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ELECTRICITE DU CAMBODGE

TECHNICAL RULE

EDC-TR-007

MV/LV Substation Maintenance Guideline

January 2022

ELECTRICITE DU CAMBODGE

Version	Date	Technical Specification Name	Authorized by : (name and signature)
1.0	May, 2022	MV/LV Substation Maintenance Guideline	Dr. PRAING CHULASA

Version	Drafted/reviewed by	Verified by	Approved by	Date
Draft1	AD			10/2021
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Draft 3	EDC/AD			02/2022

Contents

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MV/LV Substation Maintenance Procedures

1 Scope of Application

This technical rule defines the necessary checking, tests, verifications, modifications and measurements to be carried out on MV/LV substation and distribution power transformers for maintenance.

This technical rule MUST be read in conjunction with EDC-TR-001 – LVDB, transformer LV cable and LV fuses choice that give a lot of information/requirements on substations construction. Nevertheless, this EDC-TR-001 MUST BE APPROVED AND APPLIED BEFORE THIS DOCUMENT.

2 Preamble

2.1 Testing staff

Technicians performing these electrical tests and inspections shall be trained and experienced concerning the apparatus and systems being evaluated. These individuals shall be capable of conducting the tests in a safe manner and with complete knowledge of the hazards involved. They must evaluate the test data and make a judgment on the serviceability of the specific equipment.

2.2 Safety

This document deals only with verifications and electrical measurement and tests to be carried out. The safety rules and procedures are not mentioned in this document.

All parties involved must be cognizant of electricity distribution standard safety procedures. This document does not contain any procedures including specific safety procedures. It is recognized that some of the tests and inspections recommended in this technical rule are potentially hazardous.

Individuals performing these tests shall be qualified and capable of conducting the tests in a safe manner, with complete knowledge of the hazards involved and with complete application of EDC safety procedure.

3 Checking of energized substation

3.1 Checking period

This visual checking is to be done every year (maximum 18 month). The following is to be checked:

3.2 Transformer:

- Verification of corrugated tank if not corroded,
- If possible, verification good status of bushings.
- Verification of absence of oil leakage or small traces of oil especially near cover gasket and bushings,
- Check transformer thermometer in order to know the max temperature of the transformer. In addition, it is important to know the temperature a peak hours using an infrared thermometer.

3.3 Whole substation:

- Full visual checking
- partial discharge testing (corona camera)

- Visual verification of earthings and measurement
- Any other points as status of LV cables insulation, etc...

3.4 Currents measurement:

The current is then measured at peak hours only (between 6pm and 10 pm). This current measurement at peak hours could indicate that the transformer reached or passed its capacity and start to be overloaded.

3.5 Conclusion

Result of this checking are recorded.

If it is noticed one abnormal point that could lead to a defect or a lack of proper earthing value shall lead to a not energized LV/LV substation maintenance here after.

4 Maintenance of not energized MV/LV substation

4.1 Maintenance period

It is recommended to verify and maintain MV/LV substation of any type every 5 years or less if necessary.

The whole MV/LV structure and transformer must be checked.

The earthing circuit must be verified and /or modified if this one is not in accordance with the requirements of EDC-TP-002- Earthing for MV and LV networks (joint Surge Arresters/mass earthing circuit, totally separated LV neutral earthing from the substation, etc..) and earthing resistance value must be measured and the grounding must be improved if the regulatory ohm values are not reached.

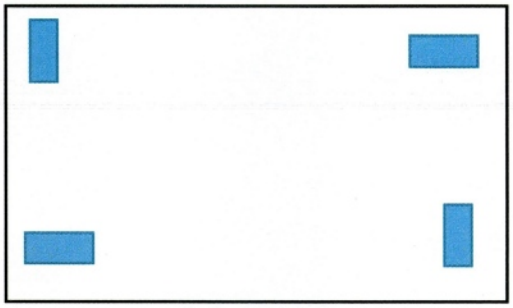
4.2 Transformer

The following verifications are to be carried out:

4.2.1 Transformer integrity

The whole transformer is verified in order to be sure that it is in perfect status.

- Verification of corrugated tank if not corroded,
- Verification of crossed wheels in case of building or prefabricated substation (if possible) ,



- Verification good status of bushings.
- Verification of absence of oil leakage or small traces of oil especially near cover gasket and bushing gaskets,

- Check transformer thermometer in order to know the max temperature of the transformer. In addition, it is important to know the temperature a peak hours using an infrared thermometer as well as currents always at peak hours. This current measurement at peak hours could indicate that the transformer reached or passed its capacity and start to be overloaded.
- Any other abnormal point.

4.2.2 Transformer testing

For hermetically sealed transformers less than 10 years old, there is no need of any testing if the visual inspection doesn't show any tank deformation or small oil leakage that could be caused by overheating.

For **hermetically sealed transformers older than 10 years** or transformers showing tank deformation and small oil leakage, the measurement of windings insulation resistance and measurement of winding resistance. A low resistance could show presence of water or other contaminants in the transformer oil.

For **breathing type transformers** (with oil tank) every 5 years the oil status (water contains) must be checked as well as the oil level in the separated tank. Additionally, the silica gel or similar product in the transformer breathing system must be checked and if the colour is pink or white, it must be replaced by new product (Blue or Orange colour).

Considering that **breathing type transformers are more subject to oil water contains** than hermetically sealed transformers, breathing type transformers windings are measured every 5 years (insulation and winding resistance)

It is strongly recommended to use specific testers for transformers.

a/ Measurement of winding insulation resistance.

Even this insulation testing can be done with a 5kV DC mega ohm meter, it is strongly recommended to do this test with a specific tester for transformer.

The purpose of this test is to determine the insulation resistance of the high-voltage winding to the ground, low-voltage winding to the ground, and the high-voltage winding to the low voltage winding.

The operating guide of the testing apparatus must be strictly followed.

This test should be done between the windings as follows:

- MV windings to the Earth
- LV windings to the Earth same as MV/Earth but the connection will be between LV-Earth.
- The MV windings to the LV windings.

As practical guide the following table may be applied:

Voltage	Test Voltage (DC) LV Side	Test Voltage (DC) MV Side	Min Insulation Resistance Value (Approx.)
11KV to 33KV (22kV)	1kV	5KV	500MΩ
33KV to 66KV (35kV)	1kV	5KV	600MΩ

(1): care the value varies with oil temperature.

If insulation resistance is less than requested values, the oil must be changed or treated.

b: Measurement of winding resistance

It is strongly recommended to use a specific testing apparatus for this winding resistance testing. Measures with simple ohmmeter do not give true values and do not allow a real verification of winding troubles during maintenance testing.

The purpose of this test is to measure the D.C. resistance of the transformer windings, this test can be done by a voltmeter and ammeter method.

This test can be done when a transformer is hot or cold, but the temperature of the winding and oil should be recorded during the test. For a transformer with delta/star windings, check the resistance as follows:

- MV winding resistance between phase A and phase B
- MV winding resistance between phase B and phase C
- MV winding resistance between phase A and phase C
- LV winding resistance between phase a and neutral n at Tap 3 (22 000V or 35 000 V)
- LV winding resistance between phase b and neutral n at Tap 3 (22 000V or 35 000 V)
- LV winding resistance between phase c and neutral n at Tap 3 (22 000V or 35 000 V)

It is mentioned that the resistance value varies with the temperature of the transformer (oil).

A brief checking with ohmmeter must show that the resistances R:

- RAB≈RAC≈RBC
- Ran≈Rbn≈Rcn

Using a specific testing equipment will allow to compare all measured winding resistances with the values mentioned in the routine test report of the transformer.

4.3 Building or prefabricated substation (OPS and PTT)

4.3.1 MV/LV equipment and connections

a) RMU

- Verification of MV connection and screen earthing to masses (cf: EDC-TR-005),
- Verification of presence of earthing wire of separable connector body (cf: EDC-TR-005),
- Verification of good operation of all RMU switches,
- Verification of the right MV fuses rating according the transformer capacity and the recommendations of RMU manufacturer. If one fuse show cracking, deformation or abnormal heating, the three MV fuses MUST be replaced by brand new ones. The old fuses must be destroyed.
- Verification of good connection of RMU to earthing circuit (not body of PPT)

b) MV cable tray

- Verification of good fixing (plastic ties) of MV transformer cables to cable tray on wall,
- Verification of connection of MV cable tray to earthing circuit.

c) transformer

- Verification of transformer MV connection and screen earthing to masses (cf: EDC-TR-005),
- Verification of presence of earthing wire of separable connector body (cf: EDC-TR-005),
- Verification of good connection of transformer to earthing circuit (not body of PPT)
- Verification of status of LV bushings and good tightening of LV cable lugs

d) LV cable tray

- Verification of good fixing against wall
- Verification of good installation and fixing (plastic ties) of LV cables to cable tray on wall,
- Verification of connection of LV cable tray to earthing circuit.

e) LVDB

- Verification of good fixing of LVDB inside the cabinet,
- Verification of incoming cable connection (compression of lugs and bolts tightening),
- Verification of good operation of LVDB switch
- Verification of monoblocks tightening on main bus bar,
- Verification of correct fuse insertion and presence of all transparent fuse holders fixed on the fuses. If transparent fuse holders are missing, they must be installed on fuses.
- Verification of good tightening of monoblock neutral bar,
- Verification of proper wiring of LV feeders
- Verification of connections of LV feeders (good compression of lugs, bolts tightening, presence of heat shrinkable tube on lug body or use of pre-insulated lugs). If one lug show heating this one must be replaced.
- Verification of LVDB frame and cabinet support earthing connection

4.3.2 Earthing circuit

As mentioned before this earthing circuit must be in accordance with EDC-TP-002. If the existing one is not in accordance with this earthing policy, this one must be reviewed.

The following is to be checked and verified:

- Verification of the full continuity and good fixing of earthing circuit as requested by EDC-TP-002
- Verification of envelop PPT and OPS connection to the earthing circuit
- Verification of metallic door and metallic airings connection to earthing circuit (built substation)
- Verification of connection of ALL masses of equipment to the earthing circuit
- **Verification of the presence of equipotential belt around the substation. If not, this must be done.**
- Verification of good connection of all earthing conductors onto the main earthing board.
- Verification of position of neutral earthing bar on main earthing board (open if neutral earthing separated from mass earthing or closed if commune. See EDC-TP-002 and requirements from Distribution management staff)

4.3.3 LV neutral earthing

The new earthing policy (EDC-TP-002) require that **LV neutral earthing being separated from the substation and then done on the first LV pole of LV network**. Exceptions are clearly mentioned in this technical policy.

So, during substation maintenance, this fact needs to be verified and corrected if necessary. (refer to drawings in page 16 and 17)

4.4 Measurements

4.4.1 Measurement of earthing circuits

The mass and neutral earthings are measured using specific earthing measurement apparatus using **Wenner method** with 4 wires that allow also soil resistivity measurement and earth coupling measurement.

2 wires earth testers are not allowed. The following apparatuses are 4 wires testers:

- **TERCA, TERCA 2 and TERCA 3 from Chauvin Arnoux**
- **KEW 4106 from Kyoritsu**
- **DET4TD2, DET4TR2, DET4TC2 and DET4TCR2 from Megger**
- **Etc...**

All must be used with their own wires and rods kits.

The method for measurement is described in EDC-TP-002 TDS. Nevertheless the user notice of each apparatus for rods installation and distances must be strictly followed: If it is requested to install a rod at 60m and another one at 100 m in straight line from the earthing to be measured, **this must be properly done, because if not, the earthing value will be wrong because will not take into account the deep layers of the soil.**

The substation mass earthing is measured first and then, similarly, the global LV neutral earthings is measured by connecting the tester lead onto neutral bar of the LVDB or on the main earthing bar.

The maximum earthing values are:

- **Masses earthing of substation: 10 Ω**
- **Global value of LV neutral earthing: 5 Ω**

In case of full underground urban MV network, the LV neutral earthing could be connected to the mass earthing provided the conditions listed in EDC-DTS-002 and TDS **are ALL satisfied**.

If the maximal values cannot be reached, earthing improvement shall be done. This is mandatory for both, mass and global LV neutral earthing.

In addition, the electrical coupling between mass earthing and 1st pole LV neutral earthing is measured according requirement of EDC-TP-002. (See here in after for coupling measurement.)

- The coupling shall not exceed 15%.

If more, the LV neutral is moved to the second pole after the substation.

4.5 Pole mounted substation

Similarly, to build or prefabricated substations the following is to be checked during substation maintenance.

4.5.1 MV/LV equipment

The following is to be verified and checked:

a) jumps

- Verification of MV jumps connection to the OHL as well as their configuration: jumps must be in straight line to the first connected equipment that must be the surge arresters.

- Verification of all MV lugs used. Bi metallic lugs with friction welding must be replaced by good withstand lugs with right hexagonal compression,

b) Surge arresters and FCO

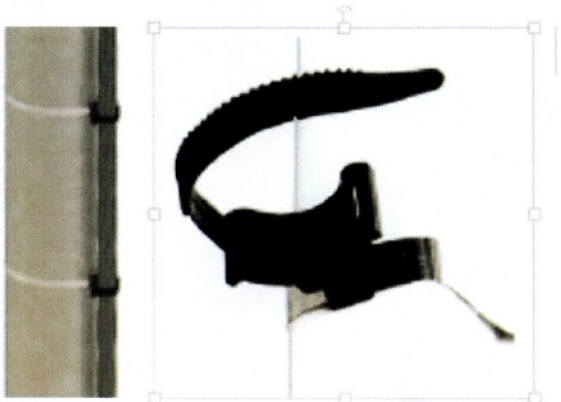
- Verification of connections bolts tightening on surge arresters and FCO
- Verification of the right expulsion fuses rating of FCO according the transformer capacity,
- Verification of integrity of surge arresters
- Verification of **the presence of ultra-flexible cable earth lead on the surge arrester**. If not, those ones must be installed,

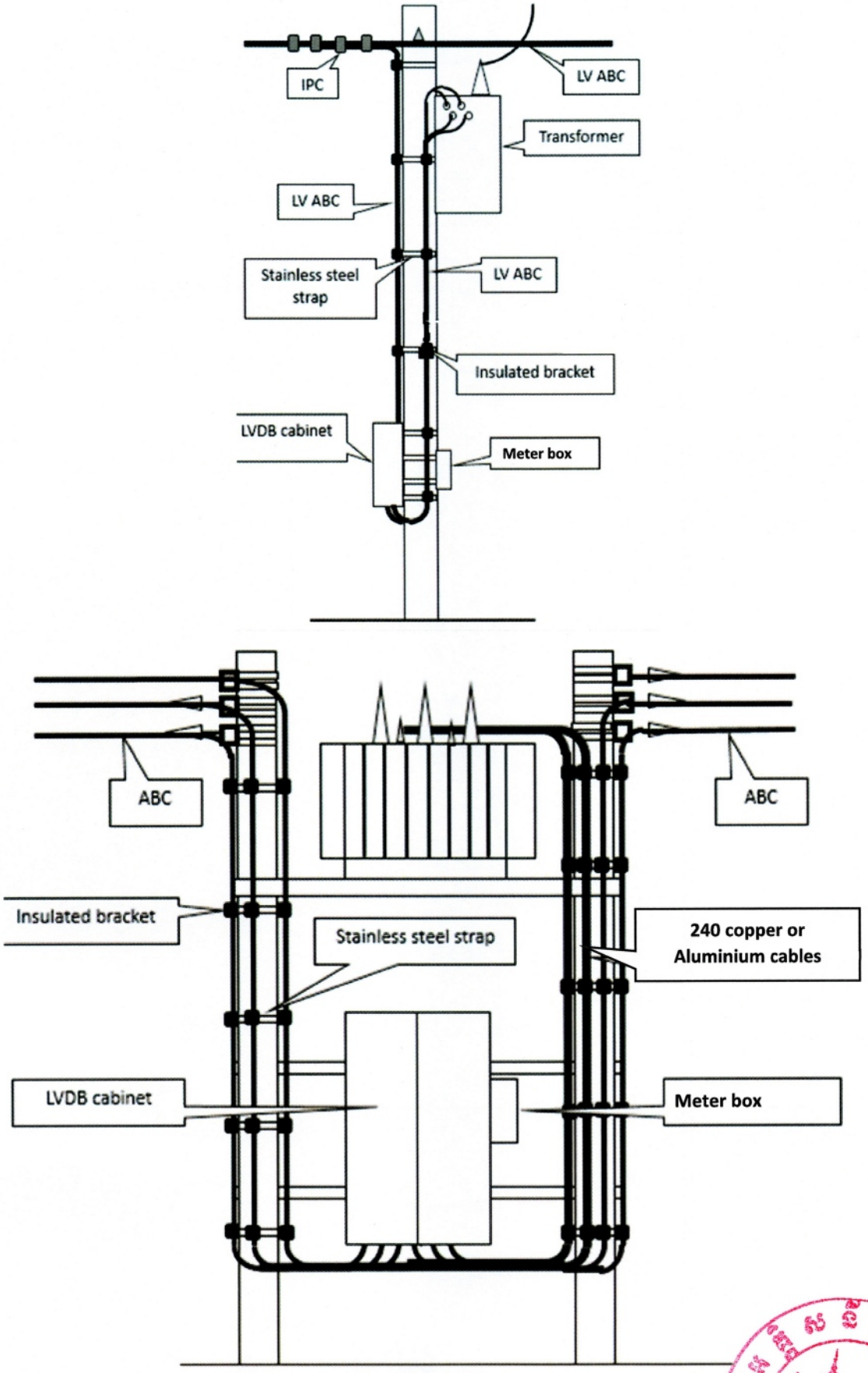
c) transformer

- Verification of lugs and transformer's MV bushing tightening as well as bushing status,
- Verification of LV lugs crimping and transformer LV bushings tightening as well as bushing status,
- Verification of corrugated tank if not corroded,
- Verification good status of bushings.
- Verification of absence of oil leakage or small traces of oil especially near cover gasket and bushing gaskets,
- Check transformer thermometer in order to know the max temperature of the transformer. In addition, it is important to know the temperature a peak hours using an infrared thermometer as well as currents always at peak hours. This current measurement at peak hours could indicate that the transformer reached or passed its capacity and start to be overloaded.
- Any other abnormal point.

d) LV cables and ABC

- Verification of good LV cables fixing along the pole as well as LV ABC feeders. **If not, LV cables must be properly attached** as follow:




IPC
LV ABC
Transformer
LV ABC
Stainless steel strap
LV ABC
Insulated bracket
LVDB cabinet
Meter box
ABC
ABC
Insulated bracket
Stainless steel strap
240 copper or Aluminium cables
LVDB cabinet
Meter box

- Verification of good fixing of LVDB inside the cabinet,
- Verification of incoming cable connection (compression of lugs and bolts tightening),
- Verification of operation of LVDB switch
- Verification of proper wiring of meter voltage circuit on the fuse block located near the LVDB main switch.
- Verification of monoblocks tightening on main bus bar,
- Verification of correct fuse insertion and presence of all transparent fuse holders fixed on the fuses,
- Verification of good tightening of monoblock neutral bar,
- Verification of proper wiring of LV feeders
- Verification of connections of LV feeders (good compression of lugs, bolts tightening, presence of heat shrinkable tube on lug body or use of pre-insulated lugs),
- Verification of LVDB frame earthing connection
- If there is trace of small animals or foreign bodies inside the LVDB cabinet, this comes from the cable penetrations inside the cabinet. So, the holes around the cable penetration (cone grommets) must be filled using self-adhesive massive (Scotch 2228 as example).

4.5.2 Pole mounted substation earthing circuit

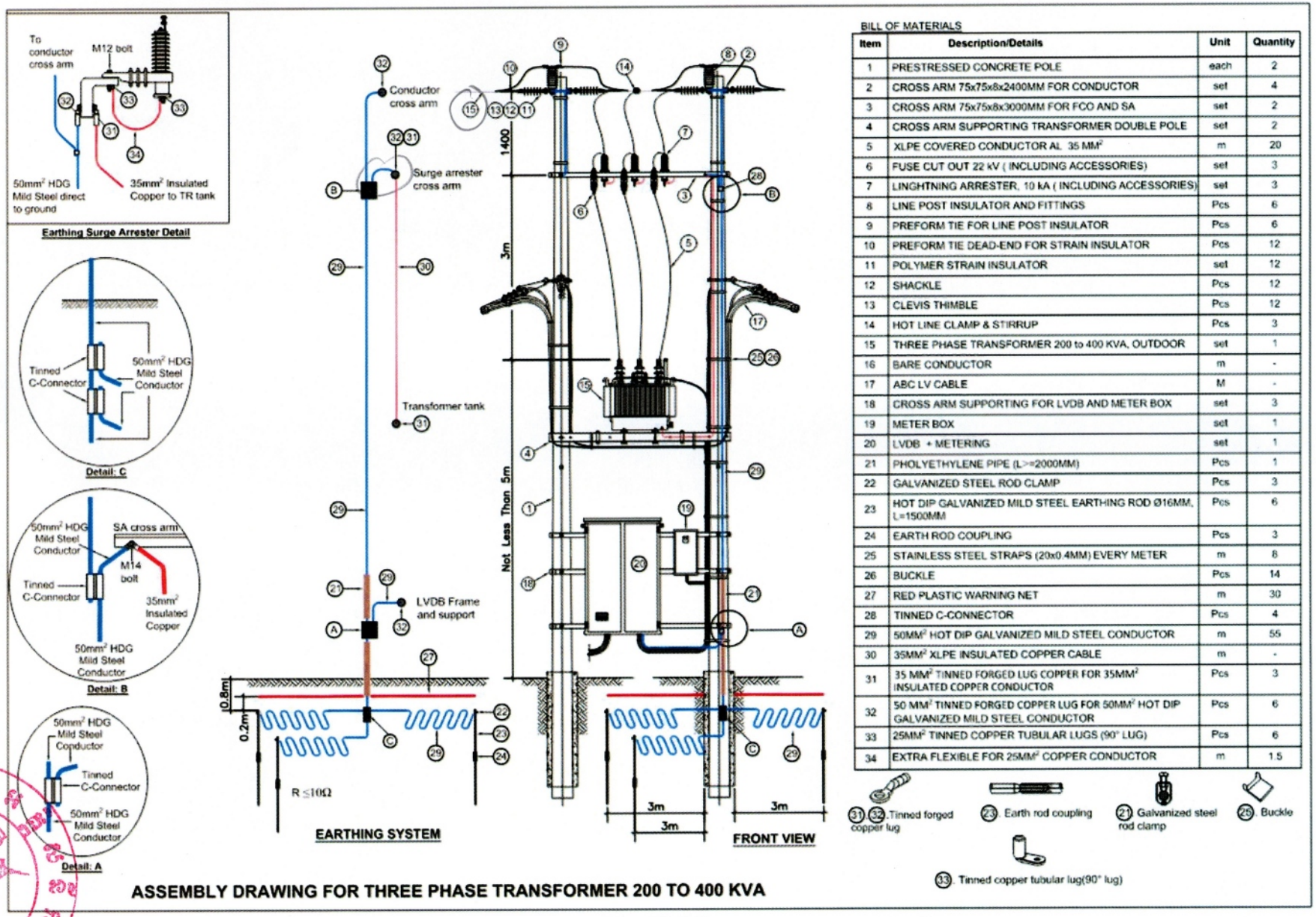
The pole mounted earthing circuit is clearly defined in EDC-TP-002: Earthing for MV and LV distribution networks and its technical data sheets.

So, if the existing earthing circuit of the substation under maintenance, this circuit MUST be re installed according the requirements of EDC-DTS-002.

The design of the earthing circuit MUST BE STRICTLY FOLLOWED. If not, the transformer will not be efficiently protected against surges.

It is recalled that the LV neutral earthing is NOT CONNECTED to the neutral bushing of the transformer but on the neutral of LV feeders on the first pole after the substation

The main earthing circuit MUST be ORIGINATED FROM THE SURGE ARRESTER CROSS ARM



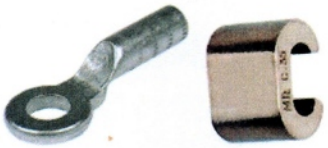
BILL OF MATERIALS

Item	Description/Details	Unit	Quantity
1	PRESTRESSED CONCRETE POLE	each	2
2	CROSS ARM 75x75x8x2400MM FOR CONDUCTOR	set	4
3	CROSS ARM 75x75x8x3000MM FOR FCO AND SA	set	2
4	CROSS ARM SUPPORTING TRANSFORMER DOUBLE POLE	set	2
5	XLPE COVERED CONDUCTOR AL 35 MM²	m	20
6	FUSE CUT OUT 22 kV (INCLUDING ACCESSORIES)	set	3
7	LINGHTNING ARRESTER, 10 kA (INCLUDING ACCESSORIES)	set	3
8	LINE POST INSULATOR AND FITTINGS	Pcs	6
9	PREFORM TIE FOR LINE POST INSULATOR	Pcs	6
10	PREFORM TIE DEAD-END FOR STRAIN INSULATOR	Pcs	12
11	POLYMER STRAIN INSULATOR	set	12
12	SHACKLE	Pcs	12
13	CLEVIS THIMBLE	Pcs	12
14	HOT LINE CLAMP & STIRRUP	Pcs	3
15	THREE PHASE TRANSFORMER 200 to 400 KVA, OUTDOOR	set	1
16	BARE CONDUCTOR	m	-
17	ABC LV CABLE	M	-
18	CROSS ARM SUPPORTING FOR LVDB AND METER BOX	set	3
19	METER BOX	set	1
20	LVDB + METERING	set	1
21	PHOLYETHYLENE PIPE (L>=2000MM)	Pcs	1
22	GALVANIZED STEEL ROD CLAMP	Pcs	3
23	HOT DIP GALVANIZED MILD STEEL EARTHING ROD Ø16MM, L=1500MM	Pcs	6
24	EARTH ROD COUPLING	Pcs	3
25	STAINLESS STEEL STRAPS (20x0.4MM) EVERY METER	m	8
26	BUCKLE	Pcs	14
27	RED PLASTIC WARNING NET	m	30
28	TINNED C-CONNECTOR	Pcs	4
29	50MM² HOT DIP GALVANIZED MILD STEEL CONDUCTOR	m	55
30	35MM² XLPE INSULATED COPPER CABLE	m	-
31	35 MM² TINNED FORGED LUG COPPER FOR 35MM² INSULATED COPPER CONDUCTOR	Pcs	3
32	50 MM² TINNED FORGED COPPER LUG FOR 50MM² HOT DIP GALVANIZED MILD STEEL CONDUCTOR	Pcs	6
33	25MM² TINNED COPPER TUBULAR LUGS (90° LUG)	Pcs	6
34	EXTRA FLEXIBLE FOR 25MM² COPPER CONDUCTOR	m	1.5

ASSEMBLY DRAWING FOR THREE PHASE TRANSFORMER 200 TO 400 KVA

The following is to be checked and verified:

- Verification of the full continuity and good fixing of earthing circuit (every meter thanks stainless steel strap) as requested by EDC-TP-002
- Verification of the extra flexible surge arrester's earthing link presence,
- Verification of **origin of earthing circuit that must be on surge arresters cross arm**
- Verification of **the insulated earthing** link between surge arresters' cross arm and transformer tank,
- Verification of connection of ALL masses of equipment to the earthing circuit (LVDB frame, LVDB cabinet supporting frame, etc...)
- Verification of earthing connecting equipment that must be as follow and compressed with the right dies,

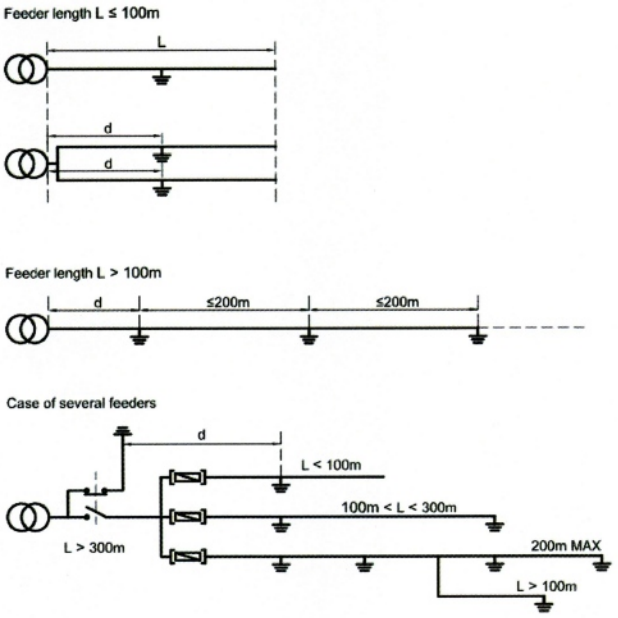


4.6 LV neutral earthing

The new earthing policy (EDC-TP-002) require that LV neutral earthing being separated from the substation and then done on the first LV pole of LV network.

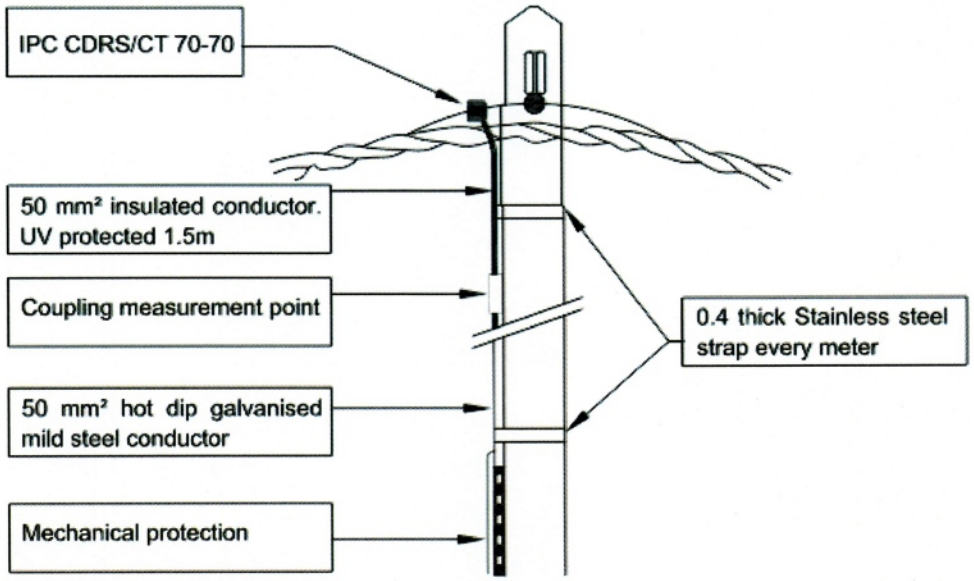
So, during substation maintenance, this fact needs to be verified and corrected if necessary. In all case a LV neutral earthing will be installed on the LV network and the old LV neutral earthing circuit connected to the transformer shall be removed. In addition, the presence of other LV neutral earthing on the LV network as follow must be checked and done if necessary:

LV Neutral Earthing



Distribution of LV neutral earthings.
- in addition to a point in the network as soon as the length of the line exceeds 100 meters;
- the number of earthing is equal to or greater than one every 200 meters of feeder network length;
- one LV neutral earthing near each major branch or group of individual branches.

First pole neutral earthing



The coupling measurement point is located about 1 meter below the ABC. It is constituted of 2 compressed tin copper forged lugs and one stainless steel bolt (see below)

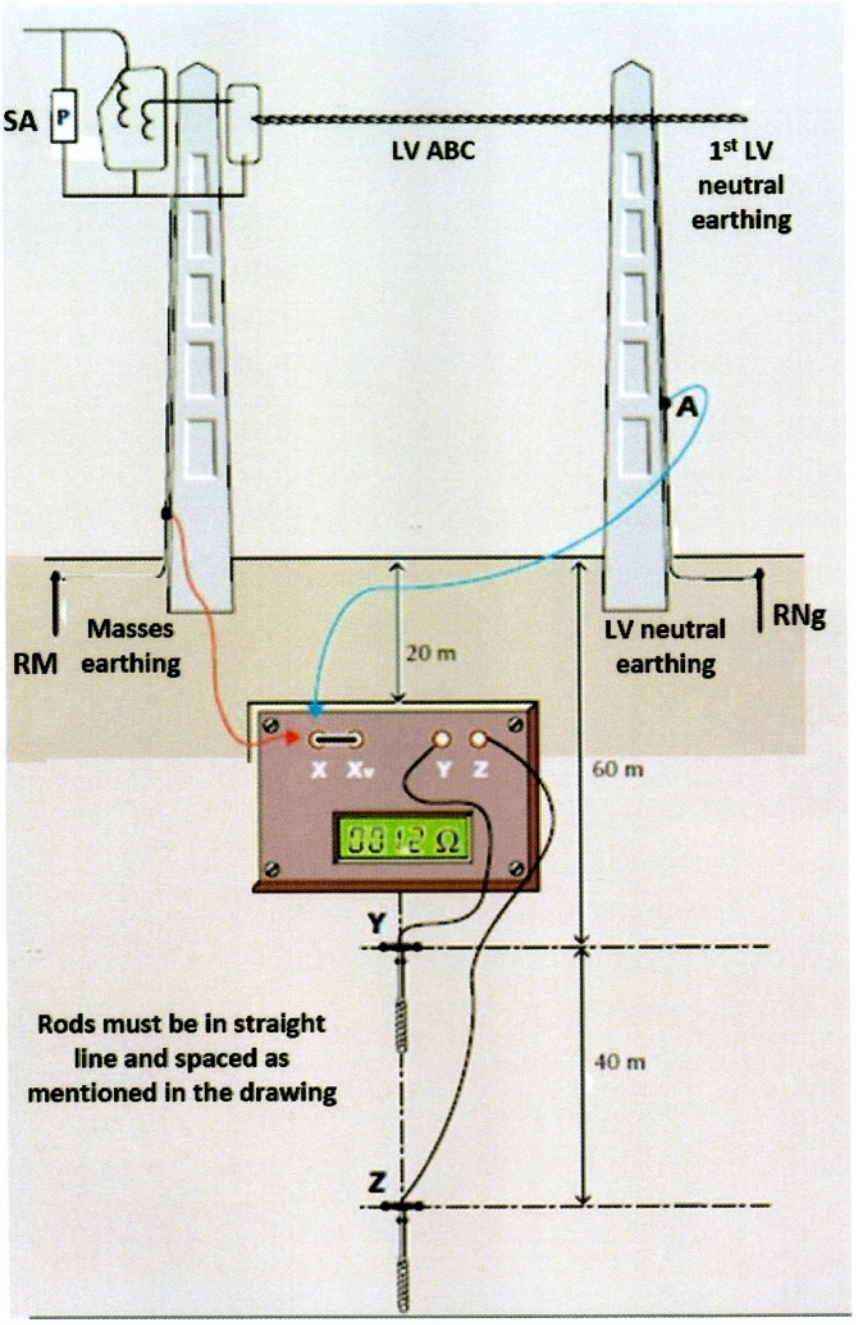
The 35 mm² copper insulated UV protected conductor of 1.5 meter length is mandatorily attached to the ABC before entering in the IPC and the outersheath is removed. Piercing is done through the insulation.

Coupling measurement point

So, during substation maintenance, this fact needs to be verified and corrected if necessary. In all case a LV neutral earthing will be installed on the LV network and the old LV neutral earthing circuit connected to the transformer shall be removed. In addition, the presence of other LV neutral earthing on the LV network as follow:

4.6.1 Measurement of earthing circuits

As mentioned above, the earthing circuits are then measured as follow by starting by mass earthing (red wire connected and blue wire disconnected) and then neutral earthing (blue wire connected and red wire disconnected):



The maximum earthing values are:

- **Masses earthing of substation: 10 Ω**
- **Global value of LV neutral earthing: 5 Ω**

In addition, and in order to be sure that the flow of a fault or atmospheric current in the mass earthing will not flow into the LV neutral, it is necessary to the electrical coupling between substation mass earthing and the nearest LV neutral earthing. The process, explained in EDC-TP-002 is as follow:

Determine the coefficient of coupling:

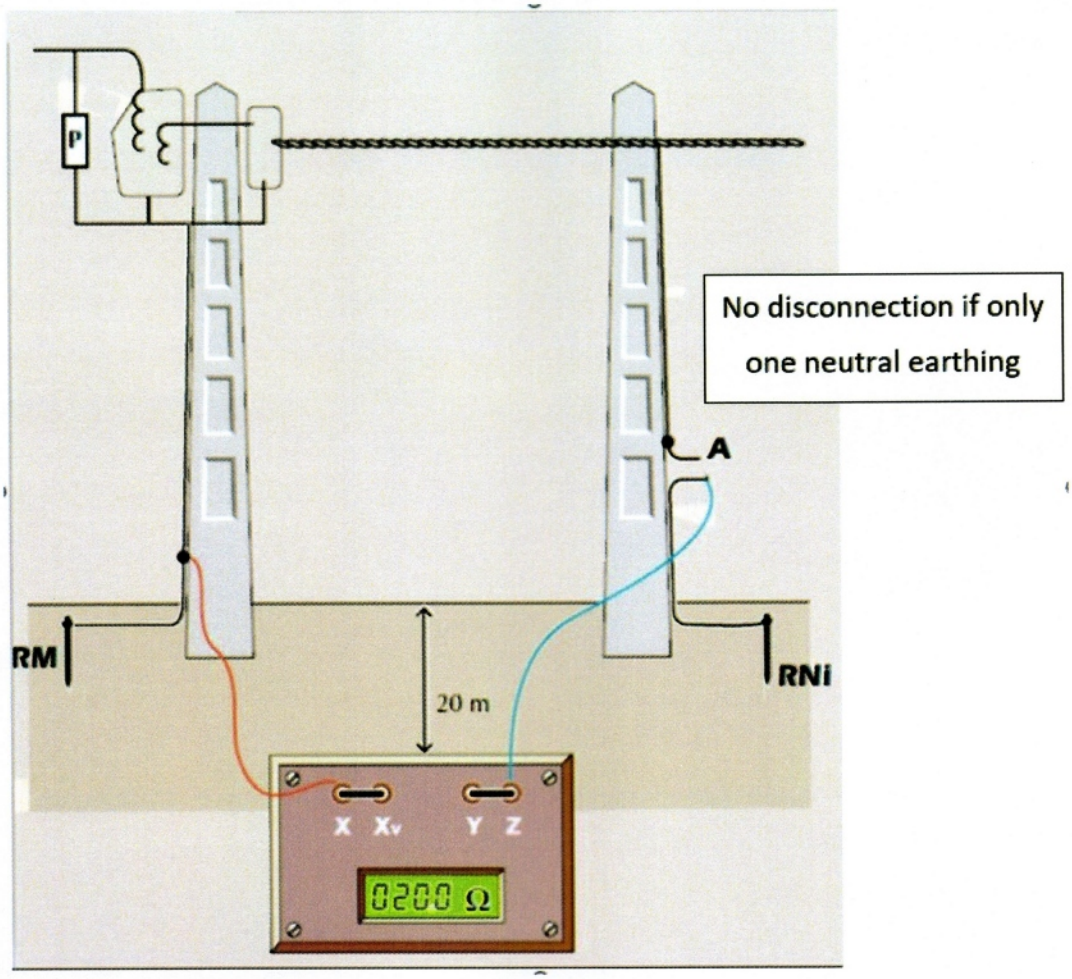
- RNg= Global Neutral earthing
- RNi= First individual Neutral earthing

1/ If there is only one neutral earthing, do not disconnect because RNg = RNi and go to step 4

2/ if there are several neutral earthings on the network, disconnect the point A and measure the resistance of the individual LV neutral earthing RNi (blue cord in place with A disconnected)

3/ Check that RNi> RNg.

4/ Proceed to RNM measurement according to the following drawing.



5/ Check that RM + RNi ≥ RNM.

6/ Calculate the coupling resistance **Rc**

$$Rc = \frac{RM + RNi - RMN}{2}$$

7/ Calculate the coefficient of coupling C

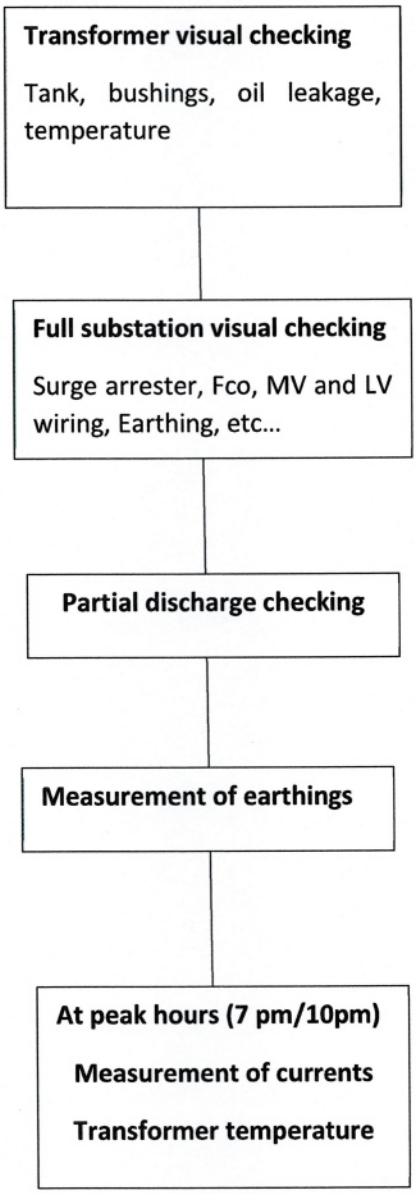
C = RC/RM

Make sure that C < 0.15.

8/ Restore the link at point A.

If C is more than 0.15, it is necessary to install the first LV neutral earthing at the second pole after the substation a,d make a new measure of electrical coupling.

5 Energized substation yearly maintenance/control flow chart



6 CHECKLIST/REPORT OF ENERGIZED SUBSTATION (YEARLY CHECK)

	Inspection Date:	
1	MV feeder reference or name	
2	Substation reference (Number or name)	
3	Substation type	PMT ☐ Built ☐ PTT ☐ OPS ☐
4	Transformer manufacturer	
5	Transformer manufacturing date	
6	Transformer Serial Number	
7	Rated capacity (kVA)	
8	Transformer Primary voltage (kV)	
9	Transformer Secondary voltage (kV)	
10	Tap number	5 ☐ 3 ☐ Other:
11	Tap max voltage	
12	Tap min voltage	
13	Number of LV feeder	
14	LVDB	Yes ☐ No ☐
15	Type of LVDB	
FCO and surge arrester and MV wiring visual status		
1	Surge arresters:	
2	FCO:	
3	Wiring	
Transformer visual status:		
1	Oil leakage: Yes ☐ Not ☐ If yes: where?: Urgent repairing: ☐	
2	Corrosion: Yes ☐ Not ☐ If yes, where?:	
3	Tank chocked or bended: Yes ☐ Not ☐ If yes, where? And detail:	

4	Max reached temperature on transformer thermometer (if possible to check):	
5	MV Bushing status (if possible to see):	
6	LV Bushing status (if possible to see):	
Partial Discharge testing (Corona camera)		
1	Partial discharges: Yes ☐ Not ☐ If yes, Where?	
	Infrared thermometer (°C)	
1	Transformer temperature:	
2	MV connections temperatures: Line: Surge arresters: FCO: MV bushings (if possible):	Comment:
3	LV connection temperature: LV bushings (if possible): LVDB incoming: LV feeders: PMT fuses:	Comment:
Currents (A)		
4	Hour of measurement: Phase 1: Phase 2: Phase 3: Neutral:	Comment:
Visual checking and measuring of earthing (Ohm)		
	Mass earthing: (Ω) Comment:	
	Arresters earthing: (Ω) Comment:	

	LV neutral earthing: (Ω) Comment:

Urgent repairing: Yes ☐ No ☐

If yes, description:

Other point to be mentioned:

Checking by (Names & Signature) :

1: 2:

3: 4: