the leading electrical & electronics monthly

ieema journal

VOLUME 11 • ISSUE NO. 12 • AUGUST 2020 • PGS. 90

ISSN 0970-2946 • Rs. 100/-

Indian Electrical Equipment Industry

Optimistic of Bouncing Back!

COVID-19
Stay Safe

See Inside

GuestArticle

ELECTRICAL SAFETY in Low Voltage System

Introduction

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, resulting in the largest pay-outs for insurance companies. Many of these accidents happen in a low voltage (LV) system.

To create a world-class electrical installation, it is highly important that the recommended best practices in IS and IEC standards must be followed without any deviations, and to make conformity assessments to these standards.

To introduce the best international electrical safety practices in LV Electrical System, a series of articles are planned in IEEMA JOURNAL on the following subjects:

1. History of Wiring regulation: National and International;
2. Concepts of safety in IEC and IS standards;
3. Mis concepts of LV system;
4. Right way of protective earthing in safety;
5. Selection of devices for safety;
6. Wires, wiring concepts, voltage drop and non-disconnection supply;
7. Protection against thermal effects in wiring inside a building;
8. Safety services and international practices;
9. Protection from EMP;
10. Inspection and testing of an LV system – International practice.

National regulations play the central role for electrical safety in every nation, followed by installation standards (code of practice), product standards and the proper implementation of these subjects. Inorder to understand this complex scenario, one shall understand the difference between National and International standards.

World Trade Organization (WTO) treaty on Technical Barriers to Trade (TBT), recognises only ISO, IEC and ITU standards as International standards. In other words, ISO, IEC and ITU are the three principal organizations in international standardisation, who have the expertise and experience to provide technical support for the growth of the global market. In simple term "International standards" are applicable only for ISO, IEC and ITU standards.

National standards from different countries such as BS (UK), VDE (Germany), NFC (French), EN (European nations), ANSI (USA) and NFPA (USA) are widely used in India claiming "International". These are national standards of the respective country or area, which is influenced by the local condition of the respective country/area. Legally as per the international trade laws, these national/regional standards are not applicable to India.

Electrical safety is often understood as – "achieved by installing an improved electrical product". Products and product standards are updated frequently (as per various national standards such as BS, VDE, EN etc), often "electrical safety" is used as a marketing tool to introduce an improved product. The installation standards and rules are neglected during design, erection and testing, there by the purpose of using an improved product is lost. We will see examples in the upcoming articles.

International Standard on LV electrical system for Design, Erection and Testing

IEC 60364 series of standards serve as a base for national wiring rules throughout the world on electrical installations of buildings. The Fundamental principles of the standard explains "Where countries not yet having national regulations for electrical installations deem it necessary to establish legal requirements for this purpose, it is recommended that such requirements be limited to fundamental principles which are not subject to frequent modification on account of technical development. The contents of Clause 13 may be used as a basis for such legislation".

The latest versions of many European wiring regulations (e.g., BS 7671 in UK, DIN VDE 0100 in Germany) follow the structure of IEC 60364 very closely but contains additional information to cater the old national practices and to simplify practical use.

Electrical safety is often understood as – "achieved by installing an improved electrical product". Products and product standards are updated frequently (as per various national standards such as BS, VDE, EN etc), often "electrical safety" is used as a marketing tool to introduce an improved product. The installation standards and rules are neglected during design, erection and testing, thereby the purpose of using an improved product is lost.

The history of national wiring regulations in some countries are

UK: BS7671

The first edition was published in 1882 as the "Rules and Regulations for the Prevention of Fire Risks arising from Electric Lighting." and settled in 1924 as "Regulations for the Electrical Equipment of Buildings" after several title changes in between. From 1981(15th edition), these regulations have closely followed IEC 60364. "The Electricity Safety, Quality and Continuity Regulations 2002" of UK recognise confirmation as per BS7671 as the requirements for an electrical installation.

Germany: VDE 0100

The first VDE standard "VDE 0100" for the safe construction of electrical systems is created in 1895. Currently DIN-VDE 0100 define the benchmark for the LV electrical installation. It follows IEC 60364.

USA: NEC or NFPA 70

The National Electrical Code is first published in 1897, it is updated every three years, the latest being the 2020 edition. NEC is a regional standard for the safe electrical wiring and equipment in USA. It is part of the national fire code series published by the National Fire Protection Association (NFPA), a private trade association. Installations that are in conformance with the NEC are also in compliance with the fundamental principles covered in clause 13 of IEC 60364.

India and Safety Regulations

Central Electricity Authority (MEASURES RELATING TO SAFETY AND ELECTRIC SUPPLY) Regulations, 2010 (called as CEAR-2010) is the applicable electrical safety regulation in India. The main objective of this regulation is to protect the public from dangers arising from the generation, transmission or distribution or trading of electricity, or use of electricity supplied or installation, maintenance or use of any electric line or electrical plant.

Important regulations in CEAR-2010 which explains safety of a LV system is

Regulation 12 to 32 under Chapter - III General safety requirements,

Regulation 33 to 39 under Chapter - IV General conditions relating to supply and use of electricity.

Regulation 40,41 and 42 under Chapter - V Safety Provisions for Electrical Installations and apparatus of voltage not exceeding 650 volts.

Safety provisions for Low Voltage in CEAR-2010 regulations, closely followed 1956 Indian electricity rule (IE rule), which in turn originated from 1937 Electricity rule. Comparison of few of the safety provisions are as follows

Precautions before connection to a supply

2010 CEAR	1956 IE rule	1937 Electricity rule
Regulation 33. Precautions against leakage before connection: 1) The supplier shall not connect with his works the installation or apparatus on the premises of any applicant for supply unless he is reasonably satisfied that the connection will not at the time of making the connection cause a leakage from that installation or apparatus of a magnitude detrimental to safety which shall be checked by measuring the installation resistance as under,-	**Regulation 48.** Precautions against leakage before connection (1)The supplier shall not connect with his works the installation or apparatus on the premises of any applicant for supply unless he is reasonably satisfied that the connection will not at the time of making the connection cause a leakage from that installation or apparatus of a magnitude detrimental to safety. Compliance with this rule shall be checked by measuring the installation resistance as provided below:	**Regulation 25.** Precautions against leakage before connection. (1) A licensee shall not connect with his works the apparatus on the premises of any applicant for a supply unless he is reasonably satisfied that the connection will not at the time of making the connection cause a leakage from that apparatus exceeding are five-thousandth part of the maximum supply demanded on the applicant's premises.

Regulation 34.	Regulation 49.	Regulation 26.
Leakage on consumer's premises:- (1) If the Electrical Inspector or the supplier has reasons to believe that there is leakage in the system of a consumer which is likely to affect injuriously the use of electricity by the supplier or by other persons, or which is likely to cause danger, he may give the consumer notice in writing that he desires to inspect and test the consumer's installation. (2) If on such notice being given the consumer does not give all reasonable facilities for inspection and testing of his installation, or when an insulation resistance of the consumer's installation is so low as to prevent safe use of electricity, the supplier may, and if directed so to do by the Electrical Inspector shall discontinue the supply of electricity to the installation but only after giving to the consumer forty eight hours notice in writing of disconnection of supply and shall not recommence the supply until he or the Electrical Inspector is satisfied that the cause of the leakage has been removed.	Leakage on consumer's premises – (1) If the Inspector or any officer appointed to assist the Inspector and authorised under sub-rule(2) of rule 4A or the supplier has reason to believe that there is in the system of a consumer leakage which is likely to affect injuriously the use of energy by the supplier or by other persons, or which is likely to cause danger, he may give the consumer reasonable notice in writing that he desires to inspect and test the consumer' s installation. (2)If on such notice being given (a)The consumer does not give all reasonable facilities for inspection and testing of his installation, or (b)When an insulation resistance of the consumer's insulation is so low as to prevent safe use of energy the supplier may, and if directed so to do by the Inspector shall discontinue the supply of energy to the installation but only after giving to the consumer 48 hours notice in writing of disconnection of supply and shall not recommence the supply until he or the Inspector is satisfied that the cause of the leakage has been removed.	Leakage on consumer's premises. If a licensee has reason to believe that there is in the system of a consumer leakage which is likely to cause danger, he may give the consumer reasonable notice in writing that he desires to inspect and test the apparatus, (2) If on such notice being given: (a) The consumer does not give all reasonable facilities for inspection and testing, or (b) a leakage from the consumer's system exceeding one five-thousandth part of the maximum supply required by the consumer is shown to exist, the licensee may forthwith discontinue to supply energy to the system in question; giving immediate notice of the discontinuance to the consumer, and need to recommence the supply until he is satisfied that the cause of the leakage has been removed.

Table 1: Comparison of regulation 33 and 34 of CEAR-2010 with IER 1956 and E-rule 1937

Probably these regulations originated from the British system practiced during 1937. Both these regulations 33 and 34 (CEAR-2010) have the following advantages and disadvantages.

Advantage

Empowers the supplier to ensure the required insulation resistance for the installation while making a connection to a consumer premise, thereby avoiding the chance of an accident. As a practice currently this test (insulation resistance test) is carried out in almost all installations. Primarily the consumer is responsible to keep the installation without leakage.

Disadvantage

Test to find out the leakage of an installation was the only available test during 1937, several modern tests were developed during the last decades, which were not included in the regulation. (These tests will be explained on a later article).

Electrical parameters of the supply which influence safety of the installation, are not included in the regulation resulting in large scale damage to consumers property.

eg. The Electricity Safety, Quality and Continuity Regulations 2002 of UK (referred as ESQCR-2002 in this article)

ESQCR-2002 Regulation-28 and Regulation-9 explains the supplier to provide following information other than phase, frequency and voltage to consumer.
Regulation 28
A distributor shall provide, in respect of any existing or proposed consumer's installation which is connected or is to be connected to his network, to any person who can show a reasonable cause for requiring the information, a written statement of;
(a) the maximum prospective short circuit current at the supply terminals;
(b) for low voltage connections, the maximum earth loop impedance of the earth fault path outside the installation;
(c) the type and rating of the distributor's protective device or devices nearest to the supply terminals;
(d) the type of earthing system applicable to the connection.
Table 2: extract from The Electricity Safety, Quality and Continuity Regulations 2002 of UK regulation 28

Electrical parameters under the control of the supplier explained in the UK Regulation (ESQCR-2002) 28 (a) and (b), influence the safety of consumer's premise during fault.

In India, majority accidents at consumer premises are due to the non-availability of similar information, which is necessary for the consumer to safeguard his installation. Earth loop impedance and the type of system earthing (such as TN-C, TN-S, TN-C-S, TT etc) applicable for the energy supplier is often "UNKNOWN" in several parts of India, resulting in violation of the section 53 of The Electricity Act 2003.

ESQCR-2002 Regulation 9 explains

Regulation 9. (Protective multiple earthing)
(1) This regulation applies to distributors' low voltage networks in which the neutral and protective functions are combined.
(2) In addition to the neutral with earth connection required under regulation 8(3)(b) a distributor shall ensure that the supply neutral conductor is connected with earth at
(a) a point no closer to the distributor's source of voltage (as measured along the distributing main) than the junction between that distributing main and the service line which is most remote from the source; and
(b) such other points as may be necessary to prevent, so far as is reasonably practicable, the risk of danger arising from the supply neutral conductor becoming open circuit.
(3) Paragraph (2)(a) shall only apply where the supply neutral conductor of the service line referred to in paragraph (2)(a) is connected to the protective conductor of a consumer's installation.
(4) The distributor shall not connect his combined neutral and protective conductor to any metalwork in a caravan or boat.
Table 3: extract from The Electricity Safety, Quality and Continuity Regulations 2002 of UK regulation 9

The UK, (ESQCR-2002) Regulation-9 intends TN-C-S system with PME (Protective Multiple Earthing) for LV electricity distribution. Energy Network Association in UK created technical requirements applicable for different type of consumers (for PME consumers and NON-PME consumers), in accordance with Regulation 9 and is followed uniformly across the country.

The UK regulation (ESQCR-2002) concentrates the requirements outside consumers electrical installation and empowers BS7671 for design, erection and testing inside consumers electrical installation. This method is simple and efficient.

Testing of an installation

CEAR-2010 regulation 40 to 42 explains the safety requirement in a LV consumers installation. A comparison of 2010, 1956 and 1937 regulations are

2010 CEAR	1956 IE rule	1937 electricity rule
Regulation 40. Test for resistance of insulation (1) 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 applied the test prescribed under regulation 33. (2) The provision under sub-regulation (1) shall not apply to overhead lines except overhead insulated cables, unless the Electrical Inspector otherwise directs in any particular case.	Regulation 60. Test for resistance of insulation (1) Where any electric supply line for use or low at medium voltage 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 applied the test prescribed under rule 48. (2) The provision of sub-rule (1) shall not apply to overhead lines except, overhead insulated cables unless the Inspector otherwise directs in any particular case.	Regulation 27. Appeal to Inspector in regard to leakage (3) If the Inspector or other officer, as aforesaid, on testing finds that the leakage from the appellant's system is less than one five-thousandth part of the maximum supply required by the appellant, the Inspector shall notify the licensee, and the licensee shall within twenty four hours, commence or continue the supply of energy, and the licensee shall pay to the appellant an amount equal to the fee paid by the appellant to the Inspector under Sub-rule (1), if the Inspector so directs.
Regulation 33. Precautions against leakage before connection:	**Regulation 48.** Precautions against leakage before connection	(note: probably regulation 27 clause 3 is modified in 1956 IER)

Table 4: Comparison of Regulation 40 of CEAR-2010 with IER 1956 and E-rule 1937

From these Regulations it is evident that the only mandatory testing required in a consumer premise is test for resistance of insulation. From 1937 until 2010, large scale development and standardisation happened worldwide on testing of a low voltage installation, almost every country made these testing's mandatory, however CEAR-2010 is silent in this subject. In this case the CEAR-2010 itself do not fulfil the requirement of Section 53 of The Electricity Act 2003.

Earthing of Transformer (& DG) Neutral and Body:

There is a practice of connecting transformer (or DG) neutral terminal to separate earth electrodes in soil, body also to separate earth electrodes in soil as insisted by various law enforcing authority (such as electrical inspector and safety officers). In few states copper plates are used for Neutral and GI pipe for body, each state has its own ways doing this earthing, claiming as if the local rule applicable for the state. However, proof of a local rule by a state is yet to be traced. In most cases the local rules of the state are typical interpretation of CEAR-2010 or IER 1956. An analysis from the regulation is as below.

Interpretation

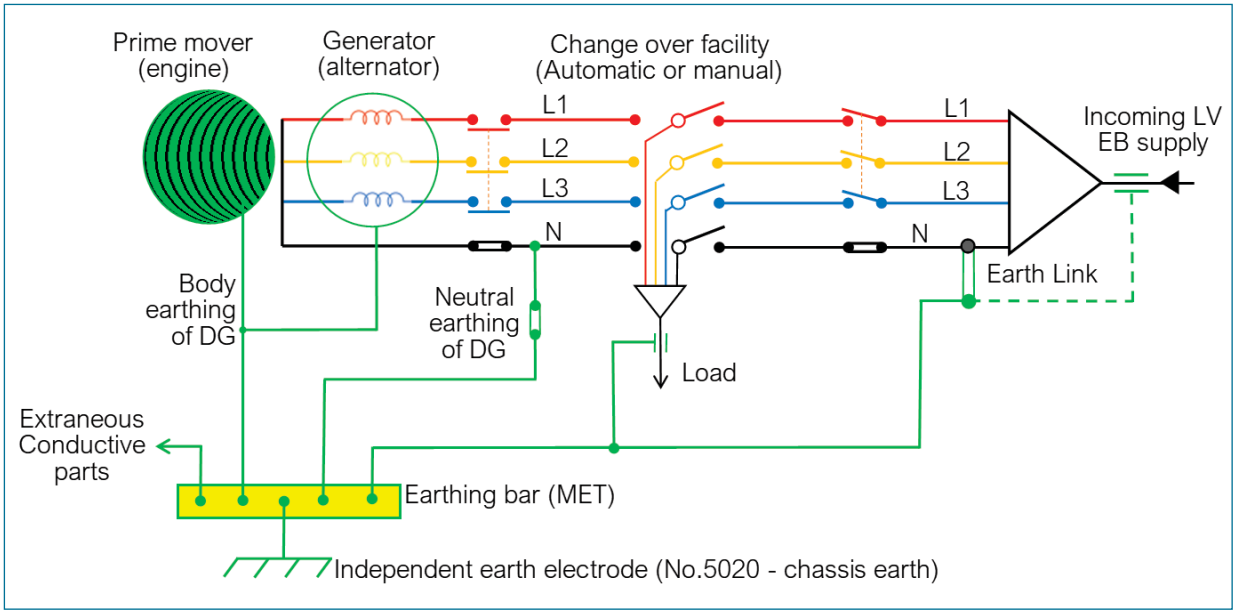
2010 CEAR	1956 IE rule	1937 electricity rule
Note: For comparison, selective part of the regulation is reproduced here under.		
Regulation 41. Connection with earth: - The following conditions shall apply to the connection with earth of systems at voltage normally exceeding 125 V but not exceeding 650 V, namely: - (i) neutral conductor of a 3-phase, 4-wire system and the middle conductor of a 2-phase, 3-wire system shall be earthed by not less than two separate and distinct connections with a minimum of two different earth electrodes or such large number as may be necessary to bring the earth resistance to a satisfactory value both at the generating station and at the sub-station. (ii) the earth electrodes so provided, shall be inter-connected to reduce earth resistance. (iii) 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 may be at the consumer's premises.	Regulation 61. Connection with earth. (1) The following provisions shall apply to the connection with earth of systems at low voltage in cases where the voltage normally exceeds 125 volts and of systems at medium voltage:- (a) Neutral conductor of a 3 phase, 4 wire system and the middle conductor of a 2 phase, 3-wire system shall be earthed by not less than two separate and distinct connections with a minimum of two different earth electrodes or such large number as may be necessary to bring the earth resistance to a satisfactory value both at the generating station and at the sub-station. The earth electrodes so provided, may be inter-connected to reduce earth resistance. It may also be earthed at one or more points along the distribution system or service line in addition to any connection with earth which may be at the consumer' s premises.	Regulation 58. Connection with earth of a multi-wire system. In every distributing system in which there is a neutral conductor, where the pressure between the neutral conductor and an outer or phase conductor exceeds 125 volts, the neutral conductor shall be connected with earth by two separate and distinct connections from the neutral bus-bar and in accordance with the following provisions, namely: (a) the connection shall be made at one point only on each distinct system, namely, at the generating station or sub-station, or both, as the case may be, and the insulation of the system shall be maintained at all other parts;
Table 5: Comparison of Regulation 41 (i) (ii) (iii) of CEAR-2010 with IER 1956 and E-rule 1937		

CEAR 2010 require neutral conductor to be earthed at two separate and distinct earth electrodes.

This part of CEAR 2010 and IER 1956 explains the requirement for a n eutral conductor and is not applicable for a Neutral terminal, whereas E-rule 1937 is about the Neutral terminal and Neutral conductor. In LV public electricity distribution, the Neutral conductor (combined PEN or CEN conductor – refer IS3043:2018 clause 4) shall be connected to earth electrode. (similar to regulation 9 of UK explained in clause 2.1.2 above)

Further interpretations

2010 CEAR	1956 IE rule	1937 electricity rule
Note: For comparison, selective part of the regulation is reproduced here under.		
Regulation 41. Connection with earth: - (xiii) neutral point of every generator and transformer shall be earthed by connecting it to the earthing system by not less than two separate and distinct connections. Definition of earthing system (s) "earthing system" means an electrical system in which all the conductors and appliances are earthed;	Regulation 67. Connection with earth. (Under CHAPTER VII - ELECTRIC SUPPLY LINES, SYSTEMS AND APPARATUS FOR HIGH AND EXTRA-HIGH VOLTAGES) (a) The neutral point of every generator and transformer shall be earthed by connecting it to the earthing system as defined in Rule 61(4) and hereinabove by not less than two separate and distinct connections:	Regulation 49. Construction, insulation and earthing of apparatus (4) Every part of a system shall be kept efficiently insulated from earth except That: (i) the neutral point of a polyphase system may be earthed at one point only; (ii) the mid-voltage point of any system, other than a concentric system, may be earthed at one point only.
Table 6: Comparison of regulation 41 (xiii) of CEAR-2010 with IER 1956 and E-rule 1937		



Picture 1: earthing of DG with change over facility with a TN-C-S incoming LV supply.

CEAR-2010 regulation (xiii) is about neutral point to be connected to an earthing system. IER 1956 regulation 67 is applicable for HV and EHV system, surprisingly IER -1956 do not contain a provision for earthing of neutral point (or terminal) of an LV system. In comparison, the 1937 E-rule seems to be perfectly made, which is a mandatory requirement even today in most systems.

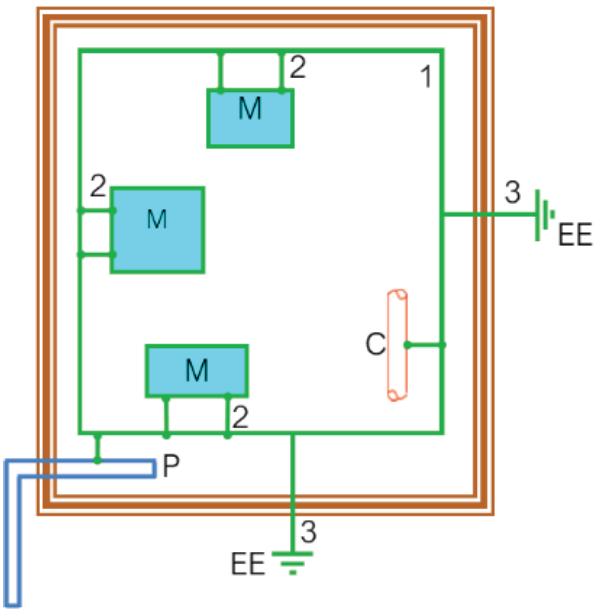
CEAR-2010 regulation (xiii) neutral point earthing shall be read along with the definition of "earthing system". Earthing system consists of several interconnected items (in green colour) as shown in the picture 1. (ref pic 38 to 43 in IS3043:2018).

Earthing system consists of an Earthing bar were DG neutral, DG body, load side and source side exposed and extraneous conductive parts are earthed by protective conductors. Simple interpretation of the clause xiii of regulation 41 is, Neutral of transformer or DG, for resilience use two connections instead of one. The regulation never recommends connecting Neutral terminal to an earth electrode.

2010 CEAR	1956 IE rule	1937 electricity rule
Note: For comparison, selective part of the regulation is reproduced here under.		
Regulation 41. Connection with earth: - (xii) the frame of every generator, stationary motor, portable motor, and the metallic parts, not intended as conductors, of 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 the owner by two separate and distinct connections with earth.	Regulation 61. Connection with earth. (2) The frame of every generator, stationary motor, portable motor, and the metallic parts(not intended as conductors) of all transformers and any other apparatus used for regulating or controlling energy and all medium voltage energy consuming apparatus shall be earthed by the owner by two separate and distinct connections with earth.	Regulation 57. Connection with earth of frames of generators, etc. The frame of every generator, stationary motor, and so far as is practicable, portable motor, and the metallic parts (not intended as conductors) of all transformers and regulating of controlling apparatus connected with the supply, shall be earthed by the owner by two separate and distinct connection with earth.

Table 6: Comparison of Regulation 41 (xii) of CEAR-2010 with IER 1956 and E-rule 1937

In this case also (table 6) Transformer (or DG) body need to be connected to earth and not to earth electrodes in soil. It is a practice in India to make duplicate earth connection (two connections) for 3 phase equipment as explained in IS3043. Similar practice is explained in the CEAR-2010.



M = Exposed conductive parts

P = Incoming metallic service

C = Extraneous conductive parts

EE = Earth electrode

1 = Equipotential bonding conductor (MET)

(in case of small domestic installations 1 starts from
the neutral link - TN-C-S network)

2 = Protective conductor in duplicate

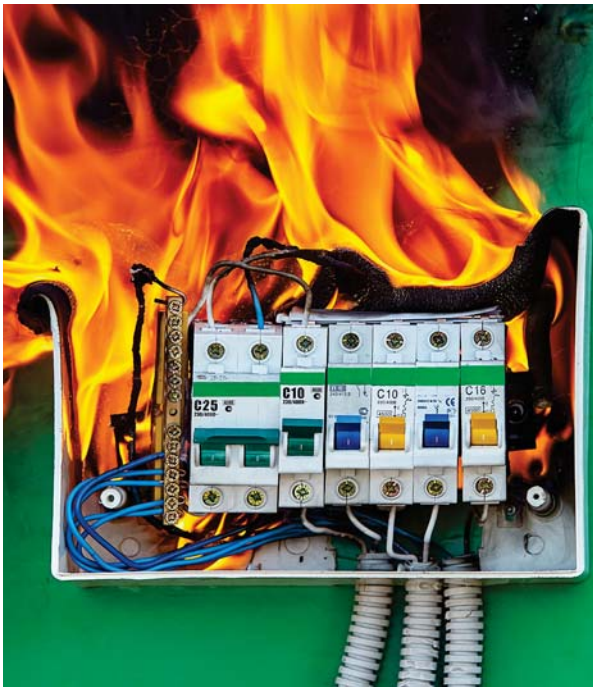
3 = Earthing conductor

* earthing of 3 phase equipment in duplicate mentioned in IS3043.

Picture 2 - earthing arrangements and protective conductors as per IS3043: 2018, FIG. 31

Misinterpretation of the regulation

Every state does not have their own regulation for electrical safety. The one and only regulation is CEAR-2010. This regulation never recommended to connect Transformer (or DG) Neutral and body to separate earth pits. The practice followed and enforced by authority is a mere misinterpretation of the regulation. This misinterpretation creates lot of safety issues, which we will see in further articles.



Conclusion

Safety requirement of LV system in CEAR-2010 need immediate update to fulfil the provisions of Section 53 of The Electricity Rule 2003 and to stop misinterpretations within the stakeholders.

Segregation of the scope of supplier and consumer is necessary in CEAR-2010.

The CEAR-2010 shall follow international practices as defined in IEC 60364 (similar to the system followed in all EU & several Asian nations)

With the current electrical safety practices carried out across India, in case of an accident consumers can sue energy supplier as they fail to meet several safety requirements in CEAR-2010.

Subjects explained here (up to clause 2.3.3) is tip of the iceberg, further articles will explain electrical hazards due to misinterpretations and introduce the good practices followed in developed countries. ■

S. Gopa Kumar

The author is a member in Working group 3 and 5 in sectional committee 37 A of IEC. MT 3, MT 12, MT 41, PT 60364-8-3, WG 43 TC-64 of IEC. National Building Code-2016 (electrical committee) of Bureau of Indian Standards. ETD 20 & ETD 30 of Bureau of Indian Standards.