PROTECTION & SWITCHGEAR

PRESENTER – U KHIN MAUNG OO
B.E (ELECTRICAL POWER) -1977
P.E (ELECTRICAL B.S) P.E -0163
P.E (ELECTRICAL POWER) P.E -836
ACPE (ELECTRICAL)

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I. PROTECTION SYSTEM

- The more reliable electricity we want, the more is need to protect it. Protection is essential to keep equipment and personnel safe from any kind of damage caused by an electrical unbalance or fault condition.
- An electrical protection system is a set of devices and rules that detect and isolate faults in an electrical system to prevent further damage and instability. The goal is to keep the power system stable and reliable, while ensuring the safety of people and equipment

1. Why a system need protection?

- **Prevent equipment damage**

By detecting abnormal conditions and clearing the faulty part, electrical protection systems can prevent further damage to equipment.

- **Improve system reliability**

By limiting failure modes, electrical protection systems can enhance the overall reliability of the system.

- **Protect people and property**

Electrical protection systems can prevent serious injuries and property damage by automatically disconnecting the power supply to a circuit when there is a fault.

- **Maintain system stability**

Electrical protection systems can keep the power system stable by isolating only the faulty components.

- **Protect against external factors**

Electrical protection systems can help protect against external factors that can affect the quality of the power supply, such as storms, floods, and accidents.

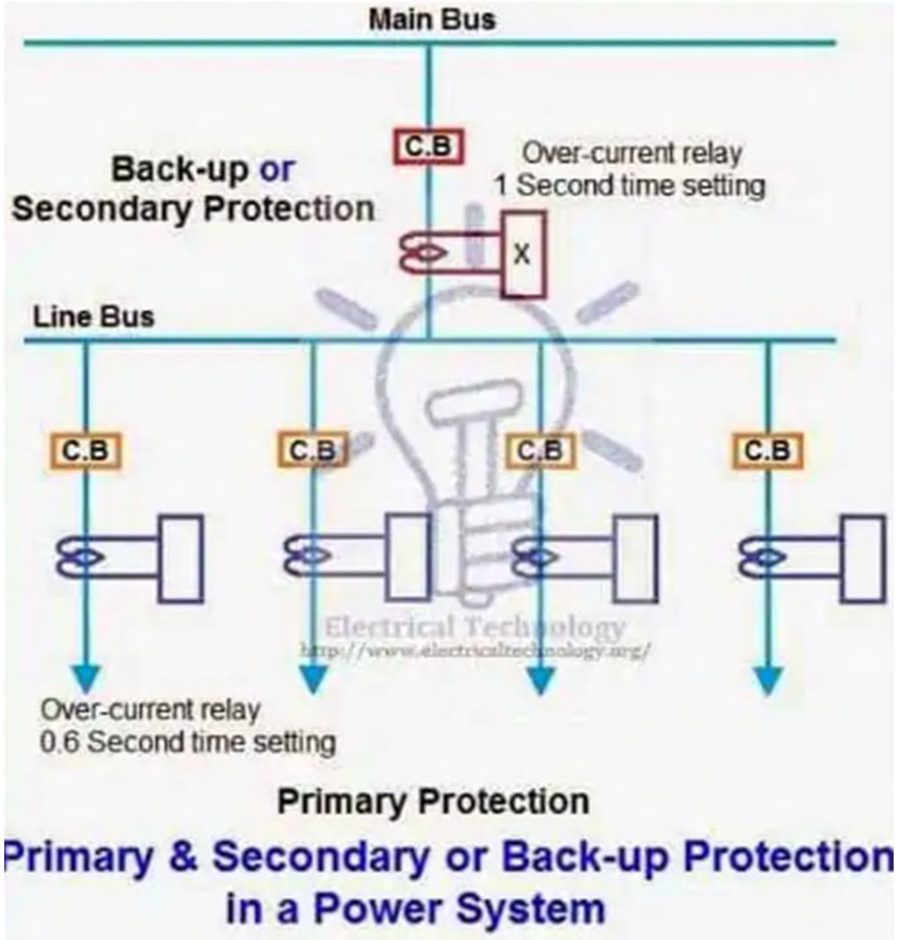
2. Primary Protection and Backup Protection

The protection into two classes, primary protection and back-up protection.

- “Primary Protection” The primary protection is the first line of defense and its responsible to protect all the power system elements from all the types of faults.

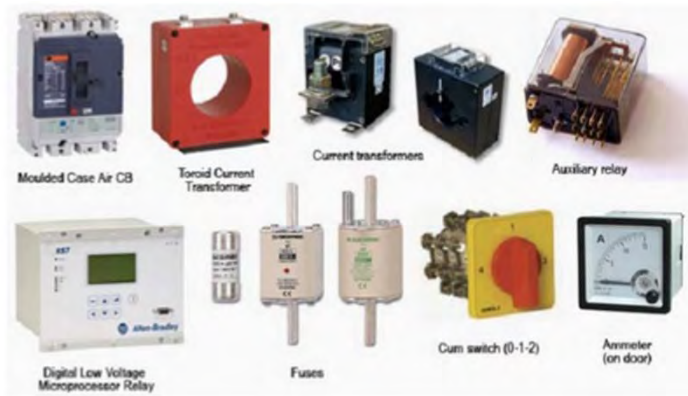
- The backup protection is provided as the main protection can fail due to many reasons like.

  - 1.Fasilure in circuit breaker
  - 2.Failure in protective relay
  - 3.Failure in tripping circuit
  - 4.Failure in d.c tripping voltage
  - 5.Less of voltage or current supply to the relay



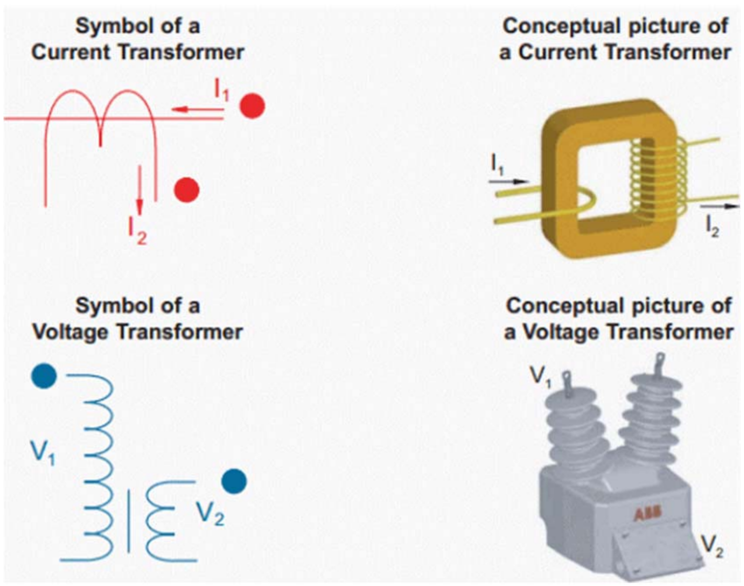
3. Elements of Protection System

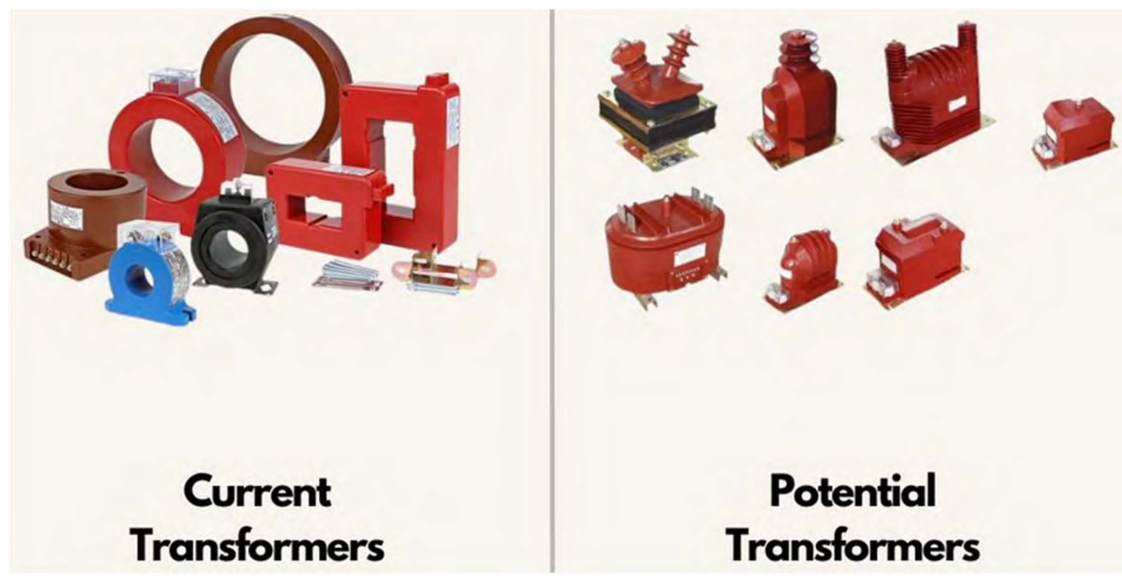
1. Instrument Transformers (Current Transformer & Potential Transformer)
2. Relays
3. Circuit breakers
4. Batteries
5. Fuses
6. Lightning Arresters



4. Instrument Transformer (PT, CT)

- Protective Relays in A.C. Power Systems are connected from the secondary circuits of C.T. & P.T.
- Current Transformers : C.T. are used for measurement and Protection. Its step down the current from high value to low current value. Their ratio is constant for given range of Primary & Secondary Current.
- Potential Transformer : P.T. are used for measurement and Protection. Its step down the high voltage to low voltage value. The ratio is constant for given range of Primary and Secondary voltage





Current Transformer (CT) :

A device which transforms the current on the power system from large primary values to safe secondary

The secondary current will be proportional (as per the ratio) to the primary current.

Working Principle of Current Transformers

The Current Transformer works on the principle of electromagnetic induction. The high current flowing through the primary winding generates a magnetic field, which induces a proportional current in the secondary winding. This induced current is a scaled-down version of the primary current, making it safe and easy to measure.

Potential Transformer (PT):

- A device which transforms the voltage on the power system from primary values to safe secondary values, in a ratio proportional to the primary value. Voltage transformer is often consists of two windings.
- The first winding is connected in star, and the star point must be earthed.
- The second winding is connected as open delta.

Working Principle of Potential Transformer

Similar to a Current Transformer, a Potential Transformer operates on the principle of electromagnetic induction. The high voltage applied to the primary winding creates a magnetic field, inducing a proportional voltage in the secondary winding. This induced voltage is a scaled-down version of the primary voltage, making it safe and easy to measure.

Differences Between Current Transformers and Potential Transformers

Parameter		*Current Transformer (CT)*	*Potential Transformer (PT)*
Definition	1	Transforms the current from a high value to a low value	Transforms the voltage from a high value to a low value
	2	It can be treated as series transformer under virtual short circuit conditions	It can be treated as parallel transformer under open circuit secondary
	3	Secondary must be always be shorted	Secondary is nearly under open circuit conditions
	4	A small voltage exists across its terminal as connected in series	Full line voltage appears across its terminals.
Primary and Secondary Windings		Primary winding has a small number of turns; secondary winding has a large number of turns	Primary winding has a large number of turns; secondary winding has a small number of turns
Measurement Purpose		*Measures Current*	*Measures Voltage*
	1	The winding carries full line current	The winding is impressed with full line voltage
	2	The primary current and excitation varies over a wide range	The line voltage is almost constant hence exciting current and flux density varies over a limited range
	3	The primary current is independent of the secondary circuit conditions	The primary current depends on the secondary circuit conditions
Core		Core made of silicon steel laminations	Core made of high-quality steel operating at low flux densities
Connection in Circuit		Connected in series with the circuit	Connected in parallel with the circuit
Transformation Ratio		High transformation ratio	Low transformation ratio
Burden and Impedance		Performance does not depend on secondary burden;low impedance	Performance depends on secondary burden; high impedance
Input Values		Input constant current	Input constant voltage
Range		Typically reduce current to 1A or 5A	Typically reduce voltage to 110V

Importance of Current Transformers and Potential Transformers in Electrical Systems

The importance of Current Transformers and Potential Transformers lies in their ability to provide critical data for power metering, grid stability, and protective relaying, which helps prevent electrical faults and enhances the safety of electrical installations:

Safety

Both Current Transformers and Potential Transformers enhance safety by reducing high values of current and voltage to levels that can be handled safely. This is crucial for protecting equipment and personnel from electrical hazards.

Efficiency

By ensuring accurate measurement and monitoring, Current Transformers and Potential Transformers help maintain the efficiency of electrical systems. They allow for precise control and management of power distribution.

Monitoring and Control

Accurate monitoring and control are essential for the stable operation of power systems. Current Transformers and Potential Transformers provide the necessary data to ensure that electrical systems operate within safe and efficient parameters.

***"CT Accuracy Class"**

Metering Class	Protection Class
0.1, 0.2, 0.2s, 0.5, 0.5s, 1 to 3	5P10, 5P10, 5P20, 10P20

5. Fundamental Requirement of Protective Relays

<u>RELAY</u>

- To control the electrical circuit by opening and closing them in response to electrical signals.
- Ensure the safe operation of connected equipment.
- Can be used to automatic process such as switching on or off at preset time
- Logic Functions

<u>Requirements of Relays</u>

➢ Reliability

*The level of assurance that the relay will function as intended.

*Reliability denotes:

-Dependability – certainty of correct operation

-Security- assurance against incorrect operation

➢ “Sensitivity”

*Relaying equipment must be sufficiently sensitive so that it will operate when required

*Must discriminate normal from abnormal condition

- **“Selectivity”**

*Performance of protective devices to select between those conditions for which prompt operation and those for which no operation , or time delay operation is required.

*Isolate faulted circuit resulting in minimum interruptions.

*Implemented through “Zone of Protection”

- **“Speed”**

*Remove a fault from the power system as quickly as possible

*Classification:

-Instantaneous – no intentional delay

-High Speed- less than 3 cycles

-Time –Delay – intentional time delay

Applications of Protective Relays

- **Overcurrent Protection**

It is used for the protection of distribution lines, large motors, equipment, etc.

- **Distance Protection**

It is used for protection of Transmission or sub-transmission lines.

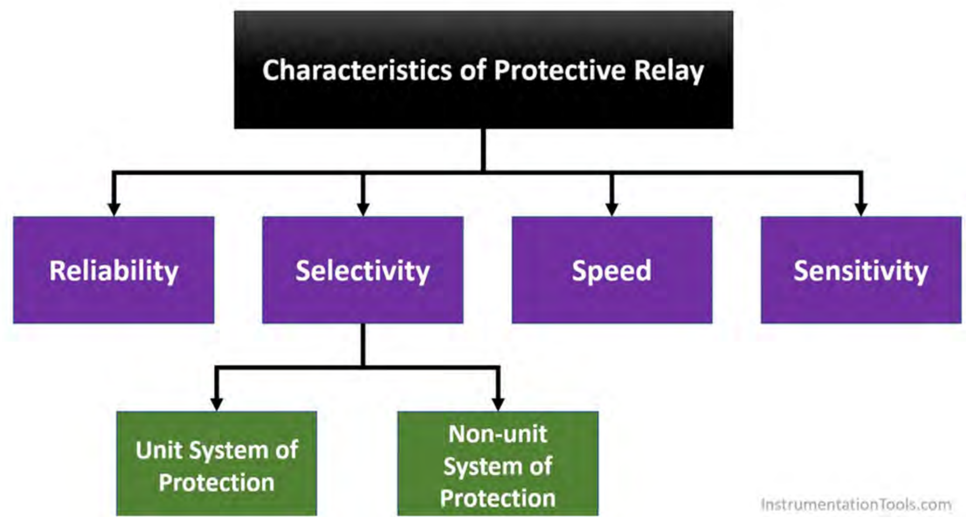
- **Carrier-current Protection**

It is used for the protection of the Extra High Voltage (EHV) and Ultra High Voltage (UHV) line.

- **Differential Protection**

It is used for the protection of transformers, generators, motors of very large size, bus zones, etc.

Types of Protective Relays



6. Qualitative review of Faults and Fault Currents

NATURE & CAUSES OF FAULTS

- Insulation failure.
- Conducting path failure.
- Over voltages due to lightning or switching surges.
- Puncturing or breaking of insulators.
- Failure of conducting path due to broken conductors.
- Failure of solid insulation due to aging, heat, moisture, overvoltage , accidental contact with earth or earth screens, flash over voltages and etc.,

FAULT IN POWER SYSTEM

- A power system fault may be defined as any condition or abnormality of the system which involves the electrical failure of primary equipment such as generators, transformers, busbars, overhead lines and cables and all other items of plant which operate at power system voltage.
- Electrical failure generally implies one or the other (or both) of two types of failure, namely insulation failure resulting in a short-circuit condition or conducting path failure resulting in an open-circuit condition, the former being by far the more common type of failure.

Symmetrical fault

Faults giving rise to equal currents in lines displaced by equal phase angles i.e 120^{o} in three phase systems.

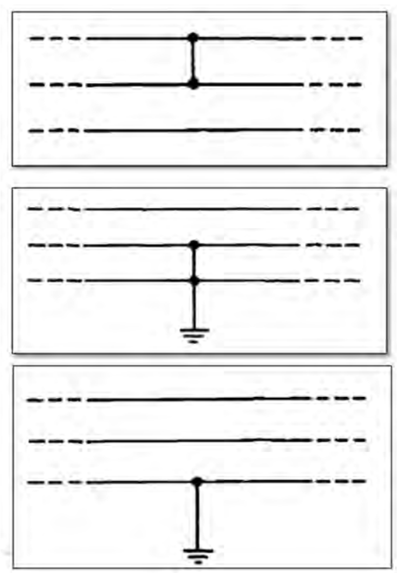
Example: short circuit of **all three phase** conductors of a cable at a single location

Unsymmetrical fault

Faults in which not all the line currents are equal and not all have the same phase.

Example (any one): single phase line to ground fault (**L-G**), two phase to ground (**LL-G**) fault and phase to phase (**L-L**) fault.

UNSYMMETRICAL FAULT

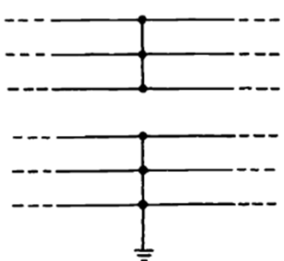


PHASE – PHASE FAULT

TWO PHASE – EARTH FAULT

SINGLE PHASE - EARTH FAULT

SYMMETRICAL FAULT



THREE-PHASE FAULT

THREE PHASE -EARTH FAULT

Abnormalities in Power Systems

Overcurrent **(overload, short circuit, open circuit)**

Ground Potential **(ungrounded equipment, touch potentials, step potentials)**

Surge Voltages **(lightning strokes, switching surges, harmonics)**

Frequency of Types of Faults

Type of Fault	% Occurrence
SLG	85
LL	8
DLG	5
3L	2 or less

Frequency of Fault Occurrence

Equipment	% of Total
Overhead lines	50
Cables	10
Switchgear	15
Transformers	12
CTs and PTs	2
Control Equipment	3
Miscellaneous	8

EQUIPMENTS & % of total fault	Causes of Faults
Over head lines (50%)	•Lighting Stroke •Earthquake •Icing •Birds •Tree branches •Kite Strings •Internal Overvoltage 
Under ground Cable (9%) 	•Damage due to digging • Insulation failure due to temperature rise •Failure of Joints
Alternator (7%)	•Stator & Rotor faults

EQUIPMENTS & % of total fault	Causes of Faults
Transformer **(10%)**	•Insulation Failure •Faults in tap changer •Overloading 
Current Transformer **&** **Potential Transformer** **(12%)**	•Overvoltage •Insulation Failure •Break of Conductors •Wrong Connections
Switch Gear **(12%)**	•Insulation failure •Leakage of air/oil/gas •Mechanical defect •Lack of Maintenance

Fault Minimization

- ***Improving the quality*** of machines, equipments, installation etc., by improving the design techniques.
- ***Adequate & reliable*** protection system control
- ***Regular maintenance*** by trained professionals
- ***Effective management*** of electrical plant

Merits of Fast fault clearing

- Helps to avoid ***permanent damage to equipment & components of the apparatus***
- ***Reduces*** the chances of risks like ***fire hazards***
- Maintains the ***continuity*** of the power supply
- Brings back the power system to the ***normal state sooner***

7. Protection of electrical power equipment

- **Generator :** Over Current, Over Voltage, Under Voltage, Under Frequency, Unbalanced Current, Loss of Excitation, Reverse Power, Winding Inter turn Fault, Winding Earth Fault etc.
- **Transformer :** Over Current, Winding Inter turn fault, Excessive Temperature Rise, Unbalance Current, Over fluxing etc.
- **Motors** : Over Current, Under Voltage, Unbalance Current, Winding Short Circuit, Stator Earth Fault, etc
- **Transmission Line** : Single Phase to ground fault, Phase to Phase Fault, three phase to ground fault, Over Current etc.

Generator protection

- Generator is the electrical end of a turbo-generator set.
  Without Generator, turbine/boiler/any Power Plant Equipment is meaningless. Generator is the most precious/valuable equipment in PP which actually converts the mechanical energy of turbine into electricity. So, Generator should be protected from faults occurring within generator and also from external faults/abnormal operating condition in the GRID which affected the generator.

- Various relays/devices are used to detect the abnormalities in operations and whenever fault conditions appear, they can give warning alarms to the operators or trip the unit automatically.

- Generally automatic tripping are provided if the time for operator to take corrective action is less or the fault is likely to cause serious damage to the unit.

Faults occurring in Transformers

- Open-Circuit faults
- Earth faults
- Phase-to-Phase faults
- Inter-Turn faults
- Overheating

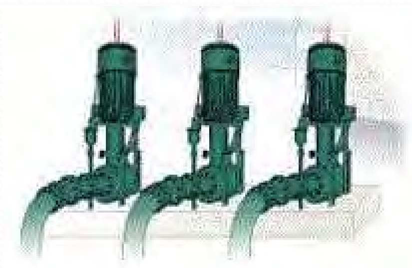
Factors in choosing Protective Gear for a Transformer

- Type of Transformer
- Size of the Transformer
- Type of Cooling
- System where used
- Importance of service for which it is required

- Open-circuit faults, earth faults, phase-to-phase faults, inter-turn faults and overheating are the fault that are likely occur in a transformer
- Relays control output circuits of a much higher power.
- Safety is increased
- Protective relays are essential for keeping faults in the system isolated and keep equipment from being damaged.

Various Industry Motor Applications

- Fan, Blower
- Pump, Compressor
- Conveyor
- Mixer
- Cranes



Types of Fault in Motors

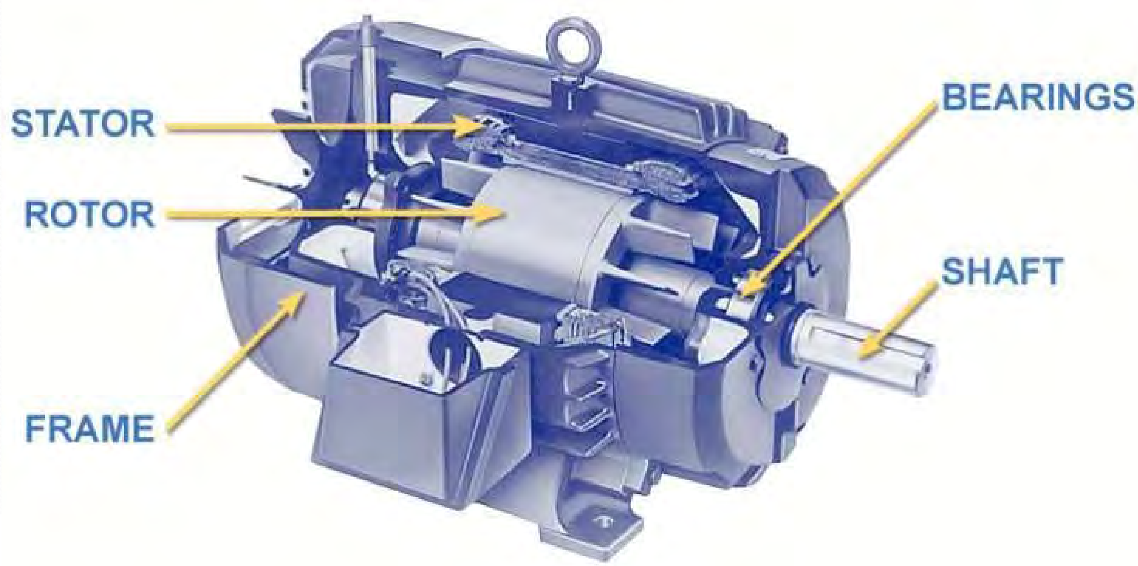
External Fault	Internal Fault
Mechanical Load	Bearing Failure
Unbalance Supply Voltage	Winding phase and earth fault
Single Phasing	
Phase Reversal	

Motor Protection Summary

- **THERMAL OVERLOAD**
- **SHORT CIRCUIT**
- **EARTH FAULT**
- **UNBALANCE**
- **BLOCKED ROTOR/STALLING PROTECTION**

Thermal Stress Causes Motor Failure

- Most of the motor failure contributors and failed motor components are related to motor overheating.
- Thermal stress potentially can cause the failure of all the major motor parts: Stator, Rotor, Bearings, Shaft and Frame.

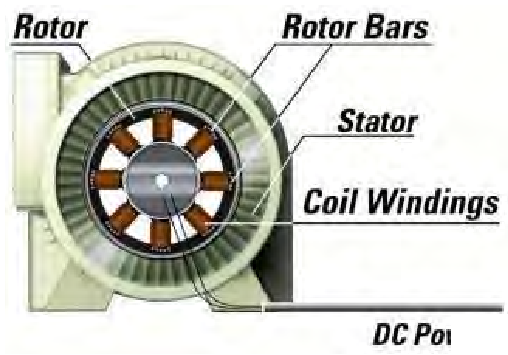


Thermal Overload

- Consider a motor is as homogenous body
- Developing heat at constant rate.
- Dissipating heat at constant rate.

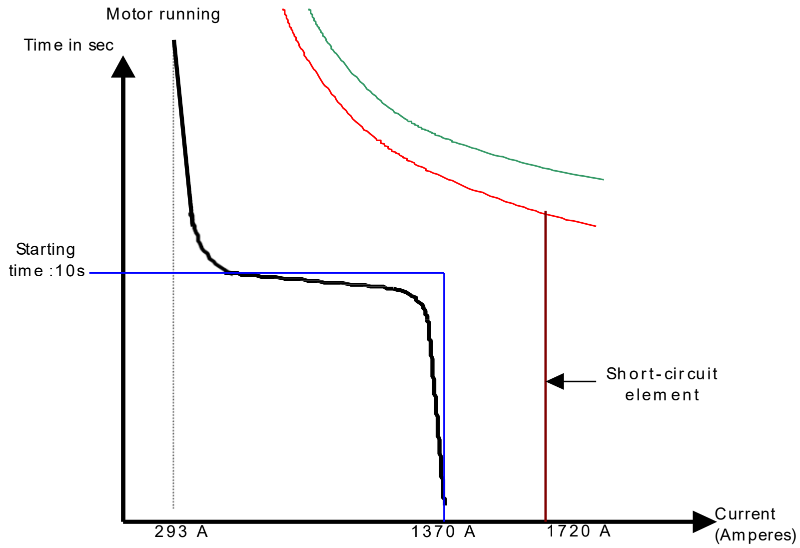
  Heat disspation is proportional to temperature rise

$$T = KI_R^2 \left(1 - e^{-t/\tau}\right)$$



THERMAL OVERLOAD cont……

SETTING CRITERIA : Thermal Element



HOT & COLD CURVES OF THE RELAY ARE TO BE MATCHED WITH THAT OF THE MOTOR

$$\text{PICKUP} = \frac{\textbf{FULL LOAD CURRENT X CT SECONDARY}}{\text{CT PRIMARY X 1.05}}$$

THERMAL ALARM (PRETRIP)

MONITORS THERMAL CONTENT & GIVES AN ALARM WHEN CONTENT REACHES 75% OF HOT TRIP TIME

LED INDICATION

THERMAL LOCKOUT

LOCKOUT RELAY PICKSUP WHEN THERMAL CONTENT EXCEEDS TRIP LEVEL & INDICATES

SHORT CIRCUIT PROTECTION

- What is:-Motor short-circuit protection - provided to cater for major stator winding faults and terminal flashovers.

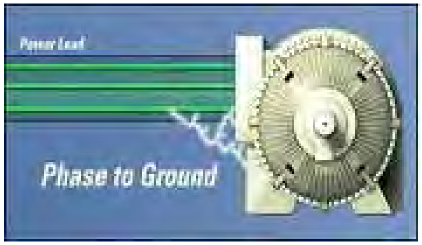
- Settings - Definite time over current relay element, set to about 130% of motor starting current and time delay set at 100ms.

SHORT CIRCUIT ELEMENT

$$\text{SETTING} = \frac{\text{1.3 X STARTING CURRENT X CT SEC.}}{\text{CT PRIMARY}}$$

Ground Fault Protection

- **What is:-**A ground fault is a fault that creates a path for current to flow from one of the phases directly to the neutral through the earth bypassing the load

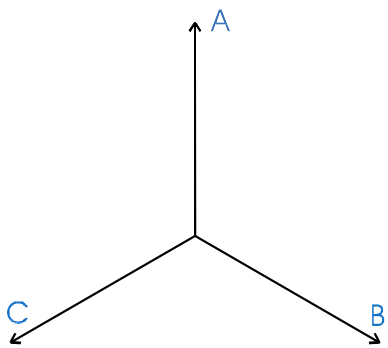


- **Ground faults in a motor occur:**
  - When its phase conductor's insulation is damaged for example due to voltage stress, moisture or internal fault occurs between the conductor and ground
- **To limit :-**the level of the ground fault current connect an resistance known as stablising resistance

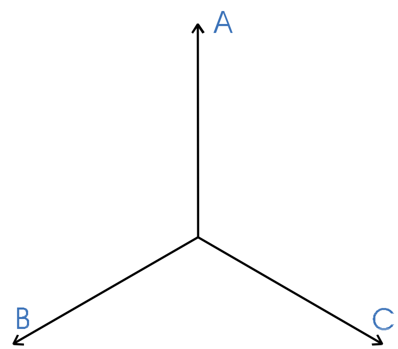
$$R_{stab} = \frac{I_{st}}{I_0}\left(R_{ct} + kR_l + R_r\right)$$

Phase Unbalance

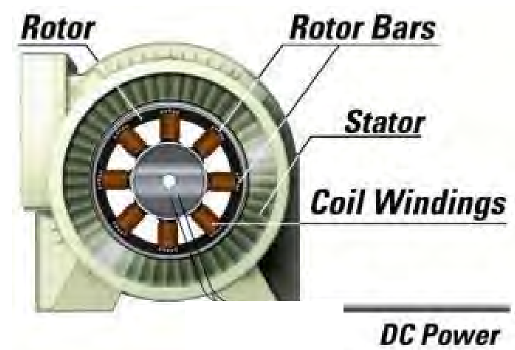
- What is:-In a balanced system the three line-neutral voltages are equal in magnitude and are 120 degrees out of phase with each other. Otherwise, the system is unbalanced.



Positive Sequence



Negative Sequence



Main causes of current unbalance

- Blown fuses
- Loose connections
- Stator turn-to-turn faults
- System voltage distortion and unbalance
- Faults

Effects

- Motor winding overheating
- Excessive vibrations
- Cause motor insulation/winding/bearing damage

Motor Protection Stalling

What is:-It happens when motor circuits are energized, but motor rotor is not rotating. It is also called locked rotor.

- Effects:

This will result in excessive currents flow given the same load. This will cause thermal damage to the motor winding and insulation.

Motor Protection Stalling

Required for

- Stalling during starting
- Stalling during running

Cases

- **Starting time < Stall withstand time**
- **Stall withstand time< Starting time**

Transmission Line Protection

- Distance Protection
- Over Current Protection
- Differential Protection.
- Main and Back up Protection

Distance Relay Protection

- The basic principle is that the apparent impedance seen by the relay reduces drastically in case of line fault.
- If the ratio of apparent impedance to the positive sequence impedance is less than unity, it indicates a fault.
- This protection scheme is inherently directional.
- Impedance relay and Mho relay use this principle.

Over Current Relay Protection

Principle of Over current Protection

- When the current in a system exceeds a predetermined value, it indicates the presence of a fault.
- Relaying decision is based solely on the magnitude of current.
- Over current relaying and fuse protection uses this principle
- Used in radial distribution systems.

Directional Over Relay Protection

- Directional Over current Protection Uses both magnitude of current and phase angle information for decision making.
- Used in radial distribution systems with source at both ends

Differential Relay Protection for Transmission Line

- By comparing the two currents either in magnitude or in phase or in both, fault can be determined.
- Its implementation requires a communication channel.
- It is extremely accurate.
- Its zone is demarkated by CTs

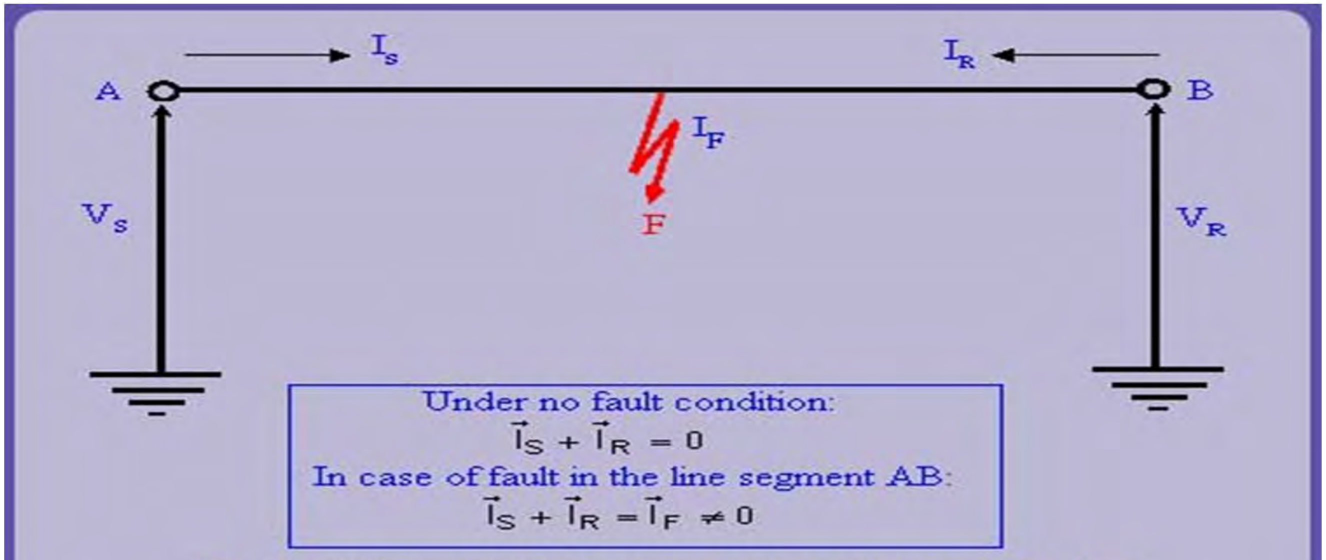


Fig 2.6 Differential Protection of Short Transmission Line

8.Methods of Arc Extinction

- High resistance method
  - a. cooling of arc
  - b. increasing the arc length
  - c. reducing the cross section of arc
  - d. splitting of arc
- Low resistance or current zero interruption
  - a. Lengthening of the gap
  - b.increasing the pressure in the vicinity of the arc
  - c. Cooling
  - d. Blast Effect

Phenomenon of arc extinction

- Energy Balance or Cassie Theory

  This theory states that if the rate of heat dissipation between the contacts is greater then the rate at which heat is generated ,the arc will be extinguished ,otherwise it will restrike.

- Recovery rate or Slepian's Theory

  This theory states that if the rate at which the ions and electrons combine to form or replaced by neutral molecules.

Arc Extinction

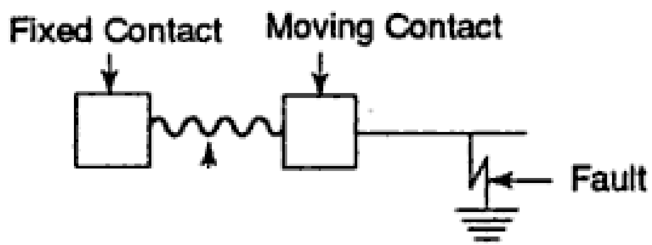


FIGURE 9.1 Separation of the contacts of circuit breaker

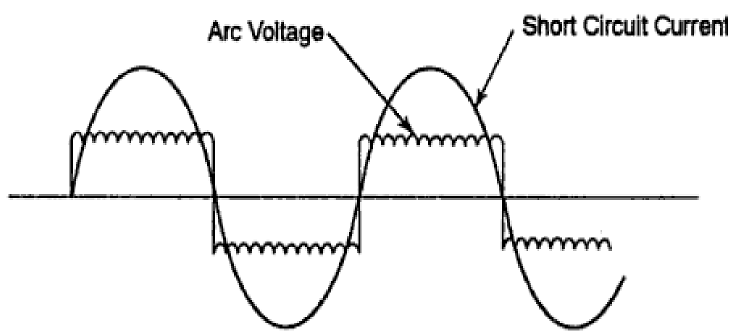


FIGURE 9.2 Short circuit current and arc voltage

Arc Voltage:

The Voltage drop across the arc is called Arc Voltage.

Arc Quenching: (C.B)

- The Arc Produced not only delays the current interruption process but it also generates enormous heat which may cause damage to the system or to the circuit breaker itself.
- Therefore main problem in a C.B is to extinguish the arc within the shortest possible time so the heat generated by it may not reach a dangerous value.

ARC PHENOMENON

During the arcing period, the current flowing between the contacts depends upon the resistance. The greater the resistance smaller the current that flows between the contacts.

The arc resistance depends upon

i)Degree of ionization (Arc resistance increases with the decrease in the number of ionized particles b/w the contact)

ii)Length of Arc (Arc resistance increases with the length of the arc)

iii)Cross section of Arc (Arc resistance increases with the decrease in X- section of the arc)

9. Ingress protection (IP) ratings guide

IP ratings are represented by combining the first and second digits of the below columns

1st numeral - solid foreign objects

0	No protection
1	Protected against solid foreign objects of 50 mm Ø and greater
2	Protected against solid foreign objects of 12,5 mm Ø and greater
3	Protected against solid foreign objects of 2,5 mm Ø and greater
4	Protected against solid foreign objects of 1,0 mm Ø and greater
5	Dust-protected
6	Dust-tight

Example: +

IP 6 5 → Protected against water jets
→ Dust-tight

2nd numeral - water

0	No protection	-
1	Protected against vertically falling water drops	Vertically falling drops shall have no harmful effects
2	Protected against vertically falling water drops when enclosure tilted up to 15°	Vertically falling drops shall have no harmful effects when the enclosure is tilted at any angle up to15° on either side of the vertical
3	Protected against spraying water	Water sprayed at an angle up to 60° on either side of the vertical shall have no harmful effects
4	Protected against splashing water	Water splashed against the enclosure from any direction shall have no harmful effects
5	Protected against water jets	Water projected in jets against the enclosure from any directions shall have no harmful effects
6	Protected against powerful water jets	Water projected in powerful jets against the enclosure from any direction shall have no harmful effects
7	Protected against the effects of temporary immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is temporarily immersed in water under standardized conditions of pressure and time
8	Protected against the effects of continuous immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is continuously immersed in water under conditions which shall be agreed between manufacturer and user but which are more severe than for numeral 7
9	Protected against high pressure and temperature water jets	Water projected at high pressure and high temperature against the enclosure from any direction shall not have harmful effects

II. SWITCHGEAR

- ❑ It is defined as the apparatus used for
  - ➢ Switching
  - ➢ Controlling
  - ➢ Protecting

The Electrical Circuits and Equipment.

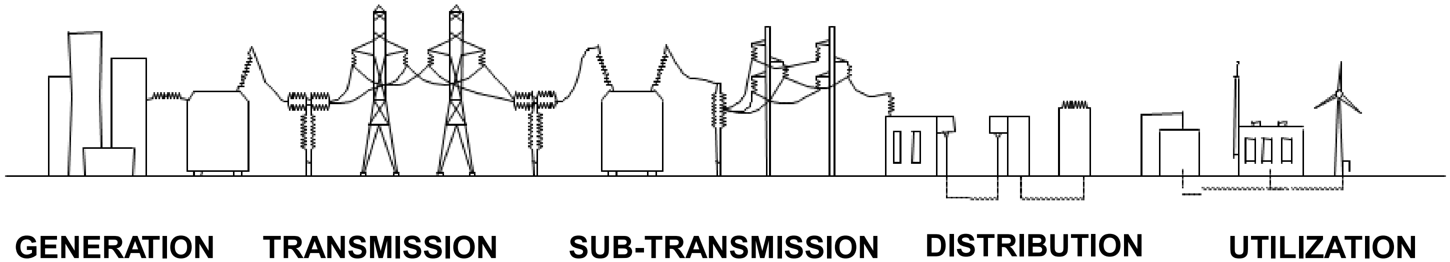
- ❑ In general, Switchgear is used for two purposes
  - ➢ Switching during normal operating conditions for the purpose of Operation and Maintenance.
  - ➢ Switching during Faults and Abnormal conditions and interrupting the fault currents.

1.Classification of Switchgear

❖ Switchgear can be classified on the basis of voltage level into the following:

- High Voltage (HV) Switchgear: above 33 KV
- Medium Voltage (MV) Switchgear : 3 KV to 33 KV
- Low Voltage (LV) Switchgear: upto 1 KV

Power Transmission + Distribution



11 kV	230 kV	132 kV	66/11 kV	400/230 V
	500 kV	66 kV	33/11 kV	
		33 kV	33/6.6 kV	

- **High Voltage (HV) Switchgear: above 33 KV**

High Voltage Switchgear – Switchgears between voltage level 33 kV up to 220 kV are classified as HV switchgear. Further, these HV switchgears are classified as Extra HV (EHV) i.e., between 220 kV to 760 kV & Ultra High Voltage (UHV) i.e. voltage level above 800 kV

2. Major Components of High Voltage Switchboards:
It comprises the following components:

- Switching Device – Vacuum Circuit Breaker (VCB), Isolators or Vacuum Contactors (VC)
- Sensing Devices – Current Transformers (CT) and Potential Transformers (PT)
- Busbars
- Measuring Devices – Meters
- Protection Devices – Relays or Fuses
- Surge Protection Devices – Surge Arrestors
- Indicating Devices – Indication Lamps and Meters
- Earthing Switch

❑ High Voltage (HV) Switchgear Functionality of Components:

- **VCB:** VCB or Vacuum Circuit Breaker is used to make or break the circuit in "ON Load" and "Off Load" conditions. The major subcomponent is the interrupter or vacuum bottle. The making and breaking happens inside the bottle under a vacuum as an arc quenching medium.

- **Current Transformer:** It is a sensing device used for the conversion of high voltage current to a current at low voltage suitable for measuring and protection devices.

- **Potential Transformer:** It is another sensing and conversion device to convert high voltage to measurable low voltage at 110V AC.

- **Bus Bar:** Current-carrying conductors connecting various high-voltage components in a designed sequence. They are characterised by current rating, fault level, creepage & clearance and arrangement of supports.

- **Measuring Devices:** These are the devices that indicate current, voltage or other derived parameters like power and energy. They take current and voltage as input for the measurement of electrical parameters. A few other devices that measure non-electrical parameters like temperature take input from thermal sensors.

- **Relay:** A protection device used to protect the system against high currents and voltages arising due to faults in the system itself or the downstream network.

- **Fuse:** A protection device to protect the system against high current due to a short circuit.
- **Surge Arrestor:** Used to divert any external voltage surge, that crept into the system, to the ground thereby protecting the system.
- **Earthing Switch:** Used to ground any floating voltage after “switching off” the main switching device during maintenance. They are interlocked with switching devices so that only one of them can be switched “ON” at a time.
- **Indication:** They are the coloured lamps indicating the different states of switching devices like “ON”, “Off”, and “Trip”. They are also used to state the healthiness of a circuit.

❑ Basic Structure of High Voltage Switchboards

These Switchboards are normally divided into three sections:

- CB compartment
- Bus Bar Compartment and
- Low Voltage Compartment

Based on the medium of insulation around the high-voltage components, the High Voltage Switchboard can be classified as

- Air Insulated Switchgear or AIS
- Gas Insulated Switchgear or GIS
- Solid Insulated Switchgear or SIS

- **Two main classes of switch gear for substation**

1. GIS (Gas insulated switch gear)
2. AIS (Air insulated switch gear)

The difference is how the energized components are insulated from each other and to earth or ground.

Gas insulated uses sulfur hexafluoride (SF_6) gas as the insulating medium. Air insulated uses the atmosphere air.

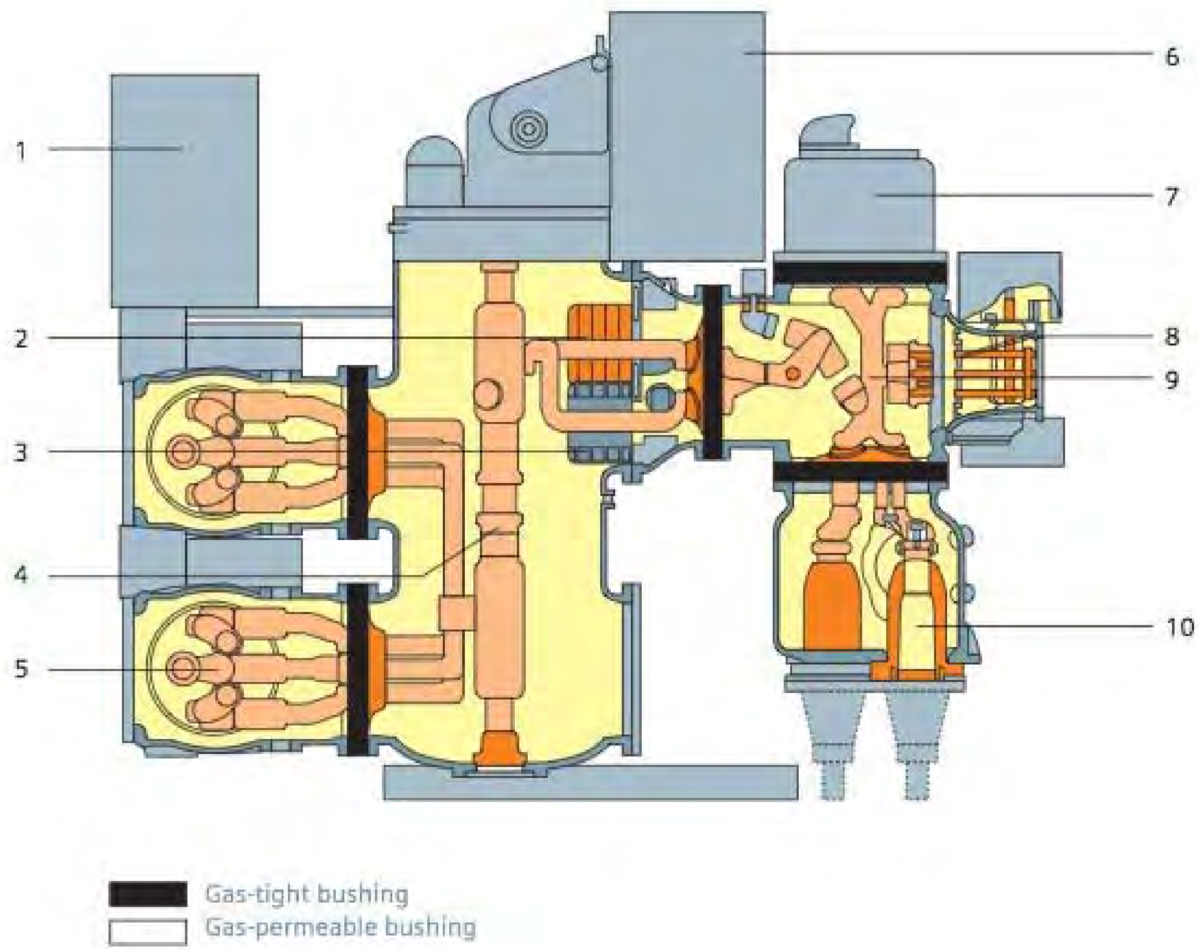
GIS Substations

- With an air insulated substation, the physical distance between each high voltage component and earth is large. Since SF6 has insulating qualities greater than air, the equivalent distance between components and earth is smaller.
- The majority of substations enclose GIS inside a building at all voltage levels. The energized sections are contained in a sealed and pressurized system.
- The equipment is provided to protect from the extreme weather conditions that affect the AIS.
- When properly installed and maintained, GIS installations will increase system reliability and provide a long service life. The high voltage electrical components that make up GIS are functionally the same as AIS. The GIS are smaller and different in appearance.

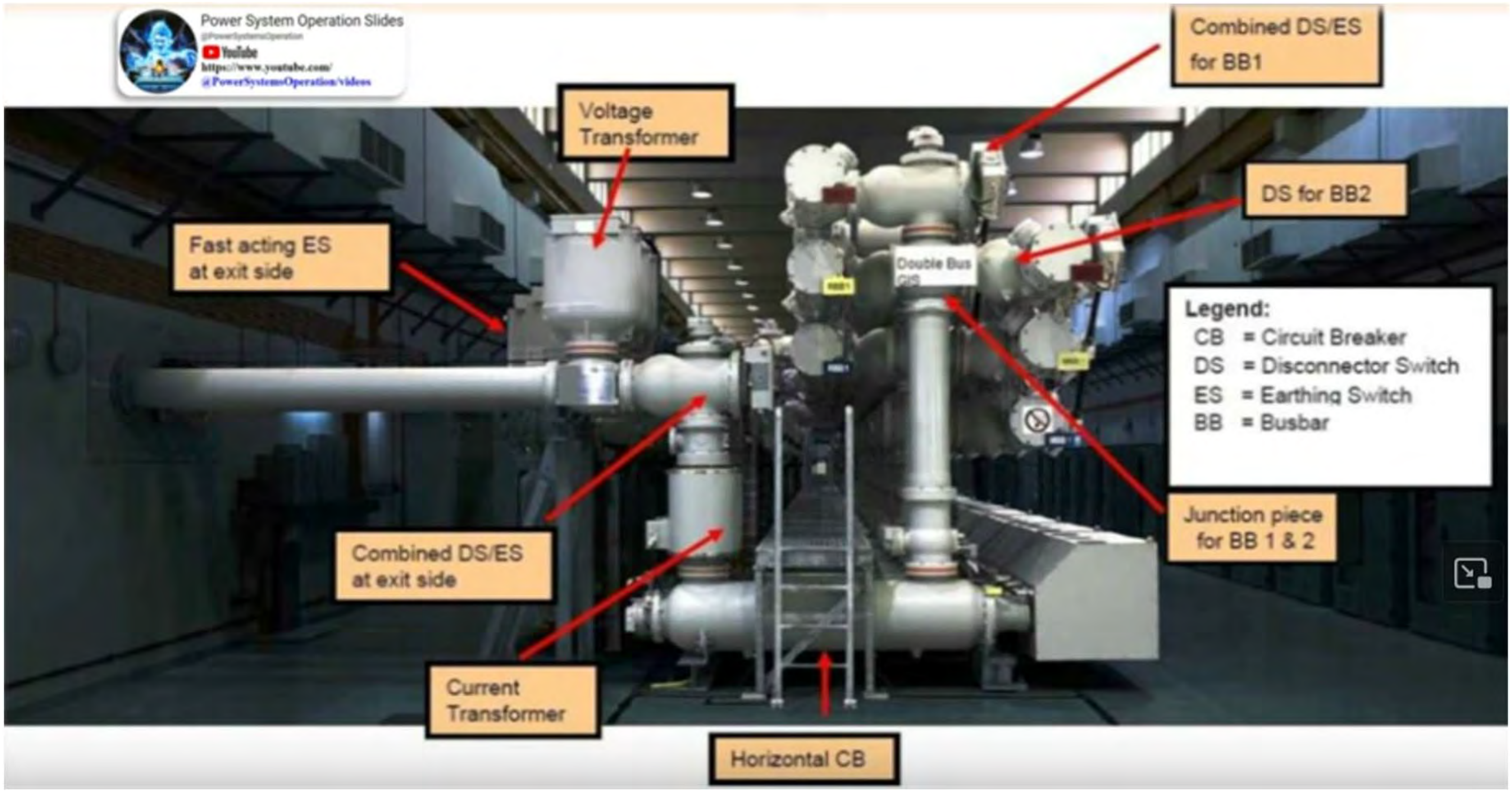
GIS Enclosures

- Metal enclosures and pressurized with SF6 gas for insulation and extinguishing the arc in the breaker.
- The gas in monitored to ensure designed insulation and interrupting properties are constant.
- A typical configuration of GIS is the double bus arrangement. Figure is a graphic representation with underground cable connections.

- This decomposition, if mixed with any amount of moisture will become toxic and corrosive.
- Maintenance staff routinely perform the handling of SF6 in gas insulated switchgear, which contains decomposition products.



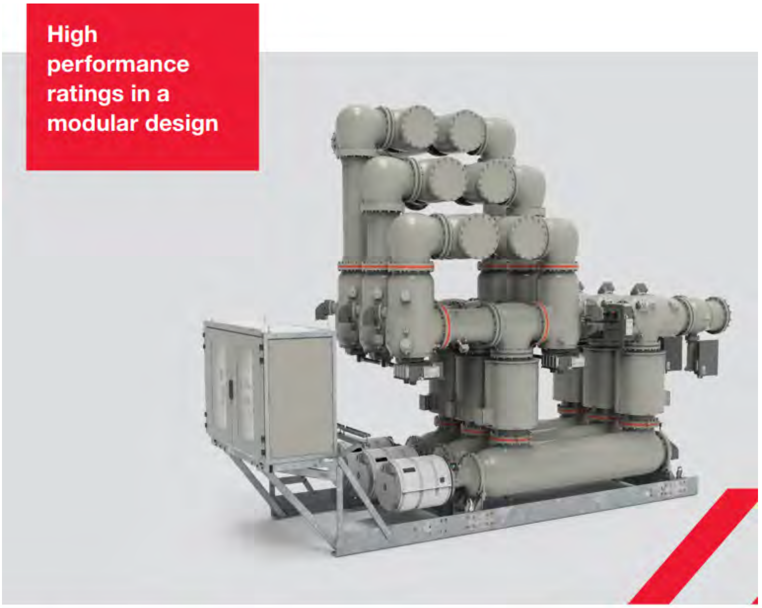
1. Integrated local control cubicle
2. Current transformer
3. Busbar II with disconnector and earthing switch
4. Interrupter unit of the circuit-breaker
5. Busbar I with disconnector and earthing switch
6. Spring-stored energy mechanism with circuit-breaker control unit
7. Voltage transformer
8. High-speed earthing switch
9. Outgoing feeder module with disconnector and earthing switch
10. Cable sealing end



Double Bus GIS Identification

GIS Devices

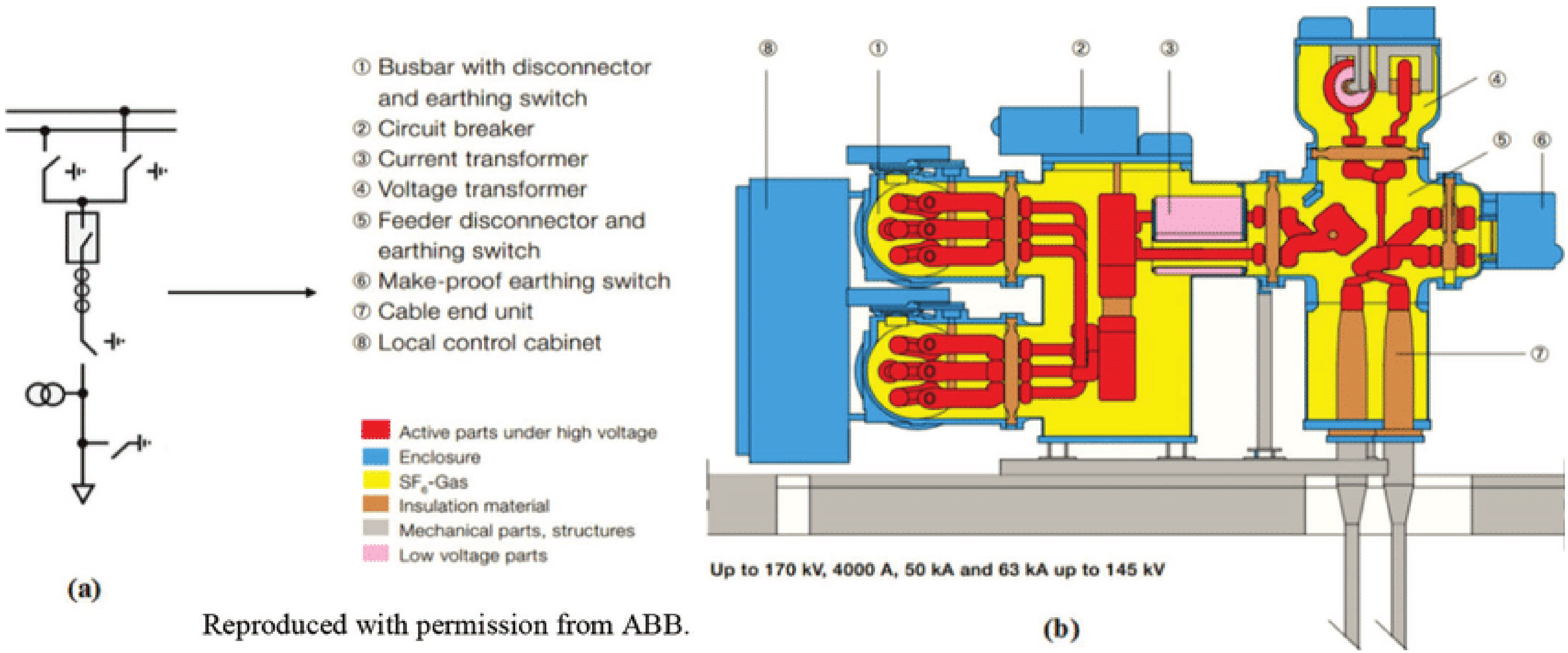
- Circuit breakers (interrupters), CB
- Disconnect (isolator) switches, DS
- Earth (ground) switches, ES
- Combined earth and disconnect switches
- Fast acting ground (earth) switches, FAES
- Load break switch, LBS
- Current transformers, CT.



High Voltage Products | Gas-insulated switchgear

❑ Gas Insulated Switchgear (GIS):

These are the High Voltage Switchboards where all high voltage components like VCB's, CT/PT and Bus bars are immersed in SF6 gas. They are comparatively smaller because of the higher dielectric strength of SF6.



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SF6 Gas

- SF6 is a man-made gas. When pure, it is insert, nontoxic, colorless, odorless, tasteless, and non-flammable.
- SF6 gas is used in GIS because it has excellent insulating and arc quenching properties. SF6 is about 5 times heavier than air, so it will collect in low areas.
- SF6 is the most potent greenhouse gas (GHG) with a global warming potential of 23,900 times more than carbon dioxide (CO2).
- Not ozone depleting gas.

❑ Air Insulated Switchgear (AIS):

AIS is a device used to control, protect, and isolate electrical equipment in a power system. AIS uses air as the insulating medium and is typically made up of components like circuit breakers, disconnect switches, and busbars.

AIS Vs GIS

Feature	AIS (Air Insulated Switchgear)	GIS (Gas Insulated Switchgear)
Tank Requirement	Not require	Required
Pressure Monitoring System	Not require	Required
Pressure Relife Device	Not require	Required
Busbar Insulation	Optional	Insulated
Compactness	Less Compact	Very Compact
Withdrawable Circuit Breaker	Available	Not Available
Safety	Standard	Safer
Maintenance Require	High Maintenance	Low Maintenance
Cost	Less Expensive	More Expensive
Additional Disconnector (DS)	Not require (If withdrawable CB provided)	May be required at cable side fi demanded by customer

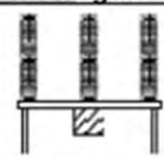
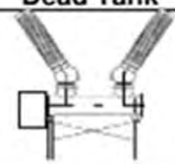
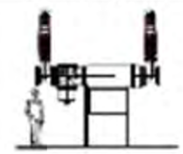
	Air-Insulated Switchgear		Gas-Insulated Switchgear	
	AIS	**DT**	**HIS**	**GIS**
	Air-Insulated Switchgear	**Dead Tank**	**Highly Integrated Switchgear**	**Gas-Insulated Switchgear**
				
characteristical type of installation	outdoor	outdoor	outdoor	indoor
metal-encapsulated circuit-breaker	-	X	X	X
metal-encapsulated disconnector	-	-	X	X
metal-encapsulated grounding switch (high speed, fault making)	-	-	X	X
busbar	air-insulated	air-insulated		gas-insulated
SF6-insulated current-transformer	-	-	X	X
SF6-insulated voltage transformer	-	-	X	X
Direct cable or SF6 / oil termination	-	-	X	X

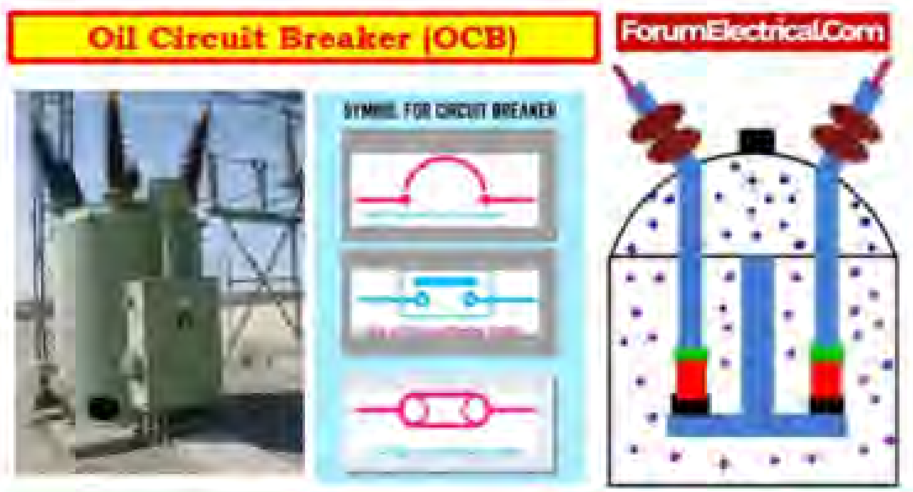
Table II. Application-Examples of air-insulated and gas-insulated switchgear.

4. Types Of High Voltage Circuit Breakers

- Oil Circuit Breakers
- Vacuum Circuit Breakers
- SF6 Circuit Breakers
- Air Blast Circuit Breakers

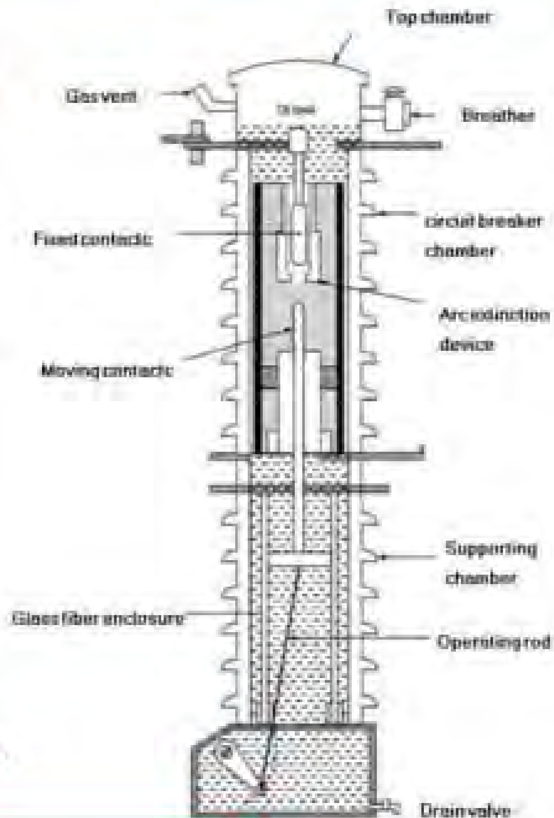
❑ Oil Circuit Breakers (OCB)

- OCB are the oldest circuit breaker types and use oil as an insulating medium for arc extinguishing.
- In this model, the switch contacts are inside insulating oil and when a fault occurs in the system, the switch contacts open inside the oil. The developing arc forms a hydrogen bubble around it, and the pressure generated prevents the arc from reigniting by accident.
- Its main advantage is that it does not require special devices to control the electric arc, in addition to the fact that the oil provides insulation between the contacts after the arc has been extinguished.
- Oil circuit breakers (OCBs) are generally utilized in high-voltage applications that require reliable current interruption. They are used in systems with voltages ranging from 33 to 220 kV and are ideal for outdoor switchyards & substations.



1. OIL CIRCUIT BREAKER

- It is designed for 11kv-765kv.
- These are of two types
  - BOCB (Bulk oil Circuit Breaker)
  - MOCB (Minimum oil Circuit Breaker)
- The contacts are immersed in oil bath.
- Oil provides cooling by hydrogen created by arc.
- It acts as a good dielectric medium and quenches the arc.



Advantages:

- Oil has good dielectric strength.
- Low cost.
- Oil is easily available.
- It has wide range of breaking capability.

Disadvantages:

- Slower operation , takes about 20 cycles for arc quenching.
- It is highly inflammable , so high risk of fire.
- High maintenance cost.

High Voltage Circuit Breaker
Vacuum Circuit Breakers (VCB)

- In VCB, the interruption of electrical current occurs within a structure normally made of ceramic known as a “vacuum blister”. This blister is fully insulated and allows a high rate of vacuum inside. Inside this blister, there are the fixed and moving contacts. The electric arc starts when the contacts separate and thanks to the vacuum and the dielectric strength (electrical insulation) in the structure, the heat generated during the arc is quickly extinguished
- Vacuum circuit breakers are classified by voltage class: for 6-10kV and 35kV devices.

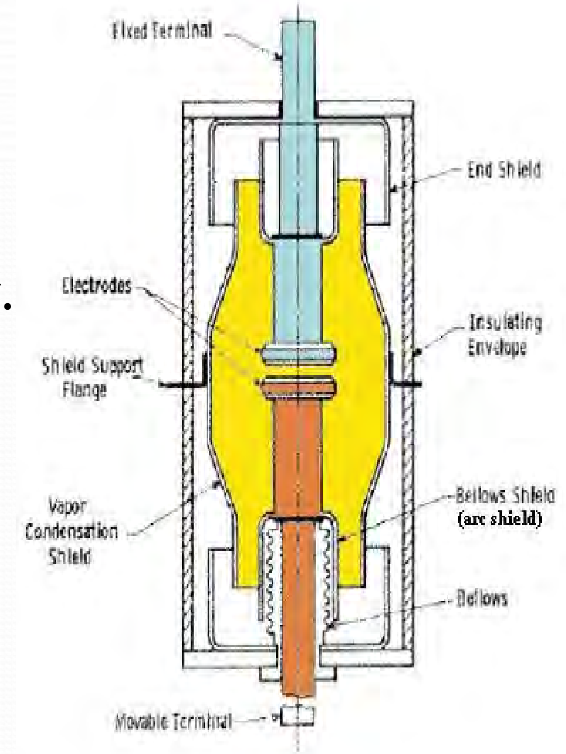
.

The current corresponds to the breaking current parameters

Rated current(A)	630	1000	1250	1600	2000	2500	3150	4000
Rated short circuit breaking current (kA)	20	20	20					
	25	25	25	25				
		31.5	31.5	31.5	31.5	31.5		
			40	40	40	40	40	40
								50

VACCUM CIRCUIT BREAKER

- It is designed for medium voltage range (3.3-33kv).
- This consists of vacuum of pressure ($1*10^{-6}$) inside arc extinction chamber.
- The arc burns in metal vapour when the contacts are disconnected.
- At high voltage , it's rate of dielectric strength recovery is very high.
- Due to vacuum arc extinction is very fast.
- The contacts loose metals gradually due to formation of metal vapours.



Representation of vacuum interrupter chamber in vacuum circuit breaker

Advantages:

- Free from arc and fire hazards.
- Low cost for maintenance & simpler mechanism.
- Low arcing time & high contact life.
- Silent and less vibrational operation.
- Due to vacuum contacts remain free from corrosion.
- No byproducts formed.

Disadvantages:

- High initial cost due to creation of vacuum.
- Surface of contacts are depleted due to metal vapours.
- High cost & size required for high voltage breakers.

Advantages:

- High speed operation as compared to OCB.
- Ability to withstand frequent switching.
- Facility for high speed reclosure.
- Less maintenance as compared to OCB.

Disadvantages:

- Little moisture content prolongs arcing time.
- Pressure should be checked frequently for frequent operation.
- Risk of fire hazards due to over voltages.
- It can’t be used for high voltage operation due to prolonged arc quenching.

❑ GCB Sulfur Hexafluoride Circuit Breakers (SF6CB)

- The main feature of SF6CB is that they use sulfur hexafluoride gas (SF6) in their operation. This gas has an excellent insulating property that makes SF6CB very effective devices.

- Furthermore, SF6 has the property of rapidly recombining after extinguishing the arc, being a much more effective cooling medium than air. Due to these properties, SF6CBs are very effective devices in medium and high voltage systems, since the gas used has excellent dielectric properties, as well as being non-flammable.

- **Power Transmission and Distribution:** SF6 circuit breakers are commonly used in high-voltage power systems to protect transformers, circuit lines, and other critical equipment.

- **Industrial Plants:** They are used in industrial facilities to protect electrical equipment from short circuits and overloads.

- **Railways:** SF6 circuit breakers are used in railway electrification systems to ensure reliable power distribution.

- **Substations:** SF6 circuit breakers are employed in substations to control and protect the electrical grid.

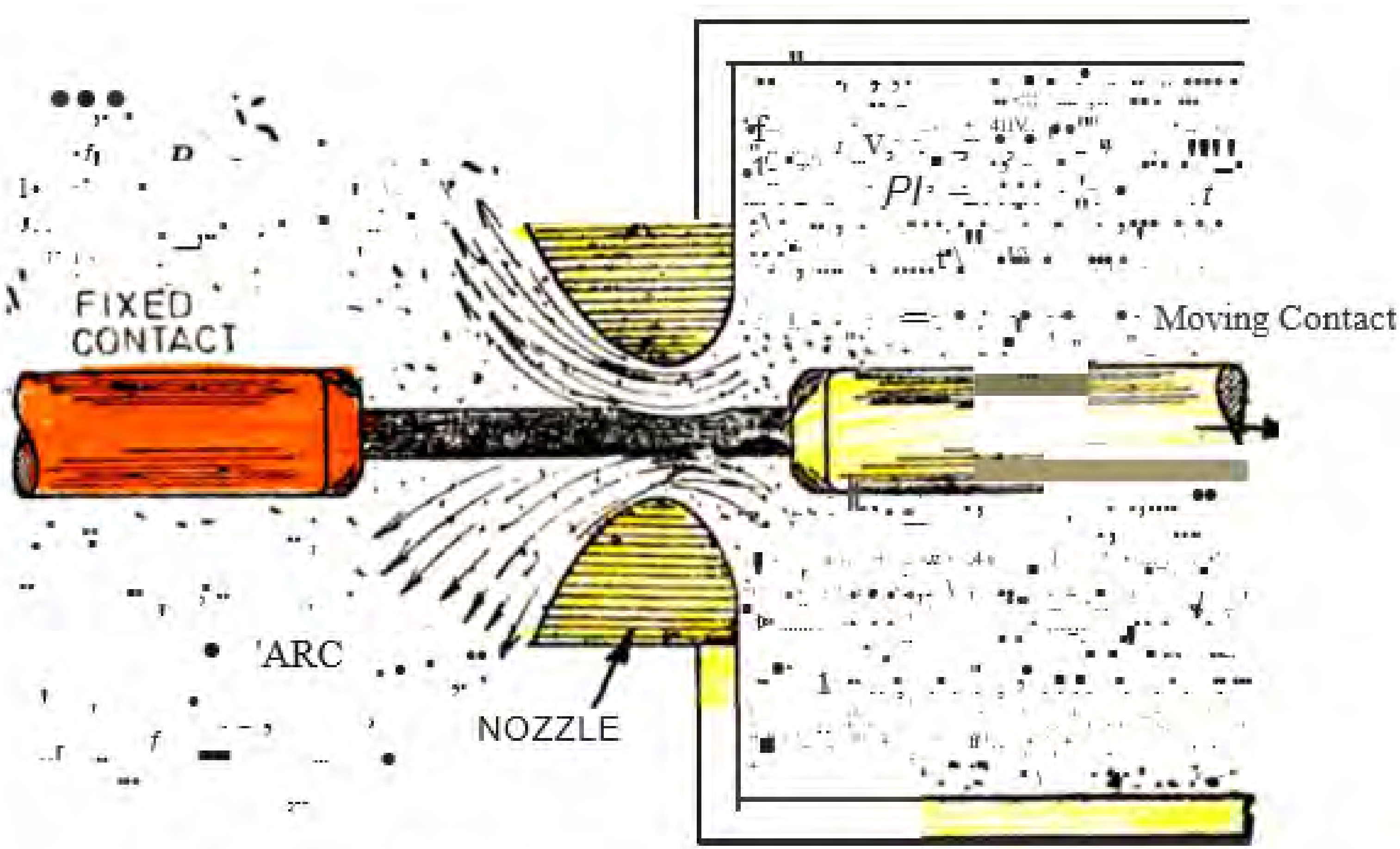
- **Power Generation:** SF6 circuit breakers can be used in power generation facilities for generator protection.

- **Renewable Energy:** They are used in renewable energy systems like wind farms and solar power plants.

Out-Door Use From (24 kV To 800 kV)

SF_6 CIRCUIT BREAKERS

- It contains an arc interruption chamber containing SF_6 gas.
- In closed position the contacts remain surrounded by SF_6 gas at a pressure of 2.8 kg/cm^2 .
- During opening high pressure SF6 gas at 14 kg/cm^2 from its reservoir flows towards the chamber by valve mechanism.
- SF_6 rapidly absorbs the free electrons in the arc path to form immobile negative ions to build up high dielectric strength.
- It also cools the arc and extinguishes it.
- After operation the valve is closed by the action of a set of springs.
- Absorbent materials are used to absorb the byproducts and moisture.



(a) Arc extinction in gas flow circuit-breakers (Gas flow from high pressure P_{i} to low pressure P_{i} *via* an insulating nozzle)

Advantages:

- Very short arcing period due to superior arc quenching property of SF_6 .
- Can interrupt much larger currents as compared to other breakers.
- No risk of fire.
- Low maintenance, light foundation.
- No over voltage problem.
- There are no carbon deposits.

Disadvantages:

- SF_6 breakers are costly due to high cost of SF_6.
- SF_6 gas has to be reconditioned after every operation of the breaker, additional equipment is required for this purpose.

AIR BLAST CIRCUIT BREAKERS

- This operates using high velocity blast of air which quenches the arc.
- It consists of blast valve , blast tube & contacts.
- Blast valve contains air at high pressure.
- Blast tube carries the air at high pressure & opens the moving contact attached to spring.
- There is no carbonization of surface as in VCB.
- Air should be kept clean & dry to operate it properly.

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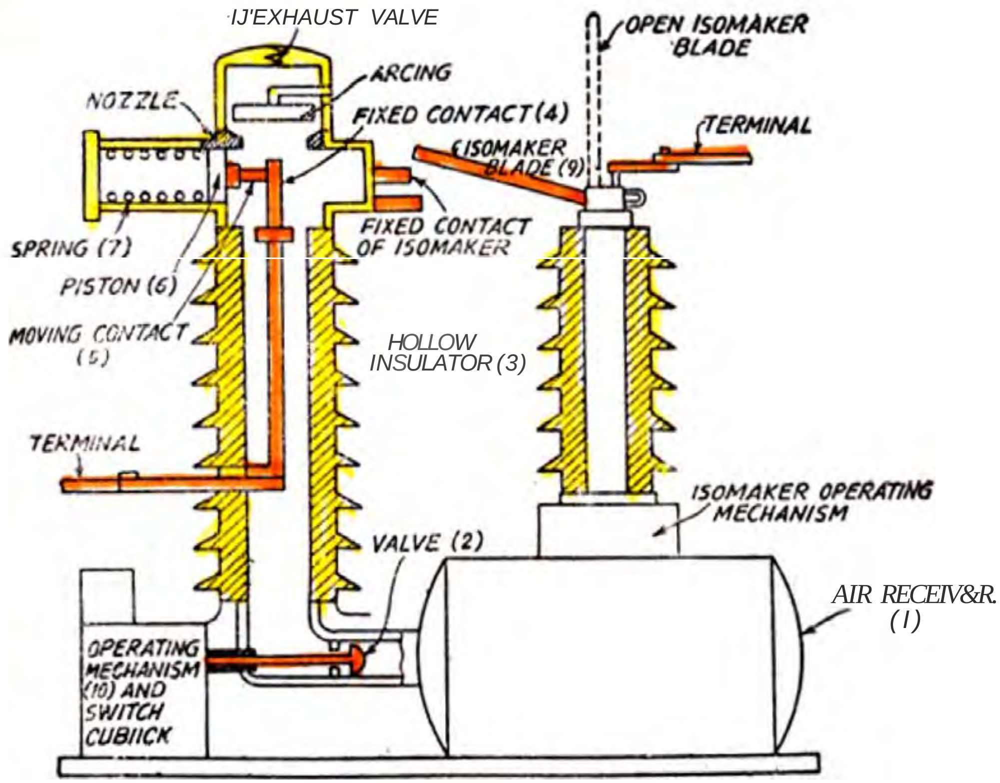


1. Air receiver,	2. Valve,	3. Hollow insulator.
4. Fixed contact.	5. Moving contact,	6. Piston.
7. Spring,	8. Exhaust valve,	9. Isomaker.

Comparison of Circuit Breakers

Factor	Oil Breakers	Air Breakers	Vacuum/SF6
Safety	Risk of explosion and fire due to increase in pressure during multiple operations	Emission of hot air and ionized gas to the surroundings	No risk of explosion
Size	Quite large	Medium	Smaller
Maintenance	Regular oil replacement	Replacement of arcing contacts	Minimum lubrication for control devices
Environmental factors	Humidity and dust in the atmosphere can change the internal properties and affect the dielectric		Since sealed, no effect due to environment
Endurance	Below average	Average	Excellent

Therefore, we conclude that circuit breaker is the most essential part of the electrical networks as it protects every device from damage. It helps us to detect the fault and area affected by it. Nowadays vacuum and SF_6 circuit breakers are widely used due to their reliable and fast operations.

❑ Low Voltage Switchgear (LV Switchgear)

➢ Low voltage switchgear, as the name implies, is designed to operate within the lower voltage range of electrical systems. While the exact voltage thresholds may vary depending on regional standards and specific applications, LV switchgear typically encompasses systems that operate below 1,000 volts (1 kV). In practice, this range often includes systems operating within the spectrum of 120V to 600V, making LV switchgear a key player in various applications.

➢ **Applications:**

The versatility of LV switchgear lends itself to a multitude of applications in residential, commercial, and industrial settings. Its primary role is to control and safeguard electrical circuits, motors, lighting systems, and an array of electrical loads in these domains. In power distribution, LV switchgear is the managing electricity in environments where lower voltage systems are the norm.

6.Key Components of LV Switchgear

- **Low voltage switchgear consists of several key components, each serving specific functions:**

- **Circuit Breakers**: Circuit Breakers are mechanical switching and protective devices. These critical devices are designed to automatically cut off electrical power when abnormal conditions, such as an overload or short circuit, occur. Depending on the application, circuit breakers come in various types, including moulded case circuit breakers (MCCBs) and miniature circuit breakers (MCBs).
- **Disconnect Switches**: Disconnect switches isolate electrical circuits from the power supply, providing a safe environment for maintenance or repairs.
- **Fuses**: Fuses provide overcurrent protection by breaking the circuit when excessive current flows through them. Unlike circuit breakers, fuses need to be replaced after they blow.
- **Busbars**: Busbars are conductive strips that distribute power within the switchgear assembly, and they provide a low-resistance pathway for electrical currents to flow.
- **Protection Relays**: These intelligent devices monitor the electrical system and initiate protective actions, such as opening a circuit breaker if an abnormal condition is detected.
- **Meters and Monitoring Devices**: Modern switchgear is often equipped with meters and sensors to monitor system performance, including current, voltage, and power quality.

❑ Functions of Low Voltage Switchgear

Electrical protection against	Isolation	Control
■ Overload currents ■ Short-circuit currents ■ Insulation failure	■ Isolation clearly indicated by an authorized fail-proof mechanical indicator ■ A gap or interposed insulating barrier between the open contacts, clearly visible	■ Functional switching ■ Emergency switching ■ Emergency stopping ■ Switching off for mechanical maintenance

- **Fault protection**

One of the primary functions of low voltage switchgear is to provide fault protection. In the event of a short circuit or overload, the switchgear's circuit breakers and protective relays work in tandem to isolate the faulty section and prevent damage to connected equipment.

- **Isolation and maintenance**

Switch disconnectors within the switchgear allow for the isolation of specific components or the entire electrical system. This feature is crucial for maintenance and repair activities, ensuring the safety of personnel working on the system by disconnecting it from the power source.

- **Load management**

Low voltage switchgear, equipped with contactors, play a vital role in managing electrical loads. They control the power supply to motors and other high-power devices, preventing overloads and ensuring the efficient operation of the electrical system.

- **Monitoring and control**

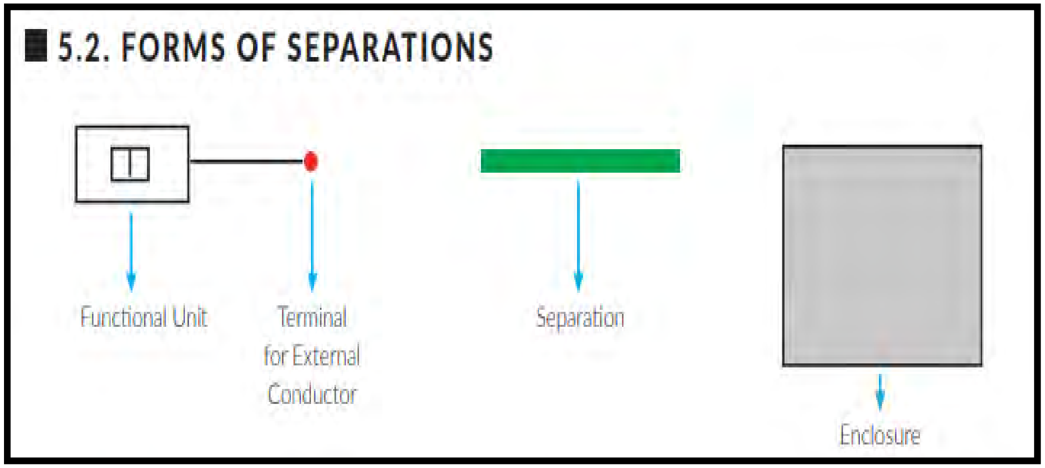
With the integration of advanced technologies, modern low voltage switchgear often come equipped with monitoring and control features. These capabilities allow for real-time monitoring of electrical parameters and remote control of the switchgear, enhancing overall system efficiency.

Low voltage switchgear and controlgear assemblies in line with IEC 61439

Example of LV Switchgear and Controlgear Assembly:
"Low Voltage Main Switch Board", power supply 2 x 800 kVA

Low voltage switchgear and controlgear assemblies (Un ≤ 1000 V AC)

7. FORMS of SEPARATION



❑ Form 1

No internal separation of the busbars, functional units, and terminals from each other.

❑ Form 2a

Separation of the busbars from the functional units. Terminals are not separated from the busbars.

❑ Form 2b

As for 2a, but with the terminals are not separated from the functional units.

❑ Form 3a

Separation of the busbars from the functional units and each functional unit from the other units. The terminals of each functional unit are not separated from each other. Terminals are not separate from the busbars.

❑ Form 3b

As per 3a, but with the terminals separated from the busbar (and functional units)

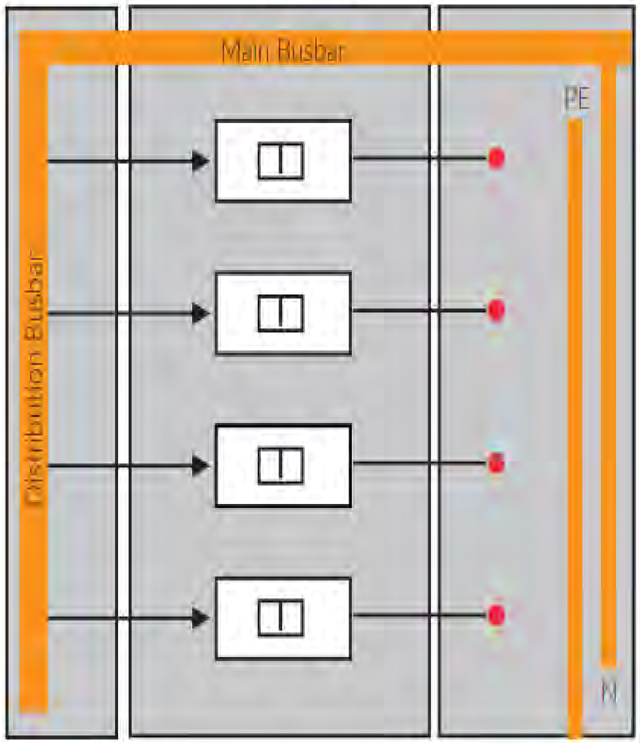
❑ Form 4a

Separation of the busbars from the functional units and each functional unit from the other units. Separation of the terminals for a functional unit from the busbars and those of any other unit. Terminals are enclosed in the same compartment as the functional unit.

❑ Form 4b

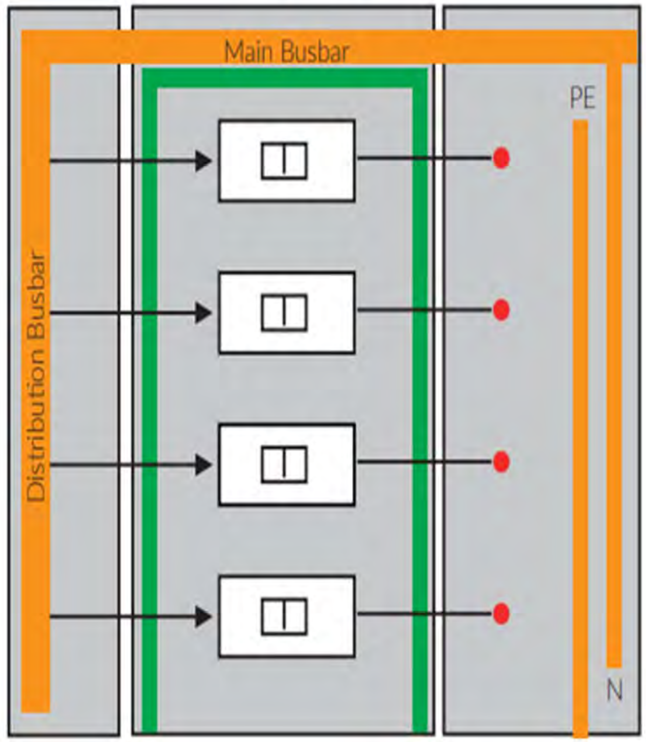
As per 4a, but with the terminals for each functional unit enclosed in their own space.

FORM 1



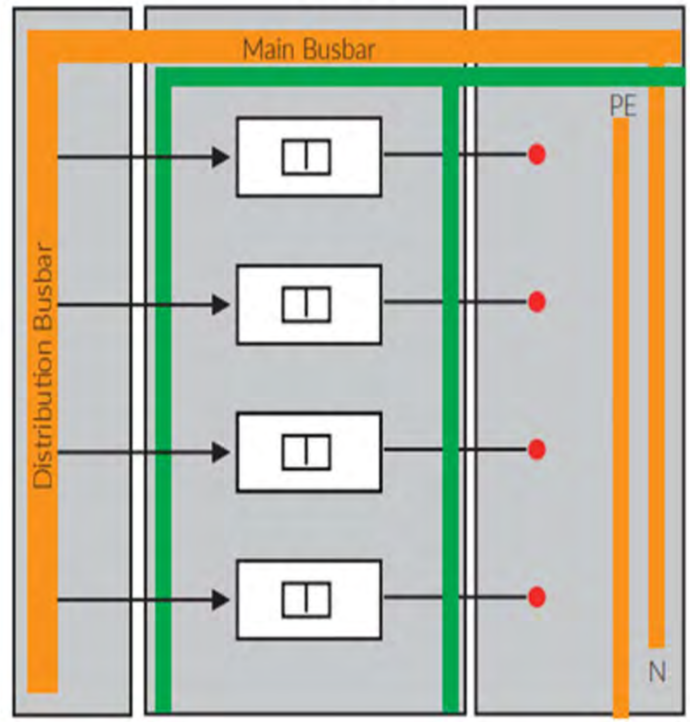
No Separation

FORM 2a



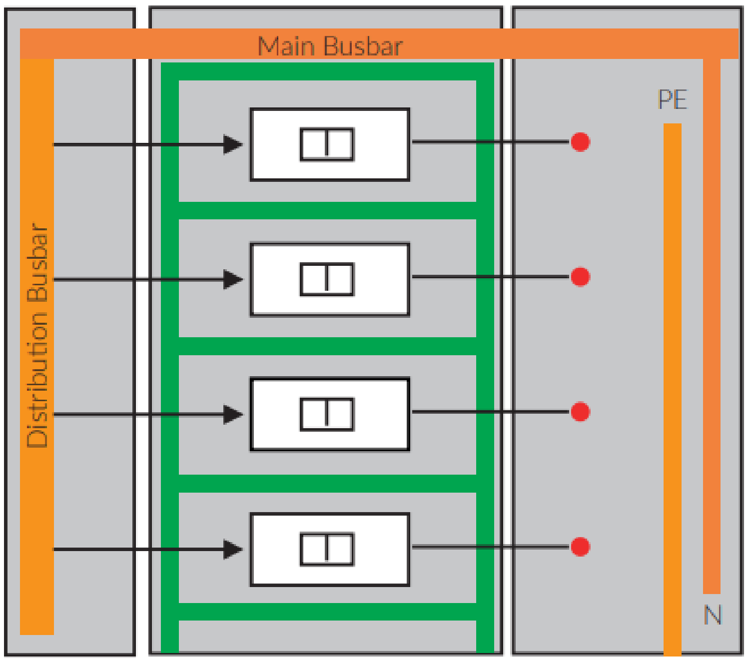
Separation of busbars from functional units. Terminals for external conductors do not need to be separated from busbars.

FORM 2b

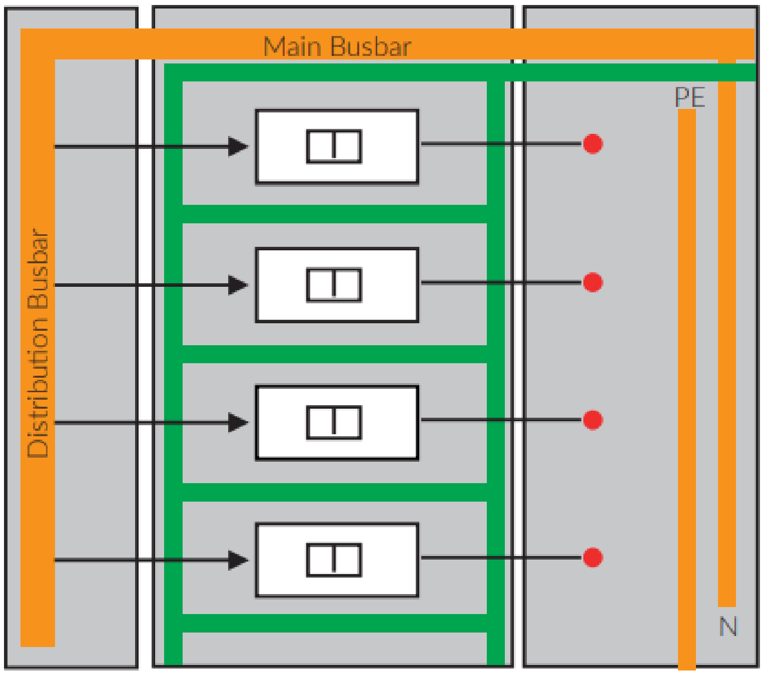


Separation of busbars from functional units. Terminals for external conductors are separated from busbars.

FORM 3a



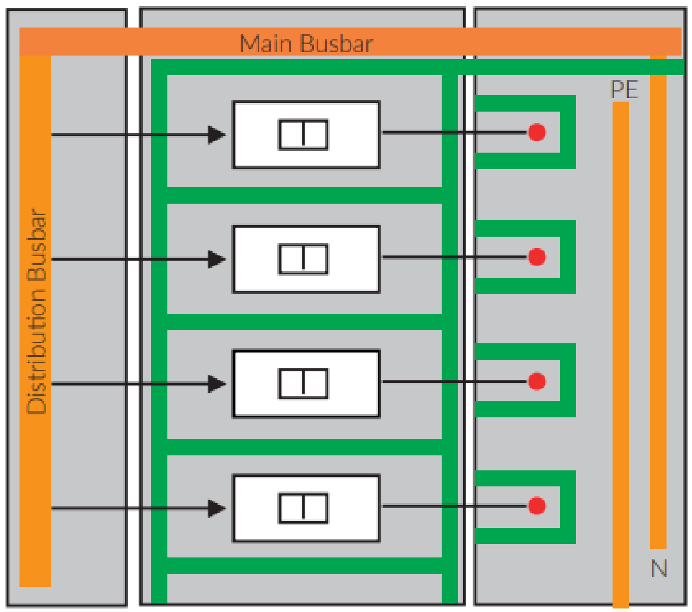
FORM 3b



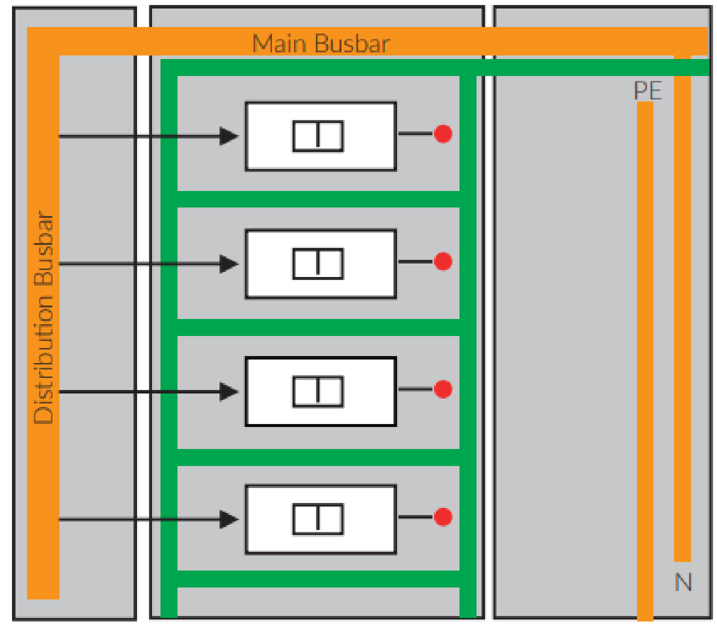
Separation of busbars from functional units and separation of all functional units from each other. Terminals for external conductors do not need to be separated from busbars.

Separation of busbars from functional units and separation of all functional units from each other. Separation of terminals for external conductors from functional units but no separation between terminals.

FORM 4b



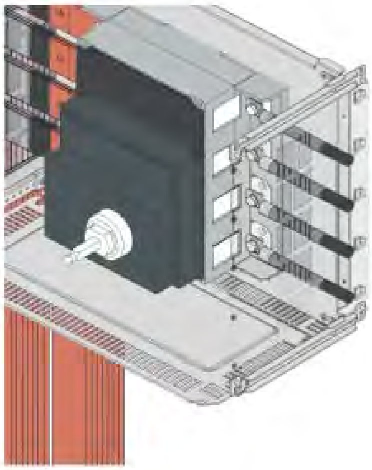
FORM 4a



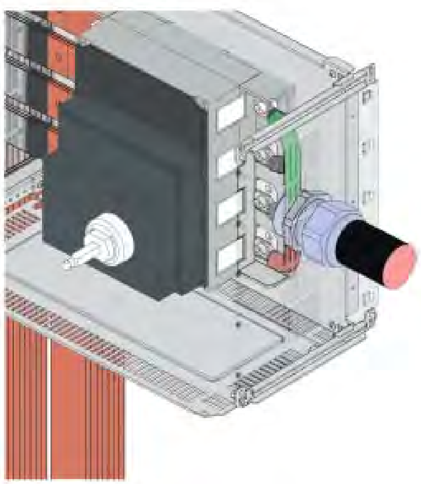
- Separation of busbars from functional units and separation of all functional units from each other, including the terminals for external conductors which are an integral part of the functional unit. Terminals for external conductors are in the same compartment as the functional unit.

Separation of busbars from functional units and separation of all the functional units from each other including terminals for external conductors. Terminals for external conductors are not in the same compartment as the functional unit but in separate individual compartments.

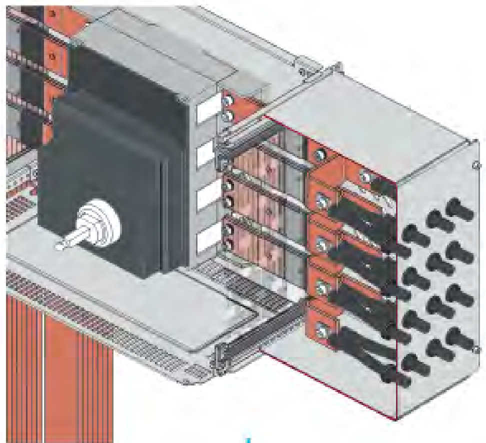
FORM 4a Type 2

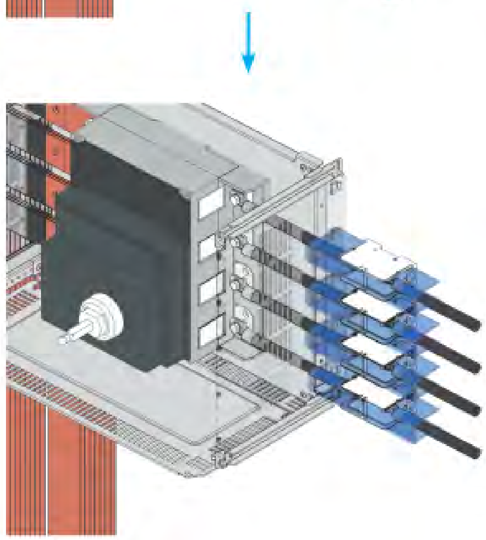


FORM 4a Type 3

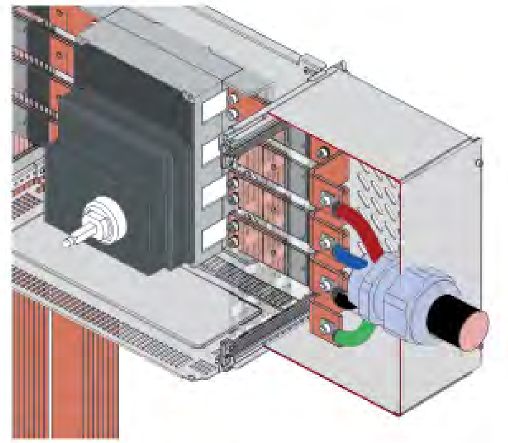


FORM 4b Type 6

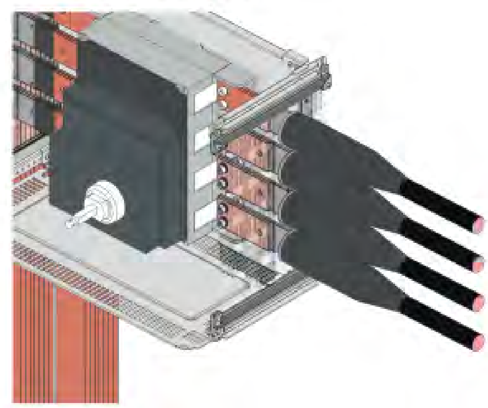




FORM 4b Type 7



FORM 4b Type 5



8.LOW VOLTAGE CIRCUIT BREAKERS

- A circuit breaker is a mechanical switching device which should fulfil the following specifications .
  - It should be capable of being safely closed in on any load current or short-circuit current within the making capacity of the device.
  - It should safely open any current that may flow through it up to the breaking capacity of the device.
  - It should automatically interrupt the flow of abnormal currents up to the breaking capacity of the device.
  - It should be able to carry continuously any current up to the rated current of the device.

Breaking Capacity

The breaking capacity of a circuit breaker is the maximum current (in r.m.s.) that flows through the breaker and the breaker is capable to interrupt at the instant of initiation of the arc during a breaking operation 24 Chapter 2 at a stated voltage under prescribed conditions. The breaking capacity is usually expressed in kA or MVA. Typical values range from 3 kA to 43 kA.

Making Capacity

The making capacity of a circuit breaker is the maximum current that will flow through the breaker and the breaker is capable of withstanding at the instance during a closing operation at a stated voltage under prescribed conditions. Typical values range from 1.4 to 2.2 times the r.m.s. value of the breaking capacity.

Types of MCB/MCCB

Type	Operating Current	Suitability
B	**[3-5]*I_{rated}**	**Resistive load**
C	**[5-10]*I_{rated}**	**Inductive load**
D	**(10-20]*I_{rated}**	**Inductive-Capacitive load**

Classification of CB according to Ratings:

MCB	**6A - 63A**
MCCB	**64A - 800A**
ACB	**Above 800A**

***Standard Sizes of CB*:-**

6A, 10A, 16A, 20A, 25A, 32A, 40A, 50A, 63A, 80A, 100A, 125A, 160A, 180A, 200A, 250A, 300A, 350A, 400A, 630A, 800A, 1000A, 1500A 1600A, 2000A, 2500A, 3000A, 3500A, 4000A, 4500A & 5000A

❑ Types of Circuit Breakers

1.Miniature Circuit Breaker (MCB)

- MCB is an automatic electro-mechanical switch, used to protect an electric circuit under abnormal conditions.
- MCB is available in Single Pole, Double Pole, Triple Pole & Four Pole MCBs
- Operating current range 6A to 63A /125A
- Thermal or thermomagnetic trip operation
- Trip setting cannot be adjusted
- MCB is more sensitive to over current than fuse

- Range of Short Ckt Current (Breaking Capacity) are 1.5kA, 3kA, 4.5kA , 10kA, 20kA & 25kA.

- Range of Instantaneous Tripping

Type	Instantaneous Tripping Current
B	Above 3 I_N up to 5 I_N
C	Above 5 I_N up to 10 I_N
D	Above 10 I_N up to 20 I_N

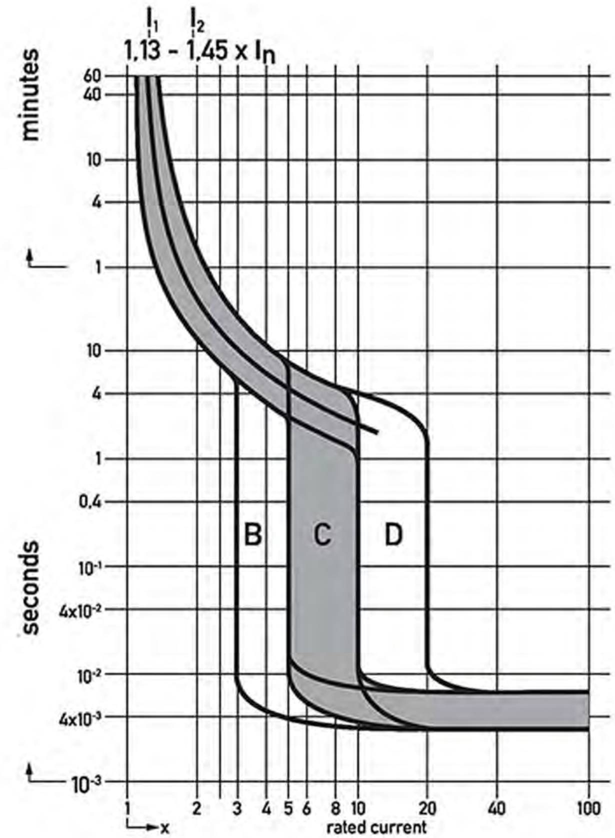
Table 7 – Time-current operating characteristics

Test	Type	Test current	Initial condition	Limits of tripping or non-tripping time	Result to be obtained	Remarks
a	B, C, D	1,13 I_n	Cold [a]	$t \leq 1$ h (for $I_n \leq 63$ A) $t \leq 2$ h (for $I_n > 63$ A)	No tripping	
b	B, C, D	1,45 I_n	Immediately following test a	$t < 1$ h (for $I_n \leq 63$ A) $t < 2$ h (for $I_n > 63$ A)	Tripping	Current steadily increased within 5 s
c	B, C, D	2,55 I_n	Cold [a]	1 s < t < 60 s (for $I_n \leq 32$ A) 1 s < t < 120 s (for $I_n > 32$ A)	Tripping	
d	B C D	3 I_n 5 I_n 10 I_n	Cold [a]	0,1 s < t < 45 s (for $In \leq 32$ A) 0,1 s < t < 90 s (for $In > 32$ A) 0,1 s < t < 15 s (for $In \leq 32$ A) 0,1 s < t < 30 s (for $In > 32$ A) 0,1 s < t < 4 s [b] (for $In \leq 32$ A) 0,1 s < t < 8 s (for $In > 32$ A)	Tripping	Current established by closing an auxiliary switch
e	B C D	5 I_n 10 I_n 20 I_n	Cold [a]	t < 0,1 s	Tripping	Current established by closing an auxiliary switch

[C] *Text deleted* [C]

a The term "cold" means without previous loading.

b [C] For $In \leq 10$ A, $t < 8$ s is permissible. [C]



Tripping characteristic B-C-D In = 10 - 63 A

2. Moulded Case Circuit Breaker (MCCB)

- The working principle for MCB and MCCBs is almost the same, but both may have different applications
- Operating Current range- 10A to 800A /1250A
- Trip setting can be adjusted
- Thermal or thermomagnetic trip operation
- Breaking Capacity – 10,20,25,35,65,85 kA (r.m.s)
- Making Capacity – 17,44,53,63,84,143 kA (Peak)

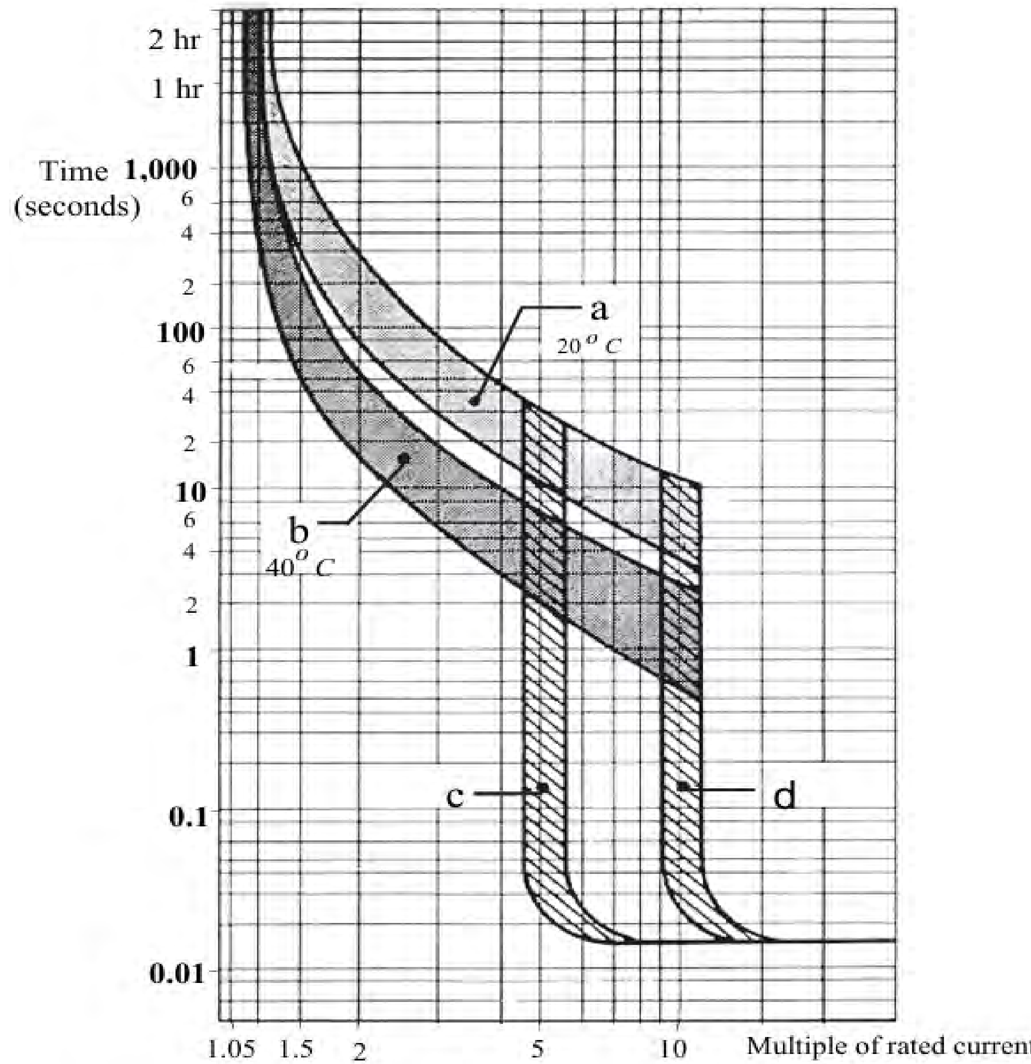


Figure 2.13 Time-current characteristic of a typical MCCB

3. Air Circuit Breaker (ACB)

- The **Air Circuit Breaker** have a compressed air storage inside. This air is released through a nozzle and produces a high-speed jet of air. This air is what is used to extinguish the arc.
- Operating Current Range: Up to 10,000A
- Trip setting is fully adjustable
- Electronically and microprocessor controlling
- Used in Low as well as High Voltage and Currents applications
- Used for protection transformers, generators, and capacitors & for main power distribution in large industrial plant
- Rated Voltage – 400,415,690V
- Rated Current – 800,1250,1600,2000,3200,5000,6500A
- Breaking Capacity – 40,65,80,120 kA (r.m.s)
- Making Capacity – 84,143,220 kA (Peak)
- Primary application in main switchboards to protect the incoming circuit fed by either a local generator or the low voltage side of a transformer directly from the power utility.
- They are also applicable for individual branch circuit protection.
- Longer life than other types of low voltage circuit breaker.

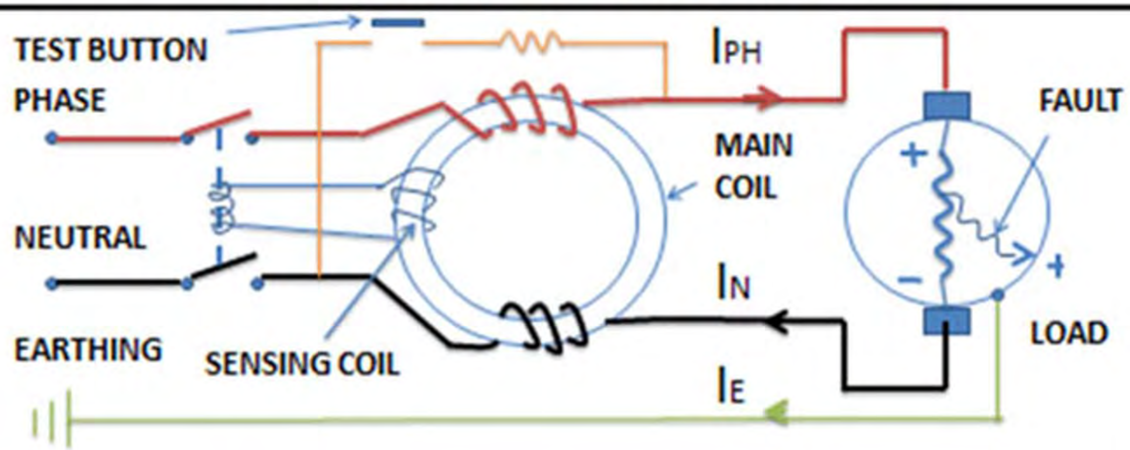
4. RCCB (Residual Current Circuit Breaker)

RCCB is also known as RCB or RCD. RCD stands for Residual Current Device, while RCB stands for Residual Current Breaker. RCCB is an electrical wiring device that disconnects the circuit as soon as it detects a current leak to the earth wire. It also protects against electric electrocution or shock caused by direct contact.

RCBO and RCCBs, are residual current protection devices. This protection is achieved by monitoring the current flow in the line and neutral. In a healthy circuit, the current flow via the line equals the return flow in the neutral.

However, this return flow may not be equal to the line's current flow in the event of any abnormalities. A residual current device will sense such a scenario and interrupt the circuit.

TYPICAL DIAGRAM OF RCCB



<u>CASE – 1</u> - **Under normal condition** - Voltage across load is 230V, Current $I_{ph} = I_N$ & $I_E = 0$.

<u>CASE – 2</u> – **When earth fault occurs** - Voltage across load remains same. Now current I_N is not same as I_{PH} some leakage current I_E flows through earth wire. This difference in current, produces a resultant in the main coil which is sensed by sensing coil & which trips the supply.

5. RCBO (Residual Current Breaker with Over-Current)

The RCBO combines the functionality of an MCB and RCD/RCCB. When there is a current leakage, the RCBO trips the entire circuit. Consequently, internal magnetic/thermal circuit breaker components can trip the electronic device when the circuit is overloaded

Preferred rated voltage

Single-phase, phase-to-neutral	: 230 V
Three-phase, three-wire	: 400 V
Three-phase, 4-wire	: 400 V

Preferred rated current (I_N)

10, 13, 16, 20, 25, 32, 40, 63, 80, 100, 125 A

Rated residual operating current ($I_{\Delta N}$)

0.006, 0.01, 0.03, 0.1, 0.3, 0.5 A

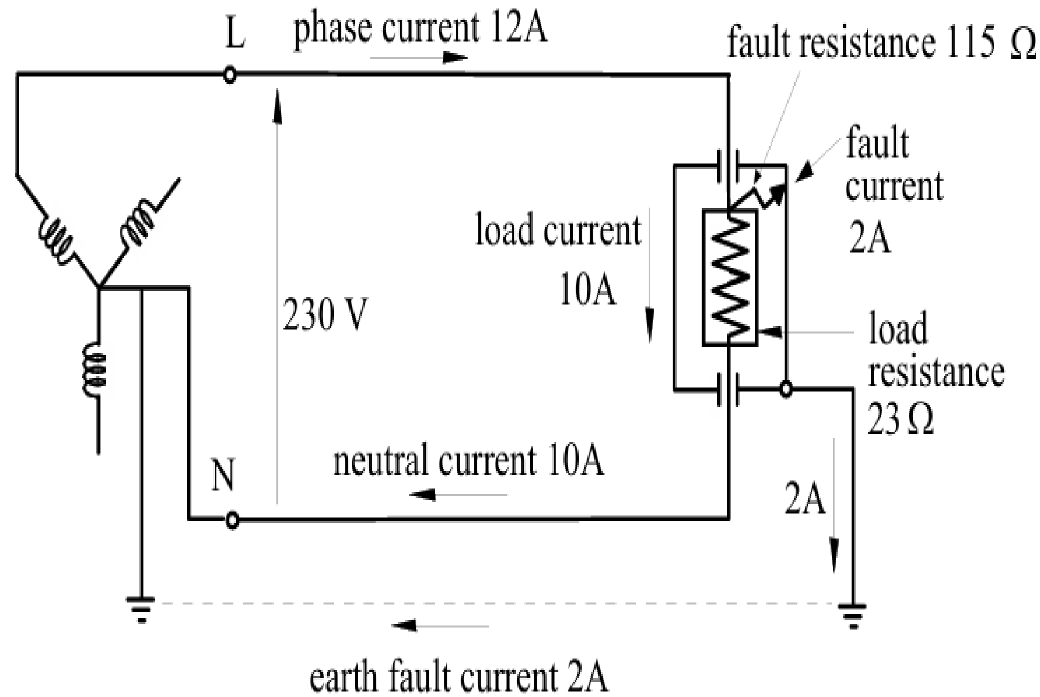


Figure 2.17 The earth leakage current

Standard value of residual non-operating current ($I_{\Delta N0}$)

0.5 $I_{\Delta N}$

Minimum value of the rated making and breaking capacity

10 I_N or 500 A whichever is greater

Rated conditional short-circuit current

This is the prospective short-circuit current passing through the RCCB at close position and the RCCB can withstand under the specified conditions.

3, 4.5, 6, 10, 20 kA

Maximum break time

0.3 s for residual current equal to $I_{\Delta N}$
0.15 s for residual current equal to 2 $I_{\Delta N}$
0.04 s for residual current equal to 5 $I_{\Delta N}$
0.04 s for residual current equal to 500 A

Other requirements

- RCCBs shall be protected against short-circuits by means of circuit-breakers or fuses.
- RCCBs are essentially intended to be operated by uninstructed persons and designed to be maintenance free.

Circuit Breaker Selection

A circuit breaker is required to perform the following three major duties of circuit breakers are as follows.

1. Protection : Circuit breakers protect people and equipment from electrical shock and damage by stopping the flow of electricity when it reaches unsafe levels.
2. Switching : Circuit breakers can be safely opened and locked open to isolate circuits, devices, and equipment for maintenance or troubleshooting.
3. Monitoring: Some circuit breakers have metering and alarm functions.

CIRCUIT BREAKER SHOULD BE SPECIFIED IN TERMS OF:

- ❑ **Nominal (rated) current**
- ❑ **Nominal (rated) Breaking capacity**
- ❑ **Nominal (rated) making capacity**
- ❑ **Impulse withstand voltage**
- ❑ **Rated frequency**
- ❑ **Number of poles**
- ❑ **Trip type**: **thermal** (only) or **magnetic**

SELECTION OF PROTECTIVE DEVICE

The selection of protective device depends upon:

(i) Prospective fault current

(ii) Circuit load characteristics

(iii) Cable current carrying capacity

(iv) Disconnection time limit.

Protective devices should be selected in the following requirements

The normal setting of the device In must be greater than of equal to the design currents I_b

$I_n \geq I_b$

2. The current carrying capacity of the conductor Iz must be greater than of equal to the rated current of the device

$I_z \geq I_n$

3. The current causing effective operation of the device I2 less than equal to 1.15 times the current carrying capacity of the conductors I_z

$I_2 \leq 1.45 \times I_z$

For MCB $I_2 = 1.45 \times I_n$

For MCCB, ACB $I_2 = 1.3 \times I_n$

For fuses to BS 88 and BS 1361

Rated current of the device, I_n is less than or equal to 0.725 x I_z

$I_n \leq 0.725 \times I_z$


Q&A