14

HRC Fuses and Their Application

Introduction—Type—Definition—Construction—HRC Fuse link—Shapes of fuse element—Specifications of a fuse link—Characteristics of a fuse—Cut-off—Classification P—Q—R, Selection of a fuse link-Protection of motor—Discrimination—Tests on fuse.

14.1. INTRODUCTION

Fuse is a simplest current interrupting device for protection from excessive currents. As such, it is used for overload and/or short circuit protection in medium voltage (upto 33 kV)* and low voltage (upto 400 V) installations. Modern High Rupturing Capacity Cartridge Fuses (HRC) provide a reliable discrimination and accurate characteristics. In some respects HRC fuses are superior to circuit-breaker.

14.2. TYPES OF DEVICES WITH FUSE

1. Semi-enclosed or Rewirable Type. The fuse which can be seen in our houses are generally of this type. The fuse carrier can be pulled out and the blown out fuse element (wire which melts) can be substituted by a new one and carrier is replaced in the fuse base.

2. Totally enclosed or Cartridge Type. The fuse element (the conductor which melts) is enclosed in a totally enclosed container and is provided with metal contacts on both sides.

This type is available in two types :

(*i*) D type (*ii*) Bolted type

3. Current Limiting Fuse-link. A fuse-link which limits current to a considerable lower value than the prospective peak.

4. Drop-out-Fuse. A fuse-link in which the fuse-carrier drop out after the operation of the fuse thereby providing isolation between the terminals.

5. Expulsion Fuse. A fuse in which the arc occurring during the operation of the fuse is extinguish by expulsion produced by the arc.

6. HRC (High-Rupturing-Capacity, *i.e.* Breaking Capacity cartridge fuse). A cartridge fuse link having breaking capacity higher than certain specified value (*e.g.* above 16 kA for medium voltage cartridge fuse).

7. Striker Fuse. A device which incorporates a fuse and a mechanical device, the operation of fuse release the striker with certain pressure and displacement. Striker is used for signalling-tripping/indication.

8. Switch-fuse. A combined unit comprising, fuse and switch.

14.3. DEFINITIONS

— **Operation of fuse-link.** Process of pre-arcing and arcing resulting in 'blowing' of fuse-link.

— **Cut-off.** The melting of fuse-element before the current reaches the prospective peak. The value of current at which the cut-off occurs is called cut-off value.

* Recently, HRC fuses have been developed for applications upto 66 kV for distribution systems.

— **Pre-arcing Time.** Time between commencement of the current loop and the cut-off.

— **Arcing Time.** Time between cut-off and final current zero.

— **Total Operating Time.** Pre-arcing time plus acting time.

— **Fuse.** Fuse is a current interrupting device which opens the circuit (in which it is inserted) by fusing the element when the current in the circuit exceeds a certain value.

— **Fuse element.** The part of the fuse which is designed to melt when the fuse operates.

— **Fuse link.** The part of the fuse which needs replacement when the fuse blows out.

14.4. CONSTRUCTION

(A) Semi-enclosed or Rewirable Fuse. Everyone is familiar with this fuse which blows out when all the hostel lamps are glowing and somebody puts on a heater. The fuse carrier can be pulled out, the new wire can be placed and the service can be restored. Thus the cost involved is very much less. However, the fuse element (wire in this case) is exposed to atmosphere. Hence it is affected by ambient temperature. Such rewirable fuses have limited breaking capacity. For example, according to I.S. : 2086—1963 the rewirable fuse of 16 A normal current have a breaking current of 2 kA and those upto 200 A normal current have a breaking current of 4 kA.

Further, the characteristic of such fuse is not certain as it is affected by ambient condition and several other aspects mentioned below. Therefore, such fuse has limited application in industrial switchgear. Its use is limited to domestic and lighting loads. For all important and costly equipment totally enclosed cartridge fuses are used because they give a reliable protection.

Disadvantages of rewirable fuse as compared to cartridge fuse

(1) *Low breaking capacity.* Hence cannot be used in circuits of higher fault level.

(2) *Absence of accurate characteristic.* Hence protection is not reliable.

(3) It is subjected to deterioration because the wire is exposed to air, hence it is oxidised. This increases the resistance causing heating.

(4) Accurate grading not possible

(5) *No current limiting feature.*

(6) Slow speed.

(7) *Risk of external flame and fire.* However it is a cheap and easily replaceable fuse. One should be cautious in selecting this type of fuse.

(B) D-Type Cartridge Fuses (Fig. 14.1). The typical fuse comprises.

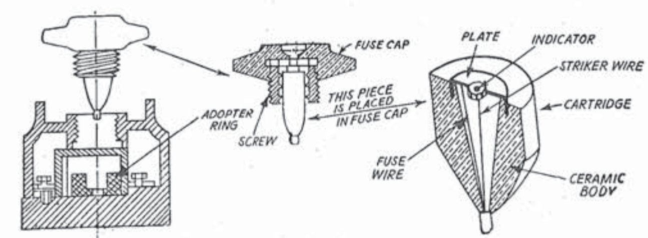

Fig. 14.1. D-type fuse.

1. Fuse base. 2. Adapter-ring. 3. Cartridge. 4. Fuse cap.

The cartridge shown in Fig. 14.1 (*a*) is pushed in the fuse cap. The cap is screwed on the fuse base. On complete screwing the cartridge tip touches the conductor and circuit between two terminal is completed through the fuse link.

(C) Link type

This type is available in two types.

(*i*) Knife blade type (Fig. 14.2).

(*ii*) Bolted type (Fig. 14.3).

(*d*) **Bolted type** (Fig. 14.3). Fuse link has two conducting plates on either ends. These are bolted on the plates of the fuse base. This type of fuse requires an additional switch so that the fuse can be taken out without getting a shock.

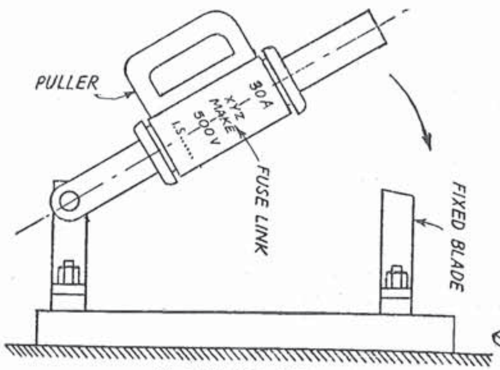

Fig. 14.2. Kinfe blade type.

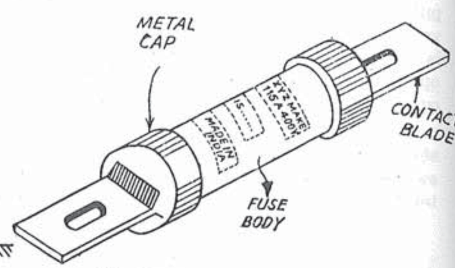

Fig. 14.3. Bolted type fuse link.

14.4.1. HRC Fuses for Semiconductor Devices and Thyristors

Solid State Devices (Diode, Thyristor etc.) are protected against surge currents by fast acting series connected HRC fuses. The HRC fuses for solid state devices have pre-arcing time less than 0.5 millisecond and arcing time less than 5 milliseconds (Ref. Fig. 14.8). The prospective short-circuit current would reach peak value in 10 milliseconds (half cycle). However with HRC fuse in circuit, the short-circuit current does *not* reach prospective peak and current is limited to a value corresponding to cut-off.

Generally, fuse is connected in series with the semi-conductor device or in series with a group of parallel connected semiconducting devices.

When a fuse blows, a part of circuit is removed from the current path.

Fig. 14.4 shows the locations of HRC fuses in single phase thyristor circuits.

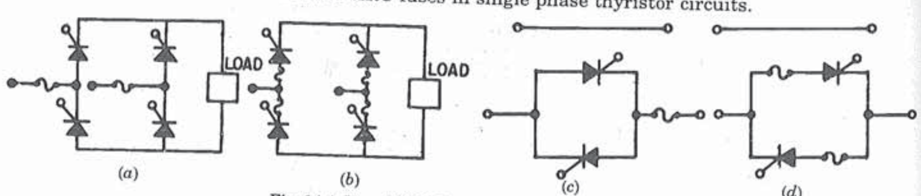

Fig. 14.4. Use of HRC fuse for thyristor protection.

Ratings of HRC Fuses for Thyristor Protection

Definitions of HRC Fuses (sec. 14.3) and Ratings (sec. 14.8) are suitably modified as follows.

1. **Rated Current.** Fuse rating is selected to suit the thyristor current in the circuit. These values are the maximum r.m.s. current permissible for the circuit and thyristor.

2. **Rated Voltage.** Fuse is rated normally in terms of r.m.s. voltage. Operating voltage must be equal or less than the rated voltage of the fuse. When fuse is used in DC circuit, the operating voltage must be lower than rated r.m.s. voltage. Manufacturers provide data on this derating.

3. **Fusing peak current.** (I_{fm}) The peak fusing current depends on maximum possible short circuit current to the circuit.

I_{fm} should be less than I_{TSM}

$$I_{fm} < 1.4\, I_{TSM}$$

I_{fm} should be less than $I''_{s\text{-}p}$ where $I''_{s\text{-}p}$ is peak of sub-transient fault current given by $I''_{s\text{-}p} = 1.6 \times \sqrt{2} \times I''_{s\text{-}rms}$

$I''_{s\text{-}rms}$ is subtransient fault current of the circuit.

4. **I^2t Value.** The I^2t value is a measure of the heat capacity of the thyristor. Generally I^2t value is given for a period of 10 m. sec. For times in excess of this, I^2t will be larger. For adequate protection against short circuit I^2t of fuse should be lower than I^2t of the thyristor. If fault current exceeds on cycle rating of the cell fuse has to perform current limiting function. Hence I^2t of the cell must be compared with total I^2t of the fuse, *i.e.* pre-arcing and arcing time. This varies with fault current and supply voltage, Published data allows such calculations to be made for combinations of fuse ratings, fault current and supply voltage.

5. **Arc Voltage.** This depends on L/R ratio of circuit.

Stresses on Solid State Devices for Selection of HRC Fuse. These include *power frequency (50 Hz) current stresses and Transient Current Stresses.*

Abnormal power frequency currents which exceed steady-stage current rating of a device occurs frequently. Under fault conditions, the equipment should be disconnected from supply to prevent to the solid-state device.

A thyristor has following current ratings :

I_{TAV} average steady state current.

I_{RMS} RMS value of steady current.

I_{TRM} repetitive peak current.

I_{TSM} non-repetitive peak surge current.

Transient current stresses are expressed in terms of Maximum di/dt and peak current. In various applications steady state ratings of the devices are specified. However, solid-state devices are prone to failure immediately or after a very short service, if the circuit is not adequately designed and protected.

To achieve reliability and long life, the entire circuit and auxiliaries should be adequately designed and protected, against peak voltage transients, maximum dv/dt, maximum di/dt and peak current. These abnormal transients are likely to occur during on/switching/off state as follows :

Maximum dv/dt peak voltage during switching off and when off transient

Maximum di/dt	When turning on
Peak current	When fully on

A capacitor is connected in parallel with a thyristor to act as a "snubber' to limit dv/dt and prevent unintentional firing and also to absorb energy from voltage spikes. A resistor of 8 to 60 Ω is generally required in series with this capacitor prevent high di/dt when the thyristor is turned on.

High voltage transients can also be limited by non-linear voltage suppressors, matched to the maximum voltage rating of the thyristor and which have sufficient energy absorbing capacity to dampen the transient.

The di/dt at turn-on can be limited by the inductance inherent in the circuit or by an inductor added in the circuit. High frequency inverters and other applications requiring high di/dt can utilize fast turn on thyristors. The magnitude and rise time of the signal applied to the gate also influence the di/dt capacity of a device. Manufacturer's recommendations should be followed.

14.5. FUSE LINK OF HRC FUSE

The fuse link is a unit in which the fuse element is enclosed. The fuse link is replaced when it blows out. (Ref. Fig. 14.6).

The outer cover is usually of steatite, a ceramic material having good mechanical strength. Epoxy resins have been recently introduced and are replacing the ceramic material.

The fuse elements are fitted inside the body. The ends of the fuse elements are connected to the metal end caps. The metal caps are screwed to the ceramic body by means of special forged screws to withstand the pressure developed under short-circuit condition. End contacts are welded to the metal end caps. These contacts bolted on the stationary contacts on the panel.

An indicator pin is provided, which indicates when the fuse blows out.

The fuse body is filled with powdered pure quartz.

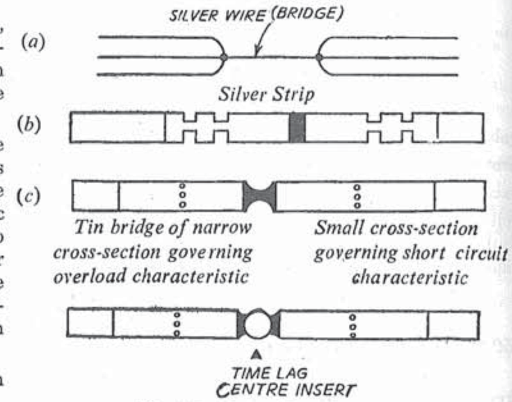

Fig. 14.5. Shapes of fuse elements.

The fuse element is of silver or copper with a special shape. Normally, the element has two or more sections joined by means of a tin joint. The element consists of several identical strips similar to those as shown in Fig. 14.5. The strips are interconnected such that the arc spreads instantly to all the strips.

The characteristic of the fuse is governed by material and shape of the fuse element.

14.6. ACTION OF HRC FUSE

Normally the fuse elements are in parts which are connected in the middle by tin bridge. The melting point of the tin bridge is precise and about 230°C.

The bridge does not melt at temperatures below the melting point. Since the melting point is higher than ambient temperature, the melting is not affected by the ambient temperature.

The current passing through fuse element produces heat which is proportional to $i^2 rt$. With a certain current, the temperature rises and the tin bridge melts producing a break in the circuit. Thereby an arc is produced. This arc immediately spreads over the neighbouring elements and they too melt. The metal vapour diffuses with the quartz powder and the product of chemical reaction produces a substance of high resistance which becomes an insulator. Thereby the space between the caps is filled with a material of high dielectric strength, as the current is interrupted.

14.7. SHAPE OF FUSE ELEMENT

The fuse elements are in the form of a wires or thin strips. The shape depends on the characteristic desired. Usually there are identical parts connected by a bridge of silver or tin.

14.8. SPECIFICATION OF A FUSE LINK

1. **Voltage Rating.** This is specified by the manufacturer. The rated voltage of the fuse should be equal to or more than :

(a) Voltage of the circuit in a single phase a.c. or two wire circuit.

(b) Line voltage in case of three phase a.c. circuit.

(c) Voltage between two outer wires in three wire d.c. circuits.

2. **Frequency.** A fuse link suitable for 50 c/s may not have same rating for other frequencies of d.c. circuits.

3. **Current Rating.** This rating is stated by the manufacturer. It is r.m.s. value of current which the fuse can carry continuously without deterioration, and with temperature rise within specified limits.

4. **Minimum Fusing Current.** The minimum current at which the fuse will melt. Asymptotic value of current from the characteristic of total operating time.

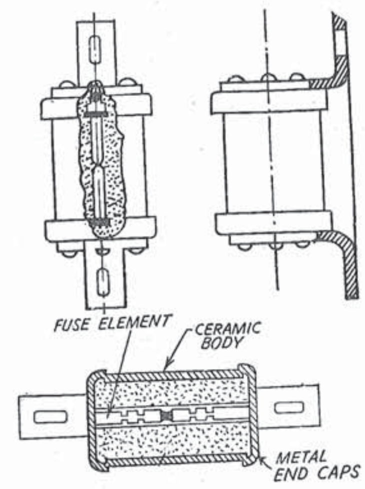

Fig. 14.6. HRC fuse link.

5. **Fusing Factor.** The ratio of minimum fusing current to the current rating, *i.e.*,

$$\text{Fusing Factor} = \frac{\text{Minimum Fusing Current}}{\text{Current rating}}.$$ Thus factor is more than 1.

6. **Prospective peak current of a circuit.** The current that would flow in the circuit if the fuse were replaced by a link of negligible impedance. Peak value of first current loop of short circuit waveform.

7. **Breaking capacity.** Highest prospective peak current under the prescribed conditions of voltage, power factor etc. which the fuse is capable of breaking. Fuse cuts-off before reaching the peak.

8. **Operation of fuse link.** Process of pre-arcing and arcing resulting in blowing of fuse link.

9. **Cut-off.** The melting of fuse-element before the current reaches the prospective peak. The value of current at which the cut-off occurs is cut-off value. Cut-off current is of instantaneous value.

10. **Pre-arcing time.** Time between commencement of the current loop and the cut-off. (ms)

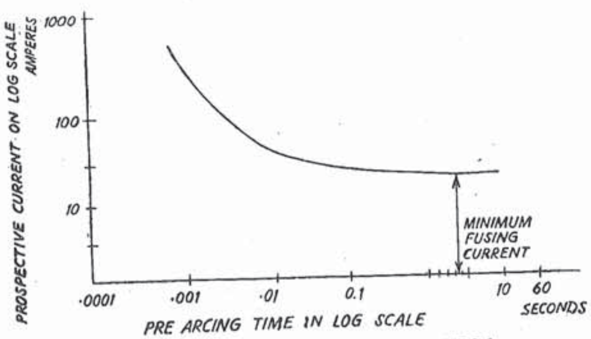

Fig. 14.7. Illustrates typical characteristic of a HRC fuse.

11. **Arcing time.** Time between cut-off and final current zero. (ms)

12. **Total operating time.** Pre-arcing time plus arcing time. (ms)

14.9. CHARACTERISTIC OF A FUSE

Normally the characteristics give pre-arcing time plotted against prospective currents upto the rupturing capacity rating of the fuse. Both the axis are plotted on logarithmic axis.

It is observed that as the prospective current increases, the pre-arcing time reduces. Further the characteristic becomes asymptotic and there is a minimum current below which the fuse does not operate. For currents near the minimum fusing current, the operating time is long. (Also refer Fig. 14.9).

14.10. CUT-OFF

The HRC fuses, slow acting of fasting, exhibit and interesting property known as *Cut-off*. The short circuit current is interrupted before it reaches the peak of first prospective current loop.

If the melting of fuse element prevents the current through the fuse link from reaching the otherwise attainable peak value the fuse to said to have cut-off. The instantaneous maximum value attained is called cut-off current.

Fig. 14.8 illustrates the *cut-off* action. On occurrence of short circuit, the current starts increasing. It would have reached a magnitude I_p if no fuse were there is protect. HRC fuse does not allow current to reach I_p. Instead, the element is cut-off and after a brief arcing time the current is interrupted. The cut-off value depends upon (1) normal current rating of the fuse ; (2) prospective current (3) the asymmetry of circuit waveform.

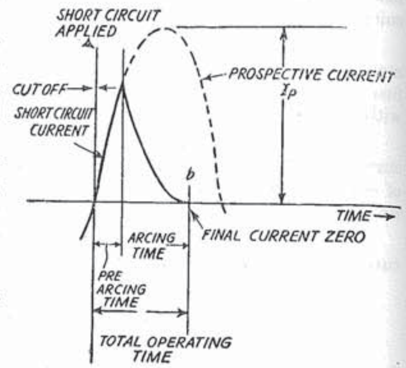

Fig. 14.8. Cut-off characteristic.

Cut-off property has a great advantage that the short circuit current does not reach the prospective peak. Hence the circuit is not subjected to electrodynamic stresses corresponding to peak prospective current. Hence the bus bar design is considerably simplified because now the maximum value of current for design purposes in cut-off value.

14.11. CLASSIFICATION AND CATEGORIES

According to B.S. : 88—1952 Fuse links are classified depending upon their fusing factor into 3 classes

Class P Fusing factor less than 1.25

Class Q Fusing factor less than 1.75

Class K Fusing factor more than 1.75

$$\text{Fusing Factor} = \frac{\text{Minimum Fusing Current}}{\text{Rated current}}$$

Quick acting and slow acting fuse. The fuse is quick acting or slow acting depending upon its characteristic. In some fuses there is a combination of these two features.

Note on categories of duty. Clause 8 of B.S. 88 : 1952 states that every fuse shall be assigned for convenience one or more of 5 categories of distinguished by the values of prospective current of test circuit stated in the table given on next page below, and denoted respectively by the number 1, 2, 3, 4, and 5, the number 1 to 4 being preceded always by the letters AC or DC respectively to whether the fuse is suitable for use in alternating-current or in direct-current and the number 5 being preceded always by the letters AC. The category of duty of which any fuse is assigned shall

be one having a distinguishing value of prospective current of test-circuit not greater than the breaking capacity rating of the fuse. The power factor of an A.C. test-circuit and the time constant of a D.C. test-circuit shall be the same for all tests for a given category of duty, and shall be of appropriate values as stated in the table 14.1.

Table 14.1.

Category of duty	*Prospective current of test-circuit (Amperes)*	*Power factor (Lagging) of test-circuit not greater than*	*Time-constant of test-circuit not less than*
AC_1 and DC_1	1,000	0.6	0.0030
AC_2 and DC_2	4,000	0.4	0.0040
AC_3 and DC_3	16,500	0.3	0.0100
AC_4 and DC_4	33,000	0.3	0.0100
AC_5	46,000	0.15	

Note. AC_4 is the highest category of duty normally required for A.C. service, only when it is known to be insufficient should category of duty AC_5 be specified.

14.12. SELECTION OF FUSE LINKS

The problem is not as simple as one may imagine. An improper blowing out of fuse itself may be comparatively insignificant but it may result in stoppage of a certain machine or failure of certain circuit. Such causes may lead to loss of production. *Hence reliable fuses should be used, which should be selected such that it will blow out under abnormal conditions only. It should not operate during temporary permissible overloads of switching surges. The following aspects should be considered in selecting the fuse :

(I) Nature of Load

(*i*) Normal current

(*ii*) Starting current, duration

(*iii*) Permissible overloads.

(*iv*) Whether steady load of fluctuating load

(II) Nature of Protection Required

(*i*) Overload of short-circuit protection.

(*ii*) Opening time slow or quick operation required.

(*iii*) Peak prospective current, desired cut-off value.

(III) Fault Current

(*i*) Fault current, peak prospective value.

(*ii*) Fusing factor desired.

(*iii*) Rupturing capacity.

(*iv*) Category of duty AC_1 and AC_5 or DC_1 to DC_4 [Refer Sec. 15.11 B].

(IV) Grading or Discrimination between other fuses and circuit breakers in the circuit.

These aspects will be discussed in the subsequently paragraphs briefly.

(*i*) **Steady load or Fluctuating load.** Fluctuating loads are those in which peaks of comparatively short durations occur. Steady loads fluctuated but a little from their normal value *e.g.* heaters.

* A vertical boring machines in a factory was out of order for two days. On tracting the trouble, it was found that a fuse in control circuit had blown. The loss was estimated to be 40 machine hours, about Rs. 24000.

In selecting a fuse for steady loads one has to decide whether to give *over-load protection of short circuit protection.* For over-load protection of steady loads class P fuses of fusing factor 1.25 are preferred. The fuses give protection against small but sustained over-currents. The fuse is selected from the available fuses on the basis of normal current of the circuit. The fuse of rated current equal to the normal current may be selected. If such fuse is not available the next greater rated current fuse is selected. The standard rated currents of fuses are as under :

2 — 4 — 6 — 10 — 16 — 25 — 32 — 50 — 63 — 80 — 100 — 125 — 160 — 200 — 250 — 400 — 500 — 630 — 800 — 1000 — 1250 amperes.

(*ii*) **Fluctuating loads.** The criterion for selection is that the fuse should not blow under transient overloads. For such feature the current/time characteristic of the fuse should be always above the transient current characteristic of the load, with enough margin. Hence it is necessary sometimes, to select a fuse rated current greater than normal current of the circuit. Further, fuses of class *Q* having fusing factor 1.75 may be suitable.

(*iii*) **Switching surges.** Switching of transformers, fluorescent lighting capacitor, motors etc. the current in-rush takes place. The fuse selected in the circuit should not blow out during the switching period. The chosen fuse should generally have a normal rating 25 to 50 per cent above the normal full load current of the protected apparatus and the fusing factor should be such that starting current is less than the fusing current.

Guidelines for Some Applications for steady-load Circuits

In circuits where the load does not fluctuate much from its normal value (*e.g.* in heating circuits) select the standard cartridge fuse-link intended for fuses having a current-rating equal to or next greater than the anticipated steady-load current. If other over-current protection is provided, or if discrimination is required, a cartridge fuse-link for a fuse of still greater current-rating may be selected.

For Fluctuating-load Circuits

When the load varies above normal in peaks of comparatively short duration, select fuse-links in accordance with the following general rules :

(*a*) *Transformers and Fluorescent-Lighting Circuits.* In general cartridge fuse-links intended for fuses of the current-rating next higher than the anticipated normal load current will stand the transient current-surge.

(*b*) *Condenser Circuits.* Select a cartridge fuse link intended for fuses for current-rating 25 per-cent greater than that of the circuit, to allow of the extra heating causing by the capacity effect.

(*c*) *Motor Circuits.* When the starting current of motor is known a suitable cartridge fuse-link can be selected by assuming that the starting current surge will persist for 20 seconds, and choosing one intended for fuses that will carry to the starting current for this time. Reference should be made to the time/current characteristics (Fig. 14.9).

When the starting current is not known, useful approximately assumptions are (*i*) that the starting current of a direct-stated motor is about 7 times of the full-load current and (*ii*) that the starting current of a motor with a 75 per cent auto-transformer starter-tapping is about 4 times the full-load current, and about 2-5 times with a 60 per cent auto-transformer starter-tapping or with a star-delta starter. For most slip-ring motors, normal running conditions, and not starting conditions, determine the fuse-link that should be used and it is ordinarily sufficient to select one capable of carrying the normal load-current.

Fuse manufacturer provides tables and graphs for general guidance in selection for motor starting, and is for use when only the supply voltage, the horse-power of the motor, and method of starting are known.

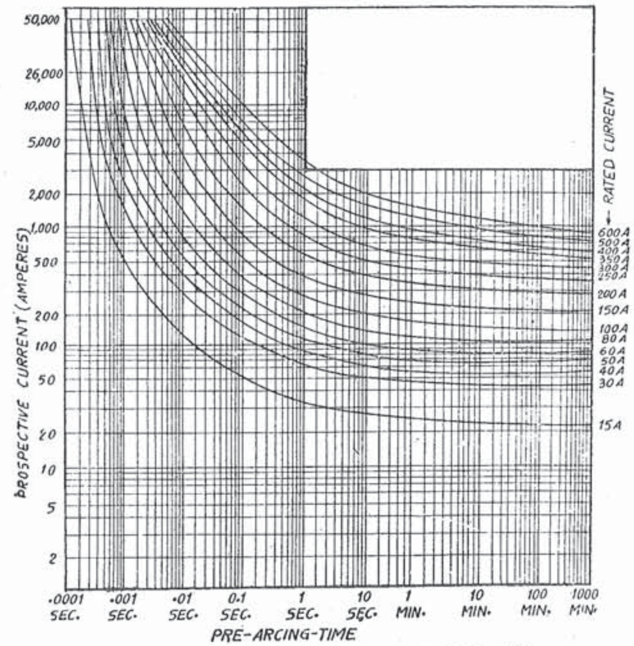

Fig 14.9. Time current characteristic of HRC fuse-link.

14.13. PROTECTION OF MOTOR*

The over-current relay provides over-current protection to the motor. Hence the fuses provide *short circuit protection* and high starting currents on locked-rotor. While choosing the fuse for the motor, the normal current of the motor is noted. The characteristic of current *vs.* time of motor for the starting period is plotted on the same graph on which the characteristic of some fuses are plotted.

The characteristic of fuse should lie above the characteristic of motor at all time. Further, there should be an appropriate margin to ensure that the fuse does not operate unduly during starting.

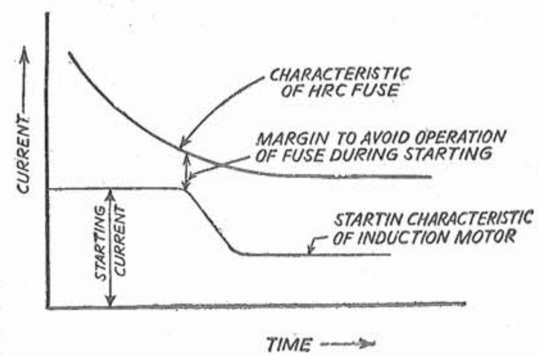

Fig. 14.10. Pre-arcing time/current characteristic of fuse matched with starting characteristics of motor.

* Also refer Ch. 31 : Protection of Motor, Sec. 15.6, 15.12.

Also, the breaking capacity of the interrupting device, *i.e.* contactor or circuit-breaking should be fully exploited.

For this purpose the other switching device should be coordinated with the fuse in such a way that for the value of fault currents upto the breaking capacity of the circuit-breaker (or contactor) the circuit-breakers operates and the fuse does not. For this purpose the characteristic of the circuit-breaker (or contactor) relay operating coil should be below the characteristic of the fuse as shown in the figure. These characteristics should intersect as a point (A) preferably above the breaking current capacity of the circuit breaker.

Here, the fuse gives back-up protection to the motor and is connected on the supply side.

When starting current of motor is not known as the following approximations may be made :

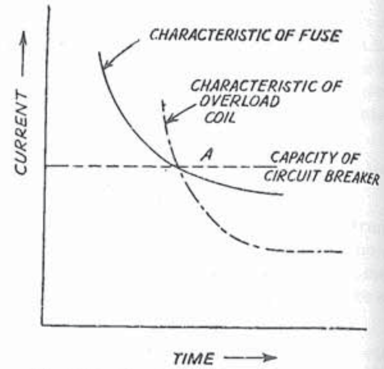

Fig. 14.11. Co-ordination between fuse and switching device, fuse on supply, circuit-breaker on load side.

	Type starting	Motor starting current X times full load current
(1)	Direct on line	7 to 8
(2)	Stator-rotor starter	1 to 2
(3)	Star-delta starter	2.5 to 3
(4)	Auto-transformer	2.5 to 4

14.14. DISCRIMINATION

When there are two or more protective equipments providing protection for the same circuit *e.g.* two or more fuses, a fuse and a circuit-breaker etc. there should be co-ordination between them. Discrimination concerns with correct operation of correct device. It means, the co-ordination between the fuse and the other equipment should be such that only the necessary device operates, the other remaining unaffected.

14.15. PROTECTION OF RADIAL LINES

Consider a simple case of two fuses *A* and *B* in series as shown in Fig. 14.12 power feed is from left to right.

A is called major fuse.

B is called minor fuse.

When fault occurs beyond *B*, only should operate and *A* should remain unaffected. This is called Proper Discrimination.

For proper discrimination in this case, the pre-arcing time of the major fuse *A* must be greater than the total operating time of minor fuse *B*.

Since the cut-off characteristic is difficult to be determined the manufacturer usually gives tables for selection of major and minor fuses base on the tests performed. Such tables are useful for selection of fuses.

As a guide rule, a ratio of 1.5 between the ratings of major and minor fuses is likely to give satisfactory discrimination upto short-circuit currents of 40 kA.

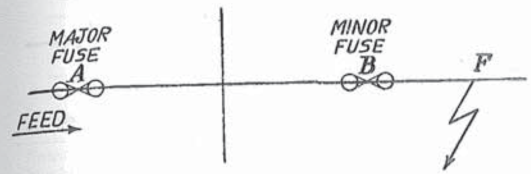

Fig. 14.12. (*a*) Co-ordination of fuses in radial circuit.

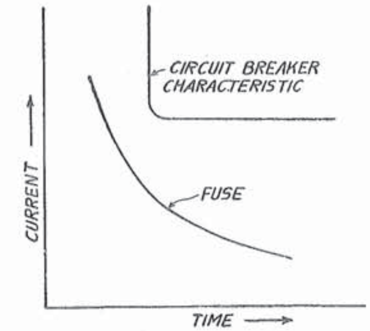

Fig. 14.12. (*b*) Fuse on load side and circuit-breaker on supply side co-ordination.

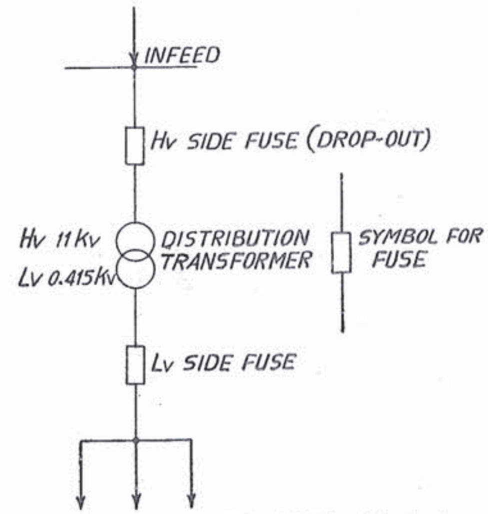

Fig. 14.12. (*c*) Co-ordination between fuses on HV and LV sides of distribution transformer.

Co-ordination of Fuse and C.B., Fuse on load side of the C.B.

In distribution boards, the circuit breakers is connected in the supply side [in-coming] : bus-bars and fuses are connected in load side. In such cases for faults on an out-going feeder, the fuse of that feeder should operate first. Circuit-breaker should be as a back-up. The characteristics of fuse and circuit-breaker should be matched such that the fuse takes less time for operation than circuit-breaker (Fig. 14.2 (*b*)]. Consider HV and LV fuses on corresponding side of a distribution transformer. Fuse on LV side should operate for faults on low voltage system beyond the LV fuse. Fuse on HV side should protect the transformer. It may be mentioned here that for economic considerations, no circuit-breaker and relays are generally provided for protection of distribution transformers below 500 kVA. The dropout fuses are used on HV side. (Refer Figs. 17.25 ; 17.26 ; 17.27).

14.16. PROTECTION OF MESHED FEEDERS WITH STEADY LOAD - BY HRC FUSES

In meshed-network fuse should have same rating may be provided for mesh connected circuit, though the short circuit current flowing to the fault may be different for each component circuit *e.g.* in Fig 14.13 when *I* total flows in Fuse I_1.

$$I_1 = I_2 + I_3 + I_4$$

If all fuses are of same rating.

I_1 will operate first, giving a satisfactory discrimination.

However in some cases the impedance of individual circuit may be quite different for example, Current 1-2 may be about 85 per cent of I-total. In such cases both fuses 1 and 2 may operate. In such cases the ratio $I_{COMPONENT}/I_{TOTAL}$ should be estimated and the fuses having accurate characteristics should be employed to discrimination.

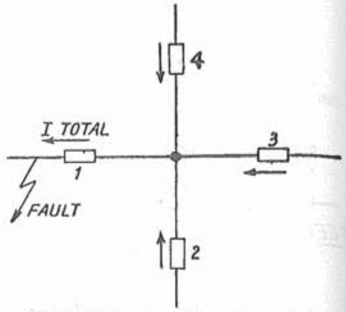

Fig. 14.13. Selection of fuse for meshed feeders.

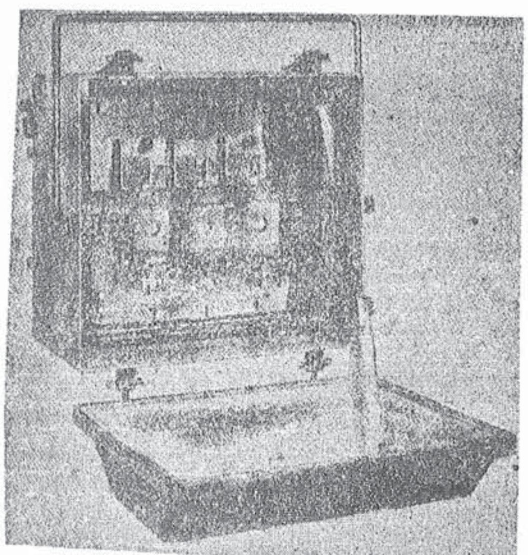

Fig. 14.14. Switch-fuse combination incorporating HRC fuses.
Courtesy : Easun Engineering Co. Ltd. India.

14.17. EQUIPMENT INCORPORATING FUSES

Switch-Fuse. The combination of switch and fuse is very widely used for voltage and medium voltages. It is a compact combination, generally metal enclosed. The ratings of switch fuse units are in the following range :

60 A, 100 A, 200 A, 400 A, 600 A, and 800 A.

They have been developed for making capacities (prospective) upto 46 kA. They can safely break, depending upon ratings, currents of the order of 3 times rated load current. Fig. 14.14 gives a view of an open switch-fuse unit. Both 3 pole and 4 pole units are available. Switch-fuse units can be installed on metal-clad switchgear.

14.18. HIGH VOLTAGE CURRENT LIMITING FUSES

Typical Applications

— Transformer protection (distribution system)
— High voltage motor protection
— Backup protection for circuit-breakers
— Capacitors protection
— Protection of underground distribution systems.

Range and Dimensions*

Rated voltage (Mean Max) kV	*Length (mm)*	*Diameter (mm)*	*Rated current Amp*
3/3.6	192	51	6.3 to 100
		76	125 to 150
3/3.6	292	51	6.3 to 100
		76	125 to 355
6/7.2	292	51	6.3 to 63
		76	50 to 164
10/12	1292	51	6.3 to 40
		76	31.5 to 100
20/24	442	51	6.3 to 40
		76	25 to 71

14.19. EXPULSION TYPE HIGH-VOLTAGE FUSE

Expulsion fuse comprises of hollow open ended tube made of synthetic resin-bonded paper. The fuse element is placed in the tube and the ends of the element are connected to suitable fittings at each end. The length of tube is generally longer than conventional enclosed fuses. The arc caused by breaking of fuse element causes decomposition of inner coating of the tube and the gases thus formed assist arc extinction. Such fuses are developed for 11 kV, 250 MVA and are used very commonly for termination of distribution transformers over-head lines, cable terminating with overhead line.

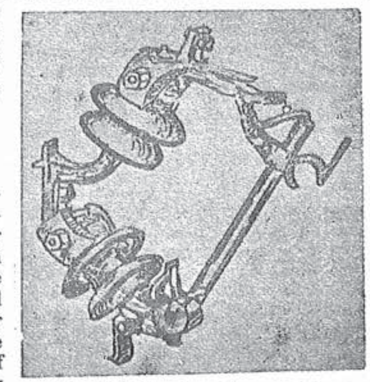

Fig. 14.15. Expulsion fuse-one pole in closed position.

14.20. DROP-OUT FUSE

The melting of the fuse causes dropping of fuse element under gravity about its lower support. Thereby additional isolation is obtained. Such fuses are used for protection of out-door transformers. When the linesman observes operation of the fuse, he can lift the complete tube from the hinge by means of a special insulator rod and brings down the tube for replacing the element. After replacing the element the tube is replaced in the hinge and the device is closed in a way similar to closing of Isolators. Drop-out-fuse-isolator combination is generally pole mounted.

* VDE 0670; IEC 282-1 ; DIN 43-625.

Striker Fuse

Striker is a mechanical device having enough force and displacement which can be used for closing signal/tripping/indicator circuits. A force of a few kg can be obtained.

14.21. TEST ON FUSE

Tests are necessary to provide the least characteristic and ratings of the fuse. All tests on fuses are type tests and at least three samples of each current rating are tested.

The tests conducted are the following :

(*i*) Rated current test, temperature rise.

(*ii*) Current time characteristics.

(*iii*) Determination of minimum fusing current. Determination of maximum non-fusing current.

(*iv*) Test of duty, *i.e.* satisfactory opening at rated voltages for current upto rupturing capacity.

(*v*) Cut-off characteristics.

(*vi*) Resistance measurements.

(*vii*) Various performance tests.

The manufacturer gives the ratings to the fuses on the basis of the Type Tests.

QUESTIONS

1. Compare 'HRC Fuse' and 'Circuit-Breaker' as interrupting devices.
2. What is the meaning of HRC fuse ? How does it operate ?
3. What is 'cut off ? How is it beneficial in protection of bus-bars ?
4. Explain the aspects to be considered in selecting a fuse.
5. What are the considerations in selecting fuse for
   (*a*) Motor protection (*b*) Transformer protection (*c*) Heaters (*d*) Lighting local.
6. Explain the following terms for HRC fuse :
   (*a*) Cut-off (*b*) Pre-arcing time (*c*) Arcing time.
7. Discuss the method of selecting the rating of HRC fuse for motor starter.
8. Define 'Normal Current' and 'Fusing Factor' for HRC fuse.
9. Write short notes on any two :
   — Drop-out fuse
   — Striker fuse
   — Characteristics of HRC fuse
   — Co-ordination of fuse with back-up breaker.
   — Co-ordination of circuit-breakers with back-up fuse.
   — Protection of low voltage induction motors.

15-A

Metal-enclosed Switchgear, Controlgear and Contactor

15.1. INTRODUCTION

In Conventional Outdoor Installations (rated 36 kV and above) the various substation equipment like circuit-breakers CTs, PTs, Isolator etc. are installed under open sky. Necessary clearances are provided between phases, phase and ground. The equipment for such outdoor switchgear are manufactured separately and are erected at site as per the switchyard layout.

For low voltages (below 1000 V) and medium high voltages (below 36 kV) the clearances required between phases, between phases and ground are relatively small. Hence all the components (busbars, circuit-breakers, fuses, CTs, PTs, Isolators, meters, instruments, Relays etc.) can be provided in/on *factory assembled metal enclosed units.* Such switchgear is called *Unit Type Metal Enclosed / Metal-clad switchgear.*

Circuit breakers rated below 1000 V and Switchgear rated below 1000 V are generally indoor type and are used at final load points. Unlike HV circuit-breakers, LV circuit-breakers may have to operate repeatedly at relatively low powers factor currents. Hence the design and specifications of low voltage switchgear and circuit-breakers is markedly different from HV Switchgear. *Controlgear* is used for switching and controlling power consuming device such as motors, furnaces, vehicles, *equipment, processes* etc. Contactors are used at switching devices for normal and overload currents. Short-circuit currents are interrupted by HRC fuses or circuit-breakers.

Control Panels are installed in control room. From control panel, the operator can know, what is happening in the plant. The operator can control, start, regulate or switch-off the main-circuits from control panels. The control panels are designed and assembled to customer's specifications.

15.2. TYPES OF SWITCHGEAR

Indoor switchgear is used for medium, low and high voltages. It is in a variety of forms these switchgear units and applications in industrial plants, production floors, workshops, power stations, sub-stations, electrical distribution networks. The indoor switchgear is used in industrial plants such as chemical, petrochemical cement, dairy, textile plants, floor mill etc. They are also used in power plants and in distribution sub-stations.

(1) Stationary cubicle type, in which the components occupy fixed positions.

(2) Draw-out type or truck type switchgear in which the circuit breaker is installed on a carriage which can be pulled out to provide isolation. (Ref. Fig. 15.2).

(3) Compound filled or SF_6 filled switchgear. In which certain enclosures are filled with dielectric liquid or the whole switchgear enclosure is filled with SF_6 gas. (Refer Chapter 7)

(4) Fuse switch units and ring mains.