



PUBLIC POWER CORPORATION S.A.
ATHENS - GREECE

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SPECIFICATION No SS-57

REVISION No.16

280MVA, 400 / 157.5 / 30kV THREE-PHASE AUTOTRANSFORMERS

I. SCOPE

The scope of the present specification is to describe PPC's requirements regarding design features, technical characteristics and testing of three – phase, 400/157.5/30kV autotransformers rated at 280MVA.

II. KEY WORDS

Autotransformers, transformers.

III. USE

The autotransformers are installed in EHV substations for the transformation of the 400KV network voltage to 150KV and 30KV levels, covering the load requirements of the 150KV transmission network and the compensation requirements of the 400KV lightly loaded overhead transmission lines, respectively.

IV. ELECTRICAL SYSTEM CHARACTERISTICS

IVA. 400KV NETWORK

- | | |
|--|--|
| 1. Nominal Voltage | : 400KV |
| 2. Maximum Operating Voltage | : 420KV |
| 3. Minimum permissible operating voltage | : 380KV |
| 4. Nominal frequency | : 50Hz |
| 5. Number of phases and conductors | : 3 |
| 6. Short Circuit level | : 40KA |
| 7. Rated duration of short circuit | : 1sec. |
| 8. Basic Insulation level | : 1550KV (peak) |
| 9. Switching impulse withstand voltage | : 1175KV (peak) |
| 10. Variations of nominal frequency | : ± 0.2 Hz |
| 11. Available auxiliary D.C. supply voltage | : 220V D.C. from substation batteries |
| 12. Available auxiliary A.C. supply voltage | : 3 – phase, 4 – conductors
230/400V A.C. |
| 13. Power frequency withstand voltage (1min) | : 680KV (r.m.s.) |
| 14. Method of earthing (grounding) | : Solidly grounded |

**IVB. 150KV NETWORK**

1. Nominal Voltage	: 150KV
2. Maximum Operating Voltage	: 170KV
3. Minimum permissible operating voltage	: 135KV
4. Number of phases	: 3
5. Number of conductors	: 3
6. Short Circuit level	: 30KA
7. Basic Insulation level	: 750KV (peak)
8. Power frequency withstand voltage (1min)	: 325KV (r.m.s.)
9. Nominal frequency	: 50Hz
10. Variations of nominal frequency	: ± 0.2 Hz
11. Method of earthing (grounding)	: Solidly grounded
12. Available auxiliary D.C. supply voltage	: 110V D.C. from substation batteries
13. Available auxiliary A.C. supply voltage	: 3 – phase, 4 – conductors 230/400V

IVC. 30KV NETWORK

1. Nominal System Voltage	: 30KV
2. Maximum Operating Voltage	: 36KV
3. Number of phases	: 3
4. Number of conductors	: 3
5. Short Circuit level	: 20KA
6. Basic Insulation level	: 250KV (peak)
7. Power frequency, withstand voltage (1min)	: 95KV (r.m.s.)
8. Nominal frequency	: 50Hz
9. Method of earthing (grounding)	: Earthed neutral (via V.T. of 30/ $\sqrt{3}$ /0.1/ $\sqrt{3}$ KV ratio, 200VA burden, class 3P).
10. Available auxiliary D.C. supply voltage	: 220V from substation Batteries
11. Available auxiliary A.C. supply voltage	: 230/400V

V. OPERATING AMBIENT CONDITIONS

Installation	: Outdoors
Limits of ambient temperature	: -25 ⁰ C to + 45 ⁰ C
Altitude	: Up to 1000 m above sea level
Other climatic conditions	: Snow, Ice and fog

VI. STANDARDS

All the technical, nominal characteristics and testing of autotransformers shall conform to the IEC 60076 standard.



VII. REQUIRED DESIGN CHARACTERISTICS OF THE AUTOTRANSFORMER

1. Type

Three-phase oil autotransformer with tertiary winding, suitable for outdoor installation.

2. Voltage ratings and number of phase windings

- Primary : 400 KV, 3 - phases
- Secondary : 150 KV, 3 - phases
- Tertiary : 30 KV, 3 - phases

3. Symbolism of autotransformers windings connection

YN auto d.

4. Nominal apparent power (capacity) ratings

Nominal simultaneous continuous capacity, with forced cooling, for 65°C average winding temperature rise, measured by resistance and up to 40°C ambient:

- Primary, 280 MVA
- Secondary, 280 MVA
- Tertiary, 60 MVA

In terms of the above capacities, the current of each auto-transformer winding shall be as follows:

- Primary and series winding, 425.4A at 380KV
- Secondary, 1154.7A at 140KV
- Tertiary, 1154.7A at 30KV
- Common winding 729.3A

5. Type of core

The type of autotransformers core will be core - form or shell - form. For the first type, the core shall consist of 3 or 5 limbs while for the shell type the core shall consist of 3 or 7 limbs.

6. Operation with existing auto-transformers

The auto-transformers shall be suitable for operation with 280MVA existing auto-transformers and for this reason the on load tap-changer (O.L.T.C.) must exactly have the following tap voltages:

**H.V.****M.V.**

	180120	
	178055	
	175950	
	173805	
	171615	
	169380	
	167105	
	164785	
	162415	
	160000	+10 steps
400kV	157535	principal tap
	155020	- 8 steps
	152450	
	149825	
	147145	
	144405	
	141605	
	138745	
	135820	

7. Insulation Levels

- H.V line terminals	420kV	SI/LI/AC : 1050/1425/630 kV
- H.V Bushings	525kV	SI/LI/AC : 1175/1550/680 kV
- M.V line terminals	170 kV	LI/AC : 750/325 kV
- M.V Bushings	170 kV	LI/AC : 750/325 kV
- H.V/M.V Neutral windings*	123KV	LI/AC : 450/185 kV
- Neutral Bushings*	123KV	LI/AC : 450/185kV
- L.V line terminals	52kV	LI/AC : 250/95 kV
- L.V Bushings	52kV	LI/AC : 250/95 kV

*IEC 60076-3 foresees an insulation level for the neutral winding of LI/AC=95/38kV but for reasons of extra safety PPC uses LI/AC=450/185kV.

8. Short circuit withstand capability

Auto-transformer shall be capable of withstanding under service conditions for 2 (two) seconds, on any tap-setting, three-phase or one-phase short circuit at the terminals of any winding without being damaged due to excessive forces or thermal effects. The thermal ability of the autotransformers to withstand short circuit shall be demonstrated by calculation in accordance with IEC-60076-5. For the calculation, it will be taken into account that the short circuit current either of three-phase or one-phase short circuit will be 40KA (2 sec).



9. Winding insulation category and connections

- 9.1. The primary and secondary windings shall be star-connected, with neutral brought out through a fully insulated bushing (450 B.I.L.) grounded directly at the grounding grid of the substation. The primary and secondary windings shall be of non-uniform insulation category.
- 9.2. The tertiary winding will be delta connected. The tertiary winding will be so designed as to withstand without damage a three phase short circuit. The normal load of the tertiary winding will be one 50MVAR shunt reactor and the 1200kVA auxiliary power transformers of the substation. The tertiary winding will be of uniform insulation category.

10. Temperature rise limits

- 10.1 The average value of the windings temperature rise will be 65°C, for ambient temperature up to 40 °C.
- 10.2 The temperature rise at top oil level will be limited up to 60°C for an ambient temperature up to 40 °C.

The limits of the temperature rise will be verified by the execution of the corresponding type test.

11. Limits of insulations resistance at 20°C

- a. For HV winding (400KV) : 1000MΩ
- b. For MV winding (150KV) : 600MΩ
- c. For LV winding (30KV) : 300MΩ

12. Impedance (in % and on 280MVA base)

- 400kV to 157.5kV : 19.6%
- 400kV to 30kV : as high as possible and not less than 51.5% at principal tap of OLTC.
- 150kV to 30kV : as high as possible and not less than 26.9% at principal tap of OLTC.

13. Limits of losses

The auto-transformer iron losses shall not exceed 72kW and copper losses at 280MVA will be less than 620kW at the principal tap position (400/157.5kV), while the cooling losses at 280MVA shall not exceed 24KW.

14. Limits of magnetizing current values

The magnetizing current of the auto-transformer, with the O.L.T.C. at the 400/157.5 tap, will not exceed for the primary voltages given below, the following values:



<u>Primary voltage</u>	<u>Magn. current in % of nominal current</u>
380 kV	0.10% |
400 kV	0.15% | tolerance + 30%
420 kV	0.35% |

The limits of the magnetizing current values will be verified by the execution of the corresponding routine test.

15. Audible noise

The audible noise level of the auto-transformer with the cooling equipment in service should not exceed the value of 85dB.

The determination of the audible noise level and the measurement methods for the various parts of autotransformers will be in accordance with IEC 60076-10/2001 and will be verified by the measurements of the relevant test.

16. Harmonics

The maximum harmonic content, produced by the subject auto-transformer on the 400kV side, shall be given in detail by the Bidders, for various operating conditions and will be confirmed by the execution of the corresponding test. In case that the execution of the test can't be performed, a written confirmation shall be given.

Harmonics of no-load current for voltage ratio 400/157.53kV shall be limited as follows:

- | | | | |
|---|------------------|-------|--------------------|
| - | third harmonic | ≤ 15% | of no load current |
| - | fifth harmonic | ≤ 20% | of " " " |
| - | seventh harmonic | ≤ 13% | of " " " |

17. Guaranteed losses

The offerer must clearly indicate in his technical and economic offer the following guaranteed losses:

- No load losses at 400KV
- Copper losses at 400/157.5KV tap and 280 MVA
- Total losses (No load + copper losses) at 400/157.5KV tap and 280 MVA
- Cooling losses at 280 MVA

VIII. ON – LOAD TAP – CHANGER (OLTC)

1. Parts of the on – load tap – changer

The on – load tap changer generally shall consist of a diverter switch, transition resistors, a tap selector and a reversing change – over selector.

The whole being operated by a driving mechanism (motor drive).



2. Type of the on – load tap – changer

Mechanical oil – immersed type or vacuum/oil (diverter switch and the transition resistors in vacuum and the tap selector and the reversing change – over selector in oil).

3. Number of tapping positions and the corresponding voltage level of each tapping position.

- a. Total number of tapping positions : 19 including one principal tap and +10/-8 tapping positions above / below of the principal tap.
- b. Voltage level of each tapping position as indicated below with a voltage range between tapping positions of 2065V to 2925V.

150KV side

1. 180120
2. 178055
3. 175950
4. 173805
5. 171615
6. 169380
7. 167105
8. 164785
9. 162415
10. 160000 + 10 steps
11. 157535 Principal tap
12. 155020 -8steps
13. 152450
14. 149825
15. 147145
16. 144405
17. 141605
18. 138745
19. 135820

4. Applicable Standards

IEC – 60214 – 1 and IEC – 60542

5. Required operating temperatures of on – load tap – changer

Tap – changer Environment	Temperature	
	Minimum	Maximum
Oil	-25° C	100° C



Vacuum	-25° C	100° C
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6. Location of the tap changer components and method of installation

A. For oil – immersed type OLTCs

- a. The diverter switch and the transition resistors shall be placed in their own compartment which shall be oil – tight.
- b. The tap selector and the reversing change – over selector shall be placed in their own compartment which shall be not oil tight and thus the tap selector can be in contact with the autotransformer oil.
- c. Both compartments which are mentioned above shall be placed inside the tank of the autotransformer.

B. For oil/vacuum type OLTCs

- a. The diverter switch and the transition resistors shall be placed in their own hermetically sealed vacuum bottle (oil – tight).
- b. The tap selector and the reversing change – over selector shall be placed in their own not oil tight compartment and thus the tap selector and the reversing change – over selector can be in contact with the autotransformer oil.
- c. Both compartments which are mentioned above shall be placed inside the tank of the autotransformer.

C. Access to the OLTC and its individual components shall be possible without disturbing connections or other parts of the autotransformer. Suitable manholes shall be available on the autotransformer tank so that the OLTC or any of its components can be removed, on site, in case of failure.

It is of paramount importance that the removal of the OLTC or any of its components does not cause any problems to any of the autotransformer parts.

7. Conservator of the OLTC

- a. The diverter switch and the transition resistors regardless of weather they are placed in an oil – tight compartment or a hermetically sealed vacuum bottle, shall have their own conservator (oil expansion tank).
- b. The conservator shall be equipped with an oil level indicator.

8. Type of oil of the OLTC

The oil used in the diverter switch and transition resistors compartment shall be mineral oil suitable for transformers, free from any PCBs or PCTs and in accordance with IEC – 60296 Standard.

9. Accessories of the diverter switch and transition resistors oil compartment

The compartment shall be equipped with a drain and filling tap.



10. Rating and other characteristics of the OLTC

- | | |
|---|-----------------|
| a. Single or three phase | : Three phase |
| b. Tapping arrangement | : Reversing |
| c. Position of tapping in winding | : Neutral – end |
| d. Rated through current | : 785 A |
| e. Maximum rated through current | : 942 A |
| f. Rated frequency | : 50Hz |
| g. Rated voltage | : 123KV r.m.s |
| h. Rated power – frequency
withstand voltage (50Hz, 1 min) | : 230 KV r.m.s |
| i. Rated lightning impulse
withstand voltage (1.2/50μs) | : 550KV peak |

11. Required protective devices for the OLTC

a. Oil – flow controlled relay

This oil – flow relay shall be installed in the pipe between the tap changer head and oil conservator and shall respond to a predetermined oil flow (due to low energy phenomena) and enable the autotransformer to be tripped.

This oil – flow relay shall be similar to MR type RS 2001 and with the following contact characteristics:

- Two (2) N.O. contacts suitable for 220V DC
One for tripping purposes and one for alarm.

b. Pressure relief device

This pressure relief device will respond in the event of the pressure in the diverter switch compartment exceeds a predetermined value (explosive energy phenomena) and enable the autotransformer to be tripped.

The pressure relief device shall be Qualitrol make and with following contact characteristics:

- Two (2) N.O contacts suitable for 220V DC, one for tripping purposes and one for alarm.

12. Motor Drive Unit (Driving Mechanism)

- a. Control : Local/Remote. For this reason the motor drive unit panel shall be equipped with a three (3) position selector switch “Off–Local– Remote”. The motor drive and control panel shall also be equipped with two (2) push buttons used in conjunction with the “Local ” position of the selector switch, for raising and lowering the voltage step of the OLTC.

- b. Emergency control : Emergency control is required and for this reason the



motor drive and control panel shall be equipped with an emergency push – button for emergency stopping of the motor drive.

- c. Supply voltage & frequency of the motor : 3ph, 400V AC, 50Hz with tolerances of 85% to 110%.
- d. Installation : Outside of the autotransformer tank and connected to the OLTC by drive shafts and gears.
- e. Motor drive and control cabinet : The motor drive and control cabinet of the motor drive unit shall be of IP55 protection as per IEC–144.
- f. Motor drive and control cabinet equipment : The motor drive and control cabinet besides the “Off – Local – Remote” selector switch, the two (2) push – buttons for raise, lowering and the emergency stop push button shall contain the following:
 - 1. A tap indicator, indicating tap position.
 - 2. Anti–condensation heaters controlled by thermostat
 - 3. A counter indicating the number of tap – changers accomplished.
- g. Manual operation : Operation of the tap – changer manually by a mechanical device blocking at the same time operation by the electric motor.
- h. Remote control and indication : The motor drive unit shall be capable of being operated from the substation’s automation control system located at the control building of the substation (raise – lowering and emergency stop). Also tap position number of operations and any alarms originated from the motor drive, will have to be displayed in the HMI center of the substation’s automation control system.
- i. Power frequency withstand voltage : 2KV, 1 minute between all live parts of auxiliary circuits and the frame.

13. Warranty

If the OLTC is MR of Germany or ABB or ZTR make, a warranty period of two (2) years from the received date must be given.



In any other case, the warranty period must be five (5) years from the received date. And in both cases the warranty shall cover any OLTC damages or damages to the autotransformer due to OLTC malfunctioning.

14. Nameplates

A. OLTC

The nameplate of the OLTC shall be included in the nameplate of the autotransformer and shall contain the following:

1. Schematic diagram of the OLTC.
2. Tap positions and corresponding voltage.
3. Tapping arrangement.
4. Rated through current for each tap position.
5. Rated voltage.
6. Rated lightning impulse withstand voltage.

B. Motor Drive

The motor drive control cabinet shall bear a nameplate of non – corrosive material and it shall contain at least the following:

1. Manufacturer's name
2. Type and serial number
3. Supply voltage
4. Frequency
5. Power of motor
6. Runtime per tap operation

15. TESTS

The autotransformer manufacturer is obliged to present to the PPC inspector OLTC's test reports while the PPC inspector is at the manufacturer's premises for the autotransformer inspection and testing.

The test reports which are to be presented shall include the following type and routine tests (one routine test only)

A. Type tests

- a. Temperature rise of contacts
- b. Switching tests
- c. Short – circuit test
- d. Transition resistor test
- e. Mechanical tests
- f. Dielectric tests

B. Routine Tests

- a. Pressure and vacuum tests
- b. Additional routine tests shall be carried out by the manufacturer of the autotransformer and they are indicated in paragraph X-1.10.



IX. BASIC EQUIPMENT OF AUTOTRANSFORMERS AND ACCESSORIES

1. Cooling system

- a. The cooling system of autotransformer will be of Oil Forced - Air Forced type (OFAF).
- b. The coolers for the autotransformers cooling shall be separately mounted and not on the autotransformer tank walls. The necessary structures for supporting the radiators, fans, etc. and all connections between the various parts shall also be furnished together with the autotransformer.
- c. The autotransformer shall be equipped with 6 independent cooling units with one of them to be on standby or with 5 independent cooling units with one of them to be on standby.
Each cooling unit will be a complete assembled set ready for installation. Each set should include radiators, fans and oil circulating pump.
- d. With five (5) or four (4) cooling units (depending on the total number of coolers) in service and at an ambient temperature of 40°C, the loss of one unit will not result in changing the auto-transformer's capability to carry its full rated load (280 MVA) and without exceeding the allowable temperature rise limits.
- e. With two (2) cooler units out of service (Five (5) or four (4) units originally in service), the autotransformer shall be able to carry 80% of its full rated load, under the previously mentioned temperature conditions.
- f. With the complete oil circulation and air cooling system out of service the auto-transformer shall be capable of operating at full load for a period of 30 minutes and at no load for a period of two hours under the previously mentioned temperature conditions.
- g. Each cooling unit shall include a fixed number of radiators, which will consist of a specific number of elements with specific dimensions, and they will be equipped with air release and a drain valves.
- h. The cooling unit shall include certain number of fans with specific dimensions, mounted below the radiators or on the side of them and will be of sufficient rating for OFAF operation.
- i. Furthermore, each cooling unit will be equipped with an oil circulating pump of suitable rating for the OFAF operation. The unit must be provided with an oil flow indicator and shut-off valves on top and bottom, so as to make possible the complete isolation of the particular cooler branch, while the auto-transformer is under load. The start – up or shutdown of any pump



must not cause malfunction of any gas or oil actuated protection device. The oil pumps must have valves at both sides to enable the easy replacement in case of damage.

The replacement or maintenance of the oil pumps should be done without to be necessary to remove the coolers.

- j. The cooling system of each autotransformer should be divided into 2 (two) groups for control purposes. Relay control will be provided to start automatically one group of cooling units as soon as the autotransformer is energized (first control group). The air fans motors of the cooling unit will be energized automatically, while simultaneously a start command will be given to all oil pumps of each cooling system unit and not only of the involved cooling unit.

During the automatic operation and while the first control group is continuously actuated, if the temperature of windings (X1, X2) exceeds a predetermined value, a command will be given via the contacts of the winding temperature indicator and via relays for the automatic energizing of the fans in the second control group.

- k. For the selection of “automatic or manual” operation of cooling system a selector switch will be available to permit the automatic or manual operation of cooling system.

For the manual operation, the activation of the first group will be done as mentioned in paragraph j. and of the second one will be done manually.

- l. All the fans and pumps motors will be of the squirrel – cage type, three phase 380V AC, of the enclosed design.

- m. All necessary automatic operation equipment for the cooling system must be assembled in a metal cabinet with IP55 protection class located on or close to the autotransformer. The grounding (earthing) of the air fans motors and oil pumps of the autotransformer cooling system will be done locally and not through the autotransformer control panel.

2. Autotransformer tank

- a. The autotransformer tank will be of BELL type or cover bolted type.
- b. The bell type tank will be connected with the autotransformer base by bolted flange.
- c. The autotransformer tank will be constructed to withstand 20 Torr at least, vacuum when it is without oil.
- d. For lifting purposes, the autotransformer tank must be provided with suitable lugs.
- e. Manholes should be provided on the tank cover and walls dimensioned no less than $50 \times 50 \text{ cm}^2$. At least, two manholes should be required on the tank cover for the access inside the autotransformer tank.
- f. Grounding pads shall be provided near the bottom of the autotransformer tank. The tank will be grounded in two points at least diagonally. The autotransformer tank should be designed so that the losses caused by circulating



eddy – currents to be minimized and also the creation of onerous temperatures at the tank surface to be avoided.

- g. The cover of the autotransformer tank should be designed in such way as to avoid the stagnation of water.

3. **Conservator tank**

The autotransformer must be equipped with a conservator tank to accommodate the changes in oil volume caused by the changes of the ambient temperature or the autotransformer load.

The conservator tank will be composed of one piece ready for installation.

The design must be of such a type as the direct contact between air and oil to be avoided. To avoid moisture entering in the oil of the conservator tank during the oil volume fluctuations, the tank will be fitted with a breather which shall contain an absorbent material (silicagel) and a drainage tank. Also for that reason, a dry air cushion will float on the oil surface and will increase or decrease as the oil volume changes. The dry air cushion will be in contact with the breather so that it is always at atmospheric pressure and the incoming air is always dry.

The silicagel crystals must be active in order to be able to absorb moisture and this property will be checked by periodical optical inspections of the silicagel crystals colour. Except for the oil level indicator a drain valve will be mounted on the tank and there will be one Buchholz relay with isolating valves on the tube connecting the conservator tank with the autotransformer body as it is described in detail in paragraph IX-13.1 of this hereby specification.

4. **Pressure relief device**

Each autotransformer will be equipped with one at least pressure relief device of QUALITROL make, type XPRD. The device will be mounted horizontally or vertically on the autotransformer tank and will operate by a spring mechanism automatically. The mechanism will hold pressed a stainless steel diaphragm, with one side of which to be exposed to autotransformer tank pressure. In case of internal over-pressures caused by internal failures, the diaphragm will open and regain its position as soon as the pressure in the tank drops below a set limit. There will also be capability for manual check of the device operation. For the annunciation of its operation, the pressure relief device will be provided with two (2) N.O. alarm contacts suitable for 220V D.C. voltage.

5. **Valves**

Each auto-transformer will be equipped with the necessary quantity of valves e.g. for draining the tank, sampling oil, isolating each cooler unit etc. Two oil filling valves diagonally situated shall be provided on the autotransformer cover. Oil filtering valve and vacuum connection valve shall be provided too.

6. **Connecting material**



All connecting material, such as bolts, nuts and lock washers must be hot-dip galvanized.

7. Tubing

The tubing on the body of the autotransformer must be as little as possible and must be arranged in a logical manner. Under any operating conditions, oil leaks from the tank joints or from joints of the oil circuit are not acceptable.

8. Autotransformer oil

The autotransformer insulation oil will be mineral suitable for transformers and in accordance with the latest IEC-60296 Standard. It shall be non-toxic and biodegradable without PCB's or PCTs etc.

Under no circumstances forced oil circulation will create a static electrification hazard in any part of autotransformer.

9. Bushings

The design of bushings will be in accordance with the IEC – 60137 Standard.

9.1 The bushings of each autotransformer winding will be of outdoor – immersed capacitance graded oil insulated type with one end exposed in ambient air and the other end immersed in the autotransformer oil.

9.2 The active part of the bushing will consist of an Oil Impregnated Paper (O.I.P.) condenser type core, impregnated with the autotransformer oil.

9.3 The insulation housing of HV, MV, LV and neutral bushings will be of high grade porcelain.
The porcelain housing will comply in all relevant respects with IEC-60233.

“Test on hollow insulators for use in electrical equipment”.

The space between the active part (core) and the insulating envelope will be oil filled (liquid-insulated bushings).

9.4 The bushings of Autotransformer are required to be of the following rating characteristics:



	H.V.	M.V.	L.V.	Neutral
1. Highest rated Voltage (phase to phase) (Um) (KV-r.m.s.)	420	170	52	123
2. Rated phase to earth operating voltage (KV – r.m.s.)	242	98	30	71
3. Rated current (Ir*)(A)	800	1250	1250	1250
4. Rated thermal short time current, 1 sec (Ith)	25Ir	25Ir	25Ir	25Ir
5. Rated dynamic current (Id)	2.5Ith	2.5Ith	2.5Ith	2.5Ith
6. Minimum cantilever withstand load (N)	≥2000	≥2000	≥800	≥1575
7. Creepage distance (mm)	12600	4675	1300	3380
8. Angle of mounting	≤30°/vertical	≤30°/vertical	≤30°/vertical	≤30°/vertical
9. Temperature limits – class of the insulating material in contact with metal parts	105°C Class A	105°C Class A	105°C Class A	105°C Class A
10. Dielectric dissipation factor (tanδ) at 1.05Um/√3 voltage	≤0.007	≤0.007	≤0.007	≤0.007
11. Maximum value of partial discharge quantity at Um operating voltage	≤10pC	≤10pC	≤10pC	≤10pC
12. Lightning impulse withstand voltage (KV)	1550	750	250	450
13. Switching impulse withstand voltage (KV)	1175	-	-	-
14. Power frequency withstand voltage (KV)	680	325	95	185

9.5 Additional characteristics of bushings.

a. Seismic withstand capabilities.

All bushings shall be capable of withstand the following seismic stresses as per IEC-61463 and IEC-60068-3-3.

1. Horizontally (axes x and y) : 0.5g (5m/s²)
2. Vertically (axe Z) : 0.25g (2.5m/s²)
3. The frequency range should be 1Hz to 35Hz.
4. Acceptable methods of seismic qualification are:
 - Qualification by vibration test or
 - Qualification by static calculation or



- Qualification by dynamic analysis

Bidders are obliged to submit in their offers, test reports or calculation by dynamic analysis, or static calculation.

Approval or not of all the above, lies on PPC's judgment.

- b. Bushings shall be designed for operation at ambient temperature from -25°C to $+45^{\circ}\text{C}$ and an altitude not exceeding 1000m.
- c. The maximum oil temperature under operating emergency conditions will be 115°C .
- d. (*) If after taking into consideration the above stated operating characteristics, the above indicated bushings rating current is less than what it should, then offerers must offer bushings with suitable rating.

9.6 Accessories:

Bushings will be equipped with the accessories below:

- a. Oil level indicator.
- b. Test tap ($\tan\delta$ tap) suitable for measurement of the dielectric dissipation factor, capacitance and partial discharge value of the bushing. The test tap will be electrically isolated from the mounting flange and will be always earthed directly when it is not used.
- c. Air release plug.
- d. Oil expansion compensator.
- e. Oil sampling and oil filling plugs.
- f. Lifting lugs if required by the manufacturer and there are no other means of lifting the bushings.

9.7 Note

Bushings with insulating housing which consists of a resin impregnated fiber tube and silicon rubber covering can be accepted providing if they cover the requirements of paragraph IX-9

9.8 Rating plates – markings

The H.V, M.V. and neutral bushings shall carry a rating plate including the following markings.

Markings for L.V. bushings that indicated below with ■ are adequate:

- Manufacture's name.
- Year of manufacture and serial number
- Maximum operating phase – phase voltage (U_m) or rated operating phase to earth voltage and rated frequency.
- Operating rated current (I_r)



- Insulation levels BIL, SIL, P.F.
- Bushings capacitance, dielectric dissipation factor.
- Mass
- Angle of mounting

9.9 Tests

The autotransformer manufacturer is obliged to present to the PPC inspector bushings test reports while the PPC inspector is at the manufacturer's premises for the autotransformer inspection and testing.

The test reports which are to be presented shall include the following type, routine and special tests:

The tests will be in accordance with IEC – 60137 Standard

A. Type tests

1. Power – frequency voltage withstand test
2. Lightning impulse voltage withstand test
3. Switching impulse voltage withstand test (for H.V. bushings)
4. Thermal stability test
5. Temperature rise test
6. Verification of thermal short – time current withstand
7. Cantilever load withstand test
8. Tightness test
9. Verification of dimensions.

B. Routine tests

1. Measurement of dielectric dissipation factor ($\tan\delta$) and capacitance at ambient temperature
2. Lightning impulse voltage withstand test
3. Power – frequency voltage withstand test
4. Measurement of partial discharge quantity
5. Test of tap insulation
6. Tightness test
7. Visual inspection and dimensional check

C. Special tests

1. Seismic test (IEC – 61463)
2. Artificial pollution test (ICE – 60507)

NOTE: Type and special test reports may not be presented if they have been previously submitted in the technical offer and have been found to be satisfactory.



- 9.10** The bushings of 400kV and 150kV shall be of MICA FIL of Switzerland or F+G or ABB or Haefely or Passoni-Villa.
The bushings of 30kV, shall be of MICA FIL of Switzerland or F+G or ABB or Haefely or Passoni-Villa or ELECTROPUTERE.

9.11 Bushing current transformers

The bushings will be equipped with bushing current Transformers as follows:

Bushing	Ratio	Core 1	Core 2	Core 3
H.V.	400/1-1-1A	40VA CL0.5	30VA CL 5P20	30VA CL 5P20
M.V.	1000/1-1-1A	40VA CL0.5	30VA CL 5P20	30VA CL 5P20
L.V.	2000/1-1A	40VA CL0.5	30VA CL 5P20	—

Complete test protocols for the above bushing current transformers shall be available at the time of inspection of the auto-transformers.

Also the secondary windings of CT's of bushings will be tested with the applying a power frequency voltage of 3KV to earth.

10. Wiring – conductors

All cables which run on the autotransformer body must be placed inside cable trays.
All windings conductors, joints and other connections shall be made of electrolytic copper. All wiring will be made by copper conductors suitably insulated and rated for an A.C. voltage test of not less than 2KV, duration 1 min. The control cables will be of 2.5mm², copper cross section at least.

11. Auxiliary power supply – Insulation of panel's equipment

Available aux. A.C. power supply : three phase voltage 220/380V 50Hz.

Available aux. D.C. power supply : 220V

All control panels equipment which are not attached to autotransformer body but by nature are galvanically connected with the autotransformer body, must be electrically insulated from the metallic frame of the panels so that autotransformer mass protection is ensured.

12. Painting requirements for the autotransformer



The autotransformer including coolers shall be painted with RAL 7040 gray color, of thickness $120\mu\text{m} \pm 20\mu\text{m}$.

13. Instruments – Relays and autotransformer protection devices

13.1. Buchholz relay

An earthquake proof Buchholz relay of EMB make, type BF 80/10 must be provided and be mounted in the pipe connecting the conservator to the autotransformer tank. This relay will be of the double float type with two sets of signaling contacts one for alarm and one for trip.

The relay is full of oil under normal conditions and due to the buoyancy its two float elements will be at the upper level. When a slight or incipient fault occurs inside the autotransformer, (e.g. local overheating, a small quantity of oil leakage etc.), small bubbles of gas will be created and trapped in the relay housing, causing its oil level to fall and simultaneously the above situated element to move, resulting in the closing of the alarm contacts.

In case that a serious fault occurs in the autotransformer (e.g. a leakage of large quantity of oil, short circuits, puncture of bushings), the gas generation will be violent causing a surge of oil inside the relay which will result in the movement of the second float element and the closing of the trip contacts.

The above mentioned contacts will be suitable for 220V D.C. voltage.

13.2. Oil Temperature Indicator

Each autotransformer will be provided with an oil temperature indicator measuring the autotransformer oil temperature at its hottest part.

The thermometer bulb is enclosed in a pocket fixed on the tank at the hottest oil region. The connection between the thermometer bulb and dial indicator is made by a flexible steel capillary tube.

The measurement will be taken via a driving motion operated by the expansion of the fluid inside the bulb and afterwards through the capillary tube will be transferred to the dial pointer.

Moreover, the autotransformer oil temperature indicator will be provided with a function for the teletransmission of the measurement from the autotransformer to the substation's automation control system. This will be achieved by mounting inside the instrument a teletransmitter with transducer of analogue output current 4-20mA.

Two (2) changeover or N.O. contacts are required to be available, one (1) for alarm and one (1) for trip, suitable for 220V D.C. voltage.

The oil temperature indicator should be of AKM, Swedish make.

13.3. Winding Temperature Indicator

The autotransformer winding temperature indicator will be functionally similar with the Oil Temperature Indicator having in addition only the heating element which is a "thermal image" of the Autotransformer winding. This element will be connected to a Current Transformer via a matching resistance unit suitably calibrated to measure the



current through the autotransformer winding. In this way, the thermal load and consequently the temperature of the winding will be measured indirectly.

For the teletransmission of the winding temperature indication from the autotransformer to the substation's automation control system, the instrument will include a tele-transmitter which can be connected with a transducer of analogue output current 4-20mA.

Referring to the electrical contacts, two (2) changeover or N.O. contacts are required at least, one (1) for alarm and one (1) for trip. In addition, for the automatic and gradual energizing of the autotransformer cooling system, two (2) changeover or N.O. contacts are required.

All contacts will be suitable for 220V D.C. voltage.

The winding temperature indicator should be of AKM, Swedish make.

13.4 Oil Flow Indicator.

Each cooling unit of the autotransformer oil forced cooling system will be equipped with an oil flow indicator showing the oil flow in the connecting pipe of each oil circulation pump of the cooling system.

One (1) normally open (NO) contact is required for alarm when the oil flow drops below a predetermined percentage value of the full flow.

The contact will be suitable for 220V D.C. (~ 0.5 A) voltage.

13.5. Oil level indicator.

The autotransformer will be provided with magnetic oil level indicator. The indicator will be mounted on the outdoor surface of the conservator having a float located inside the conservator oil. The oil level will order the float movement which by a drive shaft will cause the movement of a pointer in the dial.

One (1) normally open contact will be provided for annunciating a low oil level alarm, suitable for 220 V Σ .P. (~ 0.5A) voltage.

13.6. Gas pressure relay.

The autotransformer will be provided with a rapid pressure rise relay of QUALITROL make, detecting the excessive gas pressures caused by internal arcing in the autotransformer tank. The available trip contacts will not be actuated by normal pressure variations caused by temperature change or other mechanical shock on the autotransformer body.

13.7 Autotransformer tank-earth (mass) protection

A C.T. shall be provided to be used for the protection of the auto-transformer against earth faults, given the fact that the autotransformer tank is insulated from earth. The necessary current transformer will be included in the supply and its secondary will be connected to a relay and its primary between tank and earth.

The current transformer will have the following characteristics:

Output power	:	30VA
Ratio	:	200 / 5A



Class : 10P10

The over-current relay (supplied by PPC) which will be used in conjunction with CT will have the following characteristics:

Setting range

Stage 1

$I_E >$ (time delay) : $(0.5-4) \times I_n$ (in steps of 0.1A)

where $I_n = 5A$

Delay time : 0 to 20 sec.

Stage 2

$I_E \gg$ (instantaneous) : $(0.1-10) \times I_n$

Delay time : 0-20 sec.

13.8 Continuous moisture and gas-in-oil fault monitoring system

The autotransformer shall be equipped with a continuous moisture and gas-in-oil incipient fault monitor system, type Hydran M2, manufactured by General Electric.

The system shall include:

1. A gas-in-oil sensor to detect continuously the composite value of hydrogen (H_2), carbon monoxide (CO), acetylene (C_2H_2) and ethylene (C_2H_4), in the transformer oil.
2. Capacitive sensor to continuously monitor the moisture of the transformer oil.
3. A temperature sensor to monitor the oil temperature at the gas-in-oil sensor location.

The system shall also includes analog output cards 4-20mA for SCADA connection.

X. TESTS

The tests will be carried out in accordance with the IEC – 60076-1.2 & 3 Standards.

1. Routine tests

1.1 Measurement of winding resistance

The measurement will be performed by the supply of a direct current for each autotransformer winding per phase. The winding resistance will be measured after the autotransformer has been without excitation for at least 3hours, so as the average oil temperature and the temperature of the windings to be equal. The average oil temperature is considered as the mean of the top and bottom oil temperature.



1.2 Check of voltage ratio and connection symbol

During the test performance, the voltage ratio will be measured on each OLTC tapping and the connection symbol of the autotransformer windings will be checked.

1.3 Measurement of short circuit impedance and load loss

The measurement will be performed at rated frequency with sinusoidal voltage applied to the measured winding, with the terminals of the second winding short – circuited and of the third winding open – circuited. The measurements will be performed for three different two – winding combinations. The short – circuit impedance will be measured on the principal tapping and the two extreme tapplings. The supplied current through the measured winding will not be less than 50% of the relevant rated current (tapping current). For the load loss calculation the measured values will be corrected to the temperature of 75 °C, according to the IEC – 60076-1 Standard.

1.4 Measurement of no-load loss and current

The test will be carried out before the dielectric tests and temperature rise test. The measurement will be performed on one of the windings at rated voltage and rated frequency for the principal tapping. The remaining windings will be left open – circuited. For the test voltage adjusting, two (2) voltmeters connected in parallel will be used. The one voltmeter will measure the rms value of the voltage (V) and the other one will measure the mean value of the voltage (V').

The test voltage wave shape is satisfactory if the readings V' and V are equal within 3%. For the no-load loss calculation, the measured value of power loss P_m will be corrected according to the following formula:

$$P_o = P_m * (1 + (V' - V) / V')$$

The rms value of no-load current is measured at the same time with the losses while the mean value of readings in the three phases is taken into account.

1.5 Measurement of capacitance and dissipation factor

The measurement shall be carried out for the following connections:

- a. (HV+MV)-(LV+tank) earthed
- b. (HV+MV)-LV with tank only earthed
- c. (HV+MV+LV)-tank earthed
- d. LV-(HV+MV+tank) earthed

The test voltage shall be 10KV.

$\tan \delta \leq 0.5 \%$



1.6 Measurement of the insulation resistance

The measurements shall be carried out for the following connections and for two time periods (60 seconds and 15 seconds).

- a. (HV+MV)-(LV+earth)
- b LV-(HV+MV+earth)
- c. (HV+MV)-LV

The test voltage shall be 2.5KV.

1.7 Sealing test for the autotransformer tank

The tank with the live part of autotransformer installed in it and filled with appropriate amount of oil, shall be tested by injecting nitrogen at a pressure specified by the manufacturer. Test duration =24hours.

1.8 Autotransformer oil tests

- a. Dielectric test (breakdown voltage $\geq 220\text{KV/cm}$).
- b. $\tan\delta$

1.9 Dielectric tests

1.9.1 Separate source AC withstand voltage test (50Hz, 1min.)

The test will be made by the application of a single – phase A.C. voltage as nearly as possible on sine-wave form and not less than 40Hz. The applied voltage will be reduced to one – third of the test value at the beginning and at the end of the test.

The full test voltage will be applied for 1 min. between the terminals of the under test windings.

For the L.V. winding test, the applied voltage will be 95KV and the H.V. and M.V. windings as well as the autotransformer tank will be short – circuited and earthed.

Moreover a test voltage of 185KV will be applied to the H.V. and M.V. windings at the same time with the terminals of L.V. windings short – circuited and earthed. In case that the windings are non-uniformly insulated the test voltage value is determined by the neutral withstand insulation level for a P.F. voltage applied for 1 min.

1.9.2 Lightning Impulse test

The impulse test will be performed for each terminal of each autotransformer winding with the following test sequence:

- 1. Application of one (1) reduced level full impulse 1.2/50 μS (50%÷75% of the full test voltage)
- 2. Application of three (3) subsequent impulses at full voltage (1.2/50 μS).

The amplitude of the full impulses tested for each winding will be equal to the specified lightning impulse levels.

The terminals of windings which are not under test shall be earthed directly or through low impedance. In case of the H.V. or L.V. windings test, the non-tested



terminal of the common winding is permissible to be earthed through resistor not exceeding 400Ω.

Except for the oscillograms of the applied voltage shape and current flowing the tested winding, the capacitive probe current which is transferred to the non-tested winding will be recorded.

For the impulse test on the neutral winding, the duration of the tested impulse front time is allowed to be up to 13 μS.

1.9.3 Switching impulse test

During the test, the autotransformer will be in no-load condition and the test will be performed for each phase of the series winding at the H.V. of the autotransformer with the neutral terminal earthed. The test voltage will be 1050KV and the impulse will be applied either directly to the terminal of the winding under test or will be inductively transferred. The test sequence will consist of one reduced level full impulse application of a voltage between 50% and 75% of the full test voltage and three subsequent impulses at full voltage. The applied voltage impulse will have a front time at least 100μS and for amplitude above 945KV will have a time at least 200μS with a total duration from the virtual origin to the first zero passage of 1000μS. During the test, the impulse wave-shape and the neutral current will be recorded.

1.9.4 Long – duration induced AC voltage test (ACLD)

1. For the long duration induced AC voltage test the single – phase connection shall be used which successively shall be applied to all three H.V phases of the autotransformer.
2. The H.V/M.V neutral terminal shall be earthed.
3. The M.V terminal of the phase under test shall remain floating.
4. The H.V and M.V terminals of the phases which are not under test shall be earthed.
5. The induced voltage to the H.V terminals will be produced by the application to the autotransformer tertiary, a phase – to – phase sinusoidal voltage of frequency up to 100Hz. If the frequency of the test voltage is greater than 100Hz, the test time (sec) for the induced voltage will be given by the formula : $120(\text{fr/ft})$, where fr: rated frequency, ft : test frequency, but not less than 15 sec.
6. The time sequence for the application of test voltage for the induced AC long – duration tests to each H.V terminal shall be as follows:
 - a. Switched on at a level not higher than one – third of 121KV.
 - b. Raised to $1.1 \times U_m / \sqrt{3} = 267\text{KV}$ and held there for a duration of 5 min.
 - c. Raised to 365KV and held there for duration of 5 min.
 - d. Raised to 412KV held there for 60 seconds.
 - e. Immediately after the test time, reduced without interruption to 365KV and held there for a duration of at least 60 min to measure partial discharges.
 - f. Reduced to $1.1 \times U_m / \sqrt{3} = 267\text{KV}$ and held there for a duration of 5 min.
 - g. Reduced to a value below one – third of 121KV before switching off.



Where $U_m = 420\text{KV}$

During the whole application of the test voltage, partial discharges shall be monitored.

The test is successful if:

No collapse of the test voltage occurs.

The continuous level of partial discharges does not exceed 500pC during the long duration test at U_2

The partial discharge behavior shows no continuously rising tendency at 365KV. Occasional high bursts of non – sustained nature should be disregarded.

The continuous level of apparent charges does not exceed 100pC at $1.1 \times U_m / \sqrt{3} = 267\text{KV}$.

As long as no breakdown occurs, and unless very high partial discharges are sustained for a long time, the test is regarded as non – destructive. A failure to meet the partial discharge acceptance criteria shall therefore not warrant immediate rejection, but lead to consultation between purchaser and supplier about further investigations. Suggestions for such procedures are given in annex A of IEC-60076-3 Standard.

1.10 Operation test On – Load Tap Changer

With the tap-changer fully assembled on the autotransformer, the following operations shall be performed:

- a. With the autotransformer un-energized, eight complete cycles of operation (a complete cycle of operation goes from one end of the tapping range to the other and back again).
- b. With the autotransformer un-energized and with auxiliary voltage reduced to 85% of its rated value, one complete cycle of operation.
- c. With the autotransformer energized at rated voltage and frequency at no load, one complete cycle of operation.
- d. With one winding short-circuited and rated current in the tapped winding, 10 tap-change operations across the range of two steps on each side from the middle tapping.

After the tap-changer is fully assembled on the autotransformer, a power frequency test will be performed to the auxiliary circuits.

2. Type tests

2.1. Temperature rise test

The test will be carried out in accordance with the IEC-60076-2 Standard

The purpose of the test is to establish:

- a. The top oil temperature rise in steady – state condition with dissipation of total losses.



- b. The average winding temperature rise at rated current and with the top oil temperature rise in conditions as mentioned in the above paragraph.

For this reason the test will be performed in two steps:

1. Application of a test voltage such that the measured active power is equal to the total losses of the autotransformer. The test current will be above rated current to the extent necessary to cover the no-load loss. The test for this step may be terminated when the rate of change of top oil temperature rise has fallen below 1°C per hour and has remained there for a period of three (3) hours.
2. When the top oil temperature rise has been established, the test will immediately continue with the test current reduced to rated current of the tested winding. At the end of the hour, the resistance of the winding is measured after a rapid disconnection of the supply and is calculated by a graphical method.

The temperature rise test will be carried out before the dielectric routine tests.

3. Special tests

The special tests shall be carried out on one (1) only piece of the order.

3.1 Test with lightning impulse chopped on the tail (LIC)

The test will be carried out by the use of the same test equipment as of the lightning withstand impulse test with only the chopping gap to be added. During the full-wave impulse test and for each winding, application of chopped impulses with a peak value 10% greater than the amplitude of corresponding full impulse shall be inserted, forming the test sequence as follows:

1. Application of one reduced level full impulse $1.2/50\mu\text{S}$ (50%÷70% of full impulse)
2. Application of a full impulse $1.2/50\mu\text{S}$
3. Application of one or more reduced level chopped impulses $1.2/50\mu\text{S}$
4. Application of two (2) full level chopped impulses $1.2/50\mu\text{S}$
5. Application of two full impulses $1.2/50\mu\text{S}$

The chopping time of the chopped lightning impulse will be between $2\mu\text{S}$ and $6\mu\text{S}$.

3.2 Short – duration induced AC voltage test (ACSD)

1. For the short duration induced AC voltage test the single – phase connection shall be used which successively shall be applied to all three H.V phases of the autotransformer.
2. The H.V/M.V neutral terminal shall be earthed.
3. The M.V terminal of the phase under test shall remain floating.



4. The H.V and M.V terminals of the phases which are not under test shall be earthed.
5. The induced voltage to the H.V terminals will be produced by the application to the autotransformer tertiary, a phase – to – phase sinusoidal voltage of frequency up to 100Hz. If the frequency of the test voltage is greater than 100Hz, the test time (sec) for the induced voltage will be given by the formula : $t = 120 \times \frac{f_r}{f_t}$,
where f_r : rated frequency, f_t : test frequency, but not less than 15 sec.
6. The time sequence for the application of test voltage for the induced AC short – duration tests to each H.V terminal shall be as follows:
 - a. Switched on at 121KV.
 - b. Raised to $1.1 \times \frac{U_m}{\sqrt{3}} = 267\text{KV}$ and held there for a duration of 5 min.
 - c. Raised to 365KV and held there for duration of 5 min.
 - d. Raised to 630KV held there for the test time (paragraph 5).
 - e. Immediately after the test time, reduced without interruption to 365KV and held there for 5 min to measure partial discharges.
 - f. Reduced to $1.1 \times \frac{U_m}{\sqrt{3}} = 267\text{KV}$ and held there for a duration of 5 min.
 - g. Reduced to 121KV before switching off.

Where $U_m = 420\text{KV}$

The test is successful if:

- No collapse of the test voltage occurs.
- The continuous level of partial discharges does not exceed 500pC during the second 5 min duration test at 365 kV.
- The partial discharge behavior shows no continuously rising tendency at 365KV.
- The continuous level of apparent charges does not exceed 100pC at

$$1.1 \times \frac{U_m}{\sqrt{3}} = 267\text{KV}.$$

As long as no breakdown occurs, and unless very high partial discharges are sustained for a long time, the test is regarded as non – destructive. A failure to meet the partial discharge acceptance criteria shall therefore not warrant immediate rejection, but lead to consultation between purchaser and supplier about further investigations. Suggestions for such procedures are given in annex A of IEC-60076-3 Standard.

3.3 Measurement of zero-sequence impedance

The test will be performed at the rated frequency and between the terminals of the series and common windings and the neutral terminal. The series winding and the common winding together form one measuring circuit and the common winding alone forms the other. The zero-sequence impedance expressed in ohms per phase and is given by $3 U/I$, where U is the test voltage and I is the test current (test current per phase $I/3$).



The measurements will be carried out with a current not exceeding the difference between the rated currents on the low-voltage side and the high voltage side.

3.4 Determination of noise level

The test will confirm the allowable limit of the autotransformer audible noise level with its cooling system equipment included, is 85db.

3.5 Measurements of the harmonics of the no-load current

The measurement of the harmonics of the no-load current will be performed for the three (3) phases of the autotransformer and the magnitude of the harmonics will be stated as a percentage of the fundamental component.

3.6 Measurement of the power taken by the fan and pump motors

The measurement will be carried out so that the power requirements of the autotransformer cooling system is verified and taken into account in the total losses guaranteed by the Bidder.

This measurement shall be carried out at the same time with the temperature rise test. Any possible excess of the guaranteed losses will burden (affect) not only the autotransformer under test but all pieces of the order.

XI. FIRE PROTECTION SYSTEM OF THE AUTOTRANSFORMER

The autotransformer shall be equipped with a fire protection system which shall consist of the following:

1. The fire protection system of the autotransformer shall be the “drain and stir system 2000 S made by SERGI (France).
2. The “drain and stir system 2000 S”, basically drains some oil from the autotransformer and injects a certain amount of nitrogen in the event of a fault.
3. This “2000 S drain and stir system”, shall be used to protect the autotransformer tank against internal short – circuits.
4. This “2000 S drain and stir system”, shall be composed of the following basic components :
 - a. Buchholz relay (Not part of the SERGI supply)
 - b. Temperature detectors.
 - c. Shutter.
 - d. Fire protection cabinet.



- e. Autotransformer quick drain valve.
- f. Nitrogen cylinder
- g. Nitrogen pyrotechnic valve
- h. Pressure reducer
- i. Control box

XII. SPARE PARTS

Bidders should quote the following spare parts for each autotransformer, giving item prices.

<u>Item No</u>	<u>Description</u>
1	One H.V. bushing complete
2	One M.V. bushing complete
3	One L.V. bushing complete
4	Complete set of gaskets for all bushings, covers, radiator flanges, manholes and hand-holes for one autotransformer.
5	Cooling fan and motor set
6	Cooling pump and motor set
7	Set of replacement parts for each type of part likely to be damaged upon operation of the relays contactors instruments safety devices etc.
8	Set of replacement parts of the O.L.T.C. likely to be damaged during operation (complete set of contacts for the diverter switch.

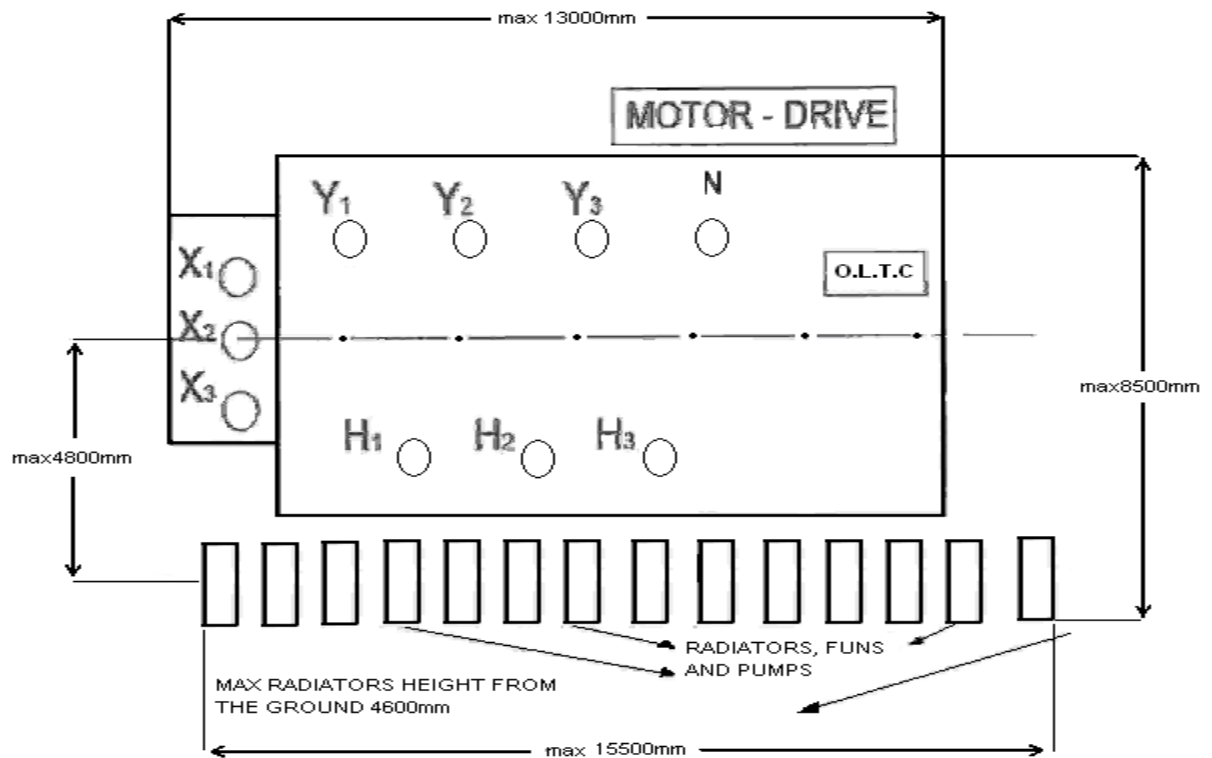
The Purchaser reserves the right to determine when signing the contract, the spare parts which Seller shall furnish on the basis of the prices set forth in his proposal or not to purchase any spare parts at all.



XIII. LOCATION SKETCH

The outline arrangement and overall dimensions of the autotransformer must be as indicated below.

Also the outline of the autotransformer with regard the side and front view shall be as indicated in sketch SK-883B.



- | | | | |
|-----|-----------------------|-----|----------------------|
| (H) | H.V. bushings (400KV) | (X) | L.V. bushings (30KV) |
| (Y) | M.V. bushings (150KV) | (N) | Neutral bushing |

XIV. AUTOTRANSFORMER TAXIING SYSTEM

Autotransformers shall be provided with wheels which will permit the movement of the completely filled autotransformer either in longitudinal or transverse direction. The wheels will run on rails and be able to rotate 90°.

The dimensions for the autotransformer taxiing shall be according to the attached sketch SK-883A.



XV. TRANSPORT, LIFTING, PULLING AND LOADING REQUIREMENTS FOR THE AUTOTRANSFORMER

For the lifting, pulling, loading and transport purposes (with the autotransformer filled with nitrogen (N_2) and with the appropriate amount of oil) the autotransformer must be equipped with a lifting and pulling arrangement as it is shown in the attached sketch SK-883B. The autotransformer must also have suitable suspension lugs with their location in relation to the main body of the autotransformer must be as shown in the attached sketch SK-883C. The dimensions and lugs shown in sketch SK-883C are mandatory.

The required transport dimensions of the autotransformer are indicated in the attached sketch SK-883-D in which the outline of the tunnel is indicated with dotted line and the outline of the autotransformer is indicated with a continuous line. The autotransformer transportation weight must not exceed 260.000Kg.

XVI. DATA TO BE SUBMITTED BY BIDDERS

1. All bidders must provide all information requested in “ATTACHMENT A” of this hereby specification as well as any proposed deviation from the present specification and the reason therefore. Failure on bidder's part to comply with this request will be taken as sufficient reason for rejection of the offer.
2. All bidders must take note of attachments B and C of this hereby specification
3. Technical pamphlets and brochures of the offered autotransformers, which will help the technical evaluation process.
4. Technical data for the OLTC and the autotransformer accessories and systems.
5. Drawings showing the outline dimensions of the autotransformers offered and any other information deemed necessary, including terminal markings.
6. A preliminary plan for the unloading and for the transportation of the autotransformer.
7. Any type test certificates for the type and special tests specified in this hereby specification.

XVII. DATA TO BE SUPPLIED BY THE SUCCESSFUL BIDDER

The Bidder shall furnish (3) three copies for approval and (5) five copies of final drawings at or before the time of shipment of the following:

- a) Assembled transformer outline drawing
- b) Dimension drawings for the taxiing and foundation of the autotransformer
- c) Autotransformers operation schematics and wiring diagrams
- d) Bushings outline drawings
- e) Nameplate drawing
- f) Terminals
- g) Current transformers wiring diagram
- h) Current transformers characteristic curves showing open circuit secondary saturation, ratio and phase angle correction.



- i) Cooling circuit control wiring diagrams
 - k) O.L.T.C. control system operation diagram and wiring diagram.
 - l) Functional diagrams and instructions of the fire protection system
 - m) Instruction manual covering installation operation and maintenance
 - n) A final plan for the unloading, loading and transportation of the autotransformer.
 - o) Two sets of photographs of the active part and internal arrangement of the autotransformers.
- Whatever of the above existing in software will be submitted in that form.

XVIII. RATING PLATES

The autotransformer will be provided with a rating plate of a non-corrosive material, fitted in a visible location showing the items indicated below:

- 1. Relevant Standard – IEC – 60076
- 2. The manufacturer's name
- 3. Serial number
- 4. Year of manufacture
- 5. Number of phases
- 6. Rated power (MVA) for each autotransformer winding and loading combination.
- 7. Rated frequency (HZ)
- 8. Rated voltages (V or KV) and tapping range.
- 9. Rated currents (A or KA)
- 10. Symbol of the windings connection
- 11. Short circuit impedance in (%) for two-winding combinations with the corresponding reference rated power.
- 12. Type of cooling.
- 13. Autotransformer total mass
- 14. Oil mass (Autotransformer insulation material)
- 15. Insulation levels
- 16. OLTC plate
- 17. Temperature rise of top oil and windings.
- 18. Type of autotransformer insulation oil
- 19. Diagram of the windings configuration
- 20. Autotransformer transportation mass.
- 21. Autotransformer untanking mass
- 22. Vacuum withstand capability of the tank and conservator.

In addition to the main rating plate with the above information, the autotransformer shall also carry nameplates with technical characteristics of auxiliary equipment, such as bushings, CTs, cooling system and OLTC according to the individual Standards.

XIX. ECONOMIC COMPARISON OF THE OFFERS

The economic comparison of the offers shall be based on the autotransformer initial cost as it will be amended after taking into consideration the terms of payment and



any custom duties and the cost of the guaranteed losses, that is the comparison will be carried out on the annual cost of the autotransformer as indicated in the attachment “B” of this specification.

For this reason, the paragraphs 1c, 1d and 1e of the attachment “B” only must be filled and the attachment must be submitted along with all others technical information in the technical offer, while the attachment “B” must be submitted completely filled in the economic offer, as well.

PACKING

The autotransformer accessories must be packed inside robust wooden boxes of maximum gross weight of five (5) tons.

The above requirement does not include the bushings of the autotransformer which must be packed separately, one bushing per one wooden box.

**SPECIFICATION No SS-57 / 16****280MVA, 400 / 157.5 / 30kV THREE-PHASE AUTO-TRANSFORMERS****ATTACHMENT "A"****INFORMATION BY SELLER**

1. Type of auto-transformer (short description)
Nominal voltage :
Number of phases :
Connections symbolism :
Rated power :
2. Core type :
 - a. Flux density at rated voltages (at no load and principal tap position) :
:
 - b. Number of core limbs :
3. Insulation levels :
:
:
:
:
:
:
:
4. Maximum permissible short circuit duration :
:
5. Over-voltage capability
a) at no load :
b) at 280.000 kVA :
6. Autotransformer connection. :
7. Insulation category of windings (uniform or non-uniform) :
:
8. Temperature rise limits :for windings
:for oil



9. Losses data

(The guaranteed losses shall be as indicated in paragraph VII-17:

9.1. <u>Voltage level</u>	<u>No load loss</u> <u>KW</u>	<u>Exciting current %</u> <u>Rating kVA (280,000)</u>
a) 380 kV
b) 400 kV
c) 420 kV

9.2. Copper and Total losses at principal tap 400 / 157.5 kV
(Cooler losses not included)

<u>Load kVA</u>	<u>Cu losses in kW</u>	<u>Total losses in kW</u>
280,000
230,000
170,000
120,000

9.3. Losses in kW due to the cooling system at 280MVA :..... kW

10. Impedances in % for 280 MVA
base and voltage ratio of 400/157.5/30kV

a) H.V. / M.V.	.....
b) H.V. / L.V.	.....
c) M.V. / L.V.	.....

11. Noise level (at rated power)

- Autotransformer without cooling	.....
- With all coolers at full operation	.....

12. Harmonics of no-load current for principal tap
(400/157.5/30kV):

a. Third harmonic	.....in% of no-load current
b. Fifth harmonic	.....in% of no-load current
c. Seventh harmonic	.....in% of no-load current

13. On - load tap changer (OLTC)

a. List all parts of the OLTC	.....

b. Type of the OLTC (e.g. oil)	.....



- c. Number of tapping positions :
.....
- d. Vacuum operating temperature (if applicable)
Minimum :
Maximum :
- e. Oil operating temperature
Minimum :
Maximum :
- f. Is the tap selector and the reversing
change – over selector in their own
not oil – tight compartment? :
.....
.....
- g. Is the diverter switch and the
transition resistors in their own
oil – tight compartment
(For oil type OLTC)? :
.....
- h. Is the diverter switch and the
transition resistors in their own
vacuum tight compartment
(For the vacuum/oil type OLTC)? :
.....
- i. Is the OLTC equipped with its
own conservator ? :
- j. Is the oil of OLTC free from PCBs or
PCTs, suitable for transformers and
in accordance with IEC – 60296? :
- k. Is the conservator equipped with
oil level indicator ? :
.....
- l. Is the diverter switch and
transition resistors compartment
equipped with a filling and
a drain tap ? :
.....
- m. Does the OLTC consist of
a three – phase unit ? :
14. Tapping arrangement :



15. Position of tapping :
16. Rated through current :
17. Maximum rated through current :
18. Rated frequency :
19. Rated Voltage :
20. Rated power frequency withstand voltage :
21. Rated lightning impulse withstand voltage :
22. Describe the oil – flow controlled relay and where it is installed :
.....
.....
.....
23. Number of N.O. output contacts of the oil – flow controlled relay :
24. Describe two pressure relief device and where it is installed :
.....
.....
.....
25. Number of N.O output contacts of the pressure relief device :
26. Time response of the pressure relief device :
27. Pressure or vacuum values for the diverter switch compartment and transition resistors :
28. Time response of the oil – flow controlled relay :
29. Is the motor drive unit suitable for Local/Remote operation? :
.....
.....



30. Is the motor drive unit equipped with emergency stop? :
31. Indicate installation position of the motor drive unit :
32. Supply voltage of the motor drive unit motor :
33. Frequency of the motor of the motor drive unit :
34. IP class protection of the motor drive unit panel :
35. Is the motor drive control cabinet equipped with :
- a. Local/Remote selector switch :
- b. Three (3) Push – buttons for raising, lowering and emergency stop :
- c. A device indicating tap position :
- d. Tap counter :
- e. Anti - condensation heaters controlled via thermostat :
- f. Supply voltage of the anti – condensation heaters :
36. Can the motor drive unit be controlled remotely ? :
37. Can tap position, number of operations and any alarms be displayed at a remote distance ? :
38. Power frequency withstand voltage of the auxiliary circuits of the motor drive unit :



39. Warranty terms :
:
:
:
40. Cooling system
- a) Type of cooling system :
 - b) Are the coolers separately mounted
and not on the tank walls? :
 - c) Is the autotransformer equipped with
six (6) independent cooling units with
one of them on standby :
 - d) Does the cooling system meet the
requirements of paragraph IX-1-d? :
 - e) Does the cooling system meet the
requirements of the paragraph
IX-1-e? :
 - f) Does the cooling system meet the
requirements of the paragraph
IX-1-f? :
 - g) Does the cooling system meet the
requirements of the paragraph IX-1-g,
h, i, j, k, l and m? :
 - h) Cooling unit data
 - 1. Number of fans per cooling unit :
 - 2. Power of the fan motor when starting :
 - 3. Power of the fan motor when running :
 - 4. Number of pumps per cooling unit :
 - 5. Power of the pump motor at start :
 - 6. Power of the pump motor when running :
41. Autotransformer tank
- a. Type :
 - b. Material of the tank :
 - c. Is the autotransformer tank in
accordance with the requirements of
paragraphs IX-2-b, c, d, e, f and g? :
42. Autotransformer conservator tank
- a. Type :
 - b. Is the conservator composed of one piece? :
 - c. Describe the method of protection against
moisture: :
:
 - d. Does the conservator meet all requirements
of paragraph IX-3; :



43. Pressure relief device for the autotransformer tank
- Type :
 - Location of installation :
 - Alarm contacts :
44. Valves
- Type :
 - Use :
45. Oil of the autotransformer
- a. Type and manufacturer :
 - b. Does the oil contain any PCBs or PCTs? :
 - c. Is the oil suitable for transformers and in all other respects in accordance with IEC-60296? :
46. Bushings
- | | H.V | M.V | L.V. | Neutral |
|--|-------|-------|-------|---------|
| a. Type | | | | |
| b. Manufacturer | | | | |
| c. Max phase-phase operating voltage (rms) | | | | |
| d. Rated phase to earth operating voltage (rms) | | | | |
| e. Rated current (A) | | | | |
| f. Rated thermal current (A) | | | | |
| g. Rated dynamic current (A) | | | | |
| h. Cantilever withstand load (N) | | | | |
| i. Creepage distance | | | | |
| j. Angle of mounting | | | | |
| k. Thermal limits – class | | | | |
| l. Dielectric dissipation factor | | | | |
| m. Partial discharges at max operating phase-phase voltage | | | | |
| n. Insulation levels | : | | | |
| | | | | |
| | | | | |
| o. Seismic withstand capability: | | | | |
| p. Indicate as to whether the bushings meet the requirements of paragraph IX-9.5 and 9.6 | | | | |
47. Bushings current transformers
(Ratio, accuracy class, burden)
- H.V. :
 - M.V. :
 - L.V. :



48. Are all cables which run on the autotransformer inside cable trays? :
49. Type of material of the winding conductors :
Cross section of the winding conductors :
50. Type and manufacturer of BUCHHOLZ :
- Location :
- Characteristics of alarm contacts :
- Characteristics of trip contacts :
51. Type and manufacturer of oil temperature indicator. :
- Characteristics of alarm contacts and trip contacts :
- Measurements teletransmission capability :
52. Type and manufacturer of winding temperature indicator. :
- Characteristics of alarm contacts and trip contacts :
- Measurements teletransmission capability (Yes or No) :
53. Type and manufacturer of oil flow indicator. :
- Characteristics of alarm contacts and trip contacts :
54. Type and manufacturer of oil level indicator. :
- Characteristics of alarm contacts and trip contacts :
55. Autotransformers mass protection system :
- Current transformer (ratio, burden, class) :
56. Type and manufacturer of gas pressure relay :
- Location of installation :
- Characteristics of alarm contacts :
57. Type and manufacturer of continuous Moisture and gas-in-oil fault monitoring system :



58. Full load regulation
a) at rated service and p.f.=1 :
b) at p.f.=0.85 :
59. Efficiency at 400/157.5/30 kV p.f.=1 p.f. = 0.85
at 280,000 kVA
at 230,000 kVA
at 100,000 kVA
at 50,000 kVA
60. Net weights and dimensions
- Transportation weight : kg
- Core and coils : kg
- Tank and fittings : kg
- Oil : kg
- Total weight : kg
- Untanking weight : kg
- Overall height (including bushings) : m
- Height over tank : m
- Projected floor dimensions related to
line through H.V. bushings:
Parallel to : m
Right angles to : m
- Description of the taxiing system :
.....
- Description of the unloading and
transportation way :
.....
61. Tests (acceptance of the specified tests) (Yes or No) :
62. Type of the fire protection system (description) :
.....
63. Color of the autotransformer :
64. Describe with what the autotransformer
tank will be filled for transport purposes :
.....
65. Type of material, manufacturer and country of
origin of the autotransformer core material :
.....
66. Limits of magnetizing current (in% of the rated
current)
at 380KV : %
at 400KV : %
at 420KV : %

**SPECIFICATION No SS-57 / 16****280MVA, 400 / 157.5 / 30kV THREE-PHASE AUTOTRANSFORMERS****ATTACHMENT "B" - INFORMATION BY SELLER****EVALUATION OF LOSSES****1. Auto-transformer first cost and losses:**

- a. Auto-transformer rating (kVA) : 280,000 kVA
- b. Auto-transformer first cost
(The auto-transformer total first cost will be computed by the Purchaser who will consider the Seller C+F price as amended after the evaluation of the proposed terms of payment). : k = EURO
- c. No-load loss
(at rated voltage 400/157.5/30kV) : A =kW
- d. Copper loss at 280,000kVA
(at rated voltage 400/157.5/30kV) : B =kW
- e. Cooling requirement (fans and pumps)
for 280,000kVA : C =kW

2. Auto-transformer annual cost

1. Transformer carrying charges (at 9.37 per cent) : $\frac{9.37K}{100} = \text{.....EURO}$
2. Capacity loss (referred to the H.V. side
(at EURO 103.4 per kilowatt-year) : $103.4 \cdot (A+B) = \text{..... EURO}$
3. Energy loss (referred to the H.V. side)
(at 0.0357EURO per kWh)
- a) No-load loss for 8,760 hours : $0.0357 \cdot A \cdot 8760 = \text{..... EURO}$
- b) Copper loss
(Load factor 42%,
Loss factor 21.8%,
loss hours 1,900) : $0.0357 \cdot B \cdot 1,900 = \text{..... EURO}$



4. Cooling power (referred to the L.V. side)
(at EURO 112 per kilowatt year)
required for 280,000kVA : 112 ° C =EURO
5. Cooling energy requirements (at 0.0372 EURO per kWh)
(Load factor 42%, Loss factor 21.8%,
Loss hours 1,900) :0.0372°C 1,900=EURO

Total annual cost (Sum of 1,2,3,4 and 5) = _____ EURO

**SPECIFICATION No SS-57 / 16****280MVA, 400 / 157.5 / 30kV THREE-PHASE AUTOTRANSFORMERS****ATTACHMENT "C"****INFORMATION BY SELLER****Penalty for excess losses:**

With regard to load and no-load losses, an auto-transformer is considered as successfully inspected if the losses ascertained during inspecting do not exceed the maximum tolerance, specified in the IEC standards versus the losses guaranteed by Seller. Otherwise the autotransformer is rejected. On each successfully inspected autotransformer, any difference in the losses versus the guaranteed ones (without tolerance), shall be negative or zero. If such difference is positive, i.e. the losses ascertained during inspection exceed the guaranteed ones (without tolerance), a penalty shall be imposed on Seller consisting of:

EURO 4441.110 - per kW of no-load losses in excess

EURO 1827.428 - per kW of load losses in excess

The corresponding amount for excess load losses shall be balanced by the corresponding amount for reduced, if any no load losses and vice-versa.

However, if this algebraic sum is negative the Seller is not entitled to any additional payment, whilst if this sum is positive the penalty shall be imposed.

Furthermore, if the cooling power ascertained during inspection exceeds the offered one, a penalty shall be imposed on Seller consisting of:

EURO 1949.626 - per kW of cooling power in excess

However, if the actual cooling power is found to be less than the offered one, Seller is not entitled to any benefit.