ANNEX A | TECHNICAL SPECIFICATIONS FOR THE COMPONENTS OF THREE-PHASE ILICETO SHIELD WIRE SCHEMES USING THE EARTH AS THE CONDUCTOR OF ONE PHASE

CONTENTS

A.1 INTRODUCTION

These technical specifications are applicable to the components of the two-SW three-phase Iliceto shield wire schemes (ISWSs) that use the earth as a phase conductor. The specifications are written for the rated voltage of 34.5 kV; however, they can be applied with minor adjustments for lower rated voltages, in particular for 30 kV with the lower test voltages of equipment specified in the technical data sheets (see Annex B).

Concerning the prospective three-shield wire (SW) three-phase SWSs described in chapter 14 of the manual, most of the components are three-phase standard apparatuses applied in conventional medium-voltage (MV) distribution networks of the same rated voltage. However, the following special components must be included: a three-phase fast automatically-closing grounding switch and power factor correction capacitors. The capacitor bank is to be specified three-phase, symmetrical, star connected with neutral solidly grounded, and continuously in service. Other characteristics of these two components are as specified in the manual for the two-SW three-phase ISWS and three-SW three-phase SWS.

The technical specifications in this Annex for the medium-voltage/low-voltage distribution transformers and for the MV/MV interposing transformers or tertiary winding of high-voltage/medium voltage step-down transformers, are also applicable for three-SW three-phase SWSs.

A.2 ENVIRONMENTAL DATA

The following table summarizes the climatic information to be used for the design of the equipment.

	UNIT	VALUE
Maximum ambient temperature	°C	
Minimum ambient temperature	°C	
Mean maximum daily temperature	°C	
Mean minimum daily temperature	°C	
Annual average temperature	°C	
Maximum solar radiation (worst case)	W/m²	
Average number of stormy days per year		
Altitude	m	
Maximum wind - Height above ground 0–30 m - Height above ground 30–50 m	 m/s m/s	
Relative humidity, average	% rel.	
Average rainfall annually	mm/year	

A.3 GROUNDING RESISTOR-REACTOR

Detailed characteristics of the grounding resistor-reactor are specified in table B.4 in Annex B. Supplementary requirements and clarifications are provided below.

The resistor shall be fabricated with special stainless steel: steel-chrome-aluminum with low increase of resistance versus temperature. The elements should be expanded mesh; however, edge-wound coils may also be accepted, subject to written approval by the employer/engineer.

If the proposed form of elements has built-in non-negligible inductance (edge-wound coils), the total reactance shall be calculated and deducted from the specified reactance of the reactor in series with the resistor, such as to obtain the specified impedance $Z = R + jX$. If the specified reactance is nil, the use of expanded mesh elements will be mandatory.

The tenderers shall state in the bids the proposed type of special stainless steel, the form of the elements, and their inherent inductance, if any.

The resistor will be housed in a steel kiosk (minimum wall thickness 2 mm). The kiosk shall be hot-dip galvanized, or stainless steel. The kiosk shall be provided with adequate openings in the bottom and sides, to allow abundant air flow for natural cooling (use of fans is not permitted). The housing will be designed such as to prevent water inlet.

The series reactor, where required in series with the resistor, should preferably be of air core type. If an indoor reactor is proposed, it may be housed in a section of the kiosk adjacent to the section housing the resistor. If an air-core outdoor reactor is proposed, it will be supported by an independent structure with minimum height of 2.25 m. Insulation of the reactor (cast resin or conventional insulation of winding wire) shall be suitable for the conditions of operation inside the kiosk (temperature, humidity, etc.) or outside, according to the proposed type.

The reactor and resistor shall be connected in series, as shown in figure 7.1, panels a and b.

If the reactor is installed externally to the kiosk housing the resistor, the connection between the reactor and resistor can be made with an insulated cable.

One terminal of the resistor shall be connected to the grounding system of the substation where it is installed via a current transformer (see table B.4 in Annex B).

One terminal of the reactor shall be connected to one of the 34.5 kV terminals of the interposing transformer, by means of an insulated cable or via an overhead bare aluminum pipe.

The roof of the kiosk shall be shaped such as to prevent water stagnation.

The openings in the bottom for cooling air inlet shall be small (or shall be protected by mesh) so as to prevent insects from entering the kiosk.

Insulators inside the kiosk shall be made of porcelain or alumina (resin insulators are not accepted).

The resistor shall be responsive to IEEE standards 32 of 1972, unless otherwise specified. The reactor shall be responsive to IEC standards 60076-6 of 2008, unless otherwise specified.

Protection of enclosure IP23 (to IEC Publ. 529) is deemed sufficient for outdoor installation.

The total mass of the active resistor elements and maximum temperature reached in normal operation, and after circulation of the specified short circuit current for 3 s, shall be informed in the bids.

A.4 FAST-CLOSING GROUNDING SWITCHES

The switches must be bipolar outdoor type, for installation in a tropical environment. The switches are required for fast grounding (no more than 200 ms) of the shield wire line, by using the energy stored in the springs, to be loaded by an electrical motor during the opening maneuver. A sturdy mechanical construction is required, suitable for frequent maneuvering in operation.

Bidders shall describe in detail the offered equipment and inform previous similar applications for reliable fast grounding.

A.5 CAPACITORS

The capacitors shall be in conformity with IEC standards 60871 Part 1-2, 1997 edition (Shunt Capacitors for A.C. Power Systems Having a Rated Voltage above 1000V), unless otherwise specified.

Standard MV p.f. correction capacitor units are appropriate, with the following special requirements (that are included in table B.18 in Annex B).

- The insulation level and test voltages are higher than required by the IEC standards, owing to the special application. The capacitor units have a rated voltage of 24 kVrms and associated test voltages (51,6 kVrms at 50 Hz; 125 kV with 1.2/50 μs atmospheric impulse). However, the capacitors are normally operated de-rated at 34.5/2 = 17.25 kV, so that, if one unit fails, the other series-connected unit can be operated temporarily over-rated at 34.5 kVrms.
- External fuses are not accepted. Fully un-fused capacitors, or capacitors with internal fuses, are acceptable.
- A routine acceptance test of the capacitor units shall be performed at AC-50 Hz, with applied voltage of 51.6 kVrms for 10 s. The DC routine test shall not be accepted.

Insulation of the capacitor elements is the standard all-polyethylene film, impregnated with non-PCB biodegradable synthetic oil.

Bushings of the capacitor units and support insulators of the capacitor units shall be made of porcelain.

Typical installation drawings of capacitor banks are shown in figures C.1a and C.1b in Annex C and in photos of the installation (in Annex D).

A.6 LOAD-BREAK SWITCHES AND FUSED CUT-OUTS

Installation of a load-break switch or fused cut-outs is to be made in the take-off structures from the HV line (see figure C.2 in Annex C). Fused cut-outs will be installed in all the pole-mounted and ground-mounted MV/LV transformer stations.

This equipment is the same as used in normal 34.5 kV distribution systems; however, it is bipolar and the phase-to-ground insulation levels shall be somewhat higher than usually specified for the 36 kV equipment, as specified in table 5.2 (chapter 5).

The insulation across open contacts of load-break switches and fused cut-outs shall be the same as for normal 36 kV equipment.

A.7 PROTECTION RELAYS AND CONTROL PANEL

The interposing transformers (ITs) that may have to be installed in some substations shall be protected by the protection relays available in the existing MV metal clad supply switchgears, to be properly checked, set, and, if necessary, supplemented. Protection will include as a minimum: an instantaneous overcurrent relay, a definite time delay overcurrent relay, and a Buchholz relay.

As shown in the typical single-line diagram of the ISWS bay (see figure 7.1, panel b), there will be no circuit breaker (CB) between the secondary winding of the IT and the SWL. The IT and SWL will be switched on and off and protected, as one block, by the CB on the MV primary side of the IT.

The protection relays of the SWL will be supplied by the two CTs to be installed in the new bay of the 34.5 kV SWL. Protection of the SWL will consist of:

- An instantaneous overcurrent relay.
- An inverse time delay overcurrent relay, with choice of various current-time curves.
- A current unbalance relay, sensing the percentage difference of the current flow on the two insulated shield wires. This relay will be set to trip with time delay (adjustable up to 10 s) if the current imbalance exceeds a certain value (adjustable from 20% to 50%). This protection is aimed at sensing high resistance to ground faults not detected by the overcurrent protection. It can be realized by means of a relay sensitive to the percentage negative sequence current, of the type used to protect the generators.
- Automatic high speed (0.5 to 2 s delay) and slow speed (15 to 180 s delay) three-phase re-closures (two-wire SWL re-closure) with a four-position pre-selector (re-closure excluded; high-speed single shot; low-speed single shot; high + low speed).

Overcurrent relays in existence in the MV supply bay may be used for protecting the SWL if their characteristics are suitable.

The overcurrent relay shall be a digital type, with capacity to record the pick-up currents and measure the actual currents.

Metering of the SWL will include:

- Voltages, currents, and active and reactive power on the primary side of IT (generally available in the MV supply switchgear)
- Voltage and currents on the 34.5 kV outgoing SWL.

Voltage on SWL side will be measured between the two insulated phases only. Currents on the SWL side will be measured in the two insulated wires and in the ground connection of the reactor-resistor (three-phase measurement).

The contractor shall design, manufacture, test, and transport a control panel for each SWL, to be housed in the space available in the control rooms of the substations. The panel will conform as far as possible in dimensions, design, color, and functionality with the line control panels in existence in the control rooms. The panel shall house the protection relays, auto-re-closing apparatuses, and auxiliary relays; the metering instruments, transducers, control circuits, and interlockings; and the mimic diagram of the SWL with command of the MV supply CB of the IT and of 34.5 kV grounding switch, alarm panel, and other devices and functions to conform with the standards applied for other MV and HV lines.

A.8 34.5 KV T-OFF SLACK SPANS FROM TYPICAL 132 KV DOUBLE-CIRCUIT AND 230 KV SINGLE-CIRCUIT LINES

Typical down lead arrangements are shown in figure C.3 in Annex C.

The T-off structure may be a lattice steel galvanized structure, as shown in figure C.2 in Annex C. Alternatively, the contractor may propose the use of a galvanized steel pole of adequate strength and same height aboveground (12 m), or a gantry consisting of two concrete or wooden poles with steel brackets, of the same height aboveground and adequate mechanical strength. A single concrete pole could also be used, if available with adequate height and strength.

The following equipment shall be installed on the T-off structure:

- N° 4 tension glass insulator rigid strings (see figure 5.1 in chapter 5, and figures C.9a and C9b in Annex C) or conventional strings formed by four cap-and-pin glass insulators (diameter = 254 mm; spacing = 127 mm)
- N° 1 2-pole load break switch provided with fuses, with manual operating mechanism (with an insulated handle at 1.5 m above ground level), if the spur MV line is long
- Alternatively to the previous bullet, if the spur line is short, N° 2 one-pole fused cut-outs with fuse holders and fuse links of specified current rating (figure C4 in Annex C)
- Where specified, power factor correction, balancing, anti-ferroresonance capacitors shall also be supported by the T-off structure (see section A.5 in Appendix A and Table B.18 in Appendix B)
- N° 2 post-type porcelain insulators for insulation and support of connecting conductors (see Figure C.2 in Annex C); not required if a two-pole concrete gantry structure is proposed
- Grounding leads and grounding rod as specified for the 34.5 kV poles (see section A.10), with a buried counterpoise connection to the grounding system of the HV tower

Surge arresters are not required at T-offs, except in the T-offs where the capacitor banks are installed.

The technical characteristics of the load-break switches and fused cut-outs are provided in tables B16 and B17 in Annex B.

If the total length of 34.5 kV lateral line does not exceed 2 km, the load break switch is not required, because energization and de-energization of the lateral line can be performed by the fused cut-outs after disconnection of all the MV/LV distribution transformers supplied by the spur line, by means of the relevant fused cut-out(s).

If the 34.5 kV spur line is very short (say, no longer than 250 m) and supplies only one MV/LV transformer, it is sufficient to install a fused cut-out in the Tee-off structure, to be used for protection of the lateral line and transformer, and for energization/de-energization of the lateral line and transformer after opening the fuse-switches on the LV side of transformer.

A.9 EARTHING SYSTEMS FOR GROUND RETURN OF CURRENT AND LV NETWORKS

A9.1 Earthing System in the HV Supply Substations of the ISWSs

In the HV supply substations, the existing earthing system is generally considered to be satisfactory. In fact, by assuming a ground resistance of 1 Ω and SWL(s) loaded at about 5 MVA, the step and touch voltages are expected to be very small, generally lower than 10 Vrms, and of no concern. Thermal stability will not pose problems.

Measurements of step and touch voltages and potential to remote earth will be performed in the dry season after commissioning of the ISWSs (see Annex E).

A.9.2 Villages

In the villages, the basic grounding principle is multiple grounding. The general arrangement is shown in figure 3.2 in section 3.2 of the manual. The concept is to connect in parallel the grounding rods of the MV/LV transformer station (see figures C.5a, C.5b, and C.5c in Annex C), with one or some other grounding rod(s) via the ground conductor installed underneath the 34.5 kV conductors in the spur lines. In particular, if the spur MV line is short, the paralleling shall be made with the grounding system of take-off HV tower connected with a galvanized steel counterpoise to the grounding rod of T-off structure (see figure 3.2 in chapter 3), and with the grounding rods at every third pole of the 34.5 kV spur line and 34.5 kV reticulation lines in the villages, if any. The following conditions shall be separately fulfilled by the above-described multiple grounding systems in the dry season:

a) The potential to remote earth shall not exceed 30 Vrms with the actual peak loads.

b) The ground resistance shall not exceed the value specified in subsection 3.2.2 (in chapter 3 of the manual) for each grounding system according to the intensity of the earth-return current to be injected.

c) Special attention shall be given to the grounding system where the shunt capacitors are installed, because an important current is injected continuously in the grounding system.

When the lateral line is longer than 600 to 700 m, only a stretch of about 600 m adjacent to the first MV/LV transformer station of the village and the 34.5 kV lines supplying other transformers in the village, if any, should be equipped with the third ground conductor, to be grounded at every second or third pole (see section A.10). The rest of the spur lines shall be equipped with only two wires, insulated for operation at 34.5 kV phase-to-Gr. Each of the resulting multiple earthing systems shall comply with requirements a) and b) above.

If the soil resistivity is very high, lowering of resistance at villages to the specified values (items a) and b) above) can be achieved in a simple and economical manner by installing some additional grounding rods in selected close-by places where soil has low resistivity, if available (in proximity of rivers or creeks, or fountains; in marshy land; in cultivated land where fertilizers are used; etc.). It should not be overlooked that a grounding rod in soil with resistivity of 50 or 100 Ωm has a ground resistance 20 times smaller than the same rod in soil with resistivity of 1,000 or 2,000 Ωm, respectively.

A.9.3 Neutral of LV Networks

The neutral of LV networks shall not be grounded at the supply MV/LV transformer station. An independent multiple grounding will be realized with grounding rods at some poles along the LV lines. The induced potential on the neutral of LV networks should be less than 5% of the measured value of potential to remote earth of the MV grounding system used for earth return of current. Separation by one LV span is usually sufficient.

A.10 EARTHING OF CONCRETE POLES OF 34.5 kV SPUR LINES

Where three wires are applied (spur lines with 2 MV insulated wires and one ground wire), the ground wire will be earthed at about every third pole. Earthing rods can be of galvanized steel rods (minimum 600 gr of zinc per sqm) with diameter ≥ 18 mm and minimum length of 3 m.

The earthing leads on poles can be copper clad conductors of adequate cross-section, protected against contacts and mechanical damage up to 2.7 m aboveground by a sturdy plastic pipe. A removable bolted link may be provided at 2.7 m above ground level, to enable the earthing rod separation for measurement of earth resistance.

The ground wire shall be supported on one side of the poles underneath the 34.5 kV energized wires (see figure C.6a, C.6b, and C6c in Annex C), by means of a shackle-type glass or porcelain insulator (insulation class 1 kV). This provision is aimed at avoiding the use of concrete or steel poles as earth conductors.

Steel stays of poles shall be insulated at a height of at least 3 m above ground level by means of a reel-type porcelain insulator.

A.11 DISTRIBUTION TRANSFORMERS

A.11.1 General Information

This part of the specifications covers the design, manufacture, factory testing, delivery, and transport to the site of installation, if required by the employer.

The latest issues of Recommendations of the International Electrotechnical Commission (IEC standards), in particular IEC 60, IEC 71, IEC 60076, IEC 137, IEC 214, IEC 296, IEC 354, IEC 542, IEC 551, IEC 567, IEC 60599, IEC 722, and IEC 815, shall apply. Supplementary standards are the German standards DIN and VDE, the British standards BS or their subsequent EURONORMs, the American standards, or specific national standards in the above-mentioned sequence, if there are no relevant IEC standards existing or if explicitly asked for in these tender documents.

Moreover, the tender shall include typical dimensional and sectional drawings of the transformers and accessories, such as the off-load tap changers, bushings, cable boxes, control cabinet, etc.

As far as practicable, equipment for all the transformers to be delivered under this part of the specifications, such as insulation oil, bushings, accessories, etc. shall be compatible and interchangeable with each other (subject to approval), so that operation, maintenance, and replacements are as simple as possible for the employer.

Each item necessary for proper completion of the work, whether especially specified in the tender documents or not, is to be included in the tender price.

A.11.2 General Design Conditions and Data

The design of the transformers shall be based on the following conditions and requirements:

- The design shall be based on site and service conditions as specified herein.
- The transformers shall be capable of operating continuously at any tap position within their specified temperature rise limits.
- The transformers shall be capable of withstanding the electrodynamic forces caused by external short circuits. The thermal duty shall be at least 3 seconds after all loading conditions as specified in IEC 354.
- Neutral points shall be brought out and shall be solidly grounded.

All specific technical data are stipulated in the technical data sheets. The transformers shall be designed and tendered in full compliance with all further applicable sections, articles, and drawings of these specifications.

A.11.3 Windings

Electrolytic copper of a high conductivity (class A, in accordance with IEC) and insulation material of high quality shall be used. The insulation material of the windings and connections shall be free from insulation compositions subject to softening, shrinking, or collapsing during service. Moreover, none of the material used shall disintegrate, carbonize, or become brittle under the action of hot oil, under all load conditions.

The coils must be capable of withstanding movement and distortion caused by all operating conditions as specified in IEC 354. Adequate barriers shall be provided between the windings and the core as well as between high-voltage and low-voltage windings.

LV windings shall be designed for at least LI: 20 kV/AC: 8 kV.

All leads or bars from the windings to the terminal boxes and bushings shall be rigidly supported. Stresses on coils and connections must be avoided.

A.11.4 Magnetic Core

The magnetic core shall be made of laminations of non-ageing, cold-rolled, grain-oriented, silicon steel of high permeability without burrs. Each lamination shall be insulated with high-quality insulation coating. The core and its clamping plates shall form a rigid unit structure, which shall maintain its form and position under the severe stresses encountered during shipment, installation, and short circuits.

Care shall be taken to secure uniformly distributed mechanical pressure over all the laminations to prevent setting the core and to limit noise and vibrations to a minimum under service conditions.

The maximum magnetic flux density in the legs and yokes of the core shall not exceed 1.65 Tesla at rated voltage and frequency in mean tap position.

A.11.5 Transformer Tank

The transformer tank shall be of the upper flange type with **bolted cover** and shall be preferably equipped with corrugated sheet steel–type radiators incorporated with the tank. Cooling fins shall be welded, if appropriate, with round stiffening rods to prevent vibration during operation of the transformers.

Only hermetically sealed tanks completely filled with oil shall be provided. Transformer tanks filled with nitrogen above the oil level are not acceptable. A suitable gauge for checking the oil level shall be provided for each transformer.

Gaskets shall be oil resistant and made of such a material that no serious deterioration will occur under service conditions. Rubber gaskets used for flange connections of the various oil compartments shall be laid in grooves. Gaskets of such material, which can be easily damaged by over-pressing (for example, any kind of impregnated/bonded cork), are not acceptable.

Lifting lugs shall be provided on the cover as well as rigid traverses under the bottom as a mounting base. Bi-directional wheels with blocking facilities shall be provided for the ground-mounted station supply transformers. Distribution transformers other than the station supply transformers shall be equipped with appropriate pole-mounting facilities of an approved design. The pole-mounting facilities to be delivered with the transformers shall be complete in every respect and shall be properly coordinated for each transformer type with the manufacturers of the pole and crossarms.

Two earthing terminals of adequate size shall be provided and installed diagonally at the bottom of the transformer tank.

A.11.6 Cooling

The transformers shall be provided with a self-cooled type of cooling system (ONAN).

A.11.7 Terminals

A.11.7.1 Bushings

Bushings shall be of the outdoor type, designed for areas with a heavily polluted atmosphere. They shall also correspond to IEC 137, shall be free from defects, and shall be thoroughly vitrified. Insulators shall be of top quality electrical grade porcelain, homogenous and non-porous, and in one piece. The glaze shall not be depended upon for insulation and shall be of a uniform shade of brown, completely covering all exposed parts of the insulator. The bushings shall be arranged on the tank cover. Uncovered HV bushings shall be equipped with adjustable removable protective gaps.

The clearances in air between live parts of the bushings and against the ground shall be not lower than specified in IEC 60076-3-1. This is applicable for all outdoor arranged bushings.

A.11.7.2 Terminal Boxes

If specified in the technical data sheets, air-filled cable connecting boxes of protection class IP55 equipped with outdoor bushings, suitable for connections of cables with outdoor sealing ends up to Um = 36 kV, shall contain the winding ends and the neutral. The bushings for the station supply transformers shall also be equipped with rigidly fixed solid gas stoppers (subject to approval).

This box, if required, shall also contain internal busbars connected to the bushings to which the corresponding connecting cables for the switchgear will be attached. The cable terminal boxes, if required, shall also be equipped with metal cable glands and shall accommodate the cable sealing ends. Suitable grounding studs with cadmium plated bolts and washers for earthing of the cable sheaths shall also be provided.

The level and design of the insulation shall comply with that of the related bushings. In case of reduced clearances and insulation barriers being provided for the HV terminals, the HV windings are subject to full wave lightning impulse tests with positive as type tests under witness of the employer and/or engineer.

A suitable hand-hole for checking the oil tightness of the bushings shall be provided in the boxes at an easily accessible location. Ingress of dust and other foreign substances, and formation of condensate in the cable boxes must be prevented by a silicagel breather connected to the cable box. The containers for the dehydrating agent and the oil trap shall not be of transparent plastics. The silicagel shall be blue colored when dry, pink colored when wet.

Connecting boxes are not required for the distribution transformers to be used in the 34.5 kV Iliceto shield wire schemes.

MV/LV distribution transformers with rated power up to 800 kVA shall be without terminal boxes.

A.11.8 Off-Circuit Tap Changers

Manually operated off-circuit tap changers shall be supplied for the distribution transformers, and shall be capable of withstanding voltage surges and 180% continuous loading without damage or excessive heating, and short circuits without injury.

The selector switch shall be operated with the transformer de-energized by a handle located on the transformer cover.

Position "1" of the tap-changer is related to the maximum high voltage.

A.11.9 Transformer Oil

The transformers shall be supplied and shipped with their initial oil filling. The insulation oil shall be pure uninhibited naphtenic-based mineral oil free from additives and shall be acid-refined with properties complying with IEC 296, class II.

The contractor is held responsible to prove the dryness and all other properties of the oil before utilization.

A.11.10 Piping and Valves

The piping required for the connection/filling of the various parts of the transformers as well as the valves required for oil draining/sampling, filling, venting, etc. are to be included.

Station supply transformers shall also be equipped with drain and filter valves with adapters of R1½″ male thread fitted with cap.

A.11.11 Measuring and Monitoring Equipment

A combined protection device for monitoring of functions as specified below shall be provided for **transformers above 1,000 kVA and below 2.5 MVA**:

- Dial-type thermometer for oil temperature with adjustable alarm and trip contacts
- Monitoring device for oil leakage and gas formation with trip contact
- Monitoring device for sudden pressure with trip contact
- Oil level gauge.

A suitable terminal box (protection class IP55) for connection of measuring and monitoring devices shall be attached to the transformer tank.

The wiring and cabling shall be of stranded copper and shall be furnished with slip-over ferrules at both ends. The wiring shall also have crimped termination. The minimum cross-section of the wiring shall be 2.5 mm^2. Termination of two conductors at one terminal point shall be made by suitable bridges and links of the terminal.

All the cables that connect the monitoring equipment, as specified previously, to the terminal boxes, shall be steel armored or laid in flexible conduit steel pipes and shall be rigidly fastened to the tank by non-corrosive metal ties or clamps.

All wiring to alarm and trip devices shall include an insulated separate protection earth conductor ("green/yellow" colored) of at least the same cross-section as the line conductor. Suitable grounding conductors shall be provided between the terminal box and related cover. Insulated grounding conductors shall be "green/yellow" colored.

A.11.12 Name Plates and Other Designation Plates

Plates made of corrosion-proof material rigidly supported shall be supplied as specified herein. Outdoor arranged plates shall be of polished stainless steel of top quality only (background clear, engraving black, depth of engraving 0.5 mm). Plates arranged inside the marshalling box, if any, may be of material in accordance with the manufacturer's standard, for example, fiberglass reinforced synthetic resin (subject to approval).

- A rating plate according to IEC 60076.
- A diagram plate showing in an approved manner the internal connections and the voltage vector relationship of the several windings in accordance with IEC 76 and, in addition, a plan view of the transformer giving the correct physical relationship of the terminals.
- For the station supply transformers, a plate showing measuring and monitoring circuits and terminal blocks. This plate shall be located inside the terminal box.

A.11.13 Drawings and Documents

Where applicable, the following drawings and documents shall be submitted for approval as a minimum requirement:

- Technical data sheets
- Painting procedure
- Specification of the insulation oil
- Outline drawing with parts list
- Circuit diagram for auxiliary wiring
- Rating plate and connection diagram
- Termination boxes

- Bushings
- Factory test procedure
- Factory test report (submitted after witness tests)
- Operation and maintenance manual.

A.11.14 Inspections and Tests

The transformers shall be subject to acceptance tests to be performed at the contractor's premises to verify their conformity with the guaranteed and other design data.

The tests shall be performed in accordance with the latest issues of the Recommendations of the International Electrotechnical Commission (IEC-standards), in particular IEC60076, supplemented by these specifications.

The contractor is obliged to submit a detailed test program for approval in due time, prior to the tests (at the latest two months before testing). A detailed time schedule showing exactly when the tests will be carried out (maximum 12 hours per working day) shall be submitted along with the test program above.

The following tests shall be performed in the presence of the employer/engineer in a number of units of each type of transformer as required by the employer/engineer:

- Measurement of voltage ratio at all tap positions
- Check of vector group by voltmeter method
- Measurement of winding resistance at all tap positions
- Measurement of impedance voltage at principal tap and extremes
- Measurement of no-load losses
- Measurement of load losses at principal tap and extremes
- Measurement of insulation resistance (R15, R60, R180,) at 2,500 V, DC
- Induced overvoltage withstand test
- Separate source overvoltage withstand test
- Applied overvoltage test at 2,000 V, AC on auxiliary wiring (if any)
- Short circuit test.

For duplicate units, test reports of tests to be performed as specified above shall be submitted.

A.11.15 Painting

A.11.15.1 General

Due to the unfavorable atmospheric conditions, particular attention should be given to the protection of all ironwork. The methods proposed and the means adopted should be fully described in the tender proposal.

All surfaces shall be thoroughly cleaned of rust, scale, grease and dirt, and other foreign matter and all imperfections shall be removed by means of approved methods.

The following treatments shall be applied:

A.11.15.2 External Surfaces

All steel surfaces shall be sand-blasted in accordance with DIN 55928 Part 4 (equivalent to SIS 055900), and shall then be painted in the following sequence:

COAT	KIND	LAYER THICKNESS
One (1) primer coat	Two-component epoxy zinc-phosphate	60 µm
One (1) intermediate coat	Two-component epoxy micaceous iron oxide	60 µm
One (1) top coat	Two-component polyurethane	40 µm
Total coating thickness (dry-film)		160 µm

The final coat of painting shall be of pore-free and homogeneous quality and shall be a uniform shade of code RAL 7032 (silica-grey).

In case of ordinary stainless steel or aluminum, one primer coat may be omitted.

If any hot-dip galvanized steel parts will be provided, the same painting method shall be applied; however, instead of two primer coats, one adhesive coat and one base coat shall be applied. In this case, the mean thickness of galvanizing shall be 70 µm.

Mechanical damage shall be repaired at the site with the original paint as above.

A.11.15.3 Internal Surfaces (Not Required for MV/LV Distribution Transformers)

Inside the transformer/reactor vessel, sand-blasting shall be performed in accordance with DIN 55928 Part 4, (equivalent to SIS 055900). After that, an oil-resistant insulating coating shall be applied to all steel surfaces in contact with the oil (for example, the tank, cover, core steel plates, etc.).

The minimum dry film thickness shall be 35 µm (color code RAL 9010 white or equivalent).

A.11.16 Capitalization of Losses

When evaluating the individual tenders received from the various bidders, the transformer losses will be capitalized as follows, unless otherwise specified elsewhere in the bidding documents:

No-load losses	$5,000.00 per kW
Load losses	$3,000.00 per kW

The auxiliary power losses (if any) will be added to the load losses.

Transformers with guaranteed losses exceeding the specified values will not be considered for the award of contract.

A.11.16.1 Guaranteed Values and Penalties

The guaranteed values tendered by the contractor in the technical data sheets will be strictly observed by the contractor and the employer.

For the guarantee data not mentioned herein, tolerances in accordance with IEC60076 shall apply.

A.11.16.2 Losses

- If the no-load losses of distribution transformers exceed the guaranteed value, the sum of the no-load losses in excess of all ordered distribution transformers of this type will be considered and an amount of **$5,000.00** for each full kW in excess will be deducted from the contract price.
- If the load losses of distribution transformers exceed the guaranteed value, the sum of the load losses in excess of all ordered distribution transformers of this type will be considered and an amount of **$3,000.00** for each full kW in excess will be deducted from the contract price.
- It is thereby understood that values of 0.5 kW and above will be rounded up to the next full kW.

A.11.16.3 Rated Power

If the test of temperature rise carried out on any transformer should reveal that the temperature rise of the transformer exceeds the values guaranteed, the rated power of the transformer will have to be down-rated to such a degree as to obtain the temperature rise guaranteed.

For each **kVA** of the actual transformer rating below the guaranteed output, an amount of **$200.00** will be deducted from the contract price of this transformer and all those transformers of the same design unless the contractor, at his own expense, modifies the transformers and gives evidence that those transformers fulfill the guaranteed values.

A.11.16.4 Noise Level

Should the noise level measured at the specified distance exceed the required values for power transformers the employer will penalize the excess at a rate of 1% of the price of the transformers per dB(A). It is hereby is understood that values of 0.5 dB(A) and above will be rounded up to the next full dB(A).

A.11.17 Rejection

The employer shall have the right to reject any transformer if the actual values are in excess of the guaranteed values by more than the margins specified hereunder (including the tolerances).

No-load losses	+15%
Load losses	+15%
Total losses	+15%
Temperature rise	0%
Noise level	+3 dB(A)
Rated power	–5%

For all of the other values, the margins stated in the IEC standards are applicable.

A.11.18 Special Requirements for the 34.5/0.4 kV Distribution Transformers of ISWSs

The general characteristics specified in the previous paragraph of this section for conventional distribution transformers are applicable, unless otherwise specified herein and/or in tables B.9 to B.15 in Annex B. These "Technical Data Sheets" shall therefore prevail in case of conflict with the previous paragraphs of this section and/or with the IEC standards.

It should be noted that the shield wire lines energized at 34.5 kVrms phase-to-ground require somewhat increased insulation levels of the MV/LV transformers (50 Hz-60 s of 82.5 kVrms and lightning impulse of 200 kV peak, instead of 70 kVrms and 170 kV peak of conventional 33 kV equipment, respectively).

The 34.5 kV and 0.4 kV bushings shall be made of brown porcelain. The arcing horns on 34.5 kV bushings shall have adjustable distance and shall be removable.

Distribution transformers shall be hermetically sealed for life. Only this alternative is therefore to be considered for bidding in tables B.9 to B.15 of the Technical Data Sheets (Annex B).

The engineer's and/or employer's inspectors shall witness the routine tests of all the transformers of the ISWS, or part of each lot selected by the inspector at the time of the factory acceptance tests.

The following types of tests will be performed in one unit of each type of transformers to be delivered for the ISWS, and will be witnessed by the engineer's and/or employer's inspector:

- Temperature rise test
- Measurement of acoustic noise level
- Lightning impulse test.

At the discretion of the engineer/employer, a short circuit type test shall be performed in one unit or a few units at the time of acceptance, to prove the transformers withstand capacity to the short circuit electrodynamic forces. The test shall be performed in accordance with IEC standards 60076-5 (last edition) in a laboratory of internationally recognized reputation. The units to be tested shall be selected by the engineer/employer.

A separate price shall be quoted only for the short circuit–type test. The price shall not be paid if the test is waived.

A.11.19 Transport

All the distribution transformers to be used in the 34.5kV Iliceto shield wire schemes shall be shipped filled with oil, with all the accessories fitted in the transformers.

A.12 34.5/0.4-0.231 KV AND 30/0.4 – 0.231 TRANSFORMER STATIONS

A.12.1 Pole-Mounted Transformers

The pole-mounted three-phase transformer stations should be built in accordance with the design in figure C.5a (dead-end station) and figure C.5b (intermediate station) in Annex C.

The gantry structure will be realized by means of two 11 m concrete poles or equivalent wooden poles of the type in general use in the 34.5 kV (or 30 kV) lines, and with galvanized steel brackets. A stay may be applied in the dead-end stations.

The standard design shall allow installation of three-phase transformers rated up to 400 kVA.

Protection against overvoltages of the three-phase transformers with rated power ≥ 200 kVA and single-phase transformers with rated power ≥ 100 kVA shall be ensured by two and one MOV surge arrester(s) (SA(s)), respectively. Three-phase transformers with rated power < 200 kVA and single-phase transformers with rated power < 100 kVA will be protected only by arcing horns. The distance between the arcing horns will be set at 145 mm and 125 mm for the 34.5 kV and 30 kV transformers, respectively. Where SAs are installed, the arcing horns will be removed or distance will be increased so as to avoid interference with the operation of the SAs.

Switching of transformers and protection of transformers against short circuits will be performed by fused cut-outs. Rated current of K-type fuse links shall be 3A, 5A, 10A, and 15A for three-phase 34.5 kV and 30 kV transformers rated at 50, 100, 200, 315, and 400 kVA, respectively. A check will be made with the manufacturer to ensure that the fuse links are not melted by the transformer inrush currents.

The minimum air clearance between live parts, phase-to-ground and phase-to-phase, shall be 50 cm.

The grounding leads along the poles shall be copperweld wire AWG7. All structural metal parts shall be bonded and effectively grounded. One of the 34.5 kV terminals of the transformer will be connected to the incoming ground conductor and connected to the grounding lead. An independent lead shall be used to connect the SAs to the buried grounding system.

It is mandatory to connect to the grounding system one of the 34.5 kV (or 30 kV) terminals of each transformer via at least 2 (two) independent grounding leads, to avert the danger for people in the case that one lead were cut. In addition to the lead installed in the MV/LV stations, the grounded 34.5 kV (or 30 kV) terminal shall be connected to the ground wire of the supply 34.5 kV (or 30 kV) line (see Figures C.5a, C.5b, and C.5c in Annex C).

The grounding system of each MV/LV transformer station shall consist, as a minimum, of three galvanized steel rods (minimum 600 gr of zinc per sqm) with diameter ≥ 18 mm and length of 3 to 4 m, driven at the corners of a triangle with minimum side of 4 m (see figures C.5a, C.5b, and C.5c in Annex C).

On the LV side, the protection and switching of 0.4-0.231 LV lines shall be performed by three-phase pole-mounted fused cut-outs rated according to the load current of the line, one set for each line.

Connections between the four LV terminals of the three-phase transformer and LV fused cut-outs, and between the latter and the LV overhead lines, will be made with single-core aluminum or copper insulated conductors of adequate cross-section.

The neutral of the LV network shall not be connected to the grounding system of the MV/LV station (see section A.9.3).

Anti-climbing devices shall be installed below the transformer support brackets.

A.12.2 Ground-Mounted Transformers

The ground-mounted transformer stations shall be built in accordance with the design in figure C.5c in Annex C, with transformers rated at 630 kVA or 800 kVA.

The electrical requirements for the 34.5 kV (or 30 kV) equipment shall be as specified in subsection A12.1; however, K-type fuse links rated at 25 A and 30 A shall be used for the 630 kVA and 800 kVA transformers, respectively.

If switching on-load of transformers rated at 630 kVA and 800 kVA is required, a manually operated load break switch with fuses shall be used instead of the fused cut-outs.

On the LV side, the protection, switching, and metering of the 0.4/0.231 kV lines will be installed in a separate LV switchboard.

Access to the transformer by un-authorized persons shall be prevented by a galvanized steel earthed fence, as shown in figure C.5c in Annex C, with height not less than 2 m. The gate shall be provided with a padlock.

A.13 INTERPOSING TRANSFORMER

A.13.1 Scope

This specification covers the design, manufacturing, testing, supply, and transport of typical three-phase power interposing transformers for the 34.5 kV three-phase Iliceto shield wire scheme (ISWSs).

A.13.2 General

A.13.2.1 Transformer Type

The primary MV supply is assumed to be 33 kV. However, the MV may be different depending on local availability (say, 10 kV, 15 kV, or 20 kV, etc.).

Transformers shall be three-phase, 50 Hz with no-load ratio 33/35.5 kV ±2 × 3.75%, oil immersed outdoor type, natural air cooled, and provided with an off-load tap changer.

The transformer shall be able to sustain the over-excitation conditions mentioned herein.

The transformer shall be provided with bushing-type current transformers, for measurement and protection as specified elsewhere in these specifications.

A.13.2.2 Service Conditions

The altitude above sea level will not exceed 2,000 m.

Air temperatures are:

- Maximum +45°C
- Annual mean not exceeding +25°C
- Minimum +0°C

The equipment is exposed to tropical conditions and therefore is subject to high sun radiation and heavy moisture condensation during the nighttime.

The area is subject to heavy storms and frequent lightning strikes.

Earthquake conditions to be taken into account shall allow for a horizontal peak ground acceleration level of 0.2 g; 80% of this value will be assumed for the vertical ground acceleration.

A.13.2.3 Standards

Unless otherwise specified herein, the transformers shall be designed and manufactured in accordance with the standards and documents listed below:

- IEC Publ. 60076-1, 2000 "Power Transformers -Part 1: General" (edition 2.1)
- IEC Publ. 60076-2, 2011 "Power Transformers - Part 2: Temperature Rise for Liquid Immersed Transformers" (3rd edition)
- IEC Publ. 60076-3, 2000 "Power Transformers - Part 3: Insulation Levels, Dielectric Tests and External Clearances in Air" (2nd edition)
- IEC Publ. 76-4, 1976 "Power Transformers - Part 4: Tappings and Connections"
- IEC Publ. 60076-5 "Power Transformers - Part 5: Ability to Withstand Short-Circuit" (last edition)

•	IEC Publ. 296	"Specification for Unused Mineral Insulating Oils for Transformers and Switchgear" (2nd edition)
•	IEC Publ. 60076-7, 2009	"Power Transformers –Part 7: Loading Guide for Oil-Immersed Power Transformers"
•	IEC Publ. 60076-10, 2001	"Power transformers. Part 10: Determination of Sound Levels" (1st edition)
•	IEC Publ. 137, 1995	"Insulated bushings for Alternating Voltages Above 1000 V" (4th edition)
•	IEC Publ. 60044, 2000	"Current Transformers"
•	IEC Publ. 567, 1992	"Guide for the Sampling of Gases and Oil from Oil Filled Electrical Equipment, and for the Analysis of Free and Dissolved Gases" (2nd edition)
•	IEC Publ. 60599, 1999	"Mineral oil Impregnated Electrical Equipment in Service. Guide for the Interpretation of Dissolved and Free Gases Analysis" (2nd edition)
•	IEC Publ. 60076-4, 2002	"Power Transformers. Part 4: Guide for the Lightning Impulse and Switching Impulse Testing - Power Transformers and Reactors" (1st edition)
•	IEC Publ. 60076-8, 1997	"Application Guide for Power Transformers"
•	IEC Publ. 616, 1978	"Terminals and Tapping Markings for Power Transformers"
•	IEC Publ. 600694	"Common Specifications for High Voltage Switchgear and Control Gear Standards" (last edition)
•	IEC Publ. 529, 1989	"Degrees of Protection Provided by Enclosures (IP Code)"
•	EN 50216	"Accessories for Power Transformers and Reactors" Parts 1 through 6

Electrical accessories (such as motors. switches, relays, cables, etc.) shall comply with the relevant IEC standards even if not expressly mentioned in this clause.

Chemical, physical, dielectric, and mechanical characteristics of materials to be used for manufacturing transformers shall comply with the requirements given by ASTM (American Society for Testing and Materials) or DIN (Deutshes Institute for Normung) or British standards.

Should it occur that during the manufacturing of the transformers the above-mentioned standards are revised, it shall be understood that, unless otherwise expressly requested or authorized in writing by the engineer, these standards shall be considered valid regardless of the revisions.

A.13.2.4 Technical Documentation Required with Tender

The following technical documentation shall be submitted with the tender:

- A technical description including information on materials, guaranteed values, type and disposition of windings, type of core, and type of insulation and impregnation used

- A preliminary drawing with the overall dimensions and weights of the transformer, including all the accessories
- A report including information on short circuit tests carried out on similar transformers, if available
- A summary of calculations for earthquake strengths; the calculations shall show the design stresses and safety factors used and the relevant types of failure
- A preliminary drawing of the proposed gaskets for the main flange
- One drawing with transport dimensions, weights, and other relevant information
- Facilities available for testing and Inspection (see section A.13.5)
- Tap changer description with photographs or drawings
- Quantity of oil (kg).

A.13.2.5 Documentation to be Furnished by the Contractor

- Outline drawings showing overall dimensions, location of terminals and cubicles, and weights and details of the under-base as necessary for the foundation design
- Electrical diagrams for all the control, protective, signaling, and alarm equipment mounted on the transformers
- Drawings of transformer transportation, with fittings for road transport and without fittings for sea transport
- Drawings of terminal blocks
- Installation and maintenance instructions.

A13.2.6 Installation and Maintenance Instructions

The contractor shall provide a manual concerning the erection, dismantling, and maintenance of transformers. In particular, this manual shall include:

- Information on handling the different parts in which transformers may be sub-assembled
- Cautions to be taken during installation
- Characteristics of all protective, signaling and alarm equipment mounted on the transformers
- Procedure for on-site treatment of the insulating oil of the transformers
- All applicable drawings
- Information on periodic measurements, checks, and maintenance
- Any other useful information
- The manual shall be in English.

A.13.2.7 Evaluation of Losses

For the purpose of comparing tenders and penalty application, the guaranteed losses of the transformers will be evaluated as listed below, unless otherwise specified elsewhere in the bidding documents:

- No-load loss at rated voltage $5,000/kW
- Load loss at rated kVA $3,000/kW

No credit shall be granted for characteristics that are found to be better than the guaranteed value. The total losses will be evaluated as listed below:

$$L_{11} = (2L_{12} + L_{13} + 0.5L_{23})/3.5$$

where:

L_{12} (kW) are load losses at mean voltage ratio

L_{13} (kW) are load losses at the highest voltage ratio

L_{23} (kW) are load losses at the lowest voltage ratio.

It is hereby understood that values of 0.5 KW and above will be rounded up to the next full KW.

A.13.3 Main Technical Characteristics

A.13.3.1 Specified Ratings

Transformers shall comply with the following characteristics, which shall be the minimum requirements.

Phases:	Three
Windings:	Two
Rating with:	
Cooling type ONAN	3 MVA – 4.5 MVA - 6 MVA (alternative to be selected)
Rated frequency	50 Hz
Rated voltage	
• Primary winding	33 kV or another MV available in the HV/MV station of installation
• Secondary winding	35.5 kV (31 kV for 30 kV Iliceto shield wire schemes)
Tap changing	Off-load (off-voltage)
Voltage regulation	35.5 kV (31 kV) ±2 × 3.75%
Connections of phases:	
• Primary winding	Delta
• Secondary winding:	Star connected, with one terminal permanently grounded, (directly or via an R-X circuit)

Connection symbol: DY5

Cooling method: Natural cooling by means of radiators fitted on the main tank suitable for the nominal ONAN ratings

Insulation:

- Primary winding Uniform
- Secondary winding Uniform

The insulation levels shall be as follows:

WINDING (KV)	INSULATION LEVELS	
	POWER FREQUENCY	LIGHTNING IMPULSE WITHSTAND VOLTAGE
	Line terminals (kV rms)	Line terminals (kV crest)
35.5 kV[a]	95	250
33 kV	70	170

[a]One terminal of the 35.5 kV winding will be operated permanently grounded, directly or via a resistor-reactor circuit. The other two terminals shall thus be operated at a potential of 35.5 kV rms phase-to-ground. This justifies the specification of the test voltages as for the 52 kV rated voltage.

Impedance voltage (base-rated power): 6% for 3 MVA rated power

6.5% for 4.5 MVA rated power

7% for 6 MVA rated power.

Temperature-rise limits:

- Windings (average): not exceeding 60°C
- Top oil: not exceeding, 55°C
- Winding hot spot: not exceeding 70°C
- Core surface: not exceeding 75°C.

The above temperature rises shall not be exceeded with the transformers operating with one radiator out of service and the tap-changer in any position.

A.13.3.2 Particular Operating Conditions

The transformers shall be able to sustain, without any danger an exceptional over-excitation causing the flux to increase, up to 1.33 times the normal flux for a duration up to 10 seconds.

The transformers shall also be able to operate continuously with the primary (33 kV) winding energized at 36.5 kV.

Maximum short circuit power of the feeding system (to be considered for the short circuit test): infinite.

A.13.3.3 Current Transformers (Optional, to Be Quoted with Separate Price)

If required in the order, current transformers shall be mounted on the 35.5 kV bushings. The electrical characteristics shall be as follows:

•	Highest system voltage	≥ 0.6 kV rms		
•	Ratio for transformers rated at:	3 MVA	4.5 MVA	6MVA
		60/5/5 A	90/5/5 A	120/5/5 A
•	Cores	1 for measuring, 1 for protection		
•	Rated continuous thermal current	1.2 rated current		
•	Rated short-time thermal current	as per IEC standards		
•	Rated dynamic current	as per IEC standards		
•	Burden	≥ 10 VA for measuring		
		≥ 10 VA for protection		
•	Accuracy class	1 for measuring		
		5 P for protection		
•	Accuracy limit factor	20 for protection.		

A.13.3.4 Tolerances

Unless specified elsewhere, transformers will be considered to comply with these specifications when the guaranteed characteristics are within the following tolerances:

	For penalty Application	For rejection
• Voltage ratio at no-load on any tapping	-	±0.5%
• Impedance voltage		
– Principal tapping	-	±5%
– On extreme taps		±10%
• No-load losses at rated voltage and at rated frequency	0	+15%
• No-load losses at 1.1 rated voltage and frequency	-	+15%
• Load-losses calculated with formula in subsection A.13.2.7	0	+15%
• No-load current at rated voltage and frequency	-	+30%
• No-load current at 1.1 rated voltage and at rated frequency	-	+30%
• Temperature rise	0	0
• Audible sound level		As per IEC Standards

A.13.4 Construction Requirements

A.13.4.1 General

Materials used shall be new, of first class quality, and free from defects and imperfections.

The contractor shall submit to the engineer a list of the proposed sub-suppliers for the main components (such as copper, insulating materials, core laminations, bushings, tap-changer, and current transformers). Said list is subject to acceptance by the engineer before the suborders are placed.

A.13.4.2 Magnetic Circuits

The core shall be of the three-legged type. The core shall be made of cold-rolled oriented-grain silicon steel, of the best quality, suitably annealed to minimize losses. Joints shall be cut at 45 degrees to facilitate flux flow from legs to yokes.

Core construction shall be sturdily clamped by means of yoke clamping structures made of fabricated steel. Upper and lower yokes shall be connected by plates of tie-rods mechanically secured to the yoke frames only, to avoid mechanical stresses on the laminations. The resulting structure shall be capable of retaining its shape under the most severe stresses met during shipment, handling, and under short-circuit conditions.

In particular, the unit is designed to withstand the acceleration induced by the earthquake levels mentioned elsewhere in these specifications and to sustain an inclination of 10 degrees.

Insulation of the core frame from the core shall be able to withstand a voltage of 2 kV rms 50 Hz for 1 minute.

Means shall be adopted to avoid hot spots.

The core shall be connected to the yoke frames and to ground at one point only by means of a copper strap, having a minimum cross-section of 160 mm^2, accessible through a hand hole. Copper bridges shall also be provided across cooling ducts (if any).

A.13.4.3 Windings

Conductors shall be made of electrolytic copper insulated by pure cellulose paper.

All weldings in windings shall be brazed.

The windings shall be conceived to sustain thermal and dynamic stresses occurring in short circuit conditions.

The primary winding (33 kV or other) shall be external. The 35.5 kV (secondary) winding shall be internal (close to the core). This requirement is justified because there will be no circuit breaker on the 35.5 kV (line) side. The transformer will be switched on and off from the primary terminals, in one block with the 34.5 kV shield wire line (SWL) connected to the 35.5 terminals. The SWL could occasionally happen to be affected by a short circuit, thereby causing, in the switched-on primary winding, the superposition of the inrush currents and short circuit currents. The transformer must be guaranteed to withstand this severe switching condition.

A.13.4.4 Tank

The tank shall be made with stiffened welded steel plates so that the transformer can be lifted, completely assembled with oil, without permanent deformation or oil leakages.

The tank is capable of withstanding without permanent deformation practically a complete vacuum (less than 1 mm Hg absolute pressure). The permissible loss of vacuum shall not exceed 6 mm Hg in 6 hours.

The tank shall also withstand a steady-state overpressure test of 1 kg/sqcm measured at tank bottom, with duration of 24 hours, without permanent deformation and leaks.

The cover shall be of the bolted type. Sufficient openings will be provided, if appropriate, to provide access to the internal connections of the bushings, when it is necessary to dismount the bushings, and also to provide access to the grounding links.

The gaskets shall be 0-ring type of synthetic rubber, seated in on-purpose milled and turned grooves or on grooves made by means of two steel bars continuously welded all around the flange, to avoid over-compression of the gaskets. Details on the gaskets and the arrangement of the gaskets shall be submitted for approval together with suitable reference to previous experience.

The tank and the cover are designed so as to leave no external pockets in which water can lodge, and no internal pockets in which oil remains when draining the tank or in which air can be trapped when filling the tank. Venting pipes, if appropriate, shall connect to gas relay all points in which air/gas may collect.

All bolts shall be made of galvanized or stainless steel.

Steel plates for jacking lugs shall be located near the corners of the base, as well as lugs for lifting the completely assembled transformer with oil, and core-coils only.

Pulling eyes near the base shall be mounted for dragging the transformer.

Two grounding terminals shall be provided near the base in the middle of the long sides

The tank bottom shall be provided with skids under the base for movement on a flat concrete surface. In addition, standing feet shall be provided for permanent stationing of the transformer.

The tank is provided with filtering, drain, and sampling valves and fittings for connection to vacuum pumps, as specified herein.

Suitable electric bridges shall ensure that all parts of the tank and all fitting frames are at the same potential.

A.13.4.5 Bushings

The bushings shall comply with IEC publication 137, 1995. The color of the porcelain shall be brown.

The primary and secondary terminals will be of the flag type, in accordance with DIN standards. The type shall be approved by the engineer.

Toroidal current transformers shall be mounted on the 35.5 kV bushings as specified elsewhere in these specifications.

A.13.4.6 Off-Load Tap-Changer

The tap-changer shall be of the rotating type. Rated current shall be not lower than 1.5 times the rated current of the 35.5 kV winding. It shall be impossible to leave the winding open or short circuited when the operating handle is placed in a locked position.

- No. of positions: 5
- Rated voltage to ground: ≥ 52 kVrms
- Insulation level to ground:
  - Power frequency: 95 kVrms
  - Lightning impulse: 250 kV peak

A.13.4.7 Oil Conservator

The oil conservator shall be located on the tank cover.

The size of conservator shall be suitable for a temperature range of 0°C to 100°C. A removable end for cleaning, or approved inspection holes, otherwise arranged, shall be provided.

The conservator shall be provided with a filling cap and draining plug, connection pipes to the gas actuated (Buchholz) relay (with suitable disconnecting valves), and to the tank (such pipes protruding at least 1 in. inside the conservator and having a slope of about 2 degrees), and with an oil level indicator with low-level alarm contact easily readable at eye level. The dial shall indicate minimum, 30°C, and maximum levels. Silicagel breather will be fitted at eye level and connected to the conservator.

A.13.4.8 Cooling

ONAN cooling shall be adopted with the rating limits specified in subsection A.13.3. The cooling equipment shall be vibration-free and oil-leak free, whatever the wind speed and atmospheric conditions.

Natural cooling shall be ensured by pressed steel radiators or tubes welded to suitably shaped headers. Radiators shall be mounted on tank walls; one stand-by radiator shall be provided; temperature rise as per subsection A.13.3 above shall not be exceeded with the stand-by radiator cut out.

Each radiator shall be connected via butterfly valves to the tank so that each radiator can be removed without putting the transformer out of service. Each radiator shall also be provided with vent and drain plugs and fitted with means to lift it.

Radiators shall be of sturdy construction and shall be securely fastened.

A.13.4.9 Control Cabinet, Terminal Blocks, and Wiring

One control cabinet shall be provided. The cabinet shall be of rigid construction and weather-, dust-, and vermin-proof and protected according to IEC publication 144, degree IP55.

If appropriate, the cabinet shall have a door with a clear glass window and shall be equipped with a heating element controlled by an adjustable thermostat to avoid condensation. Suitable natural ventilation shall also be provided.

Terminal blocks used for internal wiring of the equipment and for control, protective, and alarm wiring shall be of the modular type and made of material that is self-extinguishing or flame propagation resistant.

Terminal blocks shall be mounted on metal guides, spring retained. The guides shall be separated at least 15 cm from each other. Each row assembly shall have at least 20% spare terminal blocks for future use. Each terminal block shall have a removable marking strip.

The insulation degree of the cables shall be not lower than three (tested at 2 kVrms against earth), sheath quality R2, and shall be of type resistant to flame propagation and to the temperature that occurs in the position immediately adjacent to the tank.

All wiring terminations adjacent to the terminal blocks shall be equipped with ferrules for proper identification.

Alarm and tripping circuits shall be independent.

All the electrical external connections shall be laid in conduits. Cables shall be colored as follows:

- Red, yellow, blue — A.C. phase connections
- Black — A.C. neutral connections
- Green — Ground connections
- Grey — D.C. circuits

Circuit insulation shall be as follows:

- Power frequency withstand voltage — 2 kV rms
- Atmospheric impulse withstand voltage — 5 kV peak

A.13.4.10 Auxiliary Supplies

The auxiliary supply voltages shall be the following:

- For control circuits and space heaters, if applicable — one phase, 220 V ±10%, 50 Hz (to be confirmed in the order)
- For tripping, alarm and signaling circuits — 125 V –20% to + 10%, D.C. (to be confirmed in the order)

A.13.4.11 Oil

The supply shall include the transformer oil, plus 10% spare oil. This oil shall be new, non-inhibited, and shall meet the requirements for Class I according to IEC publication 296, 1982.

The oil shall be obtained from naphthenic crudes and shall not contain PCB.

In any case, the contractor shall submit to the engineer for approval the characteristics of the oil the contractor intends to use.

A.13.4.12 Painting

All parts of the transformer made of corrodible metals shall be painted. The surfaces inside the transformer tank (including the oil conservator) shall be protected by rust inhibiting paint of proven insolubility in hot oil (at 100°C).

The external metal surfaces shall be treated as follows:

a) Surface preparation: prior to painting, all surfaces shall be subjected to white metal blast-cleaning according to specification SSPC-SP 5-63 of the Steel Structure Painting Council. The primer shall not be applied later than 24 hours after sand blasting, and in any case before the sandblasted surfaces start rusting.

b) First coat (primer): catalyzed epoxy paints with anticorrosion pigments shall be used as a primer for the tank and radiators; synthetic paints may also be used for the radiators.

c) Finishing coat: the finishing coats for the tank and radiators shall be based on paints belonging to one of the following categories:

- Polyurethane paints
- Alkyd and silicone-based paints (30% silicone-copolymer)
- Modified vinyl paints

Intermediate coats between the priming and finishing coats may be selected by the contractor. The various coats of paint should be of contrasting colors to permit their prompt identification. The color of the finishing paint shall be subject to approval by the engineer. The minimum thickness of the paint shall be not less than 150 microns on any point of painted outdoor surfaces.

The contractor shall submit for approval the painting method the contractor intends to adopt, in particular the contractor shall specify the nominal value of the thickness of each coat. Painting of the transformers shall be completed before the routine tests. Finished painted surfaces shall be properly protected against possible damage during transport and installation. The contractor shall supply a sufficient quantity of touch-up paint to repair damaged parts.

A.13.4.13 Accessories

- 1 Buchholz relay with two floats and two independent contacts for alarm and tripping for the oil of the transformer tank with two disconnecting valves and circuit testing device
- 1 oil sampling device vacuum-tight at eye level connected with the above relay
- 1 flanged pipe for the above relay to allow removal of same
- 1 hot oil thermometer, dial type with two resettable contacts (alarm and tripping), mounted on the tank wall at a suitable level

- 1 bronze plug vacuum-tight with screwed cap for sampling oil from the main tank
- 2 bronze valves in opposite sides of the main tank (located at convenient height) for oil treatment The valves shall be vacuum-tight, threaded 1.5 in., and fitted with screwed cap. The lower valve will be used for oil draining.
- 1 valve as above for the vacuum pump
- Blind flanges to be fitted on butterfly valves of radiators (see subsection A.13.4.8)
- 2 thermometer pockets with captive screw caps
- 1 safety overpressure valve with alarm contacts
- Nameplate with transformer diagram
- Other accessories, such as lugs, valves, etc., as listed in subsections A.13.4.4, A.14.4.7, and A.13.4.8

A.13.4.14 Labels and Plates

The transformer shall be provided with one rating plate affixed in one long side of the tank. Relays and all other apparatus as well as cable and wiring terminations shall have identifying labels. All labels and plates shall be of stainless steel or other approved non-corrodible metal, shall be fitted with stainless steel screws and lettering shall not deteriorate with time. All inscriptions shall be in English and subject to approval by the engineer.

The rating plates shall show all the indications specified in IEC publication 60076-1 (plus the indication that the tank is suitable for lifting the transformer full of oil).

A.13.5 Tests

A.13.5.1 Tests on Components

Before being fitted to the transformers, all components (bushings, tap-changer, radiators, relays, etc.) shall be subjected to routine tests required by the relevant standards at the supplier's or sub-supplier's factory.

A detailed test report, proving the successful passing of such tests, shall be provided.

A.13.5.2 Acceptance Tests

The following tests shall be performed at the contractor's works prior to shipment:

TYPE TESTS:

- Temperature-rise test
- Short-circuit test (optional, at discretion of the engineer)

- Measurement of the harmonics in the no-load current
- Measurement of acoustic noise level
- Vacuum test on the tank and assembled fittings
- Leakage test on the tank and assembled fittings under oil pressure

ROUTINE TESTS:

- Measurement of voltage ratio
- Check of voltage vector relationship
- Measurement of the winding resistances
- Separate-source power-frequency withstand test
- Impulse test
- Induced overvoltage withstand test
- Measurement of no-load losses and current
- Measurement of short circuit impedance and load losses
- Measurement of loss angle
- Measurement of insulation resistance
- Checks of breakdown voltage of insulating oil
- Operation test of tap-changer
- Fitting inspection and operational check
- Check of paint protection
- Test on components

The routine tests shall be made on each transformer supplied.

The type tests shall be made on one transformer, after the routine tests.

Unless otherwise specified, the tests shall be carried out in accordance with IEC recommendations.

A.13.5.3 Type Tests

TEMPERATURE-RISE TEST

The test shall be carried out with the short-circuit test method in accordance with the procedure laid down in IEC publication 60076-2, 2011.

The test shall be continued until the requirements of the relevant clauses of IEC publication 60076-2, 2011 have been met. The winding temperature shall be ascertained by using the resistance method. The maximum inaccuracy of the measurements shall not exceed ±0.5%.

SHORT-CIRCUIT TESTS

To be carried out in accordance with the procedure laid down in IEC publication 60076-5 (last edition), unless otherwise specified herein.

Each tenderer shall inform the test station or laboratory where the short circuit test will be performed, and will quote the total cost of the test, including transport of the transformer to and from the test site.

If the tenderer has performed a short circuit test on a transformer of the same design and equivalent power rating, a test certificate shall be submitted with the tender.

The final decision whether to perform the short circuit type test shall be notified by the engineer at the time of the acceptance tests, at the engineer's discretion. A test waiver, if considered by the engineer, will in no way relieve the manufacturer of its obligation under the contract. Should the test be waived, the relevant price will not be paid.

The thermal ability to withstand short circuit shall be demonstrated by calculations while the dynamic ability shall be proved by tests.

For the latter purpose, nine short circuits will be applied as follows:

WINDING CONDITIONS	TAP-CHANGER POSITION	CURRENT IN PHASES A, B, C, AS PERCENTAGE OF SHORT-CIRCUIT CURRENT		
		A	B	C
Primary terminals (33 kV or other): Supply input: 35.5 kV (31 kV) terminals: short circuited	–7.5%	100%	consequent	consequent
	–7.5%	100%	consequent	consequent
	–7.5%	100%	consequent	consequent
	0	consequent	100%	consequent
	0	consequent	100%	consequent
	0	consequent	100%	consequent
	+7.5%	consequent	consequent	100%
	+7.5%	consequent	consequent	100%
	+7.5%	consequent	consequent	100%

The duration of each short-circuit shall be 0.5 seconds with a tolerance of ±10%.

The calculation of the short circuit first peak current and rms current shall be made by considering nil (zero) the equivalent impedance of the supply network. This compensates for the fact that the supply voltage in operation can be higher than the rated voltage (for example, 33 kV instead of 30 kV). Tolerances on peak and rms currents shall be as per IEC standards.

The testing scheme shall be one of those permitted by the IEC standards. However, the test procedures and scheme shall be discussed and approved by the engineer prior to the test.

Nine short circuit tests shall be carried out with the 35.5 kV (secondary winding) terminals short circuited (that is, with pre-set short circuit): three tests shall be in mean tap; three in highest tap; and three in lowest tap. Test procedures shall warrant that the specified peak values of the test current shall flow three times in each phase:

- When the test is made with the three-phase scheme, this is obtained by synchronizing the closing time of the short-circuiting breaker
- When a single-phase scheme is applied, this is obtained by changing cyclically the phase under test

During the test, the following measurements and checks shall be carried out:

a) Oscillographic record of applied voltages and currents to check values and duration

b) Measurement of transformer short circuit inductance before and after each test (with the bridge method, to ensure reproducibility within ±0.1%)

c) Record of the capacitive currents induced in the 35.5 kV windings, by zero-sequence repetitive impulses applied at the 33 kV terminals, before and after each test

After completion of all the short circuit tests, the following checks will be made:

a) Check of insulation by repeating the induced overvoltage and 50 Hz applied voltage tests, and by performing the atmospheric impulse test, all at 100% of specified test value

b) Visual inspection of the untanked transformer; a comparison with photos made before the tests shall also be made to check that no deformation of the connections has occurred

The test is deemed successful if:

a) The star equivalent inductance values measured before and after the tests do not differ more than 1% (one percent)

b) The insulation tests are all successful

c) Visual inspection and photos of the untanked machine provide evidence that no failures or defects have occurred (no deformation or displacement of windings, connections, support structures; no incipient flashovers; etc.)

The axial compression of the windings shall also be checked, for comparison with the compression applied before the short circuit test.

During the test, the relief valve and Buchholz relay shall not intervene. The tank and bushings shall stand the overpressure and vibrations, without any damage and any oil leak.

If the star equivalent inductance values measured before and after the short circuit test differ by more than 1% but less than 2% (two percent), the transformer could be accepted, at the engineer's discretion, only if the inspection of the completely disassembled transformer (including the windings) does not show any deformation, failure, or displacement of windings, connections, support structures, etc.

If the star equivalent inductance values measured as specified differ by 2% or more, the transformer shall be rejected straightaway and the test shall be repeated on a new or modified prototype.

MEASUREMENT OF THE HARMONICS IN THE NO-LOAD CURRENT

To be carried out according to the procedure laid down in clause 8.6 of IEC publication 60076-1, 2000.

MEASUREMENT OF ACOUSTIC NOISE LEVEL

To be carried out in accordance with the procedure laid down in IEC publication 60076-10, 2001.

VACUUM TEST ON TANK AND ASSEMBLED FITTINGS

This test shall be carried out on the tank without oil, but with core-and-coil assembly and fittings, which are mounted directly on the tank.

The test pressure (absolute pressure) in the tank shall be less than or equal to 1 mm Hg. The connection to the vacuum pump shall then be isolated to check on compliance with subsection 13.4.4.

During this test, the magnitude of any eventual permanent deformation of the tank shall be noted.

LEAKAGE TEST ON TANK AND ASSEMBLED FITTINGS UNDER OIL PRESSURE

The test shall be carried out with the transformer filled with warm oil and shall be performed at the end of the temperature-rise test.

During this test, the magnitude of any permanent deformation of the tank shall be noted.

A.13.5.4 Routine Tests

Unless otherwise agreed, tests shall be carried out in the order specified herein.

Tests shall be performed at any temperature between 10°C and 40°C.

MEASUREMENT OF VOLTAGE RATIO

To be carried out in accordance with the procedure laid down in IEC publication 76-4, 1976.

CHECK OF VOLTAGE VECTOR RELATIONSHIP

To be carried out in accordance with the procedure laid down in IEC publication 76-4.

MEASUREMENT OF THE WINDING RESISTANCES

To be carried out in accordance with the procedure laid down in IEC publication 60076-2. For the 35.5 kV winding, the measurement shall be carried out on principal and extreme tappings.

The accuracy of measurement shall be ±0.5% or better.

SEPARATE-SOURCE POWER-FREQUENCY WITHSTAND TEST

To be carried out in accordance with the procedure laid down in clause 10 of IEC publication 60076-3, 2000.

IMPULSE TEST

To be carried out in accordance with the procedure laid down in clause 12 of IEC publication 60076-3, 2000.

The position of tap-changer shall be chosen by the inspector of the engineer attending the tests. Of the N°9 1.2/50 µs impulses to be applied to the 35.5 kV terminals, three will be applied with the tap-changer in the middle position, three in the higher position, and three in the lower position.

INDUCED OVERVOLTAGE WITHSTAND TEST

To be carried out in accordance with the procedure laid down in clause 11 of IEC publication 60076-3, 2000.

MEASUREMENT OF NO-LOAD LOSSES AND CURRENT

To be carried out in accordance with the procedure laid down in clause 8.5 of IEC publication 60076-1, 2000.

The measurement of losses shall be performed using three wattmeters for low power factor, class of accuracy at least 0.5; error corrections shall be made. Voltages and currents shall be measured by instrument transformers of class 0.2 or better; errors shall be known with an accuracy of ±0.2% or better.

MEASUREMENT OF SHORT CIRCUIT IMPEDANCE AND LOAD LOSSES

To be carried out in accordance with the procedure laid down in clause 8.4 of IEC publication 60076-1, 2000.

Measurements shall be made by employing instruments and instrument transformers having the same requirements as above stated for measurement of no-load losses. The measurement shall be performed on principal and extreme tappings.

MEASUREMENT OF LOSS ANGLE (TAN DELTA OR COSINE PHI)

To be carried out between windings and between every winding and tank, by means of the Schering bridge or Doble test apparatus (with record of atmospheric conditions and correction of results to 20°C).

The same measurements shall also be carried out for terminal bushings.

MEASUREMENT OF INSULATION RESISTANCE

To be carried out between windings and between every winding and tank (at 0, 15, 30, 45, and 60 seconds) on the oil filled transformer by 5,000 V motor-driven Megger (with records of oil and atmospheric conditions and correction of results to 20°C).

OPERATION TEST OF OFF-LOAD TAP-CHANGER

To be carried out in accordance with the procedure laid down in IEC applicable standards.

FITTINGS INSPECTION AND OPERATIONAL CHECK OF ITS OPERATION

Correct operation of all fittings, mounted on the transformer during the acceptance test and unmounted, shall be checked. This check, with all accessories mounted, shall be repeated at the site.

The insulation test of the auxiliary wiring shall be carried out in accordance with the procedure laid down in clause 9 of IEC publication 60076-3, 2000.

CHECKS OF BREAKDOWN VOLTAGE OF INSULATING OIL

To be carried out in accordance with the procedure laid down in IEC publication 296, 1982.

The breakdown voltage of oil shall be not less than 60 kV for all samples drawn from the transformers. In case the oil used during the acceptance tests at works differs from the oil used at the site, this test will be performed at the site only.

CHECK OF PAINT PROTECTION

To be carried out by checking both thickness and adhesion of the film.

The measurement of the paint thickness shall be performed by employing a "paint inspection gauge." In particular, it shall be made by the direct measurement of total film thickness as well as the thickness of individual coats. Ten points shall be chosen at random on the painted surface of the transformer (radiators included); the mean of the values of each coat shall not be lower than the nominal value declared by the contractor. No value shall be lower than the minimum thickness specified by the contractor.

Film adhesion shall be verified by the cross-cut method according to DIN standard 53151-1970. The test shall be made on 10 points chosen at random on the painted surface of the transformer. The degree of alteration shall not be higher than Gtl.

A.13.5.5 Criteria for the Acceptance of Transformers

TESTS ON COMPONENTS AT THE FACTORY

All routine tests shall have a positive result within the tolerance allowed, when applicable.

The negative result of one test shall not imply the rejection of the supply, but only of the failing component, if the contractor is in a position to remedy said defect within a reasonable period of time.

FINAL TESTS ON THE TRANSFORMER AT THE FACTORY BEFORE SHIPMENT

The negative result of a type test, if considered by the engineer as essential for reliable operation of the transformers, may involve rejection of all transformers of the same type in the supply. The engineer will accept the repetition of the test if the contractor proposes to modify the design of the transformers within a reasonable period of time and to repeat, at the contractor's own expense, all type tests listed in subsection A.13.5.2.

All routine tests shall have a positive result within the tolerances allowed, when applicable.

If the negative result of a test is prejudicial to the operation of the transformer, the transformer shall be replaced or repaired at the full expense of the contractor.

A negative result of the control of paint application entitles the engineer to require, at no charge, the repainting of transformer.

FAILURE TO MEET GUARANTEES

If tests on the transformer show that the characteristics fail to meet the guaranteed values, the engineer is entitled to reject the transformer in case the tolerances stipulated in subsection A.13.3 are exceeded. If no-load and/or load losses exceed the guaranteed values, the following penalties shall be applied:

a) An amount calculated at the rate of $4,000 for every full kilowatt by which the no-load losses at rated voltage and frequency exceed the guaranteed value.

b) An amount calculated at the rate of $2,500 for every full kilowatt by which the load losses, calculated with the formula in subsection A.13.2.7, exceed the guaranteed value.

No credit shall be granted for characteristics that are found to be better than the guaranteed values.

A.13.6 Transport

Transformers shall be designed for rail, sea, and road transport.

From the contractor's works to the installation site, the transformer will be transported by rail/road/sea filled with oil and bushings. Radiators and conservator will be transported separately. All openings (including those of radiators) shall be closed by means of blind flanges.

The ship shall be trimmed so as to avoid damage to the transformer in case of rough seas.

The fittings (radiators and conservator) shall be packed with the greatest care and transported, if possible, by container.

A.13.7 Spare Parts

A list of recommended spare parts, with unit prices, for necessary maintenance of the power transformers shall be furnished with the tender.

The list shall include, but not be limited to, the following:

- One set of gaskets
- One bushing for the 33 kV winding terminals
- One bushing for the 35.5 kV winding terminals
- One oil temperature indicator
- One Buchholz relay.

Spare parts shall be interchangeable with and have the same characteristics and quality as those mounted on the transformers.

All spare parts shall be treated and packed as required to preserve them against deterioration for indefinite storage. Each spare part shall be suitably identified by a metal label.

A.14 TERTIARY WINDING OF HV/MV STEP-DOWN TRANSFORMERS

The addition of a tertiary winding to an HV/MV step-down transformer is an economic alternative to the interposing transformer (IT) for the supply of the two-SW three-phase SWLs (see the single-line diagram in figure 7.1, panel a, in chapter 7 of the manual), and also for the supply of the three-SW three-phase SWLs when needed (see chapter 14 and figure 16.1, panel a, in chapter 16 of the manual). Specification of tertiary winding is part of specification of the HV/MV step-down transformer, however it shall be in compliance with the following main characteristics:

- Rated voltage: 35.5 kV ± 2 × 3.75% (or 31 kV ± 2 × 3.75%)
- Voltage regulation: with off-voltage tap changer
- Connection: delta
- Rated power: 4 or 6 or 8 MVA, in any case ≥ 20% of the rated,
- power of the HV winding
- Impedance voltage between HV and tertiary winding: 8% to 10%, on basis of rated power of tertiary winding (from 4 to 8 MVA), respectively
- Withstand capability to electrodynamic forces caused by external short circuits: As specified in subsection A.13.5.3 of this Annex for the IT and table B.21 in Annex B

SPECIAL TECHNICAL REQUIREMENT

The tertiary winding supplies long 30-34.5 kV SWLs which are frequently struck by lightning, causing short circuits (flashover across the arcing horns of the SW insulators). It is therefore mandatory to warrant the tertiary winding withstand capability to the ϕ-to-ϕ and 3-ϕ short circuits in close proximity to the transformer terminals.

The tertiary winding shall therefore be of compact and sturdy design, in particular if the winding is proposed to be located internally to the HV winding (that is, exposed to centripetal forces). The design shall be submitted to the purchaser for approval prior to the start of manufacturing.

The bidder shall quote with separate price the transformer short circuit tests as per the last edition of IEC publication 60076-5 and as specified for the IT in this Annex. Bidders shall also specify the name of an independent internationally reputed laboratory where the test will be performed.

The employer shall notify the manufacturer if the short circuit test will be performed when the first unit of the supply will be ready for the factory acceptance tests. If the test will be waived by the employer, the relevant price will not be paid.

ANNEX B | TECHNICAL DATA SHEETS FOR THE EQUIPMENT FOR THREE-PHASE ILICETO SHIELD WIRE SCHEMES USING THE EARTH AS THE CONDUCTOR OF ONE PHASE, WITH RATED VOLTAGES OF 34.5 kV AND 30 kV

CONTENTS

ABBREVIATIONS AND ACRONYMS

Ω	ohm
µf	microfarad
µs	microsecond
φ-to-φ	phase-to-phase
φ-to-Gr	phase-to-ground
3-φ	three-phase
°C	degrees Celsius
A	ampere
AC	alternating current
Al	aluminum
ANSI	American National Standards Institute
Arms	root mean square amperes
cm	centimeter
CO	close-open
Cu	copper
daN	deca Newton
dB(A)	decibel
DC	direct current
DIN	Deutsches Institute for Normung
Dyn	delta-star with neutral
f	frequency
g	gram
HV	high-voltage
Hz	hertz
IEC	International Electrotechnical Commission
IP	protection degree
ISWS	Iliceto Shield Wire Scheme
k	kilo (1,000 times)
kA	kilo ampere
kArms	root mean square kilo ampere
kg	kilogram
kJ	kilojoule
kN	kilonewtons
kV	kilovolt
kVA	kilovolt-ampere
kVAR	kilovolt-ampere reactive
kVrms	root mean square kilovolt
kW	kilowatt
LV	low-voltage
m	meter
MCOV	maximum continuous operating voltage
MHz	megahertz
mm	millimeter
ms	millisecond
mV	millivolt
MVA	megavolt ampere
MW	megawatt
N	Newton
NC	Normally Closed
nF	nanofarad
NO	Normally Open
ONAN	oil-natural air-natural
pC	pico coulomb
p.u.	per unit
R	resistance
R.I.V.	radio interference voltage
rms	root mean square
s	second
SF6	esa fluoride of sulphur
SWL	shield wire line
SWS	shield wire scheme
V	volt
VA	volt-ampere
V-I	voltage-current
W	watt
X	reactance

INTRODUCTION

The equipment insulation requirements and the characteristics of the surge arresters have been justified and specified in subsection 5.3.4 of the manual for two-shield-wire (SW) three-phase Iliceto shield wire schemes (ISWSs) with rated voltage of 34.5 and 30 kilovolts (kV).

The switching and protection apparatuses with rated voltage of 36 kV that meet the requirements of International Electrotechnical Commission (IEC) standard 60694, Series I-European Practice, that are available in all the manufacturing countries, can be applied in two-SW "three-phase" ISWSs with operation voltage of 30 kV.

The operation voltage at 34.5 kV requires switching equipment with phase-to-ground test voltages of the 38 kV class, in accordance with the IEC standards 60694, Series II – North American Practice, which may not be available in the catalogues of manufactures in Europe and of some countries in Asia.

In this Annex, the specified data in brackets are applicable to two-SW "three-phase" ISWSs operated at 30 kV. Where only one value is specified (that is, not followed by a value in brackets), the value is applicable for the 34.5 and 30 kV operation voltages.

LIST OF APPLICABLE STANDARDS

IEC 60099-4	"Metal-oxide surge arresters without gaps for alternative current systems"
IEC 60289	"Reactors"
IEC 62271-102	"High-Voltage alternating current disconnectors and grounding switches"
IEC 62271-100	"High-voltage alternating current circuit breakers"
IEC 61869-2	"Current transformers"
IEC 61869-3	"Inductive voltage transformers"
IEC 255	"Electrical relays"
IEC 60076-1 to 10	"Power transformers"
IEC 296	"Specification for unused mineral insulating oil for transformers and switchgear"
IEC 137	"Insulated bushings for alternating voltages above 1000 V"
IEC 62271-105	"High-voltage alternating current switch-fuse combination"
IEC 62271-103	"High-voltage switches for rated voltage above 1kV and less than 52kV"
IEC 60871-1 and 2	"Shunt capacitors for a.c. power systems having a rated voltage above 1kV"
IEC 60383-1	"Insulators for overhead lines with a nominal voltage above 1 kV – Part 1 – Ceramic or glass insulators"
IEC 720	"Characteristics of line post insulators"

TABLE B.1

Metal Oxide Surge Arresters

METAL-OXIDE SURGE ARRESTERS	REQUIRED	TENDERED
Manufacturer's name and country		
Type designation		
Standard applicable	IEC 60099-4	
Rated frequency (Hz)	50	
Rated voltage (kVrms)	47 (42)	
Max. continuous operation voltage (MCOV) (kVrms)	≥38 (≥33)	
TOV capability for 1s (kVrms)	≥55 (≥48)	
Max residual voltage - With switching surges (500 A crest; front time >30 μs) (kV crest) - With lightning surges (kV crest): • with 5kA – 8/20 μs wave • with 10 kA – 8/20 μs wave	 ≤100 (≤90) ≤120 (≤110) ≤130 (≤115)	
Energy capability(kJ/kV of rated voltage)	≥3,5	
Line discharge class as per IEC	Minimum 2	
High current operation duty (4/10 μs wave; kA crest)	100	
Housing • Material • Creepage length (mm) • Ultimate cantilever strength (kN)	 Brown porcelain or polymeric ≥1050 (≥950) —	
External insulation (housing) • 50 Hz – 1' power frequency, wet (kVrms) • 1.2/50 μs lightning impulse (kV peak)	 ≥82.5 ≥200	
Pressure relief type, if applicable	—	
Counter and leakage current indicator	Not required	
Overall dimensions (mm) • Width • Height		
Mass (kg)		

TABLE B.2

Fast-Closing Grounding Switches

FAST-CLOSING GROUNDING SWITCH	REQUIRED	TENDERED
Manufacturer's name and country	—	
Type designation	—	
Standards applicable	IEC 62271-102	
Number of poles	2	
Type of construction	Outdoor	
Rated frequency(Hz)	50	
Rated voltage	52 (38)	
Closing time (ms)	≤200	
Closing mechanism	Spring type	
Opening mechanism	Motor operated	
Short circuit current duty: • Making capacity (kA peak) • 3 s momentary current rating (kA rms)	≥12.5 ≥5	
Insulation levels, phase-to-ground, between phases and across the insulating distance • 50 Hz-1 minute, wet (kVrms) • Lightning impulse 1.2/50 μs (kV crest)	95 (≥ 80) 250 (≥ 200)	
Insulators Material/color • Type • Creepage distance (mm)	Porcelain/brown C8-250 ≥ 1050 (≥ 950)	
Closing coil voltage (V-DC)	To be specified in the order	
Opening motor voltage (V-DC or V-AC)	To be specified in the order	
Emergency manual operation with individual crank	Included	
Housing of operating mechanism and control circuits	Stainless steel, IP – 55	
Auxiliary contacts	5 NO + 5 NC	
Anticondensation resistance (AC)	Included	
Overall dimensions (mm) • Length • Width • Height		
Mass (kg):		

TABLE B.3

Circuit Breaker (If Applicable)

CIRCUIT BREAKER	REQUIRED	TENDERED
Manufacturer's name and country		
Manufacturer's type designation		
Standard in force	IEC 62271-100	
Number of poles	2	
Type of circuit breaker	SF6	
Installation	Outdoor	
Rated duty cycle	0–0.3 s-CO-3 min-CO 0–0.3 s-CO-15s-CO	
Operating functions	High speed 2-pole reclosure	
Rated frequency (Hz)	50	
Rated voltage (kVrms)	52 (38)	
Highest continuous operation voltage phase-to-ground (kVrms)	38.5 (33)	
Rated current (Arms)	≥400	
Breaking capacity • Symmetrical (kArms) • Asymmetrical (kA peak)	 ≥8 ≥20	
Rated short circuit making current (kA peak)	≥20	
Short time withstand current (3 s) (kArms)	≥8	
Insulation levels, phase-to-ground and between phases • 50 Hz-1 minute wet (kVrms) • Lightning impulse 1.2/50 μs (kV peak)	 95 (≥ 80) 250 (≥ 200)	
Across open contacts • 50 Hz-1 minute wet (kVrms) • Lightning impulse 1.2/50 μs (kV peak)	 95 (≥ 80) 250 (≥ 200)	
Creepage distance of insulators, phase-to-ground (mm)	1,050 (≥ 950)	
Creepage distance of insulators, across open contact (mm)	≥900	
Make break time (ms)	—	
Opening time (mechanical) (ms)	—	
Arcing time (ms)	—	
Critical current and arcing time at critical current (A and ms)	—	

CIRCUIT BREAKER	REQUIRED	TENDERED
Max break time from 10% to 100% of rated interrupting current (tolerance nil) (ms)	60	
Max tripping delay (s)	—	
Max closing time (ms)	—	
Dead time for auto-reclosing (s)	0.3–2	
Maintenance-free interruptions: • At rated breaking current (N◦) • At 50% breaking current (N◦) • At rated nominal current (N◦)	 — — —	
Power required at rated voltage to re-load the operating mechanism (W)	—	
Rated DC voltage and operating range of trip coil (V)	To be informed in the order	
Rated DC voltage and operating range of closing coil (V)	To be informed in the order	
Power consumption of closing coil (W)	—	
Power consumption of trip coil (W)	—	
Number of trip coils	2	
Number of closing coils	1	
Supply voltage of motor (V)	—	
Power consumption of motor (W)	—	
Number and type of spare auxiliary contacts per pole:	—	
Make contacts	≥ 6	
Break contacts	≥ 6	
Closing capacity of spare contacts (A)	—	
Opening capacity of spare contacts (A)	—	
Supply voltage of heating resistors (V) (AC-50 Hz-single phase)	220	
Power consumption of heating resistors (W)		
Material of insulators	Porcelain, brown	
Reference number of drawing of insulator profile	—	

(*continued*)

TABLE B.3

Circuit Breaker (If Applicable) (*continued*)

CIRCUIT BREAKER	REQUIRED	TENDERED
Contact temperature rise: • Silver faced (°C) • Non-silver faced (°C)	 — —	
Characteristics of SF6 - Rated pressure at 20°C (bar) - Lower and higher limits of gas pressure for rated making capacity (bar) - Lower and higher limits of gas pressure for rated breaking capacity (bar) - Lower and higher limits of gas pressure causing lock-out or safety valve operation (bar) - Total capacity of circuit breaker local gas receivers. - Min time from commissioning date to first refilling (subject to formal guarantee) - Mass (kg) - Rate of escape (%) per year	 — — — — — >5 years — <1%	
Breaker drive mechanism: - Type	 Spring operated	
Type and dimensions of rollers	—	
Earthquake acceleration withstand capacity: - Horizontal - Vertical	 0.2 g 0.16 g	
Overall dimensions (mm): • Length • Width • Height	 — — —	
Net mass in operating condition (including operation mechanism) (kg)	—	

TABLE B.4

Grounding Resistors-Reactors

GROUNDING RESISTOR-REACTOR	REQUIRED	TENDERED
Manufacturer's name and country		
Type designation		
Standards applicable for resistors	IEEE-32	
Number of phases	1	
Connection:	Earthing of one 34.5 kV (30 kV) terminal of interposing transformer feeding the shield wire line	
Type of installation	Outdoor	
Rated frequency (Hz)	50	
Max. ambient temperature °C	+45	
Rated impedance, at + 20°C, R + jX (ohm): To be specified for each ISWS, on the basis of the results of the steady-state operation analysis, to be performed with the ad hoc computer program.		
Resistance variation range of each resistor by means of bolted connections: - Above rated value (Ω) - Below rated value (% of rated resistance)	 + 4 Ω, in at least 3 steps Down by –40%, in at least 4 steps	
Rated continuous current (Arms): To be specified for each ISWS, as equal to the current corresponding to the long term (say, 15–20 years ahead) load forecast.		
3 second overcurrent capacity (Arms):	To be specified, according to the calculated short circuit current	
Connection of resistor and reactor	In series (resistor on earth side)	
V-I characteristics of reactor (if reactor is required)	Linear up to at least 130% of rated current	
Insulation class of resistor and reactor (kVrms)	17.5	
Insulation type of resistor	Graded	
Material of resistor elements	Steel chrome-aluminum alloy	
Total resistance variation from no-load to rated current	≤ 4%	
Temperature of resistor elements at rated current and max. ambient temperature (°C)	380	
Max. temperature permissible of resistor elements following a 3 s 850 Arms overcurrent starting from continuous operation at rated current (°C)	≤ 780	

(*continued*)

TABLE B.4

Grounding Resistors-Reactors (*continued*)

GROUNDING RESISTOR-REACTOR	REQUIRED	TENDERED
Characteristics of HV bushing, if applicable: - Withstand test voltages • 50 Hz 1 minute wet (kVrms) • Lightning impulse 1.2/50 µs (kV crest) - Creepage distance (mm) - Material/color	 38 95 ≥ 450 Porcelain/brown	
Cooling	Natural	
Housing: • Type • Material • Protection degree • Paint color	 Self-supporting free-standing kiosk Galvanized steel with stainless steel doors IP 23 will be informed in the order	
Standards applicable for reactors	IEC 60289	
Current transformer		
Location	On connection to ground of resistor	
Type		
Rated voltage (kVrms)	3	
Ratio (A/A)	60 – 90 – 120/5/5 (to be informed in the order)	
Number of cores: • For metering • For protection	 1 1	
Burden (VA): • For metering • For protection	 ≥ 10 ≥ 10	
Accuracy class: • For metering • For protection • Accuracy limit factor for protection	 0.5 5 P 10	
Overall dimensions of resistor (mm): • Length • Width • Height	 — — —	
Overall dimensions of reactor, where applicable (mm): • Length • Width • Height	 — — —	
Mass: • Active mass of resistor material (kg) • Total mass (kg)	 — —	

TABLE B.5

Line Isolators

LINE ISOLATOR	REQUIRED	TENDERED
Manufacturer's name and country		
Type designation		
Standards applicable	IEC 62271-102	
Number of poles	2	
Installation	Outdoor	
Opening/closing	Hand operated	
Rated frequency (Hz)	50	
Rated voltage (kVrms)	52 (38)	
Highest continuous operation voltage, phase-to-ground (kVrms)	38.5 (33)	
Rated current (Arms)	≥250	
Rated short time (1 s) current (kArms)	≥8	
Rated peak current (kA crest)	≥20	
Auxiliary contacts	4 NO+4 NC	
Insulation levels, phase-to-ground and phase-to-phase		
• 50 Hz-1 minute, wet (kVrms)	95 (≥ 80)	
• Lightning impulse 1.2/50 μs (kV crest)	250 (≥ 200)	
Insulation levels, across open contacts		
• 50 Hz-1 minute, wet (kVrms)	≥85 (≥ 80)	
• Lightning impulse 1.2/50 μs (kV crest)	≥200	
Creepage distance of insulators (mm)	≥1,050 (≥ 950)	
Material/color	Porcelain/brown	
Overall dimensions (mm) • Length • Width • Height	 — — —	
Mass (kg):	—	

TABLE B.6

Current Transformers

CURRENT TRANSFORMERS	REQUIRED	
Manufacturer's name and country		
Type designation		
Standards applicable	IEC 61869-2	
Installation	Outdoor	
Rated voltage (kVrms)	52 (38)	
Highest continuous operation voltage, phase-to-ground (kVrms)	38.5 (33)	
Rated frequency (Hz)	50	
Rated primary current (Arms)	120-90-60 (to be confirmed in the order)	
Rated secondary current (Arms)	5	
Number of cores	2	
Burdens (VA) • Measuring core • Protection core	 ≥ 15 ≥ 10	
Accuracy class • Measuring core • Protection core	 0,5 5 P	
Accuracy limit factor (protective core only)	20	
Continuous thermal current rating (p.u. of rated current)	1.2	
Short time current ratings: • Thermal, 1 s (kArms) • Dynamic (kA peak)	 8 20	
Insulation level of primary winding: • Power frequency I minute withstand voltage, wet (kVrms) • Lightning impulse withstand voltage, 1.2/50 µs (kV crest)	 95 (≥ 80) 250 (≥ 200)	
Insulation level of secondary windings • Power frequency 1 minute withstand voltage (kVrms)	 5	
Internal partial discharges at 150% of rated voltage (pC)	<10	
Min. creepage distance (mm)	1,050 (950)	
Overall dimensions (mm) • Length • Width • Height	 — — —	
Mass (kg):	—	

TABLE B.7

Voltage Transformers

VOLTAGE TRANSFORMER	REQUIRED	TENDERED
Manufacturer's name and country		
Type designation		
Standards applicable	IEC 61869-3	
Type	Inductive	
Installation	Outdoor	
Rated system voltage (kVrms)	34.5 (30)	
Highest continuous operation voltage, phase-to-phase and phase-to-ground (kVrms)	38.5 (33)	
Rated frequency (Hz)	50	
Rated primary voltage (kVrms)	34.5 (30)	
Rated secondary voltage (Vrms)	100	
Rated voltage factor (p.u): • continuous • 30 s duration	 1.2 1.6	
Burdens (VA): • Measuring winding • Protection winding	 100 100	
Accuracy class: • Measuring winding • Protection winding	 0.5 3 P	
Insulation level of primary winding: • Power frequency 1 minute withstand voltage wet (kVrms) • Lightning impulse withstand voltage, 1.2/50 µs (kV crest)	 95 (≥ 80) 250 (≥ 200)	
Insulation level of secondary windings: • Power frequency 1 minute withstand voltage (kVrms)	 5	
34.5 kV bushings: • Number • Rated voltage (kVrms) • Material • Creepage length (mm)	 2 52 Porcelain, brown ≥1,050 (≥950)	
Dimensions (mm) • Height • Length • Width	 — — —	
Total mass (kg)	—	

TABLE B.8

Protection Relays and Control Panel

PROTECTION RELAYS AND CONTROL PANEL	REQUIRED	TENDERED
Manufacturer's name and country	—	
Type designation		
Standards applicable	IEC 255	
Installation	Indoor	
Characteristics of relays	See technical specifications	
Characteristics of metering instruments	See technical specifications	
Dimensions (mm) • Height • Length • Width	 — — —	
Total mass (kg)	—	

BOX B.1

Standards Applicable for Distribution Transformers (IEC, Latest Edition)

- IEC 60076: Parts from 1 to 10 - Power Transformers
- IEC 296: Specifications for unused mineral insulating oil for transformers and switchgears

TABLE B.9

Three-Phase Distribution Transformer, 100 kVA

THREE-PHASE DISTRIBUTION TRANSFORMER – 100 kVA	REQUIRED	TENDERED
Manufacturer's name and country	—	
Type designation	—	
Type	Oil immersed	
Installation	Outdoor	
Rated power (ONAN cooling) (kVA)	100	
Number of phases	3	
Rated frequency (Hz)	50	
Rated voltages (at no-load):		
• Primary winding (kV)	34.5 (30)	
• Secondary winding (kV)	0.400–0.231	
Tappings on primary winding	$\pm 2 \times 2.5\%$	
Number of tapping positions	5	
Type of tap changer	Off-voltage	
Max. continuous operation voltage of windings:		
• Primary winding (kV)	36.5 (33)	
• Secondary winding (kV)	Value consistent with primary side	
Connection group:	Dyn 11	
• Primary winding	Delta connected, with one terminal permanently grounded	
• Secondary winding	Star, with neutral grounded	
Number of windings	2	
Impedance voltage on principal tapping at 75°C (%)	4	
No-load losses (W)	≤250	
No-load current (%)	≤1,5	
Load losses at 75°C (W)	≤1,400	
Sound level [power] (dB(A))	< 48	
Insulation class	A	
Cooling method	ONAN	

(*continued*)

TABLE B.9

Three-Phase Distribution Transformer, 100 kVA (*continued*)

THREE-PHASE DISTRIBUTION TRANSFORMER – 100 kVA	REQUIRED	TENDERED
Insulation levels, primary winding • Highest system voltage (kVrms) • Power frequency withstand voltage (kVrms) • Lightning impulse withstand voltage (1.2/50 μs) (kV peak)	 36.5 (33) 82.5 200	
Insulation levels, secondary winding • Highest system voltage (kVrms) • Power frequency withstand voltage (kVrms) • Lightning impulse withstand voltage (1.2/50 μs) (kV peak)	 (3.6) 10 20	
Induced withstand voltage of HV winding with tap-changer in intermediate position (34.5 kV) (kVrms)	82.5 (70)	
Temperature rises • Windings (average) (°C) • Top oil (°C) • Winding hot spot (°C) • Core surface (°C)	 ≤60 ≤55 ≤70 ≤75	
The transformer must withstand the short circuit special test as per IEC standard 60076 part 5, on units selected at random by the employer's inspector from each lot submitted to acceptance test. Execution of short circuit tests	Yes Will be decided at employer's discretion, after manufacturing of each lot of transformers	
Short circuit test reports performed on similar transformers in an independent test laboratory	Shall be enclosed to the offer	
Short circuit power of 34.5 kV supply network for short circuit test	Infinite	
Construction		
Characteristics of windings:		
Material:		
• Primary	Cu	
• Secondary	Cu, or Al to be informed in the tender	
• Cross section	Uniform	
• Current density in copper (A/mm^2)	HV: ≤ 3; LV: ≤ 3	
Magnetic core		
Type	3 legged	
Material	Cold rolled grain oriented silicon steel	
Flux density at rated voltage and frequency, with mean tap (tesla)	≤ 1.65	
Bushings characteristics	IEC 137	
Type	Porcelain	

THREE-PHASE DISTRIBUTION TRANSFORMER – 100 kVA	REQUIRED	TENDERED
Primary bushings		
Rated voltage as per IEC 60694 (kV)	38	
Rated current (A)	≥ 250	
Withstand test voltage		
• 50 Hz-1 minute wet (kVrms)	≥ 82.5	
• Lightning impulse (1.2/50 μs) (kV crest)	≥ 200	
Creepage distance (mm)	≥ 1,050 (≥ 950)	
Secondary bushings		
• Insulation level (kV)	1.1	
Rated current (Arms)	≥ 400	
Withstand test voltage		
• 50 Hz-1 minute (kVrms)	10	
• Lightning impulse 1.2/50 μs (kV crest)	20	
Bushings number		
• Primary	3	
• Secondary	4	
Tank	Rib type	
Valves and bolts	Made of corrosion resistant material	
Painting		
• Internal surfaces, including the conservator	Protected against hot oil at a temperature of 105°C	
• External surfaces	For tropical environment, as specified in detail in the order	
Accessories required • Conservator • Oil level indicator • Oil filling plug • Pocket thermometer dial type • Skid • Filling and draining valves • Lifting eyes • Hitching holes • Rating plate	Yes	

(*continued*)

TABLE B.9

Three-Phase Distribution Transformer, 100 kVA (*continued*)

THREE-PHASE DISTRIBUTION TRANSFORMER – 100 kVA	REQUIRED	TENDERED
Overall dimensions (mm) • Height • Length • Width		
Mass • Total mass (kg) • Oil (kg)		
Alternative bid for tank hermetically sealed, for life:		
Tank	With corrugated walls completely full of oil	
Max. internal pressure between 0°C and 110°C (bar)	0,3	
Endurance test	5,000 cycles, with the oil volume variation between 0°C and 110°C	
Functions of the integrated protection relay	Gas; over temperature (alarm and trip); over pressure	

TABLE B.10

Three-Phase Distribution Transformer, 200 kVA

THREE-PHASE DISTRIBUTION TRANSFORMER – 200 kVA	REQUIRED	TENDERED
Manufacturer's name and country	—	
Type designation	—	
Type	Oil immersed	
Installation	outdoor	
Rated power (ONAN cooling) (kVA)	**200**	
Number of phases	3	
Rated frequency (Hz)	50	
Rated voltages (at no-load):		
• Primary winding (kV)	34.5 (30)	
• Secondary winding (kV)	0.400–0.231	
Tappings on primary winding	$\pm 2 \times 2.5\%$	
Number of tapping positions	5	
Type of tap changer	Off-voltage	

THREE-PHASE DISTRIBUTION TRANSFORMER – 200 kVA	REQUIRED	TENDERED
Max. continuous operation voltage of windings:		
• Primary winding (kV)	36.5 (33)	
• Secondary winding (kV)	Value consistent with primary side	
Connection group;	Dyn 11	
• Primary winding	Delta connected, with one terminal permanently grounded	
• Secondary winding	Star, with neutral grounded	
Number of windings	2	
Impedance voltage on principal tapping at 75°C (%)	4	
No-load losses (W)	≤440	
No-load current (%)	≤1.2	
Load losses at 75°C (W)	≤2,200	
Sound level [power] (dB(A))	< 51	
Insulation class	A	
Cooling method	ONAN	
Insulation levels, primary winding • Highest system voltage (kVrms) • Power frequency withstand voltage (kVrms) • Lightning impulse withstand voltage (1.2/50 μs) (kV peak)	 36.5 (30) 82.5 200	
Insulation levels, secondary winding • Highest system voltage (kVrms) • Power frequency withstand voltage (kVrms) • Lightning impulse withstand voltage (1.2/50 μs) (kV peak)	 (3.6) 10 20	
Induced withstand voltage of HV winding with tap-changer in intermediate position (34.5 kV) (kVrms)	82.5 (70)	
Temperature rises • Windings (average) (°C) • Top oil (°C) • Winding hot spot (°C) • Core surface (°C)	 ≤60 ≤55 ≤70 ≤75	
The transformer must withstand the short circuit special test as per IEC standard 60076 part 5, on units selected at random by the employer's inspector from each lot submitted to acceptance test. Execution of short circuit tests	Yes Will be decided at the employer's discretion, after manufacturing of each lot of transformers	

(*continued*)

TABLE B.10

Three-Phase Distribution Transformer, 200 kVA (*continued*)

THREE-PHASE DISTRIBUTION TRANSFORMER – 200 kVA	REQUIRED	TENDERED
Short circuit test reports performed on similar transformers in an independent test laboratory	Shall be enclosed to the offer	
Short circuit power of 34.5 kV supply network for short circuit test	Infinite	
Construction		
Characteristics of windings:		
Material:		
• Primary	Cu	
• Secondary	Cu, or Al, to be informed in the tender	
• Cross section	Uniform	
• Current density in copper (A/mm^2)	HV: ≤ 3; LV: ≤ 3	
Magnetic core		
Type	3 legged	
Material	Cold rolled grain oriented silicon steel	
Flux density at rated voltage and frequency, with mean tap (tesla)	≤ 1.65	
Bushings characteristics	IEC 137	
Type	Porcelain	
Primary bushings		
Rated voltage as per IEC 60694 (kV)	38	
Rated current (A)	≥ 250	
Withstand test voltage		
• 50 Hz-1 minute wet (kVrms)	≥ 82.5	
• Lightning impulse (1.2/50 μs) (kV crest)	≥ 200	
Creepage distance (mm)	≥ 1,050 (≥ 950)	
Secondary bushings • Insulation level (kV)	1.1	
Rated current I (A)	≥ 630	
Withstand test voltage		
• 50 Hz-1 minute (kVrms)	10	
• Lightning impulse (1.2/50 μs) (kV crest)	20	

THREE-PHASE DISTRIBUTION TRANSFORMER – 200 kVA	REQUIRED	TENDERED
Bushings number		
• Primary	3	
• Secondary	4	
Tank	Rib type	
Valves and bolts	Made of corrosion resistant material	
Painting		
• Internal surfaces, including the conservator	Protected against hot oil at a temperature of 105°C	
• External surfaces	For tropical environment, as specified in detail in the order	
Accessories required • Conservator • Oil level indicator • Oil filling plug • Pocket thermometer dial type • Skid • Filling and draining valves • Lifting eyes • Hitching holes • Rating plate	Yes	
Overall dimensions (mm) • Height • Length • Width		
Mass • Total mass (kg) • Oil (kg)		
Alternative bid for tank hermetically sealed, for life:		
Tank	With corrugated walls completely full of oil	
Max. internal pressure between 0°C and 110°C (bar)	0.3	
Endurance test	5,000 cycles, with the oil volume variation between 0°C and 110°C	
Functions of the integrated protection relay	Gas; over temperature (alarm and trip); over pressure	

TABLE B.11

Three-Phase Distribution Transformer, 315 kVA

THREE-PHASE DISTRIBUTION TRANSFORMER – 315 kVA	REQUIRED	TENDERED
Manufacturer's name and country	—	
Type designation	—	
Type	Oil immersed	
Installation	Outdoor	
Rated power (ONAN cooling) (kVA)	315	
Number of phases	3	
Rated frequency (Hz)	50	
Rated voltages (at no-load):		
• Primary winding (kV)	34.5 (30)	
• Secondary winding (kV)	0.400–0.231	
Tappings on primary winding	$\pm 2 \times 2.5\%$	
Number of tapping positions	5	
Type of tap changer	Off-voltage	
Max. continuous operation voltage of windings:		
• Primary winding (kV)	36.5 (33)	
• Secondary winding (kV)	Value consistent with primary side	
Connection group:	Dyn 11	
• Primary winding	Delta connected, with one terminal permanently grounded	
• Secondary winding	Star, with neutral grounded	
Number of windings	2	
Impedance voltage on principal tapping at 75°C (%)	4	
No-load losses (W)	≤ 620	
No-load current (%)	≤ 1	
Load losses at 75°C (W)	$\leq 3{,}000$	
Sound level [power] (dB(A))	< 53	
Insulation class	A	

THREE-PHASE DISTRIBUTION TRANSFORMER – 315 kVA	REQUIRED	TENDERED
Cooling method	ONAN	
Insulation levels, primary winding • Highest system voltage (kVrms) • Power frequency withstand voltage (kVrms) • Lightning impulse withstand voltage (1.2/50 µs) (kV peak)	 36.5 (33) 82.5 200	
Insulation levels, secondary winding • Highest system voltage (kVrms) • Power frequency withstand voltage (kVrms) • Lightning impulse withstand voltage (1.2/50 µs) (kV peak)	 (3.6) 10 20	
Induced withstand voltage of HV winding with tap-changer in intermediate position (34.5 kV) (kVrms)	82.5 (70)	
Temperature rises • Windings (average) (°C) • Top oil (°C) • Winding hot spot (°C) • Core surface (°C)	 ≤ 60 ≤ 55 ≤ 70 ≤ 75	
The transformer must withstand the short circuit special test as per IEC standard 60076 part 5, on units selected at random by the employer's inspector from each lot submitted to acceptance test. Execution of short circuit tests	Yes Will be decided at the employer's discretion, after manufacturing of each lot of transformers	
Short circuit test reports performed on similar transformers in an independent test laboratory	Shall be enclosed to the offer	
Short circuit power of 34.5 kV supply network for short circuit test	Infinite	
Construction		
Characteristics of windings:		
Material:		
• Primary	Cu	
• Secondary	Cu, or Al, to be informed in the tender	
• Cross section	Uniform	
• Current density in copper (A/mm^2)	HV: ≤ 3; LV: ≤ 3	

(*continued*)

TABLE B.11

Three-Phase Distribution Transformer, 315 kVA (*continued*)

THREE-PHASE DISTRIBUTION TRANSFORMER – 315 kVA	REQUIRED	TENDERED
Magnetic core		
Type	3 legged	
Material	Cold rolled grain oriented silicon steel	
Flux density at rated voltage and frequency, with mean tap (tesla)	≤ 1.65	
Bushings characteristics	IEC 137	
Type	Porcelain	
Primary bushings		
Rated voltage as per IEC 60694 (kV)	38	
Rated current (A)	≥ 250	
Withstand test voltage		
• 50 Hz-1 minute wet (kVrms)	≥ 82.5	
• Lightning impulse (1.2/50 μs) (kV crest)	≥ 200	
Creepage distance (mm)	≥ 1,050 (≥ 950)	
Secondary bushings • Insulation level (kV)	1.1	
Rated current I (A)	≥ 800	
Withstand test voltage		
• 50 Hz-1 minute (kVrms)	10	
• Lightning impulse (1.2/50 μs) (kV crest)	20	
Bushings number		
• Primary	3	
• Secondary	4	
Tank	Rib type	
Valves and bolts	Made of corrosion resistant material	
Painting		
• Internal surfaces, including the conservator	Protected against hot oil at a temperature of 105°C	
• External surfaces	For tropical environment, as specified in detail in the order	

THREE-PHASE DISTRIBUTION TRANSFORMER – 315 kVA	REQUIRED	TENDERED
Accessories required • Conservator • Oil level indicator • Oil filling plug • Pocket thermometer dial type • Skid • Filling and draining valves • Lifting eyes • Hitching holes • Rating plate	Yes	
Overall dimensions (mm) • Height • Length • Width		
Mass • Total mass (kg) • Oil (kg)		
Alternative bid for tank hermetically sealed, for life:		
Tank	With corrugated walls completely full of oil	
Max. internal pressure between 0°C and 110°C (bar)	0.3	
Endurance test	5,000 cycles, with the oil volume variation between 0°C and 110°C	
Functions of the integrated protection relay	Gas; over temperature (alarm and trip); over pressure	

TABLE B.12

Three-Phase Distribution Transformer, 630 kVA

THREE PHASE DISTRIBUTION TRANSFORMER – 630 kVA	REQUIRED	TENDERED
Manufacturer's name and country	—	
Type designation	—	
Type	Oil immersed	
Installation	Outdoor	
Rated power (ONAN cooling) (kVA)	630	
Number of phases	3	
Rated frequency (Hz)	50	

(*continued*)

TABLE B.12

Three-Phase Distribution Transformer, 630 kVA (*continued*)

THREE PHASE DISTRIBUTION TRANSFORMER – 630 kVA	REQUIRED	TENDERED
Rated voltages (at no-load):		
• Primary winding (kV)	34.5 (30)	
• Secondary winding (kV)	0.400–0.231	
Tappings on primary winding	$\pm 2 \times 2.5\%$	
Number of tapping positions	5	
Type of tap changer	Off-voltage	
Max. continuous operation voltage of windings:		
• Primary winding (kV)	36.5 (33)	
• Secondary winding (kV)	Value consistent with primary side	
Connection group:	Dyn 11	
• Primary winding	Delta connected, with one terminal permanently grounded	
• Secondary winding	Star, with neutral grounded	
Number of windings	2	
Impedance voltage on principal tapping at 75°C (%)	6	
No-load losses (W)	≤ 900	
No-load current (%)	≤ 0.8	
Load losses at 75°C (W)	$\leq 5{,}600$	
Sound level [power] (dB(A))	< 56	
Insulation class	A	
Cooling method	ONAN	
Insulation levels, primary winding • Highest system voltage (kVrms) • Power frequency withstand voltage (kVrms) • Lightning impulse withstand voltage (1.2/50 μs) (kV peak)	 36.5 (33) 82.5 200	
Insulation levels, secondary winding • Highest system voltage (kVrms) • Power frequency withstand voltage (kVrms) • Lightning impulse withstand voltage (1.2/50 μs) (kV peak)	 (3.6) 10 20	
Induced withstand voltage of HV winding with tap-changer in intermediate position (34.5 kV) (kVrms)	82.5 (70)	

THREE PHASE DISTRIBUTION TRANSFORMER – 630 kVA	REQUIRED	TENDERED
Temperature rises • Windings (average) (°C) • Top oil (°C) • Winding hot spot (°C) • Core surface (°C)	 ≤ 60 ≤ 55 ≤ 70 ≤ 75	
The transformer must withstand the short circuit special test as per IEC standard 60076 part 5, on units selected at random by the employer's inspector from each lot submitted to acceptance test. Execution of short circuit tests	Yes Will be decided at the employer's discretion, after manufacturing of each lot of transformers	
Short circuit test reports performed on similar transformers in an independent test laboratory	Shall be enclosed to the offer	
Short circuit power of 34.5 kV supply network for short circuit test	Infinite	
Construction		
Characteristics of windings:		
Material:		
• Primary	Cu	
• Secondary	Cu, or Al, to be informed in the tender	
• Cross section	Uniform	
• Current density in copper (A/mm^2)	HV: ≤ 3; LV: ≤ 3	
Magnetic core		
Type	3 legged	
Material	Cold rolled grain oriented silicon steel	
Flux density at rated voltage and frequency, with mean tap (tesla)	≤ 1.65	
Bushings characteristics	IEC 137	
Type	Porcelain	
Primary bushings		
Rated voltage as per IEC 60694 (kV)	38	
Rated current (A)	≥ 250	

(*continued*)

TABLE B.12

Three-Phase Distribution Transformer, 630 kVA (*continued*)

THREE PHASE DISTRIBUTION TRANSFORMER – 630 kVA	REQUIRED	TENDERED
Withstand test voltage		
• 50 Hz-1 minute wet (kVrms)	≥ 82.5	
• Lightning impulse (1.2/50 µs) (kV crest)	≥ 200	
Creepage distance (mm)	≥ 1,050 (≥ 950)	
Secondary bushings • Insulation level (kV)	1.1	
Rated current I (A)	≥ 1,250	
Withstand test voltage		
• 50 Hz-1 minute (kVrms)	10	
• Lightning impulse (1.2/50 µs) (kV crest)	20	
Bushings number		
• Primary	3	
• Secondary	4	
Tank	Rib type	
Valves and bolts	Made of corrosion resistant material	
Painting		
• Internal surfaces, including the conservator	Protected against hot oil at a temperature of 105°C	
• External surfaces	For tropical environment, as specified in detail in the order	
Accessories required • Conservator • Oil level indicator • Oil filling plug • Pocket thermometer dial type • Skid • Filling and draining valves • Lifting eyes • Hitching holes • Rating plate	Yes	
Overall dimensions (mm) • Height • Length • Width		

THREE PHASE DISTRIBUTION TRANSFORMER – 630 kVA	REQUIRED	TENDERED
Mass • Total mass (kg) • Oil (kg)		
Alternative bid for tank hermetically sealed, for life:		
Tank	With corrugated walls completely full of oil	
Max. internal pressure between 0°C and 110°C (bar)	0.3	
Endurance test	5,000 cycles, with the oil volume variation between 0°C and 110°C	
Functions of the integrated protection relay	Gas; over temperature (alarm and trip); over pressure	

TABLE B.13

Three-Phase Distribution Transformer, 800 kVA

THREE-PHASE DISTRIBUTION TRANSFORMER – 800 kVA	REQUIRED	TENDERED
Manufacturer's name and country	—	
Type designation	—	
Type	Oil immersed	
Installation	Outdoor	
Rated power (ONAN cooling) (kVA)	800	
Number of phases	3	
Rated frequency (Hz)	50	
Rated voltages (at no-load):		
• Primary winding (kV)	34.5 (30)	
• Secondary winding (kV)	0.400–0.231	
Tappings on primary winding	$\pm 2 \times 2.5\%$	
Number of tapping positions	5	
Type of tap changer	Off-voltage	
Max. continuous operation voltage of windings:		
• Primary winding (kV)	36.5	
• Secondary winding (kV)	Value consistent with primary side	

(*continued*)

TABLE B.13

Three-Phase Distribution Transformer, 800 kVA (*continued*)

THREE-PHASE DISTRIBUTION TRANSFORMER – 800 kVA	REQUIRED	TENDERED
Connection group:	Dyn 11	
• Primary winding	Delta connected, with one terminal permanently grounded	
• Secondary winding	Star, with neutral grounded	
Number of windings	2	
Impedance voltage on principal tapping at 75°C (%)	6	
No-load losses (W)	≤ 1,100	
No-load current (%)	≤ 0.75	
Load losses at 75°C (W)	≤ 7,200	
Sound level [power] (dB(A))	< 58	
Insulation class	A	
Cooling method	ONAN	
Insulation levels, primary winding • Highest system voltage (kVrms) • Power frequency withstand voltage (kVrms) • Lightning impulse withstand voltage (1.2/50 μs) (kV peak)	 36.5 (33) 82.5 200	
Insulation levels, secondary winding • Highest system voltage (kVrms) • Power frequency withstand voltage (kVrms) • Lightning impulse withstand voltage (1.2/50 μs) (kV peak)	 (3.6) 10 20	
Induced withstand voltage of HV winding with tap-changer in intermediate position (34.5 kV) (kVrms)	82.5 (70)	
Temperature rises • Windings (average) (°C) • Top oil (°C) • Winding hot spot (°C) • Core surface (°C)	 ≤ 60 ≤ 55 ≤ 70 ≤ 75	
The transformer must withstand the short circuit special test as per IEC standard 60076 part 5, on units selected at random by the employer's inspector from each lot submitted to acceptance test. Execution of short circuit tests	Yes Will be decided at the employer's discretion, after manufacturing of each lot of transformers	
Short circuit test reports performed on similar transformers in an independent test laboratory	Shall be enclosed to the offer	
Short circuit power of 34.5 kV supply network for short circuit test	Infinite	

THREE-PHASE DISTRIBUTION TRANSFORMER – 800 kVA	REQUIRED	TENDERED
Construction		
Characteristics of windings:		
Material:		
• Primary	Cu	
• Secondary	Cu, or Al, to be informed in the tender	
• Cross section	Uniform	
• Current density in copper (A/mm^2)	HV: ≤ 3; LV: ≤ 3	
Magnetic core		
Type	3 legged	
Material	Cold rolled grain oriented silicon steel	
Flux density at rated voltage and frequency, with mean tap (tesla)	≤ 1.65	
Bushings characteristics	IEC 137	
Type	Porcelain	
Primary bushings		
Rated voltage as per IEC 60694 (kV)	38	
Rated current (A)	≥ 250	
Withstand test voltage		
• 50 Hz-1 minute wet (kVrms)	≥ 82.5	
• Lightning impulse (1.2/50 µs) (kV crest)	≥ 200	
Creepage distance (mm)	≥ 1,050 (≥ 950)	
Secondary bushings • Insulation level (kV)	1.1	
Rated current I (A)	≥ 1,600	
Withstand test voltage		
• 50 Hz-1 minute (kVrms)	10	
• Lightning impulse (1.2/50 µs) (kV crest)	20	

(*continued*)

TABLE B.13

Three-Phase Distribution Transformer, 800 kVA (*continued*)

THREE-PHASE DISTRIBUTION TRANSFORMER – 800 kVA	REQUIRED	TENDERED
Bushings number		
• Primary	3	
• Secondary	4	
Tank	Rib type	
Valves and bolts	Made of corrosion resistant material	
Painting		
• Internal surfaces, including the conservator	Protected against hot oil at a temperature of 105°C	
• External surfaces	For tropical environment, as specified in detail in the order	
Accessories required • Conservator • Oil level indicator • Oil filling plug • Pocket thermometer dial type • Skid • Filling and draining valves • Lifting eyes • Hitching holes • Rating plate	Yes	
Overall dimensions (mm) • Height • Length • Width		
Mass • Total mass (kg) • Oil (kg)		
Alternative bid for tank hermetically sealed, for life:		
Tank	With corrugated walls completely full of oil	
Max. internal pressure between 0°C and 110°C (bar)	0.3	
Endurance test	5,000 cycles, with the oil volume variation between 0°C and 110°C	
Functions of the integrated protection relay	Gas; over temperature (alarm and trip); over pressure	

TABLE B.14

Single-Phase Distribution Transformer, 50 kVA

SINGLE PHASE DISTRIBUTION TRANSFORMER – 50 kVA	REQUIRED	TENDERED
Manufacturer's name and country	—	
Type designation	—	
Type	Oil immersed	
Installation	Outdoor	
Rated power (ONAN cooling) (kVA)	50	
Number of phases	1	
Rated frequency (Hz)	50	
Rated voltages (at no-load): • Primary winding (kV) • Secondary winding (kV) • Between the two energized terminals of secondary winding (kV)	 34.5 (30) 0.231 – 0 – 0.231 0.462	
Tappings on primary winding	$\pm 2 \times 2.5\%$	
Number of tapping positions	5	
Type of tap changer	Off-voltage	
Max. continuous operation voltage of windings • Primary winding (kV) • Secondary winding (kV)	 36.5 (33) Values consistent with HV side	
Number of windings • HV • LV	 1 or 2 in parallel, according to design type 2	
Impedance voltage on principal tapping, at 75°C (%) (to be measured at half power on each of the two secondary windings with the other open)	4	
No-load losses (W)	≤ 150	
No-load current (%)	≤ 1.9	
Load losses at 75°C (W)	≤ 850	
Sound level [power] (dB(A))	< 46	
Insulation class	A	
Cooling method	ONAN	

(*continued*)

TABLE B.14

Single-Phase Distribution Transformer, 50 kVA (*continued*)

SINGLE PHASE DISTRIBUTION TRANSFORMER – 50 kVA	REQUIRED	TENDERED
Insulation levels, primary winding • Highest system voltage (kVrms) • Power frequency withstand voltage (kVrms) • Lightning impulse withstand voltage (1.2/50 µs) (kV peak)	 36.5 (33) 82.5 200	
Insulation levels, secondary winding • Highest system voltage (kVrms) • Power frequency withstand voltage (kVrms) • Lightning impulse withstand voltage (1.2/50 µs) (kV peak)	 (3.6) 10 20	
Induced withstand voltage of HV winding with tap-changer in intermediate position (34.5 kV) (kVrms)	82.5 (70)	
Temperature rises • Windings (average) (°C) • Top oil (°C) • Winding hot spot (°C) • Core surface (°C)	 ≤ 60 ≤ 55 ≤ 70 ≤ 75	
The transformer must withstand the short circuit special test as per IEC standard 60076 part 5, on units selected at random by purchaser inspector from each lot submitted to acceptance test.	Yes	
Execution of short circuit tests as per previous clause	Will be decided, at the employer's discretion, after manufacturing of each lot of transformers	
Short circuit test reports performed on similar transformers in an independent test laboratory	Shall be enclosed to the offer	
Short circuit power of 34.5 kV supply network for short circuit test	Infinite	
Winding configuration	To ensure stable secondary voltages with one secondary winding at full load and the other at no-load	
Characteristics of windings:		
Material: • Primary • Secondary • Cross section • Current density in copper (A/mm²)	 Cu Cu or Al, to be informed in tender Uniform HV: ≤ 3; LV: ≤ 3	
Magnetic core		
Type	Stacked or wound	
Material	Cold rolled grain oriented silicon steel	
Flux density at rated voltage and frequency, with mean tap (tesla)	≤ 1.65	
Bushings characteristics • Standards • Type	 IEC 137 Porcelain	

SINGLE PHASE DISTRIBUTION TRANSFORMER – 50 kVA	REQUIRED	TENDERED
Primary bushings • Rated voltage as per IEC 60694 (kV) • Rated current (A) • Withstand test voltage - 50 Hz-1 minute wet (kVrms) - Lightning impulse (1.2/50 μs) (kV crest) • Creepage distance (mm)	 38 ≥ 250 ≥ 82.5 ≥ 200 ≥ 1,050 (≥ 950)	
Secondary bushings • Insulation level (kV) • Rated current, I (A)	 1.1 ≥ 400	
Withstand test voltage • 50 Hz-1 minute (kVrms) • Lightning impulse (1.2/50 μs) (kV peak)	 10 20	
Bushings number • Primary • Secondary	 2 3	
Tank	Rib type	
Valves and bolts	Made of corrosion resistant material	
Painting		
• The internal surfaces including the conservator, shall be protected against hot oil at a temperature of 105°C	Yes	
• The external surfaces shall be painted with a cycle suitable for heavy environment conditions.	Yes	
Accessories required		
• Conservator • Oil level indicator • Oil filling plug • Pocket thermometer dial type • Skid • Filling and draining valves • Lifting eyes • Hitching holes • Rating plate	Yes	
Overall dimensions (mm) • Length • Width • Height		
Mass • Total (kg) • Oil (kg)		

(*continued*)

TABLE B.14

Single-Phase Distribution Transformer, 50 kVA (*continued*)

SINGLE PHASE DISTRIBUTION TRANSFORMER – 50 kVA	REQUIRED	TENDERED
Alternative bid for tank hermetically sealed for life:		
• Tank	With corrugated walls completely full of oil	
• Max. internal pressure between 0°C and 110°C (bar)	0.3	
• Endurance test	5,000 cycles, with the oil volume variation between 0°C and 110°C	
• Functions of the integrated protection relay	Gas; over temperature (alarm and trip); over pressure	

TABLE B.15

Single-Phase Distribution Transformer, 100 kVA

SINGLE-PHASE DISTRIBUTION TRANSFORMER – 100 kVA	REQUIRED	TENDERED
Manufacturer's name and country	—	
Type designation	—	
Type	Oil immersed	
Installation	Outdoor	
Rated power (ONAN cooling) (kVA)	100	
Number of phases	1	
Rated frequency (Hz)	50	
Rated voltages (at no-load) • Primary winding (kV) • Secondary winding (kV) • Between the two energized terminals of secondary winding (kV)	 34.5 (30) 0.231 – 0 – 0.231 0.462	
Tappings on primary winding	$\pm 2 \times 2.5\%$	
Number of tapping positions	5	
Type of tap changer	Off-voltage	
Max. continuous operation voltage of windings • Primary winding (kV) • Secondary winding (kV)	 36.5 (33) Values consistent with HV side	
Number of windings • HV • LV	 1 or 2 in parallel, according to design type 2	
Impedance voltage on principal tapping, at 75°C (%) (to be measured at half power on each of the two secondary windings with the other open)	4	

SINGLE-PHASE DISTRIBUTION TRANSFORMER – 100 kVA	REQUIRED	TENDERED
No-load losses (W)	≤ 250	
No-load current (%)	≤ 1.5	
Load losses at 75°C (W)	≤ 1,400	
Sound level [power] (dB(A))	< 48	
Insulation class	A	
Cooling method	ONAN	
Insulation levels, primary winding • Highest system voltage (kVrms) • Power frequency withstand voltage (kVrms) • Lightning impulse withstand voltage (1.2/50 μs) (kV peak)	 36.5 (33) 82.5 200	
Insulation levels, secondary winding • Highest system voltage (kVrms) • Power frequency withstand voltage (kVrms) • Lightning impulse withstand voltage (1.2/50 μs) (kV peak)	 (3.6) 10 20	
Induced withstand voltage of HV winding with tap-changer in intermediate position (34.5 kV) (kVrms)	82.5 (70)	
Temperature rises • Windings (average) (°C) • Top oil (°C) • Winding hot spot (°C) • Core surface (°C)	 ≤ 60 ≤ 55 ≤ 70 ≤ 75	
The transformer must withstand the short circuit special test as per IEC standard 60076 part 5, on units selected at random by the purchaser inspector from each lot submitted to acceptance test.	Yes	
Execution of short circuit tests as per previous clause	Will be decided, at the employer's discretion, after manufacturing of each lot of transformers	
Short circuit test reports performed on similar transformers in an independent test laboratory	Shall be enclosed to the offer	
Short circuit power of 34.5 kV supply network for short circuit test	Infinite	
Winding configuration	To ensure stable secondary voltages with one secondary winding at full load and the other at no-load	

(*continued*)

TABLE B.15

Single-Phase Distribution Transformer, 100 kVA (*continued*)

SINGLE-PHASE DISTRIBUTION TRANSFORMER – 100 kVA	REQUIRED	TENDERED
Characteristics of windings:		
Material: • Primary • Secondary • Cross section • Current density in copper (A/mm^2)	 Cu Cu or Al, to be informed in the tender Uniform HV: ≤ 3; LV: ≤ 3	
Magnetic core		
Type	Stacked or wound	
Material	Cold rolled grain oriented silicon steel	
Flux density at rated voltage and frequency, with mean tap (tesla)	≤ 1.65	
Bushings characteristics • Standards • Type	 IEC 137 Porcelain	
Primary bushings • Rated voltage as per IEC 60694 (kV) • Rated current (A)	 38 ≥ 250	
• Withstand test voltage - 50 Hz-1 minute wet (kVrms) - Lightning impulse (1.2/50 μs) (kV crest)	 ≥ 82.5 ≥ 200	
• Creepage distance (mm)	≥ 1,050 (≥ 950)	
Secondary bushings • Insulation level (kV) • Rated current, I (A)	 1.1 ≥ 800	
• Withstand test voltage - 50 Hz-1 minute wet (kVrms) - Lightning impulse (1.2/50 μs) (kV crest)	 10 20	
Bushings number • Primary • Secondary	 2 3	
Tank	Rib type	
Valves and bolts	Made of corrosion resistant material	

SINGLE-PHASE DISTRIBUTION TRANSFORMER – 100 kVA	REQUIRED	TENDERED
Painting		
• The internal surfaces, including the conservator, shall be protected against hot oil at a temperature of 105°C	Yes	
• The external surfaces shall be painted with a cycle suitable for heavy environment conditions.	Yes	
Accessories required		
• Conservator • Oil level indicator • Oil filling plug • Pocket thermometer dial type • Skid • Filling and draining valves • Lifting eyes • Hitching holes • Rating plate	Yes	
Overall dimensions (mm) • Length • Width • Height		
Mass • Total (kg) • Oil (kg)		
Alternative bid for tank hermetically sealed for life:		
• Tank	With corrugated walls completely full of oil	
• Max. internal pressure between 0°C and 110°C (bar)	0.3	
• Endurance test	5,000 cycles, with the oil volume variation between 0°C and 110°C	
• Functions of the integrated protection relay	Gas; over temperature (alarm and trip); over pressure	

TABLE B.16

Fused Cut-Outs

FUSED CUT-OUTS	REQUIRED	TENDERED
Manufacturer's name and country	—	
Manufacturer's type designation	—	
Standards	IEC 62271-105 or corresponding ANSI Standards	
Rated voltage (kV rms)	38 (36)	
Highest operation voltage (kV rms)	36.5 (33)	
Rated current (A rms)	≥100	
Rated frequency (Hz)	50	
Number of poles	1	
Operating device	Manual, with insulating stick	
Short time current rating • 1 s momentary rating (kArms) • dynamic (kA, peak)	 ≥ 5 ≥ 12.5	
1 min power frequency withstand voltage, wet (rain at ANSI standards): • Phase-to-ground (kVrms) • Across the isolating distance (kVrms)	 85 (70) 88 (80)	
Lightning impulse 1.2/50 μs withstand voltage, dry: • Phase-to-ground (kV peak) • Across isolating distance (kV peak)	 200 (170) 195	
Insulators • Material • Creepage length, phase-to-ground and between terminals (mm) • Insulators' arrangement	 Porcelain, brown ≥ 1,050 (≥ 950) as per technical specification	
Fuse holder type	Drop-out if fuse is melted	
Fuse link current – time characteristic	K type	
Fuse links rated current (Arms)	Shall be informed in the order (3, 5, 10, 15, 20, 25, 30)	
Mechanical terminal load (daN)		
Reference drawing	Attached to tender	
Weight of complete cut out (kg)	—	

TABLE B.17

Load Break Interrupters

LOAD BREAK DISCONNECTOR	REQUIRED	TENDERED
Manufacturer's name and country	—	
Manufacturer's type designation	—	
Standards	IEC 62271-103	
Rated voltage (kV rms)	38 (36)	
Highest operation voltage (kV rms)	36.5 (33)	
Rated frequency (Hz)	50	
Number of poles	Bipolar	
Rated current (A rms)	400	
Rated breaking currents (Arms) • Load and loop current • Line capacitive current • Transformer no-load current	 400 ≥ 10 ≥ 10	
Short time current rating • 1 s momentary rating (kA rms) • dynamic (kA, peak)	 8 20	
Operating mechanism • Type	 Spring type, manual level, free tripping	
• Height of installation on poles above ground level (m)	Up to 9	
• Installation	Horizontal or vertical	
Power frequency withstand voltage, wet (rain at ANSI standards): - Phase-to-ground, phase-to-phase (kVrms) - Across the isolating distance (kVrms)	 85 (70) 88 (80)	
Lightning impulse 1.2/50 µs withstand voltage, dry: • Phase-to-ground and phase-to-phase (kV peak) • Across open contacts (kV peak)	 200 (170) 195	
Insulators • Material • Creepage distance (mm)	 Porcelain, brown ≥1,050 (≥ 950)	
Mechanical terminal load (daN)	—	
Reference drawing	Attached to tender	
Weight of complete cut out (kg)	—	

BOX B.2

Capacitor Banks

Capacitor banks are intended to be used for the following purposes:

- To avoid ferroresonance phenomena
- For power factor correction
- To balance the shunt capacitances of the shield wire line.

TABLE B.18

Capacitor Banks

CAPACITOR BANKS	REQUIRED	TENDERED
Manufacturer's name and country	—	
Type designation	—	
Standard applicable	IEC 60871 - Parts 1 and 2	
System ratings		
Rated operation voltage (kV)	34.5 (30)	
Rated frequency (Hz)	50	
Number of system phases	3 (2 insulated; 1 grounded)	
Max. continuous operation voltage (kV)	36.5 (33)	
A. Characteristics of single-phase capacitor banks		
Electrical ratings		
Rated voltage (kV)	48 (42)	
Rated capacitance (nF): C_{WW} = capacitance of each bank connected between the two shield wires C_{WG} = capacitance of each bank connected between each shield wire and ground To be specified for each ISWS, on the basis of the results of the operation analyses performed with the ad-hoc computer program		
Rated frequency (Hz)	50	
Number of phases	1	

CAPACITOR BANKS	REQUIRED	TENDERED
Capacitor banks output at system rated voltage of 34.5 (30) kV (kVAr): To be specified for each ISWS, on the basis of the results of the operation analyses performed with the ad-hoc computer program		
Number of single-phase banks to be supplied: To be specified for each rated kVAr (and capacitance) on the basis of the results of the computer analyses	— —	
Insulation levels of capacitor banks		
• Highest system voltage	52 (45)	
• Power frequency withstand voltage, 1 minute (wet test for supporting insulator) (kVrms)	95	
• 1.2/50 μs impulse withstand voltage for supporting insulator (kV crest)	250	
Installation	Outdoor	
Construction		
Each single-phase bank is composed of: • 2 capacitor units connected in series (see figure C.1a and C.1b in Annex C) with the characteristics specified in section B of this table. • 1 support frame made of hot-dip galvanized steel or aluminum alloy • 1 support insulator	 Yes Yes Yes	
B. Characteristics of capacitor units		
• Electrical ratings		
• Rated voltage (kV)	24 (21)	
• Max. continuous operation voltage of units (kVrms)	18.25 (16.5)	
• Rated frequency (Hz)	50	
Rated capacitances of C^1_{WW}/C^1_{WG}: To be specified for each ISWS on the basis of the results of the computer analyses		
Unit outputs at rated voltage of 24 kV (kVAr): To be specified for each ISWS on the basis of the results of the computer analyses		
Unit outputs at normal operation voltage of 34.5/2 kV (30 kV/÷2 kV) (kVAr): To be specified for each ISWS on the basis of the results of the computer analyses		
Tan delta max. %	0.02	

(*continued*)

TABLE B.18

Capacitor Banks (*continued*)

CAPACITOR BANKS	REQUIRED	TENDERED
Temperature category (°C)	–25/+45	
AC routine voltage test between terminals (50 Hz, 10 s) (kVrms)[a]	51.6 (45)	
Insulation level of capacitor units		
• Rated voltage (kV)	24 (21)	
• Power frequency withstand voltage, 1 minute (wet test for capacitor bushing) (kVrms)	50	
• 1.2/50 µs lightning impulse withstand voltage (kV crest) (only on capacitor bushing)	125	
Installation	Outdoor	
Construction		
Type of construction	1 bushing	
Hermetically sealed case	Stainless steel	
Fuses: • External • Internal	 Not allowed Acceptable, not mandatory	
Internal discharge resistors	Required	
Dielectric	All polypropylene film	
Max dielectric stress (V/µ)	60	
Oil, biodegradable, and nontoxic	PCB free	
Overall dimensions of capacitor bank (mm) • Length • Width • Height		
Mass		
- Total (kg)		. . . .

[a]*This routine test cannot be replaced by the direct current alternative test foreseen in the IEC standards.*

TABLE B.19

Rigid Insulator Strings: Alternative A

RIGID INSULATOR STRINGS	REQUIRED	TENDERED
Manufacturer's name and country	—	
Type	Rigid string with protective arcing horns	
Highest operation voltage, phase-to-ground (kV rms)	36.5 (33)	
Material and coupling:		
• Insulator discs • Cap and pin • Coupling	Toughened glass — Rigid	
Number of glass insulators per string	4	
Diameter of glass discs (mm)	255	
Spacing between discs: • Altitude ≤ 1,000 m above sea level (mm) • Altitude of 1,000 to 2,200 m above sea level (mm)	 108 120	
Creepage distance (mm)	1,200	
Length of insulator string (from coupling with tower U bolt and coupling with suspension clamp) (see figure C.9.a of Annex C) • Disc spacing of 108 mm • Disc spacing of 120 mm	 550 585	
Dry lightning impulse withstand voltage, without arcing horns: • Disc spacing of 108 mm (kV peak) • Disc spacing of 120 mm (kV peak)	 270 295	
Dry power frequency withstand voltage without arcing horn: • Disc spacing of 108 mm (kVrms) • Disc spacing of 120 mm (kVrms)	 190 200	
Wet power frequency withstand voltage, without arcing horn (rain at ANSI standards): • Disc spacing of 108 mm (kVrms) • Disc spacing of 120 mm (kVrms)	 130 143	
Electromechanical and mechanical failing load	≥ 50	
Gap distance between arcing horns, adjustable: • Disc spacing of 108 mm, range (mm) • Disc spacing of 120 mm, range (mm)	 200 to 360 240 to 400	
Additional requirement for tension strings	Bird anti-perching spike (see figure C.9a in Annex C)	
Weight of rigid string • Suspension set (kg) • Tension set (kg)		
Standards in force	IEC 60381-1	

BOX B.3

Cap and Pin 34.5 kV Insulator Strings: Alternative B applicable in the spur lines which supply the villages from the SWLs

The glass or porcelain cap and pin tension insulator strings used in the conventional 33 kV lines, formed by three units of type U70BL, are applicable as an alternative to the rigid insulator strings (table B.19), in the spur and reticulation 30 to 34.5 kV lines and in the 30 to 34.5/0.4 kV transformer stations.

TABLE B.20

Pin Type 30 to 34.5 kV Insulators

PIN TYPE 30 TO 34.5 kV INSULATORS	REQUIRED	TENDERED
Manufacturer's name and country	—	
Type designation	—	
Standards	IEC 720	
Material • Insulator • Fittings	 Porcelain, brown, Galvanized steel	
Minimum cantilever strength (kN)	6	
Dry 1.2/50 μs lightning impulse withstand voltage (kV peak)	≥250	
60 s power frequency withstand voltage • Dry (kVrms) • Wet (kVrms)	 ≥175 ≥125	
Creepage distance (mm)	≥1,050 (≥ 950)	
Puncture voltage (kVrms)	—	
Dimensions of insulator (mm) • Height • Radius of top groove • Spindle diameter • Spindle length	 >500 — —	
Max R.I.V. at 1 MHZ (mV)	—	
Net weight (kg)	—	

TABLE B.21

Interposing Transformer

INTERPOSING TRANSFORMER	REQUIRED	TENDERED
Manufacturer's name	—	
Manufacturer's type designation	—	
Service conditions - Altitude above sea level (m) - Ambient temperature (°C) • Maximum • Yearly average • Minimum	 ≤ 1,000 + 45 + 20 0	
Standards applicable (with reservations as per technical specifications)	IEC 60076 – Parts 1 to 10	
Type of transformer	Oil immersed	
Rated power (MVA)	3 – 4.5 – 6[a]	
Number of phases	3	
Rated frequency (Hz)	50	
Rated voltages (kV)		
- Primary winding	33	
- Secondary winding	35.5 (31)[b]	
Tappings on secondary winding	± 2 × 3.75%	
Number of tapping positions	5	
Regulation	Off-voltage	
Tapping power	Rated power for all taps	
Max. continuous operation voltage of windings - Primary winding (kV) - Secondary winding (kV)	 36 36.5 (33)	
Connection group - Primary winding - Secondary winding	dY5 Delta connected Star with one terminal (phase) permanently grounded	
Number of windings	2	
Impedance voltages at 75°C, base rated power (MVA): • 33 kV/35.5 (31) kV (%) • 33 kV/35.5 (31) kV + 7.5% (%) • 33 kV/35.5 (31) kV – 7.5% (%)	3 – 4.5 – 6 6.5 – 7 – 7 6.8 – 7.3 – 7.3 6.2 – 6.7 – 6.7	

(*continued*)

TABLE B.21

Interposing Transformer (*continued*)

INTERPOSING TRANSFORMER	REQUIRED	TENDERED
No-load losses - At rated voltage and 50 Hz (kW) - At 1.1 rated voltage and 50 Hz (kW)	MVA: 3; — 4.5 — 6 ≤ 3.5; ≤ 4.75; ≤ 5.7 —/—/—	
No-load current - At rated voltage and 50 Hz (%) - At 1.1 rated voltage and 50 Hz (%)	MVA: 3 – 4.5 - 6 ≤ 0.3; ≤ 0.25; ≤ 0.2;	
Load losses (at 75°C), at ratios: - 33/35.5 (31) kV (kW) - 33 kV/35.5 (31) kV + 7.5% (kW) - 33 kV/35.5 (31) kV – 7.5% (kW)	MVA: 3 – 4.5 - 6 ≤ 24; ≤ 29; ≤ 36; ≤ 23; ≤ 28; ≤ 35; ≤ 25; ≤ 30; ≤ 38;	
Sound level [power] (dB)	≤ 55	
Insulation class	A	
Cooling method	ONAN	
Insulation levels • Highest system voltage (kVrms) - Primary - Secondary • 1 minute 50 Hz withstand voltage (kVrms) - Primary - Secondary • Lightning impulse 1.2/50 μs withstand voltage (kV crest) - Primary - Secondary	 36 36.5 (33) 70 95 170 250	
Induced withstand voltage on primary Winding (kV_{rms})	72	
Temperature rises (with one radiator out of service) - Windings (average) (°C) - Top oil (°C) - Winding hot spot (°C) - Core surface (°C)	 ≤60 ≤55 ≤70 ≤75	
Can transformer withstand the short circuit special test as per IEC standard 60076 – Part 5	Yes, with energization from the 33 kV terminals and the 35.5 kV (31 kV) terminals in pre-set short circuit[c]	
Short circuit test	Optional test, will be decided by purchaser after manufacturing. The supplier should submit with tender a test certificate on a similar transformer performed by an independent test laboratory, if available.	
Short circuit power of 33 kV supply network	Infinite	

INTERPOSING TRANSFORMER	REQUIRED	TENDERED
Construction		
Characteristics of windings: - Material - Current density (A/mm²): • Primary winding • Secondary winding • Regulation winding - Insulating material	 Cu ≤ 3 ≤ 3 ≤ 3 Kraft paper	
Arrangement of windings: - 35.5 kV winding - 33 kV winding	 Internal (close to core)[c] External	
Core - Type - Material	 3-legged Cold rolled grain oriented silicon steel	
- Flux density at principal tapping at rated voltage and frequency (tesla)	≤1.65	
Bushings characteristics		
- Type	Porcelain, brown DIN standard	
Primary (33 kV) bushings - Rated voltage (kV) - Rated current (A) - Withstand test voltages a) 50 Hz-1 minute wet (kVrms) b) Lightning impulse (1.2/50 µs) (kV_{crest}) - Creepage distance (mm)	 36 ≥250 70 170 ≥900	
Secondary 35.5 (31) kV bushings - Rated voltage (kV) - Rated current (A) - Withstand test voltages a) 50 Hz-1 minute wet (kVrms) b) Lightning impulse (1.2/50 µs) - Creepage distance (mm)	 52 ≥ 250 95 250 ≥ 1,050 (≥ 950)	
Bushings number:		
- Primary	3	
- Secondary	3	
Tank type	Bolted cover	
Cooling	Radiators (see technical specification)	
Valves and bolts	Of corrosion resistant material	

(*continued*)

TABLE B.21

Interposing Transformer (*continued*)

INTERPOSING TRANSFORMER	REQUIRED	TENDERED
Painting		
Internal surfaces including the conservator	Protected against hot oil at a temperature of 105°C	
External surfaces	Painted with a cycle suitable for tropical environment conditions.	
Ability to withstand vacuum	See technical specification	
Overpressure test	See technical specification	
Accessories		
- Off-voltage tap changer on 35.5 (31) kV winding	Yes	
- Conservator with filling and drainage valves	Yes	
- Buchholz relay with two contacts	Yes	
- Pressure relief device	Yes	
- Dial type thermometer for oil, with two contacts	Yes	
- Oil level indicator with two contacts	Yes	
- Silica gel air drier	Yes	
- Set of valves for radiators	Yes	
- Radiator draining and venting devices	Yes	
- One vacuum pump connection	Yes	
- One sampling device	Yes	
- Lugs for lifting removable part and whole transformer	Yes	
- Earthing terminals	Yes	
- Swivel wheels	Yes (optional)	
- Marshalling box	Yes	
- First filling oil	Yes	
Weight of part to be havened out of tank (tons)		
Weight of filling oil (tons)		
Net weights (tons) - Core and coils - Tank and fittings - Complete unit (excluding oil)		

INTERPOSING TRANSFORMER	REQUIRED	TENDERED
Gross weight for transportation of heaviest part including oil (tons)		
Gross weight of complete unit (tons) - Without oil - With oil		
Approximate dimensions - Overall height (m) - Height over tank (m) - Length (m) - Width (m)		
Dimensions for transportation of the heaviest parts - Height (m) - Length (m) - Width (m)		

[a]*Alternative offers are required for rated power of 3, 4.5, and 6 MVA.*

[b]*Final rated voltage (in range 30–35.5 kV) will be specified in the order.*

[c]*This requirement is justified because there will be no circuit breaker on the 35.5 (31) kV (line) side. The transformer will be switched from the 33 kV terminals, in one block with the 35.5 (31) kV shield wire line, which occasionally could be affected by a short circuit.*

ANNEX C | TYPICAL DRAWINGS OF SPECIAL EQUIPMENT AND INSTALLATION OF THE 30–34.5 kV THREE-PHASE ILICETO SHIELD WIRE SCHEME USING THE EARTH AS THE CONDUCTOR OF ONE PHASE

(Some drawings are also applicable to other types of iliceto shield wire schemes)

CONTENTS

Figures

Table

FIGURE C.1.A

Lattice Pole-Mounted Capacitor Bank for “Three-Phase” ISWS

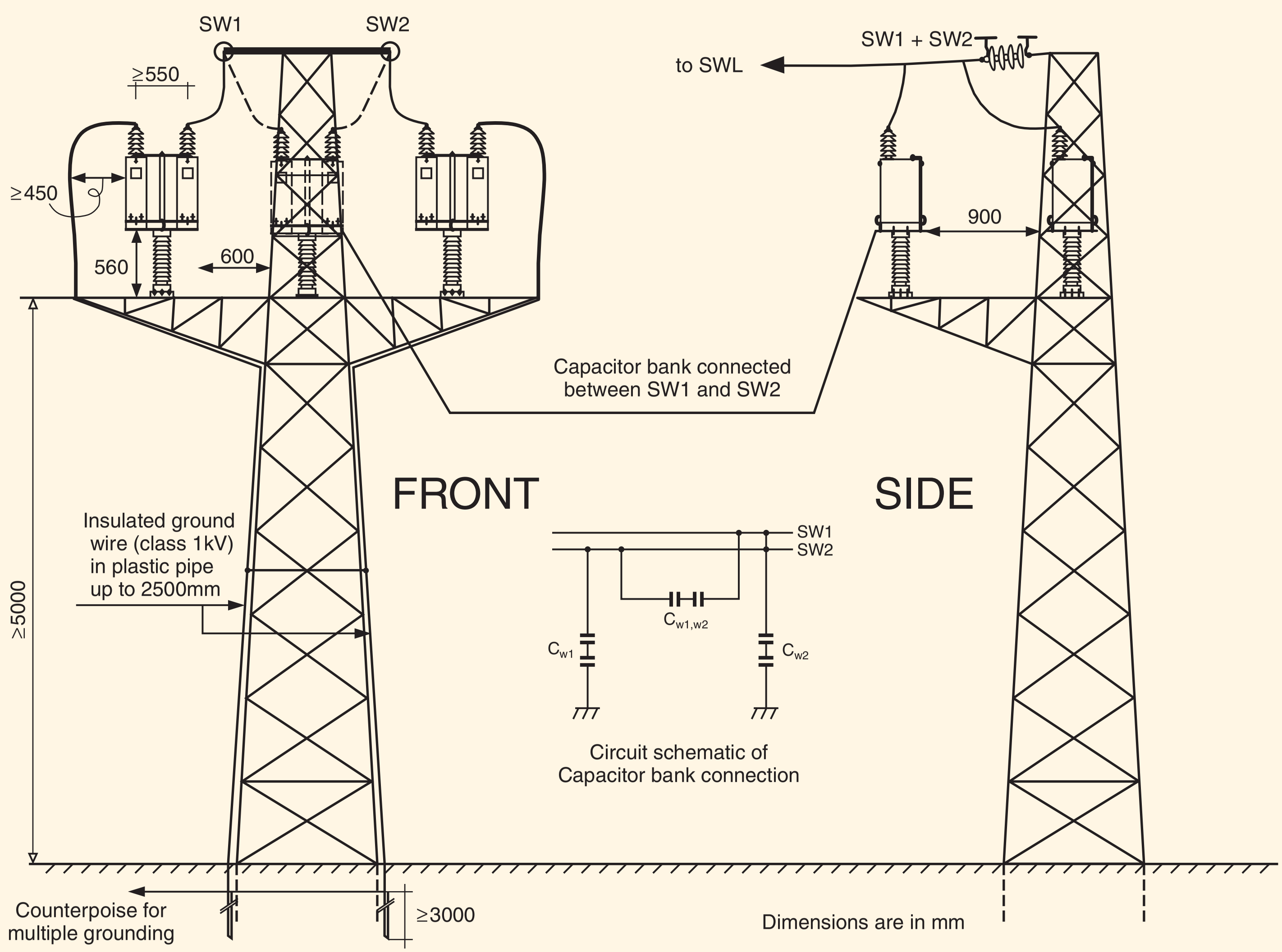


FIGURE C.1.B

Ground Mounted Capacitor Bank: Front and Side Cross-Sections

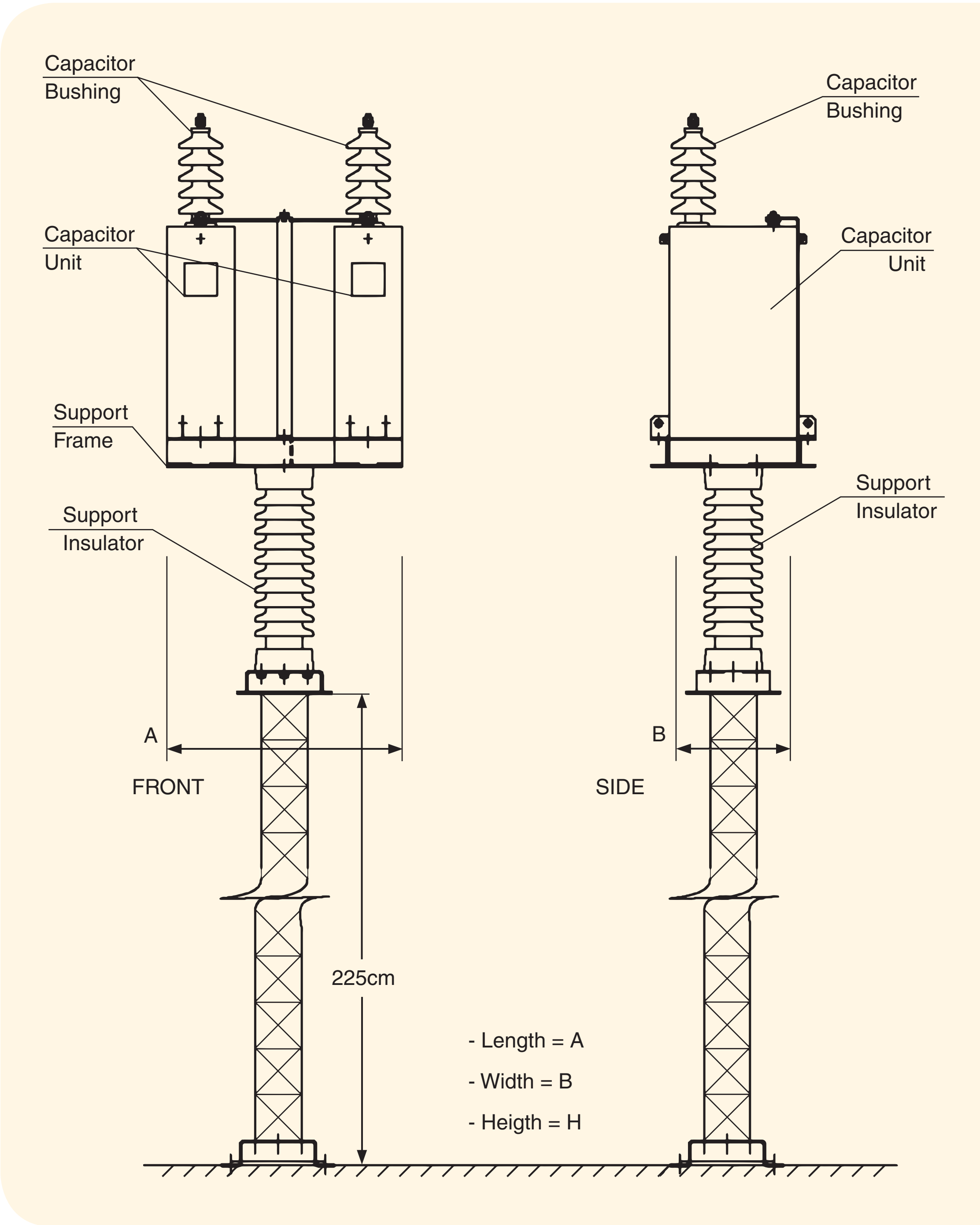
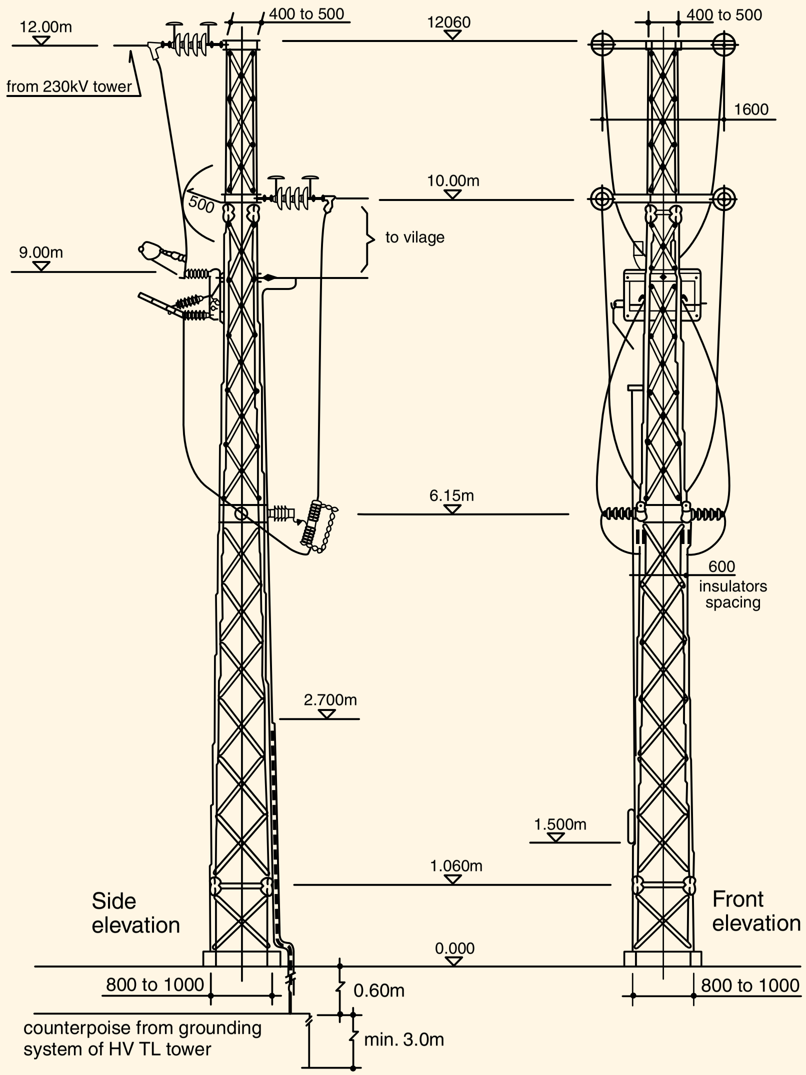
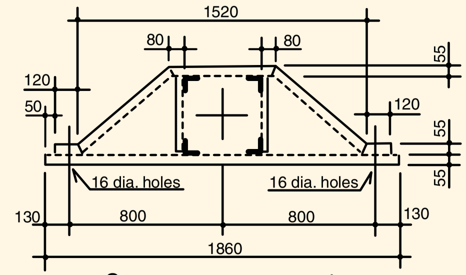


FIGURE C.2

Typical Tee-Off from the Insulated Shield Wires of a High-Voltage Line: Lattice Tower Arrangement





Crossarms arrangement

NOTE

Alternatives to the lattice steel structure can be as follows:

- galvanized steel pole
- concrete pole (or gantry of 2 concrete poles)
- 2 wooden poles gantry

FIGURE C.3.A

34.5 kV Tee-Off from the Shield Wires of a 132 kV Double-Circuit Line: Connection Span from a Suspension Tower

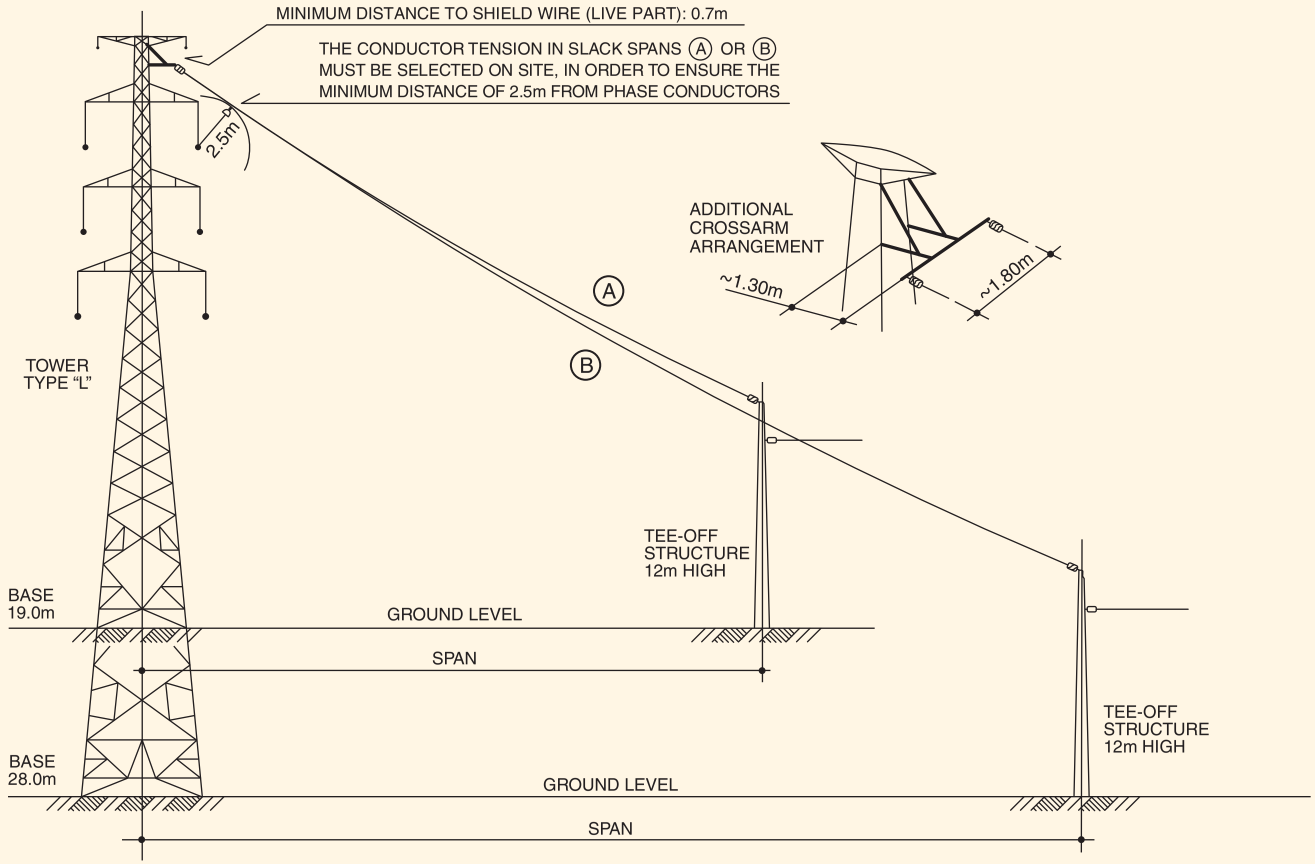


FIGURE C.3.B

34.5 kV Tee-Off from the Shield Wires of a 132 kV Double-Circuit Line: Connection Span from a Tension Tower

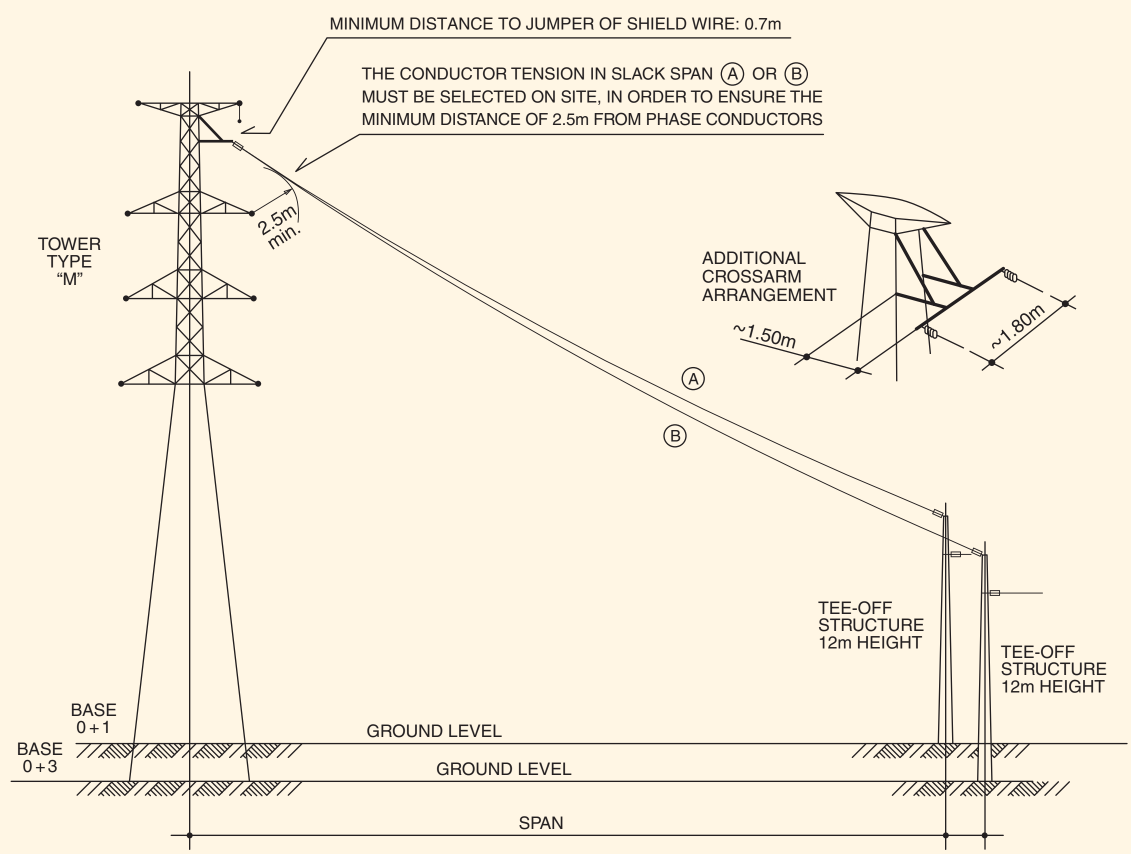


FIGURE C.3.C

34.5 kV Tee-Off from the Shield Wires of a Single-Circuit 230 kV Line: Connection Span from a Suspension Tower on the Side with One Phase Conductor

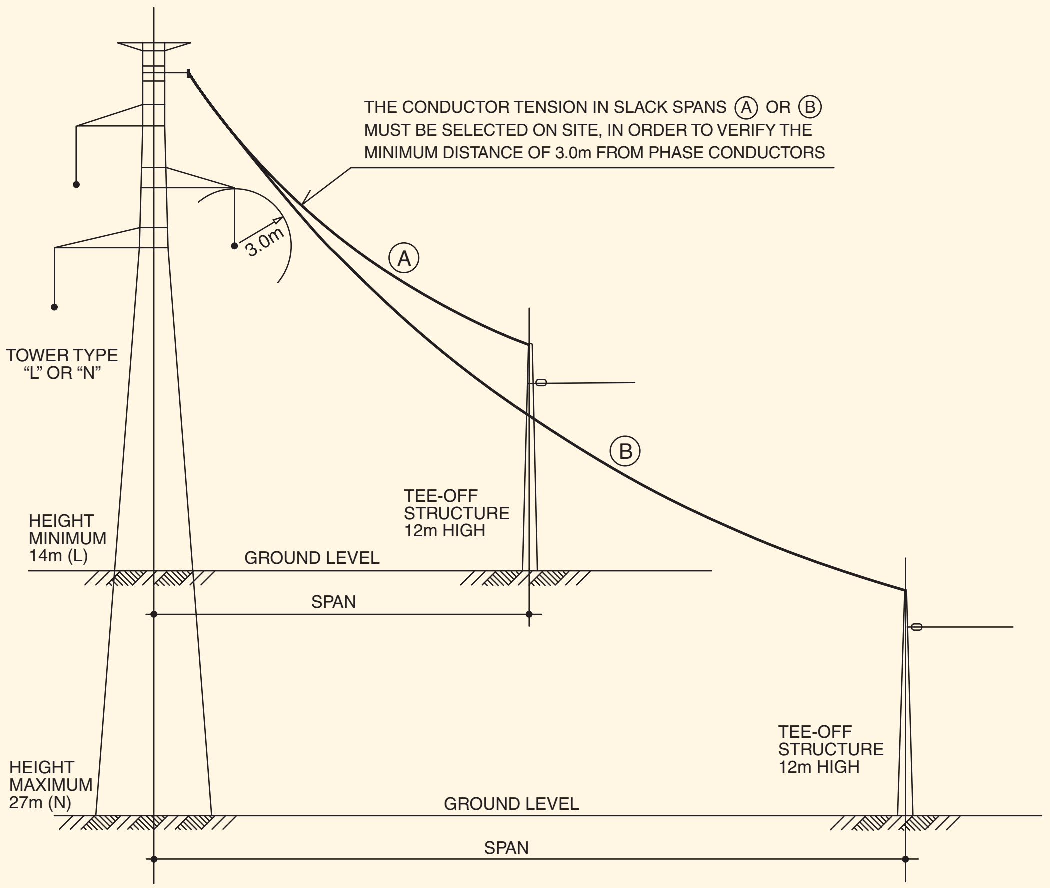


FIGURE C.3.D

34.5 kV Tee-Off from the Shield Wires of a Single-Circuit 230 kV Line: Connection Span from a Suspension Tower on the Side with Two Phase Conductors

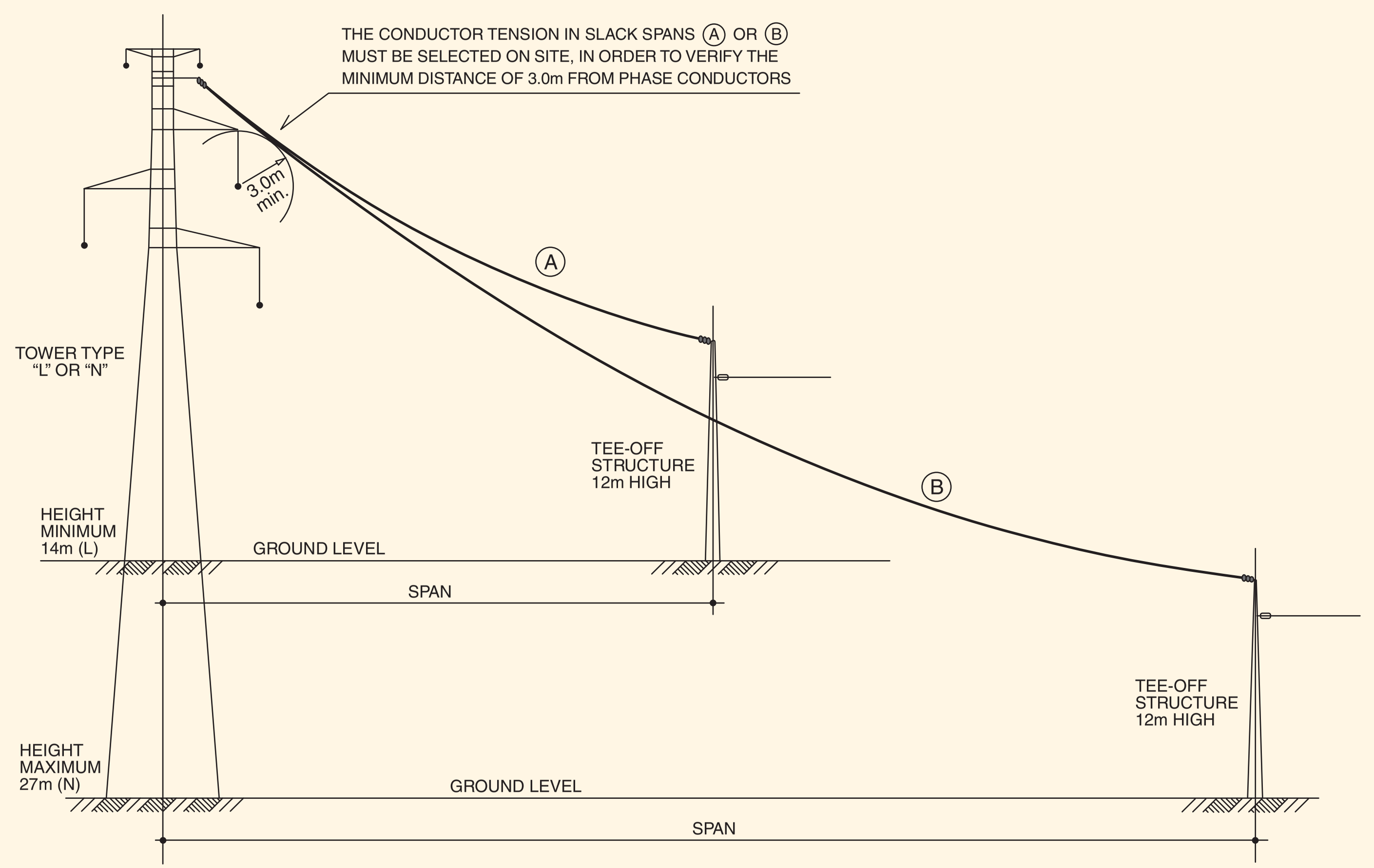
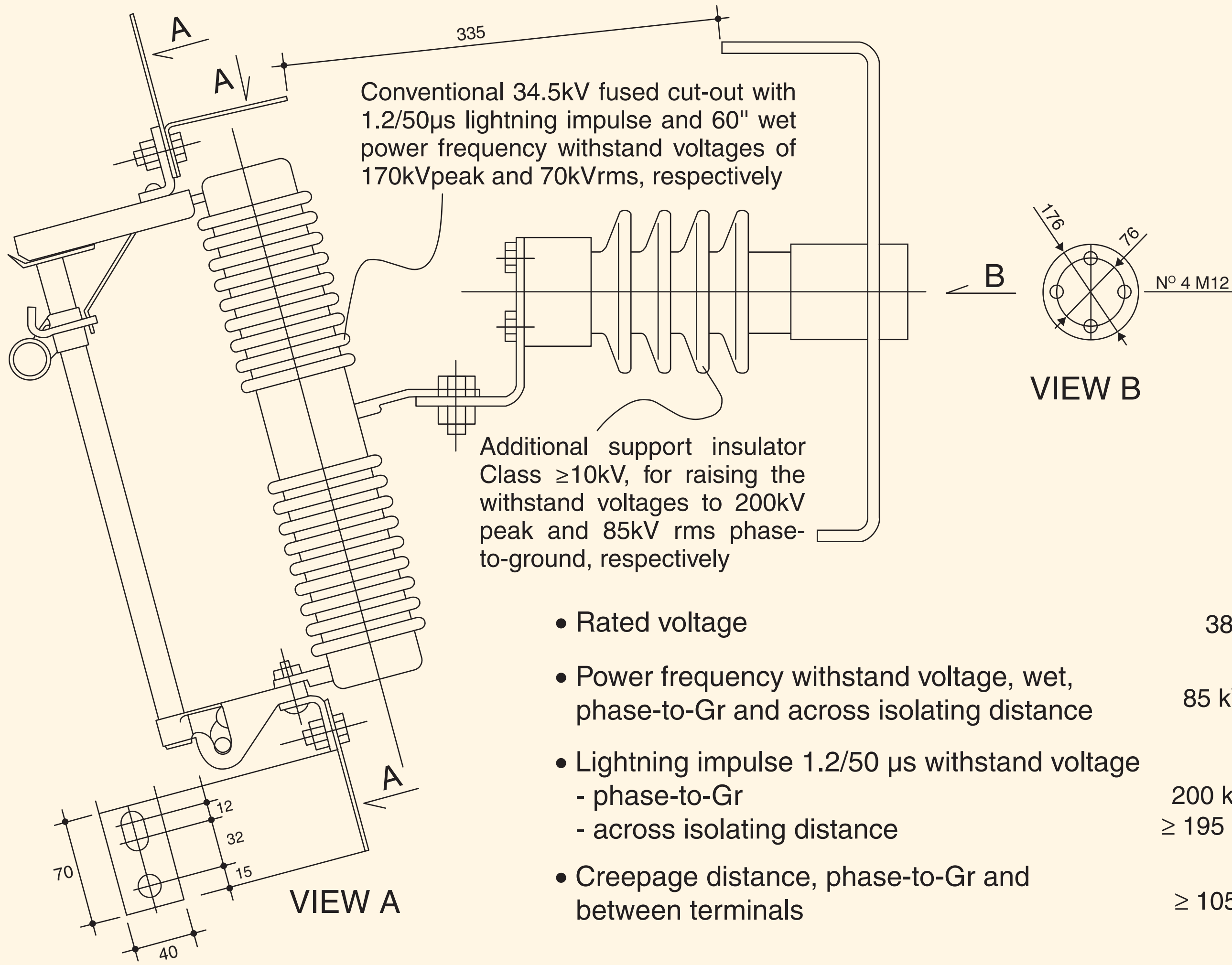


FIGURE C.4

Fused Cut-Out for a 34.5 kV Iliceto Shield Wire Scheme



• Rated voltage	38 kV
• Power frequency withstand voltage, wet, phase-to-Gr and across isolating distance	85 kVrms
• Lightning impulse 1.2/50 μs withstand voltage	
- phase-to-Gr	200 kV peak
- across isolating distance	≥ 195 kV peak
• Creepage distance, phase-to-Gr and between terminals	≥ 1050 mm

FIGURE C.5.A

Pole Mounted 34.5/0.4 kV Transformer Station (100–400 kVA): Dead-end Station Arrangement

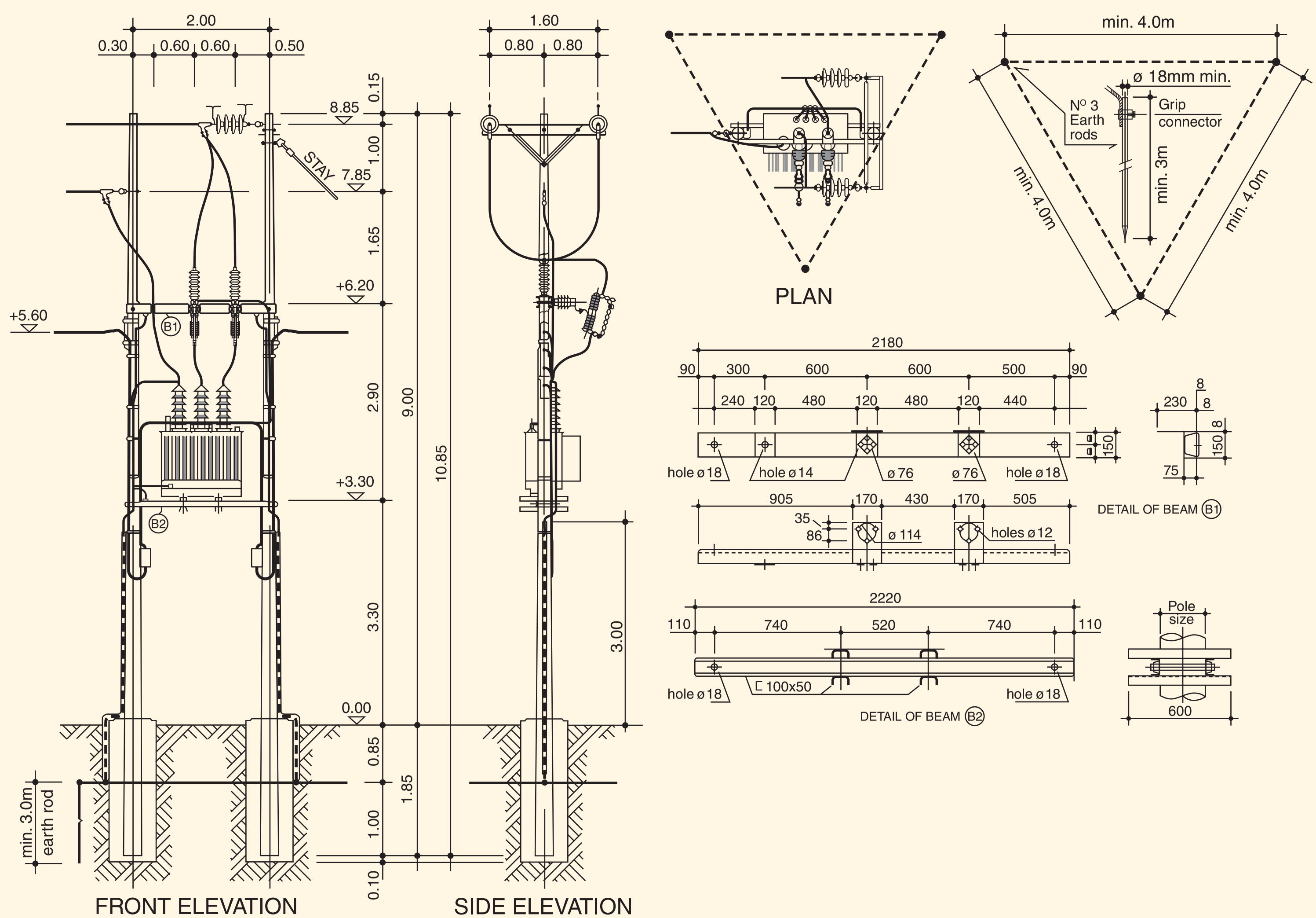


FIGURE C.5.B

Pole Mounted 34.5/0.4 kV Transformer Station (100–400 kVA): Intermediate Station Arrangement

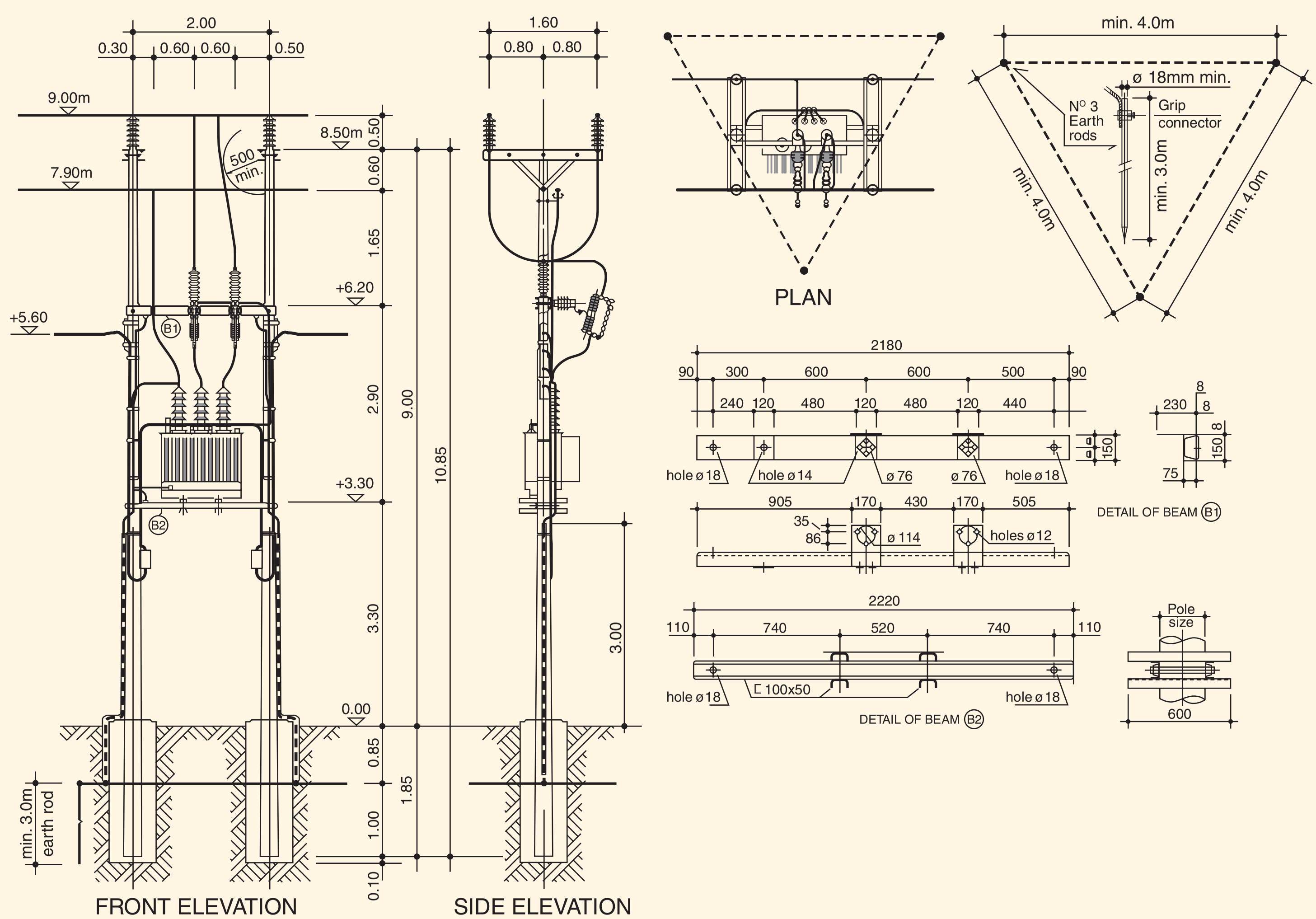


FIGURE C.5.C

Ground Mounted 34.5/0.4 kV Transformer Station (630–800 kVA): Dead-end Station Arrangement

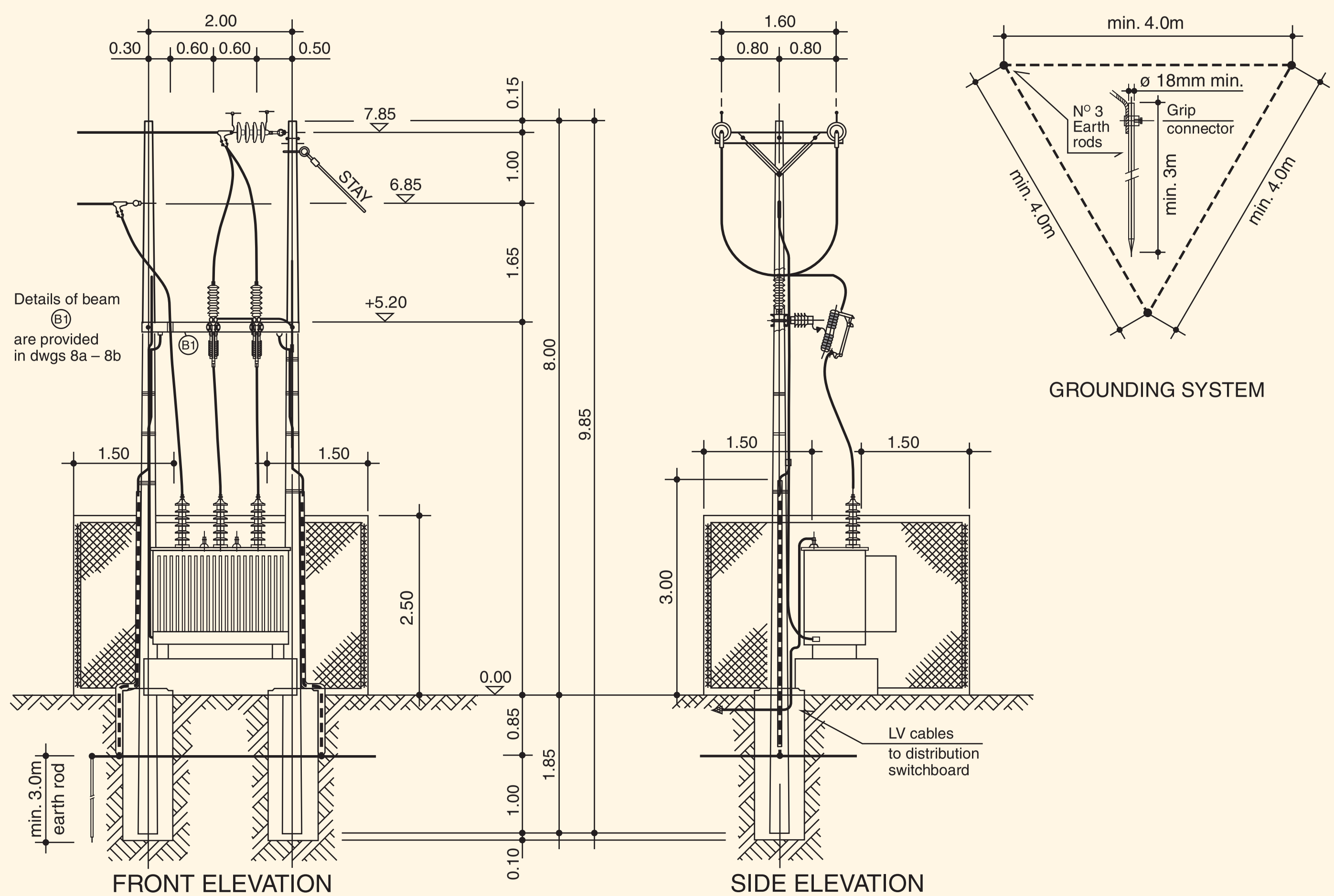
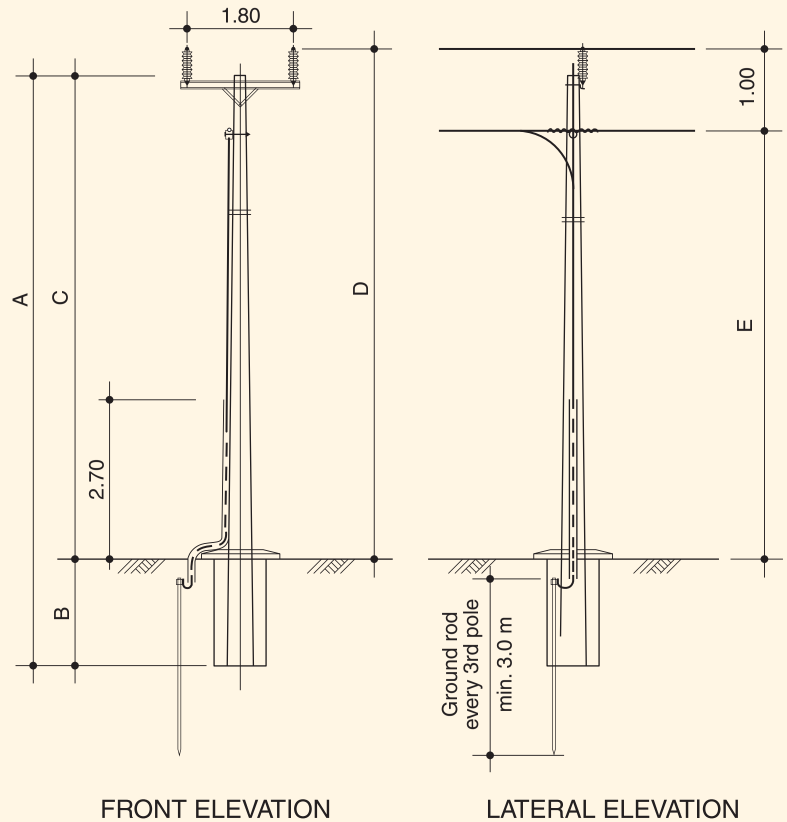


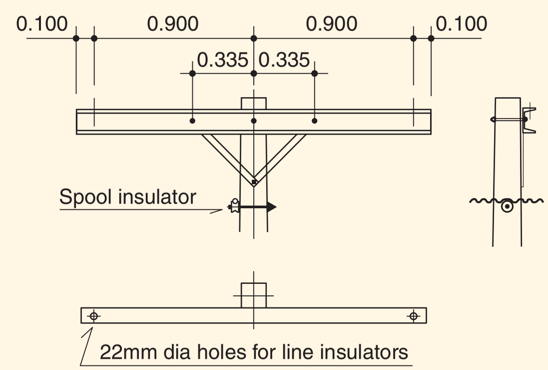
FIGURE C.6.A

34.5 kV Spur Line for a Two-Shield-Wire Three-Phase Iliceto Shield Wire Scheme with a Ground Conductor: Concrete Poles with Pin Type Insulators



A [m]	B [m]	C [m]	D [m]	E [m]	Span [m] α = 0	Span [m] α = 3°	Sag*) [m]
10	1.80	8.20	8.60	7.60	110		2.06
11	1.80	9.20	9.60	8.60	140		2.87
12	1.85	10.15	10.55	9.55	150		3.17
13	1.90	11.10	11.50	10.50	150		3.17
14	1.95	12.05	12.45	11.45	150		3.17

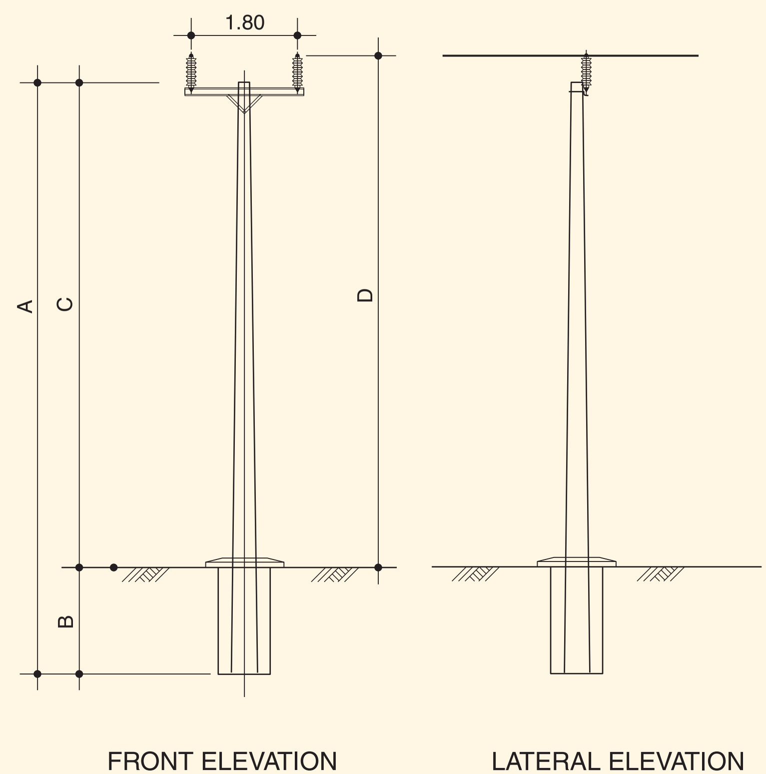
*) at +70°C, in still air



Dimensions are in meters

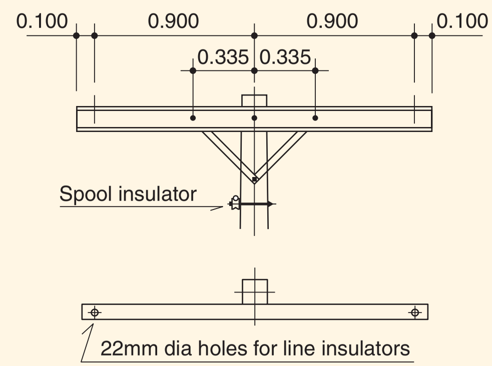
FIGURE C.6.B

34.5 kV Two-Wire Spur Line for a Two-Shield-Wire Three-Phase Iliceto Shield Wire Scheme: Concrete Poles with Pin Type Insulators



A [m]	B [m]	C [m]	D [m]	Span [m] α = 0	Span [m] α = 3°	Sag*) [m]
10	1.80	8.20	8.60	110		2.06
11	1.80	9.20	9.60	140		2.87
12	1.85	10.15	10.55	170		3.79
13	1.90	11.10	11.50	200		4.82
14	1.95	12.05	12.45	210		5.19

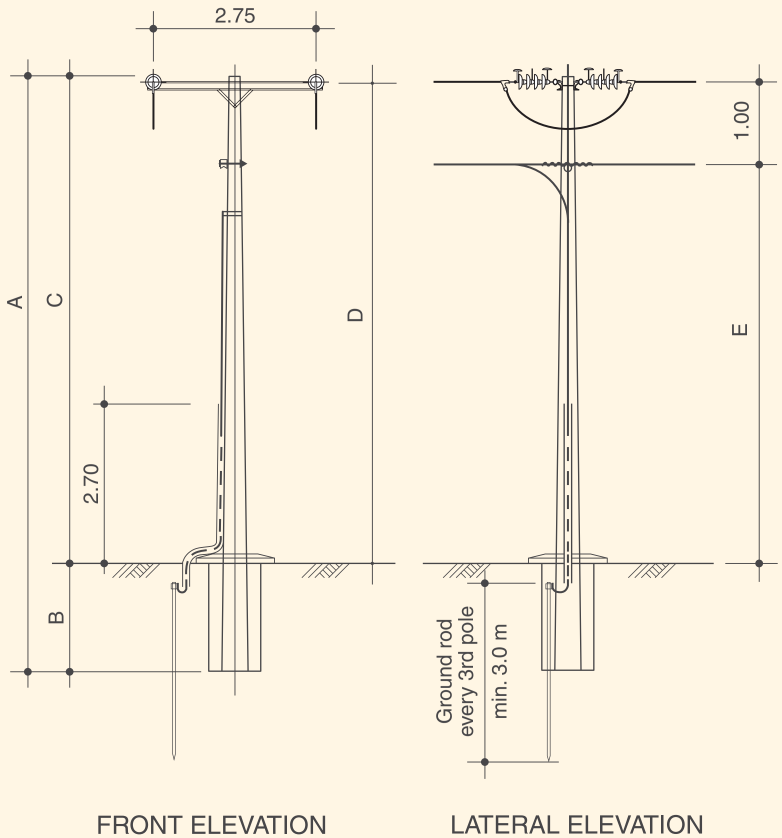
*) at +70°C, in still air



Dimensions are in meters

FIGURE C.6.C

34.5 kV Spur Line for a Two-Shield-Wire Three-Phase Iliceto Shield Wire Scheme with a Ground Conductor: Concrete Pole with Tension Insulator Strings



A [m]	B [m]	C [m]	D [m]	E [m]	Span [m] α = 0	Span [m] α = 60°	Sag*) [m]
10	1.80	8.20	8.10	7.10	100		1.82
11	1.80	9.20	9.10	8.10	130		2.59
12	1.85	10.15	9.15	9.05	150		3.17
13	1.90	11.10	10.10	10.00	150		3.17
14	1.95	12.05	11.05	10.95	150		3.17

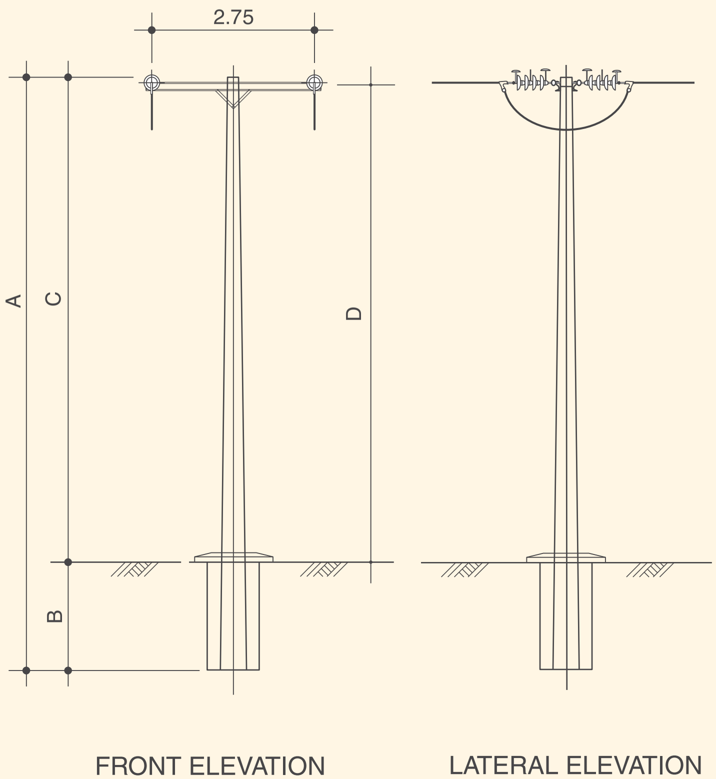
*) at +70°C, in still air

NOTE

- Heights of poles are the same as the ones of poles with line pin type insulators
- Insulator strings are formed by N° 4 cap and pin toughened glass insulators U 70 BL with disc diameter of 254 mm and spacing of 127 mm, protected by arcing rods and provided with bird antiperching devices
- Angle poles are strengthened by a galvanized steel stay
- Dimensions are in meters

FIGURE C.6.D

34.5 kV Two-Wire Spur Line for a Two-Shield-Wire Three-Phase Iliceto Shield Wire Scheme: Concrete Pole with Tension Insulator Strings



A [m]	B [m]	C [m]	D [m]	Span [m] α = 0	Span [m] α = 60°	Sag*) [m]
10	1.80	8.20	8.10	100		1.82
11	1.80	9.20	9.10	130		2.59
12	1.85	10.15	10.05	160		3.47
13	1.90	11.10	11.00	190		4.47
14	1.95	12.05	11.95	200		5.19

*) at +70°C, in still air

NOTE

- Heights of poles are the same as the ones of poles with line pin type insulators
- Insulator strings are formed by N° 4 cap and pin toughened glass insulators U 70 BL with disc diameter of 254 mm and spacing of 127 mm, protected by arcing rods and provided with bird antiperching devices
- Angle poles are strengthened by a galvanized steel stay
- Dimensions are in meters

TABLE C.1

Sag and Tension Calculation Characteristics of a Typical Conductor

• Type	AAAC 50
• Material	Aldrey alloy (Almelec)
• Cross section	48.48 mm^2
• Diameter	9 mm
• Ultimate tensile strength (UTS)	>11.635 kN
• Weight	0.1376 kg/m
• Modulus of elasticity	57000 N/mm^2
• Linear expansion coefficient	23×10^{-6} °C^{-1}
• Wind speed, v	135 km/h
• Every day stress at +20°C (referred to a UTS of 11.635 kN)	18.333%

	t = +20°C; v = 0		t = +70°C; v = 0		t = –5°C; v = 135 km/h+)	
SPAN (m)	T (kN)	SAG (m)	T (kN)	SAG (m)	T (kN)	SAG (m)
50	2.13	0.198	0.553	0.76	4.344	0.50
100	2.13	0.79	0.928	1.82	5.269	1.65
110	2.13	0.96	0.990	2.06	5.441	1.94
120	2.13	1.14	1.047	2.32	5.608	2.23
130	2.13	1.34	1.101	2.59	5.771	2.55
140	2.13	1.55	1.152	2.87	5.927	2.87
150	2.13	1.78	1.199	3.17	6.078	3.22
160	2.13	2.03	1.244	3.47	6.224	3.58
170	2.13	2.29	1.286	3.79	6.364	3.95
180	2.13	2.56	1.326	4.12	6.501	4.33
190	2.13	2.86	1.364	4.47	6.632	4.73
200	2.13	3.16	1.399	4.82	6.758	5.15
210	2.13	3.49	1.432	5.19	6.880	5.57

+) Assumed wind pressure on conductor projection is 765 N/m^2

FIGURE C.7.A

Single-Line Diagram of the 30–34.5 kV Supply Bay of Two-Shield-Wire Three-Phase Shield Wire Lines from Tertiary Winding of the High Voltage/Medium Voltage Transformer

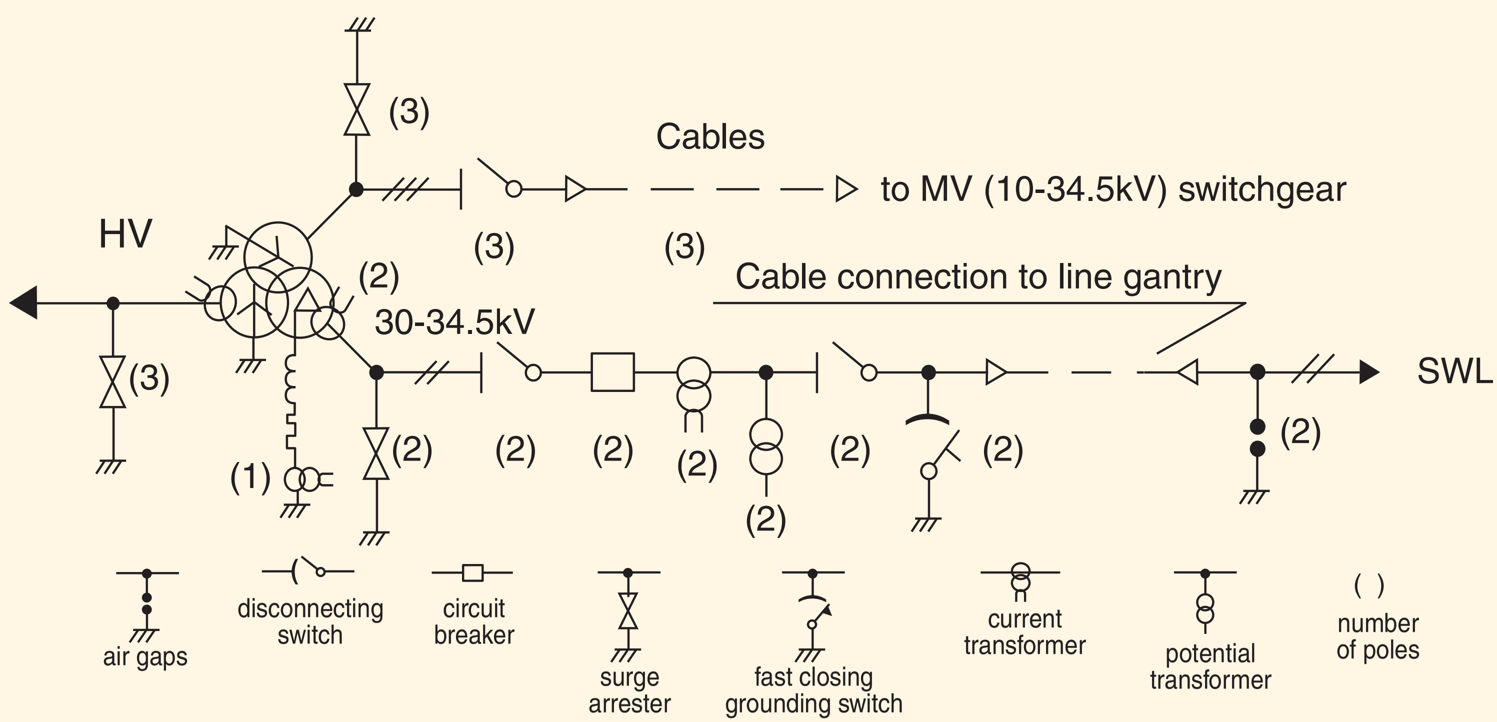


FIGURE C.7.B

Single-Line Diagram of the 30–34.5 kV Supply Bay of Two-Shield-Wire Three-Phase Shield Wire Lines from an Interposing Transformer

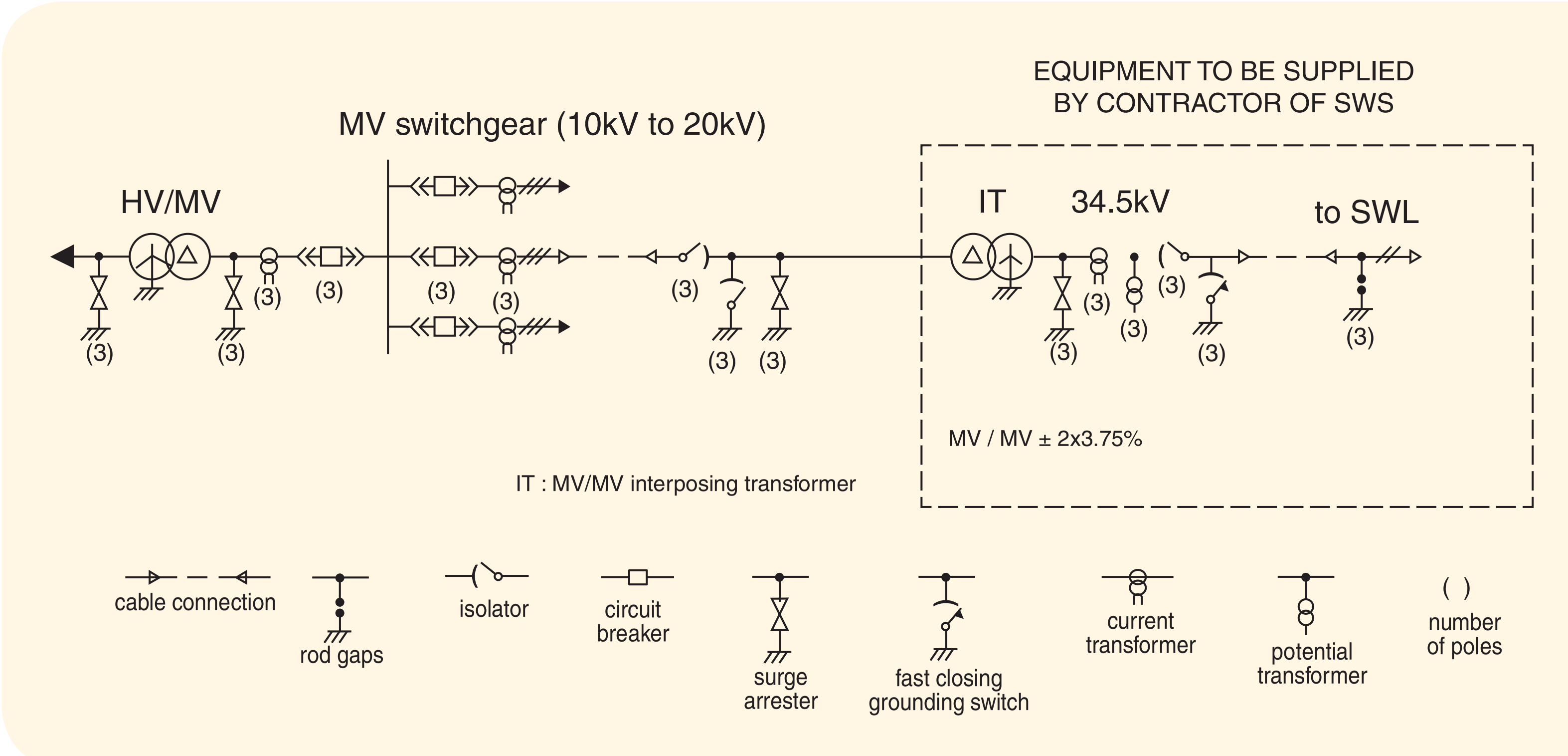
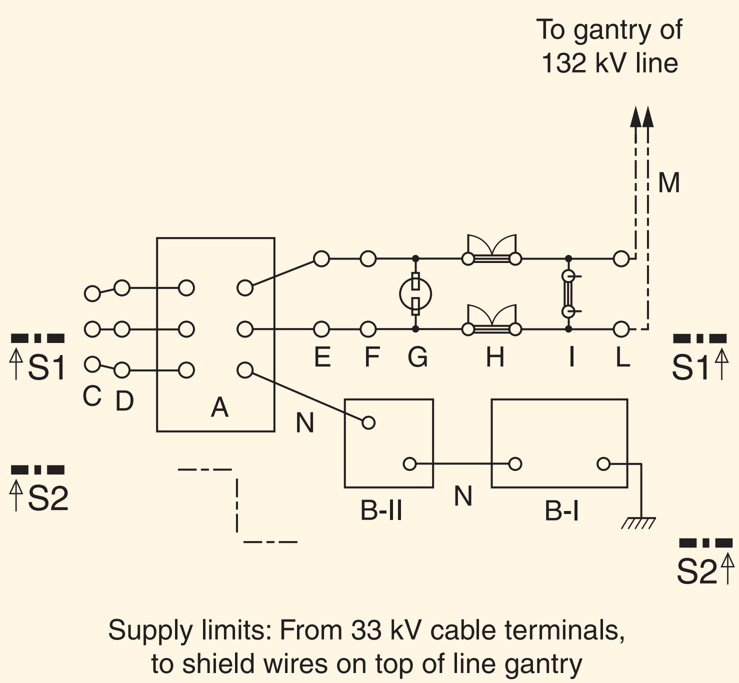


FIGURE C.8.A

Typical Preliminary Layout of the 34.5 kV Supply Bay of a Two-Shield-Wire Three-Phase Iliceto Shield Wire Scheme: Plan

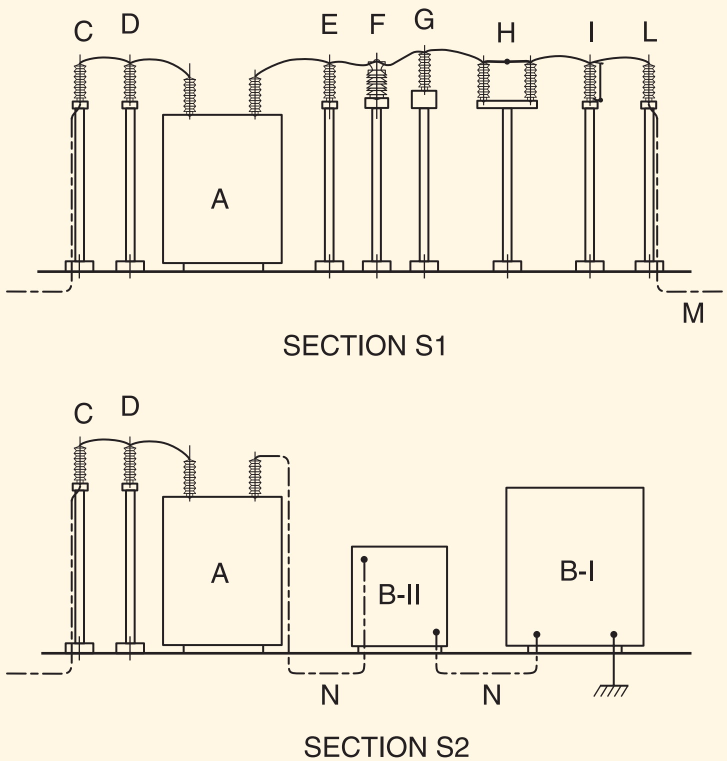


Legend

A - 33 / 34.5 kV Interposing Transformer
B - Grounding Resistor (B-I) and Reactor (B-II) if applicable
C - 33 kV supply cable terminals
D - Existing Surge Arresters (3 N°)
E - 48 kV Surge Arresters (2 N°)
F - Current Transformers (2 N°)
G - 34.5 / 0.1 kV Potential Transformer (1 N°)
H - 34.5 kV Bipolar Isolator (1 N°)
I - 34.5 kV fast closing Bipolar Grounding Switch (1 N°)
L - 34.5 kV cable terminals (2 N°)
M - Single-core cable connections to shield wires on HV line gantry (2 N°)
N - Single-core cable connections

FIGURE C.8.B

Typical Preliminary Layout of the 34.5 kV Supply Bay of a Two-Shield-Wire Three-Phase Iliceto Shield Wire Scheme: Sections



Legend

A - 33 / 34.5 kV Interposing Transformer

B - Grounding Resistor (B-I) and Reactor (B-II) if applicable

C - 33 kV supply cable terminals

D - Existing Surge Arresters (3 N°)

E - 48 kV Surge Arresters (2 N°)

F - Current Transformers (2 N°)

G - 34.5 / 0.1 kV Potential Transformer (1 N°)

H - 34.5 kV Bipolar Isolator (1 N°)

I - 34.5 kV fast closing Bipolar Grounding Switch (1 N°)

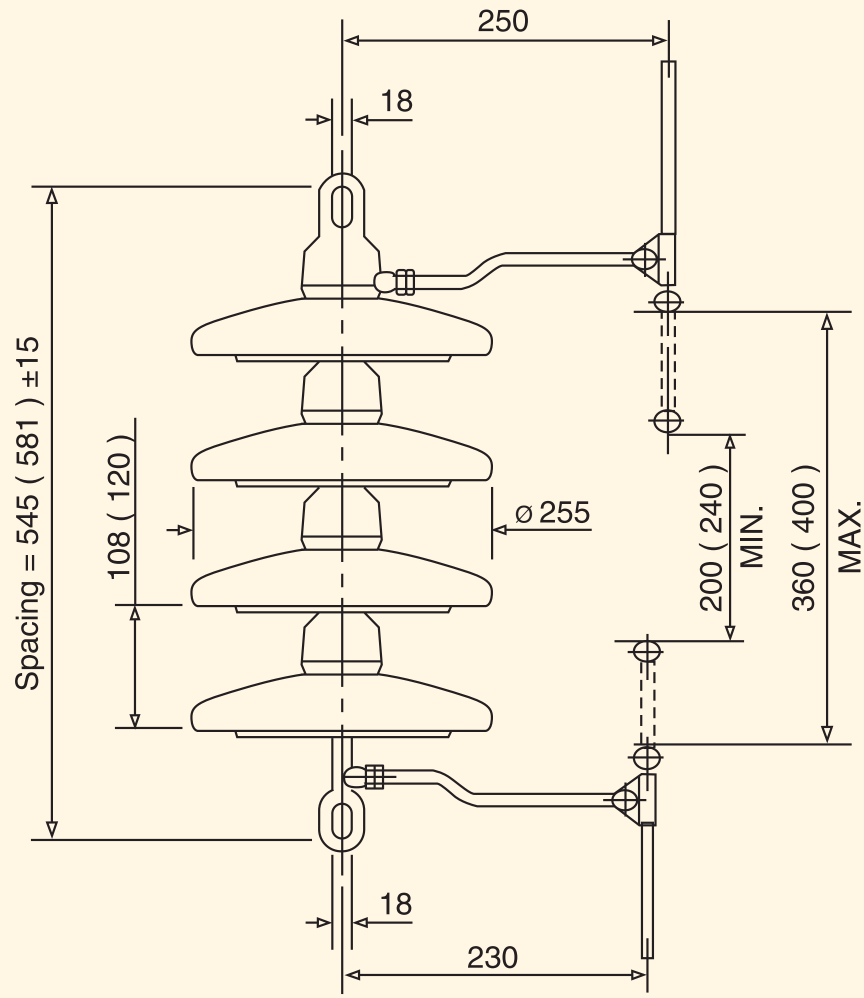
L - 34.5 kV cable terminals (2 N°)

M - Single-core cable connections to shield wires on HV line gantry (2 N°)

N - Single-core cable connections

FIGURE C.9.A

Rigid Toughened Glass Insulator String for a 34.5 kV Three-Phase Iliceto Shield Wire Scheme



- Dimensions are in millimeters
- Dimensions and withstand voltages in brackets apply for disc spacing of 120 mm
- Wet 50 Hz-60 s withstand voltage __________ 130 (143) kVrms +)
- Dry 1.2 / 50 μs impulse withstand voltage ___ 270 (295) kVpeak +)
- Creepage distance________________________ 1200 mm
- Electromechanical falling load _____________ ≥50 kN

+) without arcing horns

FIGURE C.9.B

Typical Installation Arrangement of the Rigid Toughened Glass Insulator String for a 34.5 kV Three-Phase Shield Wire Line

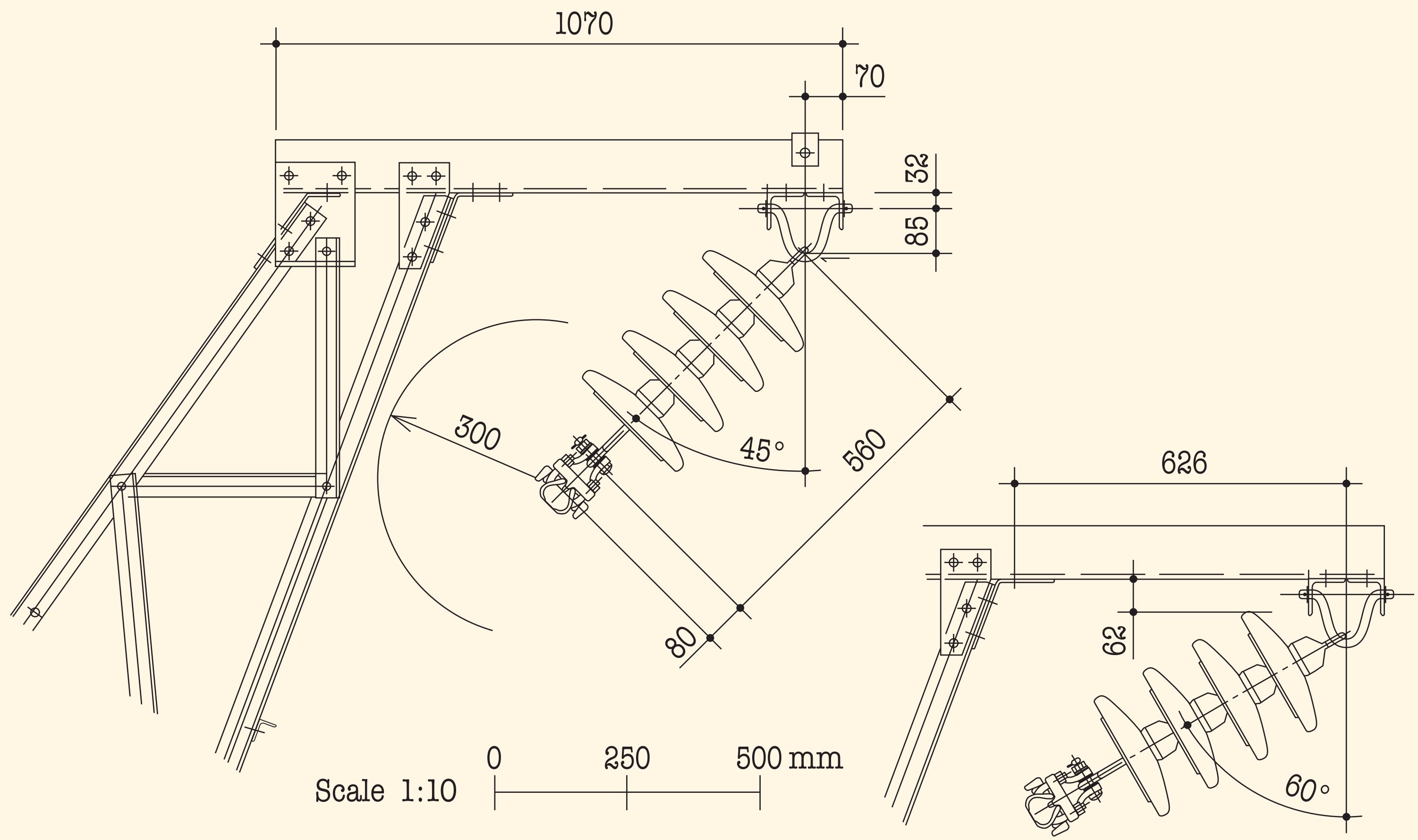


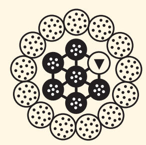
FIGURE C.10.A

Specifications for a Typical Optical Ground Wire Applicable as One Shield Wire of the Shield Wire Lines

ALCATEL CABLE	SPECIFICATION FOR SELF SUPPORTING OPTICAL FIBRE AERIAL CABLE	Telecom Product Line Product Group Optical Aerial Cables

Cable Type ASLH-D(S)bb 1 x 12 E9/125 (AA/ACS 52/30 - 7.4)

Cross Section



Design	Center	1 ACS - Wire		2,60 mm
	Layer 1	5 ACS - Wires		2,50 mm
	+	1 Steel Tube with 12 E9/125	2,10 /	2,50 mm
	Layer 2	13 AA - Wires		2,25 mm
	stranded, core and layer 1 greased			
	Cable Diameter			12,1 mm
	Cable Weight			367 kg/km
Technical Data	according to IEC standards			
	Supporting Cross Section			81,5 mm²
	Rated Tensile Strength			52,0 kN
	Modulus of Elasticity			95,4 kN/mm²
	Thermal Elongation Coefficient			16,8 10^{-6}/K
	Permissible Maximum Working Stress			267,9 N/mm²
	Everyday Stress (16% RTS)			102,0 N/mm²
	Ultimate Exceptional Stress			459,2 N/mm²
	DC Resistance			0,529 Ω/km
	Continuous Current		(Tmax=80°C; v=0,6m/s; To=35°C)	257 A
	Short Time Current		(1,0s, 20-200°C)	7,4 kA
	Maximum Permissible Installation Force			21,8 kN
	Minimum Bending Radius			182 mm
	Normal Delivery Length			4000 m
Temperature	Installation			-10 to +50°C
Range	Transportation and Operation			-40 to +80°C
Remarks	All Sizes and Values are Nominal Values Maximum Fibre Capacity per Steel Tube: 16			

FIGURE C.10.B

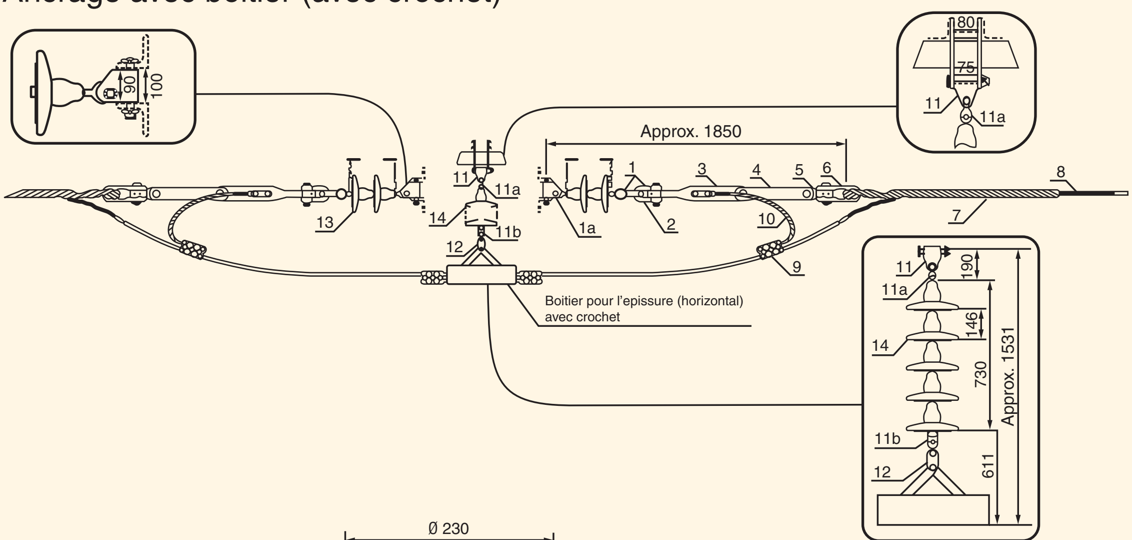
Typical Suspension Insulated Splicing and Post-type Terminal Coupling Unit of Optical Ground Wire

Accessoires pour conducteur à fibres optiques – ∅ 14,0 mm

Client : nkt cables GmbH 16.01.09
Projet : Burkina Faso – Lot 1 (Afrique)
OPPC : 74-AL3/37-A20SA – 24xG.652 – 66,1kN – 10,0kA – 14,0 mmØ
(Couche exterieure a droite)

Ancrage (33 x)

Ancrage avec boitier (avec crochet)



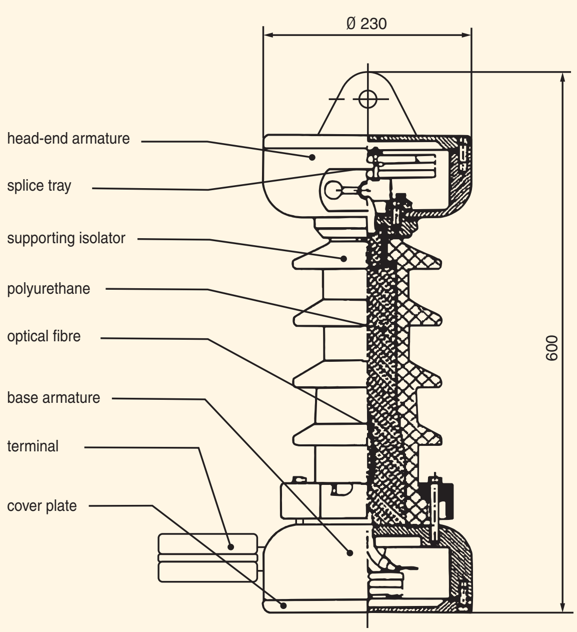
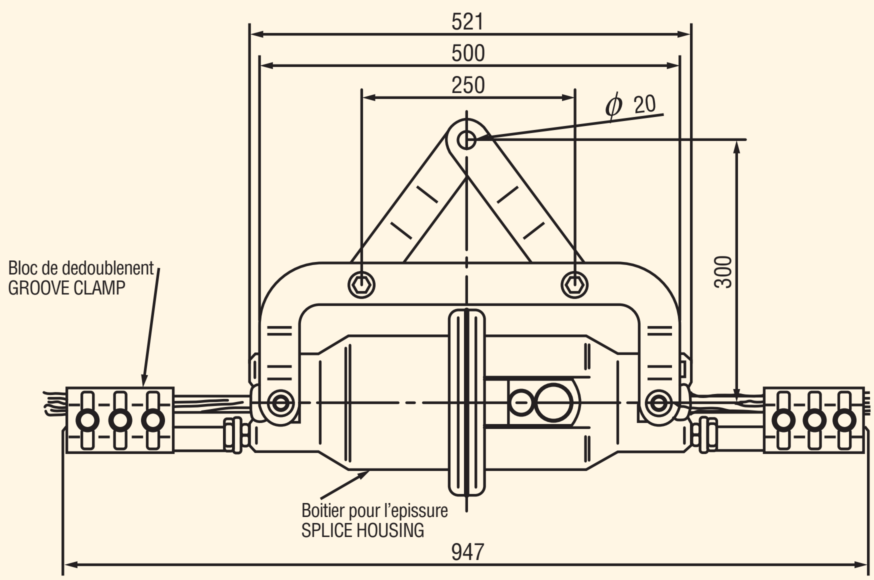
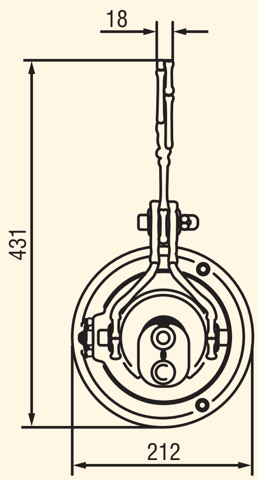


FIGURE C.10.C

Example of the Suspended Straight Splicing of the Fiber Optics and Electrical Joint of a Shield Wire





Donnees techniques:
Pcids: 14 ky
Materiales des oncrages: Alliage Al coll corrosion
Badons: Acier Inaxysable

Donnees electriques:
Tesxior: 36–420 kV

TECHNICAL DATA:
WEIGHT: 14 kg
MATERIAL: FITTINGS – ALUMINUM–ALLOY, CORROSION RESISTANT
SCREWS, NUTS, WASHERS – STAINLESS STEEL

ELECTRICAL DATA:
VOLTAGE RANGE: 36-420 kV
CURRENT TRANSMISSION BY A BYPASS

nkt cables	Boitier de jonction OPPC pour OPPC-diametre: 10,3 – 23,4 mm
	STRAIGHT JOINT CLOSURE WITH BRACKET FOR OPTICAL PHASE CONDUCTOR (OPPC)

ANNEX D | SINGLE-LINE DIAGRAMS AND PHOTOGRAPHS OF ILICETO SHIELD WIRE SCHEMES IN OPERATION

CONTENTS

INTRODUCTION: INFORMATION ON ILICETO SHIELD WIRE SCHEMES

This Annex reports the single-line diagrams of the so far implemented Iliceto shield wire schemes (ISWSs) as originally planned and built. A set of available photographs of the equipment of the ISWSs is also provided.

For several ISWSs all the villages and other loads shown in the single-line diagrams were electrified from the beginning. In some ISWSs the construction of the spur MV lines and LV networks of the villages have been staged in accordance with a priority plan. Information are provided also on the present status of operation of the ISWSs as known by the writer.

- **Ghana:** About 1,000 kilometers (km) of 161 kilovolt (kV)–50 hertz (Hz) transmission lines have been equipped with shield wire lines. The 30-34.5 kV ISWSs shown in figure D.1 have been in operation since 1989, with all the villages electrified. As of 2015, all the ISWSs shown in figure D.1 are in operation, except the Bolgatanga-Nasia ISWS that has been recently replaced by conventional 34.5 kV lines. The recovered materials are used as spare parts.
- **Brazil:** Three-phase 34.5 kV ISWSs were put in operation in 1995 in a 230 kV-60 Hz line (figure D.2).
- **Lao People's Democratic Republic:** Three Single-phase earth-return 25 kV ISWSs have been put in operation in 1996 along 190 km of 115 kV-50 Hz transmission lines. Five Three-phase 34.5 kV ISWSs have been commissioned in 2002–03 with all the villages electrified, along 335 km of 115 kV transmission lines (figure D.3) and are reported to be in operation at the time of writing. The author has no information on the current status of the single-phase earth-return SWSs.
- **Sierra Leone:** A three-phase 34.5 kV ISWS has been in operation since 2010 in the first built 161 kV-50 Hz line of the country (figure D.4). The ISWS supplies at the remote end the town of Makeni (~80,000 inhabitants) and, with a spur MV line from Makeni, the town of Magburaka (not shown in figure D.4). The ISWS Freetown-Lunsar shown in figure D.4 has not been realized due to the outbreak of a civil war in the country.
- **Ethiopia:** Three single-phase earth-return 34.5 kV ISWSs were built in the late 1990s along 200 km of 132 kV-50 Hz transmission lines (figure D.5). Reportedly, they have been replace by conventional 3-phase MV lines for supplying 3-phase motors.
- **Togo:** Three-phase 34.5 kV ISWSs are in operation along 261 km of 161 kV-50 Hz lines (figure D.6). One of the shield wires is an insulated optical ground wire (OPGW). So far 19 villages have been electrified from the ISWSs.
- **Burkina Faso:** Three-phase 34.5 kV ISWSs are in operation along 330 km of 225 kV-50 Hz transmission lines (figure D.7). One insulated shield wire is an OPGW. So far only part of the villages have been electrified from the ISWSs.

FIGURE D.1

Single-Line Diagram of an Insulated Iliceto Shield Wire Scheme in Ghana, 1989

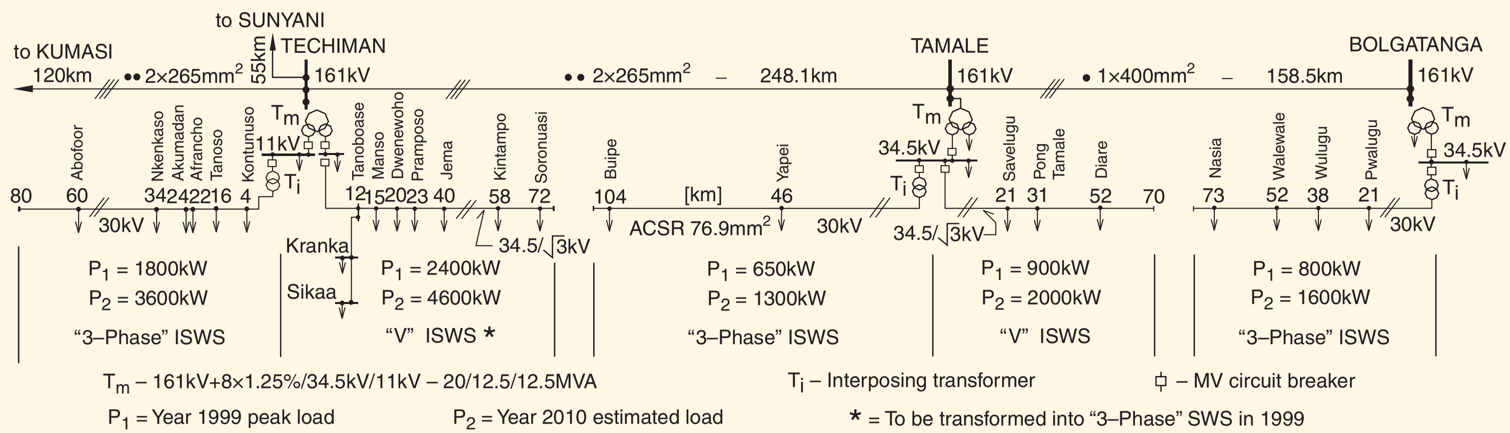


FIGURE D.2

Single-Line Diagram of the 34.5 kV 60 Hz Three-Phase Shield Wire Line in Mato Grosso, Brazil, 1995

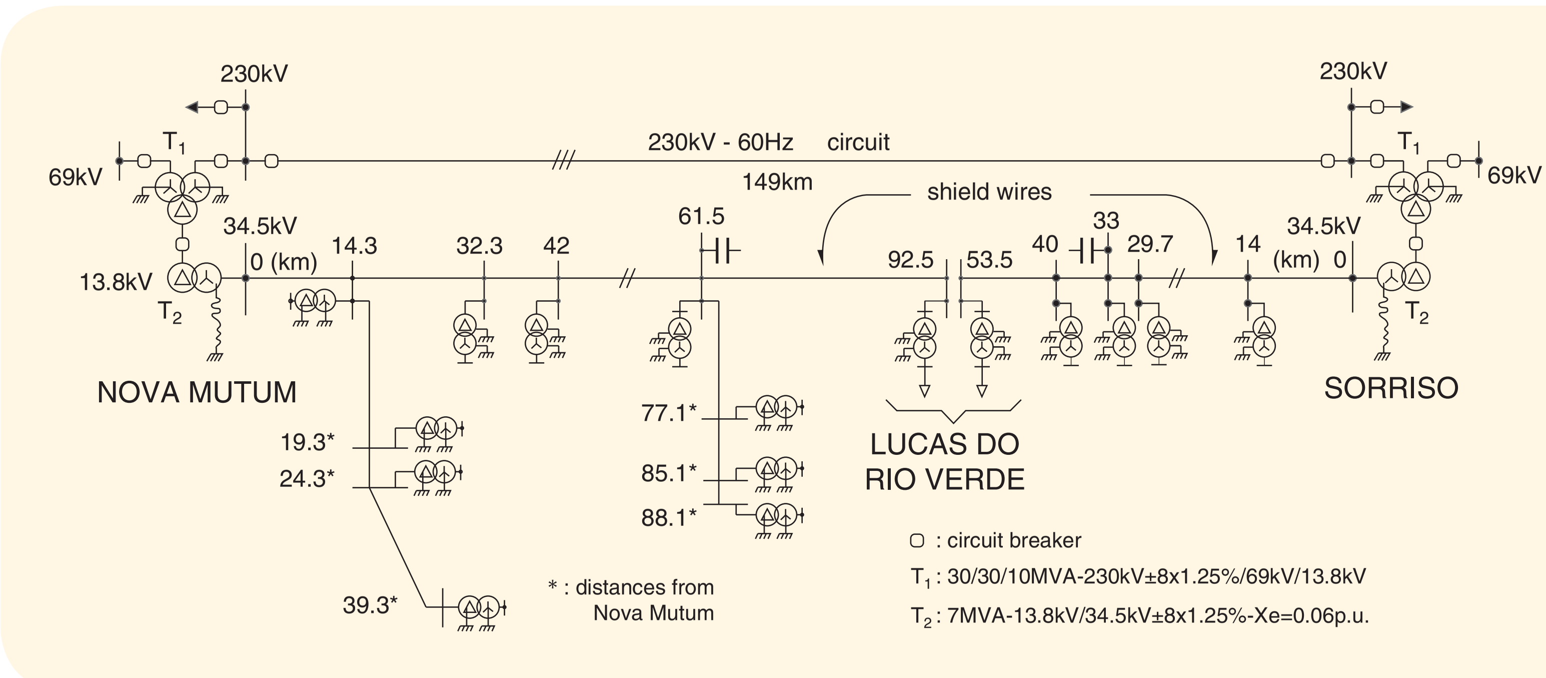


FIGURE D.3

Single-Line Diagrams of 34.5 kV Three-Phase Iliceto Shield Wire Schemes in the Lao People's Democratic Republic, 2002-3

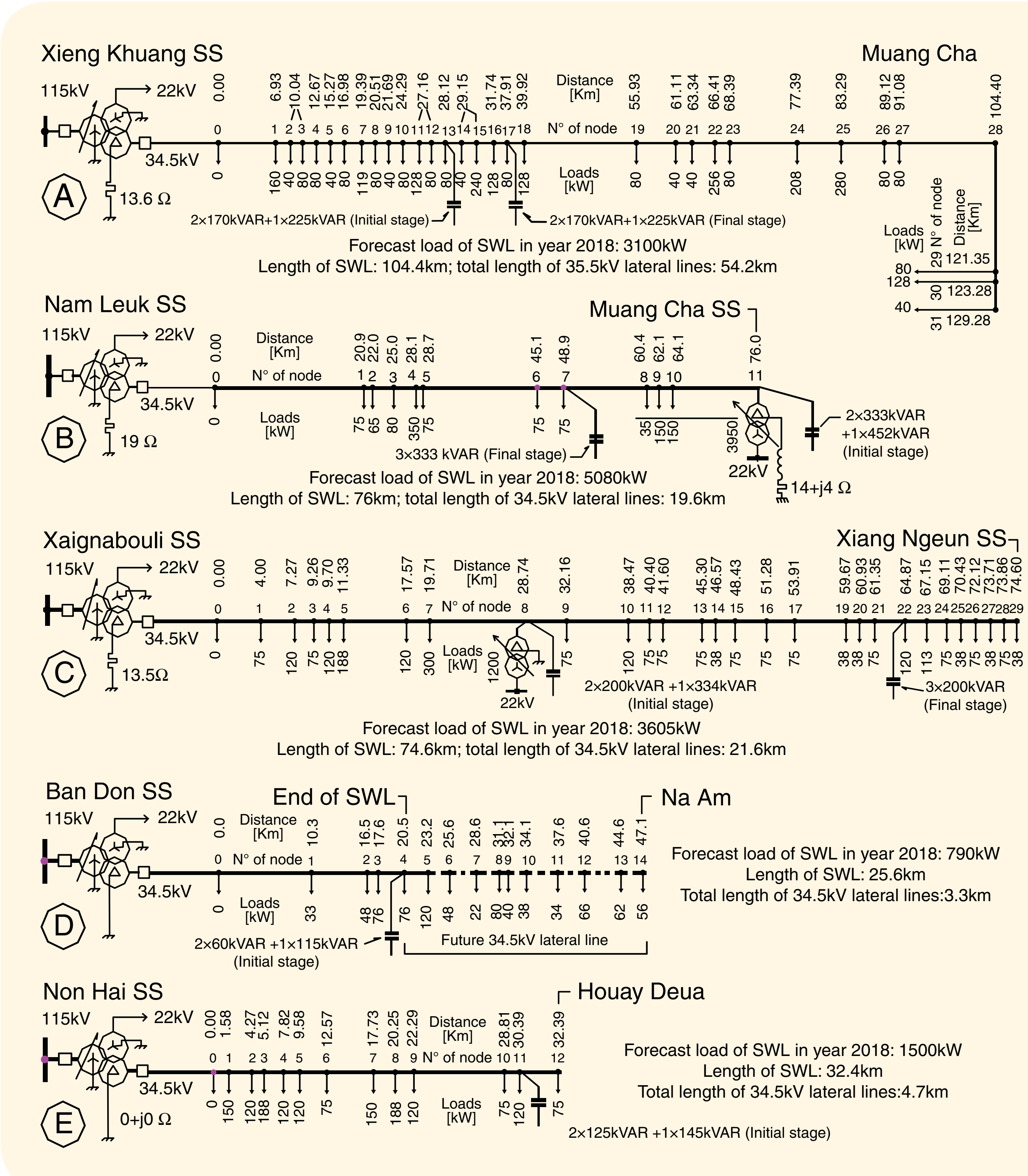
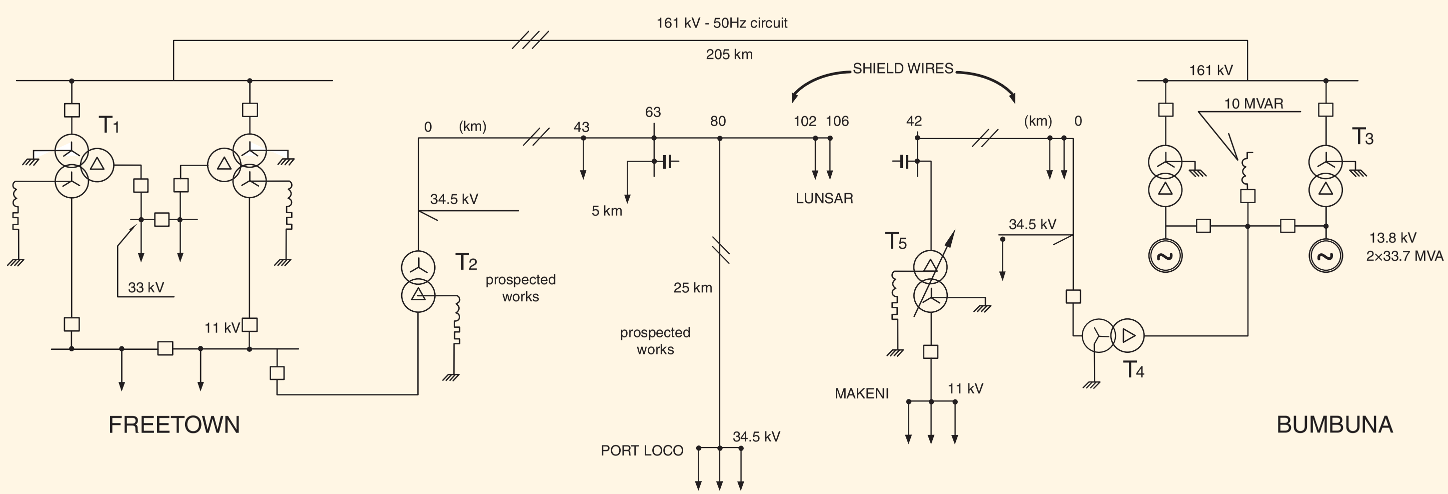


FIGURE D.4

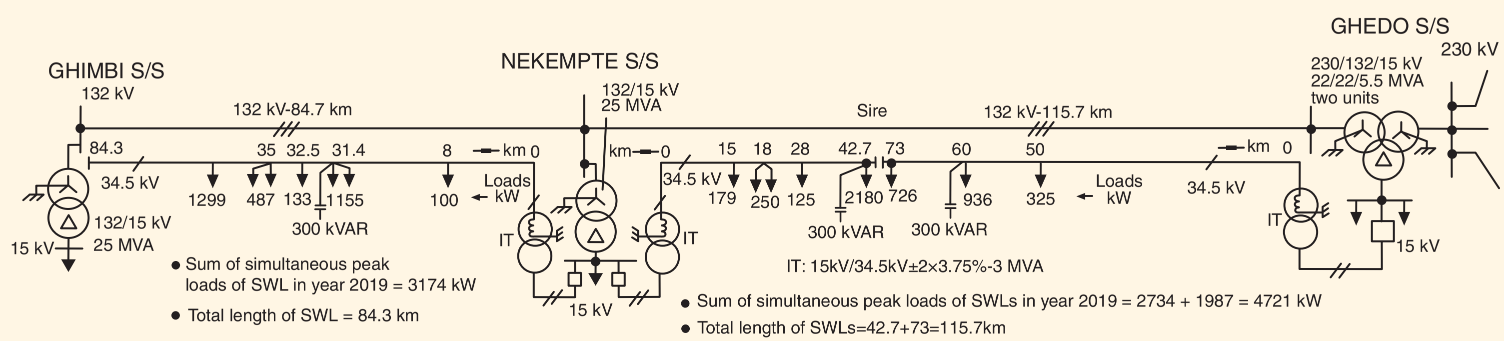
Single-Line Diagram of a 34.5 kV Three-Phase Iliceto Shield Wire Scheme in Sierra Leone, 2010



□ : circuit breaker
T_1 : 45/35/15 MVA - 161kV±10×1.25%/11.5kV/34.5kV
T_2 : 5 MVA - 11kV±2×2.5%/35.5kV-X_e=0.06 p.u. (prospected works)
T_3 : 33.7 MVA - 13.8kV/165kV±2×3.75%
T_4 : 5 MVA - 13.8kV±2×2.5%/35kV-X_e=0.06p.u
T_5 : 4 MVA - 34.5kV/11.5kV±8×1.25%-X_e=0.06p.u
T_6 : 35/35/15 - three windings, to be defined

FIGURE D.5

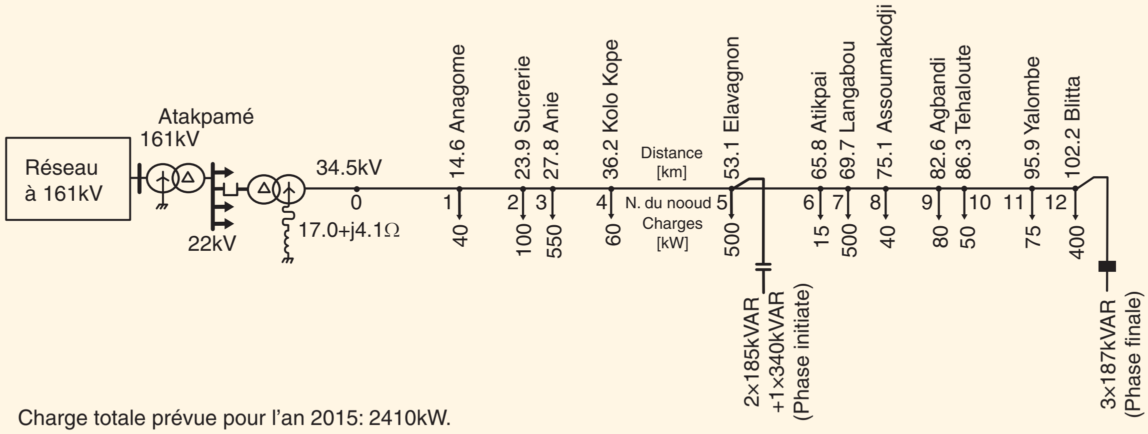
Single-Line Diagrams of a 34.5 kV Single-Phase Earth-Return Iliceto Shield Wire Scheme in Ethiopia, 2000



Note | *The operation has been discontinued.*

FIGURE D.6

Single-Line Diagrams of 34.5 kV Three-Phase Iliceto Shield Wire Schemes in Togo

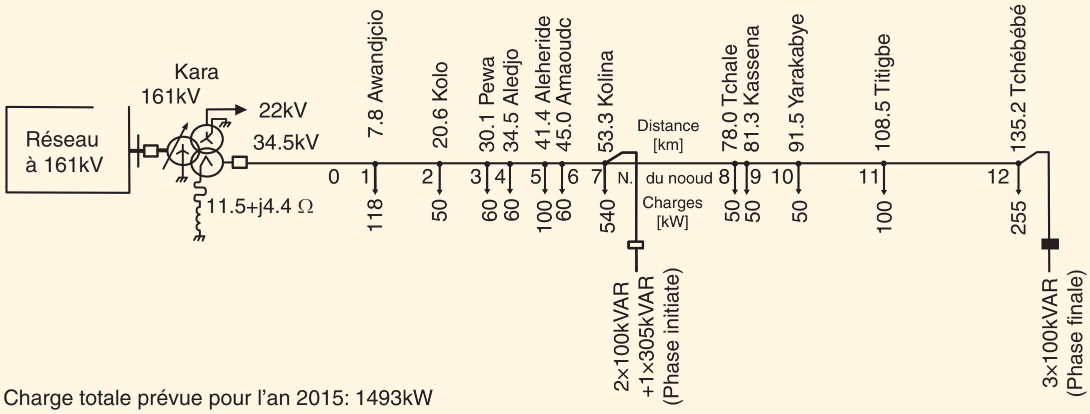


Charge totale prévue pour l'an 2015: 2410kW.

Charge maximale considérée: 3615kW (150% de la prévision de l'an 2015).

Longueur totale: 102.2km.

CDGI Al./Ac. de diametre 12.2mm.

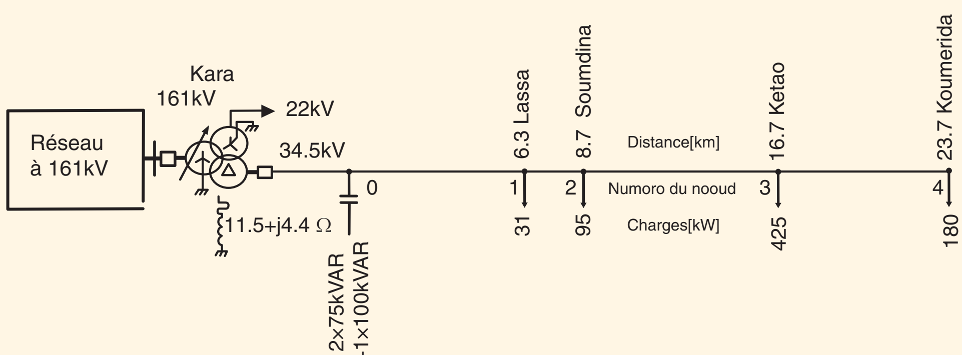


Charge totale prévue pour l'an 2015: 1493kW

Charge maximale considérée: 2239kW (150% de la prévision de l'an 2015).

Longueur totale: 135.2km.

CDGI Al./Ac. de diametre 12.2mm.



Charge totale prévue pour l'an 2015: 731kW

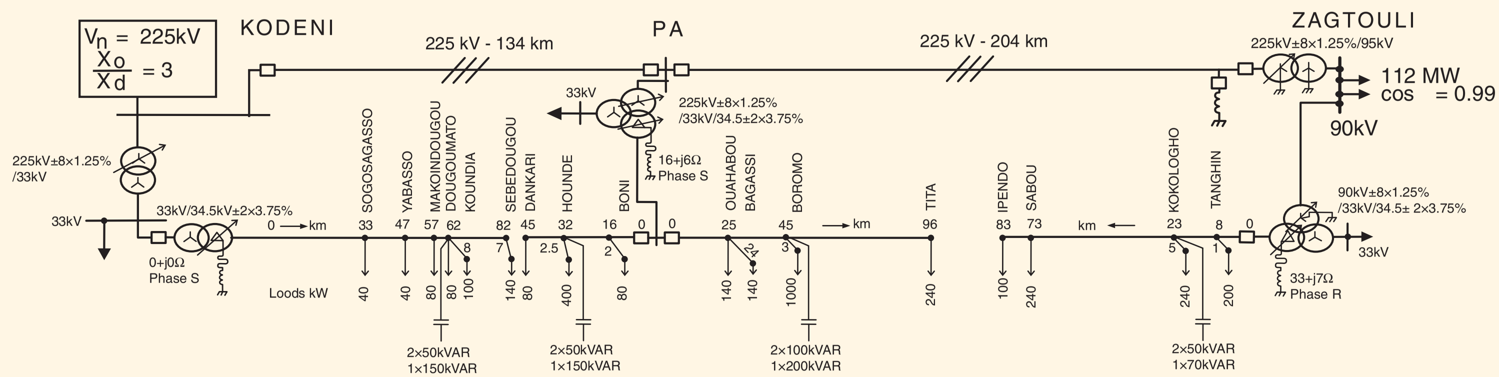
Charge maximale considérée: 1096kW (150% de la prévision de l'an 2015).

Longueur totale: 23.7km.

CDGI Al./Ac. de diametre 12.2mm.

FIGURE D.7

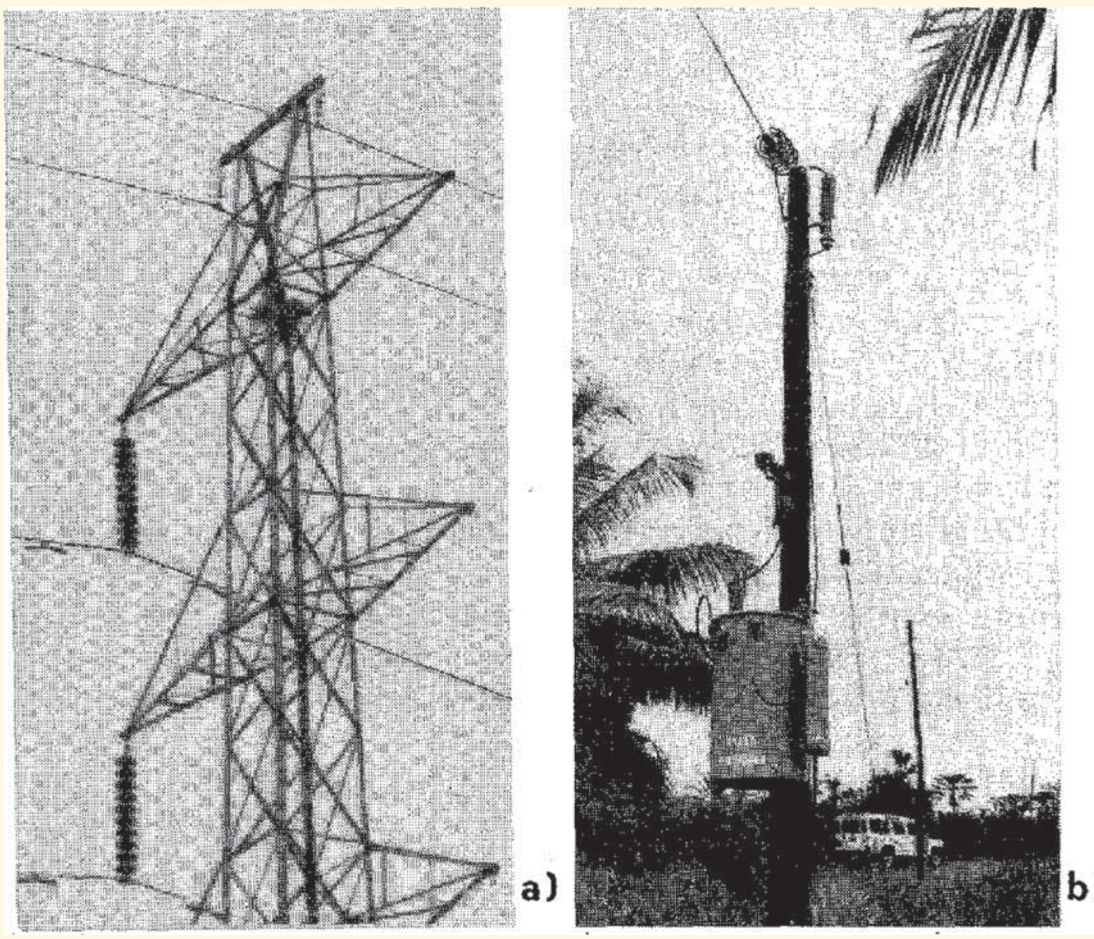
Single-Line Diagram of a 34.5 kV Three-Phase Iliceto Shield Wire Scheme in Burkina Faso



Burkina Faso - Electrification along the Bobo Dioulasso - Ouagadougou 225 kV transmission line with the "3-Phase" Iliceto Shield Wire Schemes. Loads: 200% of loads informed by Sogreah Consultants

PHOTOGRAPH D.1

Pilot 33 kV Iliceto Shield Wire Scheme Built in Ghana, 1985



a) Suspension tower with insulated shield wires; b) 100 kVA single-phase ground-return transformer station in Atabadzi. Photographed by Prof. Francesco Iliceto.

PHOTOGRAPH D.2

Suspension Tower of a 161 kV 248 km Transmission Line with Two Insulated Shield Wires, Ghana

Photographed by Prof. Francesco Iliceto.

PHOTOGRAPH D.3

Typical 30 kV Spur Line for Supply of a Village with a Three-Phase Iliceto Shield Wire Scheme, Ghana

Note | A ground conductor is strung under the two insulated phase conductors, for multiple earthing. Photographed by Prof. Francesco Iliceto.

PHOTOGRAPH D.4

Typical Intermediate Pole-Mounted Transformer Station for Public Distribution with the Three-Phase Iliceto Shield Wire Scheme, Ghana

Photographed by Prof. Francesco Iliceto.

PHOTOGRAPH D.5

Typical Terminal Pole-Mounted Medium Voltage/Low Voltage Transformer Station for Public Distribution with the Three-Phase Iliceto Shield Wire Scheme, Ghana

Photographed by Prof. Francesco Iliceto.

PHOTOGRAPH D.6

Transformer Station Supplying a Water Pumping Station, Ghana

Note | *The photo shows a 30 kV/415-240 V 3 l 5 kVA pole mounted transformer supplying a water pumping station equipped with six pumps. Photographed by Prof. Francesco Iliceto.*

PHOTOGRAPH D.7

Motors Rated at 75 kW at the Water Pumping Station of photograph D.6, Ghana

Photographed by Prof. Francesco Iliceto.

PHOTOGRAPH D.8

Transformer Station and Associated Oil Pumping Station, Ghana

Top: 30 kV/415-240 V 315 kVA transformer station supplied from a three-phase Iliceto shield wire scheme; Bottom: associated oil pumping station. Photographed by Prof. Francesco Iliceto.

PHOTOGRAPH D.9

Suspension Tower of a 230 kV 60 Hz Transmission Line with Two Insulated Shield Wires, Brazil

Photographed by Prof. Francesco Iliceto.

PHOTOGRAPH D.10
Suspension Tower of a 161 kV 200 km Transmission Line with Two Insulated Shield Wires, Sierra Leone

Photographed by Stefano Galantino/Pietrangeli S.r.l. Consultants.

PHOTOGRAPH D.11

Side View of the 34.5/10 kV 4 MVA Transformer Station That Supplies the Town of Makeni from the Iliceto Shield Wire Scheme, Sierra Leone

Photographed by Stefano Galantino/Pietrangeli S.r.l. Consultants.

PHOTOGRAPH D.12
Three-Phase Capacitor Bank, Makeni, Sierra Leone

Note | *The capacitor bank was installed as shown in figure C.1b in Annex C. Photographed by Stefano Galantino/Pietrangeli S.r.l. Consultants.*

PHOTOGRAPH D.13

Supply Bay of the Bumbuna-Makeni 34.5 kV Shield Wire Line through a 13.8/35.5 kV Interposing Transformer, Sierra Leone

Photographed by Stefano Galantino/Pietrangeli S.r.l. Consultants.

ANNEX E | MEASUREMENT OF GROUNDING RESISTANCE AND STEP AND TOUCH VOLTAGES OF GROUNDING SYSTEMS FOR EARTH RETURN OF CURRENT IN ILICETO SHIELD WIRE SYSTEMS

CONTENTS

E.1 INTRODUCTION

Measuring the potential to remote earth of grounding electrodes, V_{re}, and the step and touch voltages is easy when the Iliceto shield wire scheme is in operation, because there is a continuous current flow from the grounding system to the earth. Therefore, there is no need to use a temporary power supply and circuit arrangement to create a ground current flow. During the measurements, as much as possible, local loads should be switched-on for increasing the current flow on the earth.

E.2 POTENTIAL TO REMOTE EARTH. GROUNDING IMPEDANCE

The potential to remote earth, V_{re}, of the grounding systems is simply measured with a multimeter.

An insulated wire (cross section of 1 to 1.5 square millimeters is sufficient) is needed with a length of at least 10 times the maximum dimension of the grounding system. If this is a single grounding rod with length of 3 meters (m), a wire preferably 40 to 50 m long should be used. If the grounding system is formed by several grounding rods and/or buried conductors in an area with maximum diameter D, a wire with length about 10 D should be used.

The wire will be laid on the ground, starting from the grounding electrode (figure E.1) in the direction of the maximum expected electric field. Measurements can be repeated in two or three directions to identify the direction of the highest electric field, if this is not evident from the location of the grounding systems of the local spur medium-voltage (MV) lines and/or high-voltage (HV) transmission line (TL). At the other end of the wire, a small auxiliary electrode (of the type normally used for ground resistance measurements) shall be driven into the ground and connected to the wire. The multimeter shall then be connected between the grounding system to be checked and the wire. The multimeter reading provides the potential to remote earth, V_{re}.

If measurement of V_{re} is performed for the grounding mesh of a substation, the insulated wire should be laid in a direction orthogonal to the HV TLs provided with shield wires grounded in all the towers and/or with buried continuous counterpoise. The wire will be extended up to a distance for which V_{re} does not appreciably increase further.

Measurement of current injected into the grounding system, I_g, is usually carried out with a clamp-on ammeter on the connection to ground of one MV terminal of the medium-voltage/low-voltage (MV/LV) transformers (single-phase in figure E.1), or a capacitor bank, or the MV winding of the shield wire line supply transformer in the HV/MV station. The measurement of V_{re} and I_g allows calculation of the power frequency (50 or 60 hertz) impedance of the grounding system as follows:

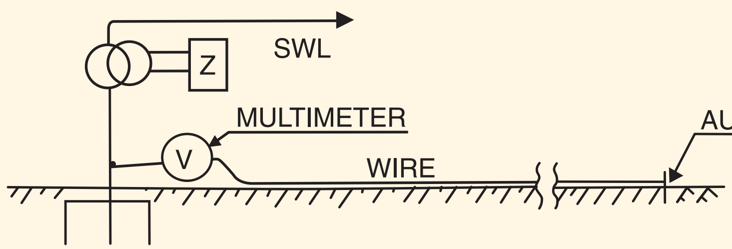
$$Z_g = \frac{V_{re}}{I_g} (\Omega) \quad \text{(E.1)}$$

Normally, Z_g is close to the resistance of the grounding system, R_g. However, in the case of use of multiple grounding electrodes distributed along an MV line, the following points should be considered:

i) Z_g can be higher than R_g, due to the importance of inductance of the ground wire supported by the poles of the MV line and connecting the various grounding electrodes (multiple grounding).

FIGURE E.1

Circuit Schematic for Measuring Potential to Remote Earth with Use of a Multimeter in an MV/LV Transformer Station



ii) The ground resistance measurement would be misleading if the measurement is performed with instruments making use of high-frequency test voltage. In fact, what is measured with an instrument using a high frequency is the impedance (**Z** = R+j2ΠfL). This can yield values considerably higher than the value of Z_g calculated with formula E.1 (at 50 hertz).

iii) The value of Z_g may differ depending on the point where the current is injected along multiple electrodes interconnected via an overhead ground wire. Ground impedance measurements should be performed with current injected in the site of installation of the MV/LV transformers and capacitor banks.

iv) *Measurement of V_{re} and calculation of Z_g with formula E.1, as described above, is the correct procedure.*

E.3 STEP AND TOUCH VOLTAGES

The step and touch voltages, V_s and V_t, can be measured with a multimeter by applying standard methods. The resistance of the human body can be considered very high and disregarded. This precautionary assumption simplifies the measurements. The assumption may yield step and touch voltages a little overestimated for the cases when the human body resistance is low.

Touch voltage is measured at a distance of 1 m from any metallic structure that can go in potential, in particular at 1 m from the structures connected to the grounding system for earth return of current, with continuous current flow. A multimeter (preset for alternating current voltage) shall be connected from the structure and a small auxiliary electrode in the ground at 1 m distance. Measurement of step voltage requires use of two auxiliary electrodes at 1m distance, radially located from the ground electrode. Step and touch voltages should be measured in various directions, to find the highest values.

In some cases, it may be difficult to measure the current injected in the earth, when the current flows to the earth via several parallel paths (for example, via the multiple grounding rods along an MV spur line).

Summation of currents measured on various electrodes can be made. If the local load is a power factor correction capacitor of known capacitance, the current can be readily calculated by dividing the shield wire to ground voltage by the capacitor impedance. Comparison of measured and calculated currents is an indicator of the integrity of the capacitor.

The measured step and touch voltages refer to the actual current, I_g, injected in the grounding system.

The step and touch voltages vary in proportion to the current flowing into the earth, and can thus be calculated for any expected current value, I_g max, when a measurement has been performed for an actual current value, I_g. The maximum step and touch voltages are the actual measured values multiplied by the ratio I_{gmax}/I_g.

E.4 ACCEPTABLE VALUES OF V_{RE}, V_S, AND V_T

To avert the risk of thermal instability (temperature run-away) of the grounding system operated for earth return of current, at the design stage the potential to remote earth, V_{re}, must be checked so that it does not exceed the value allowed by the Ollendorff formula (Equation 3.4 in chapter 3 of the manual).

V_{re} should be periodically measured in operation (at least every five years), particularly in the critical locations, during the dry season. Two requirements should be complied with:

i) V_{re} should be not higher than the maximum value allowed by the Ollendorff formula.

ii) The value of V_{re} measured for the grounding systems of the MV/LV transformer stations and capacitor banks generally should not exceed 30 V. A value up to a maximum of 50 V can be accepted only in exceptional locations.

The measured values of the step and touch voltages, V_g and V_t, are usually not higher than $0.33V_{re}$, that is, generally not higher than 10 V.

According to some national regulations, the maximum allowed value of the step and touch voltages with continuous persistence is 25 V.