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Study and Analysis of Different Types of Circuit Breaker

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Abstract: *Circuit breakers play an important role in an electrical system performance in terms of system safety, control, maintenance and cost. In some cases, the conventional mechanical circuit breakers (MCB) may be too slow for the electrical network to operate within the desired safety limits. Besides their other limitations, the MCB also forces the network elements to be rated much higher. The uses of power semiconductor devices to overcome some of their limitations are discussed in this paper. These usages are in terms of solid state circuit breaker (SCB) and hybrid circuit breaker (HCB) concepts. This paper summarizes and reviews the various circuits of SCB and HCB available in the literature. The relevant simulation results for some example circuits have also been presented in this paper. This study will provide a useful framework and point of reference for the future development of HCB and SCB technologies. The breaker can not only open a circuit in response to a current spike, but can also react to a sustained moderate current draw, just above its rated current. Operation of the circuit breaker is simple, but utilizes complex mechanisms. Essentially there are to main internal mechanisms; the trigger and the switch. The trigger is the device that senses the abnormal current load. A sharp spike in current will cause a magnetic field to form in the trigger, releasing the switch. A slightly elevated, but more constant current draw through the breaker will cause the bi-metal composition of the trigger mechanism to deflect in an arc like manner, which is also capable of releasing the switch. The circuit breaker's best point is that the device is effective and compact. The switch can be set to open or closed from the outside of the breaker's case, but can only be set to the tripped position internally, as a results of the trigger mechanism. Once the breaker has been tripped internally, it must be reset externally by switching it off, and then back on. The features enable the breaker to do several jobs at once, eliminating the need for multiple elements in the circuit. For example, it provides the user with an easily assessable on/off switch, fault protection against current spike, and fault protection against heavy current draw. On the other hand it is not 100% effective and must also be manually reset which can be problematic if it is dark and no lights are available with which to see the fuse box. Another bad point is that the circuit breaker has many moving parts, which complicates construction. Simpler or fewer parts might drive cost down and make manufacturing more efficient.*

Keywords: Circuit Breaker, Control, Mechanism, Tripped Position

I. Introduction

An electrical circuit breaker is a switching device which can be operated manually and automatically for controlling and protecting an electrical power system. As the modern power system deals with huge currents, special attention should be given during designing of a circuit breaker to ensure it is able to safely interrupt the arc produced during the closing of a circuit breaker. This was the basic definition of circuit breaker.

Many kind of abnormal conditions are there which exist in our electrical system that have the potential to damage the circuit & its components. These conditions are defined as 'FAULTS'. Further, fault is categorized as mentioned below:

- Overload
- Short Circuit
- Earth

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In order to keep our electrical components & system safe, it is mandatory to protect our system against the above faults. This leads to the need of circuit breaker.

Circuit Breakers are quite unique devices in the sense that they are mechanical devices connected to electrical system. Since the time when first electrical systems were utilized, there is always a need for a mechanism or a device that can initiate and interrupt the flow of electric current. In power system, it is often necessary to switch on or off various electrical devices and circuits like generating plants, transmission line, distribution systems, etc. either in normal operating conditions or under abnormal situations. Originally, this task is performed by a switch and a fuse connected in series with the electrical circuit. The main disadvantage of such a setup is that if a fuse is blown, it is often time consuming to replace one and restore the power supply. The other and main disadvantage is that a fuse cannot interrupt heavy fault currents. These limitations restricted the usage of switch and fuse combination to small voltage and small capacity circuits. But in case of high voltage and large current system, a more dependable way than using a switch and fuse is desired. This is achieved with the help of Circuit Breakers.

II. Different Types of Circuit Breakers

Circuit Breaker are mainly divided in the following types:

- High Voltage Circuit Breaker
- Low Voltage Circuit Breaker

These are

High Voltage Circuit Breakers

SR. NO.	TYPES	VOLTAGE LEVEL	CURRENT RATING
1.	Vaccum Circuit Breaker (VCB)	66KV	4000 AMPS
2.	Minimum Oil Volume Circuit Breaker (MVOCB)	66KV	6300 AMPS
3.	Bulk Oil Volume Circuit Breaker (BVOCB)	66KV	6300 AMPS
4.	Air Circuit Breaker (ACB)	690KV	4000 AMPS
5.	Air Blast Circuit Breaker (ABCB)	735KV	6300 AMPS
6.	Sulphur Hexafluoride Breaker (SF6)	1200KV	6300 AMPS

Low Voltage Circuit Breakers

SR. NO.	TYPES	VOLTAGE LEVEL	CURRENT RATING
1.	Miniature Circuit Breaker (MCB)	440 V	100 AMPS
2.	Moulded Case Circuit Breaker (MCCB)	440 V	630 AMPS
3.	Residual Current Circuit Breaker (RCCB)	440 V	63A, 30mA
4.	Earth Leakage Circuit Breaker (ELCB)	440 V	63A, 300mA
5.	Motor Protection Circuit Breaker (MPCB)	690 V	120 AMPS

2.1 Miniature Circuit Breaker (MCB) Circuit Diagram and It's Working

Most MCB designs are of single pole construction for use in single-phase circuits. The complete system is housed within a plastic moulding and it is made of flame-retardant high strength plastic. It results high melting point, high dielectric strength, low water absorption at saturation, low coefficient of linear thermal expansion, and high deflection temperature under load. MCBs are fitted with arc chute stack consisting of various arc chutes (metal plates) which are held by the position by an insulating material.

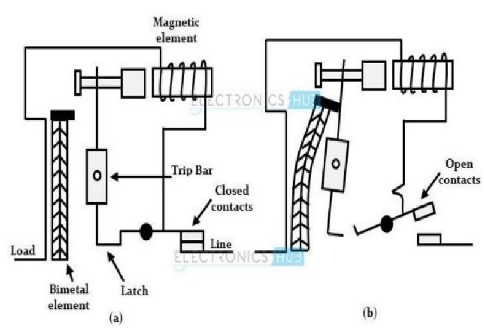

Figure 1: Circuit Diagram of Miniature Circuit Breaker (MCB)

A low resistance bimetal is used for high current MCBs and a higher resistance bimetal is used for low current MCBs. A heater may be incorporated around the bimetal to generate the sufficient heat for very low current MCBs. The magnetic tripping mechanism consists of a coil which is wounded around a tube. This tube has a spring loaded slug and the slug movement operate the tripping mechanism. The magnetic field generated by the coil during the high fault current overcomes the spring force holding the slug in position. So the movement of slug actuates the tripping mechanism. The coil is made up of thin wire with many turns for low rating MCBs and a thicker wire with fewer turns for higher heating MCBs. Depending on the required characteristics, the magnetic tripping is set by the manufacturer.

2.2 Moulded Case Circuit Breaker (MCCB) Circuit Diagram and It's Working

The MCCB working principle is simple. Let us take three different fault conditions such as Overload, short circuit, and earth fault.

A. Overload Trip

A flow of current that exceeds the rated current with predefined time limit such a fault is called overload. Actually, it is not a fault, it is a condition. The bimetallic contact involves in overload operation of the breaker; under the normal condition, it allows the current flow. If the current flow exceeds the predefined value, then it will get bend and finally, it will engage the tripping mechanism. The trip mechanism opens the breaker.

Also, bimetallic contact will not allow the breaker to reset instantly. Since it takes some time to reach its original state. Over Load, the setting will be 80% to 100% of the full load current and the dame depending upon your load demand. But the time delay will be 10 to 15secs.

B. Short Circuit / Instantaneous / Earth Fault Trip

An electromagnetic coil involves short circuit/instantaneous/earth fault protection of the breaker. Under normal conditions, the CT generates less current hence the electromagnetic field is generated by the coil is not enough to pull the plunger. Therefore, the breaker does not trip. During short circuit or instantaneous fault conditions, the CT generates high current and the coil creates a strong magnetic field. Hence the coil pulls the plunger and it will trip the circuit instantly. The typical setting of a short circuit will be 2.5Times of the overload setting and the time delay will be 0.2 to 0.5 secs. The typical setting of an instantaneous fault will be 4 Times of the overload setting and the time delay will be zero.

C. Earth Fault Leakage Trip

Earth leakage protection is quite different from other protection. It a tailor-made one. It requires additional CT which has to be installed in the moulded case circuit breaker. The output of the current transformer will be connected in star. Under normal conditions, the current flow through the star's neural point will be zero. if the leakage found in the line means, the same will be sensed at the star terminal. if the leakage flow is higher than the allowable limit means, the MCCB trip the circuit.

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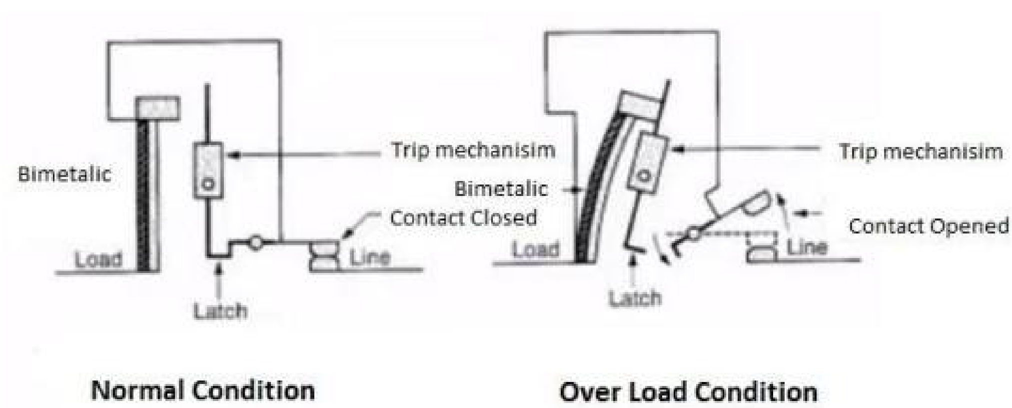

Figure 2: Circuit Diagram of MCCB

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III. Residual Current Circuit Breaker (RCCB) Circuit Diagram and it's Working

The Residual Current Circuit Breaker or RCCB is an electrical protective device that gives protection against earth fault or ground fault or earth leakage. An RCCB can give protection against electrical shock. Earth fault or earth leakage fault in a power system can cause excess heating, more power consumption, unhealthy system, burning or fire, etc. So, the protection against earth leakage is very important. RCCB is the device that can sense the leakage current in the power system and can interrupt the circuit.

The working principle of the RCCB is very simple. When there is no fault in the circuit, the phase and neutral will carry an equal current. As the equal current flows in both phase and neutral coil, they will produce the same amount of magnetic flux and as they are wound in the opposite direction to each other, the resultant magnetic flux will be zero. As the resultant flux is zero, there will be no current flow in the sensing coil or to the relay.

When earth leakage or earth fault occurs, the current will start flowing from the phase to the ground. So, an unbalanced starts current flowing through the phase and neutral. As, the unbalance current flows, the magnetic flux produced by the phase and neutral coil also be unequal. So a resultant flux will produce which cause to produce an emf in the sensing coil. As the sensing coil is in a closed circuit with the relay, a current will start flowing through the sensing coil and relay. The relay will send a signal to the circuit breaker to break the contact to disconnect the power supply or trip the RCCB.

The main function of an RCCB is to give protection against leakage current fault. It trips or turned off the power supply when a leakage current fault such as earth leakage, electric shock, etc occurs. Remember that an RCCB can not give protection against Short Circuit and Overload Fault. The RCCB can sense leakage current only, it can not sense the high current flow or short circuit current. So, an MCB is always used with an RCCB.

There are two types of RCCBs, a 2 Pole RCCB and a 4 Pole RCCB

Figure 3: Figure of RCCB

IV: Earth Leakage Circuit Breaker (ELCB) Circuit Diagram and it's Working

An Earth-leakage circuit breaker (ELCB) is a safety device used in electrical installations (both residential and commercial) with high Earth impedance to prevent electric shocks. It detects small stray voltages on the metal enclosures of electrical equipment, and interrupts the circuit if a dangerous voltage is detected.

ELCBs help detect current leaks and insulation failures in the electrical circuits that would cause electrical shocks to anyone coming into contact with the circuit. The ELCB consists of an operating coil and a trip mechanism which in turn trips the supply to the circuit. It will operate if a live terminal or conductor is touched by an earthed object or person provided the leakage current exceeds the rated operating current of the ELCB.

One of the terminals of the relay coil is directly connected to the earth while the other terminal is connected to the body of the equipment. The coil can sense the voltage difference between the earth & the body of the equipment.

If the live wire breaks or its insulation fails & comes in contact with the body of the equipment, a voltage difference appears across the terminals of the coil. As a result, the current starts to flow through the coil & it is energized. The relay starts to generate electromagnetic force. When the current exceeds a certain limit, the relay produces sufficient force to pull the latch. By doing so, the latch break opens the contacts & disconnects the power supply to the equipment & prevents electrical shock.

There are two types of Earth Leakage Circuit Breaker (ELCB)

- Voltage Operated ELCB
- Current Operated ELCB

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A voltage-operated ELCB device is used to detect a voltage to choose the Earth leakage. A single-phase voltage ELCB includes 6-terminals namely line in, line out, neutral in, neutral out, Earth, and fault. The metal body of the load is associated with the fault terminal of the Earth Leakage Circuit Breaker (ELCB) & the Earth terminal is associated with the ground. For usual working, the voltage across the trip coil is '0', as the Load's body is isolated from the supply line.

RCCB is the generally used ELCB and it comprises of a three winding transformer, that has two primary windings and also one secondary winding. Neutral & line wires work as the two main windings. A wire-wound coil is the minor winding. The flow of current through the minor winding is "0" in the stable condition. In this condition, the flux owed to the current over the phase wire will be deactivated by the current through the neutral wire, meanwhile the current, that flows from the phase will be refunded to the neutral.

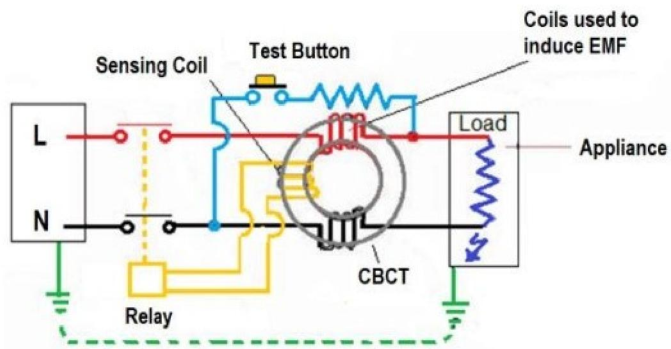

Figure 4: Circuit Diagram of ELCB

V. Difference between MCB and MCCB, RCCB and ELCB

SR. NO	PARAMETERS	MCB	MCCB
1	Abbreviation	Miniature Circuit Breaker	Moulded Case Circuit Breaker
2	Defination	Type of electrical switch which protects the circuit from overload or short circuit	Type of device which protects the equipment from over temperature and fault current.
3	Tripping circuit	Fixed	Movable
4	Pole	Available in single, double, three & four pole versions	Available in single, double, three & four pole versions
4	Rating current	100 amp	10-200amp
5	Interrupting current	1800amp	10k-200k amp
6	Remote on/off	Not possible	Possible
7	Types	B,C,D,K,Z types MCB	B,C,D,K,Z types MCCB
8	Phases	1 ph - 3ph	3ph
9	Short circuit time(mS)	About 3mS	About 9mS
10	Applications	In home wiring i.e lighting circuit and for low loads	In heavy current circuit devices
11	Uses	For domestic purpose like home wiring	For commercial and industrial use

5.1 Difference between RCCB and ELCB

SR.NO	PARAMETERS	RCCB	ELCB
1	Abbrevation	Residual current circuit breaker	Earth leakage circuit breaker
2	Definition	This circuit breaker is specified for the current functioned device	This circuit breaker is mainly specified for voltage function earth leakage devices
3	Operation	Current operate device	Voltage operate device
4	Nuisance tripping	High	Less
5	Poles	2 pole & 4 pole	2 pole & 4 pole
6	Current rating	25 Amp – 63 Amp	16 Amp – 63 Amp
7	Interupting current	30mA -300mA	30 ma – 300ma
8	Remote on/off	Possible	Possible
9	Phases	3 phase	3 phase
10	Protection	Earth leakage current	Earth leakage current
11	Connection	It is only connected to phase and neutral wire	Connected to phase, neutral as well as earth wire
12	Application	Almost all wiring system used RCCB nowadays	Not recommended, replace it with RCCB

VI. Conclusion

Several types of circuit breaker had been reviewed as the selected protection device. Form the reviewed that has been done through this paper, the observation result of the circuit breaker application, there are several conclusion that can be made. First, each circuit breaker has its categories within the low, medium, and high voltage that are widely used in power system protection. Second, each type of transmission fault have their effective circuit breaker to eliminate the fault with its configuration depends on the fault characteristic. Third, the fault does not have it fixed parameter and fixed causes. The natural phenomenon is not the only fault factor, but it has several another factor that can causes fault such as human mistakes, instrument error, and installation and setting error. Last, substation is needed to control the voltage transmitted at high voltage from the generating station. Protection system is also required in a substation.

Separate circuit breakers must never be used for live and neutral, because if the neutral is disconnected while the live conductor stays connected, a very dangerous condition arises: the circuit appears de-energized (appliances don't work), but wires remain live and some residual-current devices (RCDs) may not trip if someone touches the live wire (because some RCDs need power to trip). This is why only common trip breakers must be used when neutral wire switching is needed. To provide simultaneous breaking on multiple circuits from a fault on any one, circuit breakers may be made as a ganged assembly. This is a very common requirement for 3 phase systems, where breaking may be either 3 or 4 pole (solid or switched neutral). Some makers make ganging kits to allow groups of single phase breakers to be interlinked as required.

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