EARTHING CO

Logistics Center

Cairo Airport Egypt

M.V & L.V and L.C Earth Systems

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This paper present an general idea for earthing system going through designing earthing system with practical design of earthing system for M.V & L.V and L.C Earth Systems , ending with how to test the system and showing product specification .

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Introduction

At Earthing System

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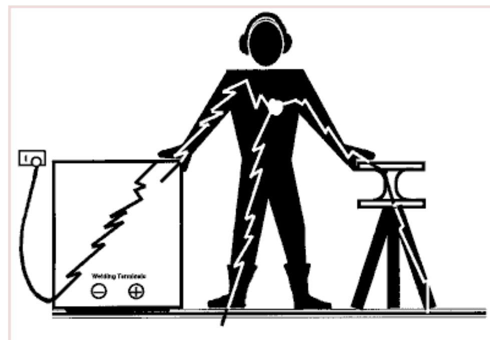
Earthing System

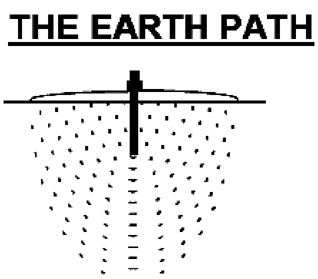
Introduction:

Earthing of either a system or equipment involves the provision of a connection to the general mass of earth. This connection should have a resistance not greater than the design value and should be capable of carrying the expected maximum fault current.



All the non-current metal parts of electrical installation shall be earthed properly. All metal conduits, trucking, cable sheaths, switchgear, distribution fuse boards, lighting fittings & fixtures and all other parts made of metal shall be bonded together and connected by means of specified earthing system.

Under normal operating condition it is important to ensure that any neutral current caused by unbalanced load return along the correct neutral conductor and do not divide and flow a long a parallel earth path. Conversely, under earth fault condition the fault current must low through the correct earth path and not via a parallel neutral path



CONNECTION OF EARTHING CONDUCTORS:

1- Main earthing conductors shall be taken from the earth connections at the main switchboards to an earth electrode with which the connection is to be made. Sub-main earthing conductors shall run from the main switchboard to the sub distribution boards. Final distribution boards earthing conductors shall run from sub-distribution boards.

2- Circuit earthing conductor shall run from the exposed metal of equipment and shall be connected to any point on the main earthing conductor or its distribution boards or to an earth leakage circuit breaker. Metal conduits, cable sheathing and armoring shall be earthed at the ends adjacent to switchboards at which they originate or otherwise at the commencement of the run by an earthing conductor ineffective electrical contact with cable sheathing. Where equipment is connected by flexible cord, all exposed metal parts of the equipment shall be earthed by means of an earthing conductor enclosed with the current carrying conductors within the flexible cord. Switches, accessories, lighting fitting etc. which are rigidly secured in effective electrical contact with a run of metallic conduit shall not be considered as a part of earthing conductor for earthing purposes, even though the run of metallic conduit is earthed.

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3- All metal clad switches and other equipment carrying single phase current shall be connected to earth by a single connection. All metal clad switches, carrying medium voltages and high voltage shall be connected with earth by two separate and distinct connections. The earthing conductors inside the building, wherever exposed, shall be properly protected from mechanical injury by running the same in GI pipe of adequate size.

4- Earthing conductors, outside the building, shall be laid 600 mm below the finished ground level.

5- Neutral conductor, sprinkler pipes or pipes conveying gas, water or flammable liquid, structural steel work, metallic enclosures for cables and conductors, metallic conduits and lightning protection stem conductors shall not be used as a means of earthing an installation or even as a link in an earthing system. The electrical resistance of metallic enclosures for cables and conductors measured between earth connections at the main switchboard shall be low enough to permit the passage of current necessary to operate fuse or circuit breakers and shall not exceed one ohm.

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Earthing System

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Electrical equipment earthing

The object of electrical equipment earthing is:

1- To ensure effective operation of the protective gear in the event of earth fault currents that might otherwise cause damage to property,
2- And to protect against danger to life through shock due to installation metalwork being maintained at a dangerous potential relative to earth.

The method used to connect such metalwork to earth has to be compatible with the type of installation and its supply system.

A primary purpose of earthing is to enable a system or equipment to be disconnected from the source of energy so as to avoid the effects of excessive currents produced under earth fault conditions. The apparatus performing this task is referred to as the protection equipment.

Factors affecting on earth resistance

The provision of a connection to the general mass of earth. This connection should have a resistance not greater than the design value and should be capable of carrying the expected maximum fault current. It is therefore necessary to consider the various factors which affect the resistance to earth and fault current capacity of the buried conductor, designated the earth electrode. These include the size and shape of the earth conductor, the soil in which it is buried and the connection of the system to it. It is also necessary to give consideration to the current density at the surface of the earth electrode and the ground potentials in its vicinity.

1-Soil resistivity

The resistance to earth of a given electrode depends upon the electrical resistivity of the soil in which it is installed. This factor may therefore be important in deciding which of many protective systems to adopt. The composition of the soil largely determines its resistivity and examples are given in Table 1. Earth resistivity is, however, essentially electrolytic in nature and is affected therefore by:

1- The moisture content of the soil.
2- And by the chemical composition
3- And concentration of salts dissolved in the contained water.

Grain size and distribution, and closeness of packing are also contributory factors since they control the manner in which the moisture is held in the soil. Many of these factors vary locally and some vary seasonally, so that Table 1 should only be taken as a general guide.

The effective resistivity depends not only on the surface layers but also on the underlying geological formation. Stratification of the soil should be taken into account when the type of electrode and its depth are being considered. It should also be noted that soil temperature has some effect, but is only important near and below freezing point, necessitating the installation of earth electrodes at depths to which frost will not penetrate. It is therefore recommended that any part of an earth electrode system within 1 m of the soil surface should not be regarded as being effective under frost conditions. While the fundamental nature and properties of a soil in a given area cannot be changed, use can be made of purely local conditions in choosing suitable electrode sites and of methods of preparing the site selected to secure the optimum resistivity. A site should be chosen in one of the following types of soil in the order of preference given:

a) Wet marshy ground

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b) Clay, loamy soil, arable land, clayey soil, clayey soil or loam mixed with small quantities of sand;

c) Clay and loam mixed with varying proportions of sand, gravel, and stones;

d) Damp and wet sand, peat. Dry sand, gravel, chalk, limestone, whinstone, granite and any very stony ground should be avoided if possible, also all locations where virgin rock is very close to the surface.

Table 1 — Examples of soil resistivity (Ω·m)

Type of soil	Climatic condition			
	Normal and high rainfall (i.e. greater than 500 mm a year)		Low rainfall and desert conditions (i.e. less than 250 mm a year)	Underground waters (saline)
	Probable value	Range of values encountered	Range of values encountered	Range of values encountered
Alluvium and lighter clays	5	See note	See note	1 to 5
Clays (excluding alluvium)	10	5 to 20	10 to 100	1 to 5
Marls (e.g. Keuper marl)	20	10 to 30	50 to 300	
Porous limestone (e.g. chalk)	50	30 to 100		
Porous sandstone (e.g. Keuper sandstone and clay shales)	100	30 to 300		
Quartzites, compact and crystalline limestone (e.g. carboniferous sediments, marble, etc.)	300	100 to 1 000		
Clay slates and slatey shales	1 000	300 to 3 000	1 000 upwards	30 to 100
Granite	1 000			
Fissile slates, schists, gneiss and igneous rocks	2 000	1 000 upwards		

NOTE Depends on water level of locality.

A site should be chosen that is not naturally well drained. A water-logged situation is not, however, essential unless the soil is sand or gravel, as in general no advantage results from an increase in moisture content above about 15 % to 20 %. Care should be taken to avoid a site kept moist by water flowing over it (e.g. the bed of a stream) as the beneficial salts may be entirely removed from the soil in such situations.

Soil treatment or replacement to improve earth electrode contact resistance may be used in special or difficult locations. If a greater degree of permanence is envisaged, it may be desirable to replace the soil immediately around an electrode with a lower resistivity material, such as:

a) A clay based material formed by the decomposition of volcanic ash, such as bentonite;

b) Concrete

c) A conductive concrete or cement made with graded granular carbonaceous aggregate in place of the conventional sand or aggregate

Such treatment may be used to advantage in rocky terrain. Where holes are bored for insertion of vertical earth electrodes, or where strip earth electrodes are laid rapidly under shallow areas having a low resistivity which overlay rock strata, suitable treatment will reduce the contact resistance with respect to the general mass of ground. The use of coke breeze as an infill is not recommended as it may result in rapid corrosion not only of the electrode itself but also of cable sheaths. The resistance, R,

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expressed in ohms, of a vertical electrode surrounded by an infill of material such as bentonite or concrete is given approximately by the following equation:

$$R = \left(\frac{1}{2\pi L}\right)\left((\rho - \rho ç)\left(Ln\left(\frac{8*L}{D}\right) - 1\right) + \rho ç\left(Ln\left(\frac{8L}{d}\right) - 1\right)\right) \quad , \rightarrow \textbf{Eq. 1}$$

ρ is the resistivity of soil, in Ohm meters (Ω·m)

ρç is the resistivity of infill material, in Ohm meter (Ω·m)

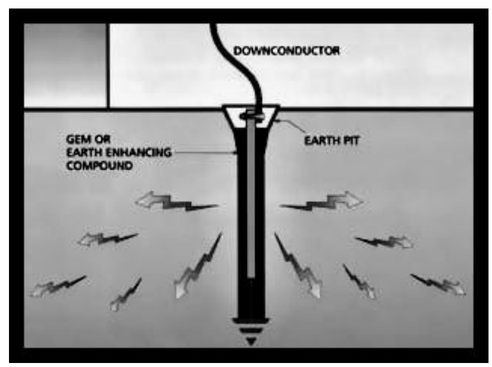
d is the diameter of electrode in meter (m)

D is the diameter of infill, in meter (m)

L is the driven length of electrode, in meter (m)

The resistivity of betonies varies from about 3 Ω·m upwards, depending on its moisture content. It is hygroscopic and will absorb available moisture from the surrounding soil. Should it become dry, due to a complete absence of moisture in the surrounding soil, its resistivity rises appreciably and it will shrink away from the electrode. The resistivity of concrete is in the range 30 Ω ·m. to 90 Ω ·m.

2-Effect of shape on electrode resistance



With single electrodes the greater part of the fall in potential occurs in the soil within a meter or so of the electrode surface, since it is here that the current density is highest. To obtain a low overall resistance, the current density should be as low as possible in the medium adjacent to the electrode, which should be so designed as to cause the current density to decrease rapidly with distance from the electrode. This condition is achieved by making the dimensions in one direction large compared with those in the other two, thus a pipe, rod or strip has a much lower resistance than a plate of equal surface area. The resistance is not, however, inversely proportional to the surface area of the electrode.

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How to Design an Earthing System?

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Resistance of earth electrodes (Rods or pipes)

The resistance to earth of a rod or pipe electrode R, in ohms, is given by the following equation:

$$R=\left(\frac{\rho}{2\pi L}\right) * \left(Ln\left(\frac{8L}{d}\right) - 1\right), \rightarrow \textbf{Eq. 2}$$

Where

L is the driven length of electrode, in meter (m)

d is the diameter of electrode in meter (m)

ρ is the resistivity of soil, in Ohm meters (Ω·m)

The curves shown in Figure 3 are calculated from this equation for electrodes of 12.5 mm, 25 mm and 100 mm diameter in a soil of 100 Ω·m resistivity. Change of diameter has a relatively minor effect, and size of pipe is generally governed by mechanical resistance to bending or splitting. It is apparent that the electrical resistance diminishes rapidly with the first meter or so of driving, but less, so at depths greater than 2 m to 3 m in soil of uniform resistivity. A number of rods or pipes may be connected in parallel and the resistance is then practically proportional to the reciprocal of the number employed so long as each is situated outside the resistance area of any other. In practice this is often assumed to be satisfied by a mutual separation equal to the driven depth. Little is to be gained by separation beyond twice the driven depth. A substantial gain is affected even at 2 m separation. Figure 4 shows the effect of inter-electrode spacing for two rod electrodes 3 m long by 15.9 mm diameter.

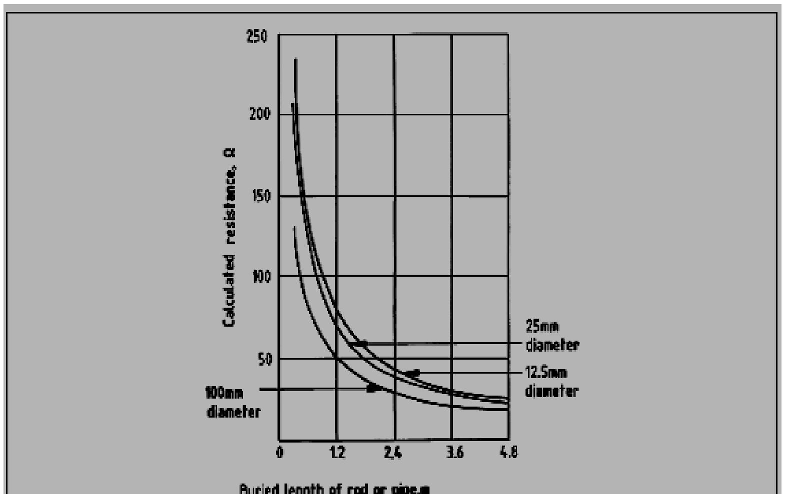

Figure 3 — Effect of buried length of rod or pipe electrode on calculated resistance for soil resistivity of 100 Ω·m (assumed uniform)

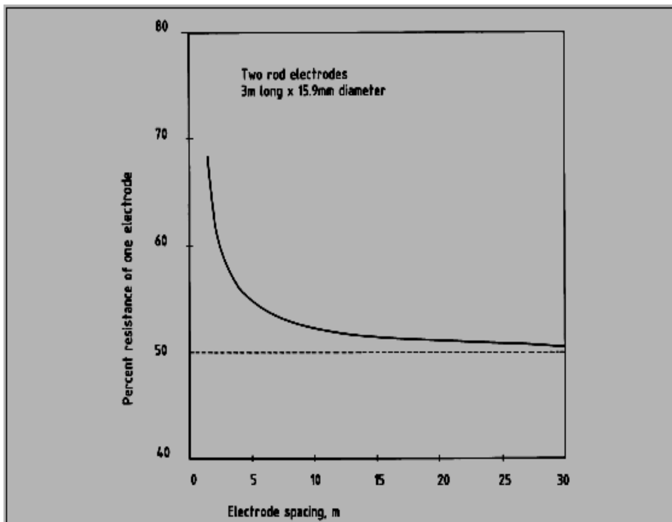

Figure 4 — Effect of inter-electrode spacing on combined resistance

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The combined resistance of rod electrodes in parallel Rn, expressed in ohms (Ω), can be obtained from the following equation:

$$R_n = R\left(\frac{1+\lambda\alpha}{n}\right) \text{ , } \rightarrow \textbf{Eq. 3}$$

In which $\alpha = \left(\frac{\rho}{2\pi Rs}\right)$, → **Eq. 4**

R is the resistance of one rod in isolation in (Ω)

s is the distance between adjacent rod, in (m)

d is the resistivity of soil, (Ω .m)

λ is a factor given in Table 2 or Table 3

n is the number of electrode (as given in Table 2 and Table 3)

The above equations assume that rod electrodes can be represented approximately by hemispherical electrodes, having the same earthing resistance, located in the soil surface. This assumption is satisfactory provided that the spacing between the rods is not less than their length. If the rods are equally spaced in a straight line an appropriate value of λ may be taken from Table 2.

Table 2 — Factors for parallel electrodes arranged in line

Number of electrode (n) along each side of the square	Factor (λ)
2	2.71
3	4.51
4	5.48
5	6.14
6	6.63
7	7.03
8	7.36
9	7.65
10	7.9
12	8.32
14	8.67
16	8.96
18	9.22
20	9.4
Note: The total number of electrode around the square is 4(n-1)	

For electrodes equally spaced around a hollow square, e.g. around the perimeter of a building, the equations given above are used with a value of λ taken from Table 3. **For three rods placed in an equilateral triangle, or in an L formation, a value of λ = 1.66 may be assumed.**

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Table 3

Number of electrode (n)	Factor (λ)
2	1
3	1.66
4	2.15
5	2.54
6	2.87
7	3.15
8	3.39
9	3.61
10	3.81

The reduction in combined earth resistance provided by additional electrodes inside the square is small, but such electrodes will reduce the potential gradient over the soil surface inside the square. A practical example of this is the use of strip electrodes forming an earth grid within the square. Table 3 may also be used for electrodes arranged in a rectangle, where n is given by (total number of electrodes/4) + 1. Provided that the length to width ratio of the rectangle does not exceed 2, the error will be less than – 6 %. Pipes may be of cast iron Table 3-Factors for electrodes arranged in a hollow square of not less than 100 mm diameter, 2.5 m to 3 m long and 13 mm thick.

Such pipes cannot be driven satisfactorily and may therefore be more expensive to install than plates for the same effective area. Alternatively, steel tubes up to 50 mm diameter, whose dimensions permit them to be driven, are sometimes employed; these are less durable than copper rods.

Driven earth rods generally consist of solid circular copper, molecular bonded clad steel, stainless steel, or galvanized steel. The preferred nominal diameters for earth rods are 9 mm, 12.5 mm and 15 mm for copper and copper-clad steel rods and 16 mm for galvanized and stainless steel rods; departures from these preferred diameters should be limited to those necessary for the provision of rolled screw threads, or taper fit tolerances. The preferred lengths of extensible earth rods are 1.2 m for 9 mm rods and 1.2 m or 1.5 m for 15 mm rods. Minimum sizes for these components should conform to the data given in Table 4.

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Table 4- Minimum sizes of components for earth electrodes

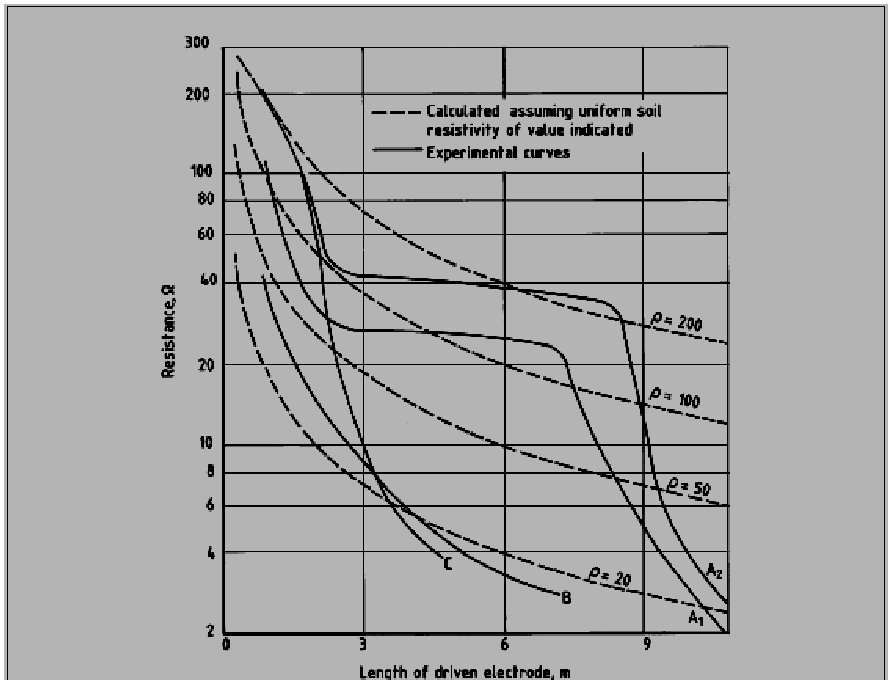
Electrode type	Cross-sectional area mm^2	Diameter or thickness mm
Copper strip	50	3
Hard drawn or annealed copper rods or solid wires for driving or laying in ground	50	8
Copper-clad or galvanized steel rods (see notes) for harder ground	153	14
Stranded copper	50	3 per strand

NOTE 1 For copper-clad steel rods the core should be of low carbon steel with a tensile strength of approximately 600 N/mm^2 and a quality not inferior to grade S275 conforming to BS EN 10025. The cladding should be of 99.9 % purity electrolytic copper, molecularly bonded to the steel core. The radial thickness of the copper should be not less than 0.25 mm.

NOTE 2 Couplings for copper-clad steel rods should be made from copper-silicon alloy or aluminium bronze alloy with a minimum copper content of 75 %.

NOTE 3 For galvanized steel rods, steel of grade S275 conforming to BS EN 10025 should be used, the threads being cut before hot-dip galvanizing in accordance with BS 729.

Cruciform and star-shaped sections are more rigid while being driven, but the apparent additional surface does not confer a noticeable advantage in current-carrying capacity or reduction of resistance. In some circumstances the addition of horizontal electrodes is advantageous. Rods may be coupled together to give longer lengths. Except in special conditions, a number of rods in parallel is to be preferred to a single long rod. Deeply driven rods are, however, effective where the soil resistivity decreases with depth or where substrata of low resistivity occur at depths greater than those to which rods, for economic reasons, are normally driven. In such cases the decrease of resistance with depth of driving may be very considerable as is shown by the measurements plotted in Figure 5 for a number of sites. For curves A1 and A2 it was known from previously sunk boreholes that the soil down to a depth of between 6 m and 9 consisted of ballast, sand and gravel, below which occurred London clay. The rapid reduction in resistance when the electrodes penetrated the latter was very marked. The mean resistivity up to a depth of 8 m in one case was 150Ω·m; at 11 m the mean value for the whole depth was 20 Ω·m owing to the low resistivity of the clay stratum. Similarly for curve C the transition from gravelly soil to lay at a depth of about 1.5 m was very effective. In the case of curve B, however, no such marked effect occurred although there was a radial reduction in average resistivity with increase in depth, as can be seen by comparison with the dotted curves, which are alculated on the assumption of uniform resistivity. Other factors that affect a decision of whether to drive deep electrodes or to employ several rods or pipes in parallel are the steep rise in the energy required to drive them with increase in depth and the cost of couplings. the former can be offset by reducing the diameter of the rods, since a 12.5 mm diameter rod can be driven to considerable depths



NOTE Values of ρ are in Ω m

Figure 5 — Calculated and experimental curves of resistance of 12.5 mm diameter driven rod electrodes

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without deformation or bending if the technique of using a large number of comparatively light blows is adopted rather than a smaller number of blows with a sledge hammer. Power-driven hammers suitable for this purpose are available. In cases where impenetrable trata or high resistivity soil occur at relatively small depths, considerable advantage may result from driving rods at an angle of about 0° to the horizontal, thus increasing the length installed for a given depth.

Horizontal strip or round conductor electrodes

Horizontal strip or round conductor electrodes have special advantages where high resistivity soil underlies shallow surface layers of ow resistivity. They are frequently in the form of untinned copper strip of not less than 25 mm by 3 mm section, but may be of bare copper conductor as used for overhead lines. The minimum size should conform to the value given in Table 4.

For a strip or round conductor electrode the resistance R, in ohms (Ω) is given by the following equation:

$$R=\frac{\rho}{P\pi L}\left(Ln\left(\frac{2L^2}{wh}\right)+Q\right), \rightarrow \textbf{Eq. 5}$$

L is the driven length of strip or conductor, in meter (m)

h is the diameter depth of electrode in meter (m)

ρ is the resistivity of soil, in Ohm meters (Ω·m)

w is the width of strip or Diameter of conductor, in meter (m)

P and Q are coefficient given Table 5 for different arrangement of electrode

The thickness of a strip electrode is usually not greater than about one-eighth of the width. Within this limitation it has a negligible effect on the electrode earth resistance. Earthing resistance is principally affected by length. For the values most frequently used, the depth of burial and diameter or width have a relatively minor effect.

Care should be taken in positioning these electrodes, especially to avoid damage by agricultural operations.

Table 5 — Coefficients for strip or round conductor electrodes

Electrode arrangement	Coefficient P	Coefficient Q: Strip	Coefficient Q: Round
Single length*	2	– 1	– 1.3
Two lengths at 90°	4	0.5	0.9
Three lengths at 120°	6	1.8	2.2
Four lengths at 90°	8	3.6	4.1

* Where two or more straight lengths, each of length L in metres (m) and of separation s in metres (m), are laid parallel to each other and connected together the combined resistance can be calculated from the following equation:

$$R_n = FR_1$$

where

R_n is the resistance of n straight conductors in parallel, in Ω;

R_1 is the resistance of one straight conductor in isolation calculated from the equation and coefficients given above, in Ω.

F has the following value:

for two lengths, $F = 0.5 + 0.078(s/L)^{-0.507}$

for three lengths, $F = 0.33 + 0.071(s/L)^{-0.408}$

for four lengths, $F = 0.25 + 0.067(s/L)^{-0.451}$ provided that $0.02 \le (s/L) \le 0.3$.

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Calculation Sheet

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M.V Earthing System (less than 2.0 Ohm)

Step 1:

Calculating the earth resistance of single electrode.

Referring to **Eq.2**

$$R=\left(\frac{\rho}{2\pi L}\right)*\left(Ln\left(\frac{8L}{d}\right)-1\right), \rightarrow \textbf{Eq. 2}$$

i- According to soil resistivity tested at Sheraton Area , **the soil resistivity ρ** is **24 Ω·m (appendix A)**

ii- Assume the depth of the rod **L is 2.4m (2 rod of 1200 X 3/4")**

iii- The Diameter of the rod **d is 0.020 m**

Substitute in the above Eq.

$$R=\left(\frac{24}{2*\pi*2.4}\right)*\left(Ln\left(\frac{8*2.4}{0.020}\right)-1\right)=9.34.\Omega$$

So, the earth resistance of single rod "R"= 9.34 Ω

Step 2:

Calculating the earth resistance of "n" multi electrode.

$$R_n=R\left(\frac{1+\lambda\alpha}{n}\right), \rightarrow \textbf{Eq. 3}$$

In which $\alpha=\left(\frac{\rho}{2\pi Rs}\right), \rightarrow \textbf{Eq. 4}$

i- Assume number of rods "**n" is 3**

ii- To obtain best efficiency of the earthing system design, the distance between two adjacent rod equal to duple the rod depth, **s=4 m**

iii- According to Bs . Page 12, for electrodes triangle in Line form so, **λ=1.66**

Substitute in the above **Eq.4**

$$\alpha=\left(\frac{24}{2*\pi*9.314*4}\right)=0.102$$

Substitute in the above **Eq.3**

$$R_n=9.34*\left(\frac{1+1.66*0.102}{3}\right)=3.64\Omega$$

So, total earth resistance of n rods is **R_n =3.64 Ω**

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Step 3:

Calculating the Cable resistance

Connecting between rods is used by Bare Copper Conductor which helps in decreasing the earth resistance system.

Referring to **Eq.5**

$$R=\frac{\rho}{P\pi L}\left(Ln\left(\frac{2L^2}{wh}\right)+Q\right), \rightarrow \textbf{Eq. 5}$$

Referring to **Table 5**, find coefficient P and Q for earthing system of round conductor arranged in straight line

P=2, q = -1.3

And by using round conductor of cross sectional area **95mm²** with length of **20 m**

By calculating the Diameter of the conductor then **w= 0.11m**,

Buried at depth **h=0.8 m**

Substitute in the above **Eq.5**

$$R=\frac{24}{2*\pi*20}\left(Ln\left(\frac{2*20^2}{0.11*0.8}\right)+(-1.3)\right)=2.81\Omega$$

So, the earth resistance of bare copper conductor 95mm² is $\boxed{R_c = \mathbf{2.81\ \Omega}}$

Step 5:

Calculating the Total earthing system resistance

$$R_t = R_n \,//\, R_c = \frac{2.81*3.64}{2.81+3.64} = \boxed{1.58\Omega}$$

So, R_t = 1.58 Ω less than required value (2 Ohm)

The design is accepted

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L.V Earthing System (less than 1 Ohm)

Step 1:

Calculating the earth resistance of single electrode.

Referring to **Eq.2**

$$R=\left(\frac{\rho}{2\pi L}\right) * \left(Ln\left(\frac{8L}{d}\right) - 1\right), \rightarrow \textbf{Eq. 2}$$

iv- According to soil resistivity tested at Sheraton Area, **the soil resistivity ρ** is **24 Ω·m (appendix A)**

v- Assume the depth of the rod **L is 2.4 m (2 rod of 1200 X 3/4")**

vi- The Diameter of the rod **d is 0.020 m**

Substitute in the above Eq.

$$R=\left(\frac{24}{2*\pi*2.4}\right) * \left(Ln\left(\frac{8*2.4}{0.020}\right) - 1\right) = 9.34\Omega$$

So, the earth resistance of single rod "R"= 9.34 Ω

Step 2:

Calculating the earth resistance of "n" multi electrode.

$$R_n=R\left(\frac{1+\lambda\alpha}{n}\right), \rightarrow \textbf{Eq. 3}$$

$$\text{In which} \quad \alpha=\left(\frac{\rho}{2\pi Rs}\right), \rightarrow \textbf{Eq. 4}$$

iv- Assume number of rods "**n" is 6**

v- To obtain best efficiency of the earthing system design, the distance between two adjacent rod equal to duple the rod depth, **s=5 m**

vi- According to Bs . Page 12, for electrodes arranged in Triangle form so, **λ=1.66**

Substitute in the above **Eq.4**

$$\alpha=\left(\frac{24}{2*\pi*9.34*5}\right) = 0.081$$

Substitute in the above **Eq.3**

$$R_n=9.34*\left(\frac{1+1.66*0.081}{6}\right) = 1.76\ \Omega$$

So, total earth resistance of n rods is **R_n =1. 76 Ω**

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Step 3:

Calculating the Cable resistance

Connecting between rods is used by Bare Copper Conductor which helps in decreasing the earth resistance system.

Referring to **Eq.5**

$$R=\frac{\rho}{P\pi L}\left(Ln\left(\frac{2L^2}{wh}\right)+Q\right), \rightarrow \textbf{Eq. 5}$$

Referring to **Table 5**, find coefficient P and Q for earthing system of round conductor arranged in straight line

P=2, q = -1.3

And by using round conductor of cross sectional area **70mm²** with length of **30 m**

By calculating the Diameter of the conductor then **w= 0.094 m**,

Buried at depth **h=0.8 m**

Substitute in the above **Eq.5**

$$R=\frac{24}{2*\pi*30}\left(Ln\left(\frac{2*30^2}{0.094*0.8}\right)+(-1.3)\right)=1.99\ \Omega$$

So, the earth resistance of bare copper conductor 70 mm^2 is $R_c = \mathbf{1.99\ \Omega}$

Step 5:

Calculating the Total earthing system resistance

$$R_t= R_n \,//\, R_c = \frac{1.99*1.76}{1.99.+1.76} = \boxed{0.93\Omega}$$

So, R_t = 0.93 Ω less than required value (1 Ohm)

The design is accepted

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L.C Earthing System (less than 0.5 Ohm)

Step 1:

Calculating the earth resistance of single electrode.

Referring to **Eq.2**

$$R=\left(\frac{\rho}{2\pi L}\right) * \left(Ln\left(\frac{8L}{d}\right) - 1\right), \rightarrow \textbf{Eq. 2}$$

vii- According to soil resistivity tested at Sheraton Area, **the soil resistivity ρ** is **24 Ω·m (appendix A)**

viii- Assume the depth of the rod **L is 3.6m (3 rod of 1200 X 3/4")**

ix- The Diameter of the rod **d is 0.020 m**

Substitute in the above Eq.

$$R=\left(\frac{24}{2*\pi*3.6}\right) * \left(Ln\left(\frac{8*3.6}{0.020}\right) - 1\right) = 6.65\ \Omega$$

So, the earth resistance of single rod "R"= 6.65 Ω

Step 2:

Calculating the earth resistance of "n" multi electrode.

$$R_n=R\left(\frac{1+\lambda\alpha}{n}\right), \rightarrow \textbf{Eq. 3}$$

In which $\alpha=\left(\frac{\rho}{2\pi Rs}\right), \rightarrow \textbf{Eq. 4}$

vii- Assume number of rods "**n" is 9**

viii- To obtain best efficiency of the earthing system design, the distance between two adjacent rod equal to duple the rod depth, **s=4 m**

ix- According to Bs . Page 12, for electrodes arranged in Triangle form so, **λ=1.66**

Substitute in the above **Eq.4**

$$\alpha=\left(\frac{24}{2*\pi*6.65*4}\right) = 0.14$$

Substitute in the above **Eq.3**

$$R_n=6.65*\left(\frac{1+1.66*0.14}{9}\right) = 0.91\ \Omega$$

So, total earth resistance of n rods is **R_n =0.91 Ω**

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Step 3:

Calculating the Cable resistance

Connecting between rods is used by Bare Copper Conductor which helps in decreasing the earth resistance system.

Referring to **Eq.5**

$$R=\frac{\rho}{P\pi L}\left(Ln\left(\frac{2L^2}{wh}\right)+Q\right), \rightarrow \textbf{Eq. 5}$$

Referring to **Table 5**, find coefficient P and Q for earthing system of round conductor arranged in straight line

P=2, q = -1.3

And by using round conductor of cross sectional area **50mm²** with length of **65m**

By calculating the Diameter of the conductor then **w= 0.079m**,

Buried at depth **h=0.8 m**

Substitute in the above **Eq.5**

$$R=\frac{24}{2*\pi*65}\left(Ln\left(\frac{2*65^2}{0.079*0.8}\right)+(-1.3)\right)=1.02\Omega$$

So, the earth resistance of bare copper conductor $50mm^2$ is $\boxed{R_c = \mathbf{1.02\ \Omega}}$

Step 5:

Calculating the Total earthing system resistance

$$R_t = R_n \,//\, R_c = \frac{0.91*1.02}{0.91+1.02} = \boxed{0.48\Omega}$$

So, R_t = 0.48 Ω less than required value (0.5 Ohm)

The design is accepted

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Appendix A
Soil Resistivity Test

Purpose

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Soft resistivity is generally measured by the same method as is used for electrode resistance. Four equally spaced test spikes are driven to a depth of up to 1 m, the depth not exceeding 5 % of their separation a (see Figure 13). (It is important to ensure that their resistance areas do not overlap.) Current is passed between the two outer electrodes and the resistance R is given by the ratio of the voltage between the inside electrodes to the current.

In homogenous soil the average resistivity (**ρ**) in ohm meters (7·m) is given by the following equation:

$$\rho \text{ (ohms-m)} = 2\pi aR$$

ρ = soil resistivity in ohm-m (Ω-m).

R = digital readout in ohms (Ω).

A = distance between electrodes in mt

The resistivity found applies to a soil depth a, so by repeating the measurement with different values of a, the average resistivity to various depths can be found and the results will indicate whether any advantage is to be gained by installing deeply driven electrodes in order to reach strata of a lower resistivity.

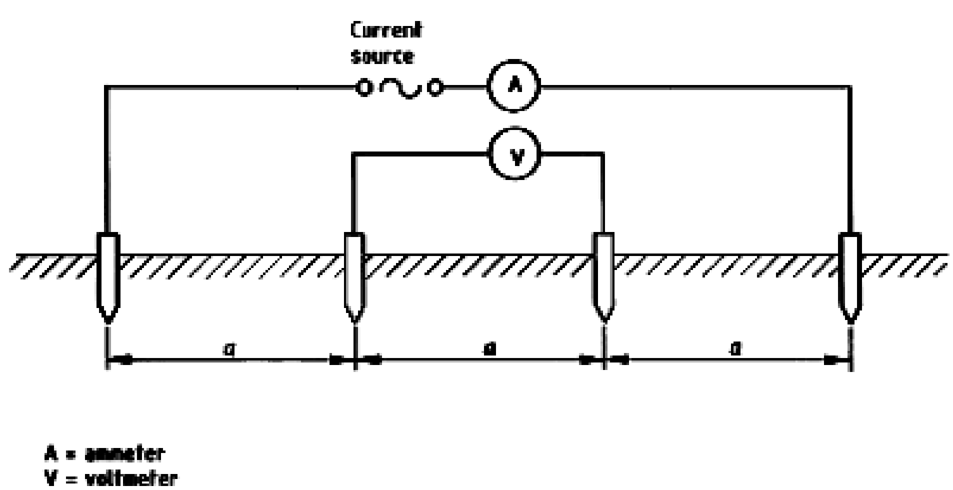

Figure 13 — Measurement of earth resistivity

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Test Result

EARTHING CO	Address:15 Islam,Hammammat El Koba,Zayton, Cairo Tel: 02 245 09 148/ 0100 900 502/ 01 99 11 99 11 E-mail: Sales@EarthingCo.com	Soil resistivity Report	
client: El-Hoda Co.	**Project Name :** Logistics Center Cairo Airport Egypt		**Date of Test: 28-6-2010**
Calculation soil resistivity Equation=2πaR			
Test result			
Test Location	**Probe Spacing (m)**	**Meter Reading (Ω)**	**Calculated Soil Resistivity (Ω.m)**
Location 1	0.5	8.5	26.73
	1	4.1	25.8
	1.5	2.7	24.98
	2	1.9	24.44
	2.5	1.5	23.15
	3	1.2	22.16
Average			24.5
			0
Location 2	0.5	8.3	25.99
	1	6.6	25.68
	1.5	5.0	24.82
	2	4.8	23.87
	2.5	3.0	22.85
	3	2.5	21.78
Average			24.2

Appendix B
Earthing Measurements

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Introduction

The Fall Of Potential method is the most recognized method for measuring the resistance to earth of a grounding system, or the ground system performance. It is based on an IEEE standard and when properly performed, it is a very accurate test.

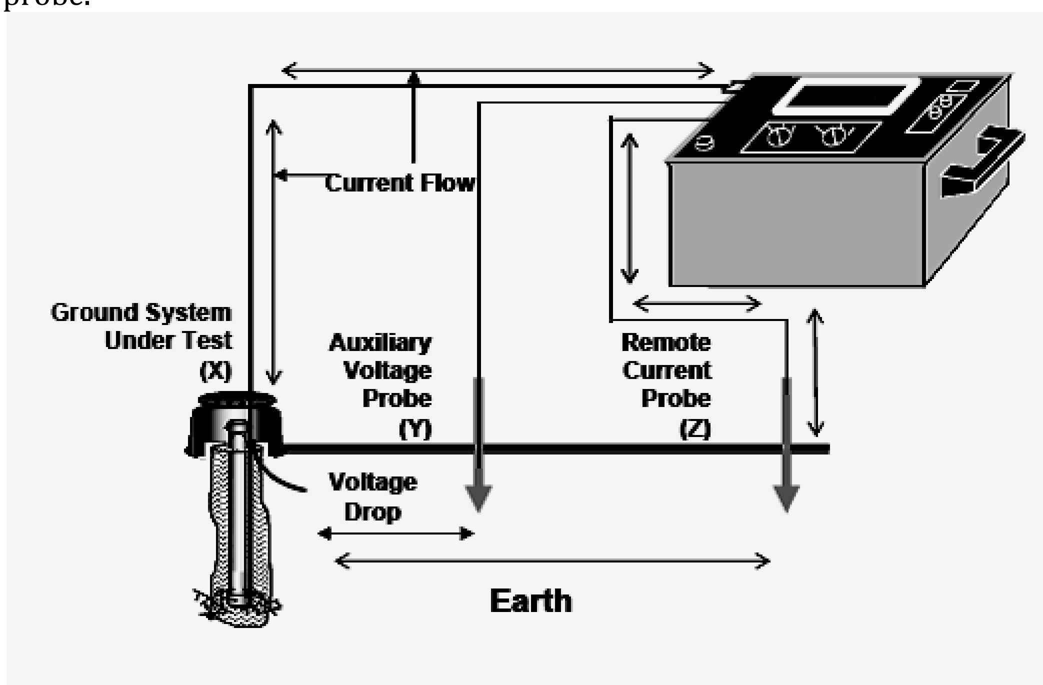
Although most people recognize that grounding is required for personnel protection, the grounding system also serves as the basis for the electrical protection of your site or facility. It determines the effectiveness of the lightning protection and surge suppression systems. Without good grounding, these systems do not function. Grounding also serves as the path for system noise to be dissipated from equipments.

Grounding systems should be tested upon installation and then annually during their service life. The initial testing establishes a performance baseline, confirms that the design specification is met and validates the quality of the installation. Annual testing ensures
the continued integrity of the system and provides protection against degradation prior to equipment damage or performance problems.

Theory

In the fall of potential test, three points of ground contact are
considered:

1. The grounding system under test (X)
2. A current probe (Z) placed some distance from the ground system under test.
3. A voltage probe (Y) that is inserted at various distances between the system under test and the current probe.



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With this method of test, the meter injects a current into the ground system under test (X). The current flows through the earth to the remote current probe (Z) and returns to the meter. As the current flows through the resistive material (earth) a voltage drop is rated. This voltage drop is proportional to the amount of current flow and the resistance of the ground system to earth.

The voltage probe (Y) is used to measure this voltage drop. The meter then knows both the amount of current flow and the resulting voltage drop. It simply uses Ohm's law to calculate and display the resistance.

The resistance is measured at several locations moving the voltage probe (Y) at regular intervals, each of them equal 10% distance XZ.

The grounding system must be electrically isolated for the 3 Point Test to be valid. If not isolated, the readings will reflect all the grounding systems in the area hooked in parallel. The reading will always be very low and have no bearing on the actual ground system resistance. The result is not an inaccurate test, but an invalid one.

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