

ELECTRICAL ACCIDENTS - ANALYSIS AND PREVENTION MEASURES

By

**Chief Electrical Inspector to Government,
Tamil Nadu Electrical Inspectorate,
Thiru.Vi.Ka. Industrial Estate,
Guindy, Chennai-600 032**

**Phone : 044-2250 0184, 2250 0227, 2250 0430,
2250 0796,**

Fax: 2250 0036

E-mail: ceig@tn.gov.in

Website: WWW.tnei.tn.gov.in

Contents

1.	<i>ELECTRICAL ENERGY SCENARIO.....</i>	<i>5</i>
1.1	<i>SOCIAL ASPECTS</i>	<i>5</i>
1.2	<i>NATURAL CALAMITIES AND ELECTRICAL ACCIDENTS.</i>	<i>5</i>
1.3	<i>RIGHT TO LIVE.....</i>	<i>5</i>
2.	<i>MECHANISM OF ELECTRICAL ACCIDENT</i>	<i>8</i>
2.1	<i>DEFINITION:.....</i>	<i>8</i>
2.2	<i>NON-LINEARITY OF HUMAN BODY RESISTANCE.....</i>	<i>8</i>
2.3	<i>VARIATION OF BODY RESISTANCE DUE TO VARIOUS FACTORS.....</i>	<i>8</i>
2.4	<i>SAFE LET- THROUGH CURRENT</i>	<i>9</i>
2.5	<i>VARIOUS MEANS OF CONTACT</i>	<i>11</i>
3.	<i>STATISTICS.....</i>	<i>14</i>
3.1	<i>VARIOUS LOCATIONS OF ACCIDENTS.....</i>	<i>14</i>
3.2	<i>VARIOUS REASONS FOR THE ACCIDENTS</i>	<i>14</i>
4.	<i>MAJOR CAUSES.....</i>	<i>16</i>
4.1	<i>NON-STANDARD ERECTION</i>	<i>16</i>
4.2	<i>POOR-MAINTENANCE</i>	<i>16</i>
4.3	<i>HUMAN ERROR</i>	<i>16</i>
5.	<i>CASE STUDY.....</i>	<i>18</i>
5.1	<i>NON-STANDARD ERECTION</i>	<i>18</i>
5.2	<i>IMPROPER MAINTENANCE</i>	<i>18</i>
5.3	<i>NEGLIGENT ACT.....</i>	<i>19</i>
6.	<i>SAFE WORK ARRANGEMENTS To AVOID HAZARDS.....</i>	<i>20</i>
6.1	<i>EARTHING</i>	<i>20</i>
6.2	<i>CLUSTER OF EARTH ELECTRODES – DE RATINGS</i>	<i>22</i>
6.3	<i>HOW AN ELCB WORKS</i>	<i>22</i>
6.4	<i>LIGHTNING ARRESTORS.....</i>	<i>24</i>
7.	<i>SAFE WORK PRACTICES</i>	<i>26</i>
7.1	<i>WORKING SPACE AND ENVIRONMENT.....</i>	<i>26</i>
7.2	<i>CONFINED SPACES.....</i>	<i>26</i>
7.3	<i>LIGHTING</i>	<i>26</i>

7.4	STORED ELECTRICAL ENERGY.....	26
7.5	STORED NON ELECTRICAL ENERGY	27
7.6	WET LOCATIONS.....	27
7.7	EMERGENCY SHUTDOWN SWITCH.....	27
7.8	CAPACITORS.....	27
8.	SHUT DOWN OR MAINTENANCE WORKS.....	29
8.1	BASIC PRINCIPLES	29
8.2	JOB BRIEFINGS	29
8.3	WORK INSTRUCTIONS	30
8.4	RESPONSIBILITIES	30
8.4.1	MANAGEMENT	30
8.4.2	SUPERVISORS	30
8.4.3	WORKERS	31
9.	PERSONAL PROTECTIVE EQUIPMENT (PPE)	33
9.1	SHOES.	33
9.2	HELMETS.....	33
9.3	EYE PROTECTORS	33
9.4	BODY BELTS AND SAFETY STRAPS.....	33
9.5	WORK GLOVES	33
9.6	RUBBER GLOVES	33
9.7	RUBBER SLEEVES AND BARRIERS.....	34
9.8	WORK CLOTHES	34
9.9	FIRE RESISTANT CLOTHING.....	34
9.10	RESPIRATORS	34
9.11	EARTHING CABLES AND HARDWARE.....	35
9.12	TAPES AND RULERS	35
9.13	METAL FASTENERS	35
9.14	EXTENSION CORDS.....	35
9.15	DOUBLE INSULATED TOOLS	35
9.16	WORK MATRICES.....	36
9.17	TRAINING	40
10.	SAFE PROCEDURE	41
10.1	DE-ENERGISING.....	41
10.2	VERIFICATION OF DE-ENERGIZED CONDITION	41

10.3 EQUIPMENT EARTHING.....	42
10.4 PERSONNEL PROTECTIVE EARTHS	42
10.5 ATTACHING AND REMOVING EARTHS	43
10.6 LOCKOUT/TAGOUT PROCEDURE.....	43
10.7 LOCKOUT	43
10.8 LOCKOUT DEVICE	44
10.9 TAGOUT	44
10.10 TAGOUT DEVICE.	44
10.11 REMOVING LOCK AND TAG	45
10.12 RE ENERGIZING	46
10.13 STRINGING ADJACENT TO ENERGIZED LINES	46
11. PERMIT-TO-WORK SYSTEM.....	48
11.1 MODEL FORM OF PERMIT-TO-WORK	48
12. REMEDIAL MEASURES.....	52
12.1 ERECTION	52
XXIV TNEB INSTALLATIONS	55
XXV P&T LINES	57
12.2 MAINTENANCE.....	58
12.3 HUMAN ERRORS.....	58
13. USEFUL TIPS ON ELECTRICAL SAFETY	59
13.1 GENERAL PUBLIC.....	59
13.2 ELECTRICAL SAFETY RULES.....	60
14. POST ACCIDENT MEASURES.....	61
14.1 MEASURES TO BE ADOPTED	61
14.2 ACCIDENTS AND INQUIRIES.....	61
14.3 INTIMATION OF ACCIDENT	62
14.4 FORM FOR REPORTING ELECTRICAL ACCIDENTS	63
15. CONCLUSION	66

1. Electrical Energy Scenario

1.1 Social aspects

Electricity literally powers our society. It is fed into our homes and businesses and public places in a vast complicated network above, on and below the earth. We work in and around this "grid" all the time.

Sophisticated life style, population explosion, increased agricultural and industrial activities etc. have accelerated the growth of electrical network. As a result, the electrical installations are becoming more complex so as to cope up with the modern machines, gadgets, multistoried building activities etc. The electrical energy conversion alone constitutes to about 35% of total energy conversion occurring globally.

Per capita electrical energy consumption is one of the indicators for assessing the development of a nation. It varies among different countries. While the developed countries enjoy about 3500 units, the national average for our country is still a meager 640 units and it stands at 1050 units for Tamil Nadu.

1.2 Natural calamities and electrical accidents.

*Every year the nation suffers from the loss of personnel and properties due to natural calamities like flood, cyclone etc. Statistics reveals that the quantum of losses to the personnel and property due to electrical accidents and electrical short circuit initiated fires almost equals that due to natural calamities. The reason as to why the general public does not feel the electrical accidents may be due to the fact that the numbers of victims are generally rural and occurrence of such accidents are dispersed throughout the State spanning throughout the year. With the available scientific arsenal in hand it is not possible to avoid natural calamities. On the other hand, **the occurrence of the electrical accidents can be minimized since most of them are due to sheer negligence of the proven principles of electrical safety.***

1.3 Right to live

Right to live enshrined in Article 21 of the Constitution of India is the fundamental right of every citizen. It derives its life breath from the Directive Principles of State Policy. Particularly Article 42, 43 and provisions of Entry 6 of List II, Entry 38 of List III in the Seventh Schedule of the Constitution enables the State Government to adopt safety measures.

The Universal Declaration of Human Rights also says:

Everyone has the right to work, to free choice of employment, to just and favorable conditions of work. (Article 23)

In exercise of the powers conferred under Section 177 of the Electricity Act 2003 (36 Of 2003), the Central Electricity Authority framed regulations for measures relating to Safety and Electric Supply repealing the Indian Electricity Rules, 1956 vide notification CEI/1/59/CEA/EI, with effect from 20th September 2010.

In this regard, the recent judgment on the fire accident that took place at the Uphar theatre, New Delhi in 1997 has to be borne in mind. The accident occurred due to multiple violations on the part of Delhi Electric Supply Undertaking, Municipal authority, and the theatre management. 59 people were dead and 103 injured in that accident. The compensation awarded by the court is 20 lakhs per dead and one lakh per injured. The importance of the judgment is that the statutory authority which licenced the theatre is also made accountable in addition to the owner of the theatre.

Case studies on electrical accidents also show that similar nature of accidents occurs at different places and times due to a poor awareness among the public. Hence smaller goals are to be set in order to eliminate at least similar nature of electrical accidents recurring throughout the country. A set of basic rules analogous to the observance of traffic rules, if inculcated in the minds of the public, will certainly fetch favorable results in avoiding such recurrences.

An analysis is hence made in this article to share the knowledge on the following areas:

- i. How an accident occurs and the mechanism.
- ii. Hazards and reasons for such occurrences.
- iii. Remedial measures to be adopted to avoid such accidents, along with few case studies.
- iv. Safe Work Practices and Personal Protective Equipment (PPE)
- v. Procedures for Shut Down or Maintenance Works
- vi. Post Accident Measures

Awareness creation through propagation of these measures, observance of work practices and infusing basic principles among the stake holders would help to reduce the electrical related accidents to a greater extend.

2. Mechanism of Electrical Accident

We often notice birds sitting pretty on live electric wires. The accident happens when the same bird sitting on the live wire bridges the metallic fitting or another phase conductor through its body. Thus a bodily contact between the two conductive parts of different electric potential results in an accident. Hence we can infer the definition as follows:

2.1 Definition:

‘When different parts of the body are subjected to a potential difference, an electrical energy is dissipated through the body and when this energy exceeds a threshold limit, electrical accident occurs’.

2.2 Non-linearity of human body resistance

All the three modes of electric current are constituted in the body. They are:

- (i.) Electron flow through hemoglobin present in the blood,
- (ii.) Semi-conducting current in view of membranes of the body
- (iii.) Electrolysis through the fluids in the body.

2.3 Variation of body resistance due to various factors

The body resistance varies with the voltage to which it is subjected. The typical values of total body resistance are ranging from about 6 Kilo-ohms at 25V, 4 Kilo-ohms at 50V, 3 Kilo-ohms at 100V and 2 Kilo-ohms at 230V. Though the body resistance is not a linear one, a typical value of the internal resistance of 500 ohms between hand to hand or hand to feet or 100 ohms between ear to ear and a skin resistance of 1000 ohms can be assigned.

The environmental factors like humidity, temperature, and, especially, the dampness affects the body resistance to a great extent. Though the skin resistance appears to be a protecting factor, it drastically reduces when the area of contact increases, or the touch potential exceeds 50V and it becomes negligible in case of abrasion.

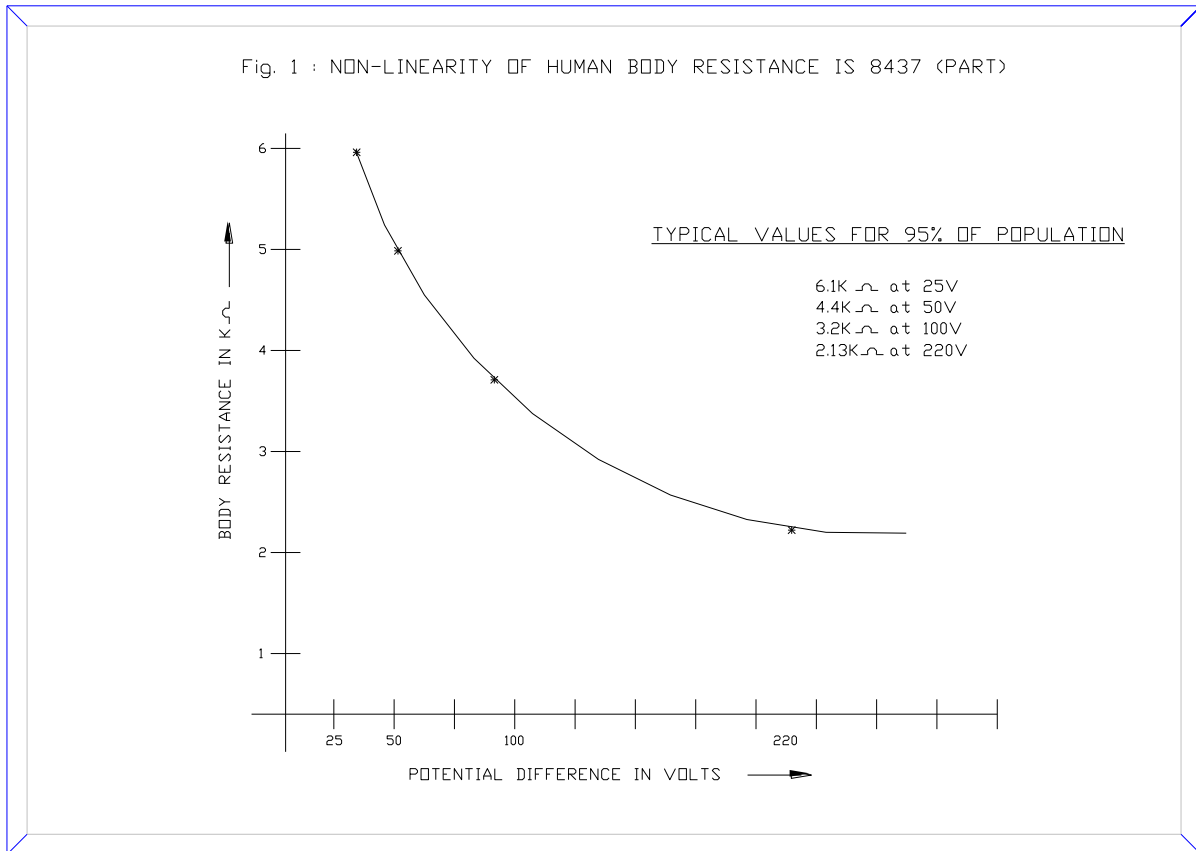


Fig.1. Variation of body resistance with reference to voltage

2.4 Safe let- through current

In view of the above variants, the main parameter that causes danger to persons is the magnitude and duration of current flow.

Based on the curves showing the effect of let through current and its duration, it has been determined that the safe let through current is determined by the expression $I_b = 0.116/\sqrt{t}$ where 'I' is current in Amps, 't' is the duration of current flow in seconds. Magnitude and duration of current flow beyond this value may lead to ventricular fibrillation, a phenomenon by which fluttering of the heart from its usual co-coordinated beats occurs resulting into death.

The following graph showing the safe let through current is self-explanatory.

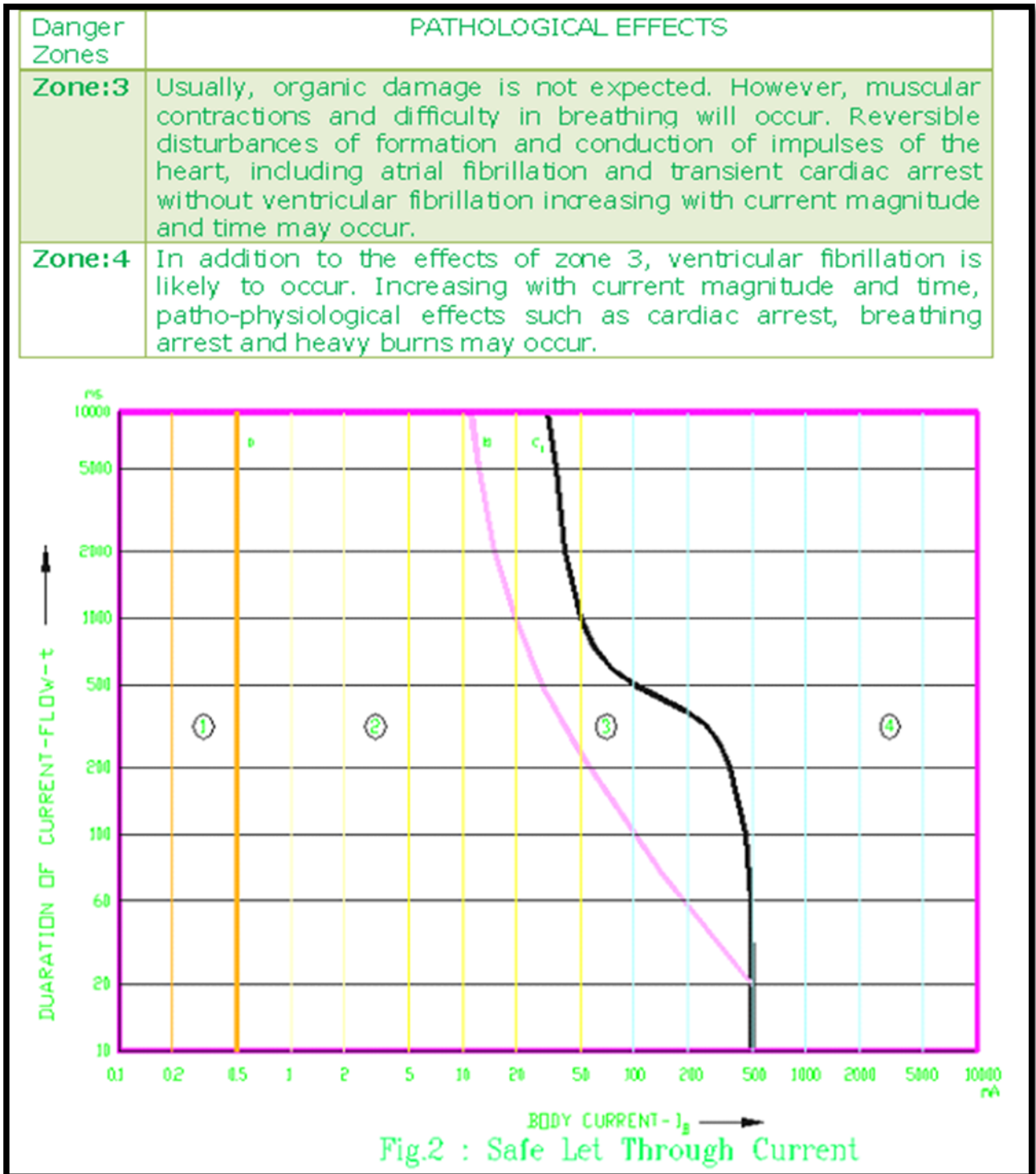


Fig.2 Patho-physiological effects for various let through currents

A person can withstand without ventricular fibrillation, the passage of a current in magnitude and duration determined by the formula:

$I_b = 0.116 / \sqrt{t}$; where ' I_b ' is the fibrillating current in Amps, ' t ' is the duration of current flow in seconds.

During an earth fault, the earth potential rises due to the flow of fault current through the impedances of earth return path. This potential rise introduces hazard to persons who happen to touch such exposed conductive part of the installation.

The remedy is either it has to be contained or its duration restricted in such a way that it does not harm persons.

Based on this principle and normal body resistance, the safe touch potential is expressed in the following table (considering a body resistance of 1000 ohms) as E_{step} (in volts) = $I_b \times 1000$

'I_b' in milli Amps or E_{touch} voltage in volts	518	366	259	164	116	82	67
'T' in seconds	0.05	0.1	0.2	0.5	1	2	3

Table 1: Safe Let through Current for the human

It can be seen that the human body is so feeble to be protected from an electric circuit. At the same time, the improved measures on electrical installation practices with the advent of developments in technology and other safety measures obviate the fear of electrocution. If shock currents can be kept below these values by a carefully designed earthing and protective arrangements, injury can be avoided.

The first few minutes of the victim are important in an electrical accident and there is a likelihood of revival if treated properly. It is important to follow up rescue procedures, resuscitation, and first aid methods to the persons who met with such accidents immediately after the occurrence of the accident. Such persons appearing dead are actually in the state of involuntary suspended animation. They should be empowered with inspirational and positive attitudes to the effect that they would be all right soon. There are cases of successful revival of such cases after a continuous effort lasting to more than an hour.

2.5 Various means of contact

Such contacts are possible by means of:

- (i.) Direct contact*
- (ii.) Indirect contact and*
- (iii.) Extraneous means.*

A direct contact involves an intentional or an inadvertent contact with the supply and a reliable / positive protection is adopted either to screen the live supply parts or to keep the supply parts out of reach. Touching a snapped conductor, curious or an ignorant access to the damaged socket outlets etc. are examples for such an act.

But an indirect contact is not sensed visually. The indirect contact involves a contact with the metallic part enclosure of electrical equipment that lost its insulation resistance. Unpleasant shock felt from a wet grinder or dipping fingers into a tub to feel the temperature rise from the immersion heater when such equipment is in circuit and is working, are certain examples for such act.

*An extraneous part is a conducting part liable to introduce a potential, generally earth potential, and not forming part of the electrical installation. **There is a likelihood of voltage being available at the water tap inside a dwelling due to an external fault occurring outside such a dwelling.** Possible sources of such hazards are:*

(i) Leakage through the metallic fixture or water pipelines inside the flat of an apartment for a fault in another flat of the apartments, especially, when the initially erected common earth electrode is abandoned from maintenance by the association/ occupants.

(ii) A broken neutral of service mains in rural distribution system where protective multiple earthing is adopted by the Supplier.

In view of poor neutral earthing conditions prevailing at the Supplier's Distribution Transformer sub-station, practice of PME earthing system at the consumer's premises (mixing of neutral with the earth in the consumer's installation) is to be discouraged; providing & maintaining consumer's own earth electrode separated from the supplier's neutral, will eliminate such hazard.

❖ *We think that Neutral & Body earth mixing is to be avoided in all locations and they require separation. Actually they should be interconnected at source only and to be avoided in other locations to eliminate multiple neutral earthing which is permissible for supplier alone that too before and at the point of supply. The ill effects of multiple neutral earthing in consumer's premises are*

i) Dangerous voltage on body frames appears in the case of neutral discontinuity of utility source;

ii) The machine receiving supply will appear dead but give shock;

In a typical circuit, a potential difference of about 100V (depending upon the circuit parameters) may appear between the ground and metallic parts of electrical equipment within the building due to a broken neutral wire outside the building and when this voltage is likely to be felt by the resident when he happens to touch such parts, such a contact will allow a current of 200mA to pass through the body. This is a magnitude sufficient to cause electrocution if persisting for a period of more than 0.5secs.

In both the above cases and locations like bath room, garage, polishing section at granite industries etc. it is difficult to ensure personnel as well as equipment protection unless the following measures are adopted:

- a) Double pole isolation for the geyser etc. fitted external to the bath room*
- b) RCB at the source end*
- c) Isolation transformer with separate earthing for this derived source of supply (Isolation transformer)*
- d) Zero sequence earth sensor scheme is adopted by window type single core balance CT for the feeders when source neutral earth lead interconnection is not effective (refer cl.9.2.3 of IS 3043)*
- e) Restricting the rating of the DBs to the fault clearing value at the point of application which is dictated by the earth loop impedance values for such portion of the installation. (cl.39.2.4.4 of IS 3043)*

3. Statistics

The people who die in electrical contact accidents each year aren't statistics. They're family, friends, co-workers, and schoolmates. Their absence leaves a void in the lives around them that can't be filled. There's no substitute for having the people we care for with us.

3.1 Various locations of accidents

Accidents occur everywhere; at the house, factory, fields etc. But the intensity varies widely; the maximum being at supplier's installations and the minimum at the government installations.

Sl. No.	LOCATION	NO. OF ACCIDENTS									
		1999 - 2000	2000 - 2001	2001 - 2002	2002 - 2003	2003 - 2004	2006 - 2007	2007 - 2008	2008 - 2009	2009 - 2010	Total
1	Generating Station	0	3	0	0	2	0	5	1	2	13
2	T & D lines - 11KV & above	129	151	139	69	142	111	144	143	163	1191
3	T & D lines - below 11KV	97	103	213	88	158	189	269	261	222	1600
4	Industrial Installations - Govt./semi Govt.	13	16	8	43	0	1	18	1	17	117
5	Industrial Installations – Private	7	5	9	105	21	1	2	9	16	175
6	Other Installations - Govt./ Semi Govt.	17	27	6	1	7	4	0	2	1	65
7	Other Installations –Private	54	37	58	39	68	43	0	0	25	324
	TOTAL	317	342	433	345	398	349	438	417	446	3485

Table 2: Location of accidents

3.2 Various reasons for the accidents

Hazard is an act or practice with the potential for an accident. In the electrical installations, the actual causes are classified broadly in to the following categories in our country:

a) Snapping of Conductors

b) Accidental contact with live electric wire/equipment

c) Violation / neglect of safety measures/lack of supervision

d) Defective appliances / apparatus / tools

e) Inadequate / lack of maintenance

f) Unauthorised work/Sub-standard construction

g) Other reasons (leakage of current, etc.)

Sl. No.	NUMBER OF ACCIDENTS										
	REASON / CAUSE	1999 - 2000	2000 - 2001	2001 - 2002	2002 - 2003	2003 - 2004	2006 - 2007	2007 - 2008	2008 - 2009	2009 - 2010	Total
1	Snapping of Conductors	131	103	138	55	100	72	101	76	93	869
2	Accidental Contact with live electrical wire / equipment	74	77	63	74	116	123	182	149	177	1035
3	Violation / Neglect of Safety measures / Lack of Supervision	48	112	131	82	81	90	46	67	90	747
4	Defective Appliances / Apparatus / Tools	19	14	24	16	23	13	44	39	45	237
5	Inadequate /Lack of Maintenance	20	12	22	11	16	12	3	5	20	121
6	Unauthorized work	4	15	34	11	28	12	19	23	8	154
7	Any other reasons	21	9	21	96	34	27	43	58	13	322
	TOTAL	317	342	433	345	398	349	438	417	446	3485

Table 3: Various causes for the accidents

It can be seen that the single major cause and location of the electrical accidents is snapping of conductors in the Supplier's (Electricity Board) installation.

4. Major Causes

However the causes already explained, can be covered under the following main categories:

- (i) **Non-standard erection***
- (ii) **Poor maintenance***
- (iii) **Human error***

4.1 Non-standard erection

Almost 35% of the electrical accidents occur due to the practice of non-standard erection. In a recent Judgment delivered by the NHRC penalizing the utility authorities, namely, the UPSEB and awarding sufficient compensation to a eleven years old boy, the importance of standard erection is implied. This boy had to undergo amputation of his both hands after an electrical accident in which he came into contact with a plinth mounted transformer which was erected in a non-standard manner at the road side without proper fencing and the live HV supply parts were accessible to the public and hence the accident.

4.2 Poor-maintenance

Twenty percent of the electrical accidents occur out of the factor poor-maintenance.

The reasons for inadequate or lack of maintenance are best known to the utilities / owners of installations. However, we are aware that lack of maintenance not only causes accidents but also results in prolonged interruption of supply affecting thereby revenue generation. It has been observed that organizations / utilities having a well-gearred regular maintenance mechanism have been able to maintain an almost accident free record resulting in high morale of the operating personnel. The cost spent on maintenance is easily compensated by the additional revenue and goodwill of the consumers.

4.3 Human error

The major area to be concentrated in the electrical safety is human error, since 45% of the accidents occur due to this factor. Also such accidents are similar in nature and occur at different places at different times.

It should be kept in mind that 'To err is human'. Routine operations are relegated to the lower levels of the brain and are not continuously monitored by the conscious mind. We would never get through the day if everything we did required our full attention. When the normal pattern or Programme of actions is interrupted for any reason, errors are like to occur. Error and accidents mainly occur due to inadequate training; lacking basic knowledge, lacking sophisticated skills, deliberate decision of not obeying instructions that they consider unnecessary. Human errors should be anticipated and system

should be devised accordingly to overcome basic errors. Accidents also occur in rare cases due to slips and lapses of attention of even well trained persons. For example, they sometime forget to observe safety devices. They know what they should do, want to do it, and are capable of doing it. But they forget to do it. Exhortation, punishment, or further training will have no effect. We must either accept an occasional error or change the work situation or incorporate specific designs so as to remove the opportunities for error or make errors less likely.

When a repair work / break down maintenance on a machine or system involves frequent switching on or off of the supply or if an action involves a prolonged activity of monotonous job, the individual will attain fatigue. This may result into a monotonous act which could lead to an inadvertent access to the supply parts forgetting the availability of supply and getting electric shock. In such cases, supervision or assistance of another person will avoid such accidents.

Violation / neglect of safety measures / lack of supervision account for 15 percent of the total reported accidents / fatalities indicates that either there is something wrong with the system or people sometimes think that they are immune to accidents and that it will happen to others only, which is not correct. Safety Rules and precautions are meant for safety of all concerned and should not be neglected at any cost. Further, exigency of work is not any excuse for by-passing the rules / safety standards.

5. Case Study

5.1 Non-standard erection

In a typical case at the outskirts of Chennai, a PWD Civil contractor undertook the work of providing huge compound wall around a prison. For facilitating the workmen, PVC OH lines were erected to a distance of about 400m using reel insulators suspended through GI bearer wires (unearthed) on casuarina pole (3m high) supports. These wires after prolonged (about four months) exposure to the Sun and Rain in an open yard gave way for deterioration of its insulation. It was also raining for two or three days prior to the accident. When a workman put his wet towel after bath from a nearby diesel pump set, he snatched the wires by instinct and got electrocuted. The lines were erected without maintaining earth clearance. A standard means of erection using UG armoured cable to such a lengthy circuit would have eliminated such an accident.

5.2 Improper maintenance

In another case, TNHB apartment at Anna nagar, Chennai a lady was found electrocuted in the bathroom, at her first floor flat. It was found during the investigation, that another resident in the second floor operated an iron box that was already defective. Instead of rectifying the iron box, the culprit managed to use it in an ingenious manner i.e., the iron box was placed on a wooden stool and then switched on. After leaving it for some time till the iron box attains heat, it was switched off and then removed from the socket outlet for ironing purpose. This practice had led to a leakage of electric current through the metallic structure of the building and the water pipe line, which lead to the first floor of the victim. After sending her children to the school, the housewife had no other members of the family. Being a wet floor (bathroom) and absence of persons to rescue her, she got electrocuted. (Pl. refer the fig. furnished below)

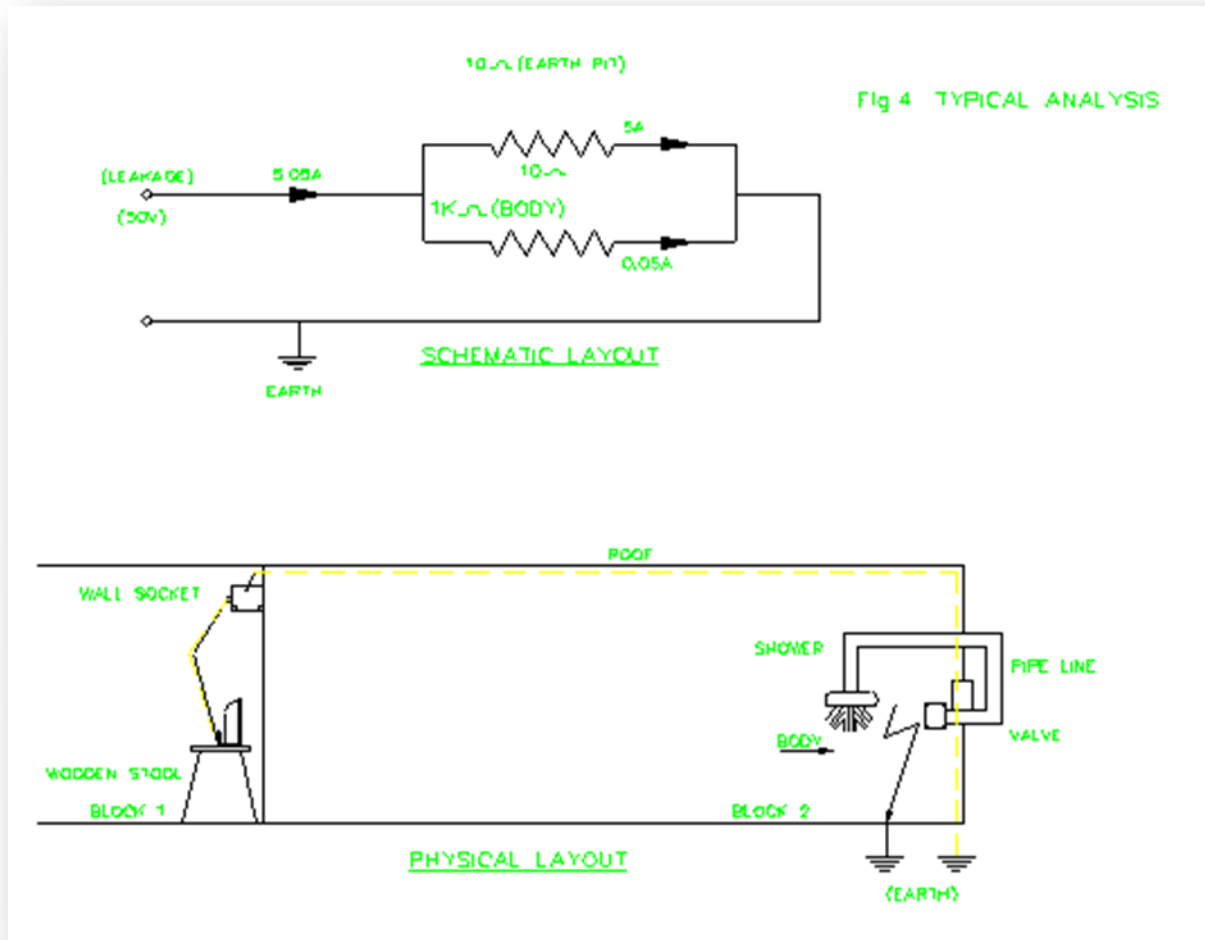


Fig.3 Leakage of electric current through the metallic structure of the building and the water pipe line leading to the first floor.

Proper maintenance of the earth electrode in the apartments, earthing of extraneous metallic parts (water pipe line) and avoidance of using faulty equipment would have eliminated such an accident.

5.3 Negligent act

In another case at the premises of an Engineering College near Ambattur, Chennai, and four persons charred to death when they were moving a trolley mounted mobile aluminium ladder in the vicinity of the TNEB 11KV Oh lines. The contract workman who were carrying out the work of fixing lamps at the street light poles, were returning with the ladder. While pushing the ladder, they failed to notice the HV lines and the ladder fouled the lines resulting into the accident. Similar accidents also occurred at Hosur, Thiruvallur and in some other places of Tamil Nadu.

6. Safe Work Arrangements To Avoid Hazards

6.1 Earthing

Understanding the principles of earthing and observing proper earthing in a consumer's premises would certainly avoid most of the electrical accidents.

Earthing is done in an electrical installation to achieve the following objectives:

- i) Provide a low impedance earth fault return path to clear the earth fault and to achieve protection.*
- ii) Limit the step and touch voltages on the accessible equipment and surfaces both during normal operation and during transients to safe levels.*
- iii) Minimise electrical noise interference in control and instrumentation systems*
- iv) Minimise the effect of lightning strikes on personnel, equipment and structures.*

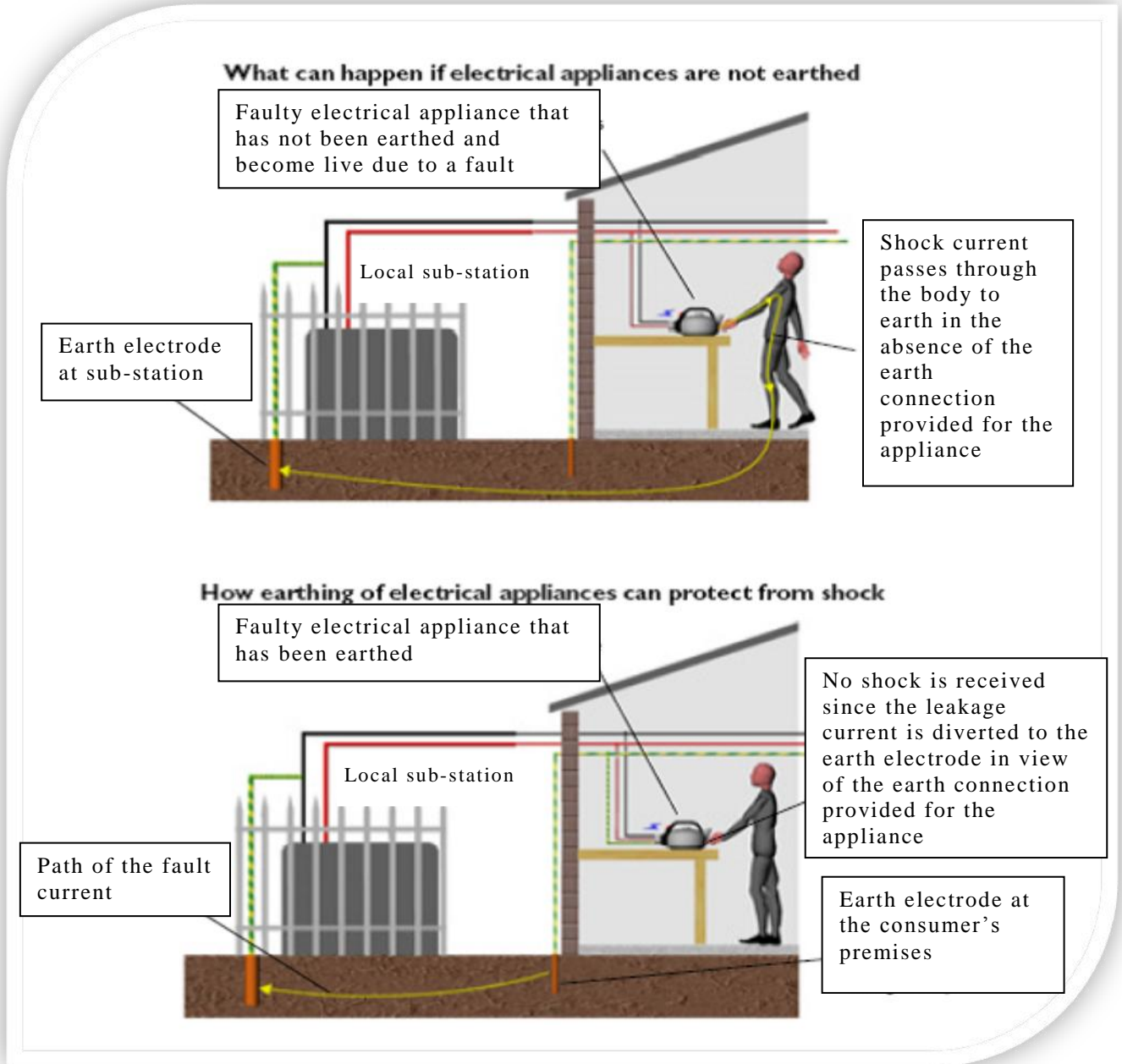


Fig.4 Earthing of electrical appliance prevents shock to the person

In the case of relying over current protective devices (like MCCB, MCB.HRC fuses etc. for downstream loads at distribution panel boards) for earth fault protection, value of earth resistance and the time current characteristics of the device should be matched to offer fault clearance within the time duration furnished in table-1 above.

The safe touch potential of 67V for 3 seconds can be taken into account for avoiding nuisance tripping of whole plant due to downstream faults, for

enabling co-ordination with the downstream protective devices and for achieving discrimination.

6.2 Cluster of earth electrodes – De ratings

When a cluster of earth electrodes are involved (i.e. when the spacing between two Electrodes is less than twice the length of the electrode), the following table can be followed to obtain the combined values. An useful rule is that earthing systems of 2-20 rods placed one length rod apart in a line, hollow triangle, circle, or square will provide a earthing resistance divided by the number of rods and then multiplied by the factor 'F' taken from the following table. Placing additional rods within the periphery of a square, circle etc. will not appreciably reduce the earth resistance below that of the peripheral rods alone.

Cluster of earth electrodes – De rating

Number of rods	2	3	4	8	12	16	20
Multiplying factor ' F'	1.16	1.29	1.36	1.68	1.8	1.92	2

Earth leakage circuit breaker is one of such a life saving device and it has to be utilized at the appropriate locations. The principle of operation of this device is explained below:

6.3 How an ELCB works

ELCBs are devices that sense when current—even a small amount—passes to earth through any path other than the proper conductor. When this condition exists, the ELCB quickly opens the circuit, stopping all current flow to the circuit and to a person receiving the earth-fault shock.

However an ELCB will not protect the user from line-to-line or line-to-neutral contact hazards. If the employee drills into an energized conductor and contacts the metal chuck or drill bit, the ELCB device will not trip (unless it is the circuit the ELCB device is connected to) as it will not detect a current imbalance.

The following figure shows a typical circuit arrangement of an ELCB designed to protect personnel.

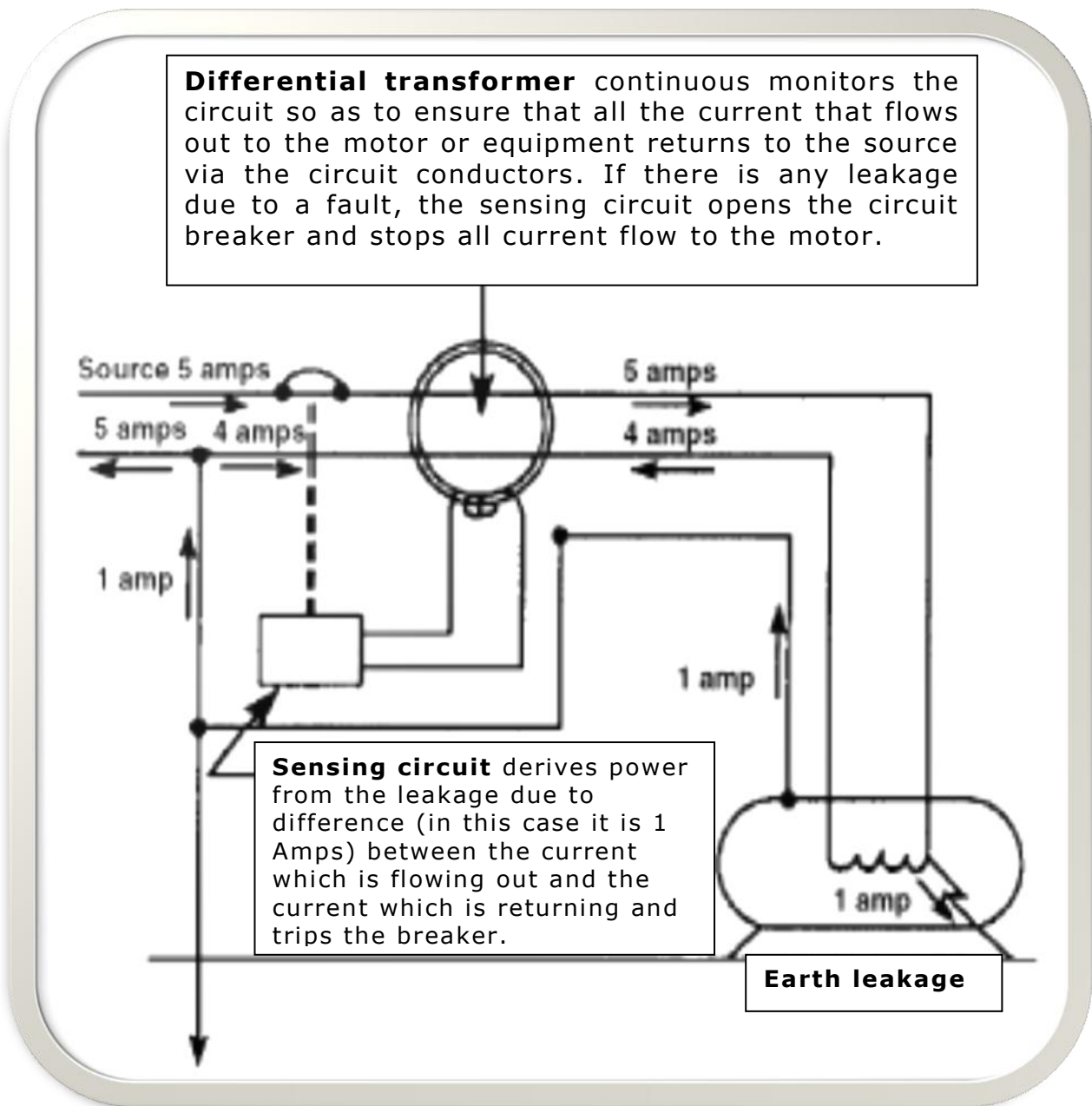


Fig.3. How An ELCB Works

The incoming two-wire circuit is connected to a two-pole, shunt-trip overload circuit breaker. The loadside conductors pass through a differential coil onto the outgoing circuit. As long as the current in both the load wires is within specified tolerances, the circuit functions normally. If one of the conductors comes in contact with an earthed condition or passes through a person's body to earth, an unbalanced current is established. This unbalanced current is picked up by the differential transformer, and a current is established through the sensing circuit to energize the shunt trip of the overload circuit breaker and quickly open the main circuit. A fuse or circuit

breaker cannot provide this kind of protection. The fuse or circuit breaker will trip or open the circuit only if a line-to-line or line-to-earth fault occurs that is greater than the circuit protection device rating.

ELCB-protected circuits is one way of providing protection of personnel using electric hand tools on construction sites, damp locations individual houses etc.

6.4 Lightning arrestors

In the existing practice, the lightning arrestor often becomes the victim and bursts out instead of protecting the transformer due to the reason that it is erected away from the transformer. The present arrangement involves a lengthy earth flat and higher air gap from the transformer winding/tank. We know that the inductance is proportional to the permeability of the medium of flux linkage (air in this case), logarithmic quantity of the length of earth lead, the distance of separation obtained between the earth flat and the transformer tank and inversely proportional to logarithmic quantity of the geometric mean radius of the earth lead. For a 100 Sq.mm and 1m length of copper earth lead spaced 1.5m away from the transformer will possess an inductance of about 1 micro-henry. This inductance will impose a reactance voltage drop across inductively coupled earth flat ($E=L di/dt$ volts). For a 10kA/micro second surge, this 1 micro-henry will impose a voltage of 10 kV/ metre length of the earth lead on the arrestor itself and also on the transformer.

Hence the following measures can be adopted:

The arrestor should be as near as possible to the equipment to be protected. It should be between the incoming line and the equipment to be protected and the Protective distances suggested below may be observed:

kV	Maximum distance
11	On transformer tank
22	On transformer tank
33	3m
44	5m
66	6m
88	6m
132	7m

- ❖ *Earth flat of the surge arrestor should be connected to transformer tank and then to the earth electrode.*

- ❖ *Neutral and surge arrestor's earth electrodes should be interconnected so that HT to transformer tank earth fault does not raise Neutral potential.*
- ❖ *LAs are positioned close to transformer tank so that length of earth flat and its reactance during steep wave front does not harm LAs itself as well as the equipment to be protected ($E=L \frac{di}{dt}$ volts).*
- ❖ *The earth flat should not have any bend so as to avoid increased reactance and to achieve minimum length.*
- ❖ *Use of steel conductor as earth flat may be discouraged in view of high permeability compared to non-magnetic Cu. or Al. conductors.*

7. Safe Work Practices

7.1 Working Space and environment

Working space around electrical enclosures or equipment shall be adequate for conducting all anticipated maintenance and operations safely, including sufficient space to ensure safety of personnel working during emergency conditions and workers rescuing injured personnel. Such equipment includes panel boards, switches, circuit breakers, switchgear, controllers, and controls on heating and air conditioning equipment.

A minimum working space 1000mm shall be provided in front of panel boards. This provides room to avoid body contact with earthed parts while working with energized components of the equipment. Where rear access is required to work on de-energized parts, a minimum of 750mm shall be provided. There shall be clearance in the work area to allow at least a 90-degree opening of equipment doors or hinged panels on the service equipment.

7.2 Confined Spaces

When temporary wiring is used in tanks or other confined spaces, an approved disconnecting means (identified and marked) shall be provided at or near the entrance to such spaces for cutting off the power supply in emergencies.

Portable electric lighting used in confined wet or hazardous locations such as drums, tanks, vessels, and grease pits shall be operated at a maximum of 12 V. However, 240-V lights may be used if protected by an earth fault circuit breaker (ELCB).

Exposed empty light sockets and bulbs shall not be permitted so as to protect personnel from accidentally contacting the live parts in the socket.

7.3 Lighting

Temporary lights shall not be suspended by their electric cords unless cords and lights are designed for this means of suspension. Wiring installed in conduit shall have bushings at all outlets and terminals to prevent abrasion and damage to the insulation.

7.4 Stored Electrical Energy

Stored electrical energy that might endanger personnel shall be placed in a safe state. Where the possibility exists that the circuit

can become energized by another source or where capacitive devices (including cables) may retain or build up a charge, the circuit should be earthed and shorted.

7.5 Stored Non electrical Energy

Stored non electrical energy in devices that could reenergize electric circuit parts shall be blocked or relieved to the extent that the circuit parts could not be accidentally energized by the device. For example, such specific devices are wound springs and pneumatic-driven devices in breakers etc.

7.6 Wet Locations

Conductors with non rated weather-proof insulation shall not be enclosed in metal raceways or used for wiring in tanks, penstocks, or tunnels. Receptacles installed outdoors, flame proof or dusty atmospheres should be of design conforming to the relevant degree of ingress protection.

7.7 Emergency Shutdown Switch

Emergency Shutdown Switch is a mechanical device located at an energy control point that positively blocks the flow of energy and can be locked in the "safe" position. Electrical equipment intended to switch current shall have a rating sufficient for the current. Such switches shall not be operated while under load, unless the devices are rated as load-break type and are so marked.

The emergency shutdown switch should be within arm's reach of the operator, be easily identifiable, de-energize all power to all equipment associated with the system, be separate from the routine on/off switch, and be located to protect the employee from moving parts. However, the emergency shutdown switch should not disconnect auxiliary circuits necessary for safety.

7.8 Capacitors

1. Capacitors may store and accumulate a dangerous residual charge after the equipment has been de-energized. Hence a hazard exists when a capacitor is subjected to high currents that may cause heating and explosion. When capacitors are used to store large amounts of energy, internal failure of one capacitor in a bank frequently results in explosion when all other capacitors in the bank discharge into the fault.

2. High-voltage cables should be treated as capacitors since they have the capability to store energy.

3. The liquid dielectric and combustion products of liquid dielectric in capacitors may be toxic.

4. Because of the phenomenon of "dielectric absorption," not all the charge in a capacitor is dissipated when it is short-circuited for a short time.

8. Shut Down or Maintenance Works

The safe procedures and practices to be adopted in electrical works whether it involves a shut down, maintenance or repair of any electrical installation/apparatus, definitely requires a thorough knowledge of engineering, safety, repair techniques and personnel should be familiar with the particular features of the installation/apparatus involved.

8.1 Basic principles

The nine principles of personal safety during the Shut-down or maintenance work are as follows:

- 1. Plan every job—Planning is the key to preventing incidents therefore, eliminating injuries. Know the work content and the sequence in which it should be accomplished before beginning the work.*
- 2. Know the safety procedures that shall be followed while performing the work.*
- 3. Use the right tool for the job—Each employee must make sure that the correct tool is used and how to use them. Ensure that the tools and instruments are in good working order and have up-to-date calibration or testing as required.*
- 4. Use procedures as tools—Even though procedures are only paper or text, they should be viewed as tools to prevent injury.*
- 5. Isolate the equipment—The best way to avoid accidental release of energy is by isolating the equipment before starting the job (lock out/tag out).*
- 6. Protect the person—The last chance to avoid an injury is to wear personal protective equipment (PPE). Each person must use all protective equipment that is needed. It is management's responsibility to provide all appropriate PPE.*
- 7. Limit access to the work area to authorized individuals who are familiar with the work.*
- 8. If unsafe conditions develop during the work process, immediately report them to the person in charge or the immediate supervisor.*
- 9. Establish emergency safety procedures to deal with electrical accidents.*

8.2 Job Briefings

The employee in charge shall conduct a job briefing and discussion with the employees involved before the start of each job. The job briefing will cover the hazards associated with the job, work

instructions involved, special precautions, energy source controls, and personal protective equipment requirements.

An employee working alone need not conduct a job briefing. However, the employee shall ensure that the tasks to be performed are planned as if a briefing were required.

If the work or operations to be performed during the work day are repetitive and similar, at least one job briefing shall be conducted before the start of the first job of each day or shift. Additional job briefings shall be held if significant changes, which might affect the safety of the employees, occur during the course of the work.

8.3 Work Instructions

Electrical work instructions should be prepared on the basis of thorough analysis of the job and its hazards and documented.

Electrical instructions may include, but not be limited to, the following:

- 1. De energizing circuits and means to prevent re energisation (lockout/tagout).*
- 2. Earthing conductors and all possible conducting parts*
- 3. Controlling associated generating equipment*
- 4. Testing of equipment to ensure safe conditions*
- 5. Provision of personal protective equipments and tools.*
- 6. Qualified personnel*
- 7. Details of the works to be performed*

If no specific instruction is available and the job is beyond the scope of written work rules, the supervisor should issue instructions pertaining to the job to be performed. The instructions should contain the essential safety rules for the job and, when documented, should be signed by the employee, a line supervisor and/or safety representative.

8.4 Responsibilities

8.4.1 Management

Management is responsible to provide a workplace that is free from recognized hazards that might cause injury, illness, or death and to comply with the specific safety standards.

Operations/Maintenance managers are responsible for implementing the Shut Down Works Programmeme by providing safe work procedures and permits for the electrical work as required. They also provide and implement other critical procedures such as lockout/tagout, testing, and safety-related work practices.

8.4.2 Supervisors

Electrical work should be directed by a supervisor, qualified by training and experience in the safety-related work practices that pertain to their respective job assignments and those of their employees.

Supervisors are responsible for knowing and implementing applicable safety policies and directives and taking action as required to provide for the safety of the personnel and operations they supervise.

This includes; taking positive action to determine and reduce, as necessary, the hazards associated with their operations; instructing employees in safe work methods and associated safety requirements; allowing only those employees that are qualified for the work to perform the work; and ensuring that employees perform their work safely.

Supervisors shall be responsible for the safety of all employees under their supervision. They shall enforce the rules that apply to the hazards involved.

Supervisors shall make certain that each new or transferred employee is instructed in the safe practices pertaining to his or her work.

Supervisors shall ensure that the appropriate employees receive instruction in appropriate emergency techniques, such as CPR, first aid, pole top and confined space rescue, warranted by the employee's duties.

Other duties of supervisors include the following:

- 1. Provide instructions on safe practices for the crew and see that they are followed.*
- 2. Periodically examine supervised employees on their knowledge of the safety rules and approved emergency techniques.*
- 3. Not allow a worker to perform any task that cannot be performed safely or for which the worker is not qualified.*
- 4. Report every injury in the prescribed manner.*
- 5. Be responsible for the care and proper use of all protective devices.*
- 6. Coach and direct employees who are working near exposed, energized wires, equipment, or apparatus.*
- 7. Prescribe, along with employees, the appropriate PPE when establishing safety related work practices.*
- 8. Under no circumstances shall the supervisor allow work to continue if safety precautions are ignored.*

8.4.3 Workers

Before work begins, the qualified worker should ensure that the job to be done is in compliance with instructions pertaining to the electrical work.

The greatest responsibility for a worker's safety lies directly with the worker. This means that all workers are responsible for performing their work in a manner that does not endanger themselves, their co-workers, or others in the area and for complying with safety rules and requirements. Workers should not rely solely on the care exercised by another for their protection. Workers are encouraged to contribute to the safety Programme and bring to the attention of their supervisors or safety representative any condition they believe is unsafe.

Workers should report any electrical hazards to their immediate supervisor. The supervisor should take all corrective actions necessary to address an employee's concerns.

Other safety responsibilities of workers include the following:

- 1. The worker should examine the work area for existing hazards and proceed in a safe manner.*
- 2. When seen in a dangerous situation, fellow workers should be warned in such a manner as to avoid confusing, startling, or suddenly alarming them.*
- 3. Before climbing poles, ladders, or other such structures or before working on scaffolds, workers shall make a careful inspection to determine whether the structures are safe and are properly supported. Workers should not carry anything in their hands while ascending or descending ladders. Small objects or tools may be carried in pockets or pouches. Larger objects, however, should be raised or lowered by use of ropes. Others working nearby or below should remain out of line of the work area in case anything should accidentally be dropped.*
- 4. It is the responsibility of each worker to attend safety meetings. Workers should also make a practice of learning safety information made available to them that will help them perform their work more safely.*
- 5. The worker shall report to the supervisor any personal injury as soon as possible.*

9. Personal Protective Equipment (PPE)

Qualified workers responsible for performing electrical work, repairs, or troubleshooting electrical equipment shall wear or use personal protective equipment (PPE), and protective clothing that is appropriate for safe performance of work.

Management shall ensure that appropriate PPE is provided and ensure that employees using PPE are trained in their proper use.

9.1 Shoes- *Employees should wear shoes or boots. No metal parts shall be present in the sole or heel of the shoes where nonconductive shoes are required.*

9.2 Helmets- *Workers shall wear helmets when working on the earth near poles, structures, buildings, or trees in which work is being done or when visiting or observing in areas where overhead work is being done.*

9.3 Eye Protectors- *Whenever eyes are in danger of being injured, workers shall wear safety goggles or other eye protectors.*

9.4 Body Belts and Safety Straps- *Line workers shall be familiar with tools like climber straps, and body belts that are used for handling or working on over head lines and poles. A careful periodic inspection shall be made of equipment used for shall be examined before each use to make certain they are in good condition.*

Employees using body belts and safety straps (work positioning equipment) should apply the following:

- 1. All body belts and safety straps shall be inspected before each use by the employee who uses them.*
- 2. Workers shall use their body belts and safety straps when doing any work involving danger of falling.*
- 3. Body belts and safety straps should not be stored with unguarded sharp tools or devices.*
- 4. Heat, sharp bends, and overstressing of body belts and safety straps should be avoided as they are injurious to leather. Wet leather should be dried slowly at moderate temperatures.*

9.5 Work Gloves- *When insulated gloves suitable for high-voltage are not required, suitable work gloves should be worn while handling materials and equipment to prevent the possibility of slivers, cuts, and skin irritation.*

9.6 Rubber Gloves- *The following requirements apply:*

- 1. Rubber gloves shall be of appropriate voltage rating for the work being performed.*
- 2. Rubber gloves issued for service shall be tested at appropriate voltage levels.*
- 3. Leather glove protectors shall be worn over rubber gloves except where leather protectors are not required.*

4. Rubber gloves shall be visually inspected and field air-tested before use each day and at other times if there is cause to suspect damage.

5. Rubber gloves shall be wiped clean of any oil, grease, or other damaging substances.

9.7 Rubber Sleeves And Barriers- Linemen's rubber insulating sleeves are worn to provide protection from electric shock and burn to the arm and shoulder areas. They are available in several different thicknesses, lengths, and designs, depending on the maximum voltage they are designed to protect against.

9.8 Work Clothes- Work clothes should be made of natural materials, such as cotton or wool, or fire resistant materials and should have full length sleeves. Sleeves should be rolled down for greatest protection.

9.9 Fire Resistant Clothing- Each employee who is exposed to flames or electric arcs does not wear clothing that, when exposed to flames or electric arc, could increase the extent of injury that would be sustained by the employee. Though the electric shock is a widely recognized hazard and involves current flow through or on the body, burn from electric arcs are not as well recognized. There is no contact required and the burns can be severe if the clothing ignites or melts. The hazards to which the employee is exposed also include the clothing breaking open due to the arc pressure blast, the heat from the electric arc and subsequent secondary fires or explosions. The extent of the employees' injury is dependent on the length of the arc gap, available fault current, duration of the arc, the distance of the employee from the arc, percentage of the body burned, the employees age, medical condition, and number of layers of the clothing system.

The proper clothing system will minimize or reduce the burn injury. Chemically dependent fire resistant fabrics are treated with flame retardant chemicals added to the fiber or treatments applied to the fabric. These treatments are activated by heat and produce gases that smother the flame. Inherently fire resistant fabrics, by their composition, do not burn in air.

9.10 Respirators- Workers shall use the appropriate respirator when necessitated.

9.11 Earthing Cables And Hardware

Personal protective earthing cables consist of appropriate lengths of suitable copper earthing cable, with electrically and mechanically compatible ferrules and clamps at each end. In addition, appropriate hot sticks are required for installing and removing the conductor-end clamps to the conductors. Hot sticks are required for attaching earth-end clamps if the earthed system and the worker are at different potentials.

Earthing clamps are normally made of copper or aluminum alloys; sized to meet or exceed the current-carrying capacity of the cable; and designed to provide a strong mechanical connection to the conductor, metal structure, or earth wire/rod.

9.12 Tapes And Rulers- *Workers should not use metal measuring tapes or tapes having metal strands woven into the fabric, brass bound rules, or metal scales when working near electrical equipment or conductors.*

9.13 Metal Fasteners- *Workers shall not wear articles such as loose chains, keys, watches, or rings if such articles increase the hazards associated with inadvertent contact with energized parts or can become caught under or snagged while climbing off or on structures, equipment or vehicles.*

9.14 Extension Cords

Use of extension cords should be minimized. Such cords shall be suitable for the intended use, such as waterproof connectors for wet or damp areas, and are subject to the same conditions as the tool or equipment cord.

Extension cords should be visually inspected before each use. Flexible cord sets used on construction sites shall contain the number of conductors required for the circuit plus an equipment earthing conductor.

9.15 Double Insulated Tools

Double insulation is a system comprised of two insulation systems (basic and supplementary) that are physically separated and are not subjected to temperature, contaminants and other deteriorating factors at the same time.

Basic insulation is applied to live parts to provide protection against electrical shock. Supplementary insulation is independent of the basic insulation and provides protection against electrical shock in case of failure of the basic insulation. Also of importance is the reinforced insulation which consists of one or more layers of

insulating material that, in itself, provides the same degree of protection as double insulation.

For example, two layers of insulation separating an armature lamination from an armature conductor is not double insulation. This is reinforced insulation. To achieve a double insulated system, one layer of insulation separates the armature lamination from the armature conductor (basic insulation) and an insulating sleeve provides a second layer between the armature lamination and the motor shaft).

Generally, double insulated equipment is constructed so that double insulation is provided between all live parts and (1) the accessible surfaces of the equipment, and (2) all inaccessible parts and surfaces that are conductively connected to the accessible surfaces of the equipment.

Under certain conditions, reinforced insulation systems are acceptable when applied to brush caps; brush-holders; commutator and end turns of armature winding switches; power supply cords; and internal wiring. Power supply cords for double-insulated tools shall be jacketed and shall not include an earthing conductor.

9.16 Work Matrices

In order to ensure safety besides convenience of working personnel, the following safety equipment matrices as prescribed by the OSHA standards are furnished for guidance:

Table -4 Job/Safety Equipment Matrix - Use those applicable to the actual job being performed on electrolytic type battery work.

Personal Protective Equipment	Fire Resistant Clothing				X
	Latex Gloves	X	X	X	X
	Apron	X	X	X	X
	Tagout and Lockout		X		X
	Goggles or Goggles and Face Shield	X	X	X	X
Tools	Insulated Hand Tools		X		X
Test Equipment	Other Approved Instrumentation	X	X	X	
Work Description		Voltage Reading	Battery Rundowns	Equalize	Torque Bolts, Lifting Heads

Table -5. Job/Safety Equipment Matrix - Use those applicable to the actual job being performed on Low Voltage Installations.

Personal Protective Equipment	Other insulated protective equipment such as gloves, blankets, sleeves, and mats.	X	X	X
	Safety Glasses	X	X	X
Tools	Insulated Hand Tools			X
	Insulated Fuse Puller		X	
Test Equipment	Other Approved Instrumentation	X		
	Clamp Ammeter	X		
	Approved Multimeter	X		
Work Description		Voltage, Current	Fuse Puller	Probing

Table -6. Job/Safety Equipment Matrix - Use those applicable to the actual job being performed on Medium Voltage Installations.

Personal Protective Equipment	Insulated protective equipment such as gloves, blankets and mats.	X	X	X	X	X	X
	Safety Belt						X
	Face Shield				X		X
	Safety Glasses	X	X	X	X	X	X
Tools	Insulated Hand Tools	X			X		X
	Breaker Jacking Tools					X	
	Insulated Fuse Puller			X			
Test Equipment	Other Approved		X				X
	Clamp Ammeter		X				
	Approved Multi meter		X				X
Work Description		Probing	Voltage , Current Reading	Pulling Control Fuses or Power	Pulling/Inserting Plug-in	Jacking Breakers In/Out on Energized MCC	Other Work-

Table -7 Job/Safety Equipment Matrix - Use those applicable to the actual job being performed High Voltage Installations.

Personal Protective Equipment	<i>Fire Resistant Clothing</i>	X	X		X
	<i>Rubber Mat</i>	X		X	X
	<i>Sleeves</i>	X	X	X	X
	<i>High-Voltage Gloves</i>	X	X	X	X
	<i>Tagout and Lockout</i>			X	
	<i>Face Shield</i>				X
	<i>Safety Glasses</i>	X	X	X	X
Tools					X
	<i>Hot Stick 5-ft Minimum</i>				X
	<i>Breaker Jacking Tools</i>		X		
Test Equipment	<i>Other Approved Instrumentation</i>	X			
	<i>High-Volt Detector</i>	X			
	<i>Glowtester</i>	X			
Work Description		<i>Voltage Reading</i>	<i>Jacking Breakers In/Out on Energized Equipment</i>	<i>High pointing De-energized Equipment</i>	<i>Pulling Fuses- No Load</i>

Table -8 Job/Safety Equipment Matrix - Use those applicable to the actual job being performed on overhead line/switchyard work

[illegible]

9.17 Training

Employees shall not be permitted to work in an area where they are likely to encounter an electrical hazard unless they have been trained to recognize and avoid these hazards. Refresher training is recommended at intervals not to exceed three years to provide an update on new regulations and electrical safety criteria. The training shall be on-the-job and/or classroom type. The degree of training provided shall be determined by the risk to the employee. This training shall be documented. Employees shall be trained and familiar with, but not be limited to, the following:

- 1. Safety-related work practices, including proper selection and use of PPE to their respective job assignments.*
- 2. Skills and techniques necessary to distinguish exposed live parts from other parts of electrical equipment.*
- 3. Skills and techniques necessary to determine the nominal voltage of exposed live parts, clearance distances, and the corresponding voltages to which the qualified person will be exposed.*
- 4. Procedures on how to perform their jobs safely and properly.*
- 5. How to lockout/tagout energized electrical circuits and equipment safely*
- 6. The skills and techniques necessary to determine the minimum approach distances corresponding to the voltages to which they are exposed.*
- 7. The proper use of the special precautionary techniques, personal protective equipment, insulating and shielding materials, and insulated tools for working on or near exposed energized parts of electrical equipment.*

10. Safe Procedure

10.1 De-energising

Whenever work is to be performed on a positively de energized system, the worker should identify and protect against any accidental contact with any exposed energized parts in the vicinity of the work.

Before any shut down works or troubleshooting is performed, sources of electrical energy shall be de energized, except where it is necessary for troubleshooting, testing, or areas that are infeasible to de energise. All energy sources shall be brought to a safe state. For example, capacitors shall be discharged and high capacitance elements shall be short-circuited and earthed.

Live parts that an employee may be exposed to shall be de energized before the employee works on or near them, unless it can be demonstrated that de energizing introduces additional or increased hazards or is infeasible because of equipment design or operational limitations. Examples of infeasibility because of equipment design or operational limitations are as follows:

- 1. Tests, 2. Adjustments, 3. Troubleshooting, 4. Interruption of life supports, 5. Removal of lighting in an area, 6. Deactivation of alarm systems, 7. Shutdown of ventilation in hazardous locations*
- 8. Shutdown of a process or system creating a greater hazard.*

Live parts that operate at less than 50 volts to earth need not be de energized if there will be no increased exposure to electrical burns or to explosion due to electrical arcs.

When an energized line or equipment is removed from service to be worked on, it shall be treated as energized until it is de energized, tagged, locked, tested and earthed.

10.2 Verification of De-energized Condition

Verification shall be made that all live circuits, parts, and other sources of electrical energy, including any mechanical energy, have been disconnected, released, or restrained. A qualified worker shall operate the equipment operating controls, perform voltage verification, inspect open switches and draw-out breakers etc. to assure the isolation of energy sources. A qualified worker shall use the appropriate test equipment to test the circuit elements and electrical parts of equipment to which employees will be exposed and shall verify that the circuit elements and equipment parts are de energized.

The voltage verification device used shall be rated for the application. Proximity testers and solenoid-type devices should not

be used to test for the absence of AC voltage because they have a lower voltage below which they will not detect voltage, even if it is present. Also, these testers will not detect DC voltage or detect AC voltage in a cable that is shielded. They are very useful in certain applications such as finding cables that go through a panel but do not terminate in the panel. However, it should be noted that just because a proximity tester does not detect voltage does not mean that the equipment or device is actually de energized. The absence of voltage can only be verified with a voltmeter rated for the application.

Voltmeters, both analog and digital, are designed for a number of applications from appliance troubleshooting to power system testing. The type of voltmeter used depends on where in the power system you are using the meter. The user must read and understand the manufacturers' instructions on the use and application of the voltmeter. When a multi-function, multi-scale meter is used, it is important for the user to select the function and scale necessary for the task being performed in order to avoid damage or destruction of the meter and injury to the employee.

Test instruments and equipment and all associated test leads, cables, power cords, probes, and connectors shall be visually inspected for external defects or damage before being used on any shift. If there are defects or evidence of damage that might expose an employee to injury, the defective or damaged item shall not be used until required repairs and tests have been made.

A record should be maintained for each instrument, by serial number or equivalent method, showing dates of inspection, calibration data as received, the date when it should be recalled from the field and a recalibration check made, and any interim repairs.

Close and secure all cover panels and doors. If all panels or doors cannot be closed, which may occur when testing, place barricades or rope-off a safety zone with non-conductive material and post prominent warning signs around the area.

10.3 Equipment Earthing

Earthing is the most effective way of protecting electrical workers from electric shock. That is why it is important to ensure that all de energized lines and equipment are earthed.

10.4 Personnel Protective Earths

Personnel protective earths shall be applied on circuits where residual charges may accumulate. The primary function of personal protective earths is to provide maximum safety for personnel while they are working on de energized lines or equipment. This will be

accomplished by making provisions that will reduce the potential voltage differences at the work site to a safe value in the event that line or equipment being worked on is accidentally reenergized, voltages induced from other energized lines, an energized line falls on the line being worked, or there is a lightning strike near the line being worked.

Earthing cables shall be available for use when work is being done on de energized lines or equipment. Earthing cables shall accommodate the maximum fault current to which the cable or equipment might be subjected. The size of the earthing cable must be selected to handle the maximum calculated fault current of the power system or specific portion thereof.

Excessive cable lengths should be avoided. Therefore, slack in the installed cables should be minimal to reduce possible injury to workers. Resistance in the cable increases with cable length, and excessive length could exceed the tolerable voltage drop across the body. Longer than necessary cables also tend to twist or coil, which reduces the effectiveness of the cable.

10.5 Attaching and removing earths

Employees attaching and removing earths shall comply with the following:

- 1. Earthing equipment should be visually inspected and all mechanical connections checked for tightness before each use.*
- 2. The surface to which the earth is to be attached should be clean before the earthing clamp is installed or a self-cleaning clamp shall be used.*
- 3. No earth shall be removed until all personnel are clear of the temporary earthed lines or equipment. When the earthing set is removed, it shall be disconnected from the line or equipment end first with an approved hot-line tool and moved to a point clear of energized conductors before the earth end is disconnected.*

When removing personnel protective earths, reverse the order they were applied. The earthing cable conductors attached to the earth bus, structure shall always be removed last.

10.6 Lockout/Tagout Procedure

Each employer shall document and implement lockout/tagout procedures to safeguard employees from injury while they are working on or near de energized electric circuits and equipment.

10.7 Lockout *is the method of applying a mechanical lockout device and a tag on an energy-isolating device by an authorized employee in accordance with established written procedures, in order to control hazardous energies. Lockout is required for mechanical*

service, break-down and maintenance operations if the procedures to be performed could involve employee exposure to energized electrical parts, to machinery that could unexpectedly start up, or to a stored energy source on the equipment or machinery.

10.8 Lockout Devices are padlocks, combination locks, or other methods (such as disconnecting conductors or removing fuses), which will effectively prevent unexpected or inadvertent energizing of a designated circuit or release of equipment or machinery. These devices shall not be used for other purposes, and shall include a means to indicate the identity of the employee applying the device.

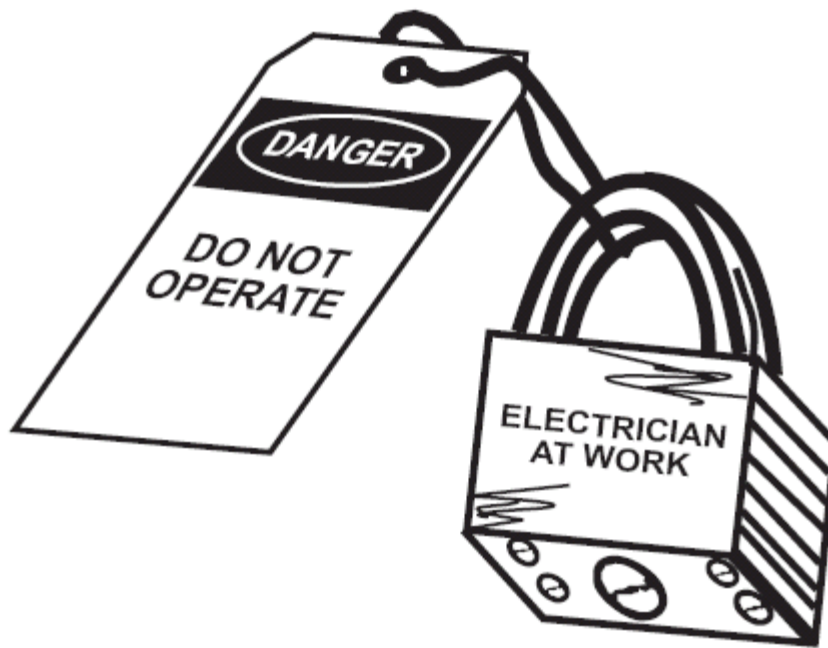


Fig.4 Typical tagout device

10.9 Tagout is the placement of a tagout device on an energy-isolating device in accordance with established written procedures to control hazardous energy.

10.10 Tagout Device is a prominent warning tag capable of being securely attached that provides a warning not to use the equipment. The tag should include reason for tag, name of person placing the tag and how that person may be contacted, and date the tag was placed. Tags must be durable and able to withstand the environment to which they are exposed for the maximum time exposure is expected. These tags shall not be used for other purposes.

Using tagout as a form of hazardous energy control is not a positive means of controlling hazardous energy and shall not be used whenever lockout is possible.

A tagout device must be placed on the plug, conductors, disconnect switch, fuse brackets, or other positive means employed.

When it is impossible to use a lock, a tagout device must be used in lieu of a lockout along with another positive means of disconnecting the circuit, equipment, or machinery. This can include unplugging the equipment (or locking out the plug), disconnecting the conductors, or removing fuses.

10.11 Removing Lock and Tag

Locks, tags, and all other safety warning devices must be left in place during all short absences such as breaks or trips to pick up parts.

When work is incomplete and temporarily suspended overnight or over a weekend, all locks, tags, and other safety warning devices must be left in place.

Ordinarily, only the person who placed the locks and tags may remove them. If the person who placed the locks and tags is not available, only his/her supervisor may cut off the locks and tags, after personally ascertaining it is safe to do so.

When an employee leaves the facility site and does not remove his/her lock(s) from the energy isolating device(s) (for example, if the employee became sick and left the site) then the responsible supervisor must attempt to contact that employee to determine if he/she will be able to return to remove the lock. If it is verified that the equipment is ready to be returned to service, and the employee is unavailable or cannot return, the supervisor must complete the Permit To Work Authorization Form, then cut the lock(s) off the energy isolating device(s).

Once the employee returns to the work site, that person must be informed that their lock was removed and the status of the equipment that was locked out (e.g., returned to service, still under lockout, etc.).

If a lockout procedure is to continue for the next work shift, the oncoming work crews must place their locks and tags on the energy isolating devices before the departing crew removes their locks and tags. Before work begins on the subsequent work shift, the oncoming crew must re-verify that all safety devices, such as blocking, are in place, that there is still zero energy in the system, and they should attempt to restart or re-energize the system before anyone enters the hazard zone.

When work is suspended for more than a weekend, the equipment or machinery must be tagged as out of service,

permanently disconnected from all energy sources, and must have its cover and access panels reinstalled. All locks and other tags must be removed.

On some machines, it may be necessary to energize or start up machinery or equipment during a lockout procedure to tune, adjust, or make measurements before the machine is fully restored to service. In those instances, all persons must clear the hazard zone of all tools and equipment, leave the hazard zone, verify that all persons are clear of any hazards, remove the necessary locks, and then the equipment can be energized. A qualified person must then make the necessary measurements or adjustments and the equipment shut down. The locked-out condition must then be re-established by repeating the exact same work steps specified on the written procedure for fully locking out the equipment.

10.12 Re Energizing

The following requirements shall be met before circuits or equipment are reenergized, even temporarily:

- ★ **Tests And Visual Inspections-** A qualified worker shall conduct tests and visual inspections to verify that all personnel have actually cleared their works and that all tools, electrical jumpers, earths, and other such devices have been removed so that the circuits and equipment can be safely energized.*
- ★ **Warning Employees-** Employees exposed to the hazards associated with reenergizing the circuit or equipment shall be warned to stay clear of circuits and equipment.*
- ★ **Removing Lock And Tag-** Each lock and tag shall be removed by observing the principles explained above.*

10.13 Stringing Adjacent To Energized Lines

No qualified employee shall be permitted to approach or take any conductive object closer to exposed energized lines or parts than the distances listed in the table 11

Employees stringing adjacent to energized lines should follow certain safe work practices. Consideration should be given to the following:

- 1. When performing work from structures, clipping crews and all others working on conductors, sub-conductors, or overhead earthing conductors should be protected by individual earths installed at every work location.*
- 2. When workers are stringing adjacent to energized lines, the tension-stringing method or other methods that prevent unintentional contact between the lines being pulled and any worker should be used.*

3. *All pulling and tensioning equipment should be effectively earthed.*
4. *A earth should be installed between the tensioning reel setup and the first structure to earth each bare conductor, sub conductor, and overhead earthing conductor during stringing across or adjacent to energized lines.*
5. *During stringing operations, each bare conductor, sub-conductor, and overhead earthing conductor should be earthed at the first tower adjacent to both the tensioning and pulling setup and at appropriate intervals. The earths should be left in place until conductor installation is completed. Except for moving-type earths, the earths should be placed and removed with a hot stick.*
6. *Conductors, sub-conductors, and overhead earthing conductors should be earthed at all dead-end or catch-off points.*
7. *An earth should be located at each side and within 10 ft. of working areas where conductors, sub-conductors, or overhead earthing conductors are being spliced at earth level. The two ends to be spliced should be bonded to each other. It is recommended that splicing be carried out on either an insulated platform or on a conductive metallic earthing mat bonded to both earths. When a earthing mat is used, it should be roped off and an insulated walkway provided for access to the mat.*
8. *The minimum approach distances shall be maintained from unearthed conductors at the work location. The earth may be omitted if the making of the earth is impractical or the resulting conditions are more hazardous than working on the lines or equipment without earthing.*
9. *However, all work shall be done as if the line or equipment were energized.*

11. Permit-To-Work System

All work on major electrical installations shall be carried out under permit-to-work system which is now well established, unless standing instructions are issued by the competent authority to follow other procedures. In extenuating circumstances, such as for the purpose of saving life or time in the event of an emergency, it may become necessary to start the work without being able to obtain the necessary permit-to-work. In such cases, the action taken shall be reported to the person-in-charge as soon as possible. The permit-to-work certificate from the person-in-charge of operation to the person-in-charge of the men selected to carry out any particular work ensures that the portion of the installation where the work is to be carried out is rendered dead and safe for working. All work shall be carried out under the personal supervision of a competent person. If more than one department is working on the same apparatus, a permit-to-work should be issued to the person-in-charge of each department.

11.1 Model form of permit-to-work

Name of the
Organization.....
.....

Department (issuing the
permit).....
.....

Permit No..... Time.....
Date.....

1. *I.....certify that the following apparatus has been made dead, is isolated from all live conductors and has been connected to earth and the work mentioned in para (3) can now be carried out in accordance with the safety rules and regulations;*
2. *For the purpose of making the above apparatus dead, the following switches/isolators/links/fuses have been opened and the section so isolated has been earthed at each isolation point and danger notice plates fixed thereon:*

Switches.....

Isolators.....

Links.....

Fuses.....

3. *Work to be carried out (testing work, if any, to be specifically mentioned)*

.....
.....
.....
.....

4. *I have also recorded the above operations in the Log Sheet/Log Book including the instructions for the person who may relieve me.*

5. *This permit is now being issued to.....*

(name of the person to whom the permit is being issued)for carrying out the work mentioned in para (3).

*(Signature of the permit
issuing authority)*

*(Designation).....
.....*

Department (receiving the permit)

.....

Permit No.

Time.....

Date.....

*I.....confirm that I have been issued this permit by.....
(name of the permit issuing officer) and have been placed in direct and continuous charge of the work mentioned in para (3) and accept the responsibility of carrying out the said work taking all necessary safety precautions to avoid danger and no attempt will be made*

either by me or by men working under my control to carry out any other work on any apparatus other than that detailed in paras (1) and (3) on the reverse.

*(Signature of the person
receiving the permit and
responsible for carrying out the
above work)*

(Designation).....

I have transferred this permit to

.....

*who will now be responsible for carrying out all the works mentioned
in para (3) on the reverse.*

.....

(Signature of the person transferring the permit)

(Designation)

.....

(Signature of the person receiving the permit)

(Designation).....

Time..... Date.....

I confirm that the work specified in para (3) on reverse has been completed and all workmen withdrawn and warned that it is no longer safe to work on the apparatus mentioned in para (1) on the reverse. I also confirm that all temporary earths and other connections made by me and by men under my control have been removed except that any precautionary steps taken by the permit issuing officer before the issue of this permit have not been interfered with by me or by men under my control. I hereby return the permit for cancellation leaving the dead apparatus ready for putting into service.

*(Signature of the person
returning the permit)*

(Designation).....

Time.....

Date.....

The work mentioned in para (3) on the reverse has been carried out; all earths made for the purpose have been removed and danger notice plates put aside. The following switches/isolators/links/fuses have been closed and apparatus put back into service. Entry has been made in the Log Sheet/Log Book.

Switches.....

Isolators.....

Links.....

Fuses.....

*(Signature of the permit
cancelling authority)
(Designation).....*

12. Remedial Measures

Keeping in mind 'Where safety ends, there the accident begins', the following safety measures are recommended for various hazards:

12.1 Erection

- (i) Statutory provisions specifying clearances to building from OH lines in rule 77 to 83 of IER1956 should be duly observed during the stage of construction itself.*
- (ii) Permission of Electrical Inspectorate is to be observed in the case of generator set, multistoried building, luminous neon signs and X-ray installations as per rule47-A, 50-a, 71 and 73 of IER 1956.*
- (iii) Proper planning and design, selection of material conforming to the national or international standards, carrying out the works through licensed contractors as per the provisions of rule-29, 45(1) of IER 1956.*
- (iv) Selection of materials according to the circumstances or applications in respect of temperature, moisture, outdoor installations, inflammable areas, paint booths etc. are to be observed as per rule 50 (1)(e) and 51(1)(d) of IER 1956 scrupulously.*
- (v) Shrouding live supply parts and keeping live parts out of reach are to be observed as per the provisions of rule 50(1)(f), 64, and 68 of IER 1956.*
- (vi) Installation of sufficient earth electrodes to minimize step and touch potential as per rule 51,61,63 and 67 of IER 1956 and as per IS 3043 are to be followed up.*
- (vii) The object of providing earth electrodes in a solid neutral earthing system for personal protection is to offer an optimum value of earth resistance which is low enough to produce a required earth fault current for actuating protective devices used in the system. Such devices could be relays in the main breaker, HRC fuses in the down stream panel boards, etc.*
- (viii) An earth layout arrangement showing the position of various earth electrodes with reference to the buildings, lawns, roads etc. may be prepared and sent along with the drawings forwarded for approval and to keep such a reference copy in their maintenance register.*
- (ix) In the earth electrodes, the various earth flats are sometimes terminated to the common bolts fastened to an insufficient size of*

clamp fitted to the earth pipes. The size of clamps should be increased suitably and various earth flats should be terminated to independent fastening bolts. Also the double clamps that are making little contact with the earth pipes may be curved suitably to achieve a maximum area of contact with the earth pipe for an efficient earthing system.

- (x) *Any earth pipe projecting above the level of masonry trough and exposed may be driven to a depth of not less than 0.3m below the earth level so as to reduce the voltage gradient around the earth electrode/earth trough. (cl.11.2 of IS 3043)*
- (xi) *If the earth flats of the generator/transformer consist of different sections using bolted joints, such an arrangement may be replaced by single length of flat or minimum number of joints using bracing/welding.*
- (xii) *Sometimes single core armoured cables laid in trefoil formation are used for long runs. In such cases, single point bonding is done by earthing the armour at the sending end only while the receiving end is kept insulated for the purpose of avoiding circulating current and for improving the current rating of the cable. With this arrangement a standing voltage will appear in the cable screen proportional to the circuit length. In the absence of any provision to limit the sheath voltage under transient conditions, the other (receiving) end of the cable should also be earthed. The metallic cable tray should also be earthed at regular intervals along the entire route with the nearby earth electrodes so as to limit the earth potential rise due to transfer of potential through the sheath.*

(xiii) **Switch Boards**

- ☒ **Compartmentalization**
 - ❖ *Large opening available between the Incomer switch gear chamber and the adjacent outgoing cable chamber*
 - ❖ *Cable chamber communicating with the feeder control chambers.*
- ☒ **Bus bars and controls**
 - ❖ *Meet the nominal as well as fault requirements*
 - ❖ *Lower sized bus bars tapped off for the vertical runs from the horizontal bus bars*
 - ❖ *Observe settings, de-rated fuses so that discrimination with the downstream controls and circuits can be achieved.*
- ☒ **Safe working**

- ❖ *The outgoing cables availed from the short bus bars extended from the controls into the cable chamber*
- ❖ *Avoid using contactors for achieving the neutral break*
- ❖ *Relevant degree of protection against ingress of moisture and dust*
- ❖ *Type test certificate of CPRI/NABL accredited laboratory*
- ❖ *Site inspection before procurement*

(xiv) *Most of the outgoing controls from the switch boards and DBs are not co-ordinated to afford protection to the cables against overload and earth fault conditions. The settings of the MCCBs and the rating of the MCBs should be selected in such a way that the following conditions are satisfied:*

- i. *The current causing effective operation of the protective device does not exceed 1.45 times the current carrying capacity of the cable.*
- ii. *The fault clearance time of the protective device shall not result in the admissible limiting temperature of the cable under short circuit and earth fault conditions being exceeded.*

(xv) *Building structural parts earthing is essential and it has to be done at the construction stage itself since it offers a reduction in combined value of resistance to the earth besides maintaining an equipotential equipment frames within the building in order to eliminate the harm (esp.to sensitive computer equipments) which is likely to arise out of strong electric field during thunder cloud and during the construction in proximity to EHV irrespective of the observance of requisite clearances.*

(xvi) *Reinforced metallic flexible hose offers very high inductive earth return coupling during earth fault. Supplement it with bare earth lead inside the hose.*

(xvii) *In the welding sets the return circuit is sometimes availed using MS flats. Heavily insulated flexible cables alone may be advised to be used for the holder as well as the return circuits of the welding set to avoid arcing caused by the flow of current through structural members.*

(xviii) *Supplementary equipotential bonding should be achieved by connecting together all the accessible extraneous conductive parts, like, water pipe line etc. with the main earth bus so as to avoid danger from extraneous voltages.*

- (xix) *Protecting circuits against overload, short circuit and earth leakage at the circuit origin are essential as per rule 50(1)(c), 29,61A of IER 1956 and IS 732.*
- (xx) *Proper termination of supply leads and cables and mechanical protection of supply and earth leads are to be carried out as per Rule 50 of IER 1956.*
- (xxi) *Supply to portable welding sets etc. should be availed using Metal clad plug (lockable type) and socket arrangement.*
- (xxii) *Pre commissioning Tests for insulation resistance, earth resistance, contact resistance at bus bars cable terminations, earth loop impedance are to be carried out before energizing an electrical installation as per rule 63 & 65 of IER 1956.*
- (xxiii) *Providing safe working clearance for the switchboards etc.*

xxiv TNEB Installations

(a) *Tap-off from the OH conductors for effecting service connection should be effected using 'U' shaped conductors followed by aerial cut-outs as per rule 31 of IER 1956.*

(b) *OH line pole supports earthing and protective multiple neutral earthing practices should be adopted as per rule 61(1)(a) and 90 of IER 1956.*

(c) *An earthing device comprising strut arrangement using GI channel and angle iron frame work with GI flat cross arm extending beyond the whole width of the OH conductor (atleast half a meter beyond the extreme conductor) should be attached to each pole at a vertical clearance of about one to two meters below the OH lines. Such a device should be connected to the neutral conductor, metallic fittings attached to the pole and to the steel reinforcement of the pole. This arrangement will cause the fouling of snapped conductor on the earthed part of the device for facilitating the efficient operation of feeder fuses at the transformer sub-station as per rule 91 of IER 1956.*

(d) *Additional pole should be inserted for the lengthy spans so as to minimise the stress on the OH conductors within the permissible limits as per rule 76 of IER 1956.*

(e) *Renewal of aged OH ACSR conductors should be done as per rule 76 of IER 1956.*

(f) *The following Safe Working Clearances for HV lines should be observed from the nearby buildings during erection and maintenance and the violations should be caused to be removed as per statutory provisions prescribed under CEA Regulations, 2010.*

Table-9: Minimum clearances to be maintained for OH Lines passing above / adjacent to any building(Regulation 58 of CEA Regulations, 2010)

Type of OH Lines	Vertical clearance	Horizontal clearance
Voltage not exceeding 650 V	2.5 metres	1.2 metre
Voltage exceeding 650 V but upto and including 11kV	3.7 metres	1.2 metre
Voltage exceeding 11kV but upto and including 33kV	3.7 metres	2.0 metres
Voltage exceeding 33kV	3.7m +0.3m for every additional 33kV or part thereof	2.0m + 0.3m for every additional 33kV or part thereof

g) The following Clearances for HV lines should be observed from the ground level during erection and maintenance.

Table 10: Minimum clearance to be provided above ground of the lowest bare conductors (Regulation 60 and 61 of CEA Regulations, 2010)

	Voltage not exceeding 650 V	Voltage exceeding 650 V but not exceeding 33kV	Voltage exceeding 650 V but not exceeding 33kV
Across the street	5.8 metres	6.1 metres	6.1 metres
Along the street	5.5 metres	5.8 metres	6.1 metres
At places other than street	4.6 metres	5.2 metres	5.2M + 0.3M for every 33KV or part thereof.

Table 11: Minimum safe working clearance to be maintained for bare conductors or Live parts of any apparatus in outdoor sub-stations, excluding overhead lines of HV and EHV installations (Regulation 44 and Schedule VII of CEA Regulations, 2010)

System Voltage	Minimum safety working clearance
----------------	----------------------------------

12 kV	2.6m
36 kV	2.8m
72.5 kV	3.1m
145 kV	3.7m
245 kV	4.3m

*Note: 1. The above values are valid for altitude not exceeding 1000metres. A correction factor of 1.25% per 100m is to be applied for increasing the clearance for altitudes more than 1000m and up to 3000m.
2. The above safety working clearances are based on an insulation height of 2.44m which is the height of lower point on the insulator (where it meets the earthed metal) from the ground.*

Table 12: Recommended span length of HV OH Lines (Regulation 67 of CEA Regulations, 2010)

All conductors shall be attached to supports at intervals not exceeding the safe limits based on the ultimate tensile strength of the conductors and the factor of safety prescribed in Regulation 57 of CEA Regulations, 2010.

Provided that in the case of OH lines carrying low and medium voltage conductors, when erected in, over, along or across any street, the interval shall not, without the consent in writing of the Inspector, exceed 65 metres

h) Relevant degree of protection against ingress of moisture and dust should be ensured during procurement itself with regard to the distribution pillar boxes in suburban areas so that live parts are made inaccessible for the general public and leakage does not occur during rainy season.

xxv P&T lines

Re-alignment of the TNEB Low Tension overhead lines and P&T lines in accordance with the statutory provisions contained in The Electricity Act, 2003 and CEA Regulations, 2010 should be carried out.

xxvi Agricultural motor pump service connection

a) The consumers availing agricultural service connections may be advised to periodically maintain it so as to replace the entire length of the supply leads by new ones in case of deterioration in its mid way, without resorting to a non-standard insulation of the exposed joints thereby leaving it accessible.

b) Ensure continuity of earth connection by renewing the eroded earth pipe and earth wire.

12.2 Maintenance

- (i) *Periodical calibration and testing of instruments and safety devices should be carried out.*
- (ii) *Preventive maintenance on equipment as per manufacturer's guidelines and BIS should be done.*
- (iii) *Testing of earth electrodes and insulation resistance of the installations at periodical intervals is important as per rule 67 of IER 1956.*
- (iv) *Latest clamp on type instruments provide direct measurement of earth loop impedance without using spikes.*
- (v) *This preventive maintenance will lead to a habit of getting addicted to important things instead of urgency addiction.*

12.3 Human errors

We got practical solutions for human errors arising out of psychological aspects also. Accordingly, the following measures are recommended:

- i. *Incorporate foolproof interlocks especially in the areas of routine operations. e.g. mechanical interlock between various sources of supply for changeover arrangement, and between earth switch/isolators with breaker etc. and operation sequence respectively.*
- ii. *Adopting work permit system scrupulously as per IS 5216.*
- iii. *Imparting training at various levels and periods.*
- iv. *Availing safety devices and displaying clear work instructions.*
- v. *Creating awareness and exhibiting safety slogans through media and seminars so as to reach the public.*
- vi. *Responding to alarms and never ignoring them by overconfident unless satisfied that it is a false indication due to defective alarm circuit etc.*
- vii. *Permitting authorized personnel only for specific type of works as per rule 3 of IER 1956.*
- viii. *Proper use of fire fighting appliances.*
- ix. *Act outwardly i.e., never get trapped into a situation known as 'tunnel vision' where one might commit a mistake based on the wrong presumption on basic ideas. In other words, never trapped to a situation get out of a problem and attack the problem externally to solve it.*

13. Useful Tips On Electrical Safety

13.1 General Public

- *Get all the electrical works done only by qualified licensed electrical contractors.*
- *Use only ISI marked electrical appliances, cables and wires.*
- *Switch off the supply before inserting and removing the plug socket outlets.*
- *Electricity supply for Refrigerator, Wetgrinder and other home appliances may be availed through pin plug sockets controlled by suitable switch controls, another third pin connected to earth.*
- *Use only ISI marked electrical appliances, cables and wires.*
- *Switch off the supply before inserting and removing the plug socket outlets.*
- *Electricity supply for Refrigerator, Wetgrinder and other home appliances may be availed through pin plug sockets controlled by suitable switch controls, another third pin connected to earth.*
- *Use 'ELCB' the 'LIFE SAVER' wherever hand held/ portable appliances are used.*
- *Replace damaged electrical components like switches, plug sockets etc., immediately when noticed.*
- *While installing the T.V. antennas*
 - *a) Don't install them nearer to the OH electrical lines.*
 - *b) Don't tie the stay wires of T.V. antenna poles to the structures of electrical installations (eg. service poles, lamp fittings etc.,)*
- *Provide and maintain earth electrodes to earth the conducting body of electrical appliances.*
- *Install switches, plug sockets etc., at an inaccessible height and away from the approach of children.*
- *Periodically test the electrical installation and replace if required. Temporary electrical wiring for the Temple Festivals, marriage functions may be carefully got done by licensed electrical contractor only.*
- *Avoid using stay wires and electrical fixtures as poles/supports to tie wires/ropes to dry wet cloths and save your family.*
- *During Car Festival, for running cars of higher pitch, seek the help of Electricity supply authorities for the safety of public.*
- *Do not Transport Vehicles, ladders etc., which are higher in height beneath the electric OH lines.*
- *Do not secure poultries/domestic animals to the electric poles or the stay wires.*
- *Don't use electric poles as support to pandals or displaying advertisement boards.*
- *If any snapped electricity conductors is noticed inform the electricity people but don't touch or go near them.*
- *Don't construct buildings near the electricity lines; consult Electricity supply officials before planning for the same.*
- *Watch your children while they are playing with kites near any electric OH lines.*

- *Don't go near the fencing of electrical transformers/ structure yard on streets for nature's call.*
- *Don't stand beneath the lengthy trees during rain with thunders. Avoid lightning strikes.*

13.2 ELECTRICAL SAFETY RULES

- *Do not renew a blown fuse until you are satisfied as to the cause and have rectified the irregularity.*
- *Do not close any switch unless you are familiar with the circuit which it controls and know the reason for its being open.*
- *Do not work on the live circuit without the express orders of the supervisor. Make certain that all safety precautions have been taken and you are accompanied by a second person competent to render First Aid and Artificial Respiration.*
- *Do not touch or tamper with any electrical gear or conductor unless you have made sure that it is DEAD AND EARTHED.*
- *Do not disconnect earthing connections or render ineffective the safety gadgets installed on mains and apparatus.*
- *Do not open or close switch or fuse slowly or hesitatingly. Do it quickly and positively.*
- *Don't use wires with poor insulation.*
- *Do not touch any electrical circuits when your hands are wet or bleeding from a cut or an abrasion.*
- *Do not work on energised circuit without taking extra precaution such as the use of rubber gloves.*
- *Don't use fire extinguisher on electrical equipment unless it is clearly marked for that purpose. Use sand and blanket instead.*
- *Do not throw water on live electrical equipment in cases of fire.*
- *Do not attempt to disengage a person in contact with a live apparatus which you can not switch off immediately. Insulate your self from earth by standing on rubber mat or dry board, before attempting to get him clear. Do not touch his body, push him clear with a piece of dry wood.*
- *Do continue artificial respiration until recovery or death is certified by doctor.*
- *Do not allow visitors and unauthorised person to touch or handle electrical apparatus or come within the danger Zone of HV apparatus.*
- *Do not test circuit with bare fingers.*



14. Post Accident Measures

14.1 Measures to be adopted

The measures to be adopted prior to an accident are outlined in the foregoing section. It is also important to follow up certain other measures during and after the occurrence of the accident. These include the rescue procedures, resuscitation, and first aid methods to the persons who met with such accidents. They should be empowered with inspirational and positive attitudes to the effect that they would be all right soon. The first few minutes of the victim are important in an electrical accident and there is a likelihood of revival if treated properly.

Though the post accident measures cannot prevent accidents they can minimize losses. The difference could be injury to death, complaint to lawsuit and business interruption to business closing.

A crisis management team should be formed in major organizations under the guidance of top management and union representatives to perform the following activities:

- *Intimation of accidents to the statutory authorities like Police, Electrical Inspector (see rule 44 of IER 1956), Factories Inspector etc.,*
- *Compensation claims control*
- *Liability claims*
- *Effective rehabilitation of injured personnel.*

Having a safety mission statement, posting posters and safety slogans, incentive Programmes, and exhorting employees to "work safely" will accomplish nothing if employees perceive that management is not truly committed to the safety.

In addition to the observance of intimation to the local police, Inspector of Factories Etc., statutory provisions of the Electricity Act, 2003 and CEA Regulations, 2010 prescribes the provisions applicable in the case of electrical accidents. The statutory provisions are furnished below for ready reference

14.2 Accidents And Inquiries.

Section 161.(1) If any accident occurs in connection with the generation, transmission, distribution, supply or use of electricity in or in connection with, any part of the electric lines or electrical plant of any person and the accident results or is likely to have resulted in loss of human or animal life or in any injury to a human being or an animal, such person shall give notice of the occurrence and of any such loss or injury actually caused by the accident, in such form and within such time as may be prescribed, to the Electrical Inspector or

such other person as aforesaid and to such other authorities as the Appropriate Government may by general or special order, direct.

(2) The Appropriate Government may, if it thinks fit, require any Electrical Inspector, or any other person appointed by it in this behalf, to inquire and report-

(a) as to the cause of any accident affecting the safety of the public, which may have been occasioned by or in connection with, the generation, transmission, distribution, supply or use of electricity, or

(b) as to the manner in, and extent to, which the provisions of this Act or rules and regulations made there under or of any licence, so far as those provisions affect the safety of any person, have been complied with.

(3) Every Electrical Inspector or other person holding an inquiry under sub-section (2) shall have all the powers of a civil court under the Code of Civil Procedure, 1908 for the purpose of enforcing the attendance of witnesses and compelling the production of documents and material objects, and every person required by an Electrical Inspector be legally bound to do so within the meaning of section 176 of the Indian Penal Code.

14.3 Intimation of Accident

Intimation of accidents.- (1) If any accident occurs in connection with the generation, transmission, supply or use of electricity in or in connection with, any part of the electric lines or other works of any person and the accident results in or is likely to have resulted in loss of human or animal life or in any injury to a human being or an animal, such person or any authorized person of the generating company or licensee, not below the rank of a Junior Engineer or equivalent shall send to the Inspector a telegraphic report within 24 hours of the knowledge of the occurrence of the fatal accident and a report in writing in **Form A** within 48 hours of the knowledge of occurrence of fatal and all other accidents. Where possible a telephonic message should also be given to the Inspector immediately, if the accident comes to the knowledge of the authorized officer of the generating company/licensee or other person concerned.

(2) For the intimation of the accident, telephone numbers, fax numbers and addresses of Chief Electrical Inspector or Electrical Inspectors, District Magistrate, police station, Fire Brigade and nearest hospital shall be displayed at the conspicuous place in the generating station, sub-station, enclosed sub-station/switching station and maintained in the Office of the in-charge/owner of the Medium Voltage (MV)/High Voltage (HV)/Extra High Voltage (EHV) installations.

The following form has to be used in connection with reporting of an electrical accident:

14.4 FORM FOR REPORTING ELECTRICAL ACCIDENTS

Form A

1. Date and time of accident.
2. Place of accident.
(Village/Town, Tehsil/Thana, District and State).
3. System and voltage of supply (Whether Extra High Voltage (EHV)/High Voltage (HV)/Low Voltage (LV) Line, sub-station/generation station/consumer's installations/service lines/other installations).
4. Designation of the Officer-in-charge of the generating company/licensee in whose jurisdiction the accident occurred.
5. Name of owner/user of energy in whose premises the accident occurred.
6. Details of victim(s):

(a) Human

Sl.No 1	Name 2	Father's Name 3	Sex of victim 4	Full Postal address 5	Approximate age 6	Fatal/non-fatal 7
------------	-----------	-----------------------	-----------------------	--------------------------------	-------------------------	----------------------

(b) Animal

Sl.No. 1	Description of animal(s) 2	Number(s)) 3	Name(s) of owner(s) 4	Address(es) of owner(s) 5	Fatal/non-fatal 6
-------------	----------------------------------	---------------------	--------------------------------	---------------------------------	----------------------

7. In case the victim(s) is/are employee(s) of supplier:-

(a) designation of such person(s);

(b) brief description of the job undertaken, if any;

(c) whether such person/persons was/were allowed to work on the job.

8. In case the victim(s) is/are employee(s) of a licensed contractor, -
(a) did the victim(s) possess any electric workmen's permit(s), supervisor's certificate of competency?

If yes, give number and date of issue and the name of issuing authority;

(b) name and designation of the person who assigned the duties of the victim(s).

9. In case of accident in the system of the generating company/licensee, was the permit to work (PTW) taken?

10. (a) Describe fully the nature and extent of injuries, e.g. , fatal/disablement (permanent or temporary) of any portion of the body or burns or other injuries.

(b) In case of fatal accident, was the post mortem performed?

11. Detailed causes leading to the accident.

(To be given in a separate sheet annexed to this form).

12. Action taken regarding first aid, medical attendance etc. immediately after the occurrence of the accident (give details).

13. Whether the District Magistrate and Police Station concerned have been informed of the accident (if so, give details).

14. Steps taken to preserve the evidence in connection with the accident to extent possible.

15. Name and designation(s) of the person(s) assisting, supervising the person(s) killed or injured.

16. What safety equipments were given to or used by the person(s) who met with this accident (e.g. rubber gloves, rubber mats, safety belts and ladders etc.)?

17. Whether isolating switches and other sectionalizing devices were employed to deaden the sections for working on the same? Whether working section was earthed at the site of work?

18. Whether the work on the live lines was undertaken by authorised person(s)? If so, the name and the designation of such person(s) may be given.

19. Whether artificial resuscitation treatment was given to the person(s) who met with the electric accident? If yes, how long was it continued before its abandonment?

20. Names and designations of persons present at, and witnessed, the accident.

21. Any other information/remarks.

Signature

Place: Name

Time: Designation

Date: Address of the person reporting

15. Conclusion

Too often safety is seen as something separate from the so-called "important" things like production, quality, and customer service because management doesn't hold people accountable. One way to show that you are really committed to safety is to make people responsible for safety activities and then to hold them accountable for those activities just as you do for production and quality.

Though electricity is invisible, it strictly obeys to the rules and it is only the persons who violate rules and attract accident.

Let us observe rules and standard practices to assure safety and derive benefits from electricity.

Let us operate on a new mindset 'Electrical accidents do not happen; they are caused'.

Let us educate general public and workmen about the safety practices based on the experience gained by us on this noble profession.

References:

1. Central Electricity Authority regulations for measures relating to Safety and Electric Supply issued vide notification CEI/1/59/CEA/EI, dt.20th September 2010 repealing Indian Electricity Rules, 1956
2. Statistics and case studies from Tamil Nadu Electrical Inspectorate
3. BIS-732: Code of Practice for wiring
4. BIS-3043: Code of practice for earthing
5. IEEE Green Book, Grounding of Industrial and Commercial Power Systems, Institute of Electrical & Electronics Engineering, Inc., New York
6. Fundamentals of electrical safety by N-Manoilov
7. BIS-8437 - Effects of electric current through human body
8. IEE regulations (1991)-16th edition
9. Earthing principles and practices by R.W.Ryder
10. BIS-5216 - code of practice for work permit system
11. Transactions on Energy summit 2001 held at Chennai
12. Transactions on Industrial safety seminar held by the Factory Inspectorate
13. The psychology of mental lapses and every day errors, Prentice- Hall, 1982 by J.Reason and K.Mycielsk.
14. IEEE 142 of 1987
15. Statistics from the Tamil Nadu Electrical Inspectorate
16. OSHA Standards

A

Accidental contact with live electric wire/equipment	13
Agricultural motor pump service connection ·	56
Artificial respiration until recovery or death is certified by doctor	59

B

broken neutral of service mains in rural distribution	11
--	-----------

C

Capacitors	26
Compensation claims control	60
Confined Spaces	25

D

Dangerous voltage on body frames in the case of neutral discontinuity	11
De Energizing	40
Defective appliances / apparatus / tools	14
Direct contact	10

E

ELCB designed to protect personnel- circuit arrangement	21
Earth flat of the surge arrestor should be connected to transformer tank	24
Earthing Cables And Hardware	34
Earthing is done in an electrical installation to achieve	19
Earth Rod	42
Effects of electric current through human body	7
Earth electrodes to earth the conducting body of electrical appliances	58
Extension cords should be visually inspected before each use	34
Extraneous means	10

H

How an accident occurs and the mechanism	6
---	----------

I

Snapped electricity conductors -don't touch	58
Indirect contact	10

L

Liability claims ·	60
Lighting	25, 26
Lightning strikes on personnel, equipment and structures	19
Lock And Tag	42,43,44,45
Lockout/Tagout Procedure	42

M

Management	29, 32
Mechanism of Electrical Accident	7
Electrical noise interference in instrumentation systems	19
Machine receiving supply will appear dead but give shock	11
Measurement of Earth loop impedance without using spikes	56

P

Per capita electrical energy consumption	5
Periodical calibration and testing of instruments and safety devices	56
Ventricular fibrillation	9
Preventive maintenance	56
Plug socket outlets	58

R

Re Energizing	45
Rehabilitation of injured personnel	60
Respirators	33
Rubber Gloves	32

S

Safe Let through Current for the human	10
Stored Electrical Energy	25
Stored Non electrical Energy	26
Stringing Adjacent To Energized Lines	45
Supervisors	29, 30

T

T.V. antenna	70
Training	29, 39

V

Variation of body resistance with reference to voltage	8
Verification Of Deenergized Condition	40

W

Work permit system	57
Working clearance for the switchboards	54
Wet Locations	26
Work Instructions	29
Work Practices	25
Workers	30