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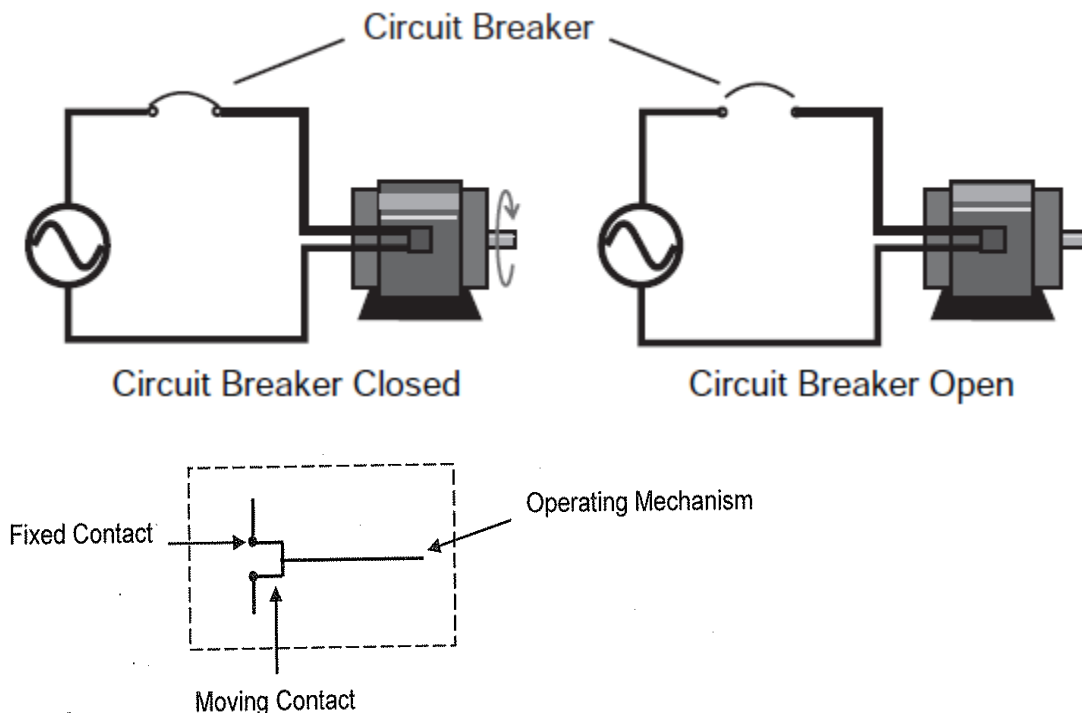
# UNIT-4

## 3.1 Circuit Breaker

Circuit breakers provide a manual means of energizing and de-energizing a circuit. Unlike fuses, which must be replaced when they open, a circuit breaker can be reset once the overcurrent condition has been corrected. Pushing the handle to the “OFF” position then back to the “ON” position restores the circuit. If a circuit reopens upon reset to the “ON” position, the circuit should be checked by a qualified electrician.

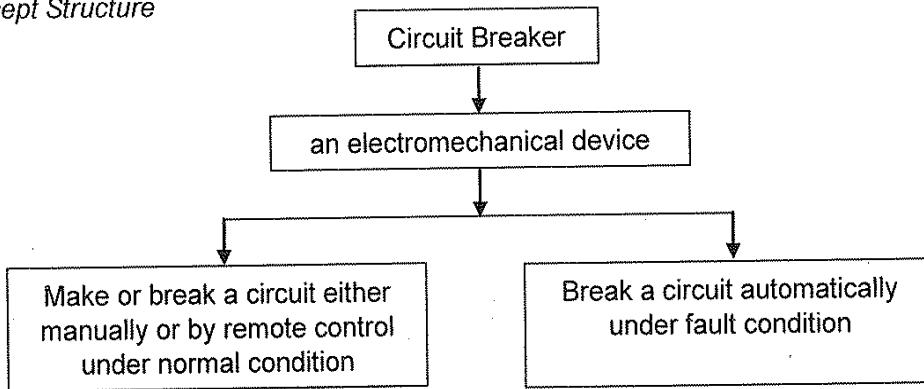
### 3.1.1 The fundamental of Circuit breaker operation

In the following illustration, an AC motor is connected through a circuit breaker to a voltage source. When the circuit breaker is closed, a complete path for current exists between the voltage source and the motor allowing the motor to run. Opening the circuit breaker breaks the path of current flow and the motor stops. The circuit breaker automatically opens when it senses a fault. After the fault has been cleared, the breaker can be closed, allowing the motor to operate.



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*Concept Structure*



### **3.2 Formation of arc during circuit breaking**

#### *3.2.1 The phenomena of Arc*

During opening of current carrying contacts in a circuit breaker the medium in between opening contacts become highly ionized through which the interrupting current gets low resistive path and continues to flow through this path even after the contacts are physically separated. During the flowing of current from one contact to other the path becomes so heated that it glows in the form of an arc.

#### *3.2.2 Arc in circuit breaker*

Whenever, the contacts of circuit breaker open while carrying load there is an arc in the medium between the separating contacts of the circuit breaker. As long as this arc is sustained in between the contacts, the current through the circuit breaker will not be interrupted totally. For total interruption of current, the arc needs to be quenched as quickly as possible. The main designing criteria of a circuit breaker is to provide appropriate technology of arc quenching in circuit breaker to fulfill quick and safe current interruption. So before going through different arc quenching techniques employed in circuit breaker, it is first necessary to understand the phenomena of arc in circuit breaker.

#### ***THERMAL IONIZATION OF GAS***

There are numbers of free electrons and ions present in the medium separating the two contacts of the circuit breaker. These free electrons and ions are so few in number that they are insufficient to sustain conduction of electricity. The gas molecules move randomly at room

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temperature. It is found an air molecule at a temperature of 300°K (Room temperature) moves randomly with an approximate average velocity of 500 meters/second and collides other molecules at a rate of  $10^{10}$  times/second. These randomly moving molecules collide each other in very frequent manner but the kinetic energy of the molecules is not sufficient to extract an electron from atoms of the molecules. If the temperature is increased the air will be heated up and consequently the velocity on the molecules increased. Higher velocity means higher impact during inter molecular collision. During this situation some of the molecules are disassociated in to atoms. If temperature of the air is further increased many atoms are deprived of valence electrons and make the gas ionized. Then this ionized gas can conduct electricity because of sufficient free electrons. This condition of any gas or air is called plasma. This phenomenon is called thermal ionization of gas.

#### *IONIZATION DUE TO ELECTRIC FIELD*

As we discussed that there are always some free electrons and ions presents in the air or gas but they are insufficient to conduct electricity. Whenever these free electrons come across a strong electric field, these are attracted by the field and acquire sufficiently high velocity. In other words, the electrons are accelerated along the direction of the electric field due to high potential gradient. During their travel these electrons collide with other atoms and molecules of the air or gas and extract valance electrons from their orbits. After extracted from parent atoms, the electrons will also run along the direction of the same electric field due to potential gradient. These electrons will similarly collide with other atoms and create more free electrons which will also be directed along the electric field. Due to this conjugative action the numbers of free electrons in the gas will become so high that the gas starts conducting electricity. This phenomenon is known as ionization of gas due to electron collision.

#### *DEIONIZATION OF GAS*

If all the causes of ionization of gas are removed from an ionized gas it rapidly come back to its neutral state by recombination of the positive and negative charges. The process of recombination of positive and negative charges is known as deionization process. In deionization by diffusion, the negative ions or electrons and positive ions move to the walls under the influence of concentration gradients and thus completing the process of recombination.

#### *3.2.3 Role of arc in circuit breaker*

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When two current carrying contacts open, an arc bridges the contact gap through which the current gets a low resistive path to flow so there will not be any sudden interruption of current. As there is no sudden and abrupt change in current during opening of the contacts, there will not be any abnormal switching over voltage in the system. Let  $i$  is the current flowing through the contacts just before they open and  $L$  is the system inductance, switching over voltage during opening of contacts, may be expressed as  $V = L.(di/dt)$  where  $di/dt$  rate of change of current with respect to time during opening of the contacts. In the case of alternating current arc is momentarily extinguished at every current zero. After crossing every current zero the medium between separated contacts gets ionized again during next cycle of current and the arc in circuit breaker is reestablished. To make the interruption complete and successful, this re-ionization in between separated contacts to be prevented after a current zero.

If arc in circuit breaker is absence during opening of current carrying contacts, there would be sudden and abrupt interruption of current which will cause a huge switching overvoltage sufficient to severely stress the insulation of the system. On the other hand, the arc provides a gradual but quick, transition from the current carrying to the current breaking states of the contacts.

### **3.3 Arc Interruption or Arc Quenching or Arc Extinction Theory**

#### *3.3.1 Arc column characteristics*

At high temperature the charged particles in a gas move rapidly and randomly, but in absence of electric field, no net motion occurs. Whenever an electric field is applied in the gas, the charged particles gain drift velocity superimposed on their random thermal motion. The drift velocity is proportional to the voltage gradient of the field and particle mobility. The particle mobility depends upon the mass of the particle, heavier particles, lower the mobility. The mobility also depends upon mean free paths available in the gas for random movement of the particles. Since every time a particle collides, it loses its directed velocity and has to be re-accelerated in the direction of electric field again. Hence net mobility of the particles is reduced. If the medium has high pressure, it becomes denser and hence, the gas molecules come closer to each other, therefore collision occurs more frequently which lowers the mobility particles. The total current by charged particles is directly proportional to their mobility. Therefore the mobility