# PRINCIPLE OF SWITCHGEAR AND SELECTION OF LOW VOLTAGE CIRCUIT BREAKERS

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## PRINCIPLE OF SWITCHGEAR AND SELECTION OF LOW VOLTAGE CIRCUIT BREAKERS

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# I. <u>“SWITCHGEAR”</u>

## ***1. Define Switchgear***

- Switchgear is the electrical apparatus that used for switching, controlling , protecting and isolating In the power system.
- Switchgear is also a combination of switching devices such as
  - protection devices
  - Switching Devices
  - Control and Sensing  Devices
- The switchgear equipment is essentially used with switching and interrupting currents either under normal or abnormal operating condition.
- It consist of devices such as switches, fuses, circuit breakers, relays and sensing & measuring devices etc.
- Basically every circuit needs switching device and protecting device.
- Switchgear is an essential part of a power system and also that of an electric circuit.
- Switchgears are used in Generation, Transmission and distribution systems, where as , Control Gears are used in Consumer Circuits.

## 2. "FEATURES OF SWITCHGEAR"

- Control and Protection of Electrical Equipment and Systems
- Maintains Stability of Electrical Power System
- Interrupts Electrical Current in the event of Faults or Over-Current
- Disconnects Electrical Equipment from the Power Supply
- Prevents Widespread Power Outages and Other Types of Electrical Failure

## 3. "MAIN FUNCTION OF SWITCHGEAR"

- Electrical Protection
- Electrical Isolation of the Electrical Installation, Circuits or Individual Equipment
- Local or Remote Switching

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

## *4. “CLASSIFICATION OF SWITCHGEAR”*

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

➢ *HIGH VOLTAGE SWITCHGEAR (Above 33 kV)*

•**Overview:** High Voltage Switchgear operate at above 35kVs of voltage and find their applications in large power systems like transmission networks and substations. Major insulation and arc-quenching ability is required due to high voltage systems.

•**Applications:** High Voltage Switchgear finds application mainly in generation and transmission systems of power, including substations and power plants.

➢ *MEDIUM VOLTAGE SWITCHGEAR (3 kV to 33 kV)*

**Overview:** Medium voltage switchgear shall be intended for systems of 1kV to 35kV. Applied mainly in transmission and distribution systems and also in large industrial plants.

**Applications:** Power transmission and distribution lines, generator systems, feeder circuits, and motors in the industrial plants.

➢ *LOW VOLTAGE SWITCHGEAR (Upto 1 kV)*

**Overview:** Low Voltage Switchgear is applied in systems whose voltage does not exceed 1kV. It is commonly found on the low voltage side of the power distribution transformers and is applied in a very expansive range of industries.

**Applications:** LV switchgear finds application in residential buildings, small commercial buildings, and industrial facilities. It governs low-voltage services and technology; hence, it’s safe for use by unskilled or non-specialized personnel.

## 5. "TWO CLASSES OF HIGH VOLTAGE SWITCHGEAR FOR SUBSTATION"

High voltage switchgear can be classified into two main types:

- GIS : Gas-Insulated Switchgear, gas-insulated switchgear uses gas, typically sulfur hexafluoride (SF6)
- AIS : Air-Insulated Switchgear, AIS switchgear utilizes air as the primary insulating medium

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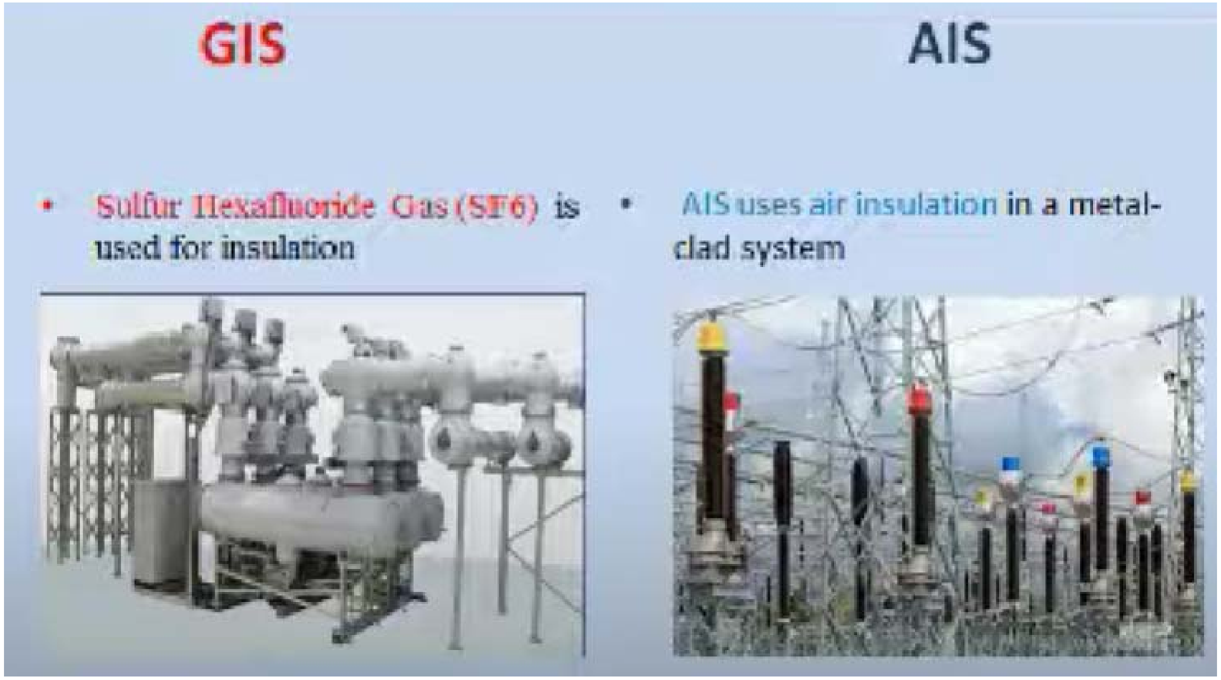


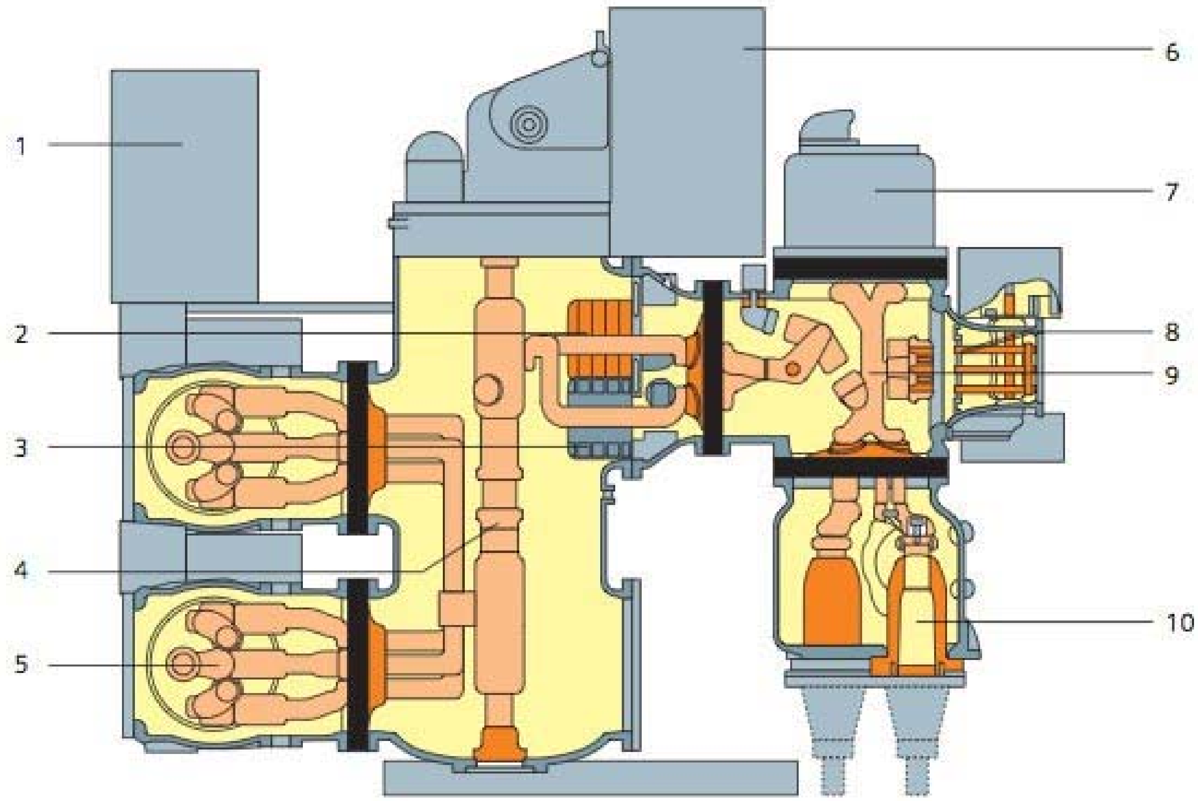
## ***GIS Substations***

- 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***

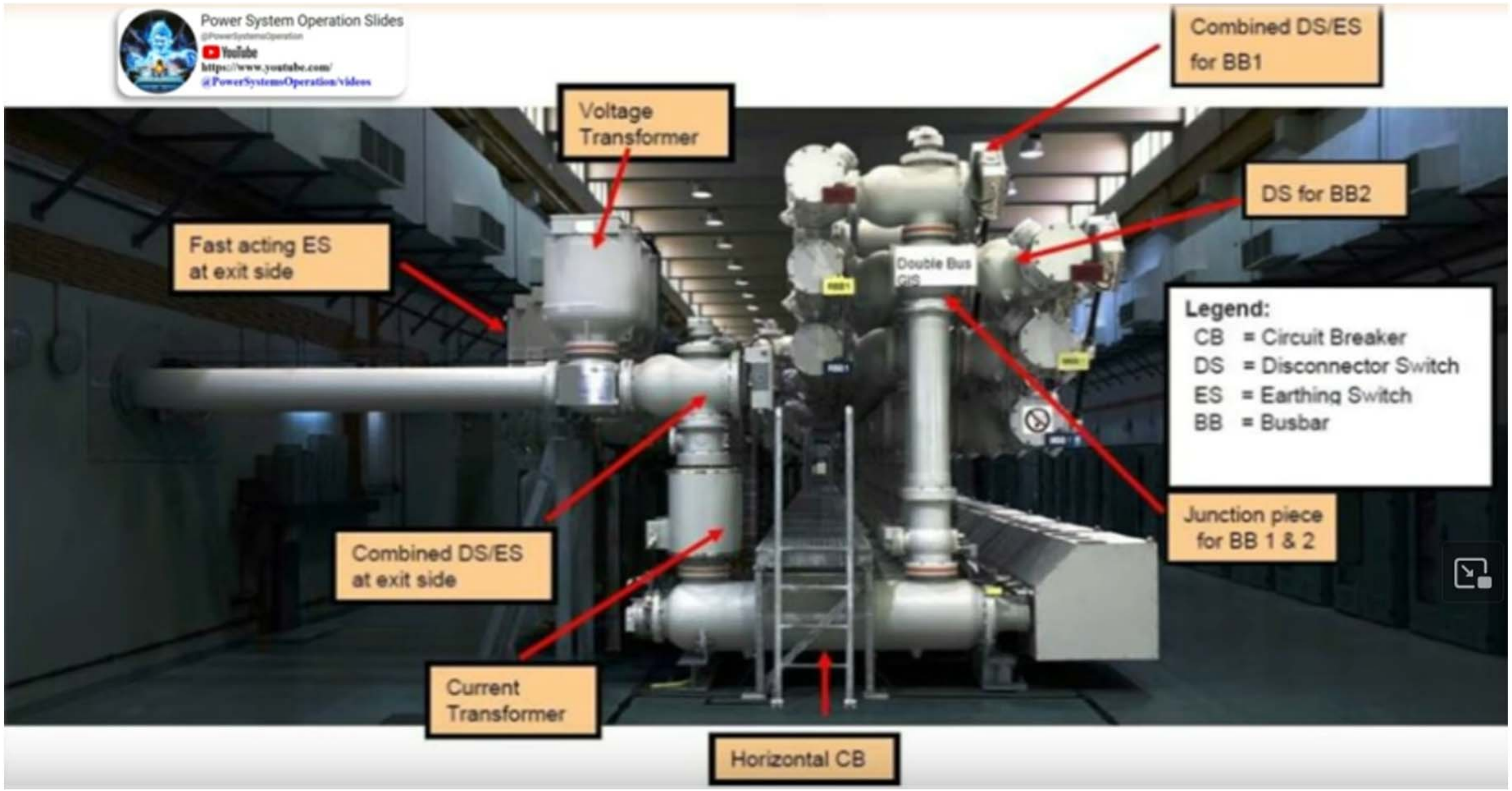
- Metal enclosures and pressurized with SF6 gas for insulation and extinguishing the arc in the breaker.
- The gas in monitored to ensure designed insulation and interrupting properties are constant.
- A typical configuration of GIS is the double bus arrangement. Figure is a graphic representation with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

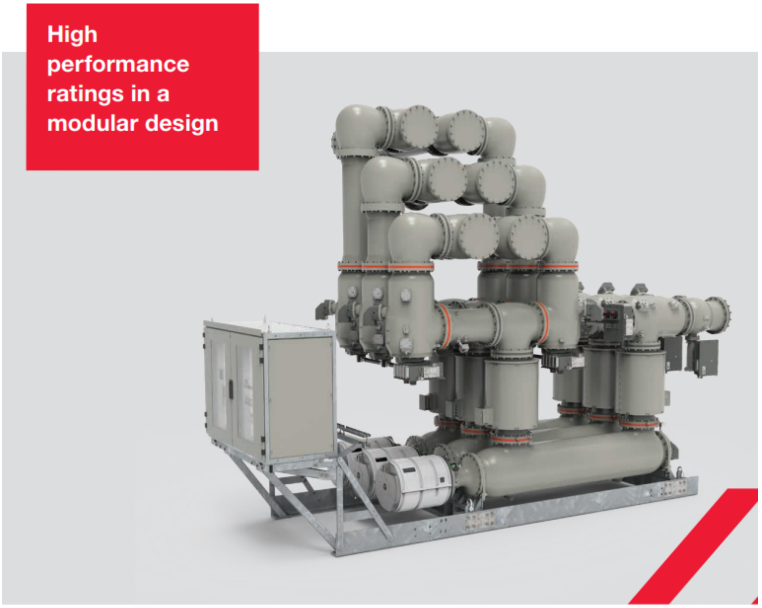
Gas-tight bushing
Gas-permeable bushing




# Double Bus GIS Identification

## ***GIS Devices***

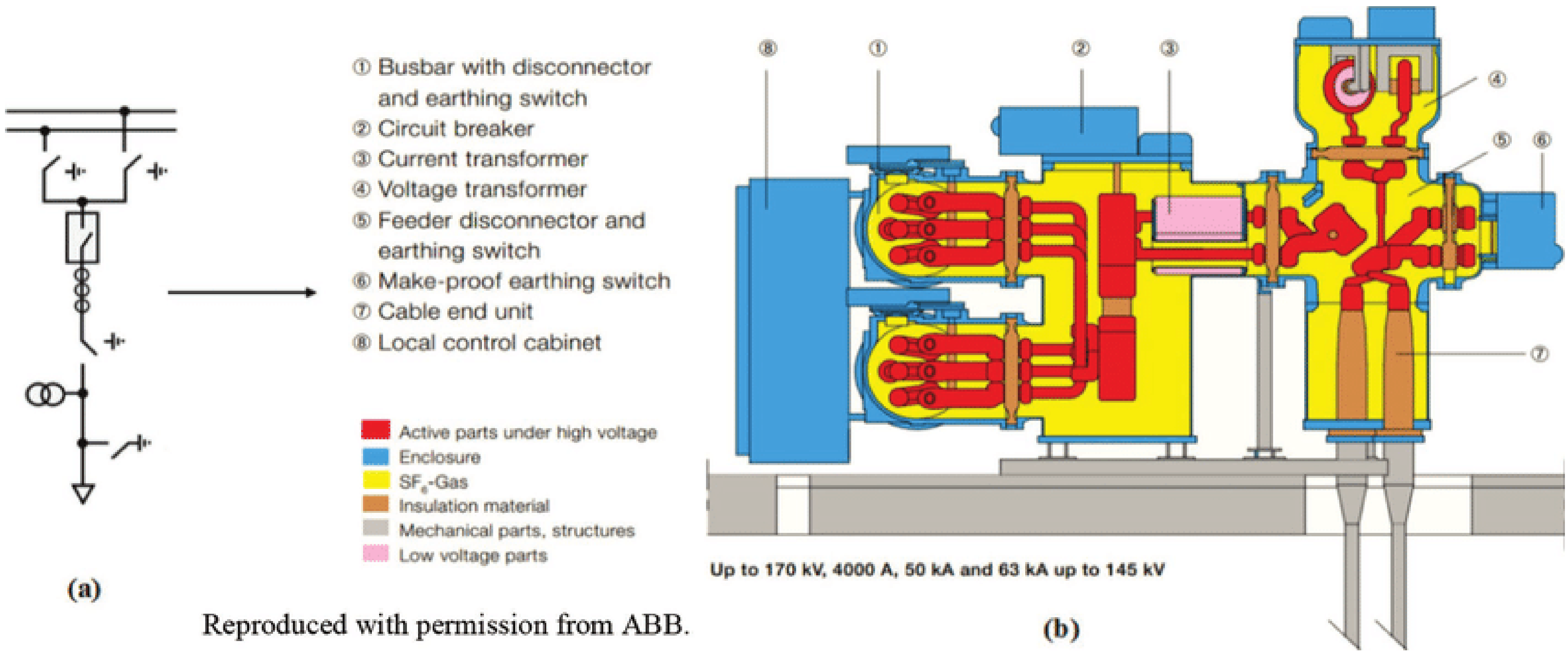
- Circuit breakers (interrupters), CB
- Disconnect (isolator) switches, DS
- Earth (ground) switches, ES
- Combined earth and disconnect switches
- Fast acting ground (earth) switches, FAES
- Load break switch, LBS
- Current transformers, CT.




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.




(a)

Reproduced with permission from ABB.

(b)

## ***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):***

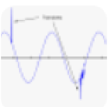
AIS is a device used to control, protect, and isolate electrical equipment in a power system. AIS uses air as the insulating medium and is typically made up of components like circuit breakers, disconnect switches, and busbars.

# 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 |

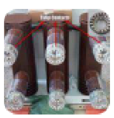
# 6. "MAJOR COMPONENT OF HIGH VOLTAGE SWITCHGEAR"


Circuit breakers

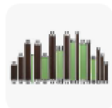

Surge arresters


Instrument transformers


Contactors


Isolate switch


Insulated Cables

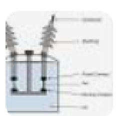

Fuses


Busbars


Switches


Current transformer


Vacuum circuit breaker


Oil circuit breaker

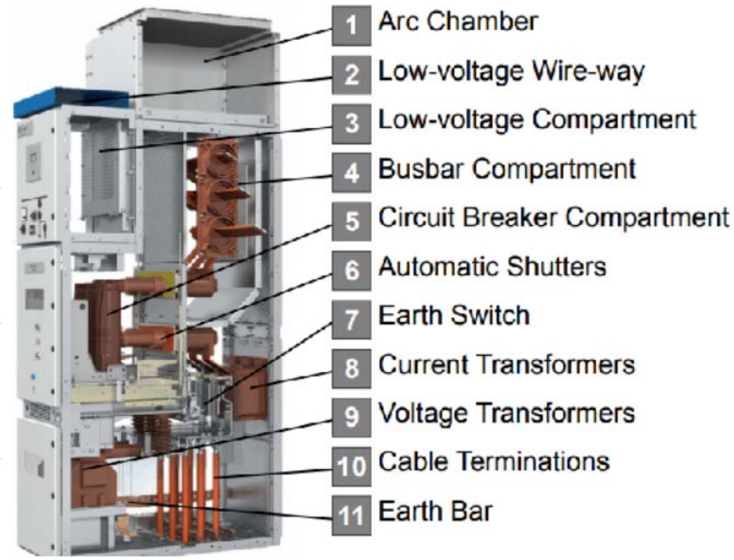

Relays


Earthing switch


Conductors


Disconnectors


Composition of switchgear





Load Break Switch


Disconnect Switch


Gas-Insulated Switchgear

Metering Equipment


**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.

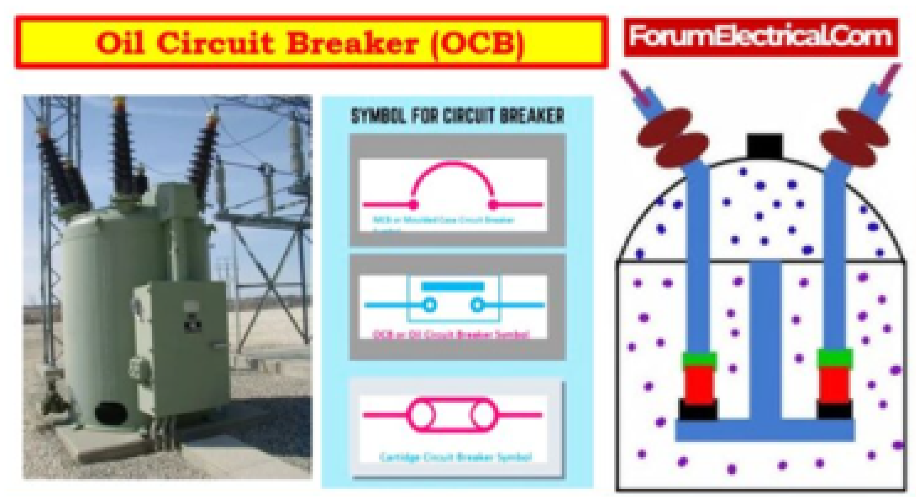
- **Indication:** They are the coloured lamps indicating the different states of switching devices like "ON", "Off", and "Trip". They are also used to state the healthiness of a circuit.

## II. Types Of High Voltage Circuit Breakers

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

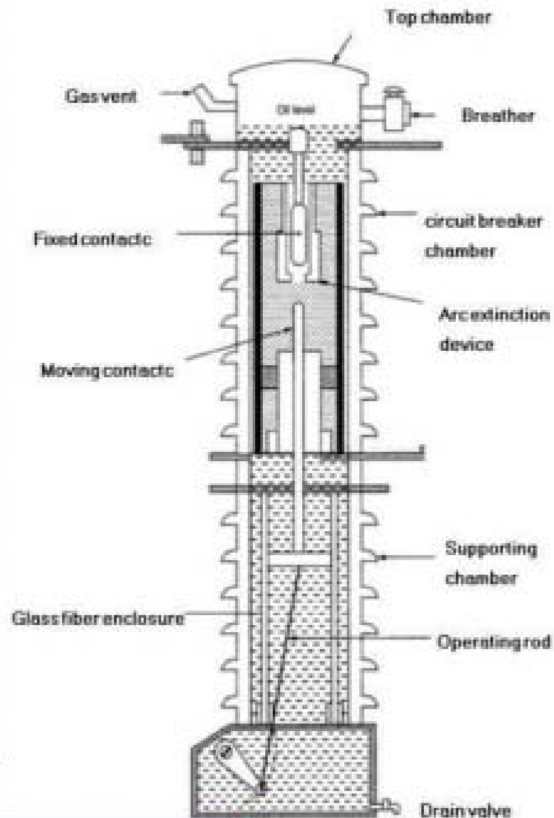
## ❑ Oil Circuit Breakers (OCB)

- 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.

## 2. 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.

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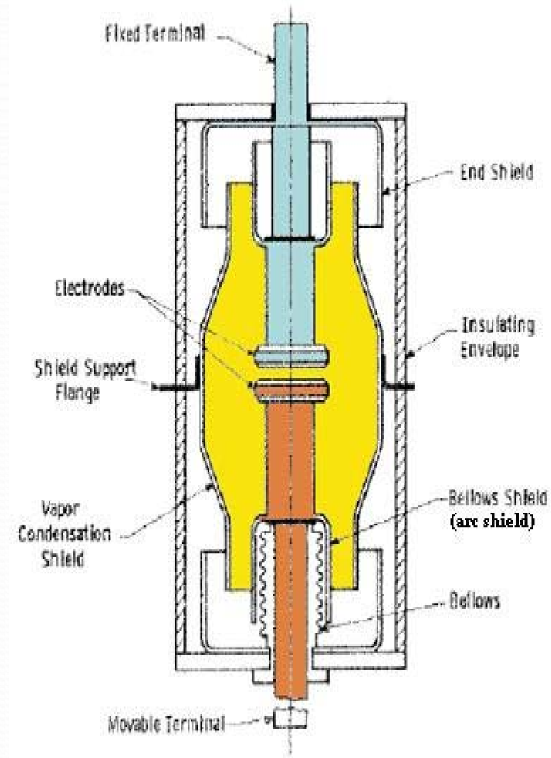
The current corresponds to the breaking current parameters

| 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.

## 3. 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.

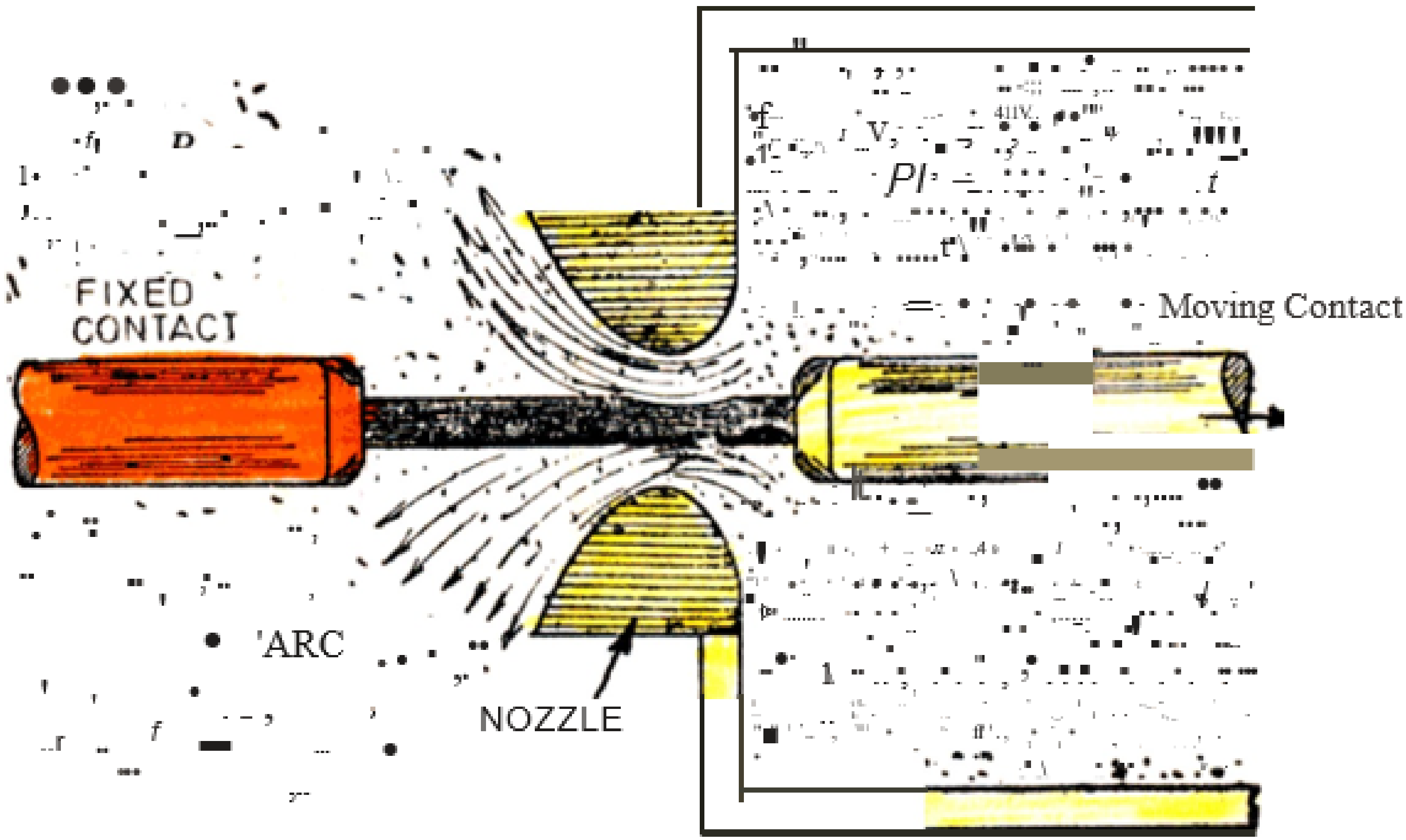
- **Power Generation:** SF6 circuit breakers can be used in power generation facilities for generator protection.

- **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)**

## SF6 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 $P_2$ to low pressure $P_1$ *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.

## ***4. 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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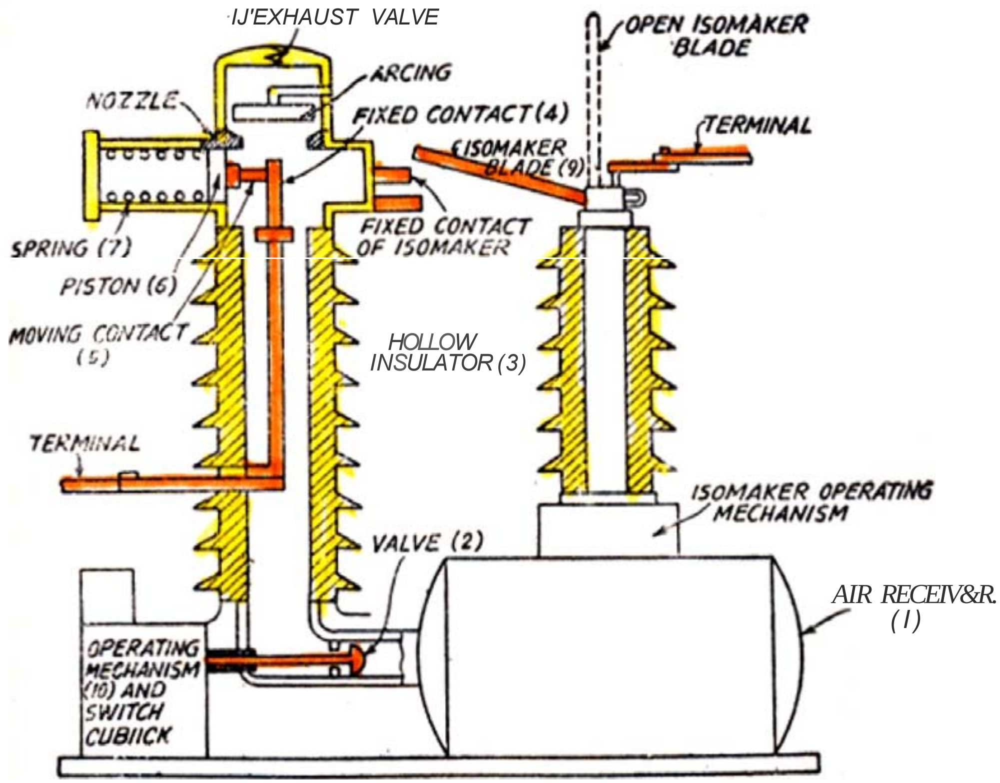



| | | |
|---|---|---|
| 1. Air receiver, | 2. Valve, | 3. Hollow insulator. |
| 4. Fixed contact. | 5. Moving contact, | 6. Piston. |
| 7. Spring, | 8. Exhaust valve, | 9. Isomaker. |

# Comparison of Circuit Breakers

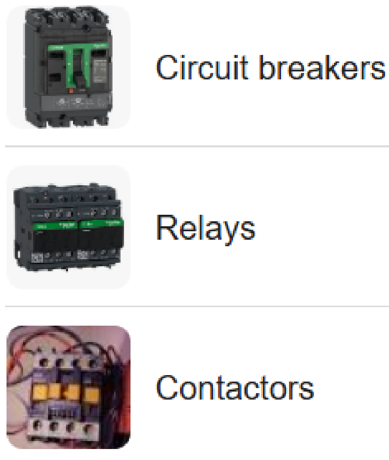
| Factor | Oil Breakers | Air Breakers | Vacuum/SF6 |
| --- | --- | --- | --- |
| Safety | Risk of explosion and fire due to increase in pressure during multiple operations | Emission of hot air and ionized gas to the surroundings | No risk of explosion |
| Size | Quite large | Medium | Smaller |
| Maintenance | 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.

## III. LOW VOLTAGE SWITCHGEAR

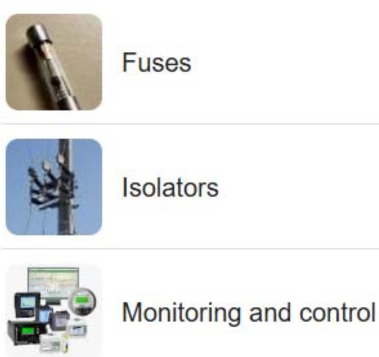
Low voltage switchgear, as the name implies, is designed to operate within the lower voltage range of electrical systems. While the exact voltage thresholds may vary depending on regional standards and specific applications, LV switchgear typically encompasses systems that operate below 1,000 volts (1 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.

# 1.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.




## 2. Functions of Low Voltage Switchgear

| Electrical protection against | Isolation | Control |
|---|---|---|
| ■ Overload currents<br>■ Short-circuit currents<br>■ Insulation failure | ■ Isolation clearly indicated by an authorized fail-proof mechanical indicator<br>■ A gap or interposed insulating barrier between the open contacts, clearly visible | ■ Functional switching<br>■ Emergency switching<br>■ Emergency stopping<br>■ 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)**

## 3. Enclosure, Ingress of Protection

### What is an Ingress Protection (IP) rating and what does it mean?

An Ingress Protection rating (IP) is essential for ensuring that electrical equipment complies with the international standard, protecting it from environmental hazards like water, dust, and debris. This minimises damage, ensures safety, and extends equipment lifespan. By providing a standardised measure of protection, IP ratings help users select internationally compliant equipment suitable for their specific application requirements, promoting reliability and regulatory adherence.

### What is an IP Code?

The IP code often indicates the suitability of electronic devices, electrical equipment, and mechanical enclosures for various environments, such as outdoor or industrial settings. The IP Code assigns a two-digit number to indicate the degree of protection. The first digit represents protection against solid objects, and the second digit represents protection against liquids.

# Ingress Protection (IP)

## Protection Against Solid Bodies Data Table

| 0 | Tests | Protection of Equipment: Non-protected | Protection of Persons: Non-protected |
|---|---|---|---|
| 1 | ø 50mm | Protected against the penetration of solid objects having a diameter greater than or equal to 50 mm | Protected against direct contact with the back of the hand (accidental contacts). |
| 2 | ø 12.5mm | Protected against the penetration of solid objects having a diameter greater than or equal to 12.5 mm. | Protected against direct finger contact. |
| 3 | ø 2.5mm | Protected against the penetration of solid objects having a diameter greater than or equal to 2.5 mm. | Protected against direct contact with a Ø 2.5 mm tool. |
| 4 | ø 1mm | Protected against the penetration of solid objects having a diameter greater than or equal to 1 mm. | Protected against direct contact with a Ø 1 mm wire. |
| 5 | | Dust protected (no harmful deposits). | Protected against direct contact with a Ø 1 mm wire. |
| 6 | | Dust tight. | Protected against direct contact with a Ø 1 mm wire. |

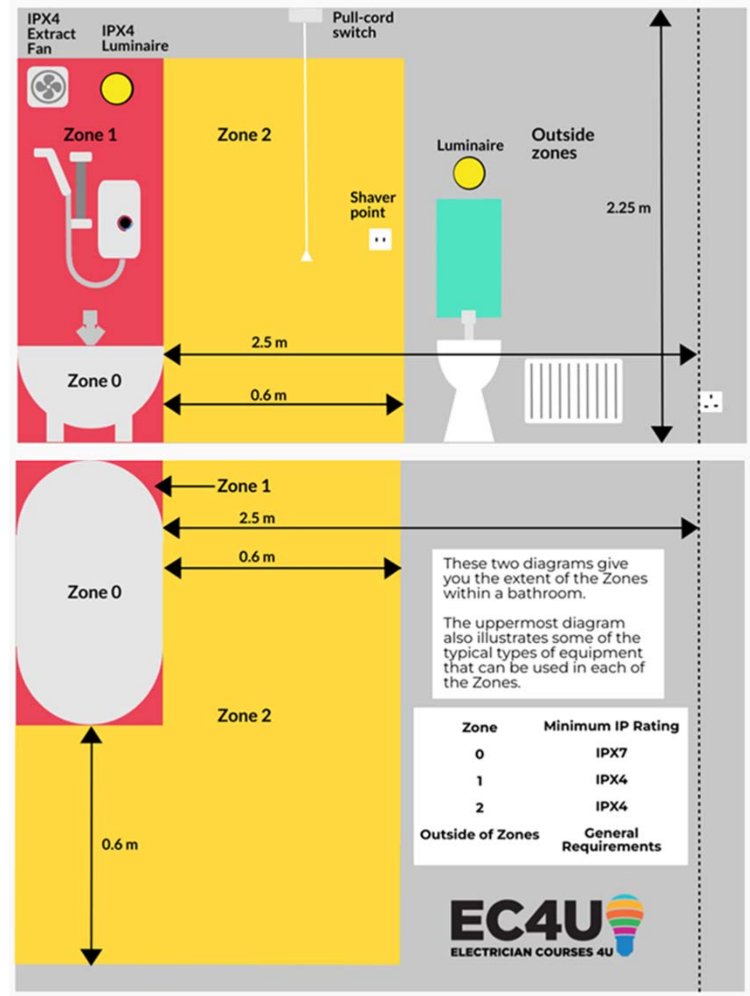
## Protection Against Liquids Data Table

| 0 | Tests | Non-protected |
|---|---|---|
| 1 | | Protected against vertical dripping water, (condensation). |
| 2 | 15° | Protected against dripping water at an angle of up to 15°. |
| 3 | 60° | Protected against rain at an angle of up to 60°. |
| 4 | | Protected against splashing water in all directions. |
| 5 | | Protected against water jets in all directions. |
| 6 | | Protected against powerful jets of water and waves. |
| 7 | 1 m, 15 cm min | Protected against the effects of teporary immersion. |
| 8 | m | Protected against the effects of prolonged immersion under specifi ed conditions. |

| Level | Protected Against Access To Hazardous Parts With |
|---|---|
| A | With the back of the hand. |
| B | With the finger. |
| C | With a ø 2.5 mm tool. |
| D | With a ø 1 mm tool. |



# BATHROOM ZONES



# 4. FORMS of SEPARATION

**Key:**

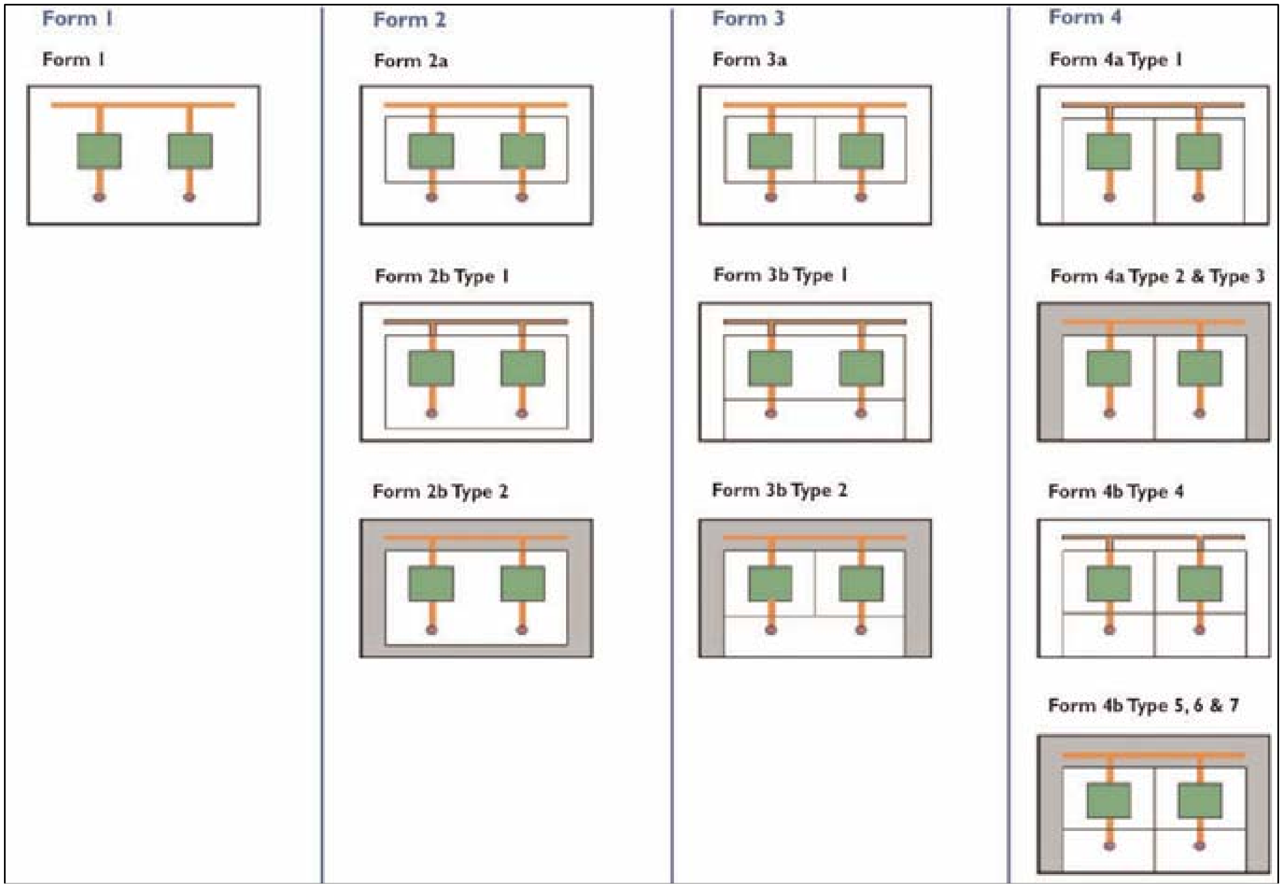

**Notes:**

*Forms of Separation can be achieved by using;*

*(i) Partitions/barriers of metallic or non-metallic material*

*(ii) The integral housing of the device*

*All diagrams from figures AA 1, 2, & 3 from Annex AA*
*Text from UK National Annex*
*Both from BS EN 61439-2*



**Form 1:**

*No internal separation is provided.*

**Form 2:**

*Functional unit separate from the busbars*

*The 'a' designation denotes terminals are not separate from the busbar*

*The 'b' designation denotes terminals are separate from the busbar*

*Type 1 utilises insulated coverings for busbar separation*

*Type 2 utilises insulated partitions and barriers for busbar separation.*

**Form 3:**
**As Form 2 plus:**

*Functional units separate from other functional units*

*The 'a' designation denotes terminals are not separate from the busbar*

*The 'b' designation denotes terminals for external conductors are in a* **separate** *compartment to the functional unit*

*Type 1 utilises insulated coverings for busbar separation*

*Type 2 utilises insulated partitions and barriers for busbar separation.*

**Form 4:**
**As Form 3 plus:**

*Terminals for external conductors separate each other*

*The 'a' designation denotes terminals within the functional unit*

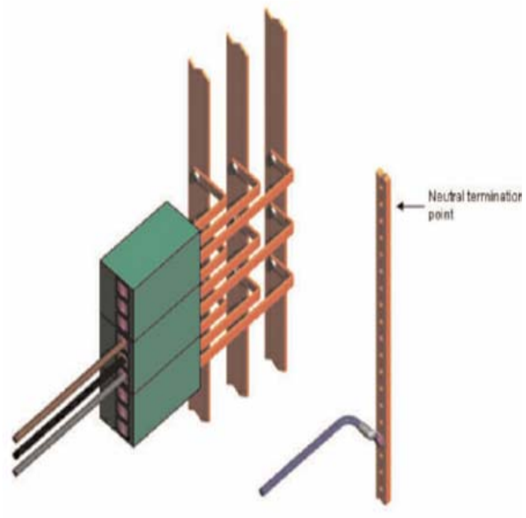
*The 'b' designation denotes terminals for external conductors are in a* **separate** *compartment to the functional unit*

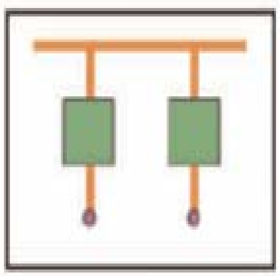
*Types 1 & 4 utilises insulated coverings for busbar separation*

*Types 2, 3, 5, 6 & 7 utilise partitions and barriers for busbar separation*

*Types 3 & 7 feature integral glanding*

*Type 5 utilises insulated coverings for terminals for external conductors.*



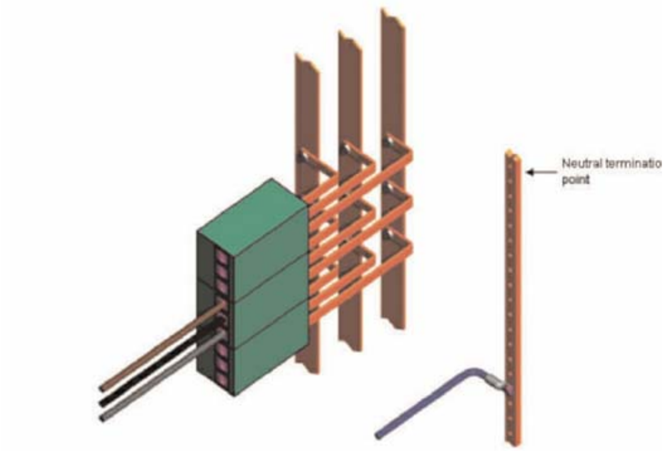
**Form 1 requires that;**

*(i) Busbars* **are not** *separated from functional units*

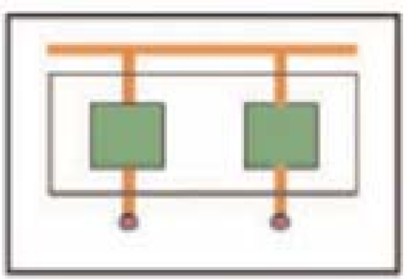
*(ii) Busbars* **are not** *separated from any incoming or outgoing termination*

*(iii) Functional units* **are not** *separated from other functional units*

*(iv) Functional units* **are not** *separated from any incoming or outgoing termination.*




The above illustration uses the "Integral Housing of the Device" as a means of separation.



**Form 2a requires that;**

*(i) Busbars* ***are*** *separated from functional units*

*(ii) Busbars* ***are not*** *separated from any incoming or outgoing termination*

*(iii) Functional units* ***are not*** *separated from other functional units*

*(iv) Functional units* ***are*** *separated from any incoming or outgoing termination*

*(v) Terminals* ***are not*** *separate from each other.*

# Form 2b Type 1

*All Form 2 assemblies are enclosed so as to provide protection against contact with internal live parts, or compartments and where there is internal separation of the busbar from the functional units.*

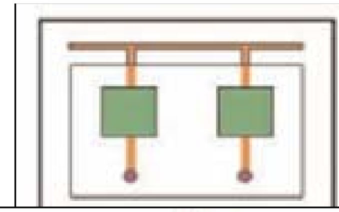
***Form 2b Type 1 requires that;***

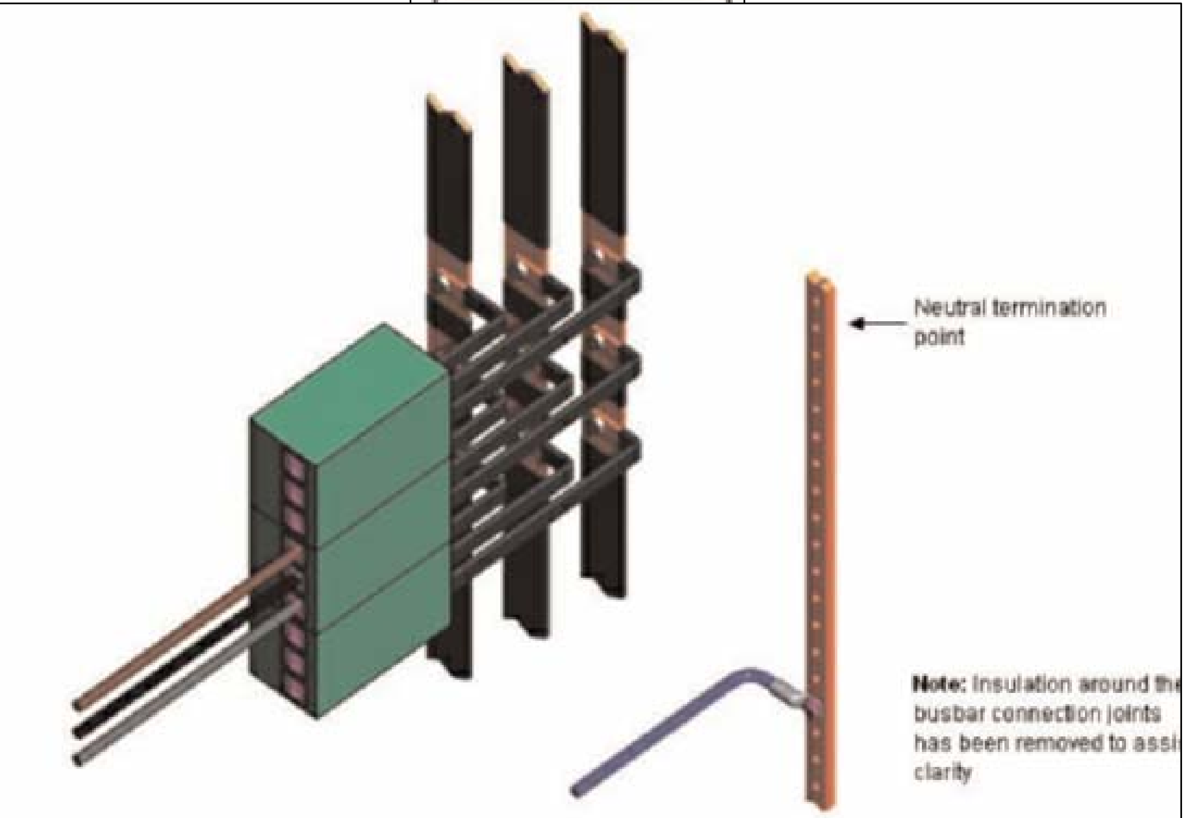
*(i) Busbars **are** separated from functional units*

## Notes:

*The 'b' designation denotes terminals are separate from the busbars.*

*The 'Type 1' designation denotes busbar separation is achieved by insulated coverings – sleeving, wrapping or coating.*



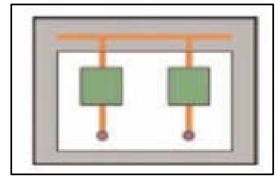


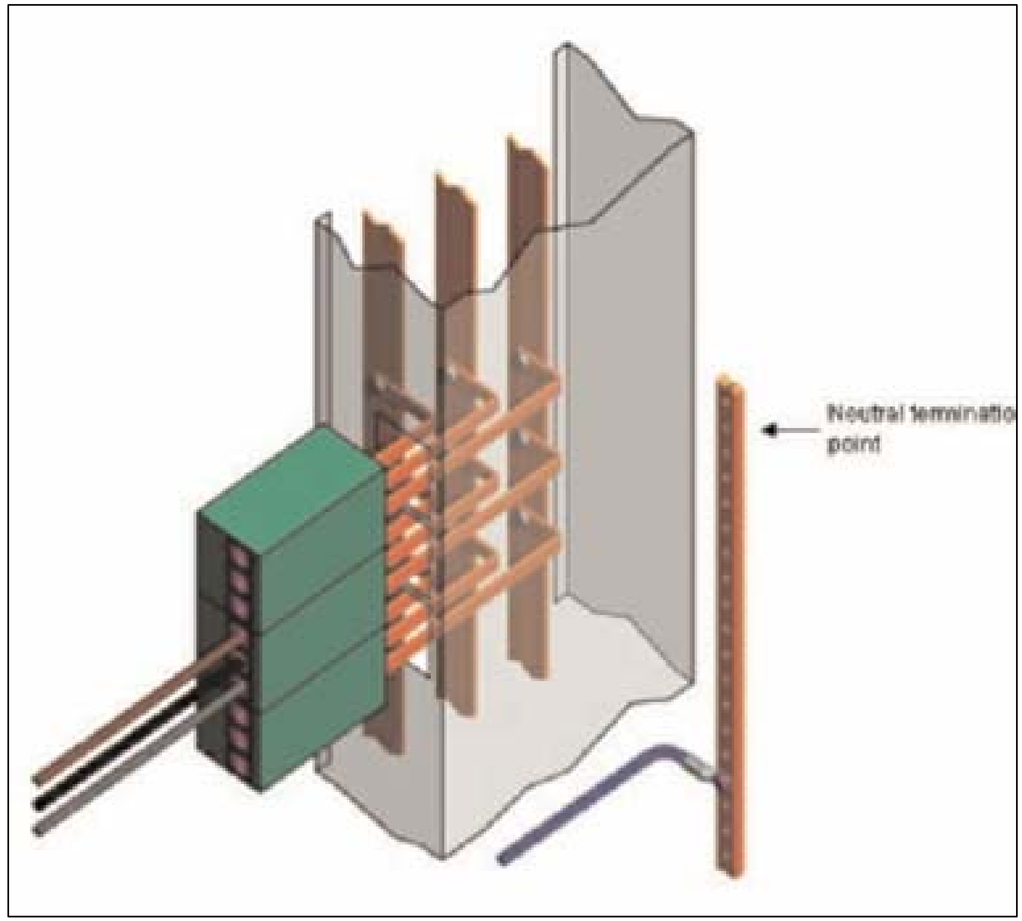

The above illustration uses the "Integral Housing of the Device" as a means of separation.
Cable terminations are integral to the device.

# Form 2b Type 2

*All Form 2 assemblies are enclosed to provide protection against contact with internal live parts, or compartments and where there is internal separation of the busbar from the functional units.*

***Form 2b Type 2 requires that;***
*(i) Busbars **are** separated from functional units.*






## Notes:

*The 'b' designation denotes terminals are separate from the busbars.*

*The 'Type 2' designation denotes busbar separation by partitions and barriers.*

***Form 3a requires that;***

*(i) Busbars **are** separated from functional units*

*(ii) Busbars **are not** separated from any incoming or outgoing termination*

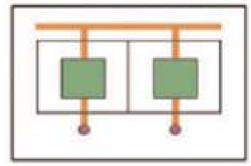
*(iii) Functional units **are** separated from other functional units*

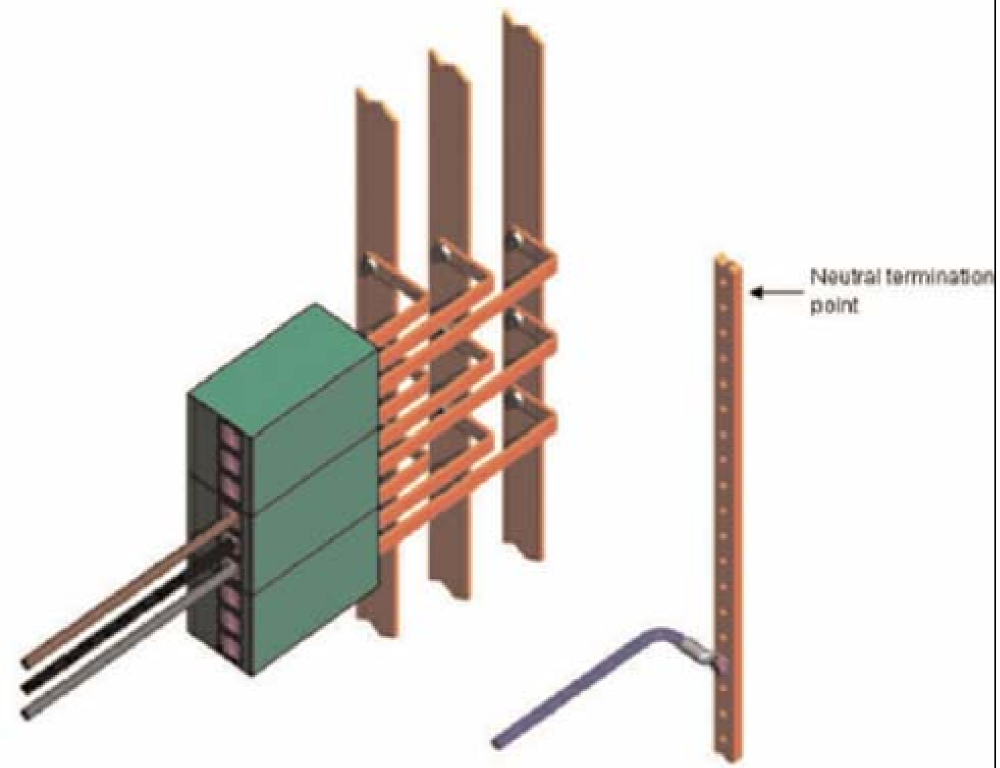
*(iv) Functional units **are** separated from any incoming or outgoing termination*

*(v) Terminals **are not** separate from each other.*

**Notes:**

*The 'a' designation denotes terminals for external conductors are not separate from the busbars.*






The illustration above is Form 3a where the Integral Housing of the device is the means of separation and the arrangement is regarded as 'Group Mounted'.

***Form 3b Type 1 also requires that;***

*(i) Busbars **are** separated from functional units*

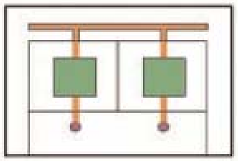
*(ii) Functional units **are** separated from other functional units*

*(iii) Terminals for external conductors **are** separated from the respective functional unit and the busbars. Terminals are not separated from other terminals for external conductors.*

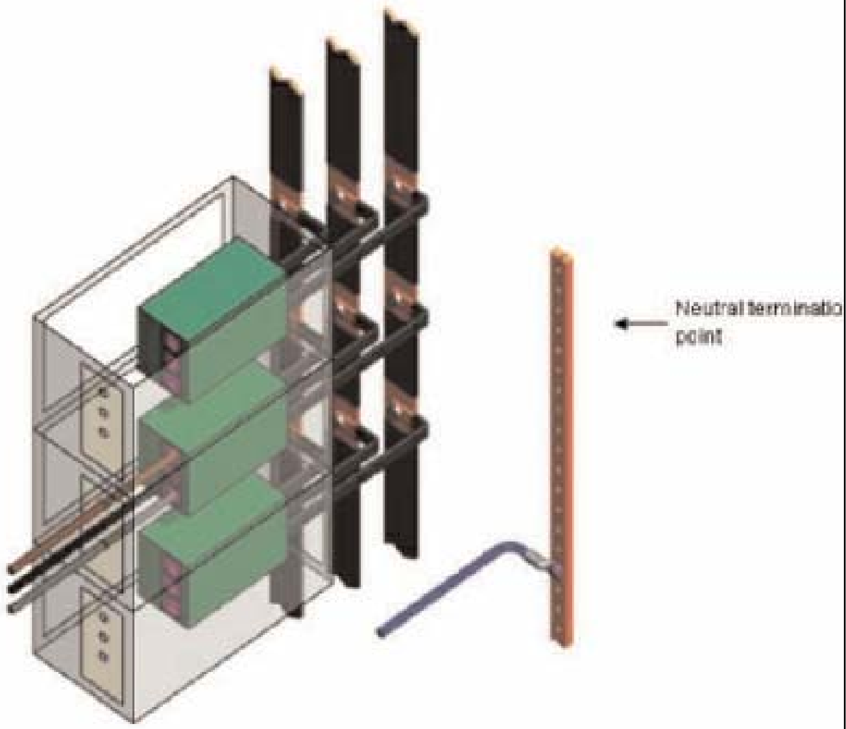
## Notes:

*The 'b' designation denotes terminals for external conductors are in a **separate** compartment to the functional unit.*

*The 'Type 1' designation denotes busbar separation is achieved by insulated coverings – sleeving, wrapping or coating.*



## Compartmentalised




The above illustration uses "Partitions and Barriers" as a means of separation and is referred to as **Compartmentalised.**

**_Form 3b Type 2 also requires that;_**

*(i) Busbars **are** separated from functional units*

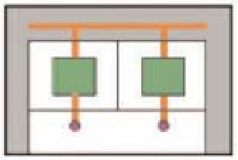
*(ii) Functional units **are** separated from other functional units*

*(iii) Terminals for external conductors **are** separated from the respective functional unit and the busbars. Terminals are not separated from other terminals for external conductors.*

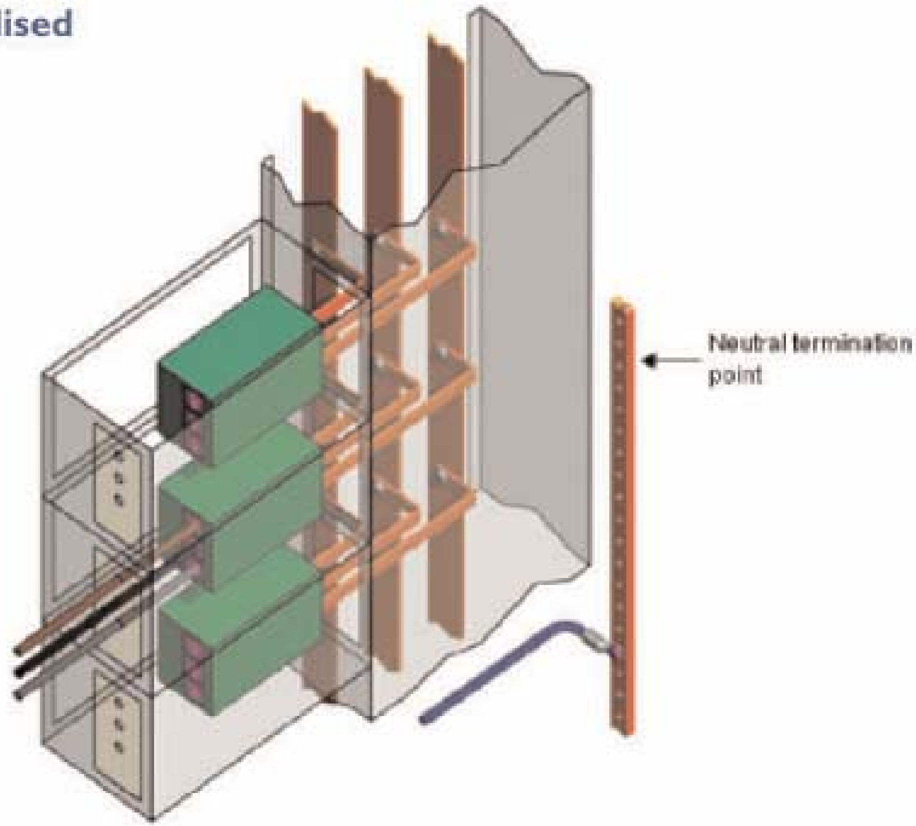
## Notes:

*The 'b' designation denotes terminals for external conductors are in a **separate** compartment to the functional unit.*

*The 'Type 2' designation denotes busbar separation by partitions and barriers.*



## Compartmentalised



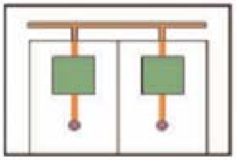

The above illustration uses "Partitions and Barriers" as a means of separation and is referred to as **Compartmentalised.**

**Form 4a Type 1 also requires the separation of;**

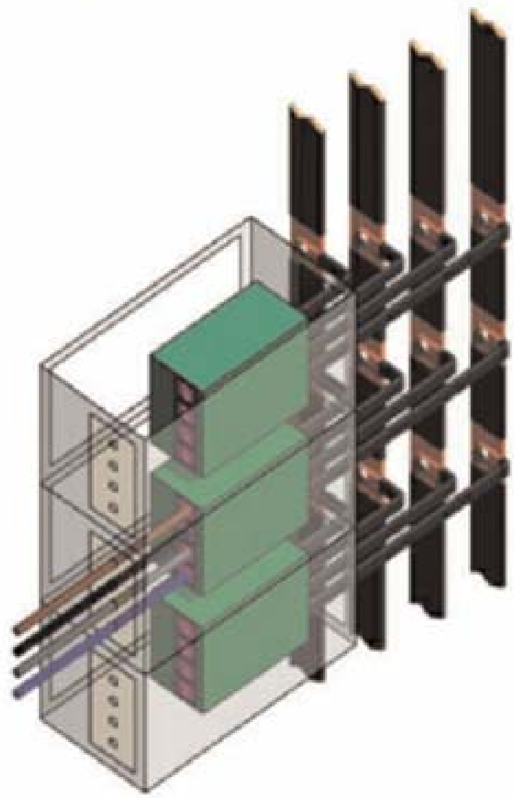
*(i) Busbars from functional units*

*(ii) Functional Units from each other*

*(iii) Terminals for external conductors from other terminals* ***and*** *from the busbars.*



## Compartmentalised



The above illustration uses a combination of clauses covering "Partitions and Barriers" and "Insulated Coverings".

### Notes:

*The 'a' designation denotes terminals for external conductors are within the* ***same*** *compartment as the functional unit.*

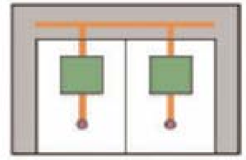
*The 'Type 1' designation denotes busbar separation is achieved by insulated coverings – sleeving, wrapping or coating.*

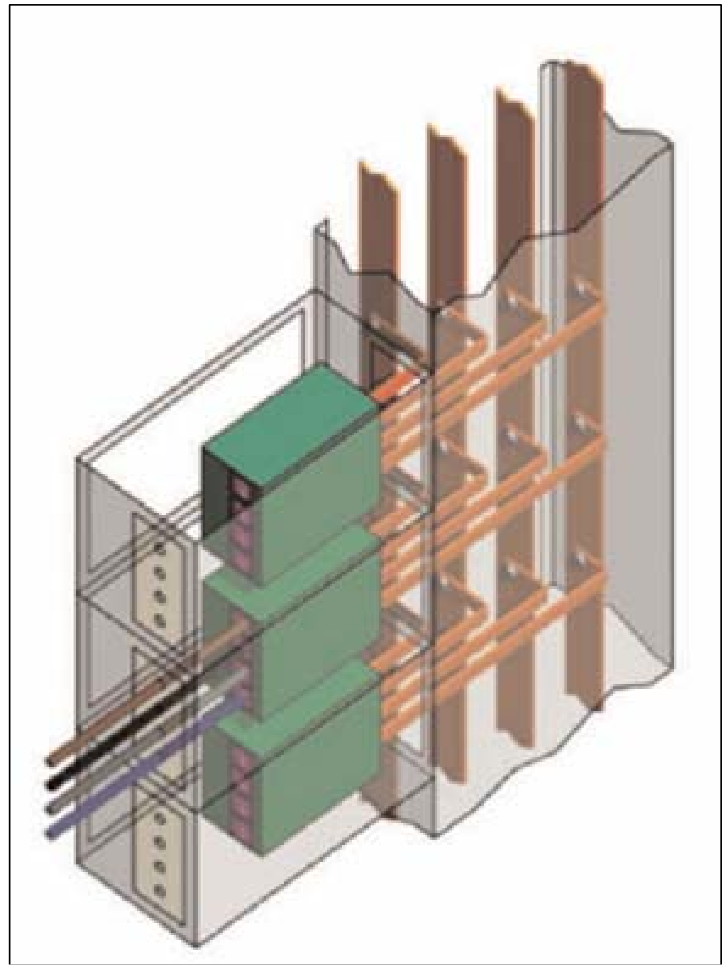
**Form 4a Type 2 also requires the separation of;**

*(i) Busbars from functional units*

*(ii) Functional Units from each other*

*(iii) Terminals for external conductors from other terminals* ***and*** *from the busbars.*





## Notes:

*The 'a' designation denotes terminals for external conductors are within the* ***same*** *compartment to the functional unit.*

*The 'Type 2' designation denotes busbar separation by partitions and barriers.*

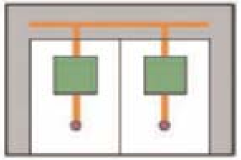
**Form 4a Type 3 also requires the separation of;**

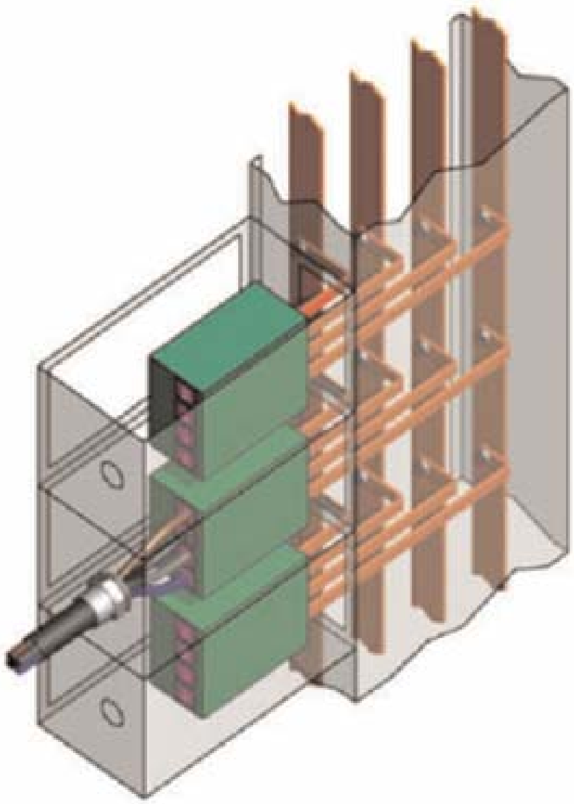
(i) Busbars from functional units

(ii) Functional Units from each other

(iii) Terminals for external conductors from other terminals **and** from the busbars

(iv) Individual, integral cable glanding facilities are to be provided for each circuit.





The above illustration uses "Partitions and Barriers" as a means of separation. Cable terminations are integral to the device.

## Notes:

*The 'a' designation denotes terminals for external conductors are within the* ***same*** *compartment as the functional unit.*

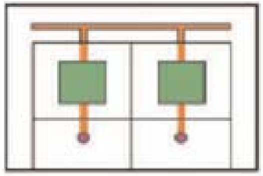
*The 'Type 3' designation denotes busbar separation by partitions and barriers.*

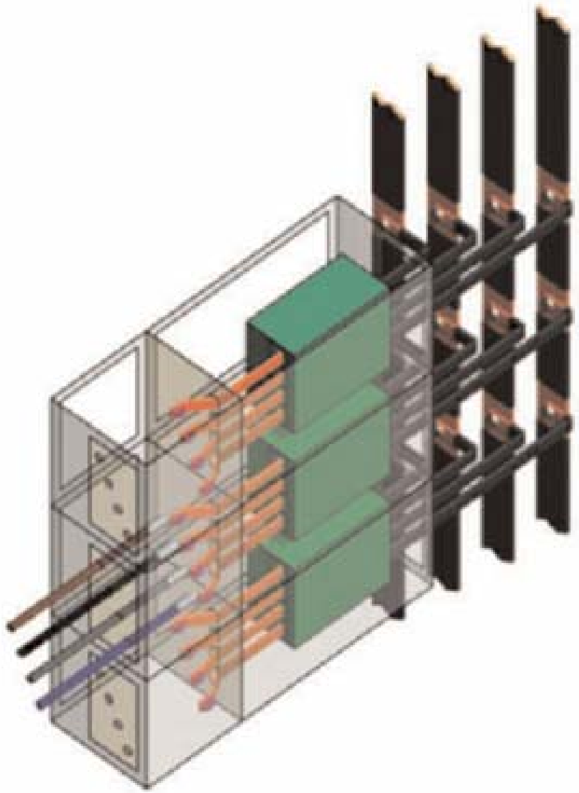
***Form 4b Type 4 also requires the separation of;***

*(i) Busbars from functional units*

*(ii) Functional Units from each other*

*(iii) Terminals for external conductors from their own functional unit, other sets of terminals **and** from the busbars.*





The above illustration uses a combination of clauses covering "Partitions and Barriers" and "Insulated Coverings" Cable terminations are extended into separate individual compartments.

## Notes:

*The 'b' designation denotes terminals for external conductors are in a **separate** compartment to the functional unit.*

*The 'Type 4' designation denotes busbar separation is achieved by insulating coverings – sleeving, wrapping or coating.*

**Form 4b Type 5 also requires the separation of;**

*(i) Busbars from functional units*

*(ii) Functional Units from each other*

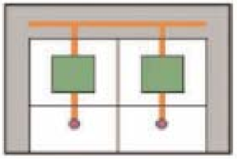
*(iii) Terminals for external conductors from their own functional unit, other sets of terminals **and** from the busbars*

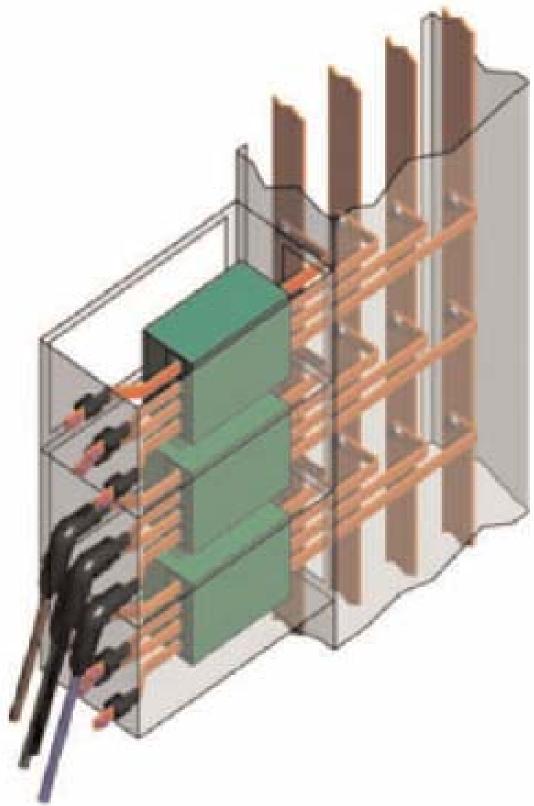
*(iv) Separation of terminals for external conductors to be achieved by insulated coverings.*

## Notes:

*The 'b' designation denotes terminals for external conductors are in a **separate** compartment to the functional unit.*

*The 'Type 5' designation denotes busbar separation by partitions and barriers with outgoing terminals separated by insulated coverings.*





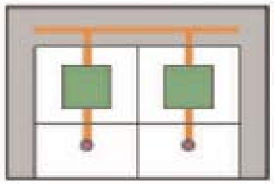
The above illustration uses "Partitions and Barriers" as a means of separation and "insulated coverings" for separation of external terminals.

***Form 4b Type 6 also requires the separation of;***

*(i) Busbars from functional units*

*(ii) Functional Units from each other*

*(iii) Terminals for external conductors from other terminals **and** from the busbars.*

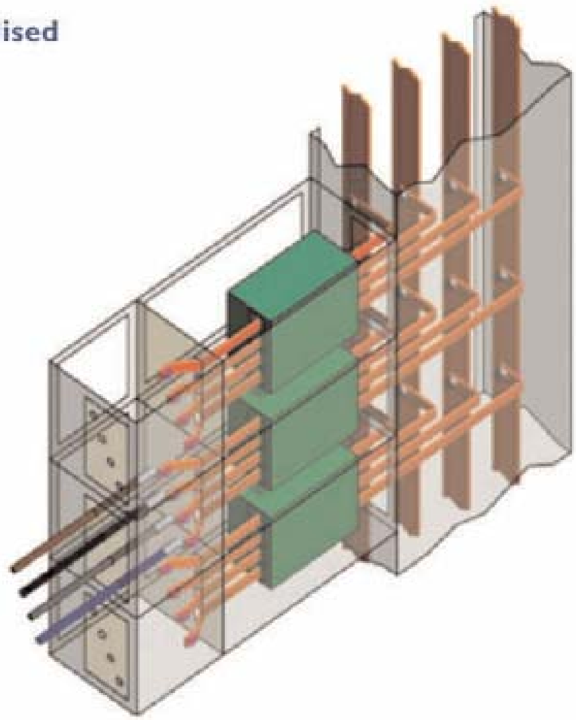


## Notes:

*The 'b' designation denotes terminals for external conductors are in a **separate** compartment to the functional unit.*

*The 'Type 6' designation denotes busbars and terminals are separated by partitions and barriers.*

**Compartmentalised**



The above illustration uses "Partitions and Barriers" as a means of separation and is referred to as **Compartmentalised.**
Cable terminations are extended into separate individual compartments.

**Form 4b Type 7 also requires the separation of;**

*(i) Busbars from functional units*

*(ii) Functional Units from each other*

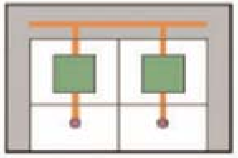
*(iii) Terminals for external conductors from other terminals **and** from the busbars*

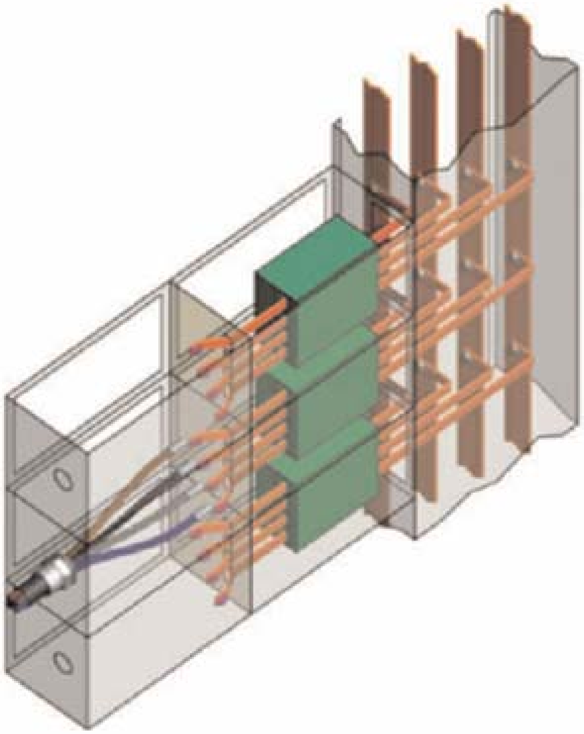
*(iv) Individual, integral cable glanding facilities are to be provided for each circuit.*

## Notes:

*The 'b' designation denotes terminals for external conductors are in a **separate** compartment to the functional unit.*

*The 'Type 7' designation denotes busbars and extended terminals are separated by partitions and barriers.*





The above illustration uses "Partitions and Barriers" as a means of separation.
Cable terminations are extended into separate individual compartments.

# 5. 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 | $[3\text{-}5]*I_{rated}$ | **Resistive load** |
| C | $[5\text{-}10]*I_{rated}$ | **Inductive load** |
| D | $(10\text{-}20]*I_{rated}$ | **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

## 6.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 $I_N$ |

## *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)

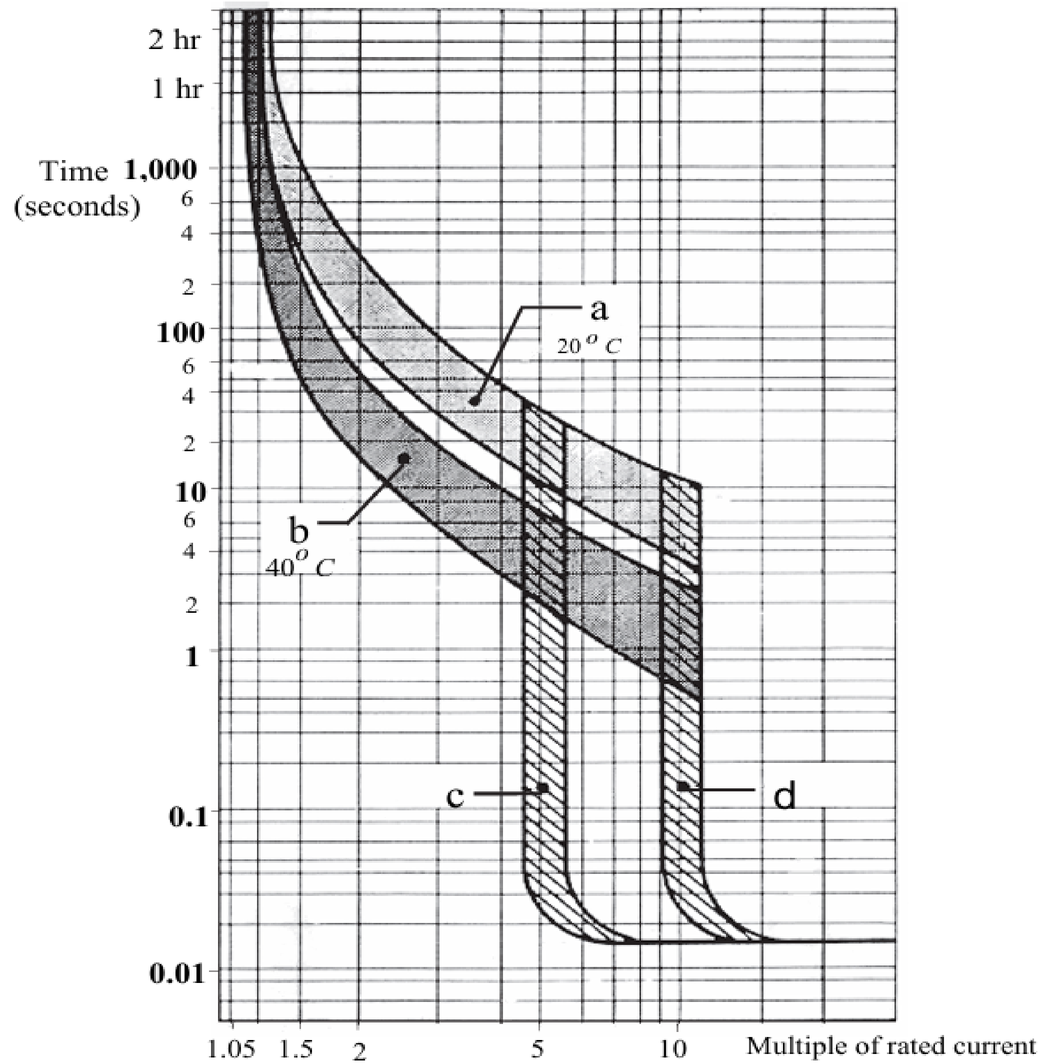



Figure 2.13 Time-current characteristic of a typical MCCB

## *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.

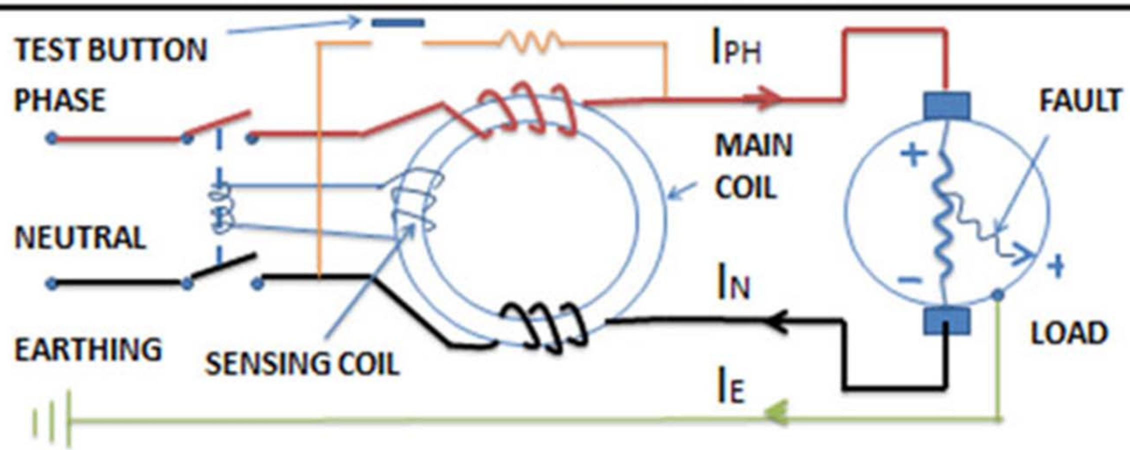
## *4. RCCB (Residual Current Circuit Breaker)*

**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

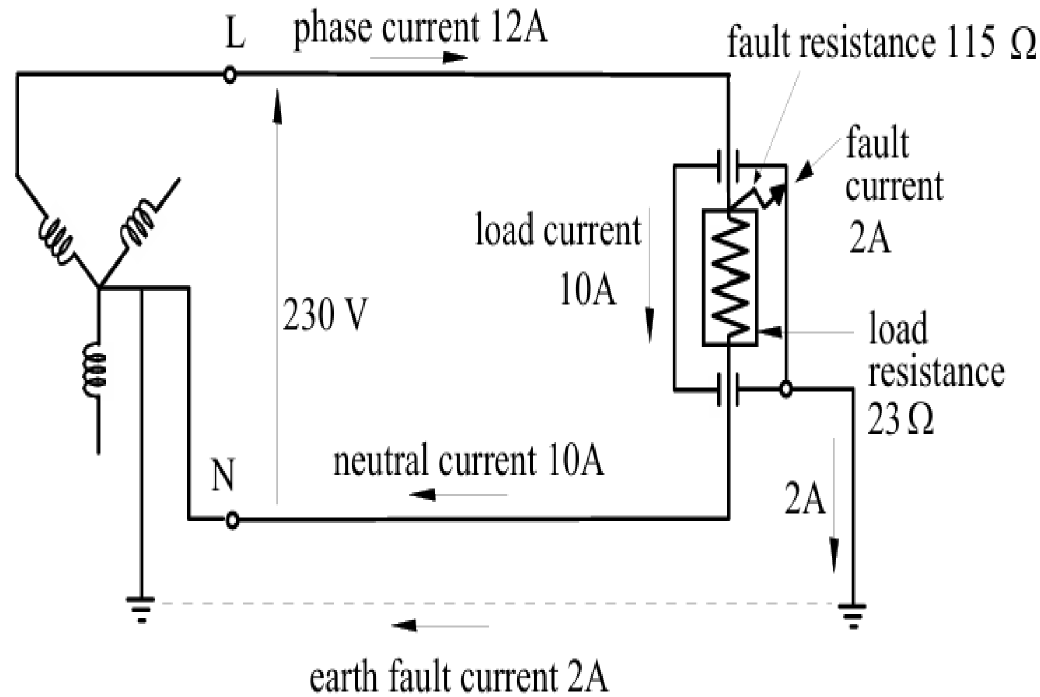



Figure 2.17 The earth leakage current

**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.

## 7. 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.

## Type of breakers based on number of pole

***Based on the number of poles, the breakers are classified as :***

- **SP – Single Pole**

  In Single Pole MCCB, switching & protection is affected in only one phase.
  **Application:** Single Phase Supply to break the Phase only.

- **DP – Double Pole – Double Throw**

  In Two Pole MCCB, switching & protection is affected in phases and the neutral.
  **Application:** Single Phase Supply to break the Phase and Neutral.

- **TP – Triple Pole – Triple Throw**

  In Three Pole MCB, switching & protection is affected in only three phases and the neutral is not part of the MCB. 3pole MCCB signifies for the connection of three wires for three phase system (R-Y-B Phase).
  **Application:** Three Phase Supply only (Without Neutral).

- **TPN – Triple Pole and Neutral**

  In TPN MCB, Neutral is part of the MCB as a separate pole but without any protective given in the neutral pole (i.e.) neutral is only switched but has no protective element incorporated. TPN for Y (or star) the connection between ground and neutral is in many countries not allowed. Therefore the N is also switches.
  **Application:** Three Phase Supply with Neutral

- **4P – Four Pole**

  4pole MCCB for 4 wires connections, the one additional 4$^{th}$ pole for neutral wire connection so that between neutral and any of the other three will supply.In 4-Pole MCCBs the neutral pole is also having protective release as in the phase poles.
  **Application:** Three Phase Supply with Neutral

***<u>Basic requirements for circuit breakers</u>***

Knowing the characteristics of circuit breakers according to product standards is a prerequisite for their proper use in installations. Consideration must be given, in particular, to the following aspects:
• protection of cables and lines at overcurrents, i.e. overload and short-circuit protection,
• protection of appliances from overcurrents (motors and generators etc.),
• protection against electric shock,
• isolation,
• reliable switching and isolation of parts of the installation,
• selective coordination and • backup protection.

***<u>Additional requirements for circuit breakers</u>*** are as follows:
• remote signalling (alarm, tripping),
• wire connection possibilities,
• low self-inherent losses,
• communication,
• measurement and analysis of electrical quantities.

## Low Voltage Circuit Breaker Selection Criteria

**1. System Voltage**

The circuit breaker should be rated for the system's voltage. In low voltage systems, this is typically less than 1,000 volts (commonly 230V, 400V, or 600V).

**2. Rated Current (In)**

The rated current is the maximum continuous current that the breaker can handle without tripping. This must match or exceed the load current of the circuit.

**3. Breaking Capacity (Icu/Ics)**

**Ultimate breaking capacity (Icu)**:The maximum fault current the breaker can interrupt without being damaged.
**Service breaking capacity (Ics)**:Typically a percentage of Icu, representing the current the breaker can interrupt multiple times without losing performance.The breaking capacity should be higher than the prospective short-circuit current at the installation point.

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**Molded Case Circuit Breakers (MCCB)**:Provide high current ratings, suitable for industrial and commercial applications.
**Miniature Circuit Breakers (MCB)**:Suitable for lower current ratings and typically used in domestic or small commercial installations.
**Residual Current Circuit Breakers (RCCB or RCD)**:Used to protect against earth faults and electrical shocks.
**Air Circuit Breakers (ACB)**:Used in large electrical systems where higher voltage and currents are involved.

## 5. Number of Poles

**Single-pole**: Protects only the phase conductor.
**Two-pole**: Protects both phase and neutral conductors.
**Three-pole**: Protects three-phase systems.
**Four-pole**: Protects three-phase systems with neutral.

## 6. Trip Characteristics

Circuit breakers come with different tripping curves (B, C, D) to handle different types of loads:
**B curve**:
For resistive loads like lighting (trips at 3-5 times the rated current).
**C curve**:
For inductive loads like motors (trips at 5-10 times the rated current).
**D curve**:
For highly inductive loads (trips at 10-20 times the rated current).

## 7. Operating Mechanism

Choose between manual, automatic, or remote-controlled mechanisms based on application and safety needs.

## 8. Environmental Conditions

Consider ambient temperature, humidity, and altitude, as these factors may affect the breaker's performance.
For harsh environments, select circuit breakers with appropriate ingress protection (IP) ratings.

## 9. Standards and Certifications

Ensure the circuit breaker complies with local and international standards (IEC 60947 for MCCB/ACB, IEC 60898 for MCBs).
Check certifications from reputable agencies (UL, CE, etc.) for reliability and safety.

## 10. Coordination with Other Protection Devices

Select breakers that can be coordinated with upstream or downstream protective devices to avoid unnecessary outages.

## 11. Additional Protection Features

| | |
|---|---|
| **Overload protection**: | For gradual load increases. |
| **Short-circuit protection**: | For instant high fault currents. |
| **Earth fault protection**: | For leakage to ground. |
| **Arc fault protection**: | For detecting arc faults in the system. |
| **Remote monitoring**: | In modern smart grid systems, circuit breakers with communication capabilities may be required. |

## 12. Space and Installation Considerations

Ensure the circuit breaker fits into the designated switchgear or panel and that enough space is available for operation, maintenance, and ventilation.

## Fundamental characteristics of a circuit-breaker

The fundamental characteristics of a circuit-breaker are:

- Its rated voltage **Ue**
- Its rated current **In**
- Its tripping-current-level adjustment ranges for overload protection **(Ir or Irth)**
- and for short-circuit protection **(Im)**
- Its short-circuit current breaking rating (**Icu** for industrial CBs; **Icn** for domestic type CBs).

***Rated operational voltage (Ue)*** :This is the voltage at which the circuit-breaker has been designed to operate, in normal (undisturbed) conditions

**Rated current (In)** :This is the maximum value of current that a circuit-breaker, fitted with a specified overcurrent tripping relay, can carry indefinitely at an ambient temperature stated by the manufacturer, without exceeding the specified temperature limits of the current carrying parts.

***Example***

A ***circuit-breaker rated at In = 125 A*** for an ***ambient temperature of 40 °C*** will be equipped with a suitably calibrated overcurrent tripping relay (set at 125 A). The same circuit-breaker can be used at higher values of ambient temperature however, if suitably "derated". Thus, the circuit-breaker in an ***ambient temperature of 50 °C*** could ***carry only 117 A*** indefinitely, or again, only 109 A at 60 °C, while complying with the specified temperature limit. Derating a circuit-breaker is achieved therefore, by reducing the trip-current setting of its overload relay, and marking the CB accordingly. The use of an electronic-type of tripping unit, designed to withstand high temperatures, allows circuit-breakers (derated as described) to operate at 60 °C (or even at 70 °C) ambient

***Frame-size rating*** :A circuit-breaker which can be fitted with overcurrent tripping units of different current level-setting ranges, is assigned a rating which corresponds to the highest currentlevel-setting tripping unit that can be fitted.

***Example***

A Compact NSX630N circuit-breaker can be equipped with 11 electronic trip units from 150 A to 630 A. The size of the circuit-breaker is 630 A.

***Overload relay trip-current setting (Irth or Ir)***

Apart from small circuit-breakers which are very easily replaced, industrial circuitbreakers are equipped with removable, i.e. exchangeable, overcurrent-trip relays. Moreover, in order to adapt a circuit-breaker to the requirements of the circuit it controls, and to avoid the need to install over-sized cables, the trip relays are generally adjustable. The trip-current setting **Ir** or **Irth** (both designations are in common use) is the current above which the circuit-breaker will trip. It also represents the maximum current that the circuit-breaker can carry without tripping. That value must be greater than the maximum load current **IB**, but less than the maximum current permitted in the circuit **Iz** (see chapter G, sub-clause 1.3). The thermal-trip relays are generally ***adjustable from 0.7 to 1.0 times In***, but when electronic devices are used for this duty, the adjustment range is greater; typically 0.4 to 1 times **In**

***Short-circuit relay trip-current setting (Im)***

Short-circuit tripping relays (instantaneous or slightly time-delayed) are intended to trip the circuit-breaker rapidly on the occurrence of high values of fault current. Their tripping threshold ***Im*** is:

- Either fixed by standards for domestic type CBs, e.g. IEC 60898, or,
- Indicated by the manufacturer for industrial type CBs according to related standards, notably IEC 60947-2.

For the latter circuit-breakers there exists a wide variety of tripping devices which allow a user to adapt the protective performance of the circuit-breaker to the particular requirements of a load (see Fig. H31, Fig. H32 and Fig. H33).

| | Type of protective relay | Overload protection | Short-circuit protection | | |
|---|---|---|---|---|---|
| Domestic breakers IEC 60898 | Thermal-magnetic | $Ir = In$ | Low setting type B $3\ In \leqslant Im \leqslant 5\ In$ | Standard setting type C $5\ In \leqslant Im \leqslant 10\ In$ | High setting circuit type D $10\ In \leqslant Im \leqslant 20\ In$(1) |
| Modular industrial(2) circuit-breakers | Thermal-magnetic | $Ir = In$ fixed | Low setting type B or Z $3.2\ In \leqslant$ fixed $\leqslant 4.8\ In$ | Standard setting type C $7\ In \leqslant$ fixed $\leqslant 10\ In$ | High setting type D or K $10\ In \leqslant$ fixed $\leqslant 14\ In$ |
| Industrial(2) circuit-breakers IEC 60947-2 | Thermal-magnetic | $Ir = In$ fixed | Fixed: $Im = 7$ to $10\ In$ | | |
| | | Adjustable: $0.7\ In \leqslant Ir \leqslant In$ | Adjustable:<br>- Low setting : 2 to 5 In<br>- Standard setting: 5 to 10 In | | |
| | Electronic | Long delay $0.4\ In \leqslant Ir \leqslant In$ | Short-delay, adjustable<br>$1.5\ Ir \leqslant Im \leqslant 10\ Ir$<br>Instantaneous (I) fixed<br>$I = 12$ to $15\ In$ | | |

(1) 50 In in IEC 60898, which is considered to be unrealistically high by most European manufacturers (Schneider Electric = 10 to 14 In).
(2) For industrial use, IEC standards do not specify values. The above values are given only as being those in common use.

## Rated short-circuit breaking capacity (Icu or Icn)

The short-circuit current-breaking rating of a CB is the highest (prospective) value of current that the CB is capable of breaking without being damaged. The value of current quoted in the standards is the rms value of the AC component of the fault current, i.e. the DC transient component (which is always present in the worst possible case of short-circuit) is assumed to be zero for calculating the standardized value.

This rated value ***(Icu)*** for industrial CBs and *(Icn)* for domestic-type CBs is normally given in kA rms. ***Icu*** (rated ultimate s.c. breaking capacity) and Ics (rated service s.c. breaking capacity) are defined in IEC 60947-2 together with a table relating *Ics* with *Icu* for different categories of utilization A (instantaneous tripping) and B (time-delayed tripping) as discussed in subclause 4.3.

| Icu | cos φ |
|---|---|
| 6 kA < Icu ⩽ 10 kA | 0.5 |
| 10 kA < Icu ⩽ 20 kA | 0.3 |
| 20 kA < Icu ⩽ 50 kA | 0.25 |
| 50 kA < Icu | 0.2 |

*Fig. H34 : Icu related to power factor (cos φ) of fault-current circuit (IEC 60947-2)*

***Other characteristics of a circuit-breaker***

***Rated insulation voltage (Ui)***

This is the value of voltage to which the dielectric tests voltage (generally greater than 2 Ui) and creepage distances are referred to. The maximum value of rated operational voltage must never exceed that of the rated insulation voltage, i.e

$$Ue \leqslant Ui.$$

***Rated impulse-withstand voltage (Uimp)***

This characteristic expresses, in kV peak (of a prescribed form and polarity) the value of voltage which the equipment is capable of withstanding without failure, under test conditions. Generally, for industrial circuit-breakers, Uimp = 8 kV and for domestic types, Uimp = 6 kV.

***Category (A or B) and rated short-time withstand current (Icw)***

As already briefly mentioned (sub-clause 4.2) there are two categories of LV industrial switchgear, A and B, according to IEC 60947-2: b Those of category A, for which there is no deliberate delay in the operation of the “instantaneous” short-circuit magnetic tripping device, are generally moulded-case type circuit-breakers, and b Those of category B for which, in order to discriminate with other circuit-breakers on a time basis, it is possible to delay the tripping of the CB, where the fault-current level is lower than that of the short-time withstand current rating (Icw) of the CB . This is generally applied to large open-type circuit-breakers and to certain heavy-duty moulded-case types. Icw is the maximum current that the B category CB can withstand, thermally and electrodynamically, without sustaining damage, for a period of time given by the manufacturer.

***Rated making capacity (Icm)***

Icm is the highest instantaneous value of current that the circuit-breaker can establish at rated voltage in specified conditions. In AC systems this instantaneous peak value is related to Icu (i.e. to the rated breaking current) by the factor k, which depends on the power factor (cos ϕ) of the short-circuit current loop.

| Icu | cos φ | Icm = kIcu |
|---|---|---|
| 6 kA < Icu ⩽ 10 kA | 0.5 | 1.7 x Icu |
| 10 kA < Icu ⩽ 20 kA | 0.3 | 2 x Icu |
| 20 kA < Icu ⩽ 50 kA | 0.25 | 2.1 x Icu |
| 50 kA ⩽ Icu | 0.2 | 2.2 x Icu |

***Rated service short-circuit breaking capacity (Ics)***

The rated breaking capacity (Icu) or (Icn) is the maximum fault-current a circuitbreaker can successfully interrupt without being damaged. The probability of such a current occurring is extremely low, and in normal circumstances the fault-currents are considerably less than the rated breaking capacity (Icu) of the CB. On the other hand it is important that high currents (of low probability) be interrupted under good conditions, so that the CB is immediately available for reclosure, after the faulty circuit has been repaired. It is for these reasons that a new characteristic (Ics) has been created, expressed as a percentage of Icu, viz: 25, 50, 75, 100% for industrial circuit-breakers. The standard test sequence is as follows:

- O - CO - CO(1) (at Ics)
- Tests carried out following this sequence are intended to verify that the CB is in a good state and available for normal service

For domestic CBs, Ics = k Icn. The factor k values are given in IEC 60898 table XIV.
In Europe it is the industrial practice to use a k factor of 100% so that Ics = Icu.

**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 $I_z$**

$$I_n \leq 0.725 \times I_z$$

# Miniature circuit breakers (MCB)

## 1 Circuit breaker characteristics

The characteristic features of the circuit breaker and the markings must be visible from the print on the cover of the device. The full scope of the requirements is described in the standard series IEC/EN 60898: Circuit-breakers for over-current protection for household and similar installations.

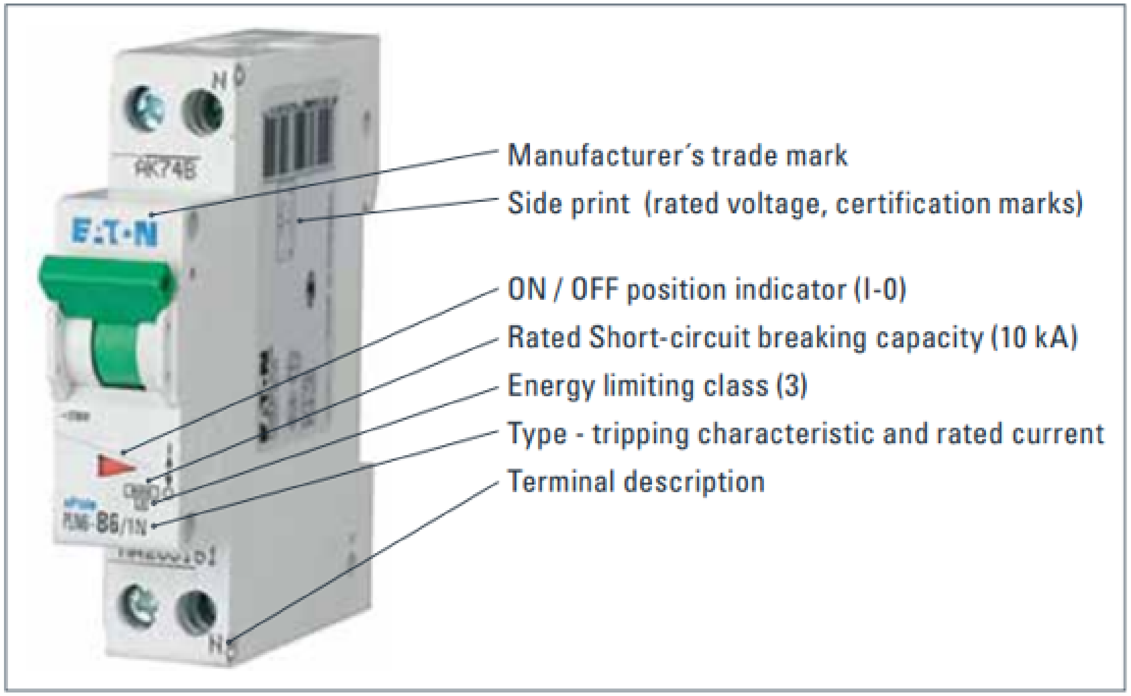



Fig. 4 Miniature circuit breaker (MCB) identification

### Switching and isolation function


Fig. 5 Symbols of circuit-breaker

## SPECIFICATION AND OPERATION

The rated current (IN) of a circuit breaker is the current that it can carry continuously, generally for a duration of more than eight hours. The rated current must not cause a temperature rise in excess of the specified values when the ambient temperature is between –5 C to 40 C. Different temperature rise limits are specified for different parts of a circuit breaker. A circuit breaker will not operate (trip) if the current passing through it is 105% to 113% of its rated current [Ref. 1, P 23], [Ref. 2, P 27]. It will take one to two hours to trip if the current passing through it is 130% to 145% of the rated current [Ref. 1, P 23, Ref. 2, P 27].

## 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 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.

**Rated Voltage**

Based on BS EN 60898 [Ref. 2], the preferred values of rated voltages are 400 V/230 V. Values of 380 V/220 V and 415 V / 240 V should progressively be superseded by the values of 400 V / 230 V.

**Current Rating**

The preferred values of rated current are : 6, 8, 10, 15, 16, 20, 25, 32, 40, 50, 63, 80 100 and 125 A.

**Short-circuit Capacity**

Instead of specifying the breaking capacity, the standard specifies the values of the short-circuit capacity. The short-circuit capacity refers to the prospective current expressed by its r.m.s. value which the MCB is designed to make (close), to carry for its opening time and to break under the specified conditions. The standard values of rated short-circuit capacity are 1.5, 3, 4.5, 6 and 10 kA. For values above 10 kA, up to and including 25 kA, the preferred value is 20 kA.

**Instantaneous Tripping**

Based on the standard range of instantaneous tripping, MCBs are classified into three types given in Table 2.1. In BS3871, they are classified as type 1 (2.7 IN to 4 IN ), type 2 (4 IN to 7 IN ) and type 3 (7 IN to 10 IN ). Another older European standard classified them as type L, G and U. Type L is similar to type 1 and types G and U are similar to type 2. In BS 3871:1984, it specifies a category of duty, namely M1 (1 kA), M3 (3 kA), M6 (6 kA) and M9 (9 kA).

**Table 2.1 Range of Instantaneous Tripping**

| Type | Instantaneous Tripping Current |
|---|---|
| B | Above 3 $I_N$ up to and including 5 $I_N$ |
| C | Above 5 $I_N$ up to and including 10 $I_N$ |
| D | Above 10 $I_N$ up to and including 50 $I_N$ |

## Time-current Characteristics

An MCB shall have a fixed and un-adjustable time/current characteristic calibrated at 300C given in Table 2.2. Typical time-current characteristics of type C MCBs from 5 A to 100 A are shown in Figure 2.9. These characteristic curves are identical to type C MCBs. By referring to the curve of the 100 A and by transferring the Y-axis from amperes to the multiples of the rated current of the MCB, the generalised time-current characteristic curves are shown in Figure 2.10 incorporating type 1, type B, type C and type 3.

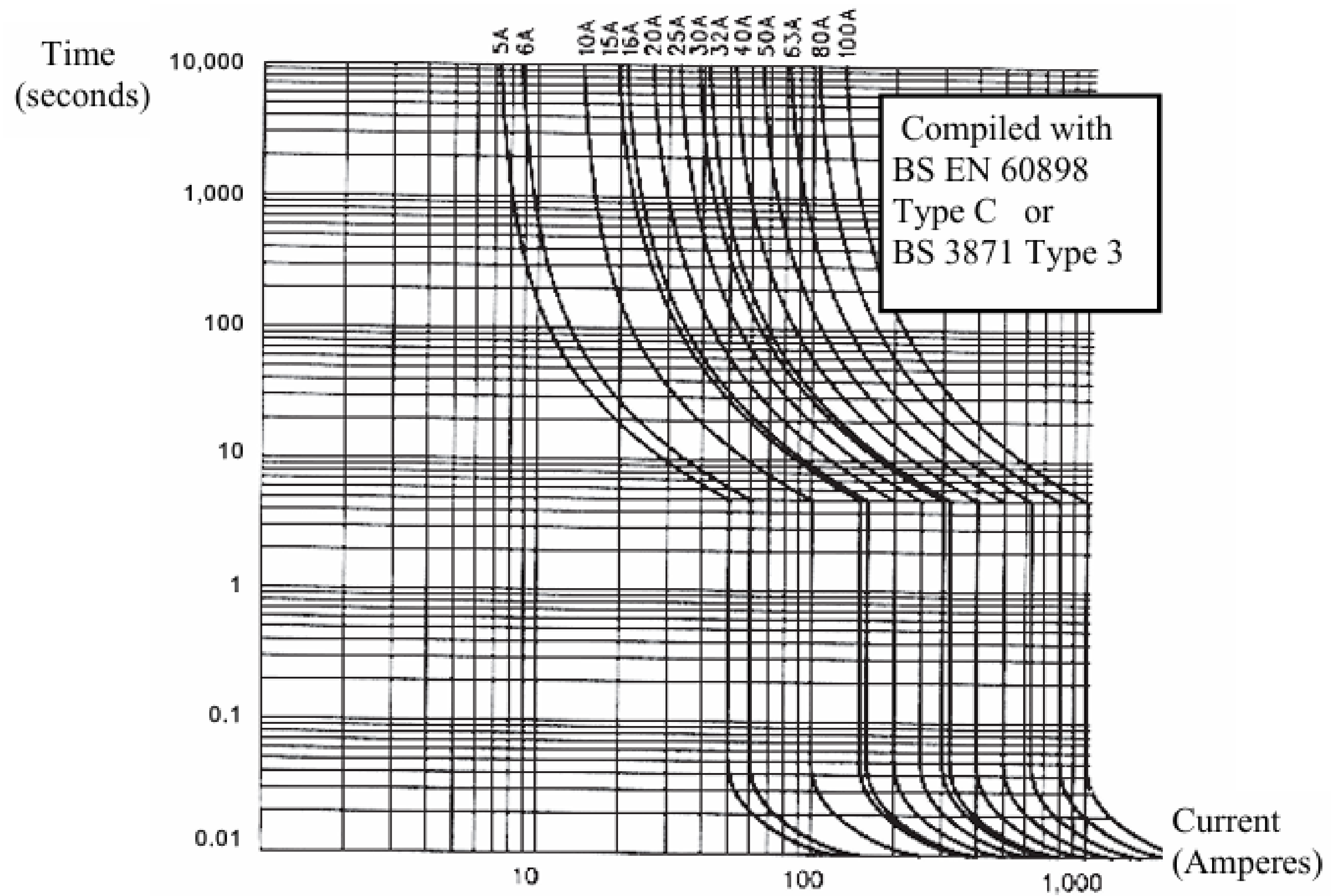



Figure 2.9 Typical time-current characteristic for type C MCB

**Table 2.2 Time-current Characteristics of MCB by BS EN 60898**

| Test | Type | Test Current | Initial Condition | Test Period | Result |
|---|---|---|---|---|---|
| 1 | B, C, D | 1.13 $I_N$ | Cold* | $t \geq 1$ h (for $I_N \leq 63$ A)<br>$t \geq 2$ h (for $I_N > 63$ A) | No tripping |
| 2 | B, C, D | 1.45 $I_N$ | Right after Test 1 | $t < 1$ h (for $I_N \leq 63$ A)<br>$t < 2$ h (for $I_N > 63$ A) | Tripping |
| 3 | B, C, D | 2.55 $I_N$ | Cold * | 1 s $< t <$ 60 s ($I_N \leq 32$ A)<br>1 s $< t <$ 120 s ($I_N > 32$ A) | Tripping |
| 4 | B<br>C<br>D | 3 $I_N$<br>5 $I_N$<br>10 $I_N$ | Cold * | $t \geq 0.1$ s<br>(i.e. Instantaneous tripping does not occur) | No tripping |
| 5 | B<br>C<br>D | 5 $I_N$<br>10 $I_N$<br>50 $I_N$ | Cold * | $t < 0.1$ s<br>(i.e. Instantaneous tripping occurs) | Tripping |

* Cold means without previous loading and at 30$^0$C.

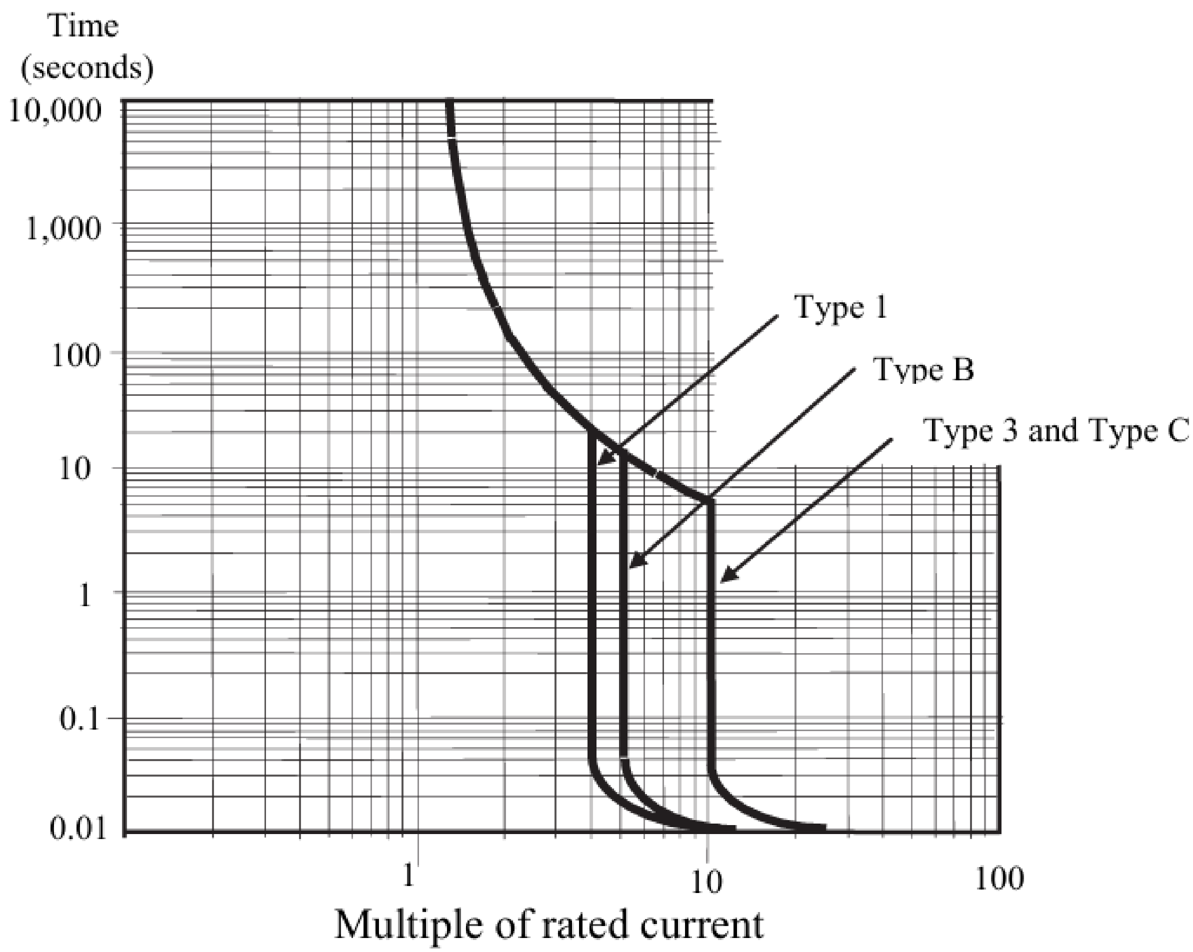



Figure 2.10 Generalised time-current characteristics for MCB

***Rated voltages***

• *Rated operating voltage (Ue)* of the circuit breaker, more commonly known as rated voltage (Ue) indicates the magnitude of voltage for which the circuit breaker is designed, most often 230/400 V AC at 50/60 Hz. The circuit breaker may have more rated operating voltages and associated short-circuit capacities.

• *Rated insulation voltage (Ui)* is the value of voltage to which voltages for dielectric tests and surface pathways apply. The tests are carried out at rated voltage at rated frequency (50/60 Hz). The rated insulation voltage (Ui) must not be lower than the rated voltage (Ue): Ui ≥ Ue

• *Rated impulse withstand voltage (Uimp)* given by the peak value of a voltage pulse with 1.2/50 µs waveform, which the electrical device is able to withstand under specified conditions without fault. The values of the air distances apply to it. The value for MCB circuit breakers is Ui = 4 kV.

***Rated current (In)***

The current assigned by the manufacturer as the current to be conducted by the circuit in continuous operation at the specified reference value of the ambient air temperature without tripping. It is identified on the circuit breaker print in combination with the tripping characteristics as follows: B16 (type B circuit breaker, In = 16 A).

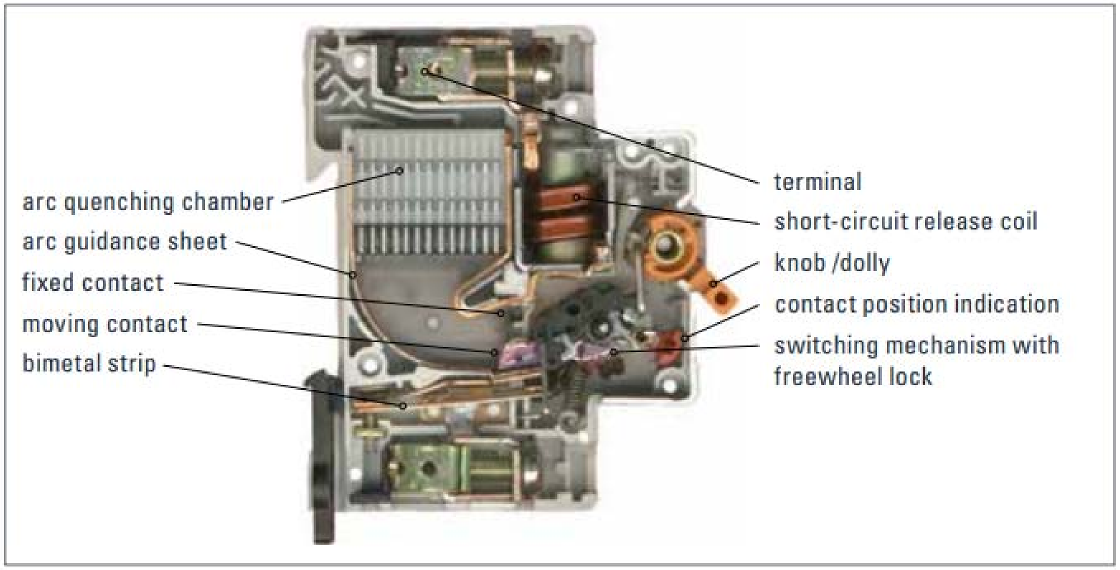



Fig. 6 MCB structural components

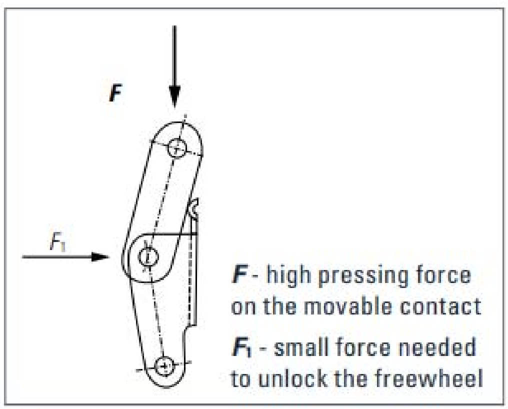



Fig. 7 Free-wheel function principle

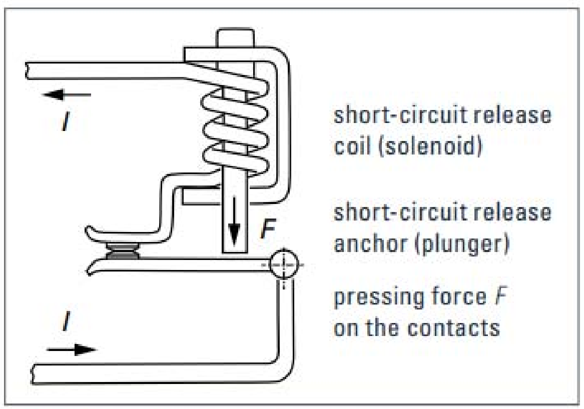



Fig. 8 The principle of the MCB current limiting function

***Structural parts of a circuit breaker (MCB) and their functions is displaed on Fig. 6. The bimetallic element is heated during the passage of small overcurrents and its displacement causes the switching lock mechanism to be unlocked. <u>The circuit breaker must shut off at currents of above 1.45xIn.</u>***

| | | |
|---|---|---|
| Design according to IEC/EN 60898-1 | | |
| Rated voltage ($U_e$) | AC: | 230/400 V |
| | DC: | 48 V (per pole, max. 2 poles) |
| Rated frequency (*f*) | | 50/60 Hz |
| Rated current ($I_n$) AC: | | max. 63 A |
| Tripping characteristic type | | B, C, D |
| Rated breaking capacity ($I_{cn}$) (acc. to IEC/EN 60898-1) | | |
| PLSM, PLZM series | | 10 kA |
| PLS6, PLZ6 series | | 6 kA |
| PLS4, PLZ4 series | | 4.5 kA |
| Back-up fuse | | |
| PLSM | | max. 125 A gL |
| PLS6 | | max. 100 A gL |
| PLS4 | | max. 80 A gL |
| Energy limiting class (selectivity class) | | 3 |
| Rated impulse withstand voltage ($U_{imp}$) | | 4 kV (1.2/50 μs) |
| Endurance | electrical | ≥ 10,000 switching operations |
| | mechanical | ≥ 20,000 switching operations |
| Line voltage connection | | optional (above/below) |

Tab. 1 Example of electrical parameters of MCBs series for household installations (PLSM series)

# MCCB

| | |
|---|---|
| Current rating | : 10, 16, 20, 32, 40, 50, 63, 80, 100<br>200, 300, 400, 630, 800, 1250 A |
| Rated voltage | : 380, 400, 415 V |
| Rated breaking capacity | : 10, 20, 25, 35, 65, 85 kA (r.m.s.) |
| Rated making capacity | : 17, 44, 53, 63, 84, 143 kA (peak) |

$20^0C$ and range 'b' refers to $40^0C$. Range 'c' refers to the magnetic release at 5 $I_N$ and range 'd' refers to 10 $I_N$. The design engineer has to specify either range 'c' or 'd' when ordering.

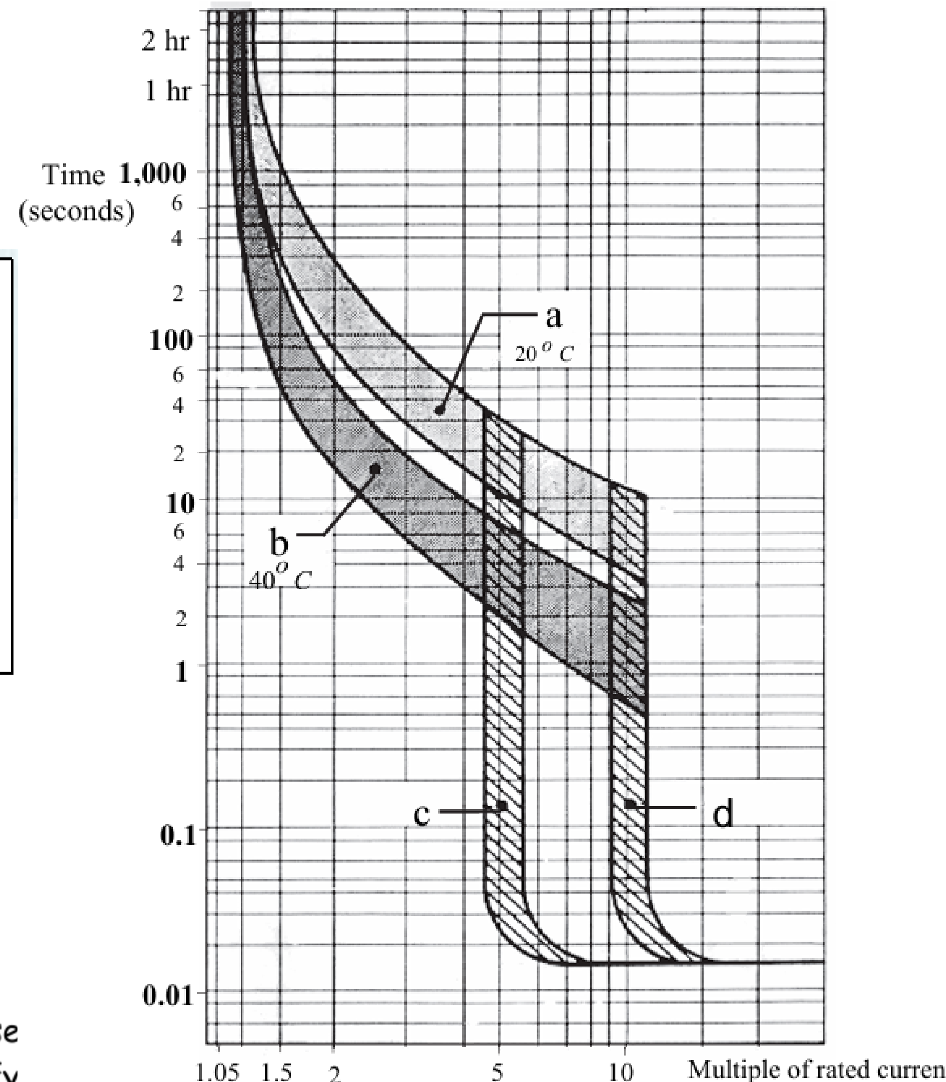



Figure 2.13 Time-current characteristic of a typical MCC

**Types of Molded Case Circuit Breakers**

MCCB manufacturers provide performance details such as amp rating, short circuit rating, and whether the unit is current limiting or non-current limiting (standard) breaker. However, the unit type isn't based on these metrics but on the tripping curves.

A trip curve is a graphical representation of how a circuit protection device behaves in response to current levels. Based on this, MCCBs are segregated into five categories:

*Type B*

The second most sensitive of all MCCB types, products in this category trip at 3 to 5 times the rated current of the unit and have a tripping time of 0.04 to 13 seconds.

This makes Type-B MCCBs well-suited for resistive applications in residential and light industrial setups. Because the surge current level of these MCCBs is relatively low, they are ideal for resistive elements and loads, such as light fixtures and domestic appliances.

*Type C*

A step above Type B MCCBs, Type C units trip at 5 to 10 times their rated current. This makes them suitable for use in commercial and industrial applications where there is a possibility of short circuit currents in the electrical system.

Their tripping time is between 0.04 to 5 seconds, and they can handle higher surges, so they work well in industrial settings with small inductive loads such as electromagnets, pumps, small to mid-sized motors, fluorescent lights, and transformers.

*<u>Type D</u>*

Their tripping time is between 0.04 to 5 seconds, and they can handle higher surges, so they work well in industrial settings with small inductive loads such as electromagnets, pumps, small to mid-sized motors, fluorescent lights, and transformers.

For example, Type D MCCBs are an ideal choice for industrial settings involving large battery charging, large winding motors, discharge lighting and X-ray machines, and other such medical/radiological equipment, etc.

*<u>Type K</u>*

For example, Type D MCCBs are an ideal choice for industrial settings involving large battery charging, large winding motors, discharge lighting and X-ray machines, and other such medical/radiological equipment, etc.

This makes them suitable for handling inductive and motor loads where a high starting current is expected.

*<u>Type Z</u>*

The most sensitive of all types of MCCBs, Type Z units will trip at 2 to 3 times their rated current. The tripping time is 0.04 to 5 seconds, which makes them an ideal choice for exceptionally sensitive devices that are easily damaged even by low current surges. Typically, such units are used in systems serving semiconductor-based IT and medical equipment.

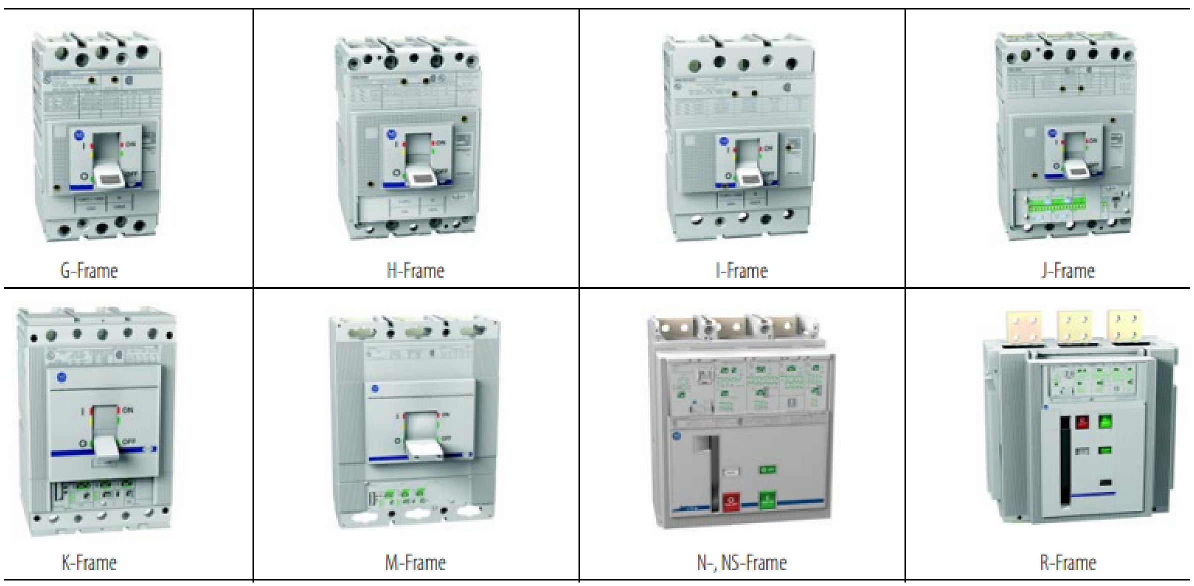
[MCCBs]() are rated based on multiple variables, and each of these impacts their performance. Manufacturers offer accurate data pertaining to these ratings, which include:

•**Rated frame current/Frame size (Inm)**: This indicates the size or the dimension of the plastic casing or shell of the unit. Also, it is indicative of the maximum current that the casing/shell of the unit can handle.

•**Rated current (In/Ie):** This is the functional range of the unit or the maximum current value above which the unit will trip.

•**Rated voltage (Ue)**: This is the functional voltage of the breaker or the continuous operating voltage that the unit is designed for. Typically, this value is close to or the same as the standard system voltage.

•**Rated insulation voltage (Ui)**: This is the maximum voltage range that the unit can resist, as per laboratory tests. This value is usually higher than the rated voltage to allow for a margin of safety.



- **Rated Impulse Withstand voltage (Uimp)**: This is the transient surge voltage that the unit is designed to handle. Testing is done at a standard size of 1.2/50Âs. So, a rating such as Uimp=8kV means that the unit was tested at a peak current of 8kV at a standard size of 1.2/50.

- **Unlimited short circuit breaking capacity (Icu)**: This is the maximum fault current that the breaker will clear, but there is a likelihood that the unit may get permanently damaged in the process.

If the fault current exceeds this value, the breaker may not trip, and it will get permanently damaged. This is a factor that impacts the cost of the unit. The breaking capacity should be higher than the possible fault current level. For residential applications, going above 10kA would be good enough.

- **Short circuit Breaking Capacity (Ics)**: This is typically a percentage of the Icu and refers to the maximum fault current at which the unit will trip without suffering permanent damage. Typically, this refers to a fault level at which the unit can trip three times and yet be reusable after a reset. The higher this value, the more reliable the unit is.

To understand how these ratings work, consider the example of a breaker that has:

•Icu: 40,000 Amperes

•Ics: 25,000 Amperes

- **Shunt trip for protection relays**: When an MCCB trip due to an external signal from a protection relay, it is known as a shunt trip. If such protection relays (sensors) are part of the electrical system, you must choose an MCCB that accepts inputs from such sensors.

# ACB

**Types of Air Break Circuit Breaker**

1.Here's a breakdown of the ACB breaker's main types:**Plain Break (Cross-Blast) ACB:** They have a simple design with contacts separating in open air, and are suitable for lower current applications.

**2.Magnetic Blowout ACB:** They use an electromagnet to deflect the arc for faster quenching.

**3.Air Chute ACB:** This ACB electrical breaker employs a compressed air chamber to extinguish the arc.

**4.Air Blast ACB:** High-pressure air circuit breakers extinguish the arc rapidly.

The ACB is currently covered under BS EN 60947 [Ref. 1, Ref. 5] with the same specification as that described in section 2.3 for MCCB. Typically, an ACB manufacturer produces breakers with current ratings in the range 800 to 5000 A and a breaking capacity up to 120 kA. The followings are some typical data for reference.

| | | |
|---|---|---|
| Rated voltage | : | 400, 415, 690 V |
| Rated current | : | 800, 1250, 1600, 2000, 3200, 5000 A |
| Rated breaking capacity | : | 40, 65, 80, 120 kA (r.m.s) |
| Rated Making capacity | : | 84, 143, 220 kA (peak) |

**Functions of Air Circuit Breakers**
Air circuit breakers (ACBs) serve several critical functions in electrical systems, ensuring protection, reliability, and safety. Understanding these functions highlights the importance of ACBs in various applications, particularly in industrial and commercial power systems.

**Overcurrent Protection**: One of the primary functions of ACBs is to protect electrical circuits from overcurrent conditions. Overcurrents can occur due to overloads or short circuits, which can damage electrical equipment and pose safety hazards. ACBs detect these overcurrent conditions through thermal or magnetic trip mechanisms and interrupt the current flow to prevent damage and maintain system integrity.

**Short Circuit Protection**: ACBs are designed to respond quickly to short circuits, which involve very high current levels that can cause severe damage in a short time. The magnetic trip mechanism in ACBs detects the sudden surge in current and triggers the breaker to open the contacts, interrupting the flow of electricity and protecting the circuit from the destructive effects of a short circuit.

**Switching Operations**: ACBs also perform switching operations, allowing for the manual or automatic opening and closing of electrical circuits. This function is essential for routine maintenance, testing, and fault isolation. By enabling controlled disconnection and reconnection of circuits, ACBs facilitate safe and efficient management of electrical systems.

**Fault Isolation**: In the event of a fault, such as a ground fault or an insulation failure, ACBs help to isolate the affected section of the electrical system. This isolation prevents the fault from spreading to other parts of the system, thereby minimizing the impact and maintaining overall system stability. Fault isolation ensures that only the faulty section is taken offline, allowing the rest of the system to continue operating.

**System Protection and Reliability**: ACBs contribute to the overall protection and reliability of electrical systems. By promptly interrupting fault currents and isolating faults, ACBs prevent damage to electrical equipment and reduce downtime. This reliability is particularly important in critical applications such as power distribution networks, industrial plants, and commercial buildings, where uninterrupted power supply is essential.

**Coordination with Other Protective Devices**: ACBs are designed to coordinate with other protective devices in an electrical system, such as fuses and relays. This coordination ensures selective tripping, where only the device closest to the fault operates, minimizing disruption to the rest of the system. Proper coordination enhances the overall protection strategy and improves system performance.

**Remote Operation and Monitoring**: Modern ACBs can be equipped with remote operation and monitoring capabilities. These features allow for the control and supervision of the breakers from a central location, enhancing convenience and safety. Remote operation facilitates quick response to faults, while monitoring provides valuable data on breaker status and system conditions.

**Arc Fault Protection**: Some advanced ACBs include arc fault detection and protection features. Arc faults can cause fires and significant damage if not promptly addressed. ACBs with arc fault protection can detect the presence of an arc and interrupt the circuit to prevent potential hazards, thereby enhancing the safety of the electrical system.

**Advantages of Air Circuit Breakers**
Air circuit breakers (ACBs) offer several advantages that make them a preferred choice for protecting electrical systems in various applications. These advantages contribute to their effectiveness in ensuring system reliability, safety, and efficiency.

**High Current Interruption Capability**: One of the primary advantages of ACBs is their ability to interrupt high current levels. This makes them suitable for use in systems with high voltage and current ratings. ACBs can handle significant fault currents, providing robust protection against overcurrent and short circuit conditions.

**Adjustable Trip Settings**: ACBs come with adjustable trip settings, allowing users to customize the protection parameters according to the specific requirements of their electrical system. This flexibility enables precise coordination with other protective devices, ensuring selective tripping and minimizing disruption to the rest of the system during a fault.

**Enhanced Safety Features**: ACBs incorporate several safety features that enhance their reliability and protection capabilities. These features include arc chutes, blowout coils, and insulation barriers, which work together to extinguish arcs and prevent the spread of faults. Additionally, modern ACBs may include remote operation and monitoring capabilities, allowing for safer and more convenient control of the breaker.

**Ease of Maintenance**: The design of ACBs facilitates ease of maintenance, which is crucial for ensuring long-term reliability and performance. Draw-out ACBs, in particular, can be easily removed from their enclosures for inspection, testing, and maintenance without disturbing the rest of the electrical system. This feature reduces downtime and simplifies maintenance procedures.

**Durability and Longevity**: ACBs are known for their robust construction and durability. They are designed to withstand harsh operating conditions, including high temperatures and mechanical stresses. This durability translates to a longer lifespan and reduced need for frequent replacements, contributing to lower maintenance costs over time.

**Versatility and Application Range**: ACBs are versatile and can be used in a wide range of applications, from low voltage to high voltage systems. They are commonly employed in industrial plants, commercial buildings, power distribution networks, and other critical infrastructure. This versatility makes them a suitable choice for various environments and operational requirements.

**Quick Response Time**: The rapid response time of ACBs is another significant advantage. The trip mechanisms in ACBs, whether thermal or magnetic, are designed to react quickly to fault conditions, ensuring prompt interruption of the current flow. This quick response minimizes the risk of damage to electrical equipment and enhances overall system protection.

**Environmental Friendliness**: ACBs do not use oil or gas as the interrupting medium, relying instead on air. This makes them more environmentally friendly compared to other types of circuit breakers that use potentially hazardous materials. The use of air as an insulating and interrupting medium reduces environmental impact and simplifies disposal at the end of the breaker's life cycle.

**Cost-Effectiveness**: Considering their long lifespan, ease of maintenance, and reliability, ACBs offer a cost-effective solution for electrical protection. The initial investment in ACBs is offset by the reduced maintenance costs and enhanced protection they provide, making them an economically viable choice for many applications.

## Applications of Air Circuit Breakers

Thanks to their versatility and reliability, ACBs find applications across industrial, commercial, and residential sectors.

**Industrial Use Cases**

•Manufacturing: ACBs protect and control power distribution in manufacturing plants, ensuring smooth operations and safety.
•Power Plants: They manage and protect electrical circuits in power generation facilities, preventing faults and outages.
•Data Centers: ACBs ensure reliable power distribution and protection in data centers, crucial for maintaining uptime and data integrity.

**Commercial Use Cases**

•Office Buildings: ACBs are used in office buildings to control and protect electrical systems, ensuring safe and efficient power distribution.
•Shopping Malls: They manage the complex electrical needs of large commercial spaces, providing reliable protection and control.
•Hospitals: In healthcare facilities, ACBs ensure uninterrupted power supply and protection for critical medical equipment.

**Residential Use Cases**

•Home Electrical Panels: ACBs are used in residential electrical panels to protect circuits from overloads and short circuits.
•Smart Homes: They play a crucial role in managing and protecting electrical systems in smart homes, enhancing safety and efficiency.

**Selection Criteria for Air Circuit Breakers**

Selecting the appropriate air circuit breaker (ACB) for a specific application involves evaluating several criteria to ensure optimal performance, safety, and reliability. These selection criteria help in matching the ACB's capabilities with the requirements of the electrical system it will protect.

**Current Rating**: The current rating of an ACB must match the maximum continuous current that the system will carry. Selecting a breaker with an appropriate current rating ensures that it can handle the load without tripping under normal operating conditions.

**Short Circuit Rating**: The short circuit rating, or interrupting capacity, indicates the maximum fault current that the ACB can safely interrupt. This rating must be higher than the potential fault current in the system. Properly matching this rating prevents damage to the breaker and ensures effective protection during short circuit events.

**Voltage Rating**: The voltage rating of the ACB should be compatible with the system's operating voltage. Using a breaker with the correct voltage rating ensures safe operation and effective insulation. ACBs are available in various voltage ratings to suit different applications, from low voltage to medium voltage systems.

**Trip Characteristics**: Different applications require different trip characteristics. ACBs offer adjustable trip settings, including thermal and magnetic trips, to accommodate various protection needs. Selecting the correct trip characteristics ensures that the breaker responds appropriately to overcurrent and short circuit conditions, providing effective protection without unnecessary interruptions.

**Operating Environment**: The environmental conditions where the ACB will be installed influence its selection. Factors such as temperature, humidity, dust, and corrosive elements need to be considered. Some ACBs are designed for harsh environments and have enhanced protection against contaminants, ensuring reliable performance in challenging conditions.

**Mounting Configuration**: ACBs come in different mounting configurations, such as fixed or draw-out types. The choice between these depends on the ease of maintenance, inspection, and replacement requirements. Draw-out ACBs are preferable in applications where minimal downtime and easy access are critical, while fixed ACBs may be suitable for more permanent installations.

**Size and Space Requirements**: The physical dimensions and weight of the ACB must be compatible with the available installation space. In applications with limited space, compact ACBs with a smaller footprint are advantageous. Ensuring adequate space for installation, operation, and maintenance is crucial for effective and safe use.

**Integration with Protection System**: The ACB should be compatible with other components of the protection system, such as relays, fuses, and other breakers. Proper coordination ensures selective tripping, where only the breaker closest to the fault trips, minimizing disruption to the rest of the system.

**Maintenance and Serviceability**: The ease of maintenance and serviceability of the ACB is an important criterion. Breakers that are easy to inspect, test, and repair reduce downtime and maintenance costs. Features like draw-out designs and modular components can enhance maintainability.

**Manufacturer and Standards Compliance**: Choosing an ACB from a reputable manufacturer ensures quality and reliability. Additionally, the breaker should comply with relevant industry standards and regulations, such as IEC or ANSI standards. Compliance with these standards ensures that the ACB meets the necessary safety and performance criteria.

**Cost and Budget Considerations**: The cost of the ACB, including the initial purchase price, installation, and long-term maintenance, should fit within the project's budget. While cost is an important factor, it should be balanced with the need for reliability, durability, and performance to ensure overall cost-effectiveness.

**Remote Operation and Monitoring**: For applications requiring advanced control and monitoring, ACBs with remote operation and monitoring capabilities are advantageous. These features allow for real-time supervision, quick response to faults, and integration with modern smart grid systems.

# RCD

## 7. Construction categories of RCDs

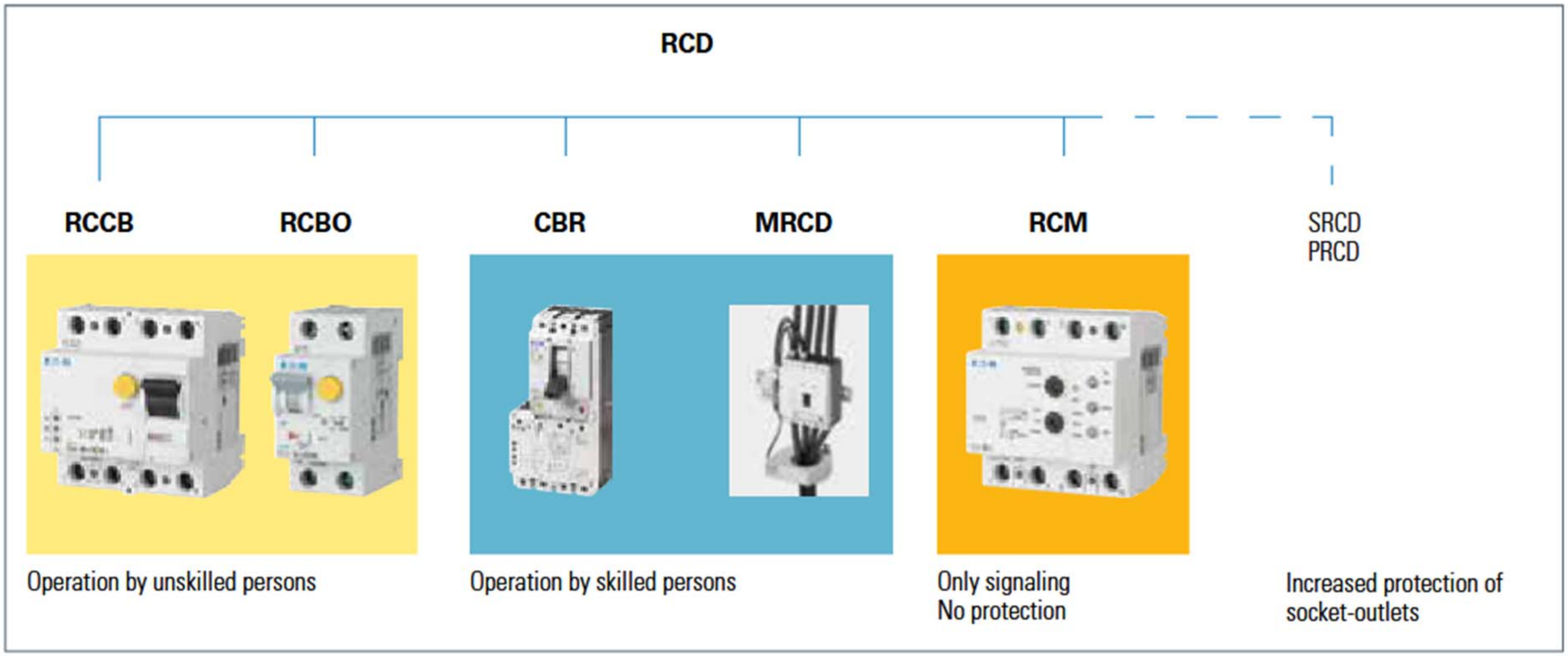



Fig. 10 Types of residual current devices

***<u>The abbreviation of RCD</u>*** is used in electrotechnical standards and technically-oriented texts as a simple representative of all possible types and designs, as below:
RCD (Residual Current Device); see IEC 60755
This is a common name for all types and variants, as mentioned below
RCCB (Residual Current operated Circuit Breaker without integral overcurrent protection); see IEC 61008 2-1, IEC 62423
A mechanical switching device designed to make, carry and break currents under normal service conditions and to cause the contacts to open when the residual current attains a given value under specified conditions It is not designed to give protection against overloads and/or short-circuits and must always be used in conjunction with an overcurrent protective device such as a fuse or circuit-breaker
***<u>RCBO</u>*** (Residual Current operated circuit Breaker with integral Overcurrent protection) see IEC 61009 2-1, IEC 62423
A mechanical switching device designed to make, carry and break currents under normal service conditions and to cause the contacts to open when the residual current achieves a given value under specified conditions In addition it is designed to give protection against overloads and/or short-circuits and can be used independently of any other overcurrent protective device within its rated short-circuit capacity

***CBR (Circuit Breaker incorporating Residual current protection);*** IEC 60947-2, Annex B
A circuit-breaker providing overcurrent protection and incorporating residual current protection either integrally (an Integral CBR) or in combination with a residual current unit which may be factory or field fitted

***Note:***The CBR and RCBO have the same application, both providing overcurrent and residual current protection In general, the term RCBO is applied to the smaller devices operated by ordinary persons (BA1), children (BA2) or handicapped persons (BA3), see Part 10 - External influences Whereas CBR and MRCD is used for devices operated by skilled persons, usually with higher current ratings related to MCCBs or ACBs (up to several thousand amperes)

***RCM*** (Residual Current Monitor); see IEC 602020
A device designed to monitor electrical installations or circuits for the presence of unbalanced earth fault currents It does not incorporate any tripping device or overcurrent protection The RCMs are not protective devices but they may be used to monitor residual currents in electrical installations RCMs produce an audible or audible and visual signal when a preselected value of residual current is exceeded

***MRCD*** (Modular Residual Current Device); see IEC 60947-2, Annex M
An independently mounted device incorporating residual current protection, without overcurrent protection and capable of giving a signal to trip an associated switching device

PRCD, PRCD-S (Portable Residual Current protective Device); see IEC 61540

SRCD (Fixed Socket-outlets Residual Current protective Device); see IEC 62640

| RCD Type | | Tripping times [ms] | | | |
|---|---|---|---|---|---|
| | | $I = I_{\Delta n}$ | $I = 2.I_{\Delta n}$ | $I = 5.I_{\Delta n}$ | $I = 500$ A |
| $\square$ | no delay for general use | ≤ 300 | ≤ 150 | ≤ 40 | ≤ 40 |
| $\boxed{G}$ | delay with a non-actuating time of min. 10 ms. | 10 - 300 | 10 - 150 | 10 - 40 | 10 - 40 |
| $\boxed{S}$ | selective with a non-actuating time of min. 40 ms. | 130 - 500 | 60 - 200 | 50 - 150 | 40 - 150 |

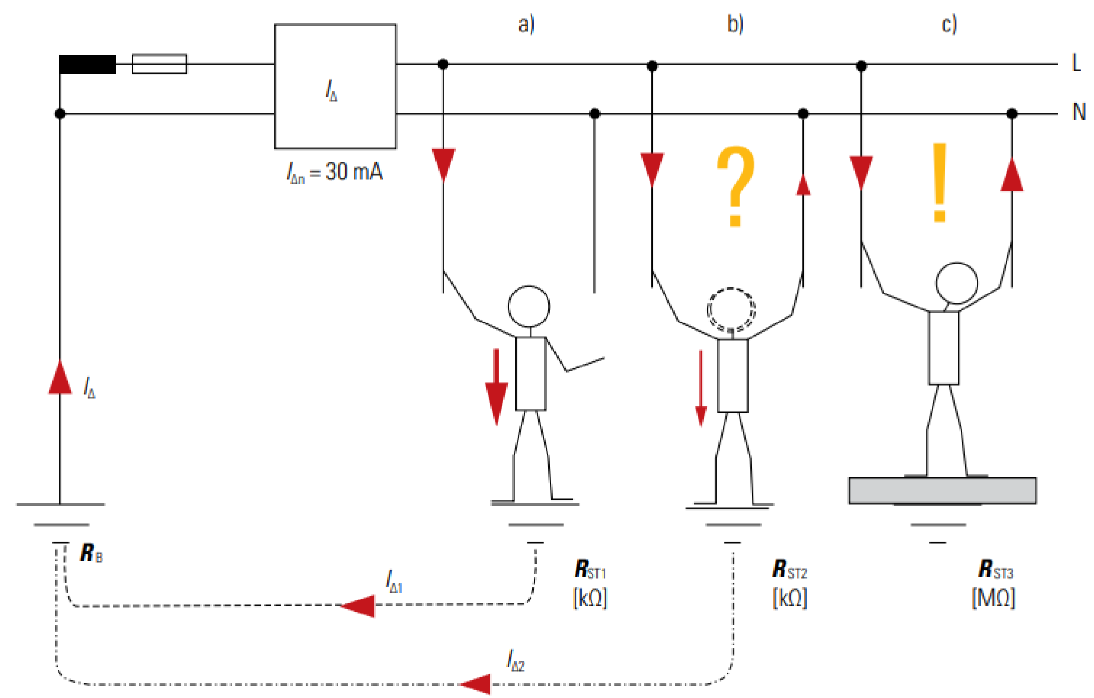
Other time-delayed (e.g. for industrial purposes) can be defined by the relevant standard or by the manufacturer.

Tab. 4 Tripping times of RCDs for AC residual currents (rated frequency 50 Hz)

An advantage of time-delayed types (G, S) is that they are significantly more reliable than RCDs without time delay. This is very important in all applications because higher RCD reliability improves the safety of entire installations.

## General conditions for use of RCD use in the low voltage installations

Generally, a residual current device with a sensitivity of 30 mA used for additional protection must be used (IEC/HD 60364-4-41:2017): • for outlets, with a rated current not exceeding 32 A, which are used by unskilled persons (people without electrical qualifications) and are intended for general use • for mobile devices designed for outdoor use with a rated current not exceeding 32 A. Exceptions are outlets used supervision or surveillance of skilled or instructed personnel and special outlets intended for connection of a special type of equipment, such as e.g. outlets for office equipment and computer technology or sockets to supply power to devices - e.g. refrigerators, unwanted switch-off of which could cause significant damage).




a) RCD trips properly
b) RCD trips, if value of residual current exceeds its tripping level
c) RCD does not detect any residual current - very dangerous situation

***TT systems*** are using residual RCDs for fault protection (protection against indirect contact) almost in all cases. Alternatively (exceptionally), overcurrent protective devices may be used for fault protection provided a suitably low value of fault loop impedance (Zs) is permanently and reliably assured. The following condition shall be fulfilled:

$R_A \times I_{\Delta n} \leq 50$ V

Where: RA the sum of the resistance [Ω] of the earth electrode and the protective conductor for the exposed conductive-parts; where RA is not known it may be replaced by fault loop impedance (ZS)

$I_{\Delta n}$ the rated residual operating current in of the RCD [A].

The disconnection times (1 second or 0,2 second ) relate to prospective residual fault currents significantly higher than the rated residual operating current of the RCD (typically > $5.I_{\Delta n}$).

***Note***: A sensitivity of 10 mA seems to be the best way for safety improvement. But the real effect on the human body is almost the same as for a 30 mA RCD. A tripping time of both versions is comparable because a human body is affected by the same electrical peak current value. A body current is limited mainly by human body resistance, which is independent of the RCD's sensitivity. On the other hand, a sensitivity of 10 mA creates many additional problems with unwanted trips because of permanent leakage currents related to electrical equipment.

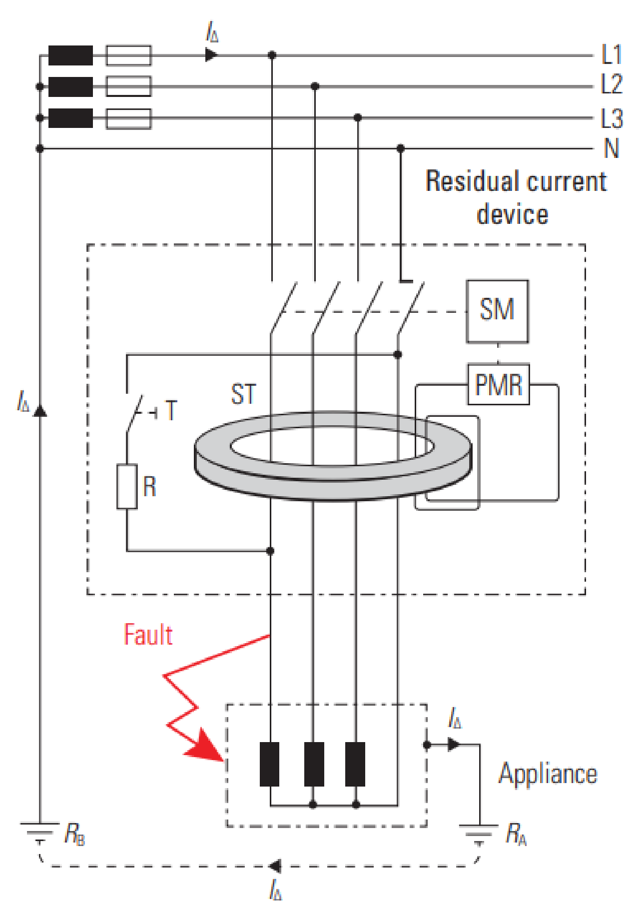
***TN systems*** are the mostly used systems, where the residual fault currents are significantly higher than $5.I_{\Delta n}$. Therefore, the disconnection times (5 s, 0,4 s).are fulfilled with high reserve where RCDs are installed, according to IEC/EN 61008-1, IEC/EN 61009-1 or IEC/EN 62423, including selective and time delayed types. Circuit-breakers providing residual current protection (CBR and MRCD according to IEC/EN 60947-2) can be used, provided the time delay is adjusted to afford compliance with maximal permissible disconnection times.

**Application of residual current devices**

| **According to IEC/ modified HD** | as protection against electric shock (AP, AD) and fire protection (F) | | | |
|---|---|---|---|---|
| | **AP** (Additional protection) | **AD** - Automatic Disconnection; at fault - by automatic disconnection from the source of power supply | | |
| | **F** - Fire Protection | | | |
| | **$I_{\Delta n}$ ≤ 30 mA** | **$I_{\Delta n}$ ≤ 100 mA** | **$I_{\Delta n}$ ≤ 300 mA** | **$I_{\Delta n}$ ≤ 500 mA** |
| **60364-4-41** Protection against electric shock | **AP** - sockets for unskilled personnel ≤ 32 A; outdoor sockets ≤ 32 A - circuits with lights in single household premises (for TN and TT) | | | |
| **60364-4-42** Protection against heat | **F** - overhead heating circuits | **AD** - can be used for AD next to devices for protection against overcurrent (OCPD); must be used for AD, if they do not comply with AD OCPD (circuit breakers or fuses) | | |
| **60364-7-701** Locations containing a bath or shower | **AP** - the entire low-voltage installation in a room with a bath tub or a shower | | **F** - TN and TT end circuits for areas with fire hazards | |
| **60364-7-702** Swimming pools and fountains | **AD** - for fountains<br>**AP** - for pools in zone 2 and for the lines delimiting the zone 0, 1, 2 | | | |
| **60364-7-704** Construction and demolition site installations | **AP** - Socket circuits ≤ 32 A; circuits for electric hand tools ≤ 32 A | | | |
| **60364-7-705** Agricultural and horticultural premises | **AP** - Socket circuits ≤ 32 A | | | **AD** - Socket circuits > 32 A |
| **60364-7-706** Conducting locations with restrictive movement | **AP** - supply to a fixed class II device | **AD** - Socket circuits > 32 A | **AD** and **F** - Circuits other than socket circuits (≤ 32 A and > 32 A) | |
| **60364-7-708** Caravan parks, camping parks and similar locations | **AP** - Single circuit breaker per one socket outlet | | | |

| | | | | |
|---|---|---|---|---|
| **60364-7-709**<br>Marinas and similar locations | **AP** - Each socket outlet, each end circuit to connect a houseboat | | | |
| **60364-7-710**<br>Medical locations | **AP** ≤ 32 A socket circuits - for medical facilities: group 1;<br>in group 2 for circuits:<br>• to move the operating table,<br>• supplying X-ray devices,<br>• to supply power to devices over 5 kVA for powering devices with non-critical functions | | | |
| **60364-7-711**<br>Exhibitions, shows and stands | **AP** ≤ 32 A socket circuits and terminal circuits (except for emergency lighting) | | | |
| **60364-7-714**<br>External lighting installations | **AP** - Built-in lighting in phone booths, bus stops, etc. | | | |
| **60364-7-717**<br>Mobile or transportable units | **AP** - When connected to a fixed electrical installation and as a complementary measure to the electrical department and for sockets for appliances outside the unit | | | |
| **60364-7-721**<br>Electrical installations in caravans and motor caravans | **AP** - to be used as a supplementary measure for AD - see the HD 60364-4-41 | | | |
| **60364-7-722**<br>Power supply of electric vehicles | Each connection point | | | |
| **60364-7-740**<br>Temporary electrical installations for structures, amusement parks etc. | End circuits for lighting, sockets ≤ 32 A, power cord devices ≤ 32 A | | | |
| **60364-7-753**<br>Heating cables and embedded heating systems | Circuits supplying heating units | | Electrical installation of each temporary structure | |

Application of residual current devices
According to IEC/ modified HD
as protection against electric shock (AP
AP (Additional protection)
F- Fire Protection
$I_{\Delta n} \leq 300$ mA




TT network is used for description here, but the same applies analogously for other networks, such as TN-S or TN-C-S

| | |
|---|---|
| SM | switching mechanism |
| TR | toroidal transformer (sensing coil) |
| PMR | Permanent Magnet Relay |
| T | test button |
| R | resistor |
| $I_\Delta$ | residual current = ground fault current |
| $R_A$, $R_B$ | resistance of the earth electrodes |

Fig. 4 Schematic of an RCD

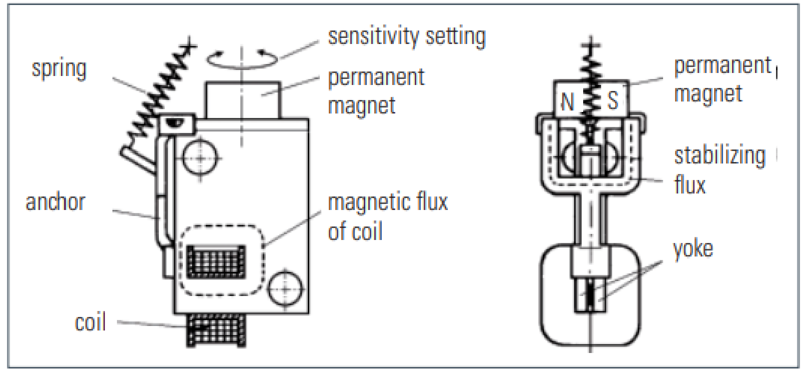



Fig. 5 Trip relay with permanent magnet (PMR)

# Main Parameters of RCDs

Parameters of RCDs are defined in product standards:

- **Rated residual operating current ($I_{\Delta n}$):** value of residual current specified by manufacturer, when the RCD must, under specified conditions, trip. This value is specified on the circuit breaker with the related operating characteristics. It is the main parameter of the residual current device and the conditions of protection against hazardous contact are related to it.
- **Residual non-tripping current ($I_{\Delta no}$):** value of residual current, at which (including lower values), the circuit breaker, under specified conditions, will not trip. Defined by the threshold of $0.5 \cdot I_{\Delta n}$.
- **Limit non-actuating time $t_{\Delta a}$ (time delay):** maximum time, for which the RCD may be exposed to a higher value of residual current than the nominal residual current value $I_{\Delta n}$ without actually activating it. This value characterizes RCDs with delay (types G, S and others, whereas for type G, the limit non-operation time is 10 ms, and for type S 40 ms). During the non-actuating time, the residual current device does not respond to residual currents.

The main parameter of a RCD is rated residual operating current ($I_{\Delta n}$). Normalized values are 10, 30, 100, 300, 500 mA, 1 A, for industrial applications up to 30 A.

- If the residual current achieves the value of 100% $I_{\Delta n}$ or more, the RCD must trip.
- If the residual current does not reach 50% $I_{\Delta n}$, it must not trip.
- The RCD can trip from 50 to 100% $I_{\Delta n}$.

Given a sensitivity of RCD of 30 mA, tripping may occur as early as once the earth leakage current of 15 mA is achieved, which causes problems in installations with higher leaking currents.

## Protection of RCCB against short-circuit and overload

The tripping ability of the residual current circuit breaker without overload protection (RCCB) is very limited. For currents up to 40 A, this value is 500 A, for In = 63 A it is 630 A, for In = 80 A it is 800 A, and for In = 100 A the tripping ability is 1000 A. Although the contacts are located in arc chambers, tripping times of 10 ms or higher (selective types with non-actuating time 40 ms) are too long to achieve a high short-circuit resistance at the contacts. Therefore an overcurrent protection must be used. Conditional short-circuit current (Ic) is the value of a short-circuit current with preliminary fuse gG/gL, where no damage to the contacts will occur. The fuse may be located anywhere on the line side.


Fig. 9 Symbol for conditional short-circuit resistance of 10 kA with upstream fuse with a stipulated value (e.g. 63 A gG/gL)

| **RCCB ($I_n$)** | **Short Circuit Protection ($I_n$)** |
|---|---|
| 16 A | 63 A gG/gL |
| 25 A | 63 A gG/gL |
| 40 A | 63 A gG/gL |
| 63 A | 63 A gG/gL |
| 80 A | 80 A gG/gL |
| 100 A | 100 A gG/gL |

Tab. 2 Maximum fuse values for short-circuit protection of RCCB

Circuit breakers have generally higher values of let through energy then fuses. If circuit breaker is used instead of fuse, the values of let through energies of respective fuse and circuit must be compared, with respect to tolerances. More accurate results are obtained from tests. Company Eaton can declare, that for the mostly used applications up to 40 A is possible replace prescribed fuses by MCBs with rated current equal to rated current of RCCB without reduction of conditional short circuit current of combination. Both types B and C of MCBs are possible.

Protection of RCCB contacts against overloading Correctly executed protection of contacts of RCCB against overload means that constantly passing current will not exceed the value of their rated current, for which they are designed. However, a different definition applies to circuit breakers. Current level, when a breaking device does not trip within agreed-upon time (typically 1 hour), is called conventional tripping current It. For instance, MCBs have It = 1,45xIn (see Part 3.4 Circuit breakers). This means that contacts may be overloaded for long periods without the circuit breaker tripping. Therefore, generally, the rated current of fuse or breaker should be one level lower than the rated current of the RCD. This must be taken into consideration in all installations with high simultaneity. Values declared by producers must be taken into account, see Tab. 3.

| **RCCB** | **Overload protection** | |
|---|---|---|
| **($I_n$)** | **xPole Series -** for residential and commercial installations | **xEffect Series** for industry |
| 16 A | 10 A gG/gL | 16 A gG/gL |
| 25 A | 16 A gG/gL | 25 A gG/gL |
| 40 A | 25 A gG/gL | 40 A gG/gL |
| 63 A | 40 A gG/gL | 63 A gG/gL |
| 80 A | 50 A gG/gL | 80 A gG/gL |
| 100 A | 63 A gG/gL | 100 A gG/gL |

Tab. 3 Protection against contact overloading of RCCB by fuses

# RCCB

**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

**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.


Q&A