POLITEKNIK MALAYSIA PORT DICKSON

POWER SYSTEM PROTECTION

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DET50083
POWER SYSTEM PROTECTION

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INTRODUCTION

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- Basic concept of protection system for protecting power system network.

INTRODUCTION

Protection In General

The word 'protection' means the full protection of a power system involves the use of protective equipment (protective gear) which is a component that is used in protection functions.

Functions of protection system are as follows:

i. isolate the damage as soon as possible.
ii. working only when absolutely required. (if there is damage).
iii. to isolate faulty components only.

This means that only protective equipment carries out its functions in the event of failure or damage to the power system. For normal usage, protective gear refers to the relay and does not include flash suppressant, coil arc and other protective equipment.

Protection of a Power System

Power system protection is needed to prevent the power system elements to be damaged in the event of failure. For any fault causes the entire system suffers from three types of failure that is:

i. Cause in each individual generator power stations, or groups of different generators in power stations for the loss of synchronization and disobedience to the power system.
ii. Risk of damage to a power station failure, and
iii. Risk of damage to the power station which is operating properly.

It is not a danger to the system, but the risk of motor synchronization in large industrial sectors such as lead tripping, coupled with serious disobedience will cause the loss of production and interference in the industrial production sector.

INTRODUCTION

The goal is not to merely cover the system. Distribution line networks also played a role in the overall system. Distribution network should be designed for multiple outputs to be connected to the burden on consumers, at least two sources of supply feeder to each distribution station.

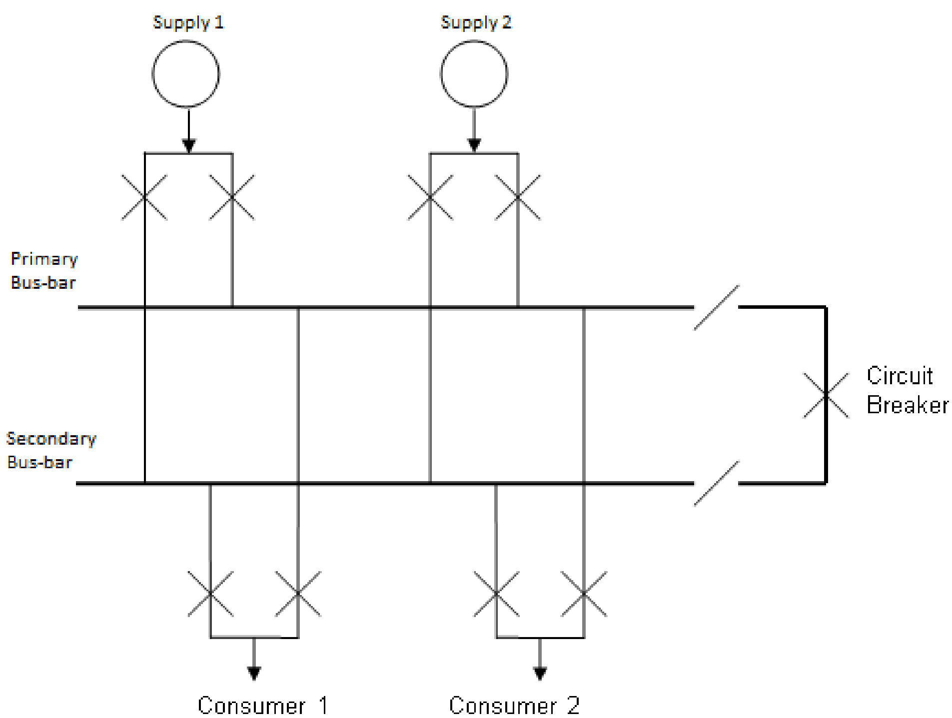


Figure 1.1 : Supply system with double bus-bar arrangement

This system needs to be more ‘selective’ in carrying out its function which is to disconnect the supply to prevent damaged lines from continuing to supply electricity. This selection is called **discrimination**.

In other words, power system protection is to maintain the power system stable by isolating only the faulty components while keeping as much of the network as feasible operational.

BASIC REQUIREMENTS

Basic requirements for evaluating power system protection

The objective of the protection system is to protect all elements/components of the power system including generators, transformers, transmission and distribution lines, busbars from the risk of damage such fault conditions that often occur in the power system. To meet the requirements for the purpose of power system protection, equipment's such as gear switches, isolator switches, circuit breakers, protection relays and so on are essential.

There are four basic requirements in performing a protection function:

i. Reliability - it performs correctly under all faults and abnormal situations of the power system for which it was designed.

ii. Selectivity - the faulty component will be detected and isolated.

iii. Sensitivity - to detect even the smallest fault.

iv. Speed – A faulty element should be disconnected as soon as possible via protective relaying, in order to improve power system stability. Reduce the amount of damage and increase the probability of one sort of fault developing into another.

TYPES OF FAULT

Types of fault that can occur in a power system and their effects.

Faults occur when two or more conductors with different potential differences come into contact with each other. These faults can be caused by equipment failure, short-circuit of overhead lines, or insulation failure caused by lightning surges. The faults in a three phase system can be classified into two main categories:

a) Symmetrical Faults

b) Unsymmetrical Faults

Symmetrical Faults

When all three conductors of a three-phase line are brought together in short-circuit conditions at the same time, symmetrical faults occur as shown in Figure 1.2.

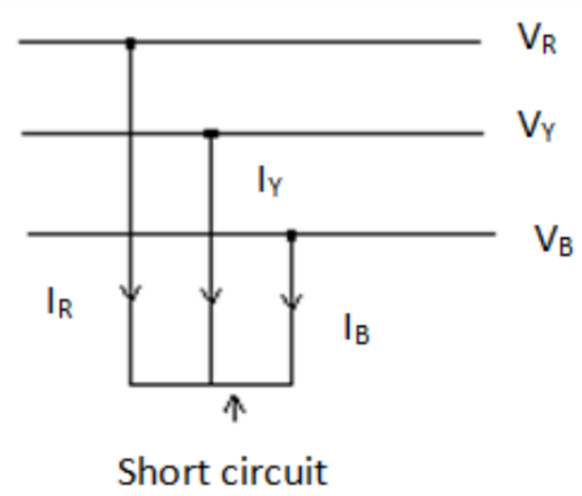


Figure 1.2 : Symmetrical Short Circuit

All three phases are short circuit . L – L – L and L – L – L – G. This type of faults gives increase to symmetrical current which equal faults currents with 120 º displacement.

TYPES OF FAULT

Unsymmetrical Faults

Those faults which give increase to unsymmetrical currents are called unsymmetrical faults. Unsymmetrical faults can show as one of the following:

i. Single phase-to-ground fault

A single phase to ground fault is a short circuit between any one of the phase conductors and the earth. It could be due to a phase conductor breaking and falling to the ground, or it could be due to the insulation between the phase conductors and the earth failing.

ii. Phase-to-phase fault

A line-to-line or phase-to-phase fault is a short circuit between any two phases.

iii. Two phase-to-ground faults

A double line to ground or a two phase to ground fault also known as a short circuit between any two phases an the earth

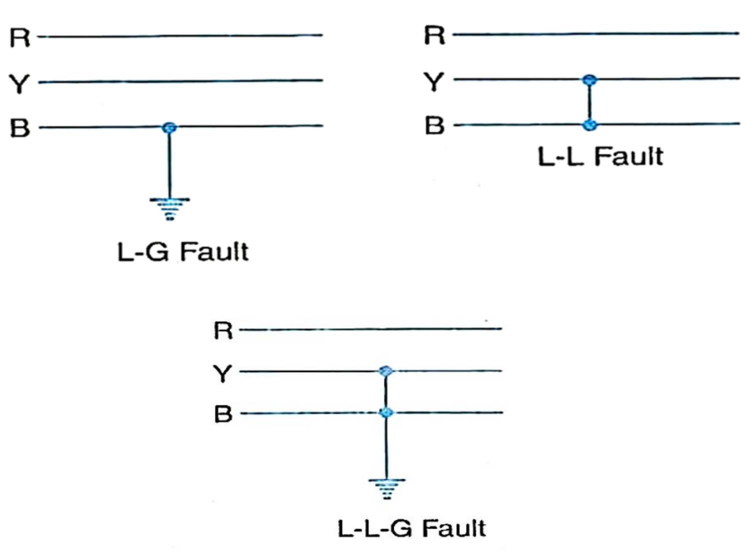


Figure 1.3 : Unsymmetrical Short Circuit

EFFECTS OF FAULT

Effects of abnormal conditions in power systems

i. Short Circuits

Short circuits can be phase to phase, phase to ground, phase to phase to ground, three-phase, or three phase to ground. Extremely low current faults with high impedance paths to extremely high current faults with very low impedance paths are examples of short circuits. All short circuits produce rise current flow in one or more phase conductors or grounding circuit. Disturbances of this type can be detected and safely isolated.

ii. Other Disturbances

Other disturbances, such as lightning, load spikes, and synchronization loss, usually have a small impact on system coordination and can be handled on a situation basis for the specific equipment that has to be protected.

iii. Overloading

Insulation overheats as a response.

iv. Overvoltage

Putting excessive stress on the insulation.

v. Under frequency

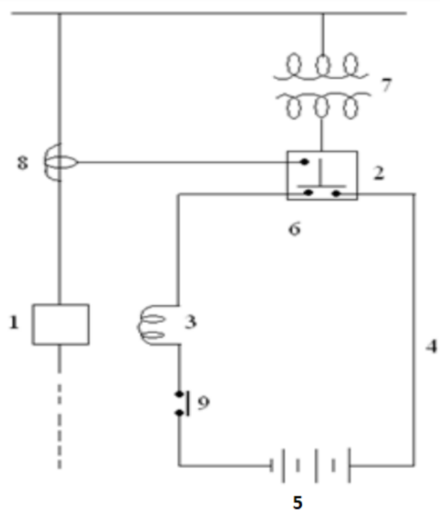
Causing a plant to respond in an irregular way.

vi. Power swings

Generators that are out of synchronization or out of step with each other.

BASIC COMPONENT OF PROTECTION

Basic components of protection



1 . Circuit Breaker
2 . Relay
3 . Trip Coil of Circuit Breaker
4 . Trip Circuit
5 . Battery
6 . Relay Contacts
7 . Potential Transformer
8 . Current Transformer
9 . Auxiliary Switch Contacts

Figure 1.4 : Basic circuit diagram of protection.

1. Voltage transformer - To decrease the primary voltage
2. Current transformer - To decrease the primary current.
3. Relays - To convert the signals and give instruction to open a circuit under abnormal condition or give alarm when the equipment is protected.
4. Fuses - To protect the equipment from over current.
5. Circuit breaker - To break the circuit carrying the short circuit current.
6. DC batteries - To provide power source to the circuit breaker trip coil.

Working of Protective Scheme

The basic connections of circuit breaker control for the opening operation shown in Figure 1.4. Dashed lines represent the protected circuit X. In abnormal condition, the relay connected to CT and PT actuates and closes its contacts. In the trip circuit, current flows from the battery. When the circuit breaker's trip coil is energized, The circuit breaker's operational mechanism is actuated, and it opens the circuit. When the fault is detected and the trip circuit is actuated by the relay then the faulty part is isolated.

BASIC COMPONENT OF PROTECTION

Under normal conditions, The contacts remain closed, and the circuit breaker continue to carry the entire load current. The e.m.f. in the secondary winding of the current transformer (C.T.) is insufficient to operate the breaker's trip coil in this condition but the contacts can be opened by manual. The resulting overcurrent in the C.T. primary winding increases the secondary e.m.f. when a fault occurs.

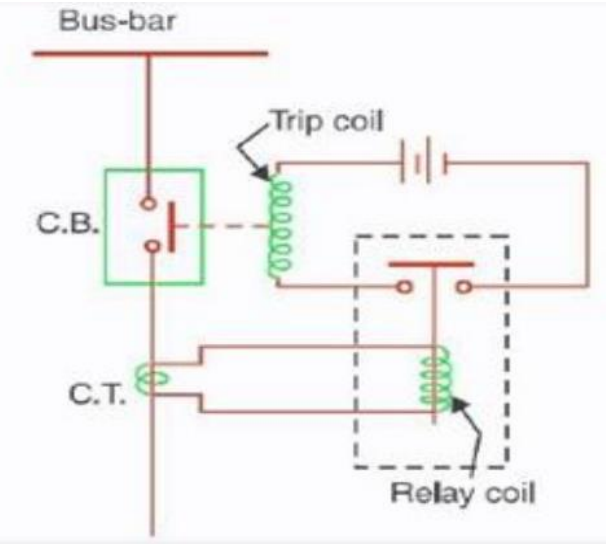


Figure 1.5 : Typical relay circuit

The breaker's trip coil is energized, and the moving contacts are pulled down, thus the contacts are opened. The oil quenches the arc during the opening operation. It's interesting to note that the relays detects a fault, whereas the circuit breaker is responsible for the actual circuit interruption.

Basic concept of protection systems

Generally, the use of a relay is to divide the system into several zones, which can be self - protected and can be separated to prevent damage. With this other system supply sources can still run the service as usual.

Power system consists generators, transformers, busbars, and transmission and distribution lines. Separate protective scheme is used for each equipment of power system, such as generator protection, transformer protection, transmission line protection and bus bar protection. Thus, for protection, a power system is divided into a number of zones. A protective zone surrounds one or two components of a power system.

BASIC COMPONENT OF PROTECTION

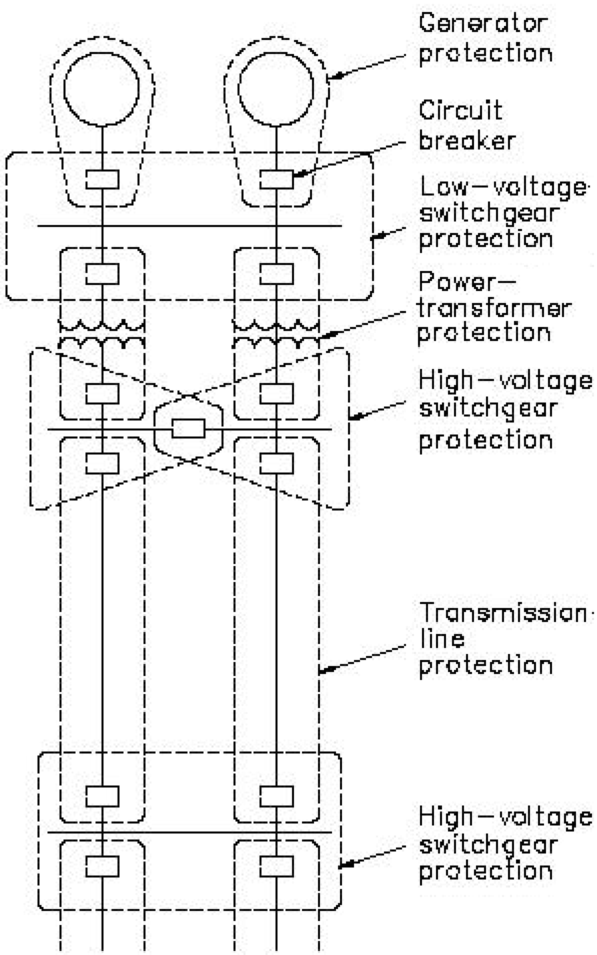


Figure 1.6 : Zones of protection on simple power system

As shown in Figure 1.6, power system protection is divided into zones based on the type of equipment and location. If one system fails to operate, the other will be ready to provide the necessary protection.

Follow the following rules to sectionalize the check zone:

1. In all cases, the check-zone demarcation points must overlap with the discriminating zone demarcation points.

2. To satisfy the reason for having two or more check zones, discriminating and check-zone currents must each be measured by separate C.T at the demarcation points.

3. There should be no auxiliary switches in the check zone's C.T circuits. In the absence of a circuit breaker, a failure on any part of one busbar must result in the immediate tripping of all circuit breakers associated with that busbar, but not the operation of the protection or the tripping of the circuit breaker associated with the adjacent busbar.

BASIC CONCEPT OF PROTECTION SYSTEM

4. If both section disconnector referred to in are closed, A fault on any part of one busbar must cause all circuit breakers allocated to that section of busbar and the section connected by the disconnector in question to trip immediately..

5. When one section disconnector is closed and the other is open on an installation with duplicate section disconnectors, a fault on any part of one busbar, including that part connected to it by the closed disconnector, must result in the immediate tripping of all circuit breakers connected to the faulted busbar, but not the operation or tripping of circuit breakers associated with the healthy section of the busbar.

Unit protection and Non unit protection

All elements in the power system need to be protected and relays play a role in operating to disconnecting network lines in the event of a malfunction. This action is called **unit protection**. It can be used to support primary protection to defend other lines. This is important because if any faults are separated, even if the coupled main protection is not operating, then thus, every element in the power system should be protected on both parts of the main relay and the backup relay.

Unit protection means a system that can detect and respond to faults that occur only within its own zone of protection. To protect a defined or discrete zone of location that is usually the zone bounded by the 2 CT is the main purpose of the unit protection scheme, it used for differential current measurement. Differential Protection relays are usually applied in Unit Protection schemes. The protection system should be designed to required criteria:

1. The breakers are not tripped in normal conditions.
2. The breaker closest to the fault only will trip in fault conditions.
3. If the closest breaker fails, the next breaker closest to the fault is used.

BASIC CONCEPT OF PROTECTION SYSTEM

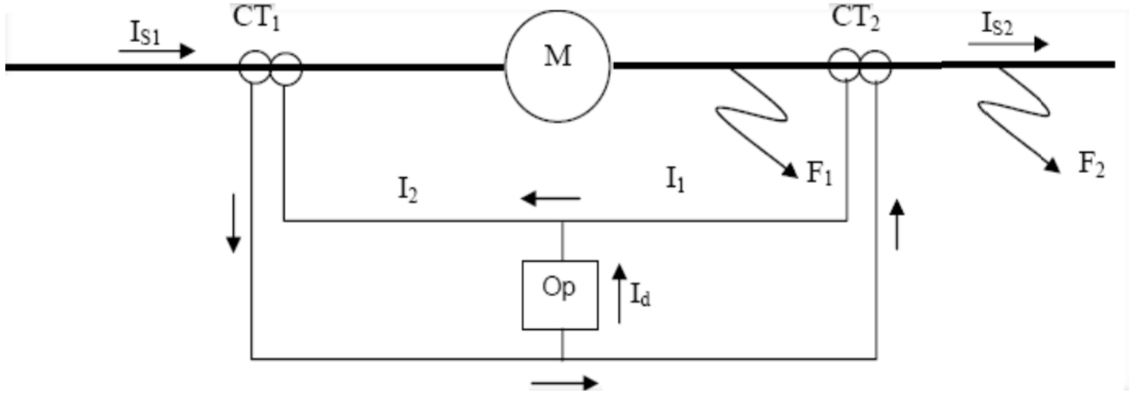


Figure 1.7 : Unit Protection

The operation of unit protection shown in Figure 1.7. The two CT is used to measure the current in and current out into the protected load M. In normal condition, IS1 will be equal to IS2, therefore, I1 = I2, thus result in Id=0. When abnormal condition, I1 ≠ I2 (Fault at F1), then Id will have the value of I1-I2. The current is then sensed by the relay, and causes the system to trip. If the fault occurs at F2, the protection system will not be able to detect the fault because its occurs outside the protection zone of the system.

Non-unit protection is a protection system that detect the outside area of protected zone. The Non-Unit protection scheme work on the system and it might overlap with another protection device in the systems. When a fault occurs, most of this protection is usually used to isolate the circuit.

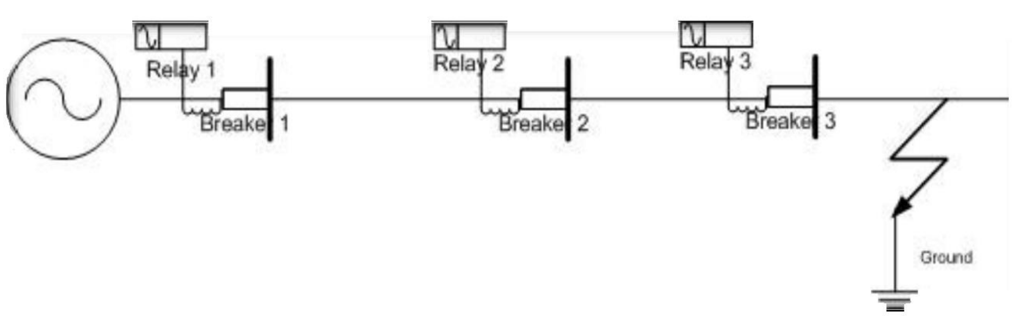


Figure 1.8 : Non-unit protection

PRIMARY AND SECONDARY PROTECTION

There are three protection relays installed in this system for the protection shown in Figure 1.8. If an instantaneous relay is used, a fault at relay 3 will trip the entire system because relays 1 and 2 can see the fault. If use IDMT (Inverse Definite Minimum Time), the relay will isolate in the smallest section, which is section 3. Note that relay at 2 will trigger after several settable times and take over (isolate) the fault if relay at 3 fail to isolate the fault. The advantage of this system is that it has a backup capability and ensures that at least one of the protective relays will remove the fault.

Primary and Secondary Protection

When a fault occur in any element of the electric power system, it must be repaired as quickly to prevent more damage. Its a normal practice to divide the protection scheme into primary and secondary protection.

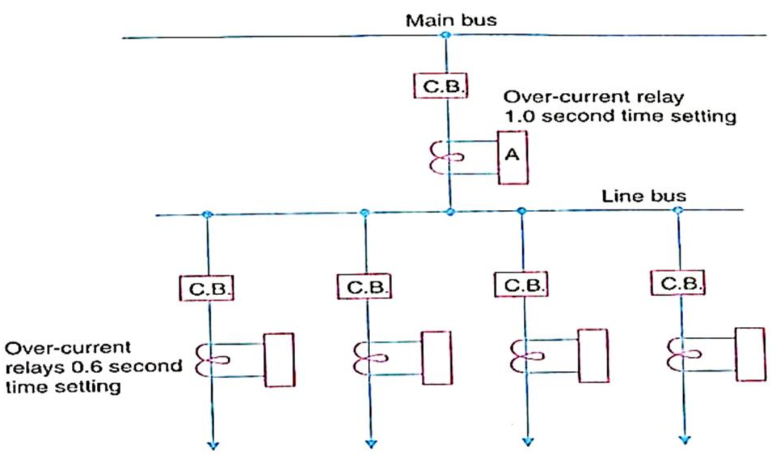


Figure 1.9 : The primary and secondary protection

The primary protection system is one that is designed to protect the power system's component parts. In Figure 1.9, each line has an over-current relay to protects the line. If a fault occurs on any line, the relay and circuit breakers will clear it.

This serves as the first line of protection and forms the primary protection. Primary relaying has an excellent service record, with well over 90% of all operations being performed correctly. However, due to faults within the relay or breaker, faults are often not cleared by the primary relay system. Back-up protection works a treat in these cases.

PRIMARY AND SECONDARY PROTECTION

Primary protection needs to operate disconnecting the line whenever one of the elements in it detects damage. It needs to be sensitive to detect faults in advance and be able to interpret the location of fault. With this, it takes care of all protection zones consisting of 1 or more elements in the power system, such as electrical machines, lines and bus bars.

Secondary protection is the second line of defense in case of failure of the primary protection. It is designed to operate with sufficient time delay so that primary relaying will be given enough time to function if it is able to. Thus, referring Figure 1.9, relay A provided backup protection for each of the four lines. If a line fault is not cleared by its relay and breaker, the group breaker's relay A will activate after a set time period and clear the entire group of lines. When backup relaying is used, a larger part of the circuit is disconnected than when primary relaying is used correctly. As a result, a greater emphasis should be made on improving primary relaying maintenance.

Secondary protection installed together with the main protection will be operated in the event of a situation that could cause the main protection to malfunction. To achieve this protection purpose, the support protection relay must have a detector element whose system does not match the system found on the main protection relay. It also has a time - delay function to slow down relay operation to allow the main protection to operate first.

QUESTION

1. What is the purpose of Protection System?
2. What is Power System Protection?
3. What are the essential equipment in power system protection?
4. List types of fault that can occur in a power system.
5. List the effects that occurs when there are abnormal conditions in power systems.
6. What is Primary Protection?
7. What is Secondary Protection?

ANSWER

1. To protect all elements and components of the power system
2. It is a protection system that can prevent the power system elements to be damaged in the event of failure / short circuit fault.
3. Equipment such as gear switches, isolator switches, circuit breakers, and protection relays.
4. Symmetrical Fault; Fault in three-phase system either with/without short-circuit to ground.

   Unsymmetrical Fault; 2 phase short-circuit in three-phase system either with/without short circuit to ground, and 1 phase in three - phase system with short circuit to ground.
5. Short circuits, lightning, load surges, loss of synchronism, overloading, overvoltage, under-frequency, and power swings
6. A main protection and serves as the first line of defense if fault occurs in the power system
7. Works when primary protection does not work and it work when needed only.

BASIC PROTECTION EQUIPMENT

- Switchgear equipment
- Low voltage circuit breaker
- Fuse
- High voltage circuit breaker

SWITCHGEAR

Switchgear

The apparatus used for protecting, switching and controlling electrical circuits and equipment. Includes current transformer, voltage transformer, circuit breaker, protection relay, electrical switch, electrical fuse, miniature circuit breaker, lightning arrestor or surge arrestor, electrical isolator and measuring instrument.

Need of Switchgear In Power System

- To isolate faulty equipment.
- To divide huge networks into parts for repair purposes.
- To reconfigure networks in order to restore power supplies.
- To control other equipment.

Basic Component Switchgear

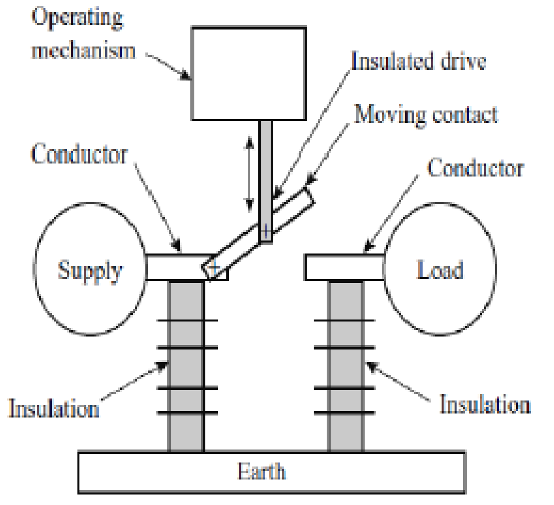


Figure 2.1 : Basic component within switchgear

The basic components within switchgear are :

- Supply side and load side conductors
- Insulation from earth to support the conductors.
- A moving contact arranged to be able to join, or separate, two conductors.
- A driving mechanism and its associated drive linkage to the moving contact.

LOW VOLTAGE CIRCUIT BREAKER

Function of Circuit Breaker

A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by short circuit.

Arc Phenomenon

When short circuit occurs, heavy current flows through the contact of circuit breaker before they are opened by the protective system. When the contacts begin to separate, the contact area decrease rapidly and large fault current causes increased current density and hence rise in temperature.

Methods of Eliminating the Arc

The are two methods of eliminating the arc in circuit breaker:

i. High resistance method.

ii. Low resistance method.

i. High resistance method

Arc resistance is made to increase with time is so that current is decrease to a value insufficient to maintain the arc. The arc is extinguished. The resistance of the arc may be increased by:

- Lengthening the arc.
- Cooling the arc.
- Splitting the arc.
- Reducing ‘x’ section of the arc.

LOW VOLTAGE CIRCUIT BREAKER

- **Lengthening the arc**

The resistance of the arc is directly proportional to its length. The arc's length can be increased by increasing the distance between contacts.

- **Cooling the arc**

Cooling helps in the deionization of the medium between the contacts. It increases the arc resistance. A gas blast directed along the arc would provide effective cooling.

- **Splitting the arc**

By splitting the arc into a series of smaller arcs, the resistance of the arc can be increased. Each one of these arcs experiences the effect of lengthening and cooling. By inserting some conducting plates between the contacts, the arcs could be split.

- **Reducing 'x' section of the arc**

If the arc's 'x' section area is lowered, a higher voltage is required to maintain the arc . In other words, the arc's resistance is increased. The cross section of the arc can be reduced by letting the arc pass through a narrow opening.

ii. Low resistance method

Employed for arc extinction in A.C circuit only. Arc resistance is kept at low where the extinguish is naturally and is prevented from restriking inspired of the rising across the contact.

LOW VOLTAGE CIRCUIT BREAKER

Basic Principles of Circuit Breaker Operation

Circuit breaker consist of two contacts, a fixed and moving contact. In normal condition, the contact closed position is carrying the normal working current. When the fault occurs in a any part of the system, a shunt coil trip and the circuit breaker will be energized. The moving contacts will be moved out by mechanical system to open the circuit.

Tripping Coil Circuit Connection In Circuit Breaker

When a fault occurs, the relay connected to current transformer and potential transformer actuates and closes its contacts. In the trip circuit, current flows from the battery. As the trip coil of circuit breaker is energized, the circuit breaker operating mechanism is actuated and it operates for the opening operation. Thus, the fault is sensed and the trip circuit is actuated by the relay and the faulty part is isolated.

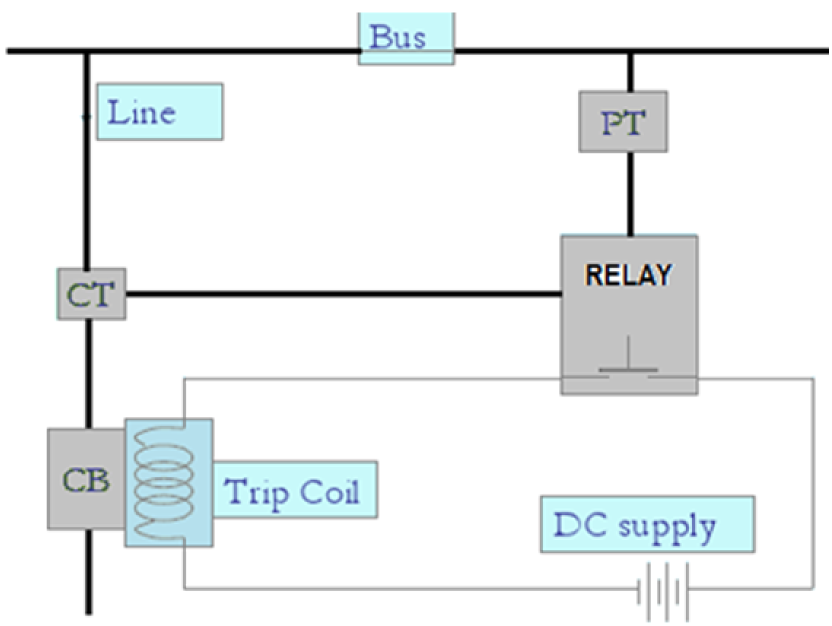


Figure 2.2 : Tripping coil circuit connection in CB

LOW VOLTAGE CIRCUIT BREAKER

Types of Low Voltage Circuit Breaker

i. Miniature Circuit Breaker (MCB)

ii. Molded Case Circuit Breaker (MCCB)

iii. Low Voltage Air Circuit Breaker (LV - ACB)

i. Miniature Circuit Breaker (MCB)

Miniature circuit breaker (MCB) is an electrical switch automatically switches off the electrical circuit during fault condition of the network means in overload condition. The rated current of MCB is not a maximum of 125 amps. It is mainly used for the domestic purpose.

Figure 2.3 : Miniature Circuit Breaker

ii. Molded Case Circuit Breaker (MCCB)

Molded Case Circuit Breaker (MCCB) is an electromechanical device which protects a circuit from overcurrent or short circuit. It is mainly used for high current applications. The rated current value reaches up to 1600 amps. It is mainly used for the industrial purpose.

Figure 2.4 : Molded Case Circuit Breaker

LOW VOLTAGE CIRCUIT BREAKER

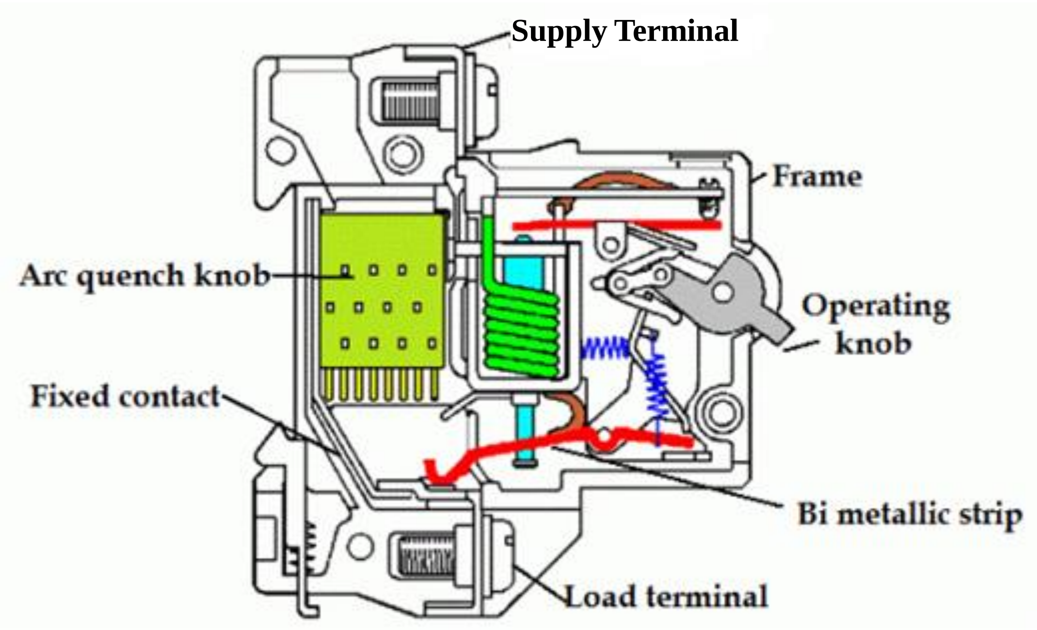


Figure 2.5 : Construction of MCB and MCCB

Operation of MCB and MCCB

Current flows through both the bimetal and the electromagnetic devices. As current flows through the bimetal device, it heats the device. The device wills the bend. If the current increases, the rate at which the device bends will be faster. When the current reaches its set value, the deflection of the bimetal device will be sufficient to hit the tripping mechanism and trip the breaker. The bimetal device's time-current characteristic is of the inverse type e.g. the higher the current, the faster the tripping time. When the current is very high such as in short circuit, the electromagnetic device will operate instantaneously and trip the breaker.

LOW VOLTAGE CIRCUIT BREAKER

MCCB available without internal (built-in) current detection device. They are fitted with an electromagnetic device known as a shunt trip which consists of a coil with a moving iron core. The coil shunt trip is connected in series with the normally open contact of an external overcurrent relay or earth-fault relay and a power source.

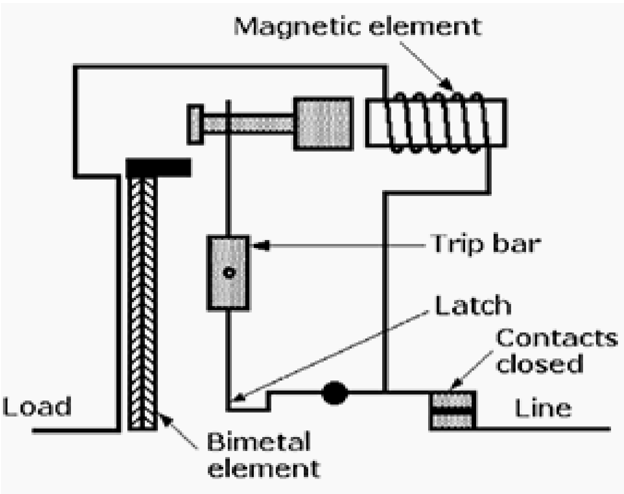


Figure 2.6 (a) : Magnetic contact close

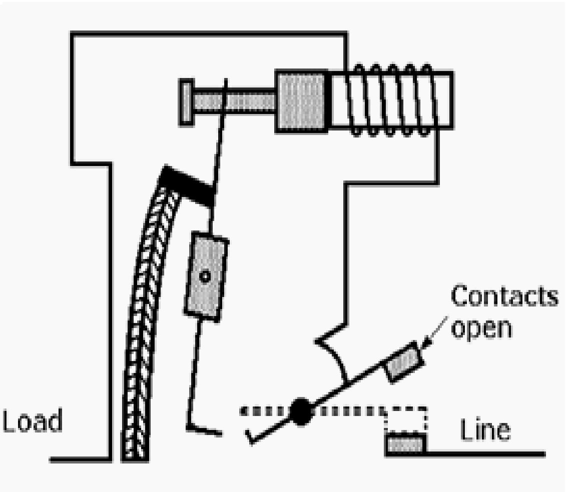


Figure 2.6 (b) : Magnetic contact open

iii. Low Voltage Air Circuit Breaker (LV-ACB)

Figure 2.7 : Air Circuit Breaker

Air Circuit Breaker is an electrical device used to provide overcurrent and short circuit protection. It is for electric circuit over 800A up to 10KA. ACB usually used in low voltage applications below 450V.

LOW VOLTAGE CIRCUIT BREAKER

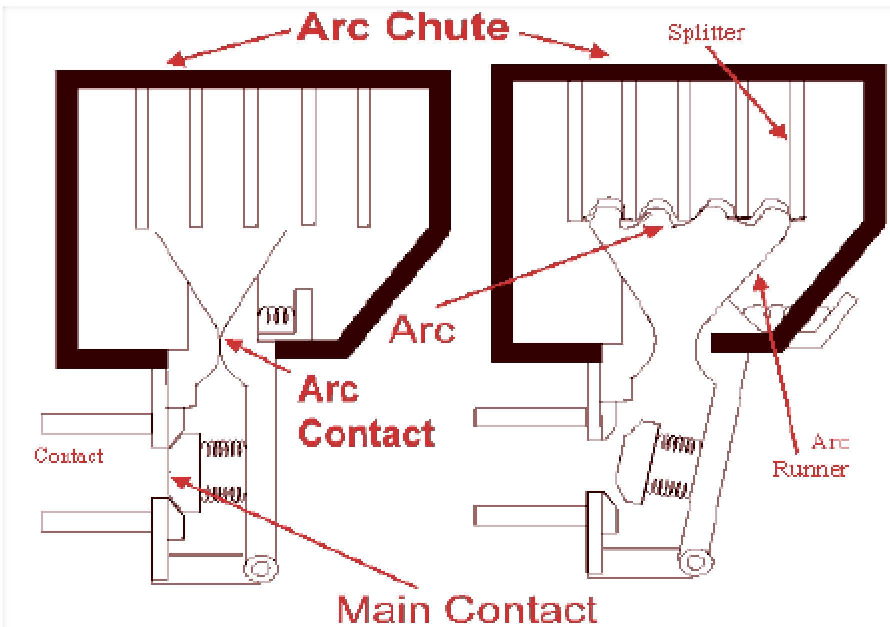


Figure 2.8 : Construction of Air Circuit Breaker

Operation of Air Circuit Breaker

The main pair of contacts carries the current at normal load and the additional pair is the arcing contact. When circuit breaker is opened, the main contacts is open. During opening of main contacts the arcing contacts are still in touch with each other. When arc is driven upwards, it enters in the arc chute consisting of splitters. The arc in chute will become colder, lengthen and split hence arc voltage becomes much larger than system voltage at the time of operation of air circuit breaker. Finally, the arc is quenched and the current zero.

FUSE

Fuse is a current sensitive device. Small and thin conductor (element) designated to melt for the purpose of breaking a circuit in the event of excessive current.

Figure 2.9 : Symbol of Fuse

Function of Fuse

A fuse is a short piece of metal inserted in the circuit, which melts when excessive current flows through it and thus breaks the circuit.

Types of Fuse

i. Rewireable Fuse
ii. Cartridge Fuse
iii. High Rapturing Capacity Fuse (HRC)

i. Rewireable Fuse

Rewirable fuse is used where low values of fault current are to interrupted. It has a base and a fuse carrier. The base is of porcelain and carries the fixed contacts to which the incoming and outgoing phase wires connected. The fuse carrier is also of porcelain and holds the fuse elements between its terminals. It can be inserted in or taken out of the base when desired.

FUSE

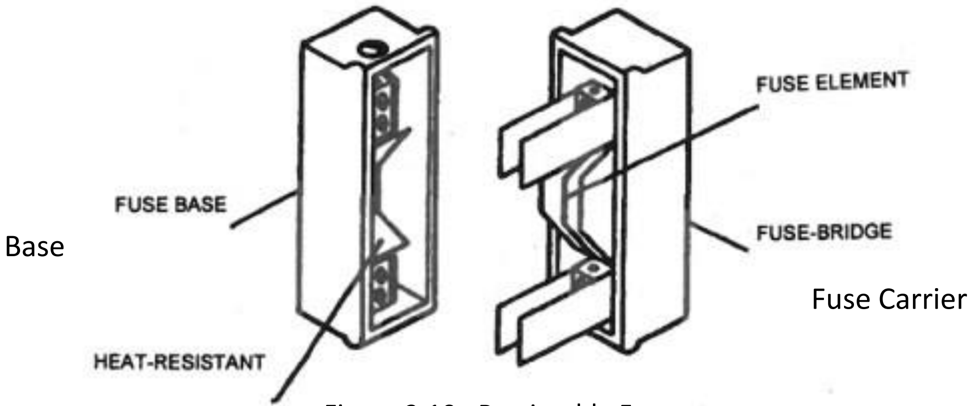


Figure 2.10 : Rewireable Fuse

Operation of Rewireable Fuse

When a short circuit occurs, the fuse element is blown out, then the circuit is interrupted. The fuse carrier is taken out and the blown out element is replaced by the new one. To restore the supply, the fuse carrier is reinserted into the base.

ii. Cartridge Fuse

The fuse element is placed in a completely sealed container with metal contacts on both sides. The cartridge is placed into the fuse cap, which is then fixed to the fuse base with a screw.

Figure 2.11 : Cartridge Fuse

Operation of Cartridge Fuse

Cartridge fuse has a thin wire or metal alloy strip in the middle and two metal caps used as contacts when connected in series to an electrical circuit. It works according to the principles of conductor melting and must be replaced with a new one when it is blown.

FUSE

iii. High Rupturing Capacity (HRC) Fuse

It consists of a heat resisting ceramic body with metal end-caps to which is welded silver curent-carrying element. The complete space within the body surronding the element is filled with powder usually quartz , which acts as an arc extinguishing agent and cooling medium.

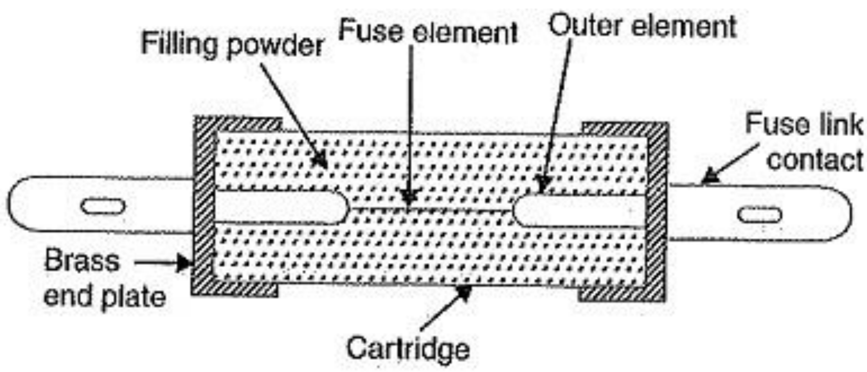


Figure 2.12 : High Rupturing Capacity Fuse

Operation High Rupturing Capacity (HRC) Fuse

Under normal conditions, the current flowing through the fuse element does not provide enough to melt the element. The heat produced is absorbed by the filling powder in the surrounding area. If a large current flows, the energy produces melts and vaporizes the fuse element before the fault current reaches the peak. The chemical reaction between the fuse vapor and filling powder produces a high resistance which helps in extinguishing the arc.

FUSE

Fuse rating calculation

Using the guideline that the fuse is rated at 125% of the normal operating current.

$$\text{Power} = Current \times Voltage$$

Therefore, $$\text{Current} = \frac{Power}{Voltage}$$

$$\text{Fuse rating} = \left(\frac{Power}{Voltage}\right) \times 125\%$$

So,

$$\boxed{\text{Fuse rating} = \left(\frac{Power}{Voltage}\right) \times 1.25}$$

Example

Calculate the fuse rating for 900W, If Voltage is 240V.

$$\text{Fuse rating} = \left(\frac{Power}{Voltage}\right) \times 1.25$$

$$\text{Fuse rating} = \left(\frac{900W}{240V}\right) \times 1.25$$

$$= 4.69 \text{ A}$$

∴ Next fuse up is a 5 amp fuse, use **5 amp fuse**.

FUSE

Differences between fuse and circuit breaker.

No	Particular	Fuse	Circuit breaker
1	Function	Detection and interruption functions.	Interruption function only.
2	Operation	Automatic.	Requires relays for automatic action.
3	Breaking capacity	Small.	Very large.
4	Operating time	Very small (0.002s).	Large (0.1 to 0.2s).
5	Replacement	Requires replacement after operation.	No replacement after operation.

HIGH VOLTAGE CIRCUIT BREAKER

Types of High Voltage Circuit Breaker

Types of High Voltage Circuit Breaker :

i. Oil Circuit Breaker (OCB)

ii. Sulphur Hexafluoride (SF6) Circuit Breaker

iii. Vacuum Circuit Breaker (VCB)

iv. Air Blast Circuit Breaker (ABCB)

Oil Circuit Breaker (OCB)

It includes separate contacts and the main function of these contact is to separate an insulating oil. It has excellent insulating properties compared air. When the fault occurs, then the contacts of the breaker will open beneath the oil. Once the arc is trapped among the two contacts of the breaker, then the heat of the arc will dissolve the surrounding oil and separates into a significant volume of gaseous hydrogen at high pressure.

Types of Oil Circuit Breaker

i. Bulk Oil Circuit Breakers

ii. Minimum Oil Circuit Breaker

Figure 2.13 : Oil Circuit Breaker

HIGH VOLTAGE CIRCUIT BREAKER

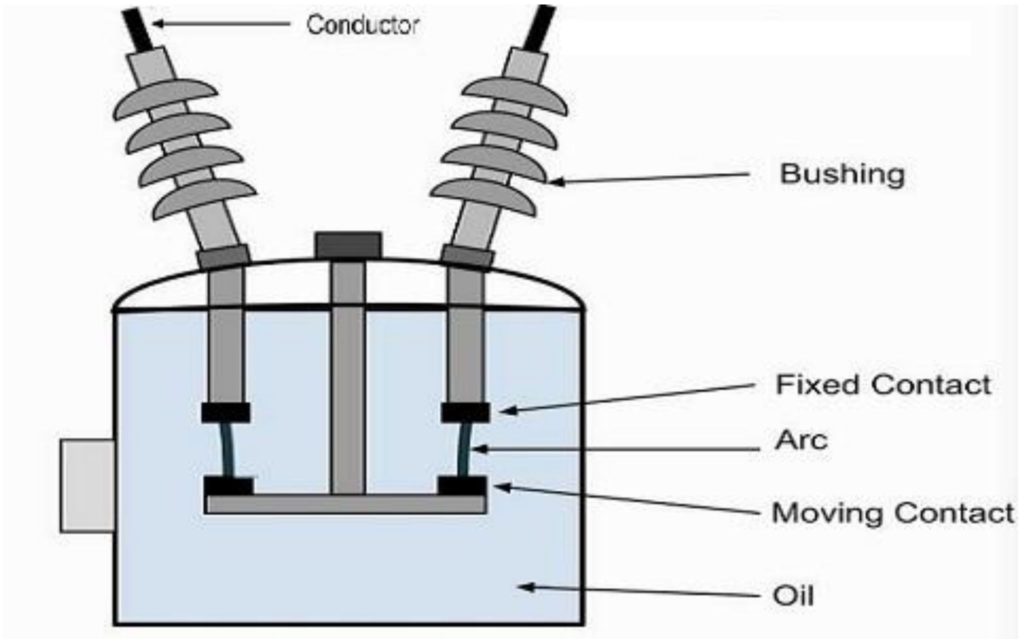


Figure 2.14 : Construction of Oil Circuit Breaker

Operation of Oil Circuit Breaker

In normal operation, the contact in the breaker will be closed as well as carrying the current. Once the faults happens within the system, then the contacts will move apart and an arc will be stuck among the contacts. An arc will produce rapidly growing gas bubble around the arc. The gas bubble is enclosed by the oil inside the totally air tight vessel and the oil surround it will apply high pressure on the bubble. Then the results highly compressed gas around the arc. As the pressure is increased the de–ionization of gas increases which helps the arc quenching. The cooling effect of hydrogen gas also helps in arc quenching in oil circuit breaker.

HIGH VOLTAGE CIRCUIT BREAKER

Advantages of Oil Circuit Breaker

- It absorbs arc energy and uses it to decompose oil into gases with great cooling properties.
- It works as an insulator and allows for a smaller clearance between live conductors and earthed components.
- The surrounding oil presents cooling surface in close proximity to the arc.

Disadvantages of Oil Circuit Breaker

- It's flammable, thus there's a risk of a fire.
- The hydrogen generated during arcing, when combined with air, may form an explosive mixture.
- During arcing, oil decomposes and becomes polluted by carbon particles, which reduces its dielectric strength. Hence, it requires periodic maintenance and replacement.

Sulphur Hexafluoride (SF_6) Circuit Breaker

Figure 2.15 : SF_6 Circuit Breaker

SF_6 circuit breaker uses Sulfur Hexafluoride gas as an air quenching medium. This gas is electronegative and dielectric strength is high, allowing it to absorb free electrons. This is very effective for high voltage applications ranging from 33kV to 800kV.

HIGH VOLTAGE CIRCUIT BREAKER

It consists of moving and fixed contacts enclosed in a chamber called an arc interruption chamber filled with SF6 gas. An SF6 gas reservoir is the source of the connection. The flow of gas from the reservoir to the arc interruption chamber is controlled by a valve mechanism.

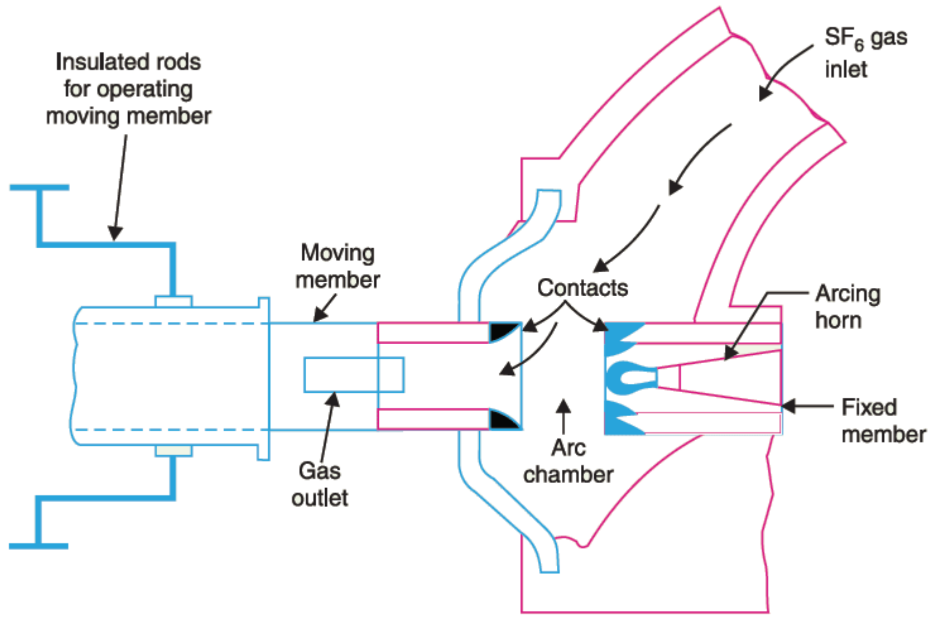


Figure 2.16 : Construction of SF6 Circuit Breaker

Operation of SF6 Circuit Breaker

In the closed position of the breaker, The contacts are mostly surrounded by SF6 gas at around 2.8kg/cm2 pressure. When the breaker operates, The moving contacts is pulled apart, and an arc is formed between them. The movement of the moving contact is synchronized with the opening of a valve which permits SF6 gas at 14 kg/cm2 pressure from the reservoir to the arc interruption chamber. The high pressure flow of SF6 rapidly absorbs the free electrons in the arc path to form immobile negative ions which are ineffective as charge carriers. As a result, the medium between the contacts rapidly builds up high dielectric strength, causing the arc to be extinguished.

HIGH VOLTAGE CIRCUIT BREAKER

Advantages of SF_6 Circuit Breaker

- Low-cost maintenance.
- It is non-flammable, thus there is no risk of fire.
- The gas has excellent insulating properties.
- Less arcing time
- The dielectric strength of SF_6 gas is 2 to 3 times that of air and can interrupt much larger currents.
- Silent operations.
- Ideal for interrupting current.
- Suitable for outdoor installation.

Disadvantages of Sf6 Circuit Breaker

- The cost of gas is high.
- Required cleaning periodically.
- Re-condition of the SF6 gas after every operation.

Vacuum Circuit Breaker (VCB)

In such breakers, vacuum is used as the arc quenching medium. Since vacuum offers the excellent insulating strength, it has far superior arc quenching properties than any other medium. For example, when contacts of a breaker are opened in vacuum, the interruption occurs at first current zero with dielectric strength between the contacts building up at a rate thousands of times higher than that obtained with other circuit breakers.

Figure 2.17 : Vacuum Circuit Breaker

HIGH VOLTAGE CIRCUIT BREAKER

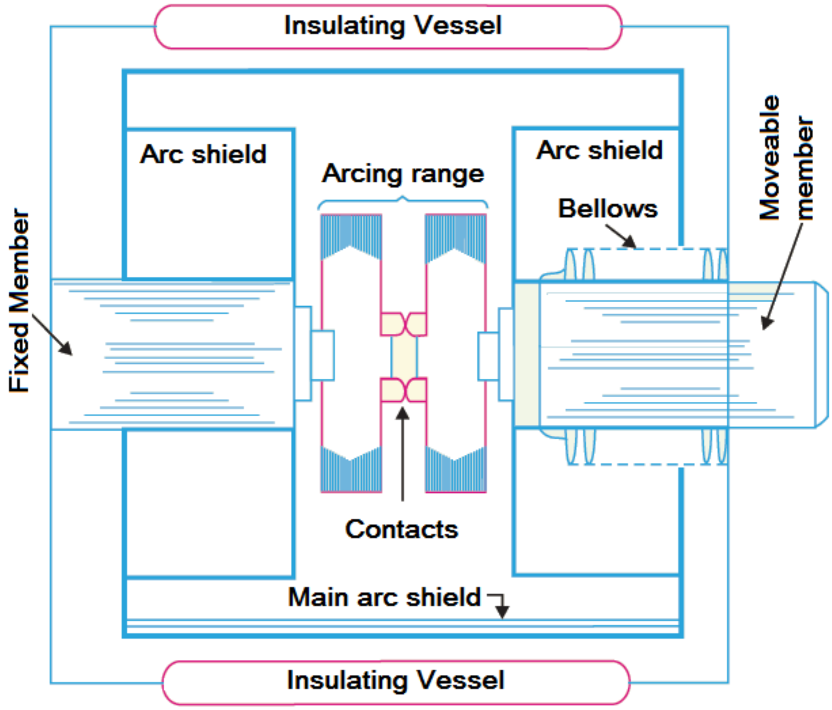


Figure 2.18 : Construction of Vacuum Circuit Breaker

Operation of Vacuum Circuit Breaker

When the breaker is actuated, the moving contact separates from the fixed contact, creating an arc between them. Arc formation is caused by the ionization of metal ions and is very dependent on the contact material. The arc is quickly extinguished because the metallic vapors, electrons and ions produced during arc are diffused in a short time and seized by the surfaces of moving and fixed members and shields. Since vacuum has very fast recovery of dielectric strength, the arc extinction in a vacuum breaker occurs with a short contact separation.

HIGH VOLTAGE CIRCUIT BREAKER

Advantages of Vacuum Circuit Breaker

- They are compact, reliable and have longer life
- There are no dangers of fire.
- During and after the operation, no gas is produced.
- They can interrupt any fault current. The outstanding feature of a VCB is that it can break any heavy fault current perfectly just before the contacts reach the define open position.
- They require little maintenance and operate quietly.
- They can successfully withstand lightning surges
- Arc energy is minimal.
- They have low inertia and hence require smaller power for control mechanism.

Disadvantages of Vacuum Circuit Breaker

- If there is a loss of vacuum owing to transit damage or failure, the entire interruption is left unused and cannot be repaired on site.
- It needs additional surge suppressors in parallel with each phase for interruption of low magnetizing currents in certain range.
- Vacuum circuit breakers are uneconomical above 36kV.
- Vacuum interrupters are costly to manufacture in small quantities.

HIGH VOLTAGE CIRCUIT BREAKER

Air Blast Circuit Breaker

As an arc quenching medium, these breakers use a high-pressure air blast. The contacts are opened in a flow of air blast established by the opening of blast valve. The arc is cooled by the air blast, which also sweeps the arcing products into the atmosphere. This rapidly increases the dielectric strength of the medium between contacts and prevents from reestablishing the arc. Then, the arc is extinguished and flow of current is zero.

Figure 2.19 : Air-Blast Circuit Breaker.

Types of Air Blast Circuit Breakers

i. Axial Blast Air Circuit Breaker.
ii. Axial Blast Air Circuit Breaker with side moving contact.
iii. Cross Blast Air Circuit Breaker.

HIGH VOLTAGE CIRCUIT BREAKER

i. Axial Blast Air Circuit Breaker.

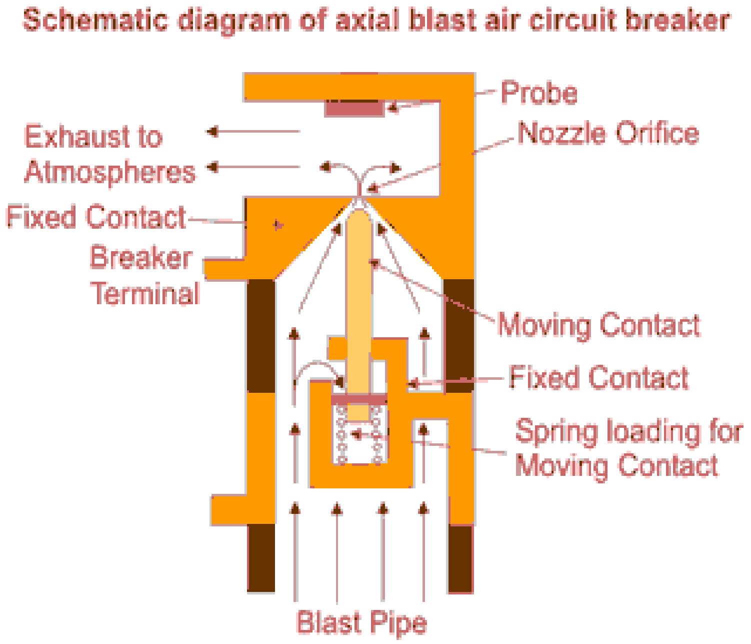


Figure 2.20 : Axial Blast Air Circuit Breaker.

Operation of Axial Blast Air Circuit Breaker.

The moving contact is in contact with fixed contact with the help of a spring pressure. There is a nozzle orifice in the fixed contact which is blocked by tip of the moving contact at normal closed condition of the breaker. When abnormal condition, the high pressure air is introduced into the arcing chamber. The air pressure will counter the spring pressure and deforms the spring hence the moving contact is withdrawn from the fixed contact and nozzle hole becomes open. Then, the high pressure air starts flowing along the arc through the fixed contact nozzle orifice. This axial flow of air along the arc through the nozzle orifice will make the arc lengthen and colder hence arc voltage become much higher than system voltage that means system voltage is insufficient to sustain the arc consequently the arc is quenched.

HIGH VOLTAGE CIRCUIT BREAKER

ii. Axial Blast ACB with side moving contact.

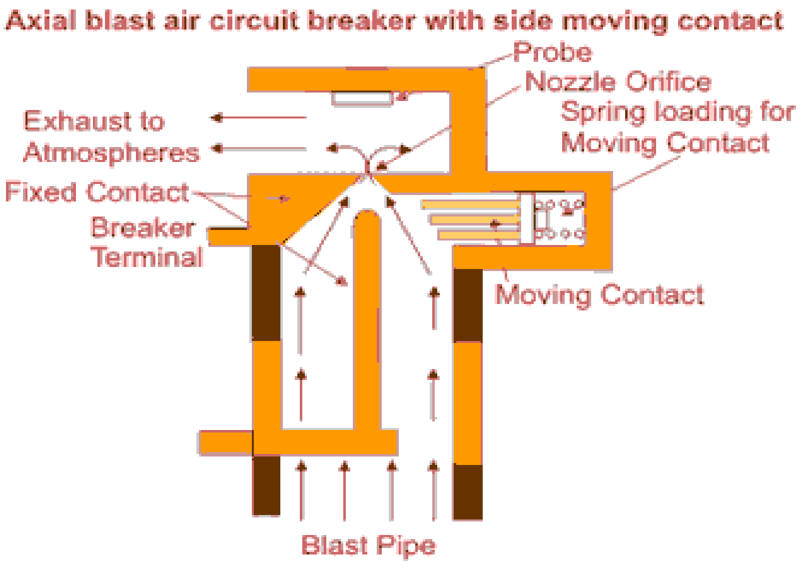


Figure 2.21 : Axial Blast ACB with side moving contact.

Operation of Axial Blast ACB with side moving contact

The moving contact is attached to a piston that is supported by a spring. In order to open the circuit breaker the air is admitted into the arcing chamber when pressure reaches to a predetermined value, it presses down the moving contact; an arc is drawn between the fixed and moving contacts. The arc is instantaneously transferred to the arcing electrode by the air blast and is consequently quenched by the axial flow of air.

HIGH VOLTAGE CIRCUIT BREAKER

iii. Cross Blast ACB.

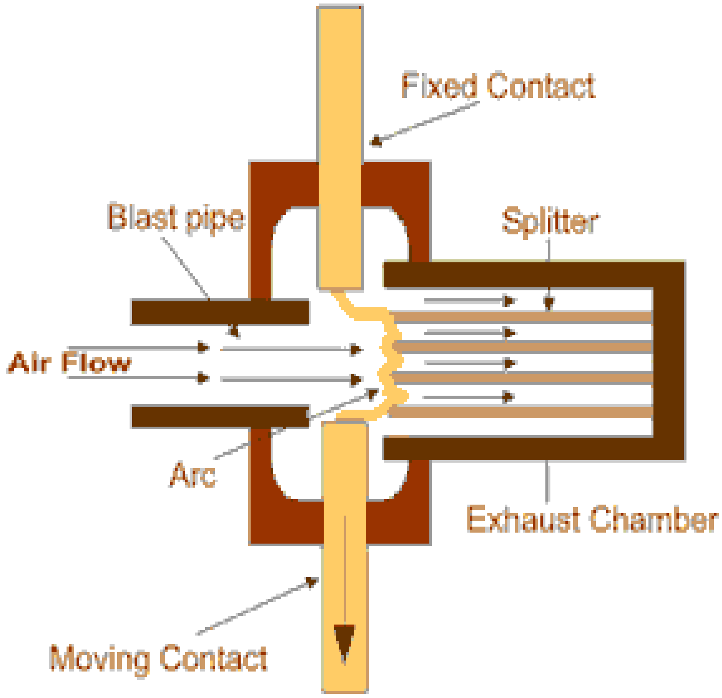


Figure 2.22 : Cross Blast ACB.

Operation of Cross Blast ACB.

The cross blast air circuit breaker operates on a simple principle. In this system of air blast circuit breaker the blast pipe is fixed in perpendicular to the movement of moving contact in the arcing chamber and on the opposite side of the arcing chamber one exhaust chamber is also fitted at the same alignment of blast pipe, so that the air comes from blast pipe can straightly enter into exhaust chamber through the contact gap of the breaker.

Arc splitters are used to spit the exhaust chamber.. When moving contact is withdrawn from fixed contact, an arc is established in between the contact, and at the same time high pressure air coming from blast pipe will pass through the contact gap and will forcefully take the arc into exhaust chamber where the arc is split with the help of arc splitters and finally, the arc is extinguished.

HIGH VOLTAGE CIRCUIT BREAKER

Advantages Air Blast Circuit Breaker

- Air blast circuit breaker is a suitable option to use where frequent operation is required because of lower arc energy.
- No risk of fire when using an Air blast circuit breaker.
- Air blast circuit breaker is small in size, because of the growth of dielectric strength is so rapid (which final contact gap needed for arc extinction is very small).
- Speed of circuit breaker is much higher during operation of the air blast.
- Quenching an arc is much faster.
- The duration of the arc is same for all values of current.
- Stability of operation can be maintained and depends on speed operation of circuit breakers.
- Lt has less maintenance.

Disadvantages of Air Blast Circuit Breaker

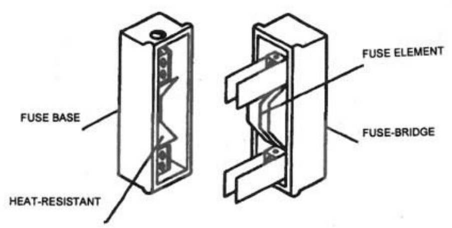
- Additional maintenance is required at the air supply plant.
- It contains high capacity air compressor.
- There is a chance of air pressure leakage from the air pipes junction.
- There is chance of a high rate rise of re-striking voltage and current chopping.
- Arc extinguishing properties are lower in the air.

QUESTION

1. State THREE (3) types of high voltage circuit breaker.
2. Define the switchgear.
3. Describe the basic operating of Circuit Breaker.
4. Discuss the design and operation of Re-wireable Fuse.
5. Explain the arc phenomenon in circuit breaker.
6. Explain the operation of Miniature Circuit Breaker.
7. Calculate the fuse rating for 4kW, 415v three phase induction motor with 0.86 power factor.
8. Interpret THREE (3) advantages and disadvantages of Vacuum Circuit Breaker.
9. *'This breaker consist of fixed contact and moving contact enclosed in a strong weather-tight earthed tank containing oil up to a certain level and air cushion above the oil level'.* By referring to the statement above, sketch the design of this breaker and explain how this breaker operates and extinguishes the arcs.
10. With the aid of a diagram, write the operation of SF6 Circuit Breaker.

ANSWER

1. Oil Circuit Breaker (OCB), Sulphur Hexafluoride (SF6) Circuit Breaker, Vacuum Circuit Breaker (VCB),Air Blast Circuit Breaker (ABCB)
2. The apparatus used for switching, controlling, and protecting electrical circuits and equipment.
3. It consist of two contacts a fixed and moving contact. In normal condition, the contact closed position carrying the normal working current. When the fault occurs in a any part of the system, a shunt coil trip and the circuit breaker will be energized. The moving contacts will be pulled out by mechanical system to open the circuit.
4. Design of Re-wireable Fuse.



Operation:

When a fault occurs, the fuse element is blown out and the circuit is interrupted. The fuse carrier is taken out and the blown out element is replaced by the new one. The fuse carrier is then reinserted in the base to restore the supply.

5. When short circuit occurs, a heavy current flows through the contact of circuit breaker before they are opened by the protective system. At the instant when the contacts begin to separate, the contact area decrease rapidly and large fault current causes increased current density and hence rise in temperature.

ANSWER

6. Current flows through both the bimetal and the electromagnetic devices. As current flows through the bimetal device, it heats the device. The device wills the bend. If the current increases, the rate at which the device bends will be faster. When the current reaches its set value, the deflection of the bimetal device will be sufficient to hit the tripping mechanism and trip the breaker. The bimetal device's time-current characteristic is of the inverse type e.g. the higher the current, the faster is the tripping time. When the current is very high such as in the event of a short circuit, the electromagnetic device will operate instantaneously and trip the breaker.

7.

Fuse rating = $\left(\frac{4KW}{415V}\right) \times 1.25$

= 12.05 A

∴ Next fuse up is a 15 amp fuse, use a **15 amp fuse**.

8. Advantages

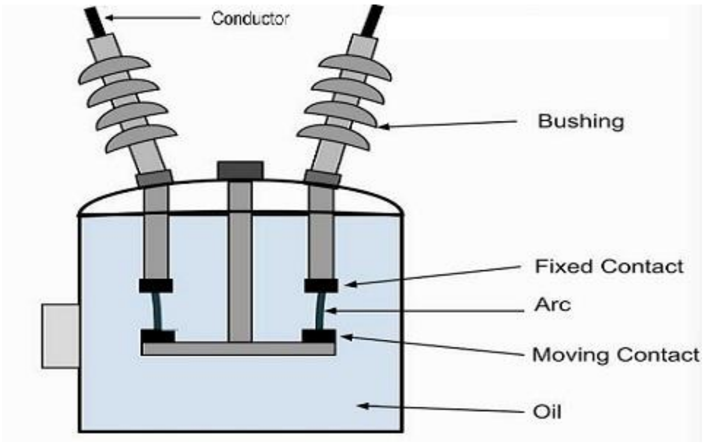
- They are compact, reliable and have longer life
- There are no fire hazards
- There are no generation of gas during and after operation

Disadvantages

- Loss of vacuum due to transit damage or failure makes the entire interruption useless and it cannot be repaired at site.
- It needs additional surge suppressors in parallel with each phase for interruption of low magnetizing currents in certain range.
- Vacuum circuit breakers are uneconomical above 36kV and SF6 breakers having equivalent properties are economical. Hence for EHV (voltages above 230kV) systems SF6 circuit breakers are employed.

ANSWER

9. Design of OCB

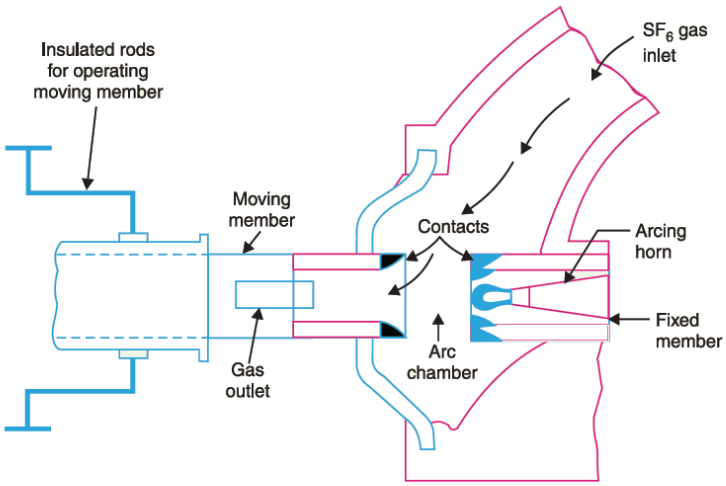


Operation:

In normal operation, the contact in the breaker will be closed as well as carrying the current. Once the faults happens within the system, then the contacts will move apart and an arc will be stuck among the contacts. An arc will produce rapidly growing gas bubble around the arc. The gas bubble is enclosed by the oil inside the totally air tight vessel, the oil surround it will apply high pressure on the bubble, which results highly compressed gas around the arc. As the pressure is increased the de–ionization of gas increases which helps the arc quenching. The cooling effect of hydrogen gas also helps in arc quenching in oil circuit breaker.

ANSWER

10. Design of SF6 CB



Operation:

In the closed position of the breaker, the contacts remain surrounded by SF6 gas at a pressure of about 2.8kg/cm2. When the breaker operates, the moving contact is pulled apart and arc is struck between the contacts. The movement of the moving contact is synchronized with the opening of a valve which permits SF6 gas at 14 kg/cm2 pressure from the reservoir to the arc interruption chamber. The high pressure flow of SF6 rapidly absorbs the free electrons in the arc path to form immobile negative ions which are ineffective as charge carriers. The result is that the medium between the contacts quickly builds up high dielectric strength and causes the extinction of the arc.

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THANK YOU

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