Electrical Earthing / Grounding

Electrical Earthing / Grounding refers to the total set of all measures used to connect an electrically conductive part, electrical equipment or electrical installation to **Earth** (or ground).

The earthing system is an essential part of power networks at both high and low voltage levels.

Is there any difference between the terms Earthing & Grounding ???

Earthing is the term used more commonly used in Britain, European and most of the commonwealth countries standards (IEC, IS).

Grounding is the term used in North American standards (NEC, IEEE, ANSI, and UL).

Q: How is an Electrical system/ Electrical equipment connected to earth (or ground) and what is the need?

Electrical Earthing is the term used for the practice in which **the non-current carrying part** of the equipment/device is connected to ground so as to provide a path to ground for the surface charge. This is done for the safety of operator so that the operator does not get a shock while using the device.

BUT

Power System Grounding / Neutral Grounding is the term used for the practice which is generally used in three phase systems **for connecting the neutral of the system to ground.** This is done in order to avoid arcing faults which happen when L-G fault occurs in a system with ungrounded neutral.

In case of L-G faults the phase voltage magnitude becomes equal to line voltage (**~ √3** times) which can cause Insulator flashover or rupture. Hence, neutral must be grounded to avoid such a situation and there are various techniques used for **Power System Grounding/ Earthing** such as

1. The solidly earthed system
2. Resistance earthed system
3. Reactance earthed system
4. Use of an earthing transformer
5. The unearthed system

Thus **Electrical Earthing** (or Electrical Grounding) and **Neutral grounding** are both techniques which involves connection to earth (ground) but have different purposes.

Electrical Earthing means connecting the *dead part (the part which does not carry current under normal conditions)* to the earth for example electrical equipment's frames, enclosures, supports etc.

Electrical Earthing is done to ensure safety or Protection of electrical equipment and human by discharging the electrical energy to the earth.

Under fault conditions the non-current carrying metal parts of an electrical installation such as frames, enclosures, supports, fencing etc. may attain high potential with respect to ground so that any person or stray animal touching these or approaching these will be subjected to potential difference which may result in the flow of a current through the body of the person or the animal of such a value as may prove fatal.

To avoid this, the non-current carrying metal parts of the electrical system are connected to the general mass of earth by means of an earthing system comprising of earth conductors to conduct the fault currents safely to the ground.

The purpose of earthing is to minimize the risk of receiving an electric shock by touching metal parts when a fault is present. Generally **green wire** is used for indicating **Earth wire.**

Grounding means connecting the *live part (it means the part which carries current under normal condition)* to the earth for example neutral of power transformer. It is done for the protections of power system equipment and to provide an effective return path from the machine to the power source.

Because of lightening, line surges or unintentional contact with other high voltage lines, dangerously high voltages can develop in the electrical distribution system wires. *Grounding provides a safe, alternate path around the electrical system thus minimizing damage from such occurrences.*

Generally **Black wire** is used for indicating **Neutral wire.**

Electrical Earthing *is used for the safety of the human body in fault conditions while* ***Neutral Grounding*** *(As neutral earth) is used for the protection of equipment. Electrical Earthing is a preventive measure while Neutral Grounding is just a return path.*

(This is explained in detail is following sections)

Earthing of electrical equipment and power systems in buildings provides a number of advantages:

1. Limitation of touch and step potentials to prevent electric shock
2. Equipotential bonding of exposed metal conductors to prevent electric shock
3. Limitation of over-voltages on equipment for prevention of damage
4. Fast operation of electrical protection and limitation of earth fault damage

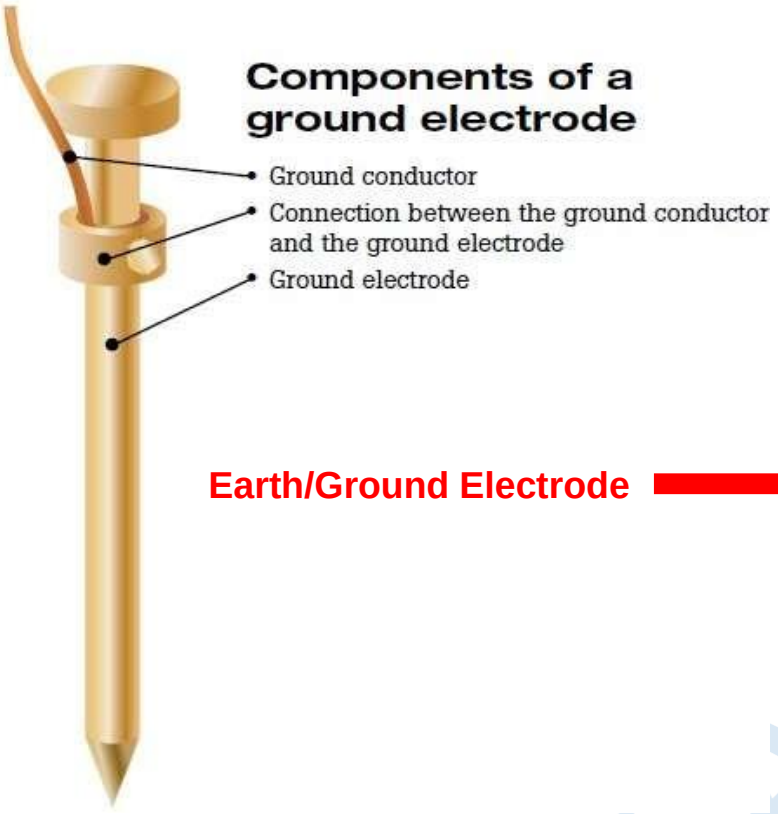
In general, all of these required functions may be reduced to just two general purposes of an earthing system:

a) To provide protection of personnel against electric shock and possible burns when in contact with bare conductive metal at the time that an electrical fault involving the metal occurs.
b) To maintain the good working order of the power system and associated equipment. (In particular, to prevent overheating and possible fire in the event of electrical faults).

Terms used in Electrical Earthing

1. **Earth:** The proper connection between electrical installation systems via conductor to the buried plate/pipe/mesh in the earth is known as Earth.
2. **Earthed:** When an electrical device, appliance or wiring systems is connected to the earth through earth electrode, it is known as earthed device or simple “Earthed”.
3. **Solidly Earthed:** When an electric device, appliance or electrical installation is connected to the earth electrode without a fuse, circuit breaker or resistance/Impedance, It is called “solidly earthed”.
4. **Earth/Ground Electrode:** When a conductor (or conductive plate) is buried in the earth for electrical earthing system. It is known to be Earth Electrode. Earth electrodes are in different shapes like, conductive plate, conductive rod, metal water pipe or any other conductor with low resistance.
5. **Earthing/Ground Lead:** The conductor wire or conductive strip connected between Earth electrode and Electrical installation system and devices in called Earthing lead.
6. **Earth/Ground Continuity Conductor (EARTH wire)** : The conductor wire, which is connected among different electrical devices and appliances like, distribution board, different plugs and appliances etc. in other words, the wire between earthing lead and electrical device or appliance is called earth continuity conductor. It may be in the shape of metal pipe (fully or partial), or cable metallic sheath or flexible wire.
7. **Sub Main Earthing Conductor:** A wire connected between switch board and distribution board i.e. the conductor is related to sub main circuits.

8. **Earth/Ground Resistance:** This is the total resistance between earth electrode and earth in ohms Ω .Earth resistance is the algebraic sum of the resistances of earth continuity conductor, earthing lead, earth electrode and earth.



Earth/Ground Electrode

Earth/ground continuity conductor or Earth Wire

That part of the earthing system which interconnects the overall metallic parts of electrical installation e.g. conduit, ducts, boxes, metallic shells of the switches, distribution boards, Switches, fuses, regulating and controlling devices, metallic parts of electrical machines such as, motors, generators, transformers and the metallic framework where electrical devices and components are installed is known as earth wire or earth continuity conductor.

The resistance of the earth continuity conductor should be **very low**

According to IEEE rules, resistance between consumer earth terminal and earth Continuity conductor (at the end) should be **≤ 1Ω**

Resistance of earth wire should be less than 1Ω

Size of Earth Continuity Conductor

Size of the Earth Continuity Conductor or Earth Wire depends on the cable size used in the wiring circuit. The cross sectional area of the Earth Continuity Conductor should not be less than the half of the cross sectional area of the thickest wire used in the electrical wiring installation.

1. **Earth wire** should be **14 SWG** in case of copper and **4mm square** in case of aluminium (SWG - standard wire gauge)
2. Minimum size of earth wire for light circuit is 1mm square for copper and 1.5mm square for aluminium.

Q. What factors affect the grounding resistance?

Ans:

There are four variables that affect the ground resistance of a ground system:

1. Length/depth of the ground electrode
2. Diameter of the ground electrode
3. Number of ground electrodes
4. Ground system design

Points in an Electrical System to be earthed

1. Earth pin of 3-pin lighting plug sockets and 4-pin power plug should be efficiently and permanently earthed.

2. All metal casing or metallic coverings containing or protecting any electric supply line or apparatus such as GI pipes and conduits enclosing VIR or PVC cables, iron clad switches, iron clad distribution fuse boards etc. should be earthed (connected to earth).

3. The frame of every generator, stationary motors and metallic parts of all transformers used for controlling energy should be earthed by two separate and yet distinct connections with the earth.

4. In a dc 3-wire system, the middle conductors should be earthed at the generating station.

5. Stay wires that are for overhead lines should be connected to earth by connecting at least one strand to the earth wires.

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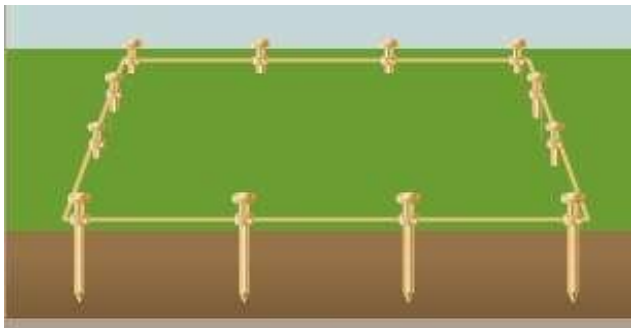
Earth system design

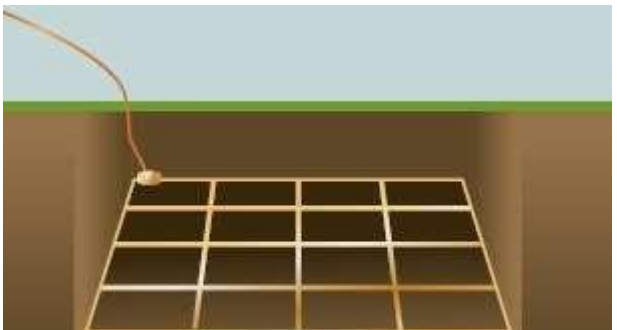
1. Simple grounding systems consist of a **single earth/ground electrode** driven into the ground. The use of a single ground electrode is the most common form of grounding and can be found in residential buildings.

Single ground electrode.

2. Complex grounding systems consist of **multiple ground rods**, **connected mesh** or grid networks, **ground plates** etc. These systems are typically installed at power generating substations, large commercial spaces, and communication tower sites. Complex networks dramatically increase the amount of contact with the surrounding earth and lower ground resistances.



Multiple ground electrodes connected.



Mesh network.

Ground plate.

Methods of Electrical Earthing

The process of Earthing or electrical grounding can be done in several ways like wiring in factories, housing, other machines, and electrical equipment. The different methods include the following.

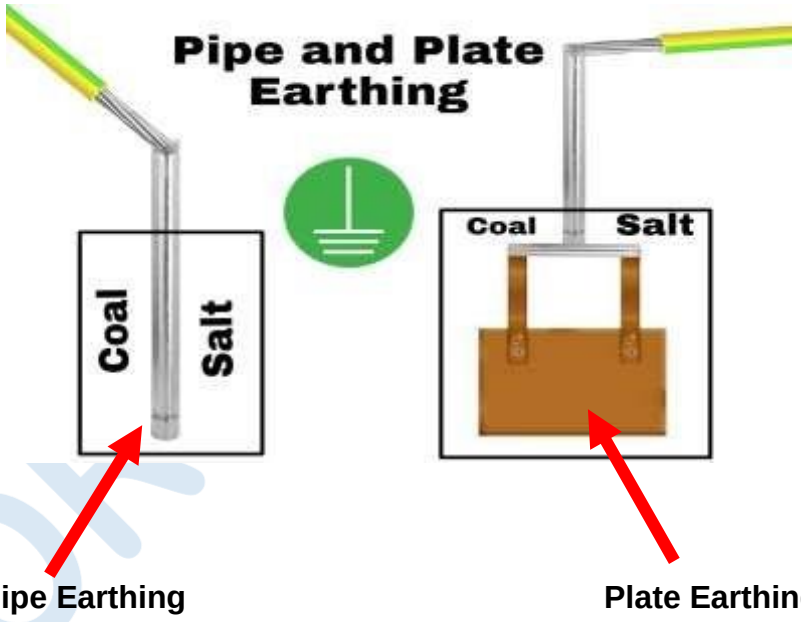
1. Plate Earthing System

In this type of system, a plate is made up of **copper or GI (galvanized iron)** is placed vertically in the ground pit less than 3meters from the earth.

2. Pipe Earthing System

A galvanized steel based pipe placed vertically in earth is known as pipe earthing, and it is the **most common type of earthing system**.

The pipe size mainly depends on the **soil type** and **magnitude of current**.
For the ordinary soil, the pipe dimension should be **1.5 inches in diameter** and **9 feet in length**.
For rocky or dry soil, the pipe diameter should be greater than the ordinary soil pipe.
The **soil moisture** will decide the **pipe's length** to be placed in the earth.



Permissible Values of Earth Resistance

IEEE recommends a ground resistance value of **≤ 5 ohms** (IEEE standard 142-2007)

Permissible Values of Earth Resistance	
Ideal value of earth resistance	Zero or Lowest earth resistance possible
Power stations	0.5 ohms
EHT stations	1.0 ohms
33KV Sub station	2 ohms
Transformer structures	< 5 ohms
Telecommunication Industry	< 5 ohms
Resistance generally found suitable for industrial plants, Sub-station and buildings and large installations	1 ohm to 5 ohms
Lightning arrestors ground resistance for Protection of buildings and allied structures (Tower foot resistance)	10 ohms

*Note: The objective is **to achieve the lowest earth resistance value possible**, that makes sense economically and physically, when contacting the earth.*

Approximate value of soil resistivity

Type of Soil	Soil Resistivity (Ωm)
Very moist (wet) swamps	**10-30**
Moist soil	**100**
Sandy clay soil	**100-150**
Concrete	**400-500**
Dry soil	**500**
Dry gravel	**1000**
Stoney/ Rock	**10000 -10^7**

Note: (only approximate values) for JE/sub engineer level exams

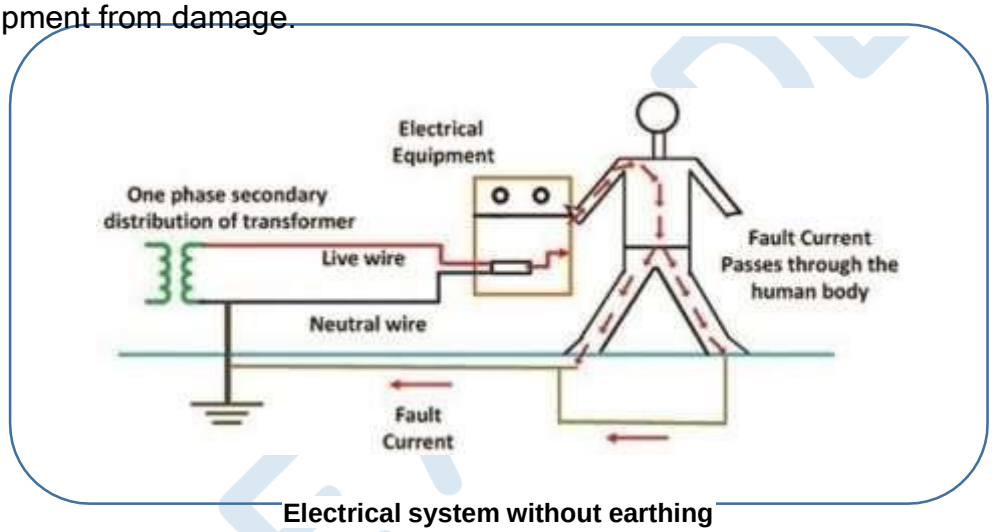
Types of Electrical Earthing

Earthing can be classified into two types:

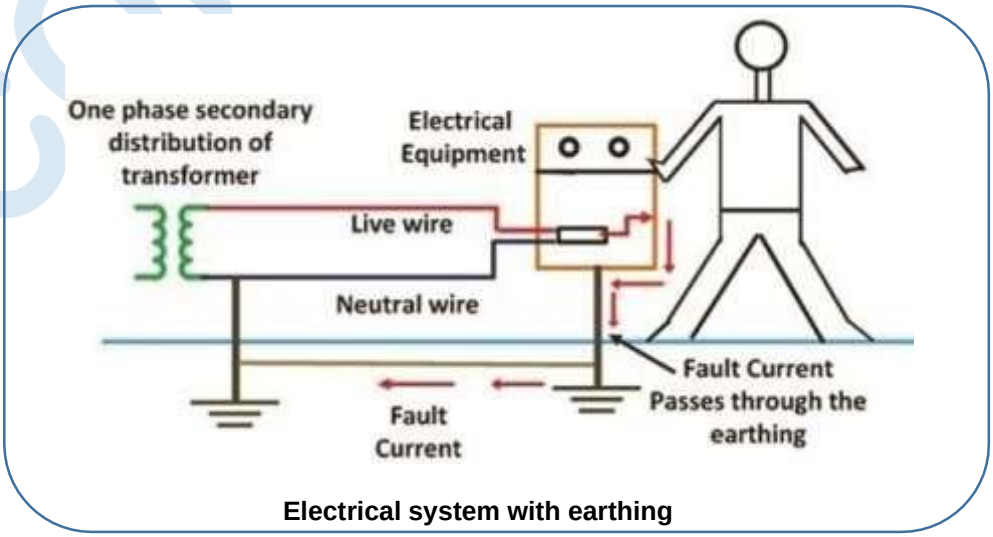
1. **Equipment Earthing (Electrical Earthing)**
2. **Neutral Grounding (or System Grounding)**

1. Equipment Earthing (Electrical Earthing)

Such type of earthing is provided to electrical equipments. The non-current carrying part of the equipment like their metallic frame is connected to the earth by the help of the conducting wire. If any fault occurs in the apparatus, the short-circuit current pass to 32the earth by the help of wire thus, protect the equipment from damage.



Electrical system without earthing



Electrical system with earthing

Equipment earthing examples:

1. Metal parts of home appliances (e.g. iron box)
2. Electric motor yoke
3. Transformer tank
4. Switchgear box
5. Operating rods of air break switches, LV & HV breaker body
6. Feeder breaker parts

2. Power System Grounding / Neutral Grounding

(Also called power system earthing or neutral earthing)

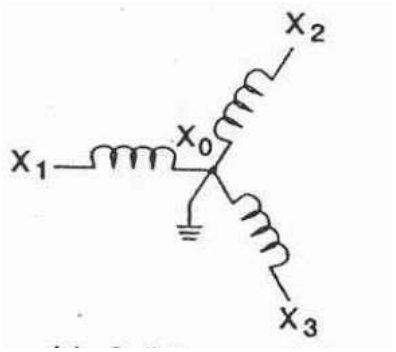
There are a variety of methods of earthing power systems and building electrical systems:

1. The solidly earthed system
2. Resistance earthed system
3. Reactance earthed system
4. Use of an earthing transformer
5. The unearthed system

1. The solidly earthed system

In solid or directly earthed system, transformer's star point is directly connected to the ground. In this system, a low-impedance path is provided for the fault current to flow to ground.

The neutral of the main power supply substation is directly connected to a **low resistance** stake/ conductor or a buried distributed mesh in the ground or connected via the Multiple Earthed Neutral (MEN) system.



Solidly earthed system

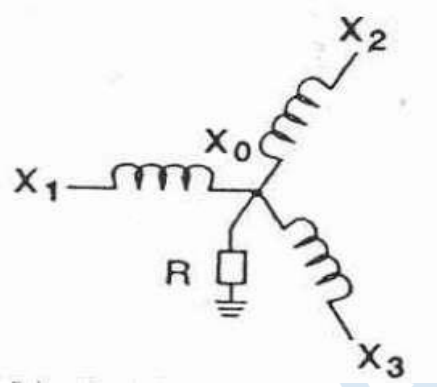
Features

1. This earthing practice is the most commonly used system
2. This earthing practice is used for low and medium voltage systems **(up to 1000 V)**

3. A low resistance ground also limits earth potential rise and thus the hazards of *touch potential and step potential* are reduced.
4. used in high-voltage transmission networks

2. Resistance Earthing System

Resistance earthing is achieved by **connecting a resistance** between the main supply neutral point and the earth stake of the grid at the substation.



Resistance Earthing System

The resistance earthing can be (1) high resistance or (2) low resistance:

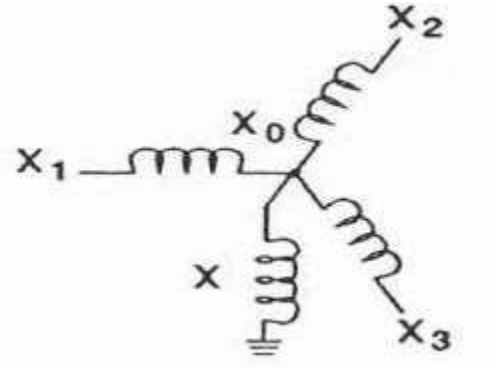
Low voltage systems will use **high resistance earthing**
High voltage systems will use **low resistance earthing**

Features:

1. The primary aim of resistance earthing is **to limit the magnitude of the fault currents.**
2. This limit in magnitude of fault current protects the equipment from damage.
3. Low resistance earthing normally limits current to a few hundred amps.
4. Resistance earthing generally requires good earth leakage protection sensitivity.
5. With low resistance fault current limit is relatively high. In India it is restricted for 50 A
6. High resistance earthing system limits the ground fault current to a value equal to or slightly greater than the capacitive charging current of that system.

3. Reactance Earthing System

Reactance earthing involves the use of a reactor in place of the resistor in the above method. It is not often used. Preferred normally only with generators.



Reactance Earthing System

4. Earthing Transformers

Earthing transformers are often used to provide earthing means for systems such as the **delta-**connected windings of transformers where a neutral point is not accessible for earthing connection.

Q. Which type of connection is valid for earthing transformers??

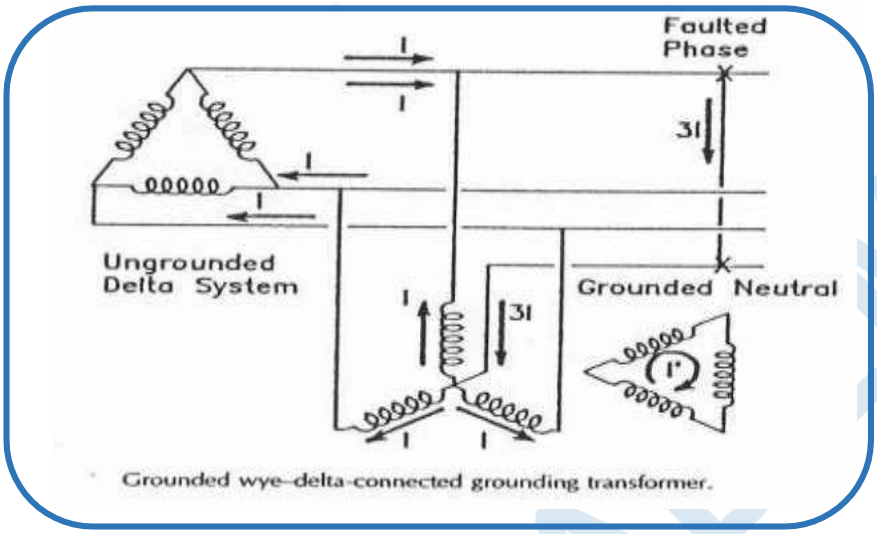
Ans:
The earthing transformer may be, a **Star-Delta (Wye-delta) transformer** with earthed neutral and shorted delta as shown below.
Star-Delta transformer is used to provide an earth path for fault current (zero sequence current) on the main unearthed delta winding.

Also **Zig-Zag** transformer using centre-tapped windings can be used for the same purpose

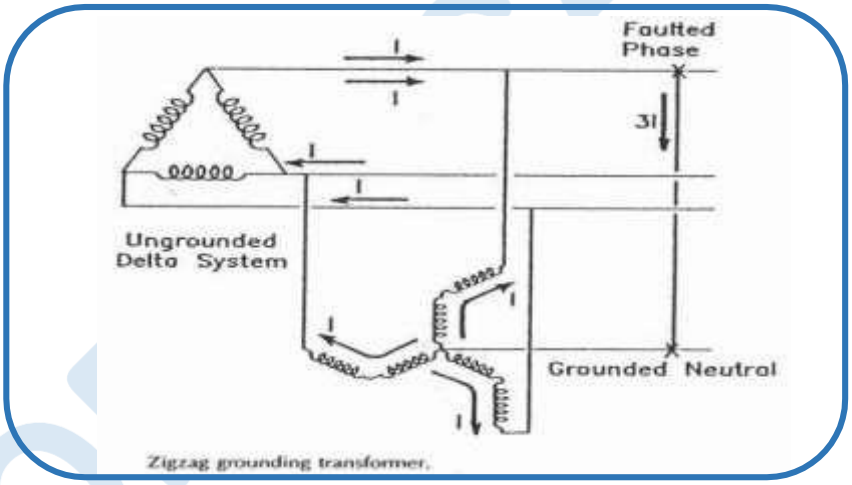
Features of Earthing/ Grounding Transformers

1. Primary winding connection - either zig-zag or grounded Wye.
2. Rated kVA - Grounding transformer is normally a short time device, its size and cost are less compared to a continuous-duty transformer of equal kVA rating. For this reason, grounding transformers are often not sized by kVA but by their continuous and short time current ratings.
3. Typical continuous current values can be as low as 5A to as high as a few hundred.

4. Continuous neutral current (this value is needed to design for thermal capacity of the grounding transformer) — the continuous neutral current is defined as **three times** the phase current or zero sequence current.



Grounded wye–delta-connected grounding transformer.



Zigzag grounding transformer.

Applications of Grounding/Earthing transformers

1. Provide a relatively low-impedance path to ground, thereby maintaining the system neutral at or near ground potential.
2. Limit the magnitude of transient overvoltages when restriking ground faults occur.
3. Provide a source of ground fault current during line-to-ground faults.
4. Permit the connection of phase-to-neutral loads when desired

5. The Unearthed System

Although there is no low value resistive earth connection in an unearthed system, **there is a capacitive coupling to earth.**

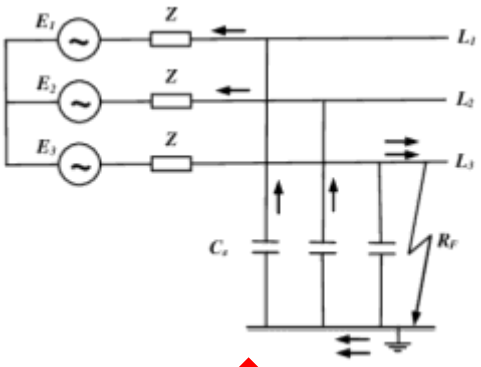
The main advantage of the unearthed system is that it allows system operation to be maintained even in the event of an earth fault.

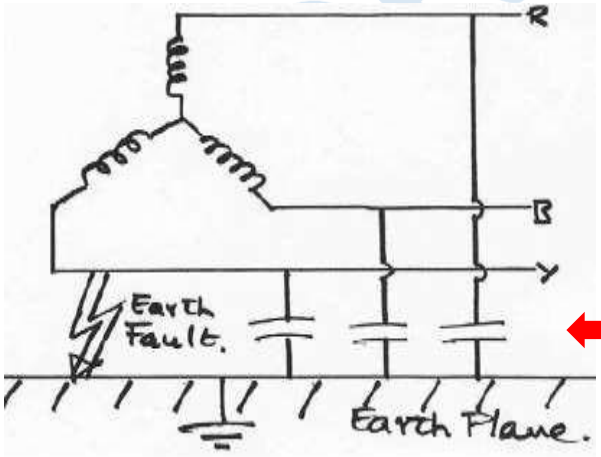
The main application of unearthed systems is in industry where it may be necessary to maintain operation even if a fault occurs.

Such a fault would cause system tripping in an earthed system. However with no electrical system earth there is very low fault current (only via the capacitance) and thus no damage to equipment and no personnel hazard.

Power supply operation will only cease when a second fault occurs: this will then cause a phase to phase fault that will then operate overcurrent protection.

*Since no active conductor with a low resistance is connected to earth, no high fault current flows in the event of a short circuit to exposed conductive part or an earth fault. The result is a low fault current the magnitude of which depends on the insulation resistances and the capacitance of the conductors and system components to earth, (*this coupling capacitance will be of high impedance, hence low fault current).





The Unearthed System with no earth connection resistance

Soil resistivity measurement

Q. What is the need to determine the soil resistivity?

Ans:

Soil Resistivity is necessary for determining the design of the grounding system for new installations (green field applications) to meet the ground resistance requirements.

The soil composition, moisture content, and temperature all impact the soil resistivity. Soil is rarely homogenous and the resistivity of the soil will vary geographically and at different soil depths. Moisture content changes seasonally, varies according to the nature of the sub layers of earth, and the depth of the permanent water table.

These earth ground testing methods are used to measure Soil Resistivity:

1. **Soil Resistivity testing using Earth Meggar / Earth Ground Testers**
2. **Loss of Potential (Fall-of-Potential)**
3. **Selective (using 1 clamp and stakes)**
4. **Stakeless Method (using 2 clamps only)**

The value of the earth resistance recommended for different power stations:

1. **Large Power Station – 0.5 ohms**
2. **Major Power Station – 1.0 ohms**
3. **Small Substation – 2.0 ohms**
4. **In all other cases – 8.0 ohms**

***NOTE**: This note is prepared on the topic Electrical Earthing for **SSC JE / KPSC, KSEB Sub Engineer/ AE level exams**, (Please refer to course outline shared in class).*

The relevance of Electrical Earthing for competitive exams / number of questions from this topic is comparatively less and an overall idea of the topic should be the ideal approach.

Additional exam specific points will be discussed in class / Q&A sessions

(Workout session on Earthing will follow in Short Note 6 & QCards)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