

# **Electric Shock and Design Optimizations of the Electrical Earthing Systems**

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**ABSTRACT:** The paper envisages that the design optimizations robust earthing of an electrical system at which the electrical potential should be maintained really zero value for the safe and secure purposes. The pertinent design characteristic ensures not only safety of a system but also limit the fault current and zero potential that of the earth. It provides also electrical return path of the fault current and reduces the insulation level of the systems by virtue of which it will be cost effective in accordance with electrical standards and integral part of the power systems. It enables to carry zero sequence current and defends against the neutral oscillation of the star connected system.

**KEYWORDS:** Earthing; Design; Optimizations; Safety of the electrical systems; and Results.

## **LIST OF SYMBOLS:**

A = Area of the plate  
D = Diameter of the rod  
d = Depth of the electrode  
I = Tolerable current of the human body  
K= Empirical constant  
L = Length of the strip, pipe or rod  
S = Size of the conductor in mm<sup>2</sup>  
R =Earth resistance  
T = Safety Separation time to clear the fault  
w = Thickness of the plate  
V<sub>s</sub> = Step potential  
V<sub>T</sub> = Touch potential  
ρ = Average soil resistivity

## **I. INTRODUCTION**

Earthing of an electrical system may be careful as integral component for the safeguard according to electricity decree which enforces head to tail of the power systems. The earthing may be off the record as commonly two categories likely equipment and system earthing. The entire systems are earthed consequently to care for zero potential or acceptable potential.

The word earthing signifies linking the neutral point of power system or the non current carrying components of the electrical equipment to the common mass of earth in such a method that the entire period an instantaneous discharge of power occurs without hazard [1], [2] & [3].

The objective of the earthing harvests a alternative corridor for the fault current to pass through without danger the power consumer. It makes certain that all uncovered conductive elements do not get in touch with a perilous potential

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of the systems. The earthing system cultivates to keep on the voltage at any segment of a power system at a specified value so as to prevent over current or unwarranted voltage on the electrical device or apparatus [4], [5], [6] & [7].

Good characteristic of the electrical earthing aptly include low permissible impedance to make sure that adequate current can pass through the protecting piece of equipment so that it isolates the supply within 0.35 seconds for the secured safeguard purposes. Fault current is characteristically higher than the full load current of the power circuit which liquefies the fuse or trips the breakers. Consequently, the pieces of equipment are isolated automatically from the power supply mains to safe and sound the systems [8], [9], [10] & [11].

## II. BASIC FEATURES OF THE GOOD EARTHING OF THE ELECTRICAL SYSTEMS

- Low electrical resistance or impedance of the power system
- Good deterioration resistance or impedance of the power system
- Anomalous fault current must be skilled to fritter away frequently

## III. PURPOSES OF THE ELECTRICAL EARTHING

An electric electrocution takes place when two part of a person's body come into sight in contact with electrical wires of a power track of power system which is by the side of different potentials, thus making a potential difference across the body. Then, the human body carries out to have resistance and when the body is coupled between two wirers at different potential of a power circuit which is shaped through the body and current flowing.

When the human body abruptly comes in contact with only one conductor, a power circuit is not produced and nothing shock takes place. When the soul body comes in contact with circuit life conductors, negative question what the voltage is there is potential for the injury as shown in the Fig. 1.

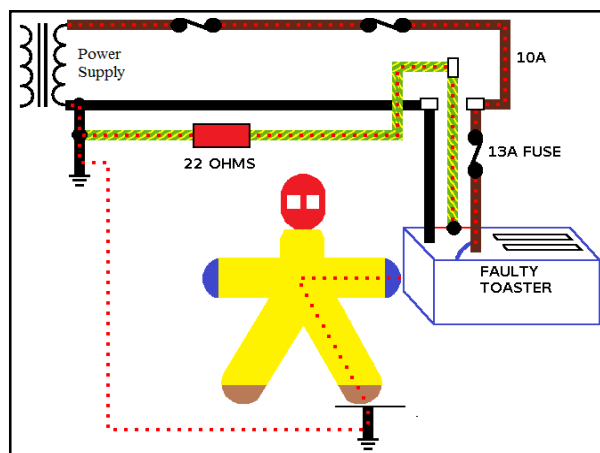


Fig. 1. Configuration of the electric shock

The anomalous potential difference indemnities the human body. The upshot of an electrocution is an answerability of what fractions of body come in slam contact with both life conductors, the resistance of each contact surface and the surface resistance of the body at the contact point as well as other issues. When the electrical contact is such that the power circuit pathway through the body is across the heart, it invites the maximum potential for fatality.

The Fig. 2 depicts the magnitude of current ( $I_s$ ) that can pass through human body at three different potential differences across the body also exposed is the source of different current magnitude equally ac and dc the definitive consequence is fibrillation which origins the heart to terminate and end result in casualty.

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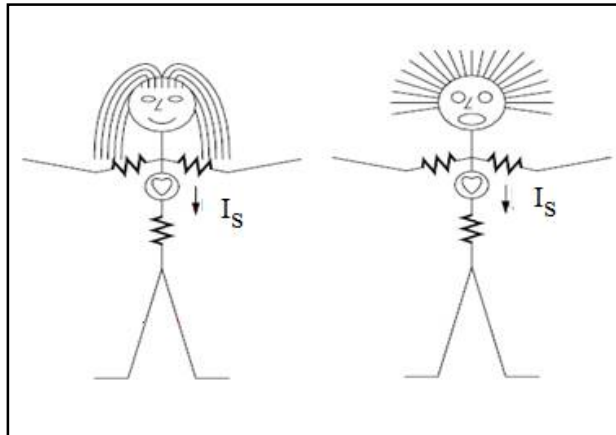


Fig. 2. Route direction of electric current due to the electric shock felt by human body

The human body's resistance fluctuates from as small as 600 ohms to as high as 700,000 ohms. As the skin become to be clammy the contact resistance drop. If the skin is damp due to sweats that have salt the resistance drop further more. When a high tension voltage such as 11kV is uneasy the body is precisely not incurable and from time to period of detonation. The detrimental electric shock also relies on other factor as shown in the TABLE I.

TABLE I.

Level of the Shock	ac@50Hz (mA)	dc (mA)	Duration of time (S)
<i>Perception</i>	1	2	2
<i>Not Let to Go</i>	15	300	1
<i>Fibrillation low</i>	500	500	0.2
<i>Fibrillation high</i>	75	400	0.4

## IV. ELECTRIC SHOCK DUE TO SHORT CIRCUIT

A short circuit is any unintentional association resistance  $R_{sc}$  across the power circuit wires between the power supply and the load as shown in the Fig. 3.

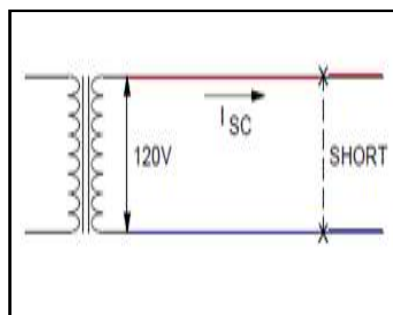


Fig. 3. Short circuit configuration of the electric shock

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A short circuit are categorized as secured shorts, fleeting shorts, crooked shorts or high impedance shorts. A bolted short which is uncommon is a very low resistance grouping such as two wires being tied together.

Most of the shorts are high resistance or those are fleeting or crooked. The high resistance short commences out as a high resistance or impedance association but normally expansion to a small impedance link.

In electrical power system shorts are categorised as phase to phase, phase to neutral, or phase to ground short. Most short are phase to ground and short which start as phase to phase or phase to neutral progress to a phase to ground shorting. While taking into account consideration short circuit and protective against the damage the customers can be source one requests to be on proverbial conditions with what is the highest amount of short circuit current that can pass in a specific power circuit.

## V. METHOD OF THE EQUIPMENT EATHING OF A SYSTEM

In case of basic insulation level breakdown, the most important objective of linking the fundamental considerations and equipment to earth is to liberate the charge gathered on them instantly earth so that forthcoming person in putting up the shutters may not have feeling of the electric shock.

The other objective is that a serious current passes through the power circuit that operates the defensive devices that is fuse or circuit breaker (CB) which is normally open the circuit.

## VI. HABITUAL EARTHING OF A SYSTEM

The traditional system of earthing christens for the digging of a large pit into which a galvanized iron (GI) pipe or a copper plate is placed in the middle layers of charcoal and salt. It has need of safeguarding and pouring of water at consistent gap. It may be classified as different categories.

## VII. PLATE EARTHING OF A POWER SYSTEM

In the plate earthing either of copper or of G.I. is buried into the earth at a deepness of not less than 3 meter from the ground level. The earth plate is entrenched in substitute stratum of coke and salts for the smallest depth of about 15 cm.

The earth wire is used as copper plate earthing and G.I. plate earthing. Both are firmly fasten to an earth plate by means of nut bolt and washer made of copper, in case of copper plate earthing and of G.I. in case of G.I. plate earthing

## VIII. PIPE EARTHING OF A POWER SYSTEM

Earthing is the best arrangement of earthing and it is cheap to run also in this scheme of earthing with a GI pipe of 38 mm diameter and 2 meters extent is entrenched perpendicularly in earth to work as an earth electrode but the deepness depends upon the soil surroundings, there is no hard and fast regulations for this earthing of a system.

The earth wire is instilling upto the damp soil. The earth wire is fixed firmly to the tip segment of the pipe with nut and bolts. The ditch area approximately the GI pipe crammed with salt and coal combination for recuperating the soil circumstances and efficiency of the earthing system.

It can confiscate meditative leakage current for the same electrode dimension in comparison to the pipe late earthing. The earth lead association with GI pipes being above the land height can be chequered for carrying out continuity test while in plate earthing. It is very complicated when it is looked-for.

In the hot period, it is to have a successful earthing three or four pail of water is poured into the channel for the improved continuity of earthing system.

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## IX. ROD EARTHING OF A POWER SYSTEM

In this coordination of earthing 12.5 mm diameter of solid rods of copper 16 mm diameter solid rod of GI or steel of empty segment of 25 mm GI pipe of span not less than 3 meters are determined perpendicularly into the earth.

In order to widen the entrenched extent of electrode under the soil, which is some time decisive to decrease the earth resistance to needed value more than one rod segments are hammered one above the other. This structure of earthing is appropriate for areas which are sandy in character. This system of earthing is extremely economical.

## X. STRIP EARTHING OF A POWER SYSTEM

In this classification of earthing strip electrode of cross sectional area not less than 30 mm into 1.6 mm of copper or 30mm x 4mm of GI or steel are hidden in horizontal ditch of minimum depth of 0.6m.

If round conductor are used their cross sectional area shall not be slighter than three if copper is used and 6mm<sup>2</sup> if GI or steel may be used. The span of concealed conductor shall be adequate to grant the mandatory earth resistance is about 0.5Ω to 2.0Ω. If it is not less than 15 m, the electrode will be as extensively dispersed as probable in an introverted directly or sphere-shaped trenches radiating from a face. This category of earthing is used in rocky earth bunk bed because it is necessitated such seats and excavation works for the plate earthing which is also highly multifarious.

## XI. PROCEDURE FOR FILLING UP NEW EARTHING PITS

**Step A:** Excavation of the earthing pit dimension 2000 x 2000 x 2500 mm depth. Shake over adequate quantity of water in the underneath and nearby stockade to become wetly only. After filling up the bottom layer of the pit up to 250 mm height from the bottom is combination black pliable soil + salt + charcoal pieces.

**Step B:** Foundation of the electrode congress should be carried out as per design method, drawing and the rest of the whole congress in the hollow as per design specifications.

**Step C:** Meeting skinny C.R.C. sheet approximately 18 to 20 SWG having size 500 mm width 3.5 meter span approximately. Making combined of three to four pieces to accomplish prerequisite of 3.5 meter length.

After preparing the cylindrical hoop from the above sheet by flexible both trimmings and unification each other. The essential diameter (D) of the cylindrical loop shall arrive approximately 1000 mm and tallness shall be 500 mm. Bringing together the two pieces of fragments of G.I. wire approximately of 8 SWG and preparing two lifting round hooks on upper side of the cylindrical ring are to be made easy the lifting of the cylindrical loop. Further, exhausting this cylindrical hoop to the electrode pipe of the electrode meeting such a technique that the electrode pipe remains in the middle of the cylindrical ring.

**Step D:** Filling up the internal part of the cylindrical loop with a combination of the homogeneous of black soft soil namely dust charcoal, the remaining part or the gap between ramparts of the pit and outer periphery of the cylindrical loop is made up mixtures of dust charcoal. After carrying out and filling work of both the mixtures up to 500 mm height, suitable ram and watering is to be done properly.

**Step E:** Thereafter pinch the cylindrical loop by again have a break it on the sheet for carrying out filling of second sheet sequence. Once again filling up the interior cylindrical part of the ring by Mixture - I and outer gap between fortifications of the pit and superficial cylindrical periphery by maturing up to height of the cylinder (i.e. 500 mm) assist of two lifting hooks and There after lift the Cylindrical ring by facilitate of two lifting handles (hooks) and again rest it on the layer for carrying out filling of 2nd layer cycle. Again fill up the inner cylindrical part of the loop by and external gap between walls of the pit and outer cylindrical margin by another mixture up to elevation of the cylinder (i.e. 500 mm).

**Step F:** Lifting the cylindrical surround by stealing hooks after appropriate ram and watering. Now again placing the cylindrical loop on upper sheet and arrange third cycle, the compilation of materials afterwards are terminated by the filling of whole hollow pouring water contented is minimum up to 25 %. Next, filling up upper leaf of the pit by trodden rock pieces or gravel of size 50 x 35 mm are taken as filling size of a cavity. It provides insulating stratum to person poignant side by the unoccupied, and to steer clear of reptile engagements consequently causing hazards.

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## XII. COMPUTING EARTH RESISTANCE

The earth resistance defines that the resistance offered by an electrode. The pertinent components of the earth resistance depends on self resistance of the electrode, resistance around the electrode of the soil , the resistance offered along the direction of the current flow of the infinite quantity of the soil, moisture contents of the soil, average soil resistivity and composition of the soil.

The earth resistance offered for the plate earthing is given as:

$$R = \frac{\rho}{A} \sqrt{\frac{\pi}{A}} \quad (1)$$

It may be written for the piping earthing is given as:

$$R = \frac{\rho}{2\pi L} \ln\left(\frac{4L}{D}\right) \quad (2)$$

Further, it can be written for the strip electrode earthing given as:

$$R = \frac{\rho}{2\pi L} \ln\left(\frac{4L^2}{wd}\right) \quad (3)$$

The earth resistance of a system is not specified as per Indian electricity rule.

## XIII. COMPUTING STEP AND TOUCH POTENTIAL

In order to design the safe and secured electrical system, the concept of the step and touch potential computing are mandatory for an electrical system.

The empirical value of the reasonable current is given as:

$$I_R = \frac{0.156}{\sqrt{T}} \quad (4)$$

Fixed Permissible touch potential is given as:

$$V_T = 0.1(1000 + 1.5\rho) \quad (5)$$

When it is variable, it may be written as:

$$V_T = 0.01(1000 + 1.5\rho) \quad (6)$$

Fixed Permissible step potential is given as:

$$V_s = 0.1(1000 + 6\rho) \quad (7)$$

When it is variable, it may be written as:

$$V_s = 0.01(1000 + 6\rho) \quad (8)$$

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### XIV. COMPUTING CONDUCTOR SIZE EARTH

The selection of the earth conductor should be chosen in such a way so that fault current should not be greater than its current density. The magnitude of the earth resistance is not constant at different places of the earth. The rocky place of earth resistance is higher than the plane area. Yet, the design theory and approaches are same to implement the earthing.

The experiential value of the conductor size is given as:

$$S = K \frac{1}{\sqrt{T}} \quad (9)$$

The value of the empirical constant (K) depends on the materials, insulation property, initial and final temperature.

In information technology (IT) coordination, a solitary insulation failure is improbable to cause unsafe currents to pass through a human body in contact with earth, since no small impedance power circuit is present for such a current to pass. On the other hand, a first insulation failure can successfully turn an IT system into an earthing system, and then a instant insulation failure can guide to hazardous body currents. Inferior quality, in a three phase scheme if one of the lives made contact with earth it would cause the other phase cores to increase phase to phase voltage comparative to earth somewhat than the phase to neutral voltage. IT systems also understanding oversized transient overvoltage than other systems.

### XV. ELECTROMAGNETIC COMPATIBILITY

In service connection, the customer has a small noise link to earth, which is unsafe from the voltage that come out on the neutral conductor as a consequence of the return currents and the impedance of the conductor. This is of rigorous significance with some type of telecommunication and measurement apparatus.

In power systems, every customer has its own high class of service connection with earth and will be unnoticed any currents that may cause by other customers on a shared power line. The electromagnetic interference (EMI) is observable using advanced oscilloscope. It is noticed if the users touched the two probes of the oscilloscope then sine wave will appear on the screen of the oscilloscope. It is the confirmations of the presence of the EMI. Further, it can be avoided by proper earthing of the power systems.

### XVI. APPLICATIONS

- Transmission and distribution systems
- Transformer neutral earthing
- Telecommunication systems
- Substations & Power generations
- Equipment body earthing
- Lightning arrestor earthing
- Water treatment plants
- College, hospitals, banks
- Bulk Industries
- Residential building

The majority contemporary residences in India have an earthing scheme. The mutual neutral and earth takes place between the adjacent transformer substation and the service connection through cut out. After this, the neutral cores are used in the entire the concealed house wiring. Older urban and suburban homes in the Indian city tend to have three wire supplies stems with the earth distribute through the lead sheath of the underground lead and paper cable.



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Some adult residence, particularly those put together before the discovery of residual current circuit breakers and wired home region networks, employ in residential service activities. This is no longer recommended practice due to lack of renovations.

Laboratory quarters, medicinal services, production place, refurbish workshops and other surroundings where there is a better than before jeopardy of insulation failure frequently employ an IT earthing agreement supplied from an isolation transformer. To alleviate the two fault question with IT systems the isolation transformers should only contribute a light loads every and or should be sheltered with particular monitoring gear usually only health check IT systems are done with such switch gear because of the expenditure.

In private ward, where the charge of a supplementary line conductor is more significant than the expenditure of a constrained earth association, service connections are usually utilized in some kingdoms particularly in older assets.

## XV. SAFETY

The insulation failure is incredibly credible to lead to a soaring short circuit current that will elicit an over current circuit breaker or fuse and isolate the line conductors. In the popular of service scheme the earth fault loop impedance will be too high to do this and so moulded case circuit breaker or residual current circuit breaker must be in employment of the service connections of the utility.

Unbalanced three phase system the potential of the earthing arrangement will shift towards that of the most loaded phase conductor. Therefore, service connections must not run across plug-socket links or bendable cables, where there is a restricted probability of contact troubles with enduring wiring. There is also a substantial menace if a cable is smashed which can be taken the border off by the employment of concentric cable fabrication or various earth electrodes.

Power networks save the cost of a low-impedance earth link at the place of each customer. Such an association like an underlying metal arrangement. It is vital to present protective earth in IT and network systems.

Power networks also put aside the asking price of an additional conductor necessary for breaking up the neutral and phase associations. However to alleviate the hazard of conked out neutrals, extraordinary cable category and plenty of connections to earth are required.

Safeguard synchronization necessitates fortification and over and over again a comfortable time delay style is highly compulsory to make available wrongness with a residual current device downstream. In characteristic to a protective earth association, a practical earth relationship may carry a current during the common operation of a machine Commonly the defensive earth is also used as a practical earth though this has need of care in some situation.

## XVI. RESULTS

The value of the earth resistance is measured by the earth tester at different equipments systems as shown in the TABLE II to accomplish safe and secured systems.

TABLE II.

Earthing equipments	Value of the Earth Resistance (ohm)
<i>Big Power Substations</i>	<i>0.5</i>
<i>Major Substations</i>	<i>1.0</i>
<i>Small Substations</i>	<i>2.0</i>
<i>Industrial Substations</i>	<i>1.0</i>
<i>Lattice Steel tower</i>	<i>3.0</i>
<i>Industrial machine &amp; Equipment</i>	<i>0.5</i>

## XVII. CONCLUSIONS

A self-protective earth link make certain that all uncovered conductive surfaces are at the identical electrical potential as the surface of the Earth to stay away from the peril of electrical shock if someone strokes a live device at which an insulation failure has taken place. It also certifies that in the case of an insulation failure, high fault current



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flows, which will activate an over current, over load, earth fault and short protection, are implemented by full-bodied earthing system. Electrical earthing system not only abide by the Indian electricity rule but also uses for the safety purposes and maintenance free operation.

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