



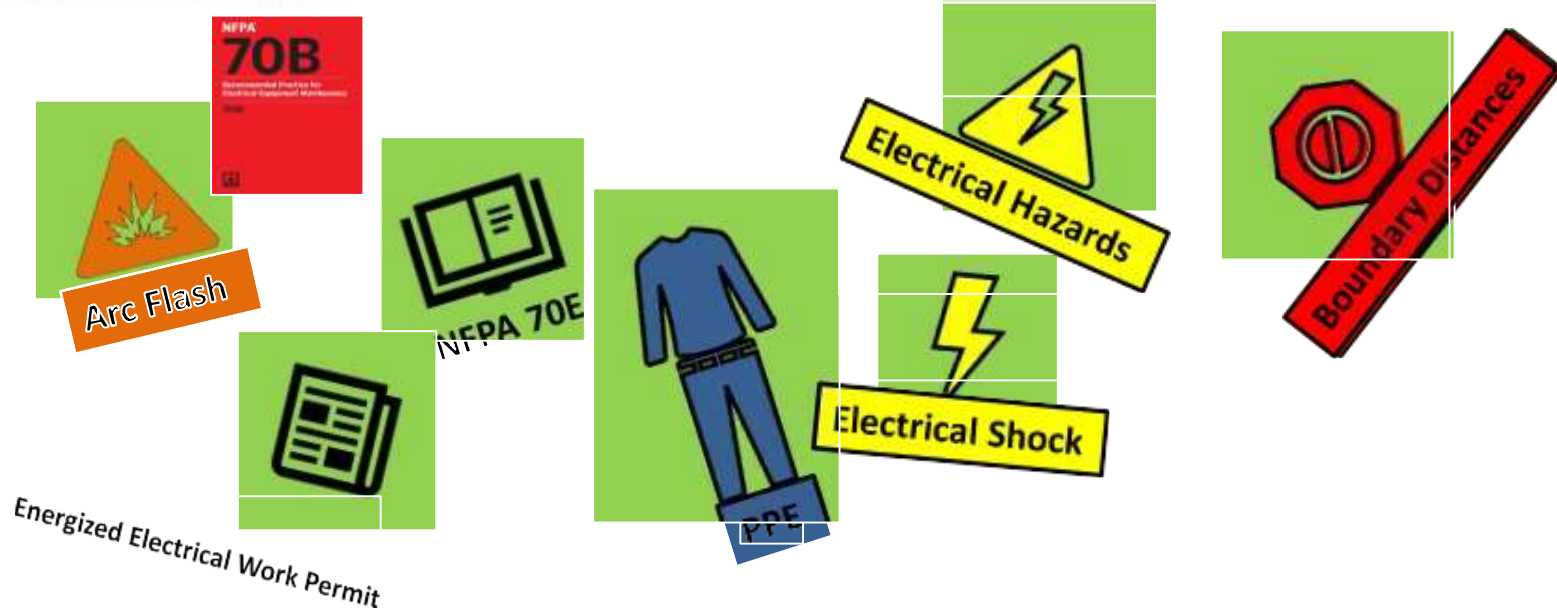
Electrical Safety Training

Conducted by:-

NORTHSTAR SAFETY SYSTEMZ PVT LTD

SCO 311, 1st Floor, Sector 40-D, CHANDIGARH - 160036

Email: info@northstar-ehs.com | northstarsafety@gmail.com | M +91 81468 11171



Electrical Safety



Training Rule

Batch **10:00 - 17:00**

Tea Break **11:45 - 12:00**
15:30 - 15:45

Lunch Break **13:00 - 14:00**

Exam online



Why this training ?

- ✓ Course not designed to teach you to work on electrical equipment.
- ✓ You will not be qualified to work on electrical equipment.
- ✓ If you spot problems with electrical equipment you should report it to your supervisor.



Objectives

- ✓ Be familiar with the fundamental concepts of electricity.
- ✓ Be familiar with the effects of electricity on the human body.
- ✓ Be able to recognize common electrical hazards.
- ✓ Be familiar with electrical protective devices.



Electrical Safety

1. Codes & Standard
2. Indian Electrical Act and Rule
3. Fundamentals of Electricity and Associated Hazard
4. Accident Prevention
5. Safety Procedures and method
6. Personal Protective Equipment and Instruments
7. Thermography
8. Harmonics
9. Arc Flash
10. Earthing
11. Lighting Protection
12. Transformer
13. Electrical Safety Audit

Electrical Safety

Codes & Standard

Codes & Standard

Sr. No	IS Code
23	IS 62305 : Part 1 : 2010 (Reaffirmed Year : 2020) Protection Against Lightning Part 1 General Principles
24	IS/IEC 62305 : Part 2 : 2010 (Reaffirmed Year : 2019) Protection Against Lightning Part 2 Risk Management
25	IS/IEC 62305 : Part 3 : 2010 (Reaffirmed Year : 2020) Protection Against Lightning Part 3 Physical Damage to Structures and Life Hazard
26	IS/IEC 62305 : Part 4 : 2010 (Reaffirmed Year : 2015) Protection Against Lightning Part 4 Electrical and Electronic Systems Within Structures



Electrical Safety

- 1. The Indian Electricity Acts 1948**
- 2. The Indian Electricity Rule 1956**
- 3. The Indian Electricity Acts 2003**
- 4. The Indian Electricity Rule 2005**

Electricity Act 2003

Part

Section

1.	Preliminary	(1 &2)
2.	National Electricity Policy And Plan	(3 to 6)
3.	Generation Of Electricity	(7 to 11)
4.	Licensing	(12 to 24)
5.	Transmission Of Electricity	(25 to 41)
6.	Distribution Of Electricity	(42 to 60)
7.	Tariff	(61 to 66)
8.	Works	(67 to 69)
9.	Central Electricity Authority	(70 to 75)
10.	Regulatory Commissions	(76 to 109)
11.	Appellate Tribunal For Electricity	(110 to 125)
12.	Investigation And Enforcement	(126 to 130)
13.	Reorganisation Of Board	(131 to 134)
14.	Offences And Penalties	(135 to 152)
15.	Special Courts	(153 to 157)
16.	Dispute Resolution	158
17.	Other Provisions	(159 to 165)
18.	Miscellaneous	(166 to 185)

The functions and duties of CEA are delineated under Section 73 of the Electricity Act, 2003. Besides, CEA has to discharge various other functions as well under Section 3 (National Electricity Policy & Plan), Section 8 (Hydro Electric Generation), Section 34 (Grid Standards), Section 53 (Provision relating to Safety and Electric Supply), Section 55 (Use of Meters) and Section 177 (Making of Regulations) of the Electricity Act, 2003.

Notified Regulation by CEA

- ✓ Metering Regulations
- ✓ Construction Standards
- ✓ Transaction of Business
- ✓ Statistics and Returns Standards
- ✓ Safety Regulations
- ✓ Grid Standards
- ✓ Grid Connectivity
- ✓ Communication Regulations

<https://cea.nic.in/regulations-category/notified-regulations/?lang=en>

THE INDIAN ELECTRICITY ACT & RULES

OBJECTIVE:

1. To regulate relation between supplier & consumer.
2. To make generation, distribution & use of electricity reasonably free from risk.

I.E ACT - 1903, 1910, 1948 & 2003

I.E RULES- 1922, 1937, 1956 & 2005

CATEGORIES OF PERSONS - ACT & RULES

- 1 Supplier of Electricity.
- 2 Owner / the consumer.
- 3 Electrical inspector.
- 4 Electrical contractor.
- 5 Authorized person.

THE INDIAN ELECTRICITY ACT & RULES

VOLTAGE DEFINITION

- LOW** - Where voltage does not exceed **250 V**
- Medium** - Where voltage does not exceed **650 V**
- High** - Where voltage does not exceed **33000 V**
- Extra High** - Where voltage exceeds **33000 V**

THE INDIAN ELECTRICITY ACT & RULES

Summary

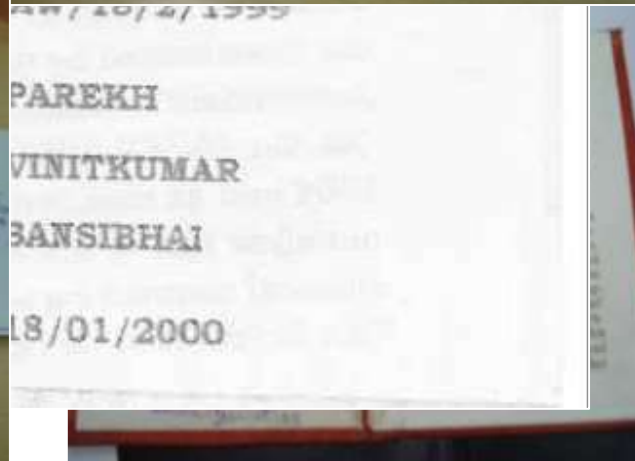
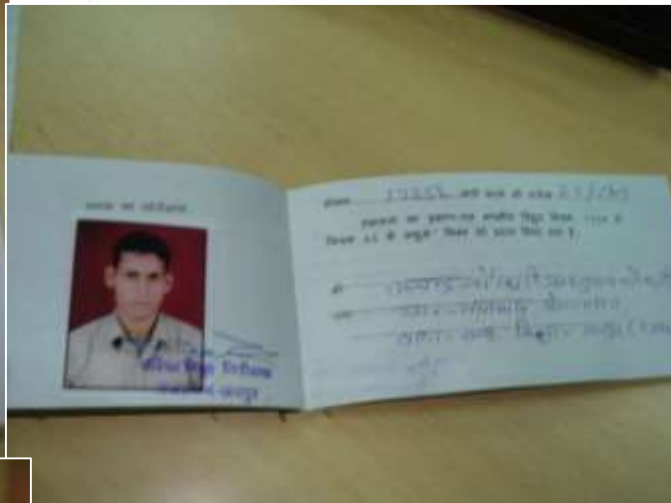
- Identification of neutral from live conductors-Rule32
- Earthed terminal at consumer's premises by supplier- Rule33
- Danger notice-Rule35
- Identification of supplies from different sources. Rule 41
- Provision for protective equipment. Rule43.
- Instruction for restoration of person suffering from shock Rule 44
- Intimation of accident. Rule 44A
- Periodic inspection of installation, Rule 46
- Installation of generator Rule47A

THE INDIAN ELECTRICITY ACT & RULES

Summary

- Supply and use of energy, Rule 50
- Provision to medium and high voltage Rule 51
- Test of insulation resistance Rule 60
- Connection with earth Rule 61
- Earth Leakage device Rule 61A
- Additional provision for use of energy at high and extra high Voltage Rule 64A
- Testing operation and maintenance Rule 65
- Connection with earth Rule 67t

License- Wireman



License - Supervisor



**Supervisors License
in Maharashtra**

प्रमाणपत्र क्र. म. प. ५०८८८

महाराष्ट्र शासन
उद्योग, ऊर्जा व कायदा विभाग
अनुज्ञापक पंडित

विद्युत पर्यवेक्षकाचे क्षमता प्रमाणपत्र

(सामकीद अधिसूचना, उद्योग व कायदा विभाग, क्र. माप्रसम-२०१२/११६२
दिनांक १५ मार्च १९६२ अन्वये प्रसिद्ध)

श्री. [REDACTED]

हे त्यांच्या अर्हातांच्या आधारे पर्यवेक्षकांची विहित परीक्षा देण्यापासून सूट मिळविण्यास पात्र आहेत याविषयी अनुज्ञापक पंडिताचे समाधान झाल्यावरून त्यांना याद्वारे हे क्षमता प्रमाणपत्र देण्यात येत आहे.

अनुज्ञापक पंडित
उद्योग, ऊर्जा व कायदा विभाग
सामकीद अधिसूचना
प्रमाणपत्र क्र. म. प. ५०८८८
अनुज्ञापक पंडित, म. प.
मुंबई अधिवासा (मि.), मुंबई

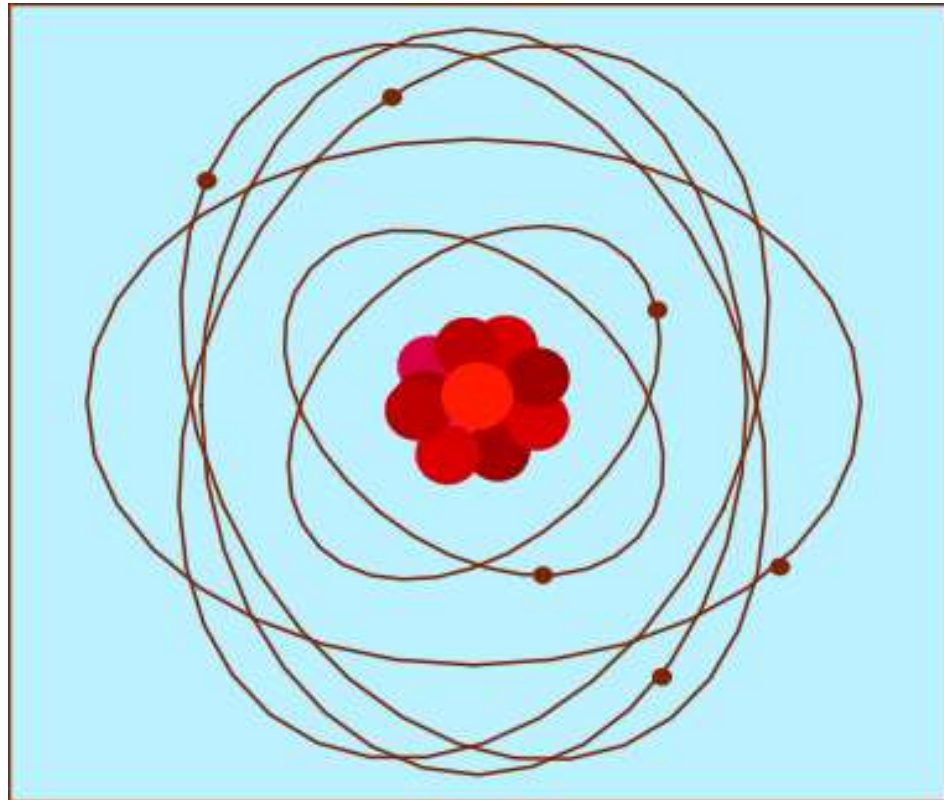
दिनांक १२/०४/२०१३

महाराष्ट्र शासन
उद्योग, ऊर्जा व कायदा विभाग
अनुज्ञापक पंडित

Electrical Safety

Fundamentals of Electricity and Associated Hazard

Fundamentals of Electricity and Associated Hazard



Fundamentals of Electricity and Associated Hazard

Flowing Electrons

- ✓ Electrons are negatively charged
- ✓ Protons are positively charged
- ✓ Opposite charges attract
- ✓ Velocity of electrons keep them in orbit around nucleus
- ✓ Electrons pulled free from the atom is what we call electricity!

Fundamentals of Electricity and Associated Hazard

“Dynamic” Electricity

- ✓ Electricity can be viewed as a dynamic process.
- ✓ Dynamic means “changing.”
- ✓ Electrons are changing—moving from one atom to another.
- ✓ This flowing of electrons is called an “electrical current.”

Fundamentals of Electricity and Associated Hazard

Static Electricity

- ✓ “Static” means stationary or unchanging.
- ✓ Electrons have been “loosened” from the atom and stay in one place.
- ✓ The electrons have “voltage” but lack a “current.”
- ✓ A conductor supplies the current—or path—for static electricity to discharge.

Fundamentals of Electricity and Associated Hazard

Electrostatic Discharge

- ✓ Electrostatic Discharge (ESD) is the process of static electrons jumping to a conductor.
- ✓ Simple experiment:
 - Rub your shoes on a carpet (this will cause a voltage to build up around your body)
 - Touch a metal doorknob (the metal is a conductor providing a path for the “flow of electrons”—high voltage electricity!!)

Fundamentals of Electricity and Associated Hazard

Conductors

- ✓ Conductors have a large number of loosely attached electrons.
- ✓ These electrons can easily be freed from the nucleus of the atom when voltage is applied.
- ✓ See this web page for a demonstration:

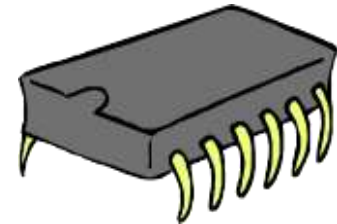
Fundamentals of Electricity and Associated Hazard

Semiconductors

✓ With semiconductor materials, the flow of electrons can be precisely controlled.

✓ Examples:

- Carbon
- Germanium
- And Silicon!!



✓ Because silicon is widely available (sand), it is the material we use for computer chips.

Fundamentals of Electricity and Associated Hazard

- ✓ To flow electricity must have a complete path.
- ✓ Electricity flows through conductors (water, metal, the human body)
- ✓ **Insulators** are non-conductors
- ✓ The human body is a conductor.

Fundamentals of Electricity and Associated Hazard

Networking Uses All Three!!

- ✓ We use conductors to provide a path for the electrical current.
 - For example, copper wire in our cables.
- ✓ We use insulators to keep the flow of electrons going in one direction.
 - For example, the plastic sheathing on cables.
- ✓ We use semiconductors to precisely control the flow of electrons.
 - For example, computer chips use silicon.

Fundamentals of Electricity and Associated Hazard

Measuring Electricity

- ✓ Voltage—force or pressure caused by the separation of electrons and protons.
Unit of measurement: Volts (V)
- ✓ Current—the path provided for the free flow of electrons in an electrical circuit.
Unit of measurement: Ampere (amp)
- ✓ Resistance—impedance or opposition to the flow of electrons: conductor=low resistance;
insulators=high resistance.
Unit of measurement: ohms (Ω)

Fundamentals of Electricity and Associated Hazard

Voltage

- ✓ AC or DC
- ✓ Level
- ✓ Frequency

Safe Voltages

- ✓ AC < 50 V
- ✓ DC < 120 V

Fundamentals of Electricity and Associated Hazard

Two Types of Current

- ✓ Alternating Current (AC)—electrical current flows in both directions; positive and negative terminals continuously trade places (polarity)
 - Example: Electricity provided by CPL
- ✓ Direct Current (DC)—electrical current flows in one direction; negative to positive
 - Example: Electricity provided by batteries

<i>S. No.</i>	<i>D.C. Supply</i>	<i>A.C. Supply</i>
1.	It does not produce convulsive reaction	It produces convulsive reaction.
2.	It hurls away (throw) the victim at high voltage and current	This property is not observed under the same circumstances in case of A.C. supply.
3.	It produces heating effect ($H = I^2 R t / J$)	It produces heating effect ($H = I^2 R t / J$)
4.	It produces electrolysis effect in human blood	It does not exhibits such a property
5.	It generally does not exhibit the holding property	It exhibits the holding property
6.	It generally does not exhibit inhibition problem	If has affinity for exhibiting inhibition problem
7.	It produces ventricular fibrillation only once	It produces ventricular fibrillation in each cycle.

Fundamentals of Electricity and Associated Hazard

There are two (2) direct hazards when working on electrical equipment

Shock



Arc Flash



- ✓ Burns
- ✓ Arc Blast
- ✓ Hazards from static charge
- ✓ Secondary Hazards

All of above may cause injury and death.

Fundamentals of Electricity and Associated Hazard

Electrical Shock – Factors which determine severity of shock



Current passing through the body



Magnitude of the Current



Duration that Current Flows Through the Body Path of the Current Through the Body



Even a voltage as low as 50 Volts and current as low as 10 mA can be fatal.

Fundamentals of Electricity and Associated Hazard

Arc Flash — Rapid release of energy due to an electrical fault.



Incident Energy measured in cal/cm^2



Typically caused by

- ✓ Equipment Failure
- ✓ Human Error



Fundamentals of Electricity and Associated Hazard

How do we protect employees?



Processes

Equipment
Design

Tools

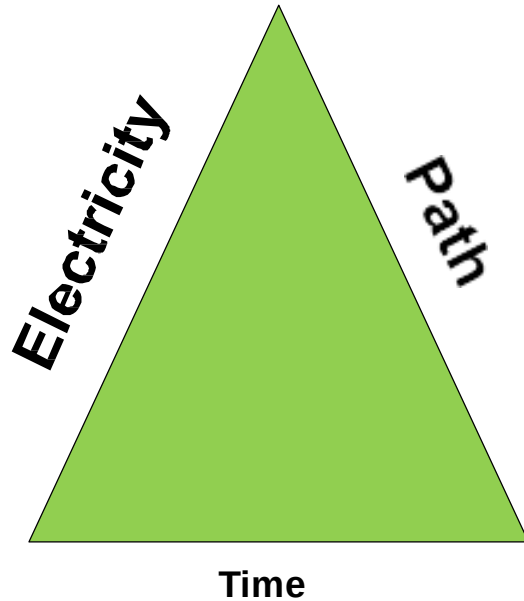
Protective
Equipment

PPE

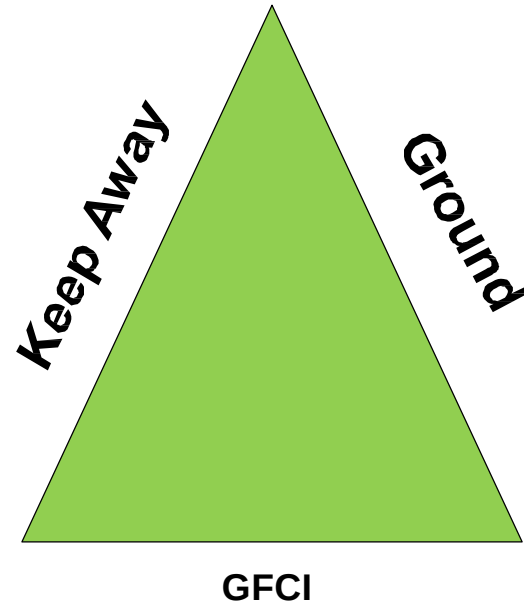
Fundamentals of Electricity and Associated Hazard

How do we protect employees?

Electrocution



Prevention



Fundamentals of Electricity and Associated Hazard

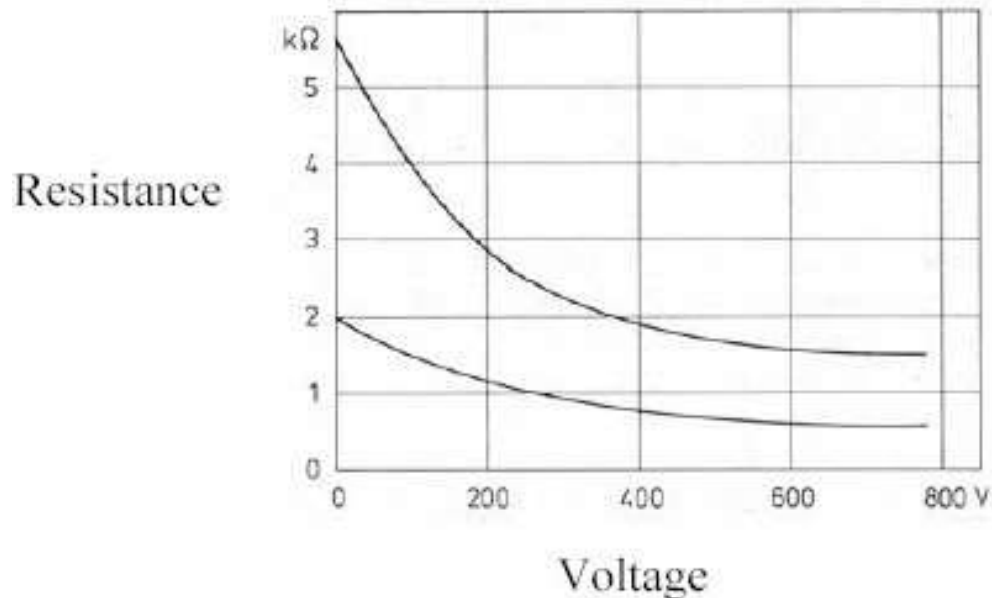
Effects on the Human Body

Current

- ✓ **More than 3 ma**
painful shock
- ✓ **More than 10 ma**
muscle contraction “no-let-go” danger
- ✓ **More than 30 ma**
lung paralysis- usually temporary
- ✓ **More than 50 ma**
possible ventricular fib. (heart dysfunction, usually fatal)
- ✓ **100 ma to 4 amps**
certain ventricular fibrillation, fatal
- ✓ **Over 4 amps**
heart paralysis; severe burns. Usually caused by >600 volts

Fundamentals of Electricity and Associated Hazard

Human body resistance



resistance of human body
upper curve : dry skin, small joints
lower curve : wet skin, strong joints

Fundamentals of Electricity and Associated Hazard

Human Shock Tolerance

Dalziel Equation

Applicable to 99.5% of population.

I_b = Current through body person could survive before onset of fibrillation of heart

K = Factor based upon body weight.

$K = 0.116$ for a person of 50 kg weight,

$K = 0.157$ for a person of 70 kg weight

T_s = Time of duration of current passing through body. Range 0.03 sec to 3.0 sec.

$$I_b = K / \sqrt{T_s}$$



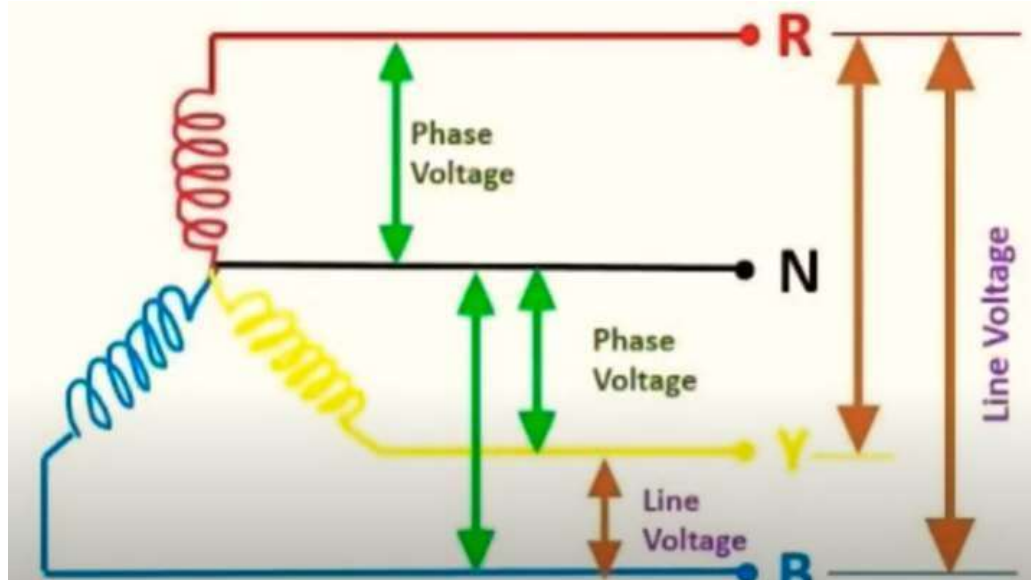
Human shock

Fundamentals of Electricity and Associated Hazard

Phase Voltage and Line Voltage

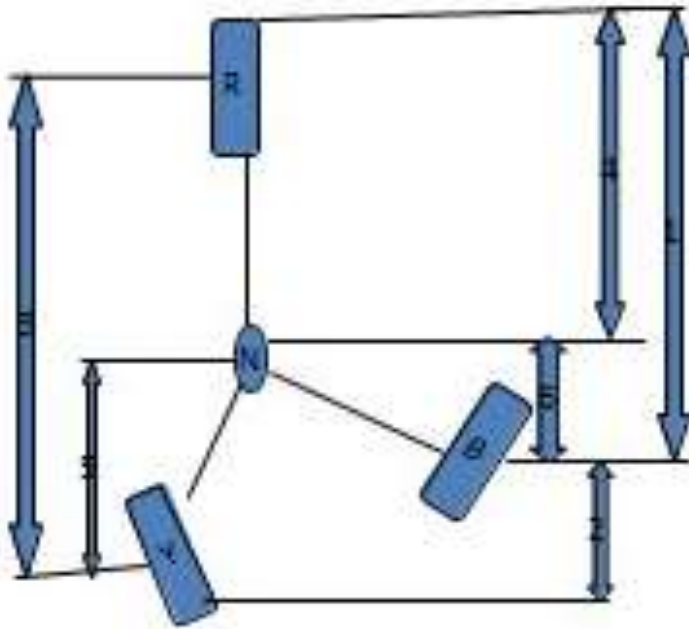
Line Voltage : R Y / Y B / R B

Phase Voltage R N / Y N / B N



Fundamentals of Electricity and Associated Hazard

Phase Voltage and Line Voltage



1V_{BR} Phase Voltage 415

2V_{YB} Phase Voltage 415

3V_{RY} Phase Voltage 415

4V_{RN} Line Voltage 230

5V_{YN} Line Voltage 230

6V_{BN} Line Voltage 230



Electrical Safety

Accident Prevention

Accident Prevention

Reasons for Electrical Accidents

- Ignorance
- Misuse
- Overload
- Poor quality of material/ appliance
- Switch in neutral instead of phase in 1- ϕ circuits
- Sparking due to loose contacts
- Not proper grounding
- Inappropriate design or workmanship
- Bad maintenance
- Use of earth in place of neutral

Accident Prevention

Reasons for Electrical Accidents

- Wrong instruments or instruments in bad condition
- Improper PPE
- Unnecessary risk by working on live parts
- Uninsulated tools
- Bypassing protection
- Improper display of hazard
- Improper or missing fence in hazardous areas
- Not testing residual voltage before starting work
- Ignoring visual or available information about status

Accident Prevention

Consequences of Electrical Accidents

- Loss of life- Entire family or families are affected.
- Loss of property
- Loss of man hours
- Refusal by other employees to replace victim's post
- Industrial relation problem
- Penal action by authorities
- Tightening of laws making working more difficult/expensive
- Bad reputation

Accident Prevention

By Planning

Plan after making detailed studies

- Arc Flash Hazard Studies
- Load flow studies
 - ❖ About Voltage , Amp., Active and Reactive power. Used for sizing equipment. Alerts about possible hazardous areas.
- Stability Studies
 - ❖ Transient and steady state stability of Power system. These studies inform about power system synchronism during slow and fast changes
- Motor starting analysis
 - ❖ It is a computer-generated model of a large motor under starting condition, how it affects power system

Accident Prevention

By Planning

- Harmonic Analysis
 - ❖ Harmonics and other power quality problems which can cause equipment malfunction, overheating of transformers, generators and motors failures and safety hazards
- Switching Transient analysis
 - ❖ Certain loads create switching transients. Switch malfunctions also creates transients. Study shows magnitude of transients and allows to develop solutions
- Reliability Analysis
 - ❖ It is a study of frequency of interruptions and number of interruptions in a year. A reliability study will help evolve strategies to operate system safely during interruption.

Accident Prevention

By Planning

- Cable Amp analysis
 - ❖ This study recommends proper size of cable for each application depending upon capacity, type of cable, route and environment.
- Ground Mat analysis
 - ❖ Study of earth resistance, touch and step voltages
 - ❖ Fault currents magnitude and duration
 - ❖ Geometry of grounding system
 - ❖ Soil resistivity
 - ❖ Probability of contact
 - ❖ Human body resistance and assumptions on conditions of individual

Accident Prevention

By Planning

- Short Circuit study and Protective device Coordination
 - ❖ Study about short circuit and earth fault currents' magnitude at various locations.
 - ❖ Study also shows protective Zone's relay coordination and selectivity
 - ❖ Time curves and coordination
 - ❖ Study of collateral damage to cables and other current carrying devices during short-circuits

This study is one of the most important from safety point of view and should be repeated every five years in an operating plant.

Accident Prevention

By Design

- Select Switch gear, cables etc. with extra capacity keeping in mind safety factor, over and above, plans for expansion
- Select arc flash protected switchgear
- Select switches for remote operation
- Select only good brand products with relevant safety certification
- Make good layout with adequate space for ingress and egress.
- Plan for adequate number of disconnect switches for isolation for maintenance
- Plan for motor disconnect switch near a motor for operation during maintenance

Accident Prevention

By Design

- By providing suitable linked switch fuse unit or circuit breaker in the primary and secondary of transformers per IE 50 (i) (b).
- By providing suitable interlocking to prevent back feeding in case of parallel operation of transformers.
- By providing suitable protective relays for forward and reverse power flow.
- All motors should have disconnected switch near motor as per IE 50 (d).
- Specify transformer with Pressure relief valve and drainpipe instead of explosion vent
- Design sufficient and strategically located safety fences to keep out unauthorized entry by man and animals.

Accident Prevention

By Design

- Plan proper routing for cables with proper ventilation and access.
- Plan for proper measuring and testing instruments
- Specify flame proof switchgear and motors in locations where they are needed.
- Plan for static earthing plates earthing tankers of Petroleum products loading and unloading.
- Use low voltage for controls.
- Purchase adequate number and type of PPE

Accident Prevention

By Design

- Select only Certified contractor
- Insist upon contractor providing proper uniform and safety kit to their worker as part of contract. Insist upon contractor's workers using them. Take adequate managerial steps to ensure compliance.
- Make quality plan for each work, discuss with contractor and inspect its implementation.
- Put safety inspectors on the job of monitoring hot work like welding, cutting by gas with adequate arrangement for fire fighting.
- Provide training in specific jobs to contractor's workers.
- Inspect contractors' tools and machines for safety. Machines e.g. welding machine, hand tools, power tools etc.
- Maintain overall discipline at work site

Accident Prevention

By Operation

- Provide training to workers
- Provide safety kits and PPE
- Provide suitable tools and measuring instruments
- Provide competent supervision
- Make detailed plan for maintenance
- Use of Predictive maintenance tools
- Provide good quality spares
- Make safety teams including workers and actively participate in their meeting

Plan for a rapid response team to provide rescue and medical aid in case accidents still do happen.

Accident Prevention

By Training

- All electrical workers should be thoroughly trained in following;
- Factory Single line diagram
- Operation and maintenance of disconnect switches
- Operation and maintenance of interlocks
- Display of danger boards
- Rescue and first aid procedures
- Emergency procedures
- Grounding procedures
- Tools and instrument training
- PPE training

Accident Prevention

Management of Electrical Hazards

- SAFER approach
- S – See it, Hazards identification
- A- Assess it, hazards assessment
- F- Fix it , Hazard control
- E- Evaluate it, Evaluate if the fix has controlled the hazard
- R- Review it , After some time review the hazard once more .

Accident Prevention



Electrical Safety

Safety Procedures and method

Safety Procedures and method

Maintenance of Electrical Equipment

- 6.1 Rotating machinery
 - 6.1.1 Generator
 - 6.1.2 Motor
- 6.2 Stationary equipment
 - 6.2.1 Switchboard & Panel
 - 6.2.2 Transformer & Bus duct
 - 6.2.3 Battery
 - 6.2.4 Charger & D.C. board
 - 6.2.5 UPS/Inverter
 - 6.2.6 Reactor/Capacitor
 - 6.2.7 Switchyard equipment
 - 6.2.8 Lighting fixture & junction box
 - 6.2.9 Test instruments for inspection
- 6.3 Protective Systems
 - 6.3.1 Relay & meter
 - 6.3.2 Earthing & bonding
 - 6.3.3 Lightning protection
 - 6.3.4 Flameproof/weather protection
 - 6.3.5 Fire alarm system
 - 6.3.6 Cathodic protection
 - 6.3.7 Electric heat tracing
 - 6.3.8 Protective & Safety appliances
- 6.4 Distribution network
 - 6.4.1 Cable/conduit wiring
 - 6.4.2 Cable duct/trench/tray support
 - 6.4.3 Overhead line
- 6.5 Outdoor switchyard
- 6.6 Switchroom/substation building
- 6.7 Safe procedures & systems



Safety Procedures and method

Energized or De-energized?

- As much as possible de-energize before start of work
- If job requires energized work, assess the hazard and use proper tools, equipment and PPE
- If control circuit is to be tested, shut power to power circuit.
- Production loss should not be the sole reason for doing energized work
- Only qualified and trained workers to do energized work

Safety Procedures and method

Energized work

- Excessive restart time in continuous process plant
- High product loss in unscheduled stoppage
- Testing electrical circuit
- Trouble shooting controls
- Infrared scan

Safety Procedures and method

Safe conditions for De-Energized work Locks and Tags



Safety Procedures and method

Safe conditions for De-Energized work Locks and Tags



Safety Procedures and method

Safe conditions for De-Energized work

- Only qualified people who know about system should switch it off.
- As far as possible switches and breakers should be remotely operated.
- No load isolating switches should not be used for load interruption.
- All energy control devices feeding the area should be opened.
- Locks and tags should be placed on energy control devices.

Safety Procedures and method

Safe conditions for De-Energized work

- All previously energized parts e.g., bus bars should be discharged and grounded.
- Voltage measurement to ensure all live parts are dead and at zero potential.
- The work areas must be inspected by qualified person to ensure no parts are still energized. This step is often missed by many.

➡ Remove all conducting material on body

e.g., rings, watches, ornaments, metal buttons etc.

Safety Procedures and method

Racking in and out metal clad breakers

- Many Arc Flash accidents happen while racking in and out of breakers
- Safe way to do so is to do this by remotely operated gear. Even a handle with long operating rod is better than manually operating from near the breaker.
- Keep face and eyes away from breaker. Stand at an angle rather than face full square on.
- Do not forget to put on PPE. Depending upon class of hazard, if required, Arc Flash suit should be put on.
- Always have two people operating the breaker. One to do the physical work and other to monitor from a distance and call for help if necessary.

Safety Procedures and method

Racking in and out metal clad breakers

- Racked out breaker's springs or pneumatic operating energy should be discharged if not done so already.
- Similarly make sure operating spring or other operating device is off before racking in the breaker. Usually, breakers have mechanical and electrical interlocks to take care of this but making sure is a good practice.

➡ External safety grounding should be done by using proper grounding connections with tested earth

bus. All previously live parts should be looped and a single ground connection should be made firmly to the earth bus by suitable clamps.

Safety Procedures and method

Re-energizing equipment

- Before re-energizing inspect thoroughly to ensure that the work which was to be done is completed satisfactorily.
- Ensure re-insulation and other closing work has been done properly. Remove temporary ground connection.
- Ensure that no tools are left where they should not be.
- Inform all concerned people to move away.
- Remove locks and tags
- Recheck that breaker spring is de-energized.
- Rack in the breaker
- Close doors
- Close switch and energize

Safety Procedures and method

Energized working

- Outdoor work only during favorable weather conditions. No work during rainy seasons and fog conditions.
- Pre-Job briefing , SHEPP
- Inspect all energized working tools and PPE
- Only qualified personnel to be near place of work
- Work only with special tools and measuring instruments.
- Reduce protective relay setting , if required
- At least two persons should work in teams with at least one person monitoring the process.

Safety Procedures and method

Types of energized work on transmission lines

- Insulator puncture detection
- Insulator replacement
- Hardware tightening/ replacement near towers
- Mid span conductor repair etc.

Safety Procedures and method

Safety Electrical One Line Diagram

- An updated single Line diagram which is made for the purpose of safety.
- It should be Accurate and should be updated from time to time
- Concise- Too much information clutters up the drawing and many important information goes hiding SEOLD should clearly show sources of power, disconnect switches, interconnections.
- Legibility- If the drawing has become old and not legible, new drawings should be made.

Electrical Work Permit

Required PPE ☐ Hearing protection ☐ F/R clothing ☐ Safety glasses with side shields ☐ Hard hat ☐ Voltage-rated gloves ☐ Arc-rated face shield ☐ Other (as required by NFPA 70E) ☐ Class E ☐ Class G Class _____			
How are unqualified persons restricted from the work area?			
4. Approvals <i>Senior Director of Utilities & Maintenance or designee</i>			
Print Name	Signature	Date	Approval
			☐ Approved ☐ Disapproved
5. Pre-Job Coordination			
Has a job briefing/discussion been conducted & documented to discuss hazards?			(check when complete)
Is emergency communications equipment on site? ☐ Radio ☐ Phone ☐ Other			(check when complete)
Do you agree the above described work can be done safely? ☐ Yes ☐ No (if no, do not perform the work)			
Name of person(s) doing the work: _____		Signature _____ Signature _____	
6. Notification			
Personnel who may be in or near the area, and may be impacted, have been informed.			
☐ Yes ☐ No		Name(s) _____	
7. Work Completion			
Electrical Work Complete: _____		Date: _____	Time: _____

Electrical Safety

Personal Protective Equipment and Instruments

Shock protection by rubber gloves and mats, ASTM D 120

- Class of rubber gloves and mats
- Class 00 ((Onlygloves) For use up to 500 VAC phase tophase
- Class 0 For use up to1000 VAC phase to phase
- Class 1 For use up to7500 VAC phase to phase
- Class 2 For use up to1700 VAC phase to phase
- Class 3 For use up to26500 VAC phase tophase
- Class4 For use up to36000 VAC phase tophase

PPE and Instruments

Rubber gloves and Shoes IS:4770:1991 (Reaffirmed 2017)

TABLE 4.2: TEST POTENTIAL, LEAKAGE CURRENT AND BREAKDOWN VOLTAGE OF GLOVES

Gloves	Maximum Working Potential (rms) of Glove Volts	Test Potential (rms) Volts	Maximum Leakage Current (rms) at Test Potential mA	Minimum Breakdown Voltage (rms) Volts
Type 1	650	5000	4	17000
Type 2	1100	10000	8	20000
Type 3	3300	15000	12	25000
Type 4	4000	20000	14	30000



PPE and Instruments

Testing intervals for rubber insulating equipment

Rubber Insulating Equipment Test Intervals

Type of equipment	When to test
Rubber insulating line hose	Upon indication that insulating value is suspect
Rubber insulating covers	Upon indication that insulating value is suspect
Rubber insulating blankets	Before first issue and every 12 months thereafter*
Rubber insulating gloves	Before first issue and every 6 months thereafter*
Rubber insulating sleeves	Before first issue and every 12 months thereafter*

*If the insulating equipment has been electrically tested, but not issued for service, it may not be placed into service unless it has been electrically tested within the previous 12 months.

PPE and Instruments

Single and double insulated

- ✓ Single insulated equipment are Class-I equipment with body earthing. They can give shock if earthing is damaged/ deteriorated.
- ✓ Double insulated equipment are class –II equipment which in addition to internal insulation have entire external surface insulated to prevent any chance of shock if touched. Such equipment are not earthed.

PPE and Instruments

Helmets for Electrical Purposes IS: 2745:1983

- ✓ Class – A. General purpose helmet with no metallic parts and no holes. Should be tested at 2.2. kV.
- ✓ Use Class-B helmets for high voltage protection
- ✓ Should be tested at 20kV for 3 min. with leakage current not exceeding 9mA.
- ✓ Both Class-A and Class-B helmets should not burn at a rate more than 7.5 cm per min.
- ✓ Water absorption after 24 hr immersion for
 - Class-A < 5%
 - Class-B < 0.5%

Residual Current Devices (RCDs)

- ✓ Works on the principle that current in a line and neutral should be equal in normal case.
- ✓ However if leakage to body takes place, part of the line current will be diverted to earth.
- ✓ This imbalance between line and neutral current is measured and tripping is applied if it exceeds preset limit.
- ✓ RCDs work at very low leakage currents so that even if earthing is improper, they can operate.

PPE and Instruments

Classes of RCDs

PPE and Instruments

Insulating Mat

INSULATING MATS LV & MV

Individual models

Reference	Class	Voltage ~	Voltage ≡	Thickness mm	m	kg
MP-11/11	0	≤ 1000 V	≤ 1500 V	2	1 x 1	2.9
MP-11/16	0	≤ 1000 V	≤ 1500 V	2	0.6 x 1	1.4
MP-42/11	3	≤ 26500 V	≤ 39750 V	3	1 x 1	4.5
MP-42/16	3	≤ 26500 V	≤ 39750 V	3	0.6 x 1	2.9
MP-42/66	3	≤ 26500 V	≤ 39750 V	3	0.6 x 0.6	1.8
MP-126/03-1	3	≤ 26500 V	≤ 39750 V	3	1.2 x 1	5.8
MP-60/05-1	4	≤ 36000 V	≤ 54000 V	5	0.6 x 1	4.4
MP-100/05-1	4	≤ 36000 V	≤ 54000 V	5	1 x 1	8.9

For placing in front of panels

Reference	Class	Voltage ~	Voltage ≡	Thickness mm	m	kg
MP-100/02-10	0	≤ 1000 V	≤ 1500 V	2	1 x 10	29
MP-60/03-5	3	≤ 26500 V	≤ 39750 V	3	0.6 x 5	14
MP-60/03-10	3	≤ 26500 V	≤ 39750 V	3	0.6 x 10	28
MP-100/03-5	3	≤ 26500 V	≤ 39750 V	3	1 x 5	25
MP-100/03-10	3	≤ 26500 V	≤ 39750 V	3	1 x 10	53.5
MP-60/05-5	4	≤ 36000 V	≤ 54000 V	5	0.6 x 5	28
MP-60/05-10	4	≤ 36000 V	≤ 54000 V	5	0.6 x 10	44
MP-100/05-5	4	≤ 36000 V	≤ 54000 V	5	1 x 5	45
MP-100/05-10	4	≤ 36000 V	≤ 54000 V	5	1 x 10	89

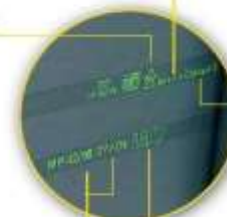
In accordance with IEC 61111
Live working tools – Insulating mats category C:
Resistant to very low temperature -40°C)

INSULATING MATS MV CLASS 3/4



In compliance with
IEC 61111.

Marking
IEC or EN.



Class.

Marking area
showing the date
of first use and
periodic testing
date.

INSULATING MATS LV CLASS 0



Traceability

PPE and Instruments

Multimeter Basics

A Multimeter is used to measure:

- Voltage
- Resistance
- Continuity (level of resistance)

When using a Multimeter, you must properly set it to either AC or DC, depending on the voltage you're trying to measure.



PPE and Instruments

Insulation Resistance



PPE and Instruments

Insulation Resistance



PPE and Instruments

ELCB Tester



HRC Puller



PPE and Instruments

Protective Shrouds



Electrical Safety

Thermography

Thermography

Thermography is a non-destructive test method that may be used to detect poor connections, unbalanced loads, deteriorated insulation, or other potential problems in energized electrical components.

The principle of infrared thermography is based on the physical phenomenon that any body of a temperature above absolute zero ($-273.15\text{ }^{\circ}\text{C}$) emits electromagnetic radiation. There is clear correlation between the surface of a body and the intensity and spectral composition of its emitted radiation.

Basic principle

Infrared thermography is a thermal imaging technique. Thermal images are captured by infrared camera which detects the infrared light radiation ($\sim 1 - 14\text{mm}$). This radiation distribution image can be converted into temperature scale and produced a temperature distribution image called thermogram, according to the Stefan Boltzmann Law. Therefore, thermography allows us to see the variations in temperature, since the amount of radiation emitted by an object increase or decrease corresponding to the change of temperature. According to different measurement methodologies, this technique can be divided into two types of inspections: Passive and Active.

Thermography

Passive thermography directly measures the surface temperature for evaluation, since the interest region will have abnormal hot-spot as compared with the surroundings. Abnormal temperature profile indicates a potential problem, where the key word is the temperature difference with respect to the surrounding, as referred as DT or extra hot spot (Remark: DT of 1 to 2 Kelvin is generally found suspicious while 4K value is a strong evidence of abnormal behaviour.) The features of interest are naturally at a high or low temperature than the background.

Active thermography measures the surface temperature for evaluation after applying the thermal excitation. An external energy source is required to produce a thermal contrast between the feature of interest and the background, since the inspected parts are usually in equilibrium with the surroundings. The defects can be detected by the flaw's anomalous heat transfer response with considering the factor of time evolution after applied the thermal excitation

The frequency at which **infrared inspections should be conducted** depends on the type of operations, environmental conditions, importance of the equipment, electrical current load and the age of the electrical equipment. In general, an **infrared inspection should be conducted** on electrical equipment on an annual basis

Thermography

Visual Identification



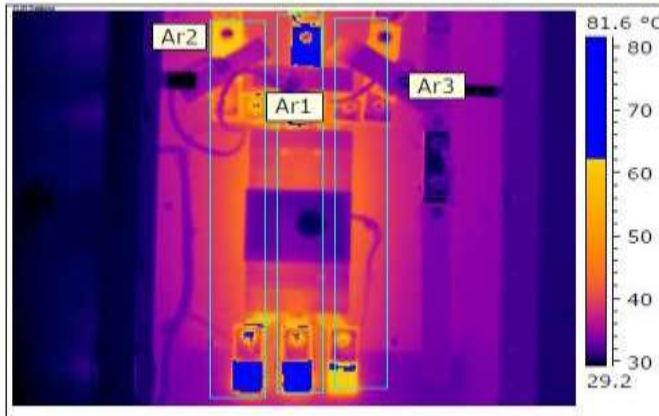
Equipment Location

APFC main Panel (250kvar)
MCCB I/C Y-phase & O/G B-phase Busbar Nut bolts

Object Parameter	Value
Emissivity	0.95
Label	Value
Ar1: Max	81.9 °C
Ar2: Max	76.7 °C
Ar3: Max	62.3 °C

Infrared Thermal image Date of Scanning 18,19-01-2018

File Name: FLIR1654.JPG



Priority	Temperature	Remarks
I	>80°C	Repair Immediately
II	>60-80°C	Repair earliest opportunity
III	>45-60°C	Investigate during next scheduled maintenance
IV	<45°C	Record and continues monitor

Electrical Safety

Harmonics

Harmonics

- ❖ Detect and eliminate harmonics: why?
- ❖ Definition and origin of harmonics
 - ✓ Definition of harmonics
 - ✓ Origin of harmonics
- ❖ Essential indicators of harmonic distortion and measurement principles
 - ✓ Harmonic distortion indicators - Power factor
 - ✓ Harmonic distortion indicators - Crest factor
 - ✓ Harmonic spectrum
 - ✓ R.m.s. values
 - ✓ Usefulness of the various indicators of Harmonic distortion
- ❖ Harmonic measurement in electrical networks

Harmonics

- ❖ Main effects of harmonics in electrical installations
- ❖ Effects of harmonics - Resonance
- ❖ Effects of harmonics - Increased losses
- ❖ Effects of harmonics - Overload of equipment
- ❖ Effects of harmonics - Disturbances affecting sensitive loads
- ❖ Effects of harmonics - Economic impact
- ❖ Harmonics standards
- ❖ Solutions to mitigate harmonics
- ❖ Basic solutions to mitigate harmonics
- ❖ Harmonic filtering
- ❖ The method to optimize harmonics mitigation

Harmonics

Detect and eliminate harmonics: why?

Harmonic disturbances

Harmonics flowing in distribution networks represent disturbances in the flow of electricity. The quality of electrical power is deteriorated, and the efficiency of the system is decreased.

Here are the main risks linked to harmonics:

- ✓ Overload of distribution networks due to the increase of r.m.s. currents,
- ✓ Overload of neutral conductors, which current can exceed the phase currents,
- ✓ Overload, vibration and premature ageing of generators, transformers and motors as well as increased transformer hum,
- ✓ Overload and premature ageing of Power Factor Correction capacitors,
- ✓ Distortion of the supply voltage that can disturb sensitive loads,
- ✓ Disturbance in communication networks and telephone lines.

Harmonics

Detect and eliminate harmonics: why?

Economic impact of disturbances

All these disturbances have an economic impact:

- ✓ Premature ageing of equipment means it must be replaced sooner, unless oversized right from the start,
- ✓ Overload on the distribution network means higher equipment rating, increased subscribed power level for the industrial customer,
and increased power losses,
- ✓ Unexpected current distortion can lead to nuisance tripping and production halt.

Harmonics

Detect and eliminate harmonics: why?

A necessary concern for the design and management of electrical installations Harmonics are the result of the always expanding number of power electronic devices. They have become abundant today because of their capabilities for precise process control and energy saving benefits. Typical examples are Variable Speed Drives in the Industry, and Compact Fluorescent Lamps in commercial and residential areas.

International standards have been published in order to help the designers of equipment and installations. Harmonic emission limits have been set, so that no unexpected and negative impact of harmonics should be encountered. In parallel to a better understanding of effects, solutions have been developed by the Industry.

Harmonic consideration is now a full part of the design of electrical installations

Harmonics

Definition:

The presence of harmonics in electrical systems means that current and voltage are distorted and deviate from sinusoidal waveforms.

Harmonic currents are caused by non-linear loads connected to the distribution system. A load is said to be non-linear when the current it draws does not have the same waveform as the supply voltage. The flow of harmonic currents through system impedances in turn creates voltage harmonics, which distort the supply voltage.

On Figure M1 are presented typical current waveforms for single-phase (top) and three-phase non-linear loads (bottom).

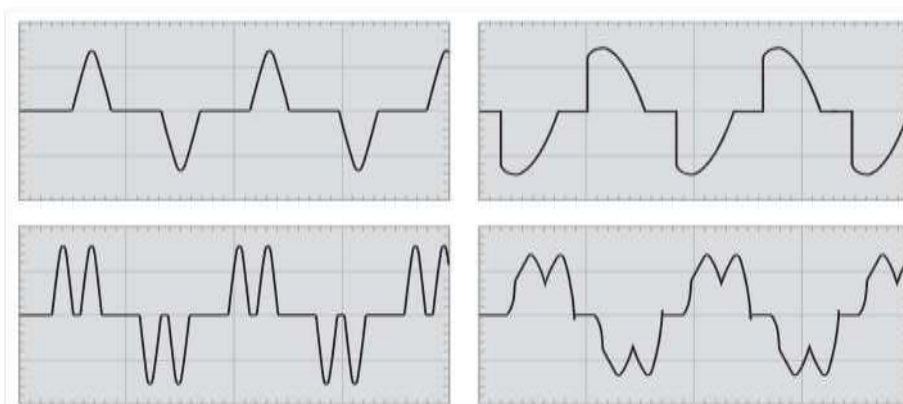


Fig. M1 – Examples of distorted current waveforms

Harmonics

Figure M2 shows an example of a current wave affected by harmonic distortion on a 50Hz electrical distribution system. The distorted signal is the sum of a number of superimposed harmonics:

- ✓The value of the fundamental frequency (or first order harmonic) is 50 Hz,
- ✓The 3rd order harmonic has a frequency of 150 Hz,
- ✓The 5th order harmonic has a frequency of 250 Hz,
- ✓Etc...

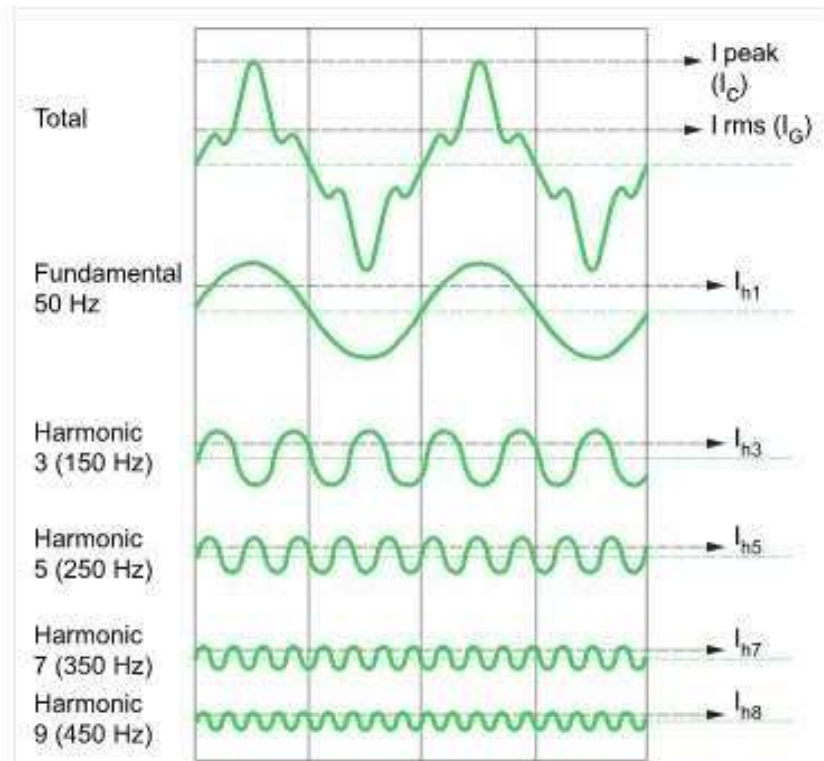


Fig. M2 – Example of a current containing harmonics and expansion of the overall current into its harmonic orders 1 (fundamental), 3, 5, 7 and 9

Harmonics

Individual harmonic component (or harmonic component of order h)

The individual harmonic component is defined as the percentage of harmonics for order h with respect to the fundamental. Particularly:

$$U_h(\%) = 100 \frac{U_h}{U_1} \text{ for harmonic voltages}$$

$$i_h(\%) = 100 \frac{I_h}{I_1} \text{ for harmonic currents}$$

Total Harmonic Distortion (THD)

The Total Harmonic Distortion (THD) is an indicator of the distortion of a signal. It is widely used in Electrical Engineering and Harmonic management in particular.

For a signal y, the THD is defined as:

$$THD = \sqrt{\sum_{h=2}^{h=H} \left(\frac{Y_h}{Y_1} \right)^2} = \frac{\sqrt{Y_2^2 + Y_3^2 + \dots + Y_H^2}}{Y_1}$$

THD is the ratio of the r.m.s. value of all the harmonic components of the signal y, to the fundamental Y_1 .

H is generally taken equal to 50, but can be limited in most cases to 25.

Note that THD can exceed 1 and is generally expressed as a percentage.

Harmonics

Current or voltage THD

For current harmonics the equation is:

$$THD_i = \sqrt{\sum_{h=2}^{h=H} \left(\frac{I_h}{I_1} \right)^2}$$

By introducing the total rms value of the current: $I_{rms} = \sqrt{\sum_{h=1}^{h=H} I_h^2}$

we obtain the following relation:

$$THD_i = \sqrt{\left(\frac{I_{rms}}{I_1} \right)^2 - 1}$$

equivalent to:

$$I_{rms} = I_1 \sqrt{1 + THD_i^2}$$

Example: for THDi = 40%, we get:

$$I_{rms} = I_1 \sqrt{1 + (0.4)^2} = I_1 \sqrt{1 + 0.16} \approx I_1 \times 1.08$$

For voltage harmonics, the equation is:

$$THD_u = \sqrt{\sum_{h=2}^{h=H} \left(\frac{U_h}{U_1} \right)^2}$$

Harmonics

Origin of harmonics

Harmonic currents:

Equipment comprising power electronics circuits are typical non-linear loads and generate harmonic currents. Such loads are increasingly frequent in all industrial, commercial and residential installations and their percentage in overall electrical consumption is growing steadily.

Examples include:

- ✓ Industrial equipment (welding machines, arc and induction furnaces, battery chargers),
- ✓ Variable Speed Drives for AC or DC motors^[1],
- ✓ Uninterruptible Power Supplies,
- ✓ Office equipment (PCs, printers, servers, etc.),
- ✓ Household appliances (TV sets, microwave ovens, fluorescent lighting, light dimmers).

Harmonics

Harmonic voltages

In order to understand the origin of harmonic voltages, let's consider the simplified diagram on Fig. M3.

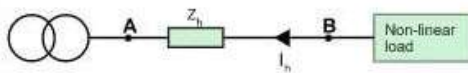


Fig. M3 – Single-line diagram showing the impedance of the supply circuit for a non-linear load

The reactance of a conductor increases as a function of the frequency of the current flowing through the conductor. For each harmonic current (order h), there is therefore an impedance Z_h in the supply circuit.

The total system can be split into different circuits:

- One circuit representing the flow of current at the fundamental frequency,
- One circuit representing the flow of harmonic currents.

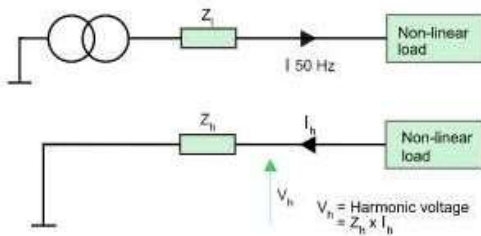


Fig. M4 – Split of circuit into fundamental and harmonic circuits

When the harmonic current of order h flows through impedance Z_h , it creates a harmonic voltage U_h , where $U_h = Z_h \times I_h$ (by Ohm's law).

The voltage at point B is therefore distorted. All devices supplied via point B receive a distorted voltage.

For a given harmonic current, the voltage distortion is proportional to the impedance in the distribution network.

Harmonics

Flow of harmonic currents in distribution networks

The non-linear loads can be considered to inject the harmonic currents upstream into the distribution network, towards the source. The harmonic currents generated by the different loads sum up at the busbar level creating the harmonic distortion.

Because of the different technologies of loads, harmonic currents of the same order are generally not in phase. This diversity effect results in a partial summation.

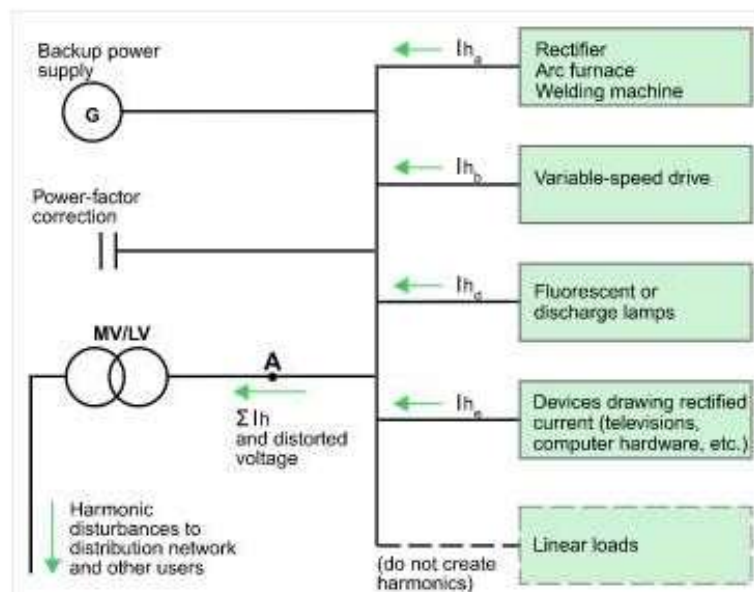


Fig. M5 – Flow of harmonic currents in a distribution network

Harmonics

Essential indicators of harmonic distortion and measurement principles

A number of indicators are used to quantify and evaluate the harmonic distortion in current and voltage waveforms, namely:

- ✓ Power factor
- ✓ Crest factor
- ✓ Harmonic spectrum
- ✓ R.m.s. value

These indicators are indispensable in determining any necessary corrective action.

Harmonics – Main Effect on Electrical Installation

- ✓ Resonance
- ✓ Increased losses
- ✓ Overload of equipment
- ✓ Disturbances affecting sensitive loads
- ✓ Economic impact

Harmonics - Solution to mitigate harmonic

Basic solutions to mitigate harmonics To limit the propagation of harmonics in the distribution network, different solutions are available and should be taken into account particularly when designing a new installation.

- ✓ Position the non-linear loads upstream in the system
- ✓ Group the non-linear loads
- ✓ Create separate sources
- ✓ Transformers with special connections
- ✓ Install reactors
- ✓ Select the suitable system earthing arrangement

Harmonics - Solution to mitigate harmonic

Harmonic filtering

1. Passive filters
2. Active filters (active harmonic conditioner)
3. Hybrid filters
4. Selection criteria

1. Passive filters - Typical applications

- ❖ Industrial installations with a set of non-linear loads representing more than 500kVA (variable-speed drives, UPSs, rectifiers, etc.)
- ❖ Installations requiring power-factor correction
- ❖ Installations where voltage distortion must be reduced to avoid disturbing sensitive loads
- ❖ Installations where current distortion must be reduced to avoid overloads

Harmonics - Solution to mitigate harmonic

Harmonic filtering

2. Active filters (active harmonic conditioner) - Typical applications

- ✓ Commercial installations with a set of non-linear loads representing less than 500kVA (variable-speed drives, UPSs, office equipment, etc.)
- ✓ Installations where current distortion must be reduced to avoid overloads.

3. Hybrid filters - Typical applications

Industrial installations with a set of non-linear loads representing more than 500kVA (variable- speed drives, UPSs, rectifiers, etc.)

- ✓ Installations requiring power-factor correction
- ✓ Installations where voltage distortion must be reduced to avoid disturbing sensitive loads
- ✓ Installations where current distortion must be reduced to avoid overloads
- ✓ Installations where strict limits on harmonic emissions must be met

Harmonics - Solution to mitigate harmonic

4. Selection criteria

a) Passive filter

It offers both power-factor correction and high current-filtering capacity. Passive filters also reduce the harmonic voltages in installations where the supply voltage is disturbed. If the level of reactive power supplied is high, it is advised to turn off the passive filter at times when the percent load is low.

Preliminary studies for a filter must take into account the possible presence of a power factor correction capacitor bank which may have to be eliminated.

b) Active harmonic conditioners

They filter harmonics over a wide range of frequencies and can adapt to any type of load. On the other hand, power ratings are limited.

c) Hybrid filters

They combine the performance of both active and passive filters.

Harmonics - Solution to mitigate harmonic

Harmonic audit of MV and LV networks

By calling on an expert, you are guaranteed that the proposed solution will produce effective results (e.g. a guaranteed maximum THD)

A harmonic audit is carried out by an engineer specialized in the disturbances affecting electrical distribution networks and equipped with powerful analysis and simulation equipment and software.

The steps in an audit are the following:

- ✓ Measurement of disturbances affecting current and phase-to-phase and phase-to-neutral voltages at the supply source, the disturbed outgoing circuits and the non-linear loads

Harmonics - Solution to mitigate harmonic

Harmonic audit of MV and LV networks (Continue)

- ✓ Computer modelling of the phenomena to obtain a precise explanation of the causes and determine the best solutions
- ✓ A complete audit report presenting:
 - The current levels of disturbances
 - The maximum permissible levels of disturbances (refer to IEC 61000, IEEE 519, etc.)
- ✓ A proposal containing solutions with guaranteed levels of performance
- ✓ Finally, implementation of the selected solution, using the necessary means and resources.

Harmonics – Maximum Voltage

Fig. M23 – Maximum admissible harmonic voltages and distortion (%)

		LV	MV	HV
Odd harmonics non-multiple of 3	5	6	5	2
	7	5	4	2
	11	3.5	3	1.5
	13	3	2.5	1.5
	$17 \leq h \leq 49$	$2.27 \frac{17}{h} - 0.27$	$1.9 \frac{17}{h} - 0.2$	$1.2 \frac{17}{h}$
Odd harmonics multiple of 3	3	5	4	2
	9	1.5	1.2	1
	15	0.4	0.3	0.3
	21	0.3	0.2	0.2
	$21 \leq h \leq 45$	0.2	0.2	0.2
Even harmonics	2	2	1.8	1.4
	4	1	1	0.8
	6	0.5	0.5	0.4
	8	0.5	0.5	0.4
	$10 \leq h \leq 50$	$0.25 \frac{10}{h} + 0.25$	$0.25 \frac{10}{h} + 0.22$	$0.19 \frac{10}{h} + 0.16$
THD _U		8	6.5	3

Harmonics –

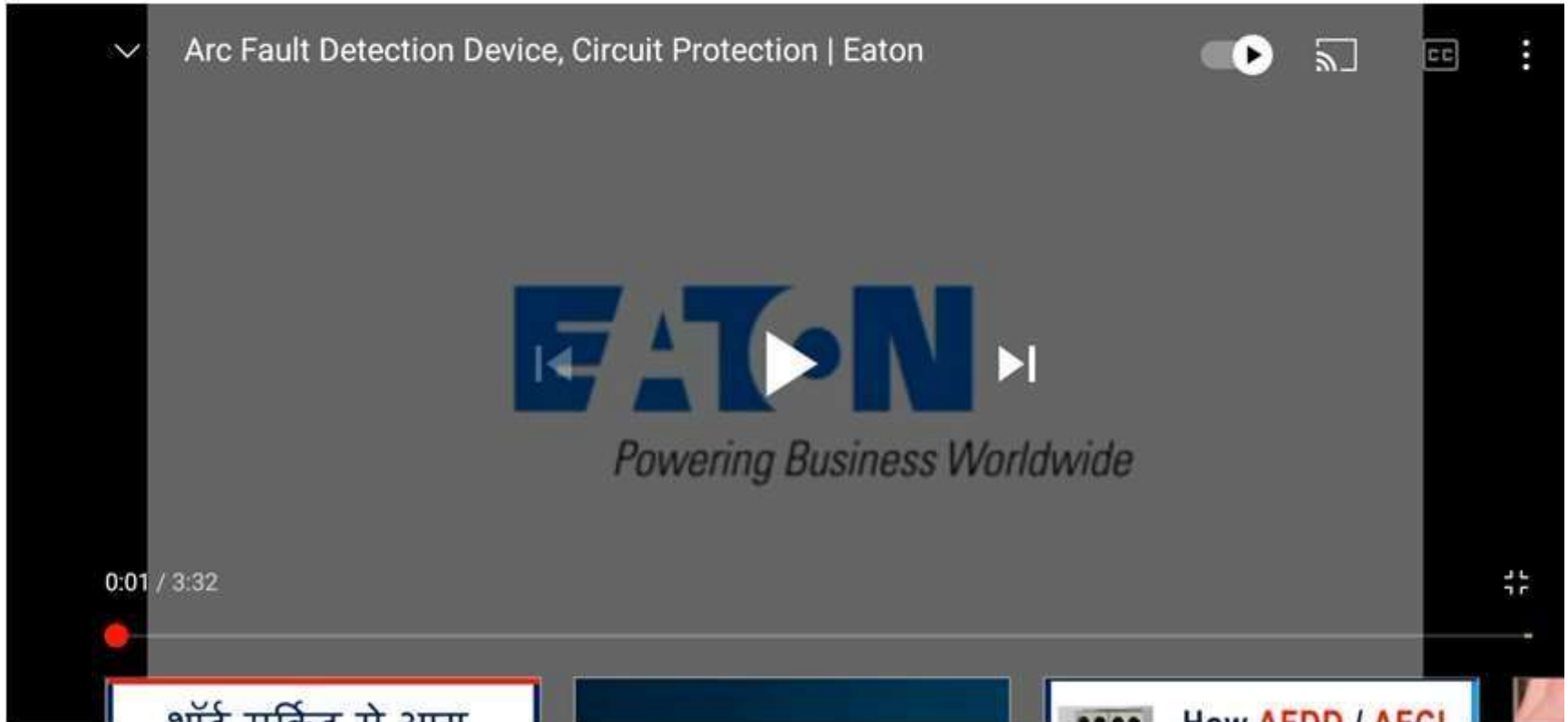
Fig. M10 gives the maximum harmonic voltage in order to meet the requirements of standard EN50160: "Voltage characteristics of electricity supplied by public distribution networks", for Low and Medium Voltage.

Fig. M10 – Values of individual harmonic voltages at the supply terminals for orders up to 25 given in percent of the fundamental voltage U_1

Odd harmonic non-multiples of 3		Odd harmonic multiples of 3		Even harmonic	
Order h	Relative amplitude U_h : %	Order h	Relative amplitude U_h : %	Order h	Relative amplitude U_h : %
5	6	3	5	2	2
7	5	9	1.5	4	1
11	3.5	15	0.5	6...24	0.5
13	3	21	0.5		
17	2				
19	1.5				
23	1.5				
25	1.5				

Electrical Safety

ARC Flash



Arc Flash

Arc flash is caused by one of the several reasons

- ✓ Dielectric breakdown causes short circuit and limiting impedance is low.
- ✓ When air becomes superheated, and metal vaporizes
- ✓ When high current is broken

Conditions conducive to Arc Flash

- ✓ High voltage
- ✓ High current
- ✓ Overheating of conductors
- ✓ Large inductance in the circuit

Dangers of Arc flash

Arc Flash can cause many of the following injuries

- ✓ Shock
- ✓ Burns
- ✓ Blindness
- ✓ Deafness
- ✓ Can burn almost any type of clothes increasing danger of secondary burns.

➡ Arc Flash can cause second degree burns at very large distance.

Arc Blast

- ✓ In confined space Arcing heats, up air rapidly
 - ✓ Air Expands rapidly
 - ✓ Can blow out panel doors, shatter insulators and even knock down walls
 - ✓ Throw molten metal over large distance
 - ✓ Can puncture eardrum
- ➡ Normal panel doors are not designed to withstand Arc Blast pressure.
Specially designed panel doors are needed.

Dangers from Arc Flash/ Arc Blast

- ✓ **Pressure:** at a distance of 24" (61cm) from an electrical arc associated with a 22 kA arcing fault a person can be subject to a force of 500lb (225kg); furthermore, the sudden pressure wave may cause rupture of the eardrums or permanent injuries;
- ✓ **Temperatures** of an arc can reach about 34,232 °F (19,000°C; the surface of the Sun is 6,000°C)
- ✓ **Sound:** electrical arc sound levels can reach 160 db, (a jet engine at 100' (30m) is 140 db).

Burns

Electric shock causes local burns but Arc Flash can cause extensive burns in face, Chest, Back and limbs.

- First degree Burn- Superficial burns on the skin, Painful but no permanent damage.
- Second degree burn- Skin and growth tissues are burnt. Growth of skin is slow. Usually leaves scar.
- Third degree burn- Skin and growth glands are also burnt. Skin can not grow without grafting. Leaves scar and some permanent damage.

Hazards from Static Charge

- Static charge accumulate on human body specially during winter by rubbing against clothes
- It may also be passed through touching charged surface
- Rapid transfer of electric charge to and from human body can give severe electric shock
- Electric charge develops when liquid passes through pipe lines both on liquid as well as in pipe line
- Specially hazardous when transferring petroleum or other easily ignitable liquids.

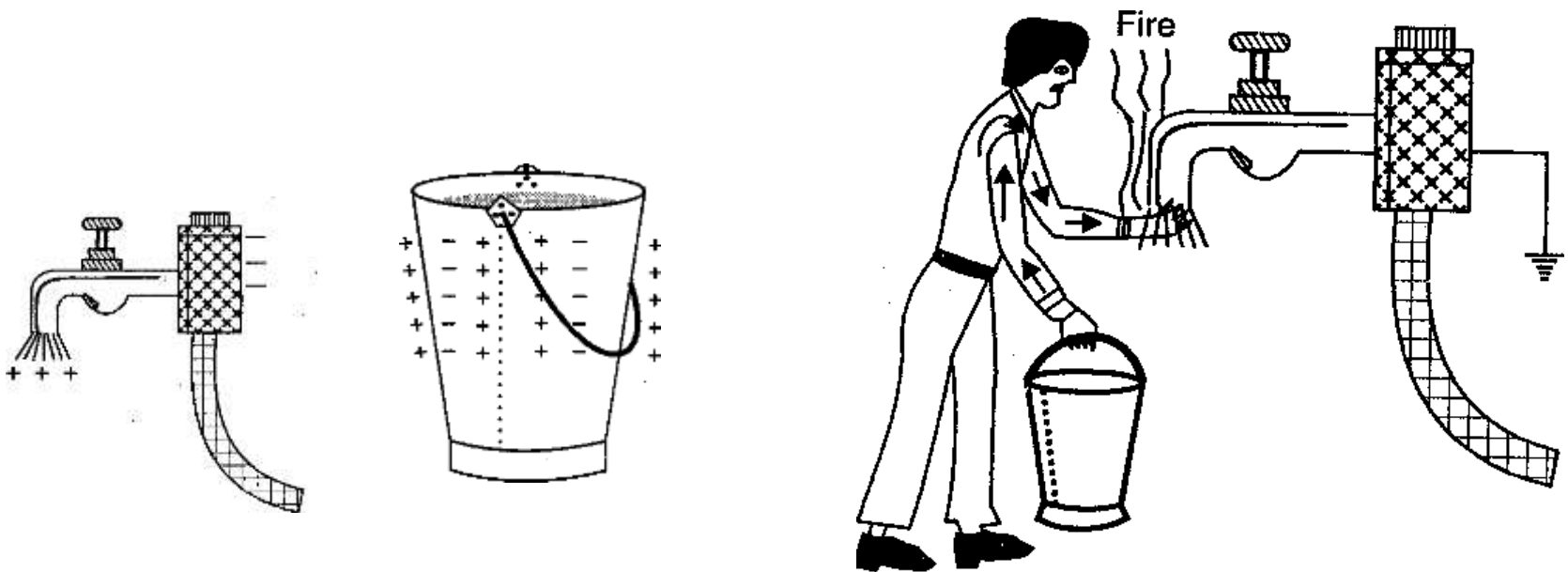
Hazards from Static Charge

Static charge accumulates during

- Agitation or mixing of liquid or solid material.
- Transfer of material
- Running on belt conveyor
- Pneumatic conveying

Hazards of static electricity

Filling inflammable liquid



Secondary Hazard

- Shock can cause person to fall down from height and cause fractures or death
- Person may fall on the live conductor and continue receiving shock till help is available
- Person may drop tools etc. on live parts causing arc flash
- Short circuits can cause fires leading to large scale deaths and injuries.
- Arc Flash can start secondary fires.

Fire Hazard

- Cause of fire is some time attributed to electrical causes e.g., short circuit. Actually, it is very difficult to start a fire with electricity alone.
- Fire needs three elements to start and sustain viz.
 - Combustible material near source of heat, which can easily catch fire, e.g., Oil-soaked rags, polythene, Pharmacol, fuel, paper, cloth, some volatile chemicals etc.
 - Source of heat which may be provided by electricity.
 - Oxygen or air.

Fire Hazard

- Electric causes could be of following types which may start a fire;
 - Short circuit in an unprotected circuit e.g., unprotected circuit. Sometimes a short circuit may not have enough current to trip protection device but may cause arcing which in contact with combustible material may catch fire.
 - Overload where wires may get overheated, but protection device does not trip as in case of very high setting.
 - Arcing can cause nearby combustible material to catch fire.
 - Overheating or failure of a fitting which first catches fire, and the other material nearby catches fire.

Prevention of electric Fire

- Electric causes could be of following types which may start a fire;
- Short circuit in an unprotected circuit e.g., unprotected circuit. Sometimes a short circuit may not have enough current to trip protection device but may cause arcing which in contact with combustible material may catch fire.
- Overload where wires may get overheated, but protection device does not trip as in case of very high setting.
- Arcing can cause nearby combustible material to catch fire.
- Overheating or failure of a fitting which first catches fire, and the other material nearby catches fire.



Incidence of Arc Flash

An arc flash can occur while;

- Doing work on live system e.g., bus bars, switches etc.
- Racking in breaker
- Touching any live part by a tool
- Spontaneously when air and metal parts become overheated in closed space like panelboards

Phases of Arc Flash

- ✓ **Compression Phase:** The volume of the air where the arc develops is overheated due to the release of energy. The remaining volume of air inside the cubicle heats up from convection and radiation. Initially there are different temperatures and pressures from one zone to another;
- ✓ **Expansion Phase:** From the first instant of internal pressure increase, a hole is formed through which the superheated air begins to escape. The pressure reaches its maximum value and starts to decrease from the release of hot air;
- ✓ **Emission Phase:** Due to continued contribution of energy by the arc, nearly all the superheated air is forced out by an almost constant overpressure;
- ✓ **Thermal Phase:** After the expulsion of the air, the temperature inside the switchgear nears that of the electrical arc. This final phase lasts until the arc is quenched, when all the metals and the insulating materials coming into contact undergo erosion with production of gas, fumes and molten material.

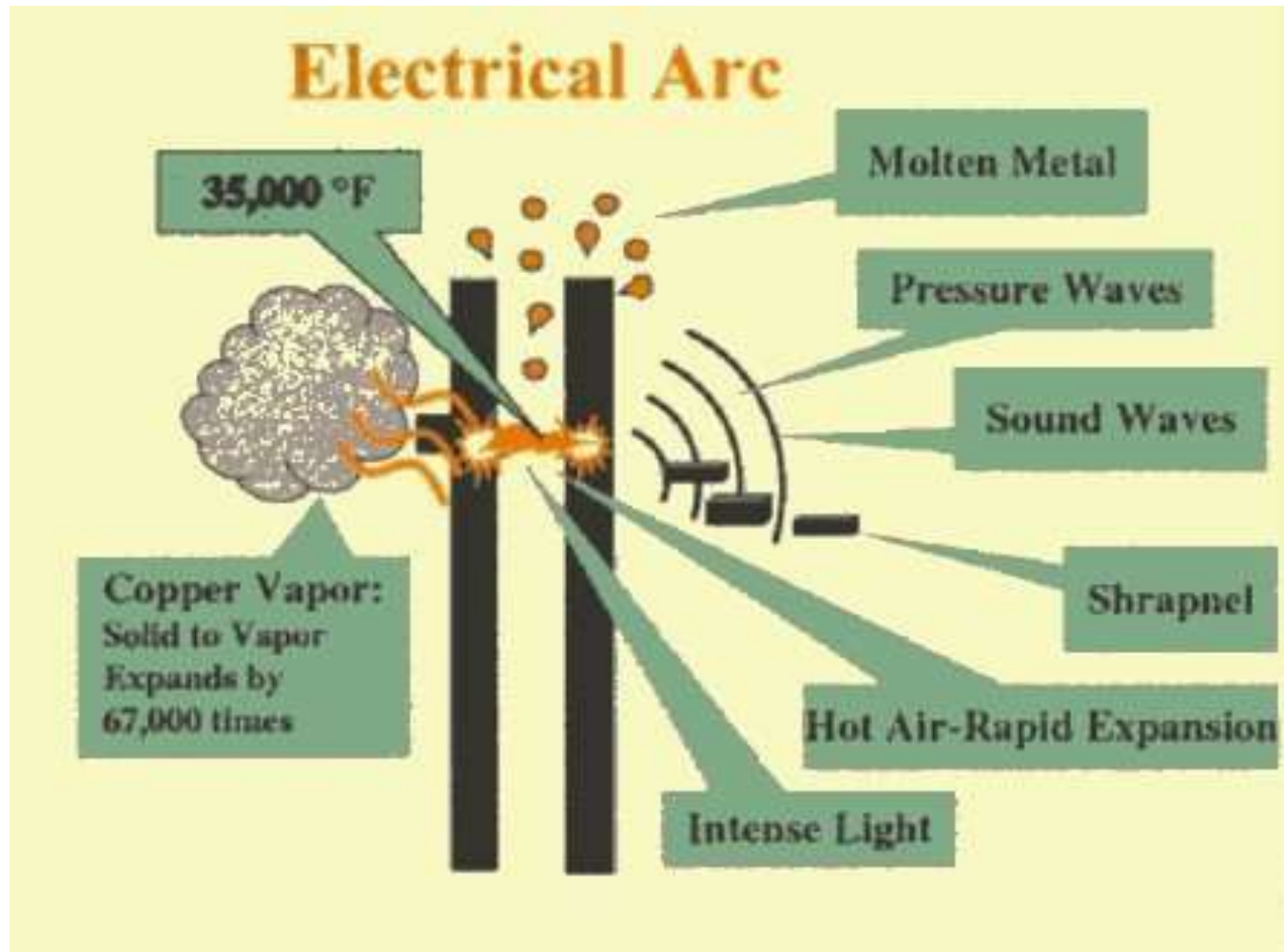
Properties of Arc Flash

Arc is a very heavy current passing through air under certain conditions.

- The current further heats up air through which it passes and creates state of Plasma or ionized air.
- This plasma is conductive and supports flow of current.
- This current creates strong thermo-magnetic force.
- This force moves plasma through space
- Temperature at the core of arc can be $> 20,000^{\circ}\text{K}$

Properties of Arc Flash

- Large part of heat is radiated to large distance
- It can inflict second degree burns at a distance of even 12 feet
- All type of clothing can be set on fire by arc flash
- Molten metal flies at large distances
- In oil immersed devices like transformers, arc flash on bushings can set fire to oil and destroy entire transformer and even may set establishment on fire



Flash Energy

- Light- Intense light is emitted which can cause loss of sight temporarily
- Heat is intense in the form of radiation and conduction to the person intouch.
- Mechanical- In form of blast

Heat energy intensity is measured as cal/cm^2

Incident Flash Energy

Defined as Arc Flash energy experienced by a person Depends upon

- Bolted short circuit current
- System Voltage
- Distance from arcing electrode
- Duration of fault
- Absorbent coefficient of the victim
- Box effect

Arcing Current as per IEEE 1584-2002

For voltages less than 1000V:

$$\begin{aligned} \log_{10}(I_a) = & K + 0.662 \log_{10}(I_{bf}) + 0.0966V + 0.000526G \\ & + 0.5588V \log_{10}(I_{bf}) - 0.00304G \log_{10}(I_{bf}) \end{aligned}$$

Where I_a = Arcing Current

K = Constant: (-0.153 for open configuration and -0.097 for box configuration)

I_{bf} = RMS Symmetrical component of bolted fault current (kA). Range 700A to 1,06,000 A

V = System phase to phase voltage (kV), Between 208 V to 15,000 V phase to phase

G = Gap between arcing conductors (mm). (13 to 152 mm)

Arcing Current as per IEEE 1584-2002

For voltages equal to or greater than 1000V:

$$\text{Log}_{10}(I_a) = 0.00402 + 0.9831 \text{Log}_{10}(I_{bf})$$

Where I_a = Arcing Current

I_{bf} = Bolted fault current

Example-1

Open configuration

$V=415$ Volts , $I^{bf} = 2000A$, Gap = 20 mm, $I^a = 1407A$

Box configuration

$V=415$ Volts , $I^{bf} = 2000A$, Gap = 20 mm, $I^a = 1601A$

Example-2

$V=11000$ Volts ,

$I_{bf}=3000A$,

$I_a=2972A$

Arcing Voltage

It is the voltage that appears across the contacts of the circuit breaker during the arcing period.

As soon as the contacts of the circuit breaker separate, an arc is formed. The voltage that appears across the contacts during arcing period is called the arc voltage. Its value is low except for the period the fault current is at or near zero current point. At current zero, the arc voltage rises rapidly to peak value and this peak voltage tends to maintain the current flow in the form of arc.

Characteristics;

1. Arc voltage starts low and tends to rise. Periodically voltage may drop for Arcs of longer duration.
2. Arc Voltage is proportional to Arc length and therefore Arc Energy is proportional to Arc length.
3. Arc voltage calculations at best are estimations only and are approximate at best.
4. Range may vary between 214.4 V/m to 91.4V/m

Arc Flash Energy IEEE 1584-2002

Normalized Energy

$$\log_{10}(E_n) = K_1 + K_2 + 1.081[\log_{10}(I_a)] + 0.0011 G$$

Where

E_n = Incident Energy (J/cm²) normalized for time and distance { Time = 0.2 sec.,

Distance = 610 mm }

K_1 = Constant -0.792 for open and -0.555 for box K_2

= Constant 0 for un-grounded and high resistance system and -0.113 for grounded system

G = Gap between conductors mm

Arc Flash Energy IEEE 1584-2002

Actual Energy

$$E = 4.184 C_f E_n \{t/0.2\}^{610^x/D^x}$$

Where

E = Incident energy (J/cm²)

C_f = Calculation factor = 1.0 for System $V > 1$ kV and
= 1.5 for system voltage $V \leq 1$ kV

t = Arcing time in sec

D = Distance from arcing point to worker

x = Distance factor dependent upon voltage { See Table 4 for x in IEEE 1584-2002 }

Human Tissue tolerance to heat

Table 1 Human Tissue Tolerance to Heat, Second Degree Burn A

Exposure Time s	Heat Flux		Total Heat		Calorimeter ^B Equivalent		
	kW/m ²	cal/cm ² s	kWs/m ²	cal/cm ²	$\Delta T^{\circ}\text{C}$	$\Delta T^{\circ}\text{F}$	ΔmV
1	50	1.2	50	1.20	8.9	16.0	0.46
2	31	0.73	61	1.46	10.8	19.5	0.57
3	23	0.55	69	1.65	12.2	22.0	0.63
4	19	0.45	75	1.80	13.3	24.0	0.69
5	16	0.38	80	1.90	14.1	25.3	0.72
6	14	0.34	85	2.04	15.1	27.2	0.78
7	13	0.30	88	2.10	15.5	28.0	0.80
8	11.5	0.274	92	2.19	16.2	29.2	0.83
9	10.6	0.252	95	2.27	16.8	30.2	0.86
10	9.8	0.233	98	2.33	17.3	31.1	0.89
11	9.2	0.219	101	2.41	17.8	32.1	0.92
12	8.6	0.205	103	2.46	18.2	32.8	0.94
13	8.1	0.194	106	2.52	18.7	33.6	0.97
14	7.7	0.184	108	2.58	19.1	34.3	0.99
15	7.4	0.177	111	2.66	19.7	35.4	1.02
16	7.0	0.168	113	2.69	19.8	35.8	1.03
17	6.7	0.160	114	2.72	20.2	36.3	1.04
18	6.4	0.154	116	2.77	20.6	37.0	1.06
19	6.2	0.148	118	2.81	20.8	37.5	1.08
20	6.0	0.143	120	2.86	21.2	38.1	1.10
25	5.1	0.122	128	3.05	22.6	40.7	1.17
30	4.5	0.107	134	3.21	23.8	42.8	1.23

^A Stoll, A. M. And Chianta, M. A., "Method and Rating System for Evaluation of Thermal Protection," Aerospace Medicine, Vol 40, 1969, pp.1232-1238.

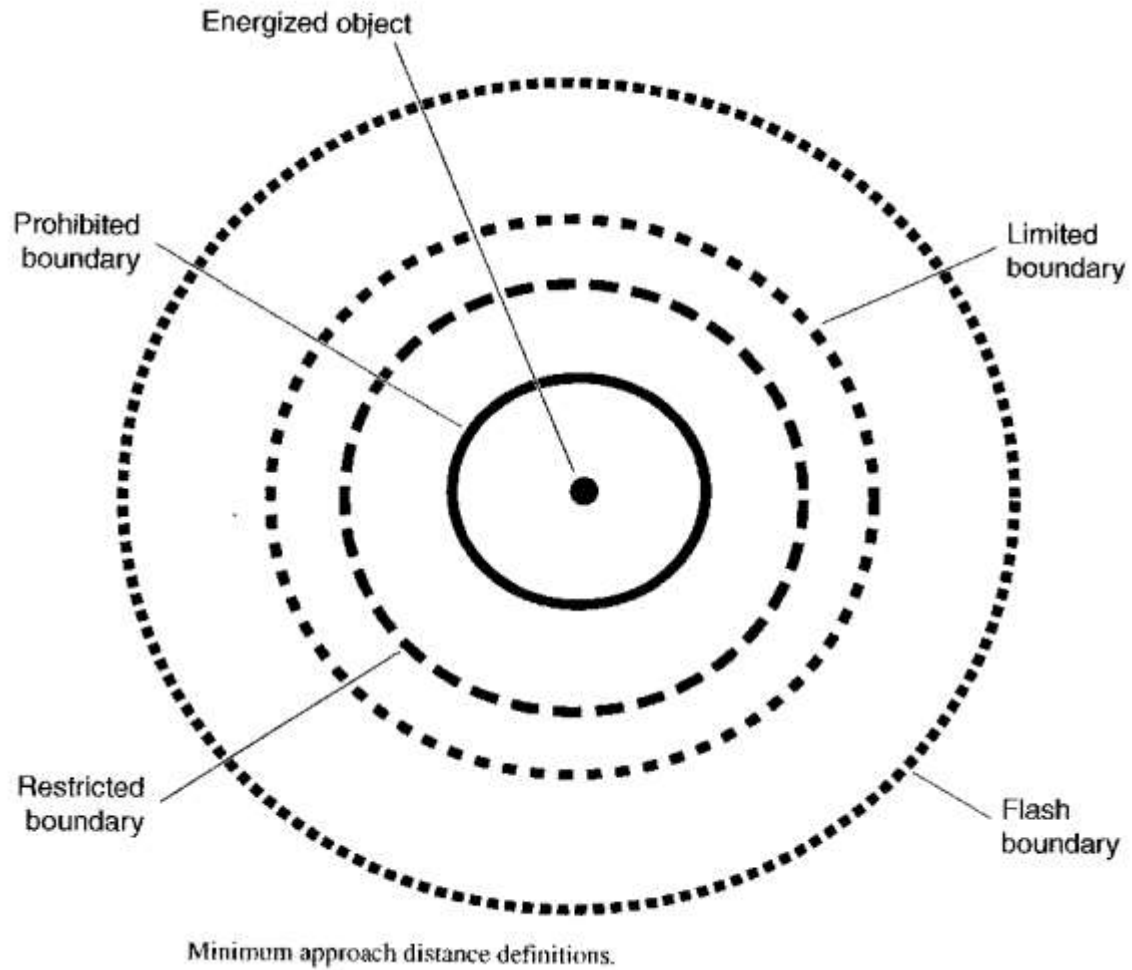
^B Iron/constantan thermocouple.

Factors affecting injury by Arc Flash

Distance	The amount of damage done to the recipient diminishes by approximately square of the distance from the arc. Twice as far means one-fourth the damage. (Empirical evidence suggests that the actual value may be somewhat different because of the focusing effect of the surroundings.)
Temperature	The amount of energy received is proportional to the difference between the fourth power of the arc temperature and the body temperature ($T_a^4 - T_b^4$).
Absorption coefficient	The ratio of energy received to the energy absorbed by the body.
Time	Energy received is proportional to the amount of time that the arc is present.
Arc length	The amount of energy transmitted is a function of the arc length. For example, a zero length arc will transmit zero energy. Note that for any given system, there will be an optimum arc length for energy transfer.
Cross-sectional area of body exposed to the arc	The greater the area exposed, the greater the amount of energy received.
Angle of incidence of the arc energy	Energy is proportional to the sine of the angle of incidence. Thus, energy impinging at 90° is maximum.

Temp. vs. Distance from Arc

Arc Sphere Diameter		Distance from Center					
		20"	24"	30"	36"	60"	120"
In.	cm.	50.8 cm.	61 cm.	76.2 cm.	91.4 cm.	152 cm.	305cm.
1	2.54	69F	47F	31F	21F	8F	2F
2	5.08	274F	191F	122F	85F	30F	8F
3	7.62	619F	429F	275F	191F	69F	17F
4	10.2	1100F	764F	489F	339F	122F	31F
6	15.2	2474F	1718F	1100F	764F	275F	69F
8	20.3	4398F	3054F	1955F	1358F	489F	122F
10	25.4	6872F	4772F	3054F	2121F	764F	191F
12	30.5	9896F	6872F	4398F	3054F	1100F	275F
16	40.6	17593F	12217F	7819F	5430F	1954F	489F



Shock & Flash Protection boundaries

- **Restricted Approach Boundary (RAB)**- A shock protection boundary to be crossed by only qualified persons. When crossed, shock protection techniques and equipment is required.
- **Prohibited Approach boundary**- A shock protection boundary to be crossed by only qualified persons. When crossed, same protection is to be used as with live contact.
- **Flash Protection boundary**- Distance at which incident energy levels equals 1.2 cal/cm^2 for fault clearing time of 0.1 sec or more. For fault clearing time less than 0.1 sec, this can be considered a distance at which incident energy level is 1.5 cal/cm^2 .

Shock Protection Boundary

Nominal system voltage range, phase to phase	<u>Limited approach boundary</u>		Restricted approach boundary; includes inadvertent movement adder	Prohibited approach boundary
	Exposed movable conductor	Exposed fixed circuit part		
0 to 50	Not specified	Not specified	Not specified	Not specified
51 to 300	10 ft 0 in.	3 ft 6 in.	Avoid contact	Avoid contact
301 to 750	10 ft 0 in.	3 ft 6 in.	1 ft 0 in.	0 ft 1 in.
751 to 15 kV	10 ft 0 in.	5 ft 0 in.	2 ft 2 in.	0 ft 7 in.
15.1 kV to 36 kV	10 ft 0 in.	6 ft 0 in.	2 ft 7 in.	0 ft 10 in.
36.1 kV to 46 kV	10 ft 0 in.	8 ft 0 in.	2 ft 9 in.	1 ft 5 in.
46.1 kV to 72.5 kV	10 ft 0 in.	8 ft 0 in.	3 ft 3 in.	2 ft 1 in.
72.6 kV to 121 kV	10 ft 8 in.	8 ft 0 in.	3 ft 2 in.	2 ft 8 in.
138 kV to 145 kV	11 ft 0 in.	10 ft 0 in.	3 ft 7 in.	3 ft 1 in.
161 kV to 169 kV	11 ft 8 in.	11 ft 8 in.	4 ft 0 in.	3 ft 6 in.
230 kV to 242 kV	13 ft 0 in.	13 ft 0 in.	5 ft 3 in.	4 ft 9 in.
345 kV to 362 kV	15 ft 4 in.	15 ft 4 in.	8 ft 6 in.	8 ft 0 in.
500 kV to 550 kV	19 ft 0 in.	19 ft 0 in.	11 ft 3 in.	10 ft 9 in.
765 kV to 800 kV	23 ft 9 in.	23 ft 9 in.	14 ft 11 in.	14 ft 5 in.

[illegible]

Class of Arc Flash Hazard

The NFPA 70E 2004 standard provides 5 Arc Rating levels

- Class 0 for incident energy up to 1.2 cal/cm²
- Class 1 for incident energy up to 4 cal/cm²
- Class 2 for incident energy up to 8 cal/cm²
- Class 3 for incident energy up to 25 cal/cm²
- Class 4 for incident energy up to 40 cal/cm²

Table 3: Personal Protective Equipment (NFPA 130.7(C)(15)(c))

PPE CATEGORY 1	PPE CATEGORY 2
Minimum Arc Rating of 4 cal/cm² Arc Rated Clothing: • AR long-sleeve shirt and pants, or AR coverall • AR face shield, or AR flash suit hood • AR jacket, parka, rainwear, or hard hat liner (as needed)  Protective Equipment: • Hard hat • Safety glasses or safety goggles • Hearing protection (with inserts) • Heavy-duty leather gloves • Leather footwear (as needed)	Minimum Arc Rating of 8 cal/cm² Arc Rated Clothing: • AR long-sleeve shirt and pants, or AR coverall • AR flash suit hood, or AR face shield and AR balaclava • AR jacket, parka, rainwear, or hard hat liner (as needed)  Protective Equipment: • Hard hat • Safety glasses or safety goggles • Hearing protection (with inserts) • Heavy-duty leather gloves • Leather footwear

Table 3: Personal Protective Equipment (NFPA 130.7(C)(15)(c))

PPE CATEGORY 3	PPE CATEGORY 4
Minimum Arc Rating of 25 cal/cm² Arc Rated Clothing: • As required: AR long-sleeve shirt, AR pants, AR coverall, AR flash suit jacket, and/or AR flash suit pants • AR flash suit hood • AR gloves • AR jacket, parka, rainwear, or hard hat liner (as needed) Protective Equipment: • Hard hat • Safety glasses or safety goggles • Hearing protection (with inserts) • Leather footwear (as needed)	Minimum Arc Rating of 40 cal/cm² Arc Rated Clothing: • As required: AR long-sleeve shirt, AR pants, AR coverall, AR flash suit jacket, and/or AR flash suit pants • AR flash suit hood • AR gloves • AR jacket, parka, rainwear, or hard hat liner (as needed) Protective Equipment: • Hard hat • Safety glasses or safety goggles • Hearing protection (with inserts) • Leather footwear (as needed)

Arc Flash Hazard Analysis

Reasons for arc flash Hazard Analysis

- To know hazard level at each location
- To know safe boundaries for approach
- To determine suitable clothing for approaching near live area
- To know suitable PPE for workers to work on live parts

Arc Flash Hazard Analysis

Necessary information for doing Arc Flash hazard analysis;

- Bolted fault current at each location
- Clearing time for the source side protective device
- Working distance for energized work
- ATPV (Arc Thermal Performance Value) for PPE combinations use at site
- Site specific issues e.g. ingress, egress, working space, illumination etc.

Steps required to do Arc Flash Hazard Analysis

- Site assessment and data gathering
- Short circuit analysis
- Protective device coordination
- Use of software for detailed analysis.
- IEEE standard 1584-2002 comes with software
- Commercial software e.g. SKM Power, ETAP, Arc Pro, Buss Man, Easy Power etc are quite good.
- Other free wares are available on the net
- Check www.cadickcorp.com and www.oberoncompany.com

Arc Flash Labeling

- Depending upon Arc Flash analysis Various locations will have different classes of Arc Flash Hazard
- Labels clearly describing hazard class, Flash hazard boundary, Limited approach, Restricted approach, Prohibited approach, Incident Energy level, Recommended clothing etc. is prominently put at locations in a way that it can not be missed by workmen.

What Equipment Requires An Arc Flash Label?



Switchboards

Ideal for un-terminated wires or cables needing superior abrasion and chemical resistance.



Panel Boards

Ideal for general marking of terminated or unterminated cables and wires that may be curved or become curved.



Industrial Control Panels

Ideal for terminated cables or wires that may need additional abrasion or chemical resistance.



Motor Control Centers

Ideal for getting larger amounts of data on small diameter wire and cables such as fiber optic cables.



Production Line

Ideal for multi-conductor cables or bundled wires/cables.



Disconnect Switches

Ideal for multi-conductor cables or bundled wires/cables.

What Equipment Requires An Arc Flash Label?

1

Danger or Warning header.

A common guideline is to use the "Danger" header when the voltage is over 600 or when the incident energy is over 40 cal/cm². If it is less than this threshold, an orange "Warning" header is typically used.

2

"Incident Energy at" is the corresponding working distance.

The Institute of Electrical and Electronics Engineers (IEEE) defines this as, "the dimension between the possible arc point and the head and body of the worker positioned in place to perform the assigned task."

3

"Min. Arc Rating" is the incident energy.

A measurement in calories/cm² or Joules/cm² of thermal energy at a working distance from an arc fault.

4

Arc Flash Boundary.

This is the shortest distance at which a person working at the time of an arc-flash may receive permanent injury (the onset of a second degree burn or worse) if not properly protected by flame-resistant (FR) clothing.

5

Personal Protective Equipment (PPE).

Each hazard risk category requires a different level of protection. Categories range from 1 to 4. Category "0" was removed in the NFPA 70E 2015 Changes.

6

"Limited Approach" and "Restricted Approach" fields are related Shock Hazard Approach Boundaries.

These boundaries are defined in more detail in our Arc Flash Workplace Safety Guide. The "prohibited approach" boundary was removed in the 2015 NFPA 70E edition.

7

"Shock Risk When Cover is Removed".

The voltage of the equipment.

 WARNING 		
Arc Flash and Shock Hazard		
Appropriate PPE Required		
21 inch	Flash Hazard Boundary	
1.58 cal/cm ²	Flash Hazard at 18 inches	
Class 1	FR Shirt & Pants	
480 VAC	Shock Hazard when cover is removed	
00	Glove Class	
42 inch	Limited Approach (Fixed Circuit)	
12 inch	Restricted Approach	
1 inch	Prohibited Approach	
Bus: 1DPB Prot: CB ATS-2 N		
 Electrical Reliability Services, Inc. 3150-B East Birch Street Brea, California 92821 (714)961-2888		
Job#: 300xxxx	Prepared on:	August 27, 2004
Warning: Changes in equipment settings or system configuration will invalidate the calculated values and PPE requirements		

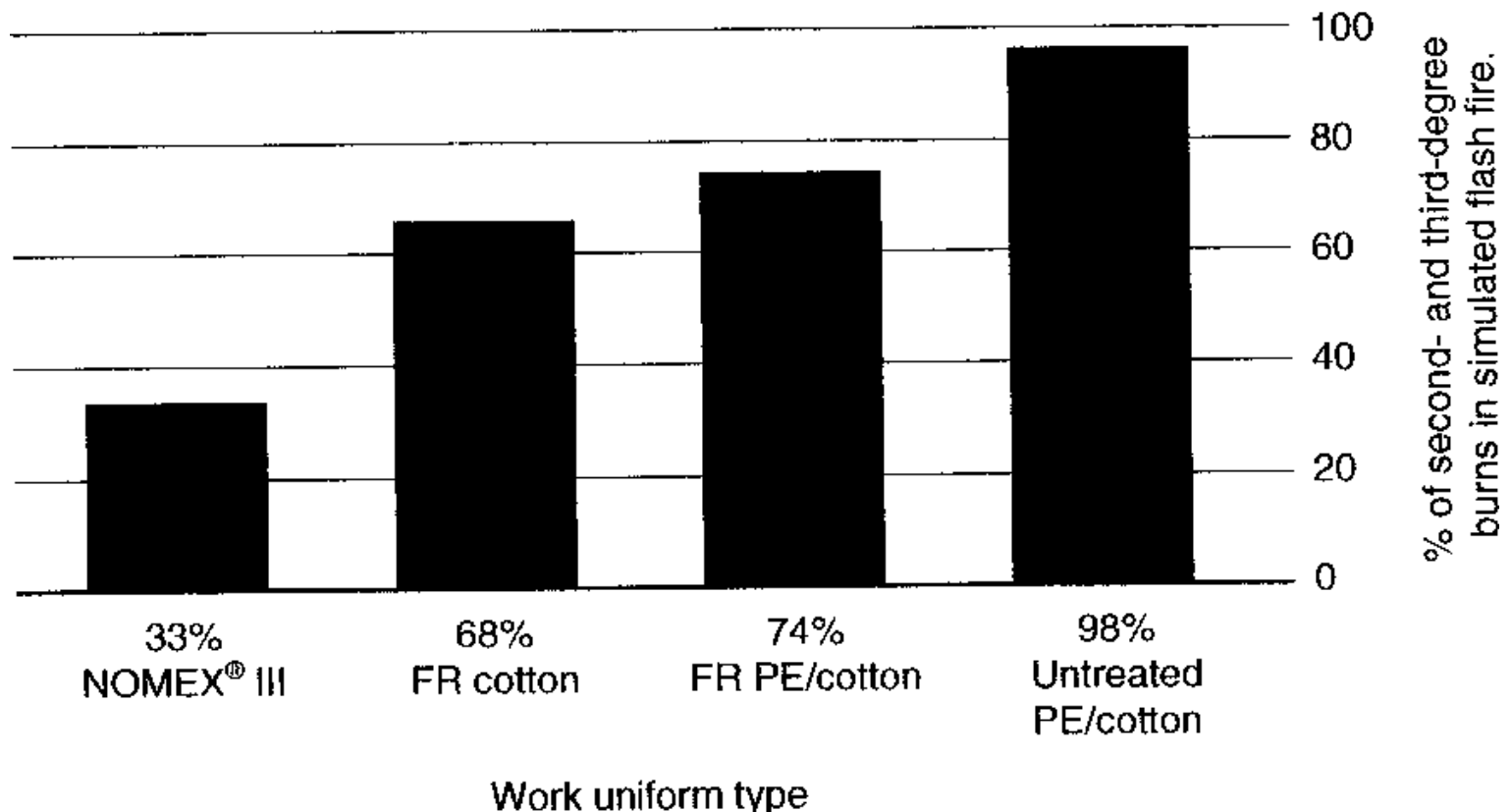
 DANGER 		
NO PPE AVAILABLE		
ENERGIZED WORK PROHIBITED		
334 inch	Flash Hazard Boundary	
144 cal/cm ²	Flash Hazard at 18 inches	
Dangerous!!!	No FR Class Found	
480 VAC	Shock Hazard when cover is removed	
00	Glove Class	
42 inch	Limited Approach (Fixed Circuit)	
12 inch	Restricted Approach	
1 inch	Prohibited Approach	
Bus: MDS Prot: MDS MAIN		
 Electrical Reliability Services, Inc. 3150-B East Birch Street Brea, California 92821 (714)961-2888		
Job#: 300xxxx	Prepared on:	August 27, 2004
Warning: Changes in equipment settings or system configuration will invalidate the calculated values and PPE requirements		

PPE for Arc Flash

Material for Arc flash resistant clothing should;

- Be in two part; One overall or long jacket and other face shield
- Be made from Flame Resistant (FR) material
- Gloves are also of same material. Additionally, rubber gloves are put on over this glove for electrical insulation
- Typically, heavier grade NOMEX or PBI is used
- ATPV should be 40cal/cm²

Thermal performance of NOMEX® III flame retardant cotton, flame retardant polyester/cotton blend, and untreated polyester/cotton blend.





Flash suit.



Face shield for flash suit.

Arc Flash PPE Category Method

Table 130.7(C)(15)(a) Arc Flash PPE Categories for Alternating Current (ac) Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Panelboards or other equipment rated 240 volts and below Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	1	485 mm (19 in.)
Panelboards or other equipment rated greater than 240 volts and up to 600 volts Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	2	900 mm (3 ft)
600-volt class motor control centers (MCCs) Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	2	1.5 m (5 ft)
600-volt class motor control centers (MCCs) Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	4	4.3 m (14 ft)
600-volt class switchgear (with power circuit breakers or fused switches) and 600-volt class switchboards Parameters: Maximum of 35 kA available fault current; maximum of up to 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	4	6 m (20 ft)
Other 600-volt class (277 volts through 600 volts, nominal) equipment Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	2	1.5 m (5 ft)
NEMA E2 (fused contactor) motor starters, 2.3 kV through 7.2 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Metal-clad switchgear, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Metal enclosed interrupter switchgear, fused or unfused type construction, 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Other equipment 1 kV through 15 kV Parameters: Maximum of 35 kA available fault current; maximum of up to 0.24 sec (15 cycles) fault clearing time; minimum working distance 910 mm (36 in.)	4	12 m (40 ft)
Arc-resistant equipment up to 600-volt class Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A
Arc-resistant equipment 1 kV through 15 kV Parameters: DOORS CLOSED and SECURED; with an available fault current and a fault clearing time that does not exceed the arc-resistant rating of the equipment*	N/A	N/A

N/A= Not applicable

Arc Flash PPE Category Method

130.7

ARTICLE 130 — WORK INVOLVING ELECTRICAL HAZARDS

Table 130.7(C)(15)(b) Arc Flash PPE Categories for dc Systems

Equipment	Arc Flash PPE Category	Arc Flash Boundary
Storage batteries, dc switchboards, and other dc supply sources Parameters: Greater than or equal to 100 volts and less than or equal to 250 volts Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)		
Available fault current less than 4 kA	2	900 mm (3 ft)
Available fault current greater than or equal to 4 kA and less than 7 kA	2	1.2 m (4 ft)
Available fault current greater than or equal to 7 kA and less than 15 kA	3	1.8 m (6 ft)
Storage batteries, dc switchboards, and other dc supply sources Parameters: Greater than 250 volts and less than or equal to 600 volts Maximum arc duration and minimum working distance: 2 sec @ 455 mm (18 in.)		
Available fault current less than 1.5 kA	2	900 mm (3 ft)
Available fault current greater than or equal to 1.5 kA and less than 3 kA	2	1.2 m (4 ft)
Available fault current greater than or equal to 3 kA and less than 7 kA	3	1.8 m (6 ft)
Available fault current greater than or equal to 7 kA and less than 10 kA	4	2.5 m (8 ft)

Notes:

(1) Apparel that can be expected to be exposed to electrolyte must meet both of the following conditions:

(a) Be evaluated for electrolyte protection

Informational Note: ASTM F1296, *Standard Guide for Evaluating Chemical Protective Clothing*, contains information on evaluating apparel for protection from electrolyte.

(b) Be arc rated

Training

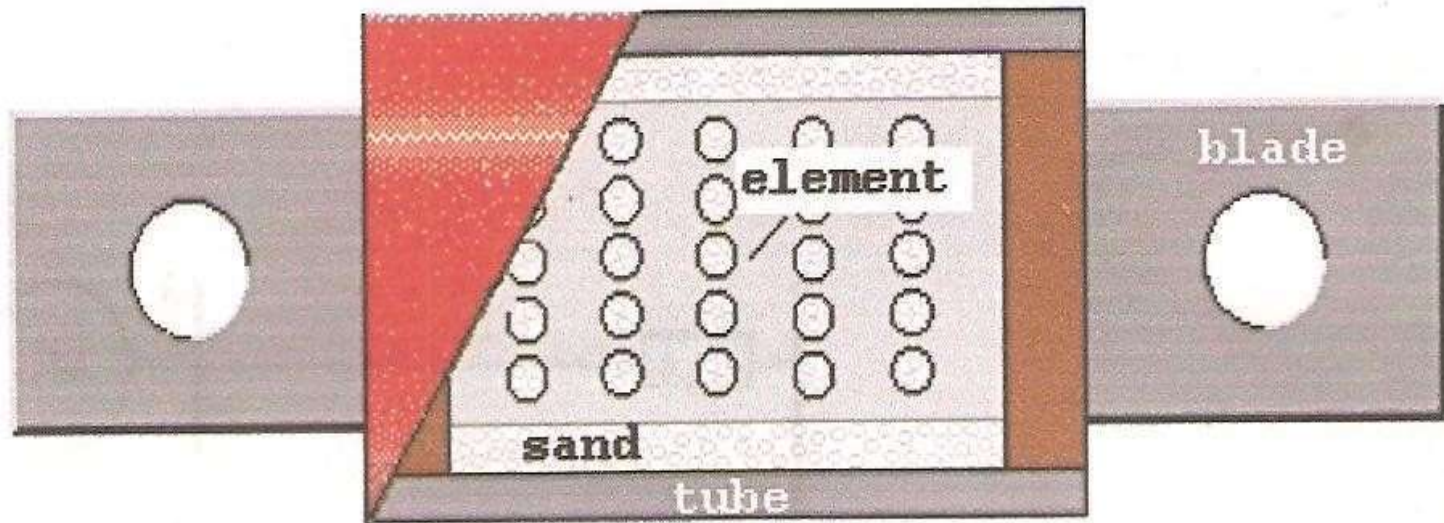
- ✓ Workers who are required to do hot work on live parts are to be trained for this type of work.
- ✓ Training in safety
- ✓ Precautions to be taken
- ✓ Tools permitted to be used
- ✓ Instruments permitted to be used
- ✓ PPE training

Mitigation of Arc Flash Hazard

Strategies

- ✓ Reduction of bolted fault current
- ✓ Reduction in response time of Protection system
- ✓ Increase of working distance
- ✓ Reduced relay settings during hot work
- ✓ Arc Detection devices

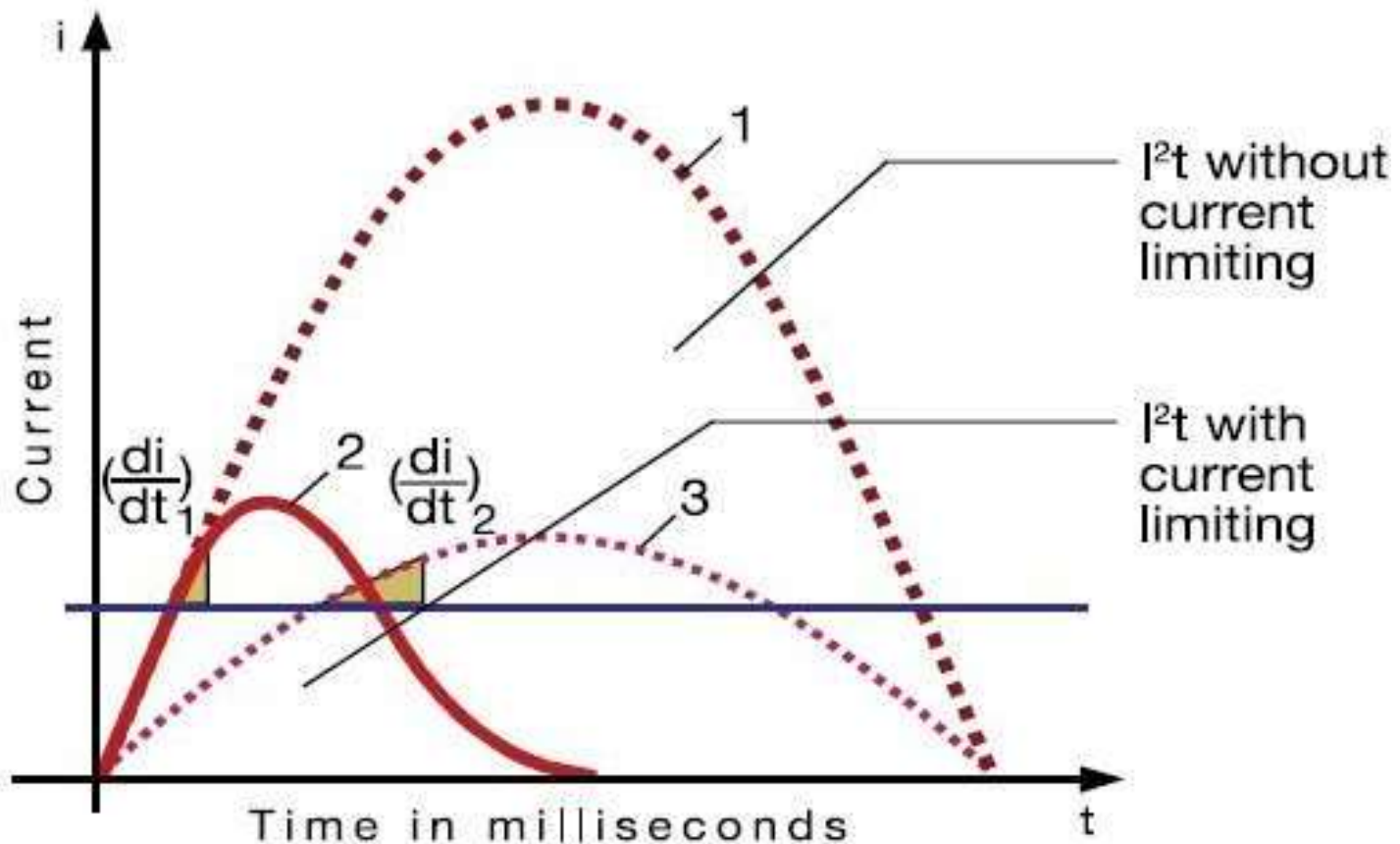
Reduction of Bolted current; Use Current limiting Fuse



Reduction of Bolted current; Use Current limiting Fuse/ Circuit Breaker

- Fuse/ Circuit breaker should clear fault within half cycle
- Reduces voltage sag duration
- Reduces transients and thus improves power quality

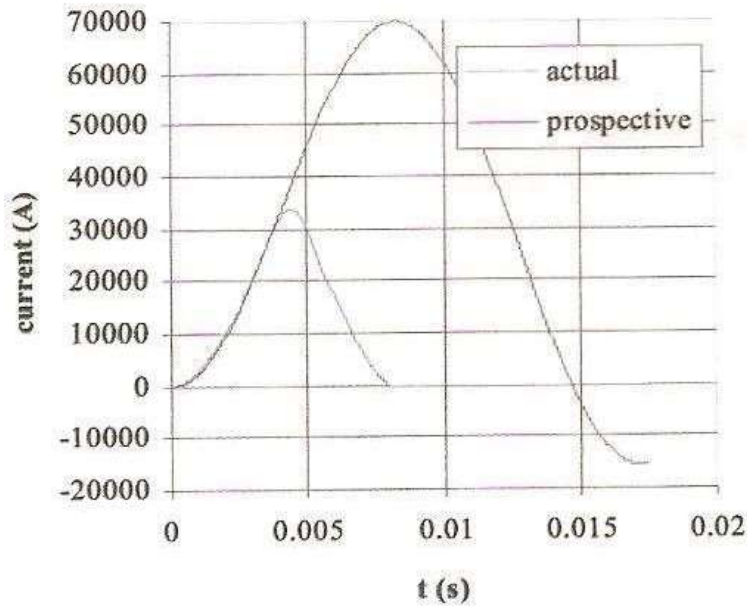
Principle of Current limiting



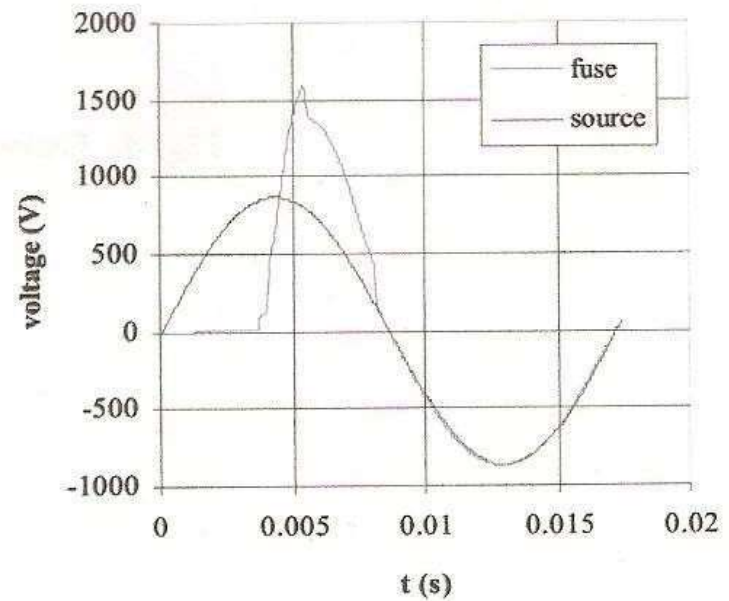
Reduction of fault current

Current; Actual and

Prospective

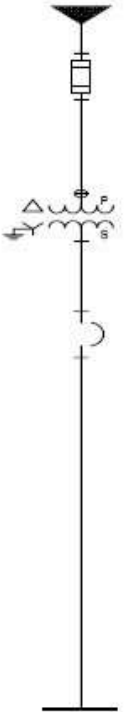
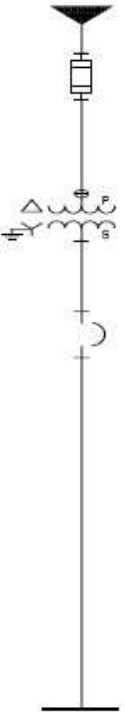


Voltage: Source and fuse



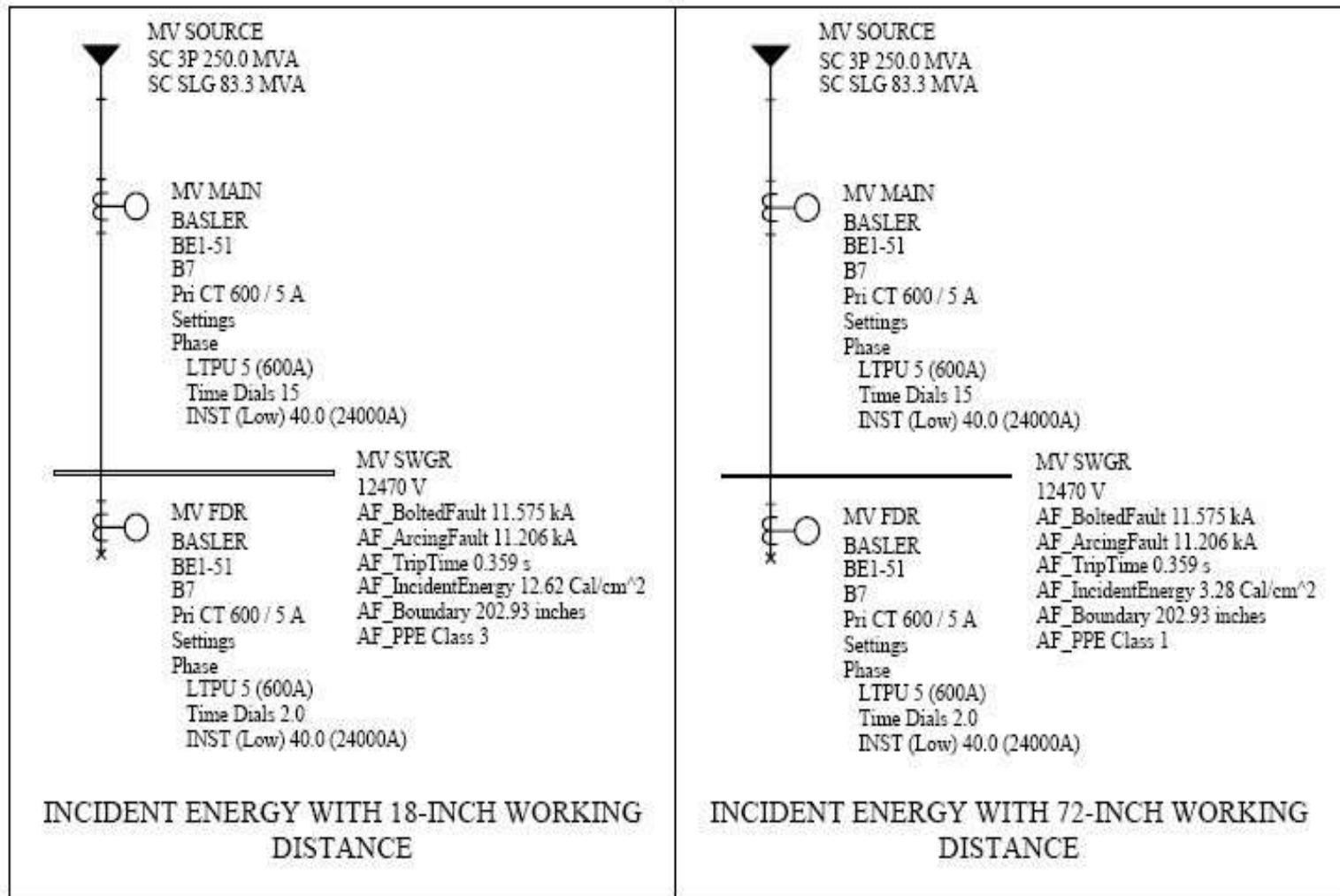
Reduction in response time

- By protective relay coordination, correct the response time
- Use of lower operating time relays
- Bus differential protection
- Use of lower settings reducing operating time

 UTILITY SOURCE SC 3P 250.0 MVA SC SLG 83.3 MVA UTILITY FUSE S&C SM-4, 14.4kV E-Rated 3E-200E Standard Speed Sensor/Trip 125.0 A T-UTILITY 1500.0 kVA Z% 5.0000 % X/R 6.5404 CB MAIN CUTLER-HAMMER SPB, RMS 510/610/810/910 LSI, 400-3000AF Sensor/Trip 2000.0 A Plug 2000.0 A Settings Phase LTPU (0.5-1.0 x P) 1 (2000A) LTD (2-24 Sec.) 7 STPU (2-8 x LTPU) 4 (8000A) STD (0.1-0.5 Sec.) 0.5 (I² T In) INST (2-10 x P) M2(10) (20000A) Ground GFPV (2000A Plug) E (1000A) GFD (0.1-0.5 Sec.) 0.3 Sec. (I² T In) MAIN SWBD 480 V AF_BoltedFault 32.219 kA AF_ArcingFault 17.815 kA AF_TripTime 0.744 s AF_IncidentEnergy 38.66 Cal/cm² AF_Boundary 149.74 inches AF_PPE Class 4 INCIDENT ENERGY WITH MAIN BREAKER OPERATIONAL	 UTILITY SOURCE SC 3P 250.0 MVA SC SLG 83.3 MVA UTILITY FUSE S&C SM-4, 14.4kV E-Rated 3E-200E Standard Speed Sensor/Trip 125.0 A T-UTILITY 1500.0 kVA Z% 5.0000 % X/R 6.5404 CB MAIN CUTLER-HAMMER SPB, RMS 510/610/810/910 LSI, 400-3000AF Sensor/Trip 2000.0 A Plug 2000.0 A MAIN SWBD 480 V AF_BoltedFault 32.219 kA AF_ArcingFault 17.815 kA AF_TripTime 1.503 s AF_IncidentEnergy 78.14 Cal/cm² AF_Boundary 229.93 inches AF_PPE Class Dangerous!!! INCIDENT ENERGY WITH FAILURE OF MAIN BREAKER
---	---

Increase working distance

- Incident energy is inversely proportional to square of distance.
- Hence increasing working distance can increase safety immensely
- Distance can be increased by;
- ❖ Using remote operated racking, remote operated breaker closing and opening and using extension tools and hot sticks.



Reduced relay settings during hot work

- Temporarily reduce relay settings during hot work. (Instantaneous settings just above peak demand)
- Least expensive solution
- Numerical relays can have two programs ; one for normal operation and another for Hot Work
- SCADA control can also implement this program.

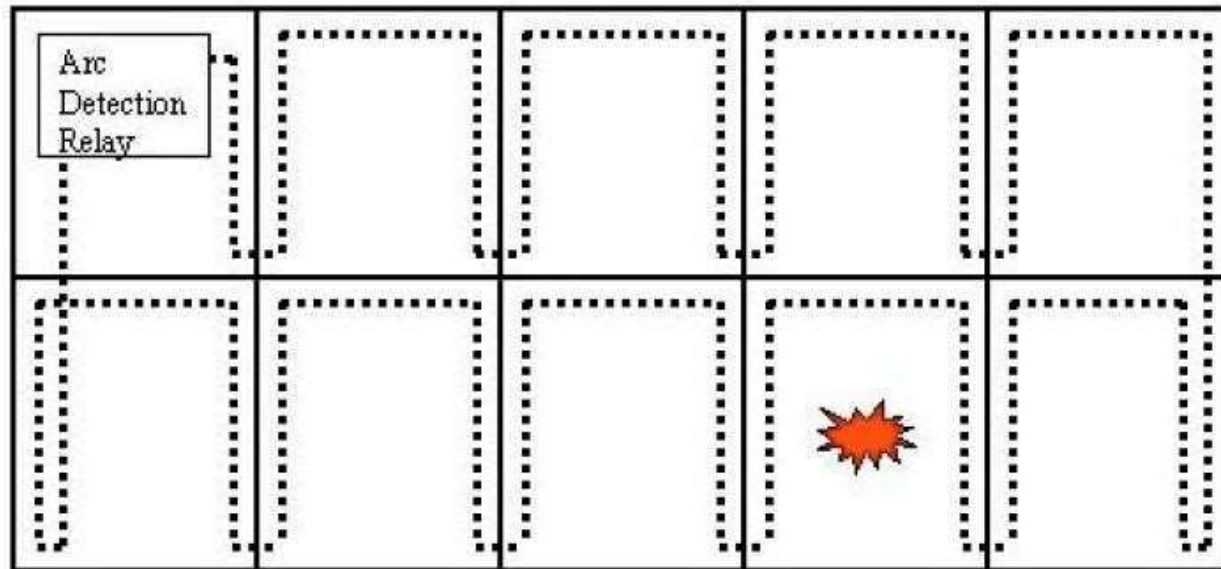
Arc Detection devices

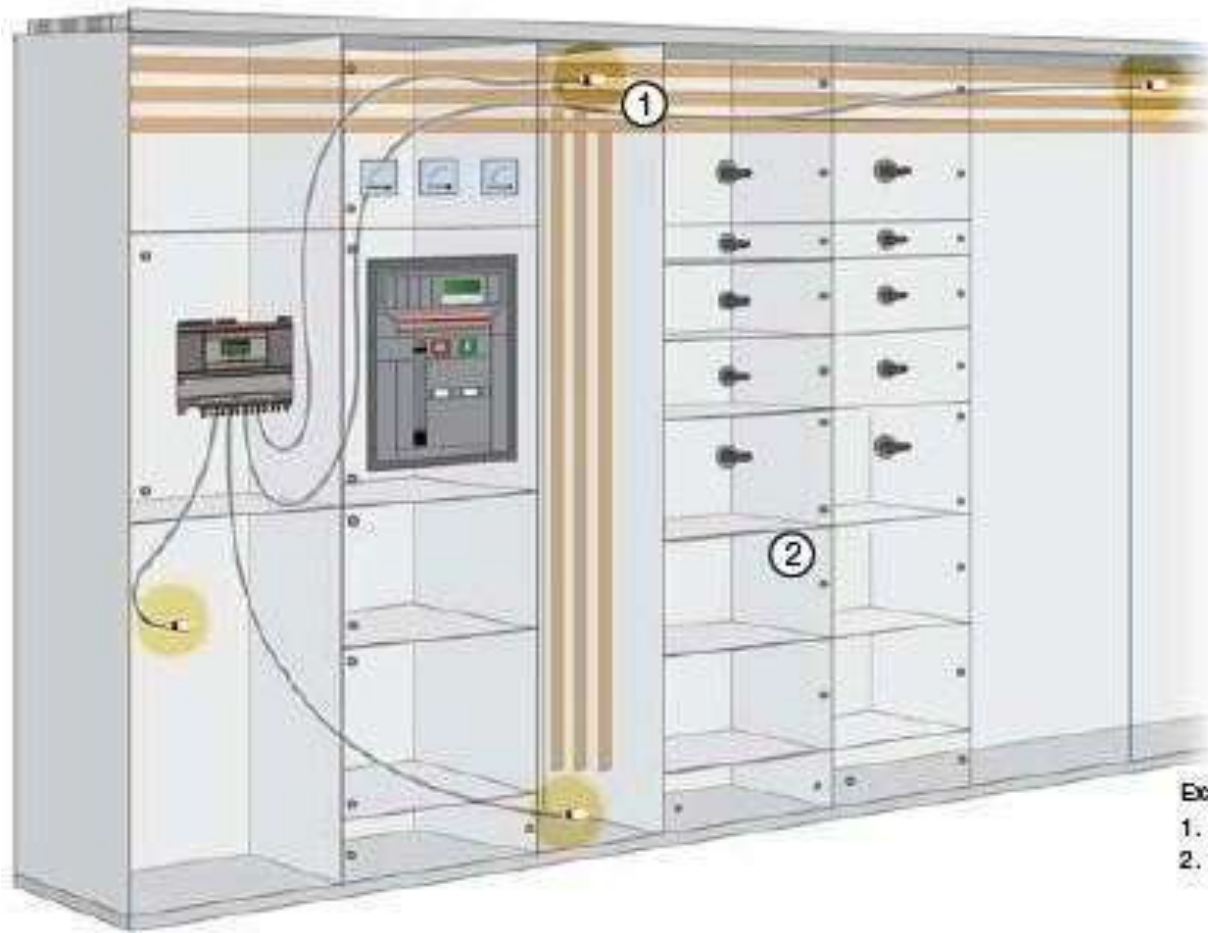
Principle

- ✓ Arc results in very bright light flash whose intensity is much higher than sun light or any other illumination used.
- ✓ Optical sensors, based upon sudden increase in intensity of light, sense beginning of arc flash and give signal to trip coil of breaker.
- ✓ To protect a zone optical fiber cable without outer sheath is run throughout the protected zone.
- ✓ Optical sensor can send signal within 2.5 msec. of start of the flash.

Optical Fiber Cable Routing

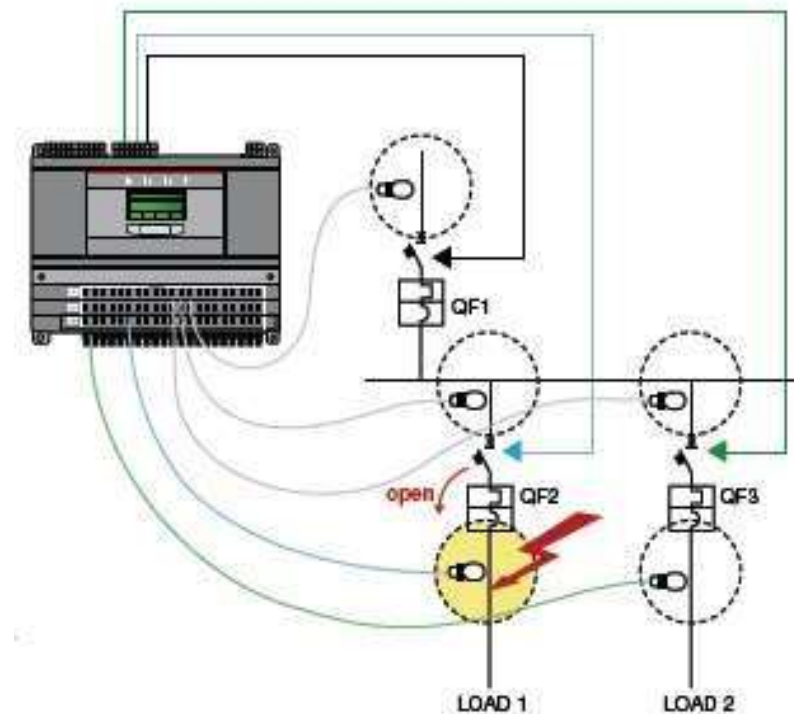
Arc-flash relays are microprocessor-based devices that use optical sensors to detect the onset of a **flash**. ... Installing an **arc-flash relay** to rapidly detect developing **arc** flashes greatly reduces the total clearing time and the amount of energy released through an arcing **fault**.





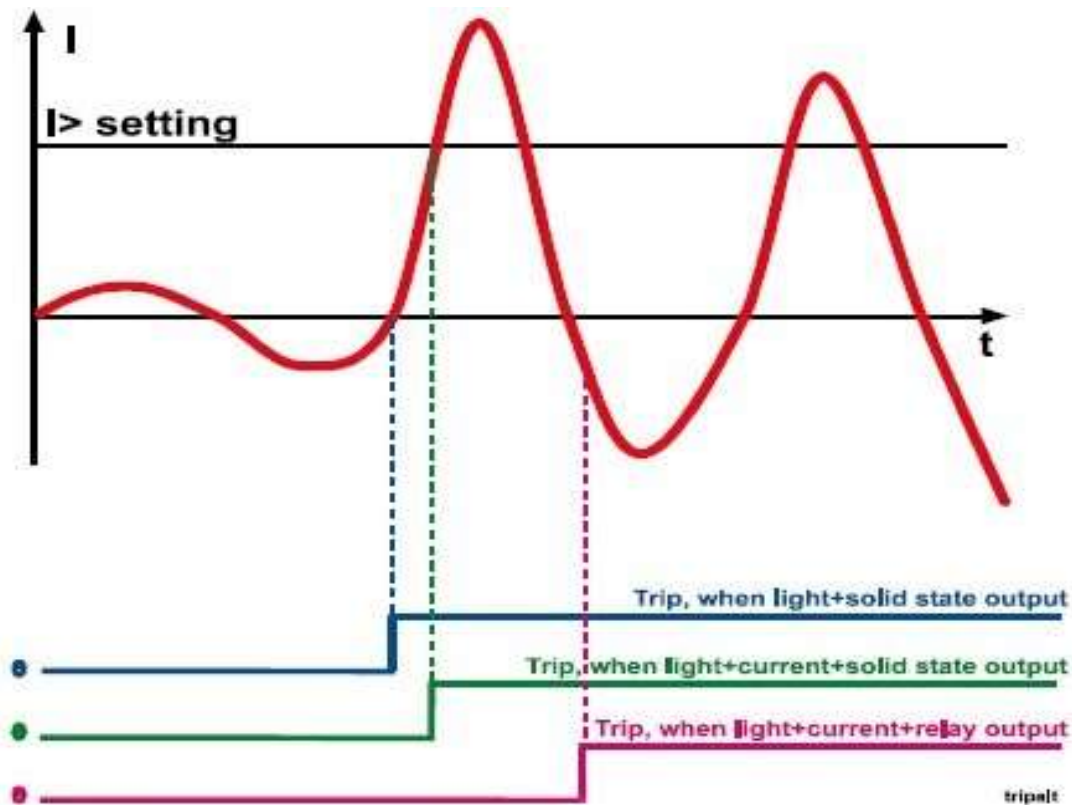
Example showing the position of detectors in:
1. Horizontal and vertical bus bar system
2. Circuit-breaker cubicle

ABB TVOC2 Arc Guard

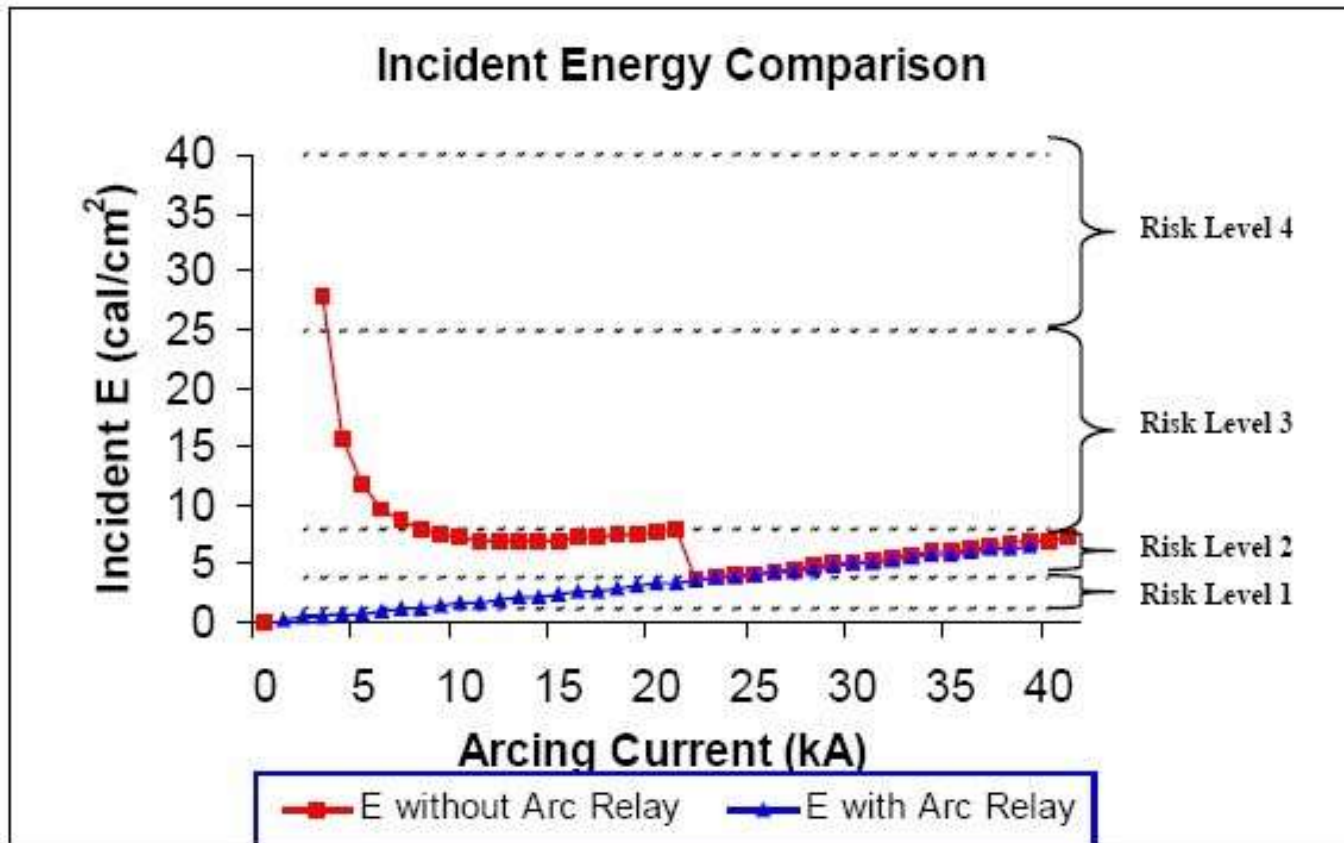


QF1 and QF3 closed: LOAD 2 **supplied**
QF2 opened

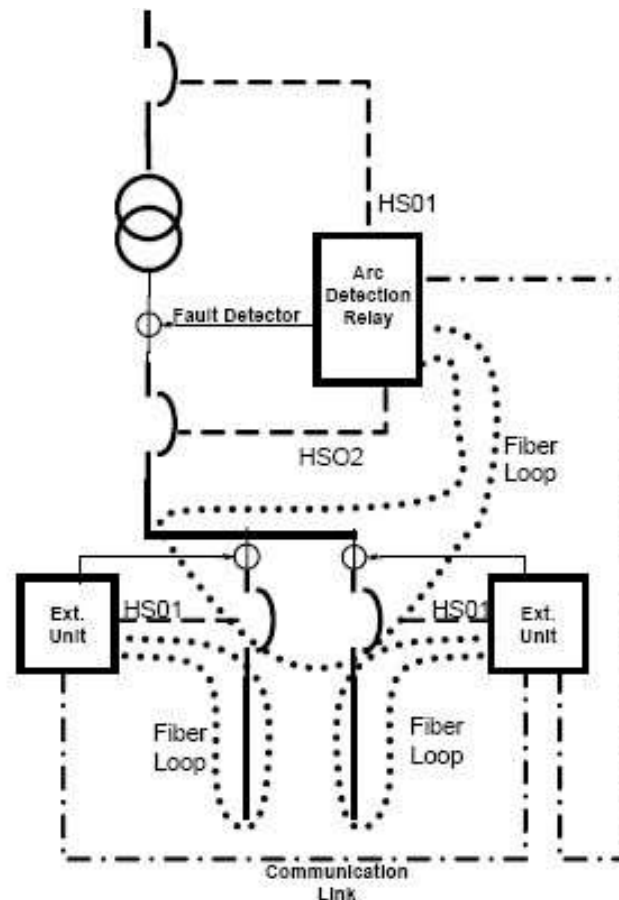
Tripping time comparison



Incident energy reduction



Arc Detection relay covering a zone



Simple Steps in reducing Arc Flash Hazard

- Increase working distance through longer handle tools, hot sticks, remotely operated, motorized operation.
- Infrared ports for scanning.
- Change work location e.g. primary side of transformer.
- Ensure power on LED lights are all working.

Electrical Safety

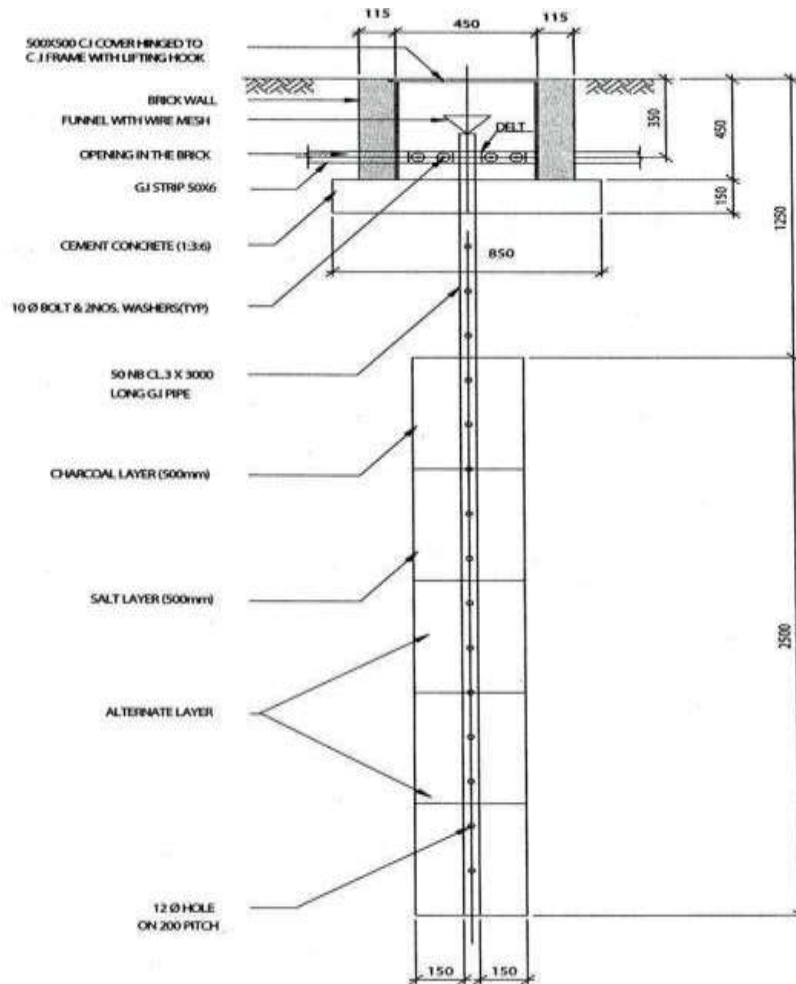
Earthing
A Zero Potential surface

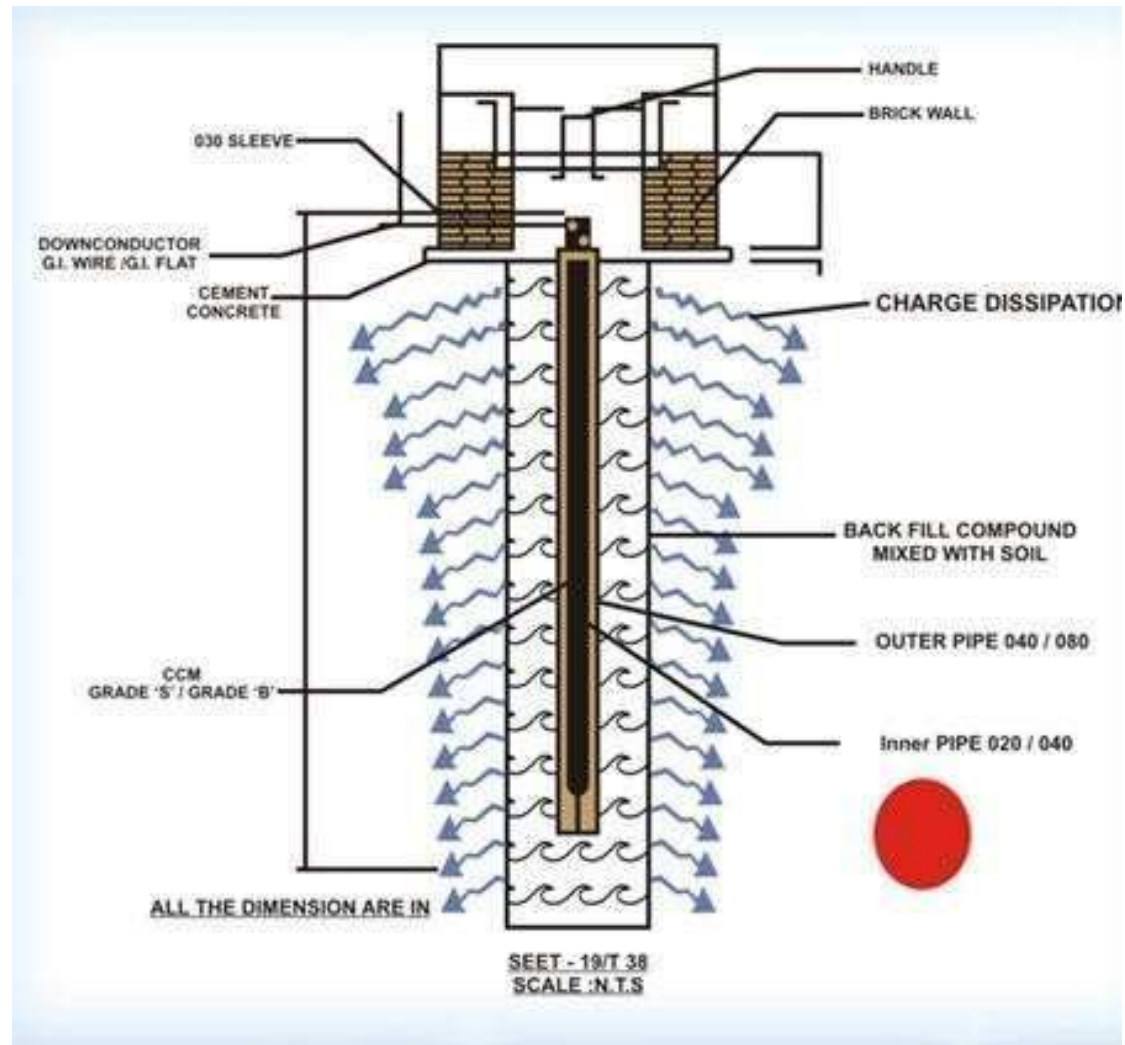
Reasons for earthing

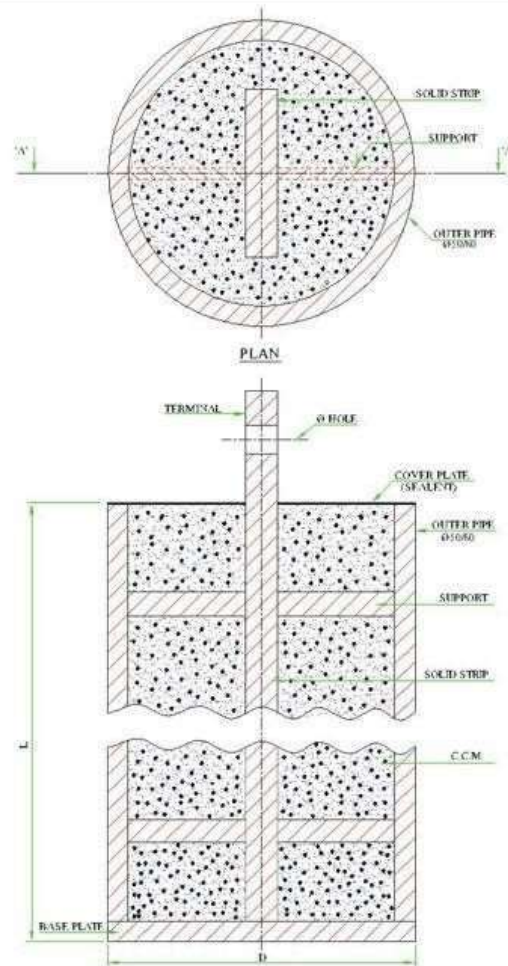
- To create a reference voltage
- To create a safe zero potential surface.
- To create a return path for neutral currents
- To reduce transients
- To reduce harmonics

Earthing Pit

- Earth surface has high resistance and therefore we have to create a pit which maintains low resistance bonding with earth and brings out a low resistance connection which can be distributed.
- Neutral has to be earthed either directly or through grounding resistors to create reference voltage other wise lines can assume very high voltages which can be a serious safety threat.







NOTE:
1. NOT TO SCALE

J.M.V. EARTHING ELECTRODE
SECTION VIEW FROM A-A

Earthing in hard rock area

- Possible options
- Locate earthing near a surface or deep-water body and connect earthing mat to it.
- Bore through granite up to underground water body and sink metal plates into it and connect earthing mat to it.
- Chemically treat soil to increase conductivity.

Requirements from earthing

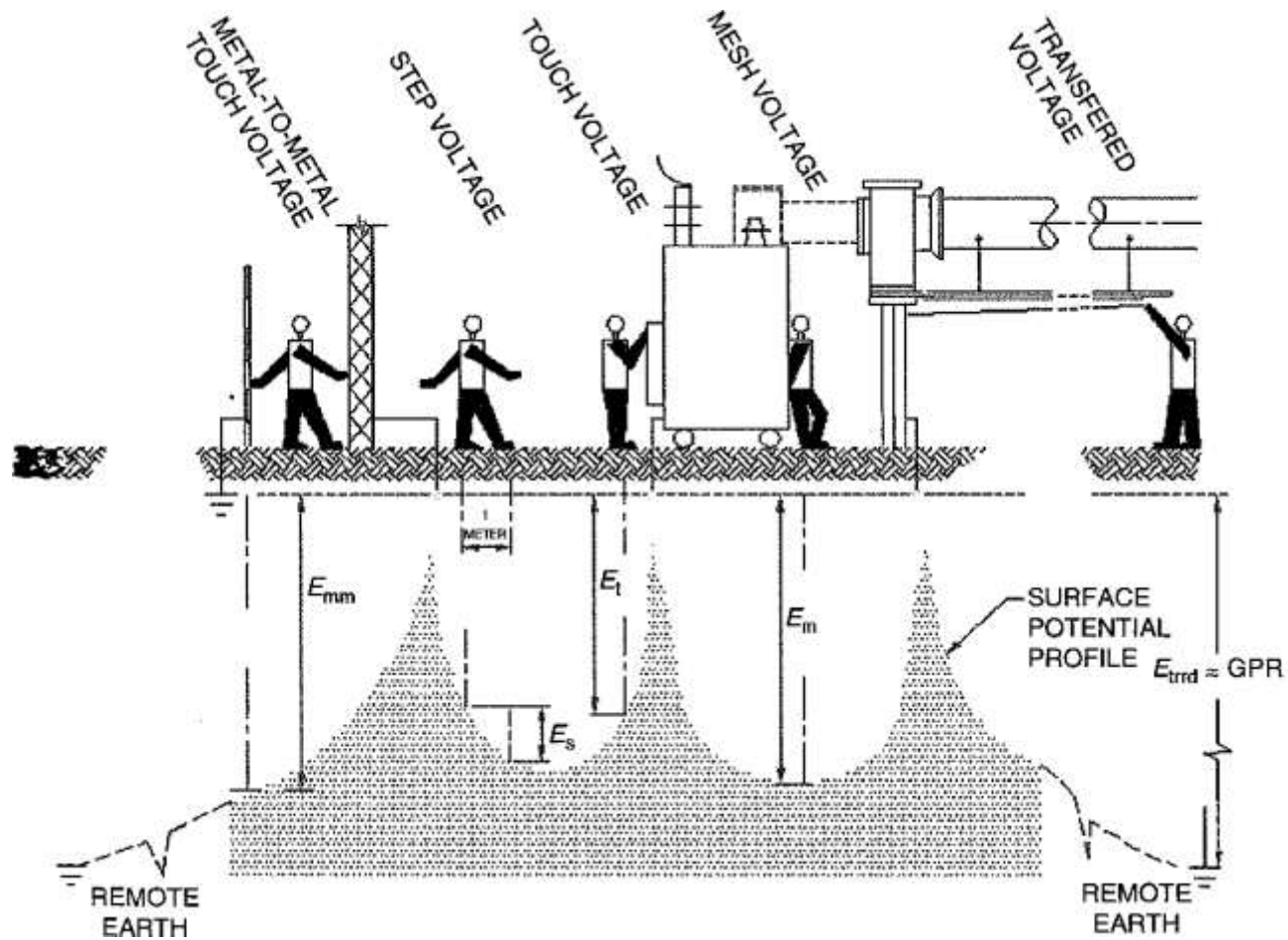
- For substations and industrial users, recommended earthing resistance should be between 0.1 ~ 1.0ohms
- If resistance is higher, saline water should be added to the pit.
- Many pits should be connected together to create a low resistance path for large short circuit current without creating large voltage drop
- Every motor, panel and switchgear's body should be earthed at two places.
- Neutral of generators and Transformers should be connected to two earthing pit which are independent of body earthing pits.

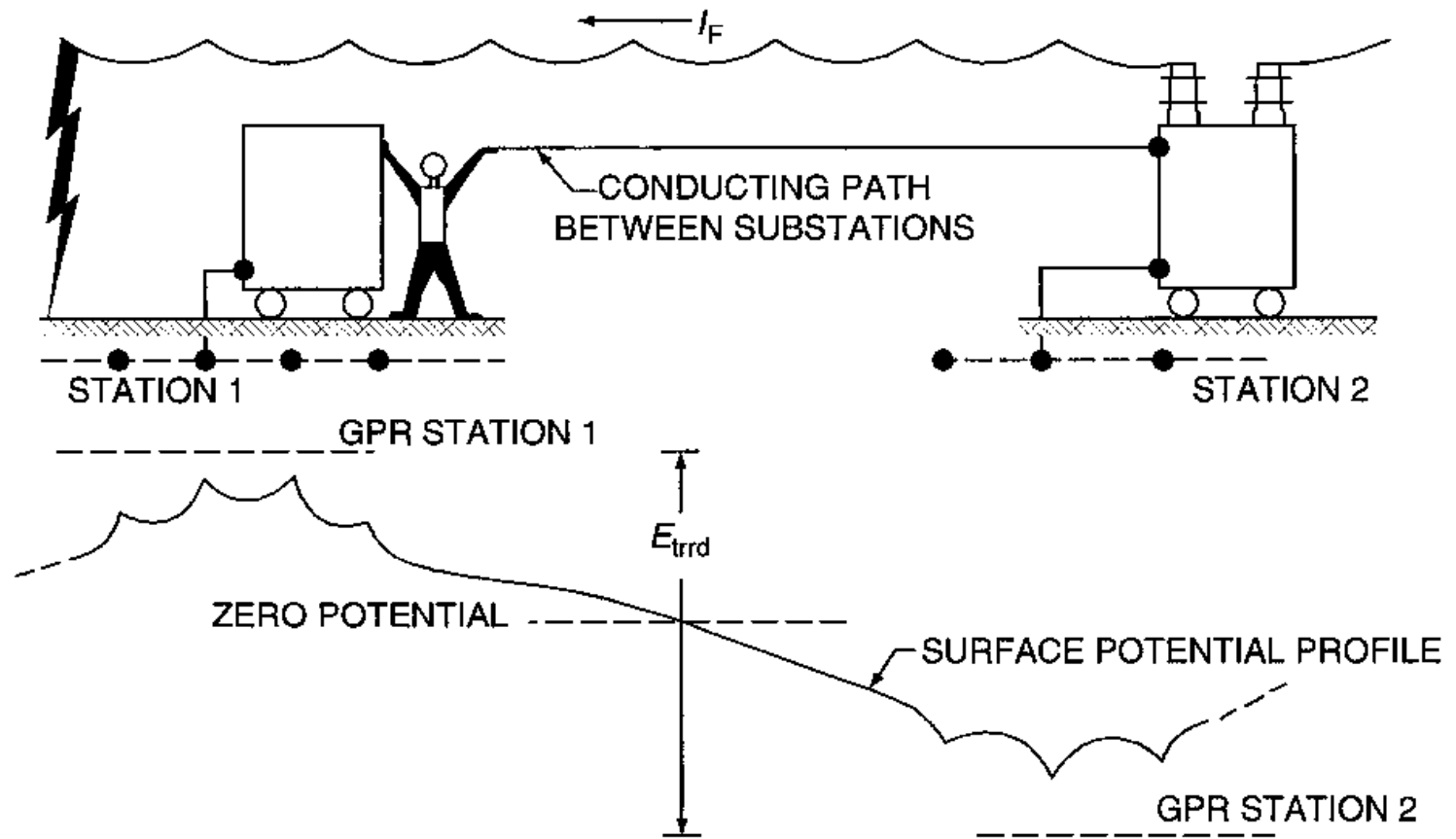
Some important notes

- Water pipes should not be used for earthing
- Lead sheathing and armor of cables should be earthed.
- Wherever RCC poles are used as in substations, Four poles can be tied with earthing strip and then connected to earthing pit.
- Earthing electrode should not get corroded. GI or tinned copper is preferred. Aluminum can be used above ground connections

Substation Shock Hazard

- ✓ **Metal to metal touch voltage.** A situation when two metal structure within substation are simultaneously in contact with body.
- ✓ **Step voltage.** Difference in ground surface potential experienced by a person bridging 1 m gap with his feet without contacting any other earthed object.
- ✓ **Touch voltage.** Voltage difference between earthed object which a person is touching and ground on which a person is standing during earth fault condition.
- ✓ **Mesh voltage.** The maximum touch voltage with in a mesh of the ground grid.
- ✓ **Transferred voltage.** A special case of touch voltage where a voltage is transferred into or out of a substation from or to a remote point outside.





Substation Earthing

Criteria

1. Low resistance
2. Low Steppotential
3. Low touchpotential

Recommended Earthing resistance values

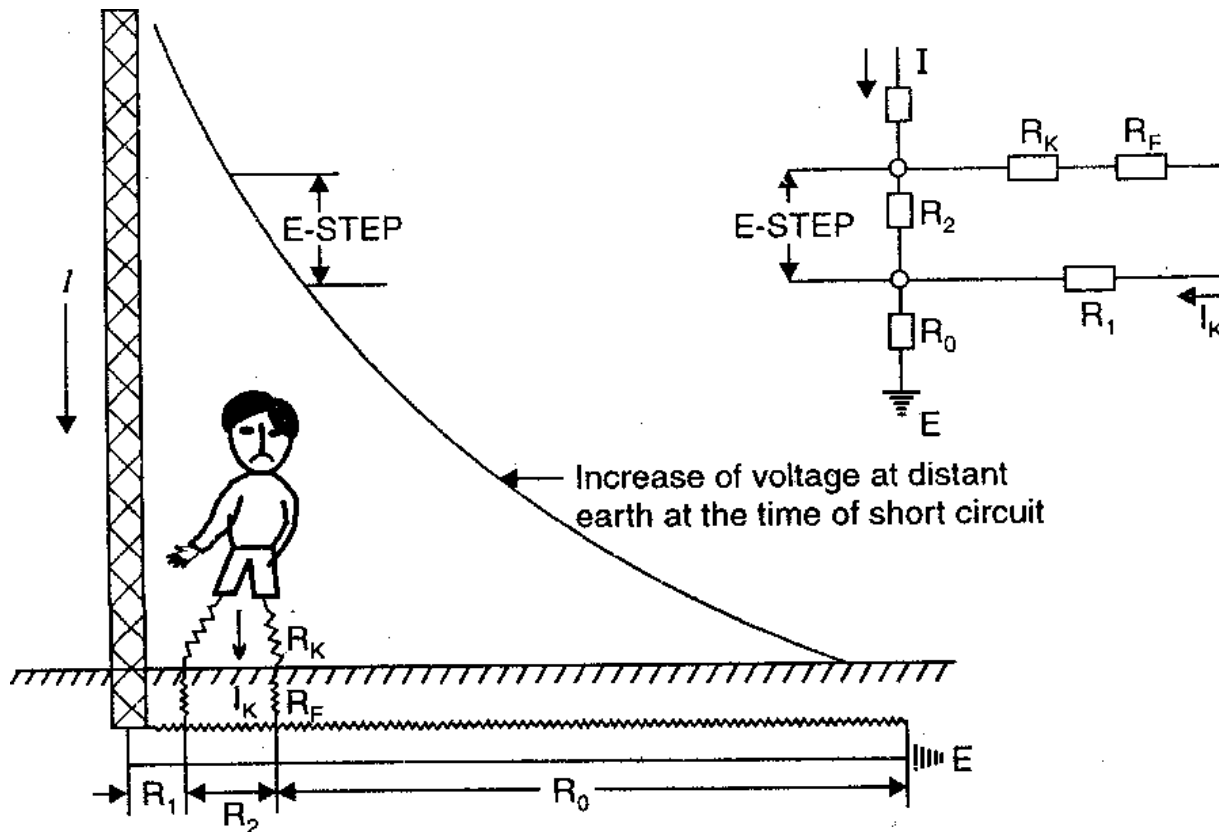
- EHV AC Installations <0.01 ohm
- HV installations >33 kV <0.5 ohm
- MV installation between 1~33kV <0.5 ohm
- LV Installation up to 1.0 kV <1~2 ohm
- Large Residential buildings < 2 ohms
- Individual residential bldg. < 4 ohm

Step and touch potentials are well understood as safety hazards in many situations involving energized power sources. What is not as well understood is that dangerous step and touch voltages can exist on non-energized lines because of electromagnetic coupling, and this is a daily danger for transmission line workers. Continuous monitoring is needed with alarms to warn when dangerous voltages are present.

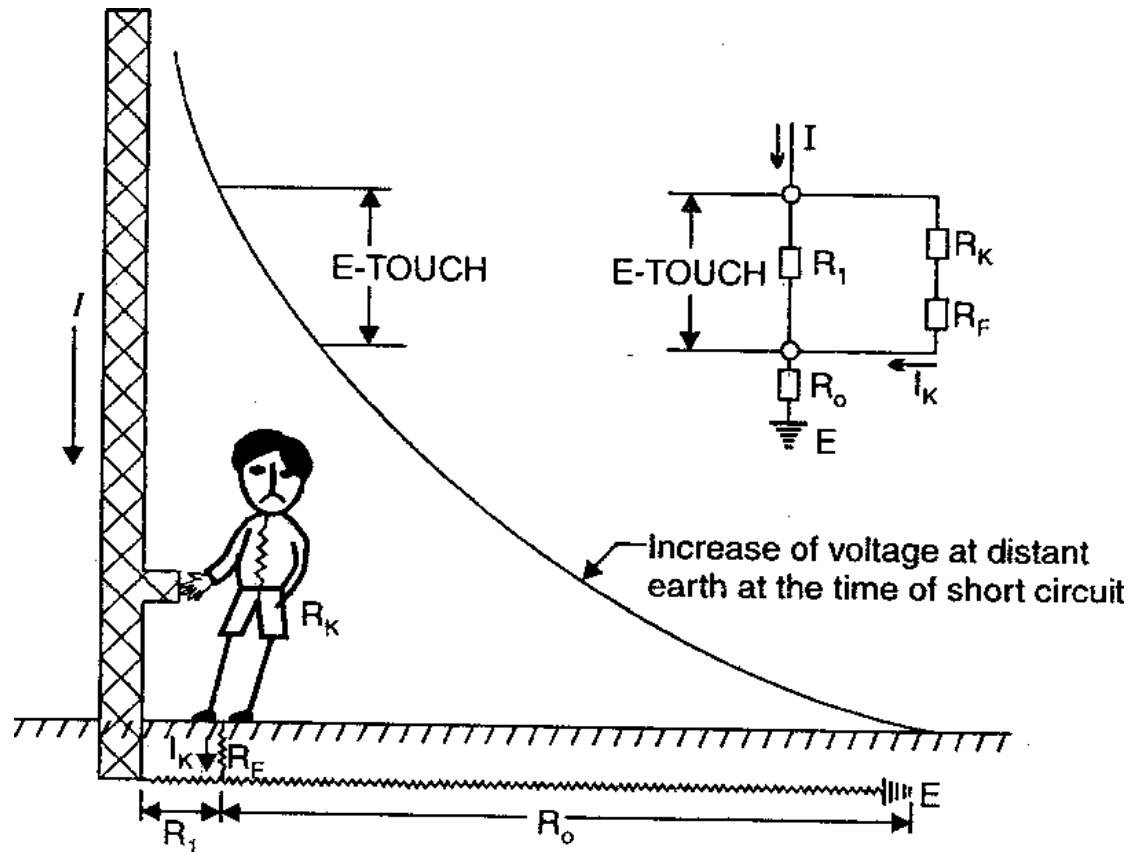
The Occupational Safety and Health Administration (OSHA) defines step potential as the voltage between the feet of a person standing near an energized grounded object. See Figure 1. It is equal to the difference in voltage between two points at different distances from the energized object. A person could be at risk of injury during a fault simply by standing near a grounded object that has an electrical charge.

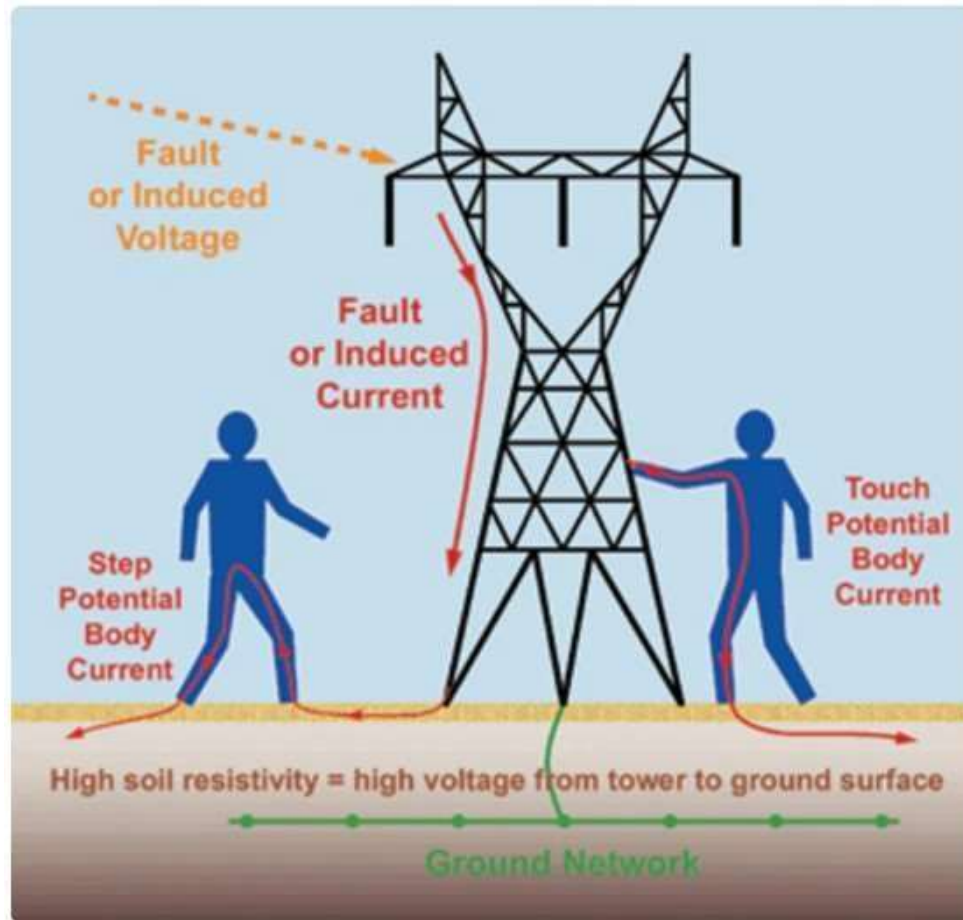
Touch potential is the voltage between an energized object and the feet of a person in contact with the object. It should be noted that touch potential could be nearly the full voltage across the grounded object if that object is grounded at a remote point from where the person is in contact with it. A crane that is grounded to the system neutral and contacts an energized line, for example, would expose any person in contact with the crane or its uninsulated load line to a touch potential nearly equal to the full line

Step potential hazard



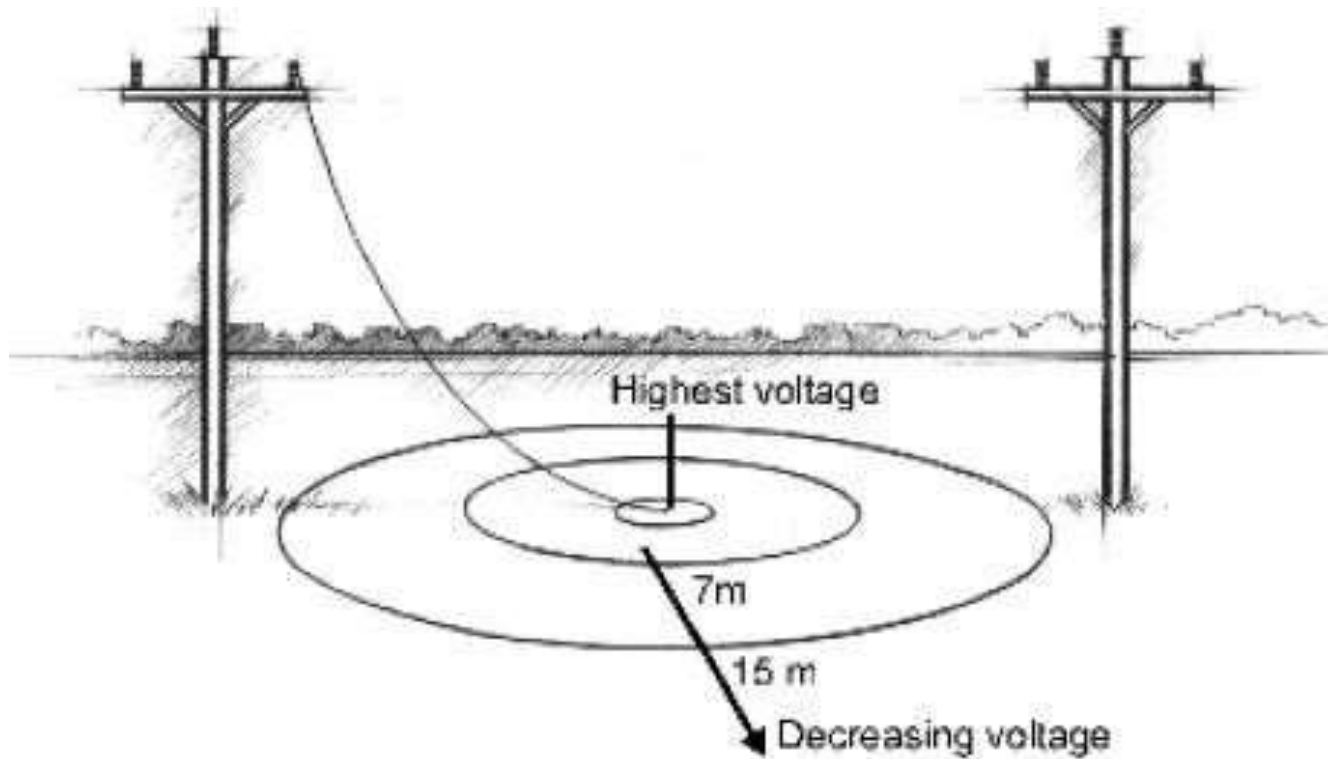
Touch Potential Hazard



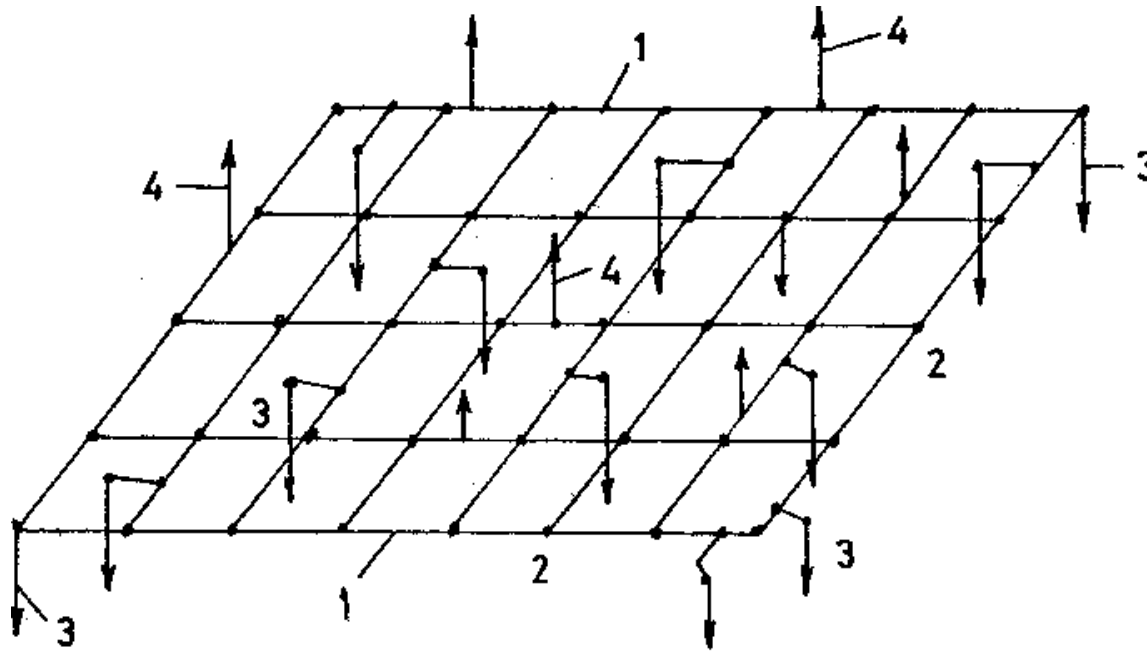


<https://www.youtube.com/hashtag/steppotential>

Step Potential Voltage Ring



Earthing mesh



- | | |
|-------------------------------|--------------------|
| 1. Horizontal earthing rods | 2. Welded joint |
| 3. Vertical electrodes/spikes | 4. Vertical risers |

Three-dimensional view of the Earthing System.

Earthing Grid resistance

$$R_g = \rho \left[\frac{1}{L_T} + \left\{ \frac{1}{S_q \cdot R_t \cdot (20A)} \right\} \left\{ 1 + \frac{1}{(1+1/h * S_q \cdot R_t \cdot (20/A))} \right\} \right]$$

Where ;

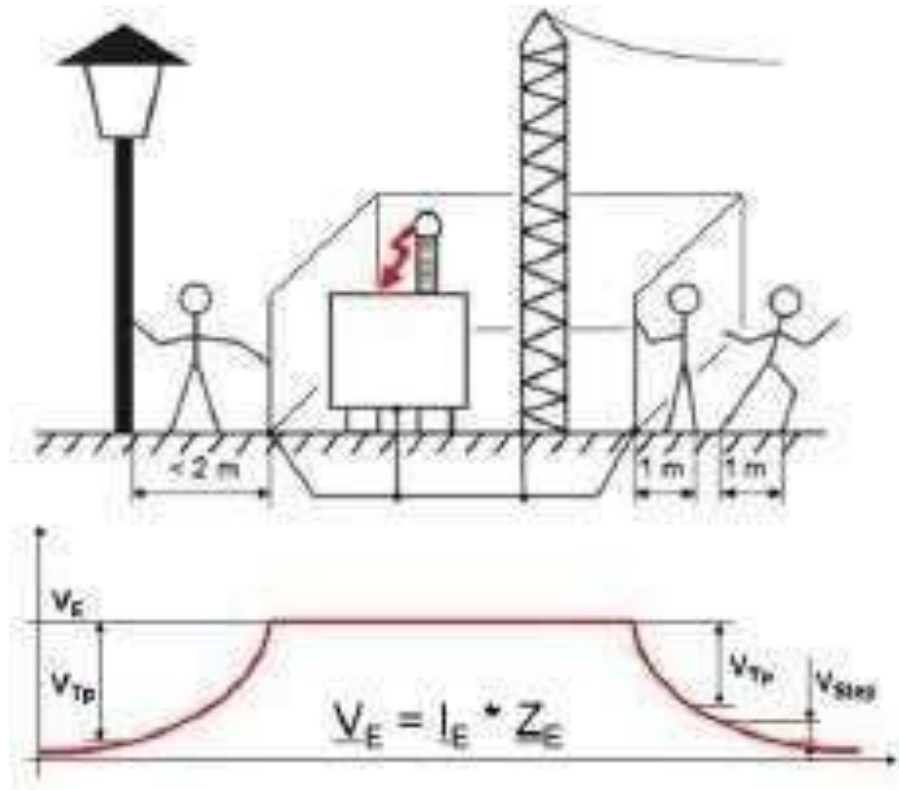
R_g = Substation ground resistance, Ω

ρ = Soil resistivity , $\Omega \cdot m$

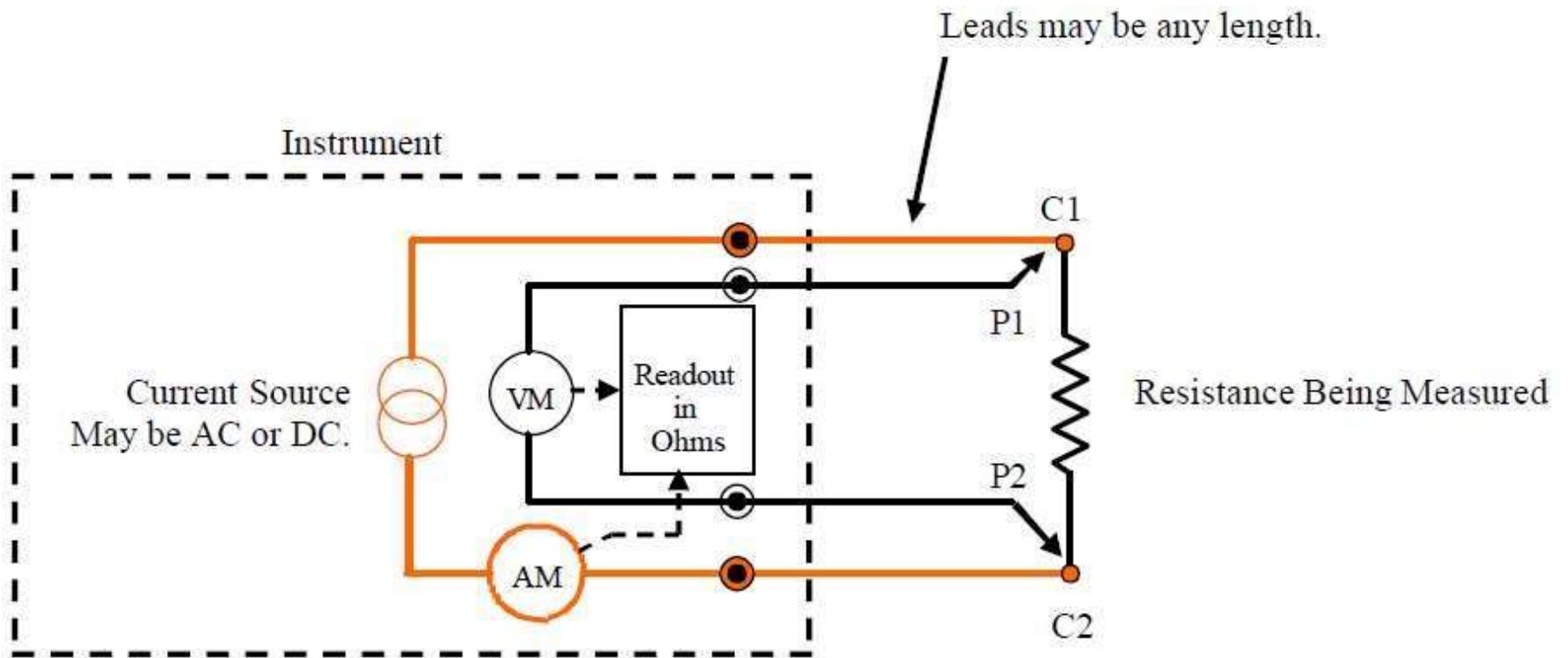
L_T = Total buried length of conductors, m A = Area occupied by ground grid , m^2

H = Depth of grid, m

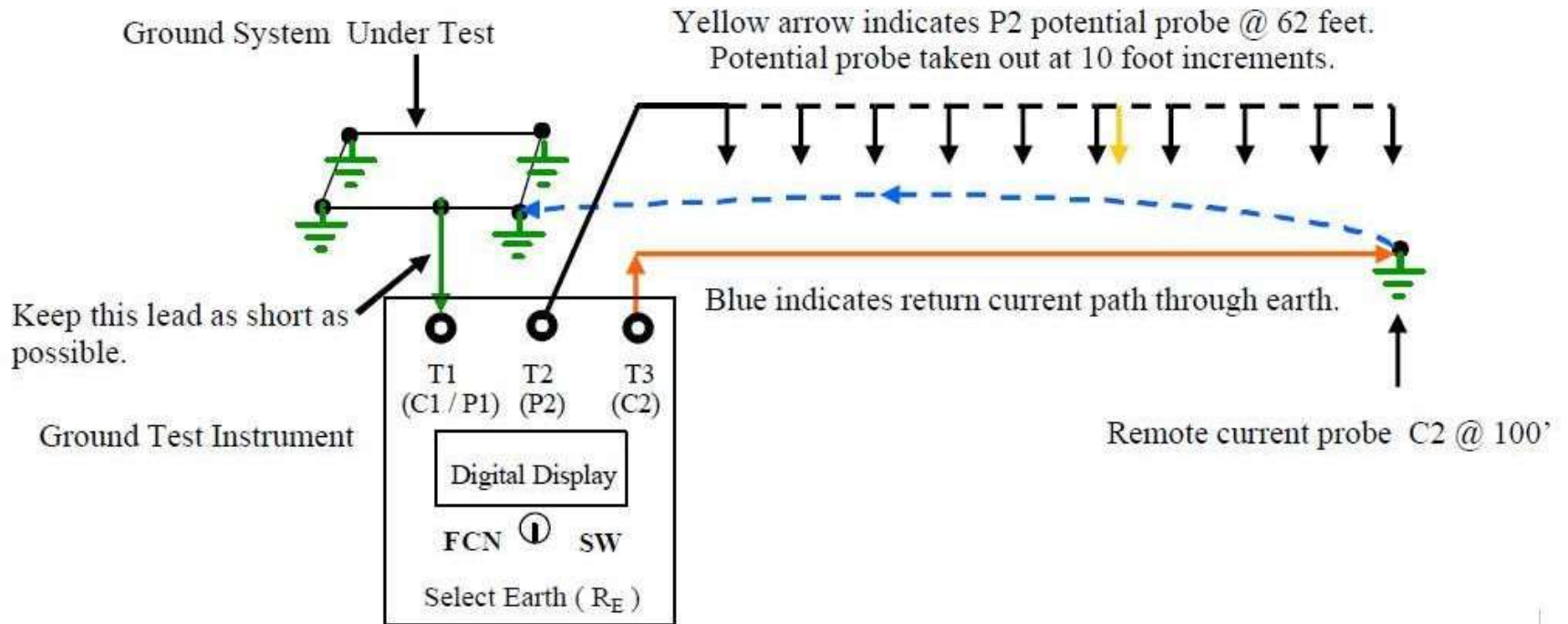
Voltage gradient around substation under earth fault condition



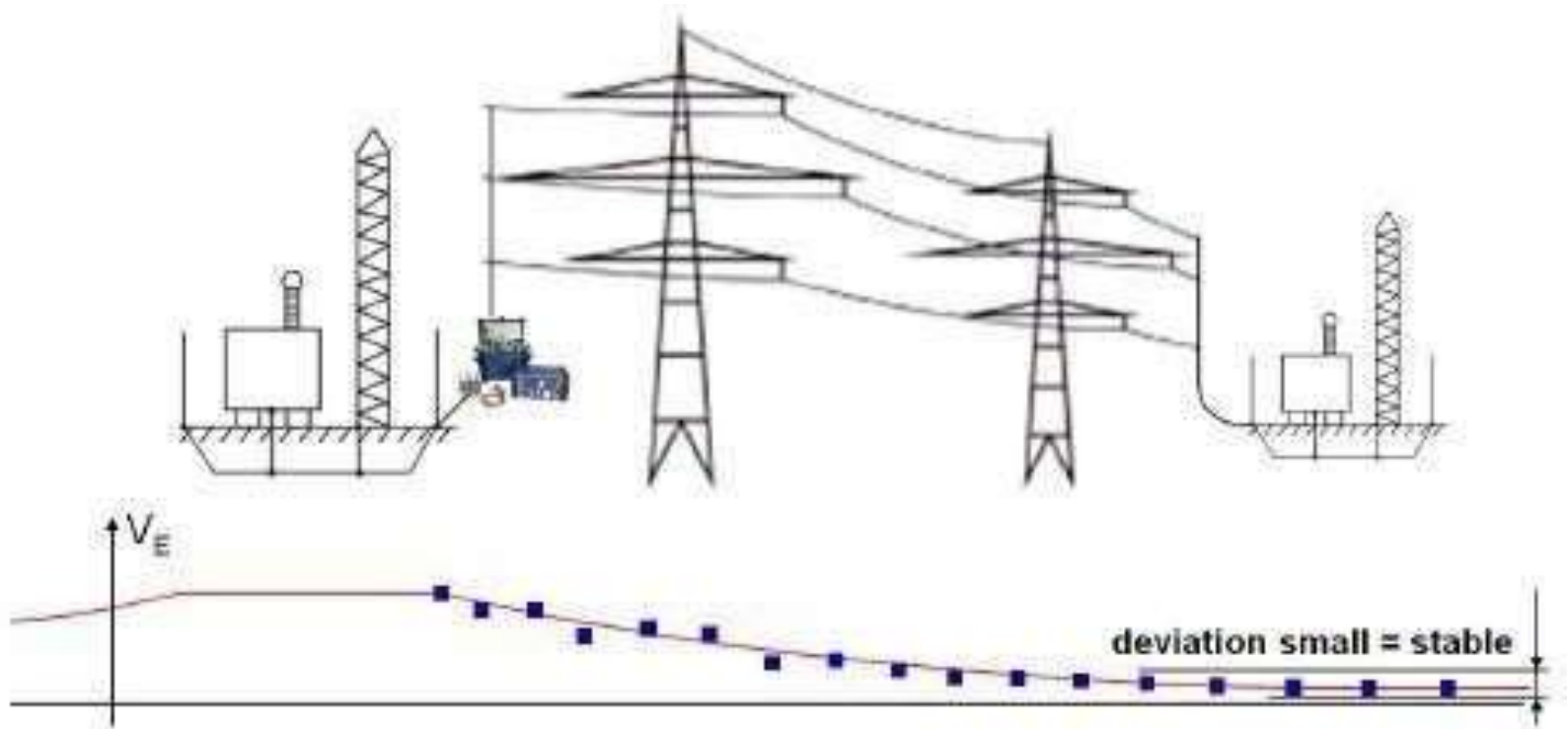
Four-Point Measurement Diagram







Earthing resistance testing



Earthing connections(IEC 60364)

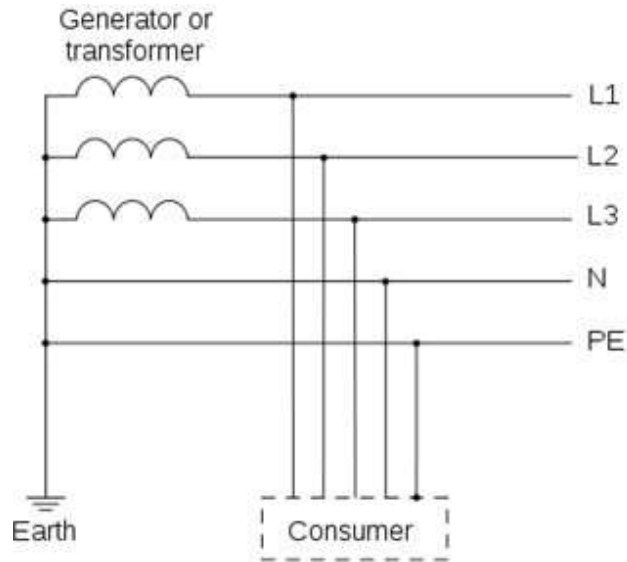
Three types

- TN- Transformer or generator neutral is earthed and body (PE) is separately earthed. Transformer neutral and PE is brought to the consumer point.

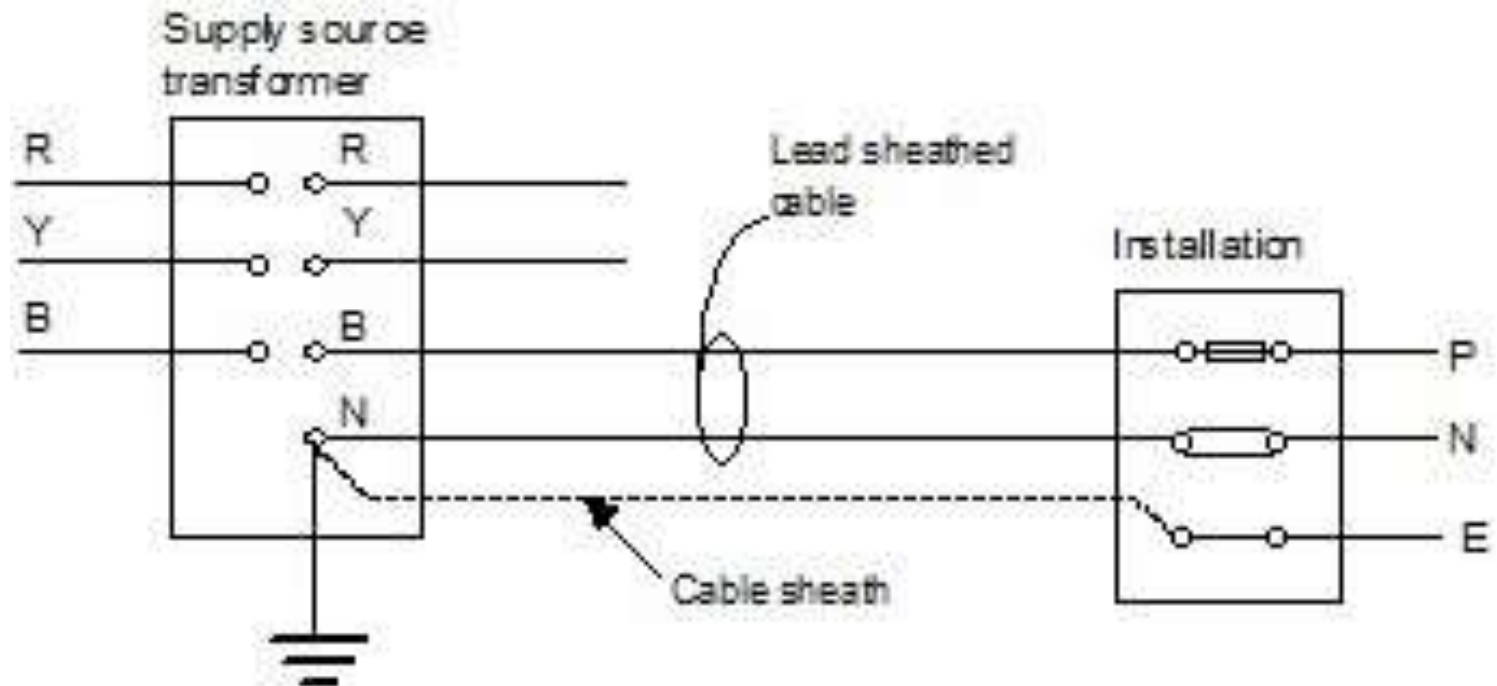
There are three variants of TN viz. TN-S, TN-C and TN- C-S

- TT. Earth connection from transformer is not brought up to consumer. Consumer is earthed directly at site.
- IT. Transformer is not earthed.

Earthing connections

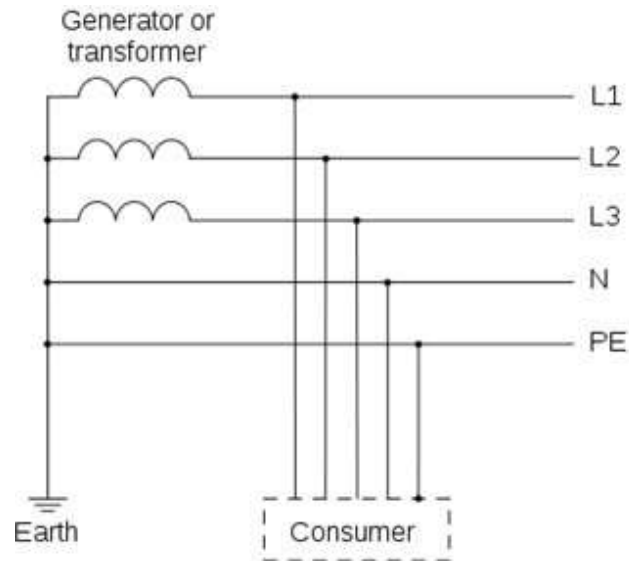


- TN-S Earthing
- PE (Protective Earthing) and N are separate conductors are connected only near power source. They are not connected outside the powersource.



TN-S SYSTEM

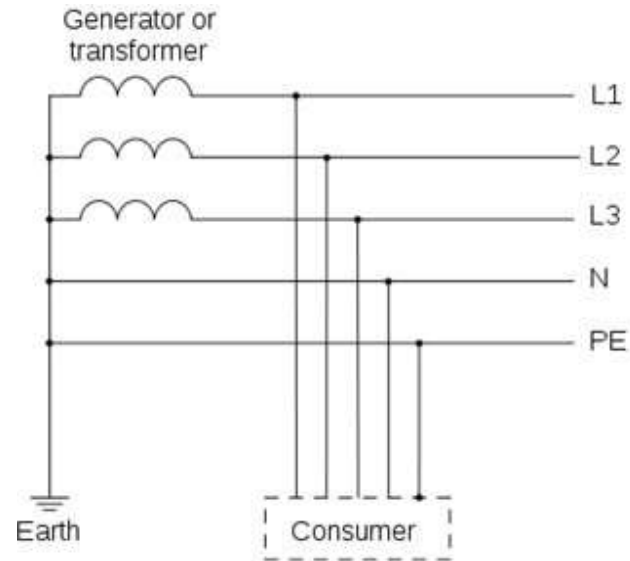
Earthing connections

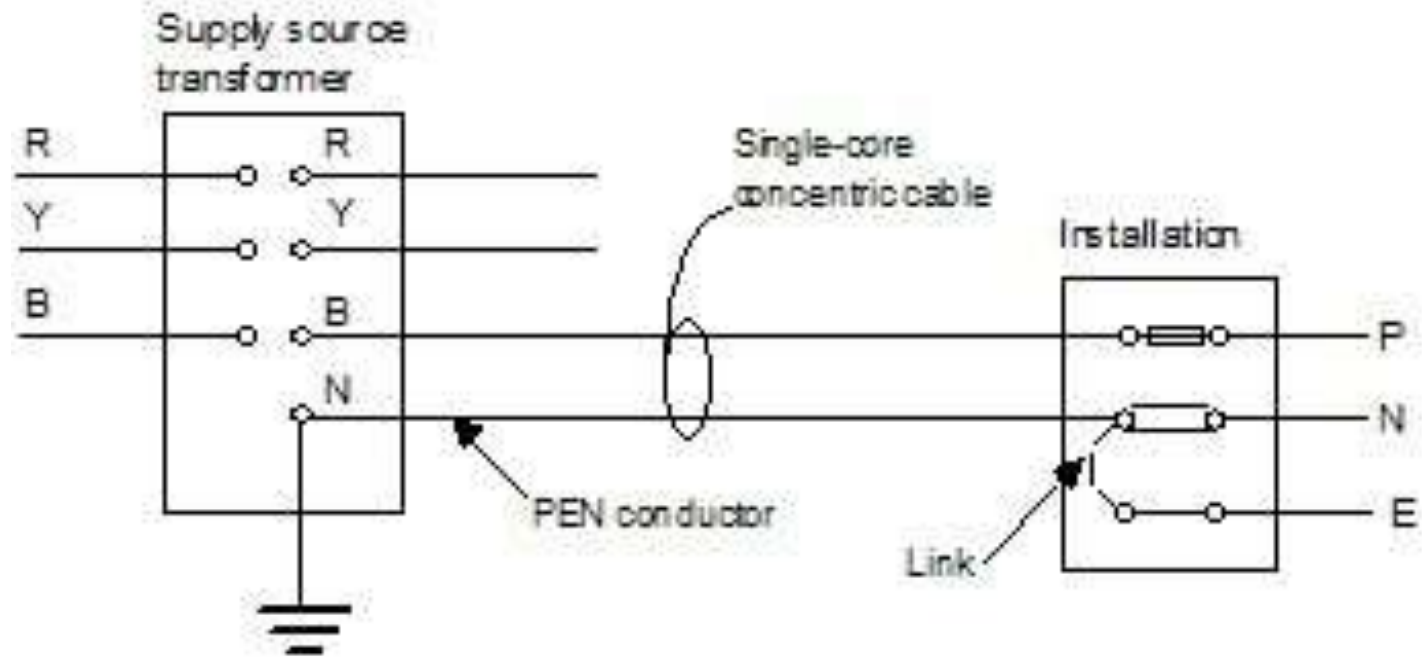


- TN-C Connection
- Combined PE & N connection all the way from transformer to consumer.

Earthing connections

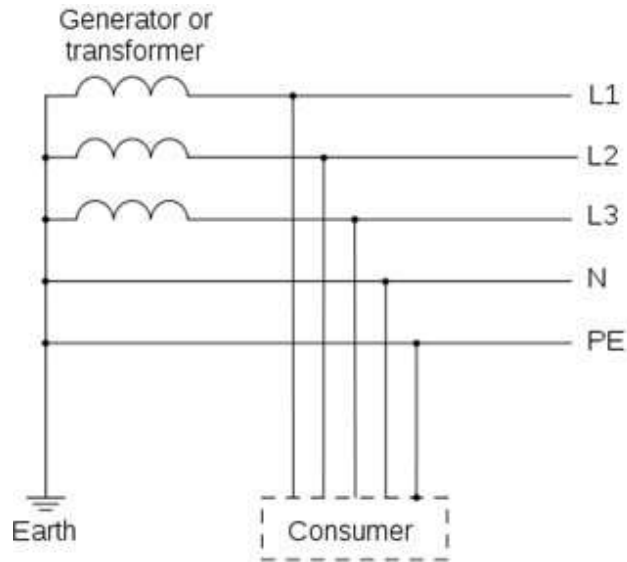
- TN-CS Earthing
- Combined PEN conductors from transformer to consumer distribution point and
- Separate PE & N conductors in indoor wiring and flexible electrical cords
- Also called PME (Protective Multiple earthing)



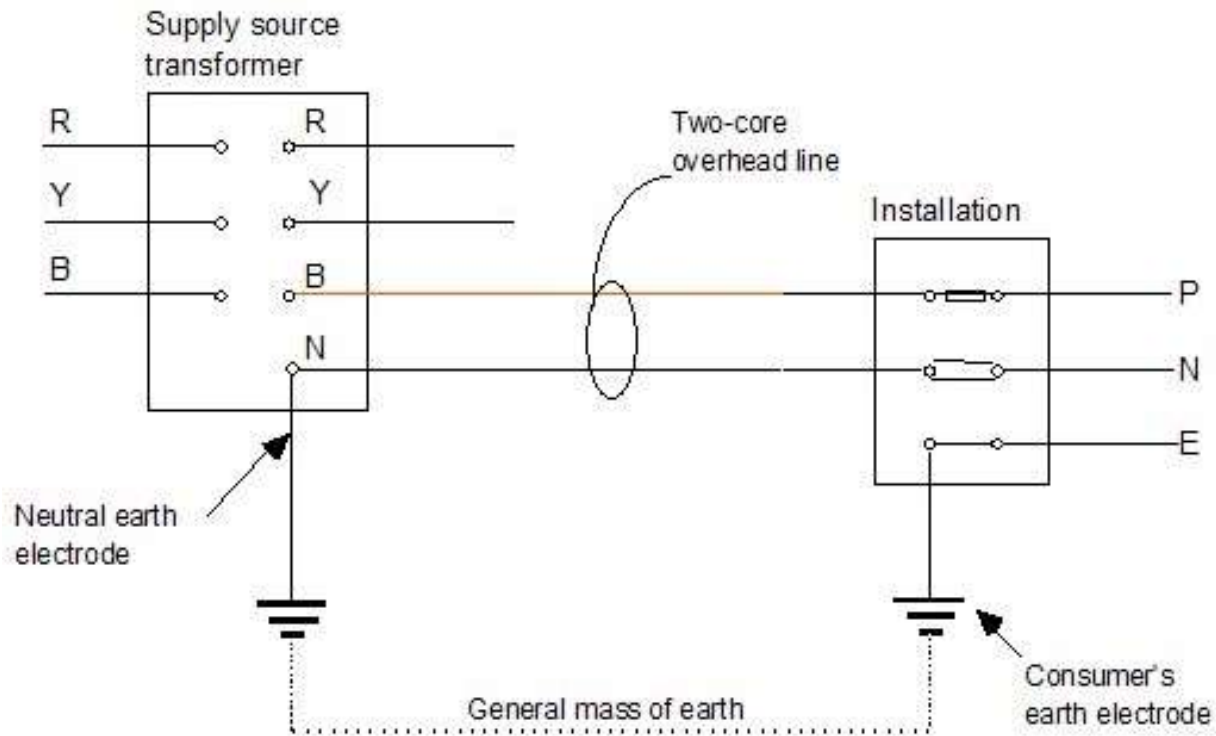


TN-C-S SYSTEM

Earthing connections



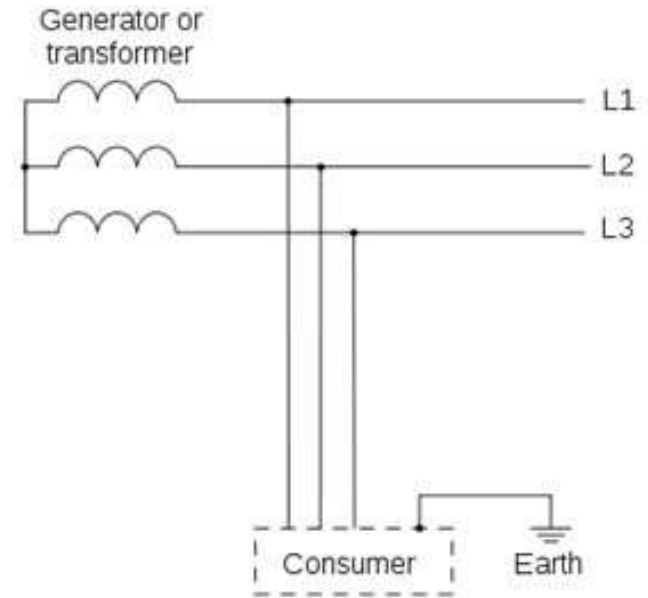
- TT earthing
- PE is provided at the consumer end independent of any connection at the transformer
- Has low noise and is preferred for electronic and tele-communication equipment.
- Usually works with RCD



IT SYSTEM

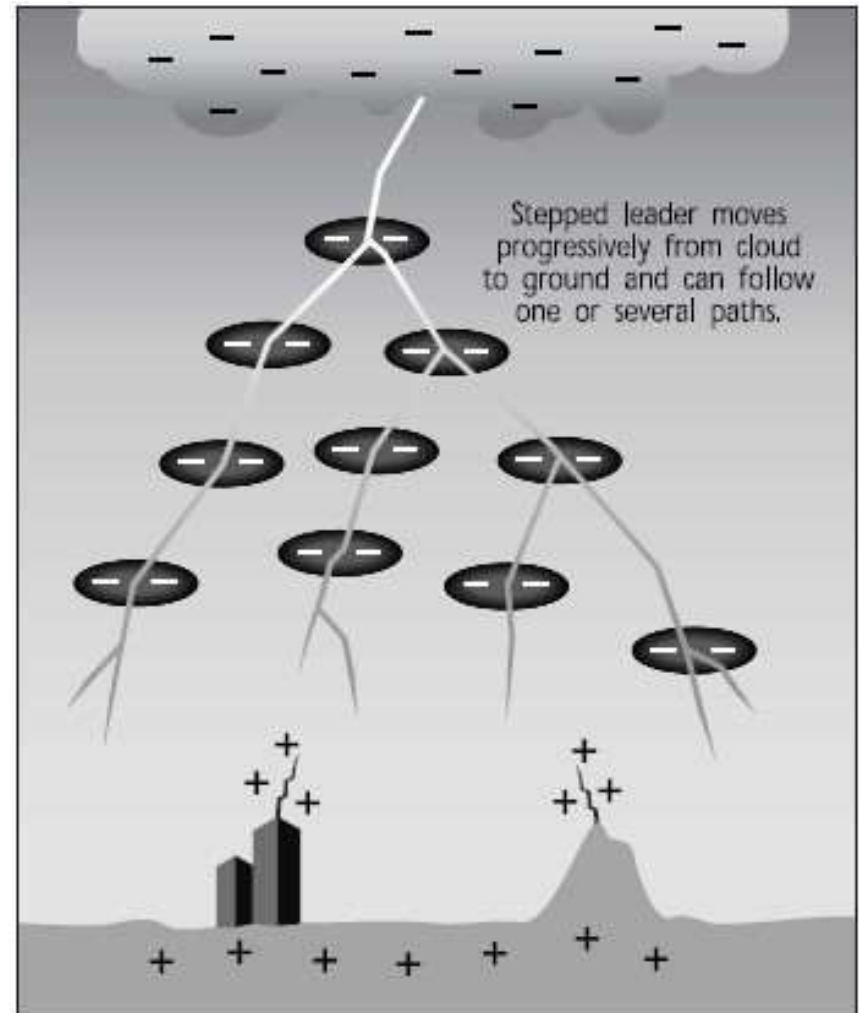
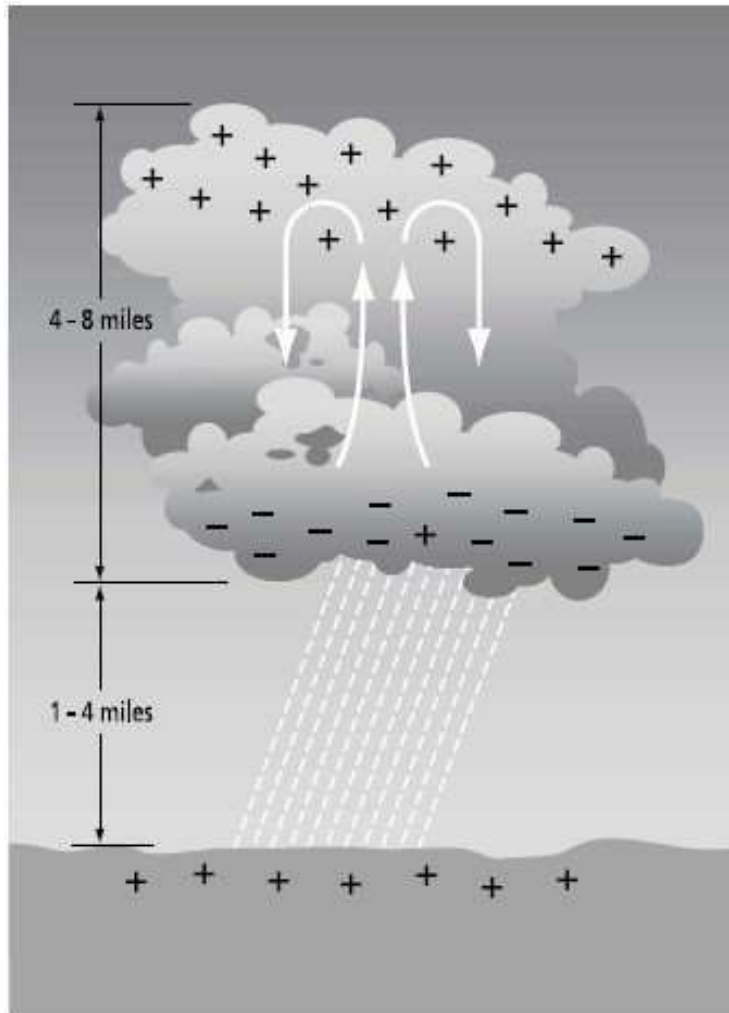
Earthing connections

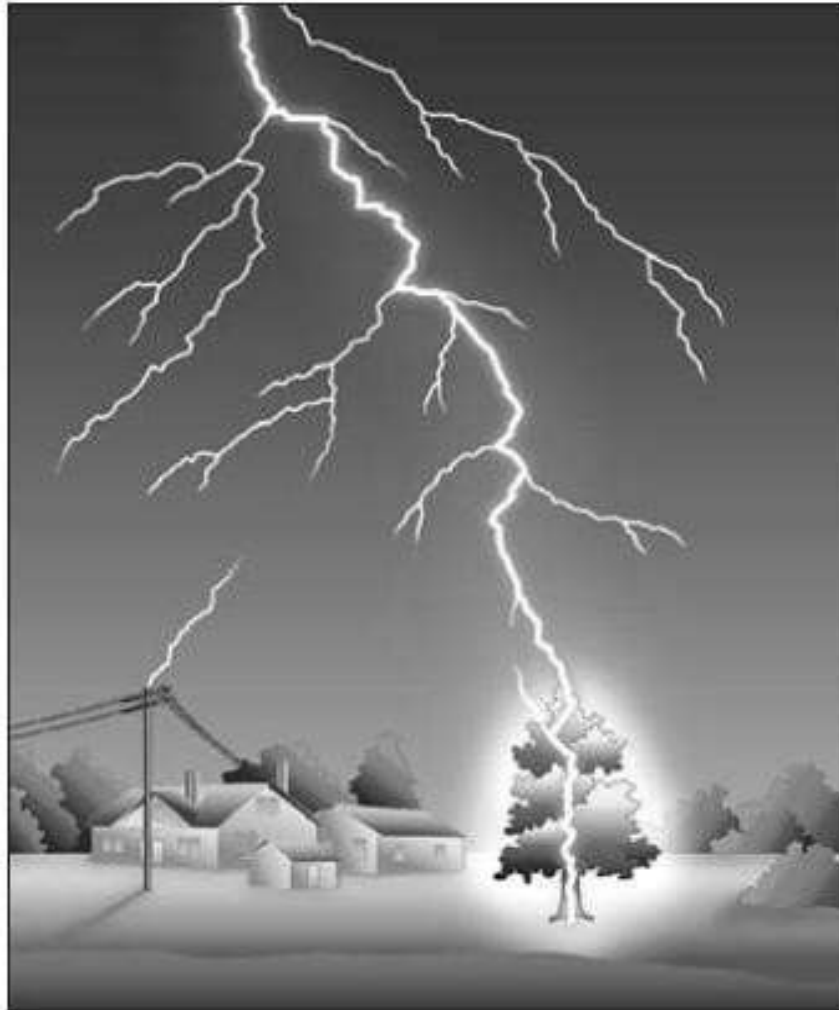
- IT Earthing
- No earthing is provided at all (Or high impedance earthing) on the distribution side.
- Consumer provides earthing at site.
- Insulation monitoring device is needed to monitor impedance.



Electrical Safety

Lighting Protection

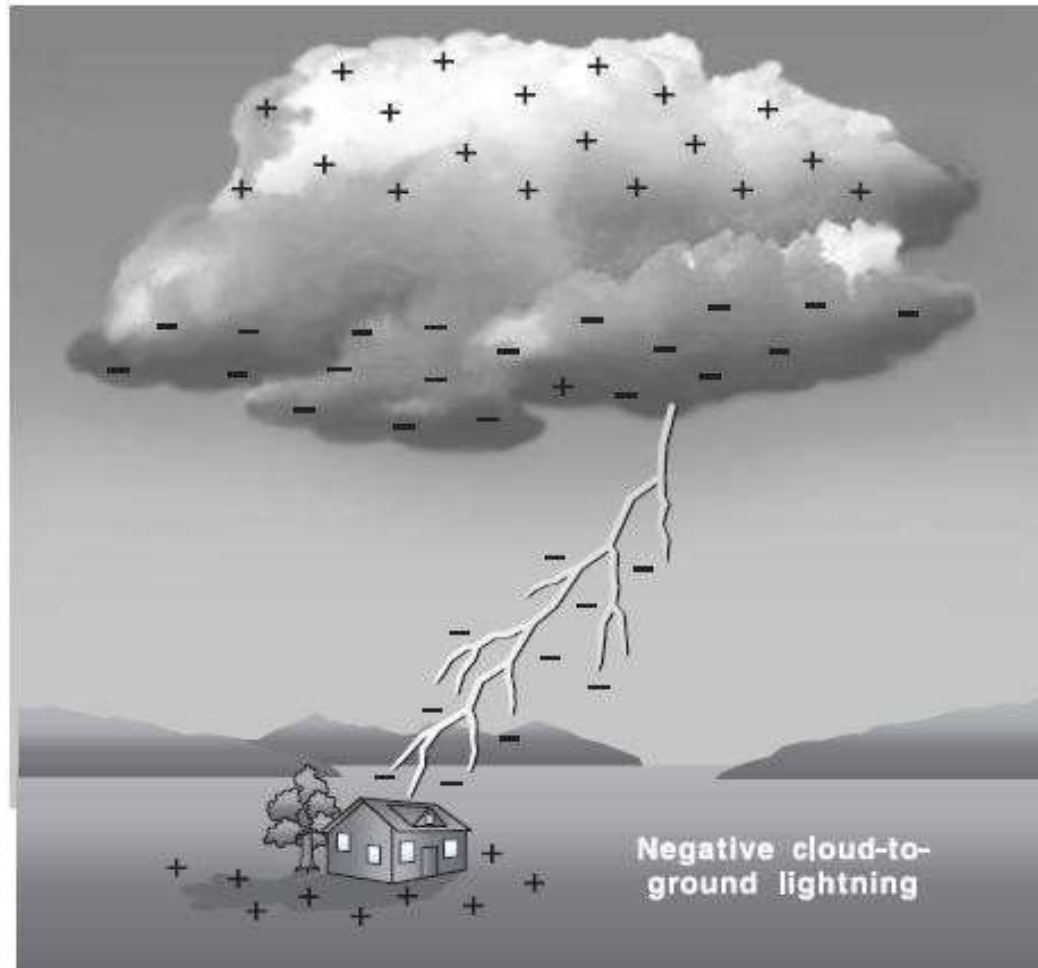




Negatively charged strike

Properties

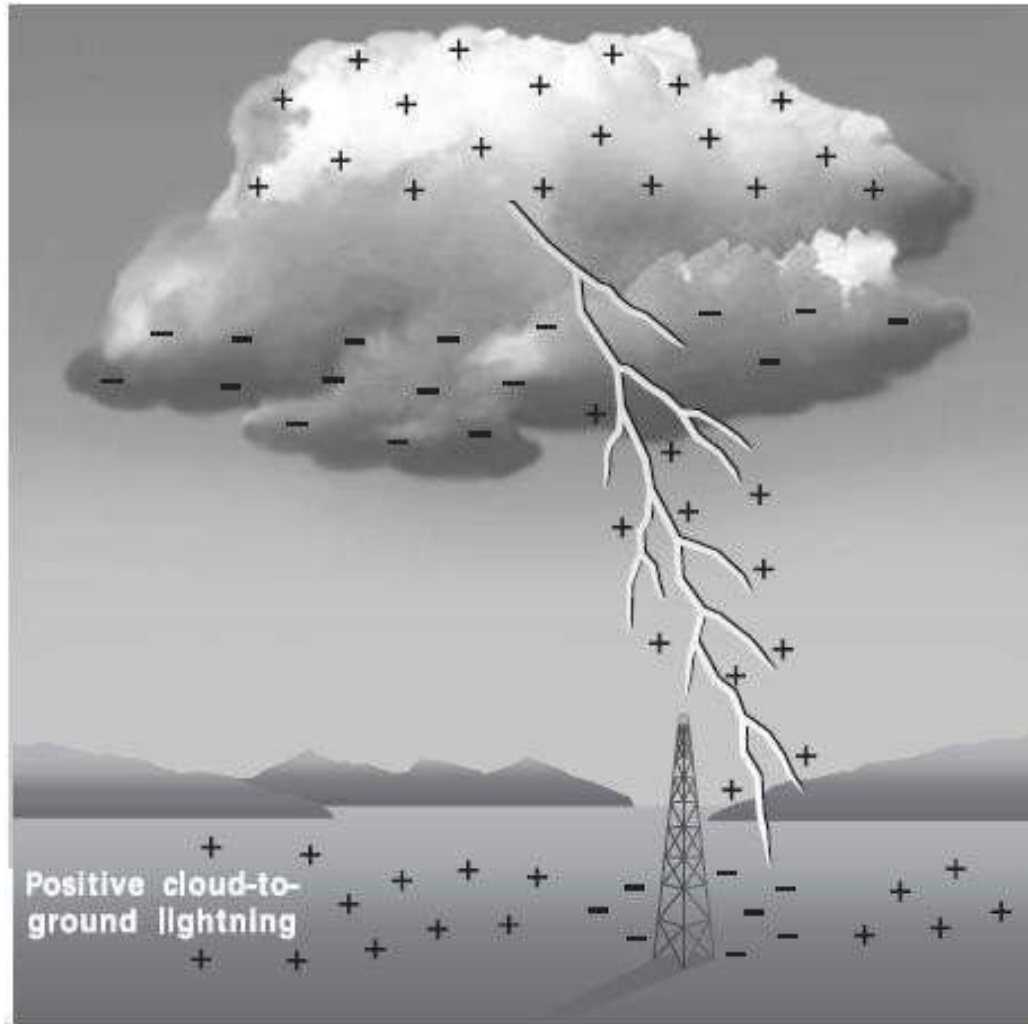
- Occurs almost 90% of the time
- Re strikes are frequent
- Lower peak current compared to positive strike
- Rapid rate of rise of current
- Total rise time compared to positive strike
- Shorter duration of strike
- Energy content is lower compared to positive strike



Positively charged strike

Properties

- Less frequent, around 10% of the time
- Re strike does not occur
- Peak current is higher ($\sim x2$)
- Slower rate of rise of current ($\sim x0.1$)
- Total current rise time is longer ($\sim x4$)
- Strike duration is longer ($\sim x4$)
- Total energy content is higher ($\sim x10$)



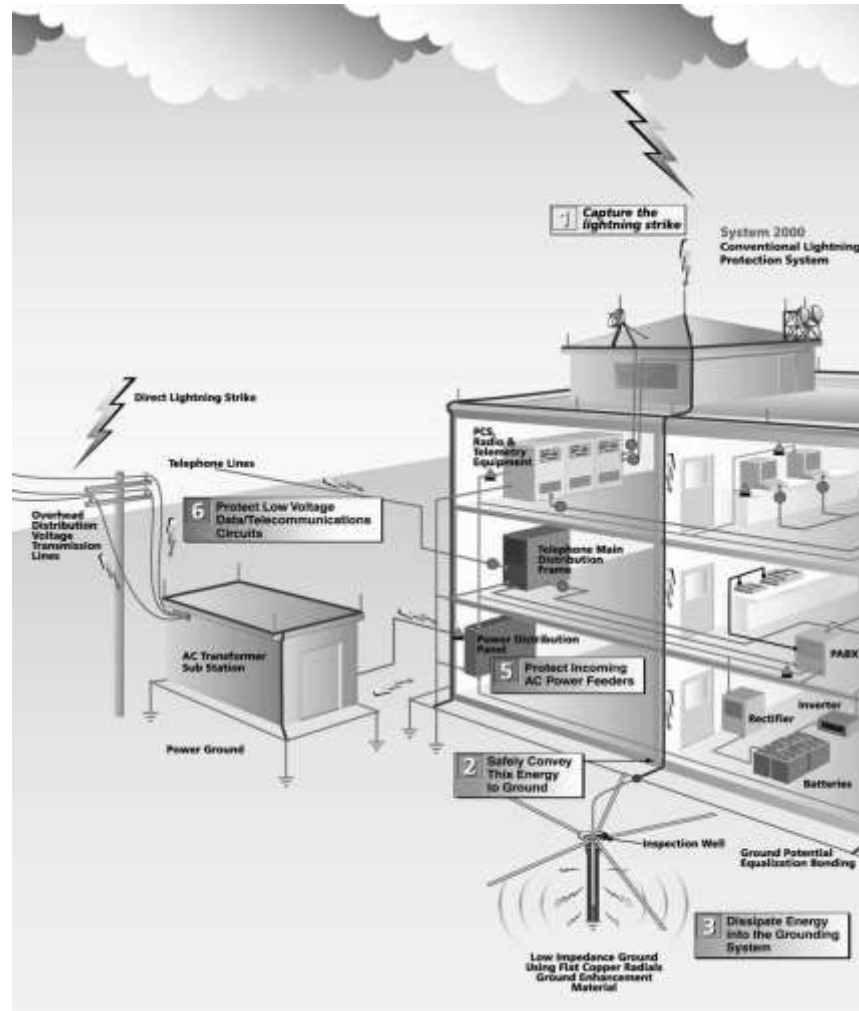
Comprehensive scheme of Lightning protection

1. **Capture the lightning strike.** Capture the lightning strike to a known and preferred attachment point using a purpose- designed air terminal system.
2. **Safely convey this energy to ground.** Conduct the energy to the ground safely via a purpose-designed down conductor.
3. **Dissipate energy into the grounding system.** Dissipate energy into a low impedance grounding system.
4. **Bond all ground points together.** Bond all ground points to eliminate ground loops and create an equipotential plane.

Comprehensive scheme of Lightning protection

5. **Protect incoming AC power feeders.** Protect equipment from surges and transients on incoming power lines to prevent equipment damage and costly operational downtime.

6. **Protect low voltage data/telecommunications circuits.** Protect equipment from surges and transients on incoming telecommunications and signal lines to prevent equipment damage and costly operational downtime.



Lightning

Effects of Lightning on Electrical System

- Lightning produces resistive voltage drop raises voltage steeply
- Lightning current rises at very high rate $\sim 10\text{kA/sec}$. Such high current causes rise in inductive voltage and across the line.
- Both produce dangerous voltages around lightning earth.
- Conductor is very quickly heated up if discharge is continuous and may cause fire
- The two lightning conductors experience strong magnetic repulsion which may cause them to break and then structure can get damaged.

Zones of lightning protection

- For vertical or horizontal conductors it is 45° .
- For two vertical conductors whose height is equal and distance between them is less than twice their height, the zone of protection between the two is 60° , and away from two conductors is 45° .
- Recommended distance between two arrestors should be

$$D = 0.3 R + H/15n$$

Where D is required clearance between two lightning conductors in m

R is combined earthing resistance of earth termination H is height in m

N number of down conductors

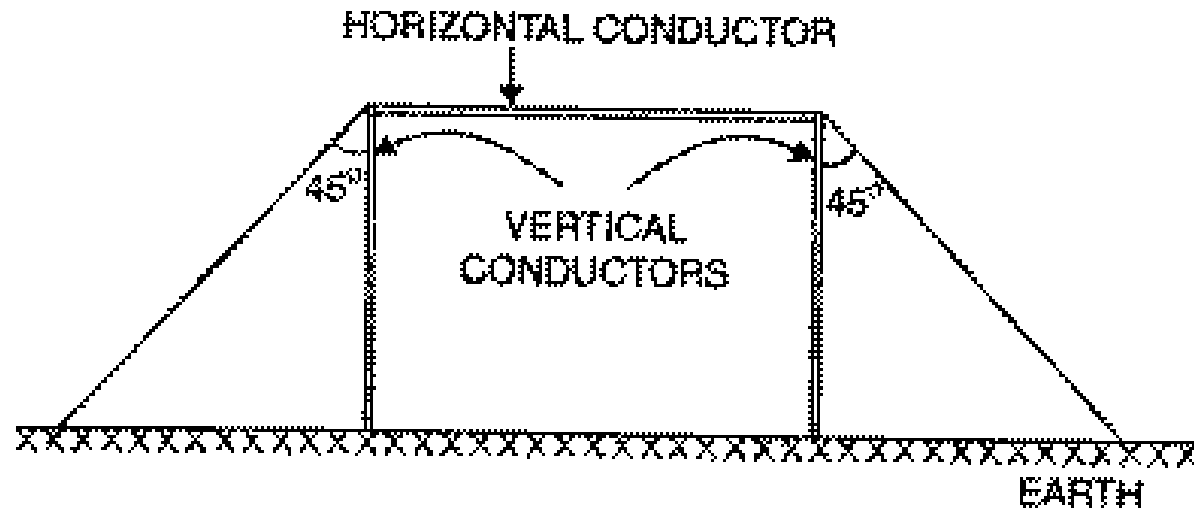
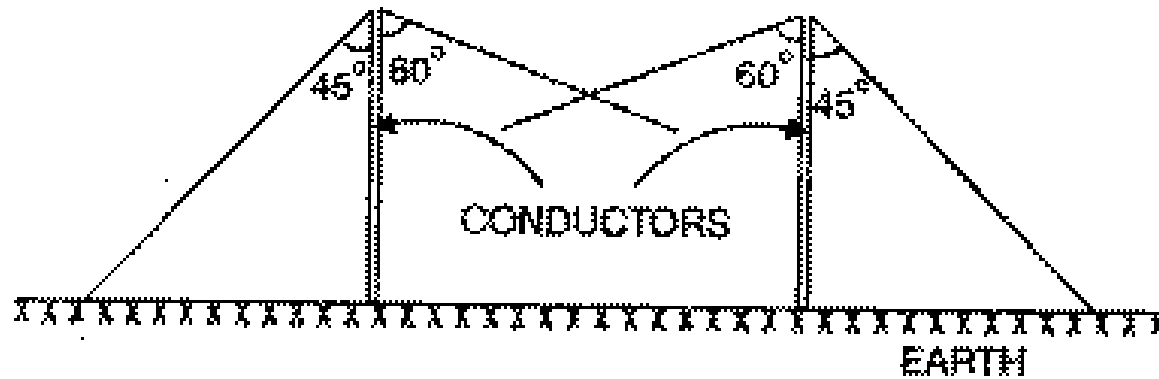
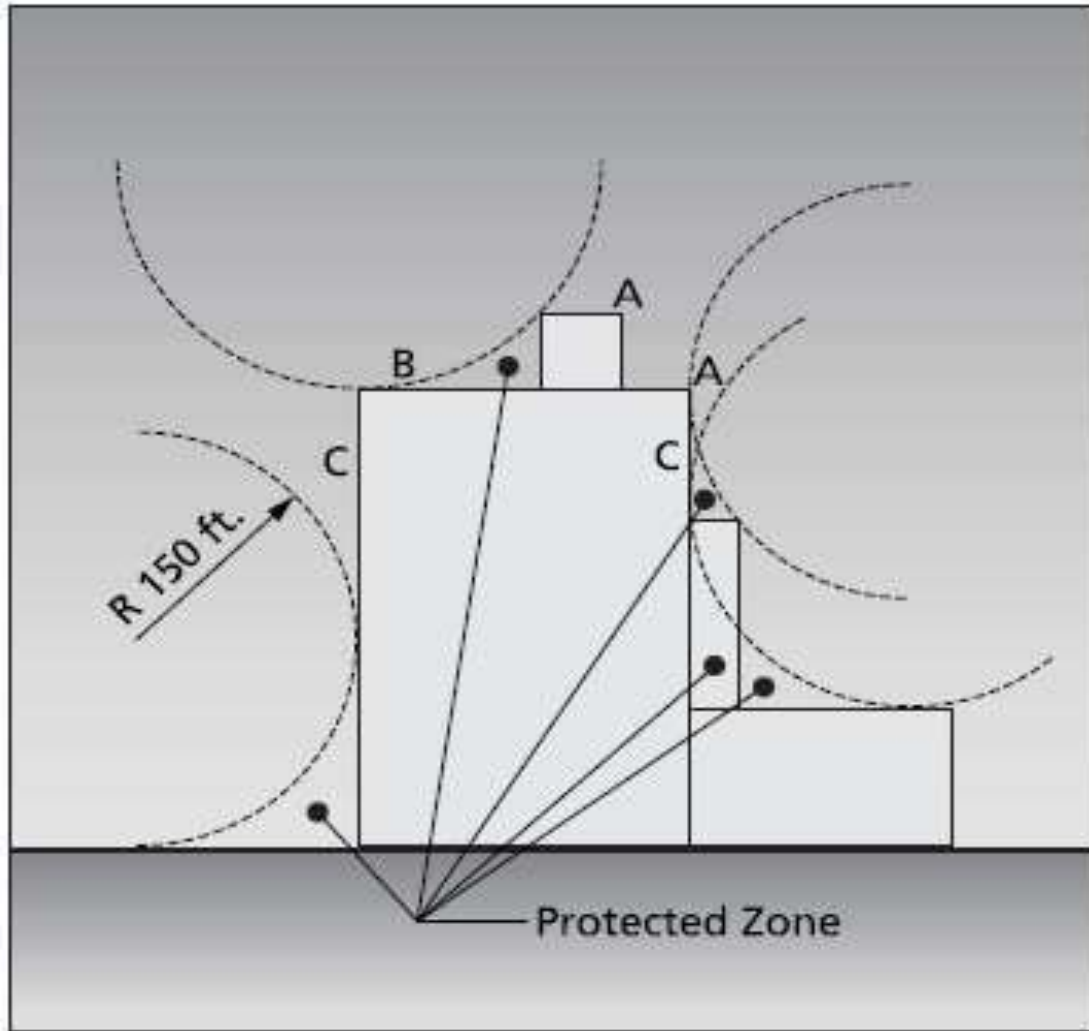


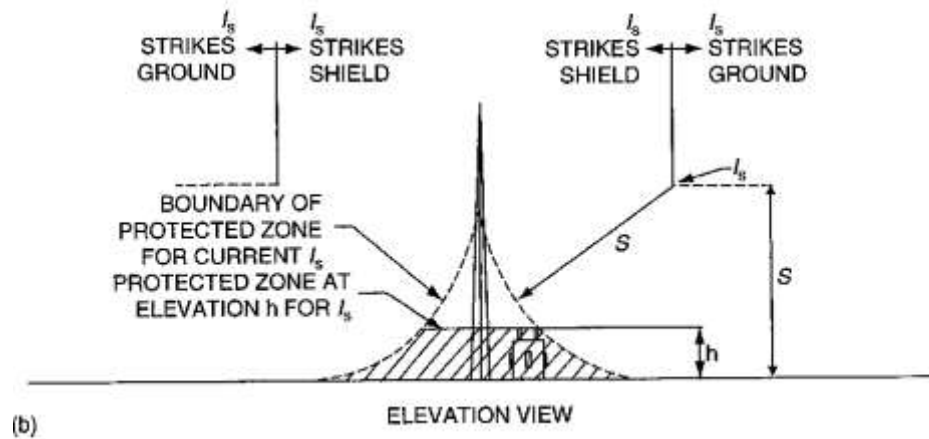
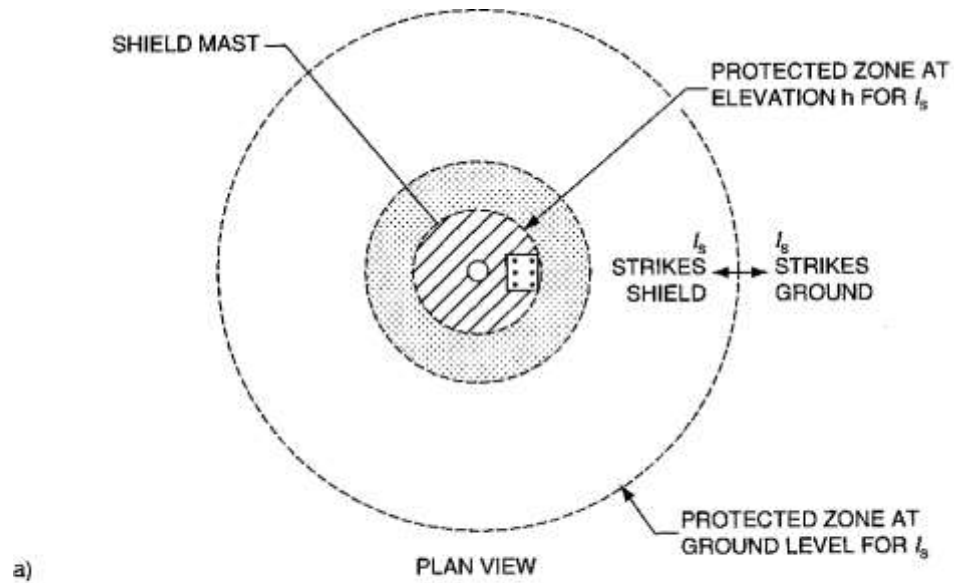
Fig 3.S. (a)

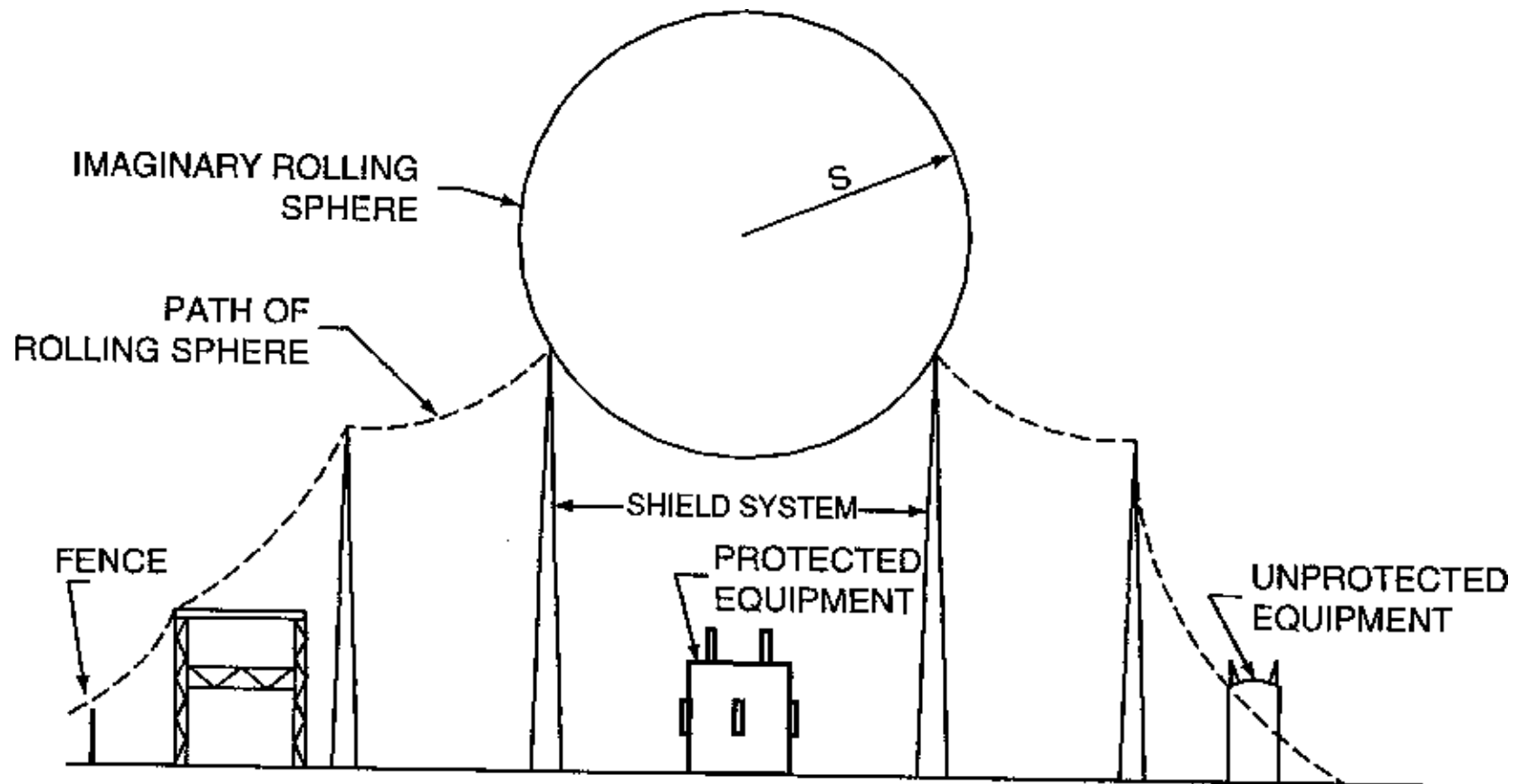


Rolling sphere method

- Based upon Electro geometric model (EGM)
- Dependent upon peak discharge current
- Relates striking distance to peak discharge current
- For higher current radius of sphere is bigger and therefore protected zone is bigger
- Protected area not touching sphere
- Points touching sphere are unprotected







Some important points for Lightning protection

- Earthing resistance should be maintained less than 4 ohms.
- Number of down conductor should be one for 100 m and there after one every 300m.
- Distance between horizontal conductors should be 9m and rules as per IS 2309-1989 should be followed.
- All structure on top of building should be bonded electrically to air termination network.
- One down conductor to cover 100 m²
- Minimum of two down conductors

Some important points for Lightning protection

- Thereafter one conductor to cover 300m^2
- For buildings taller than 30m down conductors are distributed around outside walls of the building as per IS 2309-1989.
- Lift shafts are not to be used for fixing down conductors
- Each down conductor terminates to network of earthing connection separately and it should be possible to disconnect and test it.

Lightning safety

- If in open, take shelter in a building or a car.
- Never stand near a tree.
- Do not lie down. If lightning strikes ground near by , high current can pass through the body.
- Put feet together, crouch down and put head between legs without touching ground.
- If in-door, avoid touching phone, plumbing, electrical appliances.

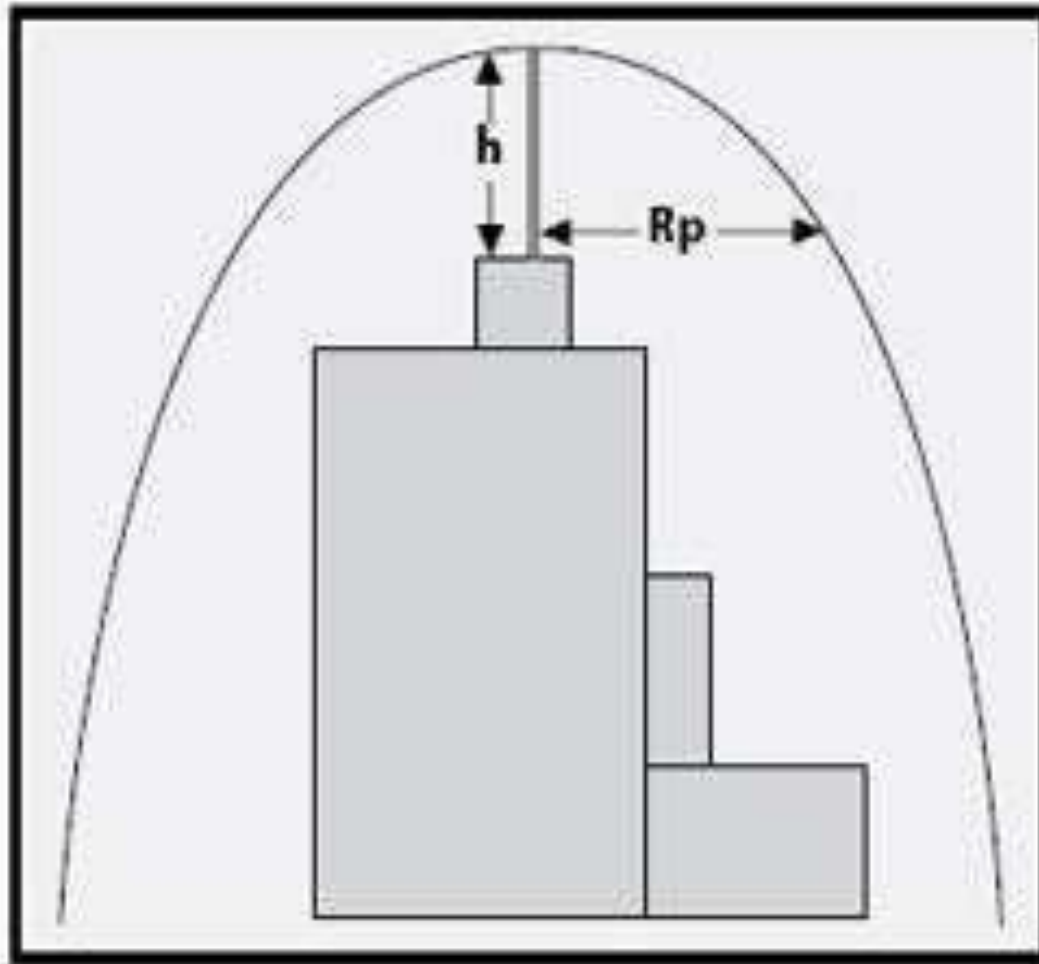
Active Lightning Terminals

- Lightning rods with Radioactive tips. Increases range by emitting ions in the air.
- Early Streamer Emission. A triggering mechanism sends high voltage pulses when charged clouds appear over the rod. This process generates an upward streamer which extends protected zone.
- Lightning protective device. Uses an array of multiple needles instead of single point electrode. Charge cloud generated by the need Lear ray neutralizes cloud charge and reduces chances of lightning strike.



ESE Lightning Terminals

An Advanced Lightning Protection System



Claimed Benefits of ESE system

- Protected area is much bigger than conventional system
- Current levels are lower therefore one down conductor is sufficient
- Voltage rise is less
- Only one earth pit is sufficient as current level is low
- Tested in high voltage laboratory
- High life

Radius of protection

$$R_p = \text{Sq. Rt.} [h(2D-h) + \sqrt{L}(2D + \sqrt{L})]$$

Where: R_p = Radius of protection

h = height of air terminal above tallest structure to be protected

$D = 20\text{m}$ for Level-1 $D = 30\text{m}$ for Level-2

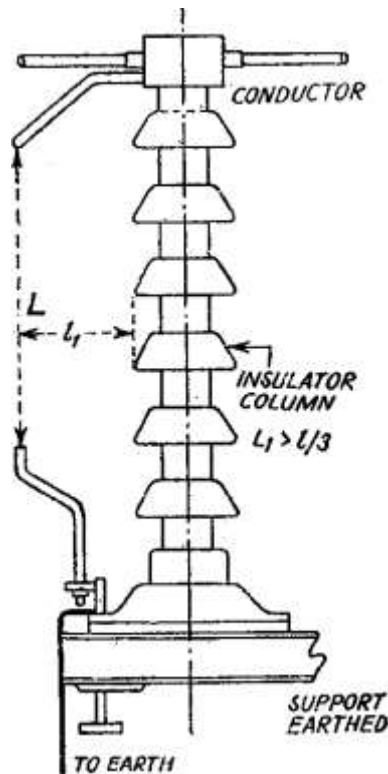
$D = 45\text{m}$ for Level-3 $D = 60\text{m}$ for Level-4

$$\sqrt{L} = V \text{ (m/ s)} * \sqrt{T} \text{ (s)}$$

V = Average velocity of streamer

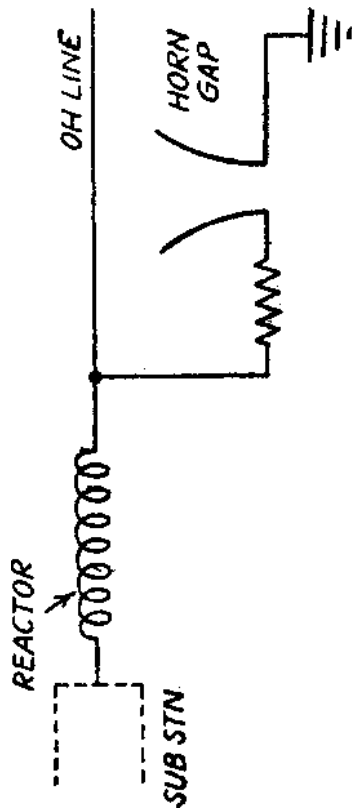
$\sqrt{T}$ = Early streamer time from ESE tests

Surge arrestors/ suppressors



- Rod gap used for protection of insulators
- $L_1 > L/3$
- Gap (L) fixed to flash over at 80% of insulator flashover point
- Difficult to precisely predict flash overvoltage
- Voltage sag
- No arc quenching device

Horn gap



- Flashover occurs at the base of the horn and moves out and is extinguished
- Resistance limits the fault current
- V/I characteristics not precise

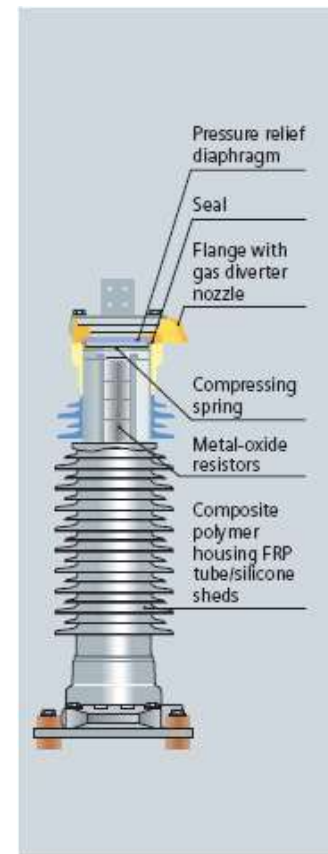
Gapped SiC arrestors

- Made from SiC discs connected in series.
- Gap between the discs breaks the arc in several smaller arcs and quenches quickly
- Size of disc to determine fault current withstanding capability and number of discs to determine operating and impulse voltage level.
- V/I characteristics not very precise

Gapless ZnO surge arrestors

- ZnO discs in contact with semiconductor material
- Semiconductor has negative voltage dependent characteristics
- Size of disc to determine fault current withstanding capability and number of discs to determine operating and impulse voltage level.
- V/I characteristics is precise

High Voltage Surge Arrestors



Electrical Safety

TRANSFORMER

Transformer

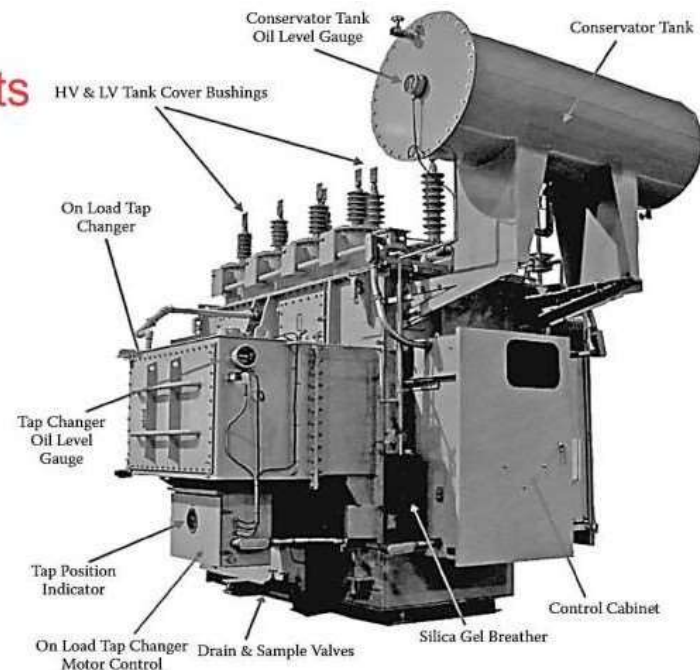
A transformer is an energy coupling device that takes electrical energy at one voltage (from its source) and transforms it to another voltage. The new voltage may be higher (stepped up) or lower (stepped down), or it may remain the same as the input voltage

<http://www.electricalunits.com/protection-of-transformer/>

2.3 CONSERVATOR:

This is a reservoir for oil. Whenever the oil in the transformer contracts during low temperature the oil is drawn from this and when the temperature is high the oil expands and the excess volume of oil goes into this and is store.

Key Components



Transformer - Protection

The power transformer is costly equipment and highly reliable pieces of equipment of the Sub- station. So, the protection of transformer is the most vital. Different types of faults may occur in the transformer, if the fault sustains for a long time, the transformer will damage. Therefore, it is required to trip the transformer from both ends i.e H.V & L.V side of the transformer as soon as possible when any fault occurs. **The power transformer should also be protected from lightning surges, switching surges, arcing grounds etc. For protecting from the surges, lightning arrester are used at both end of the transformer.**

The others different protections for the transformer are given below:

1. Over current and Earth fault protection.
2. Differential protection for transformer.
3. Differential magnetic-balance protection.
4. Restriction Earth fault (REF) protection.
5. Buchholze Relay protection.
6. Thermal protection (i.e WTI & OTI protection).
7. Pressure released Device (PRD) protection.
8. Fuse Protection.

PRD (Pressure Relief Device) is a device which is used for avoiding high oil pressure builds up inside the transformer during fault conditions. It is fitted on the top of the main tank. The PRD allows rapid release of excessive pressure that may be generated in the event of a serious fault. This device is fitted with an alarm/trip switch.

Transformer - Protection

The WTI means **winding temperature Indicator** and OTI means **Oil Temperature Indicator** which indicates the winding temperature & oil temperature of the transformer and operates the alarm, trip, and cooler control contacts. This instrument operates on the principle of thermal imaging and it is not an actual measurement.



Transformer - Protection

The WTI means **winding temperature Indicator** and OTI means **Oil Temperature Indicator** which indicates the winding temperature & oil temperature of the transformer and operates the alarm, trip, and cooler control contacts. This instrument operates on the principle of thermal imaging and it is not an actual measurement.

Buchholz Relay of Transformer Buchholz relay is a gas-actuated relay which is used for protection of oil filled transformers/reactors fitted with conservators against low oil level and internal faults. The Buchholz relay is provided with two hinged floats/buckets which on tilting operate mercury switches inside the oil tight enclosure. Mercury switches in turn actuated alarm and trip circuits depending upon nature of fault.

Testing on site:-

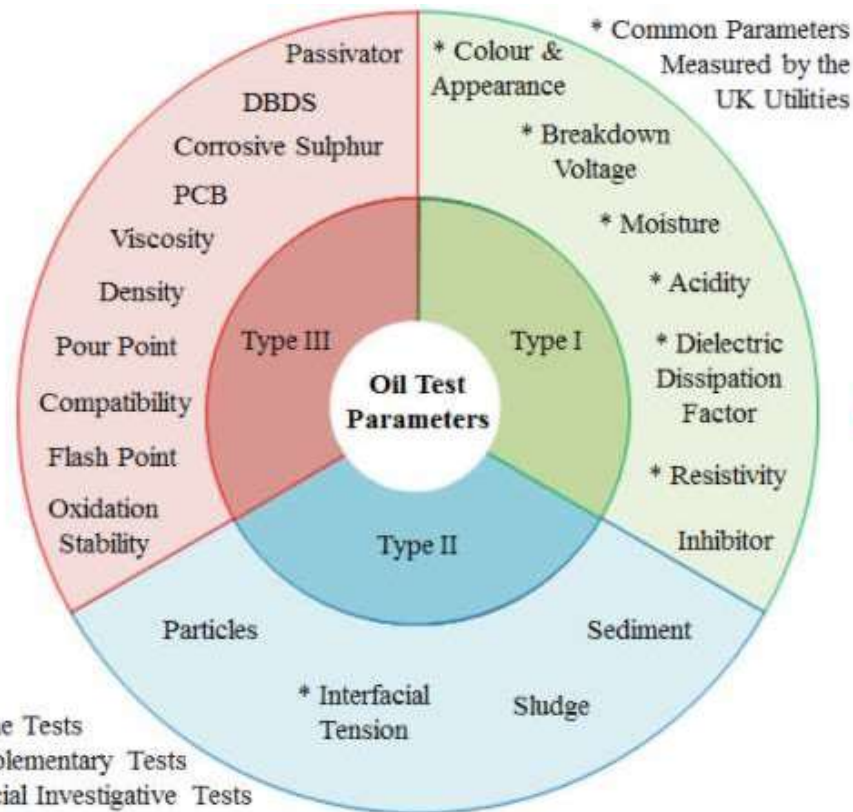
Air may be introduced slowly through the petcock provided either at the top or bottom. Oil level will gradually fall till the upper switch operates the alarm circuit.

Fault analysis after nature of gas collected from Buchholz relay:

By studying the nature of gas collected, fault analysis can be made as shown in Table below:-

Nature of Gas	Probable fault
1. Colorless & neutral	Air trapped in oil or in insulation
2. Grayish white with pungent smell non-inflammable.	Overheating of insulation, press board etc.
3. Yellowish inflammable	Decomposing of wood insulation.
4. Dark grey inflammable	Flash over in all. Excessive overheating due to fault of major nature

Transformer Oil Test



Oil test parameters for transformer ageing assessment [11]

Transformer Oil - BDV

BDV test means Breakdown Voltage Test. It is done for checking the dielectric strength of the oil of the **Transformer**. Dielectric strength means the maximum capacity to withstand voltage of insulating oil. This test shows the dielectric strength of Transformer oil.

In transformer oil has mainly two purposes, first for insulation, second as cooling of Transformer core and other winding. So while designing Transformer oil use in transformer depends on voltage rating. So testing of oil is done according to voltage rating. For the purpose of BDV test, oil sample from Transformer is taken in a Sample Bottle. While taking sample of oil from transformer, Sample bottle should be flushed well by Transformer oil and oil in Sample bottle should be vented properly so that atmospheric moisture could not ingress in the sample oil.

Breakdown Voltage is measured by observing at what voltage, sparking straits between two electrodes emerged in the oil, separated by specific gap. **Low value of BDV indicates presence of moisture content and conducting substances in the oil.** For measuring BDV of transformer oil, portable BDV measuring kit is generally available at site. In this kit, oil is kept in a pot in which one pair of electrodes are fixed with a gap of 2.5 mm (in some kit it 4 mm) between them.

Now slowly rising voltage is applied between the electrodes. Rate of rise of voltage is generally controlled at 2 KV/s and observe the voltage at which sparking starts between the electrodes. That means at which voltage dielectric strength of transformer oil between the electrodes has been broken down. A typical value of BDV Test result for 220 / 6.6 kV Transformer oil is 65 kV and moisture content should be less than 10 ppm

Transformer Oil - Acidity

Causes of Acidity in Insulating Oil

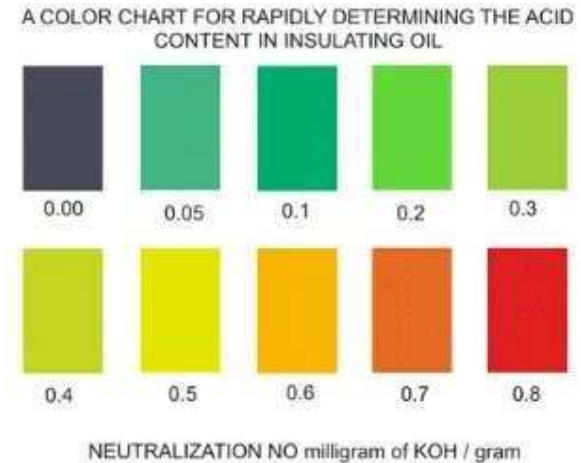
In insulating oil in the transformer may occasionally come into contact with air. It may be during opening any blanking or due to leakage in the oil tanks or in associated pipe lines. Because of that the oxidation reaction in the transformer oil takes place, which further be accelerated due to temperature and presence of catalysts like iron, copper and dissolved metallic compounds in the transformer oil.

Effects of Acidity in Insulating Oil

Increased acidity of the oil, causes decrease in resistivity of the oil. It also increases the dissipation factor of the oil. Excessive oxidation accelerates the slug formation rates in the oil. It may also causes abnormal deterioration of paper used for insulation in the transformer windings.

How do we measure Acidity of Insulating Oil?

The acidity of insulating oil is generally measured by the required quantity in milligram of KOH to entirely neutralize the acidity of a specific quantity in gram of the oil. Acidity of an insulating oil is 0.3 mg KOH / g means 0.3 milligram of KOH is required to neutralize 1 gram of that insulating oil.



Transformer Oil - Acidity

Acidity Test Kit

We can determine the acidity of transformer insulating oil, by a simple portable acidity test kit. It consists of one polythene bottle of rectified spirit (**ethyl alcohol**), one polythene bottle of **sodium carbonate solution** and one bottle of **universal indicator (liquid)**. It also consists of clear and transparent test tubes and volumetrically scaled syringes.



Procedure of Acidity Test for Insulating Oil

- ✓ For that we have first to take exactly 1 gram of insulating oil. We normally do this by taking 1.1 milliliter of the oil to be tested by provided volumetric syringe. Actually, 1.1 milliliter oil is taken as 1 gram of oil.
- ✓ Before test we have to extract the dissolved acid in the oil. That we do by adding exactly 1 ml of rectified spirit (ethyl alcohol) in the test sample. This is because the acid produced in the mineral oil is highly soluble in the alcohol.
- ✓ After shaking the test sample well we add 1 ml of sodium carbonate in the sample. Sodium carbonate is the most suitable alkali for that purpose because it does not change its characteristics much when comes in contact with atmosphere during use.
- ✓ At last after re-shaking the sample mixture we have to add 5 drops of universal indicator in the sample.

Transformer Oil Certificate

OIL TEST REPORT

Date: 19.03.17

NAME OF CLIENT :- [REDACTED]

1) TRANSFORMER :-

- a) Location :- Utility I
- b) Make :- Mahati Electrical
- c) Serial No :- 2007/1369
- d) Rating 1) KVA :- 2000 KVA
2) Voltage Ratio: - 33000/433V
- e) Number Of Phase :- 3 Phase
- f) Out Door / Indoor :- Outdoor
- g) Oil Quantity :- 1970 Ltrs

2) B.D.V. TEST:-

- a) Before Filtration :- 42 KV Trip 2.5 mm Gap
- b) After Filtration :- 65 KV 1 Min Stand

3) ACIDITY TEST :-

:- 0.05 mg /koh /gm.

- * Oil Test in Presence of :- [REDACTED]
- * Our Technicians Name :- [REDACTED]

Remark:- OK



OIL TEST REPORT

Date: 19.03.2017

NAME OF CLIENT :- [REDACTED]

1) OLTC :-

- a) Location :- Utility I
- b) Make :- CTR
- c) Serial No :- 2722527
- d) Oil Quantity :- 700 Ltrs

2) B.D.V. TEST:-

- a) Before Filtration :- 35 KV Trip 2.5 mm Gap
- b) After Filtration :- 62 KV 1 Min Stand

Remark:- OK



Transformer – Silica Gel

The purpose of these **silica gel** breathers is to absorb the moisture in the air sucked in by the **transformer** during the breathing process. ... **Silica gel** in the breather will be blue when installed and they turn to pink color when they absorb moisture which indicates the crystals should be replaced.

Silica gel Breather is cylindrical type container which is fitted to the conservator tank through a pipe line which is totally filled with silica gel crystals used for absorbing any moisture present in the air during breathing action of transformer due to expansion and contraction of transformer oil in the transformer. The size of Breather depends on the volume of transformer main tank as well as quantity of transformer oil in the transformer. A oil pot is connected under the breather. The details of silica gel Breather is shown in figure.

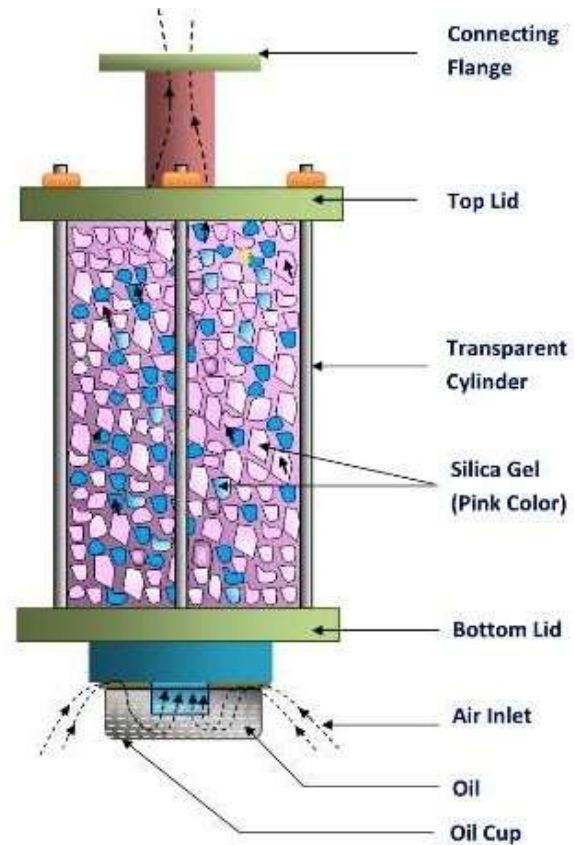
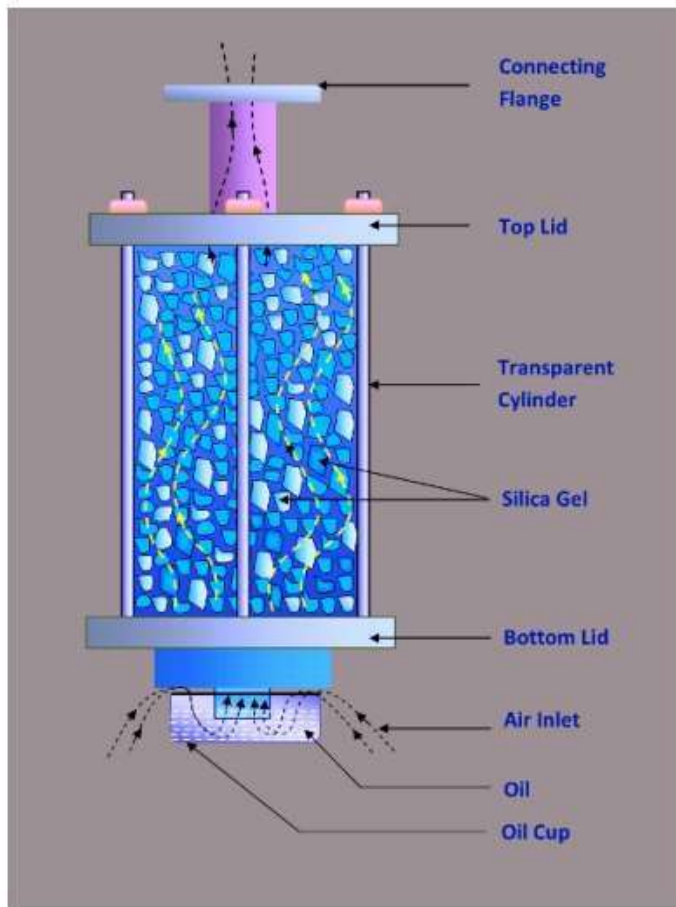
When the Silica gel breather is first installed, the crystals have a blue tint, and after a period of operation, the colour of the tinted crystals gradually changes to pink, this is an indication that the silica gel is becoming saturated and losing its absorbent properties. When there is a preponderance of pink crystals the silica gel should be changed or reactivated.

Silicagel may be reactivated by heating in a thin pan at a temperature of 150°C to 200°C for two to three hours when the crystals should have regained their original blue tint.

Before filling the container with silica gel, clean and dry all parts of the breather. Verify that the oil level in the oil cup is correct or not –correct.

Finally ensure that the breather is not choked and is free for passage of air.

Transformer – Silica Gel



Transformer – Losses



Losses in a Transformer

Transformer – Dos and Donts

DO'S	STEEL & POWER DON'TS
1. Ensure all safety arrangements while working on electrical installation. 2. Ensure that all tool & tackles are in good working condition. 3. Check the protection system periodically. 4. Check silica gel regularly. 5. Check and thoroughly investigate the transformer whenever any alarm or protection system is operated. 6. Examine the bushings for dirt deposit, coats and clean them periodically. 7. Attend the bushing leakage immediately. 8. Do earthing of all points before starting maintenance work. 9. Keep all spares away from dirt. 10. Avoid un-balance loading on phases. 11. Clean conservator thoroughly before refilling. 12. Ensure proper functioning of Buchholz relay. 13. Ensure periodic testing of transformer oil.	1. Don't use under capacity lifting jacks. 2. Don't leave any loose connection. 3. Don't meddle with protection system. 4. Don't allow conservator oil level to fall below 1/4th level. 5. Don't parallel transformer which do not full fill the necessary conditions. 6. Don't allow unauthorized entry near the transformer. 7. Don't overload the transformer than the specified limit. 8. Don't over tight the nuts & bolts to stop any leakage. 9. Don't overlook any unusual noise/ occurrence noticed in the substation. 10. Don't use fuses higher than the prescribed ratings on HT and LT sides. 11. Don't tamper with earthing connections. 12. Don't keep the breather pipe open or exposed. 13. Don't ignore safety rules during maintenance work. 14. Don't re-energize the faulty transformer unless the Buchholz gas is analyzed.

Electrical Safety

Electrical Safety Audit

**Tool for identification of Electrical
Hazard**

Electrical Safety Audit – Typical Scope

- Physical inspection of the plant with reference to applicable Indian standards, Indian Electricity Rules and other relevant codes of Practice & identifying electrical hazards (shocks, fires, etc.).
- Reviewing the role of electrical safety in the total safety system.
- Review of protection devices / system of the electrical installation.
- Review of adequacy of cables, motors, etc. based on actual load current measurements and cable current carrying capacities.
- Examination of adequacy of plant lightning protection system as per national and international standards to suggest recommendations as per applicable standards.
- Review of the hazardous area classification carried out in the plant as per IS: 5572 and to review the selection, installation of special electrical equipment as per IS: 5571 to suggest recommendations as per applicable standards.
- Review of electrical accidents to identify root cause of the accidents.
- Review the EPM (Electrical Preventive Maintenance) programme in the plant and to examine the documentation, checklists, work permit, test records, etc. and to suggest recommendations as per applicable standards.
- To identify training needs of the plant employees from the point of view of electrical safety.
- To evaluate the earthing system (installation and maintenance) in the plant based on IS 3043 and to suggest recommendations.
- Review of the following test records, evaluating the test results and to suggest recommendations as per applicable standards.
 - Transformer oil test.
 - Insulation Resistance Tests.
 - Earth Resistance tests.

Electrical Safety Audit – Typical Checklist

Compliance to Statutory Rules

- Applicability of rules (Indian electricity Rules, Petroleum Rules, etc.)
- Compliance to inspector's reports
- Submission of accident intimation reports, forms, etc. in time
- Intimation of inspector before energizing new / changed electrical installation

Electrical Shock/ Flash / Injury Hazards

- RCCBs –selection, installation and maintenance
- Aspect of Nuisance Tripping and bypassing of RCCBs
- Bypasses fuses, MCB (Miniature Circuit Breaker), etc.
- Use of re-wirable fuses
- Earthing defects
- Use of double insulated (class II) tools, centre tapped power supply, extra-low voltage equipment for confined spaces
- Accessible live parts
- Electrical rubber mat
- Wrong identification of equipment / feeders
- Defective electrical portable tools
- Are the necessary PPEs (Personal Protective Equipments) used?
- Interlocks provided for multiple power sources?

- Is the interlocking system in place?
- Are MCC (Motor Control Centers) /PCCs (Power Control Centers) / DBs (Distribution Boards) maintained to avert flash incidents?
- Operational clearance as per IER 51
- Tripping hazards due to loose cabling/cords, etc.
- Adequacy of illumination in electrical rooms/around panels, DBs, etc.
- Stand-by power supply (Diesel Generator set)

Electrical Preventive Maintenance

- Is there an EPM programme in place?
- Is the programme implemented? What is the slippage?
- Are the relevant standards (statutes and non- statutory) referred and incorporated in the EPM programme?
- Electrical Tests, Records, Test Procedure and periodicity (earth resistance, insulation resistance tests)
- Is the EPM programme only documented?
- Transformer tests (dielectric strength, acidity, sludge deposits, dissolved gases, etc.) and periodicity
- Periodic calibration of meters (ammeter, voltmeter, relays, temperature gauges) and test instruments (insulation resistance megger, earth resistance megger, multi-meters, etc.)

Electrical Safety Audit – Typical Checklist

◦ Electrical Fire Hazards

- Storage of combustible materials near electrical equipment / fuse units
- RCCBs
- Master switch in warehouses
- Proper cable joint procedures as per manufacturer
- Earthing defects
- Use of non-standard fuse wires
- Bypassing of protection devices
- Deteriorated insulation
- Selection, deployment of PFEs (Portable Fire Extinguishers)
- Sealing of cable passes, openings, baffle walls (Passive Fire Protection)
- Tracking possibility
- Unused openings in live panels, etc.
- Possibility of ground fault / short circuit
- Mechanical protection to cables
- Loose terminations due to improper supports, crimping
- Improper gland installation, wrong lug size
- Over-rated fuses, wrongly set protection relays, etc.

Earthing System

- Installation as per approved design?
- Installation and Maintenance as per IS 3043?
- Earth resistance measured periodically?
- Test procedure
- Acceptable earth resistance values
- Is the earthing system modified when electrical installation is modified?
- Are neutral earth pits independent and separate?
- Are earth pits identified?
- Are two and distinct earth connections provided?
- Is the earth continuity tested?
- Is bonding and earthing carried out to avoid ESD hazards?

Competency and Adequacy of Electrical Personnel

- Competency of electrical O&M personnel
- Understanding of electrical hazards
- Are the operating and maintenance procedures amended after accidents?
- Awareness of latest electrical protection devices, hazards, etc.
- Workmanship
- Adequacy of electrical personnel
- Frequency and severity of electrical accidents
- Nature of electrical accidents
- Safety attitude

Electrical Safety Audit – Typical Checklist

Electrical Safety Training

- Need for electrical safety training
- Training content identification
- Periodicity
- Competency of faculty members
- Objective of training

Electrical Accident Investigation Procedure

- Is every accident / near-miss electrical accidents investigated in detail?
- Is the root cause identified and included in the APP (Accident Prevention Programme)?
- Are the recommendations incorporated in the O&M procedures/ work permit
- Are these accident causes given importance in safety training sessions?

Importance of Electrical Safety in the Overall Safety System

- Periodicity of comprehensive ESAs
- Understanding of electrical hazards
- Electrical checkpoints in the safety checklist
- Electrical safety items the in safety committee agenda
- Implementation priority for electrical hazards
- Electrical Work Permit System
- Electrical Operating Procedures
- Electrical hazard identification techniques used (Electrical HAZOP, Electrical Job safety analysis, etc.)

○ Lightning Protection

- Is the Lightning protection system as per IS 2309?
- Are the numbers of down conductors direct and adequate?
- Are all the structures and building under the zone of protection?
- While reviewing lightning protection, are both the plan and
 - elevation of structures, etc. considered?
- ESP (Electronic system Protection) for electronic system / equipment
- Is the earthing for the electrical and lightning systems interconnected?
- Are the storage tanks / chimneys and other special structures protected?
- Earth electrodes- maintenance / periodic tests / acceptable value
- Awareness of basic concepts of lightning such as types of
 - lightning, predictability factor, protection concepts, etc.
- Are hazardous areas classified as per IS 5572?
- Are the special electrical equipment's selected and installed as per IS 5571?
- Are the electrical equipment's maintained as per IS 2148 and IS 13346?
- Review of area classification in case of process change / plant modification, etc.
- Approval of area classification drawings as per statutory rules
- Maintenance of flame-proof equipment's
- Use of ordinary electrical equipment in hazardous areas
- Awareness of O&M personnel about hazardous area and

Electrical Safety Audit – Typical Checklist

Electrical Single Line Diagram / Lay Out Diagram / Equipment Layout / Electrical Control diagram

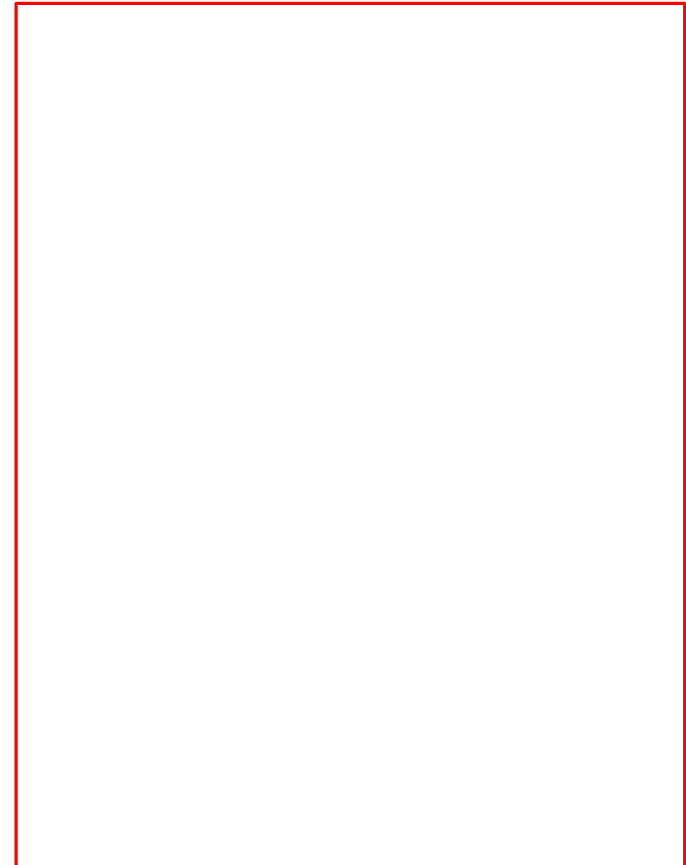
- Unauthorized Temporary Installations?
- Updated?
- SLD reflects the actual installation?
- Duly approved by statutory authorities?

Electrical Protection System

- Are the protection relays in place and set in the main PCC / MCC?
- Are the relays set in accordance with calculated, design parameters in mind?
- Are they calibrated and tested periodically?
- Availability of HRC fuses, standard fuse wires, MCBs, MCCBs, RCCBs, etc.
- Are the transformer protection devices in place?
(Bucholtz Relay, Oil Temperature Relay, Winding Temperature relay, Silica Gel Breather, Explosion Vent, etc.)

Electro-Static (ES) Hazards and Control

- Are the ES hazards identified in the plant?
- Are the non-conductive parts where ES hazards are identified, bonded & earthed?
- Is the concept of equip-potential bonding and ESD hazards clear to O&M personnel?
- Does the tanker (carrying flammable chemicals) de-canting procedure, switch-loading, etc. defined and made clear to all concerned?





Thank you!
Expert in ELECTRICAL SAFETY
Audit & Training

