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NATIONAL FEDERATION OF ENGINEERS FOR ELECTRICAL SAFETY

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Practical guide on

ELECTRICAL SAFETY AUDITS IN HOSPITALS

Based on

National Electrical Code of India 2023 (SP-30)

Including legal requirements of electrical safety in Hospitals and Medical locations

Guide on ELECTRICAL SAFETY AUDITS IN HOSPITALS

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Author: S Gopa Kumar, National President, NFE.
Published for the awareness on electrical safety in Hospitals.
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About the author

This guide is prepared by S. Gopa Kumar, National President of NFE. He is a member in MT 40, TC 64 of IEC responsible for maintaining IEC 60364-7-710 and ETD 20 of BIS responsible for NEC 2023 & IS17512. The contents of this guide are from various IS, IEC and ISO standards.

In case of clarifications or queries, readers are requested to notify gopa0904@gmail.com.
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National Federation of Engineers for Electrical Safety

About NFE: National Federation of Engineers for Electrical Safety (NFE) is an organization founded by esteemed professionals dedicated to enhancing electrical safety in the country. Within one year of time, we have got more than 1200 members. NFE is a registered society and a not-for-profit organisation.

VISION: To make every electrical installation free of accidents such as electrocution and fire due to short circuits and increasing the reliability of the electrical installation, thus contributing to the saving of life and property and supporting sustainable development.

MISSION: We shall strive to achieve our vision through getting accredited for product and personnel certification which shall focus on electrical safety by design, manufacturing, installation and maintenance of electrical product & installation by competent and qualified manpower using quality resources including product, processes and procedures.

ESPCS Scheme: Electrical Safety Professionals Certification Schemes (ESPCS) of NFE provide a platform for certification of skills and competency of professionals working in Electrical design, Electrical installation and Electrical Safety Verification based on ISO 17024. NFE certified ESPCS professionals can be utilized for designing, erection and initial verification of Electrical Installations.

FLIT Professionals: Fault Loop Impedance Test (FLIT) is a part of Verification to ensure efficiency of automatic disconnection of supply, thereby ensuring some amount of safety against electric shock and thermal effects (fire) in Low Voltage Electrical Installations. FLIT is included in the CEA safety Regulation 2023 as a mandatory test in every electrical installation. Modern electrical safety standards (Including NEC 2023, IS 17900 - Lifts, IS 732, IS 3043) demand verifying the efficiency of automatic disconnection during commissioning and periodically. NFE certified FLIT professionals can be utilized for safety audits, to ensure electrical safety audits in Hospitals.

PREFACE

Electrical infrastructure in India is increasing rapidly, so is the number of accidents due to electricity. It is seen that one out of two fire accidents in buildings are attributed to electrical reasons such as a short circuit. The loss of properties due to fire from electricity is not yet ascertained, however it's worth 1000's of crores annually. Many of these accidents happen in a low voltage (LV) system.

Electrical Installation in Hospitals and medical locations are critical due to the working environment and sensitivity such as:

- WET Areas, where the chance of electric shock is high for the patient and the medical staff,
- Life supporting equipment connected to patients having applied parts bypassing skin,
- Oxygen enriched areas, where the chance of fire is high,
- Highly sensitive electronic systems,
- Medical electrical equipment or system, vulnerable to Electro Magnetic Environment (EMI),
- Availability of power and stand-by power, change over etc.
- Safety services and challenges in evacuation.

This guide is conceived to be used as a guide on "Electrical Safety Audits in Hospitals". The guide also covers several mandatory safety requirements in medical locations in Annex B.

This guide explains safety rules in NEC 2023, IS732, IS17512, IS 13450-1 and IS/IEC 62353. Electrical installations and equipment complying to these standards offer a high degree of electrical safety and reliability.

Each of the referred standard have their own requirement of verification, which are covered in this guide.

This guide will be a handy tool for any person interested in planning or conducting an electrical safety audit in Hospitals. Annex B can be used for designers to have an idea on electrical safety requirements in Medical Locations.

For any technical clarification on the guide, users are requested to directly contact gopa0904@gmail.com. This document will be continuously updated. Hence users are required to download the latest version of the Guide from publications www.nfees.org

ACKNOWLEDGEMENTS

This handbook is the culmination of collective insights and standards developed by numerous organizations dedicated to electrical safety. We, The National Federation of Engineers for Electrical Safety, extend our deepest gratitude to the following bodies for their invaluable contributions.

Central Electricity Authority (CEA), for their comprehensive Regulations on Electrical Safety.

Bureau of Indian Standards (BIS), for their role in harmonizing the Indian standards with international best practices, ensuring a global standard of safety.

International Electrotechnical Commission (IEC), for their comprehensive international safety standards which have been a guiding framework.

The Directorate General of Health Services (DGHS) for their technical advice on public health, medical education and health care in India.

National Accreditation Board for Hospitals & Healthcare Providers (NABH) for establishing and operating accreditation programme for healthcare organisations.

Association of Healthcare Providers (India) for their work to educate its members and at the same time, advocating with the government, regulatory bodies and other stake holders on issues relating to Universal Healthcare Services.

Consortium of Accredited Health Care Organizations (CAHO) for their work in transforming healthcare quality and safety.

We also acknowledge the efforts of all the electrical engineers, technicians, and safety officers whose daily diligence in adhering to these standards ensures a culture of safety at the workplace. Their commitment to excellence is the backbone of our handbook.

Last but not the least we profusely thank all members of the NFE for their positive suggestions in enhancing the value of this handbook.

Suggestions for the improvement of the Handbook are most welcome and may be sent to gopa0904@gmail.com with the subject heading “Electrical Safety Audits in Hospitals”.

S Gopa Kumar,
National President,
National Federation of Engineers for Electrical Safety,
Chennai, India.

प्रो.(डॉ.) अतुल गोयल
Prof. (Dr.) Atul Goel
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DIRECTOR GENERAL OF HEALTH SERVICES

सत्यमेव जयते

भारत सरकार
स्वास्थ्य एवं परिवार कल्याण मंत्रालय
स्वास्थ्य सेवा महानिदेशालय
Government of India
Ministry of Health & Family Welfare
Directorate General of Health Services

Message

We all are well aware of the recent unfortunate and grave incidents of fire accidents in the medical facilities in the nation. The constant use of a wide array of electrical devices and machinery, from life-saving medical equipment to everyday operational tools, increases the risk of electrical faults and overheating. Hospitals store various flammable substances, including oxygen cylinders, chemicals, and medical supplies, which can exacerbate the impact of electrical fires. Unlike many other establishments, hospitals operate 24/7, meaning electrical systems are under constant strain without the benefit of periodic shutdowns for maintenance.

Moreover, the critical nature of medical locations—with patient conditions, treatment criticality, oxygen-rich areas, wet areas, and the use of electrical devices that bypass the skin—significantly heightens the risk of fire ignition and electrocution for both patients and staff.

In this background it is high-time to for us all to strictly establish and implement measures of national fire safety standards of India both in letter and spirit:

Regular Electrical Safety Audits: Hospitals should conduct periodic, thorough inspections and audits of all electrical systems, equipment, and wiring to identify and rectify potential hazards promptly.

Training and Awareness Programs: Implement regular training sessions for all hospital staff to ensure they are well-versed in electrical fire safety protocols, emergency response procedures, and the correct use of electrical equipment.

Fire Detection and Suppression Systems: Ensure the installation and routine testing of advanced fire detection systems, such as smoke detectors and automatic fire suppression systems, in all critical areas of the hospital.

Maintenance of Electrical Equipment: Establish a rigorous maintenance schedule for all electrical equipment, including regular checks, servicing, and timely replacement of faulty components.
Emergency Preparedness: Develop and regularly update a comprehensive emergency response plan specifically for electrical fires.

I am happy to know that M/S National Federation of Engineers for Electrical Safety is publishing a guide on Electrical Safety Audits in Hospitals, based on the National Electrical Code of India 2023 and other IS/IEC standards. We congratulate them and are sure that such a guidebook will be useful to every hospital.

I request the hospital administration, healthcare workers, non-medical personnel and all the other support staff to prioritize this matter.

I recommend all Hospitals and Medical locations to carryout Inspection and Testing recommended in IS standards to make them electrically safe.

24 June 2024

(Atul Goel)

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NABH
ISQua Membership
ISQuaEEA International Society for Quality in Health Care External Evaluation Association Accredited Organisation 2022-2026
IEEA International Society for Quality in Health Care External Evaluation Association Accredited Standards 2020-2024

National Accreditation Board for Hospitals & Healthcare Providers
(Constituent Board of Quality Council of India)

NABH/Gen/2024/4433 June 25, 2024

Message

Dr. Atul Mohan Kochhar
MD, DNB, MNAMS, FAAD
CEO, NABH

Dear Colleague,

Recently, there has been a significant spike in fire incidents due to electrical faults, making it imperative to highlight a crucial aspect of patient safety i.e. electrical safety in healthcare facilities.

As an organisation committed to healthcare quality and patient safety, NABH understands the critical role that electricity plays in enabling hospitals to perform essential medical procedures and maintain life-saving equipment. However, this dependence also exposes us to possible threats that can impair patient care and result in substantial losses.

To address these challenges proactively, NABH urges all healthcare institutions to prioritise electrical safety through rigorous audits and strict adherence to best practices. This requires ensuring that electrical systems are not only correctly installed and maintained but also subjected to regular inspections to identify and mitigate potential hazards.

NABH applauds the recent initiative by the National Federation of Engineers for Electricity Safety (NFE) to create a guidebook specifically for electrical safety audits in hospitals. This resource will surely be a useful tool for our institutions, offering direction on recognising possible hazards, implementing preventative measures, and fostering a safety-conscious culture among healthcare personnel.

Let us continue to prioritise safety as a core value and work collaboratively to create a safer environment for all.

Jai Hind,

Thanking you,

Sincerely yours,

(Dr. Atul Mohan Kochhar)
CEO-NABH

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MESSAGE

Dr. Giridhar Gyani
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We keep hearing incidences of FIRE across variety of buildings or institutions. It amounts to huge losses in terms monetary aspects in general and loss of human lives in particular. Besides it results in shutting down of particular institute / enterprise which amounts to huge financial loss on recurring basis. Surprisingly we also are by and large aware about the root causes of such fire incidences but are unable to initiate preventive measures in structured manner. Developed countries like UK and Australia report that in 50% cases malfunction of electrical equipment or related circuits are responsible for fire incidences. In India vast majority of fire incidences are attributed to electrical short circuit. Surprisingly FIRE NOC does not cover electrical safety audit.

We know that electrical short circuit or similar malfunction in electrical equipment can occur through **Damaged Wiring**, **Faulty Appliances**, **Overloaded Circuits** & **Poor Installation** among others. Improper wiring or connections can lead to short circuit and thereby FIRE. **Simple Prevention** measures by way of; **Regular Inspections**, **Quality Installations**, **Circuit Protection** & **Avoiding Overloading** can minimise if not prevent fire incidences. All these measures are part of electrical fire safety audit.

Talking about hospitals, an electrical safety audit is a critical process due to the unique and demanding nature of healthcare environments. Here are the primary reasons why conducting an electrical safety audit in hospitals is essential:

1. **Life-Sustaining Equipment**: Hospitals rely heavily on electrical devices that support patient life functions, such as ventilators, monitors, and defibrillators. Ensuring these devices are safe and reliable is paramount.
2. **Highly Flammable Materials**: Hospitals contain oxygen tanks and other flammable materials. Electrical faults can ignite these, leading to potentially catastrophic fires.
3. **Complex Electrical Systems**: The extensive use of electrical systems in hospitals increases the risk of short circuits and other electrical malfunctions that could lead to fires.
4. **Uninterrupted Power Supply**: Reliable electrical systems are crucial for the continuous operation of critical medical equipment. Power failures or electrical faults can disrupt medical procedures and compromise patient care.
5. **Regulatory Requirements**: Hospitals must comply with stringent local and national electrical safety regulations. Regular audits help ensure compliance and avoid legal and financial penalties.

National Federation of Engineers for Electricity Safety (NFE) has emerged as key organization in our country, which has pool of trained experts to conduct electrical safety audit. It is time that regulatory authorities rely on NFE and issue advisory to this effect. Association of Healthcare Providers (India), which represents vast majority of hospitals has issued advisory for member hospitals to get the maintenance staff get trained by NFE. This will enable them to focus on preventive measures as well as in combating the fire incidences. National & State government must include Electrical Safety Audit before issuing Fore NOC.

I congratulate NFE is coming out with Guide booklet on Electrical Safety Audits in Hospitals.

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MESSAGE

Dr Vijay Agarwal
President, CAHO
www.caho.in

Dear Colleagues and Partners in Healthcare,

It is with great pride and a sense of responsibility that we present this comprehensive handbook on electrical safety audits in hospitals, brought to you by the National Federation of Engineers for Electrical Safety. Fire accidents, particularly those originating from electrical sources, pose a significant threat to the safety of patients, healthcare workers, and the infrastructure of our medical institutions.

Too often, the response to fire incidents in hospitals revolves around firefighting measures and emergency responses. While these are undoubtedly crucial, we must emphasize the paramount importance of preventing such incidents from occurring in the first place. This guide is meticulously prepared to provide foundational knowledge on conducting electrical safety audits in hospitals and clinics, aiming to eliminate the risk of fire ignition from electrical sources.

The measures outlined in this handbook are designed to equip healthcare facilities with the necessary tools to avoid electrical fires proactively. These guidelines are rooted in the National Electrical Code of India 2023, IS 732, and IS 17512 standards, ensuring that our practices are up-to-date and adhere to the highest safety norms. Compliance with the CEA safety regulations is not only a best practice but a mandatory legal requirement, as stipulated in regulation 14(2).

CAHO is committed to promoting safety in all healthcare institutions. We urge all stakeholders to diligently follow the protocols and recommendations outlined in this handbook. By doing so, we can collectively enhance the safety of our medical environments, safeguarding the well-being of those who rely on our care and services.

Let us commit to a safer future by embracing these electrical safety measures and working towards a culture of prevention and preparedness.

Warm regards,

Dr Vijay Agarwal
President, CAHO

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Guide on
ELECTRICAL SAFETY AUDITS IN HOSPITALS

1 INTRODUCTION

Fire accidents due to electrical reasons are critical in Hospitals and Medical locations. Often users are guided to follow firefighting measures as a remedy to fire accidents in hospitals, however importance should be given to STOP the ignition of fire from electricity. This guide is prepared to give basic information on electrical safety audits in Hospitals and Medical locations.

Electrical safety from fire in medical locations includes measures to prevent the ignition of fire from electricity.

The safety audits mentioned in this guide are based on the National Electrical Code of India 2023, IS 732 & IS 17512. Compliance with CEA safety regulation is a mandatory legal requirement in every electrical installation (refer regulation 14(2)).

2 THE SAFETY REGULATIONS OF GOVT OF INDIA

Legal requirement for electrical safety: Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations 2023 (hereinafter called CEA regulations) is a mandatory legal requirement.

For the understanding of the users of this guide, this guide explains a few important regulations applicable to electrical installations within the Hospital and Medical locations, including a supply voltage up to 650 V AC. Safety requirements at the point of commencement of supply up to 650 V AC are included in this guide.

Note: Safety requirements of supply lines in distribution or HV supply lines including point of commencement of supply are not included in this guide.

Some of the important regulations applicable to electrical installation within a building and their explanations are included in Annex A.

3 ELECTRICAL SAFETY AUDITS

3.1 CRITICALITY IN HOSPITAL AND MEDICAL LOCATIONS.

Electrical Installation in Hospitals and medical locations are critical due to the working environment and sensitivity such as:

- WET Areas, where the chance of electric shock is high for the patient and the medical staff,

- Life supporting equipment connected to patients having applied parts bypassing skin,
- Oxygen enriched areas, where the chance of fire is high,
- Highly sensitive electronic systems,
- Medical electrical equipment or system, vulnerable to Electro Magnetic Environment (EMI),
- Availability of power and stand-by power, changeover etc.
- Safety services and challenges in evacuation.

To keep the electrical installation, including connected equipment free from electric shock and fire (e.g. fire due to short circuit), it is necessary to accurately and timely diagnose possibilities of electrical faults. To ensure safety, protection systems mentioned in NEC 2023 shall be implemented, initial and periodic safety audits shall be carefully undertaken.

Auditor: This document is to define the safety requirements in Hospitals and Medical locations. The person who makes the safety audits shall be competent enough and should understand safety requirements in various standards referred to in this guide. (see Bibliography for more information). He should have knowledge on the practical application of various safety measures and should have different testing equipment for this purpose (see Annex C)

Note: Detailed safety audit format is included in clause 4.

3.2 SAFETY AUDITS FOR HOSPITALS

The following standards are to be referred to in case of clarifications.

1. IS732: clause 6 or IEC 60364-6.
2. IS17512 clause 9 or IEC 60364-7-710 clause 710.6
3. The standards referred to in respective parts.

The Inspection and tests mentioned in 3.2.1 and 3.2.2 are necessary. For new hospitals, 100 % compliance is possible if the design, selection and erection are carried out as recommended in the above standards. In the case of existing hospitals, maximum verification recommended in clause 4 can be followed. In case any of the clauses in clause 4 are not carried out, the respective clause shall be kept empty in the audit report with a note, “Not Conducted” or “NC”.

Note: Thermography is not recognised as an efficient measure to ensure electrical safety in Hospitals and Medical Locations, hence it is not considered in IS/IEC/ISO standards (ISO has withdrawn the draft standard). Relaying Thermography in electrical installation diverts the importance of fundamental safety requirements, hence it has to be avoided or to be carried out as an additional maintenance measure.

3.2.1 INSPECTION

The inspections mentioned are mandatory for all locations (e.g. Unclassified, Group 0, Group 1 and Group 2 locations, see Annex B). The results are to be mentioned in the formats in Clause 4.

1. **Protection against electric shock**: Inspect whether the protective equipotential bonding is carried out in accordance with picture B5 in all locations. For Group 1 and Group 2 medical locations inspect the supplementary equipotential bonding is carried out in accordance with picture B5.
2. **Presence of fire barriers:** Inspect the openings in wall, floors and sealing where cables are travelling from on electrical area to the other (e.g electrical room to a safe room, all floors in case of a vertical shaft, vertical shaft to a safe area etc), find out the status of fire sealants in each area. If the openings are sealed, the make, type, the test report of the manufacturer and method of installation need to be recorded.
3. **Precautions against propagation of fire:** Inspect the battery rooms and record the type of ventilation used, the fuel is not stored close to electrical installation, ……
4. **Protection against thermal effects:** Inspect the location where electrical panels and major electrical equipment are installed and ensure that high temperature in electrical equipment (e.g. air conditioner wall mounted with a stabilizer) does not ignite fire to materials below them (e.g. curtains, beds, an unintended appliance, etc).
5. **Coordination of Protective device and conductors:** Check the coordination of protective device and conductors for current-carrying capacity, voltage drop and fault loop impedance including choice and setting of protective and monitoring devices. (This needs to be either calculated or simulated after conducting a test).
6. Presence and correct location of isolating and switching devices in each panel/location.
7. Location and usage of equipment appropriate to external influences such as temperature, humidity, altitude, water, dust, corrosive substance, mechanical shock, vibration, flora (mould growth), fauna etc.
8. Neutral and protective conductors correctly identified (includes easy measures for identification) in each circuit,
9. Single pole switching devices connected in the line conductors,
10. Presence of diagrams, warning notices or other similar information,
11. Identification of circuits, overcurrent protective devices, switches, terminals, etc,
12. Adequacy of connection of conductors (where possible with a continuity measurement test with an instrument of minimum 10 Amps),

13. Accessibility of equipment for convenience of operation, identification and maintenance.
14. Avoidance and protection from Electromagnetic, electrostatic and ionizing influences, which includes shielding, screening and bonding of cables and wires, usage of protective measures against electrostatic effects (see B12),
15. Inspect whether SPDs are installed, the location of SPD's, type and connecting wire length of SPD's and make a conclusion whether they satisfy IS/IEC 62305-4 requirements are to be recorded.
16. Verification of the integrity of the facilities for the electric supply system for safety services.
17. Mathematical/software verification of the compliance of the selectivity of the electric supply system for safety services regarding planning documents and calculation.
18. Mathematical/software verification of the applied protective measures for compliance with the requirements for medical locations of group 1 and group 2 with attention to the requirements of selectivity between overcurrent protective devices.
19. Visual verification including the verification of test reports, isolating transformer and Medical IT systems comply with the requirements of IT system classified as "Medical IT". (e.g. Medical IT system is made of Isolating transformers in accordance with IEC 61558-2-15, Medical Insulation Monitoring Device (MED-IMD) in accordance with IEC 61557-8 (Annex A and Annex B), insulation fault location system in accordance with IEC 61557-9 (Annex A).

3.2.2 TESTING

The following tests shall be carried out and should be made in the following sequence. In case of failure of any tests, the result should be informed to the user, it is to be rectified, failed test and remaining tests are to be carried out. Tests from Sl. No 1 to 4 are made in mains "OFF" and isolated condition. Tests in Sl. no 5 to 10 need the power supply mains. Test in Sl. No. 11 is carried out in portable and pluggable equipment including medical equipment.

Efficiency of Automatic disconnection of supply should be carried out for all sources in all possible combinations (e.g. With each supply transformer connected, with each DG connected, with UPS etc).

1. Continuity of conductors,
2. Insulation resistance of the electrical installation,
3. Protection by SELV, PELV or by electrical separation,
4. Floor and wall resistance/impedance,
5. Automatic disconnection of supply,
6. Additional protection,

7. Polarity test,
8. Test of the order of the phases,
9. Functional and operational tests,
10. Voltage drop,
11. Portable Appliance Test (PAT),
12. Functional test of change-over devices,
13. Functional test of MED-IMD and the overload monitoring systems of medical IT systems and acoustical/visual alarm systems,
14. Measurements to verify that the supplementary equipotential bonding follows 6.1.3.1.5 of IS17512.
15. Integrity of the electric supply system for safety services required by Cl 7 of IS17512).

3.3 PERIODICITY OF INSPECTION AND TESTING

Periodic verification includes all subjects related to electric shock, automatic disconnection and fire as explained in clause 3.2.1 and 3.2.2. The subjects which are omitted by the auditor during periodic verification shall be recorded in the formats, including the reason for omission.

Table 1 – Recommended periodic verification in medical locations

1	Functional testing of change-over devices	12 months
2	Functional testing of the medical insulating monitoring devices (MED-IMD) and overload monitoring system of medical IT systems and acoustical/visual alarm systems	
3	Measurement of the equipotential bonding including supplementary equipotential bonding	36 months
4	Functional testing of electric supply system for safety services 1. Loading of UPS to 80 % of rated power and in battery for 15 min, 2. Loading of DG's to 80 % of rated power for 60 min.	monthly
5	Loading of DG's to 80 % of rated power for 120 min.	12 months
6	Generators black start testing	
7	Checking the tripping of RCDs at $I_{\Delta n}$	
8	Visual inspection, functional tests and measurements of the electrical installation, especially to verify the protection against electric shock, including the settings of adjustable protective devices	
9	Functional test of the lighting of exit signs, escape routes, locations for switchgear and control gear	

3.4 EXCEPTIONS FOR CLINICS AND SMALL HOSPITALS

The measures mentioned in 3.2 is applicable for all Hospitals. However, for small organisations, if all subjects cannot be covered, the following minimum requirements are necessary.

- Maintain the best practices mentioned in Annex F.
- Ensure that the rating of MCB's and wires are selected properly.
- Make fault loop impedance test (NFE certified FLIT professional will be helpful in this case),
- Test RCD's with RCD tester
- Make PAT test of all pluggable appliances

4 REPORTING OF SAFETY AUDITS

Safety audits include Inspection and Testing. All Inspections and Testing mentioned in 3.2.1 and 3.2.3 are essential at least once, preferably before using the installation. In existing hospitals where there is difficulty in conducting all subjects, some of them can be omitted, provided the auditor records the omissions and the reason for omission. The recommended periodic verification in table 1 are to be carried out without omission. The audit report duly signed by the auditor, acknowledged by the management, can become the basis for improvements if necessary.

Note: The auditor shall have knowledge of electrical installation in general locations and medical locations and is skilled enough to carry out the audit.

4.1 REPORT FORMAT FOR INSPECTION

REPORT OF INSPECTION			
Details of Hospital including Name address and contact persons responsible for rectification and the name of person who coordinates the inspection. Note: Responsible person is preferably the head of the organisation.			
#	Type of Inspection	Status	Remark
1	Protection from Electric Shock		
1.1	Basic protection against direct electric shock as per IS 732 Cl 4.2		
1.2	Existence of Main Protective Equipotential Bonding	YES / NO	
1.2.1	If YES, Convenience of testing	YES / NO	
1.2.1.1	Explain in words about Main Equipotential Bonding including sizes, provision for individual testing etc.		
1.2.1.1	Answer of 1.b		
1.3	No of Group 1 and group 2 locations	In nos	
1.3.1	No of locations where existence of Supplementary Equipotential Bonding can be inspected	In nos	
1.3.2	Locations where convenience of testing exist	In nos	
1.3.3	Explain in words about Supplementary Equipotential Bonding including sizes, provision for individual testing etc.		
1.3.3	Space for answer of 1.2.3		
Note: Sl. no 1.3.1 to 1.3.3 should be repeated in each Group 1 and Group 2 location			
2	Presence of fire barriers		
2.1	Usage of fire sealants. .	YES/NO	
Note: If more than 50 % locations are not sealed, the recommended answer is NO, and further answers in sl. No 2.1 can be omitted.			
2.1.1	Total number of locations where cables penetrate from one zone to other.		
2.1.2	Number of locations visible and accessible for inspection.		

2.1.3	Number of locations which are sealed with fire sealants.		
2.1.4.1	Make of fire sealant, (with model and type) and verification of test report.		
2.1.4.2	Confirmation of implementation as per the test conditions in the test report.	YES/NO	
Note: Sl no 2.1.4 should be repeated in each location			
3	Precautions against propagation of fire.		
3.1	Requirement in battery room. (For more information refer IEC 60364-5-57).		
	Space for answer of 2.2.1		
3.2	Explain electrical installation in Fuel storage		
	Space for answer of 2.2.2		
3.3	Explain electrical installation in storerooms, where inflammable materials such as alcohol based sterilizing substances are stored.		
	Space for answer of 2.2.3		
4	Protection against thermal effects:		
4.1	Building is classified by the characteristics of external influences “Conditions of evacuation in an emergency (BD)”	YES/NO	
4.2	Is the wiring systems in escape routes are as per IS 732 Cl no 4.3.2.2.1.		
	Space for answer of 4.2		
4.3	Is Cl no 4.3.2.2.3 and Cl no 4.3.2.2.2 of IS 732 followed in all escape route	YES/NO	
4.4	Does the accessible parts of the electrical system protect against burns, if temperature of the equipment exceeds table 2 of IS 732 as per cl no 4.3.3.	YES/NO	
4.5	Inspect the location where electrical panels and major electrical equipment are installed and ensure that a high temperature in electrical equipment is not igniting fire *(e.g. curtains, beds, linens, appliances, etc. below*		

	appliances such as air conditioners, storage of materials closer to electrical equipment).		
5	Protective devices and Conductor coordination		
5.1	Check the coordination of protective device and conductors for current-carrying capacity, voltage drop and loop impedance by design verification.	YES/NO	
5.1.2	If YES. Total No of circuits		
5.1.3	No of circuits which are complying		
5.1.4	No of non-compliant circuits		
5.1.5	Give an overview of non-compliances		
	Space for answer of 5.1.5		
5.2	Mathematical verification of the compliance of the selectivity of the electric supply system for safety services regarding planning documents and calculation.	YES/NO	
5.2.1	No of non-compliant circuits		
5.2.2	Give an overview of non-compliances		
	Space for answer of 5.2.2		
5.3.	Mathematical verification of the applied protective measures for compliance with the requirements for medical locations of group 1 and group 2 with attention to the requirements of selectivity between overcurrent protective devices.		
5.3.1	No of non-compliant circuits.		
5.3.2	Give an overview of non-compliances.		
	Space for answer of 5.3.2		
5.4	Selectivity verification for residual current devices and for OCPD's to disconnect only the faulty systems and not affect other systems.		

5.4.1	No of non-compliant circuits.		
5.4.2	Give an overview of non-compliances.		
	Space for answer of 5.4		
6	Erection of Equipment		
6.1	Are the electrical equipment selected as per table 7 of IS 732, as per the external influences of the location.	YES/NO	
6.1.1	Number of equipment external influences not considered and what are the influences not considered.		
	Space for answer of 6.1.1		
6.2	Selection and erection of wiring systems such that the external influence in the location is taken care as per Cl 5.2.3 of IS 723.	YES/NO	
6.2.1	What are the influences not considered.		
	Space for answer of 6.2.1		
7	Identification and other information		
7.1	Are the neutral conductor, protective conductor (PEN conductor at point of commencement of supply) currently identified as per IS 732 cl no 5.1.4.3.	YES/NO	
7.2	Are the protective devices arranged and identified as per IS 732 cl no 5.1.4.4.	YES/NO	
7.3	Are diagrams, warning notices or other information available as per IS 732 cl no 5.1.4.5 and 5.3.7.3.1.3.	YES/NO	
8	Electromagnetic compatibility of the electrical system and SPD.		
8.1	Does any equipment require functional earthing.	YES/NO	
8.1.1	How is the functional bonding done in the building.		
	Space for answer of 8.1.1		

8.2	Is the structure electrically bonded to MET at various locations.	YES/NO	
8.3	Is the cable management system done as per IS 732 cl no 4.5.4.6.1 and 4.5.4.7.	YES/NO	
8.3.1	Explain the cable management system in detail.		
	Space for answer of 8.3.1		
8.2	Protection from conducted over voltages.		
8.2.1	No of locations where SPD is necessary		
8.2.2	No of locations where SPD is installed		
8.2.3	Type of SPD installed in main panel.		
8.2.4	Location of SPD's installed and its connecting wire length.		
	Space for answer of 8.2.2		
Note: 8.2.4 is to repeat in every location where SPD's are installed.			
9	Medical IT system		
9.1	Number of Group 2 locations.		
9.2	Number of Group 2 locations where Medical IT system is installed.		
9.3	Maximum capacity of Medical IT source (in kVA).		
9.3.1	Compliance of each medical IT system to IS 17512.		
	Space for answer of 9.3.1		
9.3.2	Compliance of Isolating transformers to IEC 61558-2-15.	YES/NO	
9.3.3	Compliance of Medical Insulation Monitoring Device to IEC 61557-8	YES/NO	
9.3.4	Compliance of Insulation fault location system to IEC 61557-9.	YES/NO	
9.3.5	Availability of Continuity resistance monitoring.	YES/NO	

9.3.6	Distance between medical isolation panel and group 2 location (in meters).		
Answer for 9.3.1 to 9.3.6 shall be repeated for each group 2 location.			
Note: Maximum capacity of each Medical IT system is 10 kVA. UPS with isolation transformers are not Medical IT.			

4.1.1 Notes for Inspection and Periodic Audits.

1. NEC 2023 recommends periodic inspection every two years; however, visual inspection is recommended annually.
2. Periodic inspection need not cover all the clauses in the format if they are already inspected. However, periodic verification includes all subjects related to electric shock, automatic disconnection and fire.
3. Ensure that the Statutory compliance of reports issued by the Electrical Inspectorate and fire license issued by the Fire Service Department are available (if applicable).

4.2 REPORT FORMAT FOR TESTING

Distribution Circuit Testing and Data Collection Form							**Doc. No.:**		
							Date:		
							Date of testing:		
Circuit Name/ Distribution board name									
Circuit location									
Incoming details									
OCPD details							Local OCPD		Upstream OCPD
Make									
Type and Model (MCB/MCCB or any OCPD)									
Rating (A)									
Breaking capacity									
Remarks									
Conductor/cable details									
Type of conductor (CU/AL/GI)							*Live:*		*PE:*
Cross sectional area in sq.mm.							*Phase:*		*Incoming PE:*
							Neutral:		*Outgoing PE:*
Conductor/ cable length (meter)							*Live conductor:*		*PE conductor:*
Parameters/Reference	R-Y	Y-B	R-B	R-N	Y-N	B-N	R-PE	Y-PE	B-PE
Insulation resistance (MΩ)									
Voltage(V)									
loop impedance (Ω)									
Prospective fault current (kA)									
RCD details	*Make:*			*Type A/B/AC/F*				mA rating:	
Operating current (mA)	*R*			*Y*			*B*		
Operating time 1*$I_{\Delta n}$	*R*			*Y*			*B*		
Operating time 5* $I_{\Delta n}$	*R*			*Y*			*B*		
Test button operation	*R*			*Y*			*B*		
Polarity check	*Yes or no:*								
Remarks:									

4.2.1 Notes for Testing

Test for Efficiency of Automatic Disconnection shall be carried out in all the following conditions.

1. The test points for the outgoing MCBs should be the load ends (final termination point of the circuit to the equipment or socket).
2. The OCPDs should be tested for the loop impedance for both Mains and Generator supply.
3. Every OCPD protecting a circuit with a stabiliser should be tested for the fault loop impedance at the final point of the circuit after the stabiliser.
4. Every OCPDs protecting outgoing circuits of UPS/Inverter should tested for fault loop impedance in the main ON and Mains OFF mode.

4.3 TESTING of ME and MES

Testing of ME & MES is generally carried out by the Bio Medical Engineer. Maintaining ME and MES is important to ensure safety. The contents in 4.3 and Annex G are for the information of the user of this guide.

The following tests are to be carried out in ME and MES after every repair or maintenance. Detailed periodic testing necessary for Medical Electrical Equipment are included in Annex G.

1. Protective Earth Resistance (ref IS/IEC 62353 cl 5.3.2)
2. Earth Leakage Current (ref IS/IEC 62353, Table E1),
3. Touch or Enclosure Leakage Current (ref IS/IEC 62353, Table E2),
4. Patient Leakage Current (ref IS/IEC 62353, Table E3),
5. Patient Auxiliary Leakage Current
6. Mains on Applied Part (MAP) Leakage Current

Annex A
EXPLANATIONS FROM REGULATIONS APPLICABLE IN HOSPITAL

Regulation 5
Electrical Safety Officer.

Sub Regulation (3) & part of sub regulation (2)

For every electrical installation including factory registered under the Factories Act, 1948 (63 of 1952) with more than 250 kW connected load and mines and oil-field as defined in the Mines Act, 1952 (35 of 1952), with more than 2000 kW connected load, the owner of the installation or the management of the factory or mines, as the case may be, shall designate Electrical Safety Officer under sub-regulation (1) and having qualification and experience specified in sub-regulation (2), for ensuring the compliance of the safety provisions laid under the Act and the regulations made thereunder:

Provided that the Electrical Safety Officer shall carryout recommended periodic tests as per the relevant standards, and inspect such installations at intervals not exceeding one year, and keep a record thereof in Form I or Form II or Form III or Form IV, as the case may be, of Schedule II of these regulations; test reports and a register of recommendations in regard with safety duly acknowledged by owner; compliances made thereafter; and such records shall be made available to the Electrical Inspector, as and when required.

Explanation on Regulation 5:

The management of every Hospital or Medical establishment having a connected load more than 250 kW shall designate an Electrical Safety Officer.

Qualification: *The Electrical Safety Officer shall possess a degree in Electrical Engineering with at least five years of experience in operation and maintenance of electrical installations or a Diploma in Electrical Engineering with at least ten years of experience in operation and maintenance of electrical installations:*

Responsibility*: The Electrical Safety Officer shall carry out recommended periodic tests as per the relevant standards, and inspect such installations at intervals not exceeding one year, and keep a record thereof*

Regulation 14
General safety requirements pertaining to construction, installation, protection, operation and maintenance of electric supply lines and apparatus.

Sub Regulation (1) (2) & (3)

(1) All electric supply lines and apparatus shall be of sufficient rating for power, insulation and estimated fault current and of sufficient mechanical strength, for the duty cycle which they may be required to perform under the environmental conditions of installation, and shall be constructed, installed, protected, worked and maintained in such a manner as to ensure safety of human beings, animals and property.

(2) Save as otherwise provided in these regulations, the relevant standards including National Electrical Code and National Building Code shall be followed to carry out the purpose of these regulations and where relevant Indian standards are not available, international standards shall be followed and in the event of any inconsistency, the provisions of these regulations shall prevail.

(3) The material and apparatus used shall conform to the relevant standards.

Explanation on Regulation 14

(1) Electrical installation shall be kept always in safe condition.

(2) NEC 2023 and NBC 2016 are to be followed to ensure safety requirements of this regulation.

(3) All products used shall conform IS standards, in the absence of IEC standards. (products as per other standards can be used in the absence of an IS and/or an IEC standard).

Regulations applicable at the point of commencement of supply

Regulation 15, 16, 17 & 18

15. Service lines and apparatus on consumer's premises
16. Switchgear on consumer's premises
17. Identification of earthed and earthed neutral conductors and position of switches and switchgear therein
18. Earthed terminal on consumer's premises.

Explanation on Regulation 15 to 18

The major responsibility of this regulation is applicable to the electrical energy supplier (DISCOM or Licensee). The consumer shall also ensure that the installation of the licensee under his control is kept in a safe condition.

These regulations play a major role in safety at consumer premise. Refer Annex D for more information. Supply not conforming to regulations 15 to 18 may lead to accidents in consumer premise.

Explanation on Regulation 31

Electrical installation in hospital can be energised or connected to the Licensee, only if the works are carried out by the electrical contractor licenced in this behalf by the State Government and on its behalf under the direct supervision of a person holding a certificate of competency and by a person holding a permit issued or recognised by the State Government

32. Periodic inspection and testing of installations

(1) (para2) Electrical installation below or equal to the notified voltage shall be self-certified by the owner or supplier or consumer, as the case may be.
(3) The periodic inspection and testing of installation of voltage equal to or below the notified voltage belonging to the owner or supplier or consumer, as the case may be, shall be carried out by the owner or supplier or consumer and shall be self-certified for ensuring observance of safety measures specified under these regulations and the owner or supplier or consumer, as the case may be, shall submit the report of self-certification to the Electrical Inspector in the Form I or Form II or Form III or Form IV, as the case may be, of Schedule II.

Provided that the electrical installation so self-certified shall be considered as duly inspected and tested only after the report of self-certification is duly received by the office of Electrical Inspector and if not acknowledged by the Electrical Inspector within three working days, it shall be deemed to be received:

Explanation on Regulation 32

Note: The explanation is made considering the notified voltage in most states are above 440 or 650 volts. Internal wiring and electrification in hospitals are less than this voltage. Medical equipment may have higher operating voltage, which is the subject of the respective product standard.

Periodic verification shall be carried out by either owner or supplier or consumer, observing all requirements of the regulation and shall submit (or get acknowledgement) the report of self-certification to the Electrical Inspector in the

recommended forms (Form I or Form II or Form III or Form IV of schedule II) and submit / get acknowledgement from electrical inspector within 3 days of test.

Periodicity: Specified by the state government or 5 years.

Note: NEC 2023 provides a much lower periodicity depending upon the categorization of building. This is explained in annex E of part 1 section 17 of NEC 2023.

***33. Testing of consumer's installation**.*

(1) Upon receipt of an application for a new or additional supply of electricity and before commencement of supply or recommencement of supply after the supply has been disconnected for a period of six months, the supplier shall either test the installation himself or accept the test results submitted by the consumer when same has been duly signed by the licensed electrical contractor:

Provided that in case of voltage level equal to or below the notified voltage, Chartered Electrical Safety Engineer can also test the installation on request of owner.

(2) The testing and verifications shall be carried out as per relevant standards.

(3) The testing equipment shall be calibrated by a Government authorised or National Accreditation Board for Testing and Calibration Laboratories accredited laboratory at periodical interval as per the periodicity specified by them.

(4) The supplier shall maintain a record of test results obtained at each supply point to a consumer, as per the forms provided in Schedule III.

(5) If as a result of such inspection and test, the supplier is satisfied that the installation is likely to be dangerous, he shall serve on the applicant a notice in writing requiring him to make such modifications as are necessary to render the installation safe and may refuse to connect or reconnect the supply until the required modifications have been completed.

Explanation on Regulation 33

For New/Additional/reconnection of supply, the consumer shall submit the test reports as per the relevant standards (e.g. NEC 2023) to the Energy Supplier. For Low Voltage either the contractor or the Chartered Electrical Safety Engineer can carry out this test.

Explanation on Regulation 34

All electrical energy Generators (e.g. Dg / SOLAR PV) above a certain capacity as decided by the state government are to be inspected by the Electrical Inspector before commissioning.

Note: check the capacity of generators above which inspection by electrical inspector is required.

Note 1: Regulations 35 and 36 are about leakage in consumer premises, applicable to energy supplier.
Note 2: Regulation 37 is the requirement of circuit breaker at the origin of installation. Refer an expert for more information. They are not explained in this guide.

38. Provisions for supply and use of electricity in multi-storeyed building more than fifteen metre in height.

(1) The connected load and voltage of supply above which inspection is to be carried out by an Electrical Inspector for a multi-storeyed building of more than fifteen metre height shall be notified by the Appropriate Government.

(2) Before making an application for commencement of supply or recommencement of supply after an installation has been disconnected for a period of six months or more, the owner or occupier of a multi-storeyed building shall give not less than thirty days notice in writing to the Electrical Inspector specifying therein the particulars of installation and the supply of electricity shall not be commenced or recommenced within this period, without the approval in writing of the Electrical Inspector.

(3) The following safety measures shall be provided in the multi-storeyed buildings of more than fifteen metre height and other premises such as airports, hospitals, hotels, places of entertainment, places of worship, cultural centers, stadium, academic buildings, test labs, industrial installations, installation with explosive or flammable material, railway or metro stations and other public buildings, namely: –

(i) the supplier or owner of the installation shall provide at the point of commencement of supply a suitable isolating device with cut-out or breaker to operate on all phases except neutral in the three-phase, four-wire circuit and fixed in a conspicuous position at not more than 1.70 metre above the ground so as to completely isolate the supply to the building in case of emergency;

(ii) the owner or occupier of a multi-storeyed building shall ensure that electrical installations and works inside the building are carried out and maintained in such a manner as to prevent danger due to shock and fire hazards, and the installation is carried out as per the relevant standards;

(iii) no other service pipes and cables shall be taken through the ducts provided for laying of power cables and all ducts provided for power cables and other services shall be provided with fire barrier at each floor crossing;

(iv) the Fire Retardant Low Smoke and Low Halogen power cables shall be used in building of more than fifteen metre height as per relevant standards:
Provided that Halogen Free Flame Retardant power cables as per the relevant standards shall be used in airports, hospitals and hotels irrespective of height;

(v) distribution of electricity to the floors shall be done using bus bar trunking system;

(vi) lightning protection of the building shall be as per the relevant standards;
(vii) verification of electrical wiring of the building shall be carried out as per the relevant standards; and
(viii) electricity meter shall not be installed in the passage of staircase.

Explanation on Regulation 38

Multi-storeyed building is classified as buildings with more than 15 meter height. Sub regulation (3) requires hospitals to be included in the safety requirements of Regulation 38.

Note: There can be different explanations in different documents. For electrical installations above 15 meters, Regulation 38 applies, irrespective of other definitions. However, for hospitals the regulation applies.

(1) A device for isolation shall be installed near the point of commencement of supply to isolate supply to the building in case of emergency. (including supplies from DG/SOLAR PV etc).
(2) The installation shall follow Standards (e.g. NEC 2023).
(3) Ducts for power cable shall be exclusive for that purpose and are sealed at every floor by passive fire sealant.
(4) Halogen free cables shall be used in all Hospitals (called as Zero Halogen wires).
(5) Busbar turning has to be used for distribution of power to every floor. (an alternate busbar system for a parallel connection is also recommended in some states).
(6) Lightning protection as per standard (e.g. NBC 2026 or IS/IEC 62305).
(7) Verification of electrical wiring as per standard (e.g. NEC 2023, part 1 section 17 or IS732).

Note: *Conditions applicable to installations of voltage exceeding 250 Volts are in regulation 39. These conditions include, safety measures for basic protection and fault protection. The safety measures applicable in Hospitals are explained in Annex B.*

42. Test of insulation resistance.
Where any electric supply line for use at voltages not exceeding 650 V has been disconnected from a system for the purpose of addition, alteration or repair, such electric supply line shall not be reconnected to the system until the supplier, or the owner has carried out the test.

Explanation on Regulation 42

Insulation resistance test shall be carried out before connection/reconnection of every line to the system.

43. Connection with earth.

The following conditions shall apply to the connection with earth of systems at voltage exceeding 50 V but not exceeding 650 V, namely:

(i) neutral conductor of a three phase, four-wire system and the middle conductor of a two-phase, three-wire system shall be earthed as per the relevant standards;

(ii) neutral conductor shall also be earthed at one or more points along the distribution system or service line in addition to any connection with earth which shall be at the consumer's premises;

(iii) in the case of a system comprising electric supply lines having concentric cables, the external conductor or armour of such cables shall be earthed by two separate and distinct connections with earthing system;

(iv) in a direct current system, earthing and safety measures shall be as per the relevant standards;

(v) every building shall have protective equipotential bonding by interconnecting the exposed and extraneous conductive parts as per the relevant standards;

(vi) the alternating current systems which are connected with the earth as provided in this regulation shall be electrically interconnected: Provided that each connection with the earth is bonded to the metal sheathing and metallic armouring, if any, of the electric supply lines;

(vii) the frame of every generator, stationary motor, portable motor, and the metallic parts, not intended as conductors, all transformers and any other apparatus used for regulating or controlling electricity, and all electricity consuming apparatus, of voltage exceeding 250 V but not exceeding 650 V shall be earthed by two separate and distinct connections with earth by the owner as specified in the relevant standards;

(viii) all metal casing or metallic coverings containing or protecting any electric supply line or apparatus shall be connected with the earth and shall be so joined and connected across all junction boxes and other openings as to provide good mechanical and electrical connection throughout the length:

Provided that the conditions mentioned in this regulation shall not apply, where the supply voltage does not exceed 250 V and the apparatus consists of wall tubes or brackets, electroliers, switches, ceiling fans or other fittings, other than portable hand lamps and portable and transportable apparatus, unless provided with the earth terminal and to class-II apparatus and appliances of the relevant standards:

Provided further that where the supply voltage is not exceeding 250 V and where the installations are either new or renovated, all plug sockets shall be of the three pin type, and the third pin shall be permanently and effectively earthed;

(ix) All earthing systems shall, –

(a) consist of equipotential bonding conductors capable of carrying the prospective earth fault current without exceeding the allowable temperature

limits as per relevant standards in order to maintain all noncurrent carrying metal works reasonably at earth potential and to avoid dangerous contact potentials being developed on such metal works;

(b) have earth fault loop impedance sufficiently low to permit adequate fault current for the operation of protective device within the time stipulated in the relevant standards; and

(c) be mechanically strong, withstand corrosion and retain electrical continuity during the life of the installation and all earthing systems shall be tested to ensure effective earth bonding as per the relevant standards, before the electric supply lines or apparatus are energised;

(x) all earthing systems belonging to the supplier shall in addition, be tested for resistance on dry day during the dry season at least once in a year;

(xi) earth fault loop impedance shall be tested to ensure the automatic operation of the protective device and a record of every earth test made and the result thereof shall be kept by the supplier for a period of not less than two years after the day of testing and shall be available to the Electrical Inspector when required;

(xii) earth fault loop impedance of each circuit shall be limited to a value determined by the type and current rating of the protective device used such that, on the occurrence of an earth fault, disconnection of the supply shall occur before the prospective touch voltage reaches a harmful value; and

(xiii) the neutral point of every generator and transformer shall be earthed by connecting it to the earthing system not by less than two separate and distinct connections.

Explanation on Regulation 43

Read the sub regulations as per sl. no.

(i) Neutral earthed systems as per the relevant standards shall be used in Hospitals (e.g. TN-S is recommended in NEC 2023).

Sub regulation (ii) and (iii) are applicable at distribution (not after point of commencement of supply) and (iv) is applicable for DC.

(v) every building shall have protective equipotential bonding (see NEC 2023, part 1 section 18, figure 1).

(vi) metal sheathing and metallic armouring of the electric supply lines are to be bonded to MET of the building.

(vii) exposed conductive parts of all 3 phase equipment are to be earthed by two separate and distinct connections with MET

Note: example of Earth in a building is Main Earth Terminal (also called as main Earth Busbar).

(viii) earth continuity (PE) conductor along the lines shall provide good mechanical and electrical connection throughout the length. Single phase class II appliance may not need connection to earth, however, all plug sockets shall be of the three-pin type, and the third pin shall be permanently and effectively connected to PE conductor.

(ix) All earthing systems shall have PE conductors capable of carrying the prospective earth fault current, have protective equipotential bonding, low earth fault loop impedance to ensure efficient automatic disconnection within the stipulated time, sufficiently strong and retain continuity until the lifetime of the installation. Continuity resistance is to be tested before energising the supply.

Note: NEC 2023-part 1 section 17, for maximum resistance requirements for continuity test.

(x) Testing of earthing by supplier.

(xi) The supplier shall test and keep the record of earth fault loop impedance and efficiency of fault protection by automatic disconnection of supply for period of two years.

(xii) The user (hospital owner/management) shall make earth fault loop impedance of each circuit and ensure efficiency of fault protection by automatic disconnection.

(xiii) neutral terminal of every generator and transformer shall have two separate and distinct connections to MET.

Note the definition in regulation. (v) “earthing arrangement or earthing system” means all the electric connections and devices involved in the earthing of a system, an installation or equipment.

44. Residual Current Device.
The use of electricity to electrical installation, shall be controlled by a residual current device to disconnect the supply having rated residual current and duration as per the relevant standards:
Provided that in domestic installation, residual current device having residual operating current not exceeding 30 milliampere shall be used:
Provided further that such protective device shall not be required for supply lines having protective devices which are effectively bonded to the neutral of supply transformers and conforming to regulation 76.

Explanation on Regulation 44

1. *Electricity to be used through an RCD for automatic disconnection as per the standard.*
1. *Domestic installation needs an RCD of $I_{\Delta n} \geq 30$ mA. (not applicable to Hospitals)*

2. *RCD is not required in TN system.*

The concept of shock protection is
Basic Protection (direct contact) + Fault Protection (indirect contact) + additional protection if necessary (in case of failure of basic and/or fault protection).

Fault protection by protective equipotential bonding and automatic disconnection of supply is the established safety measure. Refer regulation 43 for equipotential boning and automatic disconnection by fault loop impedance test. In case of failure of automatic disconnection by OCPD, the only measure is to achieve the same with an RCD.
Note: All electrical installations cannot run with an *RCD of* $I_{\Delta n} \geq 30$ *mA,* due to nuisance tripping.
Hence the regulation 43 and 44 together can be read as below

1. Fault protection by automatic disconnection: ensure automatic disconnection by earth fault loop impedance test and disconnection of OCPD such as an MCB. In case of failure of disconnection by an OCPD, use an RCD for automatic disconnection.
2. Additional protection by RCD of $I_{\Delta n} \geq 30$ mA is required in TN/TT system in the following cases in all installations. This requirement is in addition to fault protection.
   a. Socket-outlets with a rated current not exceeding 32 A; and
   b. Mobile equipment for outdoor use.
   c. Luminaires, which may be accessed by ordinary people.
   d. Outdoor electrical equipment (e.g. Street lights, EV charging, vending machines, coolers etc, also need additional protection by RCD).

Note: There are four types of RCD's for use in AC systems. They are Type AC, Type A, Type F and Type B. Type A RCD is required for LED lights and computer power supplies.

Annex B
ELECTRICAL SAFETY REQUIREMENTS IN HOSPITALS.

B 1: Introduction

The mandatory electrical safety requirements in Hospitals and Medical Locations are included in various standards referred to in B2.

Electrical Installation in Hospitals and medical locations are critical due to the working environment and sensitivity such as:

- WET Areas, where the chance of electric shock is high for the patient and the medical staff,
- Life supporting equipment connected to patients having applied parts bypassing skin,
- Oxygen enriched areas, where the chance of fire is high,
- Highly sensitive electronic systems,
- Medical electrical equipment or system, vulnerable to Electro Magnetic Environment (EMI),
- Availability of power and stand-by power, change over etc,
- Safety services and challenges in evacuation.

B2: Reference

The following standards are referred.

1. National Electrical Code of India 2023 (SP-30): 2023 - All chapters of NEC 2023 are applicable. Requirements of medical locations are included in part 3 section 9.
   Note: Compliance with NEC 2023 (SP-30) is made mandatory in the CEA safety regulations. Ref regulation 14 (2).
2. IS732: 2018 - Code of practice for electrical wiring.
3. IS17512: 2022 - Requirements for Electrical Installations in Medical Locations
4. IS 13450 (all parts): Medical Electrical Equipment - Basic Safety and Essential Performance.
   Note: Compliance with IS standards is made mandatory in the CEA safety regulations. Hence all products used shall be as per IS standards. In the absence as per IEC standards. Ref regulation 14 (3).
5. IS/IEC 62353: Medical Electrical Equipment - Recurrent Test and Test after Repair of Medical Electrical Equipment
6. IEC 61340-6-1 Electrostatics – Part 6-1: Electrostatic control for healthcare – General requirements for facilities.

B3: Definitions

1. Applied Part: Part of the medical electrical equipment which in normal use comes into physical contact with the patient for the equipment to perform its function, or can be brought into contact with the patient, or needs to be touched by the patient. They are classified into Type B, Type BF, Type CF.

	Type B: No electrical contact with patient and maybe earthed		Type BF: Electrically connected to patient but not directly to heart		Type CF: Electrically connected to the heart of the patient

Note: Defibrillation-proof applied parts are not covered in this document

2. Category AP: Rating for ME equipment or an ME equipment part complying with specified requirements on construction, marking and documentation to avoid sources of ignition in a flammable anesthetic mixture with air.
3. Category APG: Rating for ME equipment or an ME equipment part complying with specified requirements on construction, marking and documentation to avoid sources of ignition in a flammable anesthetic mixture with oxygen or nitrous oxide.
4. FLAMMABLE ANAESTHETIC MIXTURE WITH AIR: Mixture of a flammable anesthetic vapour with air in such a concentration that ignition can occur under specified conditions.
5. FLAMMABLE ANAESTHETIC MIXTURE WITH OXYGEN OR NITROUS OXIDE: Mixture of a flammable anesthetic vapour with oxygen or with nitrous oxide in such a concentration that ignition can occur under specified conditions.
6. Medical locations are classified into Group 0, Group 1 and Group 2.
   a. Group 0: Medical location where medical electrical equipment can be brought into contact with the patient or needs to be touched by the patient.
   b. Group 1 is a location where medical electrical equipment is used externally.
   c. Group 2 is a location where medical electrical equipment is used in applications such as intracardiac procedures, operating theatres and vital treatment where discontinuity of the supply can cause danger to life.
7. ME equipment: Medical electrical equipment having an applied part or transferring energy to or from the patient or detecting such energy transfer to or from the patient and which is provided with not more than one connection to a particular supply main and intended by its manufacturer for use in the diagnosis, treatment, or monitoring of a patient or for compensation or alleviation of disease, injury, or disability.
8. ME system: Combination, as specified by its manufacturer, of items of equipment, at least one of which is ME equipment to be inter-connected by functional connection or by use of a multiple socket-outlet.
9. OXYGEN RICH ENVIRONMENT: Environment in which the concentration of oxygen is greater than 25 % for ambient pressures up to 110 kPa or the partial

pressure of oxygen is greater than 27,5 kPa at ambient pressures exceeding 110 kPa.

10. Suitability for use in an OXYGEN RICH ENVIRONMENT: ME EQUIPMENT and ME SYSTEMS intended for use in an OXYGEN RICH ENVIRONMENT shall be classified for such use,
11. Supply mains: Source of electrical energy not forming part of ME EQUIPMENT or ME SYSTEM.

B4: Coordination between Architect, Civil engineers, Air Conditioning Bio Medical and Electrical system designers.

For the safe and reliable operation of modern electrical and electronic installation, the natural steel used for the construction of the building shall be used as a part of the electrical installation, lightning protection and EMI reduction measures. Modern measures such as foundation earthing and supplementary equipotential bonding at group 1 and group 2 medical locations can be achieved by utilizing the construction steel. Integrating down conductors for lightning protection in the structural steel increases the efficiency of protection. In order to implement these safety measures, close coordination between various stakeholders is necessary.

Coordination between these stakeholders is also required for various legal and technical requirements. More information can be found on IS18732 clause 5.

All stakeholders are requested to note that,

a. Biomedical equipment manufacturers demand dedicated earth electrodes for sensitive equipment. This demand is a mistake and a violation of standards and regulations. Fire from these devices is due to non-operation of protective device due to the mistake. Hence this demand shall not be entertained. Such equipment needs an independent connection to the common earth terminal of the location. (e.g. equipotential bonding bus bar of the location).
b. ME equipment and system engineers shall note that ME equipment as per IS 13450-1 can operate with a potential up to 230 V between Neutral Conductor (N) and Protective Earth Conductor (PE). Functional earthing of ICT equipment shall be made based on the requirements of ISO/IEC 30129. All protective and functional earthing conductors should be connected to one single main earthing terminal.

B5: Coordination between electrical and ME equipment and system.

Medical locations are classified into Group 0, Group 1 and Group 2 for the purpose of electrical safety.

Group 1 and Group 2 medical locations are places where applied parts of the ME equipment are extensively used. Any potential difference between applied parts could endanger the patient. The application of medical electrical equipment may introduce hazards due to several reasons as follows:

1. A device's inability to carry out its intended function (such as a ventilator failing to keep the patient ventilated) or an error in function (e.g. Excessive drug delivery by an infusion pump, excessive temperature in a baby incubator).
2. Energies (e.g in the form of electrical or thermal) delivered when functioning normally, e.g.(1) leakage current or functional current flowing from a cardiac defibrillator or from high frequency surgical equipment unit through unintended pathways in the patient or operator (2) exposure to radiation of an unintended part of the patient or operator (3) exposure of the patient or operator to ultrasonic energy or accelerated elementary particles (4) excessive heating or cooling of the patient.
3. Equipment faults, (e.g. fire, electric shock, explosion, expelled parts, excessive ionizing or non-ionizing radiation resulting from equipment malfunction, leakage or overexposure, excessive temperatures of accessible surfaces leading to burns).
4. Fire or explosion resulting from ignition of flammable material within the vicinity of the ME equipment.
    a. Mechanical failures in normal and fault conditions.
    b. Incorrect installation of ME equipment, e.g. Inadequate earthing of a class-1 ME equipment.
    c. Incorrect selection and use of ME equipment, (e.g. The use of ME equipment having a type bf or type b applied part to carry out an intracardiac procedure, selection of an incorrect energy scale while using an internal cardiac defibrillator).
    d. Electromagnetic interference, (e.g. Interference of an ECG display by high frequency surgical equipment, generation of interference with adjacent medical electrical equipment by strong magnetic fields emanating from a display).
    e. Release of corrosive, poisonous or hot liquids or gases or contact with biologically unsafe materials.
    f. Disposal of material and byproducts resulting from the use of medical electrical equipment, (e.g. The disposal of radioactive substances used in nuclear medicine).

ME equipment and ME systems, or parts of such equipment or systems, shall be designed and tested to IS 13450. Following clauses from standards are mentioned with explanations to have a coordination between electrical and bio medial installations.

a. IS 13450-1 clause 4.10.1: Supply Mains to ME equipment and ME system shall satisfy minimum overvoltage category II, unless specified by the manufacturer.
b. IS 13450-1 clause 4.10.1: Supply Mains to ME equipment and ME system shall have no voltage more than 110 % or lower than 90 % of the nominal voltage between any of the conductors of the system or between any of these conductors and earth.

Note: ME Equipment and System conforming to IS 13450-1/IEC 60601-1 can operate in IT system. The neutral to earth voltage of supply mains can be up to 230 volts. The demand of a low voltage (e.g. 3 V, 5 V etc) between Neutral and PE conductors of the supply mains is not essential. The manufacturer may designate the minimum qualifications for service personnel and train them to avoid confusion while installing the ME Equipment and System.

c. IS 13450-1 clause 7.9.3: The technical description ME equipment shall provide all data that is essential for safe operation, transport and storage, and measures or conditions necessary for installing the ME EQUIPMENT, and preparing it for use, particularly “special installation requirements such as the maximum permissible apparent impedance of supply mains”. To ensure timely operation of protective device, the measurement of impedance of supply mains shall be carried out for different sources such as supply from Transformer, DG, UPS etc and the value shall be compared with the protective device.
d. Equipment in Hospitals require special care for the power supply impedance (e.g X-ray machine). A conventional X-ray unit uses high power during Radiography. The power used during this time will be multiple times the power consumed during standby mode; however, it is for a short time of few mS. Some application also used a burst of exposures which may exist for few seconds. The selection of protective device (such as Fuse / MCB) and the input impedance of the supply system shall meet the requirements of safety and short time requirements of high power. E.g. for a high power 3 phase X-ray machine the input impedance between phases shall be up to 100 mΩ. These requirements shall be fulfilled by testing the impedance of supply mains.
e. ME equipment and ME systems, before putting into service, during maintenance, inspection, servicing and after repair or on occasion of recurrent tests shall be tested as per IEC 62353 to assess the safety, satisfying all test conditions recommended in IEC 62353. The necessary tests in addition to visual inspection are measuring continuity resistance of protective earthing, measurement of insulation resistance and equipment leakage current in the equipment and applied part.

B6: Additional requirements for ME equipment and ME systems used in conjunction with oxygen rich environments.

The risk of fire in an oxygen rich environment in/from ME equipment and ME systems, shall be reduced as far as possible under normal condition or single fault conditions.

An unacceptable RISK of fire is considered to exist in an oxygen rich environment when a source of ignition is in contact with ignitable material and there is no means that would limit the spread of a fire. A source of ignition is considered to exist in an oxygen rich environment when any of the following conditions exist in normal condition and single fault conditions.

a. the temperature of the material is raised to its ignition temperature,
b. temperatures could affect solder or joints causing loosening, short circuiting or other failures that could result in sparking or raising the temperature of the material to its ignition temperature,
c. parts affecting safety crack or change their outer shape exposing temperatures exceeding 300 °C or sparks due to overheating,
d. temperatures of parts or components could exceed 300 °C,
e. sparks provide adequate energy for ignition.

Single fault conditions related to oxygen rich environments in conjunction with ME equipment and ME systems are failure of a ventilation system, failure of a barrier, failure of a component that creates a source of ignition, failure of insulation providing the equivalent of at least one means of patient protection but less than two means of patient protection that could create a source of ignition and failure of a pneumatic component that results in leakage of oxygen-enriched gas.

ME equipment, its parts or components shall not ignite flammable anaesthetic mixture with oxygen or nitrous oxide. This requirement applies both in normal use and in the event of single fault condition. Available fuels and oxygen concentrations should be taken into consideration while designing the installation. All ME equipment and ME system shall be designed and tested to IS 13450 and ensure that the ignition of fire does not happen under the worst-case scenario.

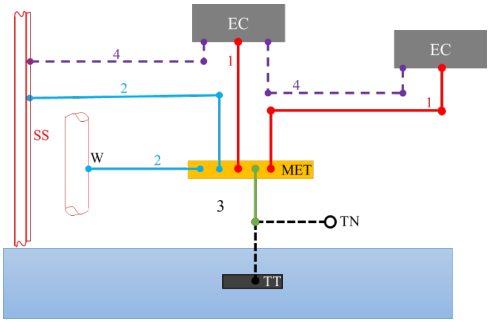
a. External exhaust outlets of an oxygen rich environment shall not be located so that risk of ignition occurs because of any electrical component (which could cause a spark in normal use or single fault condition) mounted on the outside of the ME equipment or an ME system.
b. Electrical connections within a compartment containing oxygen rich environments under normal use shall not produce sparks because of loosening or breaking unless they are limited in power and energy to the values identified in IS 13450.
c. Parts or components of category APG ME equipment that operate in a flammable anaesthetic mixture with oxygen or nitrous oxide shall be supplied from a power supply source that is isolated from earth by at least insulation equal to one means of patient protection and from electrical parts by insulation equal to two means of patient protection.
d. ME equipment, its parts and components that heat a flammable anaesthetic mixture with oxygen or nitrous oxide shall be provided with a non-self-resetting thermal cut-out, as an additional protection against overheating. the current-carrying part of the heating element shall not be in direct contact with the flammable anaesthetic mixture with oxygen or nitrous oxide.

B7: Electrical installation in GENERAL LOCATIONS

Refer NEC 2023 Part 1 (all sections) for electrical requirements for hospitals and medical locations.

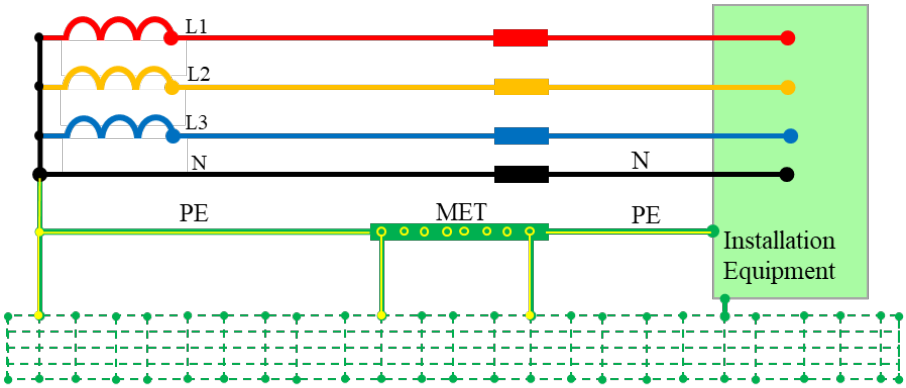
A comprehensive assessment shall be performed along with medical staff and the persons responsible for medical safety, to identify the proper electrical supply requirements for the ME equipment, ME systems and supporting electrical equipment intended to be used. Having identified these requirements, the appropriate classification for the medical location shall be determined. In order to determine the extent of a medical location, all possible patient positions shall be considered. Where assessment shows any given location that falls into both group 1 or group 2 categories, the location shall be classified as group 2. The assessment shall consider the effects of discontinuity of the electric supply on the ME equipment or ME systems. The following subjects shall not be compromised.

a. TN-S power supply as recommended in NEC 2023 shall be carried out in General, Group 0 and Group 1 locations. Refer NEC 2023 - part 1 section 18 clause 5 for more information.
b. The conventional touch voltage shall not exceed 50 VAC and disconnection time < 0.4 seconds in the final circuits up to 63 amps in unclassified and group 0 locations. (Group 1 and Group 2 locations, the voltage is <25 V AC).
c. Cables used for fixed wiring shall have either class 1 or class 2 conductors, as classified by IS 8130/IEC 60228. Cables with class 5 and class 6 conductors shall not be used for fixed wiring.
d. RCDs, where required shall be selected according to the type of residual current they may be subject to. Type AC RCDs shall not be used.
e. For distribution circuits, especially with multiple tap-off points, busbar trunking is recommended.
f. Automatic transfer switching/automatic change-over shall be installed for safety services and other essential loads.
g. Electrical installation of Overvoltage category III and IV at fixed part of the installation, Category II for all pluggable equipment.
h. Effective shielding and cable routing measures.
i. Every equipment shall comply with relevant Indian Standard wherever available. In the absence of the relevant Indian Standard, IEC standards may be used. Selection of the equipment shall conform clause 5 of IS 732. Consideration shall be given to the following points from the respective clause of IS 732 and shall conform to provisions of NEC 2023. Refer clause 7 of IS 18732 for further information.



EC - exposed conductive part (Panel board body)
MET - main earthing terminal
SS - structural steel (extraneous conductive part)
W - metallic water pipe (extraneous conductive part)
TT - earth electrode in a TT or IT system
TN - other means of earthing in a TN system eg. connection to earthed point of the power system
1 - circuit protective conductor
2 - main protective bonding conductor
3 - earthing conductor
4 - supplementary protective bonding conductors (additional bonding if required)
1,2,3,4 - protective conductors

Fig. B1: Protective equipotential bonding, earthing and protective conductors.



Grid interconnecting Neutral of the source and exposed conductive parts in the installation (grid reduces the earth fault loop impedance)

Fig. B2: System with separate Protective Earth conductor (TN-S) and protective multiple earthing (PME).

B8: ZONES OF RISK

Zones of Risk in the operating theatre when using flammable anaesthetic mixtures of anaesthetic gases and cleaning agents are classified as below.

Flammable Anaesthetic Atmosphere: Mixture of a flammable anaesthetic vapour and/or a vapour of a flammable disinfection or cleaning agent with air in such a concentration that ignition may occur under specified conditions.

Flammable Anaesthetic Mixture: Mixture of a flammable anaesthetic vapour with oxygen or with nitrous oxide in such a concentration that ignition may occur under specified conditions.

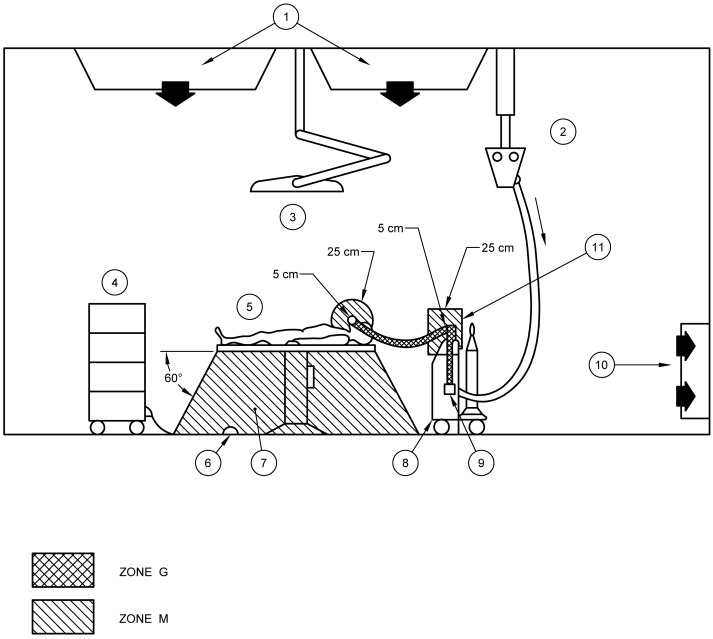
Zone G: Volume in a medically used room in which continuously or temporarily small quantities of flammable anaesthetic mixtures may be produced, guided or used including the surroundings of a completely or partly enclosed equipment or equipment part up to a distance of 5 cm from parts of the equipment enclosure where leakage may occur because such parts are unprotected and liable to be broken, subject to a high rate of deterioration, or liable to inadvertent disconnection.
Where the leakage occurs into another enclosure which is not sufficiently ventilated and enrichment of the leaking mixture may occur, such an enclosure and possibly the surroundings of it (subject to possible leakage) up to a distance of 5 cm from said enclosure or part of it is regarded as a Zone G.

Zone M: Volume in a medically used room in which small quantities of flammable anaesthetic atmospheres of flammable anaesthetics with air may occur. A Zone M may be caused by leakage of a flammable anaesthetic mixture from a Zone G or by the application of flammable disinfection or cleaning agents. Where a Zone M is caused by leakage, it comprises the space surrounding the leakage area of a Zone G up to a distance of 25 cm from the leakage point.

Explosion Protection:

a. When the administration of flammable anaesthetic atmospheres or flammable anaesthetics or flammable cleaning and/or disinfection agents with air or oxygen and nitrous oxide is intended, special measures to avoid ignitions and fire are necessary. These measures include mainly the use of antistatic flooring.
b. Effective ventilation and the application of a suction system on anaesthesia equipment assist in reducing flammable concentrations of flammable anaesthetic mixtures in the patient environment, the anaesthetist's working-place and the operating table. The effectiveness of a ventilation, system may be subjected to National Regulations. Zones of risk exist only when flammable anaesthetics or flammable cleaning and/or disinfection agents are used.
c. Requirements on construction, marking and documentation of medical electrical equipment of category AP or APG are given in IS 13450 (Part 1).

d. Mains plug connections, switches, power distribution boxes and similar devices, which may cause ignition shall be kept outside zones of risk.



1. Ventilation system,
2. Ceiling outlet with sockets for electric power gases (for example, oxygen), vacuum and exhaust ventilation system for medical electrical equipment,
3. Operation lamp,
4. Equipment,
5. Operating table,
6. Foot switch,
7. Additional zone M due to the use of flammable disinfection and/or cleaning agents,
8. Anaesthesia apparatus,
9. Exhaust system for anaesthesia gases,
10. Exhaust ventilation system,
11. Parts unprotected and likely to the broken.

Fig. B3: Example of different zones in a medical location

B9: PATIENT ENVIRONMENT

In locations where the position of the patient can be predetermined this provision may be restricted to extraneous conductive parts.

The continuous current between the equipotential bonding bar and any exposed conductive part as well as any extraneous conductive part in the patient environment shall not exceed 10 µA in normal condition for frequencies from dc to 1 kHz. The current may also be indicated as a continuous voltage with a limit of 10 mV between the parts.

a. During the test it is assumed that fixed and permanently installed medical electrical equipment is operating.
b. 'Normal conditions' means 'without any fault in the installation and in the medical electrical equipment'.

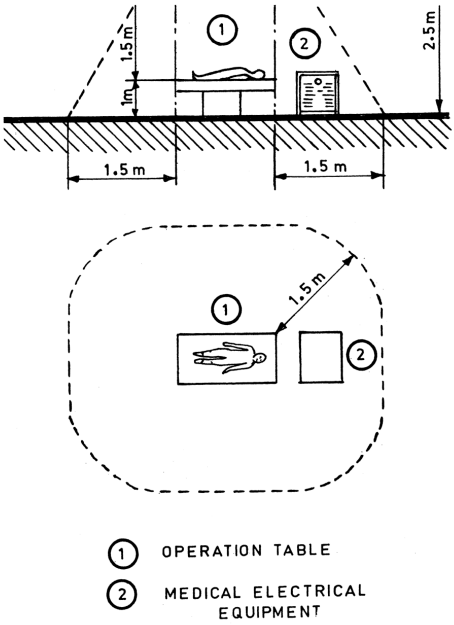


Fig. B4: Patient Environment

B 10: Electrical installation in MEDICAL LOCATIONS

B 10.1 General Requirements

Refer NEC 2023 Part 3 section 9 for electrical requirements for medical locations. Refer Annex B (part 3, section 9) for examples for allocation of group numbers and classification for safety services of medical locations.

In medical locations of group 1 and group 2, the conventional touch voltage shall not exceed 25 VAC and disconnection time of 0.2 seconds. The disconnection time can be 0.5 second for medical IT system with distributed neutral.

In medical locations of group 1 and group 2 for safety services and standby systems, the distribution system shall automatically change over from the main distribution network to alternate source such as an UPS for essential medical and non-medical loads. Preferably UPS with electrical separation (e.g. with isolation transformer) shall be considered with a TN-S system downstream.

Note: UPS with Isolation Transformer is different from medical IT system. Refer B 11 for more information.

In case of a single fault in the power supply, a total loss of power shall be prevented for medical locations of group 2. This may be achieved by provision of two independent supply lines, and/or a UPS within the same fire section for supplying the medical IT system, or a UPS that supplies a number of group 2 locations.

In Group 2 medical locations, an IT system shall be used for final circuits and where the same final circuit is connected to more than one ME equipment or ME system, located within the patient environment. The supply of final circuits for socket-outlets for ME equipment and ME systems used for life-support of the patient shall not be automatically disconnected in the event of a first fault. Refer NEC 2023 - part 3 section 9, clause 6.1.3.1.1.3 for more information (See B 11 for more information).

In each medical location of group 1 and group 2, supplementary equipotential bonding shall be installed and connected to the equipotential bonding bus bar for the purpose of equalizing potential differences between the parts, located in the “patient environment”. Refer NEC 2023 - part 3 section 9, clause 6.1.3.2 for more information (See 10.2 for more information).

Note: The equipotential bonding bus bar shall be located in or near the medical location. In each distribution board or in its proximity, an additional equipotential bonding bar shall be provided to which the supplementary equipotential bonding conductor and protective earth conductor shall be connected. Connections shall be so arranged that they are clearly visible and easily disconnected individually.

Examples of the allocation of group numbers and classification for safety services of medical locations are provided in Table B1.

Table B1 – Classification of Group 0 to Group 2 locations

Medical location	Group			Class	
	0	1	2	≤0.5 s	>0.5s ≤15 s
1. Massage room	x	X			X
2. Bedrooms		X			
3. Delivery room		X		X[a]	X
4. ECG, EEG, EHG room		X			X
5. Endoscopic room		X[b]			X[b]
6. Examination or treatment room		X			X
7. Urology room		X[b]			X[b]
8. Radiological diagnostic and therapy room, other than mentioned under 21		X			X
9. Hydrotherapy room		X			X
10. Physiotherapy room		X			X
11. Anesthetic room			X	X[a]	X
12. Operating theatre			X	X[a]	X
13. Operating preparation room		X	X	X[a]	X
14. Operating plaster room		X	X	X[a]	X
15. Operating recovery room		X	X	X[a]	X
16. Heart catheterization room			X	X[a]	X
17. Intensive care room			X	X[a]	X
18. Angiographic examination room			X	X[a]	X
19. Haemodialysis room		X			X
20. Magnetic resonance imaging (MRI) room		X			X
21. Nuclear medicine		X			X
22. Premature baby room			X	X[a]	X

[a] Luminaries and life-support medical electrical equipment which needs power supply within 0.5s or less.

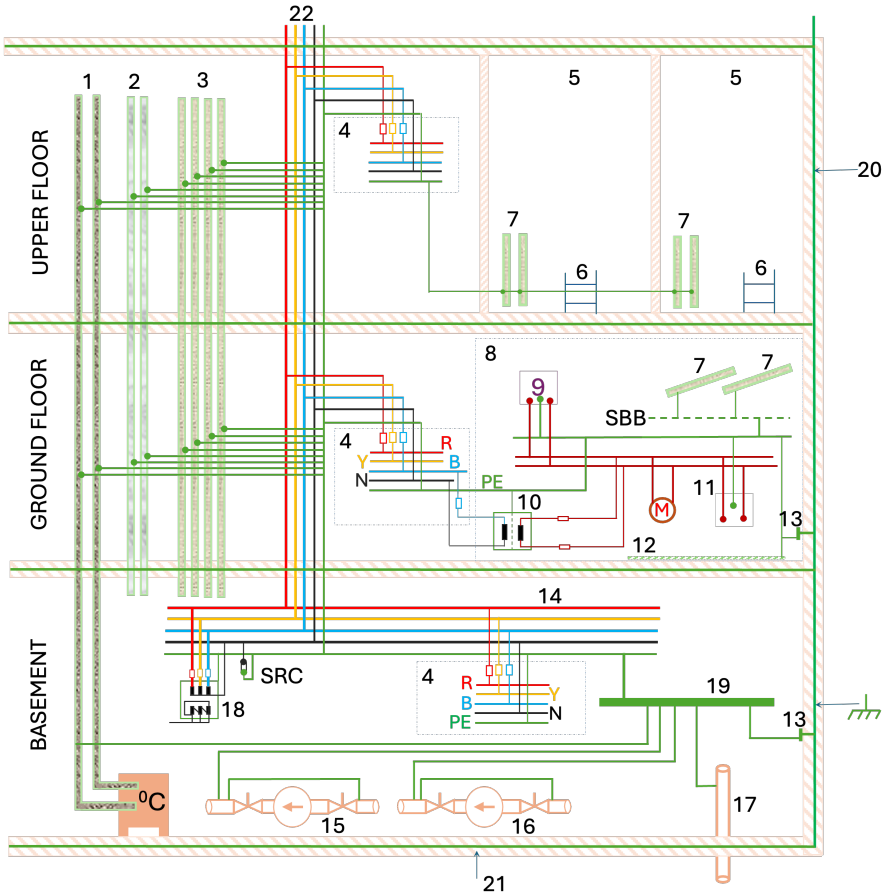
[b] Not being an operating theatre.

B 10.2 SUPPLEMENTARY PROTECTIVE EQUIPOTENTIAL BONDING

Supplementary protective equipotential bonding in Group 1 and Group 2 Medical locations shall include extraneous-conductive-parts, screening against electrical interference fields, connection to conductive floor grids, metal screen of the isolating transformer. Fixed conductive non-electrical patient supports such as operating theatre tables, physiotherapy couches and dental chairs should be connected to the equipotential bonding conductor unless they are intended to be isolated from earth.

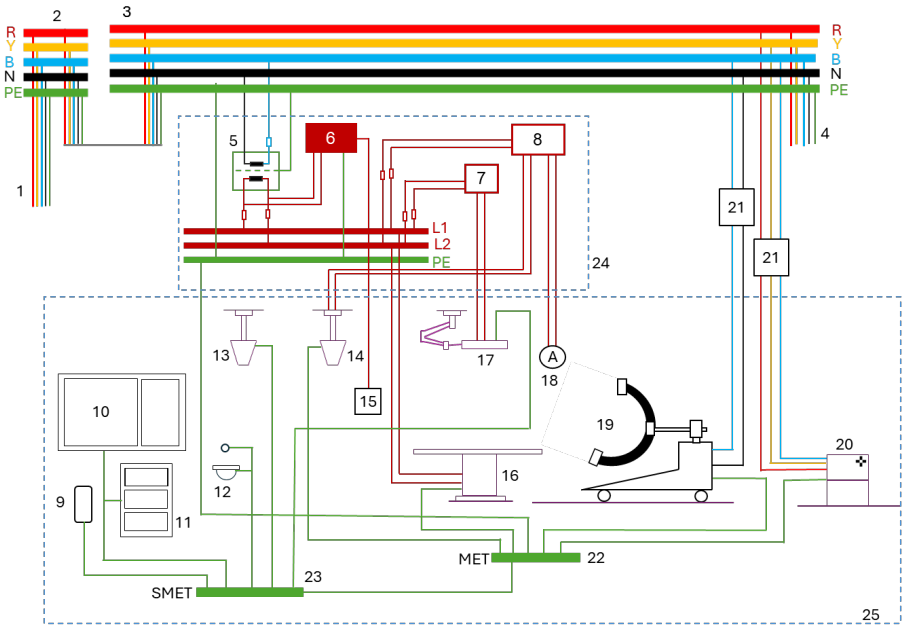
- extraneous-conductive-parts, unless they are intended to be isolated from earth,
- screens against electrical interference fields, if installed,
- connection to conductive floor grids, mesh and tapes, including those for static protection, if installed,
- metal screens of isolating transformers, cable shields, etc., via the direct path to the protective earthing conductor.

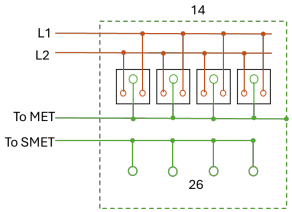
The resistance between simultaneously accessible exposed-conductive-parts, including the terminals for the protective conductor of socket-outlets and of fixed equipment, extraneous conductive parts and the equipotential bonding points shall not exceed 0.2 Ω to meet the requirement of < 25 V touch voltage.

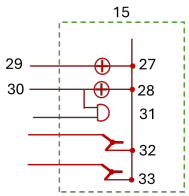


1 Heating / Air condition pipes 2 Water supply 3 Gas supply 4 Distribution board 5 General ward 6 Hospital bed 7 Metal pipes (water, oxygen, etc) 8 Group 2 medical location 9 Insulation monitoring device 10 Medical isolating transformer 11 Socket outlet	12 Antistatic Grid 13 Bonding for PME 14 Main Distribution Board 15 Water meter 16 Gas meter 17 Wastewater 18 Transformer 19 MET 20 Down Conductor of LPS 21 Foundation earth 22 Busbar trunking	R, Y, B phase conductors N Neutral conductors PE Protective Earth Conductor SBB Supplementary Bonding Bar M Class 2 ME equipment. SRC System Referencing Conductor Chassis earth (5020)
SRC = Neutral earthing of Transformer through a link – Preferably inside Main Distribution Board		

Fig. B5: Example of an electrical installation in a medical establishment







1. Feeder from the main service entrance	15 Alarm device for the insulation monitoring device (example)
2. Distribution of the floor supply system	16 Operating table (electrically driven)
3. Operating theatre distribution panel	17 Operating lamp
4. Safety supply system	18 Ampere meter for special safety
5. Medical isolating transformer	19 X-ray equipment
6. Insulation Monitoring Device	20 Sterilizer
7. Special safety supply system E1	21 Residual-current protective device
8. Special safety supply system E2	22 MET: Main Earthing Terminal of the location
9. Central heating	23 SMET: Sub earthing terminal of the location
10. Metal window-frame	24 Medical IT system
11. Metal cabinet for instruments	25 Group 2 medical location
12. Meal washing-basin and water supply	26 Terminals for equipotential bonding
13. Ceiling stand with outlets for gas supply	27 Operation (button)
14. Ceiling stand with mains socket outlets (with terminals for equipotential bonding,	

enclosure connected to the protective, conductor bar)	28 Warning (button) 29 Green 30 Red 31 Buzzer 32 Stop button for buzzer 33 Test button L1, L2, L3 = phase conductors N = neutral conductor All protective and functional earthing system and conductors there of including connections are shown in green colour

Fig. B6: Schematic presentation of protective conductors and equipotential bonding in operating theatres

B 11: MEDICAL IT SYSTEM

Medical IT system is made of Isolating transformers in accordance with IEC 61558-2-15, Medical Insulation Monitoring Device (MED-IMD) in accordance with IEC 61557-8 (Annex A and Annex B), insulation fault location system in accordance with IEC 61557-9 (Annex A).

Note: To ensure continuity of supply, in case of Interruption of normal electrical service an UPS supply is preferred as input to the Medical IT system. UPS with isolation transformers can not be considered as a Medical IT system.

Overload and over temperature in the isolation transformer must be monitored. The selection of an isolating transformer for medical IT systems with a short-circuit voltage suitable for the protection against overcurrent of the primary side and those of the final circuits is suitable for the design of the medical IT system. In addition to information given by a remote insulation warning, the following events could be constantly displayed.

- status of the power supply lines for medical locations of group 2,
- circuit breaker tripping,
- other disorders that are important for the operation of the medical location,
- malfunction of communication systems.

The status of the medical IT system should forward all information to technical staff. An indelible and easily readable written explanation shall be provided in the medical location, which includes the meaning of each type of signal, alarm and the procedures to be followed in case of a first fault

B 11.1: MEDICAL ISOLATING TRANSFORMERS

Isolating transformer for medical IT systems for the supply of medical locations
isolating transformer used for the supply of medical IT system for group 2 medical locations, designed to be permanently connected and with double or reinforced insulation between each part of the transformer (body, screen, circuits, thermal

sensitive device) except between the core and the body. Transformers shall be non-short-circuit proof transformers in accordance with the short circuit characteristic or protection against abnormal use.

Symbol of non-short-circuit proof isolating transformers for medical IT systems for the supply of group 2 medical locations

The rated output voltage shall not exceed 250 V AC for single-phase or three-phase transformers (phase-to-phase voltage). The rated output shall not be less than 0,5 kVA and shall not exceed 10 kVA. Where several transformers are needed to supply equipment in one medical location, they shall not be connected in parallel.

If a three-phase transformer is used for the supply of single-phase loads, the construction or the method of connection shall be such, that no voltage increases to more than 250 V on the load side, even in case of unbalanced load and other possible faults on the primary side. Under these conditions, three-phase transformers with secondary windings in either star or delta connection are acceptable.

If the supply of three-phase loads via an IT system is also required, a separate three-phase transformer shall be provided for this purpose.

B 11.2: MEDICAL INSULATION MONITORING DEVICE (MED-IMD)

Medical Insulation Monitoring Device (MED-IMD) in accordance with IEC 61557-8 (Annex A and Annex B) are suitable for this purpose. The auditor shall inspect the test report of the MED-IMD system to ensure compliance.

MED-IMDs shall be capable of monitoring the insulation resistance including symmetrical and asymmetrical allocation of the insulation resistance R_F and to give an insulation warning if the insulation resistance R_F between either the system and earth or the system and the PE-connection or the system and another reference point for equipotential bonding falls below the specified response value R_{an}, including the relative uncertainty of R_{an}.

The insulation warning indication should take place once when the insulation resistance R_F falls below 50 kΩ. For MED-IMDs with adjustable response value the lowest setting shall be ≥ 50 kΩ.

Some types of earth fault relays using a voltage asymmetry (voltage shift) in the presence of an earth fault as the only measurement criterion and, as a consequence, detecting only asymmetrical insulation faults, are not insulation monitoring devices.

B12: SAFETY SUPPLY SYSTEM

Interruption of normal electrical service in medical establishments may cause hazardous situations. Therefore, it is necessary to provide an uninterrupted power supply for vital services.

In some medically used rooms, a special safety supply system should be provided additionally. It supplies life supporting equipment and the operating table lighting, for a relatively short time if the mains supply or the safety supply system fails, or the switchover time cannot be tolerated.

The safety supply system is intended to supply electrical energy for a longer period to essential circuits of the medical establishment if the mains supply fails by external causes. The essential services are

B 12.1 LIGHTING

Essential lighting requirements will vary considerably in different locations, depending on the importance and nature of the work. In some instances, for example, operating table lighting in operating suites, and the critical working areas in the delivery room and recovery rooms, the degree and quality of emergency lighting should be approximately equal to that of the normal lighting. Even in these areas, however, considerable reduction in the general lighting may be acceptable. Ample socket-outlets connected to essential circuits should be available to enable portable lighting fittings to be used for any tasks outside the critical working area-which require a higher standard of lighting.

No general recommendations can be made for the emergency lighting arrangements for stairs and corridors as needs will differ considerably according to the design and size of the hospital. As a general guide, safety lighting should be provided to enable essential movement of staff and patients to be carried out in reasonable safety. Safety lighting should also be provided in public waiting spaces, at entrances and exits, and in corridors used by members of the public, ambulance staff, etc. External emergency lighting will normally be restricted to the accident and emergency entrance areas.

B 12.2 SOCKET OUTLETS

Socket-outlets should be so distributed that in each area where essential equipment will be used, socket-outlets connected to at least two separate subcircuits are available.

Socket outlets in operating rooms for the connection of X-ray equipment for fluoroscopy should be supplied from an essential circuit.

Electrical services, including automatic controls, which are essential for the safe operation of sterilizing equipment in operating theatre and the central sterile supply department should be supplied from an essential circuit.

Blood banks and other clinical refrigerators are usually equipped with temperature retaining facilities which will satisfactorily safeguard against power failures of several hours' duration. Nevertheless, they shall be supplied from an essential circuit.

Motors of surgical suction plant should be connected to an essential circuit. It is desirable that the motors should be so arranged that once they are switched on they will restart automatically, following an interruption of supply.

Safety supply systems for facilities for ventilation and air-conditioning purposes will usually apply only to plants which serve areas which are entirely dependent on mechanical ventilation and have no facilities for natural ventilation or where mechanical ventilation services are essential for clinical reasons.

Where alternate ventilation systems (e.g. two ventilator systems in one location) are used, safety service system is necessary for one of the systems, thus ensuring air supplies of approximately 50 percent of the normal rate. Changeover switches, however, should be provided, to enable either of the ventilation systems to be connected to the emergency service.

Table B2: Socket outlets in Essential service

Sl no	Department	No of socket outlets connected to essential circuits
1	Operating suits	All
2	Intensive care room and operating rooms in accident and emergency department	All
3	Delivery rooms	All
4	Post-anaesthetic recovery rooms	All
5	Intensive therapy units	All
6	Radiological diagnostic room	All
7	Ward accommodation set aside for patient dependent on electrically driven equipment, for example, respirators, rocking beds, artificial kidney machines, etc.	All
8	Special baby care units	All
9	Pathology laboratories	2
10	Wards where essential equipment such as suction apparatus will be used	2 sockets outlets for wards containing 1 to 4 beds and, pro rata, where the number of beds exceeds 4

Any mains energized alarm and control circuits should be so arranged that they are automatically connected to the safety supply system in the event of a power failure.

In biochemical laboratories and in the pharmacy about 50 percent of the normal load should be supplied from essential circuits.

It is reasonable to assume that only essential equipment will be used in these areas during periods of power failure. The recommendation that all sockets are connected to the Essential Circuits provides the most convenient choice of socket outlets at any time and simplifies installation.

B13: ELECTROSTATIC DISCHARGE (ESD) & ELECTROSTATIC ATTRACTION (ESA)

Four different hazards of static electricity are generally recognized: ESD damaging or disrupting electrical equipment, contamination caused by ESA, ignition of flammable substances and electrostatic shock to people.

B13.1 ELECTROSTATIC DISCHARGE (ESD).

Electrostatic discharges can cause losses of the functions of instrumentation during patient care, increasing the risks to human safety. Insufficient electrostatic control may also cause unnecessary repair costs of medical equipment, as well as corruption of data affecting the quality and reliability of medical operation.

ESD can be an ignition source in hyperbaric oxygen facilities and other locations where the oxygen concentration exceeds 23.5 % by volume.

The incidence of unpleasant electrostatic shocks to people has increased due to the increased use of highly insulating materials such as plastics. An electrostatic discharge occurs when a human body approach close enough to an object with different electric potential to exceed the electric breakdown field strength. ESD energy can be high enough to cause painful sensations to patients and healthcare personnel, resulting in involuntary movements, which can lead to accidents.

The risk of electrostatic shock can be reduced to tolerable levels by earthing of personnel and other conductors, and by correct selection of materials.

B13.2 ELECTROSTATIC ATTRACTION (ESA).

Electrostatically charged surfaces attract airborne particles. Increased deposition of Microorganisms onto charged surfaces, including the airways, human skin, and open wounds, can contribute to the incidence of hospital infections. Electrostatic sources of contamination and nosocomial infection can be healthcare personnel, patients, or the environment. All objects that come into contact with patients can be considered as potentially contaminated.

Cleaning, disinfection and sterilizing can prevent transmission of infective agents. However, because of the human factor, complete certainty in cleanliness cannot be achieved without adequate control of the environment. Avoidance of electrostatic

attraction (ESA) decreases airborne microbe contamination and improves overall cleanliness in healthcare. The reduction in charge carried by airborne submicron contaminants will additionally reduce the deposition of such contaminants in the airways, thereby reducing the load placed on the body's immune system. Charge accumulation and high surface charge densities can be reduced to tolerable levels by earthing of personnel and other conductors, and by correct selection of materials.

B13.3 ELECTROSTATIC CONTROL MEASURES.

Electrostatic control measures in medical locations are as per Table B3

Table B3: Electrostatic control measures

Location	Control Method			
	Earthing of personnel via footwear and flooring	Earth other conductors via flooring or direct connection	Use of conductive or dissipative materials	Use of low charging materials
Unclassified	Not mandatory			Recommended
Group 0	Recommended	Recommended	Recommended[a]	Recommended
Group 1	Recommended	Recommended	Recommended[a]	Recommended
Group 2	Required	Required	Recommended[a]	Recommended
[a] Conductive and dissipative materials should only be used if earthing is provided.				

Note: 'earthing' and 'grounding' are used synonymously. The above recommendations are based on IEC 61340-6-1.

Materials for electrostatic control can limit the generation of electrostatic charge or quickly dissipate electrostatic charge or suppress/attenuate electrostatic field/electrostatic potential associated with residual electrostatic charge. To a certain extent, these functions are related. For example, a material that is able to dissipate charge faster than it is generated will appear to be one that limits the generation of charge. However, in some cases, the functions can be independent. Some materials that do not dissipate charge quickly, can show limited accumulation of charge or low measured surface potential. The Materials are classified based on resistive properties and are Electrostatic conductive materials, Electrostatic dissipative materials and Electrostatic insulating materials. Refer IEC 61340-6-1 for more information.

Annex C
TYPE OF TEST INSTRUMENTS FOR SAFETY AUDITS IN HOSPITALS

The competent Medical Electrical Safety Auditor shall use the following meters and infrastructure while carrying out the safety audits.

1. Meters capable of testing (e.g multi-function meter)

    - Continuity of conductors (low current test)
    - Insulation resistance of LV and ELV system (500 V and 250 V respectively)
    - Floor and wall resistance measurement meter (for insulated floors and walls)
    - Fault Loop Impedance and prospective fault current
    - RCD test (Type AC, A, F and B type RCDs)
    - SPD tester
    - Polarity tester
    - Phase sequence (for 3 phase input to fixed equipment)
    - Voltmeter, Ammeter, etc

2. PAT Tester: Portable Appliance tester for testing equipment used for General application and used for Medical Electrical Equipment are different.

3. Accuracy of Meters and High current tests.

    Multi-function meters are often low current meters. For more accurate measurements, meters with high current are necessary e.g.

    - Continuity resistance measurement with meters of 10 Amps to 25 Amps are required for Switchgear and Controlgear assemblies and for testing of supplementary equipotential bonding in medical locations.

    - Fault Loop Impedance meter with test currents of > 200 Amps is required for testing impedances in locations where protective devices more than 250 Amps are used.

4. Instruments required for testing ME and MEC (Bio Medical Equipment) are included in Annex G.

Annex D
TYPE OF SYSTEM EARTHING AND SAFETY REQUIREMENTS

The earthing systems are classified as TN System, TT System and IT System. In TN/TT system safety is achieved by disconnection of supply during a fault whereas in IT system continuity of supply is possible during first fault.

a. *TN System* - has one or more points of the source of energy directly earthed, and the exposed and extraneous conductive parts of the installation are connected by means of protective conductors to the earthed point(s) of the source, ***that is, there is a metallic path for earth fault currents to flow from the installation to the earthed point(s) of the source***. TN systems are further sub-divided into TN-C, TN-S and TN-C-S systems.

b. *TT System* - has one or more points of the source of energy directly earthed and the exposed and extraneous conductive parts of the installation are connected to a local earth electrode or electrodes that are electrically independent of the source earth(s).

c. *IT System* — has the source either unearthed or earthed through a high impedance and the exposed conductive parts of the installation are connected to electrically independent earth electrodes.

Earthing of the source *(sometimes called as system earthing or system reference earthing),* is done to have a balanced potential in the network. In a 3 phase 4 wire system, star point of the transformer is earthed *(Neutral)*. A 3 phase 3 wire system is earthed through a neutral earthing transformer. These are the commonly used, other methods are explained in IS 732.

The first letter T in the network denotes the source earthing. “T” Terra is a French word meaning “direct connection to earth” *(soil or foundation steel)*.

First letter - Relationship of the power system to earth:

T = direct connection of one point to earth;

I = all live parts isolated from earth, or one point connected to earth through a high impedance.

Second letter - Relationship of the exposed conductive parts of the installation to earth.

T = direct electrical connection of exposed conductive parts to earth, independent of the source earthing;

N = direct electrical connection of the exposed conductive parts to the earthed point of the source earthing *(in a.c. systems, the earthed point of the source earthing is normally the neutral point or, if a neutral point is not available, a line conductor or earthed via an earthing transformer).*

Subsequent letters (if any) – Arrangement of neutral and protective conductors.

S = protective function provided by a separate conductor *(separate from the neutral conductor or in a.c. systems earthed phase)*.
C = protective functions and neutral are combined in a single conductor *(PEN conductor)*.

D.1 Different networks

D.1.1 TN-C network: Protective conductor and Neutral are combined in the installation. OCPD is the primary protective device. Low fault loop impedance is assured by the metallic fault return path to the source. Neutral conductor does two jobs Protective Earth + Neutral (PEN). In TN-C the letter C stands for "Combined" PE and N. *(TN-C is not allowed in Hospitals).*

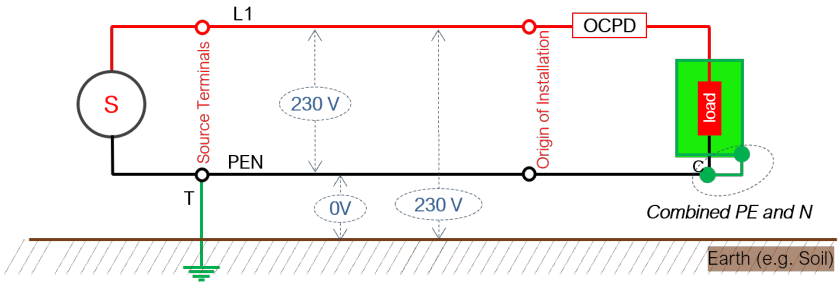


Figure D.1 TN-C network

D.1.2 TN-S network: Exposed conductive parts *(body)* of the installation is connected to the earthed terminal of the source by a separate protective conductor. Low fault loop impedance is assured by the metallic fault return path to source. OCPD is the primary protective device. Letter S stands for "Separate" N and PE. *(TN-S is recommended in Hospitals, except in Group 2 location where Medical IT is used).*

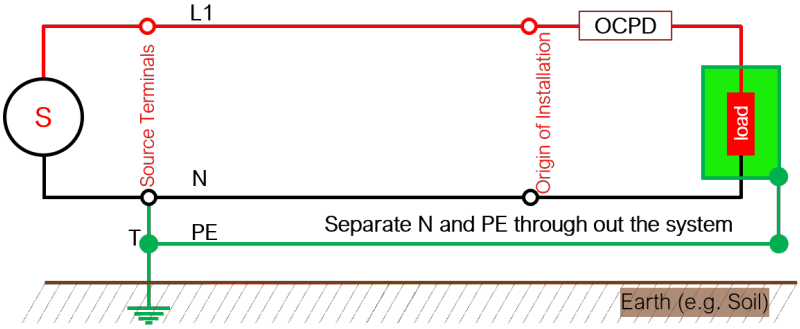


Figure D.2 TN-S network

D.1.3 TT network: Earthing at source and installation are electrically independent.

High fault loop impedance. 30 mA RCD at origin of installation is mandatory for earth fault protection as per IS732.

(Note - Neutral is not earthed at distribution. No link between neutral and earth at origin of installation).

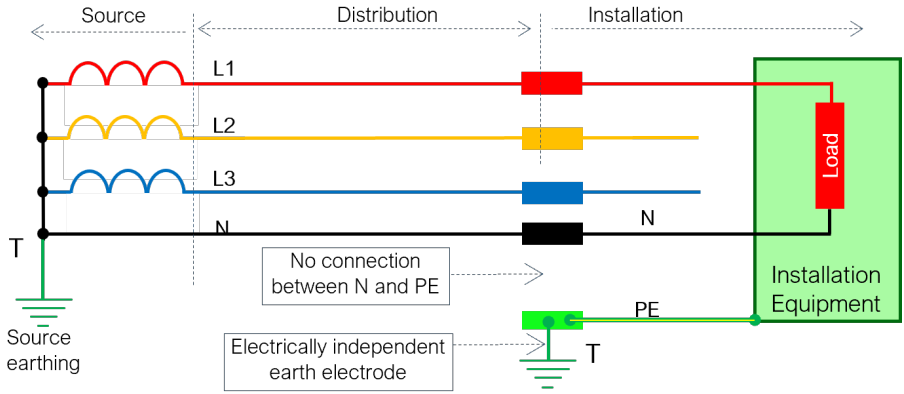


Figure D.3 TT system - Source earth and installation earth are electrically independent. High fault loop impedance. Require an RCD for earth fault protection.

All exposed conductive parts collectively interconnected by protective conductors with a MET and to an earth electrode common to all those parts. For compliance with the requirement, the following shall be fulfilled:

$$R_A \times I_a < U_C$$

where

R_A = resistance of the earthed system for exposed conductive parts,

I_a = operating currents of the disconnecting series device or settings of shunt relays and

U_C = conventional voltage limit *(50 V in general case and 32 V in case of relays with time lag).*

Note:

1. *Low earth fault loop impedance achievable in TN system cannot be fulfilled in TT system. Residual current devices (e.g. RCCB / ELCB / CBCT & ELR) shall be used for earth fault protection.*
2. *The maximum allowed residual current on these protective devices is 30 mA for human protection and 300 mA for fire protection.*

Maximum earth electrode resistance in TT system protected by RCD's and limit touch voltage < 50 V *(ref table 14 and cl.24.4 of IS 3043)*

30 mA RCD = 1666 Ω

300 mA RCD = 166 Ω

D.1.4 IT network

IT network is used in places where continuity of supply is desired. In IT system source is either unearthed or earthed through a sufficiently high impedance *(at the neutral point, artificial neutral point, or a line conductor).* The exposed conductive parts of the installation are earthed independently or collectively.

Supply can continue without disconnection during a single fault. However the supply shall be disconnected during a double fault.

IT systems can be adopted for limited areas of installation such as operation theatres in hospitals, control circuits in a substation, supply to Instrumentation system in a process industry, lighting system in inaccessible areas in an industrial environment, BMS & security supply to a building, safety services such as firefighting system *(e.g. escape route lighting, smoke detectors, ventilation pumps),* etc.

Insulation monitors are necessary in an IT system to monitor the insulation resistance or first fault. Residual current monitors will enhance the safety in an IT network.

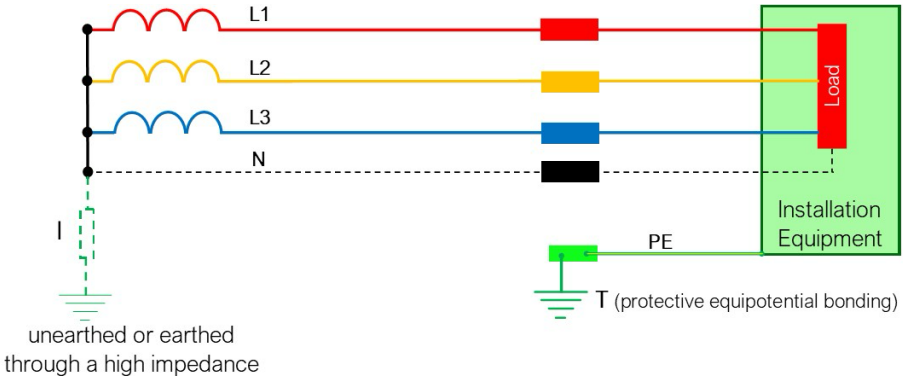


Figure E.4 IT system with insulation monitoring

D.2 Earthing of Low Voltage electric supply by supplier

D.2.1 Public electricity supply from a common transformer – *(cl. 4.0 – IS 3043:2018)*

Commonly used system in low voltage electricity supply is TN-C-S with **P**rotective **M**ultiple **E**arthing ***(PME)***. In this system the neutral and protective conductors at distribution are combined. The PEN conductor is referred as a combined neutral and earth *(CNE or PEN)* conductor, which is earthed at the source and extremities of the distribution and point in between. Multiple earthing of the PEN conductor ensures that if the conductor becomes open circuit for any reason *(probably cut or snapped)*,

exposed conductive parts at the installation remain connected to earth and the voltage between the installation and local earth is substantially reduced.

OCPD *(cut-out fuse)* at the incoming provide fault protection in the installation.

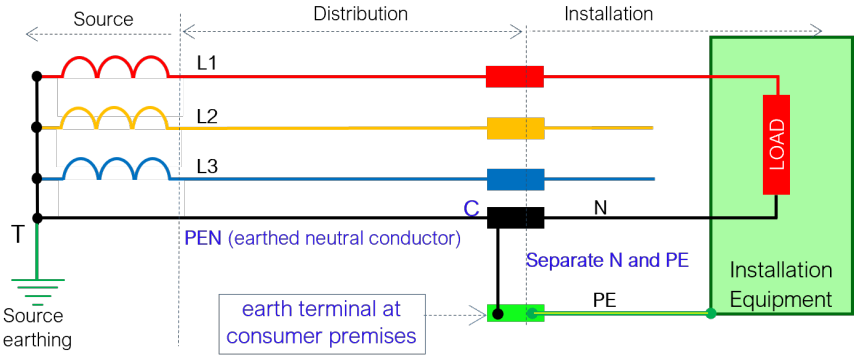


Figure D.5 Basic TN-C-S network

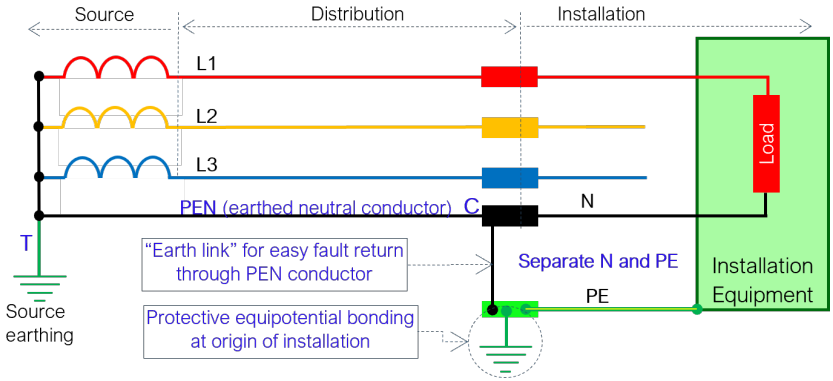


Figure D.6 TN-C-S network with protective equipotential bonding at origin of installation

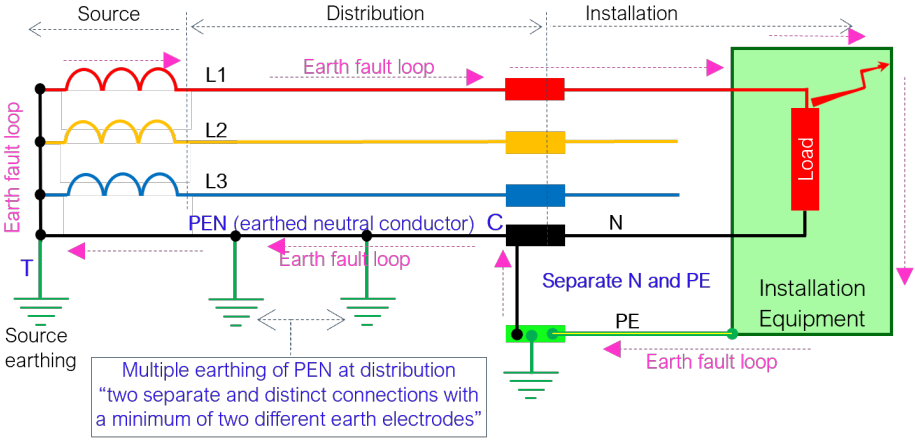


Figure D.7 TN-C-S network with Protective Multiple Earthing (PME) ref. clause 4 of IS 3043:2018)

Earth fault loop for a consumer premise in a TN-C-S system with PME, decides the disconnection of incoming protective device. Higher impedance may lead to non-disconnection of the protective device and accident.

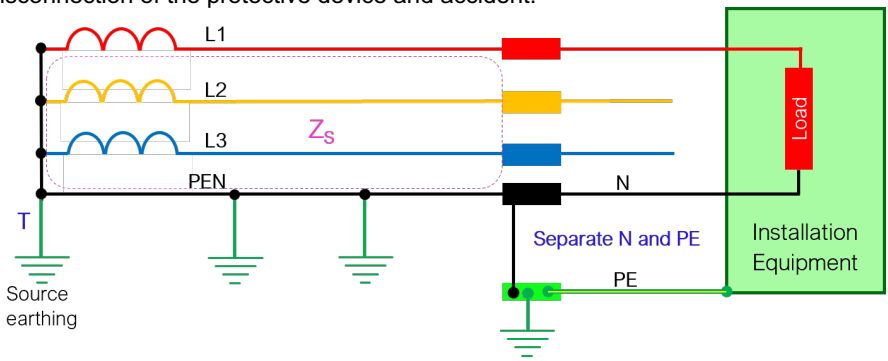


Figure D.8 Z_S Earth Fault loop of the supply system

Note: impedance of the transformer (transformer internal impedance) and impedance of the line and PEN conductor from transformer up to the origin of installation decide the earth fault loop impedance of power supply system.

Earth fault loop impedance Z_S of the power supply system decide the fault current at the origin of the installation. The information about Z_S is a critical factor to decide the incoming OCPD rating at the consumer premise to achieve safety *(automatic disconnection of supply during fault).* This information shall be provided by the electricity supplier to every consumer for the purpose of deciding suitable earth fault protection measures by the consumer at his premise in addition to the protection

provided by the electricity supplier. OCPD's shall be used as primary protective device. RCD's shall provide additional protection.

D.2.2 Earthing of Industrial and Commercial premise

IS 3043:2018 recommends to adopt the TN-S system with PME, the neutral *(source earthing)* is solidly connected to the MET and earthing grid.

Earthing system at the consumer premise for voltages above 230 V should be designed as a **P**rotective **M**ultiple **E**arthing ***(PME)*** system with a separate protective conductor ***(TN-S).*** PME is made to reduce the earth fault loop impedance and to ensure reliable disconnection of supply during an earth fault. In this system, source earthing and the non-current carrying metal parts at the installation are interconnected by PE conductor and PME grid.

There is no need to design the earth electrodes *(such as plate, pipes and rod in soil)* for the appropriate thermal withstand capacity, assuming that the total fault current is passing through the earth electrodes.

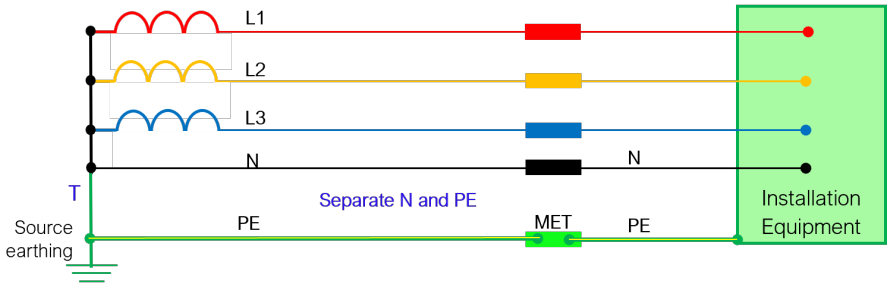


Figure D.9 Illustration of Basic TN-S system without PME. (system with separate protective conductor)

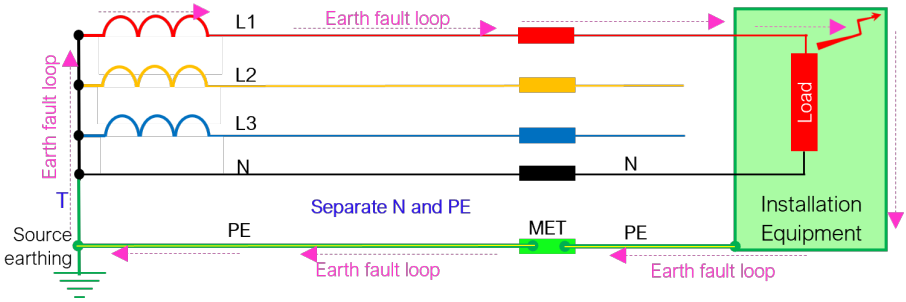


Figure D.10 Illustration of Earth fault loop in Basic TN-S system

Condition of automatic disconnection by an OCPD in TN network :

$$Z_s \times I_a < U_o$$

Where
Z_s = fault loop impedance;
I_a = current ensuring the automatic operation of disconnecting device;
U_o = conventional voltage limits.

In addition to the PE conductor, PME grid interconnect source earthing and exposed conductive parts in the installation and reduces the earth fault loop impedance. Lower earth fault loop impedance leads to higher fault current resulting in quick disconnection of supply. Fault current returns through the PE conductor and PME grid ***(two distinct and separate fault return paths).***

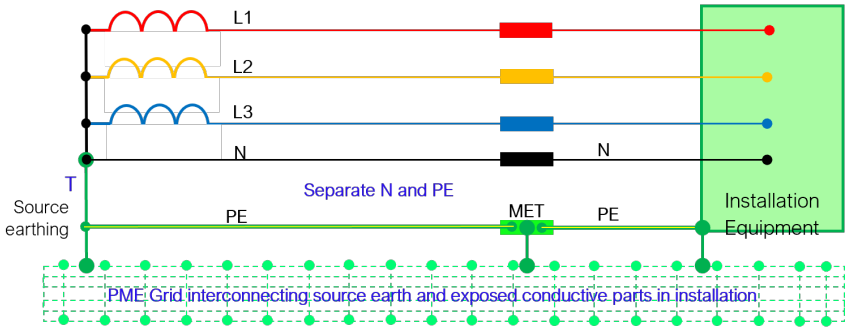


Figure D.11 Illustration of Basic TN-S system with PME grid interconnecting source earthing and exposed conductive parts in the installation.

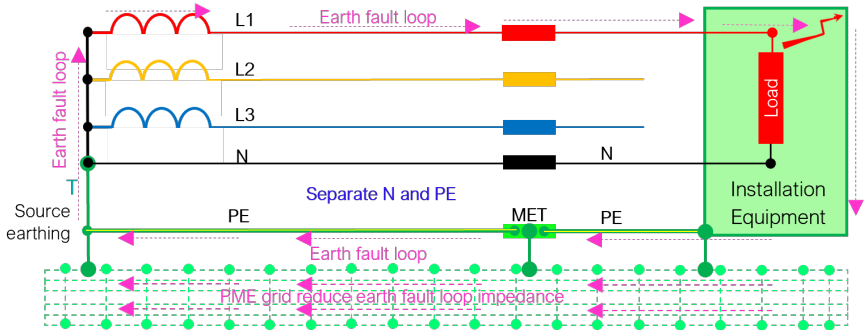


Figure D.12 Illustration of earth fault loop in TN-S system with PME grid.

The continuity resistance of the fault return path through the PME grid should be maintained as low as possible *(depending upon the fault loop impedance)* and in no

case greater than one ohm. *(IS 3043:2018 – 27.2.3).*

Note: Continuity resistance do not mean the resistance of an earth electrode in soil.

In case of EHT substations, where there is a possibility of the ground potential attaining very high values in the event of an earth fault *(of the order of 5 kV and above)*, the earth grid design should be based on the tolerable limits of the potential gradient in the substation area, and the step and touch potential due to fault conditions. *(IS 3043:2018 – 27.2.4).*

Note: This clause also means earth grid in substations to reduce touch and step potentials shall be considered for voltage above 33 kV.

As far as the value of the earth resistance is concerned, the objective from the point of safety consideration is not to attain a minimum value of the earth resistance as is sometimes understood. But the consideration should be whether there is adequate co-ordination between the practically obtainable value of the earth resistance and the setting of the protective relays. *(IS 3043:2018 – 27.1.3).*

Practice which has been followed until now, is to design the earth electrodes for the appropriate thermal withstand capacity, assuming that the total fault current to be passing through the earth electrodes. This is true in the case of an earthing system which is not interconnected with neutral earthing (TT/IT system). *(IS 3043:2018 – 27.3.1).*

However, in the case of a PME system where the neutral of the supply transformer and the non-current carrying metal parts in the system are interconnected by the common earth grid, which is designed for the prospective fault current, there is no reason to design the earth electrodes assuming that total earth fault current is dissipated through the earth electrodes. In the case of an interconnected system, earth fault current is returned to the neutral mostly through the interconnected system. *(IS 3043:2018 – 27.1.3).*

Note

1. *Interconnected system consists of protective conductor running along with live conductors and an earth grid running in soil/concrete.*
2. *TN-S system with PME in industrial and commercial installation - earth electrode (such as plate or pipe) sizing and calculations are not necessary.*

The expected fault current in PME grid is up to 80 % of the expected total fault current. Hence the PME grid shall be able to handle this fault current. *(IS 3043:2018 – 27.3.1).*

D.2.3 Wrong installation: *Public electricity distribution*

Sometime this network is called as TT network. Missing link between neutral terminal and earth terminal at consumer installation *(No low-impedance fault return path)*. Increased fault loop impedance result in lesser fault current and non-disconnection during fault. PEN conductor becomes N. Improper TT due to earthing at distribution.

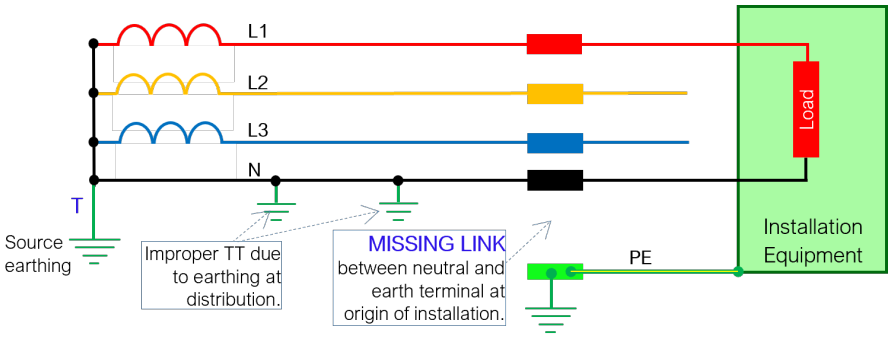


Figure E.13 Wrong installation in public LV distribution.

D.2.4 Wrong installation: *Industrial and commercial system*

Industrial and commercial installation often follow the below method. Each Transformer and DG neutral is connected to two earth pits and body to two different earth pits. Electrical panels, UPS, Lift, electronic equipment, etc, are connected to different earth pits in soil. Higher fault loop impedance result in non-disconnection of supply and "FIRE DUE TO SHORT CIRCUIT". Other erroneous practices are explained in Annex E.

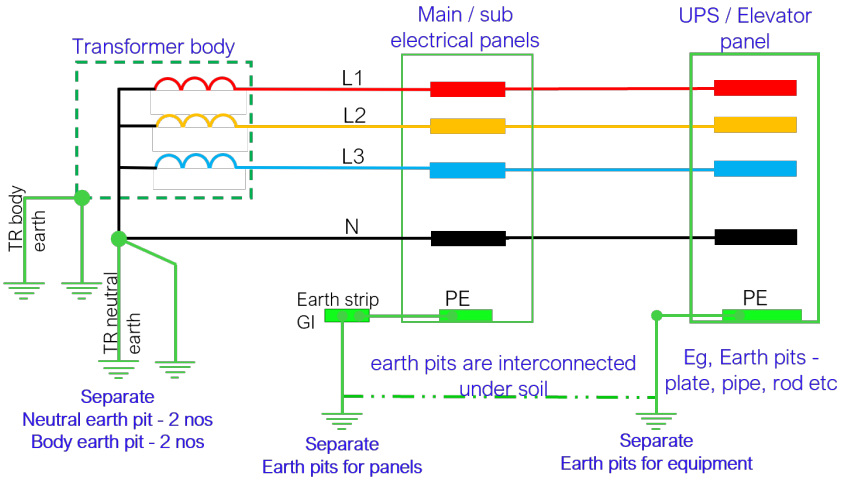


Figure D.14 Wrong concept of earthing followed in Industrial and commercial installation.

Annex E
ERRONEOUS PRACTICES

Paradigm shift – The need of the hour to improve electrical safety in India.

Accidents due to electrical reasons are at its peak in India. The total number of people getting affected due to electrical accidents are 1000's annually. One out of two fire accidents in buildings is attributed to electrical reasons such as a short circuit.

Modern safety devices are used in India expecting good results, unfortunately the wrong installation practices followed, beat the purpose.

Myths in earthing: The word "earth" and "earthing" is understood as an electrode in soil. Other myths are the derivations from this concept.

E.1 Myth: Separate earth pit - Standards and regulations recommend connection to two separate earth pits for transformer neutral, transformer body, DG neutral, DG body, UPS neutral, UPS body, Panel body, elevator, each and every electrical appliance. All earth electrodes under soil need interconnection under soil as a grid.

Fact: IS 3043 / IS 732 *(or any other standards)* recommend any of the above. The subject of earthing is about achieving safety during an earth fault by implementing various electrical safety rules. The most common rule is "protective equipotential bonding and automatic disconnection of supply" ***(also called earthed equipotential bonding and automatic disconnection of supply)*.**

Note: Ref. following clauses of IS standards
IS 3043:2018, cl. 11.1.3, cl. 23, fig 38 to 41 showing neutral and body connection to earth busbar (MET).
IS 732:2019, cl. 4.2.11, cl. 4.2.15, cl. 5.2.4, annex FF

Making separate connections to the earth pit from every equipment is not only wrong practice, but the primary reason for electrical failures and accidents.

E.2 Myth: Chemical earth pit to improve the system - Chemical earth, digital earth, pipe in pipe, plate in pipe, NCE charge electrode, earth enhancing compound, chemical compound, granule backfill compound, carbon earth, gel earthing electrode and other attractive names. Some of them claim that they can absorb lightning, fault current and solve major electrical problems. They are capable of providing an earth pit resistance close to 1 ohm in any soil.

Fact: Resistance of an earth electrode in soil does not play a major role in a LV system *(including neutral of the source, UPS, electronics etc).* The compounds used are fly ash, bentonite, carbon flakes, graphite, cement etc. Except conductive cement, others seem to be creating problems to earth electrodes in the long run. *(This is the reason bentonite materials are not allowed in RDSO for railway application)*

E.3 Myth: Neutral requires two separate and distinct connections to earth electrodes in soil as per CEA regulation 43.

Fact: Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2023, demand the following in Regulation 43.

- Earthing as per the standards (e.g. IS 732 / IS 3043 / NEC 2023)
- Protective equipotential bonding in every building
- Efficient automatic disconnection by testing Fault loop impedance in every circuit.

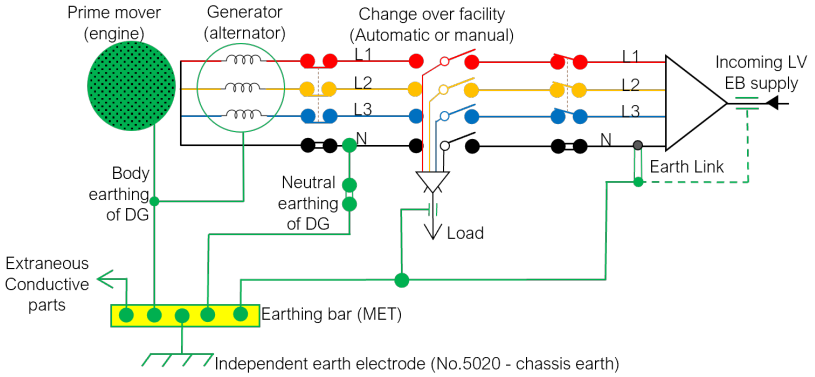


Figure E.1 DG & mains change over (fig 38 from IS 3043:2018)

Earth terminals connected to Earth Bar **(MET)** are,

1. Engine, alternator and Neutral of DG,
2. Incoming EB supply: TN-C-S system.
3. Earth of load.
4. The earth bar is also connected to extraneous conductive parts and
5. Independent earth (no 5020 - chassis earth).

E.4 Myth: Earth pit of 1 ohm is required for safety and operation of electronics.

Fact: Resistance of an earth pit in soil does not influence an LV electrical installation. No standards mentioned a value of 1 ohm for an earth pit or an earth grid in an LV system including DG or transformer.

E.5 Myth: Chemicals in a chemical earth pit produce low resistance.

Fact: Resistance of an electrode to soil is influenced by the (1) resistance of the metal electrode, (2) contact resistance to soil and (3) the resistivity of the surrounding soil. Out of these 3, the main influencing factor is the soil resistivity surrounding the electrode over an area of few meters. Chemicals which influences this much soil will leach in a short time and of no use after few months. Some compounds help in

reducing the contact resistance between the electrode and soil, hence can be used in rocky areas to have some reduction in the resistance of an earth electrode. However, a value in the range of 1 ohm or 100 ohm does not influence the total LV system.

E.6 Myth: the best way of installing an earth electrode is to use with a chemical compound.

Fact: Best results are achieved by hammering the electrode in soil. However this is not possible in rocky areas, hence an enhancing compound such as conductive concrete may help in getting better results.

E.7 Myth: Earth pit resistance influence the tripping time of a protective device.

Fact: Earth fault loop impedance *(not earth pit resistance)* influence the tripping time of a protective device.

E.8 Myth: Lightning protection require an earth electrode of 10 ohms.

Fact: Type A electrodes can have an optional resistance of 10 ohm. However, the recommended practice for modern buildings is Type B earthing which is a ring earthing or a foundation earth electrode. *(Ref. cl.5 of this guide)*.

E.9 Myth: Earthing in high-rise buildings: Type A, vertical rod electrodes are installed in basements inside the periphery of buildings, in order to dissipate lightning current to earth

Fact: This is a violation of standard IS/IEC 62305-3.

The standard explains, "*Type A arrangement comprises horizontal or vertical earth electrodes installed outside the structure to be protected connected to each down conductor or foundation earth electrodes not forming a closed loop".*

E.10 Myth: Grounding & earthing: Grounding is for transformer neutral and earthing is for metal objects in an installation.

Fact: Both terms are the same. "Grounding" is used in USA and "Earthing" is used in IEC/ISO standards (*ref clause B.13.3 of this guide*).

F.11 Practice of earthing: An electrical system may work without a fault for years. Good earthing practices ensure that the installation is safe during fault. However wrong practices explained in Fig E.2 create accidents during fault. The IEC 61000-5-2 (earthing and bonding for EMC) prohibit the usage of the wrong practices in Fig E.2.

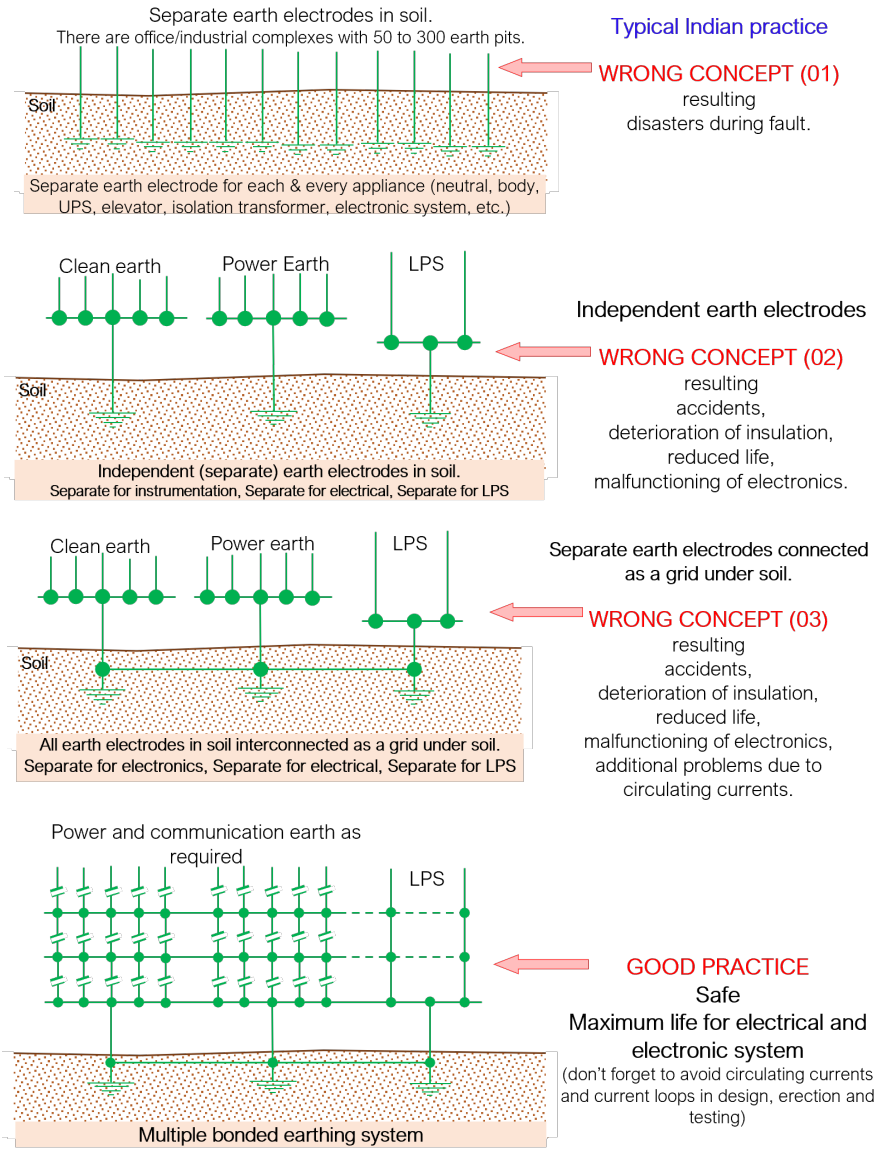


Figure E.2 Wrong concept and Good Practice of earthing

The below figure is a 3-D representation of the good practice of earthing in a building with various electrical and electronics.

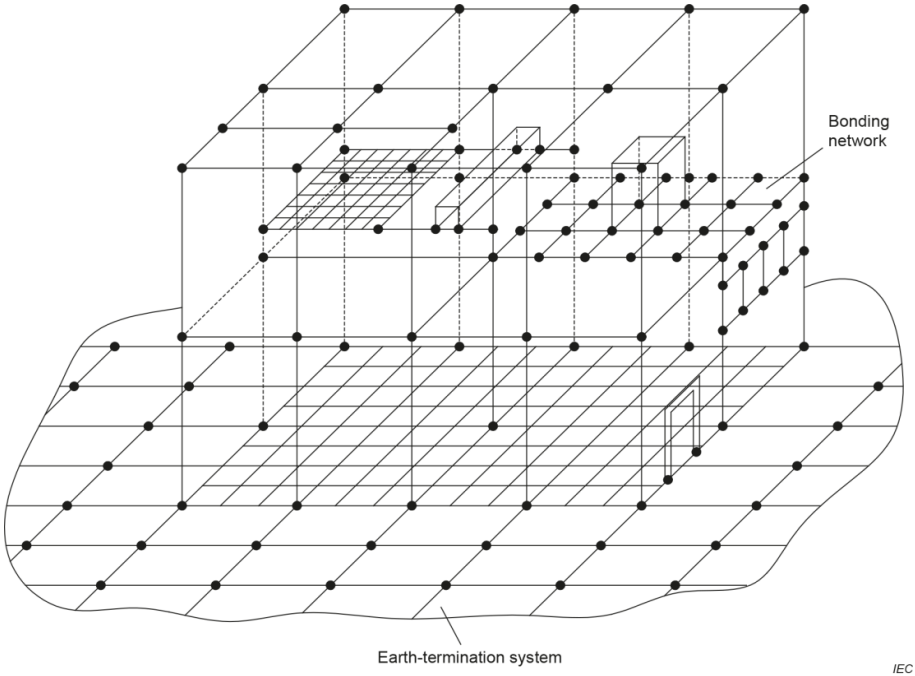
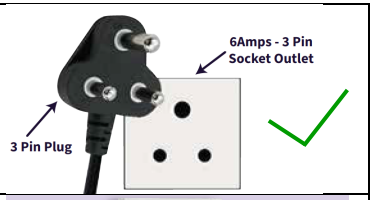
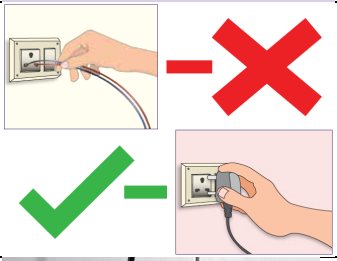
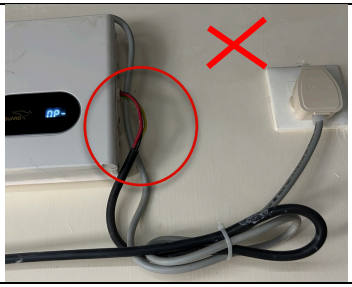


Figure E.3: A 3-Dimentional representation of good earthing in concrete building.

Annex F
WIRING REQUIREMENTS

F.1 DO's and DONT's

1	All plugs and sockets shall be of India type. 3 pin plugs are to be used for class 1 equipment. 2 pin plugs are allowed for class 2 equipment.	
	Use 6 amps plug and socket for appliances up to 1000 Watts. For higher rated appliances, use 16 amps.	
	An easily accessible and identifiable switch should be provided near sockets to disconnect the power in an emergency.	
	Never connect bare wire ends directly to the socket outlets, always connect through plugs.	
	Don't put multiple appliances in one socket	
	Do not connect any loose wires to extension boards. It should be with	

	proper electric plug which should be inserted in the extension boards. Use only good quality extension boards and with proper ampere rating. It should have fuse protection to prevent any short circuits. Use only 3 wire type extension cords. Do not use any modified extension cords with multiple wire joints. Use only cords, connection devices and fittings equipped with strain relief mechanism. Always remove the plug top by pulling the plug, the cord should not be used for pulling the plug. Do not use flexible cords that have been damaged or modified. Ensure that all socket outlets installed on extension cords are incorporated with shutters. Avoid using extension leads along the walkways and corridors.	
2	All wires are fixed properly are installed inside conduits and are not exposed outside even a few cm's. The exposed wire inside the circle in the picture is a danger.	
	Socket outlets, electrical appliances, etc. should be located safely in such a way that they don't come in contact with water.	

F2: Use of MCB's are RCCB's

1. Every circuit to be protected with an MCB (use Type B MCB 6 amps for lighting circuits and for 6 amps sockets)
2. Minimum size of wire for circuits are 1.5 mm^2 Copper for light fittings and 2.5 mm^2 Copper for power sockets.
3. Every circuit should have a phase wire, a neutral wire and an earth wire, all three are of the same size.

4. The incoming Distribution board should have an RCCB of 30 mA. If the number of equipment used are more than 15 nos, these RCCBs may trip due to higher leakage current in that case, the incoming can be equipped with an RCCB of 300 mA and all individual circuits should have 30 mA RCCB.
5. If available use Type A RCCB since most loads are electronic.

F3: Coordination of MCBs and wires

MCBs are to protect the wiring. The wires in the circuit should withstand the over current for the time the MCB is expected to trip. hence MCB's are wirings downstream are to be coordinated.

Annex G
PERIODIC TESTING OF MEDICAL ELECTRICAL EQUIPMENT

ME and MES are to be periodically tested as recommended in the standard to ensure safety of patient, medial staff and environment. The list of ME, test parameters and generic name of test equipment are listed below.

Medical Equipment to be Tested	Test Equipment / Instrument	Parameters to be Tested
All Medical equipment need mandatory testing for electrical safety as per IS13450-1, & IS/IEC 62353	Electrical Safety Analyser	Voltage, Load Current, Protective Earth Resistance, Earth Leakage Current, Enclosure Leakage Current, Patient Aux Leakage Current, Patient Leakage Current, Differential leakage current, Mains on Applied Part (MAP) Leakage Current, Insulation Resistance, Earth Resistance
All Types of Ventilators	Ventilator/Gas Flow analyser and Electrical Safety analyser	Tidal Volume Inspiratory & Expiratory, Minute Volume, Peak Inspiratory & Expiratory Flow, Oxygen %, Breath Rate, Inspiratory & Expiratory Time, Inspiratory & Expiratory ratio, Peak Inspiratory Pressure, Positive End Expiratory Pressure, Inspiratory Pause Pressure, Mean Airway Pressure, Flow, Pressure, Humidity, Temperature, Altitude, Lung Compliance, Gas type
BIPAP		Inspiratory Positive Airway Pressure, Expiratory Positive Airway Pressure, Breath Rate, Inspiratory Time
CPAP		Pressure Tests
Anaesthesia Workstations / Boyles Apparatus		O2 & N20 Flow Test, Oxygen%, CO2%, N2O %, Sevoflurane %, Isoflurane %, Desflurane%, Halothane% and Enflurane%
Insufflator		Flow & Pressure Test
Oxygen Concentrator		Flow Test & Oxygen %
HFNC & HFOT		Flow Test, Temperature& Oxygen %
Flow Meter		Flow
Vacuum Gauge		Negative Pressure

Suction Machine		Negative Pressure
Tourniquet		Pressure
Neo Puff		Pressure
Nebulizer		Flow & Pressure
Multipara Monitors / Patient Monitors	Vital Signs Simulator & Electrical Safety analyser	Heart Rate, Respiration, NIBP, IBP, Spo2, Temperature, Arrythmia, Pressure Relief, Cardiac output
Sphygmomanometer		Manometer & Leakage Rate
Digital BP Apparatus		Non-Invasive BP Test
NIBP Monitor		Heart Rate, Amplitude & Arrythmia Test
ECG Machine		Spo2 Accuracy & Pulse Rate
All Types of Pulse Oximeter		Heart Rate, Respiration, NIBP, IBP, Spo2, Temperature & Apnea Alarm Test
Apnea Monitor		Heart Rate & Arrythmia Test
TMT Machine		NIBP Test
Infusion Pump	Infusion Device tester & Electrical Safety analyser	Flow, Volume, Bolus, Back Pressure Alarm
Syringe Pump		Flow, Volume, Bolus, Back Pressure Alarm
PCA Pump		Dual Flow, Volume
Electro Surgical Unit/Diathermy	Electro Surgery analyser & Electrical Safety analyser	Output Power, Current, Peak to Peak Voltage, Crest Factor, Power Distribution Test, REM/CQM Test, HF Leakage Current, Vessel Sealing Test, Frequency, Foot switch simulation
Defibrillator	Defibrillator/Transcutaneous Pacer analyser & Electrical Safety analyser	Energy, Sync, Charge Time, Discharge time, R wave detection
External Pacemaker		Output Rate, Pulse Amplitude, Pulse Width, Energy Test
Automated External Defibrillator		Performance Test
All Types of Infant Incubators	Incubator analyser &	Temperature, Sound Level, Airflow, Humidity

Radiant Warmers	Electrical Safety analyser	Temperature, Skin Probe Accuracy Test

Notes:

Notes:

About the author

This guide is prepared by S. Gopa Kumar, National President of NFE. He is a member in MT 40, TC 64 of IEC responsible for maintaining IEC 60364-7-710 and ETD 20 of BIS responsible for NEC 2023 & IS17512. The contents of this guide are from various IS, IEC and ISO standards.

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Guide on ELECTRICAL SAFETY AUDITS IN HOSPITALS

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