Power-system protection is a branch of electrical power engineering that deals with the protection of electrical power systems from faults through the isolation of faulted parts from the rest of the electrical network. The objective of a protection scheme is to keep the power system stable by isolating only the components that are under fault, whilst leaving as much of the network as possible still in operation.

Components:

Protection systems usually comprise five components:

- Current and voltage transformers to step down the high voltages and currents of the electrical power system to convenient levels for the relays to deal with. Also, to monitor and give accurate feedback about the healthiness of a system

  Protective relays to sense or detect the fault and initiate the operation of the circuit breaker to isolate or disconnection of the faulty circuit.

  OR

  During abnormal conditions relaying system sense the conditions and close the trip circuit of the circuit breaker.

  OR

  To convert the signals from the monitoring devices, and give instructions to open a circuit under faulty conditions or to give alarms when the equipment being protected, is approaching towards possible destruction

Some of the types of protective relays include

- Magnitude relays
- Impedance relays
- Directional relays
- Pilot relays
- Differential relays

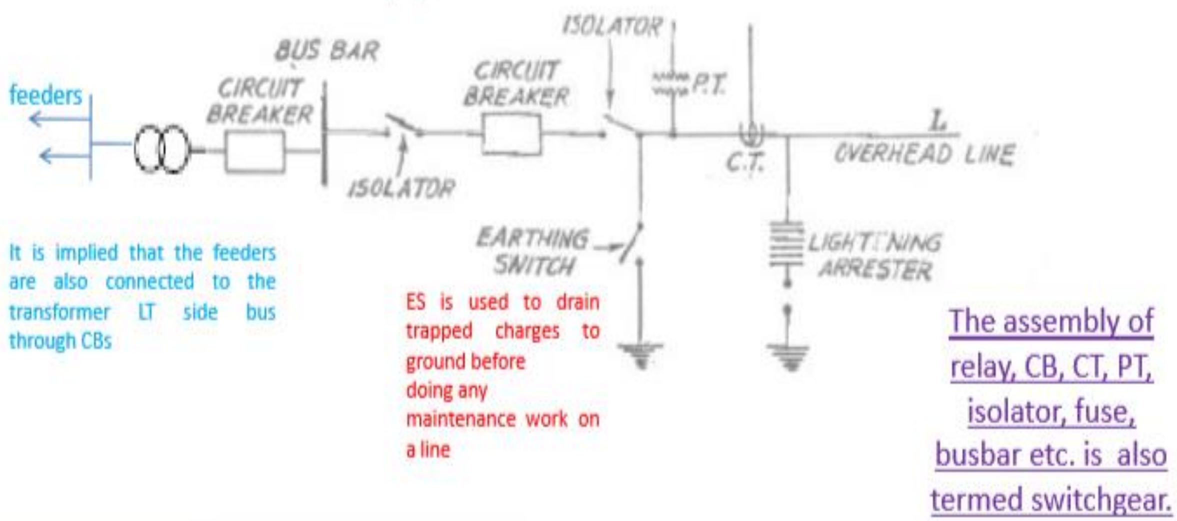
- Circuit breakers to open/close the system based on relay and auto recloser commands;

  During any fault conditions, there will be a high stress of fault current is being experience by Power network or electrical equipment, so fault must be cleared asap to take it back to the normal condition and also quenching the arc produced by the fault. A **circuit breaker** is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overcurrent, typically resulting from an overload or short circuit. Its basic function is to interrupt current flow after a fault is detected. Unlike a fuse, which operates once and then must be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation

- Batteries to provide power in case of power disconnection in the system Communication channels to allow analysis of current and voltage at remote terminals of a line and to allow remote tripping of equipment. These give uninterrupted power source to the relays and breakers that is independent of the main power source being protected

For parts of a distribution system, fuses (Self-destructing to save the downstream equipment being protected) are capable of both sensing and disconnecting faults.

Basic equipment in a substation



Isolator provides additional safety during any maintenance work. This is a no-load device i.e. designed to be switched on or off under no load condition.

Following sequence is used for the operation of switches and CB

During Opening a line:
1.Trip CB
2.Open isolator
3. Close earthing switch

During closing a line:
1. Open earthing switch
2. Close isolator
3. Close CB

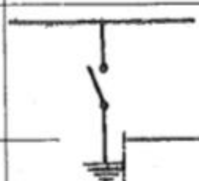
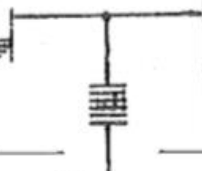
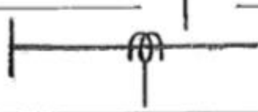
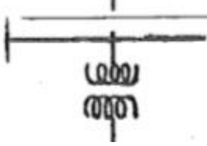
Switchgears are used both to de-energize equipment to allow work to be done and to clear faults downstream

The earliest central power stations used simple open knife switches, mounted on insulating panels of marble or asbestos. Power levels and voltages rapidly escalated, making opening manually operated switches too dangerous for anything other than isolation of a de-energized circuit.

By the early 20th century, a switchgear line-up would be a metal-enclosed structure with electrically operated switching elements, using oil circuit breakers. Oil-filled equipment allowed arc energy to be contained and safely controlled

Today, oil-filled equipment has largely been replaced by air-blast, vacuum, or SF_6 equipment, allowing large currents and power levels to be safely controlled by automatic equipment

AC Sub-station equipment*

S. No.	*Symbol*	*Equipment*	*Function*
1.		Circuit-breaker	Switching during normal and abnormal conditions, interrupt the fault currents.
2.		Isolator (Disconnecting switch)	Disconnecting a part of the system from live parts under no load condition.
3.		Earthing-switch	Discharge the voltage on the lines to earth after disconnecting them.
4.		Surge arrester	Diverting the high voltage surges to earth and maintaining continuity during normal voltage.
5.		Current transformer	Stepping down the current for measurement protection and control.
6.		Potential transformer (Voltage transformer)	Stepping down the voltage for the purpose of protection, measurement and control.

Purpose of power system protection
• Isolate faults as quickly as possible
• Goals:
→Safety
→Avoid damage to the equipment
→Stability

Economy: Relays can be simpler, smaller, and cheaper given lower-level relay inputs.

Accuracy: Power system voltages and currents are accurately reproduced by instrument transformers over large operating range

Characteristics of a good protection system
• Reliability
→ Operate dependably even after months of being idle

• Selectivity
→Avoid unnecessary false trips

• Speed
→Any intentional delays should be precise

• Economy

• Simplicity
→Complexity reduces reliability and increases cost à Incompatible objectives require compromises

What must happen when a fault occurs?
• Detect the fault
→Differentiate between normal and abnormal conditions

• Locate the fault
→Minimize the part of the system that will be de- energized

• Isolate the fault
→Open the circuit

Sequence of event
• Fault occurs
→ Changes currents and voltages

• Sensors detect these changes

• Relays use these sensors to decide:
→Whether a fault has occurred
→Whether something needs to happen

• Relays trigger the opening of circuit breakers to isolate the fault

Components of a protection system

• Sensing

• Decision-making

• Amplification/Switching

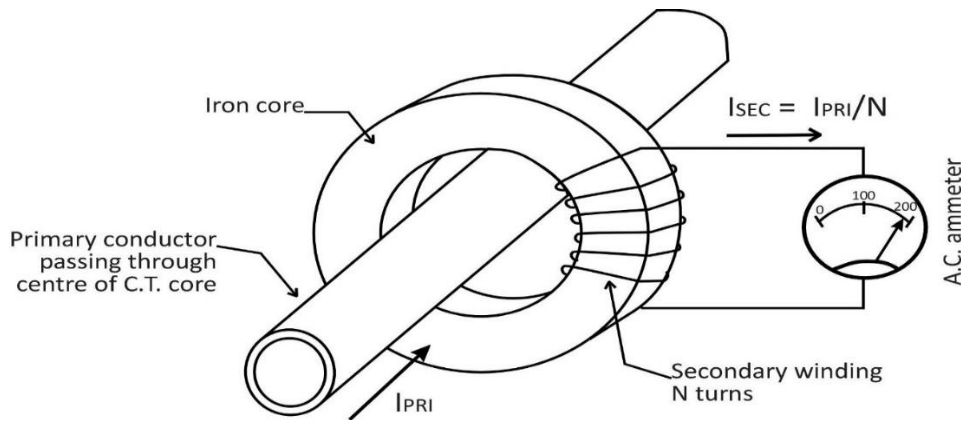
- In electric power distribution, voltage power line transferring power from a distribution substation to the distribution transformers
- In electric power distribution, A **busbar** (or **bus bar**) is a strip of metal used to conduct electricity within an electrical substation, distribution board, electric switchboard or other electrical equipment. A busbar is usually a flat or hollow piece of copper, brass or aluminium. It allows heat to be released quickly because of its relatively large surface area.

Feeder is network of conductors which feeds power in different localities from sub-station usually at 11kv. It makes power reach near the consumers where 11kv is stepped down to 230/440v for uses. According to purposes and requirements feeders are divided into four groups 1. Radial feeder 2. Ring Feeder 3. Parallel feeder 4. Meshed System

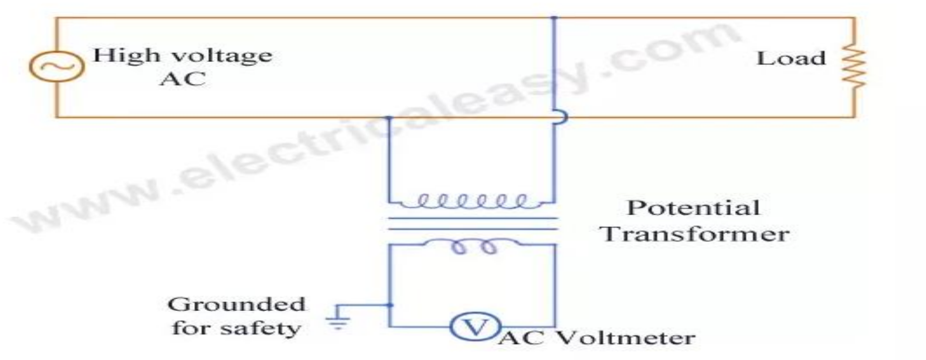
A trip unit is the part of a circuit breaker that opens the circuit in the event of a thermal overload, short circuit or ground fault. An open circuit will not conduct electricity because either air, or some other insulator has stopped or broken the flow of current in the loop.

There are two types of trip units, electromechanical (also called thermal magnetic) and electronic. An electromechanical trip unit has moving parts; it combines a current-sensitive electromechanical device with a thermal-sensitive device and the two devices work together to determine when to mechanically open the circuit. An electronic trip unit is programmable device which measures and times current flowing through the circuit breaker and initiates a trip signal when appropriate.

A current transformer is a device which produces an alternating current in its secondary which is proportional to the alternating current in its primary. A current transformer (C.T.) is used where the current is too high to measure directly, or the voltage in the primary circuit is too high, Current transformers are generally used to measure currents of high magnitude. These transformers step down the current to be measured, so that it can be measured with a normal range ammeter. A Current transformer has only one or very few number of primary turns. The primary winding may be just a conductor, or a bus bar placed in a hollow core (as shown in the figure). The secondary winding has large number turns accurately wound for a specific turns ratio. Thus, the current transformer steps up (increases) the voltage while stepping down (lowering) the current. Generally current transformers and ammeters are used together as a matched pair in which the design of the current transformer is such as to provide a maximum secondary current corresponding to a full-scale deflection on the ammeter.



Potential transformers are also known as **voltage transformers** and they are basically step-down transformers with extremely accurate turn's ratio. Potential transformers step down the voltage of high magnitude to a lower voltage which can be measured with standard measuring instrument. These transformers have large number of primary turns and smaller number of secondary turns.



$$\text{Turns Ratio} = \frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{I_S}{I_P}$$