number of CT locations	According to Contractor design, functionally equivalent to the existing PST units
Number of cores	As required for all protection, control, monitoring and metering functions, including spare cores
Protection cores	Class PX or equivalent
Metering cores	According to IEC 61869-2 and Purchaser requirements
Continuous thermal rating	According to transformer rating
Short-time thermal current (Ith)	According to system fault level
Dynamic current (Idyn)	According to system fault level
Rated burden	To suit connected devices
Knee-point voltage	According to protection calculations; not inferior to the existing PST design
Excitation current	As low as reasonably achievable
Secondary winding resistance	To be declared
Ratio error	According to IEC 61869-2
Phase displacement	According to IEC 61869-2
Polarity	Clearly marked
Test reports	Individual report for every CT core
Documentation	Complete CT core allocation schedule

The Contractor shall verify that the selected current transformers are suitable for the specified protection, monitoring and temperature-imaging functions, including burden, accuracy, short-time current withstand, dynamic current withstand, thermal current withstand and the required performance under all specified operating and fault conditions.

The Contractor shall provide the following documentation:

- CT Core Allocation Schedule;
- CT Data Sheets;
- Excitation Curves for every protection core;
- Knee-point calculations;
- Protection coordination calculations;
- CT wiring diagrams;

- Terminal diagrams;
- Factory test reports for each individual CT core.

The CT design, performance and saturation characteristics shall be at least equivalent to those of the existing phase-shifting transformers installed at Divača Substation. The Purchaser reserves the right to reject CTs that provide inferior protection performance or reduced saturation margins.

15.10 Measuring, monitoring and protection equipment

The PST shall be fitted with a local control and marshalling cabinet mounted on the PST tank in a position easily accessible from ground level or from an approved service platform.

All cabinets shall be of weather-proof and corrosion-resistant design, suitable for outdoor installation under the specified service conditions. The degree of protection shall be not lower than IP55, unless otherwise specified. The cabinet shall be adequately ventilated and equipped with an anti-condensation heater controlled by a thermostat or hygrostat.

Internal illumination shall be provided by LED lighting fixtures of standard commercial type. The lighting shall be operated by door contacts and by a manual control switch.

The cabinet shall contain the required control, monitoring, protection, signalling and marshalling equipment associated with the PST auxiliaries, including termination of all secondary circuits. The internal arrangement of the cabinet shall keep protection, control, measurement, auxiliary AC, auxiliary DC and communication circuits clearly separated from each other, permitting easy and safe inspection, testing, maintenance and replacement of each item without disturbing the others.

Electrical connections between sensors, current transformers, protection devices, monitoring equipment and all other accessories and the local control cabinet shall be installed in corrosion-resistant metallic conduits, cable ducts or raceways of adequate size. They shall be securely fastened to the PST tank or supporting structure and arranged so as to prevent mechanical damage, vibration, water accumulation and excessive thermal stress.

The main technical data, location and dimensions of all measuring, monitoring and protection devices shall be described in the tender and shown on the relevant PST drawings. The arrangement shall be subject to purchaser approval.

The PST shall be monitored through the distributed microprocessor-based substation supervisory and control system. All required signals shall be made available for protection, control, monitoring, alarm, event recording and remote supervision.

Where signals are required by more than one system, enough mutually independent, potential-free and electrically decoupled contacts shall be provided. Protection and trip circuits shall be clearly separated from alarm, indication, monitoring and control circuits.

As a minimum, measuring and protection devices shall provide the following number of potential-free contacts:

- at least one contact for each alarm or signalling function;
- at least two independent contacts for each trip function.

In addition to potential-free contacts, standardised analogue outputs 4–20 mA shall be provided for remote monitoring where specified. Digital communication signals shall also be provided where applicable, for the ETOS system, online monitoring equipment and station control system integration.

The following measuring, monitoring and protection equipment of PST shall be supplied as a minimum:

a) One double-float Buchholz relay for thetank, equipped with test cock, gas sampling facility, shut-off valves and sufficient independent contacts for alarm (2x) and trip functions (2x).

b) One dial-type oil temperature indicator with maximum demand indicator and with enough independent and adjustable contacts for cooling control system (2x), alarm (1x) and tripping purposes (2x). The range of temperature indication shall be 0 °C to 160 °C. The device must be equipped with analog isolated current output 4-20 mA.

c) One resistance-type temperature sensor, Pt100, three-wire connection, for remote measurement of top-oil temperature (4-20 mA). The Manufacturer shall provide the measuring value/temperature characteristic.

d) One winding temperature indicator system for local and remote monitoring of winding temperature, with enough adjustable contacts for cooling control system (2x), alarm (1x) and tripping purposes (2x). The range of temperature indication shall be 0 °C to 160 °C. The device must be equipped with analog isolated current output 4-20 mA.

e) Fibre-optic winding temperature monitoring equipment connected to the fibre-optic sensors installed in the windings and oil cooling channel in core, as specified in the winding section. The system shall provide local and remote indication, alarm and trip functions, event recording and communication with the PST monitoring system.

f) Current transformers for winding temperature indicator and OLTC , monitoring or other specified functions (in accordance with Section 15.9). These current transformers shall not be of protection class P. Means shall be provided for external calibration by current injection into the current-transformer secondary circuit.

g) There will be an agreed number of current transformers at the neutral point.

h) One magnetic-type oil level indicator for the main oil conservator, with at least two independent adjustable contacts for low and high oil level alarm.

i) One magnetic-type oil level indicator for the OLTC oil conservator compartment, with at least two independent adjustable contacts for low and high oil level alarm.

j) One protection relay for the OLTC oil compartment, such as an oil-flow relay, oil surge relay or equivalent protection device according to the approved MR VACUTAP arrangement (e.g., MR RS2001) with potential independent protection contacts (2x).

k) Two spring-operated pressure relief device or pressure relief valve on the main transformer tanks, then on each OLTC compartment, and on the intermediate throat connections...,provided with a trip contacts (2x) as specified.

l) Monitoring, control and diagnostic equipment associated with the ETOS system for the VACUTAP on-load tap-changer and ARS, including OLTC position, operation counter, motor-drive status, alarms, trips, maintenance indication, event recording and communication interface to the station control system.

The Buchholz relay shall be provided with two electrically separate contacts as a minimum:

- one contact activated by slow gas formation, to be used for alarm;
- one contact activated by heavy gas formation, sudden oil flow or low oil level, to be used for tripping.

The Buchholz relay shall be provided with shut-off valves. Where technically feasible and approved by the Manufacturer, a bypass arrangement may be provided to allow relay replacement without draining the main tank. Any testing, isolation or replacement of the relay while the PST is in service shall be subject to theManufacturer’s approved operating and safety procedure.

Each oil compartment shall be protected separately. The main PST tank, the OLTC and all associated compartments of PST shall have separate protection, monitoring and alarm/trip functions.

Gas sampling and functional testing of the Buchholz relay shall be possible without draining the PST oil. The relay shall be located in a position that allows safe access for inspection, testing, gas sampling and maintenance from ground level, ladder or approved service platform.

All protection and monitoring devices shall be arranged so that alarm and trip functions are clearly identified. Trip contacts shall be wired to dedicated terminal blocks and shall be galvanically separated from alarm and indication circuits.

All measuring and monitoring equipment shall be suitable for the specified environmental conditions, auxiliary supply system, electromagnetic environment and substation control philosophy. The equipment shall comply with the applicable IEC standards and the general technical specifications.

The Contractor shall submit complete documentation for the measuring, monitoring and protection equipment, including at least:

- list of all measuring, monitoring and protection devices;
- Manufacturer and type designation of each device;
- technical data sheets;

- setting ranges and proposed settings;
- contact functions and contact ratings;
- analogue output ranges, including 4–20 mA signals;
- digital communication interfaces and protocols;
- terminal diagrams;
- wiring diagrams;
- cabinet layout;
- alarm and trip matrix;
- interface list for the substation control system;
- test and commissioning procedures;
- maintenance instructions.

15.11 On-line monitoring system

The offered PST shall be equipped with a complete on-line monitoring system, hereinafter referred to as OLM. The OLM shall provide continuous monitoring, diagnostics, data acquisition, data storage, alarm handling, event recording and communication with the substation control system and the central on-line monitoring system. The OLM shall be fully integrated with the PST measuring, monitoring and protection equipment the ETOS and other systems.

The OLM supply and installation shall include, as a minimum:

- supply, installation and commissioning of all measuring and sensor equipment installed on or inside the PST;
- supply, installation and commissioning of the local OLM control module or control box on the PST;
- supply, installation and commissioning of the OLM server in the substation control house;
- communication connections between sensors, measuring equipment, the local OLM control module, the local control cabinet, the OLM server in the substation control house and connection to the existing Purchaser diagnostic centre;
- supply and laying of optical communication cables between the local OLM control module and the OLM server in the substation control house;
- support of analogue and digital communication with sensors and intelligent electronic devices;
- connection, calibration and parameterisation of fibre-optic temperature sensors installed in the PST windings and oil cooling channel;

- connection, calibration and parameterisation of the ETOS system to the OLM;
- supply and installation of all applicable software on the OLM server located in the substation control house;
- supply and installation of application software for measurement, calculation, evaluation, display and storage of monitored quantities;
- parameterisation of all sensors, measured values, calculated values, alarms, events and communication interfaces;
- integration into the central on-line monitoring system (DAC SCADA);
- start-up, testing and commissioning of the complete OLM;
- technical documentation, including detailed design documentation, erection documentation, commissioning documentation and as-built documentation.

The central on-line monitoring system, hereinafter referred to as DAC SCADA, is intended for direct monitoring and diagnostics of PST, power transformers and variable shunt reactors. It enables robust and fast multi-user access, permanent data storage, data processing, data analysis and display using web-based technologies and tools.

Local OLM data shall be transmitted to the DAC SCADA by means of a service application capturing raw-format data, including process values, events and alarms.

The Contractor shall ensure complete interoperability of the supplied OLM with the above-described DAC SCADA. The OLM shall support communication with DAC SCADA by means of Modbus TCP, IEC 61850, or web services. The final communication protocols, signal lists, data structure, timestamps, alarm classes and interface requirements shall be agreed with the Purchaser during detailed design.
The Contractor shall include the PST in the common DAC SCADA. Operating data, diagnostic values, calculated values and alarm/event states shall be simultaneously visible. The Contractor shall enable storage of all parameter values, calculated values and alarm/event states of the PST OLM in the ELES central database.
The OLM shall be designed so that no data from sensors or local monitoring equipment is lost in the event of a short DAC SCADA downtime or temporary communication interruption. Local buffering of data, events and alarms shall be provided. After communication is restored, buffered data shall be automatically transferred.

15.12 Measuring equipment and sensors

The OLM shall include all required measuring equipment and sensors. Where technically possible, sensors and intelligent devices shall support analogue or digital communication, such as Modbus TCP, DNP3 or IEC 61850.

The following PST quantities shall be captured and monitored as a minimum:

- top-oil temperature;
- bottom-oil temperature;
- ambient temperature;
- temperatures of incoming and outgoing radiator oil pipelines;
- dissolved gas and moisture in oil, including at least hydrogen, carbon monoxide and moisture measurement, e.g. Morgan Schaffer Calisto 2 or technically equivalent equipment approved by the purchaser;
- operating current taken from the internal instrument current transformer;
- gas accumulation in the Buchholz relay;
- power factor or dielectric dissipation factor where applicable;
- operating voltages from external VTs;
- transient overvoltages, capacitance and dielectric dissipation factor / power factor of HV bushings, e.g. OMICRON MONTRANO, MR MSENSE BM or technically equivalent equipment approved by the purchaser (test tap shall be approved by bushing Manufacturer);
- tap-changer/ARS monitoring data from ETOS, including tap position, number of switching operations, switching sequence, switching time, motor-drive status, diagnostic information and maintenance indicators;
- OLTC/ARS oil temperature, where applicable;
- vibration sensors (measuring range 5 Hz to 10 kHz (e.g. WISE- or technically equivalent equipment approved by the purchaser)) – (3) three pieces on each tank.
- status of all relevant protection, alarm and trip devices;
- status of auxiliary systems, communication links and monitoring devices.

The OLM software shall provide calculation, evaluation, display, storage and reporting of measured and calculated parameters. As a minimum, the software shall provide the following functions:

- calculation of winding hot-spot temperature in accordance with IEC 60076-7;
- calculation or estimation of relative moisture content of paper insulation;
- evaluation of insulation ageing in accordance with IEC 60076-7;
- calculation of ageing rate of insulation in accordance with IEC 60076-7;
- calculation of cumulative ageing rate;
- calculation or estimation of actual losses;
- calculation or indication of bubbling temperature;
- indication and recording of overvoltage events in all three phases;
- indication and recording of overcurrent events in all three phases, with a sampling time of 20 ms or less;
- evaluation of OLTC contact usage based on actual current and tap position;
- monitoring of PST bushing capacitance change;
- monitoring of bushing dielectric dissipation factor / power factor;

- trend analysis of measured and calculated values;
- alarm and event evaluation;
- diagnostic reporting.

The OLM software shall also provide the following capabilities:

- review of archived data and reports;
- review of main operating and diagnostic parameters;
- statistical data analysis;
- archiving of measured data, calculated values and analysis results;
- monitoring of sensor-to-server communication connections;
- supervision of sensor operation and sensor status;
- examination of connected equipment status;
- data archiving in a standardised database, preferably MS SQL or another database approved by the purchaser;
- automatic backup and duplication of stored data for security reasons;
- display and download of any selected combination of monitored data;
- simultaneous display of operating data and alarm states of each transformer or PST included in the on-line monitoring system, including units from other substations where applicable;
- graphical display of each transformer or PST, including a picture or schematic representation of the corresponding device;
- retrieval of limit values for measured process values by the Purchaser's DAC SCADA, including low-active, low-inactive, high-active and high-inactive limits, where required;
- alarm visualisation;
- annunciation of alarm states to responsible personnel via intranet, internet, e-mail, SMS, mobile application or other approved method;
- user parameterisation of alarm levels, limit values, historical database processing and other user-defined settings.

All offered software shall be inspected and approved by the Purchaser before commissioning. The software shall be user-friendly and shall allow access from personal computers via an appropriate server through the Purchaser's intranet and, where approved, through secure internet access. Connected users shall be able to use the permitted display, diagnostic and reporting functions according to their access rights.
The software shall allow user parameterisation of alarm thresholds, warning thresholds, calculation parameters, historical data handling and other configurable functions. Access to parameterisation functions shall be protected by user authentication and access-level management.

Data shall be stored locally with high time resolution. After a defined period, average values of each measured quantity shall be automatically stored in the long-term database. All asynchronous phenomena, including alarms, trips, trip-change operations, status changes and communication failures, shall be stored separately with exact date, time, measured value and event description.

All events and alarms shall be time stamped. The time-synchronisation method shall be agreed with the purchaser and shall be compatible with the substation control and monitoring system.

Software updates shall be supplied to the Purchaser free of charge for at least three years after the first installation and commissioning. Updates shall include correction of software errors, compatibility improvements and security updates. Updates shall not reduce any functionality accepted during commissioning.

Main OLM elements installed on the PST shall be designed and manufactured by a recognised equipment Manufacturer with proven experience in power engineering and transformer/reactor monitoring systems.

The OLM shall be designed so that servicing and elimination of potential failures can be performed using standard components, without the need for returning equipment to the Contractor, except where specialised factory repair is unavoidable.

The OLM Manufacturer shall provide sufficient training to the Purchaser's personnel to enable operation, first-level diagnostics, data retrieval, parameterisation, backup handling and basic service intervention on the server unit and local monitoring equipment. The system shall be designed so that qualified personnel of the Purchaser or the Purchaser's authorised Contractor can restore normal operation by using the supplied operation and maintenance instructions.

The software upgrades, user interface, alarm texts, monitor screens and display masks shall be provided in the Slovene language. Technical documentation shall be provided in English and, where required by the Purchaser, also in Slovene.

The Contractor shall submit complete OLM documentation, including at least:

- OLM architecture diagram;
- list of all sensors and monitoring devices;
- Manufacturer and type designation of each sensor and device;
- measuring ranges and accuracy data;
- communication protocol descriptions;
- signal list for OLM, ETOS, substation control system and DAC SCADA;
- database structure and data-storage concept;
- alarm and event list;
- calculation methods and applied standards;
- software description;
- cyber-security and user-access concept;

- time-synchronisation concept;
- cabinet and server arrangement drawings;
- cable and fibre-optic connection diagrams;
- terminal diagrams;
- parameterisation list;
- testing and commissioning procedures;
- backup and restore procedure;
- operation and maintenance manuals;
- training programme for purchaser personnel;
- as-built documentation.

The complete OLM, including all sensors, communication links, server equipment, software, ETOS interface, bushing sensor interface and DAC SCADA integration, shall be tested during commissioning. The test shall verify correct measurement, calculation, alarm generation, event recording, data storage, communication, visualisation and data transfer to the central monitoring system.

15.13 Erection works

Erection works shall contain:

- connection points for PST sensors erection (in the factory and on site),
- measuring sensors erection,
- control box erection (controle module),
- system server erection
- communication connections between sensors and control box realization,
- optical cable: control box – system server in the relay house and connection (distance of appx. 200 m),
- software installation for substation server and user computers, which shall be connected to the server via intranet/internet in both substations,
- parameterization (alarm levels) for supervised PST,
- integration into the central monitoring system DAC SCADA.

15.14 Winding and core temperature optical sensors

Direct measurement of winding and active-part hot-spot temperatures shall be provided by fibre-optic temperature sensors installed in the Phase Shifting Transformer. Since the PST consists of a series unit and an exciting/regulating unit installed in separate transformer tanks, each unit shall be equipped with its own independent fibre-optic temperature measuring system. Each fibre-optic temperature measuring system shall have at least twelve measuring channels. At least twelve fibre-optic temperature sensors shall be

installed in the series unit and at least twelve fibre-optic temperature sensors shall be installed in the exciting/regulating unit.

For each unit, the sensors shall be distributed among the three phases and located at positions where the highest winding and active-part temperatures are expected. For each unit, at least ten sensors shall be installed in the windings and at least two sensors shall be installed in selected core, oil cooling channel or other active-part locations where elevated temperatures may occur.

The preliminary number, location and function of each sensor shall be proposed by the Manufacturer based on thermal design calculations. The final locations of the fibre-optic temperature sensors shall be reviewed and agreed with the Purchaser during the design review and before manufacture.

Each fibre-optic temperature measuring system shall include sensors, tank-wall feedthroughs or connection interfaces, local temperature indication on or near the corresponding PST tank, and communication with the PST on-line monitoring system. The on-line monitoring system shall provide separate indication, alarming, trending and data recording for the series unit and the exciting/regulating unit.

The sensors and measuring equipment shall be suitable for continuous operation in hot transformer oil and under the specified electromagnetic, thermal, mechanical and dielectric conditions. They shall be compatible with the winding insulation system, drying process, oil impregnation process, thermal expansion, vibration and expected service life of the PST.

Fibre-optic sensors and measuring equipment manufactured by FISO, LumaSense/Luxtron, Neoptix, or technically equivalent equipment approved by the Purchaser, are acceptable.

The Contractor shall submit sensor layout drawings, installation procedure, channel identification list, calibration certificates, factory test results, commissioning test results and operation and maintenance instructions.

15.15 PST tanks, Conservators and Oil Preservation System

The PST shall consist of two independent transformer units:

- Series Unit;
- Exciting Unit.

Each unit shall be installed in its own welded transformer tank and equipped with its own conservator and associated oil preservation system.

The complete mechanical design shall comply with the applicable requirements of the IEC 60076 series of standards.

Each PST tank shall be fabricated from welded structural steel plates of adequate mechanical strength suitable for transformer applications. The tank shall withstand, without permanent deformation, all mechanical loads arising during:

- factory testing;
- transport;
- lifting;
- installation;
- normal operation;
- short-circuit conditions;
- seismic events specified for the installation site.

The tank design shall be verified by structural calculations. Where appropriate, finite element analysis (FEA) may be used to demonstrate compliance. The tanks shall be completely oil-tight and weatherproof throughout the PST's service life. No oil leakage shall be permitted under normal operating conditions. The tank and all welded joints shall withstand:

- full vacuum during oil filling;
- repeated vacuum treatment during maintenance;
- an internal overpressure of at least 100 kPa;
- all pressures resulting from operation of the pressure relief devices.

The complete PST shall withstand, without permanent deformation or oil leakage, all pressure conditions specified by IEC 60076. The transformer cover shall be welded or bolted using corrosion-resistant fasteners. The sealing system shall ensure reliable long-term leak-tightness while permitting repeated removal during maintenance. The tank geometry shall prevent accumulation of rainwater on external surfaces. Internal surfaces shall be designed to avoid trapping of air or gas pockets during oil filling. The design shall facilitate complete oil filling, vacuum treatment, oil circulation and complete drainage.
All covers shall be provided with suitable lifting lugs. All inspection openings shall permit safe inspection and maintenance of the active part. Openings shall be provided as necessary for:

- bushings;
- current transformers;

- OLTC/ARS connections;
- internal inspection;
- maintenance;
- lifting of the active part;
- online monitoring equipment;
- future accessories if required.

All studs, bolts and nuts shall be made of corrosion-resistant material, hot-dip galvanised steel or stainless steel, as appropriate for the location and service conditions. All bolted joints exposed to atmosphere shall be protected against corrosion and loosening.

All nozzles shall project above the tank cover sufficiently to prevent ingress of rainwater. Each PST tank shall be provided with at least five thermometer pockets located at positions corresponding to the highest top-oil temperatures. The pockets shall permit removal or replacement of sensors without lowering the transformer oil level. Unused pockets shall be sealed with oil-tight threaded plugs. The thermometer pockets shall be suitable for installation of:

- resistance temperature detectors (RTDs);
- capillary thermometers;
- electronic temperature sensors;
- online monitoring equipment.

Each PST tank shall be designed for transport and installation as a complete unit.
Suitable lifting lugs shall be provided for:

- lifting the complete active part;
- lifting the empty tank;
- lifting each unit during transport;
- removal of the tank cover.

Each PST unit shall be equipped with jacking pads suitable for hydraulic lifting during installation, maintenance and transport preparation. Each jacking pad shall be designed to withstand the maximum loads occurring during lifting of the transformer unit. The PST shall be designed for installation directly on a reinforced concrete foundation. The Manufacturer shall provide a suitable support arrangement ensuring uniform load distribution to the foundation. Where required by the mechanical design, anti-vibration pads or equivalent resilient supports shall be provided between the transformer base and the concrete foundation. The proposed solution shall be submitted to the Purchaser for approval. The support structure shall be designed to withstand all static and dynamic loads arising during operation, transport, short-circuit conditions and the specified seismic conditions without excessive stresses or permanent deformation.

The PST shall be designed so that no mechanical adjustment or re-tightening is required following transport under normal transport conditions. The Contractor shall provide all necessary information concerning:

- foundation loading;
- support reactions;
- centre of gravity;
- lifting points;
- jacking points;
- transport dimensions and weights;
- installation tolerances.

The transformer base frame shall be designed to accommodate differential foundation settlement within the tolerances specified by the Contractor without introducing excessive mechanical stresses into the transformer tanks, bushings, interconnecting pipework or other accessories.

The oil and mechanical connections between the Series Unit and the Exciting Unit shall accommodate:

- construction tolerances;
- foundation settlement;
- thermal expansion;
- operational vibration;
- seismic displacement.

No excessive mechanical stress shall be transferred from one tank to the other. Where necessary, flexible metallic expansion joints shall be provided. The interconnecting pipework shall permit isolation of each PST unit for maintenance. The design shall permit independent oil treatment of each PST unit.

Each PST tank shall be equipped with its own conservator. Where the OLTC/ARS has a separate oil compartment, an independent conservator shall also be provided. The conservator capacity shall accommodate the total oil volume variation corresponding to oil temperatures between –25 °C and +120 °C. The conservators shall be suitable for vacuum oil filling. The conservators shall be installed above the highest point of the oil system. The piping arrangement shall prevent accumulation of gas between the PST tank and the conservator.

Each conservator shall be equipped with an oil preservation system employing a synthetic rubber air cell (diaphragm) preventing direct contact between transformer oil and atmospheric air. The oil preservation system shall permit vacuum oil filling without removal of the diaphragm. Each conservator compartment shall be equipped with:

- oil level indicator (The oil level indicator shall be mounted at an accessible location, with the indicator positioned between 0.8 m and 1.8 m above the finished operating level to ensure safe and convenient visual inspection.);
- low oil level alarm;

- high oil level alarm;
- dehydrating breather;
- oil trap where applicable.

Each conservator shall be connected to the transformer tank through a Buchholz relay installed in accordance with IEC requirements. The Buchholz relay shall be removable without disconnecting the conservator from the transformer. Isolation valves shall be provided on both sides of the relay. A bypass arrangement shall permit maintenance of the relay where appropriate.

All piping, valves and fittings shall be manufactured from corrosion-resistant materials suitable for long-term outdoor service. Pipework shall withstand the same pressure and vacuum conditions as the PST tank. All valves shall be clearly marked to indicate OPEN and CLOSED positions. All valves shall remain accessible after installation. Oil-tight joints shall use machined flanges with high-quality elastomeric gaskets suitable for transformer oil and long-term service. The gasket arrangement shall prevent over-compression and ensure metal-to-metal contact where appropriate. All unused connections shall be sealed with blind flanges or threaded caps.

Each PST tank shall be equipped, as a minimum, with:

- tank drain valve;
- oil filling connection;
- upper oil sampling valve;
- middle oil sampling valve;
- lower oil sampling valve;
- oil filtration connections;
- air release valves;
- conservator drain valve;
- conservator filling connection;
- radiator isolating valves;
- OLTC/ARS oil system valves where applicable;
- valves for connection of an on-line dissolved gas analysers;
- lifting lugs suitable for lifting the tank;
- four jacking lugs close to the tank base;
- pulling eyes close to each corner of the tank, with an opening not less than 50 mm in diameter;
- pulling eyes designed so that each one can withstand the full pulling force during sliding or skidding of the tank;
- provisions for brackets for transport on side-beam railway cars;

  provisions for bracing during transport on a low-bed trailer.

The ladder shall be equipped with a protection system to secure personnel against falling. The PST cover shall be provided with certified fall-arrest anchorage points for securing personnel safety harnesses during inspection and maintenance activities on the PST.

The exact number and locations of valves shall be proposed by the Contractor and approved by the Purchaser.

Each oil-filled compartment shall be equipped with adequately sized spring-operated pressure relief devices. The number and location of the devices shall be determined by the Contractor based on pressure rise calculations. Each pressure relief device shall:

- operate below the hydraulic test pressure;
- reseal automatically after operation;
- include at least two trip contacts;
- direct discharged oil safely towards the oil collection system.

The discharge arrangement shall prevent oil from being expelled onto bushings, cable connections, cooling equipment or operating walkways.

The Contractor shall submit together with the Tender:

- tank drawings;
- conservator drawings;
- interconnecting piping drawings;
- transport drawings;
- lifting drawings;
- jacking arrangements;
- valve schedule;
- pressure calculations;
- corrosion protection specification;
- oil preservation system description;
- maintenance instructions.

15.16 Dehydrating breather

Each conservator compartment requiring connection to ambient air shall be equipped with a dehydrating breather and an oil trap or oil seal.

The dehydrating breather shall be a maintenance-free, self-regenerating and the quality class of MR products. It shall be equipped with silica gel and an automatic regeneration heater activated when the silica gel reaches the specified moisture level. Under normal service conditions, replacement of silica gel shall not be required.

The breather shall be suitable for the site environmental conditions specified in the General Technical Specifications. The auxiliary supply voltage shall be 230 V AC, and signal contacts shall be suitable for 220 V DC control circuits.

The breather shall provide alarm and status signals for power supply failure, heater or regeneration failure, high moisture condition and device fault. The heater supply shall be supervised by suitable current monitoring so that failure of the regeneration function is detected and signalled.

Where two breathers are installed for the same oil system, a three-way valve or equivalent arrangement shall ensure continuous operation of at least one breather during inspection, maintenance or replacement of the other.

The breather shall be arranged so that the passage of air is through the dehydrating medium and so that unnecessary continuous exposure of the silica gel to ambient atmosphere is prevented. Local indication of moisture condition shall be provided by colour change or equivalent indication.

All breathers shall be installed at an accessible height, approximately from 80 to 180 cm above ground level or above the relevant service platform, allowing safe inspection and maintenance.

A diaphragm or air-cell system shall be provided in the conservator to separate the oil from ambient air, as specified in the conservator section. No chemical-type on-line oil filter shall be used as oil preservation equipment.

The Contractor shall submit the breather type designation, operating principle, auxiliary supply data, alarm and signal list, valve arrangement, mounting details and maintenance instructions.

15.17 Piping, valves, joints, stainless steel flange and gaskets

All necessary drain valves, filling valves, shut-off valves, isolating valves, check valves, air-release plugs, sampling valves, blanking plates, end fittings, pipe connections and associated accessories shall be supplied in sufficient quantity to suit the size, arrangement and maintenance requirements of the PST.

The arrangement shall allow safe oil filling, draining, filtering, vacuum treatment, oil sampling, venting, inspection, maintenance and removal of components attached to the tank, conservator, radiators and OLTC oil system.

All valves shall comply with DIN EN 12266-1, 2,. The final number, type, size and location of all valves shall be subject to Purchaser approval.

All valves, fittings, pipes, joints, stainless steel flanges and seals shall be designed and manufactured from materials suitable for continuous operation in hot transformer oil and for outdoor service under the specified environmental conditions. They shall not deteriorate due to oil, temperature, ageing, humidity, ultraviolet radiation, corrosion, vibration or other service influences.

Every element shall be designed so that it can be easily inspected, maintained, isolated or replaced. All piping and valve arrangements shall be clearly accessible and shall not obstruct access to bushings, radiators, conservator, Buchholz relay, OLTC equipment, measuring devices, sampling points or other accessories.

All valves up to and including DN 50 shall be made of brass, gunmetal or another approved corrosion-resistant material. Larger valves may have cast-iron bodies with gunmetal or equivalent corrosion-resistant fittings, subject to purchaser approval.

Each valve shall be provided with a clear and durable position indicator showing whether the valve is open or closed. Where necessary, valves shall be capable of being locked or sealed in the required operating position.

All oil-tight joints shall be made with machined flanges and approved gasket types. The gasket material and sealing arrangement shall be submitted for purchaser approval. Means shall be provided to prevent over-compression of gaskets. All joint faces shall be arranged to prevent ingress of water and leakage of oil, with the minimum practicable gasket surface exposed to oil and air.

All gaskets between metallic parts shall be designed so that, after tightening, metal-to-metal contact or another approved compression-limiting arrangement is achieved. O-ring gasket technology shall be applied wherever feasible.

All valves, pipe ends, flanges and joints that are not in use shall be closed with suitable oil-tight end fittings, screw caps, blanking plates or blind flanges.

All piping shall be arranged with suitable slopes and venting points to avoid air pockets during oil filling and to enable complete draining where required. Pipes shall be adequately supported and protected against vibration, mechanical damage, thermal expansion and transport stresses.

All valves, pipes, fittings, joints and gaskets shall be correctly identified, labelled and documented in the PST drawings and in the final valve schedule. The valve schedule shall include valve number, function, type, size, material, location, normal operating position and associated interlocks or alarms where applicable.

The PST shall be equipped with the following valves and connections as a minimum.

The PST tank shall be equipped with:

a) one DN 50 drain valve arranged so that the tank can be completely drained of oil;

b) two DN 50 oil-filtering and oil-treatment valves, located near the bottom of the tank and diagonally opposite near the cover level, suitable for connection of oil-treatment equipment in accordance with purchaser requirements and, where applicable, IEC 60567;

c) one valve or connection for vacuum pump connection, with characteristics and position to be agreed during detailed design;

d) three oil-sampling valves, arranged for sampling from the following levels:

- top oil level;

- approximately middle tank height;
- bottom tank level.

The oil-sampling valves shall be routed, where necessary, to an accessible operating height so that oil samples can be taken safely during normal PST operation and at a safe distance from live parts. Sampling arrangements shall comply with IEC 60567 where applicable. Unless otherwise agreed with the Contractor and approved by the Purchaser, the sampling and oil-treatment connections shall be located at suitable positions near the tank bottom and at two diagonally opposite corners, where practicable.

The conservator system shall be equipped with:

a) one valve arrangement for the oil pipe bypassing the Buchholz relay, where a bypass is provided;

b) two isolating valves for isolation and removal of the Buchholz relay;

c) one oil filling plug or filling valve;

d) one drain valve arranged so that the conservator compartment can be completely drained of oil;

e) additional valves and fittings required for separate conservator compartments, including the main PST oil compartment and the OLTC/ARS oil compartment, where applicable.

Radiators shall be equipped with valves at each connection point between the tank and the radiators or between the radiator headers and the separate cooling system, in accordance with the PST cooling-system requirements.

Each radiator or radiator group shall be provided with isolating valves at the inlet and outlet, enabling isolation and removal without draining or lowering the oil level in the main tank. Each radiator and radiator header shall also be provided with vent and drain plugs.

The OLTC/ARS oil system shall be provided with all valves, drain connections, filling connections, sampling connections, isolating valves, protection-relay connections and conservator connections required by the approved VACUTAP design.

The OLTC/ARS oil compartment and associated conservator section shall be arranged so that filling, draining, sampling, venting, protection-relay testing and maintenance can be performed safely and without contamination of the main PST oil system.

The Contractor shall submit complete documentation for piping, valves, joints and gaskets, including at least:

- piping and instrumentation arrangement;
- valve schedule;
- material specifications for valves, pipes, fittings and gaskets;
- gasket and flange details;

- valve normal operating positions;
- filling, draining and venting procedure;
- oil sampling arrangement;
- oil filtering and vacuum-treatment connection details;
- radiator isolation arrangement;
- Buchholz relay isolation and bypass arrangement;
- OLTC/ARS oil-system valve arrangement;
- maintenance and replacement instructions.

15.18 PST pressure relief valves / devices

The PST tank shall be equipped with approved pressure relief devices of spring-controlled type, suitable for rapid release of internal overpressure that may occur in the oil-filled tank and associated oil-filled connection parts.
The number, size, operating pressure and location of the pressure relief devices shall be determined by the Manufacturer based on the tank design, oil volume, internal pressure withstand capability and applicable standards, and shall be submitted to the Purchaser for aproval.
Each pressure relief device shall be of adequate size and shall operate at a static pressure lower than the hydraulic test pressure of the tank. The pressure relief device shall be designed and selected so as to prevent permanent deformation or damage to the tank under internal fault or abnormal pressure conditions.

Each pressure relief device shall be equipped with two independent potential-free change-over contacts (normally open); one dedicated for transformer trip. Remote monitoring of the pressure relief devices shall be possible. Activation of any pressure relief device shall generate an alarm in the local control cabinet and in the remote monitoring/control system.

Each pressure relief device shall be provided with a mechanical operation indicator, clearly visible from operating height and from a safe distance from live parts. It shall be possible for operating personnel to determine locally, without danger, whether a pressure relief device has operated.

The pressure relief devices shall preferably be mounted on the tank cover. Each device shall be provided with a skirt or equivalent arrangement extending at least 25 mm into the tank in order to prevent gas accumulation below the device and to avoid obstruction of gas flow. The discharge from each pressure relief device shall be directed away from the PST top cover, bushings, operating positions, access paths, measuring devices and other equipment. Suitable oil discharge pipes, ducts or extensions shall be provided to lead discharged oil safely down to the oil collector or oil containment system.
Measures shall be taken to protect personnel, surrounding equipment and structures against oil splashes and hot oil discharge in the event of operation of the pressure relief

device. The pressure relief devices shall be designed and tested in accordance with IEC/EN 50216 - 5. Type-test and routine-test certificates shall be submitted to the purchaser. The OLTC oil compartment/tap-changer tank shall be equipped with a pressure relief device providing equivalent safety functionality to that of the main oil tank, unless the approved MR VACUTAP design provides another Contractor-approved pressure protection arrangement. The OLTC pressure relief device shall also be equipped with local indication and remote alarm signalling.

The Contractor shall submit complete documentation for the pressure relief devices, including at least:

- manufacturer and type designation;
- number and location of devices;
- rated discharge capacity;
- operating pressure;
- reset characteristics, where applicable;
- contact arrangement and contact rating;
- local mechanical indication arrangement;
- remote alarm signal arrangement;
- oil discharge direction and discharge piping arrangement;
- compliance and test certificates according to IEC/EN 50216-5;
- installation and maintenance instructions.

15.19 Identification plates

The PST shall be provided with identification, rating, instruction and warning plates made of approved corrosion-resistant material suitable for continuous outdoor service under the specified environmental conditions. All plates shall be permanently fixed, durable, weather-resistant, UV-resistant and clearly legible throughout the service life of the PST. The inscriptions shall be in Slovenian, unless otherwise specified by the Purchaser.

The following plates shall be supplied as a minimum:

- a rating plate in accordance with IEC 60076;
- a diagram plate showing the plan view of the PST and the correct physical relationship, designation and phase sequence of all terminals;
- a valve and air-release plate showing the location, designation and function of all oil valves, sampling valves, drain valves, filling valves, filtering valves, air-release cocks, air-release plugs and other relevant oil-system components;
- a warning instruction on the valve plate requiring the operator to refer to the maintenance instructions before applying vacuum treatment;
- information on insulating liquid, including mineral insulating oil type in accordance with IEC 60296, where applicable;

- numbered identification plates for all oil valves, cocks, fans where applicable, breathers, oil-level indicators, sampling points and other accessories requiring identification;
- valve-mounted plates or labels whose inscriptions shall correspond exactly to the designations shown on the valve plate and in the valve schedule;
- a plate or durable diagram showing all electrical circuits, terminal blocks and external connection designations. This plate shall be located on the inner side of the hinged door of the marshalling cabinets or local control cabinet;
- a lifting, jacking and pulling plate showing the points for jacking, lifting and pulling, the permissible load-carrying capacities and the necessary dimensions and permitted angles of lifting ropes or slings;
- connection designation plates for all terminals and external connection points.

All plates related to terminal designations, operating positions, valve identification, oil sampling and safety instructions shall be clearly visible and readable from normal operating level or from the designated service platform.The Contractor shall submit the proposed wording, material, dimensions, fixing method and location of all identification plates for purchaser approval before manufacture.

15.20 Grounding terminals

Each PST tank shall be provided with four grounding terminals, located diagonally near the bottom corners of the tank.
The grounding terminals shall be of stainless-steel flag type or copper-faced steel pads of adequate size. They shall be designed to carry the specified lower-voltage system short-circuit current for at least 3 s without thermal or mechanical damage.
The grounding terminals shall be welded directly to the PST tank and shall provide a reliable, low-resistance and corrosion-resistant connection to the station grounding system. Each grounding terminal shall be provided with suitable holes, bolts, nuts and washers for connection of the station grounding conductor. The terminal dimensions, drilling pattern and permissible conductor size shall be submitted for purchaser approval.
All grounding connections, bonding conductors and grounding identification markings shall be coloured yellow green in accordance with applicable standards. All metallic parts of the tank, cover, pipework, radiators, conservator, cabinets, cable ducts, support structures and accessories shall be electrically bonded to the main tank grounding system. The bonding arrangement shall ensure equipotential connection of all accessible metallic parts.

The Contractor shall submit the grounding arrangement drawing, including the location, dimensions and material of grounding terminals, conductor connection details and short-circuit withstand verification.

Particular attention shall be paid during welding of stainless-steel grounding terminals to the PST tank to prevent contamination of the stainless-steel surface with carbon steel particles or other foreign materials. The Manufacutrer shall ensure that appropriate

welding, grinding, cleaning and passivation procedures are applied to preserve the corrosion resistance of the stainless steel. Any contamination, corrosion or surface defects that could impair the long-term performance or increase the contact resistance of the grounding connection shall not be accepted.

15.21 Anticorrosion protection

Departures from or additions to this Technical Specification shall be clearly specified in the tender documentation and shall be subject to approval by the Purchaser.

Each PST tank and all associated metallic equipment shall be adequately protected against corrosion for continuous outdoor service under the specified environmental conditions. The anticorrosion protection system for the PST tank and associated equipment shall be based on an epoxy-polyurethane coating system, colour RAL 7038, in accordance with SIST EN ISO 12944 and the requirements given in Table 9. Application and execution of coating works shall follow the recommendations of SIST EN ISO 12944-7.

The anticorrosion protection of PST and associated equipment shall be performed after successful completion of the leak test.

The construction of the tank and associated equipment shall allow access to all parts requiring surface preparation, painting, inspection, repair and maintenance.

Transformer radiators shall be protected by hot-dip galvanizing in accordance with Table 8: Anticorrosion protection of PST radiators and the recommendations of SIST EN ISO 14713-2 and SIST EN ISO 1461. Radiators shall not be painted unless otherwise approved by the Purchaser.

The proposed anticorrosion protection system, including coating materials, surface preparation method, surface roughness, dry-film thickness, curing conditions, repair procedure and inspection plan, shall be submitted to the Purchaser for approval before application.

Inspection personnel shall be certified according to NACE Level II or III, FROSIO Level II or III, or shall have other equivalent competence supported by many years of documented and qualified professional experience.

The inspection plan shall cover at least the inspections specified in Table 11.

Table 8: Anticorrosion protection of PST radiators

Item	Requirement
Expected service life of corrosion protection according to SIST EN ISO 14713-1	**VH — Very High**
Corrosivity according to SIST EN ISO 14713-1	**C4 — High**

Item	Requirement
Design recommendations	Recommendations according to **SIST EN ISO 14713-2** shall be followed.
Surface treatment	**Hot-dip galvanizing according to SIST EN ISO 1461**
Zinc layer thickness	Minimum average coating thickness: **70 µm**
Acceptance criteria	Average coating thickness: minimum **85 µm**; local coating thickness: minimum **55 µm**, according to Table 3 of SIST EN ISO 1461.

Table 9: Anticorrosion protection of PST tank

Item	Requirement
Expected service life of corrosion protection according to SIST EN ISO 12944-1	**H — High**
Corrosivity according to SIST EN ISO 12944-2	**C4 — High**
Special exposure	External surfaces: sunlight / UV exposure. Internal surfaces: transformer oil.
Design requirements	Design features shall comply with Annex C of **SIST EN ISO 12944-3**.
Design recommendations	Best practice examples according to Annexes A, B and D of **SIST EN ISO 12944-3** shall be followed.
Pretreatment requirements prior to surface preparation	Minimum preparation grade **P2** according to **SIST EN ISO 8501-3**. The preparation grade shall be checked before transport to the surface protection facility.
Surface preparation according to SIST EN ISO 8501-1	Rust grade before preparation: **A or B**. Surface preparation: abrasive blast-cleaning to preparation grade **Sa 2½**.
Surface roughness according to SIST EN ISO 8503-2	**Medium G**, grit blast profile.

Table 10: Protective coating specification

Coating layer	Internal surfaces	External surfaces — system C4.10 according to Table C.4, Annex C, SIST EN ISO 12944-5
Primer	Epoxy polyamide primer	Zinc-rich epoxy primer
Dry-film thickness of primer	**80 µm**	**60 µm**
Intermediate coating	None	Epoxy polyamide coating with micaceous iron oxide
Dry-film thickness of intermediate coating	—	**80 µm**

Coating layer	Internal surfaces	External surfaces — system C4.10 according to Table C.4, Annex C, SIST EN ISO 12944-5
Topcoat	None	Acryl-isocyanate / polyurethane topcoat, **RAL 7038**
Dry-film thickness of topcoat	—	**60 µm**
Total dry-film thickness	**80 µm**, maximum **120 µm**	**200 µm**

The zinc-rich epoxy primer shall contain zinc dust pigment equal to or greater than 80 % by mass in the dry film. The zinc dust pigment shall comply with ISO 3549.

The acceptance criteria for total dry-film thickness shall be according to ISO 19840, using the 80/20 rule.

Internal surfaces in contact with transformer oil shall be coated with an oil-resistant epoxy coating compatible with hot mineral insulating oil according to IEC 60296. The internal coating shall not adversely affect the insulating oil, the solid insulation system or the long-term dielectric properties of the PST.

Table 11: Inspections

Type of inspection	Method / standard	Requirement	Minimum scope	Comment
Cleanliness of compressed air	**ASTM D4285**	According to ASTM D4285	Random testing	Test shall be performed with a white cotton cloth.
Oil and grease in abrasives	**ASTM D7393**	According to ASTM D7393	Every quarter	Applies to circulating abrasives.
Climatic conditions	**SIST EN ISO 8502-4**	Air temperature: minimum **10 °C**. Surface temperature: minimum **10 °C** and at least **3 °C above dew point**. Relative humidity: maximum **85 %**.	Before and after each coating step, at least twice per shift	The coatingManufacturer may specify additional or more stringent requirements.
Rust grade	**SIST EN ISO 8501-1**	Rust grade **A or B**	100 % of the whole surface	Before start of surface preparation.
Preparation grade	**SIST EN ISO 8501-3**	Minimum **P2**	100 % of the whole surface	Before start of surface preparation.

Type of inspection	Method / standard	Requirement	Minimum scope	Comment
Blast-cleaned surface	**SIST EN ISO 8501-1**, **SIST EN ISO 8503-2**, **SIST EN ISO 8502-3**	Preparation grade **Sa 2½**. Surface roughness: **Medium G**. Dust quantity: maximum rating **2**. Dust particle size: maximum rating **1**.	100 % of the whole surface	Before application of the first coating layer / primer. The Client shall have the opportunity to perform inspection.
Visual inspection of painted surface	Visual inspection	Each coat shall be continuous and covering, without unacceptable runs, drops, pores, holidays, cracks, inclusions or other surface defects.	100 % of the whole surface	Applies to both flat surfaces and edges.
Dry-film thickness	**ISO 19840**	According to the approved coating specification	According to ISO 19840	Acceptance according to ISO 19840, 80/20 rule.
Adhesion	**SIST EN ISO 16276-1**	Minimum **5 MPa**	According to SIST EN ISO 16276-1	Not applicable to hot-dip galvanizing.

The dry-film thickness shall be measured and documented after application. The Manufacturer shall submit coating inspection records, including at least:

- surface-preparation records;
- climatic conditions during coating application;
- coating material batch numbers;
- dry-film thickness measurements;
- adhesion test results;
- repair records;
- final inspection reports.

All coating damage occurring during manufacture, transport, erection or commissioning shall be repaired in accordance with the approved repair procedure and the coating Manufacutrer’s instructions. Repaired areas shall provide the same level of corrosion protection as the original coating system.

Galvanized components shall be protected in accordance with the applicable standards and shall be compatible with adjoining painted surfaces, fasteners and support structures. Contact between dissimilar metals shall be designed to avoid galvanic corrosion.

15.22 Support Reactions

The Manufacturer shall provide documentation clearly defining the magnitude and direction of loads and support reactions at all equipment supports.
The documentation shall include support reactions for at least the following load cases:

- permanent load, including the self-weight of the complete equipment;
- transport and handling loads, where applicable;
- operational loads, where applicable;
- earthquake load.

The effect of earthquake loading shall be analysed separately for all three orthogonal directions: X, Y and Z. The coordinate system used for the analysis shall be clearly defined in the documentation and shown on the relevant drawings.
The results shall be presented in tabular form for each individual support. For each support, the Manufacturer shall state at least:

- support identification;
- support location;
- load case;
- vertical reaction;
- horizontal reactions in X and Y directions;
- resulting force;
- direction of the reaction;
- uplift force, where applicable;
- sliding force, where applicable;
- overturning moment, where applicable;
- required anchoring force, where applicable.

For line supports, the support reactions shall be given separately at the beginning and at the end of each support, as proposed in the schedules of technical data.
The support-reaction documentation shall be sufficiently detailed to enable design and verification of the foundations, anchor bolts, support structures and any seismic restraints required for the PST installation.

The Manufacturer shall submit the calculation method, assumptions, applied load combinations, seismic input data, safety factors and final support-reaction tables for purchaser approval.

15.23 PST Foundation and layout drawings

The PST shall be installed on a reinforced concrete foundation. The PST shall be supported by six steel line supports. The arrangement, dimensions and positions of the line supports shall be coordinated with the PST tank design, transport arrangement, jacking points, pulling points and the support reactions specified by the Manufacutrer.

To prevent overturning, sliding or excessive displacement of the PST during a seismic event, the PST shall be anchored to the foundation. Anchoring shall be provided at four points on each long side of the PST, i.e. at a total of eight anchoring points, unless otherwise justified by theManufacturer and approved by the Purchaser.

The Manufacturer shall provide all necessary data for the design and verification of the foundation and anchoring system, including:

- total equipment weight;
- centre of gravity;
- support reactions under permanent load;
- support reactions under seismic load in X, Y and Z directions;
- uplift forces;
- horizontal forces;
- sliding forces;
- overturning moments;
- required anchoring forces;
- recommended anchor dimensions and arrangement;
- permissible tolerances for foundation levelness and alignment.

The foundation, steel line supports and anchoring system shall be designed to withstand all loads occurring during installation, operation, maintenance, short-circuit conditions where applicable, wind loading and seismic loading.

The layout drawings provided in the Technical Specification form an integral part of this Technical Specification and shall be considered mandatory design input. The Contractor shall ensure that the proposed PST design, including its overall dimensions, interfaces and ancillary equipment, is fully compatible with the future installation of the third PST as indicated in the drawings.

The final foundation and anchoring arrangement shall be coordinated with the Manufacturer's support-reaction documentation and shall be submitted for Purchaser approval before construction.

16 ERECTION REQUIREMENTS

16.1 Erection works at site

The complete erection, assembly, installation and preparation for commissioning of the PST and all associated equipment at site shall be within the scope and responsibility of the Contractor. The erection company, if different from the Contractor, shall be nominated by the Contractor and shall be subject to approval by the Purchaser. Such approval shall not release the Contractor from full responsibility for the quality, completeness, safety and timely execution of all erection works.
The PST shall be assembled as far as practicable at the Manufacturer's works. All remaining erection, assembly, installation, connection, adjustment and preparation works required at site shall be carried out by the Contractor.
The Contractor shall provide all labour, supervision, tools, special tools, lifting equipment, jacks, transport devices, temporary supports, consumables and auxiliary equipment required for safe and complete erection of the PST, cooling system, conservator, bushings, OLTC equipment, monitoring equipment, control cabinets, pipework, valves, accessories and all other components included in the supply.
The Contractor shall organise and perform all site transport, unloading, lifting, positioning and handling of equipment and components that have to be assembled to the PST. The Contractor shall ensure that the erection organisation, personnel, equipment and working methods are suitable for the specified works and that the Purchaser has no additional expenses or obligations, except for agreed supervision, coordination and witnessing activities.
All erection works shall be performed in accordance with the approved erection procedure, Manufacturer's instructions, project documentation, General Technical Specification, applicable laws and regulations, site safety rules and good engineering practice.
The Contractor shall prepare and implement all necessary health and safety measures, environmental protection measures, method statements, risk assessments, lifting plans, transport plans, fire protection measures, security arrangements and emergency procedures required for the erection works.
For site transport and erection activities, the Contractor shall comply with the safety plan and site rules provided by the Purchaser, as well as with all applicable health, safety and environmental requirements. The Contractor shall consider that other equipment and systems at site may remain in normal operation and may be energised during the erection works. All works shall therefore be planned and executed so as not to endanger personnel, existing equipment or the continuity of operation of other systems.

The Contractor shall be responsible for protecting the PST and all delivered equipment against mechanical damage, moisture ingress, contamination, corrosion and any other deterioration during storage, handling, erection and installation at site.

16.2 Erection supervision

The Contractor shall provide qualified and experienced specialists for supervision and execution of erection, assembly, installation and preparation for commissioning of the PST and associated equipment.
The Contractor shall supervise all erection and assembly activities to ensure that the equipment is installed in accordance with the Manufacturer's requirements and that all contractual guarantees remain valid.
The Contractor shall prepare and submit an erection supervision programme, including:

- description of supervision activities;
- required number and qualification of specialists;
- estimated duration of supervision and erection activities;
- working schedule;
- required site conditions;
- required interfaces with the Purchaser and other contractors;
- list of special tools and lifting equipment;
- health and safety requirements;
- associated costs, where applicable.

The Contractor shall ensure that any subcontractor engaged for erection or assembly works is competent, properly equipped, adequately supervised and fully informed of the applicable technical, safety and environmental requirements. The use of subcontractors shall not limit or reduce the Contractor's responsibility.

16.3 Other requirements

The Contractor shall prepare and submit a detailed written erection manual covering all site activities required for the PST and associated equipment. The erection manual shall include, as a minimum:

- unloading and site transport procedure;
- lifting and handling instructions;
- storage requirements;
- assembly sequence;
- installation of radiators, conservator, bushings, OLTC equipment, control cabinets, monitoring equipment, pipework, valves and accessories;
- oil filling, oil treatment, vacuum treatment and venting procedure;
- mechanical alignment and tightening instructions;
- electrical connection and earthing instructions;
- protection of equipment during erection;
- cleanliness requirements;
- required tools and special tools;

- inspection and check points;
- safety precautions;
- environmental protection measures;
- final inspection procedure before testing and commissioning.

All erection requirements shall comply with the General Technical Specifications. Any additional erection devices, jacks, lifts, temporary structures, special tools or auxiliary equipment required for proper and safe erection shall be included in the Contractor's scope of supply.
After successful completion of erection, the Contractor shall immediately proceed with the specified testing and commissioning procedures in accordance with this specification and the approved test programme. After completion of erection and before commencement of commissioning tests, the Contractor shall issue an official erection completion report confirming that all erection works have been completed and that the equipment is ready for testing.
The Contractor shall provide all necessary technical data related to the PST to other contractors involved in the project, where such data are required for connection of the PST to other systems. All exchanged technical data affecting interfaces, installation, operation, protection, control, monitoring or safety shall be submitted to the Purchaser for approval. Informative data may be exchanged directly with other contractors, with the Purchaser being kept informed.
During erection, the Contractor shall cooperate with the Purchaser, the site coordinator and all other contractors involved in the project. The Contractor shall coordinate its works with the overall site schedule and shall not interfere with erection, testing or operation of other equipment.
The Contractor shall be responsible for local transport, lifting, positioning, assembly and auxiliary power supply required for its own erection works, unless otherwise explicitly stated in the contract. Any requirements for temporary power supply, compressed air, water, lighting, storage area, crane access or other site facilities shall be clearly stated by the Contractor in advance.

After completion of erection, the Contractor shall remove from site all packaging materials, temporary supports, waste materials, tools, unused consumables and other objects used during transport, storage and erection of the PST and associated equipment. The working area shall be left clean, safe and ready for testing and commissioning.

In case of disagreement between contractors during erection, the Purchaser shall give the final decision regarding coordination and interface issues. Such decision shall be binding for all project participants. This shall not release the Contractor from its contractual responsibility for the correct and complete erection of the PST and associated equipment.

17 INSPECTION AND TESTS

Tests shall be performed to verify that all materials, components, assemblies and the complete PST comply with this specification, the guaranteed technical data, approved drawings, applicable standards and the intended operating conditions. All tests shall be carried out in accordance with the applicable IEC standards, particularly the relevant parts of IEC 600-76-57-1202, IEC 60076, etc.
Unless otherwise agreed between the Manufacturer and the Purchaser, the tests shall be performed in the sequence required by the applicable standards and by the approved inspection and test plan.
The Manufacturer shall submit all certificates, test reports, measuring records, calibration certificates and other evidence required to demonstrate conformity of the equipment.
The Manufacturer shall also perform any additional tests not explicitly listed in this specification but required by applicable standards, the approved design, safe operation, completeness of supply or by the Purchaser.
All testing devices, measuring instruments, test equipment, calibration equipment, temporary connections and auxiliary equipment required for testing shall be provided by the Manufacturer. All measuring instruments shall have valid calibration certificates traceable to recognised standards.
The Contractor shall notify the Purchaser in writing of the date, time, place and scope of each witnessed test at least four weeks before the planned test date. The final test date shall be confirmed and approved at least 14 days before the test. The Purchaser or the Purchaser’s representative shall have the right to witness any test, inspection or verification activity.
Certified test reports shall be submitted to the Purchaser immediately after completion of each test or within the agreed period. Final acceptance shall be subject to review and approval of the test reports by the Purchaser.
The Purchaser reserves the right to request an independent expert opinion or independent verification of test results, measuring methods, type-test evidence, routine-test results or special-test results.
All deviations from specified, guaranteed or standard values shall be documented in the manufacturing and test records. Necessary corrective actions shall be listed, described and submitted to the Purchaser for review. In the event of deviations, non-conformities or doubtful results, the Purchaser may require interruption of testing, additional diagnostics, corrective works and repeated testing of the affected equipment or assemblies.
If any repair, replacement or modification of equipment is required after factory tests or site tests, the Contractor shall perform the necessary works without delay and shall submit all repeated test results to the Purchaser for approval.

Tests shall be used to verify whether the material and devices comply with the specification. All tests must be executed in the way to consider operation conditions. All test results shall be submitted to the Purchaser for supervision and approval. Purchaser is reserving a right to get another independent opinion (checking correctness of the measuring results, tests, type tests…).

All tests shall be executed according to IEC standard requirements (including with the correct sequence of tests), if not differently agreed between Contractor and Purchaser.

Contractor must submit certificates and other evidence about impeccability of the equipment.

Contractor shall execute also all other tests, which are not mentioned in these specifications, but they are necessary for completeness and equipment security, if required by the Purchaser.

All necessary testing devices and instruments shall be provided by the Contractor.

Contractor shall announce the Purchaser about date, time and scope of testing at least four (4) weeks before tests, test date shall be approved at least 14 days before execution. Contractor must allow Purchaser or his representative to be present at any test procedure. Certified test report must be submitted to the Purchaser immediately after each test.

All deviations from the required values shall be documented in the manufacturing records. Necessary corrective actions shall be enlisted and described and examined by Purchaser and Contractor representatives. At any deviations, the project manager can demand in name of the Purchaser an interruption and repeated testing/diagnostics of equipment or additional modules found unsuitable. Tests shall be applied to verify whether the material and devices comply with the specification. All test results shall be recorded and submitted to the Purchaser for supervision and approval. Purchaser is reserving the right to get another independent opinion (regarding evaluation correctness of testing and measuring results, in particular the type tests results).

If after factory or on site testing, for any reason repair of the equipment or replacement of any parts are necessary, the Contractor shall finish all works as soon as possible. The Contractor shall submit to the Purchaser all results of repeated tests.

17.1 Factory tests

Factory tests shall be carried out at the Manufacturer's works in accordance with the approved QA/QC plan, inspection and test plan, applicable IEC standards and this specification.
Based on the QA/QC plan, the Purchaser shall define inspection points, witness points and hold points at which the Purchaser or the Purchaser's representative intends to be present.

During manufacture of the various PST parts, the Purchaser may require any part, assembly or component to be inspected or tested in the presence of the Purchaser or the Purchaser's representative. The Contractor shall therefore systematically inform the Purchaser in writing when equipment or components are ready for inspection or testing.
Where material samples, oil samples, insulation samples or other test samples are required, the Contractor shall prepare and provide them in accordance with the approved test programme. Tests requiring independent verification shall be performed by an independent accredited laboratory or institution approved by the Purchaser.
The complete PST shall be subject to factory acceptance tests (FAT), at the Manufacturer's works in the presence of the Purchaser or the Purchaser's representative. The purpose of the FAT is to verify conformity with guaranteed data, approved design documentation, this specification and applicable standards.

Detailed test procedures and acceptance criteria shall be submitted to the Purchaser for approval before testing.
The no-load and load losses shall be measured at the relevant tap positions specified in Clause 13.4 and compared with the corresponding guaranteed values specified in Table 12 (Clause 21). The measurements and any applicable corrections to reference temperature shall be performed in accordance with IEC 60076-1 and the approved FAT procedure. The assessment of exceedances of the guaranteed losses and the corresponding contractual consequences shall be governed by the Contract.

Factory tests shall comprise:

- routine tests;
- type tests, where required;
- special tests, where required;
- functional tests;
- inspections and verifications;
- tests on accessories, monitoring systems and auxiliary equipment.

Routine tests

The following routine tests are required on all PST's:

- visual inspection;
- dimensional check of the PST main dimensions;
- check of general construction and appearance;
- check of nameplates, identification plates and terminal markings;
- verification of drawings, terminal arrangement and phase sequence;
- measurement of winding resistance (13.5);
- measurement of voltage ratio, no-load phase angle and verification of phase displacement at all 65 tap positions (32A–0–32R), in accordance with IEC/IEEE 60076-57-1202, (13.6);
- measurement of short-circuit impedance at all 65 tap positions (32A–0–32R), and measurement of load losses at the specified tap positions, in accordance with IEC/IEEE 60076-57-1202, and the approved FAT programme (13.7);
- measurement of no-load loss and current and harmonics (13.9);
- dielectric routine tests (13.12);
- tests on on-load tap-changers (13.13);
- leak testing with pressure for liquid-immersed transformers (tightness test) (13.14);
- check of the ratio and polarity of built-in current transformers;
- check of core and frame insulation for liquid-immersed transformers with core or frame insulation (IEC 60076-1 or IEEE Std C57.12.00);
- determination of capacitance between each winding and earth and where possible between windings;

- measurement of DC insulation resistance between each winding and earth and where possible between windings;
- measurement of dissipation factor (tan δ) of the insulation system capacitances;
- measurement of capacitance and tan δ of bushings;
- measurement of CT's;
- functional tests of marshalling cabinet, control circuits, alarms, trips and auxiliary circuits;
- Frequency Response Analysis, FRA, as a reference fingerprint test;
- transformer Oil Analysis (measurement of dissolved gases in dielectric liquid from each separate oil compartment except diverter switch compartment (oil testing before and after dielectric tests);
    - dissolved gas analysis, DGA, before and after dielectric tests and after temperature-rise test;
    - 2-FAL analysis, HPLC, before and after dielectric tests and after temperature-rise test);
- verification of tightness of oil-filled compartments, as applicable;
- verification of grounding and bonding connections;
- Calculation of PEI at the OLTC neutral position (position 0)
- final inspection before dispatch.

Verification of phase-angle and short-circuit impedance characteristics

The measured no-load phase-angle characteristics and short-circuit impedances shall be documented for all 65 tap positions (32A–0–32R).

The FAT report shall include the measured values, the corresponding guaranteed design values and the deviations for each tap position. The results shall be presented in tabular and graphical form.

Phase-angle measurements shall be documented for the relevant phase pairs, using a consistent terminal reference and sign convention. Short-circuit impedance measurements shall be reported on a common base of 600 MVA and 400 kV, with the applicable reference conditions and measurement configuration clearly stated.

The measured characteristics shall be compared with the guaranteed design characteristics and the reference characteristics of the two existing PST units.

The Contractor shall update the compatibility assessment required under Clause 15.6 using the actual FAT measurement results. The assessment shall demonstrate that the measured characteristics comply with the contractual acceptance criteria for parallel operation.

Any deviations exceeding the agreed acceptance criteria shall be reported to the Purchaser and resolved before factory acceptance of the PST.

DGA and 2-FAL results before and after dielectric tests and after temperature-rise test shall be evaluated in accordance with applicable IEC and CIGRE guidance. Oil sampling and analysis shall be carried out in accordance with the applicable standards, including IEC 60567 and IEC 60475 where relevant.

Capacitance and tan δ measurements shall be corrected to 20 °C. The temperature correction factors used shall be submitted by the Contractor and included in the test report. Unless otherwise specified or justified by the Contractor and approved by the Purchaser, the following maximum tan δ values shall apply:

- winding insulation: 1.0 %;
- bushings: 0.5 %;
- insulating oil: 0.2 %.

The partial discharge level of the PST shall not exceed 100 pC during the routine induced voltage withstand test in accordance with IEC 60076-3, unless more stringent acceptance criteria are specified in the Technical Specification or the approved test programme.

Type tests

The following type (design) tests are required on the first unit of each design:

- temperature-rise test (13.8);
- dielectric type (design) tests (13.12);
- determination of noise level (13.10);
- measurement of zero sequence impedance (13.11);
- measurement of the power taken by the fan and OLTC/ARS.

Temperature-rise test requirements: Gas chromatographic analysis of oil shall be performed before and after the temperature-rise test. Oil sampling shall be performed in accordance with applicable IEC standards. DGA results shall be evaluated in accordance with IEC 60599 and relevant IEC/CIGRE guidance.

The temperature-rise test shall include sufficient time to reach thermal stability. Where core hot-spot or active-part thermal behaviour is to be verified, the test shall include a period of stable saturated temperature, with duration to be agreed in the approved test programme.

Temperature-rise measurements shall be performed using conventional oil temperature indicators/winding temperature indicators and the installed fibre-optic temperature sensors. The fibre-optic temperature measuring system shall be operational during the temperature-rise test and shall be demonstrated during the test.

During the test, the hottest fibre-optic probes for each phase shall be identified. Temperature data from all fibre-optic probes shall be recorded and included in the test report. The values measured by the fibre-optic sensors shall be considered informative only

and shall be used for comparison with the values obtained from the conventional OTI and WTI instruments. The values measured by the fibre-optic sensors shall not be used as the acceptance criteria for compliance with the specified temperature limits and guaranteed values, which shall be verified in accordance with the applicable IEC standards.

Special tests

The following special tests shall be performed when required by the Purchaser, this specification, the applicable standards or the approved test programme:

- dielectric special tests (13.12);
- vacuum deflection test (IEC 60076-1);
- vacuum tightness test on site (IEC 60076-1);
- pressure deflection test (IEC 60076-1);
- measurement of frequency response (IEC 60076-18);
- check of external coating (ISO 2178 and ISO 2409 or as specified);
- mechanical test or assessment of tank for suitability for transport (to Purchaserspecification);
- determination of the weight of each PST unit arranged for transport by calculation or, if required by the purchaser at the enquiry stage, by measurement;
- j) transient voltage measurements, for example low voltage impulse [recurrent surge oscillograph (RSO)] and/or resonant frequency measurements.
- Inspection of the tank corrosion protection system;
- Inspection of the corrosion protection of associated equipment;
- degree of polymerisation and moisture of paper insulation

The complete PST vacuum test and overpressure test shall be performed in accordance with the approved procedure. The test pressures, duration, acceptance criteria and measuring method shall be submitted to the Purchaser for approval before testing.

17.2 On site tests

Acceptance tests

The PST shall be subject to site acceptance tests, SAT, after transport, erection, oil filling, oil treatment and final assembly on the foundation.

The purpose of the site tests is to verify that the PST and all associated equipment have been transported, erected, connected, filled, treated, tested and commissioned correctly and are suitable for safe operation.

All site tests shall be performed in the presence of the Purchaser or the Purchaser’s representative. The tests shall verify conformity with this specification, the approved design documentation, guaranteed characteristics, Manufacutrer’s instructions and applicable standards.

The detailed measuring methods, test conditions, test sequence, energisation requirements and acceptance criteria shall be agreed between the Contractor and the Purchaser in the approved site test programme. Any special requirements concerning grid operation, energisation, or outage planning shall be agreed in advance.

All required standard and special test equipment, insulation testers, measuring bridges, high-voltage measuring sources, current sources, auxiliary supplies, calibration equipment and all other equipment necessary for site testing shall be provided by the Contractor.

At least the following measurements, inspections and tests shall be carried out at site:

- **Receiving Inspection – External Inspection**
  - Inspection of the PST tank and welded joints;
  - Inspection of the tank corrosion protection system;
  - Inspection of the corrosion protection of associated equipment;
  - Inspection of bushings;
  - Inspection of the Buchholz relay;
  - Inspection of the pressure relief device;
  - Inspection of the oil temperature indicator;
  - Inspection of the OLTC protection relay;
  - Inspection of the winding temperature indicator;
  - Inspection of control and marshalling cabinets;
  - Inspection of the transformer oil level indicator;
  - Inspection of the OLTC oil level indicator;
  - Inspection of the conservator air cell (rubber bladder).
- **Receiving Inspection – Internal Inspection**
  - Inspection of the PST core grounding connections;
  - Inspection of HV bushing internal connections;
  - Inspection of neutral bushing connections;
  - Inspection of OLTC and ARS (Advance-Retard Switch) connections;
  - Inspection of the mechanical integrity of the windings;
  - Inspection for traces of moisture.
- **Inspection of PST Installation and Operation – External Equipment**
  - Inspection of the cooling system;
  - Inspection of cooling fans;
  - Inspection of butterfly valves;

- Inspection of oil distribution pipework;
- Inspection of conservators;
- Inspection of conservator air cells;
- Inspection of support brackets and structures;
- Inspection of bushings;
- Inspection of the OLTC motor drive, limit switches, gearbox and mechanical linkages;
- Inspection of instruments and gauges;
- Inspection of the OLTC protection relay;
- Inspection of the Buchholz relay;
- Inspection of the ARS oil compartment Buchholz relay;
- Inspection of the moisture sensor;
- Inspection of the dissolved gas monitoring system;
- Inspection of the pressure relief device;
- Inspection of the oil and winding temperature indicators;
- Inspection of resistance temperature detectors (RTDs);
- Inspection of fibre-optic temperature sensors;
- Inspection of built-in current transformers;
- Inspection of the transformer oil level indicator;
- Inspection of the OLTC oil level indicator;
- Inspection of conservator air cells;
- Inspection of the gas collection device;
- Inspection of the monitoring system.

– **Inspection of PST Installation and Operation – Internal Equipment (Control Cabinets)**

- Inspection of cabinet heaters;
- Inspection of cabinet lighting;
- Functional test of cooling fan control;
- Functional test of the complete alarm panel;
- Verification of oil and winding temperature indicator settings;
- Inspection of the cleanliness of the control cabinets.

– **Measurements and Tests after Transformer Installation**

- Vacuum test (48 hours);
- Complet transformer oil analysis: Before first oil filling of the PST on site an examination shall be carried out to check the PST oil quality acc. to IEC 60296 and IEC 61125.

  Oil sampling at site shall be performed after oil filling and oil treatment, after completion of erection and before energisation. Further samples shall be taken after energisation and after an agreed initial operating period, if required by the Purchaser.

  Oil tests shall include, as a minimum:
  - physical-chemical oil analysis in accordance with IEC 60422:
    - breakdown voltage;
    - water content;
    - acidity;
    - interfacial tension;
    - dielectric dissipation factor;
    - resistivity;
    - antioxidant content.
  - DGA;
  - 2-FAL content
  - any additional tests required by the Purchaser or the oil supplier.

  Sampling, handling and analysis of oil and gas samples shall be carried out in accordance with applicable IEC standards and the approved test programme.
- Functional tests of protection systems and auxiliary equipment;
- Measurement of voltage ratio and vector group;
- Measurement of winding resistance;
- Measurement of phase-angle shift;
- Measurement of insulation resistance;
- Measurement of capacitance and dissipation factor (tan δ);
- Measurement of bushing capacitance and dissipation factor (tan δ);
- Frequency Response Analysis (FRA);
- Calibration of the thermal imaging system and breakdown voltage test of the insulating oil.
- measurement of FDS (frequency analysis of dielectrics),
- final inspection before energisation.

Test reports and acceptance

All site test results shall be recorded in certified test reports. The reports shall include measuring methods, instruments used, calibration data, ambient conditions, oil temperature, test conditions, measured values, acceptance criteria and conclusions.
The Contractor shall submit complete site test reports to the Purchaser for approval. The PST shall not be released for energisation until all mandatory site tests have been successfully completed and the Purchaser has accepted the relevant test results.
Any non-conformity detected during site tests shall be corrected by the Contractor. After correction, the relevant test shall be repeated, and the repeated test results shall be submitted to the Purchaser for approval.

18 QUALITY CONTROL DOCUMENTATION

Documents officially certified must be sent to the Purchaser, not later than FAT date.

18.1 QA certificates

- Insulated copper conductors,
- Steel sheet core,
- Hard insulation materials,
- Insulation oil,
- Construction steel,
- Wiring cables,
- Paint and its oil resistance.

18.2 Test reports

- Bushings,
- Current transformers,
- Radiators,
- Auxiliary cubicles,
- OLTC/ARS
- OLM
- Interphase inspection report.

18.3 Functional test and QA certificates

- Buchholz relay,
- Protection relay for the OLTC oil compartment

- Over-pressure valve,
- Bushing sensors
- Top oil temperature indicator,
- Pt 100 temperature measuring sensors,
- On-line monitoring system,
- Gas sensors,
- Humidity sensors,
- Optical temperature sensors,
- Winding temperature indicator,
- Magnetic oil level indicators,
- Capillary contact thermometer,
- On load tap changer,
- On load tap changer motor drive,
- ETOS control system,
- Voltage regulation,
- Conservator synthetic diaphragm or air-cell bag and dehydrating breathers,
- Vibration sensors,
- PST tank test documents,
- Overpressure and vacuum test report,
- Anticorrosive protection inspection report.

18.4 Interphase inspection report

- Magnetic cores,
- Windings,
- Active part,
- Active part drying.

19 CONTRACTOR DOCUMENTATION

Before the start of PST manufacture, the Contractor shall submit a complete document list for the project. The list shall include all drawings, calculations, data sheets, manuals, procedures, test plans, test reports, certificates and other documents to be prepared for the project in accordance with the Purchaser's requirements and established practice.

The document list shall include, as a minimum:

- document title;
- document number;
- document revision;
- document type;
- planned submission date;
- required approval date;
- document status;
- language;
- editable/original format;
- PDF format;
- classification of the document;
- indication whether the document is submitted for approval, review, information or final documentation.

The Purchaser shall review and approve the document list as part of the design review process. The Contractor and the Purchaser shall agree the submission dates for all documents that are relevant to the project schedule during contract clarification or contract signing.

No manufacture of the relevant PST parts shall start before the corresponding design documents, drawings and calculations have been submitted to and approved by the Purchaser, where approval is required.

The Contractor shall submit all documents in electronic format. Final documentation shall be submitted in both PDF format and editable/original format, unless otherwise agreed. Drawings shall be submitted in PDF and CAD format. Data sheets, schedules and lists shall be submitted in PDF and editable spreadsheet or word-processing format, as applicable.

Documents required for operation, maintenance, transport, erection, safety and identification shall be provided in Slovene language, unless otherwise approved by the Purchaser. Technical design documentation may be submitted in English, unless otherwise specified.

The following documents shall be submitted as a minimum.

19.1 General project documentation

- documentation classification plan;
- complete project document list with planned dates of issue;
- document submission schedule;
- document approval schedule;
- design review document package;
- list of applicable standards;
- list of deviations from this specification, if any;
- list of guaranteed technical characteristics;
- PST technical data sheet;
- equipment list with Contractors and type designations;
- list of all seals on PST (with indication of type, dimensions and material);
- list of cables installed on PST (own use, control, signaling cables, etc.);
- list of spare parts and special tools;
- list of consumables;
- list of interfaces with other project systems;
- general arrangement drawing of the PST;
- temporary/preliminary dimension drawing;
- final dimension drawing;
- transport drawing,
- PST equipment and device list, in Slovene language;
- identification and rating plate drawings, in Slovene language;
- diagram plate and terminal designation plate drawings;
- valve plate and valve identification drawings;
- lifting, jacking and pulling plate drawings,
- open BIM, for further details, see Chapter 8 of this document.

19.2 Active part and electrical design documentation

- core design description;

- winding design description;
- cross-sectional drawing of main and regulation windings;
- provide schematic/principal drawings of the winding and core;
- core grounding principle and drawing;
- winding insulation concept;
- dielectric stress calculations;
- impulse-voltage distribution assessment;
- chopped lightning impulse withstand assessment, where applicable;
- voltage-current characteristic;
- magnetic characteristic calculation;
- flux-density calculations;
- short-circuit force withstand calculation;
- inrush-current calculation and/or simulation report;
- thermal calculation;
- winding hot-spot temperature assessment;
- radial temperature-gradient assessment;
- vibration assessment;
- noise-level calculation or prediction;
- calculation of losses;
- calculation of reactance and regulation range;
- support-reaction calculation;
- seismic resistance calculation;
- calculated no-load phase-angle characteristics for all 65 tap positions (32A–0–32R), including the relevant phase-angle relationships between the S and L terminals;
- calculated short-circuit impedance characteristics for all 65 tap positions, expressed in percent on a common base of 600 MVA and 400 kV;
- comparison of the calculated phase-angle and short-circuit impedance characteristics with the reference characteristics of the two existing PST units;
- compatibility assessment report for parallel operation of two and three PST units, including the calculation of circulating currents, load sharing and relevant operating limitations;
- description of the calculation methods, equivalent circuit models, assumptions and operating scenarios used in the compatibility assessment;
- assessment of relevant tap-position combinations and temporary differences during coordinated tap-changing operations;
- final compatibility assessment updated on the basis of the measured FAT characteristics of the new PST.

19.3 OLTC/ARS documentation

- OLTC/ARS technical data sheet;
- confirmation of Reinhausen manufacture;
- exact VACUTAP type designation;
- exact ETOS configuration;
- OLTC switching diagram;
- regulation scheme;
- regulation switch operation diagrams;
- tap-position table;
- time span for changing between tap positions;
- OLTC rated through-current;
- rated step voltage;
- rated switching capacity;
- insulation level to ground;
- number of operating positions;
- motor-drive unit data sheet;
- motor-drive , type and motor voltage;
- motor-drive electrical power consumption data;
- OLTC protection relay details;
- ETOS signal list;
- ETOS communication interface description;
- ETOS integration documentation;
- OLTC maintenance intervals and service instructions;
- OLTC routine and type-test certificates according to IEC 60214-1.

19.4 Bushings and current transformers

- bushing technical data sheets;
- bushing Manufacturer and type designation;
- confirmation of resin-impregnated condenser, oil-free design;
- confirmation of manufacture in the European Union or Switzerland, unless otherwise approved;
- bushing dimension drawings;
- bushing insulation levels;
- bushing creepage distances;
- bushing capacitance and tan δ reference values;

- bushing terminal drawings and mechanical terminal-load limits;
- bushing replacement procedure;
- compliance evidence according to IEC 60137;
- composite insulator compliance evidence according to IEC 61462 and IEC 62217;
- current transformer technical data sheets;
- CT arrangement drawings for phase and neutral bushings;
- CT accuracy, burden and short-time current data;
- CT test reports and certificates according to IEC 61869.

19.5 Tank, cooling system and oil system documentation

- PST tank design drawings;
- tank cover and manhole arrangement drawings;
- tank structural drawings;
- tank accessories arrangement;
- gasket and sealing details;
- welding and weld-testing procedures;
- tank vacuum and overpressure test procedure;
- conservator arrangement drawing;
- conservator air-cell/diaphragm documentation;
- Buchholz relay arrangement;
- pressure relief device arrangement;
- pressure relief device certificates according to IEC/EN 50216-5;
- cooling system drawings;
- radiator arrangement drawings;
- radiator data sheets;
- N-1 cooling-capacity verification;
- piping and instrumentation arrangement;
- valve schedule;
- oil filling, draining, filtering, sampling and venting procedure;
- oil sampling arrangement;
- self-regenerating dehydrating breather documentation;

- anticorrosion protection system;
- coating system data sheets;
- coating inspection and repair procedure.

19.6 Measuring, monitoring, protection and auxiliary systems

- cooling control cabinet dimension drawing;
- protection and signalling cabinet dimension drawing;
- OLTC cabinet dimension drawing;
- on-line monitoring cabinet/device box dimension drawing;
- marshalling cabinet layout;
- wiring diagrams;
- terminal diagrams;
- cable laying drawing for control, signalling, measurement and auxiliary supply cables;
- list of alarms and trips;
- alarm and trip matrix;
- list of potential-free contacts;
- list of analogue signals, including 4–20 mA signals;
- list of digital communication signals;
- control and protection equipment data sheets;
- measuring system drawings;
- primary protection documentation;
- Buchholz relay technical documentation;
- oil temperature and winding temperature indicator documentation;
- fibre-optic temperature measurement system technical documentation;
- optical sensor layout;
- position of winding temperature sensors, to be confirmed during design review;
- calibration certificates for sensors and measuring equipment;
- on-line monitoring system documentation;
- OLM architecture diagram;
- OLM sensor list;
- OLM signal list;
- OLM/DAC SCADA integration documentation;
- MR ETOS to OLM interface documentation;
- communication protocol description;
- database and data-storage concept;
- cyber-security and user-access concept;

- software description;
- monitoring display/mask documentation;
- documentation for integration into the central monitoring system.

19.7 Foundation, transport and erection documentation

- proposal of PST foundation according to the corresponding drawing;
- support-reaction documentation;
- foundation and anchoring data;
- seismic anchoring requirements;
- transport drawing;
- transport plate;
- transport elaborate in Slovene language;
- transport, lifting and handling instructions;
- railway and road transport arrangement;
- storage instructions;
- on-site erection works description;
- erection manual;
- lifting plan;
- site transport and handling plan;
- oil filling and vacuum treatment procedure at site;
- fall-protection system documentation;
- health, safety and environmental plan for erection activities;
- interface requirements for other contractors.

19.8 Quality, inspection and test documentation

- QA/QC plan;
- inspection and test plan;
- list of witness points and hold points;
- factory testing detailed description and plan;
- on-site testing detailed description and plan for S/S Divača;
- list of test equipment;
- calibration certificates for test equipment;
- material certificates;
- welding certificates and weld inspection reports;
- drying process report/protocol;
- oil test reports;

- factory test reports;
- type-test reports;
- special-test reports;
- SAT reports;
- non-conformity reports, where applicable;
- corrective action reports, where applicable;
- final inspection reports;
- final acceptance documentation.

19.9 Operation and maintenance documentation

- training program;
- operation manual for the PST, in Slovene language;
- maintenance manual for the PST, in Slovene language;
- operation and maintenance manuals for all main accessories, in Slovene language where required;
- OLTC operation and maintenance manual;
- ETOS operation and maintenance manual;
- OLM operation and maintenance manual;
- dehydrating breather operation and maintenance manual;
- bushing maintenance and testing instructions;
- cooling system maintenance instructions;
- oil sampling and oil testing instructions;
- spare parts catalogue;
- special tools list;
- recommended maintenance schedule;
- troubleshooting instructions;
- emergency procedures;
- commissioning instructions;
- as-built documentation.

19.10 Dynamic thermal model of the PST

The Contractor shall provide information on the feasibility of developing a dynamic thermal model of the PST, enabling monitoring of the thermal state of the equipment during

operation and assessment of the permissible loading or short-term overloading capability based on actual operating and ambient conditions.

Where applicable, the model should consider at least the following:

- actual PST loading;
- ambient temperature;
- thermal inertia of the active part and cooling system;
- oil and winding temperatures, or equivalent hot-spot temperature;
- cooling mode;
- previous operating regime;
- permissible temperature limits and ageing of the insulation system.

The Contractor shall specify whether such a model can be developed on the basis of the PST design, type-test and/or factory data, and shall identify the input measurements and signals required for its use during operation. The Contrctor shall also state whether the model can be integrated into the purchaser's existing monitoring, diagnostic, SCADA and/or EMS systems.

19.11 Carbon footprint of PST manufacturing

The Contractor shall provide information on the estimated carbon footprint generated during the manufacturing of the PST. The scope of the calculation shall be an LCA, Life Cycle Assessment, in accordance with ISO 14040/ISO 14044. The LCA results shall be prepared in a format suitable for possible subsequent EPD (Environmental Product Declaration) calculations.

Final as-built documentation shall be submitted after completion of erection, testing and commissioning. It shall include all approved final drawings, calculations, data sheets, manuals, certificates, FAT reports, SAT reports, commissioning reports and any modifications introduced during manufacture, transport, erection or commissioning.

20 TENDERER DOCUMENTATION

The Tenderer shall submit at least the following data required by the Tender:

- Documents required in the General Tender Specification;
- Equipment and works specification, including fully completed Schedules of Technical Data with guaranteed values;
- Calculation of losses;
- Calculation of noise level;
- Preliminary thermal design calculations at 420 kV and 440 kV (continuous operation; for information only);
- Technical description of the proposed PST, its construction, operating principle, auxiliary equipment and regulation philosophy, supported by relevant catalogues and technical documentation;
- Preliminary general arrangement and principal electrical drawings of the PST;
- Information on the materials used for the magnetic cores, windings and winding insulation;
- Drawings, catalogues and technical documentation for standard components installed on the PST;
- Description of the manufacturing processes for the magnetic cores and windings;
- Description and supporting evidence of the procedure for final assembly of the PST at the factory.
- Electrical and regulation characteristics
- Preliminary calculated no-load phase-angle characteristics for all 65 tap positions (32A–0–32R), presented in tabular and graphical form. The documentation shall include the phase-angle increment between consecutive tap positions, an assessment of linearity and symmetry of the regulation characteristic, and a comparison with the corresponding characteristics of the two existing PST units.
- Preliminary calculated short-circuit impedance characteristics for all 65 tap positions, expressed as percentages on a common base of 600 MVA and 400 kV, presented in tabular and graphical form. The characteristics shall be compared with the corresponding reference characteristics of the two existing PST units.
- A preliminary technical compatibility assessment demonstrating the suitability of the proposed PST for parallel operation with the two existing PST units, based on the reference characteristics provided by the Purchaser. The assessment shall identify any relevant differences in electrical and regulation characteristics.
- A technical description of the proposed regulation principle, including the OLTC and Advance-Retard Switch (ARS), regulation sequence, tap-changing philosophy, functional interlocking principles and intended coordinated operation with the existing PST units.
- A written statement issued by the OLTC/ARS Manufacturer confirming the technical suitability and compatibility of the proposed OLTC/ARS arrangement with the corresponding equipment and regulation arrangements of the two existing PST units. The statement shall address the relevant operating sequences,

interface requirements and suitability for integration into the intended common parallel control system, including the future MR ETOS-based arrangement.

- Identification of all proposed deviations from the specified phase-angle and short-circuit impedance characteristics, as well as any known restrictions or special conditions affecting parallel operation. Where no deviations or restrictions are proposed, this shall be explicitly stated.
- Testing and reference documentation
- A list of the applicable routine and type tests for the proposed PST and for comparable PST installations.
- An example of a type-test report and an example of a routine-test report for a comparable phase-shifting transformer satisfying the applicable reference requirements. The documentation shall contain sufficient technical information to verify the relevance and comparability of the referenced equipment.
- Details of at least one reference project involving the parallel operation of two or more PST units. The reference shall identify the installation, relevant technical ratings, number of PST units, regulation/control arrangement and operational experience.
- Proposed timetable for PST production and supply, provided in an editable MS Project format and as a printed or PDF copy;
- Proposed document submission and approval schedule;
- Proposed training programme;
- Any other documents required by this Technical Specification or the General Tender Specification.

For the design review, see Clause 19.

Documentation for the designing of civil works (PST foundation) shall be submitted to the Purchaser at least three (3) months after signing the contract.

21 SCHEDULES OF TECHNICAL DATA

Table 12: Schedules of Technical Data

Three-phase Phase-Shifting Transformer				
Item	**Description**		**Requested values**	**Tender data (guaranteed)**
	Manufacturer			
	Country of manufacture			
	Transformer type		Three-phase Phase-Shifting Transformer	
	Installation		Outdoor Ambient temperature without direct solar radiation in accordance with IEC 60076-2 -25 to 40 °C	
	Degree of protection: – control and marshallig cabinets – terminal boxes		 min. IP55 (IEC 60529) min. IP65 (IEC 60529)	
	Cooling method		ONAN/ONAF	
	Frequecy	Hz	50	
	Expected service life	Years	≥ 40	
	Applicable standards		IEC 60076-57-1202 and IEC 60076 series	
1	**GUARANTEED VALUES**			
1.1*	**NOMINAL VALUES**			
	Continuous throughput power rating	MVA	600	
	PST type throughput power rating	MVA	(410)	
	Number of phases		3	
	Rated voltage S and L side	kV	400	
	No Load Phase Angle shift	°	± 40 [°] ± 1 % (± 0,4 °) 0 ° ± 0,1 °	
	On load tap changer range	steps	± 32	
	Rated current	A		
	No load current in % of the rated current: – 90 % rated voltage – 100 % rated voltage – 105 % rated voltage – 110% rated voltage	 % % % %		 …… …… …… ……
	Short-time withstand current (2 s)	kA	50	
	Short circuit voltages at rated voltage, 0° phase shift	%	20 ± 5 % (relative)	

	Short circuit voltage at rated voltage, max. phase shift value	%	25 ± 5 % (relative)	
	No load losses at 0° phase shift	kW	115 + 0 %	
	No load losses at maximum phase shift value	kW	225 + 0 %	
	Short circuit losses at 0° phase shift	kW	970 + 0 %	
	Short circuit losses at maximum phase shift value	kW	1840 + 0 %	
	No-load phase-angle characteristics for all 65 tap positions (32A–0–32R)	°	To be submitted as a separate schedule	
	Short-circuit impedance characteristics for all 65 tap positions (32A–0–32R)	%	To be submitted as a separate schedule, based on 600 MVA and 400 kV	
	Homopolar impedance (Z_0)	%		
	Maximum permissible magnetic flux density under the most unfavourable normal continuous U/f operating conditions	T	1.85 + 0 %	
2.	**TEMPERATURE RISE**			
	Max. temperature rise at rated power: – Average winding – Top oil – Winding hot spot	K	60 + 0 % 55 + 0 % 73 + 0 %	....
3.	**INSULATION LEVELS**			
	– Series winding – Exciting winding-exciter – Tapped winding – Exciting winding-series	kV	420	
	Separate-source AC withstand voltage test (60 s): – Exciting winding neutral – Tapped winding neutral – Auxiliary winding	 kV_{rms} kV_{rms} kV_{rms}		 ....
	Induced voltages with increased frequency: – Series winding – Exciting winding – Exciting winding-exciter – Tapped winding	Hz kV_{rms} kV_{rms} kV_{rms} kV_{rms}		....
	Impulse voltage: – Switching impulse S+L terminals connected toghether	kV	1050	.....

	– Lightning/CW impulse S, L – Lightning-neutral		1425/1550 CW 450	…… ……
4.	***PST OIL AND PAPER***			
4.1	Factory tests:			
	- Manufacturer			
	- Manufacturer's designation			
	additional requirements for PST oil before and after dielectric tests, temperature rise test, and other tests:		maximum permissible concentration increases:	
	- H_2	µl/l (ppm)	< 10	
	- CH_4	µl/l (ppm)	< 5	
	- C_2H_6	µl/l (ppm)	< 5	
	- C_2H_4	µl/l (ppm)	< 2	
	- C_2H_2	µl/l (ppm)	< 0,1	
	- 2FAL	mg/kg (ppm)	< 0,01	
	Insulating paper after PST drying process			
	- PST paper Manufacturer		Wiedmann	
	- average degree of polymerization value of all DPv samples		≥ 1100	
	- average degree of polymerization value of an individual DPv sample		≥ 1050	
	- moisture content of the paper insulation	%	max. 0.5	
4.2	PST oil after filling in PST before energization	oil quality level in accordance with the requirements of IEC 60422:2024, Table 3, with the exception of the additional requirements specified by the Purchaser:		
	- water content	mg/kg (ppm)	max. 5	
	- acidity	mg KOH/g	max. 0,01	
	- interfacial tension	mN/m	min. 40	
	- oxidation stability		acc. to IEC 61125	
	-inhibitor content		>90% of original value	
4.3	PST oil (before filling):			
	- quantity of oil per PST	t		
	- Manufacturer		SHELL or NYNAS	
	- Manufacturer's designation		Diala S4 ZX-I or Nytro 4000X	
	- type of oil		Type A (fully inhibited high grade oil)	
5.	***BUSHINGS***			
5.1	HV line bushings			

	Manufacturer		Hitachi Energy	
	Type			
	- material		composite	
	- insulation level	kV	420	
	- rated voltage	kV		
	- rated current	A		
	- short time current (1s)	kA	50	
	- power frequency over voltage withstand test - on dry	kV rms		
	- power frequency over voltage withstand test - on wet	kV rms	650	
	Basic Insulation Level (Equal to dry lightning impulse withstand voltage)	kV	1550	
	Dry switching impulse	kV	1050	
	- cantilever force maximum	N		
	- creepage distance	mm	≥ 11500	
5.2	HV neutral bushing:			
	Manufacturer		Hitachi Energy	
	Type			
	- material		composite	
	- insulation level	kV	123	
	- rated voltage	kV		
	- rated current	A		
	- short time current (1s)	kA	50	
	- power frequency over voltage withstand test - on dry	kV rms		
	- power frequency over voltage withstand test - on wet	kV rms	230	
	- impulse over voltage test - lightning impulse	kV	550	
	- cantilever force maximum	N		
	- creepage distance	mm	≥ 3625	
6.	***COOLING SYSTEM ONAN/ONAF***			
6.1	Cooling system: – ONAN – ONAF	% 	 80 100	 …… ……
6.2	Number of cooler banks: – Serial unit – Excitation unit			 …… ……
	Rated power of one cooling fan motor	kW		
	Number of the PST cooling fans			

	Max. number of cooling fans started at the same time			
	Total power of all PST auxiliraies if they work together with full load	kW		
7.	**NOISE LEVEL**			
7.1	Noise level (method sound pressure) at rated voltage, rated frequency, no load operation, at max. position of OLTC and without fans, acc. to IEC 60076-10	dB	70	
7.2	Noise level (method sound pressure) at short circuit with 100 % fans in operation, acc. to IEC 60076-10	dB	72	
8.	***MECHANICAL CONSTRUCTION***			
8.1	Maximums withstand pressure in PST tank (over operation pressure) and pertinent oil pipelines and accessories for 24 hours without leakage-acc. to IEC 60076-1-11.8	kPa		
8.2	Full vacuum in PST tank and in pertinent oil pipelines and accessories without permanent distortion - acc. to IEC 60076-1-11.11	kPa		
9.	**WEIGHT AND DIMENSIONS**			
9.1	Exciting unit: – length – width – height – weight – active part weight – oil weight	 m m m kg kg kg		 …… …… …… …… …… ……
9.2	Series unit: – length – width – height – weight – active part weight – oil weight	 m m m kg kg kg		 …… …… …… …… …… ……
9.3	Gross weight of completely assembled PST	kg		……
9.4	Dimensions of completely assembled PST with cooling system: – length	 m		 ……

	– width – height	m m		……

* The Tenderer shall provide the guaranteed design values of no-load phase angle and short-circuit impedance for all 65 tap positions (32A–0–32R) as a separate technical schedule. The characteristics shall be provided in tabular and graphical form and shall form part of the guaranteed technical data. The specified short-circuit impedance tolerances at zero and maximum phase shift do not replace the requirement to demonstrate compatibility with the existing PST units throughout the complete regulation range. Compliance with the general manufacturing tolerances shall not, by itself, be considered sufficient evidence of suitability for parallel operation. The compatibility requirements specified in Clause 15.6 shall also be fulfilled.

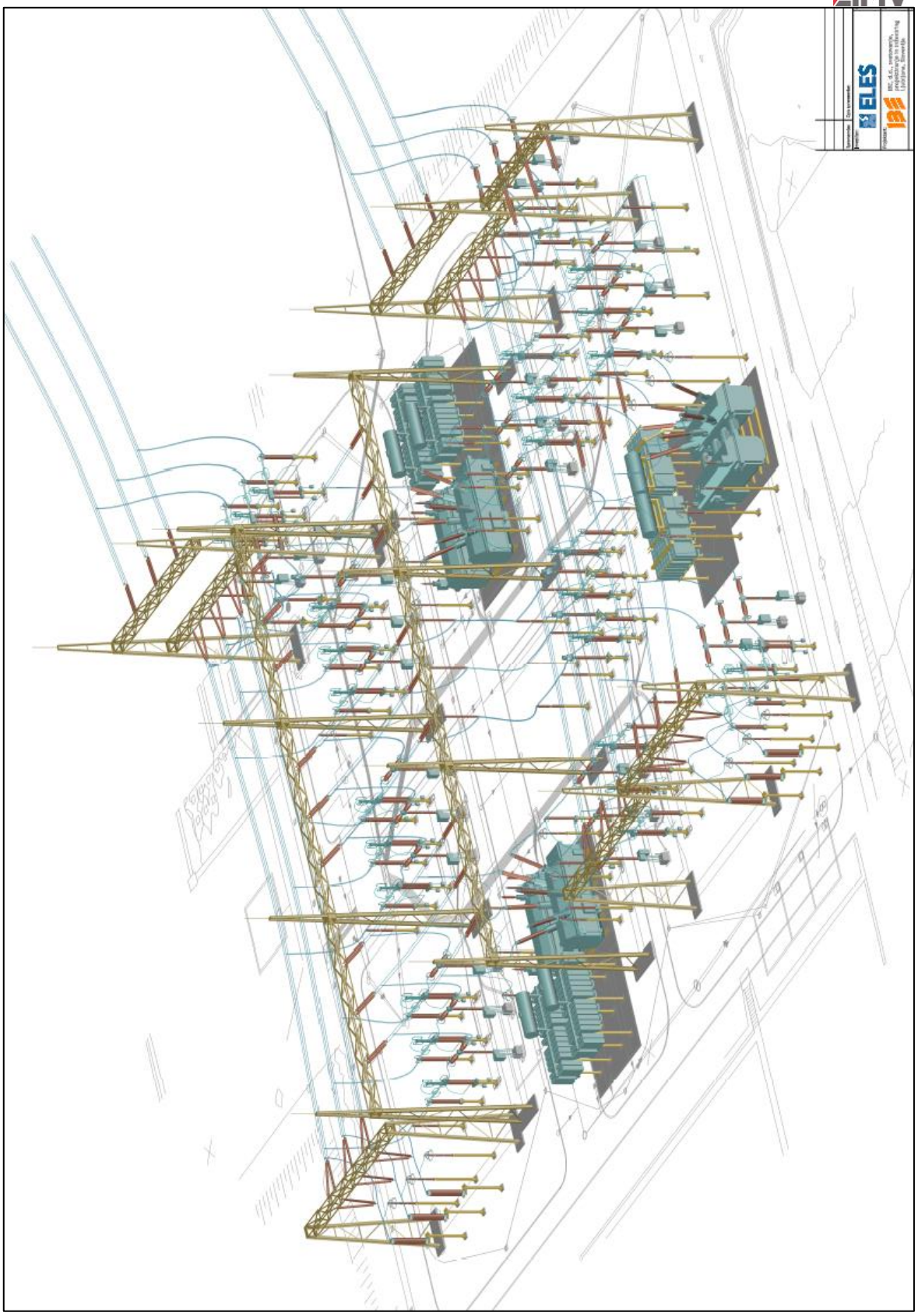


Figure 10: Isometric View of the Third PST Layout at Divača Substation

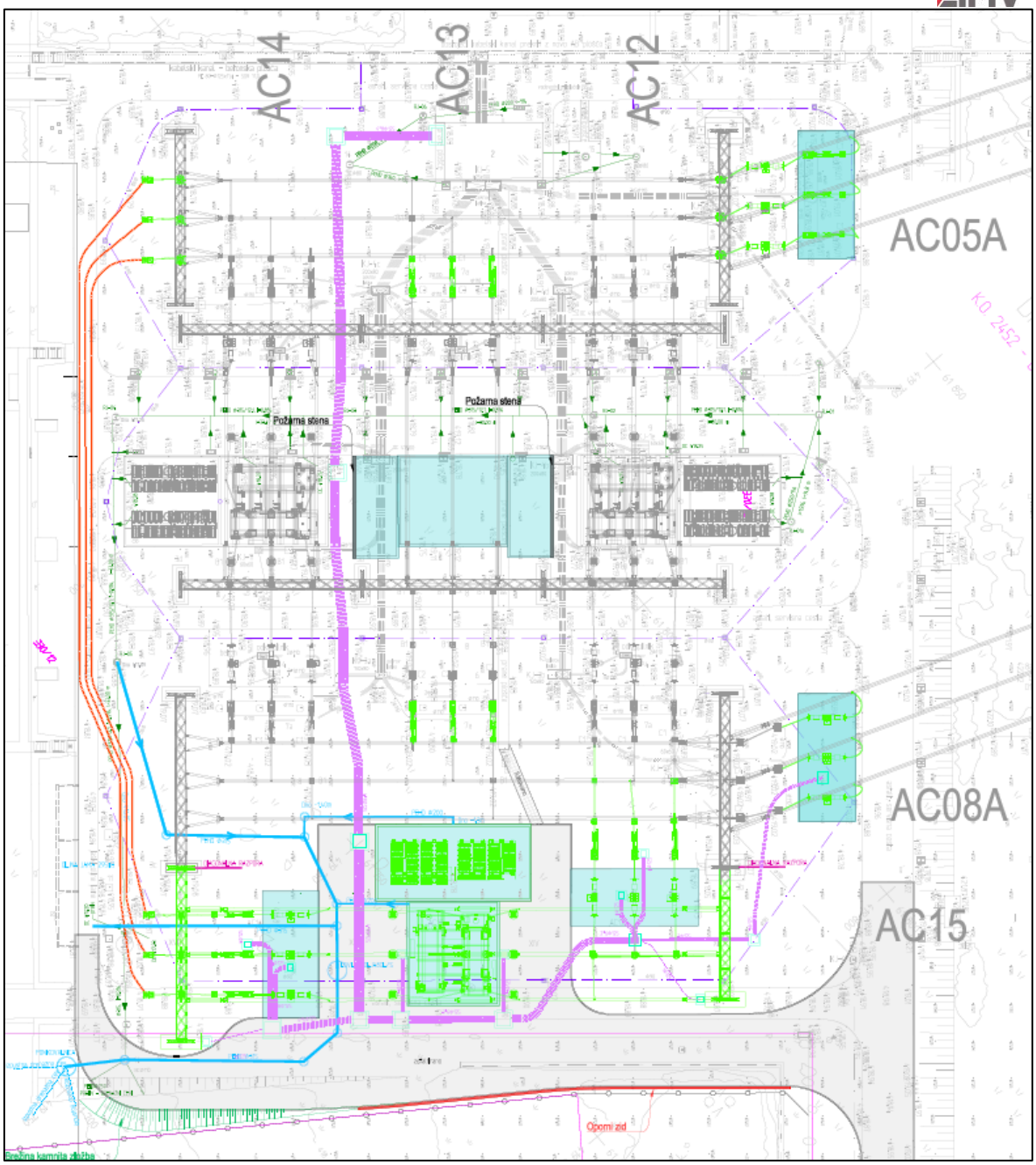


Figure 11: Electrical Drawing – Third PST Installation at Divača Substation

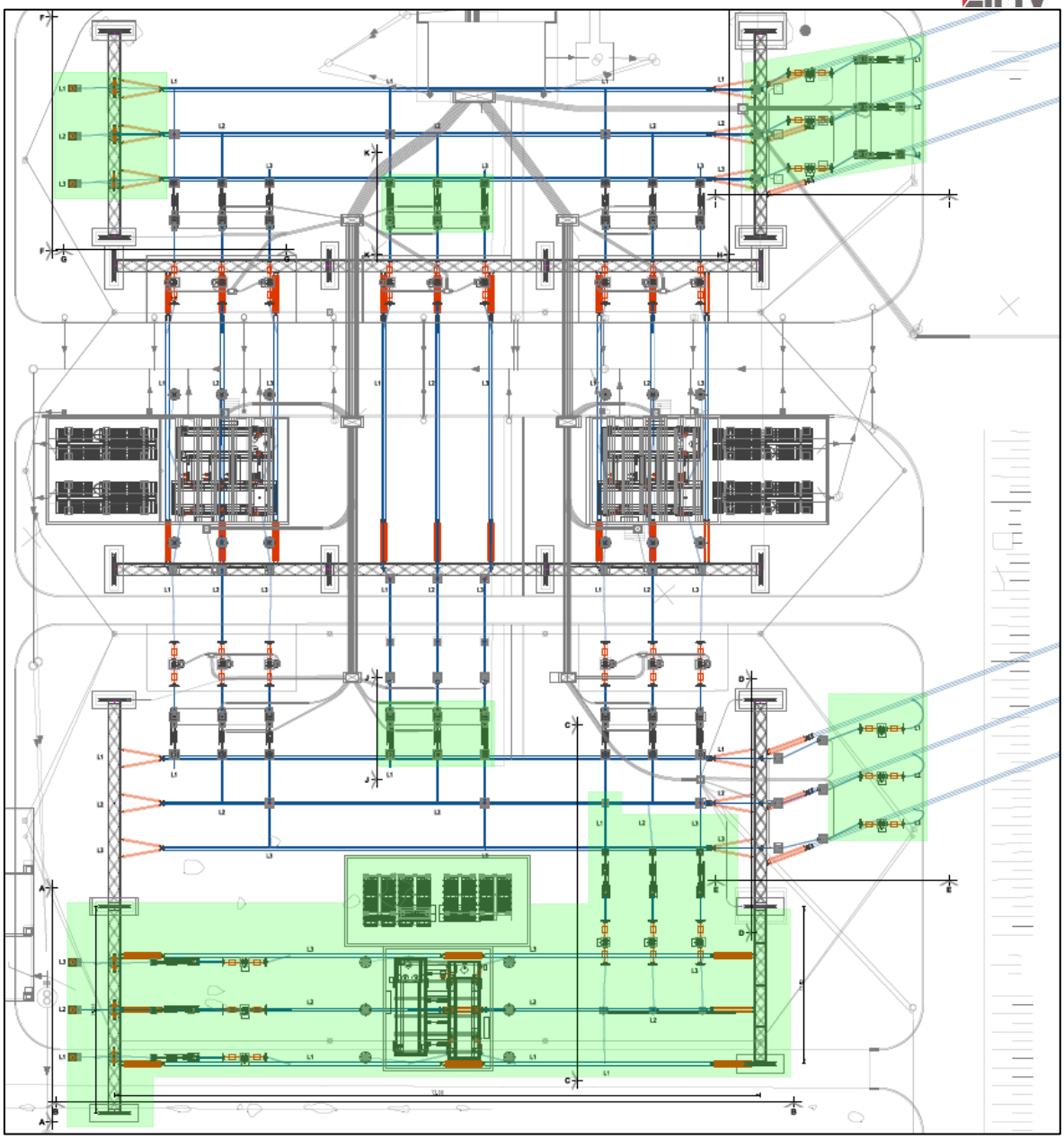


Figure 12: Plan View of the Third PST Layout at Divača Substation