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LOW VOLTAGE CIRCUIT BREAKERS (MCBs) AND COORDINATION OF FUSES IN DISTRIBUTION NETWORK

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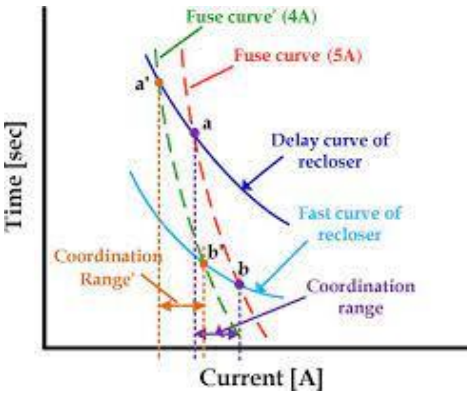
Abstract
Among the best-known electrical devices are fuses and they are hugely in use throughout the electrical design systems. Apart from its advantageous features, it has some drawbacks nowadays. A study in respect of the total clearing time for a new type of fuse based on controllable fusing concept is proposed. The validation of the new concept has been carried out experimentally using different current values. This controllable fusing method can be used within an over-current protection system especially in the semiconductors protection.

INTRODUCTION

A fuse is an over-current protective device with a circuit-opening fusible element that is heated and severed by the flow of over-current through it. For circuits operating at 600 volts and above, the fuses are referred to as power fuses. A fuse is used to protect circuits and equipment against overload and short circuits. The fundamental characteristics of a fuse element include a low melting point and high conductivity. Fuse operation is based on the heating effect of the current flowing through the element. During normal operation, heat is dissipated quickly into the surrounding air, and the element remains below its melting point. However, in the event of a fault in the circuit, the current will exceed the limiting value and cannot dissipate heat quickly enough, causing the element to melt and break the circuit.

Fuses have the following properties:

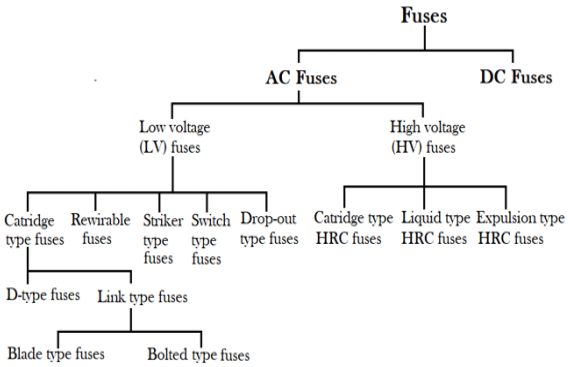
i. Inverse time current characteristics.
ii. Their ratings can range from a few milliamperes (mA) to several kiloamperes (kA).
iii. They come in various forms and shapes, depending on their application [1].



Fuses are typically categorized into two main groups:

Low-voltage fuses

High-voltage fuses
Low-voltage fuses can be further classified into two subcategories:
a. Semi-enclosed or Rewireable type
b. Cartridge type or totally enclosed



Low voltage Fuses

Rewirable Fuse (also known as Kit-Kat Fuse): These fuses are made from porcelain or ceramic insulators and are recognized as "kit-kat fuses." They represent one of the simplest and most cost-effective forms of fuses. They are particularly suitable for domestic wiring, such as in houses. Additionally, they are easy to replace and reuse when they blow out.

These fuses consist of a fuse carrier and a fuse base. The base is typically constructed from porcelain, while the fuse carrier employs lead, tinned copper, or aluminum elements.

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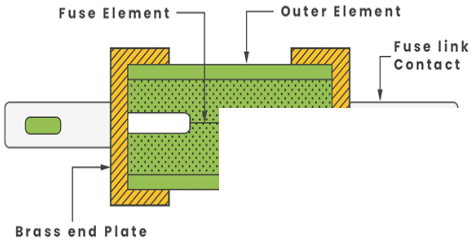


Ceramic fuse

Advantage

•Low cost
•Wire may be easily available.

Disadvantage

•Wrong size of wire fitted in fuse can cause wrong operation at high current which may be dangerous for the protected circuit and not adequate for electrical arc extinguish.

2. Current limiting Fuse – These are cartridge-type of fuse.

Advantage

•The wire is enclosed in a cartridge-type container.
•Un-matched fuse cannot be fitted since it comes with different size for different current.

•The deterioration of the fuse wire does not occur; it is also more reliable in operation.

3. High Rupturing Capacity (H.R.C) - It is a cartridge-type with silver element connected between two end contacts of a ceramic tube filled with a special quartz powder.

This type of fuse is very reliable in performance and does not deteriorate and has a high speed of operation [4].

Advantages of HRC fuses

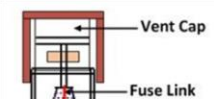
1. Cheap compared with other types of circuit interrupters.
2. Simple and easy to install
3. It has a reliable operation
4. High breaking capacity (HRC)
5. It operates fast and does not deteriorate with time
6. Consistent in performance

Disadvantages of HRC fuse

1. Before power supply can be restored the fuse has to be replaced.
2. The fuse is not selective or discriminating in operation.
3. It cannot be used for very high voltage protection. Classification of LV fuses.

In IEC standard, two classes of LV cartridge fuse are widely used:

1. For smaller installation and domestic, type gG/gL (for lighting circuit)
2. For industrial installations, type gM (for motor protection) or aM (for short-circuit currents only).



Examples of Low Voltage Fuses

High Voltage Fuses

High Voltage Fuses: These are same in characteristics and ıse but differs in size and shape. A typical example of a High Voltage Fuses is the Dropout fu[illegible].

Fuse Coordination Terms

Current rating: Is the nominal rated current in Amps marked on the fuse body that the fuse will carry continuously without deteriorating.

Fusing current: Is defined as the minimum value of current at which the fuse element or fuse wire melts. Its value will be more than the current rating of the element.

Fusing current depends upon various factors such as:

1. Types of material used
2. The cross sectional area

3. Length
4. Diameter of wire
5. Types of enclosure employed.

The approximate value for fusing current of a round wire is given as:

$$\mathbf{I = K\sqrt{d^3}}$$

Where:

I = fusing current

k = constant depending upon the material of the wire

d = diameter of the wire in inches.

For semi enclosed or rewire-able fuse which employs copper wire as the fuse element, fusing factor is equal to 1.9 - 2.0

For the standard duty cartridge fuses, the fusing factor is equal to 1.2 -1.45.

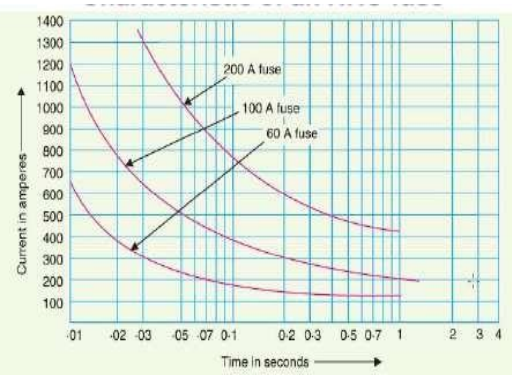
Breaking capacity: is the maximum current that can be safely interrupted by the fuse. Some fuses are designated as high rupture capacity (HRC).

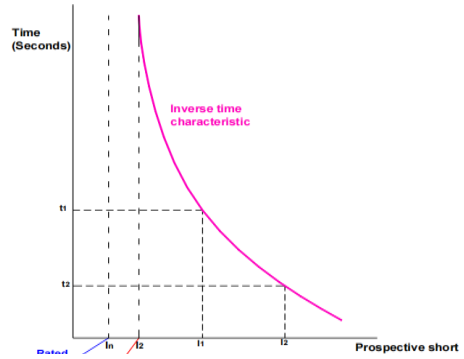
Voltage rating: this indicates the maximum circuit voltage in which the fuse can be used [3].

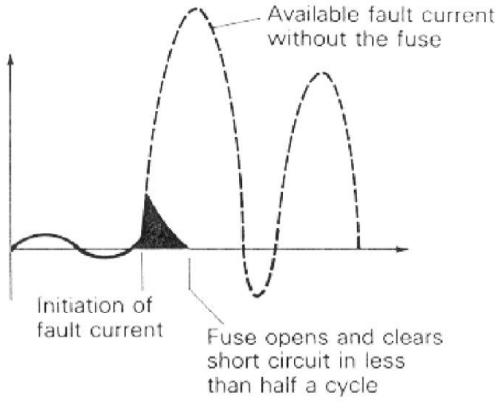
Basic Characteristics Of Fuses

1. A fuse consist of one or more silver wire or ribbon element called fusible element
2. The fusible element should melt instantaneously when high currents flows through it disconnecting the protected circuit.

The time current characteristic curves.



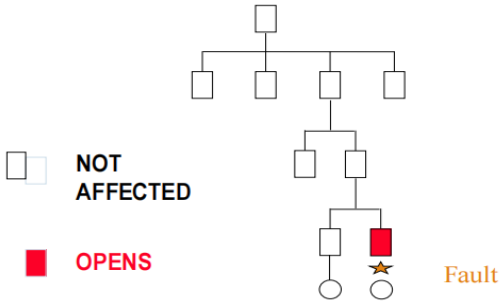




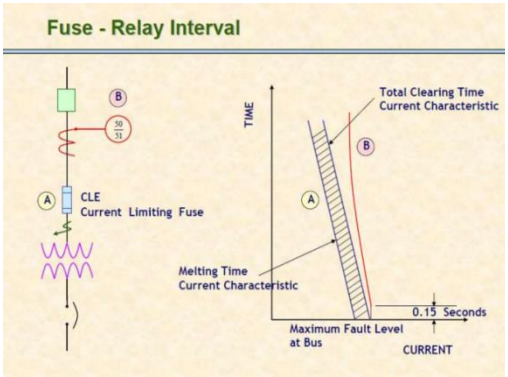
Coordination

- Coordination is the proper selectionof series connected over-current protective devices which will isolate only that portion of an electrical system which has been overloaded or faulted.
- In potential over-current condition, Series connected fuses are said to be selective if the downstream fuse will clear all faults before the upstream fuse opens or is damaged.

Selective Coordination



Typically de-rated by 25% for operation at 25ºC to avoid nuisance blowing.
2. Overload current and time interval in which the fuse must open.
3. Application voltage (AC or DC Voltage).
4. Inrush currents, surge currents, pulses, start-up currents characteristics.
5. Ambient temperature.
6. Applicable standards agency required.
7. Considerations: Reduce installation cost, ease of removal, mounting type/form factor etc [5].

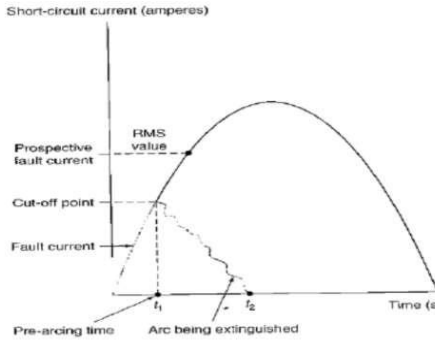


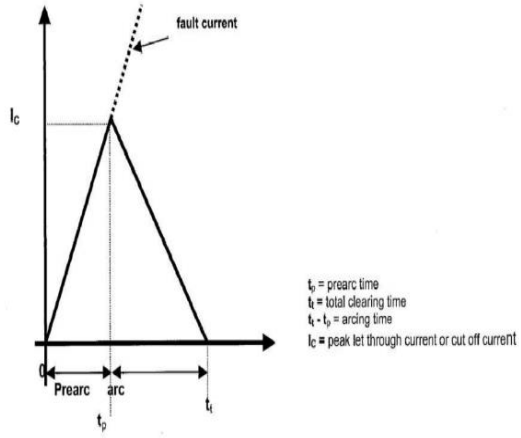
Areas of Application of Fuse

In the operating trade, fuse co-ordination is applied in:

1. *Station DC systems* which supply controls, relays, emergency lighting circuits etc
2. *Voltage transformation secondary circuits* which supply relays, voltage regulators etc.
3. *Station service AC circuits* which supply motors, lighting, heaters etc.
4. *Radial or loop distribution circuits.*

Short circuit Current Process





The fuse installed to protect a circuit against short circuit current must be able to break the current at $I_2\ t_1$.
For any conductor, its melting time depends on the $I_2\ t_1$ factor.
This factor can be calculated by:

1. **For copper conductors**

$$I^2\,t = 11.5\ x\ 10^4 A^2\ log_{10}\ \frac{273 + \theta_m}{273 + \theta_o}$$

For Aluminum conductors

$$I^2\,t = 5.2\ x\ 10^4 A^2\ log_{10}\ \frac{273 + \theta_m}{273 + \theta_o}$$

W
I =
t = Duration of the short circuit (s)
A = cross - sectional area of the conductor (mm^2)
$^0\theta$= Initial temperature of the conductor (^oC).
θm =Final temperature of the conductor (^oC)

Low Voltage Circuit breaker

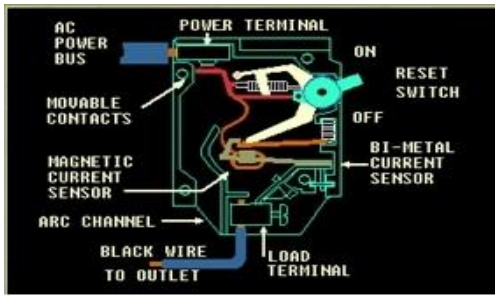
A circuit breaker (CB) is an automatically switchable device that protects an electrical circuit from overload or short circuit.
The main advantage is when operates can be reset. It has varying sizes and current rating.

Examples of Low Voltage Circuit Breakers

Types of Low Voltage Circuit Breaker

1. Magnetic circuit breakers:

Which uses a solenoid (electromagnet) and pulling force increases with the current.



The function of the trip unit or the solenoid is to create a magnetic field. This happens as current passes through trip unit/solenoid, due to the changing magnetic flux, magnetism will develop in it, resulting in the creation of a magnetic field around the solenoid.
The closed contacts are held, in case of **overload or short-circuit,** the current in the solenoid increases beyond the rating of the CB, the solenoid will pull and releases the latch which then allows the contacts to open by spring action [4].

Areas of Application

Magnetic circuit breakers are extensively used across electrical designs as a result of their reliability and speed:

a. *Automotive Industry:* These breakers are applied in vehicles for the protection of electrical systems from voltage surges.
b. *Residential and Commercial Buildings:* Used in control panels to protect short circuits and over-currents.
c. *Industrial Applications:* It offers protection for:machinery, industrial equipment.

2. **Thermal-magnetic circuit breakers** Thermal breakers use a bimetallic strip, which heats and bends with increased current, and release the latch. This type is commonly used with motor control circuits.

For applications of CB at low voltage (less than 1000 V) are: -

1. *Miniature Circuit Breaker (MCB):*

MCB rated current not more than 100 A. MCB is used for1-phase and 3-phase applications, rated current: International Standard IEC (at ambient air temperature of 30 °C) are: (6,10,13,16,20,25,32,40,50,63,80 and 100) Ampere.

Note: -The circuit breaker is labeled with the rated current in ampere, but without the unit symbol "A".

Instead, the ampere figure is preceded by a letter "B", "C", "D', "K" or "Z" that indicates the instantaneous tripping current (the minimum value of current that causes the circuit-breaker to trip) without intentional time delay (i.e., in less than 100 ms).

2. *Molded Case Circuit Breakers (MCCB)*

Thermal or thermal-magnetic operation. Tripping current may be adjustable. Mainly is used for 3-phase circuits and for currents larger than 100A and up to 1600A. Mainly is used in industrial applications to protect cables and equipment.

Types of these C. Bs are shown below:

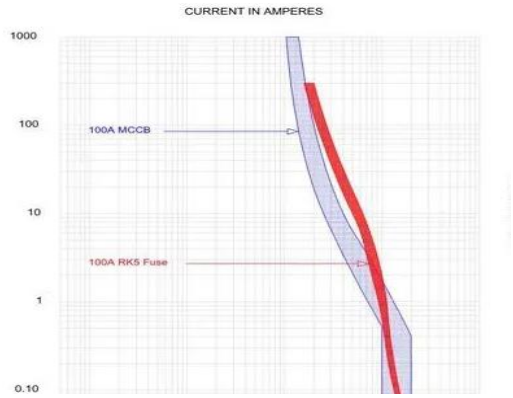
3. Other types of circuit breakers – These are breakers for protections against earth faults to trip an over-current device such as:

1. *Residual Current Device (RCD) or Residual Current Circuit Breaker (RCCB):* - These CBs disconnects a circuit when it detects that the electric current is not balanced between the phase conductor and the neutral conductor. Its circuit is made such that at every instance it compares the value of incoming and outgoing circuit current, whenever it is not equal, the residual current which is basically the difference between the two currents actuates the circuit to trip/switch off.

2. *Residual Circuit Breaker with Over-current protection (RCBO)*: - Combines the functions of an RCD and an MCB in one package.

3. *Earth leakage circuit breaker (ELCB)*: -This type of CB detects earth current directly rather than detecting imbalance.

The only difference between Residual current CB and Earth leakage CB is their connections. RCCB does not require earth connection rather it monitors only the live and neutral conductors. In addition, RCCB detects current flow to the earth even in an equipment without earthing.



Generic fuse and circuit breaker time current curves

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