EEE4227: POWER SYSTEM PROTECTION
TERM: MID-TERM

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Books to have in collection

- Text book:
  - Principles of Power Systems” by V.K. Mehta & Rohit Mehta
- Reference book:
  - “Switchgear Protection And Power Systems” by Sunil S.Rao
  - “Protective Relaying” by C. Ressell Mason

Topics to be covered in mid-term

- Basic ideas about switchgear and Fuse(Lecture 01)
- High voltage and low voltage circuit breaker(CB) (Lecture 02)
- TRV and RRRV of a CB (Lecture 03)
- Switching of CB (Lecture 04)
- CB testing, Auto reclousure, Interlocking and neutral grounding, lightening arrestors (Lecture 05)
- Protective relays (Lecture 06)

Lecture 01
Part 01- Basic ideas of switchgear
Part 02- Fuse

Part 01-Introduction to switchgear

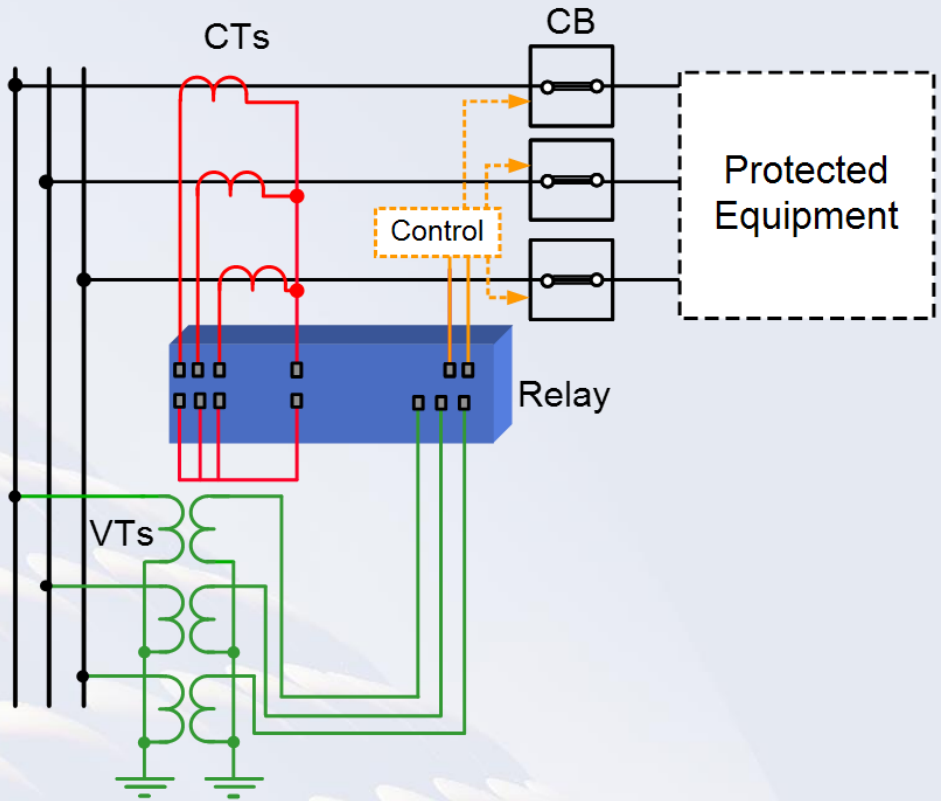
- What is switchgear??
  - General term covering a wide range of equipment concerned with switching and protection. All equipment associated with fault clearing process is covered by the term switchgear.

- Significance/Importance of switchgear and protection
  - Normal routine switching, control and monitoring
  - Automatic switching during abnormal and faulty operating conditions such as short circuits, under-voltage and over voltage

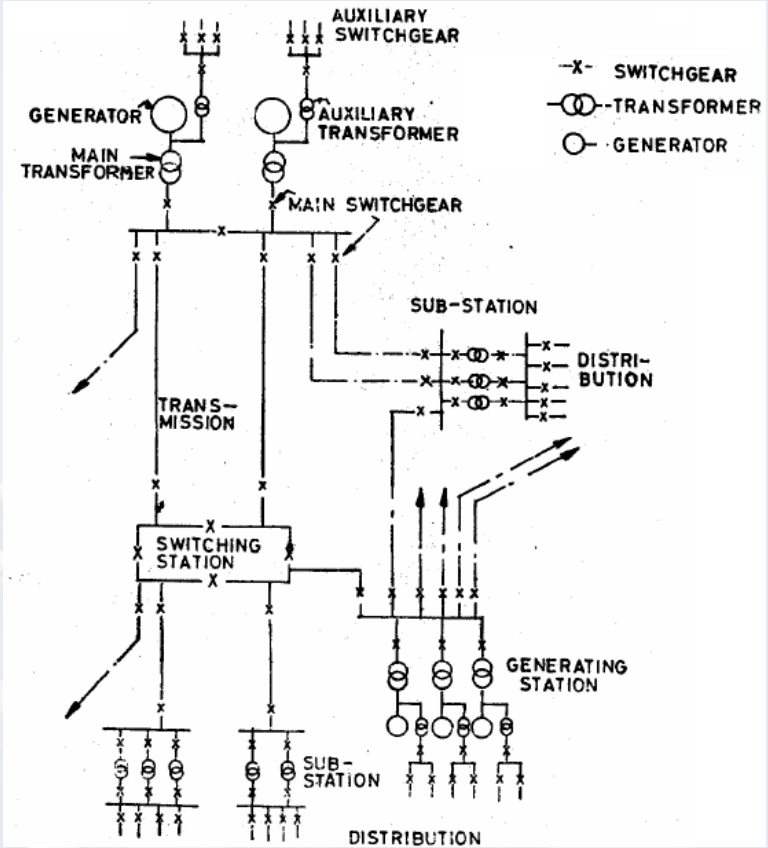
Switchgear equipment

- Switches
  - Air-break switches
  - Isolators or disconnecting switches
  - Oil switches
  - Earthing switches
- Fuses
- Circuit breaker
- Relays
- Control panels
- Lighting arrestor
- Current transformers, CT
- Potential transformers, PT

3-phase diagram of a protection scheme



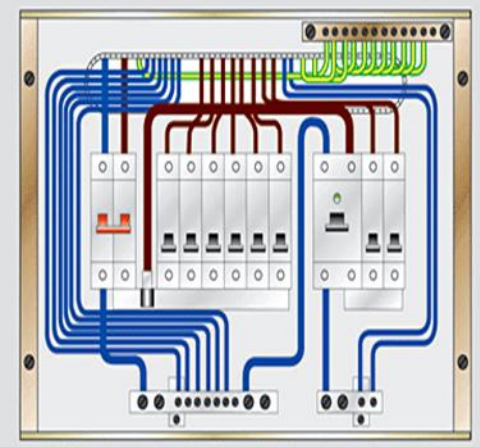
Location of switchgear in power systems

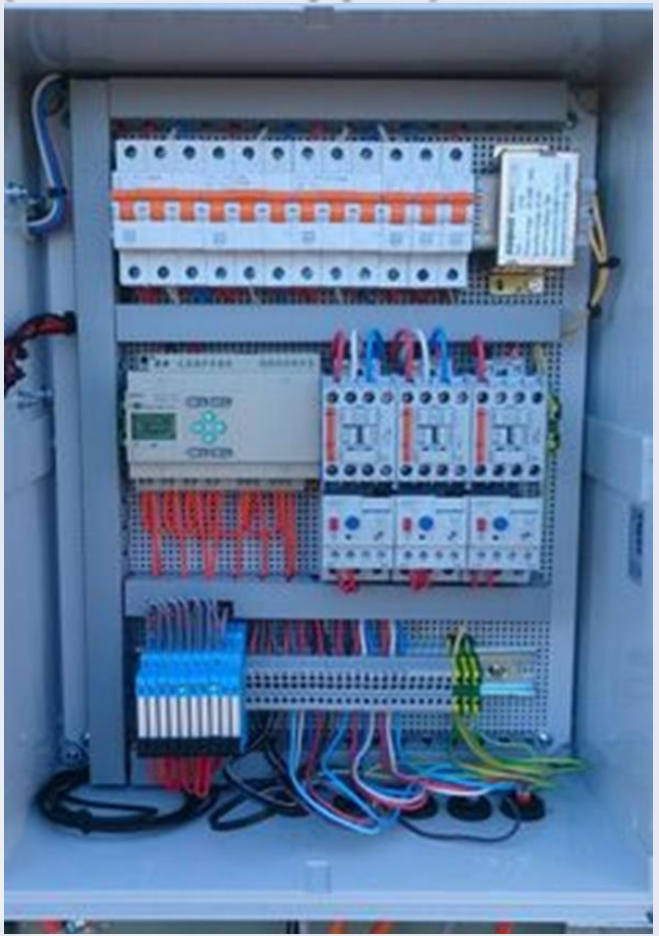


Features of Switchgear

- Complete reliability
- Absolutely certain discrimination
- Quick operation
- Provision for manual control
- Provision for instruments

Switchgear Accommodations (Indoor type)





Switchgear Accommodations (Indoor type)

Switchgear Accommodations (Outdoor type)

Switchgear Accommodations (Outdoor type)

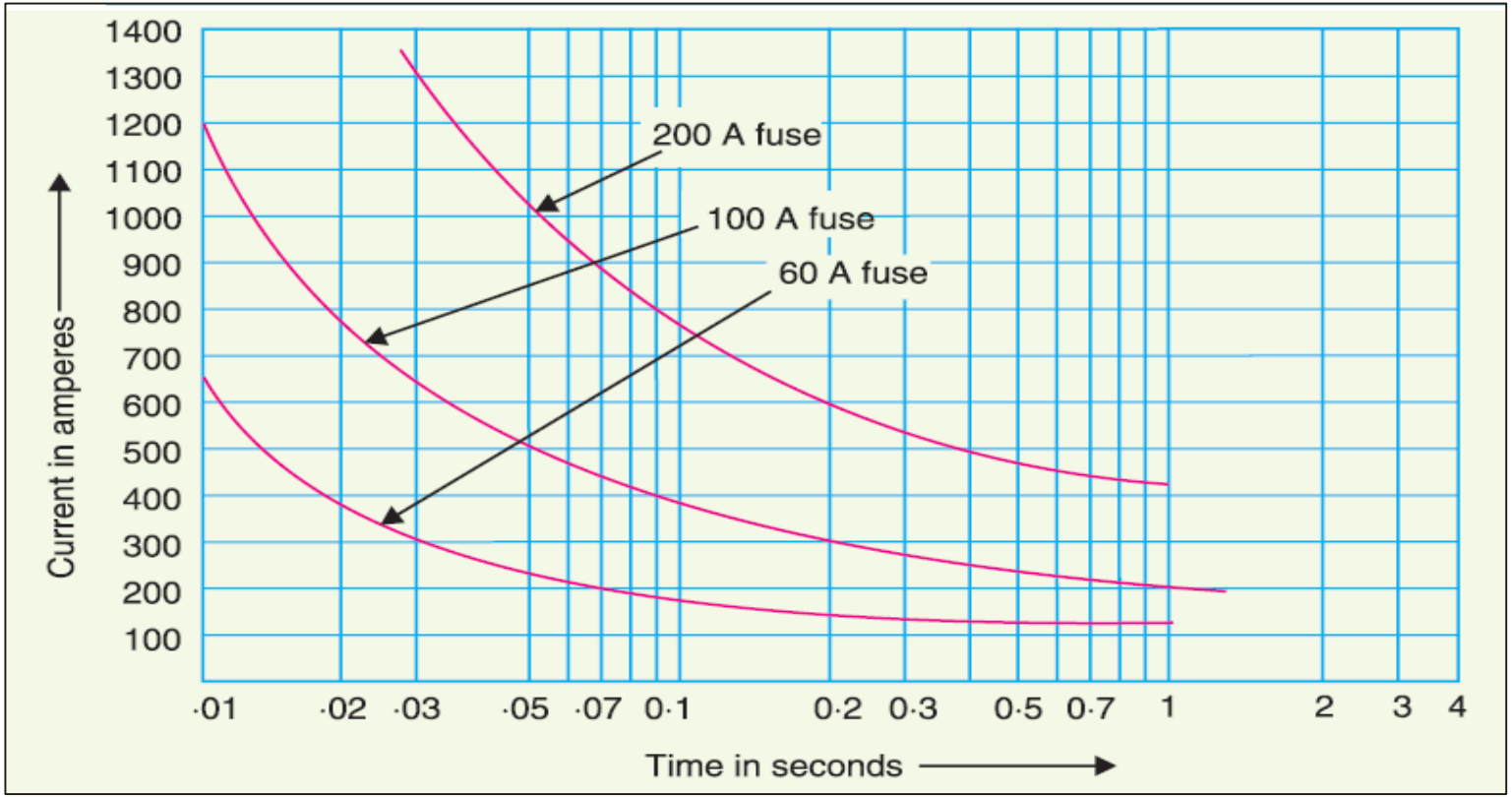
Switchgear Accommodations (Outdoor type)

End of part 01

Part 02- Fuse

- What is 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.

Time-current characteristics curve (TCC) of a fuse material



Advantages of a fuse as a protecting device

- Cheapest form of protection available
- Requires no maintenance
- Operation is inherently completely automatic unlike a circuit breaker which requires an elaborate equipment for automatic action
- Can break heavy short-circuit currents without noise or smoke
- Smaller sizes of fuse element impose a current limiting effect under short-circuit conditions

Disadvantages of a fuse as a protecting device

- Considerable time is lost in rewiring or replacing a fuse after operation
- On heavy short-circuits, discrimination between fuses in series cannot be obtained unless there is sufficient difference in the sizes of the fuses concerned
- The current-time characteristic of a fuse cannot always be co-related with that of the protected apparatus

Desirable characteristics of a fuse material

- Low melting point *e.g.,* tin, lead
- High conductivity *e.g*., silver, copper
- Free from deterioration due to oxidation *e.g*., silver
- Low cost *e.g*., lead, tin, copper

No material possesses all the characteristics therefore, a compromise is made in the selection of material for a fuse

Fuse element material

- Most commonly used materials are lead, tin, copper, zinc and silver
- For small currents up to 10 A, tin or an alloy of lead and tin (lead 37%, tin 63%) is used
- For larger currents, copper or silver is employed

Present trend is to use Silver

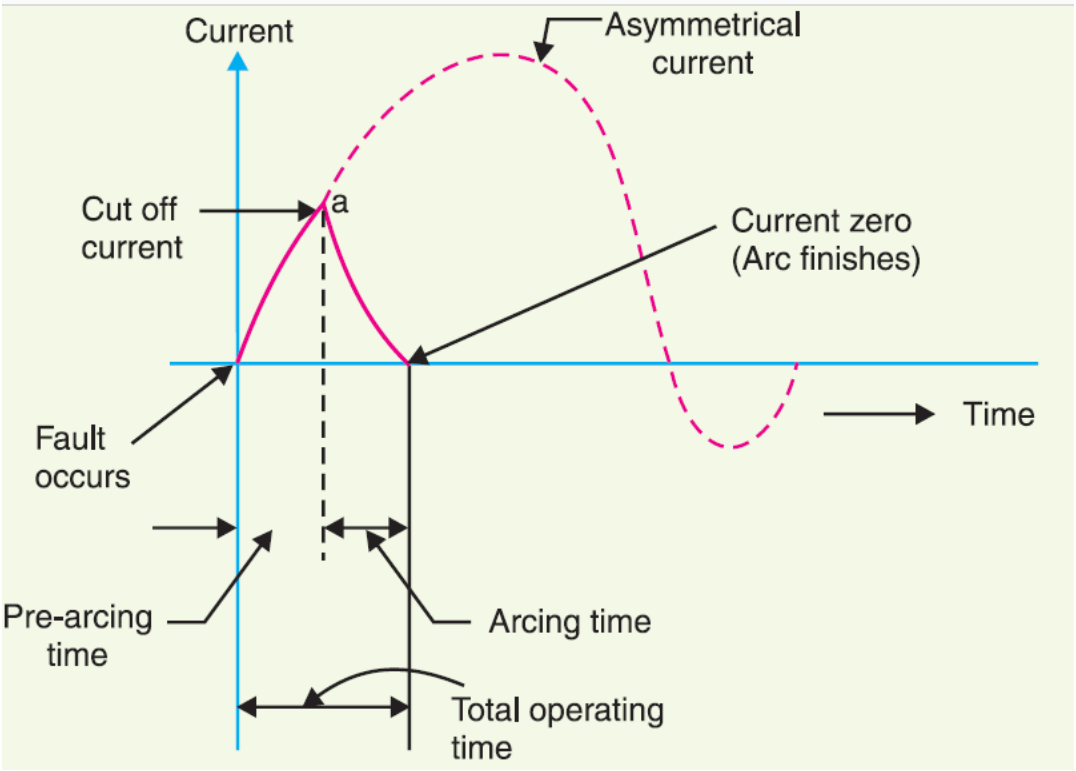
Fuse element material(why silver preferable?)

- It is comparatively free from oxidation.
- It does not deteriorate when used in dry air.
- The coefficient of expansion of silver is so small that no critical fatigue occurs. Therefore, the fuse element can carry the rated current continuously for a long time.
- The conductivity of silver is very high

Important terms (related to fuse material) to be known

- Current rating of fuse element
- Fusing current
- Fuse constant
- Fusing factor
- Prospective Current
- Cut-off current
- Pre-arcing time
- Arcing time
- Total operating time
- Breaking capacity

Analysis of a fuse



Types of fuse

Semi-enclosed/Re-wire able Fuse

Drop out Fuse

Totally Enclosed/cartridge Fuse

HRC (High Rupturing capacity) cartridge Fuse

Fuse law

The current carrying capacity of a fuse element mainly depends on the metal used and the cross-sectional area but is affected also by the length, the state of surface and the surroundings of the fuse. When the fuse element attains steady temperature,

Heat produced per sec = Heat lost per second by convection, radiation and conduction

or I^2R = Constant × Effective surface area

or $I^2\left(\rho\frac{l}{a}\right)$ = constant × d × l

where d = diameter of fuse element

l = length of fuse element

$\therefore$ $I^2\frac{\rho\, l}{(\pi/4)\, d^2}$ = constant × d × l

or I^2 = constant × d^3

or $I^2 \propto d^3$

Fuse law

- For a round wire, the approximate relationship between fusing current *I* and diameter *d* of the wire is-

$$I = Kd^{3/2}$$

- where *k* is a constant, called the *fuse constant*. Its value depends upon the metal of which the fuse element is made.

Mathematical problem

- A fuse wire of circular cross-section has a radius of 0·8 mm. The wire blows off at a current of 8A. Calculate the radius of the wire that will blow off at a current of 1A.
- Solution-

$$I^2 \propto r^3$$

$$\left(\frac{I_2}{I_1}\right)^2 = \left(\frac{r_2}{r_1}\right)^3$$

$$r_2 = r_1 \times \left(\frac{I_2}{I_1}\right)^{2/3} = 0 \cdot 8 \times \left(\frac{1}{8}\right)^{2/3} = \mathbf{0{\cdot}2\ mm}$$

Practice problem

- In a fuse, aluminum is used as fuse wire. The cross-section area of that fuse is $300mm^2$. The wire blows off at a current of 10 A. Calculate the radius of the wire of same material that will blow off at a current of 3 A.

End of part 02

- Reference-
- Chapter 20/ Principles of power systems/ V.K.Mehta & Rohit Mehta.

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