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Post-Show Report

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COVID-19
Stay Safe

Neutral to Earth potential, Safety Hazards and Digital Grounding

Note: This article relies on the established standards and methods adopted universally and it considers the solidly earthed low voltage supply, which is common in the industrial and commercial premises.

Current flowing through the protective conductor (earth wire) during normal conditions is always a threat to electrical safety in Low Voltage installations. A continuous current flow through protective conductor more than a threshold level creates accidents such as shock, sparks, and fire. Although functional earthing is essential to minimize the neutral to earth potential in sensitive devices and electronic gadgets, there is no compromise in the provision of protective earthing and equipotential bonding to safeguard the equipment and personnel. The role of protective conductor and equipotential bonding is hence imperative and mandatory.

Observance of the following conditions are to be fulfilled for the avoidance risk to the occupants:

1. Minimum Insulation resistance between Live conductors (line and neutral together) and protective conductor shall be higher than 1 MΩ.
2. Maximum PE Conductor Current in equipment (not due to a fault in a.c system) is as per the following Table 1. Additional safety measures like reinforced insulation of equipment, safety extra low voltage system, reinforced equipotential bonding etc. shall be necessary when the limits prescribed in the Table are exceeded.

Table 1: Maximum PE conductor current in equipment	
Rated current of equipment	Maximum PE current
0 to 2 A	1mA
2A to 20 A	0.5 mA/A
Higher than 20 A	10 mA

Table 1: Example of PE conductor current in permanently connected equipment

3. Isolating device having a leakage current across open poles exceeding 6 mA per pole is determined as the end of its life.
4. It is also recommended not to use TN-C system inside a building, where Neutral and Protective conductors are combined, due to various reasons including non-effectiveness of RCD's.

These recommendations are to ensure NIL/Minimum protective conductor current.

The minimum insulation resistance of 1 MΩ between Neutral, and Earth means the neutral and earth shall be separate downstream the point of commencement of supply. Inappropriate connection of neutral and protective conductor will lead to partial neutral current flow through the protective conductor. Electrical installation shall avoid this neutral circulating current, if not, is certainly a violation of electrical safety.

> Quote from IEEE142 "In a commercial or industrial building the neutral or grounded circuit conductor is connected to ground at the service equipment (main panel) and at the secondary side of a separately derived system (isolation transformer). It is not unusual to find the branch circuit distribution panel neutral bus bar connected to the metallic panel frame (ground), which is a violation of the NEC. One study showed 20% of the neutral conductors accidentally faulted to ground in circuits supplying lighting fixtures. With multiple connections of the neutral conductor to ground on the same power system, a portion of the load current flowed on the equipment grounding system to which the electronic equipment was referenced. This current flow transferred voltages into the grounding system of the electronic equipment, causing errors or worse".

Neutral to earth voltage – a case study.

The typical installation where the case study is made, due to the unbalance in load (and due to single phase loads), Neutral current exist (varies depending upon the variation in connected load), which produced a voltage between 5 and 8 volts between Neutral and PE conductor.

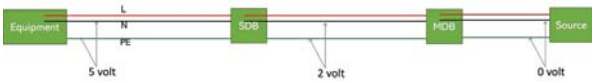


Fig 1: Example of N to PE voltage due to Neutral current

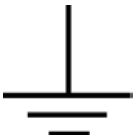
Neutral to earth voltage–Is it a problem???

There is an apprehension within the electronics engineers that the voltage between neutral and earth creates malfunction and failure in electronic equipment, as a result engineer working in the field of electronic equipment always recommend a neutral to earth voltage less than 1 volt. Such a generic assumption of neutral to earth voltage and any nonstandard mitigation does not have any technical ground, the fact remains,

Class 1 Electronic equipment which require functional earthing shall have separate Protective earth terminal (PE) and functional earth terminal (FE).

Class 2 and Class 3 equipment doesn't require protective earthing, but functional earthing may be required.

It is the responsibility of the manufacturer to provide proper marking based on the safety / functionality requirement in the terminals of those equipment.



No. 5017 Earth: To identify an earth terminal in cases where neither the symbol 5018 nor 5019 is explicitly stated.

No. 5018 Functional earth (FE): To identify a noiseless (clean) earth terminal, of a specially designed earthing system to avoid causing malfunction of the equipment. e.g. connection of sensitive electrical equipment or circuits directly to the PE conductor or to a functional earthing conductor (FE), to minimize common mode disturbance.

Note: If the internal electronics of an equipment require a reference voltage to operate, FE terminal is necessary.

No. 5019 Protective earth (PE): To identify any terminal which is intended for connection to an external conductor for protection against electrical shock in case of a fault, or the terminal of a protective earth electrode. (e.g. protective conductor connecting point to an electrical equipment).

Fig 2: earthing symbols, reference numbers and specific application.

A class 1 equipment may require separate terminals with symbols 5018 and 5019, depending upon its design. Class 2 and Class 3 equipment doesn't require PE, if FE is necessary, appropriate markings shall be included in the product. However, in all the cases voltage between neutral and PE conductor is irrelevant. Remember in an IT system with distributed neutral, the voltage between N and PE can be up to 230 volts.

Misunderstanding: Neutral to earth voltage is due to poor neutral earthing	Fact: Neutral to earth voltage is due to current flow in neutral conductor and its resistance.
An equipment without any protective earth connection may show a voltage between neutral and body of that equipment, however is solved by connecting the equipment to PE conductor	

(Note: PE and FE will be explained in a separate article)

False claim of Digital Grounding as a solution to reduce N and PE voltage

The device called Digital Grounding Device or Intelligent Grounding Module is used in places where electronic devices are installed, especially in Telecommunication sites, control and process plants and industrial automation to reduce the voltage between N and PE.

The Device and the Claim: The Digital Grounding device consists of a plastic box, with 3 phase input through a 2.5 sq.mm. long wire, a busbar mounted outside the box which can accommodate about 10 connections of M8 Bolt and a surge counter (as fig 3). The claim is, these devices doesn't require connection to an earth electrode. In addition, it is claimed that this device will eliminate the potential between Neutral and PE conductors in the installation. It protects the connected electronic device against harms from Neutral to earth voltage, problems due to earthing and from transient and lightning surges. At the outset it looks like a fantastic solution for solving multiple problems faced by the electronic and telecommunication installation.

Fig 3: Digital Grounding Device installed in an industry.

According to the manufacturer, internally the device consists of electrodes which dissipate the current from neutral, nullifying the current. As a result, the Digital Grounding Device reduces the voltage between Neutral conductor and PE conductor in an electrical installation. It is also a mandatory condition that this device is used within 5 meters close to the equipment which require N to PE voltage less than 1 volt.

In practical, the device is having 3 lines + neutral input connected by a 2.5 Sq.mm. wire through 63 amps 4 pole MCB as shown in the picture. It has a busbar mounted outside the box, where all earth conductors from nearby equipment are connected.

The Installation

The typical installation where the case study is made, the device is installed closer to control panels of a process machine. This device reduced the voltage between Neutral and Earth conductors to a low level. While inspecting it is found that when the device is installed, the neutral and earth conductors are getting shorted. As a result, the voltage between these conductors become zero.

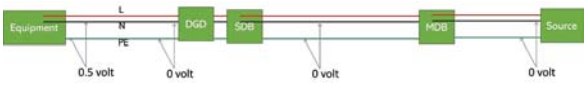


Fig 3: N to PE voltage after installing Digital Grounding Device

Practically due to DGD, the lines from transformer up to this device become TN-C. Partial neutral current flows through the earth conductor.

This kind of a network (combining PE and Neutral) inside consumer premise will lead to the following problems.

- Electrical shock due to voltage and continuous current flow at protective conductor.
- Fire due to sparks in the earth wire (while doing maintenance or due to loose contact or due to change in current).
- EMC issues (e.g. Communication devices will malfunction and fail)

This voltage is often termed as noise and there are several ways for mitigation without violating the earthing arrangements prescribed in the standards. Any nonstandard means of mitigations like dedicated earth electrode, interconnecting neutral and earth at the downstream locations apart from the source earthing can, camouflage the situation temporarily and such a practice can create danger to the occupants.

Also, provision of multiple earth electrode does not have a role in reducing the neutral potential.

Such nonstandard methodology cannot be applied for the mitigation of radiated emissions, where the

noise voltage is impressed in the supply and signal system due to electric, magnetic, electrostatic and electromagnetic interferences.

TN-C is banned inside an installation in several countries, however in India such a regulation doesn't exist. IS732 explained the ill effects in several clauses as below. In the case of an inappropriate design of an installation forming part of a TN system with multiple sources some of the operating current may flow through unintended paths. These currents may cause fire, corrosion and electromagnetic interference.

Quotes from IS732

4.5.4.4.3.1 It is recommended that TN-C systems should not be maintained in existing buildings containing, or likely to contain, significant amounts of information technology equipment. TN-C-systems shall not be used in newly constructed buildings containing, or likely to contain, significant amounts of information technology equipment.
NOTE — Any TN-C installation is likely to have load or fault current diverted via equipotential bonding into metallic services and structures within a building.
4.5.4.4.3.2 In existing buildings supplied from public low-voltage networks and which contain, or are likely to contain, significant amounts of information technology equipment, a TN-S system should be installed downstream of the origin of the installation (*see* Fig. 31). In newly constructed buildings, TN-S systems shall be installed downstream of the origin of the installation (*see* Fig. 31).
4.5.4.4.3.3 In existing buildings where the complete low-voltage installation including the transformer is operated only by the user and which contain, or are likely to contain, significant amounts of information technology equipment, TN-S systems should be installed (*see* Fig. 32).
4.5.4.4.3.4 Where an existing installation is a TN-C-S system (*see* Fig. 33), signal and data cable loops should be avoided by
a) changing all TN-C parts of the installation shown in Fig. 33 into TN-S, as shown in Fig. 31, or
b) where this change is not possible, by avoiding signal and data cable interconnections between different parts of the TN-S installation

The other claims of DGD are as an effective Surge arrester, limit voltage due to reverse current and it measure earth electrode resistance.

DGD as a Surge Protector (240 kA surge arrester)

It is a mandatory requirement that every surge protector connected parallel to the line shall have a maximum lead length of 500 mm. Higher lead length create more voltage drop in the connecting wires, resulting in non-operation. In this case, the lead length was more than 5 meters, as a result the device cannot be considered as an affective surge arrester. In contrast this device could be a possible source of fire and accident in the industry due to fault current flow through 2.5 sq.mm neutral conductor, Line to neutral short circuit current flowing to the PE conductor through the 2.5 sq.mm neutral conductor, non-operation of 63 Amps MCB in case of a fault/short circuit inside DGD.

DGD as a monitor to measure earth electrode resistance

It is a fact that electrical engineers expect a low resistance for every earth electrode in soil and monitoring this resistance looks fantastic idea. Every failure in electrical and electronic system is blamed due to poor earthing. However, the fact is "**earth electrode resistance doesn't have any role in safety and reliability of an electrical or electronic system in an installation with TNS earthing arrangement**". Hence the question to be asked is "**what is the purpose of monitoring earth electrode resistance**"??.

Conclusion

1 Neutral to earth voltage is due to neutral current from unbalanced/single phase loads.

2 DGD installed in the premise where the case study is made, failure in customers electronics continued even after installing DGD, which is an indication that DGD are useless.

3 DGD could create serious safety hazards due to neutral circulating current (electrocution and fire) anywhere in the premise.

4 Partial Fault current will flow through neutral, the connected 2.5 sq.mm wire may not be able to withstand the fault current and could ignite fire.

5 Partial short circuit current (L to N) will flow through PE conductor, The connected 2.5 sq.mm wire may not be able to withstand the fault current and could ignite fire.

6 MOV's in a surge protector are supposed to end the life in short circuit. These devices require protective measures against internal short circuit. However, the 2.5 sq.mm wires and the 63 amps MCB mismatches this requirement. This is also a possible cause of fire.

7 DGD as a device to reduce voltage between N and PE will lead to disaster, hence it is strongly recommended to ensure a minimum insulation resistance of 1 MΩ between N and PE conductors.

8 Digital grounding is a baseless propagation of eliminating neutral to earth potential, could become a dangerous practice if adopted. ■

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Member
IEC TC64 (LV electrical installation) MT3, MT12, MT40, MT41, PT60364-8-3, WG43.
TC 81 (Lightning protection) MT 3, MT 14, WG 18, AHG 19, MT 21.
SC 37 A (SPD's) WG03 & 05.
BIS Electrical committee (NBC-2016), ETD 20 (NEC, IS3043, IS732), ETD 30 & ETD 50