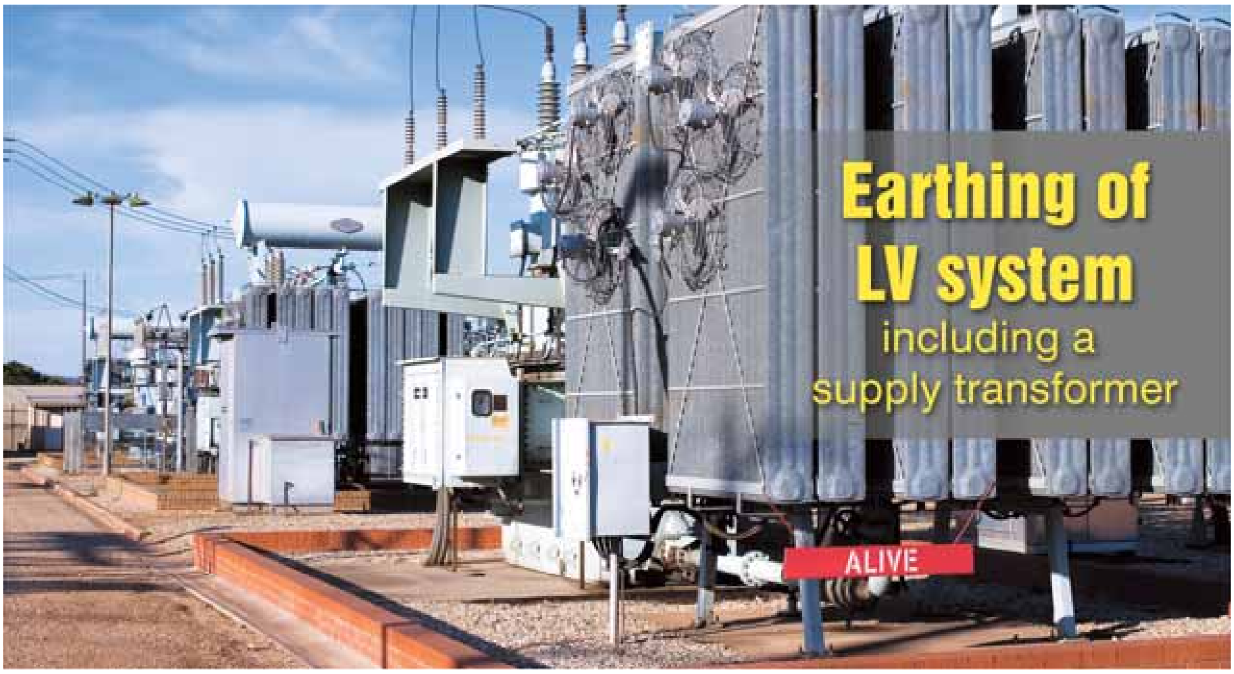
Earthing of LV system including a supply transformer



Earthing is done as per IS3043 since several decades. Section 3 of IS3043 explains about the earth fault protection requirement in a consumer installation.

Mis interpretation of IS3043

General practice followed is to connect body and neutral of transformer to separate earth pit (either rod/pipe or plate) in soil. Equipment such as panels, UPS, Lift etc are connected to different earth pits as well. Typically in a modern IT office complex, 100's of such earth pits,each for specific equipment is installed and maintained.

Often users demand special earth pits called as chemical earth / pipe in pipe earth / digital earth etc, believing that these earth pits brings safety. Earth electrodes tested to handle very high short circuit current of up to 50 kA is also on demand, claiming the fault current at LV side of transformer is 50kA. Often electrical engineers are happy and proud if they make an earth pit with a resistance nearing 1 ohm, finally bringing the subject of earthing to the performance of an earth pit.

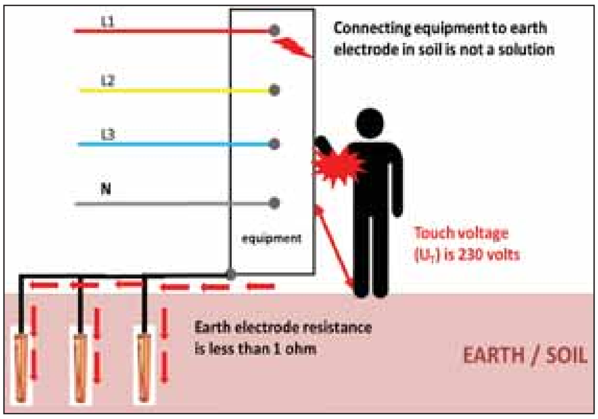
Unfortunately IS, IEC or any other recognized standards ask for direct connection of every equipment to earth pits in soil. Too much concentration on separate earth pits increases the chance of fire and accidents in a building. Unfortunately standard enforcing agencies recommend this wrong method of earthing even in Oil and petroleum industry, which may lead to catastrophic accident.

Two mis-concepts of earthing which compromise safety

- General belief - connecting equipment to an earth electrode in soil with a less resistance to bring safety of the equipment and human being.
- Reduced earth resistance means fault current goes safely to soil without creating damages.

Both these concepts do not bring benefit to the user, but divert the subject of safety to an undesired direction. Almost every "fire due to short circuit" is due to the above concept followed all over the country. Utilities, safety officers, safety auditors, designers …… etc. are equally responsible for the above mis-concept which increases the chance of accidents due to electricity for human beings and equipment.

Fig 1: Touch voltage (ref table 1) create shock hazard even if the equipment is connected to a low resistance earth electrode.



IS3043 is one of the most user friendly standards available worldwide. The standard explains reason for each requirement to achieve safety, which is rarely found in other international standards. IS3043 is the most mis-interpreted standard for LV application. (eg IS3043 do not recommend to connect transformer neutral and body directly to earth electrode in soil for LV application, but mis-understood widely)

IEEE 80

One of the new trends of earthing in LV power supply transformer is to create an earth grid in soil calculated as per IEEE80 standards. Large sized earth grids are installed, calculated based on LV side fault current (up to 50 KA) and soil resistivity in order to reduce the touch and step potential during fault. The fact being, IEEE80 is applicable to substations and not to supply transformer of an LV system. IS3043 in clause 22.2.4 explains to make earth grid to reduce touch and step potentials for EHT substations, practically from 66kV onwards. Use of IEEE 80 to make an earth grid for LV system including a transformer is wrong.

Requirement as per IS3043

Basic and fault protection (direct and indirect contact) can be achieved by several measures. IS3043 primarily explains about protection of earthed and unearthed system by equipotentialisation and automatic disconnection of supply. Automatic disconnection protects against touch voltage and heating of conductors. This method necessitates coordination of system earthing and characteristics of protective devices.

Earthing starts with the power supply, which is earthed in order to get stable voltage between live conductors and earth. As a result of the earthed supply, exposed and extraneous conductive parts in an installation may experience large potential differences during an earth fault. Protective measures shall ensure disconnection of supply with in certain time (Table-1). During this time exposed and extraneous conductive parts shall not experience a potential difference harmful enough to create an accident such as an electric shock.

For the purpose of safety and reliability, earthing system is divided in to various types of networks (called as system earthing) such as TN, TT and IT. Out of the three

- TN – Fault current return though the protective conductor to earthed terminal of transformer. OCPD does the job of automatic disconnection of supply.
- TT – Fault current return through soil. As a result higher fault currents are not possible and every installation need an earth fault protector such as an RCD.
- IT – is un earthed system which is not supposed to create an accident during the first fault. Installations where continuity of supply is important than disconnection of supply, IT supply can be used.
- TN systems are further divided into TN-C, TN-S and TN-C-S

Table 1

Disconnecting Times For Different Touch Voltages (IS3043, IS 732 & NEC SP:30-2011)						
Prospective Touch Voltage Uc	Condition 1(DRY)			Condition 2(WET)		
	Z1 I t			Z2 I t		
(V)	(Ω)	(mA)	(s)	(Ω)	(mA)	(s)
25	—	—	—	1075	23	5.000
50	1725	29	5.000	925	54	0.470
75	1625	46	0.600	825	91	0.300
90	1600	56	0.450	780	115	0.250
110	1535	72	0.360	730	151	0.180
150	1475	102	0.270	660	227	0.100
220	1375	160	0.170	575	383	0.035
280	1370	204	0.120	570	491	0.020
350	1365	256	0.080	565	620	—
500	1360	368	0.040	560	893	—
1 Dry or moist locations, dry skin and significant floor resistance.						
2 Wet locations, wet skin and low floor resistance.						

Unawareness about the type of system earthing and its applicability, public electricity distribution is complicated used by utility. Internationally the accepted methods are TN-C-S or TT for public electricity distribution and TN-S for industrial installation. The new draft amendment, CEA regulation insist TN systems. In the existing regulations, earthed neutral terminal explained shows the network is TN-C-S with PME, which is nothing but the system, followed in UK. Requirements in the regulation are mis-interpreted and often TT networks are used in LV public electricity distribution (some time along with earthed neutral in distribution). As a result of wrong use, protective device inadequate and often do not disconnect the supply during fault, resulting in accident such as fire and electrocution.

Occurrence of an earth fault in an installation creates potential difference between simultaneously accessible exposed and extraneous conductive parts creating shock hazard. Fault current cause an excessive temperature rise creating fire hazard as well.

Earthed equipotential bonding and automatic disconnection of supply recommended in IS3043 provide a high degree of protection against both hazards. In TN system, the earth fault loop impedance has to be low enough to allow adequate earth fault current to cause an over current protective device (eg. Fuse, MCB) to operate in a sufficiently short time (table 1).

Fig 2: Safety by automatic disconnection of supply is achieved by tripping the main protective device (OCPD)such as fuse/ mcb/mccb within the prescribed time (ref table 1)

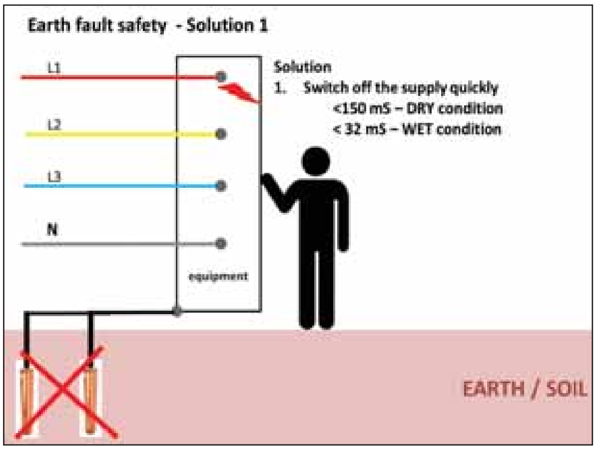


Fig 3: Safety by barrier (not a subject of IS3043). Earth electrode in soil is not important

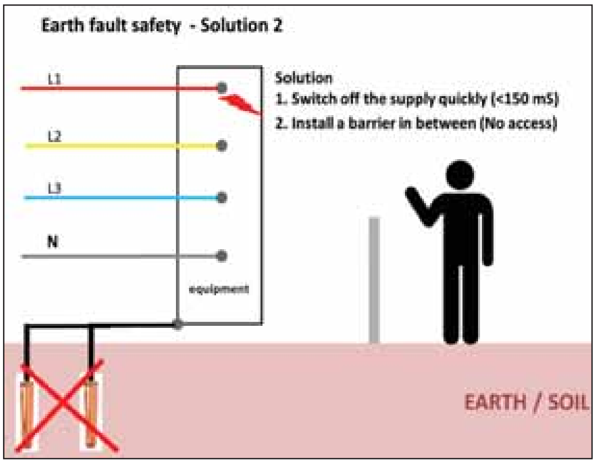


Fig 4: High floor resistance (not a subject of IS3043). Earth electrode in soil is not important

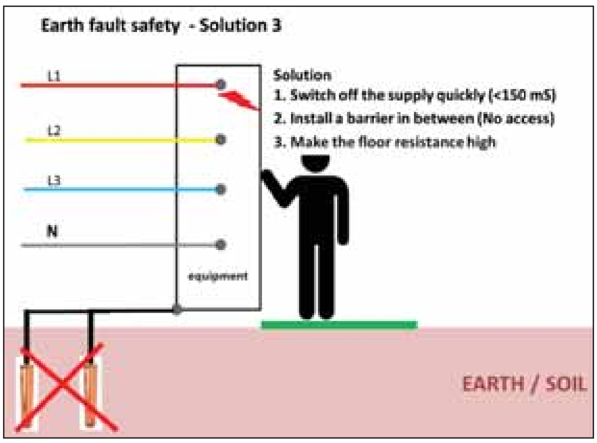


Fig 5: Floor equipotentialisation. Earth electrode in soil is not important

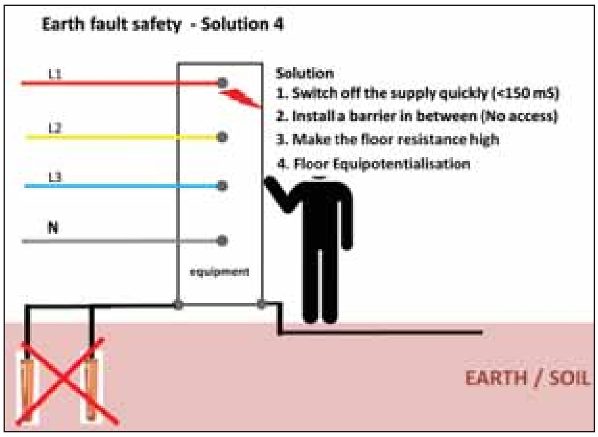
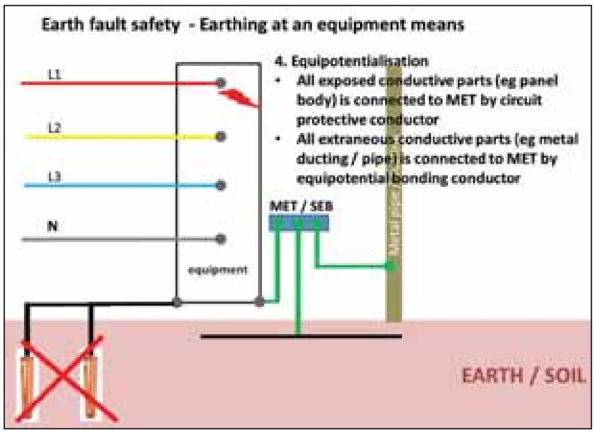


Fig 6: Correct way of equipment earthing as per IS3043. Earth electrode in soil is not important



Safe electrical system as per IS3043

Earthing for "Safety" is achieved by routing earth fault current back to the source ensuring "Automatic disconnection of power supply with in the stipulated time" by the protective device. Delayed disconnection of fault result in electrical hazard.

Fault current returning back to neutral of the source via the fault (or faulty device) is the fault loop. Fault loop impedance determines the amount of loop current, which influences the disconnection time. IS 3043 and IS 732 provide information on fault loop impedance calculation and protective device selection. Fault loop impedance with in the limit ensures safety by allowing sufficient fault current to flow, due to which the protective device automatically disconnects the supply. As per IS 3043 in a TN network "the characteristics of protective devices and the cross sectional area of the conductor shall be so chosen that if a fault of negligible impedance occurs anywhere between phase conductor or exposed conductive part and protective conductor, automatic disconnection of the supply will occur within possible minimum time".

Fault loop impedance is the important factor deciding the fault current, which in turn decide the disconnection time of protective device. IS 3043 explains that the loop impedance need to be calculated or measured in every circuit. Further it explains "In general, every circuit is provided with a means of over current protection. If the earth fault loop impedance is low enough to cause these devices to operate within the specified times (that is, sufficient current can flow to earth under fault conditions), such devices may be relied upon to give the requisite automatic disconnection of supply. If the earth fault loop impedance does not permit the over current protective devices to give automatic disconnection of the supply under earth fault conditions, the first option is to reduce that impedance. It may be permissible for this to be achieved by the use of protective multiple earthing or by additional earth electrodes.

Earth electrodes shall be used at the TN-C part of the public electrical distribution (earthed neutral conductor or PEN conductor earthed throughout the public electricity distribution). Protective multiple earthing (PME) as an earth grid used in the TN-S part of the network is an additional measure to reduce fault loop impedance which offers high degree of safety.

Conclusion

For 230/400 volt application including a supply transformer

1. Earth grid as per IEEE80 is not applicable for LV system including a supply transformer.
2. Connecting transformer Neutral separately to one or two earth electrode in soil is wrong.
3. Connecting transformer body separately to one or two earth electrode in soil is wrong.
4. Connecting electrical apparatus (panels, UPS, lift etc) separately to an earth electrode in soil is wrong.
5. Above measures (2 to 4) create serious accidents. IS3043 do not recommend to make such connections.
6. Earthed equipotential bonding and automatic disconnection of supply is the correct way of earthing. For this purpose in TN network, protective conductor is more helpful to achieve safety. Vertical earth electrodes such as rods/pipes/plates in soil are additional to create equipotential is at ion.
7. Safety is achieved by implementing one of the established network (system earthing) as per IS3043 and installation of proper protective device.
8. Measurement of fault loop impedance and ensuring disconnection of protective device in every circuit is mandatory as per IS3043.

Note: This paper is specific about earthing as per IS3043, misinterpretation of IS3043 and IEEE80 standard. ■

Mr. S. Gopakumar

Managing Director of CAPE electric pvt ltd. Member of National Building Code (NBC-2016)