Lecture 04:

Fuses

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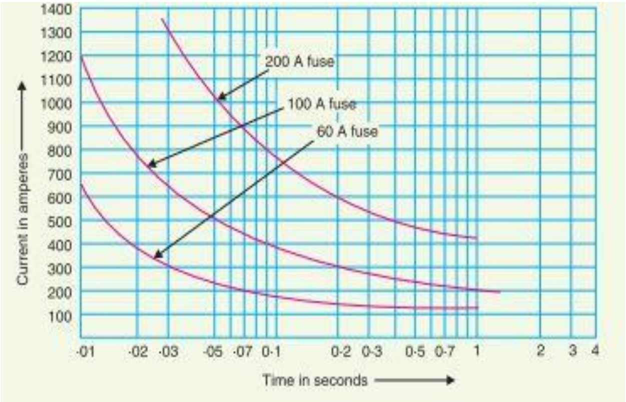
Fuses

Definition: *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.*

The fuses element material has following properties:

- *Low melting point*
- *High conductivity*
- *Least deterioration due to oxidation e.g. silver, copper etc.*
- *Used in series with circuit to be protected*
- *Carries normal current without overheating*
- *Inverse time-current characteristics*



Fuses

Advantages:

- *Cheapest form of protection available*
- *No maintenance required*
- *Automatic operation unlike C.B (requires elaborative equipment)*
- *Breaks heavy short-circuit without noise or smoke*
- *Suitable for overcurrent protection due to inverse time-current x-tics*
- *Operation time can be made much shorter than with the C.B*

Disadvantages:

- *Replacement/Rewiring is time consuming*
- *Discrimination between fuses in series is difficult on heavy short-circuit*
- *Time-current x-tics cannot always be co-related with that of protected apparatus*

Fuses: Desirable Characteristics

The satisfactory function to be performed, a fuse element must have following desirable characteristics:

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

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

Fuses: Element Materials

Most commonly used materials for fuse element:

- *Lead, tin, copper, zinc, and silver.*
- *Tin, alloy of lead and tin (lead 37%, tin 63%) for current upto 10A*
- *Copper or silver for large currents*
- *Tinned copper is used to avoid deterioration from oxidation*
- *Zinc (strip only) where considerable time-lag is required*
- *Time-lag (does not melt very quickly with a small overload)*

Silver is mostly used despite its cost due to following reasons:

- *Free of oxidation*
- *No deterioration when used in dry air*
- *Coefficient of expansion is small (no fatigue: can carry normal current for a very long time)*

Fuses: Element Materials

Silver is mostly used despite its cost due to following reasons:

- *High conductivity, less mass required, finally fast operation*
- *Low specific heat, increase in resistance near melting point, instant transition from melting to vaporization, results in fast operation*
- *Silver vaporizes at a temp. much lower than the on at which its vapor will readily ionize. Therefore, when an arc is formed through the vaporized portion of the element, the arc path has high resistance. As a result, short-circuit current is quickly interrupted.*

Fuses: Important Terms

- *Current rating of fuse element*
- *Fusing current* $(I = k d^{1/2})$
- *Fusing factor*
- *Prospective current*
- *Cut-off current*
- *Pre-arcing time*
- *Arcing time*
- *Total operating time*
- *Breaking Capacity*

Fuses: Important Terms

Current rating of fuse element:

- *Normal current flowing through fuse*
- *Depends on temp. rise of contacts, fuse material, and surrounding*

Fusing current:

- *At which fuse melts and breaks the circuit*
- $I = kd^{1/2}$ *(k is called fuse constant, depends on metal of fuse element)*
- *Sir W.H. Preece's value of "k" for various metals*

S. No.	Material	Value of k	
		d in cm	d in mm
1	Copper	2530	80
2	Aluminium	1873	59
3	Tin	405·5	12·8
4	Lead	340·6	10·8

Fusing current depends upon various factors:

- *Material of fuse*
- *Length (inverse relation of length and current)*
- *Diameter*
- *Size and location of terminals*
- *Previous history*
- *Type of enclosure used*

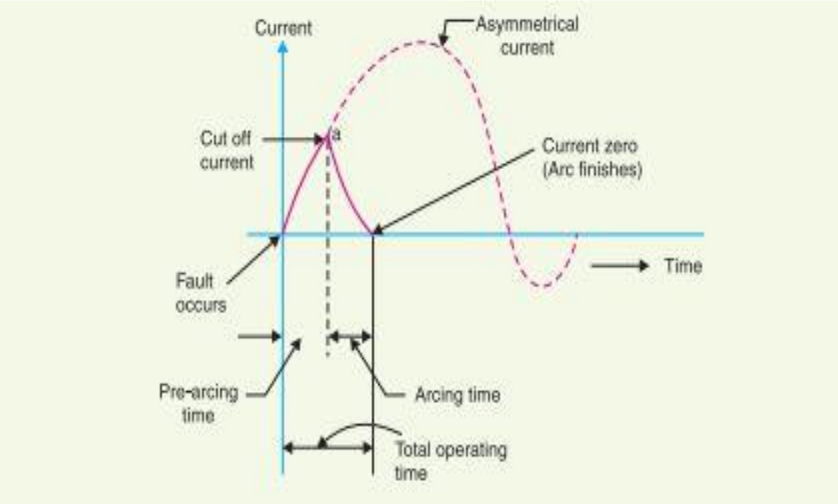
Fuses: Important Terms

Fusing factor:

It is the ratio of minimum fusing current to the current rating of the fuse element i.e.

$$Fusing\ Factor = \frac{Minimum\ fusing\ current}{Current\ rating\ of\ fuse}$$

- *Always greater than 1*
- *Less FF greater deterioration*
- *For rewirable, semi enclosed, copper wire fuse FF is 2.*
- *Lower FF is for enclosed cartridge fuse using silver or bimetallic element.*

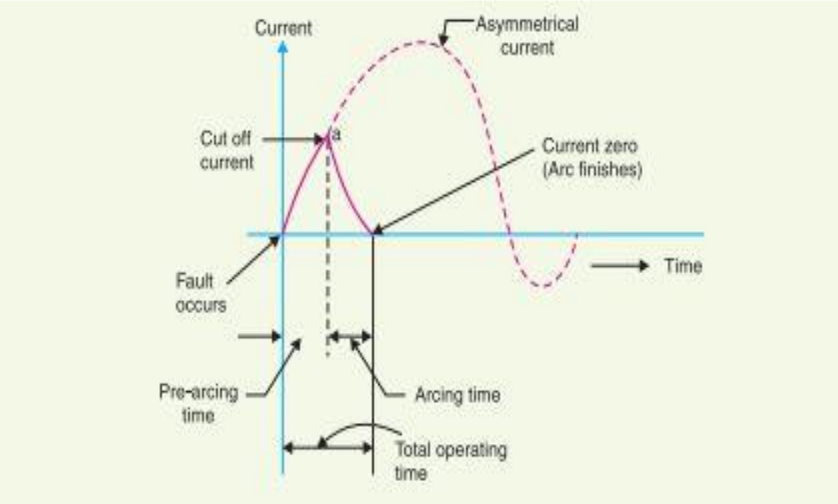


Fuses: Important Terms

Prospective current:

It is the r.m.s value of the first loop of the fault current obtained if the fuse is replaced by an ordinary conductor of negligible resistance.

As shown in figure, how a.c current is Cut-off by a fuse. Normally fault current has a very high first loop, but it due to heat generated by it melts the fuse. The r.m.s value of the first loop of fault current is known as prospective current.



Fuses: Important Terms

Cut-off current:

It is the maximum value of fault current actually reached before the fuse melts.

The heat generated is sufficient to melt the fuse element well before the peak of first loop is reached (point ‘a’ in above figure). Which is known as cut-off current. It depends upon:

- *Current rating of fuse*
- *Value of prospective current*

Pre-arcing time:

Arcing time:

Total operating time:

Breaking capacity: *It is the r.m.s value of a.c. component of maximum prospective current that a fuse can deal with at rated service voltage.*

Types of Fuses

It the simplest current interrupting device for protection against excessive currents.

Generally fuses may be classified into:

- *Low voltages fuses*
- *High voltage fuses*

Fuses are installed with isolating switch in series to avoid the accidental contact of user with the live wire or they must be shielded in absence of isolating switch.

Low Voltage Fuses

Low voltage fuses can be subdivided into two classes *viz.,*

- *Semi-enclosed re-wireable fuse*
- *High rupturing capacity (H.R.C.) cartridge fuse*

Semi-enclosed re-wireable fuse:

Re-wireable fuse (also known as kit-kat type) is used where low values of fault current are to be interrupted. It consists of (i) a base and (ii) a fuse carrier.

It has following two **advantages**:

- *Replacement of fuse element without any danger*
- *Cost of replacement is negligible*

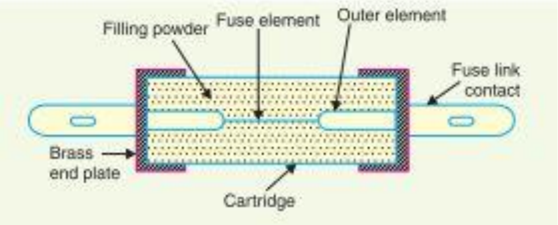
Fuses: Semi-enclosed Rewireable Fuse

Disadvantages:

- *Wrong size of improper material can be possibly replaced*
- *Low breaking capacity cannot be used for heavy currents*
- *Current rating decreased over time due oxidation*
- *Uncertain protective capacity as it is affected by ambient conditions*
- *Accurate calibration of the fuse wire is not possible because fusing current is very much depends upon the length of the fuse element.*
- *These are used only for domestic and lighting loads.*

Fuses: High Rupturing Capacity (H.R.C) Cartridge Fuse

The uncertain and low breaking capacity of semi-enclosed rewireable fuses is overcome in H.R.C cartridge fuse.



- *Heating resisting ceramic body with metal end caps*
- *Caps are welded silver current-carrying element*
- *Surrounding body is filled with filling powder*
- *Filling powder may be chalk, plaster of paris, marble dust which act as quenching and cooling medium*
- *The chemical reaction b/w the silver vapour and the filling powder results in the formation of a high resistance substance which helps in quenching the arc.*

Fuses: High Rupturing Capacity (H.R.C) Cartridge Fuse

Advantages:

- *Capable of clearing high and low fault current*
- *Do not deteriorate with age*
- *High speed of operation*
- *Reliable discrimination*
- *No maintenance*
- *Economical*
- *Consistent performance*

Disadvantages:

- *Have to be replaced after each operation*
- *Heat produced may affect the associated switch*

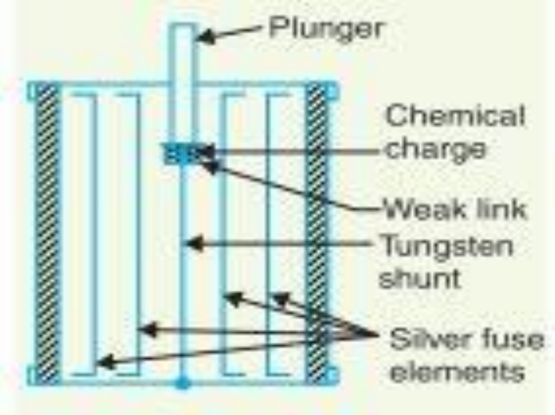
Fuses: High Rupturing Capacity (H.R.C) with Tripping Device

When the fuse blows out under fault conditions, the tripping device causes the circuit breaker to operate.

The rigid metallic caps are connected by a number of silver fuse elements. At one end a plunger is connected through a fusible link, chemical charge and tungsten wire to the other end of the cap with hits the tripping mechanism of the C.B and causes it to operate.

Fault current first blows the silver fuse element and then transferred to tungsten wire.

The weak link in series with the tungsten wire gets fused and causes the chemical charge to be detonated. This forces the plunger outward to operate the circuit breaker. The travel of plunger is so set that it ejected from the fuse body under fault conditions.



Fuses: High Rupturing Capacity (H.R.C) with Tripping Device

Advantages over a H.R.C. fuse without tripping device:

- *In case of 1-phase, the plunger operates and the tripping mechanism of C.B to open all the three phases and prevents "Single phasing".*
- *No need to consider the effect of full short circuit current. This permits the use of a relatively inexpensive C.B.*
- *The fuse-tripped C.B is generally capable of dealing with fairly small fault currents itself. This avoids the necessity for replacing the fuse except after highest currents for which it is intended.*

Low voltage H.R.C fuses may be built with a breaking capacity of 16000A to 30000A at 440V. They are extensively used on low voltage distribution system against over-load and short-circuit conditions.

Fuses: High Voltage Fuses

Intensive research by the manufacturers and supply engineers has led to the development of high voltage fuses. Some of high voltage fuses are:

- Cartridge Type
- Liquid Type
- Metal Clad Fuses

Cartridge Type:

- *Same as low voltage fuse, except some design features are changed*
- *Fuse in the form of Helix to avoid corona at high voltage*
- *Two fuse elements in parallel; low resistance (silver wire) and high resistance (tungsten wire)*
- *Upto 33kV with breaking capacity of 8700A*
- *Ratings of the order of 200A at 6.6kV and 11kV*
- *50A at 33kV are also available.*

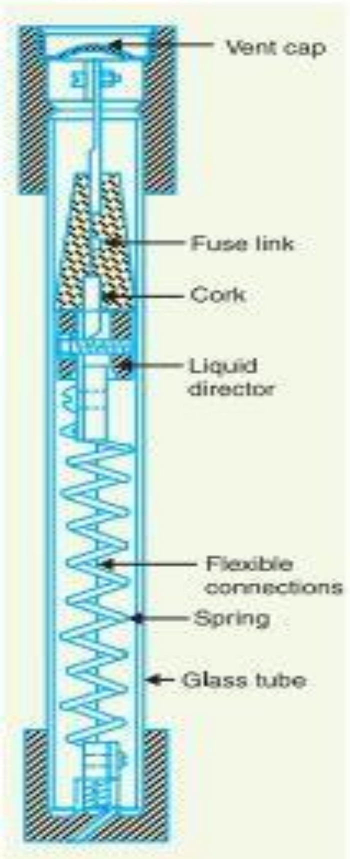
Fuses: High Voltage Fuses

Liquid Type:

- *Filled with carbon tetrachloride*
- *Rated current 100A upto 132kV*
- *Breaking Capacity of 6100A*
- *Sealed with brass caps*

When fault current occurs the fuse wire is blown out. The fuse melts and the spring retracts part of it through a baffle (or liquid director) and draws it well into the liquid. The small quantity of gas generated at the point of fusion forces some part of liquid into the passage through baffle and there it effectively extinguishes the arc.

Metal Clad Fuse: *it is oil immersed fuse, developed as substitute for the oil C.B. These are used for high voltage circuits and operate most satisfactorily under short-circuit conditions approaching their capacity.*



Fuses: Current Carrying Capacity

Current carrying capacity mainly depends on the type of metal used and cross sectional area but is affected by the length, state of surface and surrounding of the fuse.

When the fuse element attains steady temperature,

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

*I^2*R= Constant* x *Effective Surface Area*

$$I^2R = \text{Constant} \times \text{Effective surface area}$$

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

$$d = \text{diameter of fuse element}$$

$$l = \text{length of fuse element}$$

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

$$I^2 = \text{constant} \times d^3$$

$$I^2 \propto d^3$$

Comparison of Fuse and C.B

S. No.	Particular	Fuse	Circuit breaker
1.	*Function*	It performs both detection and interruption functions.	It performs interruption function only. The detection of fault is made by relay system.
2.	*Operation*	Inherently completely automatic.	Requires elaborate equipment (*i.e.* relays) for automatic action.
3.	*Breaking capacity*	Small	Very large
4.	*Operating time*	Very small (0·002 sec or so)	Comparatively large (0·1 to 0·2 sec)
5.	*Replacement*	Requires replacement after every operation.	No replacement after operation.

Thank you !

For any query you can contact me through class group on Whatsapp or can call on my cell number from 10:00 AM to 04:00 PM.