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Descriptive Analysis of Modern Circuit Breakers and over-current Protection Devices

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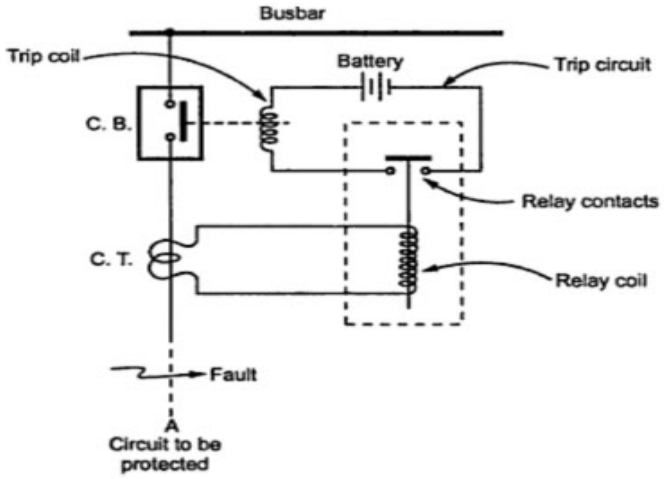
Abstract
Modern world with an extra exponential growth rate is made possible due to countless science innovations, electricity is one of them. Engineers have developed various well organized distribution systems for electrical power distribution. But without safety precautions these easy power system can leads to hazards, such as fire caused by short circuits. Annual damage due to electrically caused fire is about $643.9 million per annum in an analysis of National Fire Protection Association. Various safety precautions were Fuses of various type, but modern methods involves Circuit Breakers. This paper analysis the various types of modern circuit breakers and mechanism behind them.

Keywords: Circuit Breakers**,** Over Current Device, Siemen Circuit, Air Blast & SF6 Breakers, Thermal Magnetic Overcurrent.

1. Introduction



The circuit breaker is the special device which does all the required switching operations during current carrying condition. The modern power system deals with huge power network and huge numbers of associated electrical equipment. During short circuit fault or any other types of electrical fault these equipment as well as the power network suffer a high stress of fault current in them which may damage the equipment and networks permanently. For saving these equipment and the power networks the fault current should be cleared from the system as quickly as possible. Again after the fault is cleared, the system must come to its normal working condition as soon as possible for supplying reliable quality power to the receiving ends. In addition to that for proper controlling of power system, different switching operations are required to be performed. So for timely disconnecting and reconnecting different parts of power system network for protection and control, there must be some special type of switching devices which can be operated safely under huge current carrying condition. During interruption of huge current, there would be large arcing in between switching contacts, so care should be taken to quench these arcs in circuit breaker in safe manner.

2. Operating Mechanisms

The circuit breaker mainly consists of fixed contacts and moving contacts. In normal "on" condition of circuit breaker, these two contacts are physically connected to each other due to

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applied mechanical pressure on the moving contacts. There is an arrangement stored potential energy in the operating mechanism of circuit breaker which is realized if switching signal given to the breaker. The potential energy can be stored in the circuit breaker by different ways like by deforming metal spring, by compressed air, or by hydraulic pressure. But whatever the source of potential energy, it must be released during operation. Release of potential energy coils (tripping coils and close coil), whenever these coils are energized by switching pulse, and the plunger inside them displaced. This operating coil plunger is typically attached to the operating mechanism of circuit breaker, as a result the mechanically stored potential energy in the breaker mechanism is released in forms of kinetic energy, which makes the moving contact to move as these moving contacts mechanically attached through a gear lever arrangement with the operating mechanism. After a cycle of operation of circuit breaker the total stored energy is released and hence the potential energy again stored in the operating mechanism of circuit breaker by means of spring charging motor or air compressor or by any other means.

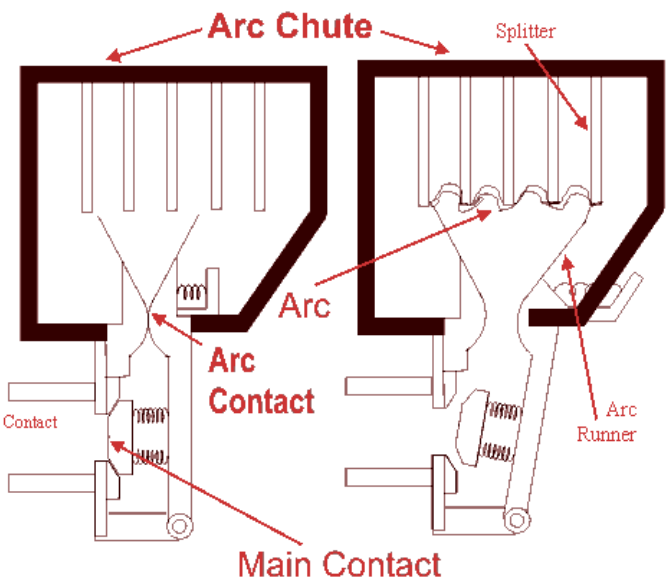
3. Circuit Breaker Classification

3.1 Oil circuit breaker

In oil circuit breaker the fixed contact and moving contact are immerged inside the insulating oil. Whenever there is a separation of current carrying contacts in the oil, the arc in circuit breaker is initialized at the moment of separation of contacts, and due to this arc the oil is vaporized and decomposed in mostly hydrogen gas and ultimately creates a hydrogen bubble around the arc. This highly compressed gas bubble around the arc prevents re-striking of the arc after current reaches zero crossing of the cycle.

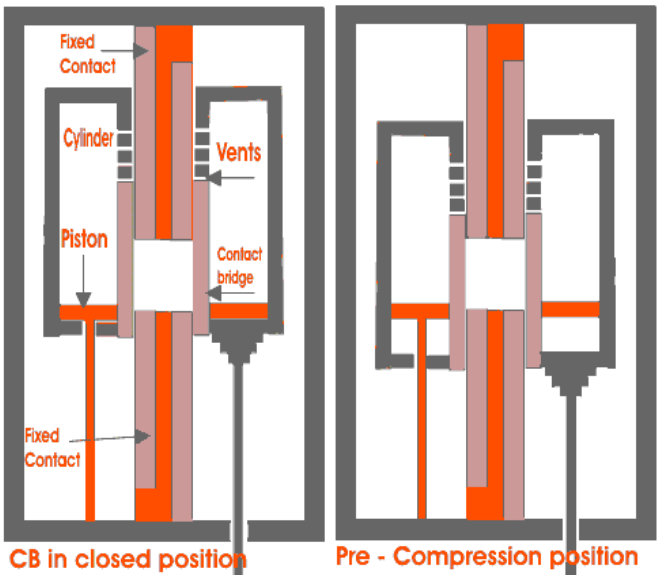
3.2 Air circuit breaker

It works by prevent the reestablishment of arcing after current zero by creating a situation where in the contact gap will withstand the system recovery voltage. It increases the arc voltage by cooling the arc plasma. As the temperature of arc plasma is decreased, the mobility of the particle in arc plasma is reduced, hence more voltage gradient is required to maintain the arc. It increase the arc voltage by lengthening the arc path. As the length of arc path is increased, the resistance of the path is increased, and hence to maintain the same arc current more voltage is required to be applied across the arc path. That means arc voltage is increased. By Splitting up the arc into a number of series arcs also increases the arc voltage.



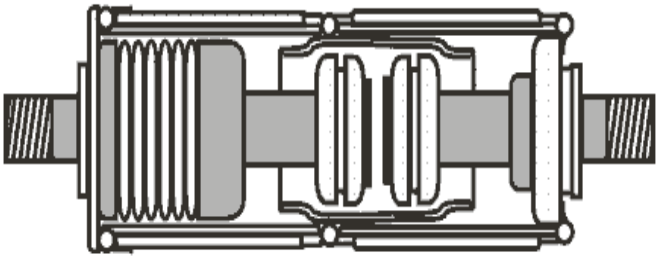
3.3 SF_6 circuit breaker

In this circuit breaker the current carrying contacts operate in Sulphur hexafluoride or SF_6 gas. SF_6 has excellent insulating property. SF_6 has high electro-negativity. That means it has high affinity of absorbing free electron. Whenever a free electron collides with the SF_6 gas molecule, it is absorbed by that gas molecule and forms a negative ion. These negative ions obviously much heavier than a free electron and therefore over all mobility of the charged particle in the SF_6 gas is much less as compared other common gases. We know that mobility of charged particle is majorly responsible for conducting current through a gas.



3.4 Vacuum circuit breaker

A vacuum circuit breaker is such kind of circuit breaker where the arc quenching takes place in vacuum. The technology is suitable for mainly medium voltage application. For higher voltage vacuum technology has been developed but not commercially viable. The operation of opening and closing of current carrying contacts and associated arc interruption take place in a vacuum chamber in the breaker which is called vacuum interrupter. The vacuum interrupter consists of a steel arc chamber in the center symmetrically arranged ceramic insulators. The vacuum pressure inside a vacuum interrupter is normally maintained at 10^{-6} bar.



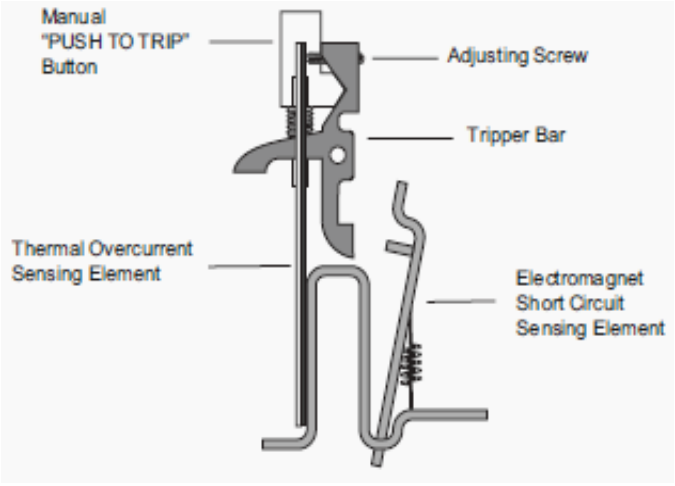
3.5 Others Types Includes

- Spring operated circuit breaker;
- Pneumatic circuit breaker;
- Hydraulic circuit breaker.

4. Thermal-Magnetic Circuit Breakers

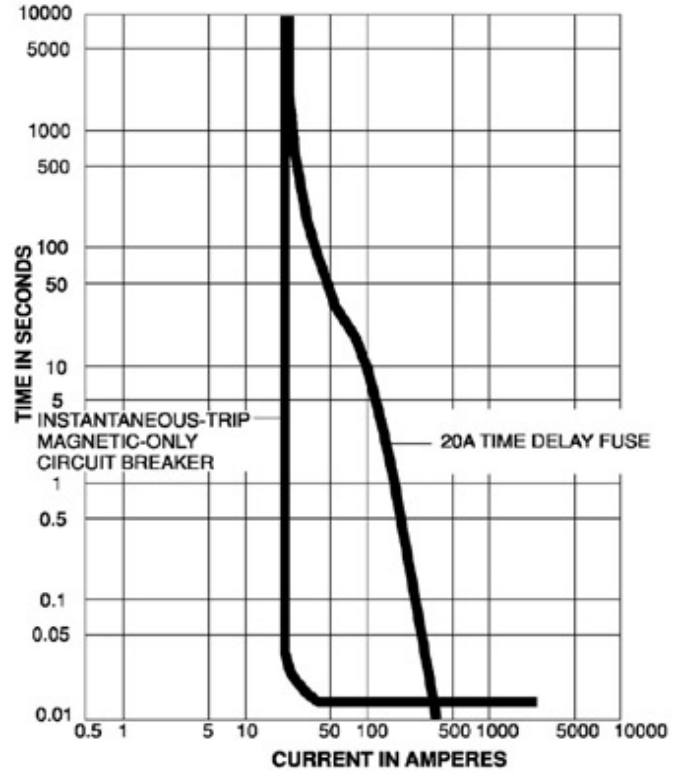
Ideally suited to protect against overcurrent and short circuit of equipment in telecommunications, process control and other industrial applications where sophisticated equipment

requires a high precision performance. It consist of a latching type bimetal is combined with a magnetic coil to ensure protection and genuine physical contact isolation. This provides the joint benefits of delayed operation for low level overcurrent protection and fast magnetic action of higher value short circuits, disconnecting the faulty circuit within milliseconds.



These circuit breakers utilize two techniques to detect electrical faults. The first includes an electromagnet that is sensitive to large surges in electrical currents. Electrical surges can cause short-circuiting, which is bad for all electrical appliances. The electromagnet responds instantly to such dangerous situations by shutting off the flow of electricity so that your appliances are protected. The second technique used in these common household circuit breakers is a thermal bimetallic strip that responds to prolonged low-level electrical surges or overloads of electrical currents. Excessive electrical currents will heat the bimetallic strip enough to bend it towards a trip bar that turns the circuit off.

5. Circuit Breaker Characteristic



Above characteristic Curve shows the time-current characteristics of the most common of these types of overcurrent devices for a standard 20-ampere (A) device. For instantaneously protection, a magnetic-only circuit breaker unlatches and trips (opens the power circuit) immediately on reaching the preset ampere value, as does the thermal-magnetic-trip circuit breaker. However, the instantaneous-trip setting on a thermal-magnetic-trip circuit breaker is normally set at a higher ampere rating than would be a magnetic-only breaker because the thermal element of the thermal-magnetic-trip circuit breaker adequately provides protection within the ampere range of maximum safe operating current. The thermal-magnetic-trip breaker curve and the curve of the time-delay fuse are very similar to each other because the thermal-magnetic-trip breaker curve is designed to mimic the curve of the time-delay fuse.

6. Industrial Applications

6.1 As Plug-in Circuit Breaker

This kind of breaker is named as the plug-in breaker for switchboards. This can be connected to the main busbar of the switchboard directly to assist with the standardization design, the safety, the enlargement of circuits, and the time saving of power outage at the maintenance of an equipment.

6.2 Fire Resistance Breakers

This kind of breaker is named as a fire resistance breaker for using within the emergency power switchboards.

6.3 Circuit Breakers for Special Purpose

These breakers include various types. In case of depending on a kind and a characteristic of the load, no standard MCCBs or ELCBs are used.

6.4 DSN Switches

As a result of making a DSN switch by omitting the overcurrent tripping device of a MCCB, it is used as a switching device having high operating capacities.

6.5 For Use in Particular Environment

The breaker is used in the varied environment. For using in the environment different from standard conditions, several type of breakers are provided to each special environment.

7. Acknowledgment

I wish to thank my mentors and college for supporting me in completing my work on Circuit Breakers Analysis and Modern Use. I also wish to thank my parents for providing me with assets that helped me completing research regarding this study.

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