SUBSTATIONS, CAPACITORS & ACR'S SECTION 7

1. DISTRIBUTION SUBSTATIONS

General

1. Prior to the activation of a transformer, the work group shall:
   - Ensure that the reticulation system neutral is clearly identified and marked by the letter **"N".**
   - Identify and confirm the reticulation system neutral by conducting a visual and appropriate electrical test.
2. After both the transformer and reticulation neutrals have been positively identified:
   - Establish the connection between these two neutrals.
   - Connect the LV earth to the transformer neutral terminal, to the neutral busbar, or the neutral conductor between the transformer and the reticulation, whichever is appropriate.
   - Correctly identify and complete the connections between the reticulation active/s or phases and their corresponding transformer terminals via the transformer LV isolators, fused isolators or fuses.
   - On completion of all wiring work, ensure that the transformer LV isolators/fuses are left open.
   - Confirm the installation and accuracy of all labelling attached to installations prior to commissioning.
   - Set the transformer to the designated tap position for the substation location along the feeder.
   - Ensure all E&SC/bonders are removed and any Access Authority is cancelled, and in the case of new equipment, that the necessary clearance is available.

Distribution transformer phasing and connections

Overhead pole and platform mounted transformers are used to supply single and three phase Low Voltage power. For information regarding the electrical properties of transformers see Section 2, Electrical Theory.

Phasing

When erecting new transformers it is critical to establish the direction of supply and correct phase rotation. This will determine which side of the pole the transformer should be erected on. Figure 1 shows the options obtainable.

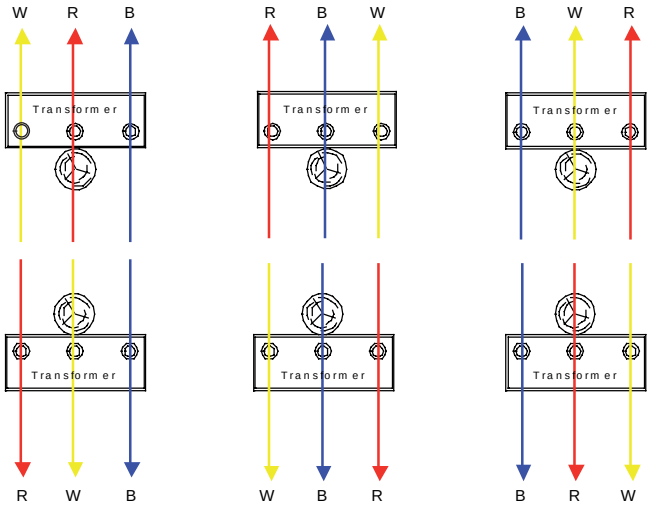
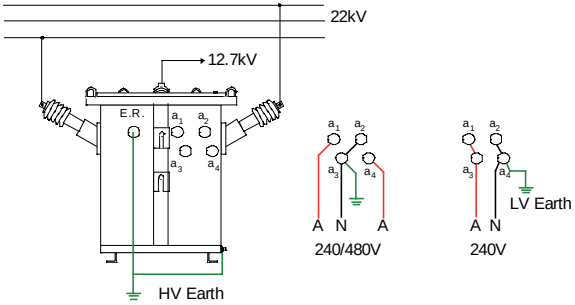


Figure 1

Transformer connections

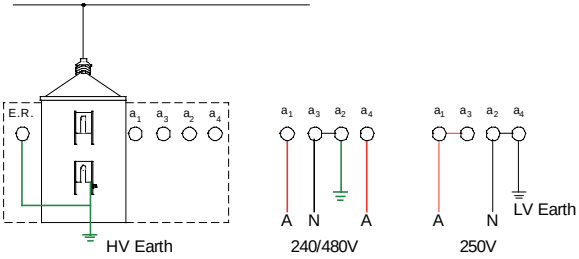
In the case of single phase transformers (including SWER Isolating and SWER distribution transformers), decide which of the LV terminals is to be designated the neutral. This will depend on the reticulation voltage required (i.e.: 240 volts only or 240/480 volts). Refer also to the connection diagram on the transformer nameplate to obtain the correct bridging of terminals.

SWER isolating transformer



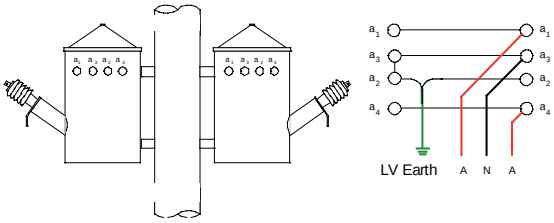
The physical arrangement of the LV bushings will vary from model to model. Check name plate details and terminal markings.

SWER distribution transformer



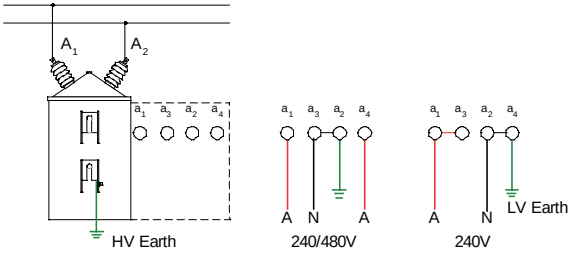
Some SWER transformers have only one LV winding, so either one of the terminals marked a_1 or a_2 can be made the neutral.

SWER distribution transformers in parallel

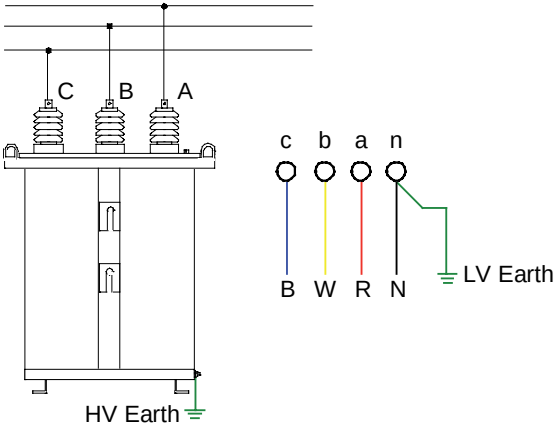


Both transformers should be the same make and tap selectors must be on the same setting.

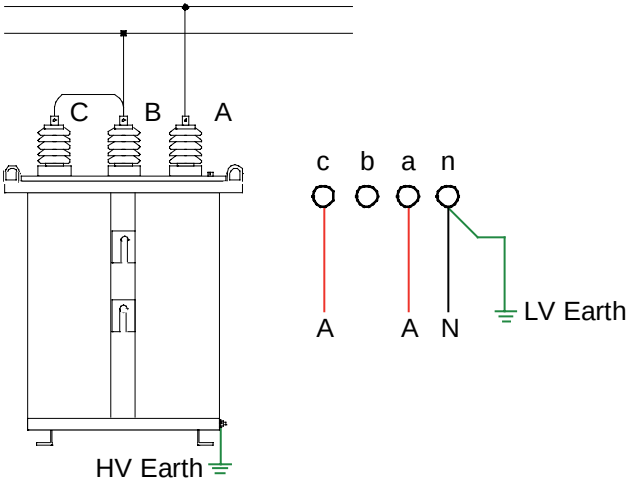
Single phase distribution



Three phase distribution



"Rodgers Connected" Three phase



Transformer kVA output is 82% of nameplate kVA rating, i.e. 200kVA will supply 164kVA of balanced load.

Voltage output is 250/500 volts.

Active LV terminals are 'a' and 'c'.

Vector group must be DYN11.

Distribution transformer commissioning

If all precommissioning installation and insulation test results are achieved, confirm cancellation of any outstanding Access Authorities, receipt of any service clearances the removal of operational earths and then energise the transformer on the HV side.

With the transformer LV isolators open, carry out the transformer NO LOAD checks:

- Using an approved voltmeter with a minimum range of 0-600V, test at the transformer side of the open LV isolators/fuses, to ensure that the voltage is acceptable.

Three phase transformer

TEST POINTS	ACCEPTABLE READING
R phase - Neutral W phase - Neutral B phase - Neutral	247 – 252 Volts (maximum 442V)
R phase - W phase W phase - B phase B phase - R phase	427 – 436 Volts (maximum 442V)

Single phase transformer

TEST POINTS	ACCEPTABLE READING
Actives - Neutral	247 – 252 Volts (maximum 255V)
Active - Active	494 – 504 Volts (maximum 510V)

A phase sequence test shall be carried out in the following situations when dealing with a three phase transformer:

1. Where the transformer **cannot** be paralleled with any other three phase transformer.

   - Using an approved phase sequence tester, connect the Red, White and Blue leads of the tester to the corresponding phases on the transformer side at the transformer LV isolators. The correct result is achieved when the tester indicates "sequence is correct".

   - Where there are no transformer blade isolators, such as a kiosk substation with a 3 phase LV switch, the test shall be conducted at

the earthing point of the LV bus, at test points where provided, or when possible at the customers switchboard.

2. Where the transformer **can** be paralleled with any other three phase transformer.

- A phasing-out test shall be performed in all cases where a three phase transformer can be paralleled with another three phase transformer. Using a voltmeter, the test is to be conducted between the two live circuits at the transformer LV isolators or, where this is not considered appropriate an initial phase sequence test shall be performed at the transformer followed by a further test at the normal paralleling point, as follows:

  – Ensure that both circuits to be phased out are alive by conducting phase to phase and phase to neutral voltage checks on each circuit separately. Record readings of phase to neutral voltage when using voltage tester for voltage comparison.

  – Carry out a test from one circuit to another across the open points with a neon tube tester or voltage tester, i.e.:

Neon Tube Voltage Tester

Red phase > Red phase	No Lights
White phase > White phase	
Blue phase > Blue phase	

Voltage Tester

Red phase > Red phase	0 – 15 Volts See Note
White phase > White phase	
Blue phase > Blue phase	

NOTE: When using a voltage tester a voltage may indicate depending on the voltage difference of the tested circuits. (e.g. Transformer side volts minus circuit volts 252V – 243V = 9V voltage difference). If voltage range is higher than the voltage difference further investigation of the voltage should be as per distribution company procedures.

Only where a single phase transformer can be paralled with another single phase transformer by means of LV isolators shall a phasing out test be considered necessary.

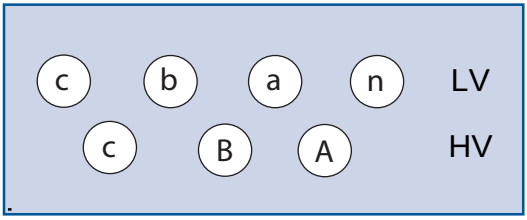
Distribution transformer insulation testing

In the case of existing installations, isolations and Access Authorities may be required.

When carrying out insulation testing, ensure no surge diverters are connected.

3 Phase Transformers

Identify the low voltage neutral bushing by checking for the letter "N" marked on the tank and/or by referring to the nameplate, which shows the relative physical position of all bushings.



Confirm that the transformer is isolated (HV and LV); if required issue an Access Authority and conduct the following tests.

TEST		CORRECT RESISTANCE (MΩ)
HV	A-B, A-C, B-C	ZERO*
	A to transformer tank	HIGH
LV	a-b, a-c, b-c, a-n	ZERO
	a to transformer tank	HIGH
HV-LV	A-a	HIGH

**** Repeat on all tap positions and then reset the tap changer to the required position.***

Single phase & SWER transformers

In the case of single phase transformers (including SWER Isolating and SWER distribution transformers), decide which of the LV terminals is designated the neutral. This will depend on the reticulation voltage, (i.e. 240 volts only or 240/480 volts). Refer also to the connection diagram on the transformer nameplate to obtain the correct bridging of terminals.

NOTE: with SWER transformers an "A" bushing is replaced by a SW (HV terminal) and an ER (the HV earthing terminal).

TEST		CORRECT RESISTANCE (MΩ)
HV	A-A or SW-ER	ZERO*
	A or SW to transformer tank	HIGH
LV	a1-a4, a1-a2/a3	ZERO
	a to transformer tank	HIGH
HV-LV	A or SW-a1	HIGH

Repeat on all tap positions and then reset the tap changer to the required position.

IMPORTANT NOTES:

The High Voltage Earth of Single Wire Earth Return (SWER) substations carries current (i.e. it is part of the HV circuit).

If the earth is disconnected (or broken) whilst the transformer is energised, then the transformer side of the open point **WILL BE ALIVE** at line voltage.

A Safe to Approach Test shall be conducted on approach and on energisation of SWER substations. Refer Sec7: page 14.

Personnel working at the site of a SWER substation shall double check the HV earth and its connections, to ensure its continuity prior to energising or re-energising the transformer, or before performing any work on an energised substation.

Distribution earthing systems

1. Common Multiple Earthed Neutral (CMEN)

A "common" earthing installation is a distribution earthing arrangement where all high voltage & low voltage equipment is connected to a single common earth.

A CMEN earthing system provides an effective earth to all distribution system installations within the CMEN area. The LV neutral conductor is permanently connected to earth and is connected to a number of "Common" or "Bonded" distribution substation earths, HV distribution equipment earths (e.g. concrete poles or HV installation), LV earths and customer earths.

The impedance to ground of a CMEN conductor formed in this way is less than 1 Ohm.

2. Interconnected Multiple Earthed Neutral (MEN)

The Neutral conductor is earthed at each substation with the substation neutrals interconnected (bridged) at LV open points.

The Neutral is earthed at each customer's premises.

3. Individual (MEN)

Neutral conductor is earthed at substation and customer's premises, but NOT interconnected with any other substation.

4. Direct Earthing

Neutral earthed at substation and continuous earth conductor between substation and customer's premises.

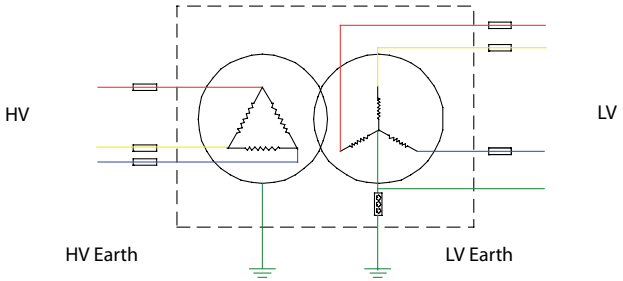
Neutral is not earthed at the customer's premises.

Substation earthing arrangements

1. Separate HV and LV Earths

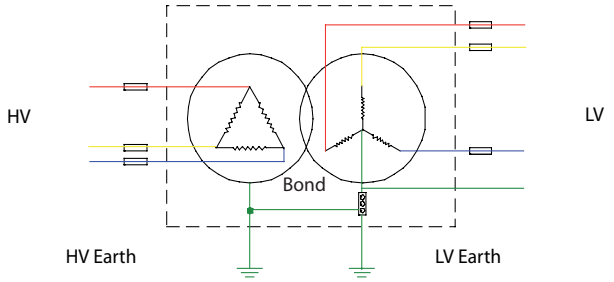
H.V. and L.V. earths are separate and distinct both on the structure and in the ground.

- The HV earth is bonded to the transformer tank, HV switchgear, HV surge diverter, any exposed metal parts containing or supporting the HV conductors, metallic HV cable sheaths and all metallic parts mechanically connected thereto.
- The LV earth shall be bonded to the main LV neutral, any exposed metal parts containing or supporting the LV conductors, metallic LV cable sheaths and all metallic parts mechanically connected thereto.



2. Bonded HV and LV Earths

A bonded earth is a distribution substation earthing arrangement where separate HV and LV earths have been electrically bonded or connected. The bond is made on the earth side of the LV test link.



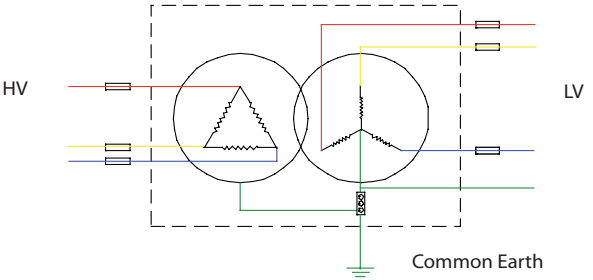
3. Common Earthing

A common earth is a distribution substation earthing arrangement employing a single common HV/LV earth.

The common HV/LV earth is bonded to:

- The transformer tank, HV surge diverters, any exposed metal parts containing or supporting the HV conductors and all metallic parts mechanically connected thereto.
- The main LV neutral, any exposed metal parts containing or supporting the LV conductors and all metallic parts mechanically connected thereto.
- Any metallic cable sheaths

Wear LV gloves when handling test leads and when disconnecting or connecting the LV earth test link.



4. SWER Substations

SWER substations use the Separate HV and LV earthing arrangement.

IMPORTANT NOTES:

The high voltage earth of Single Wire Earth Return (SWER) substations carry current (i.e. It is part of the HV circuit).

If the earth is disconnected (or broken) whilst the transformer is alive, the transformer side of the open point WILL BE ALIVE at line voltage (12.7kV).

Personnel working at the site of SWER substations shall double check the H.V. earth and its connections to ensure its continuity before energising or re-energising the transformer, or before performing any work on a live substation.

Current may flow in the earthing system.

Substation earth testing

Earth testing is required to ensure the integrity of the electrical system and ensure the effectiveness of the earth.

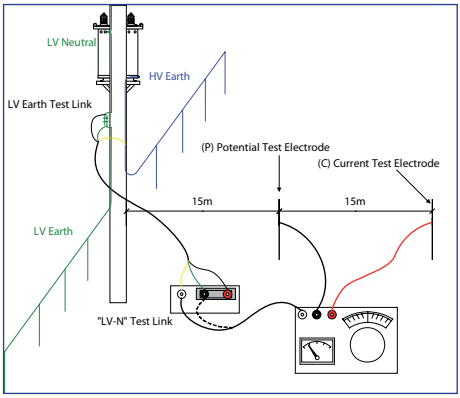
SWER substations shall be de-energised before testing of the earthing system unless specified by distribution company procedures.

Ensure all earth connections are restored to normal before leaving the job site.

'Earth testing shall be carried out at intervals specified by Distribution company procedures and the results shall not exceed the limits specified in TABLE 1 on page 21 in this Section.'

- Do not disconnect or reconnect the LV earth link unless the LV-N test link is closed.
- Open the LV-N test link for no more than 2-3 minutes while testing with the L.V earth link disconnected. The substation is operating without a proven LV earth while the test link is open.

Setup for earth resistance testing



Transformer fuse ratings

Transformer fuse ratings take into account many considerations such as the primary voltage, transient load/magnetising inrush currents, short time current withstand characteristics, cyclic overload, fuse type and the transformer type, i.e. SWER, kiosk, indoor and pole type.

Refer to Company Procedures for Transformer Fuse Ratings.

2. HV POLE TYPE CAPACITORS

General

1. Only authorised HV operators who have been instructed and trained in the switching of HV capacitor banks shall operate them.
2. HV fuses shall not be used to break capacitive currents. The Vacuum switches are to be opened prior to the HV fuses.
3. After HV isolation a minimum of 5 minutes must be allowed prior to application of earths.
4. To declare high voltage capacitors safe for the issue of an Electrical Access Permit, the neutral as well as the actives shall be earthed and, in addition, each individual capacitor shall be discharged to earth before it is touched.

3. AUTOMATIC CIRCUIT RECLOSERS (ACR'S)

When access to an ACR is given for maintenance, remote control capabilities shall be disabled.

4. SAFE TO APPROACH TEST

General

1. Any person who approaches a SWER substation with the intention of carrying out work on or in the vicinity of the pole and/or earthing system shall perform a Safe to Approach Test. This includes Isolating and Distribution type SWER substations and SWER transformers providing auxiliary supplies, e.g. ACR's.

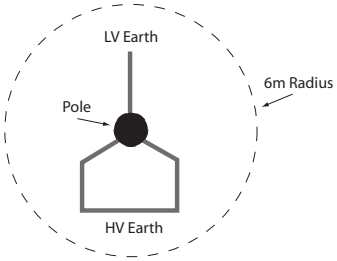
2. A safety assessment shall be undertaken taking into consideration the following:

   - Obvious broken or missing HV earthing connections on the pole and transformer
   - Signs of vegetation near the pole drying out or dying
   - Smoke or steam rising from the ground near the pole

Test procedure

1. Set Modiewark Tester at 240 volts

2. Prove tester is working by rubbing on clothing. Light should flash on and/or beeper sound. (Self test type will have an ongoing intermittent beep)



3. Take the Modiewark tester and insulating stick and stand approximately 6 metres from the pole.

4. Stand directly in line with one of the HV earth cover-strips on the pole.

5. Grasp insulated stick near the end.
6. Place the Modiewark close to ground.
7. Walk slowly towards the pole scanning immediate ground area around you.
8. If tester light goes ON and audible tone "sounds-off", do NOT proceed further and report faulty earth condition.
9. Identify fault – if possible.
10. If possible & SAFE to do so, remove hazard by isolating the substation (e.g. remotely).
11. If the tester light remains OFF continue until Modiewark is at the base of pole where earth enters the ground. Raise Modiewark tester up the pole until light goes ON (close proximity to HV conductors to test tester) then lower tester.

If there is a possible danger to the public, prohibit entry by the use of:

- Warning signs and barriers.
- A member of the work party to remain on site and issue warning.

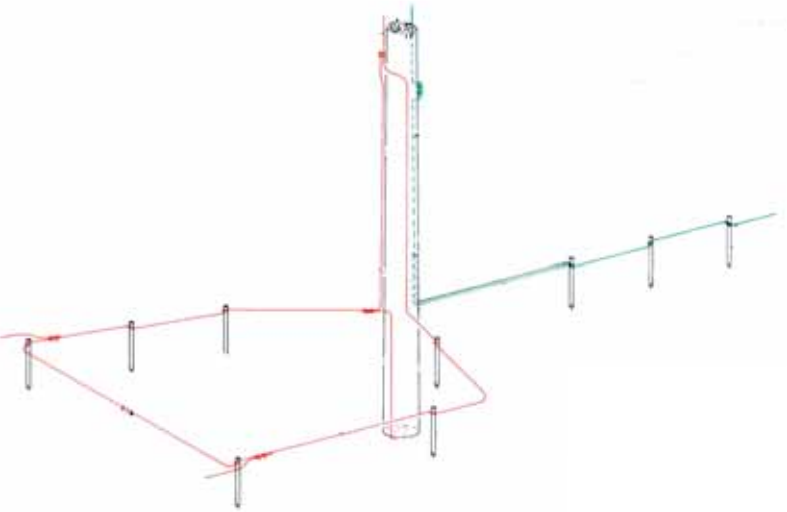
Energisation

1. When energising SWER transformers the operator must ensure:
   - Normal visual inspection of the structure, including integrity (testing/Meggering if required) of the earthing systems have been carried out.
   - Maintain clearance (6m) from HV and LV earthing systems by all personnel.
   - The load has been isolated.
   - That they use the appropriate method to avoid step & touch potentials by use of a ladder, EWP or energise remotely.
   - A Safe to Approach Test shall be completed immediately after energisation by the operator or crew.
   - Should the installation be faulty, immediately isolate the substation and take appropriate action.

5. SWER EARTHING LAYOUT

Legend _____ HV Earth conductor

_____ LV Earth conductor



6. SUBSTATION EARTH RESISTANCE VALUES

TABLE 1

EQUIPMENT	Maximum Resistance of Earth System to Ground			Maximum Resistance to Ground with Neutral Connected		Testing Requirements	
	HV	LV	Common	Common Earth System	Separate Earth System	Common Earth System	Separate Earth System
Pole/Ground/Indoor Substation	10Ω	> 50 kVA 10Ω < 50 kVA 30Ω	10Ω	1Ω*	10Ω 30Ω	Common earth Common earth with neutral connected	HV & LV earth
Kiosk Substation	5Ω	10Ω	10Ω	1Ω*	10Ω	Common earth Common earth with neutral connected	HV & LV earth
SWER Distribution Substation	10Ω	30Ω	N/A	N/A	30Ω	N/A	HV & LV earth
SWER Isolating Substation	2Ω	30Ω	N/A	N/A	30Ω	N/A	HV & LV earth
HV Switch	10Ω	N/A	N/A	N/A	N/A	N/A	HV earth
HV Fuse/Isolator/ Sectionaliser	10Ω	N/A	N/A	N/A	N/A	N/A	HV earth
HV Surge Arrester	10Ω	N/A	N/A	N/A	N/A	N/A	HV earth
HV Cable Termination	10Ω	N/A	N/A	N/A	N/A	N/A	HV earth
ACR	10Ω	N/A	N/A	N/A	N/A	N/A	HV earth
HV Concrete Pole	10Ω	N/A	N/A	N/A	N/A	N/A	HV earth
HV Line Capacitors	10Ω	N/A	N/A	N/A	N/A	N/A	HV earth

* In CMEN systems the maximum resistance to ground of the common earth (with neutral connected) is 10Ω.