AC Yard – Current Transformers – Equipment Specification

Equipment specification

Converter Station (S1, S2, S3, S4)

valid for:

#TL11-CA01-Q01-BC01/-BC02
#TL11-CA10-Q01-BC01/-BC02
#TL11-CA20-Q01-BC01/-BC02

#TL23-CA01-Q01- BC01/-BC02
#TL23-CA10-Q01- BC01/-BC02
#TL23-CA20-Q01- BC01/-BC02

#TL12-CA01-Q01- BC01/-BC02
#TL12-CA10-Q01- BC01/-BC02
#TL12-CA20-Q01- BC01/-BC02

#TL24-CA01-Q01- BC01/-BC02
#TL24-CA10-Q01- BC01/-BC02
#TL24-CA20-Q01- BC01/-BC02

Tyrrhenian Link **2 x 500 MW**

Terna Rete Italia S.p.A. **Contract: 3000088478 (TLE) / 3000088480 (TLW)**

DMS Identifier E4A000001239962

Export Control Classification:

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Index of Revisions

Rev.	Date	Remark	Originator	Reviewer	Approver
00	Sep 08, 2023	First Issue	D. Vertemati	F.Onofri	S.Sonal
01	Oct 23, 2023	Updated as per comments	D. Vertemati	F.Onofri	S.Sonal
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Abbreviations:

TL	Tyrrhenian Link
CT	Current Transformer
ZPA	Zero Period Acceleration
USCD	minimum specific creepage distance
MCOV	Maximum Continuous Operating Voltage
LIPL	Lightening Impulse Protection Level
SIPL	Switching Impulse Protection Level
LIWV	Lightening Impulse Withstand Voltage
SIWV	Switching Impulse Withstand Voltage
PFWV	Power Frequency Withstand Voltage
BVCC	Base Voltage for Creepage Distance
SLL	Static-specified long-term load
SSL	Dynamic-specified short-term load

1 Introduction

This specification applies to the design, manufacturing and testing of main equipment to be supplied for “Tyrrhenian Link” VSC HVDC Double Bipolar Interconnection with marine electrodes for East Link and West Link.

The interconnector is located at:

• S1 Eboli converter station – Campania, Italy (East Link)

• S2 Termini Imerese converter stations – Sicily, Italy (East Link)

• S3 Selargius converter station – Sardinia, Italy (West Link)

• S4 Termini Imerese converter stations – Sicily, Italy (West Link)

The overall project involves two sections- the East Link and the West Link. In the East Link, the undersea cable shall extent from Eboli converter station (S1) to Termini Imerese converter station (S2). In the West Link, the undersea cable shall extent from Selargius converter station (S3) to Termini Imerese converter station (S4).

The following words and expressions shall have the meanings assigned hereby to them, except where the context requires otherwise.

• “TL11” means S1 - Eboli converter station for East Link

• “TL12” means S2 - Termini Imerese converter station for East Link

• “TL23” means S3 – Selargius converter station for West Link

• “TL24” means S4 - Termini Imerese converter station for West Link

• “Client” means Terna Rete Italia, TERNA Group

• “Contractor” means Siemens Energy – CoPa Consortium

• "Manufacturer" means the person or persons, firm or company assigned to execute the works as defined by the scope of supply, described hereunder.

• “Equipment Specification” refers to this document.

• "Standards" means international, regional and national standards as well as guidelines of Client or the Contractor. Further details are supplied in Par. 5.

The project- specific conditions i.e. system data, environmental conditions and additional information are given in [R01].

2 Scope of Supply

The scope of supply includes design, manufacture, test and documentation as specified herein and in compliance with the applicable Standards (given in clause 6). Any deviation to the standards or to this equipment specification needs the written consent of the Client.

The scope of supply comprises of:

- the units mentioned under clause 7,
- all spare parts in accordance with clause 2.1, given in total in clause 7,
- optionally the special tools in accordance with clause 2.2.

The AC Current Transformers shall be delivered with corona rings if necessary, secondary terminal box, internal wiring and terminals. All supplementary material necessary for erection, i.e. nuts, bolts, washers, etc. shall be also included.

Nuts and bolts for fixing the equipment on the foundation are not included in Manufacturers scope of supply. However the Manufacturer shall state his minimum requirements on these nuts and bolts (e.g. strength, quality, etc.) in his outline drawings.

2.1 Spare Parts

It is the intention to use components with an identical design in order to minimize number of necessary spare parts. The minimum quantities of spare parts are given in clause 7.

2.2 Special Tools and Maintenance Equipment

Equipment for which no special tools are needed during installation, maintenance, repair or replacement is preferred. However, if special tools are needed, they shall be clearly identified and included in the scope of supply.
The AC Current Transformers have to be provided with means for lifting to facilitate safe and rapid motion, installation and replacement. All movable parts shall be properly fixed during transport in order to avoid damages.

2.3 Interfaces

Interfaces are:

Primary terminals: see chapter 3.2

Earthing terminals: see chapter 3.1.3 and 3.5

Insulator mounting base: Necessary fixing details to be given in outline drawings.

Mounting pedestals: Base fixing details to be given in outline drawings.

Foundation plates: The foundation plates shall be designed for the use of anchor bolts.

The use of welding as fixing method is not accepted.

Dimensional drawings submitted by the Manufacturer shall include details of these interfaces, as well as footprints (including fixing details), pedestals, structure.

3 Design Requirements

3.1 Normal and special Service Conditions

The CEI EN 61869-1 standard applies.
All equipment and material provided by the Manufacturer shall be new, free from defects and of the same type, standard and quality as mentioned in this Equipment Specification. All workmanship shall be of the highest industrial standard, of accepted engineering practice, in accordance with the relevant standards and to the entire satisfaction of the Client. Any deviation to these standards or to this Equipment Specification shall be stated and requires the written consent of the Client.

3.1.1 Normal service conditions

The § 4.2.5 of Standard CEI EN 61869-1, with the integrations indicated in § 3.1.2, applies.

3.1.2 Special Service Conditions

The enhanced reliability CTs must meet the requirements for normal service conditions for equipment installed outdoors, with a -25°C / +50°C temperature category.
The enhanced reliability CTs must be suitable for environments with "d" (heavy) pollution level (SPS) according to the Technical Specification IEC TS 60815-1.
The enhanced reliability CTs must meet the high seismic qualification level (zero period acceleration ZPA equal to 5 m/s2) according to the Standard CEI EN 62271-207 for seismic testing with oscillogram (time-history).
Terna reserves the right to request, in case of need, equipment suitable for special service conditions, such as, for example, installation at heights above 1000 m asl, installation in environments with "e" (very heavy) pollution level (SPS), etc.

The salinity level to be considered is **112g/l.**

3.1.3 Earthing system

The CEI EN 61869-1 standard applies with the clarification that the enhanced reliability CTs must be suitable for installation in systems with neutral effectively earthed.

3.1.4 Nominal Values

The CEI EN 61869-2 standard applies, with the following clarifications:

- the nominal characteristics of the enhanced reliability CTs are shown Chapter 8;
- with reference to § 6.4 of the CEI EN 61869-1 Standard, the insulation class provided for the windings of the enhanced reliability CTs corresponds to a maximum over-temperature of 50 K (class A corrected for maximum ambient temperature above 40°C);
- overtemperature due to solar radiation equal to 15°C
- the standard condition for the equipment filling gas corresponds to a conventional temperature of 20°C and an atmospheric pressure of 101.325 kPa (1 atm).

3.2 Design and Construction

The enhanced reliability CTs must have the primary on the busbar and the secondary at toroidal core. The internal insulation must be made of SF6 or SF6 / solid gas.
The overall dimensions, for each type of CT are given in Figure 1 of these Specifications.

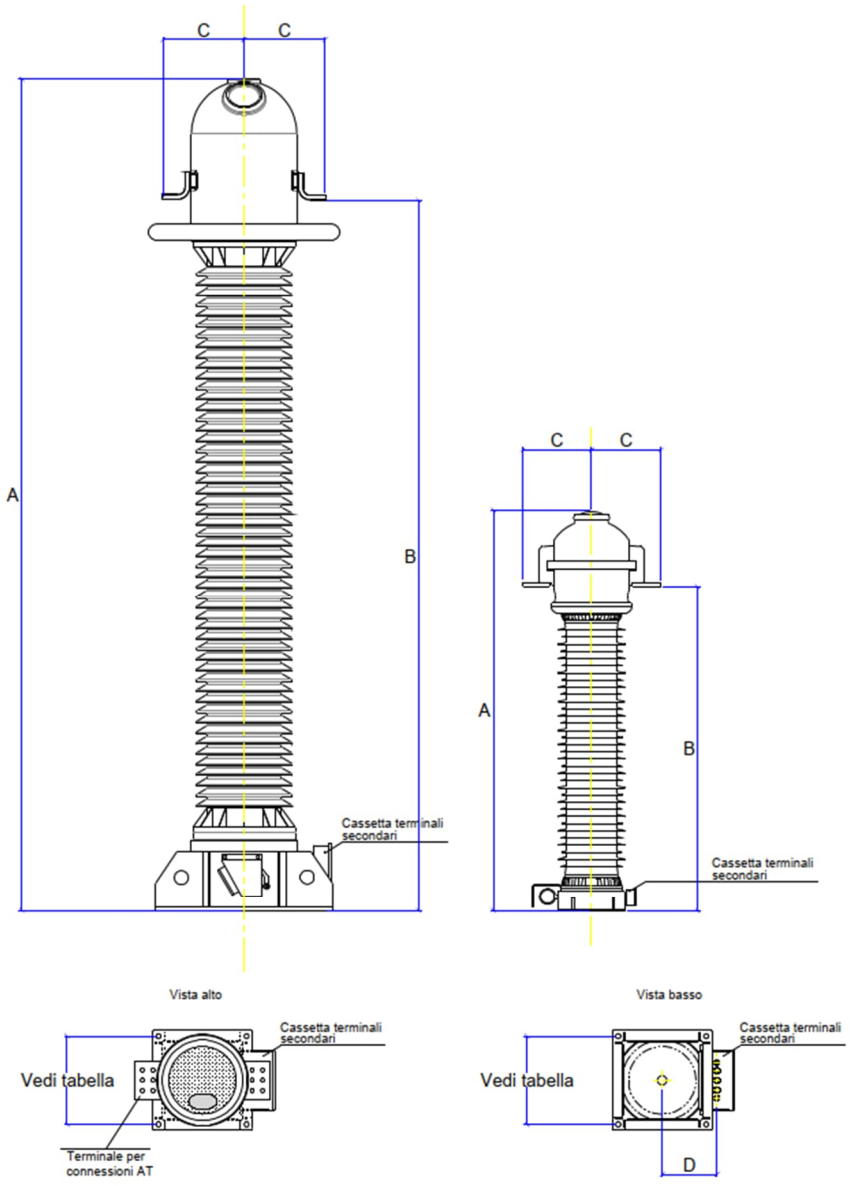


Figure 1 - Overall Dimensions

Tensione [kV]	A [mm]	B [mm]	C [mm]	D [mm]
420	>= 5200	>=4500	<= 600	>= 235

Dimensions of the Terna standard support plates supports are shown in Figure 2.

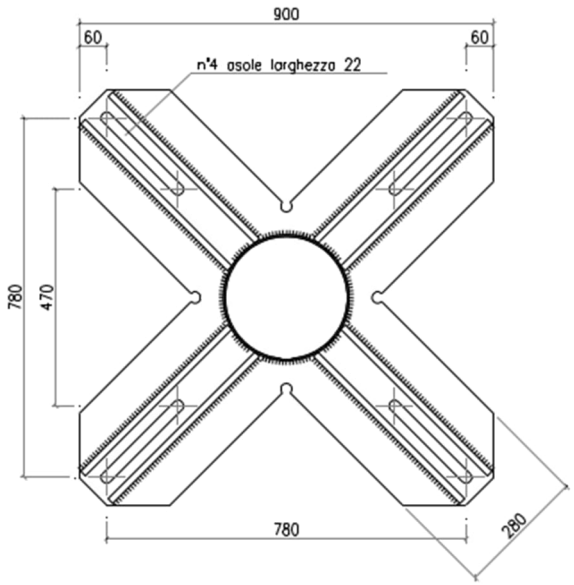


Figure 2 - Support plates dimensions

The dimensions of the CT interfaces are shown in Figure 3.

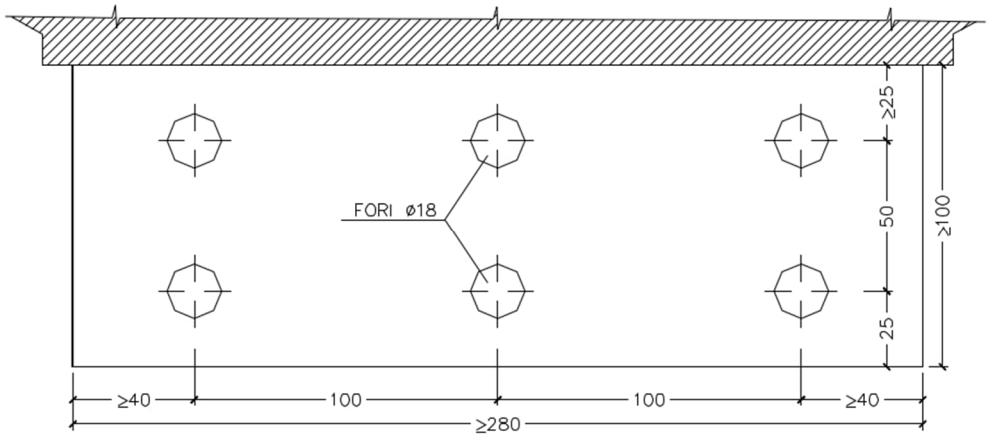


Figure 3 - HV interace terminals

The ratios change must preferably be made through the sockets on the secondary windings.
At the base of the CT there must be a M12 bolt, made of stainless steel (included in the supply), for connection to the station earth grid. The bolts required to fasten the CTs on the respective metal supports must also be supplied with CT.
The lifting attachments must be suitable for handling the CT with the normal lifting devices.

The secondary terminal box must be easily accessible and have adequate dimensions, in order to allow easy implementation of the connections. It must have a protection rating not less than IP44, as defined by the CEI EN 60529 Standard, and must be provided with a suitable ventilation system, equipped with an anti-insect device, in order to avoid the formation of condensation.
Three separate terminal blocks must be provided for the CT secondary windings terminals, for the connections to the gas density control auxiliary contacts and for the 4...20 mA transmitter (two-wire system) of the gas monitoring device referred to in § 3.2.1.3. The terminal blocks must be positioned in separate compartments obtained in the secondary terminal box by means of suitable metal diaphragms. The dimensions of the compartments must allow the easy implementation of the connections.
In each compartment of the secondary terminal box there must be a earthing collector, provided with holes and relative M6 bolts for connecting the cable shields. The earth collectors must be electrically connected to each other and to the M12 bolt for the equipment connection to the station earth grid, by means of copper conductors with cross section not less than 16 mm2 and insulated with a two-colour yellow-green sheath.
The terminal blocks must be suitable for the connection of 4 + 16 mm2 section conductor lines by means of screws, threaded terminations equipped with nuts or indirect clamping terminals conforming with CEI EN 60947-7-1 and CEI EN 60947-7-2.
The insulating body of the terminals must be made of non-hygroscopic material with high surface resistance, non-deformable and resistant to thermal stresses. The metal body of the terminals must be made of non-oxidizing material.
The lower part of the compartment must be provided with special metal cable glands for the passage of cables having ø 12 ÷ 16 mm in number corresponding to the measurement and protection cores, to which No. 4 cable glands must be added for the connections to the gas monitoring device. The cable glands must be positioned as shown in Figure 1 so that the relative cables do not interfere with the of the CT metal support structure.
Alternatively, it is allowed to place the terminal blocks for connection to the gas monitoring device referred to in § 3.2.1.3 in other boxes, separated from that containing the secondary terminals, having characteristics similar to it, also this provided with the earthing collector and cable glands mentioned above. The boxes must be positioned on the same side of the terminals of the CT secondary windings. The measurement core terminals placed inside the secondary terminal box must be able to be sealed by means of a special cover, non-metallic and not removable with the terminal block itself, to allow the use of this core for fiscal measures. It must also be possible to seal the primary ratios change, if present.

3.2.1 Requirements for gases used in the equipment

3.2.1.1 General considerations

The CEI EN 61869-1 standard applies.

3.2.1.2 Gas quality

The CEI EN 61869-1 standard applies with clarification that the CEI EN 60376 standard applies for the first filling gas SF6 and the CEI EN 62271-4 standard applies for the use and handling of the SF6 gas in the equipment;

3.2.1.3 Gas monitoring device

The CEI EN 61869-1 standard applies, with the provisions given below.

The CTs must be equipped with a colored sector device for the display, control and remote monitoring of the SF6 gas density, placed in a position clearly visible from the ground and not interfering with the metal support.

The device must allow remote monitoring of the gas density through an integrated 4...20 mA transmitter (two-wire system). It must allow to control the gas density by means of two intervention levels to be used, through dedicated auxiliary contacts electrically separated from each other, for the following functions:

- 1st gas level: alarm (top up);
- 2nd gas level: alarm (safety).

The alarm threshold for 1st gas level must be set at a value that differs by at least 0.05 MPa from the nominal filling pressure; the 2nd gas level alarm must be set at a value that differs by at least 0.05 MPa from the pressure corresponding to the alarm threshold for the 1st gas level.

It must be possible to check the functionality of the device without removing it and keeping the equipment pressurized (by means of a shut-off valve and test connection). It must also be possible to replace it keeping the equipment pressurized.

The accuracy class of the device must be 2% and must be guaranteed throughout the temperature range required for the CT; the acceptance tests of this sub-component must provide that a sample equal to 5% of the supply batch is subjected to the accuracy class verification in a climatic chamber at 60°C. The device must be hermetically closed; the tightness of the crate must be tested on each production piece using helium gas. The same technical solutions listed in § 3.2.1.4 must be followed to guarantee the expected loss rate. The transparent part must be made of material that does not become opaque if exposed to UV rays (for example polycarbonate or accident prevention glass).

The device must be provided with a suitable cover (cap) to minimize the transient effects of solar

radiation. The alarm contacts for minimum gas pressure must comply with the standard CEI EN 60947-5-1 and have the following nominal characteristics:

Nominal characteristics of the alarm contacts for minimum gas pressure	
Nominal operating voltage, Ue	110 Vdc
Nominaloperating current, Ie	> 1A
Rated insulation voltage, Ui	2 kVAc for 60s
Breaking capacity	0.2 A with L/R < 20 ms
Minimum number of operations	10,000

The connections to the device must be implemented using cables with flexible fire retardant conductors in accordance with CEI EN 60332-3-24, and with low development of corrosive, toxic and/or excessive fumes in compliance with CEI EN 60754 -1/2 and CEI EN 61034-2, with insulation level U0 / U = 0.6 / 1 kV, pertaining to the terminal block E for interfacing with the Station Protection, Command and Control System, composed of indirect clamping terminals conforming with the Standards CEI EN 60947-7-1 and CEI EN 60947-7-2, for conductors with cross section up to 6 mm2.

3.2.1.4 Gas seal

The CEI EN 61869-1 standard applies, with the provisions given below.
The system to be taken into consideration is the closed pressure system, according to the provisions of CEI EN 62271-1, with the clarification that the manufacturer must declare an annual loss rate not exceeding 0.1%.
To guarantee this loss rate the following solutions must be applied:

- double seal for each pressure coupling;
- O-ring gaskets made of material suitable for the specified operating temperature range and resistant to corrosive agents normally present on site;
- adequate corrosion protection for the gas tight flange surfaces and for the O-ring gaskets;
- surface finish of the couplings with roughness not higher than 0.8 µ m;
- lubrication of each coupling with grease.

During the acceptance tests of the sub-components, the following components must be submitted to leak tests with helium (with 100% sampling):

- castings, before any surface treatment;
- the gas control device and the related fittings;
- the terminal blocks of the secondary windings.

The CT must be equipped with a gas filling and topping up system consisting of two DILO DN8 male connections (for the 420 kV voltage level one of the two connections can be DILO DN20, male), equipped with a check-valve, placed at the base of the CT. These connections must be

placed in a suitable position to allow the CT filling/refilling with SF6 gas, without using elbow accessories and without interfering with the metal support.

3.2.1.5 Pressure control device

The CEI EN 61869-1 standard applies.

3.3 Requirements for solid materials used in the equipment

The CEI EN 61869-1 standard applies.

3.4 Requirements for overtemperature of parts and components

The Standard CEI EN 61869-2 applies with the clarification that the insulation class provided for the CT windings corresponds to a maximum overtemperature of 50 K.

3.5 Requirements for earthing the equipment

The CEI EN 61869-1 standard applies.

3.6 Requirements relating to external insulation

The CEI EN 61869-1 standard applies, with the provisions given below.

- The insulator shall be designed according to PRHM0220 (par. 9)
- The withstand salinity value must be 112g/l
- The insulation withstand voltages are shown in chapter 8.The enhanced reliability CT must be equipped exclusively with composite insulators, in compliance with standards CEI EN 62217 and CEI EN 61462.
- For the external coating only the following type silicon rubber shall be used:
  - HTV (High Temperature Vulcanized) with a content of ATH (tri-hydrated alumina) not less than 45% by weight;
- The maximum total electric field, with the equipment subjected to the maximum phase-to-earth voltage, must not exceed the value of 0.42 kVRMS/mm for more than 10 mm along the entire surface of the silicone rubber (air side).
- The verification of the total maximum electric fields on the surface of the silicone rubber must be carried out through the finite element analysis. During the product certification phase the manufacturer must provide to Terna a report which shows the results of the finite element analysis containing, for each equipment tested, the following significant information for verification purposes:
  - dimensional characteristics of the fiberglass tube, of the silicone rubber coating and of the metal flanges (diameters, thickness, angles, bending radii, etc.);

- electrical characteristics of the fiberglass tube and the silicon rubber coating material (relative electric permittivity εr at 50 Hz and 20°C, tanδ dissipation factor 5 at 50 Hz and 20°C, specific electric mass resistivity in direct current ρ at 20°C,etc.);
- maximum and minimum dimensions and order of the mesh used for the finite element model; for this purpose the mesh must be refined by increasing the number and/or order of the elements up to the solution convergence.

- The minimum specific creepage distance (USCD) must be according to the most conservative result between:
  - Requirements from PRHM0220 par 11.2
  - not less than 43.3 mm/kV and corrected in accordance with the Technical Specifications IEC TS 60815-3, taking into account the diameter as indicated in § 10.2 of the above mentioned Technical Specifications and considering HTM with possible loss of hydrophobicity.

3.7 Mechanical prescriptions

The CEI EN 61869-1 standard applies, with the following clarifications:

- The CTs must be provided with horizontal connecting plates, in aluminium or nickel-coated copper, for interfacing with the system, complying with the indications in Figure 3.
- the static loads to be applied during the tests in each terminal are indicated in the following table:

Voltage level [kV]	FR (longitudinal) [daN]	FR (transversal) [daN]	FR (vertical) [daN]
420	1330	840	600

Table 1 - Mechanical loads

3.8 Requirements for protection against internal arc faults

The standard CEI EN 61869-1 applies with the clarification that the CTs must be fitted with a hermetically sealed safety device against overpressures resulting from internal arc. This device must be suitably protected against shocks, accidental damage and surface corrosion phenomena. The device must be placed in the highest part of the CT and must be protected by a suitable cover to ensure a protection rating of at least IP23 in the event of accidental breakage with slow gas leakage. Any leakage of incandescent gases must not involve people in normally accessible places in the system and must not cause damage to the surrounding equipment.
The intervention pressure P_{int} of the safety device must be:

$$P_{Int} \geq 1.2 \bullet P_{prog} + P_{\Delta Device}$$

with PΔDevice tolerance of the intervention pressure of the safety device, indicated by the Manufacturer of the device and between zero and + 10%, and Pprog design pressure, i.e. the maximum pressure that gas can reach in the following extreme thermal operation conditions:

- current equal to the permanent thermal current (1.2 • Ip)
- ambient temperature equal to the maximum operating temperature of (+ 50°C)
- overtemperature due to solar radiation equal to 15°C

The intervention pressure of the device must be suitable to avoid its untimely intervention.

3.9 Protection ratings of the enclosure

The CEI EN 61869-1 standard applies.

3.10 Electromagnetic compatibility (EMC)

The CEI EN 61869-1 standard applies.

3.11 Corrosion

The CEI EN 61869-1 standard applies, with the provisions given below.
The metal parts in contact with the atmosphere must be made of stainless steel, aluminium alloy or protected with hot dip galvanizing coatings, in compliance with the UNI EN ISO 1461 standard.
Any ferrous parts placed inside the secondary terminal box can be painted or protected with electrolytic zinc plating having classification code Fe/Zn 12, in compliance with the UNI EN ISO 2081 standard.
The nuts and bolts and other small parts for fastening the electrical and mechanical components must be in stainless steel; the nuts and bolts with diameter greater than 12 mm can be protected with hot dip galvanizing coatings, in compliance with the Standard UNI EN ISO 1461.
All mechanical processing must be completed before the protective treatments.

The formation of galvanic pairs between different materials in contact with each other must be avoided. The head castings must be painted on the outer surface only with a 9010 colour epoxy coating according to the RAL classification in compliance with the UNI EN ISO 12944-2/5 Standards, with a C5 corrosion category and very high (vh) durability.

3.12 Markings

The CEI EN 61869-2 standard applies, with the provisions given below.
Each CT must be equipped with a plate, installed on the metal base part or on the outside of the secondary terminal box, which shows the data required by § 6.13 of the Standards CEI EN 61869-1 and CEI EN 61869-2 and the following information:

- Equipment code (to be defined)
- serial number and year of construction;
- gas relative pressure corresponding to the nominal density, at 20°C;
- gas mass density;
- other data required by the Community Regulations (EC) regarding the labelling of devices containing fluorinated gases.

On the outside of the secondary terminal box door there must be a plate, indelible and resistant to atmospheric agents, showing the following information:

- connection diagrams of the secondary windings and those of the primary sections, if any, in relation to the respective transformation ratios;
- connection diagram of the gas density control device, with indication of the gas relative densities corresponding to the two intervention levels.

3.13 Fire risk

The CEI EN 61869-1 standard applies.

3.13.1 Transient Stresses

In addition to the steady state conditions, the equipment will be stressed with transient currents and voltages as given in [R02].Combinations as well as repetitions of the transient stress cases can follow in a very short time frame. The equipment must be designed to be capable of withstanding the stresses (including combinations and repetitions) without any adverse influence on its lifetime.

4 Tests

All the test activities and quality aspects shall be performed by the Contractor according to PRHM0050_00 and other specification there mentioned (i.e. PT500ST and PRHM0046).

4.1 Factory Tests

The Manufacturer has to provide all instruments, equipment and facilities required to conduct the factory tests. All test documentation, including test specification and any existing test reports shall be submitted together with an Inspection and Test Plan.
This test documentation shall be basis for the performance of the tests and shall include all test levels, acceptance criteria and test descriptions.

Factory tests have to be performed only on fully assembled equipment as per outline drawings. This requirement shall be assured and a confirmation document shall be sent to the Contractor by the Manufacturer as part of the visual inspection before the tests.

The repetition of type tests may not be needed, the supplier must refer to PRHM0050_00 (par. 2.1).

4.1.1 Type Tests

Type tests have to be carried out in order to ascertain that, with regard to design, and materials, the equipment complies with the specified characteristics and operational requirements. The Manufacturer shall propose a test program, which shall at least include the following tests:

Pos.	Type Test	Standard
A	Temperature rise test	IEC 61869-2 cl. 7.2.2
B	Impulse voltage tests on primary terminals (contains LIWL and SIWL test)	IEC 61869-2 cl. 7.2.3
C	Wet test for outdoor type transformers	IEC 61869-2 cl. 7.2.4
D	Electromagnetic Compatibility tests (contains RIV test)	IEC 61869-2 cl. 7.2.5
E	Accuracy Verification Test	IEC 61869-2 cl. 7.2.6 IEC 61869-2 cl. 7.2.6
F	Verification of the degree of protection by enclosures	IEC 61869-2 cl. 7.2.7
G	Pressure test for the enclosure	IEC 61869-2 cl. 7.2.9
H	Short-time current test	IEC 61869-2 cl. 7.2.201

Pos.	Integrative Type Test	Standard
I	Safety devices test	Ref. [R03] par. 7.6.1
J	Gas absence tightness test	Ref. [R03] par. 7.6.2
K	Seismic Qualification	IEC 62271-207
Pos.	**Special Test**	**Standard**
L	Measurement of capacitance and dielectric dissipation factor	IEC 61869-1 cl. 7.4.3
M	Transmitted overvoltage test	IEC 61869-1 cl. 7.4.4
N	Mechanical tests	IEC 61869-1 cl. 7.4.5
O	Internal arc fault test	IEC 61869-1 cl. 7.4.6
P	Enclosure tightness test at high and low temperatures	IEC 61869-1 cl. 7.4.7
Pos.	**Test related to insulators**	**Standard**
Q	Tests related to coating material	Ref. [R03] par. 7.8.1
R	Artificial contamination test	Ref. [R03] par. 7.8.3

Table 2: List of Type Tests

NOTE: Sequence of tests shall be as CEI EN 61869-1

4.1.1.1 General considerations

The CEI EN 61869-1 standard applies.

4.1.1.2 Temperature rise test

The standard CEI EN 61869-2 applies with the clarification that the CTs must be subjected to two separate heating tests, to be carried out in the sequence indicated without interruption, on the equipment filled with SF6 gas at the minimum operating density, corresponding to the 2nd gas level:

- test at the rated permanent thermal current: the test must be carried out by applying a current equal to the permanent rated thermal current (1.2 • Ip) to the CT, for the time necessary to achieve thermal stability (temperature variation below 1 K each hour);
- test at the rated emergency thermal current: when the thermal stability is reached, the CT must, be subjected, without interruption, for 1 h to the emergency thermal current equal to (1.5 • Ip).

Windings in overload conditions must comply with the overtemperature limits indicated in § 3.4

4.1.1.3 Impulse voltage tests on primary terminals

The CEI EN 61869-2 standard applies, with the following clarifications:

- the test must be performed with SF6 gas at the minimum operating density, corresponding to the 2nd gas level;
- for the atmospheric impulse withstand test, on the primary terminals, 3 series of 15 consecutive positive polarity pulses and 15 negative polarity pulses must be applied, with a maximum interval of 1 h between one series and the next; the atmospheric impulse withstand values are shown in Chapter 8.
- the CT passes the atmospheric impulse withstand test on the primary terminals if the conditions prescribed for the Um< 300 kV case are verified;
- § 7.2.3.3 of the above mentioned Standard is not applicable since the pulse operation test must be carried out in the rain, in accordance with § 4.1.1.4

4.1.1.4 Wet test for outdoor type transformers

The CEI EN 61869-1 standard applies, with the following clarifications:

- the test must be performed with SF6 gas at the minimum operating density corresponding to the 2nd gas level;
- where in chapter 8 indicates a operating impulse withstand value, the test must be carried out by applying this impulse; otherwise, the test must be carried out by applying the power frequency withstand voltage for 60 s.

4.1.1.5 Electromagnetic Compatibility tests (contains RIV test)

The CEI EN 61869-1 standard applied with the clarification that the radio interference level must not exceed 2500 µV at a test voltage equal to 110% of the rated phase-to-ground voltage of the equipment.

4.1.1.6 Accuracy verification test

The CEI EN 61869-2 standard applies, with the following clarifications:

- the test frequency must be 50 Hz. The ratio error and the angle error at the nominal frequency for the CT measurement cores must be measured by circulating through the primary winding a substantially sinusoidal current with a value equal to 5%, 20%, 100%, 120% and 150% of the nominal primary current, for each transformation ratio, and with a performance between 25% and 100% of the nominal performance; for the certified measurement cores of the current transformer, the corresponding measurement class must be ensured with also with performance equal to zero;

- the safety factor for measuring instruments (FS) must be determined using the indirect test method according to § 7.2.6.202 of CEI EN 61869-2;
- in the direct test for measuring the composed error of the current transformer protection cores indicated in § 7.2.6.203 of the Standard CEI EN 61869-2, the secondary winding must be connected at a performance equal to the nominal value with an inductive power factor equal to 0.8.

4.1.1.7 Verification of the degree of protection by enclosures

The CEI EN 61869-1 standard applies.

4.1.1.8 Pressure test for the enclosure

The CEI EN 61869-1 standard applies.

4.1.1.9 Short-time current test

The CEI EN 61869-2 standard applies, with the following clarifications:

- the test must be performed with gas at zero relative pressure, using dry air or nitrogen instead of the SF6 gas;
- the short circuit must be implemented on the minimum transformation ratio.

4.1.1.10 Safety devices test

The safety device test against overpressures resulting from internal arc has the purpose of verifying the safety device suitability to the extreme operating conditions indicated in § 3.8 of the present specification, in order to avoid its untimely intervention.
The safety device test must be performed after the mechanical tests.
The current transformer, filled with SF6 gas at the nominal operating density, must be installed in the same position in which it is installed in the system inside a climatic chamber at the extreme operating temperature of 50°C, and the ΔT measured during the heating test indicated in § 4.1.1.2 of the present specification, and the ΔT due to solar radiation indicated in § 3.8 of the present specification.
During the entire test, the internal gas pressure must be registered, detecting the maximum value Pmax.

4.1.1.11 Gas absence tightness test

The test must be performed with the CT filled with SF6 gas at zero relative pressure, powering it at a voltage of 1.1 • Um / $\sqrt{3}$ kV at 50 Hz, maintained for 1 h. The CT test is successful if no discharge

occurs.

4.1.1.12 Seismic qualification

The CEI EN 62271-207 standard applies, with the following clarifications:

- § 6 of the above mentioned Standard is not applicable;
- the vibration response analysis must comply with CEI EN 600682-57 and must determine the critical frequencies in the test frequency range, and the damping ratio; the vibration response analysis must be repeated at the end of the test to check for any variations in the critical frequencies;
- for seismic qualification it is necessary to use the oscillogram test method (time-history) with tri-axial excitation, complying with the CEI EN 60068-2-57 standard; for the vertical direction severity the direction factor is 0.5; the seismic simulation waveform must produce a test response spectrum that is the response spectrum envelope (RRS) for the high qualification level (zero period acceleration ZPA equal to 5 m/s2) and for the damping ratio determined with the vibration response analysis; if it is not possible to determine the damping ratio, a response spectrum (RRS) corresponding to 2% damping is applied; the peak acceleration value in the oscillogram must be equal to or greater than the zero period acceleration (ZPA) in the reference response spectrum (RRS);
- the test must be carried out on the entire metal support system and equipment, in the configuration most similar to the operating one;

Before proceeding with the shaking table test, the supplier is requested to submit a seismic qualification by calculation note of the assembly of the component plus the respective supporting steel structure. The preliminary steel structure to be considered is shown in D E DS1000 U ST 00002_02.

It is responsibility of the supplier to provide the final design of the steel structure that will be used during the shaking table test. The steel structure used during shaking table test is included in supplier's scope.

- the test must be carried out at the equipment nominal filling pressure; if required by the safety requirements of the test laboratory, it is possible to fill the equipment with nitrogen or dry air at the nominal pressure;
- the test result is positive if there are no cracks or compression deformations, and if there are no significant variations of the equipment operation, before and after the test, with reference to the following values:
    - gas hermetic seal;
    - measurement of the main current path resistance;
    - measurement and protection accuracy class;

- functionality of the gas monitoring device and its auxiliary contacts.

4.1.1.13 Measurement of dielectric capacitance and dissipation factor

The CEI EN 61869-2 standard applies.

4.1.1.14 Transmitted overvoltage test

The CEI EN 61869-1 standard applies.

4.1.1.15 Mechanical tests

The CEI EN 61869-1 standard applies, with the following clarifications:

- the tests must be carried out before the enclosure tightness test at ambient temperature according to § 7.3.7 and before the safety device test referred to in § 4.1.1.10, with the CT filled with gas at a pressure of 0.02 to 0.05 MPa and placed in vertical position;
- the test loads are indicated in § 3.7 of this specification;
- the tests are successful if no obvious damage (deformation, breakage or leakage) is noticed.

4.1.1.16 Internal arc fault test

The CEI EN 61869-2 standard applies, with the following clarifications:

- the short-time thermal current values are shown in Chapter 8; the fault current duration must be 0.5 s.
- for the execution of the test the CT must be installed in the same position in which it is installed in the system; the test can be performed by filling the equipment with nitrogen or dry air;
- the inner arch must be triggered by using a 2 to 3 mm diameter copper wire, positioned in the highest electric field area, either if it in the enclosure or in the head;
- during the test the following must be registered:
  - the current applied
  - arc voltage
  - the pressure before, during and after the intervention of the safety valve measured in a single point
  - the moment of intervention of the safety valve
- at the end of the test the conformity to the requirements reported in § 5.102 of the CEI EN 62271-203 Standard for the protection level 2 must be demonstrated; cracking of the composite insulator is allowed, without material projection from its outside.

4.1.1.17 Enclosure tightness test at high and low temperatures

The standard CEI EN 61869-1 applies with the clarification that the test must be performed after the

safety device test as indicated in §4.1.1.10, using the test method 1 (cumulative method) of the Qm test indicated in the Standard CEI EN 60068-2-17:

- the CT, filled with gas at the nominal operating density and placed in a vertical position, in a climatic chamber, at an ambient temperature between 15°C and 35°C, must be enclosed in a watertight enclosure; the CT must be left in this condition for not less than 4 hours, to allow any leakage to stabilize;
- after this period of time, any gas contained inside the sealed enclosure must be measured (initial measurement);
- subsequently the temperature of the air inside the climatic chamber must be brought to -25°C and kept at this value for a time not less than 24 h;
- then it gradually returns to the ambient temperature and the measurement of the gas content inside the watertight enclosure is repeated (intermediate measurement);
- subsequently the temperature of the air inside the climatic chamber must be brought to +50°C plus the ΔT measured during the heating test indicated in § 4.1.1.2 of these Specifications, and the ΔT due to solar radiation indicated in § 3.8 of these Specifications; this temperature must be maintained for a period of time not less than 24 h;
- it gradually returns to ambient temperature and the measurement of the gas content inside the watertight enclosure must be repeated (final measurement);
- the yearly leakage rate must be determined, based on the difference between the final measurement and the initial measurement, with relation to the total time of the test cycle;
- the test has a positive result if the gas leakage rate does not exceed 0.1% each year.

4.1.1.18 Tests related to coating material

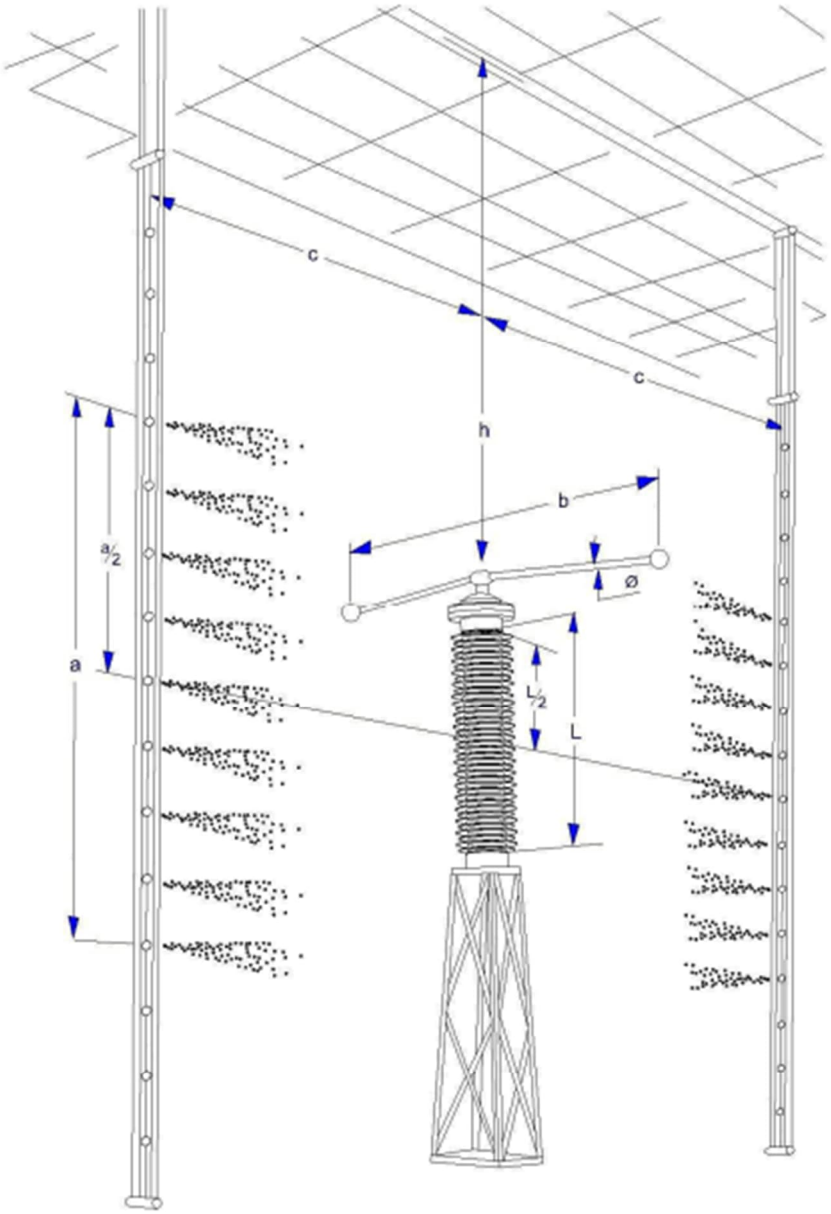
The following tests must be performed on the composite insulators:

- external insulation fingerprint: the test must be carried out following the methods indicated in Annex A of INS AA S 01;
- hardness test: § 7.3.1 of the CEI EN 61462 standard applies;
- flammability test: § 7.3.4 of CEI EN 61462 applies with the clarification that the test must be performed applying method B (vertical combustion test), according to Standard CEI EN 60695-11-10, for class V-0 material;
- tracking and erosion test: § 7.3.3 of CEI EN 61462 Standard and the tests described in Annex B of INS AA S 01 apply.

4.1.1.19 Artificial contamination test

An artificial contamination test must be carried out in order to check the withstand salinity of the CTs external insulation. The test must be carried out on the complete equipment, with full-scale insulator, assembled with a vertical axis on a stand in order to reproduce the normal operating

arrangement, and according to the test requirements indicated in the figure below:



$a = L + 2 \cdot 0{,}6\ m$
$b = 1{,}5 \cdot L\ (\geq 2\ m)$
$c = 3\ m \pm 5\ cm$
$h \geq 1{,}5\ m$
$Ø = 0{,}015 \cdot L\ (\geq 25\ mm)$

The method for carrying out the test is the salt fog method referred to in § 5 of the Standard CEI EN 60507, and taking into account the following clarifications and additions:

- before starting the test, the surface of the insulator must be carefully cleaned with an

appropriate solvent and rinsed with distilled water, in order to eliminate all traces of dirt and grease;

- during the test, the CT must be powered continuously at a test voltage equal to the maximum phase-earth voltage of the system, and with a frequency between 48 and 52 Hz;
- the saline solution and the nebulizing system must comply with the provisions of § 5.2 and 5.3 of the above mentioned standard respectively; the salinity value of the solution is indicated in § 3.2 of the present specification; the axis of the nebulizer columns must be arranged parallel to the axis of the CT;
- before carrying out the leak test referred to in par. § 5.4 of the above mentioned Standard, the insulator must be submitted to one of the pre-conditioning processes described below:
  - the pre-conditioning process provided for in § 5.5 of Standard CEI EN 60507 applies, even if the external insulation is made of silicone rubber; at the Supplier's discretion, the insulator parts pre-conditioning can be applied;
  - the insulator must be subjected to a voltage equal to 80% of the maximum phase-to-earth voltage of the system, applied for 3 hours in a contaminated atmosphere with a salinity value equal to the withstand salinity indicated in § 3.2 of these Specifications; at the end of the pre-conditioning phase the fog must be evacuated from the chamber, the insulator must be rinsed with tap water and then the leak tests have to be carried out.
- if the Supplier decides to apply the pre-conditioning process provided by the CEI EN 60507 Standard, if for any reason it is not possible to complete this process, on the complete insulator or on parts, then the Supplier must submit the insulator to the pre-conditioning process at a voltage value equal to 80% of the maximum phase-to-earth voltage of the system, as described above;
- after the pre-conditioning process, the CT must be subjected to a series of 12 tests lasting one hour each, applying the maximum phase-to-earth voltage of the system, with a salinity value equal to the withstand salinity indicated in chapter 3.2; the time interval between the end of the pre-conditioning and the start of the series tests must not exceed 30 minutes; said interval must also be respected between the end of a single test and the beginning of the next one;
- the CT withstand salinity test with the saline fog method is successful if the withstand value (no discharges during the tests) is obtained in 8 individual tests on the series of 12 tests.

4.1.2 Routine Tests

The routine tests must be conducted on each unit to prove the quality of manufacture. The Manufacturer shall propose a test program, which shall at least include the following tests:

Pos.	Routine Test	Standard
A	Industrial frequency withstand tests on primary terminals	IEC 61869-1 cl. 7.3.1
B	Measurement of partial discharges	IEC 61869-1 cl. 7.3.2
C	Industrial frequency voltage withstand test between the sections	IEC 61869-1 cl. 7.3.3
D	Industrial frequency withstand test on secondary terminals	IEC 61869-1 cl. 7.3.4
E	Accuracy verification test	IEC 61869-1 cl. 7.3.5
F	Markings verification	IEC 61869-1 cl. 7.3.6
G	Enclosure tightness test at ambient temperature	IEC 61869-1 cl. 7.3.7
H	Enclosure pressure test	IEC 61869-1 cl. 7.3.8
I	Determination of secondary winding resistance (Rct)	IEC 61869-2 cl. 7.3.201
J	Test of the knee point (Ek) and excitation current at Ek nominal F.E.M.	IEC 61869-2 cl. 7.3.203
K	Overvoltage test between the coils	IEC 61869-2 cl. 7.3.204
Pos.	**Integrative Routine Test**	**Standard**
L	Visual examination and verification that the construction requirements comply with the certified prototype	Ref. [R03] par. 7.7.1
M	Checking the protective coatings	Ref. [R03] par. 7.7.2

Table 3: List of Routine Tests

The order of the tests is not standardized, but determination of errors shall be performed after the other tests.

4.1.2.1 Industrial frequency voltage withstand tests on primary terminals

The CEI EN 61869-2 standard applies.

4.1.2.2 Measurement of partial discharges

The CEI EN 61869-1 standard applies, with the following clarifications:

- the partial discharges level must be measured with the SF6 gas at the minimum operating density, corresponding to the 2nd gas level;
- the test must be performed even in the absence of elements with solid insulation;
- the test voltages and the maximum permissible levels for partial discharges are shown below, they coincide with those in Table 3 of the standard CEI EN 61869-1:

Voltage level [kV]	Test voltage [kVeff]	Permissible level of partial discharges [pC]
420 - 245 - 170 - 145	U_m	10
	1,2 • U_m / V3	5

4.1.2.3 Industrial frequency voltage withstand test between the sections

The standard CEI EN 61869-1 applies by applying the 3 kV voltage for 60 s in succession between the short-circuited terminals of each section.

4.1.2.4 Industrial frequency voltage withstand tests on secondary terminals

The CEI EN 61869-1 standard applies, with the following clarifications:

- the test must be carried out by applying the 3 kV voltage for 60 s in succession between the short-circuited terminals of each winding and the earth;
- an insulation test must also be performed on the circuits pertaining to the gas density control device, applying 2 kV voltage for 60 s between each independent circuit and the others connected to ground.

4.1.2.5 Accuracy verification test

The CEI EN 61869-2 standard applies, with the following clarifications:

- the test frequency must be 50 Hz.
- the ratio error and the angle error at the nominal frequency for the CT measurement cores must be measured by circulating through the primary winding a substantially sinusoidal current with a value equal to 5%, 20%, 100%, 120% and 150% of the nominal primary current, for each transformation ratio, and with a performance between 25% and 100% of the nominal performance; for the certified measurement cores of the current transformer, the corresponding measurement class must be ensured with also with performance equal to zero;
- in the direct test for measuring the composed error of the current transformer protection cores indicated in § 7.2.6.203 of the Standard CEI EN 61869-2, the secondary winding must be connected at a performance equal to the nominal value with an inductive power factor equal to 0.8.

4.1.2.6 Markings verification

The standard CEI EN 61869-1 applies with the clarification that it is necessary to verify the

requirements indicated in the general part of chapter 3.2 and the dimensional characteristics indicated in Figure 1.

4.1.2.7 Enclosure tightness test at ambient temperature

The CEI EN 61869-1 standard applies, with the following clarifications:

- the test must be carried out at room temperature on all the CTs filled to the nominal density with SF6 gas or suitable tracer gas, according to the test method 1 (cumulative method) of the Qm test reported in the Standard CEI EN 60068-2-17, with the clarification that the stabilization time must not be less than 4 hours, and the waiting time between the initial and the final measurement must not be less than 24 hours.
- the tests are deemed to have been successful if the loss rate measured is not higher than 0.1% each year;

The Manufacturer may use different methods for measuring the leakage rate, which must have the same accuracy as the one indicated above.

4.1.2.8 Enclosure pressure test

The CEI EN 61869-1 Standard applies integrated, if necessary, with the applicable mandatory provisions of the law in force (Ministerial Decree 1 December 1980 as integrated by Ministerial Decree of 10 September 1981, and subsequent amendments and integrations).

4.1.2.9 Determination of secondary winding resistance (Rct)

The standard CEI EN 61869-2 applies with the clarification that the of the secondary winding resistance value (Rct) measured of each core must comply with the values shown in Chapter 8..

4.1.2.10 Test of the knee point (Ek) and excitation current at Ek nominal F.E.M.

The standard CEI EN 61869-2 applies with the clarification that the magnetization curve of each core must be measured by applying a suitable sinusoidal excitation voltage, at the nominal frequency of 50 Hz, to the secondary terminals of all the transformer windings, while the remaining terminals are in open circuit condition, and measuring the excitation current.

4.1.2.11 Overvoltage test between the coils

The CEI EN 61869-2 standard applies.

4.1.2.12 Visual examination and verification that the construction requirements comply with the certified prototype

A visual examination must be carried out to verify the absence of external imperfections and

defects. The visual inspection must be performed by comparing the construction characteristics of the equipment submitted to the test with those of the certified prototype.

4.1.2.13 Checking the protective coatings

The UNI EN ISO 1461 Standard applies, with the clarification that the zinc layer thickness must be determined with magnetic flow devices, according to standards UNI EN ISO 2178 and UNI EN ISO 2064, making from 5 to 10 measurements on each component, uniformly on the various surfaces, avoiding edges and angled parts.
The other types of protective coatings must be checked according to their characteristics established during the type tests.

4.1.3 Sample tests

The Standard CEI EN 61869-1 applies with the clarification that the sample test program must also include the tests indicated below.

Pos.	Sample Test	Standard
A	Lightning impulse test on main terminals	IEC 61869-1 cl. 7.2.3.2
B	Determination of the instrument security factor (FS) of measuring current transformers	IEC 61869-2 cl. 7.5.2
C	Fingerprint of the coating material of polymer insulators	Ref. [R03] par. 7.5.3

4.1.3.1 Lightning impulse test on main terminals.

The Standard CEI EN 61869-1 applies with the clarification that the test must be carried out in accordance with § 4.1.1.3 of the present specification, limited to the atmospheric impulse withstand test only on the primary terminals.

4.1.3.2 Determination of the safety factor for measuring instruments (FS) of measuring current transformers

The Standard CEI EN 61869-2 applies with the clarification that the test must be performed using the indirect test method according to § 7.2.6.202 of the above mentioned Standard.

4.1.3.3 Fingerprint of the coating material of polymer insulators

The test must be carried out in compliance with the provisions contained in Annex A of INS AA S 01, on a sample of silicon rubber taken from one of the insulators provided, in order to verify that the material has the same composition as the one subjected to a fingerprint test during

the product certification phase (see § 4.1.1.18).

4.1.4 Special tests

Current transformer type TL01_M_02 -BC02 for energy metering purposes shall be UFT certified.

4.2 Site Tests

The Manufacturer has to propose a program for pre-commissioning checks. Pre-commissioning checks shall ensure that the equipment has suffered no damage in transit, has been properly installed in the field, is safe to energize, load or start-up and will perform and operate as specified and designed. Objectives, procedures and methodologies shall be detailed in the program.

5 Quality Assurance (QA)

For the Quality Assurance requirements please refer to [R01].
For quality aspects, the supplier must refer to PRHM0050_00 (par. 1.2) and other specification there mentioned (i.e. PT500ST and PRHM0046_00).

6 Standards

At least the following standards are applicable and mentioned here for guidance.

Standard	Title	Issued
CEI EN 61869-1	Instrument transformers – Part 1 General requirements	2010
IEC 61869-2	Instrument transformers – Part 2 Additional requirements for current transformers	09/2012
IEC TS 60815-1	Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles.	2008
CEI EN 62271-207	Apparecchiatura ad alta tensione – Parte 207: Qualificazione sismica per assiemi di apparecchi con isolamento in gas per tensioni nominali superiori a 52 kV	2014
CEI EN 60529	Grado di protezione degli involucri (Codice IP)	1997
CEI EN 60947-7-1	Apparecchiature a bassa tensione – Parte 7-1: Apparecchiature ausiliarie – Morsetti componibili per conduttori di rame	2010
CEI EN 60947-7-2	Apparecchiature a bassa tensione – Parte 7-2: Apparecchiature ausiliarie – Morsetti componibili per conduttori di protezione in rame	2010
CEI EN 60376	Specifiche di qualità tecnica per esafluoruro di zolfo (SF6) per utilizzo in apparecchiature elettrotecniche	2006
CEI EN 62271-4	Apparecchiatura ad alta tensione – Parte 4: Procedure per la manipolazione del gas esafluoruro di zolfo (SF6) e delle sue miscele	2014
CEI EN 60947-5-1	Apparecchiature a bassa tensione – Parte 5-1: Dispositivi per circuiti di comando ed elementi di manovra – Dispositivi elettromeccanici per circuiti di comando	2005
CEI EN 60332-3-24	Prove sui cavi elettrici e a fibre ottiche in condizioni di incendio. Parte 3-24: Prova per la propagazione verticale della fiamma su fili o cavi montati verticalmente a fascio – Categoria C	2010
CEI EN 60754-1	Prova sui gas emessi durante la combustione di materiali prelevati dai cavi – Parte 1: Determinazione del contenuto di gas acido alogenidrico	2015
CEI EN 60754-2	Prova sui gas emessi durante la combustione di materiali prelevati dai cavi – Parte 2: Determinazione dell'acidità (mediante la misura del pH) e della conduttivit	2015
CEI EN 61034-2	Misura della densità del fumo emesso dai cavi che bruciano in condizioni definite – Parte 2: Procedura di prova e prescrizioni	2006
CEI EN 62271-1	Apparecchiatura di manovra e di comando ad alta tensione –Parte 1: Prescrizioni comuni	2010
CEI EN 62217	Isolatori polimerici per interno ed esterno utilizzati per tensioni nominali superiori a 1000 V – Definizioni generali, metodi di prova e criteri di accettazione	2013

CEI EN 61462	Involucri isolanti compositi - Involucri pressurizzati e non pressurizzati per apparecchiature elettriche con tensione nominale superiore a 1000 V – Definizioni, metodi di prova, criteri di accettazione e raccomandazioni per il progetto	2008
IEC TS 60815-3	Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 3: Polymer insulators for a.c. systems	2008
UNI EN ISO 1461	Rivestimenti di zincatura per immersione a caldo su prodotti finiti ferrosi e articoli di acciaio – Specificazioni e metodi di prova	2009
UNI EN ISO 2081	Rivestimenti metallici e altri rivestimenti inorganici – Rivestimenti elettrolitici di zinco con trattamenti supplementari su ferro o acciai	2009
UNI EN ISO 12944-2	Pitture e vernici – Protezione dalla corrosione di strutture di acciaio mediante verniciatura – Parte 2: Classificazione degli ambienti	2018
UNI EN ISO 12944-5	Pitture e vernici – Protezione dalla corrosione di strutture di acciaio mediante verniciatura – Parte 5: Sistemi di verniciatura protettiv	2018

Table 4: List of applicable standards mentioned for guidance

7 Bill of Quantities

Item	Designation	Description	Quantity per station	Quantity in total
TL01_M_01	#TL11-CA10-Q01-BC01 #TL11-CA20-Q01-BC01 #TL12-CA10-Q01-BC01 #TL12-CA20-Q01-BC01 #TL23-CA10-Q01-BC01 #TL23-CA20-Q01-BC01 #TL24-CA10-Q01-BC01 #TL24-CA20-Q01-BC01	HV AC Current transformer	6	24
TL01_M_02	#TL11-CA10-Q01-BC02 #TL11-CA20-Q01-BC02 #TL12-CA10-Q01-BC02 #TL12-CA20-Q01-BC02 #TL23-CA10-Q01-BC02 #TL23-CA20-Q01-BC02 #TL24-CA10-Q01-BC02 #TL24-CA20-Q01-BC02	HV AC Current transformer	6	24
TL01_M_03	#TL11-CA01-Q01-BC01 #TL12-CA01-Q01-BC01 #TL23-CA01-Q01-BC01 #TL24-CA01-Q01-BC01 #TL11-CA01-Q01-BC02 #TL12-CA01-Q01-BC02 #TL23-CA01-Q01-BC02 #TL24-CA01-Q01-BC02	HV AC Current transformer	6	24
TL01_S_01	Spare Unit	HV AC Current transf.		3*
TL01_S_02	Spare Unit	HV AC Current transf.		3*
TL01_S_03	Spare Unit	HV AC Current transf.		3*

Table 5 : Bill of quantities

* (S2 and S4 station will have common spare, ref.to Id 205 of the document “Allegato 3A 20230223_Tender 37298 - TL - RFQ - Clarification sheet - TERNA_STEP 2”)

8 Technical Data

8.1 Calculation basis

The CT suitability check was performed with the relay manuals [R07], [R08], [R09] internal guidelines, CT-Dim, excel sheets, calculator, IEC-61869, and data from [R10]. Eboli converter station is considered for this calculation as a reference for all other converter stations as it has the highest value for max. short circuit level (ssc).

Station: #TL11 Eboli S1 – STATION A
Nominal voltage: 380 kV
Rated frequency: 50 Hz
Rated short-circuit withstand current: 63 kA
Max. symmetrical short-circuit: 32.2 kA
Max. symmetrical short-circuit considered: 40 kA
Primary system time constant: Tp = 50 ms
Length of the AC underground cable: L = 4.25 km
Type of AC underground cable: Cu, 1x2500mm2
Assumed resistance (per unit length): R'= 0.01 Ω/km
Assumed reactance (per unit length): X'= 0.26 Ω/km
Assumed setting of zone 1: kZ1 = 85 %

8.2 AC Cable Protection – CT Adequacy Check

CT Type: 5PR (IEC 61869-2)
CT ratio: 1000/1 A, Icth=150%
Rated accuracy limiting factor ALFr: 60
Rated accuracy burden Sn: 10 VA
Assumed secondary winding resistance Rct: 4Ω
Secondary limiting E.M.F. for protective curr.: 840 V
Cable lead run: 290m+20m -> 350m used, 6mm², return factor 2

$$R_{lead} = 0.02 \frac{\Omega \cdot mm^2}{m} \cdot \frac{700\ m}{6\ mm} \approx 3\ \Omega \rightarrow\ S_{lead} = 3\Omega \cdot (1A)^2 = 3\ VA$$

Check for SIP5 7SL87:

$$ALF_o = ALF_r \frac{S_n + S_{ct}}{S_{lead} + S_{ct}} = \mathbf{120}$$

$$ALF_{o_{87L_{int_{req}}}} \geq 0.5\frac{I_{sc,max,int}}{I_{pn}} \approx \mathbf{20} \rightarrow \boldsymbol{ok}$$

$$ALF_{o_{87L_{ext_{req}}}} \geq 1.2\frac{I_{sc,max,ext}}{I_{pn}} \approx \mathbf{48} \rightarrow \boldsymbol{ok}$$

$$|Z_s| = 1.1\frac{U_n}{\sqrt{3}\cdot I_{scA}} \approx 6\ \Omega;\quad R_s = \frac{|Z_s|}{\sqrt{1+(\omega T_p)^2}} \approx 0.4\ \Omega;\quad X_s = \sqrt{{Z_s}^2 - {R_s}^2} \approx 6\ \Omega$$

$$X_{lim} = k_{z1}\cdot l\cdot X' \approx 1\ \Omega;\quad R_{lim} = k_{z1}\cdot l\cdot R' \approx 0.04\ \Omega$$

$$X_{scB} = X_{lim} + X_s \approx 7\ \Omega;\quad R_{scB} = R_{lim} + R_s \approx 0.44\ \Omega$$

$$|Z_{scB}| = \sqrt{{R_{scB}}^2 + {X_{scB}}^2} \approx 7\ \Omega;\quad I_{scB} = 1.1\frac{U_n}{\sqrt{3}\cdot Z_{scB}} \approx 35\ kA;\quad T_{p\_lim} = \frac{X_{scB}}{\omega R_{scB}} \approx 53\ ms$$

$$ALF_{o_{21L_{IscA_{req}}}} \geq 2\frac{I_{scA}}{I_{pn}} = \mathbf{80} \rightarrow \boldsymbol{ok}$$

$$ALF_{o_{21L_{IscB_{req}}}} \geq 5\frac{I_{scB}}{I_{pn}} = 175 \rightarrow see\ note$$

(with minimum SC current = 81.5 -**ok**)
(also with 1600/1A tap, with maximum SC current = 109.38 -**ok**)
(also with 3200/1A tap, with maximum SC current = 54.69 -**ok**)

Check for RED670:

$$E_{alreq_{87L_{int}}} \geq \frac{I_{k,max,int}}{I_{pn}}(R_{ct} + R_{lead})I_{sn} = \mathbf{280\ V} \rightarrow \boldsymbol{ok}$$

$$E_{alreq_{87L_{ext}}} \geq 2\frac{I_{k,max,through}}{I_{pn}}(R_{ct} + R_{lead})I_{sn} = \mathbf{560\ V} \rightarrow \boldsymbol{ok}$$

$$E_{alreq_{21L_{quad_{IscA}}}} \geq \frac{I_{scA}}{I_{pn}}(R_{ct} + R_{lead})I_{sn} = \mathbf{280\ V} \rightarrow \boldsymbol{ok}$$

$$E_{alreq_{21L_{quad_{IscB}}}} \geq 4\frac{I_{scB}}{I_{pn}}(R_{ct} + R_{lead})I_{sn} = 980\ V \rightarrow see\ note$$

(with minimum SC current = 450.8 -**ok**)
(also with 1600/1A tap, with maximum SC current = 612.5 -**ok**)
(also with 3200/1A tap, with maximum SC current = 306.25 -**ok**)

Noted: The protection core is suitable for 87L and 21L. For near-faults, high-ssc in Z1 the core is suitable. For faults close to the end of distance underreaching Z1, the fault might be seen in overreaching Z2. In fact, this is acceptable since 2x Line Current Differential protection is used as

main function while the distance works as backup delayed scheme. Furthermore, for the worst-case assumption there was considered higher max. ssc. For lower ssc, the above scenario also fulfils the requirement.

Additionally, in order to meet the TERNA's standard specification for CTs, additional taps of 1600 and 3200 can also be added to the CTs.

8.3 Converter Transformer and Connection Protection – CT Adequacy Check

Check for SIP5 7UT8 connection and transformer bushing core (line side):

CT Type: TPY (IEC 61869-2)
CT Ratio: 1000/1 A, Icth=150%
Transient dimensioning factor Ktd: 5
Rated symmetrical short-circuit factor Kssc: 15
Rated resistive burden: 2 Ω

$K_{td}K_{ssc} \geq \mathbf{12.5} \rightarrow \boldsymbol{ok}$

$K_{td}K_{ssc} \geq 0.4\frac{I_{sc,max,int}}{I_{pn}} \approx \mathbf{26} \rightarrow \boldsymbol{ok}$

$K_{td}K_{ssc} \geq 1.5\frac{I_{sc,max,ext}}{I_{pn}} \approx \mathbf{60} \rightarrow \boldsymbol{ok}$

Check for SIP5 7UT8 transformer bushing core (converter side):

CT Type: TPY (IEC 61869-2)
CT Ratio: 1400/1 A, Icth=150%
Transient dimensioning factor Ktd: 5
Rated symmetrical short-circuit factor Kssc: 15
Rated resistive burden: 2Ω

$K_{td}K_{ssc} \geq \mathbf{12.5} \rightarrow \boldsymbol{ok}$

$K_{td}K_{ssc} \geq 0.4\frac{I_{sc,max,int}}{I_{pn}} \approx \mathbf{19} \rightarrow \boldsymbol{ok}$

$K_{td}K_{ssc} \geq 1.5\frac{I_{sc,max,ext}}{I_{pn}} \approx \mathbf{43} \rightarrow \boldsymbol{ok}$

8.4 Metering CT Adequacy Check

CT Type: 0.2Fs5 (IEC 61869-2)
CT Ratio: 1000/5 A, Icth=150%

Rated accuracy burden Sn: 60 VA

Energy Meter burden: 0.25VA (assumed the same value for PMU) = 0.01Ω

Cable lead run: L = 180m used

Cross-section: 6mm², return factor 2

The effective wire burden of a two-wire connection of CT and relay according to length, cross-section, copper resistivity and secondary nominal current:

$$R_L = R_{20} \times L \times [1 + \alpha(T - 20)]$$

RL = Lead wire resistance

R20 = CT lead resistance per unit length

L = total length of the CT lead wires

α = Temperature coefficient of Resistance of copper conductor at inferred absolute zero of temperature

α = 1/234.5 = 0.004

T = Final temperature of the wire (T=75oC)

CT lead resistance per unit length (6mm2) = 0,00308 Ω/m

Total CT Cable Resistance (Two Way) = RL = 0.665Ω

Total Burden = 0.68Ω, with safety margin of 25% = 0.84Ω

Burden VA (I^2R) = 21.10VA

The offered CT is suitable since the Total Burden is between 25%-100% of the CT burden.

8.5 Main Circuit Parameters Study – Short Circuit Current

Parameter		Unit	Eboli	Term. Imerese	Selargius
Short Circuit Level for Equipment Rating (network side)					
Three Phase Symmetrical Short Circuit Current	I_k''	kA	50/63[4)]	50/63[4)]	50/63[4)]
Network Damping	X/R	-	11-16	11-16	11-16
Max. Short Circuit Level					
Three Phase Symmetrical Short Circuit Current	I_k''	kA	32.2	22.3	14.7
Nominal Voltage	U_n	kV	380	380	380
Short Circuit Power	S_k''	MVA	21200	14700	9700
Network Damping	X/R	-	11-16	11-16	11-16
Min. Short Circuit Level					
Three Phase Symmetrical Short Circuit Current	I_k''	kA	16.3	7.6	5.6
Nominal Voltage	U_n	kV	380	380	380
Short Circuit Power	S_k''	MVA	10700	5000	3700
Network Damping	X/R	-	11-16	11-16	11-16

8.6 Technical data

Doc. Ref.:		**P-020235_EC_BC111_TL01_EEC010_00_Annex1**				**Project name: Thyrrhenianl Link**	
Doc. Title:		**Technical Data Sheet, AC Current Transformer (CT)**					
	English	**Converter Stations**			S1, S2, S3, S4	S1, S2, S3, S4	S1, S2, S3, S4
		Location designation			#TLxx-CA10-Q01-BC01 #TLxx-CA20-Q01-BC01	#TLxx-CA10-Q01-BC02 #TLxx-CA20-Q01-BC02	#TLxx-CA01-Q01-BC01 #TLxx-CA01-Q01-BC02
		Items		**Units**	TL01_M_01 -BC01	TL01_M_02 -BC02	TL01_M_03 -BC01, -BC02
		Modularisation Number	Basic Type				
			Type Description				
		Supplier	Offer number				
			Offer Item				
			Offer date				
1		**Main Data**					
1.2		Application			AC HV yard CTs	AC HV yard CTs	AC HV yard CTs
1.3		Type of device			inductive CT	inductive CT	inductive CT
1.4		Insulation Location according to Insulation Coordination			L	L	L
1.5		Installation location	(indoor / outdoor)		outdoor	outdoor	outdoor
1.6		Type of insulation	(oil / SF6 / epoxy resin, clean air)		SF6	SF6	SF6
1.7		Type of insulator	(composite/porcelain/ epoxy resin)		Composite – HTV with ATH >45%	Composite – HTV with ATH >45%	Composite – HTV with ATH >45%
1.8		Internal arc protection class IEC 61869-1, cl. 6.9	(class I or class II)		2	2	2
1.9		Surface treatment			Hot Dip Galvanizing	Hot Dip Galvanizing	Hot Dip Galvanizing
1.10		Special features				UTF certified	
2		**Electrical data**					
2.1		Rated primary voltage	(ph - ph)	kV	420	420	420
2.3		Rated frequency f_r		Hz	50	50	50
2.4		Rated short-time thermal current (I_{th})		kA	63	63	63
2.5		Short-time duration		s	1	1	1
		Power frequency withstand voltage		kVpeak	680	680	680
2.6		LIWV (Lightning impulse withstand voltage)		kVpeak	1550	1550	1550
2.7		SIWV (Switching impulse withstand voltage)		kVpeak	1175	1175	1175
2.8		Base voltage for creepage calculation (BVCC)	(ph - gnd)	kV	242,5	242,5	242,5
2.10		Reference Specific creeepage distance (RSCD)		mm/kV	43,3	43,3	43,3
2.11		Minimum creepage distance based on RSCD (to be updated considering SSCD adding the correction factors)		mm	10500	10500	10500
2.12		Requirements for AC Voltage Indoor/Outdoor Insulator Shed Profiles (as per IEC 60815-2/3)					
2.13		Creepage factor CF (l/s)	Porcelain (non-HTM)		NA	NA	NA
2.14			Composite / Hybrid (HTM)		<4,2	<4,2	<4,2

2.15		Max. RIV level at 1.1*Um / √3	(ph - gnd)	µV	2500	2500	2500
2.16		Rated primary current I_N		A	3200	3200	3200
2.17		Rated cont. thermal current factor		%	1,2	1,2	1,2
		1 h Emergency Rated thermal current factor		%	1,5	1,5	1,5
		Dynamic Rated current factor		%	2,5	2,5	2,5
2.18		Current to be measured		A	915	915	915
3		**Core data**					
3.1		**Core no.**		-	1	1	1
3.2		Core function		-	Connection Prot Sys 1	Energy Metering	Connection Prot Sys 1
3.3		Ratio		A/A	1000/1 ext. 150%	1000/5 ext. 150%	1000/1 ext. 150%
3.4		Rated burden		VA	-	60	-
3.5		Accuracy class			TPY, Kssc=15, Ktd>5, Rb=2 Ω	0.2Fs5	TPY, Kssc=15, Ktd>5, Rb=2 Ω
3.6		Isc short-circuit (duration)		kA (s)	63 (1s)	-	63 (1s)
3.9		**Core no.**			2	2	2
3.10		Core function		-	Connection Prot Sys 2	PMU	Connection Prot Sys 2
3.11		Ratio		A/A	1000/1 ext. 150%	1000/5 ext. 150%	1000/1 ext. 150%
3.12		Rated burden		VA	-	60	-
3.13		Accuracy class			TPY, Kssc=15, Ktd>5, Rb=2 Ω	0.2Fs5	TPY, Kssc=15, Ktd>5, Rb=2 Ω
3.14		Isc short-circuit (duration)		kA (s)	63 (1s)	-	63 (1s)
3.17		**Core no.**			3	-	-
3.18		Core function			AC Cable Prot Sys 2	-	-
3.19		Ratio		A/A	3200-1600-1000/1A, Icth=150%	-	-
3.20		Rated burden		VA	10	-	-
3.21		Accuracy class			5PR60	-	-
3.22		Isc short-circuit (duration)		kA (s)	63 (1s)	-	-
3.25		**Core no.**			4	-	-
3.26		Core function			AC Cable Prot Sys 1	-	-
3.27		Ratio		A/A	3200-1600-1000/1A, Icth=150%	-	-
3.28		Rated burden		VA	10	-	-
3.29		Accuracy class			5PR60	-	-
3.30		Isc short-circuit (duration)		kA (s)	63 (1s)	-	-
4		**Mechanical data**					
4.1		Terminal forces, static		kN	1330	1330	1330
4.2		Terminal forces, dynamic		kN	3000	3000	3000
4.3		On-site testing of the gas-density meter without deinstallation (e.g.WIKA Valve Testing Device)			Yes	Yes	Yes
4.4		Seismic Qualification Factor			AF5	AF5	AF5
5		**Project related data**					
5.1		Minimum ambient temperature		°C	-25	-25	-25
5.2		Maximum ambient temperature		°C	+50	+50	+50
5.3		Solar radiation		W/m²	1000	1000	1000

9 List of References

Ref. No.	Document No.	Title
[R01]	PIFR20100C17535	General Data
[R02]	PIFR20100C12520	Transient Stresses & Insulation Coordination
[R03]	INS AA S 01	Trasformatori di corrente ad alta tensione ad affidabilità incrementata
[R04]	PT500ST	Prescrizioni tecniche per la verifica della conformità dei prodotti approvvig
[R05]	PRHM0220 15.10.2021	Dimensionamento degli isolatori e degli spazi in aria delle stazioni di conversione
[R06]	PRHM0050_00	Converter Stations - Factory Tests, On-Site Tests and Trial Operation
[R07]	tbd	SIPROTEC 5 Distance Protection, Line Differential Protection, and Breaker
[R08]	tbd	Line differential protection RED670 Version 2.2 IEC Application manual, Relion 670
[R09]	tbd	SIPROTEC 5 Transformer Differential Protection, 7UT82, 7UT85, 7UT86,
[R10]	P-020235_EC_30110#TL01&EED010 PIFR20100C12515	Main Circuit Parameters Study Converter Station

Table 6 - List of References