

Earthing – Myths & Facts

Jayanta Khan

Larsen & Toubro Limited

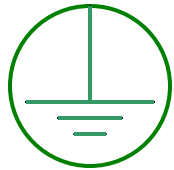
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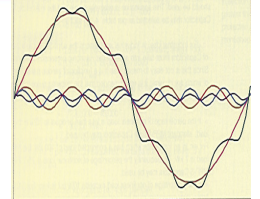
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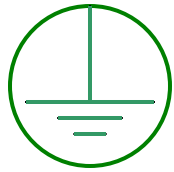
COPPER
International Copper Promoters Council (India)



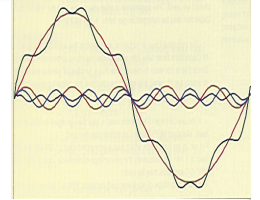
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“Problems in industrial/commercial premises wiring & grounding account for a large share of all reported power quality problems. The greatest number of wiring and grounding problems is in the feeders and branch circuits serving critical loads. The first activity in checking for PQ problems is to survey the soundness of the power distribution system and grounding system, supplying the equipment.”

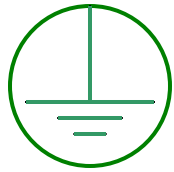


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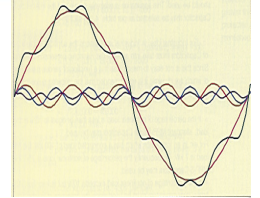


“Through error or oversight, intentional or unintentional, the grounding system in many cases is not installed in accordance with the requirements of the National/International Standards or Local Electrical Codes of Practice”. (vide Clause 6.4.1 of IEEE 1100).

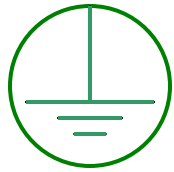
Even if installed properly, proper maintenance of the earthing system is questionable, mostly guided by incorrect practices.



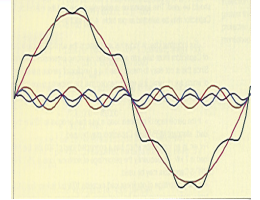
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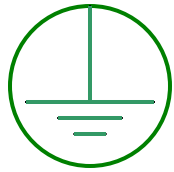
The most popular word among electrical professionals would, perhaps, be ‘Earthing’ or ‘Grounding’. Also, perhaps, the least understood. Many of you must have come across certain strange practices and beliefs in earthing of industrial electrical power systems. This presentation aims to discuss some of such practices & beliefs and to allay the misbeliefs.



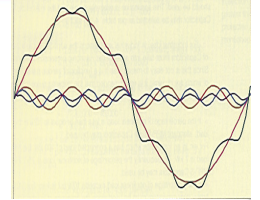
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***Myth:** ‘Grounding’ implies connection of current carrying parts to ground, like transformer or generator neutral and ‘Earthing’ implies connection of non-current carrying parts to ground, like metallic enclosures.*

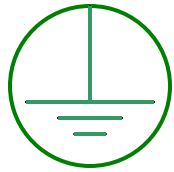


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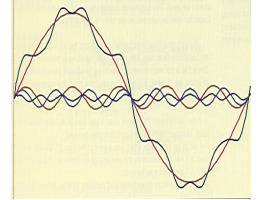


Fact: As per IS 3043-1987, vide Cl. 0.7, **the terms ‘earthing’ and ‘grounding’ are synonymous.**

Perhaps the different nomenclature is due to the usual conflicting usage of English language between the Americans & the British. While the British termed it as ‘earthing’, the Americans termed it as ‘grounding’. IEC & IS Standards refer as ‘earthing’, while IEEE & ANSI Standards refer as ‘grounding’.

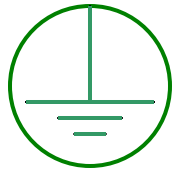


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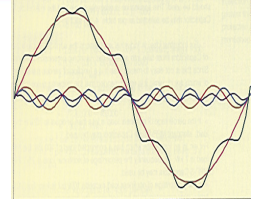


To quote from IEC 60050:

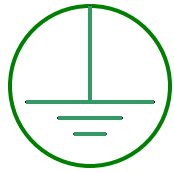
“The terms ‘earth’ as well as ‘ground’ have both been in general use to describe the common power/signal reference point interchangeably around the world in the Electro-technical terminology. While the USA and other North American countries favor the use of the term ‘ground’, European countries including the UK and many other Eastern countries prefer the term ‘earth’”.



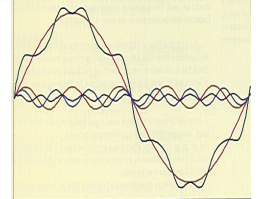
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To quote from “Earthing Practice” – CDA Publication 119 – 1997 (vide BS 7430:1991 Code of Practice for Earthing): *“It is worth noting that in Europe we tend to use the term earthing, whilst in north America, the term “grounding” is more common. The IEEE definition of grounding is: “Ground (ground system) - A conducting connection, whether intentional or accidental, by which an electric circuit or equipment is connected to the earth or some conducting body of relatively large extent that serves in place of the earth.”*

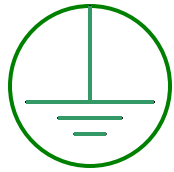


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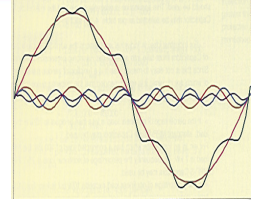


For use within Europe, if the generally accepted terms were replaced as below, then the meaning remains the same.

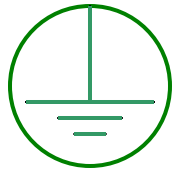
“Earth (earth system) - A conducting connection, whether intentional or accidental, by which an electric circuit or equipment is connected to the mass of earth or some conducting body of relatively large extent that serves in place of the mass of earth.”



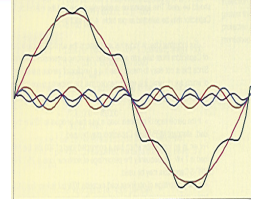
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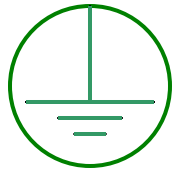
Myth: Natural earth serves as a return path for fault current.



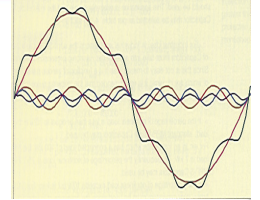
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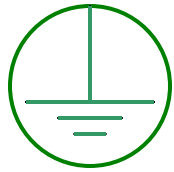
Fact: Though this may be true in some cases, one would be surprised to note that natural earth is a very poor conductor of electric current. Yes! The typical resistivity of the general mass of earth is about 100 Ohm-m. Compare this with the resistivity of Copper, which is, 1.7×10^{-8} Ohm-m ($0.017 \text{ Ohm-mm}^2/\text{m}$) and that of GI, which is, 1×10^{-7} Ohm-m ($0.1 \text{ Ohm-mm}^2/\text{m}$).



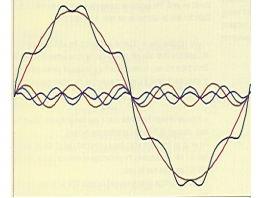
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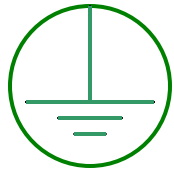
Definitely, natural earth is much more resistive than Copper or GI. Even the Indian Standard (IS 3043-1987) recognizes this fact. It mentions in its clause 0.3 that **‘the earth now rarely serves as a part of the return circuit, but is being used mainly for fixing the voltage of the system neutrals’**.



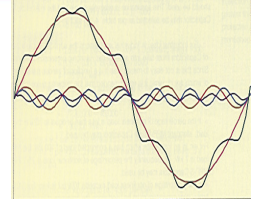
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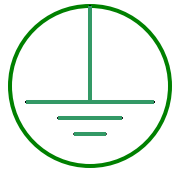
That is why the recent practice is to use a metallic conductor, as the return path for the fault current. This conductor is termed the ‘PEN’ conductor (in TN-C systems) or the ‘PE’ conductor (in TN-S systems). The PEN or the PE conductor are earthed at one or many places along its length, only to bring its potential close to the **earth potential**, which, **conventionally is taken as zero** (vide Cl. 2.7 of IS 3043).



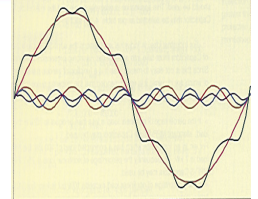
Earthing – Myths & Facts



***Myth:** Copper Earth Electrodes are better than GI or Steel Earth Electrodes*



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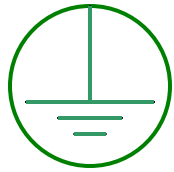
Fact: If one considers a plate electrode, the approximate resistance to earth is:

$$R = \frac{\rho}{A} \sqrt{\frac{\pi}{A}} \quad \text{Ohms (IS 3043)}$$

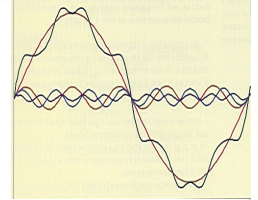
where,

ρ = Resistivity of the soil in Ohm-m

A = Area of both sides of the plate in m^2



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Similarly, for Rod or Pipe Electrodes,

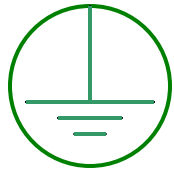
$$R = \frac{100 \rho}{2 \pi l} \log_e \frac{4l}{d} \quad \text{Ohms}$$

where,

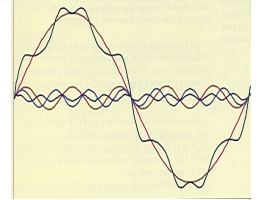
ρ = Resistivity of the soil in Ohm-m

l = Length of the Rod or Pipe in cm

d = Diameter of the Rod or Pipe in cm.



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And, for Strip or Conductor Electrodes,

$$R = \frac{100 \rho}{2 \pi l} \log_e \frac{2l^2}{wt} \quad \text{Ohms}$$

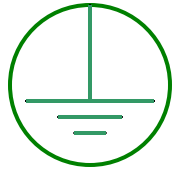
where,

ρ = Resistivity of the soil in Ohm-m

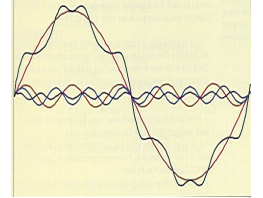
L = Length of the Strip in cm

w = Depth of burial of the electrode in cm

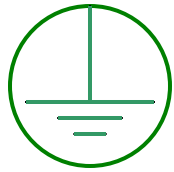
t = Width (in the case of Strip) or Twice the diameter
(in the case of Conductor) in cm.



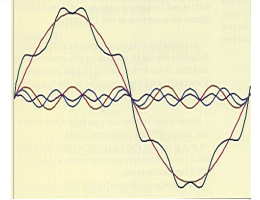
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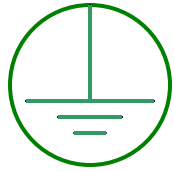
As can be seen from the above formulae, only the resistivity of the soil and the physical dimensions of the electrode play a major role in determining the electrode resistance to earth. The material resistivity is not considered anywhere in the above formulae.



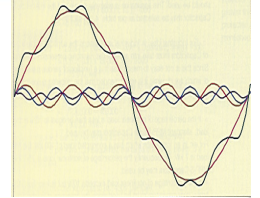
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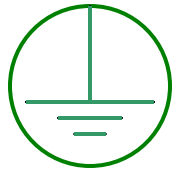
Hence, irrespective of the material of construction of the earth electrode, any material of given dimensions would offer the same resistance to earth. Of course, the material of construction does matter, while sizing the earthing conductor or the protective conductor. Because, the short time withstand current ratings do vary according to the material of construction of the conductor.



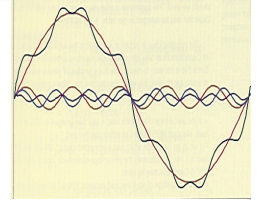
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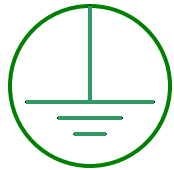
Myth: Plate Earthing is better than Pipe Earthing



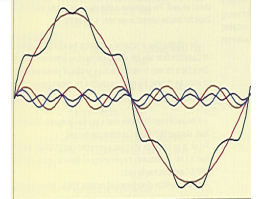
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Fact: It is not uncommon to find that (Copper) plate earthing is preferred – rather insisted upon, by some designers – (at least for system earthing (i.e.) to earth the neutrals of Transformers & Generators) over Pipe or Rod or Strip Earthing. This is because of the belief based on Ohm's Law that more surface area means less resistance.

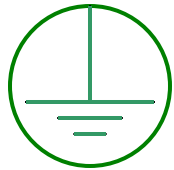


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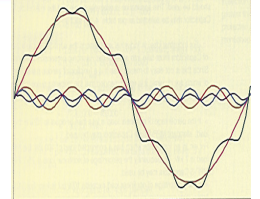


To examine this, let us consider a Copper plate electrode of size 1.2m x 1.2m x 3.15mm thick. Assuming a soil resistivity of 100 Ohm-m, the resistance of this electrode to earth will be:

$$R = \frac{\rho}{A} \sqrt{\frac{\pi}{A}} \text{ Ohms} = \frac{100}{2.88} \times \sqrt{\frac{3.14}{2.88}}$$
$$= 36.27 \text{ Ohms}$$

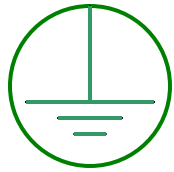


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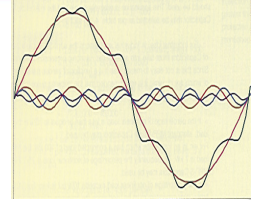


Now, consider a GI Pipe Electrode of 50 mm Diameter and 3 m Long. Assuming a soil resistivity of 100 Ohm-m, the resistance of this electrode to earth will be:

$$\begin{aligned} R &= \frac{100 \rho}{2 \pi l} \log_e \frac{4l}{d} \quad \text{Ohms} \\ &= \frac{100 \times 100}{2 \times 3.14 \times 300} \times \log_e \frac{4 \times 300}{5} \\ &= 29.09 \Omega. \end{aligned}$$



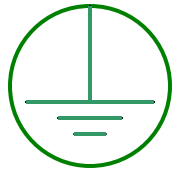
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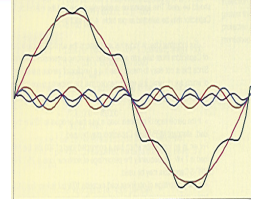
As can be seen from the above calculation the GI Pipe electrode offers a much lesser resistance than even a copper plate electrode.

IS 3043 too acknowledges this fact vide Cl.

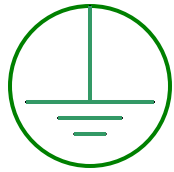
9.1.1, wherein it states that *‘a pipe, rod or strip has a much lower resistance than a plate of equal surface area’*.



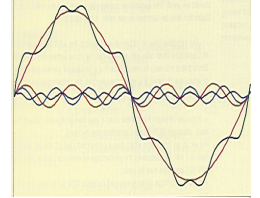
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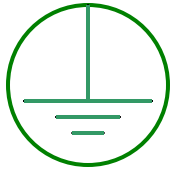
***Myth:** More water, less resistance; It is observed that in some installations, to bring down the earth resistance value, buckets and buckets of water is poured into the earth pit (that too, days just before the Electrical Inspector is due to arrive for inspecting the installation)*



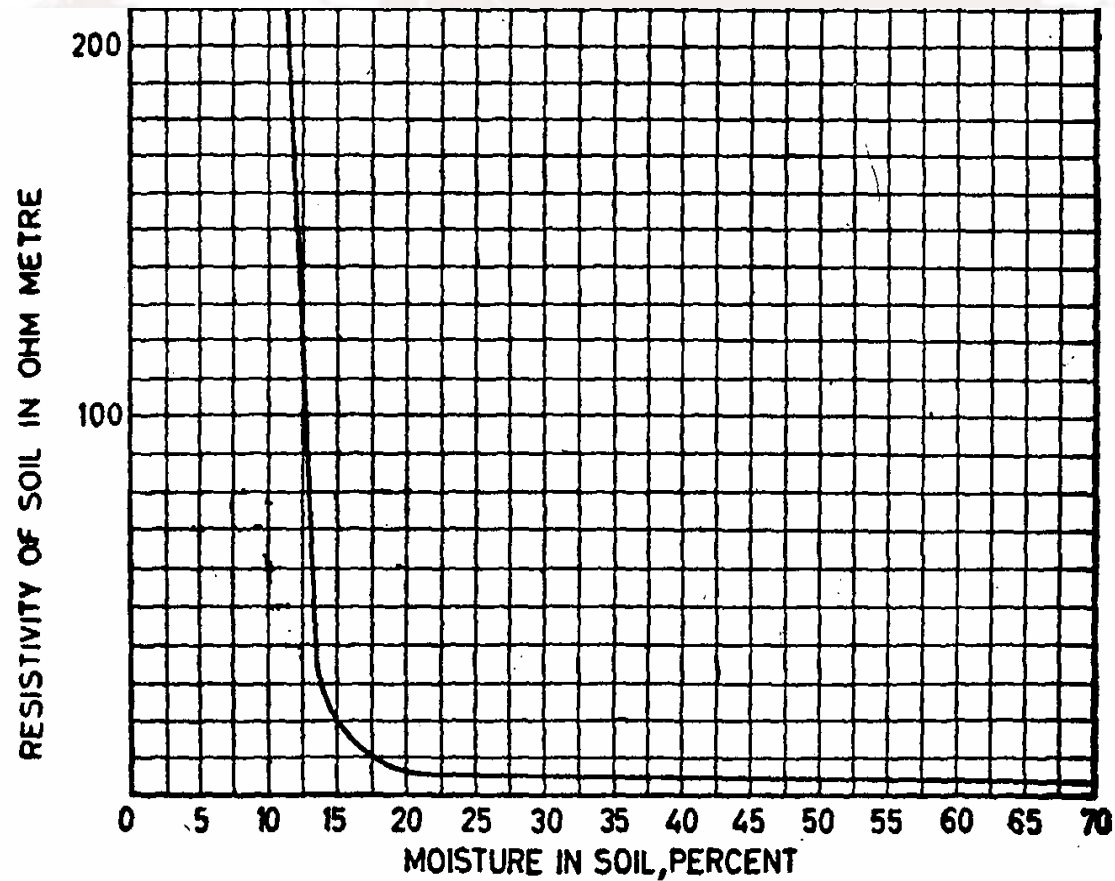
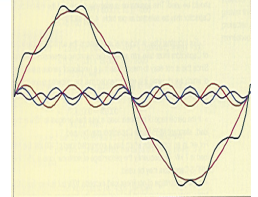
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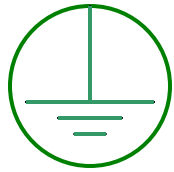
Fact: The resistance to earth of a given earth electrode depends upon the electrical resistivity of the soil in which it is installed. Moisture content is one of the controlling factors of earth resistivity.



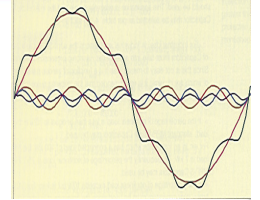
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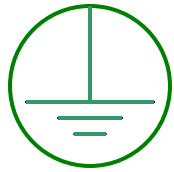
Variation of Soil Resistivity with Moisture Content



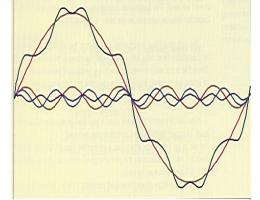
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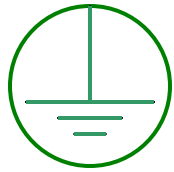
As can be seen from the above graph, above about 20 percent moisture content, the resistivity is very little affected. Below 20 percent, the resistivity increases abruptly with the decrease in moisture content. A difference of a few percent moisture content will, therefore, have a marked difference in the soil resistivity, if moisture content falls below 20 percent.



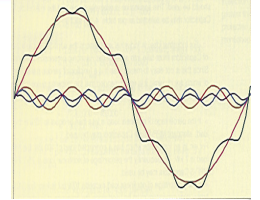
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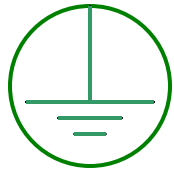
If the moisture content is already above 20 percent, there is no point in adding barrels of water into the earth pit, except perhaps wasting an important and scarce national resource like water.



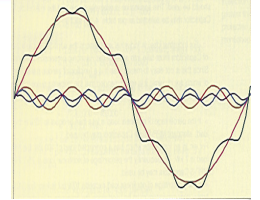
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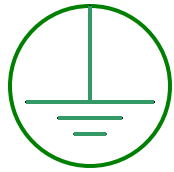
The normal moisture content of soil is 10 percent in dry seasons to 35 percent in wet seasons, averaging between 16 and 18 percent. Dry earth weighs about 1440 kg per cubic metre and 10 percent moisture content means about 144 kg of water per cubic metre of dry soil.



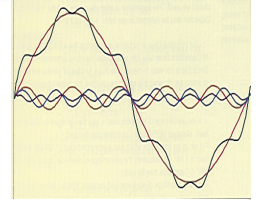
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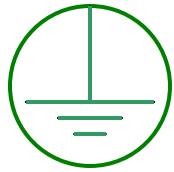
Also, it should be noted that moisture alone is not the dominant factor in the low resistivity of soil. If the water is relatively pure, it will have a very high resistivity and unless it contains sufficient natural elements to form a conducting electrolyte, just the abundance of water will not provide the soil with good conductivity.



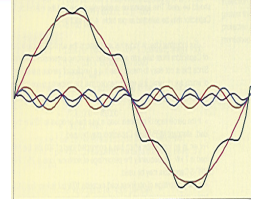
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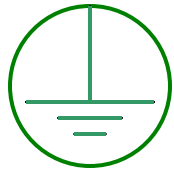
***Myth:** More salt, less resistance; it was also observed in some installations that the earth pit is filled to the brim with salt and charcoal (this too, just days before the Electrical Inspector is due to arrive for inspecting the installation).*



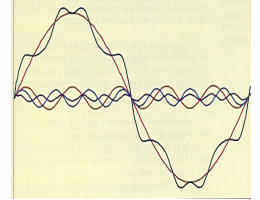
Earthing – Myths & Facts



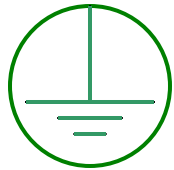
Fact: To reduce soil resistivity, it is necessary to dissolve in the moisture, normally contained in the soil, some substance, which is highly conductive in its water solution. The most commonly used substances are salt & charcoal in suitable proportion.



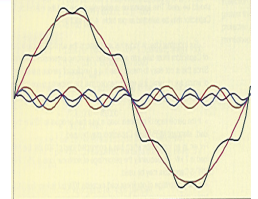
Earthing – Myths & Facts



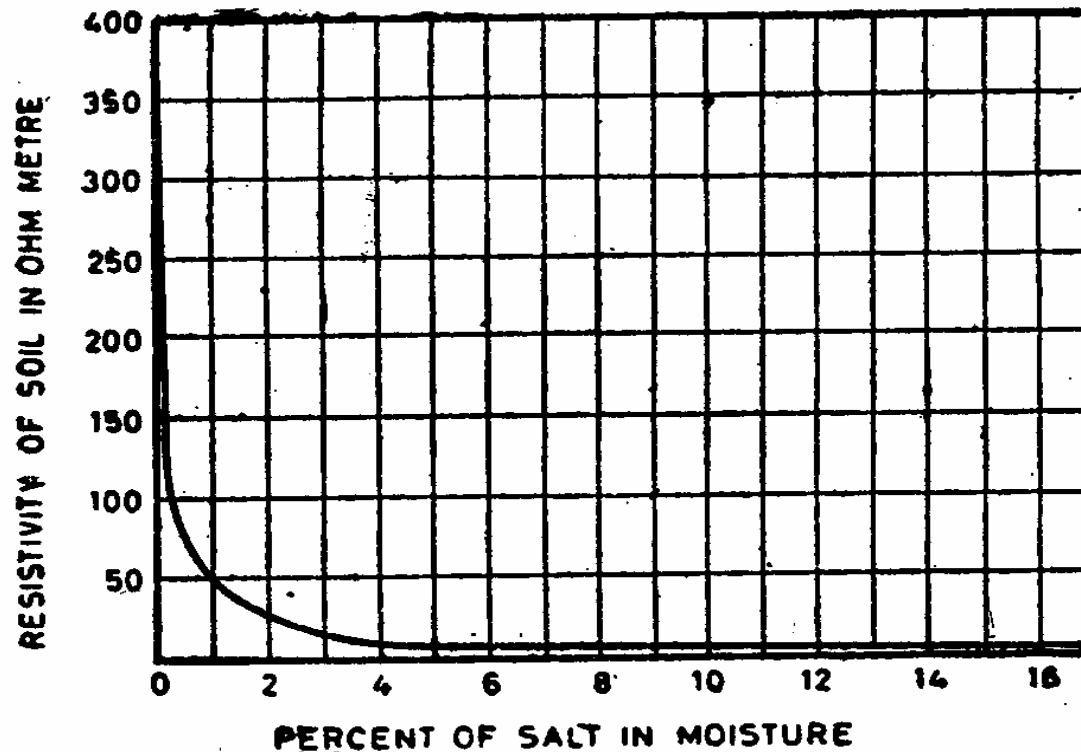
It must be noted that the additive substance would reduce the resistivity of the soil, only when it is dissolved in the moisture in the soil. Dry additives do not serve any purpose at all. So, there is no point again, in just filling up the pit with salt & charcoal.

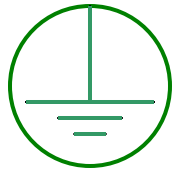


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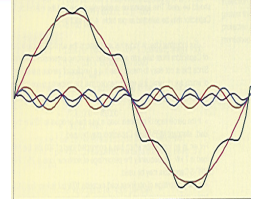


Also, the reduction in soil resistivity effected by the salt content is shown in the curve below:

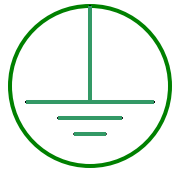




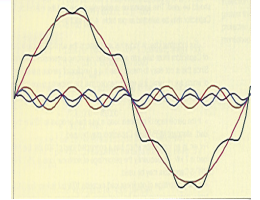
Earthing – Myths & Facts



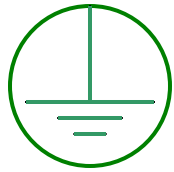
As can be seen from the above, the curve flattens off at about 5 percent. A further increase in salt content will give a very little decrease in soil resistivity. The salt content is expressed in percent by weight of the moisture content in the soil. Considering 1M^3 of Soil, the moisture content at 10 percent will be about 144 kg. (10 percent of 1440 kg). The salt content shall be 5% of this (i.e.) 5% of 144kg, that is, about 7.2kg.



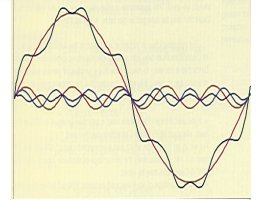
Earthing – Myths & Facts



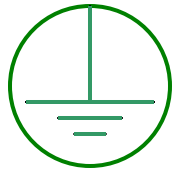
So, water addition should be about 144 kg and salt addition shall be about 7.2 kg per cubic metre of dry soil. Any further additions will not give appreciable benefits.



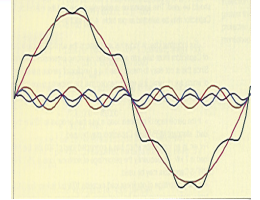
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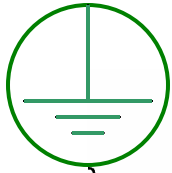
Myth: Deeper the earth pit and longer the earth pipe/rod, lesser will be the resistance



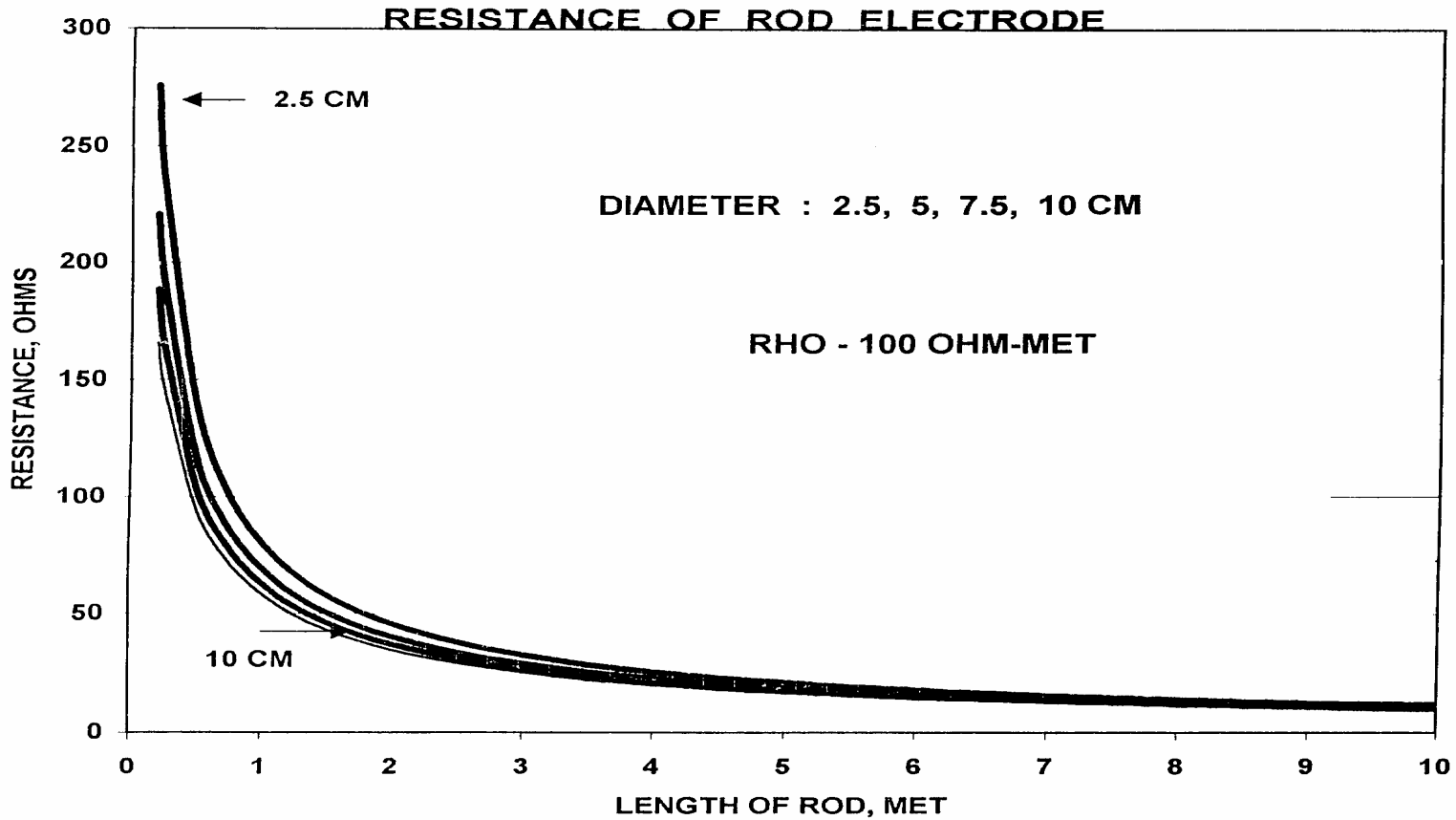
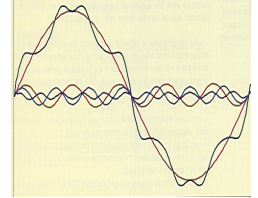
Earthing – Myths & Facts

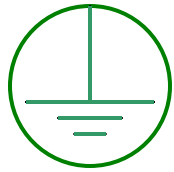


Fact: The resistance to earth of a pipe or rod electrode diminishes rapidly within the first few feet of driving, but less so at depths greater than 2 to 3m in soil of uniform resistivity. As can be seen from the graph, after about 4m depth, there is no appreciable change in resistance to earth of the electrode. Except in special cases, a number of rods in parallel are to be preferred to a single long rod.

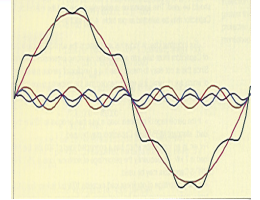


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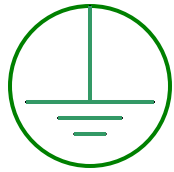




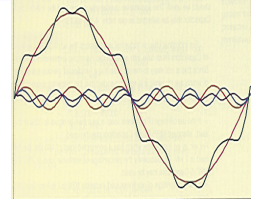
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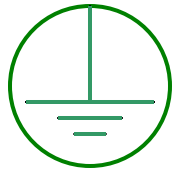
When a number of rods or pipes are connected in parallel, the resistance is practically proportional to the reciprocal of the number employed, provided each electrode is situated outside the resistance area of any other electrode. (The ideal separation distance would be the sum of the depths of the two electrodes).



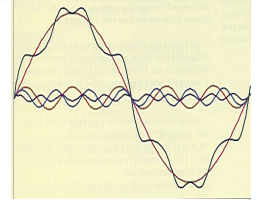
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Conclusion: Only some of the many myths practiced in the earthing of industrial electrical power systems are discussed in the above article. It is hoped that some of the myths and misbeliefs are cleared now. It is also felt that the purpose of this article will be served only when better practices are followed in industrial electrical power system earthing.



Earthing – Myths & Facts

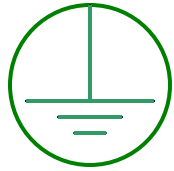


References:

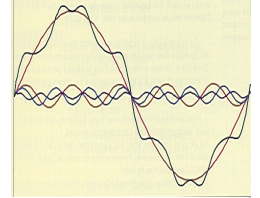
IS 3043-1987: Indian Standard Code of Practice for Earthing

IEEE Std. 142-1991: IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems

Earthing Practice – CDA Publication 119-1997



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THANK YOU

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