1(a)

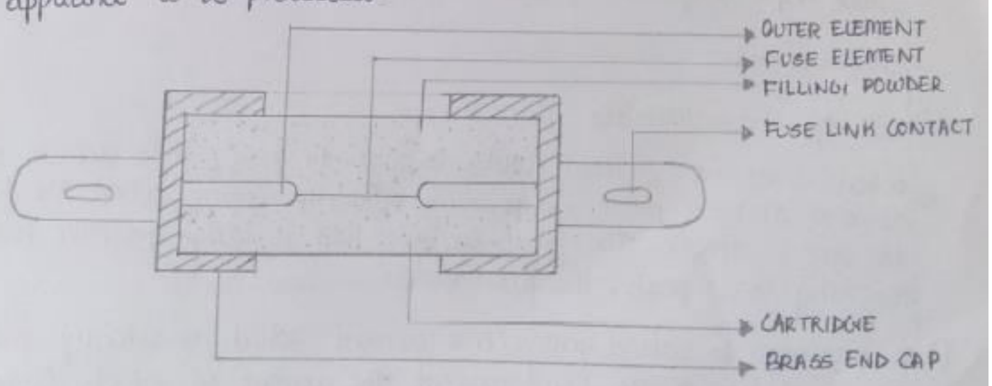
1)(a) Explain the difference between Isolating switch and load break switch.

Ans:

ISOLATING SWITCH	LOAD BREAK SWITCH
(i) In order to disconnect the part of a power system for maintenance and repair purposes, isolating switches are used.	(i) A load breaking switch is a disconnecting device capable of making and breaking the circuits at normal load currents.
(ii) It doesnot have any current breaking or current making capacity.	ii) It is capable of making and breaking the circuits at normal load currents also known as load interrupting switch.
(iii) The isolater switch has the additional ability to earth the isolated circuit, to provide additional safety.	(iii) The modern load breaking switch with switch fuse provides a compact instantly opening-closing with rolling or friction contact

1(b)

A fuse is a small piece of metal connected between two terminals mounted on the insulated base. It is always connected in series with the circuit appliance to be protected.



CONSTRUCTION OF HRC FUSE

CONSTRUCTION :

(i) The body of this fuse is of heat resisting ceramic with metal end caps. The metal used for end caps is generally brass.

(ii) Between the end caps, the fixed elements are mounted, which are welded to the end caps. The fuse elements which is generally silver is attached between the fixed element.

(iii) The body of the fuse is cylindrical in shape. The body space surrounding the fuse element is completely filled with a filling powder.

(iv) The filling powder is generally quartz, sand, plaster of pair or marble dust. It is selected such that its chemical reaction with silver vapour forms very high resistance substance. This helps in arc quenching and acts as a cooling medium.

(v) The filling powder can absorb the heat at a very high rate and it does not evolve appreciable gas.

WORKING :

(i) Under normal condition, the current flowing through the fuse element is rated or below rated current. Hence the temperature of the element is well below its melting point. Hence fuse contines to carry current safely without overheating.

(ii) When a short circuit of fault occurs, current increases to very high value, increasing the temperature of the element upto its melting point temperature. Hence the fuse element melts before fault current reaches to its peak value.

(iii) The silver vapourises after melting. The chemical reaction between silver vapour and the filling powder forms a high resistance substance which helps in quenching the arc very quickly.

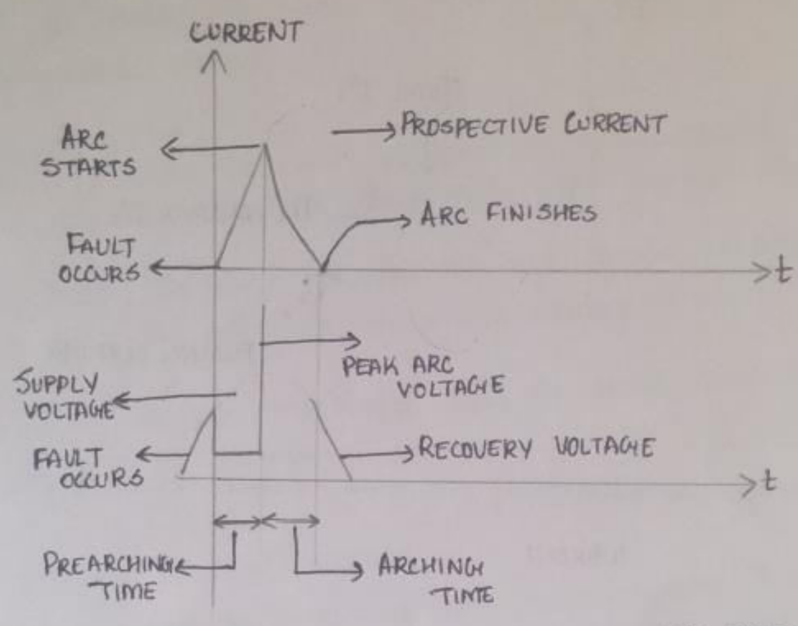
2(a)

(i) Cut-off characteristics

a) When excessive current flows through the fuse, fuse element starts melting at one or more point, depending upon the design. When the fuse melts the arc is struck. The fault current has a large positive peak but before reaching to its peak, the fuse blows.

b) This current is called prospective current which is actually r.m.s value of the first loop of the fault current. The current at which fuse melts and arc starts is called Cut-off current.

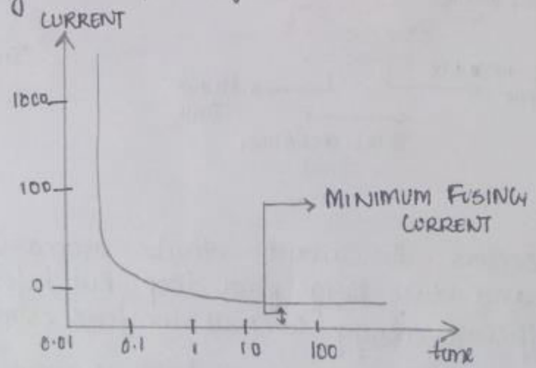
When the fault occurs voltage momentarily reduces and when fuse melts with arc formation, the arc voltage reaches to a value which is several times more than the supply voltage. This depends on the fuse length and the CS. When arc completely vanishes, recovery voltage becomes normal.



CUT-OFF CHARACTERISTICS OF HRC FUSE

TIME – CURRENT CHARACTERISTICS

The HRC fuse shows inverse time-current characteristics. As fault current value becomes high, the operating time becomes less.



TIME - CURRENT CHARACTERISTICS OF HRC FUSE

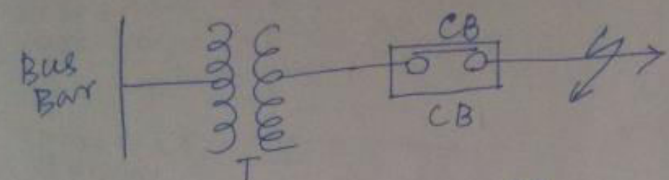
2(b)

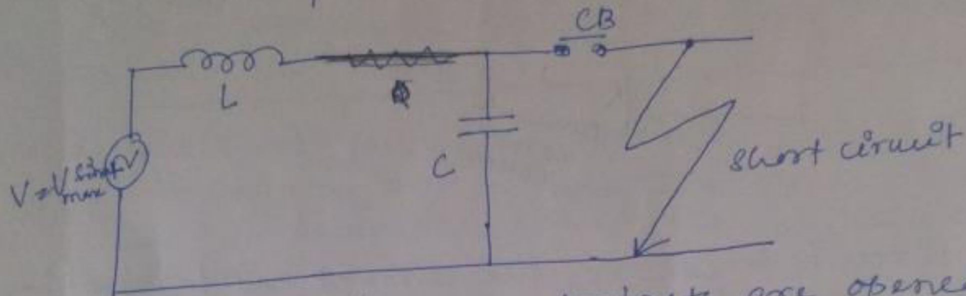
This theory states that is the rate at which the ions and the electrons combine to form the or are replaced by the neutral molecules. i.e the rate at which the gap recovers its dielectric strength is faster than the rate which voltage stress rises; the arc will be extinguished.

- The arc may be interrupted for a brief period but it again restrike. So in this process when the current is at zero value, the fresh air is entered to neutral the electrons. for this also in method is applied:

↳ Lengthening the gap
↳ Increasing the pressure of the arc
↳ Cooling
↳ Blast effect : By blowing a stream of air throug the arc ionized particles between the contacts are swept away and replaced by unionized particl These particles increased the dielectric strengt of the medium considerably.

(3)





When the breaker contacts are opened and the arc finally extinguishes at some current zero, a voltage 'V' is suddenly applied across capacitor & across the circuit breaker.

$i = i_L + i_C$

or $i = \frac{1}{L}\int V\,dt + C\frac{dV}{dt}$

or; $\frac{di}{dt} = \frac{V}{L} + C\frac{d^2V}{dt^2}$ — (i)

Assuming zero time at zero currents when $t = 0$, and further $V = V_{max}\cos\omega t$ $\left[\because \frac{1}{L}\int V_{max}\cos\omega t = \frac{1}{\omega L}V_{max}\sin\omega t\right]$

$i = \frac{V_{max}}{\omega L}\sin\omega t$ (before the opening of circuit breaker)

$\frac{di}{dt} = \frac{V_{max}}{\omega L}\,\omega\cos\omega t$

$\therefore t = 0;\ \left|\frac{di}{dt}\right| = \frac{V_{max}}{L}$ Putting the value in eq (i);

$\therefore \frac{V_{max}}{L} = \frac{V}{L} + C\frac{d^2V}{dt^2}$

So the standard equation is;

$$V = V_{max}\left(1 - \cos\frac{t}{\sqrt{LC}}\right)$$ → Expression for restriking voltage

* Rate of rise of restriking $= \frac{dV}{dt}$

$$\frac{dv}{dt} = \frac{V_{max}}{\sqrt{LC}} \sin \frac{t}{\sqrt{LC}}$$

Rate of rise restriking is maximum when it derivative is zero; $\frac{d^2V}{dt^2} = 0$; $\frac{dv}{dt}$ = maximum

$$\Rightarrow \frac{d^2v}{dt^2} = \frac{V_{max}}{\sqrt{LC}} \cos \frac{t}{\sqrt{LC}} \times \frac{1}{\sqrt{LC}} = 0.$$

$$\Rightarrow \frac{V_{max}}{LC} \cos \frac{t}{\sqrt{LC}} = 0$$

$$\because \cos \frac{t}{\sqrt{LC}} = 0 = \cos \frac{\pi}{2}$$

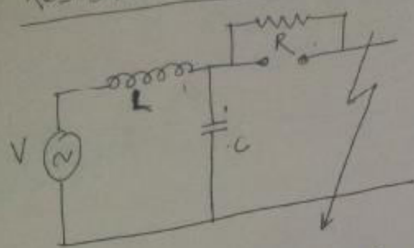
$$\text{or; } \frac{t}{\sqrt{LC}} = \pi/2$$

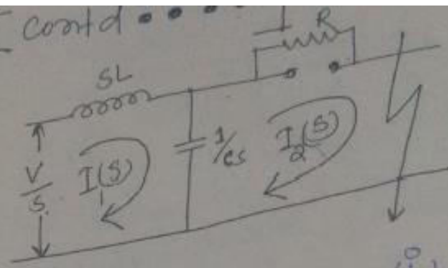
$$\Rightarrow t = \sqrt{LC}\,\pi/2$$

$$\therefore \boxed{RRRV_{max} = \frac{V_m}{\sqrt{LC}}}$$

(4)

Resistance switching [contd....





In loop-1; $\frac{V}{S} = \left(LS + \frac{1}{CS}\right) I_1(S) - \frac{1}{CS} I_2(S)$ —— (i)

In loop 2; $0 = \left(R + \frac{1}{CS}\right) I_2(S) - I_1(S)\frac{1}{CS}$

$\hookrightarrow I_1(S)\frac{1}{CS} = \left(R + \frac{1}{CS}\right) I_2(S)$ ---- (ii) $\Rightarrow I_1(S) = (1 + CRS) I_2(S)$ —— (iii)

Substitute (iii) in eq^n (i) we get;

~~$\frac{V}{S} = \left(LS + \frac{1}{CS}\right)\left(R + \frac{1}{CS}\right) I_2(S)$~~

$$\frac{V}{S} = \left(LS + \frac{1}{CS}\right)(1 + CRS) I_2(S) - I_2(S)\frac{1}{CS}$$

$$= \left(SL + CLRS^2 + \frac{1}{CS} + R - \frac{1}{CS}\right) I_2(S)$$

$$\therefore \frac{V}{S} = \left(RLCS^2 + LS + R\right) I_2(S)$$

$$\therefore \frac{V}{s} = \left(RLCs^2 + Ls + R\right) I_2(s)$$

$$\therefore I_2(s) = \frac{V}{s(s^2RLC + Ls + R)}$$

$$= \frac{V/LCR}{s(s^2 + s\,{}^1/_{CR} + {}^1/_{LC})}$$

$$= \frac{V}{R}\left\{ {}^1/_s - \frac{(s + {}^1/_{CR})}{(s^2 + \frac{1}{CR}s + {}^1/_{LC})} \right\}$$

$$= \frac{V}{R}\left\{ \frac{1}{s} - \frac{s + \frac{1}{2CR}}{(s + {}^1/_{2CR})^2 + \frac{1}{LC} - \left(\frac{1}{2CR}\right)^2} - \frac{{}^1/_{2CR}}{\left(s + \frac{1}{2CR}\right)^2 + \frac{1}{LC} - \left(\frac{1}{2CR}\right)^2} \right\}$$

Putting $a = \frac{1}{2CR}$

$b = \frac{1}{LC} - \left(\frac{1}{2CR}\right)^2$

$$I_2(s) = \frac{V}{R}\left[\frac{1}{s} - \frac{s+a}{(s+a)^2 + (\sqrt{b})^2} - \frac{a}{(s+a)^2 + (\sqrt{b})^2}\right]$$

Taking inverse laplace;

$$i_2(t) = \frac{V}{R}\left[1 - e^{-at}\cos\sqrt{b}\,t - {}^a/_b\, e^{-at}\sin\sqrt{b}\,t\right]$$

$$= {}^V/_R\left[1 - e^{-at}\left(\cos\sqrt{b}\,t + {}^a/_b \sin\sqrt{b}\,t\right)\right]$$

Therefore restriking voltage;

$$V_g = V\left[1 - e^{-at}\left(\cos\sqrt{b}\,t + {}^a/_b \sin\sqrt{b}\,t\right)\right]$$

and the (damped) natural frequency;

$$f_n = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{1}{4C^2R^2}}$$

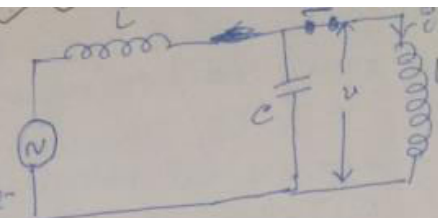
If the resistance is given a value equal to or less than $\frac{1}{2}\sqrt{L/C}$, the oscillatory nature of the transient will vanish & the R.R.R.V. will be kept within the rating of the breaker. Hence for critical damping

$R = \frac{1}{2}\sqrt{L/C}$ Resistance

→ Imp. Expression of critical Resistance to eliminate transient oscillator.

marks

5(a)



The necessity of interrupting small inductive current arises while disconnecting transformers on noload. No-load current of transformer i.e magnetising current are almost at zero power factor lag. The current is smaller than normal rating of the breaker.

When interrupting low inductive currents such as magnetizing currents of transformer, shunt reactor, the rapid deionization of contact space and blast effect may cause the current to be interrupted before it is natural zero. This phenomenon of interruption of current before its normal or natural zero is called current chopping.

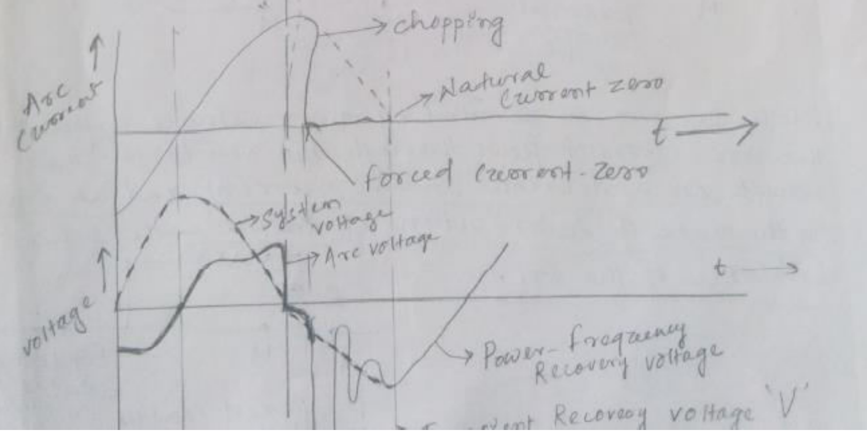
... interruption occurres; the ...

chopping.

When current interruption occurs; the energy stored in inductance is diverted to the capacitance at the moment of current interruption i.e.

$\frac{1}{2}Li^2 = \frac{1}{2}CV^2$ Joules $\Rightarrow Li^2 = CV^2$ V = prospective current voltage

$V = i\sqrt{L/C}$ and $f_n = \frac{1}{2\pi\sqrt{LC}}$



5(b)

Ans: $C = 0.025\mu F = 0.025 \times 10^{-6} F$

Reactance $= 2\pi f L = X_L = 8$

$\Rightarrow L = \frac{X_L}{2\pi f} = \frac{8}{2\pi \times 50} = 0.0255 H$

Resistance is connected $R = 600\Omega$

(i) $f_n = \frac{1}{2\pi} \frac{1}{\sqrt{LC}}$

$= \frac{1}{2\pi\sqrt{0.025 \times 0.0255}} = 6.3 KHz$

(ii) Damped frequency; $f_n' = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{1}{4C^2R^2}}$

$= \frac{1}{2\pi}\sqrt{\frac{1}{0.0255 \times 0.025 \times 10^{-6}} - \frac{1}{4 \times (0.025 \times 10^{-6})^2 \times 600^2}}$

$= 3.41 KHz$

(iii) Critical value of Resistance to eliminate the transient condition;

$R = 0.5\sqrt{L/C} = 0.5\sqrt{\frac{0.0255}{0.025 \times 10^{-6}}} = 504.6\Omega$

(iv) Let the resistance 'R' connected across the CB;

= one fourth of the ~~damped~~ natural oscillation

$= \frac{6.304}{4} =$ ~~0.8525 Hz or 852.5 KHz~~ $= f_n' = 1576\ Hz$

Substituting $L = 0.0255\ H$

$C = 0.025 \times 10^{-6}$

$f_n' =$ ~~852.5~~ $1576\ Hz$

$$\therefore 1576 = \frac{1}{2\pi}\sqrt{\frac{1}{0.0255 \times 0.025 \times 10^{-6}} - \frac{1}{4C^2R^2}}$$

$$\Rightarrow 1576 = \frac{1}{2\pi}\sqrt{\frac{1}{0.0255 \times 0.025 \times 10^{-6}} - \frac{1}{4 \times (0.025 \times 10^{-6})^2 R^2}}$$

~~$\therefore R = 509.3$ Ans~~

$R = 520.8\ \Omega$

6

Breaking capacity :-

Breaking capacity of CB is of two types;

(i) Symmetrical breaking capacity

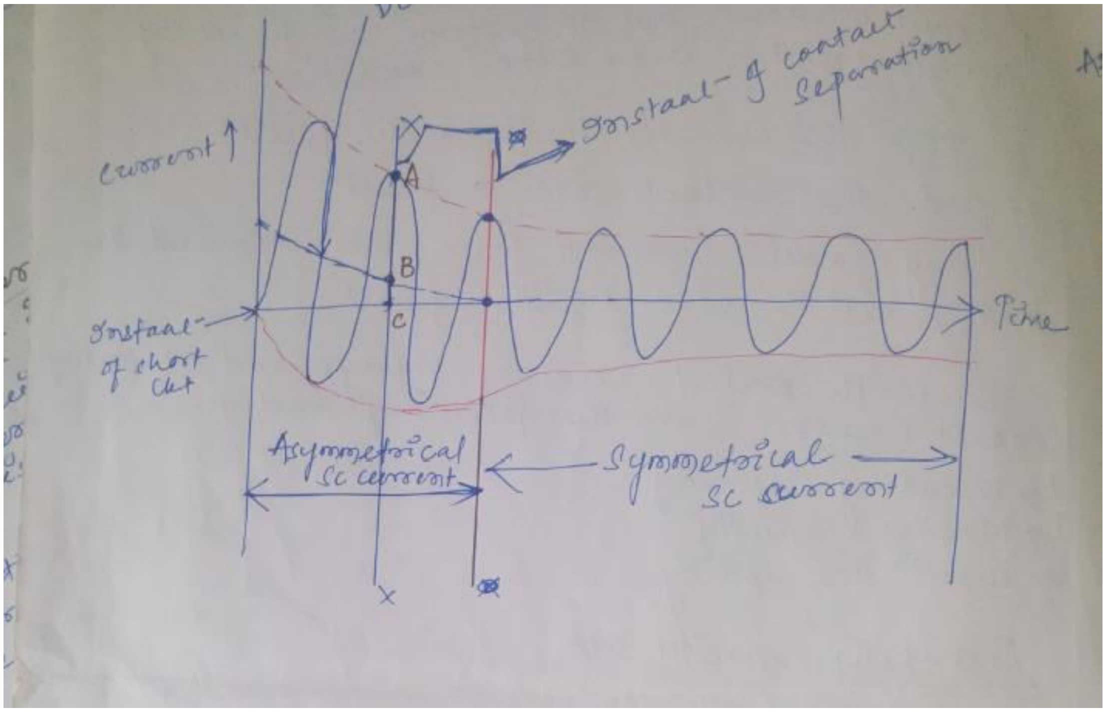
(ii) Asymmetrical breaking capacity

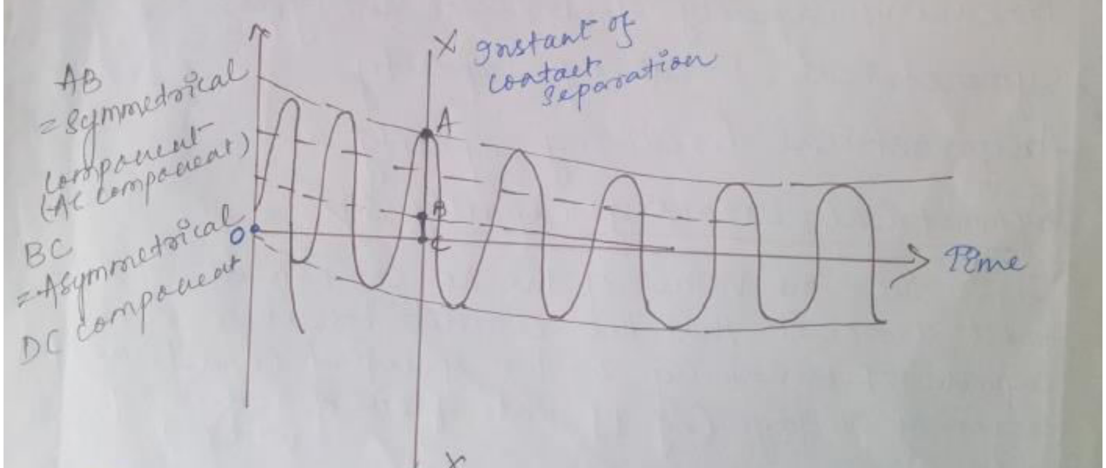
Symmetrical breaking capacity :-

It is the rms value of the ac component of the fault current that the circuit breaker is capable of breaking under specified conditions of recovery voltage. (eg: pf, rate of rise of restriking voltage)

Asymmetrical Breaking :-

It is the rms value of the total current comprising of both ac and dc components of the fault current that the circuit breaker can break under specified condition of recovery voltage.





$AB = x$ = Maximum value of a.c component

$BC = y$ = dc component of short ckt current

Symmetrical breaking current = rms value of ac component

$$= \frac{AB}{\sqrt{2}}$$

Asymmetrical breaking current = rms value of total current

Asymmetrical breaking capacity current is given by:

$$I_{asym} = \sqrt{\left(\frac{AB}{\sqrt{2}}\right)^2 + (BC)^2}$$

∴ Breaking capacity $= \sqrt{3} \times V \times I$ MVA

V = rated service voltage in KV

I = Rated symmetrical breaking current in KAmps

The rated asymmetrical breaking current is taken by 1.6 times the rated symmetrical current.

Making Capacity :→

The possibility of a circuit breaker to be closed on short circuit is also considered.

∴ Making current $= \sqrt{2} \times 1.8 \times$ Symmetrical breaking current

∴ Making current = 2.55 × Symmetrical breaking capacity

Here multiplication by $\sqrt{2}$ is obtain the peak value & 1.8 multiplication due to dc component taken into account.

Short-time current Rating :→

The circuit breaker must be capable of carrying short ckt current for a short period while another circuit breaker has to detect the fault.

The rated short time current is the rms value (total current both dc and ac components) of the current that the circuit breaker can carry safely for a specific period.

Short-time current Rating → Rms value of total current (Both ac and dc component current)

Rated voltage, current and frequency :->

Rated maximum voltage at which the operation of the circuit breaker is guaranteed. The specified voltage is slightly more than the rated nominal voltage.

The rated current is the rms value of the current that a CB can carry continuously w/o any temp. rise in excess of its specific limit.

The rated frequency is also mentioned by the manufacture. It is the frequency at which the CB has been designed to operate. The standard frequency is 50Hz.

(7)

(i) Axial-blast air circuit breaker. Fig 19.9 shows the essential components of a typical axial-blast air circuit breaker. The fixed and moving contacts are held in the closed position by spring pressure under normal conditions. The air reservoir is connected to the arcing chamber through an air valve. This valve remains closed under normal conditions but opens automatically by the tripping impulse when a fault occurs on the system.

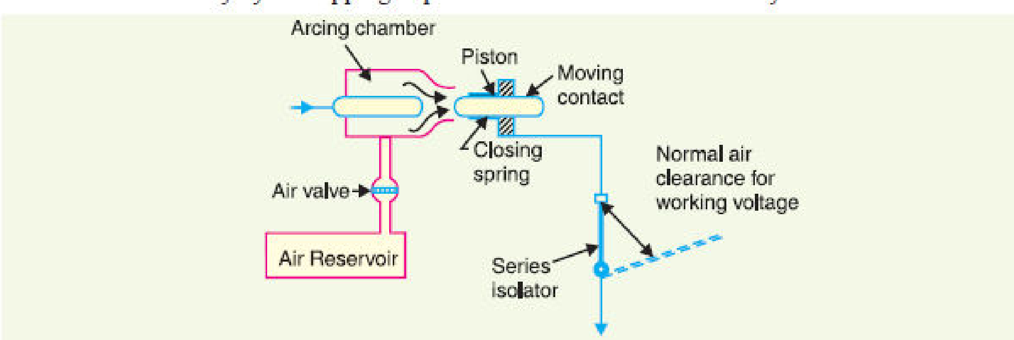


Fig. 19.9

When a fault occurs, the tripping impulse causes opening of the air valve which connects the circuit breaker reservoir to the arcing chamber. The high pressure air entering the arcing chamber pushes away the moving contact against spring pressure. The moving contact is separated and an arc is struck. At the same time, high pressure air blast flows along the arc and takes away the ionised gases along with it. Consequently, the arc is extinguished and current flow is interrupted.

It may be noted that in such circuit breakers, the contact separation required for interruption is generally small (1·75 cm or so). Such a small gap may constitute inadequate clearance for the normal service voltage. Therefore, an isolating switch is incorporated as a part of this type of circuit breaker. This switch opens immediately after fault interruption to provide the necessary clearance for insulation.

19.16 Vacuum Circuit Breakers (VCB)

In such breakers, vacuum (degree of vacuum being in the range from 10^{-7} to 10^{-5} torr) is used as the arc quenching medium. Since vacuum offers the highest 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.

Principle. The production of arc in a vacuum circuit breaker and its extinction can be explained as follows : When the contacts of the breaker are opened in vacuum (10^{-7} to 10^{-5} torr), an arc is produced between the contacts by the ionisation of metal vapours of contacts*. However, the arc is quickly extinguished because the metallic vapours, electrons and ions produced during arc rapidly condense on the surfaces of the circuit breaker contacts, resulting in quick recovery of dielectric strength. The reader may note the salient feature of vacuum as an arc quenching medium. As soon as the arc is produced in vacuum, it is quickly extinguished due to the fast rate of recovery of dielectric strength in vacuum.

Construction. Fig. 19.12 shows the parts of a typical vacuum circuit breaker. It consists of fixed contact, moving contact and arc shield mounted inside a vacuum chamber. The movable member is connected to the control mechanism by stainless steel bellows. This enables the permanent sealing of the vacuum chamber so as to eliminate the possibility of leak. A glass vessel or ceramic vessel is used as the outer insulating body. The arc shield prevents the deterioration of the internal dielectric strength by preventing metallic vapours falling on the inside surface of the outer insulating cover.

Working. When the breaker operates, the moving contact separates from the fixed contact and an arc is struck between the contacts. The production of arc is due to the ionisation of metal ions and depends very much upon the material of contacts. The arc is quickly extinguished because the metallic vapours, 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 rate of recovery of dielectric strength, the arc extinction in a vacuum breaker occurs with a short contact separation (say 0·625 cm).

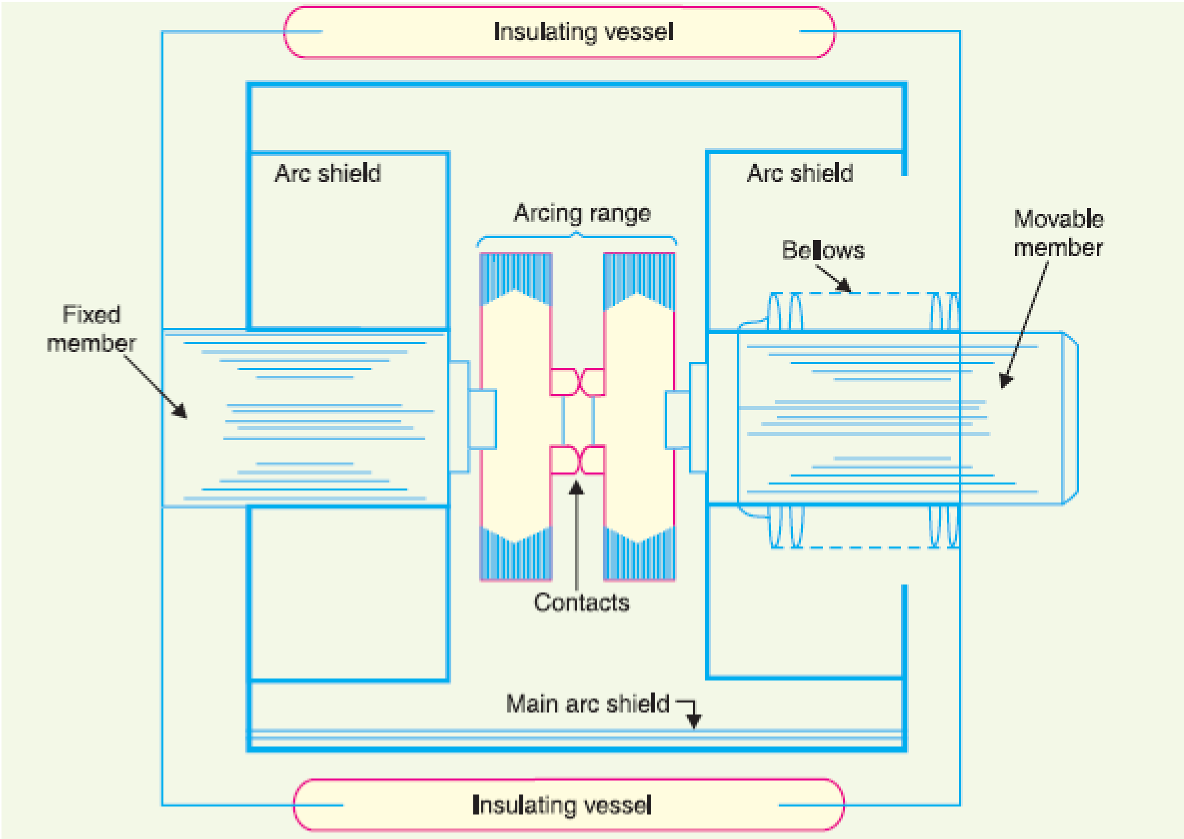

Insulating vessel
Arc shield
Arc shield
Arcing range
Movable member
Bellows
Fixed member
Contacts
Main arc shield
Insulating vessel

Fig. 19.12