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Central Networks Earthing Manual

Section E2

Earthing Guidance Notes

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Revision Log

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	<p>Revision and update of section to be issued as part of a combined Earthing Manual.</p> <p>The main alterations are:-</p> <p>Section E1 and E2 have been re-arranged/revamped for increased clarity.</p> <p>Section E2.2 to E2.5 - greater detail on recent changes to earthing policy, including classification of Distribution sites as either Hot or Cold.</p> <p>Section E2.7 - detailed requirements for provision of Primary Substation Hot site register</p> <p>Section E2.8 - detailed description of earth systems used throughout Company's networks from LV to 132kV, including new 11kV NER earthing arrangements.</p>				
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E2 Earthing Guidance Notes

E2.1 Introduction

There have been few changes to Electricity Supply Industry earthing standards and practices since the introduction of Protective Multiple Earthing in the 1970's.

However, the widespread introduction of electronic equipment used in conjunction with telephone lines (i.e. fax machines, computer modems etc.) has highlighted the issue of Earth Potential Rise (EPR) and Transferred Potentials.

There have been incidents of damage to electronic equipment during supply system earth faults and also transfers of potential into telecommunications systems. The European telecommunications industry has been increasingly concerned over the danger to their equipment and staff from transferred potentials.

The problem has been further exacerbated by the use of cables with plastic oversheaths (Alpex, PIAS, Triplex etc). This means there is now more reliance on substation earth electrodes instead of the lead cable sheaths that provided much of the earthing system in the past. Another factor is the reduction in size of distribution plant which enables substations to be built on smaller plots which are then more difficult to earth.

This has resulted in the European telecommunications industry driving through changes to earthing standards that now place onerous duties on the electricity supply industry to protect persons from electric shock due to Earth Potential Rise which results in Touch, Step & Transfer Potentials.

This legislation is risk assessment based. The effects of electricity on persons varies between people depending on such things as their age, state of health, type of footwear duration of fault etc, Also the effectiveness of earthing system varies according to soil types, surface cover material, weather conditions etc. It is incumbent on individual electricity companies to design, install and maintain their systems such that they satisfy the objectives set by of legislation.

This section of the Earthing Manual highlights the main changes now incorporated into Central Networks standards in order to fulfil our obligations.

E2.2 What are Significant Recent Changes?

- **Hot/Cold Distribution Sites**

The greatest recent change is the classification of ground mounted distribution sites as either 'Hot' or 'Cold'.

- **One Ohm Rule**

Previously, regulations permitted combining HV and LV earths at ground mounted distribution sites when the resistance was below 1 ohm. This rule is no longer valid for new sites.

- **3m Separation Pole Mounted Earths**

In the past HV and LV earths were separated by 3m at pole mounted transformers. This separation is now no longer sufficient.

- **11kV Neutral Earthing**

A new NER arrangement has been adopted for earthing of 11kV systems.

E2.3 What makes a distribution substation ‘Hot’ or ‘Cold’?

At Grid or Primary Substations the EPR will be calculated on a site by site basis. However, this approach is not practicable for distribution sites because of the large numbers involved, therefore some simplified rules are used to determine ‘Hot’ or ‘Cold’ status. These rules are:-

- The site is considered ‘**Cold**’ if the installation is connected to a Primary or Grid Substation via an underground cable without any overhead line in the route. In this case the majority of the earth fault current will return to source via the cable sheath and not through the ground – hence the EPR will be below 430 volts. The HV & LV Earth can be combined.
- The site is considered ‘**Hot**’ if there is **not** a continuous underground cable back to the Primary or Grid Substation. Earth fault current must return to source through the ground and this causes an EPR which is assumed to be above the 430 volt limit. The HV & LV Earths must be segregated to prevent voltages in excess of 430 volts from being transferred into the LV neutral/earth system

The alternative backfeeding arrangements must also be considered when assessing the hot/cold status. For normal running conditions the site may be cold (i.e. underground fed) but could be classified as hot if all the alternative backfeeds have overhead lines as part of the circuit back to the source. If the normal feed is all underground and at least one backfeed is also all underground then the site can be classified as cold since the substation is unlikely to be disconnected from a low resistance primary substation site.

To achieve an EPR less than 430 volts at an overhead fed 11kV distribution substation, then the overall earth value would typically need to be less than 0.3 - 0.5 ohms. Often it is impractical to achieve such low earth resistance values at distribution sites hence the HV and LV earths will usually be segregated. However, if it is decided to combine the HV and LV earths then a site specific calculation **must** be made to confirm the EPR is actually below 430volts.

Existing distributions sites shall be assessed to determine the site classification when significant material changes occur. This is especially important when an 11kV network is being reconfigured to make sure a site is not inadvertently made hot without further precautions being taken.

Also distribution substations may also become hot if they are connected via cable to a nearby Hot Primary or Grid site.

E2.4 Segregated HV and LV earths at Distribution Substations

It is accepted that at some sites the earths will be unnecessarily segregated. This is particularly true in large villages or small towns which have a reasonably large earth system which is ‘islanded’ because the incoming circuits are all overhead. If the cost of segregation is prohibitively high or impractical then the cost of a full earthing study may be justified.

*In the past most pole transformers have had separate HV/LV earths, whereas the vast majority of ground mounted substations have had a combined HV/LV earth. Previously the regulations permitted joining the HV and LV earths when their combined resistance was less than 1 ohm. **This has now changed – the old ‘1 ohm rule’ is no longer valid for new sites.***

If in doubt, treat it as ‘Hot’ and segregate the two earths.

The LV earth system must be located outside of the 430 volt potential contour that surrounds the HV earth electrode during an 11kV earth fault. This distance varies and depends on the type of installation, the local soil resistivity value and the size of the HV earth mat. In very high resistivity soils this separation can be over 40 metres for a pole mounted site.

*Typically pole mounted HV & LV earths were separated by 3 metres to avoid transferring excessive voltages via the ground. **The 3m separation distance is now no longer sufficient.***

The new separation distances have been calculated by an earth modelling computer programme and are detailed in Section “E5 Distribution Standard Earthing Layouts”.

E2.5 Standard Distribution Earthing Methodology

Because there are numerous distribution installations, standard earthing arrangements have been adopted. The following three sections of the Earthing Manual can be used to predict the type and size of the earth system for the most common values of soil resistivity.

- E3 Soil Resistivity Measurements**
- E4 Earth Electrode Resistance Tests**
- E5 Distribution Standard Earthing Layouts**

This will help advise landowners of the extent of proposed earthing excavation before work starts and to estimate the quantity of earthing materials required to complete the installation.

E2.6 Difficult or non-standard situations

The Distribution Standard Earthing Layouts are designed to cover the majority of situations and a standard solution should be the first approach. Sometimes this may mean placing a transformer some distance away from a third party installation in order to maintain adequate HV/LV segregation.

However, there will be occasions where the standard approach is not practical or the soil resistivity is so high that specialist advice is required to overcome specific site difficulties. The cost of this has to be borne by the project.

For advice please contact the Central Networks Earthing Specialist or initiate a survey using one of the approved earth consultants listed in [Section AE1.1](#).

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E2.7 Hot Primary and Grid Sites

All Primary or Grid sites shall have the EPR assessed and the details recorded on the Company's hot site register. This information shall be made available to the relevant telecommunications companies. The owner of the Central Network's hot site register shall be listed on the Energy Networks Association's, Rise of Earth Potential website to provide the telecommunication companies with a point of contact. The information to be made available on request is:-

- Hot/Cold site classification (based on either 650 or 430 volt limits)
- Grid Reference or address of the site
- Extent of the hot zone (if known), otherwise quote 100m (as detailed in ENA ER S36).

Hot Primary/Grid sites require an isolation unit fitting to all incoming telecomms circuits. Telecomms circuits passing through the hot zone surrounding a primary or grid site require no specific precautions unless the EPR at the point of the telecomms circuit exceeds 1700 Volts for sites with fast protection clearance (i.e. less than 0.2 seconds) or 1150 volts for slower protection clearance times. ENA ER S36 provides more detail.

Where reasonably practicable all new primary/grid sites shall be designed as cold sites. Where a cold site is impractical then any distribution sites that are cable connected to the new site shall be assessed to determine the EPR at that location. If the distribution site is declared hot for a fault at the primary substation then the HV and LV earths must be segregated.

In general new LV supplies feeding a Primary or Grid site shall be derived from a dedicated on-site transformer. This transformer should not be used to provide LV supplies to customers off the site. If in doubt or where existing LV supplies are involved with supplying off-site third parties then refer to the Central Networks Earthing Specialist for further advice.

E2.8 Methods of Earthing used on the Company's Networks

An application guide is available that provides greater detail on neutral earthing requirements for the Company's HV and EHV networks. Figure E2.1 shows typical neutral earthing arrangements found on Central Networks systems.

E2.8.1 132kV Network

The 132kV network is a three wire, three phase network, except for the railway traction supplies which is a single phase 25kV system, with one pole earthed.

All 400/132kV and 275/132kV transformers have their star points solidly connected to earth. Transformers at 132/66kV, 132/33kV and 132/11kV will also have the star point of each 132kV winding solidly connected to earth, in effect forming a multiple earthed system. This multiple direct earthing gives rise to the large earth fault currents experienced on the 132kV system.

E2.8.2 66kV & 33kV Networks

The 132/66kV and 132/33kV transformers are usually delta connected on the secondary side. These 33 or 66kV windings will be earthed by an earthing transformer. In the past the earthing

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transformer may have been low impedance in which case an NER would also be required to limit the earth fault current to an acceptable value.

For new installations each earthing transformer should be high impedance to limit the prospective earth fault current to match the full load current of the main transformer up to a maximum of 1000Amps.

Table E2.3 Earth fault limits for 132/33 and 132/66kV transformers

Main Transformer rating (MVA)	33kV High Impedance Earthing Transformer -Earth Fault Rating (Amps)	66kV High Impedance Earthing Transformer – Earth Fault Rating (Amps)
15	260	-
20	350	175
30	525	260
40	700	350
45	800	400
60	1000	525
75	1000	650
90	1000	800
120 and above	1000	1000

E2.8.3 25kV Networks

This is a single phase system for provision of supplies for railway traction systems. One pole of the secondary output of the 132/25kV winding is solidly earthed. The pole to be earthed is governed by and set out in Engineering Recommendation P24 “A. C. Traction Supplies to British Railways.”

E2.8.4 11kV (& 6.6kV) Networks

Depending on the vector group, 132/11kV, 66/11kV and 33/11kV transformers can have the secondary winding either delta or star connected. These transformers will be earthed on the secondary side either by an earthing transformer (if delta connected) or via the star point.

Historically, small rating transformers (typically those less than 10MVA) had their secondary neutral solidly connected to earth. On all other transformers the secondary neutral was impedance earthed i.e. via a resistor or reactor.

There are a number of existing arrangements for NER configurations at 11kV. In general either one NER was used across the site to earth all the transformer neutrals or alternatively each transformer had its own individual NER.

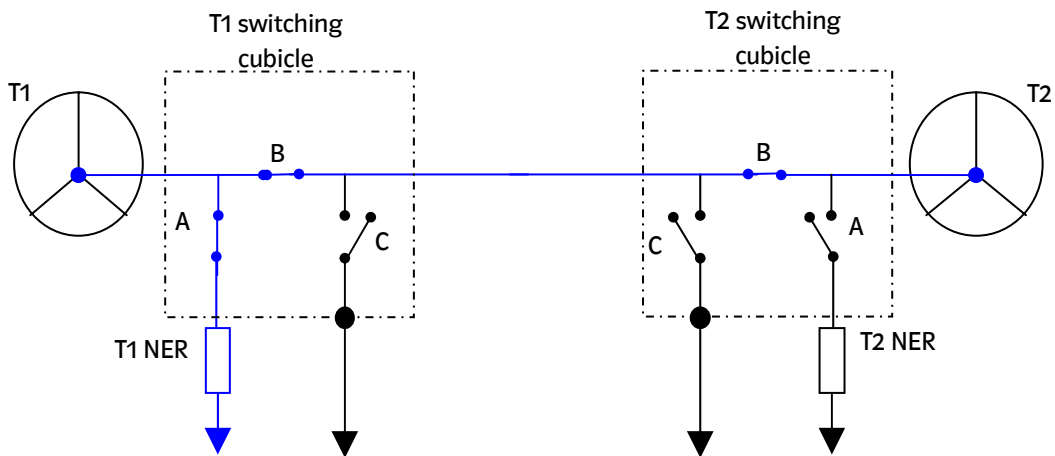
The existing 11kV neutral earthing philosophy has three main requirements:-

- to limit the overall prospective earth fault currents for any site to be less than 1500Amps for normal running arrangements. This has the benefit of reducing EPRs throughout the whole 11kV network.
- to ensure there is sufficient earth fault current to operate protection at remote ends of the 11kV network.

- to ensure the transformer neutrals are **not** solidly earthed at any time. This prevents excessive earth fault currents from occurring on the network.

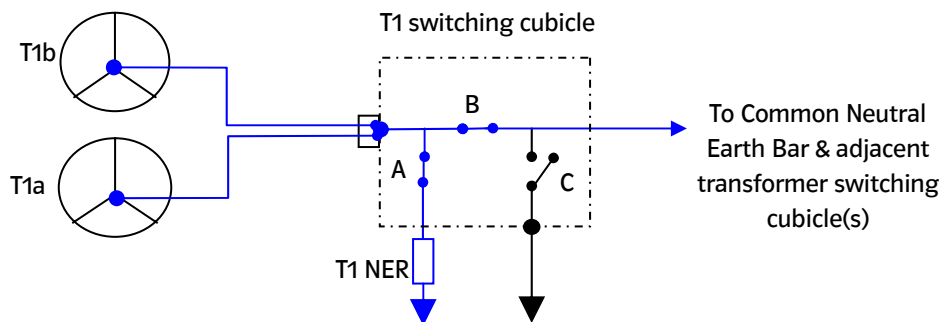
This can be achieved in a number of ways and depends on the number of transformer at the site. This often involves the use of a specially designed switching cubicle for each transformer which controls the NER running arrangements across the site. It should be noted that the new philosophy prevents the use of high impedance earthing transformers at 11kV. The preferred 11kV NER size is 1000Amps but this can be modified to either 750 or 1500 Amps as detailed in the Neutral Earthing Application Guide.

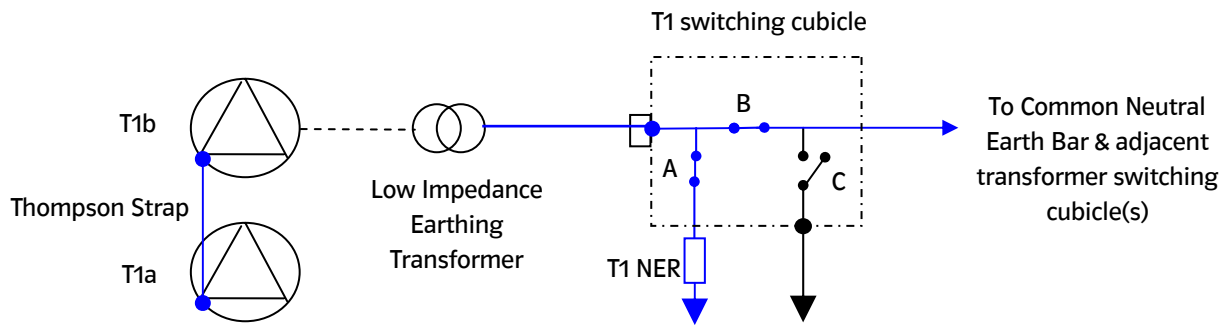
For new systems a typical arrangement would be as shown in the figure below. The switches would be configured so that one NER earths all transformers. The other ‘un-used’ NER would be available when a transformer is switched out for maintenance.



Some double secondary transformers (also known as double bubble or three winding transformers) having delta secondaries have been installed using only one earthing transformer in conjunction with a Thompson Strap. The Thompson Strap is an electrical connection installed within the transformer tank between the two blue phase (or L3) secondary windings. By convention the earthing transformer is then connected to the ‘b’ secondary winding. This arrangement also provides an earth return path for faults fed from the ‘a’ winding. The use of Thompson Straps is still permitted.

The new NER policy can still be applied to double secondary transformers as shown below.





The earthing transformers in these situations will be a low impedance type. A nominal impedance must be designed into the earthing transformer to guard against the effects of a direct short circuit of the associated NER.

In a very few instances the transformer secondary may be earthed by using an Arc Suppression Coil (ASC or Petersen Coil). The ASC is 'tuned' to the capacitance of the 11kV cables and overhead lines connected to the substation. This will minimise current at the fault position during a single phase to earth fault condition. If the fault persists then the system will automatically revert back to the normal resistor earthing arrangement.

The 11/0.415kV distribution transformers have a delta connection on the primary winding and subsequently are therefore not earthed on the 11kV side.

E2.8.5 Earthing of Low Voltage Networks

The low voltage side of a three phase distribution transformer is star connected. This star point forms the neutral of the LV system and will be solidly connected to earth at all times. For single phase transformers one terminal will be designated as the neutral point and will again be solidly connected to earth.

LV distribution networks can have a separate protective conductor (sheath earth system) or this can be combined with the neutral conductor (PME). Engineering Recommendation G12/3 details the specific requirements for the application of PME on low voltage networks.

- All new underground LV networks shall be constructed using CNE cables to establish a network suitable for the provision of PME terminals.
- All new overhead LV networks shall be constructed using Aerial Bundled Conductors (ABC) suitable for providing PME terminals.

Wherever substantive work (e.g. refurbishment, diversions etc..) is undertaken on LV networks then the network shall be brought up to a standard to provide PME supplies. This work should also ensure existing sheath earth customers do not have their existing earthing terminal compromised.

E2.8.5.1 Provision of LV Earthing Terminal

The provision of a LV earthing terminal has been achieved by various means in the past. The present company policy with regard to the provision of a LV earth terminal is detailed below :-

PME Terminal (TN-C-S)

All new supplies, or existing customers requesting a load increase, will normally be offered a PME terminal. However, for reasons of safety some installations are not suitable for a PME earth terminal in which case a TT supply will be offered (see Section E6.3 for a detailed list of exceptions). Under the ESQC Regulations, the Company is not obliged to offer a free PME earth terminal to existing customers that do not already have a PME earth.

Sheath Earth Terminal (TN-S)

The Company has an ongoing obligation to maintain the integrity of the sheath earth terminal of customers which already have this type of earthing. If an existing sheath earth customer requests a service alteration or in the event of a fault repair then the existing sheath earth must be maintained unless the customer request a PME earth terminal instead. A sheath earth terminal shall not be made available to new customers (or existing customers if they do not already have an earth terminal).

PNB Earthing

PNB is a special method of earthing, similar to PME, where the neutral earth is installed at or adjacent to the customer's installation instead of at the transformer position. This method can still be used provided the supply is from a dedicated pole mounted transformer supplying a single customer..

No Company Earth Terminal (TT)

It is not possible for the Company to provide a PME earthing terminal where :-

- i) the customer's installation does not conform to the statutory regulations regarding the provision of PME supplies.
- ii) the customers property is deemed to be unsuitable for a PME supply.

In these circumstances the PME terminal shall be rendered inaccessible to prevent unauthorised access by third parties and the customer must be advised that it will be necessary to provide their own alternative means of earth fault protection (e.g. their own earth electrode and suitably sized RCD).

Figure E2.1 Typical Examples of Existing Neutral Earthing Arrangements

