इरिसेट IRISET

# TC5

# EARTHING & SURGE PROTECTION FOR TELECOM INSTALLATIONS

Indian Railways Institute of
Signal Engineering and Telecommunications
SECUNDERABAD - 500 017

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INDIAN RAILWAYS INSTITUTE OF SIGNAL ENGINEERING & TELECOMMUNICATIONS, SECUNDERABAD - 500 017

Issued in February 2014

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# EARTHING & SURGE PROTECTION FOR TELECOM INSTALLATION

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|---|---|
| Prepared | Jayarajan D, ICT2 |
| Approved By | C.K. Prasad, Professor - Tele |
| DTP and Drawings | K.Srinivas, JE (D) |
| Edition No | 02 |
| No. of Pages | 50 |
| No.of Sheets | 26 |





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# CHAPTER-1

# SURGES AND THEIR EFFECTS ON S&T INSTALLATIONS

## 1.1 Introduction:

**1.2** Signal and Telecommunication systems such as electronic interlocking, Digital axle counters, Track circuits, ISDN exchanges .OFC communication, Data network, Control communication etc are functioning round the clock for the safe and smooth running of trains over Indian Railways. These systems consist of sophisticated devices such as ICs, Micro processors and Micro controllers and they are prone to transient surge voltage and currents. Hence, it is required to safe guard these systems from surges so as to ensure uninterrupted service rendered by them and also to avoid replacement cost due to damages.

## 1.3 What are surges

Surges are transient phenomena involving build-up of potentials and flow of currents of magnitudes several times higher than the normal working currents and voltages, resulting in partial or complete damage of equipment or reduction in life of components / equipment.

Surges are caused by:

- Lightning discharges
- Switching on/off of inductive loads (for example transformers, coils, & motors)
- Ignition and interruption of electric arcs (for example welding process )
- Tripping of fuses and circuit breakers.
- Power transitions in other large equipments on the same power line.
- Malfunctioning caused by the power supply companies.
- Short circuits.

### 1.3.1 Result of surges:

- Interruption of the service rendered by the equipment.
- Replacement cost of the circuit or the equipment.

A study conducted by IEC (International Electrotechnic Commission) in several countries revealed that the loss (cost of damages) due to lightning is next to negligence in handling equipment (Please refer table 1.1)

| Cause | Loss as % of Total Loss |
|---|---|
| Negligence | 36.1% |
| Surges | 27.4% |
| Burglaries | 12.9% |
| Floods/Storms | 6.9% |
| Others | 16.7% |

**Table 1.1 Losses (Cost of Damages) due To Various Reasons**

## 1.4 How Does Lightning Take Place?

Lightning takes place due to accumulation of electric charges in cloud mass in atmospheric conditions that prevail in thunderstorms. Thunder storms and the resultant lightning have different mechanisms in tropical regions and temperate regions.

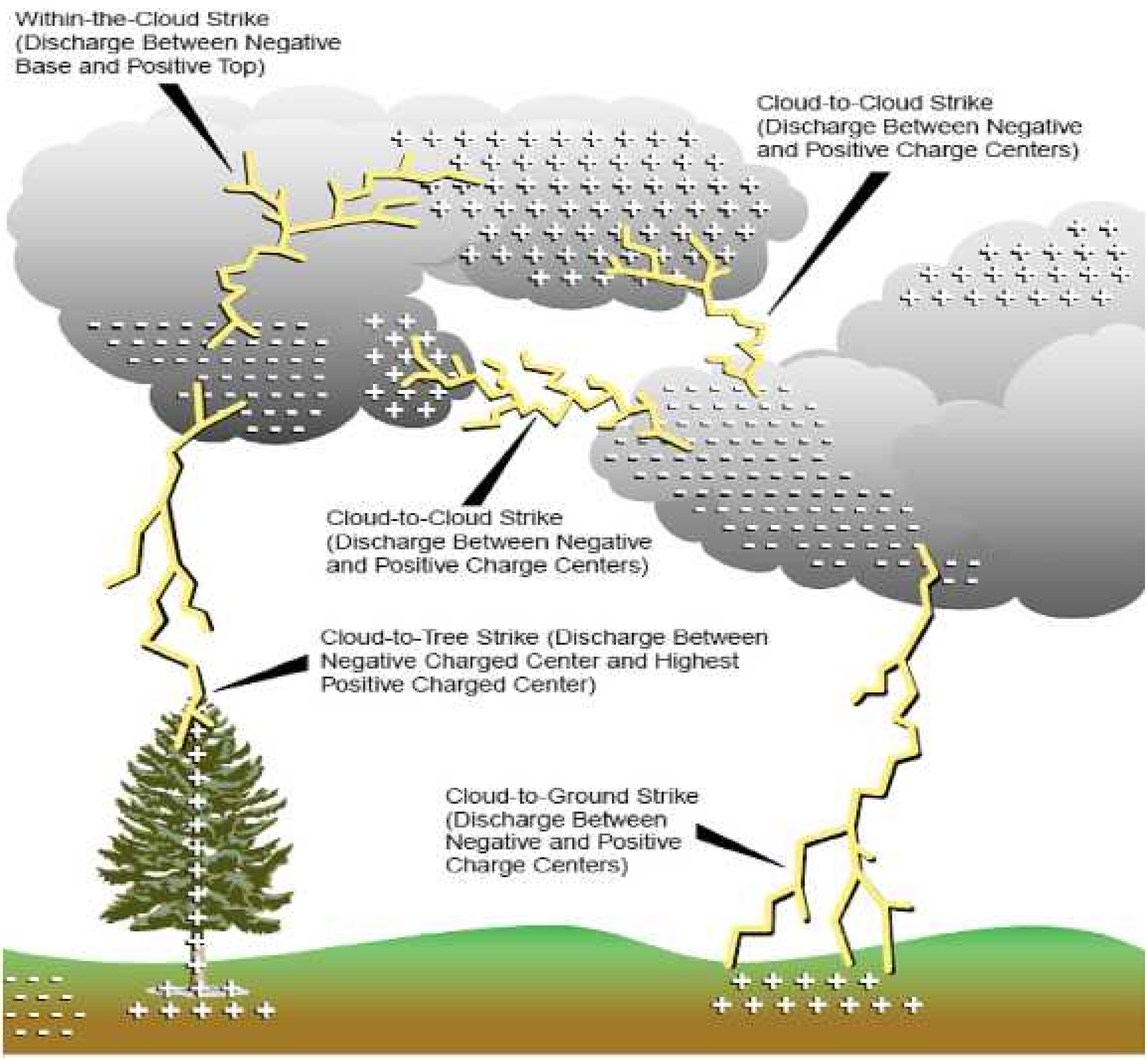
In tropical regions, thunderstorms are known as heat storms. These are caused by warm air drifting up pushing down the cold air. This causes formation of single or many ‘cloud cells’ spanning several kilometers.

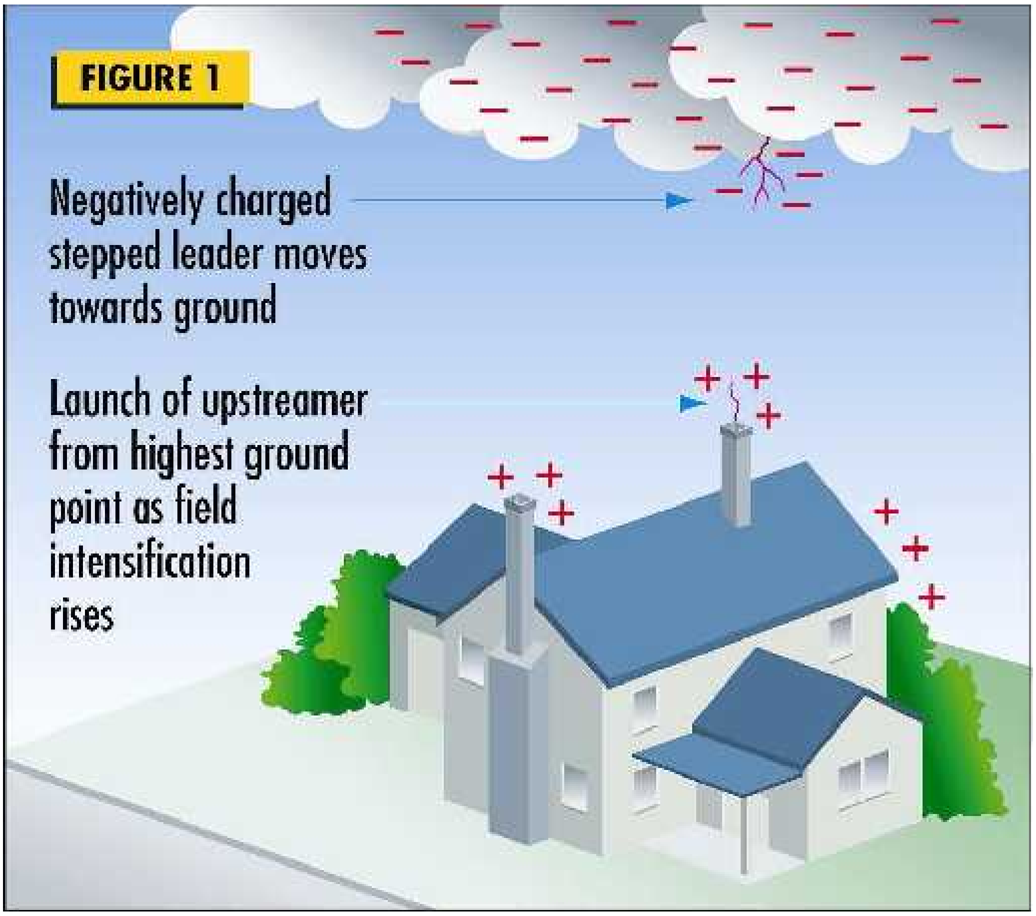
In temperate regions, thunderstorms are known as frontal storms. Cloud frontal waves push-up the warm air. This causes formation of large number of ‘cloud cells’, each spanning many kilometers and successively spaced.

Violent up-draught of air through centre of cloud cell causes the following

1. Ice crystals are positively charged
2. Water droplets negatively charged
3. Positive charge centre lies in upper part of atmosphere (about 10000 m) & negative charge centre in lower part (about 5000 m) in case of heat storms in tropical regions
4. Positive charge centre lies in upper part of atmosphere (about 6000 m) & negative charge centre in lower part (about 2500 m) in case of frontal storms in temperate region.

The lower negatively charged part of the cloud electro-statically induces positive charge on the ground directly below it. More concentration of positive charge takes place on raised structures such as trees and buildings. On building up of potential, the negative charge will be accelerated towards the ground and it is called as the ‘Stepped leader’. When lightning begins, a step leader comes from the cloud to the ground. The step leader is not very bright but it propagates for a short distance and stops for a while, then proceeds in different direction and stops again. This process repeats many times, making a zigzag path filled with negative charge. These high speed electrons ionize air molecules thus providing a conducting path for the stroke. When the step leader comes close to the ground a strong electric field is created which drives the positive charge on the ground to neutralize the negative charge in the path. This is called the returning stroke which is also called as the 'Streamer'. This returning stroke is much brighter than the step leader. Hence lightning is flow of positive ion, mostly from raised structures on earth to the cloud above. What we see as lightning is a discharge which actually goes from the ground to the cloud. The returning stroke is the origin of intense light, heat and sound in lightning. Lightning also takes place within the same cloud and between different clouds. But our concern is the lightning between cloud and ground which may ruin the S&T equipments partially or completely.






### Summarizing the lightning process, the following points are noteworthy

Negative electrical charges build up within clouds

Electric field intensification

Positive charges gather on ground

Air breakdown leads to stepped Leader

Further electric field intensification

Strong upward positive streamer generation

Positive upward streamer meets the downward step leader

conducting path forms

Visible lightning flash

### 1.5 Physical Effects of Lightning

Lightning has the following physical effects:

1. Heating of air up to 30000 $^{0}$ K
2. Creation of pressure shock wave
3. Flow of current of magnitudes 10 kA to 200 kA
4. Heavy potential difference of the order of 1 to 10 Million Volts

Fortunately, the above effects are transients (short lived) and are to be discharged through suitable protection mechanisms to safeguard electrical and electronic installations.

Surge current due to lightning is expressed in 3 parameters:

1. Surge amplitude
2. Time taken by the surge to reach it's maximum value
3. Time taken by the surge to fall to it's half max. value

**Example:** 10 kA 8/20 micro sec. means surge of 10 KA amplitude, taking 8 micro sec to reach peak value and 20 micro sec. to fall to half peak value (of 5 kA)

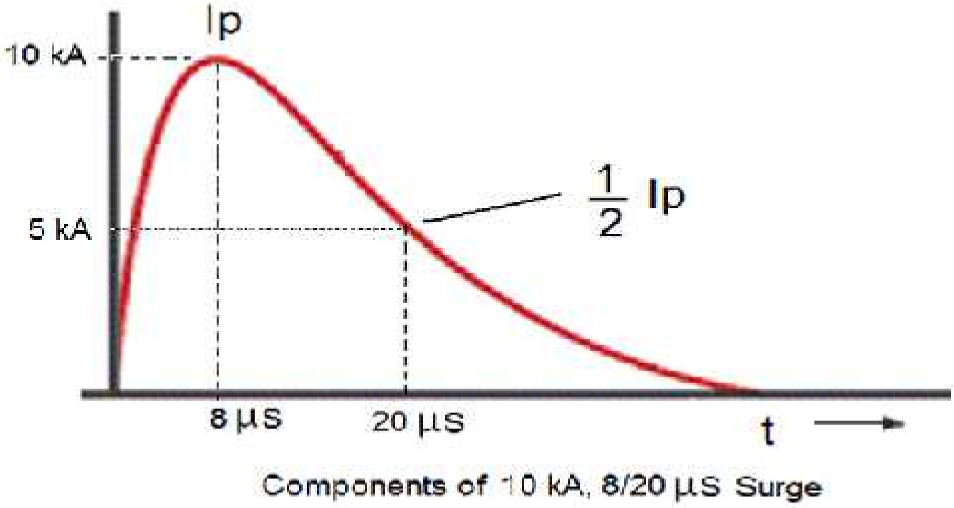



**Fig 1 Parameters of surge current**

Normally, we encounter surges of 200kA 10/350 micro sec., 50 kA 10/350 micro sec., 15 kA 8/20 micro sec., as per severity of lightning.
Area under the curve gives the damaging energy of lightning surge.

## 1.6 Concept of Lightning Protection Zones

Lightning strike can be –

1. Direct strike on equipment room
2. Indirect strike (despite use of lightning arrestor connected to earth through down conductor)
   - Galvanic coupling , through metallic conductor coming in contact with surge
   - Capacitance coupling due to capacitive effect caused by parallel surface
   - Inductive coupling due to conductors, parallel to surge movement / discharge path

Hence, the concept of protection zones is to be understood for any electrical installation. Please refer to fig. 1.3 marking the protection zones and correlate with the description in table

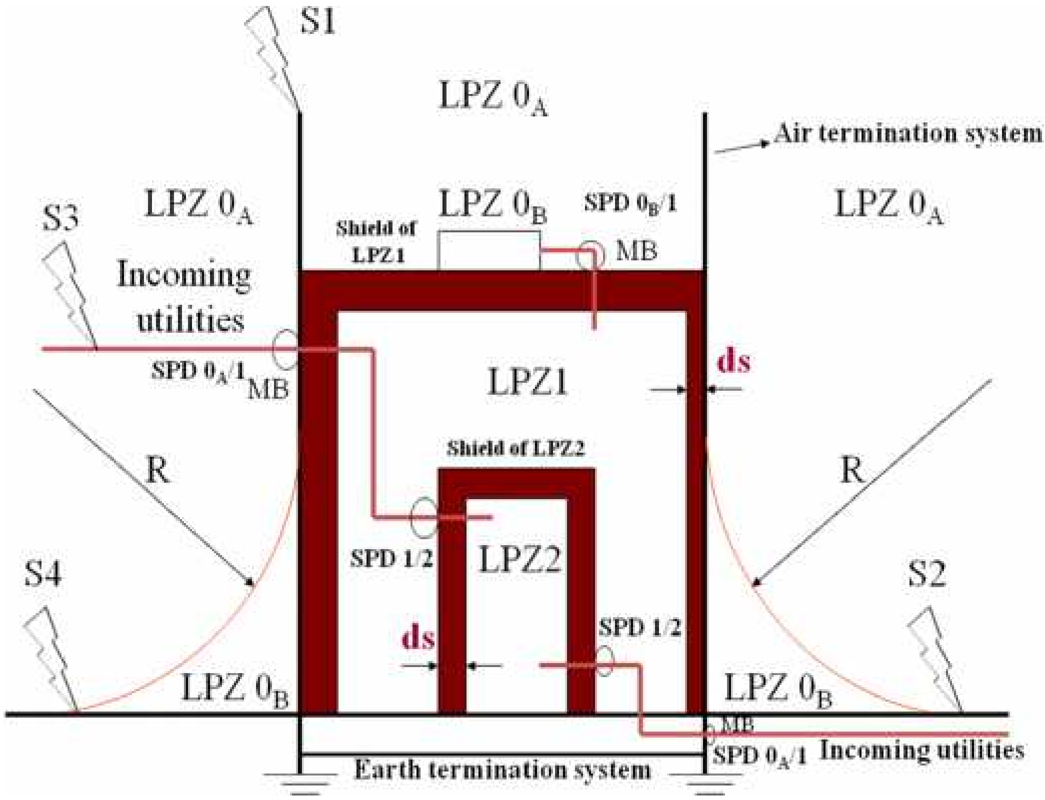



**Fig. 1.3 Lightning Protection Zones**

| Zone | Details |
|---|---|
| **LPZ $0_A$** | **Direct strikes - Full lightning current - Full magnetic field** |
| **LPZ $0_B$** | **No direct strikes - Partial lightning or induced current - full magnetic field** |
| **LPZ1** | **No direct strikes - Partial lightning or induced current - Damped magnetic field** |
| **LPZ2** | **No direct strikes - Induced current - Further damped magnetic field** |

**Table 1.2 Interpretations of Lightning Protection Zones**

Having identified the lightning protection zones, what needs to be done is –

1. Provision of equi-potential bonding system comprising of external earthing system joined to equi-potential bus bar inside
2. Provision of surge arrestors as per specifications, connected to the earthing system
   - To filter and clamp the transients at power entry point
   - To ensure stage-wise reduction of surge voltage to harmless level

Earthing system is discussed in chapter-2, surge arrestors in chapter-3 and RDSO specifications regarding earthing are presented in chapter-4.

## Objective:

1) Surges involve voltages and currents which are ___________________ than the working voltages and currents.
2) Ice crystals are ___________________ charged whereas water droplets are __________________ charged.
3) In lightning the air gets heated up to ___________________ degrees Kelvin.
4) The magnitudes of electric currents resulting due to lightning are between _____________.
5) Lightening results in building up of potentials of the order of _______________.
6) Meaning of 200 KA 10/350 surge _______________________________________.
7) Lightning protection zone LPZA means ____________________________.
8) Lightning protection zone LPZ1 means ____________________________.
9) Which lightning protection zone comes under direct strike? ________________________.
10) Positive charge center lies in ______________________and negative charge center lies in __________________ part of atmosphere.

## Subjective:

1) What is surge? And what are its causes?
2) How does lightning take place?
3) What are the physical effects of lightning?
4) In how many ways lightning strike takes place?
5) Mention about lightning protection zones? What is to be done after identifying lightning protection zones?
6) What are the surge parameters and how are they represented?

# CHAPTER-2

# FUNDAMENTALS OF EARTHING

## 2.1 Earthing De-Mystified:

The very first question that crops up on earthing is "Is earth a good conductor?" Earth, as per material phenomenon, is a bad conductor. Table 2.1 confirms the same.

| Material | Resistivity |
|---|---|
| Copper | 1.7 X 10 $^{-8}$ Ohm. Meter |
| GI | 10 $^{-7}$ Ohm. Meter |
| Wet soil | 10 Ohm. Meter |
| Moist soil | 100 Ohm. Meter |
| Dry soil | 1000 Ohm. Meter |
| Bed rock | 10000 Ohm. Meter |

**Table 2.1 Resistivity of various materials**

Then, why at all earthing is done?

We resort to earthing, not because it is good conductor, but because earth is ideal equipotential surface. A very large charge is required to raise potential of earth everywhere. In other words, effect of injected fault current is felt only locally. Fault current returns to source in case of Generation/Transmission systems and surges by-pass equipment in other cases.

Having understood material property and equipotential surface phenomenon of earth, let us turn our attention to earth electrodes i.e. the conductors used for earthing, their shapes, sizes etc.

## 2.2 Earth Resistance

### 2.2.1 What Determines Earth Resistance?

When we talk about earth resistance, **two components** are to be considered: **Electrode resistance and electrode to earth resistance.**

Electrode resistance is the resistance of Material used (i.e. in the shape and size of electrode). Obviously, we have to use metallic bodies like GI/Copper electrodes, to keep electrode resistance << 1 Ohm.

The resistance offered by earth to spread of electric field is called 'Electrode to earth resistance'. It is important because current injected into earth by the electrode causes electric field set-up which causes potential difference. 'Electrode to earth resistance', which depends on soil resistivity and geometry and size of electrode, is also required to be low to make earth resistance (electrode resistance plus electrode to earth resistance ) less than 1 Ohm.

Electrode to earth resistance depends on

- Geometry and size of electrode
- Soil resistivity

### 2.2.2 Pipe Electrode

In case of pipe electrode, electrode to earth resistance is given by:

$$R = (\rho / 2\pi L) [\ln \{8L / 2.7183 D\}]$$

Where L is length of electrode, D is diameter and ρ is soil resistivity

From the above formula, it can be easily inferred that electrode material is not of concern in deciding the value of electrode to earth resistance. If the length of electrode is more, electrode to earth resistance is less. However, electrode has to be metallic (GI/Copper) to keep electrode resistance very low, as already discussed in section 2.2.1.

A very important point to be kept in mind is two parallel electrodes not necessarily reduce electrode to earth resistance to half. If the length of electrode is L, we have to consider soil in the hemisphere of radius L as the deciding portion of soil for electrode to earth resistance. This implies, each electrode requires exclusive soil in a hemi-sphere of radius L. So, if electrode to earth resistance with one electrode is R, it can be R/2 with two electrodes only if the electrodes have separation of 2L.

### 2.2.3 Strip or Plate Electrode

In case of strip electrode / plate electrode, electrode to earth resistance is given by:

$$R = \rho/2\pi L\ [\ln(8L/T) + \ln(L/h)-2+(2h/L)-(h/L)^2]$$

L is length, h is depth of laying and T is thickness

As can be seen, L has major influence, T has minor influence.

For several years, electrical sub-stations were being provided with earthing plates of large area, which could not solve problems of high ‘electrode to earth’ resistance. Finally, having understood implications of above formula, electrical engineers started providing electrode-grids for the sub-stations.

### 2.2.4 Methods of Reducing Earth Resistance:

As Electrode to earth resistance depends on soil resistivity, it has to be reduced. The simplest way to do so is

- By adding salt, charcoal and sand mixture to the pit
- By adding earth enhancement material.
- By using a bigger grounding electrode
- By burying the ground electrode as deep as possible
- By having parallel ground electrodes with a distance of 10m between them

**<u>Resistivity of different Soils</u>**

| Soil | Resistivity in Ohm-Cm |
|---|---|
| Surface soil, loam, etc. | 100 - 5,000 |
| Clay | 200 - 10,000 |
| Sand and gravel | 15,000 - 100,000 |
| Surface limestone | 10,000 - 1,000,000 |
| Shale | 500 - 10,000 |
| Sandstone | 2,000 - 200,000 |
| Granites, basalts, etc. | 100,000 |
| Decomposed gneisses | 5,000 - 50,000 |
| Slates, etc. | 1,000 - 10,000 |

**Table 2.2**

When large number of earth systems is to be taken care, it is difficult to keep track of retreatment. Hence, provision of maintenance free earth is recommended. It essentially consists of filling the earth pit augered by earth-enhancement material like bentonite clay. For one pit associated with each pipe electrode, it is recommended to use at least 20 kg of bentonite clay. If less amount of bentonite clay is used, we may get low value of resistivity initially, but with passage of time, the resistivity increases.

### 2.2.5 Ring Earth System:

Ring earth system comprises of:

1. Equi-potential bonding of earth electrodes planted externally (outside the building) as a ring.
2. Provision of equi-potential bus-bar or ring inside equipment room.
3. Joining the external and internal rings.

### Objective:

1) Even though the earth is a bad conductor, the reason for choosing earthing as a protective means ___________________________.
2) Resistivity of dry soil________________________________.
3) Resistivity of wet soil _______________________________.
4) The fault currents return to the source in case of ____________________ systems.
5) Electrode to earth resistance has to be very ____________________.
6) The parameter which depends on shape and size of an electrode is _________________.
7) To keep the electrode to earth resistance value low, the length of electrode has to be _______________________.
8) By using two electrodes the earth resistance becomes half only if the distance between the two electrodes is ______________________.
9) When a strip or plate electrode is used which parameter of it has major influence on earth resistance? _____________________.
10) The factors which keep soil resistivity to a lower value are ___________________________.

### Subjective:

1) Why do we go for earthing even though the earth is a bad conductor?
2) What are the factors that determine earth resistance?
3) Give the values of resistivity of different soils.
4) How can the soil resistivity be reduced? And what is the periodicity of this process and why?
5) When a maintenance-free earth does is required? And how is it prepared?
6) Explain about ring earth system.

# CHAPTER-3

# SURGE PROTECTION DEVICES

## 3.1 Classes of SPDs & Parameters of SPDs

Classes of SPDs depend on the classes of protection, which in turn depend on the LPZ (Lightning Protection Zone) under consideration. Classes of SPDs are:
Class-A, Class-B, Class-C and Class-D.

Whatever be the class of SPD, the technical parameters listed in table 3.1 are the parameters of importance for each SPD.

| Parameter | Symbol | Meaning |
|---|---|---|
| Nominal Voltage | $U_0$ | Power supply system for which SPD is meant |
| Rated Voltage | $U_C$ | Maximum continuous operating voltage which can be connected to SPD |
| Temporary Over Voltage | $U_T$ | Voltage which can be withstood by SPD (or safely disconnect) when applied for a specific duration (5 m sec. or 200 m sec.) |
| Voltage Protection Level | $U_P$ | Limiting voltage across terminals of SPD under surge condition (mentioned for different surge currents /nominal surge current) |
| Voltage Withstand | $U_W$ | Insulation withstand level (4 levels 1.5/2/4/6 KV) |
| Impulse Current | $I_{imp}$ | Peak value of 10/350 micro sec. current that can be handled (Used for Class-A test rating) |
| Nominal Discharge Current | $I_n$ | 15 impulses of $I_n$ of 8/20 micro. sec. can be withstood (Used for Class-B test rating) |
| Follow-Up Current | $I_f$ | Current delivered by the distribution system which can be safely extinguished by SPD |
| Response Time | $T_r$ | Activation (closure) time |

**Table 3.1 Parameters of SPD**

### 3.2.1 Class- A Protection (Lightning Protection)

Class-A protection is essentially external lightning conductor on top of building connected to ground through a down conductor.

As can be seen in fig.1.3, surroundings outside the building fall in LPZ0 (Lightning Protection Zone-0). In this zone, 50% of lightning energy is transferred to ground. Balance 50% enters the building through power service cables, Telecom conductors etc.

Regarding class-A protection, it may please be noted that:

1. Lightning conductor can be single spike / multiple spike / dome.
2. Lightning conductor shall not touch the structure.
3. Down conductor shall be cable rated for HV (50 sq.mm cross section of stranded copper conductors) for structures of 80m or high (if 60 or more lightning days in a year). For other places, 40 mm X 6 mm MS flat insulated from building to be used.
4. Availability of class-A protection for the buildings is to be ensured by coordinating with electrical counter parts. It cannot be assumed to be present.
5. Provision of class-A protection for microwave or cellular towers is the responsibility of S&T department. For these towers, there is no need to provide down conductor. Tower angles serve the purpose. However, electrodes to be connected to tower legs and ring-earth to be provided. This ring is to be joined to external ring of equipment room and internal ring.
6. If rectangular waveguide is used, the waveguide has no sheathing; hence it has galvanic connection to the tower body and does not cause flow of surge to equipment. If elliptical waveguide is used, the sheath insulates the waveguide from tower body. So, any surge caught up by waveguide at antenna level can flow to the equipment. To safeguard against this danger, elliptical waveguides are to be connected to tower body using waveguide earthing kits. Each kit has copper rope of 1 m length with lugs on both ends. One end is soldered to waveguide exterior by gently pealing the sheath alone. Other end is bolted to tower body. Waveguide earthing is to be done at 10 m intervals.

**Fig 3.1 Class ‘A’ protection**

### 3.2.2 Class- B Protection

Please refer fig.1.3 showing LPZ. Class-B protection is the first stage protection, i.e. before the equipment, at mains distribution panel. These SPDs operate on arc chopping principle

Lightning currents handled are:

- 10/350 micro sec. pulses
- 100 kA amplitude between N & E
- 50 kA amplitude between R/Y/B & N

Class-B SPDs are to be provided between each phase & neutral and neutral & earth.

Parameters of class-B SPDs as per RDSO specifications are tabulated in table 3.2

| Parameter | Value / Limit |
|---|---|
| Nominal Voltage ($U_0$) | 230 V |
| Maximum Continuous Operating Voltage (Uc) | >253 V |
| Temporary Over Voltage ($U_t$) | 300V |
| Lightning Impulse Current Between R/Y/B & N | > 50 kA, 10/350 micro sec. for each phase |
| Lightning Impulse Current Between N & E | > 100 kA, 10/350 micro sec. |
| Response Time (Tr) | <200 n sec. |
| Voltage Protection Level (Up) | <1.5 kV |
| Short Circuit Withstand & Follow Up Current Extinguishing Capacity Without Back-Up Fuse (Isc) | >10 kA |
| Operating Temperature / RH | 70 $^{o}$ C / 95% RH |

**Table 3.2 Parameters of class-B arrestors**

The following questions arise in readers’ minds as they go through the table.

1. Why neutral to earth protection has higher rating than phase to neutral protection?
2. What is meant by follow-up current? Why shall follow-up current be extinguished?

The answers are:

1. If there is nearby direct strike of lightning, the site goes to higher potential w.r.t. sub-station or transformer earth. Hence, neutral to earth protection has higher rating than phase to neutral protection.

2. The SPD closes path to discharge surge impulse. The power supply system also sends current through this closed path which is known as ‘Follow-up current’. The magnitude of follow-up current similar to short-circuit current can cause tripping of CBs, fuses and can strain the conductors. But, follow-up current rises slowly compared to lightning induced currents; hence can be and shall be extinguished.

### 3.2.3 Class- C Protection

Class-C protection comprises of fast acting MOV to provide effective surge protection with low let through voltage. It is provided between phase and neutral. Surge rating taken care is 50 kA 8/20 micro sec pulses.

Class-C SPD shall be a single compact device. More MOVs in parallel shall never be provided.

Class-C SPD shall have following additional features:

- Indication (shows red) when device failed.
- Thermal disconnection of device when it starts having heavy leakage current due to ageing / handling several surges.
- Potential free contact for remote monitoring.

Parameters of class-C SPDs as per RDSO specifications are tabulated in table 3.3

| Parameter | Value / Limit |
|---|---|
| Nominal Voltage ($U_0$) | 230 V |
| Maximum Continuous Operating Voltage (Uc) | 300 V |
| Lightning Impulse Current Between R/Y/B & N | > 10 kA, 8/20 micro sec. for each phase |
| Response Time ($T_r$) | <25 n sec. |
| Voltage Protection Level (Up) | <1.6 kV |
| Operating Temperature / RH | 70 $^o$ C / 95% RH |

**Table 3.3 Parameters of class-C SPDs**

Provision of class-B and class-C SPDs is illustrated in fig.3.2

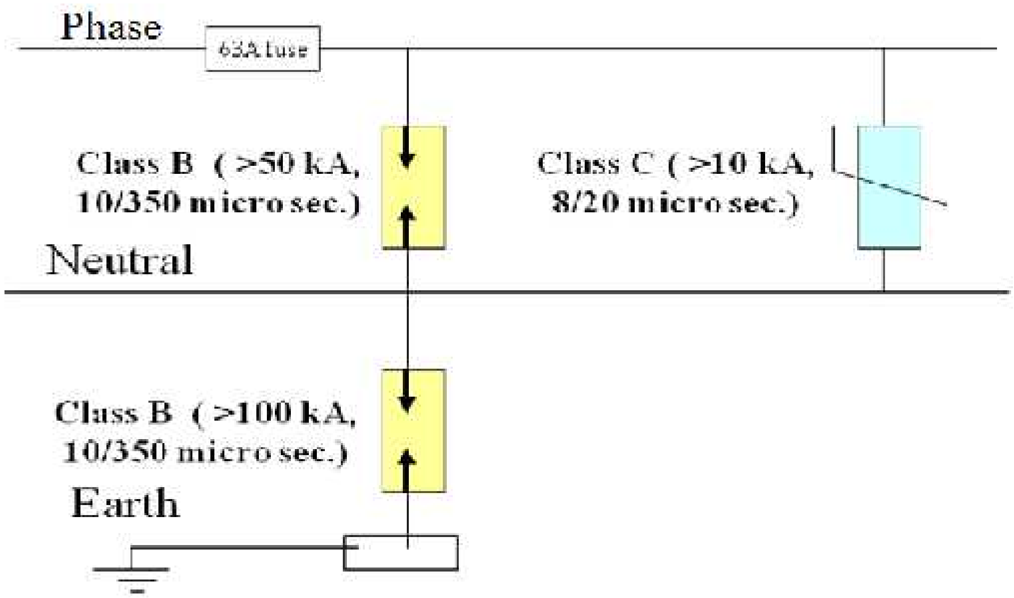



**Fig.3.2 Provision of class-B and class-C arrestors**

**It may please be noted that:**

1. If supply/data/telecom lines (AC/DC) are carried through overhead lines or cables above ground to any nearby building or any location outside equipment room, additional Class-C arrestor shall be used at such location
2. Total length of conductors used on either side of class B or class C SPD to be less than 50 cm. Else, use V-type connection as shown in fig.3.2

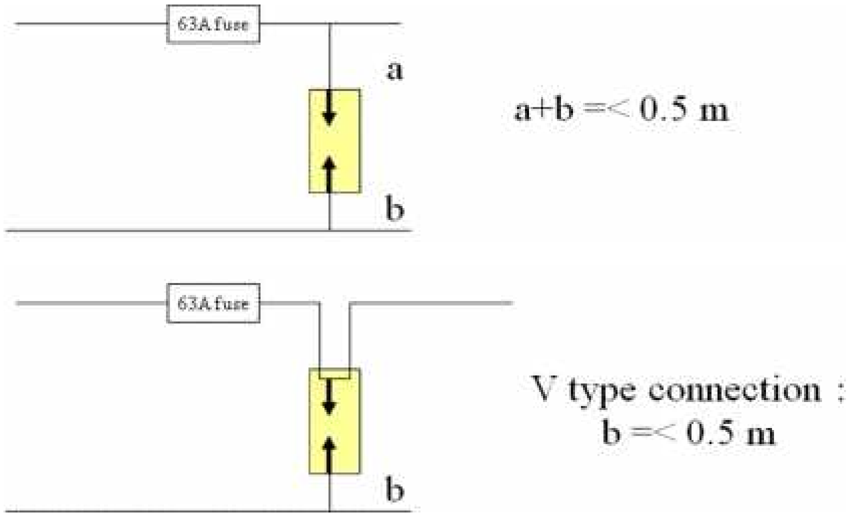



**Fig.3.3 Restriction regarding length of conductors used to connect class-B and class-C SPDs**

The conductors used to connect these SPDs have distributed inductance of 1 µH per meter. This implies 1 kV voltage build-up for 1 kA rise in1 micro sec. Hence, such restriction is to be observed in their lengths.

3. Size of conductor to connect class-B SPD shall be 16 sq.mm and class-C SPD shall be 6 sq.mm.

### 3.2.4 Class-D Protection

All external data/ power supply (AC/DC) lines connected to electronic equipment are to be provided with class-D SPDs at both ends of the conductors.

Class-D SPDs comprise of MOVs and GDs and combinations. Their ratings are given voltage (supply) wise. These SPDs shall have following additional features:

1. Indication (shows red) when device failed
2. Thermal disconnection of device when it starts having heavy leakage current due to ageing / handling several surges
3. Potential free contact for remote monitoring

Parameters of class-D SPDs as per RDSO specifications are tabulated in table 3.4

## Power Line Protection

The device for power line protection shall be of Class D type. This shall have an indication function to indicate the prospective life and failure mode to facilitate the replacement of failed SPDs. This shall be thermal disconnecting type and equipped with potential free contact for remote monitoring. This protection shall be in compliance to IEC 61643-1 and VDE -0675 Pt. 6 with following characteristics:

| Parameter | For various circuits | | | | |
|---|---|---|---|---|---|
| | **24V** | **48V** | **60V** | **110V** | **230V** |
| Nominal Voltage ($U_0$) | 24V | 48V | 60V | 110V | 230V |
| Max. Continuous Operating Voltage (Uc) | 30V | 60V | 75V | 150V | 253V |
| Rated Load Current ($I_L$) | 16A | 16A | 16A | 16A | 16A |
| Nominal Discharge Current (In) 8/20 micro sec | ≥ 700A | ≥ 700A | ≥ 700A | ≥ 2KA | ≥ 2KA |
| Maximum Discharge Current (Imax) 8/20 micro sec | ≥ 2 KA | ≥ 2 KA | ≥ 2 KA | ≥ 5 KA | ≥ 5 KA |
| Voltage Protection Level (Up) | ≤ 200V | ≤ 350V | ≤ 500V | ≤ 700V | ≤ 1100V |
| Response Time (Tr) | ≤ 25 ns | ≤ 25 ns | ≤ 25 ns | ≤ 25 ns | ≤ 25 ns |

**Table 3.4 Parameters of class-D SPDs**

## Signaling / Data Line Protection

These devices shall preferably have an indication function to indicate the prospective life and failure mode to facilitate the replacement of failed SPDs. If the device has any component which comes in series with data/ signalling lines, the module shall have "make before break" feature so that taking out of pluggable module does not disconnect the line. This protection shall be in compliance to IEC 61643-21 & VDE 0845 Pt. 3 with the following characteristics:

| Parameter | For Various Circuits | | | |
|---|---|---|---|---|
| Nominal Voltage($U_0$) | 5V | 12V | 24V | 48V |
| Arrester Rated Voltage($U_C$) | 6V | 13V | 28V | 50V |
| Rated Load Current ($I_L$) | ≥250mA | ≥250mA | ≥250mA | ≥250mA |
| Total Discharge Current, 8/20 µs ($L_n$) | ≥20KA | ≥20KA | ≥20KA | ≥20KA |
| Lightning Test Current, 10/350 µs | ≥2.5KA | ≥2.5KA | ≥2.5KA | ≥2.5KA |
| Voltage Protection Level ($U_P$) | ≤10V | ≤18V | ≤30V | ≤70V |

**Table 3.5**

Note: Minor variations from above given parameters shall be acceptable

## 3.3 Calculations to select SPDs:

### Case-1: Single Exposed Structure (Please refer fig.3.3)

Considering availability of class-A protection (lightning protection system comprising of lightning arrestor, down conductor and earthing), 50% of surge can be considered to be passed to ground. In fact, most of lightning surge is passed to ground by a well-provided class-A system.

Remaining surge will be about 5%. So, in consideration of 50% surge remaining is to take it with high safety margin.

This implies, Is/2 is remaining where 'Is' is surge current due to lightning. So, each of the power supply lines (3 phases, 4 lines) take 25% Is/2. This implies, for 200 kA 10/350 micro sec. surge, each power supply line requires protection against 25 kA, 10/350 micro sec. surge. As already discussed, phase to neutral SPDs are rated 25 kA, 10/350 micro sec. and neutral to earth SPDs are rated as 50 kA, 10/350 micro sec.

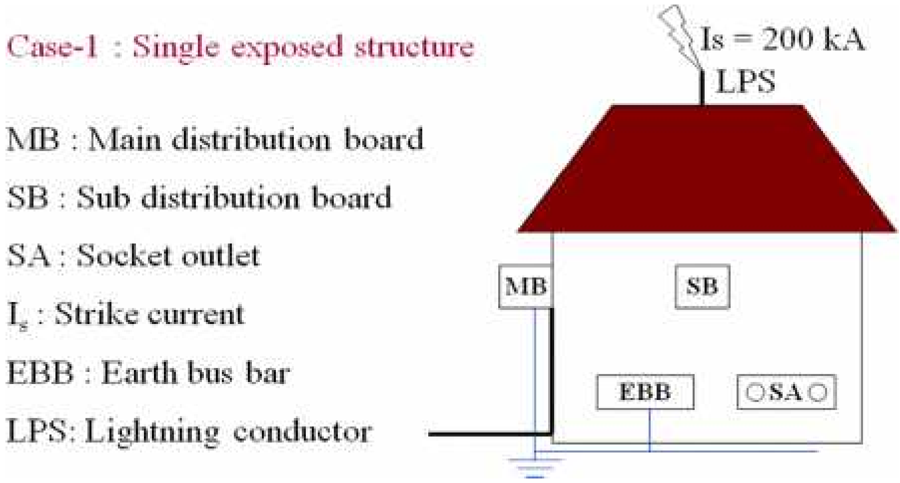



**Fig.3.4 Determination of SPD rating for single exposed structure**

## Case 2: Two Adjacent Structures with Same Earth Resistance (Refer Fig.3.4)

In this case, surge current on incoming utilities for each building is 50% of Is/2 i.e. Is/4 (since Is/2 is already passed to earth by class-A protection). So, each power supply line has surge of 1/4$^{th}$ of Is/4 i.e. 12.5 kA, 10/350 micro sec. in case of lightning surge of 200 kA,10/350 micro sec..

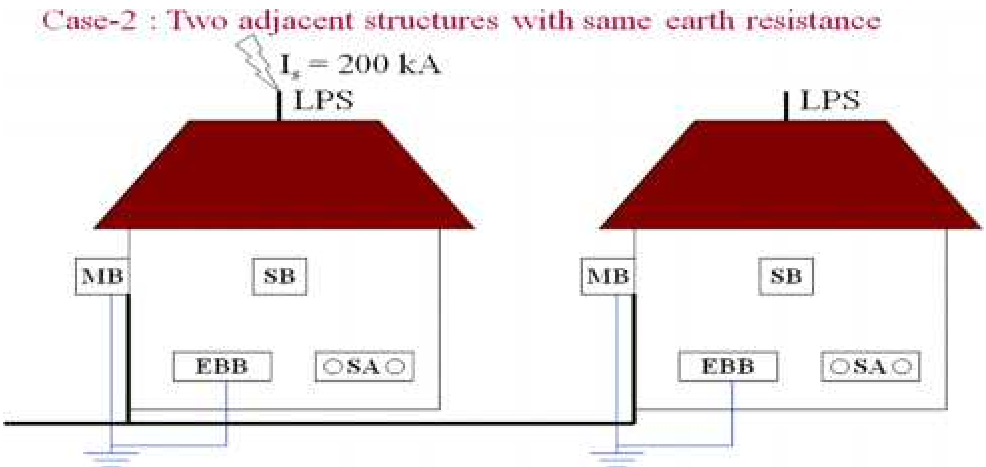



**Fig.3.5 Finding SPD rating for two adjacent structures with same earth resistance**

## Case-3: Two Adjacent Structures with Different Earth Resistances (refer fig.3.6)

Let Ra, Rb be the earth resistances of the structures A and B respectively. Considering 50% of Is is taken care by class-A protection, the surge to be taken care by incoming utility lines of structures A and B are given by :

$I_a = (Is/2) / [1+R_a/R_b]$ $I_b = (Is/2) / [1+R_b/R_a]$

**So, if structure-B has higher earth resistance, he is not the sufferer but structure-A is the sufferer!!!**

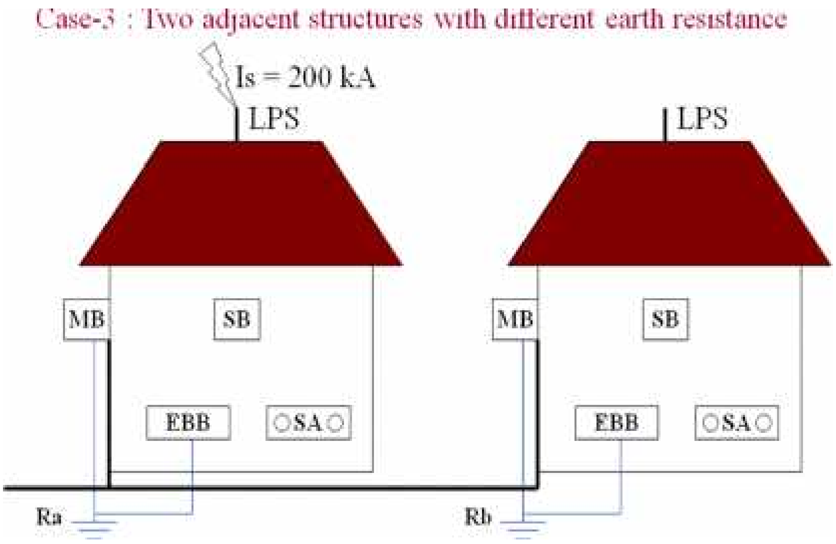



**Fig.3.6 Two adjacent structures with different earth resistances**

Hence, we always provide equi-potential bonding of ear thing (joining earthling-rings) for adjacent structures. Here, adjacent means separation below 20 m.

## 3.4 Electromagnetic immunity class of SPDs:

In addition to classes of SPDs discussed so far, IEC (International Electro technical Commission) defined electromagnetic immunity classes of SPDs. These are tabulated in table 3.5

As per estimated surge based on number of incoming utility lines, one has to choose rating of SPD of class-B or C or D as well as its immunity class.

| Class As Per IEC 61000-4-5 | $U_{CC}$ (Withstand open circuit voltage level of 1.2/50 micro sec. wave-shape) | $I_{SC}$ (Withstand short circuit current level of 8/20 micro sec. wave-shape) |
|---|---|---|
| 1 | 4 kV | 2 kA |
| 2 | 2 kV | 1 kA |
| 3 | 1 kV | 0.5 kA |
| 4 | 0.5 kV | 0.25 kA |

**Table 3.6 Electromagnetic Immunity Classes of SPDs**

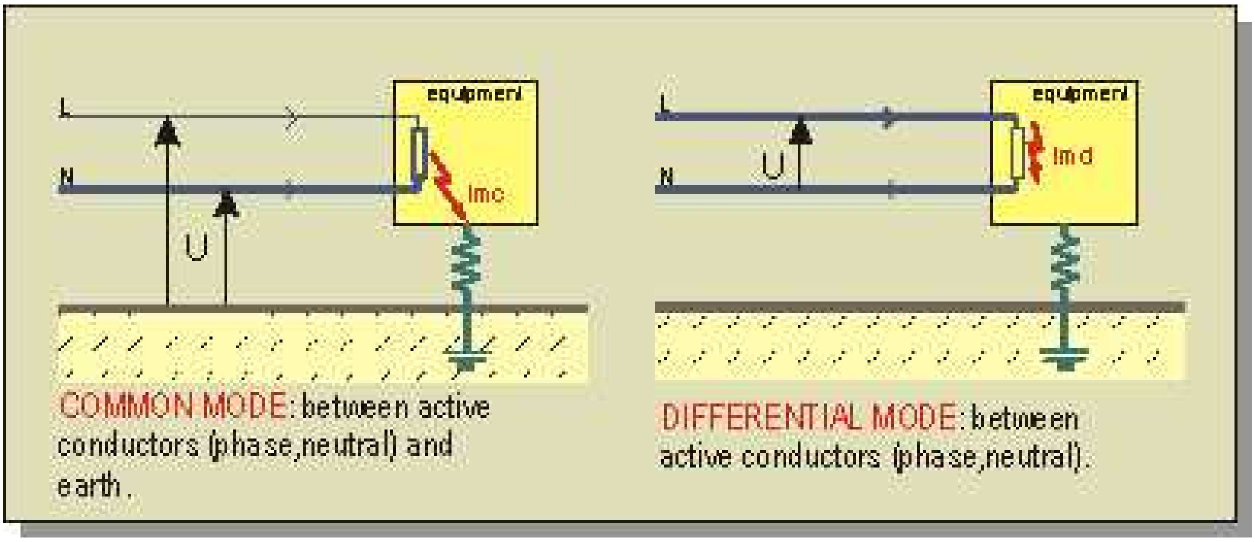



**Fig 3.7 Common mode and Differential mode**

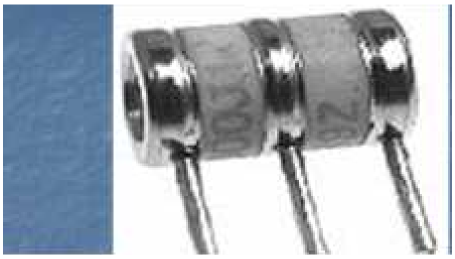
**Common or asymmetric mode:** Perturbations between an active conductor and earth (phase-earth or neutral-earth), with risk of dielectric damage.

**Differential or symmetric mode:** Perturbations between active conductors, (phase-phase or phase-neutral), especially dangerous for electronic equipment.

## 3.5 Some of the surge protection devices are as given below

- Spark gaps (air gaps)
- Gas discharge tubes (GDTs)
- Zener diodes (avalanche diodes)
- Metal oxide varistors (MOVs)
- Transobers
- Relays
- Fuses
- PTCR (Positive Temperature Coefficient Resistor
- TBU (Transient Blocking Unit)

SILICON AVALANCHE DIODE



GAS DISCHARGE TUBE

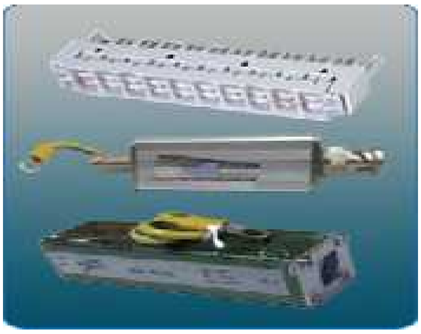
METAL OXIDE VARISTORS

**Fig.Some of the surge protection devices**

Class B SPD

Class C SPD

**Class (BHC) SPD**



**Class D SPD**

**Fig. Class B, C, (BHC) and D SPDs**

**Objective:**

1) Surge protection devices are divided into _____________________ classes.

2) Response time of an SPD means its ____________________________time.

3) The class A protection is offered by a ______________________.

4) If an elliptical waveguide is used between antenna and communication equipment that is to be earthed at _____________________ intervals.

5) Class B protection is the _____________ stage. Protection provided at ______________.

6) Class B SPDs operate on ____________________ Principle.

7) Class B SPDs are to be provided between neutral to ___________________.

8) Among neutral to earth and neutral to phase protection which one needs to have rating? ______________________.

9) Surge rating taken care by class C protection is ________________.

10) The date and power supply lines to electronic equipment need to be provided with class _____________________ protection.

11) The total length of the conductors used on either side of class B or class C protection SPD should be less than _________________________.

12) Size of conductor connecting

    a. class B SPD shall be __________________sq.mm
    b. class C SPD shall be __________________sq.mm

**Subjective:**

1) List out the technical parameters of SPDs.

2) What are the classes of SPDs? And explain about class A protection.

3) Explain about class B protection and its parameters

4) Explain about class C protection and its parameters

5) Explain about class D protection and its parameters

6) Why neutral to earth protection has high rating than phase to neutral protection?

7) What is meant by follow-up current? Why shall it be extinguished?

8) What do you mean by first stage and second stage of protections?

# CHAPTER-4

# RDSO SPECIFICATIONS FOR EARTHING SYSTEM FOR TELECOM INSTALLATIONS

## 4.1 Introduction

RDSO Spec.no.RDSO/SPN/197/2008 covers the specifications of earthing system for S&T installation. These are presented in this chapter.

These specifications set forth general, operational, technical, performance, type test & acceptance test requirements of earthing system for telecom installations.

These specifications are based on Indian Standard code of practice for earthing vide IS 3043-1987.

## 4.2 The Objective of Earthing System

The objective of an earthing system is to provide as nearly as possible a surface under and around a station which shall be at a uniform potential and as nearly zero or absolute earth potential as possible. The purpose of this is to ensure that, in general, all parts of apparatus other than live parts, shall be at earth potential, as well as to ensure that operators and attendants shall be at earth potential at all times. By providing such an earth surface of uniform potential under and surrounding the station, there can exist no difference of potential in a short distance big enough to shock or injure an attendant when short-circuits or other abnormal occurrences take place. Also sometimes earth is used for carrying current from one place to another in a circuit such as telegraph systems etc. Thus the purpose of the earth may be one or more of the following:

1. To afford safety to personnel against shock by earthing the casing or other exposed parts.
2. To provide a return path as, for example, in block instruments, unbalanced HF serial circuits, unbalanced three phase power supply system etc.
3. To protect equipment against build up of unduly high voltages by earthing protective devices like surge arrestors and lightning dischargers.
4. To ensure safe and reliable operation of equipment by eliminating/limiting voltage and currents due to EMI and RFI by earthing of metallic sheathing and armoring of cables.
5. To provide path for heavy fault currents to ensure effective and quick operation of protective devices, as in power supply induced systems.

### 4.2.1 System Earthing & Equipment Earthing

Earthing associated with current-carrying conductor is normally essential to the security of the system and is generally known as system earthing, while earthing of non-current carrying metal work and conductor is essential to the safety of human life, animals and property, and is generally known as equipment earthing.

## 4.3 TERMINOLOGY

For the purpose of this document, the following definitions shall apply.

1. **Bonding Conductor -** A protective conductor providing equipotential bonding.
2. **Earth -** The conductive mass of the earth, whose electric potential at any point is conventionally taken as zero.
3. **Earth Electrode -** A conductor or group of conductors in intimate contact with and providing an electrical connection to earth.
4. **Earthing Conductor -** A protective conductor connecting the main earthing terminal (or the equipotential bonding conductor of an installation when there is no earth bus) to an earth electrode or to other means of earthing.
5. **Earth Grid -** A system of grounding electrodes consisting of inter-connected conductors buried in the earth to provide a common ground for electrical devices and metallic structures. (Note-The term ‘earth grid’ does not include earth mat’).
6. **Earth Mat -**A grounding system formed by a grid of horizontally buried conductors and which serves to dissipate the fault current to earth and also as an equipotential bonding conductor system.
7. **Electrically Independent Earth Electrodes -** Earth electrodes located at such a distance from one another so that the maximum current likely to flow through one of them does not significantly affect the potential of the other(s).
8. **Equipotential Bonding -** Electrical connection keeping various exposed conductive parts and extraneous conductive parts at a substantially equal potential.
9. **Equipotential Line or Contour -** The locus of points having the same potential at a given time.
10. **Exposed conductive part -** A conductive part of equipment which can be touched and which is not a live part but which may become live under fault conditions.
11. **Functional Earthing -** Connection to earth necessary for proper functioning of electrical equipment.
12. **Main Earthing Terminal -** The terminal or bar (which is the equipotential bonding conductor) provided for the connection of protective conductors and the conductors of functional earthing, if any, to the means of earthing.
13. **Mutual Resistance of Grounding Electrodes -** Equal to the voltage change in one of them produced by a change of one ampere of direct current in the other and is expressed in ohms.
14. **Potential Gradient** (at a point) - The potential difference per unit length measured in the direction in which it is maximum.

15. **Protective Conductor -** A conductor used as a measure of protection against electric shock and intended for connecting any of the following parts:-
    a. Exposed conductive parts,
    b. Extraneous conductive parts,
    c. Main earthing terminal, and
    d. Earthed point of the source or an artificial neutral.

16. **Resistance Area** (For an Earth Electrode only) - The surface area of ground (around an earth electrode) on which a significant voltage gradient may exist.

17. **Step Voltage -** The potential difference between two points on the earth's surface, separated by a distance of one pace that will be assumed to be one metre in the direction of maximum potential gradient.

18. **Touch Voltage -** The potential difference between grounded metallic structure and a point on the earth's surface separated by a distance equal to the normal maximum horizontal reach, approximately one meter.

## 4.4 SOIL RESISTIVITY

### 4.4.1 Effect Of Nature Of Soil On Soil Resistivity

The resistivity of soil depends upon the moisture content, chemical composition of the soil and concentration of salts dissolved in the contained moisture. Grain size, mode of distribution and closeness of packing also effect the resistivity as these factors control the manner in which the moisture is held in soil. Many of these factors vary locally and some seasonally, and as such soil resistivity varies not only from location to location but also from season to season. Besides, the areas where the soil is stratified, the effective resistivity also depends upon the underlying geological formation.

### 4.4.2 Effect Of Moisture Content On Soil Resistivity-

Moisture content is one of the controlling factors in earth resistivity. Above about 20 percent moisture, the resistivity is very little affected; while below 20 percent the resistivity increases very abruptly with decrease in the moisture content. A difference of a few percent moisture will therefore, make a very marked difference in the effectiveness of earth connection if the moisture content falls below 20 percent. The normal moisture content of soil ranges from 10 percent in dry seasons to 35 percent in wet seasons, and an approximate average may be perhaps 16 to 18 percent.

### 4.4.3 Effect Of Temperature On Soil Resistivity

Temperature also affects the resistivity of the soil. However, it is of consequence only around and below the freezing point, which means that earth electrodes should be installed at depths where frost cannot penetrate.

The temperature coefficient of resistivity for soil is negative, but is negligible for temperatures above freezing point. At about $20^0$C, the resistivity change is about 9 percent per degree

Celsius. Below $0^0$C the water in the soil begins to freeze and introduces a tremendous increase in the temperature coefficient, so that as the temperature becomes lower the resistivity rises enormously. It is, therefore, recommended that in areas where the temperature is expected to be quite low, the earth electrodes should be installed well below the frost line. Where winter seasons are severe, this may be about 2 metres below the surface, whereas in mild climates the frost may penetrate only a few centimetres or perhaps the ground may not freeze at all. Earth electrodes which are not driven below the frost depth may have a very great variation in resistance throughout the seasons of the year. Even when driven below the frost line, there is some variation, because the upper soil, when frozen, presents a decided increase in soil resistivity and has the effect of shortening the active length of electrode in contact with soil of normal resistivity.

## 4.5 Location of Earth Pit:

Where there is option, site should be chosen in one of the following types of soil in the order of preference given:-

a) Wet marshy ground;
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, granite and very stony ground should be avoided, and also all locations where virgin rock is very close to the surface.

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 percent. Care should be taken to avoid a site kept moist by water flowing over it (for example, the bed of stream) as the beneficial salts may be entirely removed from the soil in such situations.

## 4.6 Earth Electrodes:

### 4.6.1 Effect Of Shape On Electrode Resistance:

With all electrodes other than extended systems, the greater part of the fall in potential occurs in the soil within a few feet 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 requirement is met 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.

## 4.6.2 Resistance Of Common Types Of Earth Electrodes:

### Plate Electrode:

The approximate resistance to earth of a plate can be calculated from:

$R = \rho L / A$ i.e., Resistance = (Resistivity x Length) / Area

Where

$\rho$ = resistivity of the soil (assumed uniform) in $\Omega$.m and

A = area of both sides of the plate (in $m^2$)

Where the resistance of single plate is higher than the required value, two or more plates may be used in parallel and the total resistance is then inversely proportional to the number employed, provided that each plate is installed outside the resistance area of each other. This normally requires a separation of about 10m but for sizes of plate generally employed, a separation of 2m is sufficient to ensure that the total resistance will not exceed the value obtained from the above formula by more than 20 percent. Even at the latter spacing, it is generally more economical to use two plates in parallel, each of a given size, than one of twice that size. The size employed is, therefore, normally not greater than 1.2mx1.2m.

### Strip or Conductor Electrodes:

These have special advantages where high resistivity soil underlies shallow surface layers of low resistivity. The resistance R is given by:

$R = [\,(100\rho/2\pi l) \log_e (2l^2 / w\,t)\,]$ Ohms

Where

P = resistivity of the soil (in $\Omega$.m) (assumed uniform)

l = length of the strip in cm;

w = depth of burial of the electrode in cm; and

t = width (in the case of strip) or twice the diameter (for conductors) in cm.

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

Earth resistance decreases first sharply and then after slowly with increase in electrode length. The effect of conductor size and depth over the range normally used is very small.

If several strip electrodes are required for connection in parallel in order to reduce the resistance, they may be installed in parallel lines or they may radiate from a point. In the former case, the resistance of two strips at a separation of 2.4m is less than 65 percent of the individual resistance of either of them.

## 4.6.3 Selection Of Metals For Earth-Electrodes:

Although electrode material does not affect initial earth resistance, care should be taken to select a material that is resistant to corrosion in the type of soil in which it will be used. Tests in a wide variety of soils have shown that copper, whether tinned or not, is entirely satisfactory (subject to the precautions given in this sub clause), the average loss in weight of specimens 150mm x 25mm x 3mm buried for 12 years in no case exceed 0.2 percent per year.

Corresponding average losses for unprotected ferrous specimens (for example, cast iron, wrought iron or mild steel) used in the tests were as high as 2.2 percent per year. Considerable and apparently permanent protection appears to be given to mild steel by galvanizing. The test showing galvanized mild steel to be little inferior to copper with an average loss not greater than 0.5 percent per year. Only in a few cases was there any indication in all these tests that corrosion was accelerating and in these cases the indications were not very significant.

### 4.6.4 Current Density At The Surface Of An Earth Electrode:

An earth electrode should be designed to have a loading capacity adequate for the system of which it forms a part, that is, it should be capable of dissipating without failure the energy in the earth path at the point at which it is installed under any condition of operation on the system. Failure is fundamentally due to excessive temperature rise at the surface of the electrode and is thus a function of current density and duration as well as electrical and thermal properties of the soil.

In general, soils have a negative temperature coefficient of resistance so that sustained current loading results in an initial decrease in electrode resistance and consequent rise in the earth fault current for a given applied voltage. As soil moisture is driven away from the soil-electrode interface, however, the resistance increases and will ultimately become infinite if the temperature-rise is sufficient.

Three conditions of operation require consideration, that is, long-duration loading as with normal system operation; short-time overloading as under fault conditions in directly earthed system, and long-time over loading as under fault conditions in systems protected by arc-suppression coils.

The little experimental work which has been done on this subject by experts at the international level has been confined to model tests with spherical electrodes in clay or loam of low resistivity and has led to the following conclusions:

a) Long-duration loading due to normal unbalance of the system will not cause failure of earth-electrodes provided that the current density at the electrode surface does not exceed $40 A/m^2$. Limitation to values below this would generally be imposed by the necessity to secure a low-resistance earth.

b) Time to failure on short-time overload is inversely proportional to the specific loading, which is given by i2, where i is the current density at the electrode surface. For the soils investigated, the maximum permissible current density, i is given by

$$i = 7.57 \times 10^3 / \sqrt{(\rho\ t)}\ A/m^2$$

Where

t = duration of the earth fault (in s) and

ρ = resistivity of the soil (in Ω .m)

Experience indicates that this formula is appropriate for plate electrodes.

### 4.6.5 Cross Sectional Area Of Protective Conductor:

The cross sectional area of every protective conductor which does not form part of the supply cable or cable enclosure shall be, in any case, not less than:

a) 2.5 $mm^2$, if mechanical protection is provided and
b) 4 $mm^2$, if mechanical protection is not provided.

### 4.6.6 Measurement of Earth Resistance:

- Earth resistance is measured using Earth tester.
- Earth tester is a four terminal instrument with a voltage source and a meter to show resistance value in ohms.
- Earth tester gives soil resistance and electrode resistance but earth electrode resistance can be neglected as it is negligible.
- Earth tester also consists of accessories like spikes or rods, connecting wires etc.

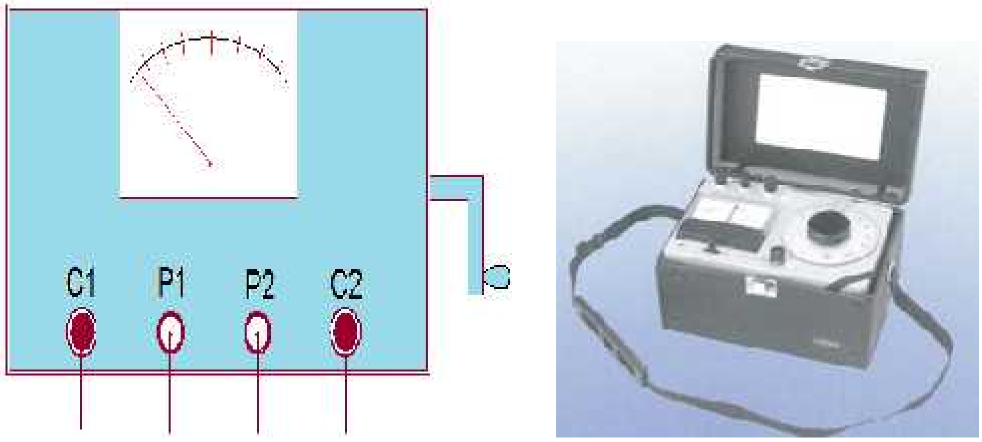



**Fig 4.1 Earth testers**

### 4.6.7 Practical methods of measuring earth resistance:

Following are the methods used in measuring earth resistance

- Fall of potential method which is a three terminal method
- Dead earth method which is a two terminal method
- Clamp on test method

### 4.6.8 Principle of earth testing:

Earth resistivity is measured using four terminal instruments. Four small sized electrodes are driven to the same depth and equal distance apart in a straight line as in Fig 4.2. The terminals C1 & C2 are called current reference electrodes, P1 &P2 are called potential reference electrodes. Four separate lead wires connect the electrodes to the four terminals of the instrument. Hence, the name, four terminal method.

In the figure below C1and C2 are called current reference rods and P1 and P2 are called potential reference (voltage) rods.

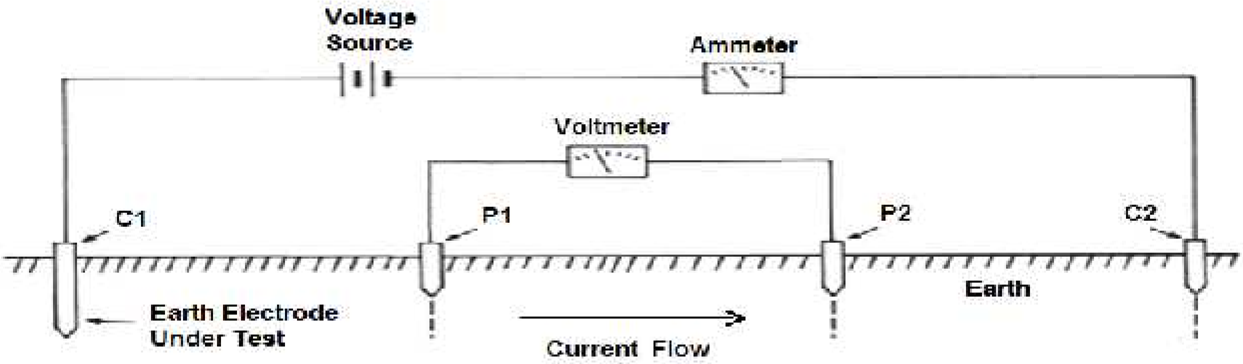



Fig 4.2 Principle of Earth testing

### 4.7.1 Fall of Potential (3-Terminal) method of measuring Earth Resistance:

In the three terminal methods C1 and P1 are shorted. If the distance between actual earth electrode (C1) and current reference electrode C2 is 100 feet then the distance between C1 and P2 should be 62 feet.

The resistance 'R' is given by

R=V / I    V is the reading of voltmeter in volts and I is the reading of the ammeter in amperes.

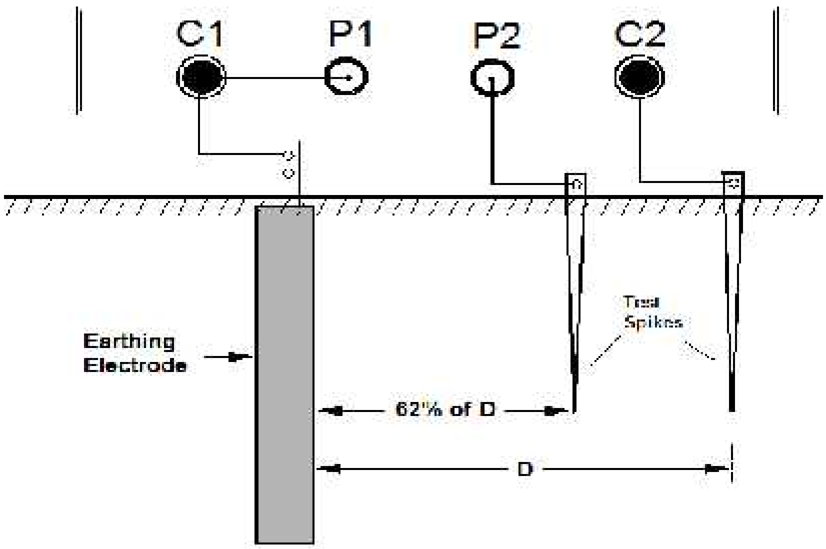



Fig 4.3 Fall of potential method-three terminal method

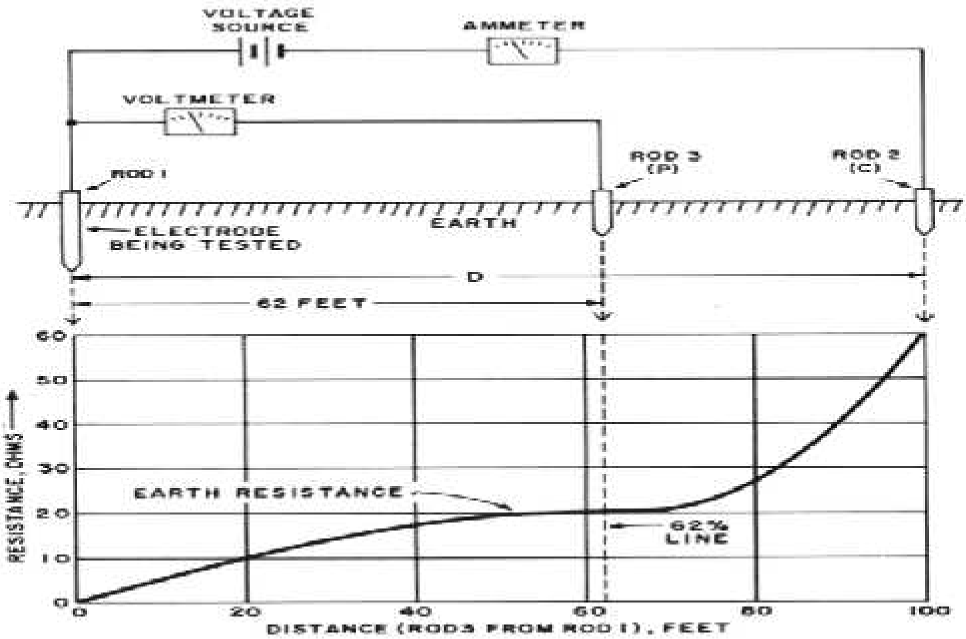



**Fig 4.4 Three terminal method of earth resistance method**

## 4.8 Sphere of influence of earth electrode:

The volume of earth mass surrounding the earth electrode in which spreading of electrical charges takes place is called the sphere of influence and the current radiates in all directions from the earth electrode. The earth mass surrounding the earth can be imagined to be made up of shells of equal thickness. The shell closest to the electrode has the smallest area, hence it has the highest earth resistance and as the shells distance increase from the electrode, the surface area also increases with decreasing earth resistance.

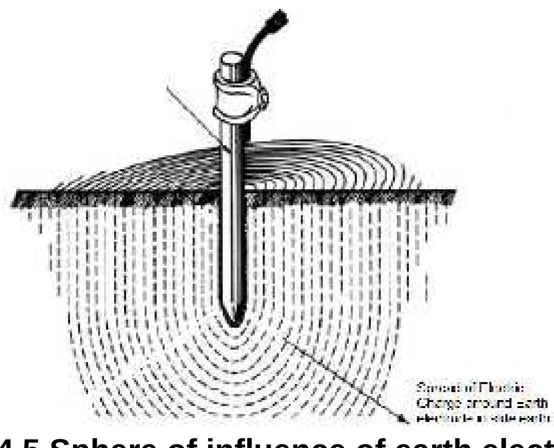
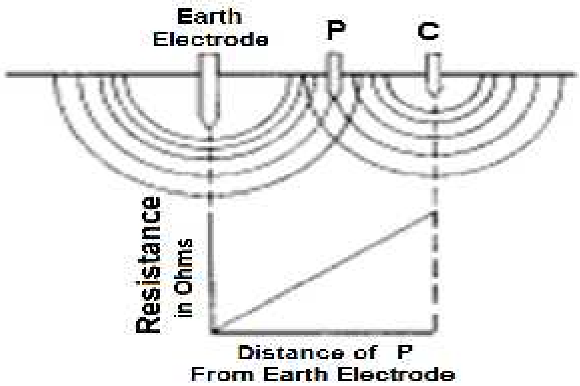


**FIG 4.5 Sphere of influence of earth electrode**

Hence care shall be taken while measuring earth resistance that placing of earth rods should be outside the influnce of one another. And even while providing multiple earth pits for reducing the earth resistance value, same rule should be followed.



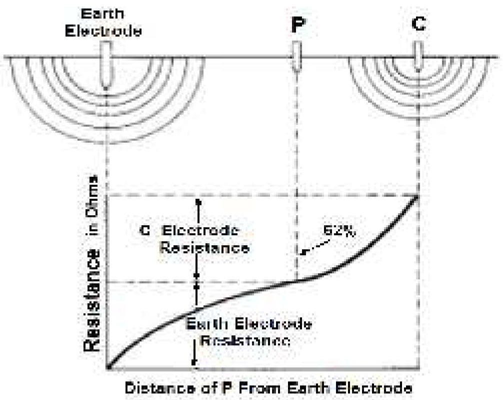




**FIG 4.6 Wrong placing of C** **Fig 4.7 Correct placing of C**

### 4.8.1 Earth resistance with two electrodes

When two earths to be provided then the seperating distance between the earth electrodes must be equal to twice the length of the electrode or greater than that.

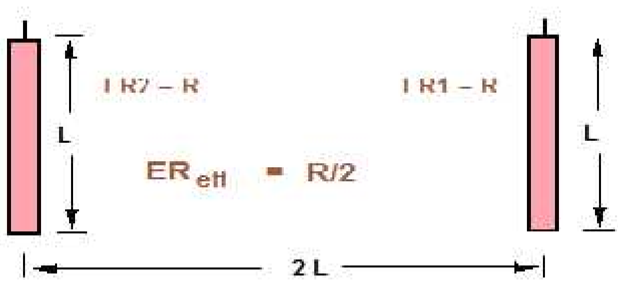



**Fig 4.8 Correct placing of earth electrodes**

### 4.8.2 Dead earth method of measuring earth resistance: (Two terminal method)

This is the simplest method of measuring earth resistance in which water pipe is used as the second terminal.

In this method c1 is shorted with P1 and P2 with C2. Earth electrode is connected to C1P1 and water tap is connected to C2 P2.

With this method, resistance of two electrodes in series is measured — the driven rod and the water system.

### 4.8.3 Precautions to be taken Dead Earth method are:

1. The water pipe system must be extensive enough to have a negligible resistance.
2. The water pipe system must be metallic throughout, without any insulating couplings or flanges.
3. The earth electrode under test must be far enough away from the water-pipe system to be outside its sphere of influence.

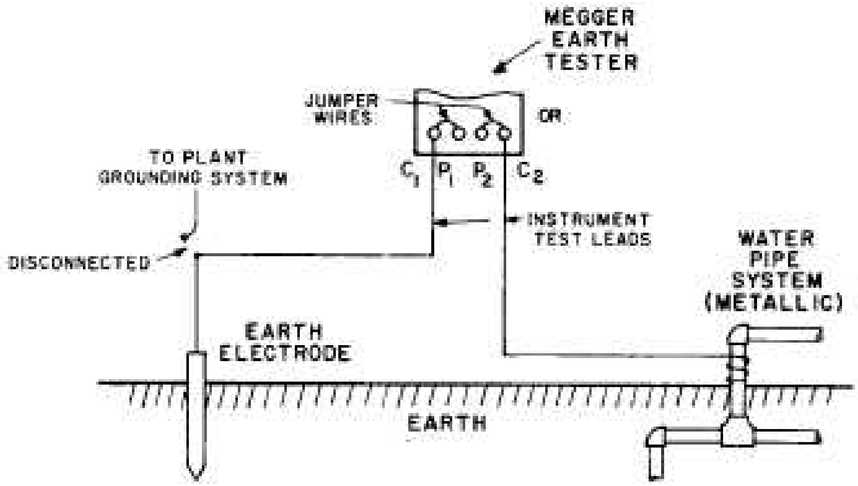



**Fig 4.9 Earth resistance by Dead earth method**

***Note*** – In most cases, there will be stray currents flowing in the soil and unless some steps are taken to eliminate their effect, they may produce serious errors in the measured value. If the testing current is of the same frequency as the stray current, this elimination becomes very difficult and it is better to use an earth tester incorporating a hand-driven generator. These earth testers usually generate direct current, and have rotary current-reverser and synchronous rectifier mounted on the generator shaft so that alternating current is supplied to the test circuit and the resulting potentials are rectified for measurement by a direct reading moving-coil ohm-meter. The presence of stray currents in the soil is indicated by a wandering of the instrument pointer, but an increase or decrease of generator handle speed will cause this to disappear.

The source of current shall be isolated from the supply by a double wound transformer.

At the time of test, where possible, the test electrode shall be separated from the earthing system.

The auxiliary electrodes usually consist of 12.5mm diameter mild steel rod driven up to 1 m into the ground.

All the test electrodes and the current electrodes shall be so placed that they are independent of the resistance area of each other. If the test electrode is in the form of rod, pipe or plate, the auxiliary current electrode C shall be placed at least 30m away from it and the auxiliary potential electrode B midway between them.

### 4.8.4 Earth resistance measurement by Clamp-on method:

The Fall of potential method of earth testing so far discussed is extremly reliable and highly accurate. But it has its own drawbacks and they are:

- It is time consuming and labour intensive.
- Induvidual ground electrodes must be disconnected from the system to be measured.
- There are situations where diconnection is not possible.

The Clamp-on test method performs a stakeless test, meaning no earth probes(spikes) are used. This is done without disconnecting the earth conductor from the equipment. In this method a known voltage is induced in a loop circuit and measures the resultant current flow and calculate the loop resistance of the circuit. Clamp on earth testing is employed in large eletrical and electronic installations, where earth resistance of large number of earth locations have to be measured with minimum labour and with out consuming much time.

**Fig 4.10 Clamp-on earth tester**

## 4.9 Earth detector circuit

The diagram of a simple Earth detector circuit is given below in Fig 4.11 meant for monitoring the earth resistance. When the earth resistance value rises above, e.g. > 1 Ohm, Relay releases and activates Buzzer and LED giving out audio/visual alarm. (Relay drop can be adjusted by the preset) AR is voltage operated relay.

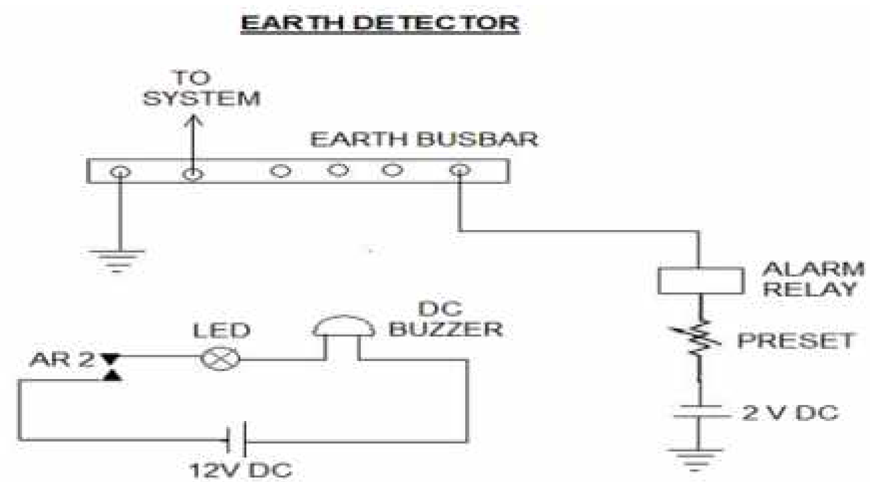



**Fig 4.11 Earth detector circuit**

## Objective:

1) The RDSO specification not applicable for S&T installations is _______________.
2) The main purpose of providing earthing is ___________________.
3) Surge arrestors and lightning dischargers offers protection against build up of _______________.
4) System earthing is associated with ____________________.
5) Equipment earthing is associated with ______________________.
6) Step voltage means potential difference between two points on earth surface. separated by a distance of ______________________.
7) The potential difference between grounded metallic structure and a point on the earthing surface is known as __________________ voltage.
8) Mention a factor affecting soil resistivity? ________________________.
9) Mention any single soil used for locating an earth electrode? _________________
10) Method used for measuring earth electrode resistance is __________________.

## Subjective:

1) What is the objective of earthing system?
2) What is the difference between system earthing and equipment earthing?
3) Define the following terms

   a) Bonding conductor  b) Earth grid  c) Earth mat

4) Explain the following terms
   a. Electrically independent earth electrodes
   b. Equi-potential bonding
   c. Equi-potential line

5) Explain these terms

   a) Potential gradient  b) Protective conductor

6) What is the difference between the following terms

   a) Step voltage  b) Touch voltage

7) What is Soil Resistivity? What are the factors affecting soil resistivity?
8) What factors do you consider for selecting the location of earth electrode?
9) What are the types of earth electrodes used? And mention advantages of each.
10) How do you measure earth electrode resistance using fall of potential method? Explain with diagram.

# CHAPTER 5

# CODE OF PRACTICE FOR EARTHING AND BONDING SYSTEM FOR S&T EQUIPMENTS

**(RDSO SPECIFICATION NO. RDSO/SPN/197/2008)**

## 5.1 Scope

This document covers earthing & bonding system to be adopted for signalling equipments with solid state components which are more susceptible to damage due to surges, transients and over voltages being encountered in the system due to lightning, sub-station switching etc. These signalling equipments include Electronic Interlocking, Integrated Power supply equipment, Digital Axle counter, Data logger etc.

## 5.2 References

| | |
|---|---|
| IS 3043 | Code of practice for earthing |
| ANSI/UL 467 | Grounding & bonding equipment |
| IEEE 80 | IEEE guide for Safety in AC sub-station grounding |
| IEEE 837 | Standard for qualifying permanent connections used in sub-station grounding |
| IEC 62305 | Protection against lightning |

### 5.3 Characteristics of Good Earthing System

### (a) Excellent Electrical Conductivity

i. Low resistance and electrical impedance.
ii. Conductors of sufficient dimensions capable of withstanding high fault currents with no evidence of fusing or mechanical deterioration.
iii. Lower earth resistance ensures that energy is dissipated into the ground in the safest possible manner.
iv. Lower the earth circuit impedance, the more likely that high frequency lightning impulses will flow through the ground electrode path, in preference to any other path.

### (b) High corrosion resistance

i. The choice of the material for grounding conductors, electrodes and connections is vital as most of the grounding system will be buried in the earth mass for many years. Copper is by far the most common material used. In addition to its inherent high conductivity, copper is usually catholic with respect to other metals in association with grounding sites, which means that it is less likely to corrode in most environments.

### (c) Mechanically Robust and Reliable.

### 5.4 Acceptable Earth Resistance value

The acceptable Earth Resistance at earth busbar shall not be more than 1 ohm.

## 5.5 Components of Earthing & Bonding system

The components of Earthing & Bonding system are:

(a) Earth electrode,
(b) Earth enhancement material,
(c) Earth pit,
(d) Equi-potential earth busbar,
(e) connecting cable & tape/strip and
(f) All other associated accessories.

## 5.6 Design of Earthing & Bonding system

### 5.6.1 Earth Electrode

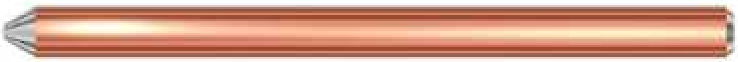


**Fig 5.1 Earth electrode**

(a) The earth electrode shall be made of high tensile low carbon steel circular rods, molecularly bonded with copper on outer surface to meet the requirements of Underwriters Laboratories (UL) 467-2007 or latest. Such **copper bonded** steel rod is preferred due to its overall combination of strength, corrosion resistance, low resistance path to earth and cost effectiveness.
(b) The earth electrode shall be UL listed and of minimum 17.0mm diameter and minimum 3.0mtrs. long.
(c) The minimum copper bonding thickness shall be of 250 microns.
(d) Marking: UL marking, Manufacturer's name or trade name, length, diameter, catalogue number must be punched on every earth electrode.
(e) Earth electrode can be visually inspected, checked for dimensions and thickness of copper coating using micron gauge. The suppliler shall arrange for such inspection at the time of supply, if so desired.

### 5.6.2 Earth Enhancement Material


**Fig.5.2 Earth enhancement Material**

Earth enhancement material is a superior conductive material that improves earthing effectiveness, especially in areas of poor conductivity (rocky ground, areas of moisture variation, sandy soils etc.). It improves conductivity of the earth electrode and ground contact area. It shall have following characteristics-

(a) Shall mainly consist of Graphite and Portland cement. Bentonite content shall be negligible.
(b) Shall have high conductivity, improves earth's absorbing power and humidity retention capability.
(c) Shall be non-corrosive in nature having low water solubility but highly hygroscopic.
(d) Shall have resistivity of less than 0.2 ohms-meter. Resistivity shall be tested by making a 20cm. cube of the material and checking resistance of the cube at the ends. The supplier shall arrange for such testing at the time of supply, if so desired. Necessary certificate from National/ International lab for the resistivity shall also be submitted.
(e) Shall be suitable for installation in dry form or in a slurry form.
(f) Shall not depend on the continuous presence of water to maintain its conductivity.
(g) Shall be permanent & maintenance free and in its "set form", maintains constant earth resistance with time.
(h) Shall be thermally stable between $-10^0$ C to $+60^0$ C ambient temperatures.
(i) Shall not dissolve, decompose or leach out with time.
(j) Shall not require periodic charging treatment nor replacement and maintenance.
(k) Shall be suitable for any kind of electrode and all kinds of soils of different resistivity.
(l) Shall not pollute the soil or local water table and meets environmental friendly requirements for landfill.
(m) Shall not be explosive.
(n) Shall not cause burns, irritation to eye, skin etc.
(o) Marking: The Earth enhancement material shall be supplied in sealed, moisture proof bags. These bags shall be marked with Manufacturer's name or trade name, quantity etc.

### 5.6.3 Backfill Material

The excavated soil is suitable as a backfill but should be sieved to remove any large stones and placed around the electrode taking care to ensure that it is well compacted. Material like sand, salt, coke breeze, cinders and ash shall not be used because of its acidic and corrosive nature.

## 5.7 Construction of Unit Earth Pit: Refer typical installation drawing no. **SDO/RDSO/E&B/001**.

(a) A hole of 100mm to 125mm dia shall be augured /dug to a depth of about 2.8 meters.
(b) The earth electrode shall be placed into this hole.
(c) It will be penetrated into the soil by gently driving on the top of the rod. Here natural soil is assumed to be available at the bottom of the electrode so that min. 150 mm of the electrode shall be inserted in the natural soil.
(d) Earth enhancement material (minimum approx. 30-35 kg) shall be filled into the augured/dug hole in slurry form and allowed to set. After the material gets set, the diameter of the composite structure (earth electrode + earth enhancement material) shall be of minimum 100mm dia covering entire length of the hole.

(e) Remaining portion of the hole shall be covered by backfill soil, which is taken out during auguring /digging.

(f) A copper strip of 150mmX25mmX6mm shall be exothermically welded to main earth electrode for taking the connection to the main equi-potential earth busbar in the equipment room and to other earth pits, if any.

(g) Exothermic weld material shall be UL listed and tested as per provisions of IEEE 837 by NABL/ ILAC member labs.

(h) The main earth pit shall be located as near to the main equi-potential earth busbar in the equipment room as possible.

## 5.8 Construction of Loop Earth by Providing Multiple Earth Pits

(a) At certain locations, it may not be possible to achieve earth resistance of ≤1ohm with one earth electrode /pit due to higher soil resistivity. In such cases, provision of loop earth consisting of more than one earth pit shall be done. The number of pits required shall be decided based on the resistance achieved for the earth pits already installed. The procedure mentioned above for one earth pit shall be repeated for other earth pits.

(b) The distance between two successive earth electrodes shall be min. 3mtrs. and max. upto twice the length of the earth electrode i.e. 6 mtrs. approx.

(c) These earth pits shall then be inter linked using 25X2 mm. copper tape to form a loop using exothermic welding technique.

(d) The interconnecting tape shall be buried at depth not less than 500mm below the ground level. This interconnecting tape shall also be covered with earth enhancing compound.

**Fig.5.3 Exothermic welded earth terminal**

## 5.9 Measurement of Earth Resistance

The earth resistance shall be measured at the Main Equi-potential Earth Busbar (MEEB) with all the earth pits interconnected using Fall of Potential method as per para 37 of IS: 3043.

## 5.10 Inspection Chamber

(a) A 300X300X300 mm (inside dimension) concrete box with smooth cement plaster finish shall be provided on the top of the pit. A concrete lid, painted black, approx. 50 mm. thick with pulling hooks, shall be provided to cover the earth pit.

(b) Care shall be taken regarding level of the floor surrounding the earth so that the connector is not too deep in the masonry or projecting out of it.

(c) On backside of the cover, date of the testing and average resistance value shall be written with yellow paint on black background.

### 5.11 Equipotential Earth Busbar and its connection to equipments & Surge protection devices in the Equipment room:

Refer typical bonding connections drawing no.SDO/RDSO/E&B/002.

#### 5.11.1 Equi-potential Earth Busbars

There shall be one equi-potential earth busbar for each of the equipment room i.e. IPS/Battery charger room and EI/Relay room. The equi-potential earth busbars located in individual rooms shall be termed as Sub equi-potential busbars (SEEB). The equi-potential earth busbar located in the IPS /Battery charger room and directly connected to Class 'B' SPDs and the main earth pit shall be termed as Main equi-potential earth busbar (MEEB).

The EEBs shall have pre-drilled holes of suitable size for termination of bonding conductors. The EEBs shall be insulated from the building walls. Each EEB shall be installed on the wall with low voltage insulator spacers of height 60mm. The insulators used shall have suitable insulating and fire resistant properties for this application. The EEBs shall be installed at the height of 0.5m from the room floor surface for ease of installation & maintenance. All terminations on the EEBs shall be by using copper lugs with spring washers.

### 5.12 Bonding Connections

To minimize the effect of circulating earth loops and to provide equi-potential bonding, "star type" bonding connection is required. As such, each of the SEEBs installed in the rooms shall be directly connected to MEEB using bonding conductors. Also, equipment/racks in the room shall be directly connected to its SEEB. The bonding conductors shall be bonded to their respective lugs by exothermic welding.

**5.13** All connections i.e., routing of bonding conductors from equipments to SEEB & from SEEBs to MEEB shall be as short and as direct as possible with min. bends and separated from other wiring. However, connection from SPD to MEEB shall be as short as possible and preferably without any bend.

**5.14** Materials and dimensions of bonding components for connection of individual equipments with equipotential bus bar and earth electrode shall be as given below.

| Component/Bonding | Material | Size |
|---|---|---|
| Main equipotential earth busbar (MEEB) | Copper | 300X25X6 mm (min.) |
| Sub equipotential earth busbar (SEEB) | Copper | 150X25X6 mm (min.) |
| Individual equipments to SEEB using copper lugs with stainless steel nuts and bolts. | Multi-strand single core PVC insulated copper cable as per IS:694 | 10 sq.mm |
| SEEB to MEEB using copper lugs with stainless steel nut and bolts. | Multi-strand single core PVC insulated copper cable as per IS:694 | 16 sq.mm |
| Surge protection devices (SPD) to MEEB using copper lugs with stainless steel nut and bolts. | Multi-strand single core PVC insulated copper cable as per IS:694 | 16sq.mm |
| MEEB to main earth electrode | Multi-strand single core PVC insulated copper cable as per IS:694 (Duplicated) | 35sq.mm |
| Main earth pit to other earth pit in case of loop earth | Copper tape | 25X2 mm |

**Drawing of Earthing & Bonding System**

The complete layout with dimensions of the earthing & bonding system shall be submitted by the supplier after commissioning.

**Warranty**

The supplier shall be responsible for complete supply, installation & commissioning of the earthing & bonding system. The warranty of such system shall be 60 months from date of commissioning. During this period, any failure of earthing system due to improper materials & bad workmanship shall be attended free of cost by the supplier.

**Maintenance of earthing & bonding system**

The maintenance schedule should cover verification of earthing system conductors and components, verification of electrical continuity, measurement of earth resistance, re-fastening of components and conductors etc.

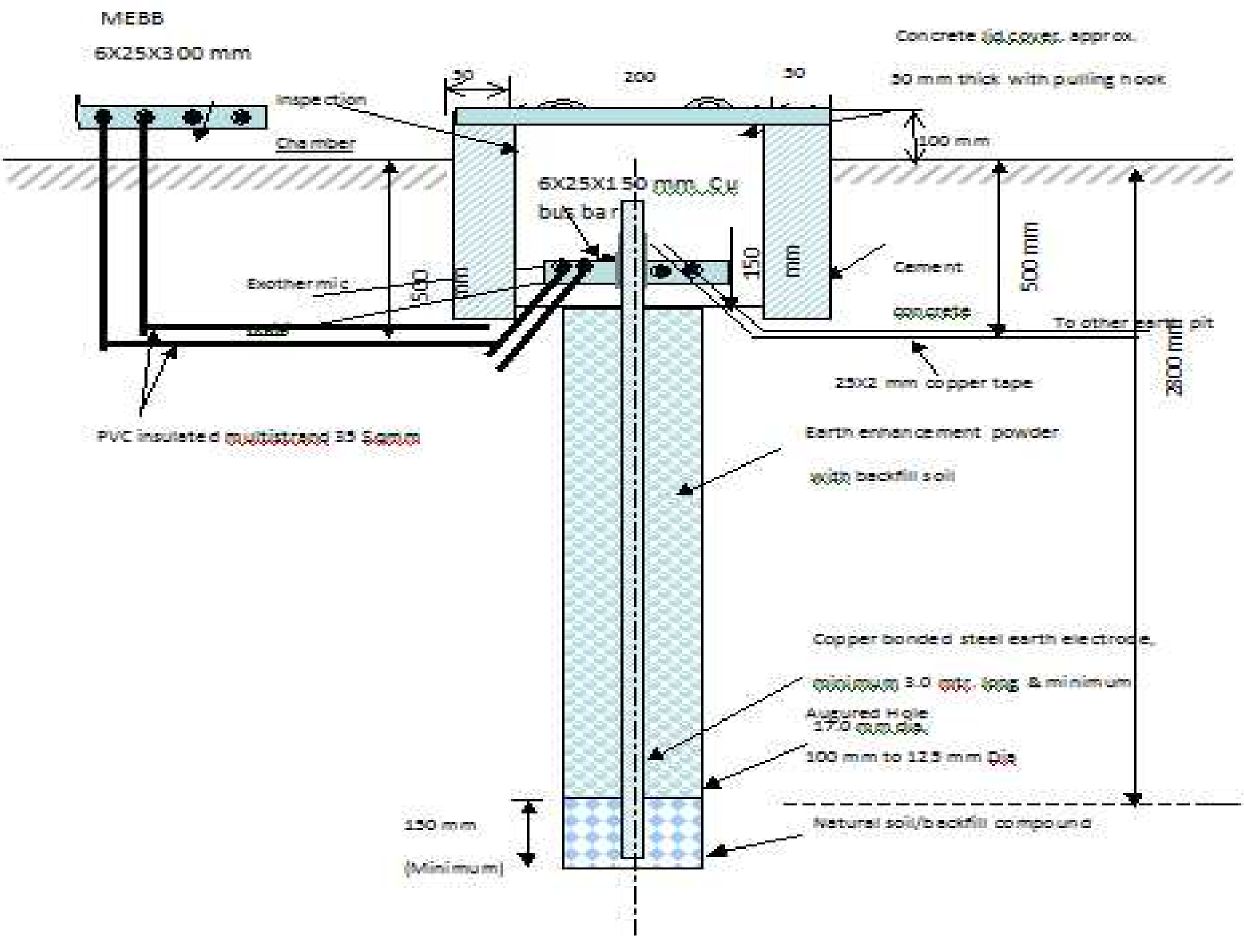



**Fig.1 Earthing arrangement for S & T installations**

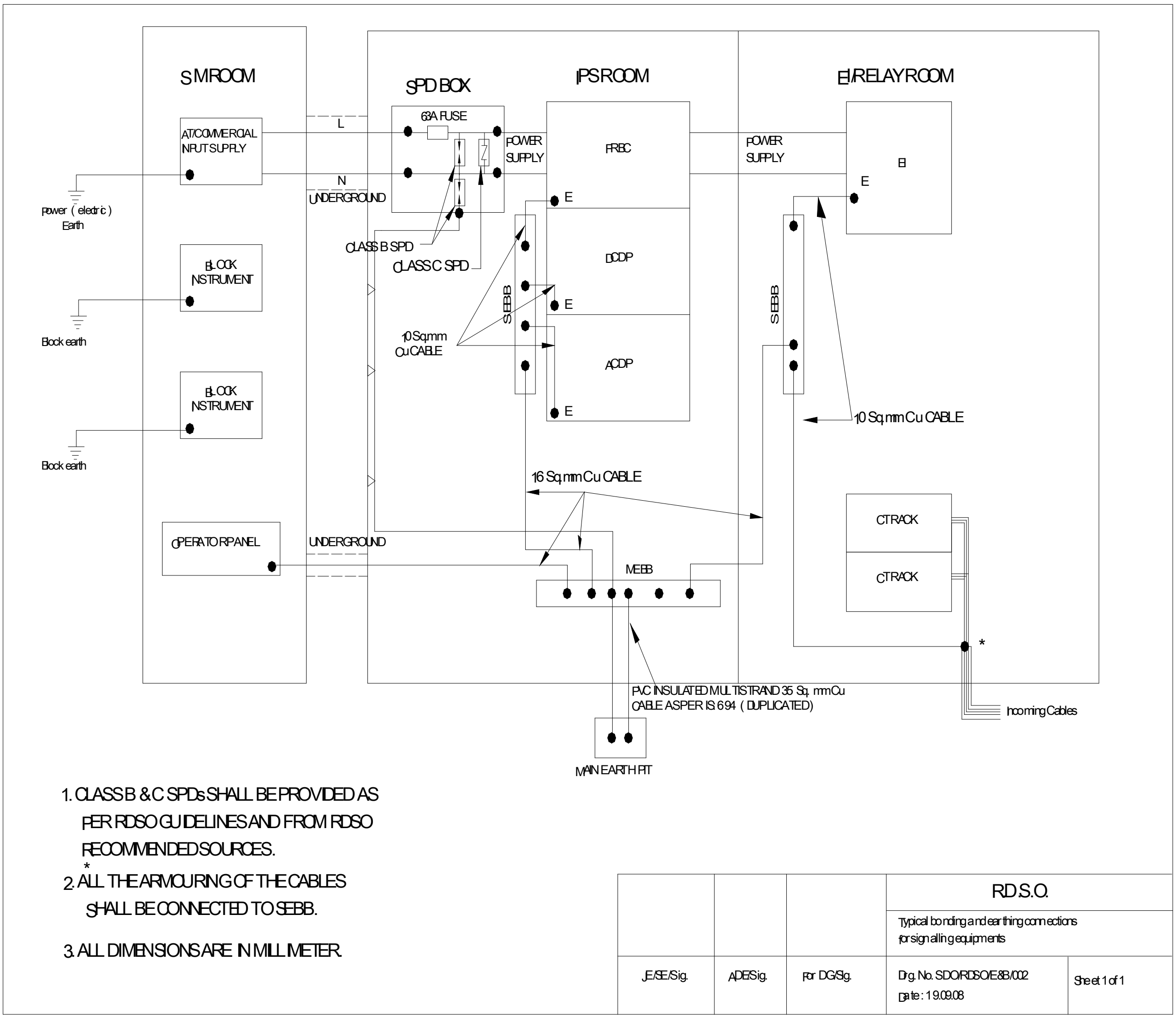



**Fig.2 Typical earthing and bonding arrangement for signalling installation**

**Objective:**

1) One of the characterisation of a good earthing system is ____________________________.
2) Sites not suitable for location of earth electrodes ___________________________________.
3) Acceptable earth resistance value at busbar is _____________________________________.
4) Mention any two components of earthing & bonding system __________________________.
5) Earth electrode shall be made of high tensible low carbon steel rods molecularly bonded with ______________________ on outer surface.
6) Earth enhancement material should be a __________________________ that improves earthing effectiveness.
7) The depth of an earth pit shall be about ________________________ meters.
8) Loop earth is constructed using _______________________________earth pits.
9) MEEB stands for __________________________________________________________.
10) Expansion of SEEB__________________________________________________________.

**Subjective:**

1) What is the importance of earthing?
2) Mention the characteristics of good earthing system.
3) What are the components needed for earthing and bonding system?
4) Explain the design of earthing and bonding system?
5) What is **Unit Earth Pit** and how do you construct it?
6) Explain the construction of loop earth.
7) Mention the material and their dimensions of bonding components.
8) What are the characteristics of earth enhancement material?
9) Why common bonding is required for S&T installations?
10) What is chemical earthing?

# CHAPTER-6

# SURGE PROTECTION DEVICES FOR TELECOMMUNICATION EQUIPMENTS

**(RDSO/SPN/TC/98/2011 Rev.0)**

This specification covers selection and testing of surge protection devices for protection of telecommunication/data line side of equipments of Indian Railways. The nomenclature used in this specification is generally as per IEC 61643-21.

## 6.1 General Requirements

**6.1.1** The device shall conform to IEC 61643-21/ ITU-T K11/12/30 or other equivalent International/ national standards for all the relevant clauses of that standard/recommendation and generally covering the parameters (or equivalent parameters) given in this specification.

**6.1.2** Radioactive materials or other harmful material must not be adopted for protective devices.

**6.1.3** Temperature rise in the operation of device shall not endanger personal safety.

**6.1.4** Electrical characteristics: The manufacturer shall submit the following parametric values for each model of SPD wherever they are applicable. These values shall be such that they will not affect the normal working of intended application:

- Insulation resistance
- Series resistance
- Capacitance
- Insertion loss
- Return loss
- Near End cross talk
- Current response time

**6.2 Terminal and connectors:** Terminal and connectors of the SPD shall meet the requirements as per IEC 61643-21 or other equivalent International/ National standards.

All the surge protective components used in the SPD (like GD tube, PTC etc.) shall conform to the relevant ITU/ IEC or any other similar standard/recommendation.

- The pluggable SPDs shall conform to vibration tests in plugged in condition.
- The pluggable SPD shall hold firmly when inserted in the base or IDC module, giving good electrical connection.
- Insulating parts of the housing shall be non-flammable / self extinguishing.
- The SPD shall reach its overstressed fault mode in a safe manner without causing fire hazard, an electrical hazard or emission of toxic fumes
- All earth leads shall be connected together inside the SPD and extended to the earth when inserted into the IDC module.
- Plugging in and plugging out the SPD shall not result in degradation of SPD performance.

### 6.3 Parameters of SPDs to be provided on telecom/data line side of the equipments:

Protection device for the subscriber line of the exchange for protection of subscriber line card. (To be provided at the first cable termination point nearest to the entry to Exchange room i.e. at MDF).

The device shall have voltage switching device like GD tube (voltage limiting device) and self restoring current limiting device like PTC as minimum components.

a) The arrester shall be pluggable into IDC module (insulation displacement connection module) commonly known as LSA disconnection block or KRONE type MDF/IDF. The device shall be complete with all accessories like arrangement for extending earth terminal etc.
b) Maximum Continuous DC voltage: 170 V
c) Nominal Current: 120 mA
d) Total nominal discharge current (8/20 µs pulse) : 10 kA
e) Nominal AC discharge / AC durability between line to earth both for current limiting and voltage limiting devices: 2.5 A rms for 1 sec.
f) Impulse limiting voltage/ Let through Voltage Line – Ground tested at 1 KV/µs pulse : 1000 V
g) DC spark over voltage: 230 V (-20% to +30%)
h) Operating temperature range : -10ºC to +60ºC
i) Relative humidity : 5% to 95%
j) Degree of ingress protection: IP 20.
k) Bandwidth: 2.3 MHz minimum
l) No of wires: One pair / 10 pairs
m) The voltage limiting device shall fail in short circuit mode and current limiting device shall fail in high resistance or open circuit mode.
n) Optional feature (if required by purchaser): Indication for High resistance/ open circuit state of current limiting device.

**6.4** Protection device for analog ports (2 wire/ 4 wire) of Primary digital Mux (For FXS/ FXO/ hot line/ 4 Wire E & M) To be provided at the first cable termination point nearest to the entry of PD Mux room. This device can also be used for protection of voice frequency circuits working like 2/4 wire DTMF telephone, 2 wire gate telephone. For 4 wire circuits, two 2 wire devices or one 4 wire device to be used. These devices are to be used for Modems, LAN Extender also**.**

Connection method: Screw/ screw less termination / Pluggable device along with base / Or LSA termination/ RJ 11 (As per purchaser’s requirement).

a) Maximum Continuous DC voltage : 170 V
b) Total nominal discharge current (8/20 µs pulse) : 10 kA
c) Impulse limiting voltage/ Let through Voltage Line – Ground tested for 1 KV/µs pulse: 1000 V
d) DC spark over voltage of voltage limiting component: 230 V (-20% to +30%)
e) Operating temperature range: -10ºC to +60ºC
f) Relative humidity : 5% to 95%
g) Degree of ingress protection: IP 20.
h) Bandwidth: 2.3 MHz minimum

i) No of wires : 2 wire/ 4wire
j) The voltage limiting device shall fail in short circuit mode.
k) Nominal load current: Not less than 120 mA.

**6.5 Data protection device for connection on the Ethernet LAN (10 Base-T, 100 Base –Tx) for protection of nodes.**

a) Max. continuous DC Voltage : 6 V DC
b) Total Nominal discharge current line-Ground (8/20 μs pulse): 2.5 kA
c) Impulse limiting voltage/ Let through Voltage Line – line (1kV/μs pulse): 18 V
d) Impulse limiting voltage/ Let through Voltage Line – Ground (1 KV/μs pulse): 1000 V
e) Operating temperature range: -10ºC to +60ºC
f) Relative humidity: 5% to 95%
g) Degree of protection: IP 20.
h) Connection method: RJ45
i) Bandwidth: 100 MHz
j) No. of wires: 4

**6.6 Data protection device for connection on the Ethernet LAN (10 Base-T, 100 Base –Tx) with Power over Ethernet for protection of nodes. This device can be used for IP based passenger amenities applications also.**

a) Max. continuous DC Voltage: 57 V DC
b) Total Nominal discharge current line-Ground (8/20 μs): 5 kA
c) Impulse limiting voltage/ Let through Voltage Line– line (1kV/μs pulse): 180 V
d) Impulse limiting voltage/ Let through Voltage Line – Ground for (1kV/μs pulse): 1000 V
e) Operating temperature range : -10ºC to +60ºC
f) Relative humidity: 5% to 95%
g) Degree of protection: IP 20 for Indoor application and IP 54 for outdoor applications.
h) Connection method: RJ45
i) Bandwidth: 100 MHz
j) No. of wires: 8

**6.7 Data protection device (as per IEC 61643-21) for connection on the Giga bit Ethernet (1000 Base -T) with for protection of nodes.**

a) Max continuous DC Voltage: 3.2 V DC
b) Total Nominal discharge current line-Ground (8/20μs): 2.5 kA
c) Impulse limiting voltage/ Let through Voltage Line– line (1kV/μs pulse): 10 V
d) Impulse limiting voltage/ Let through Voltage Line – Ground for (1kV/μs pulse): 1000V
e) Operating temperature range : -10ºC to +60ºC
f) Relative humidity : 5% to 95%
g) Degree of protection: IP 20.
h) Connection method: RJ45
i) Bandwidth: 500 MHz
j) No. of wires: 8

**6.8 Data protection device for connection on the Giga bit Ethernet (1000 Base - T) with Power over Ethernet for protection of nodes. This can be used for other IP based passenger amenities application also.**

a) Max. Continuous DC Voltage: 57 V DC
b) Total Nominal discharge current line-Ground (8/20μs): 5 kA
c) Impulse limiting voltage/ Let through Voltage Line– line (1kV/μs pulse): 180 V
d) Impulse limiting voltage/ Let through Voltage Line – Ground (1kV/μs pulse): 1000 V
e) Operating temperature range: -10ºC to +60ºC
f) Relative humidity: 5% to 95%
g) Degree of protection: IP 20 for Indoor application and IP 54 for outdoor applications.
h) Connection method: RJ45
i) Bandwidth: 500 MHz
j) No. of wires: 8

**6.9 Device for protection of RS 485 interfaces.**

a) Max continuous DC Voltage: 13 V DC
b) Total Nominal discharge current ((8/20μs) line-Ground: 10 kA
c) Impulse limiting voltage/ Let through Voltage Line – Line (1kV/μs pulse): 40V
d) Impulse limiting voltage/ Let through Voltage Line – Ground (1kV/μs pulse): 1000 V
e) Operating temperature range : -10ºC to +60ºC
f) Relative humidity : 5% to 95%
g) Degree of protection; IP 20 for Indoor application/ IP 54 for outdoor applications.
h) Connection method: screw/screw less terminal
i) Band width: 5 MHz
j) No of wires to be protected: 2
k) Nominal load current: 100 mA

**6.10 Device for protection of 25 watt VHF base station sets, to be provided on coaxial cable.**

a) Max continuous DC Voltage: 180 V
b) Nominal load Current: 1 Amp
c) Nominal discharge current ((8/20μs) Core-Ground: 10 kA
d) Impulse limiting voltage/ Let through Voltage Core – Ground (1kV/μs pulse): 1000 V
e) Operating temperature range: -10ºC to +60ºC
f) Relative humidity: 5% to 95%
g) Degree of protection: IP 20 for providing near the equipment and IP 54 for providing near antenna.
h) Connector: BNC / N / UHF connector or any other connector (As specified by the purchaser)
i) Bandwidth: 200 MHz Minimum
j) Insertion loss 0.2 dB maximum in 136-174 MHz
k) Power handling: 50 Watts
l) Characteristic impedance: 50 ohms

**6.11 For protection of power supply port of telecom devices working on 230 V AC and kept in users premises like yard masters room, ASM room etc,**

a) This device shall be housed to provide Min 3 Nos of 3 pin Indian style sockets.
b) 5.9.2 It shall be provided with indication regarding faulty/ healthy condition.

# ANNEXURE – I

**IEC and other standards regarding SPDs:**
Protection against lightning electromagnetic impulse:
**IEC 61312 – 1:** General principles
**IEC 61312 – 2:** Shielding, bonding and earthing inside structures.
**IEC 61312 – 3:** Requirement of surge protective devices.
**IEC 61312 – 4:** Protection of equipments in existing structures.

**IEC 62305-1 Part-1: Protection of structures against lightning, general principles:** It introduces terms and definitions, lightning current parameters, damages due to lightning, protection needs and measures, basic criteria for protection of structures and services as well as parameters simulating the effects of lightning on LPS components.

**IEC 62305-2 Part-2: Risk Management:** It introduces the risk assessment method, the assessment of risk components for structures and the services.

**IEC 62305-3 Part-3: Physical damage and life hazard:** It is related to lightning protection systems (LPS), protection measures against injuries of living beings due to touch and step voltages and it offers a guideline for design, installation, maintenance and inspection of LPS.

**IEC 62305-4 Part-4: Electric and Electronic systems within structures:** It considers the protection against lightning electromagnetic pulses, general principles, earthing and bonding inside structures, magnetic shielding and line routing, requirement of surge protective devices(SPD), protection of equipments in existing structures.

**IEC 62305-5 Part-5: Services:** Telecommunication lines (fiber optic lines and metallic conductor lines), power lines and pipelines are concerned.

**IEC 61643-1:** SPD performance requirements and testing methods.
**IEC 61643-12:** SPD selection and application principles.
**IEC 62305-LP:** Application of SPDs.

**UL 1449- Edition 3:** UL 1449 3$^{rd}$ edition applies to devices used to repeatedly limit transient voltages on 50/60 Hz circuits 1000 volts and below. This is an increase in voltage from 2$^{nd}$ edition which covered devices 600 volts and below.

**ANSI/IEEE C62-41:** The recommended practice covers the origin of surge voltages, rate of occurrence and voltage levels in unprotected circuits, wave shapes of representative surge voltages, energy, source and impedance.

**AS/NZS 1768-2007: Lightning protection:** This standard sets out guidelines for the protection of persons and property from hazards arising from exposure to lightning. The recommendations specifically cover the following applications.

(a) The protection of persons, both outdoors, where they may be at risk from the direct effects of a lightning strike, and indoors, where they may be at risk indirectly as a consequence of lightning currents being conducted into the building.
(b) The protection of a variety of buildings or structures including those with explosives or highly flammable contents and mines.
(c) The protection of sensitive electronic equipment (e.g. fax machines, modems, computers) from over voltages resulting from a lightning strike to the building or its associated services.