4

The Arc-Extinction

Introduction—Matter and Plasma—Ionization—Deionization—Electric Arc—Arc Formation in Circuit-Breaker—Modes of Arc Extinction—Zero Point Extinction—Electronegative Gases—Vacuum Arc—Arc Interruption Theories—Slepian's Theory—Cassie's Energy Balance Theory—Summary.

4.1. INTRODUCTION

The electric arc is a type of a electric discharge between electrodes. In circuit-breakers, the arc persists during the brief period after separation of current carrying contacts. The circuit-breaker should be capable of extinguishing the arc without getting damaged. The arc plays an important role in the behaviour of the circuit breaker. The interruption of d.c. arcs is relatively more difficult than a.c. arcs. In a.c. arcs, as the current becomes zero during the regular wave, the arc vanishes and it is prevented from restriking. In this chapter we shall study technical aspects regarding the arc and the techniques employed for arc extinction.

The arc extinction duty, though not frequent, produces highest stresses on the circuit-breaker. The techniques adopted for the arc extinction can be classified into the following three categories:

— **High resistance interruption.** The resistance of the current path is increased rapidly resulting in the increased voltage drop. The arc gets extinguished when the system voltage can no longer maintain the arc, due to high value of the voltage drop. This principle is used in d.c. circuit-breakers and air-break type a.c. circuit breakers of relatively low capacities of the order of a few hundred MVA. The energy stored is system inductance is gradually dissipated in the arc.

— **Current zero interruption.** The arc is interrupted at natural current zero of the alternating current wave and the dielectric strength of the contact-gap is increased to such an extent that it can withstand the voltage stress across it.

— **Artificial current zero interruption.** This is used for breaking DC currents in HVDC systems.

4.2. THE MATTER AND PLASMA

In the physical world, the matter manifests itself in various states known as solid, liquid and gaseous states. Each substance consists of molecules formed of atoms with their nucleus and orbiting electrons. Normally the molecules and atoms are electrically neutral, *i.e.*, the positive and negative charges are equal. However, the matter can be *ionized*. The ionized matter consists of charged particles such as ions and electrons. Consider the gas in a container, the temperature being gradually increased. Initially the molecules experience a motion in all sorts of directions. At higher temperatures the velocity of the particles increases and they collide against particles coming in their way. At temperatures of the order of 3000° K the molecules break up into simpler forms such as simpler molecules and atoms. This process is called dissociation. If the temperature is further increased (to about 6000° K) the internal forces which hold the electrons to the atoms are affected and the electrons manage to escape. The atom becomes truly charged and the electrons may attach a neutral atom or may remain free. The matter is thus ionized. Further increase in temperature enhances the process of ionization and *Plasma* state is reached. The plasma consists of charged

particles. The conductivity of plasma depends upon number of ions per unit volume. Plasma is conducting medium for electric current.

The non-ionized gas is generally a good dielectric medium. Even dissociated gas is a dielectric. However the ionized gas is a conducting medium. In circuit-breakers the contact space is ionized by the following causes:

(1) Thermal ionization of gas.

(2) Ionization by collision of particles.

(3) Thermal emission from surface of contacts.

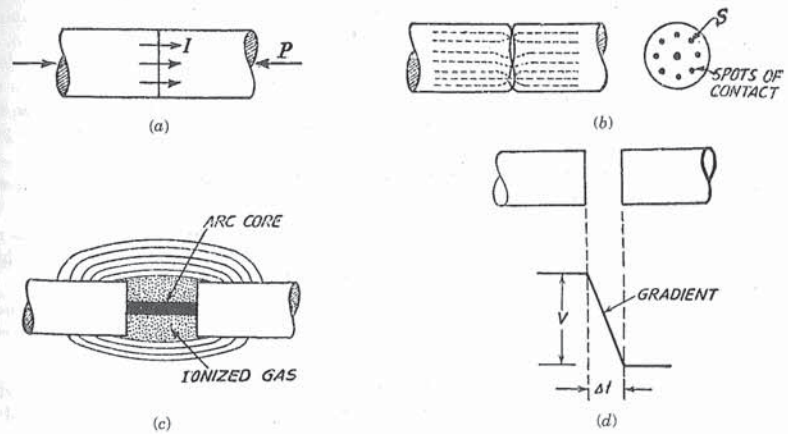
(4) Secondary emission from surface of contacts.

(5) Field emission from the surface of contacts.

4.3. IONIZATION OF GASES

(*a*) **Thermal Ionization.** At normal temperatures the molecules of gas are in a state of constant agitation and they move at various velocities in various directions. A molecule at velocity V and mass m possesses kinetic energy equal to $1/2\ mV^2$. At temperature about 3000°C the molecules break up in simpler forms and further to atoms. This process is known as dissociation. At higher temperatures (about 6000°C) the agitation of these atoms is vehement and their impact against each other can produce ionization by mutual collision. This type of ionization brought about by heat is called thermal ionization.

(*b*) **Ionization by Collision.** A particle (electron, ion or molecule) at a higher velocity (produced by electric field) may strike another particle. Thereby the energy of the moving particle is imparted to the other one. This energy may be enough to dislodge the electrons from atoms. Such ionization is called ionization by collision.



(*a*) Contacts pressed at high pressure in closed position

(*b*) Pressure reduced. Hence contact area reduced. Current concentrated on a few spots of high current density.

(*c*) Contacts separated, arc down, arc is surrounded by ionized gas and hot column of gas. (See Front Cover — The Arc).

(*d*) The voltage gradient = $V/\Delta l$

If $V = 1$ kV, $\Delta l = 1$ mm, Gradient = 1000 V/mm

Fig. 4.1 Electron emission.

(c) **Thermal Emission from Surface of Contacts.** In closed position, the contacts are pressed against each other at a high pressure causing plastic and elastic deformation. As the contacts start separating, the pressure between contacts reduces first. Thereby the true area of contact is reduced to area of a few spots on the surface. The current crosses the contact surface at the spots producing high current densities. Therefore, spots of high local temperature are produced on the surface of contacts. Next the arc has high temperature as the energy is dissipated in the form of heat. BY virtue of these causes thermal emission takes place at contact surface. (Fig 4.1)

(d) **Secondary Emission at Contact Surface.** The electrons move rapidly under the influence of strong electric field between the contacts and strike the surface of the other contact. Thereby they produce emission from contact surface by collision.

(e) **Field Emission at Contact Surface.** If the voltage gradient at the surface of the contact is high (even more than 1000 V/cm) the electrons can be dislodged from the surface of the electrode. As the contacts separate, the distance between them being too small, initially, high potential gradient (kV/cm) appears near the contact surfaces. The gradient can be more than 10^6 V/cm. and is enough to breakdown the gas. The ionization produced by electric field is called field emission [Fig. 4.1 (d)].

(f) **Photoemission.** The electron emission from contact surface caused by incidence of light energy is called photoemission.

4.4. DEIONIZATION

Deionization can take place by the processes of recombination or attachment as well as by process of diffusion and drift. These have been discussed here very briefly.

(a) **Recombination.** If a gas containing positive ions and electrons there is a tendency for these to come together and combine to form a neutral atom. This phenomenon is termed as recombination. Recombination takes place directly in gas, and is important in the process of arc extinction. As the ions penetrate from the heavily ionized space near the arc to the walls of the container, electrons reach the walls first as they are light. As the walls are of insulating materials electrons cannot escape and the inner side of container, is negatively charged. Thereafter the wall inner surface repels electrons and attracts positive ions. Thereby the combination takes place between positive ions and negative charges.

(b) **Diffusion.** The electrons from highly ionized space diffuse to the surrounding weakly ionized space. This is an important process in building up of dielectric strength.

(c) **Conduction of Heat.** Conduction of heat brings down the temperature and assists recombination. The particles of higher temperature travel to the space at lower temperature. In this way kinetic energy is removed from the ionized space between the contacts.

In circuit-breakers the deionization is an important process because it assists arc extinction.

4.5. ELECTRIC ARC

The electric arc is a self-sustained discharge of electricity between electrodes in gas or vapour, which has a voltage drop at cathode of the order of minimum or minimum exciting potential of gas or vapour.

When D.C. voltage applied to electrodes places at a small clearance, say a few centimeters, is gradually increased a flow of current takes place through gas. This phenomenon is called discharge in gas. The volt-ampere characteristic has several distinct zones classified as glow discharge, townsend discharge and arc discharge. During arc discharge the voltage across the electrode is low and current is high. The current is limited by external impedance. The voltage across arc decrease as the current increases. The arc is self-sustained discharge.

The arc has a brightly burning core of high temperature ranging from 6000° to 25,000°K. If the arc is cooled the temperature increases. This is rather perplexing. The cooling reduces its

diameter and thereby the current density increases resulting in higher temperature. The current density of arc core is several thousand amperes per cm^2. The central core is surrounded by a column of hot gases at a temperature of about 1000° K down to a low temperature.

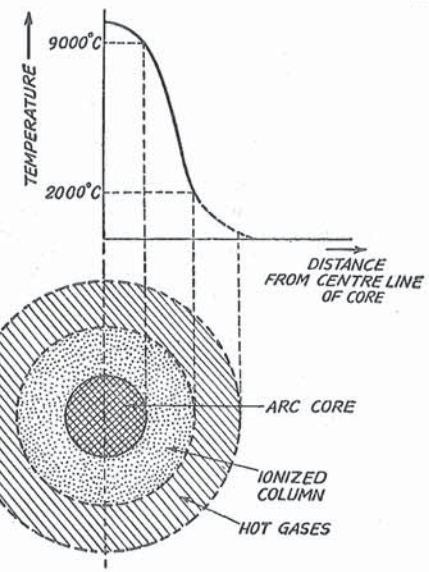


Fig. 4.2. Temperature zones in the arc.

The volt-ampere characteristics of a steady are is given by an equation,

$$V_{\text{arc}} = A + Bd + \frac{C + Dd}{i_{\text{arc}}} \qquad ...(4.1)$$

where d = length of arc

V_{arc} = voltage across arc

i_{arc} = current in arc

A, B, C, B = constants.

$$A + \frac{C}{i_{\text{arc}}}$$

in arc cathode plus anode voltages

$$\left(B + \frac{D}{i_{\text{arc}}}\right)d$$

is the component of voltage across the length of the arc. For lengthy arcs this component should be considered and for small length arc this component should be neglected. Hence Eq. (4.1) reduces to

$$V_{\text{arc}} = A + \frac{C}{i_{\text{arc}}} \qquad ...(4.2)$$

for small legnth arc.

The voltage across arc reduces as the current increases as shown in Fig. 4.3.

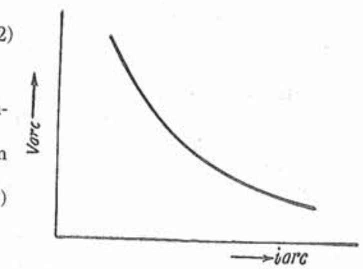


Fig. 4.3 Static characteristic of arc.

The energy dissipated in the steady arc is the form of heat is given by

$$E_{\text{arc}} = V_{\text{arc}} I_{\text{arc}} t \qquad (4.3)$$

where E_{arc} = Energy in joules

V_{arc} = Voltages in volts

i_{arc} = arc current in Amps.

t = Duration of arc in sec.

The time t is of the order of 0.02 sec. in a.c. circuit-breakers.

The energy in the system is given by

$$E_s = 1/2 L i^2 \text{.....joules} \qquad ....(4.4)$$

In AC system instantaneous current i is zero during the end of every half cycle. At this instants the energy in the system is also zero. Arc can be interrupted at such natural current zeros. The arc quenching is related with system energ, arc energy.

4.6. ARC FORMATION IN A.C. CIRCUIT-BREAKERS

As discussed earlier, the separation of contacts leads to high local temperatures on the contact surface. The electrons are emitted from contact surface by thermal secondary field and photoemission. The gases between contact space are ionized by thermal ionization by collision. The space between the contact is in the state of plasma and therefore, is conducting. Thereby, arc discharge takes place between the contacts as the current carrying contacts separate.

Fig. 4.4 illustrates the characteristics of a.c. arc current and voltage with respect to time. The voltage across the arc is in phase with the arc current as arc current is predominantly resistive. The voltage across the arc reverse with the current. At current zero, the voltage across the contact reverses.

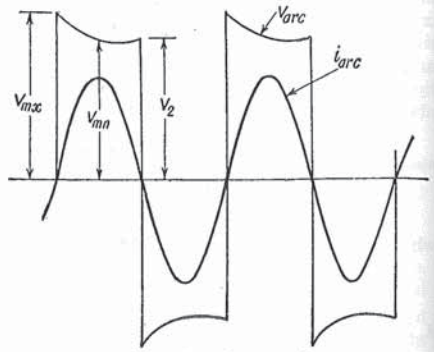


Fig. 4.4 Waveform of a.c. arc: Current and voltage V_s time.

4.7. MODES AT ARC EXTINCTION

Two modes of arc interruption can be identified :

(1) High resistance interruption.

(2) Low resistance or zero point-interruption.

(3) Artificial current zero principle (Ch. 16)

4.7.1. High Resistance Interruption, Blow-Out coils

The high resistance interruption is obtained by increasing the resistance of the arc.

$$r_{arc} = \frac{V_{arc}}{i_{arc}}$$

Assuming i_{arc} to be constant the resistance of the arc can be increased by increasing voltage of the V_{arc}. From Eq. (4.1), *i.e.*

$$V_{arc} = A + Bd + \frac{C + Dd}{i_{arc}}$$

where d is the length of the arc, we understand that the arc voltage hence the arc resistance can be increased by increasing length of the arc.

In high resistance interruption method the length of the arc is increased so as to increase the voltage across the arc.

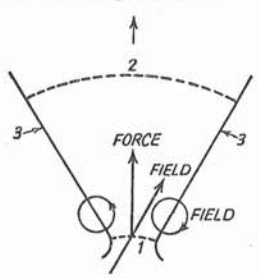
The voltage of the arc is increased till it more than the system voltage across the contacts. At this point the arc gets extinguished.

The method is used in low and medium voltage a.c. and d.c. circuit breakers (Refer Sec. 5.2).

The arc resistance is increased by the following methods :

(*a*) **Lengthening the arc by means of arc runners** (Refer Fig. 4.5 and also Ref. Sec. 5.2)

Arc runners are horn-like blades of conducting material, which are connected to arcing contacts with their tips radiating upwards in 'V' shape. The arc originates at the bottom and blows upwards by electromagnetic force. The tips of the arc more upwards along arc runners or arc horns rapidly. The length of the arc increases and the arc is extinguished.

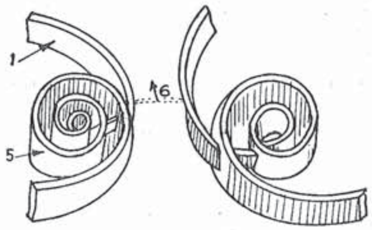


1. Initial position of arc
2. Final position of arc.
3. Arc runners (in vertical plane)
4. Field (in horizontal plane)
5. Force due to electrodynamic forces (in vertical plane)

Fig. 4.5 Function of the arc runners.

(*b*) **Splitting of Arc** (Refer Fig. 4.7)

The arc is elongated and split by arc splitters. These are specially made plates of resin bonded fibre glass. These are placed in the path perpendicular to the arc and the arc in pulled into them by electromagnetic force experienced by the arc by means of magnetic field applied in proper direction so as to pull the arc upwards. When the arc is pulled in space between the plates, it gets elongated constrained split and cooled. By virtue of these effects the arc gets extinguished. Fig. 4.7 illustrates the arrangement of magnetic blow out coils extinguished Fig. 4.7 illustrates the arrangement of magnetic-blow out coils employed in air magnetic circuit-breakers.



1. Arc runners (metallic)
2. Arc splitters
3. Elongated arc
4. Arc in process of travelling
5. Blow-out coils (metallic)
6. Origin of Arc

Fig. 4.6. Details of blow-out coil (See Fig. 4.7)

(*c*) **Cooling of Arc.** Cooling of the arc brings about recombination of ionized particles. Cooling removes the head from the arc. Cooling is brought by bringing the arc is contact with cooler air.

4.7.2. Low Resistance of Zero Point Extinction

This method is employed in a.c. arc interruption. Actually the alternating current passes through zero 100 times per seconds in 50 cycles current wave. At every current zero the arc vanishes for a brief moment. However, the arc appears again with the rising current wave. In a.c. circuit-breakers the arc is interrupted at a current zero. At current zero, the space between contacts is deionized quickly by introducing fresh unionized medium such as oil or fresh air, or SF_6 gas, between the contacts. The dielectric strength of the contact space increases to such an extent that the arc does not continue after current zero. A high voltage may appear across the contacts. The voltage may re-established the arc if the dielectric strength of gap is less than the restriking voltage. In that case the arc continues for another half cycle and may get extinguished at next current zero.

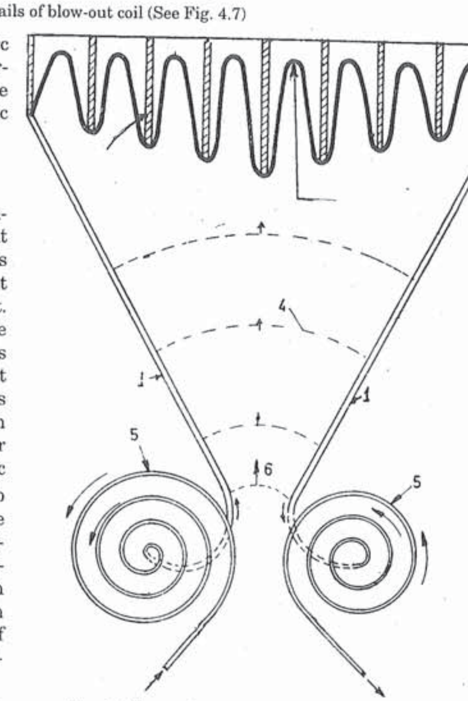


Fig. 4.7 The configuration of magnetic blow-out coils.

In various types of circuit-breaker designs, the provision is made to remove the hot gases from the contact space immediately after the arc so as to fill the contact space by fresh dielectric medium of high dielectric strength.

The arc extinction process can, therefore be considered to have three phases

— Arcing phase, — current zero, — post arc phase.

The arcing phase is governed by temperature stresses due to the arc. Every attempt is made in the interrupter design to remove the heat of arc quickly by radial and axial flow of gases. The experimentation has shown that the power arc cannot be broken abruptly. However, the arc diameter can be reduced to a low value by the flow of a gases over the arc. The arc diameter reduces during a portion of the a.c. wave approaching current zero. At current zero, the arc diameter reduces to a very low value and arc gets extinguished. But the contact space contains hot gases. These are removed by fresh dielectric medium having high dielectric strength. Hence the interrupter design attempts a removing the heat from the arc during the arcing period and flushing the contact space with fresh dielectric medium during the post-arc period.

The abilities of various media used for arc-interruption are generally different. As the various media used for arc extinction have different densities, thermal conductivities, dielectric strengths, arc-time constants, etc. the designs of interrupters using different media have distinct differences.

4.8. ARC INTERRUPTION THEORIES

Several theories have been postulated to explain the arc interruption but they are not perfect. However some theories have helped in the development of circuit-breaker. The first theory was that of Slepian of U.S.A., postulated in 1928-30. Later in 1931, Prince (also from U.S.A.) postulated displacement theory. Cassies of U.K. put forward another theory in 1938. Mayer of Germany put forward another theory similar to Classie's theory. Some of these theories have been briefly reviewed.

(*a*) Slepian's Theory. Splepian described the arc extinction process as the race between dielectric strength and restriking voltage. After current zero, there exists a residual column of ionized gas. If the dielectric strength builds up rapidly so that it is always greater than the restriking voltage, the arc does not restrike. If dielectric strength is less, the arc restrikes. Referring to Fig. 4.8 the three curves are the following:

— dielectric strength against time curves (*a*) and (*c*)

— restriking voltage against time, curve (*b*) (TRV)

According to the theory, if the dielectric strength of contact gap is more than the restriking voltage as shown by curve (*a*) above (*b*) the arc gets extinguished. But if the dielectric strength builds as in curve c, the arc restrikes.

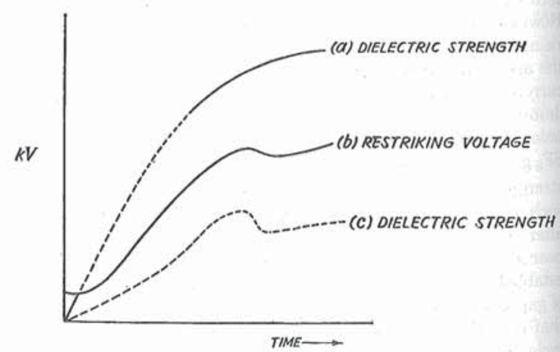


Fig. 4.8 Growth of dielectric strength and transient recovery voltage.

The theory assumes that the restriking voltage and build up of dielectric strength are comparable quantities. The assumption is not quite correct. These two entities are not identical. Secondly this theory does not consider the energy relations in the arc extinction. This theory does not cover the arcing phase, hence it is incomplete. Slepian was the first to point out that the restriking voltage plays an important role in arc extinction.

(*b*) Energy Balance Theory. Cassie made the following assumptions in his Energy Balance Theory :

(1) Arc consists of a cylindrical column at a substantially uniform temperature over its cross-section with well defined boundary. There is a uniform distribution of energy in this column *i.e.*, volume energy density is constant for the complete column of the arc.

(2) The temperature remains constant.

(3) The cross-section of arc adjusts itself to accommodate the arc current.

(4) Power dissipation is proportional to arc cross-sectional area of arc column. Cassie expressed the energy equation as

$$\frac{dQ}{dt} = EI - N \qquad ...(4.3)$$

where Q = energy content/cm of arc length

E = volts/cm

I = total current

N = total power loss/cm.

Breakdown occurs if power feed in the arc is more than power loss. The theory is approximately true for high currents. Mayer's theory is similar to Classie's theory but with different assumptions. This theory does not cover post-arc phase, hence it is incomplete.

Summarising the arc extinction can be obtained at current zero by building up dielectric strength of arc rapidly and by dissipating the energy fed into the arc.

Both the theories mentioned above give certain understanding of the arc extinction phenomenon. **The arc extinction process in circuit-breaker is influenced by several aspects such as**

— Speed of contact.

— Material of contact

— The pattern of flow of quenching medium.

— Magnitude of arc current and variation of arc diameter.

— Energy liberated during arcing, energy in system inductance.

— Rate of rise of transient recovery voltage.

— Rate of gain of dielectric strength.

— Instant of contact separation with respect to voltage, current.

As the governing parameters arc very much diverse in character, the arc extinction process becomes too complex for analysis. The arc-extinction process can be considered in three different zones:

— arcing zone. — current zero zone. — post arc zone.

During the arcing zone, the thermal stresses produced by the arc are predominant. In every circuit-breaker, an attempt is made to reduce the arc diameter by using various techniques.

The current zero zone provides transition.

During post arc zone, the voltage stresses become predominant. In every circuit-breaker, and attempt is made to introduce fresh dielectric medium between contact space after final current zero, is that the dielectric strength is rapidly regained.

4.9. ARC EXTINCTION IN OIL

The arc decomposes the dielectric oil. The gases formed due to the decomposition of the oil cause increase in pressure within the chamber fitted in the interrupter. The flow of gases is channelised through the vents in the chamber. The arc gets extended into the vents and is cooled by the flowing gases. The gases contain about 70% of hydrogen which has good dielectric strength. After the arc extinction the contact space is filled with fresh dielectric oil. In some circuit-breakers a piston attached to the moving contact causes the oil flow in the contact space assuring a rapid gain of dielectric strength. In some other designs, the interrupter is pressurised by nitrogen gas. The pressure on the oil ensures the flushing of contact space with fresh dielectric oil after final arc interruption. The amount of gas formed during the arcing is proportional to the arc current. Such circuit-breakers are called 'Internal energy type circuit-breakers' (Refer Ch. 8 for detail analysis).

4.10. ARC EXTINCTION IN VACUUM

When the contact of vacuum interrupter are separated the arc is drawn between them. The current leaves the electrodes from small, intensely hot spot (or spots). The metal vaporizes from the spots. The vapour stream constitutes the plasma in vacuum arc. The vapour formed is proportional to rate of vapour emission, which is proportional to the current in arc. Therefore, at current zero the plasma may vanish. Therefore the arc is interrupted at current zero. The vacuum has high dielectric strength, hence the arc may not restrike. The contact material shape are very important. Arc time constant of vacuum is lowest.

4.11. ARC EXTINCTION IN AIR-BLAST

In air-blast circuit, breakers the air flows from high pressure reservoir to the low atmospheric pressure during the arc extinction process. The flow rate is governed by the throat diameter of the nozzle, the pressure difference and the nozzle profile. The design is such that almost supersonic speeds of flows are achieved. The axial flow of air at high velocity causes rapid reduction in the diameter of the arc and the arc does not reappear after the final current zero.

4.12. ARC EXTINCTION IN SF_6 GAS*

In plasma, most of the current is carried by electrons. In certain gases like SF_6 the atoms and molecules have the property of attracting electrons to form negative ions. Negative ions are heavier than electrons and move slowly, thereby the resistance of plasma increases rapidly. Therefore electronegative gas like SF_6 is excellent arc extinction medium.

The arc extinction process in SF_6 gas is based on axial heat dissipation. The gas flows from high pressure to the low pressure through a well designed nozzle over the arc. The flowing gases take away the heat of the arc causing reduction in the diameter of arc. After current zero, the medium regains its dielectric strength very rapidly. This property of rapid recovery of the dielectric strength is due to the electronegativity of the gas.

4.13. ARC TIME CONSTANT

The time required by the quenching medium to gain original dielectric strength after final current zero. It is expressed in microseconds.

QUESTIONS

1. Explain the arc extinction process is alternating current circuit breaker.
2. State the theories postulated to explain the arc extinctions phenonmenon. What is the significance of restriking voltage in the arc extinction process?
3. An electric arc of 5 cm has a current of 1000 amperes and voltage across the arc is 25 volts. Calculate the energy consumed by the arc in one second.

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* *Puffer type SF_6 circuit-breakers are becoming popular for HV & EHV systems Whole Breaker is filled with gas at 5 kgf/cm^2.*

Puffer type single pressure SF_6 circuit-breaker uses Puffer principle for arc exinction. A cylinder called Puffer cylinder is attached to the moving contact. Puffer cylinder moves against fixed piston during opening stroke. The SF_6 gas trapped in the Puffer cylinder is compressed due to relative movement between the puffer cylinder and the piston. The gas pressure in puffer cylinder depends upon the speed of Puffer cylinder. Higher opening speeds (6 to 7 metres/sec) are used. The compressed gas in Puffer cylinder is released through convergent-divergent nozzles. The gas flows with almost supersonic velocity over the arc. Arc diameter is reduced to zero. Arc is quenched at first or second current zero. Dielectric strength is regained due to electronegativity of SF_6 gas.

Self-Extinguishing Principle : The heat of arc generates pressure which forces the arc in hollow moving contact. The arc gets lengthened and cooled. The arc is exinguished at current zero. For smaller current the puffer principle is used.

5

Air-Break Circuit-Breaker

Introduction—Design features—Heavy duty air-break circuit-breaker—Low voltage air breaker circuit-breaker—Arc extinction by means of magnetic field—D.C. air breaker circuit-breaker—Summary

5.1. INTRODUCTION

The air at atmosphere pressure is used as an arc extinguishing medium in Air-Break Circuit-Breakers. These circuit-breakers employ the high resistance interruption principle. The arc is rapidly lengthened by means of the arc runners and arc chutes and the resistance of the arc is increased by cooling lengthening and spliting the arc. The arc resistance increases to such an extent that the voltage drop across the arc becomes more than the supply voltage and the arc extinguished.

Air-breaker circuit-breakers are used in d.c. circuits and a.c. circuits upto 12 kV.

The air-break circuit-breakers are generally indoor type and installed on vertical panels or indoor draw-out type switchgear.

A.C. air-break circuit-breakers are widely used in indoor medium voltage and low voltage switchgear. Typical reference values of ratings of air-break circuit-breakers are:

460 V, 400—3500 A,	40—75 kA.
3.3 kV, 400—3500A,	13.1—31.5 kA.
6.6 kV, 400—2400 A,	13.1—20 kA.

Magnetic field is utilised for lengthening the arc in high voltage air-break circuit-breakers.

5.2. CONSTRUCTION OF AIR-BREAK CIRCUIT-BREAKER

In the air-break circuit-breaker the contact separation and arc extinction takes place in air at atmospheric pressure. Fig. 5.1 (a) shows the closed current carrying contacts. As the contacts are opened arc is drawn between them. The arc core is a conducting path of plasma. The surrounding medium contains ionized air. By cooling the arc, the diameter of arc core is reduced. The arc is extinguished by lengthening the arc, cooling the arc and splitting the arc. The arc resistance is increased to such an extent that the system voltage cannot maintain the arc and the arc gets extinguished at current zero of AC wave.

Fig. 5.1 (c) illustrates the normal arrangement of an air-break circuit-breaker. This type of breaker is used for medium and low voltages.

There are two sets of contacts: Main contacts and Arcing contacts. Main contacts conduct the current in closed position of the breaker. They have low contact resistance and are silver plated. The arcing contacts (2) are hard, heat resistant and are usually of copper alloy. While opening the contact, the main contacts dislodge first. The current is shifted to the arcing contacts. The arcing contacts dislodge later and arc is drawn between them (3). This arc is forced upwards by the electromagnetic forces and thermal action. The arc ends travel along the Arc Runner (Arcing horns.) The arc moves upwards and is split by arc splitter plates (5) as shown by the arrow (4). The arc is extinguished by lengthening, cooling splitting etc. In some breakers the arc is drawn in the direction of the splitter by magnetic field.