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Internal Assesment Test - III

Sub:	POWER SYSTEM PROTECTION						Code:	18EE72
Date:	27-12-22	Duration:	90 mins	Max Marks:	50	Sem:	7th(A & B)	Branch:	EEE

Answer Any FIVE FULL Questions

		Marks	OBE	
			CO	RBT
1	Explain the recovery rate theory and energy balance theory of arc interruption in a circuit breaker.	[10]	CO5	L2
2	Explain the interruption of capacitive current in the circuit breaker with a neat sketch and waveform.	[10]	CO5	L2
3	Explain the working of Air axial blast circuit breaker with the help of neat sketch.	[10]	CO5	L2
4.a	What are the advantages and disadvantages of SF6 circuit breaker?	[4]	CO5	L1

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4.B	A 132kV system, the reactance and capacitance up to the location of the circuit breaker is 3 ohms and 0.015μF, respectively. Calculate the following (a) The frequency of transient oscillation (b) The maximum value of restriking voltage across the contacts of the circuit breaker (c) The maximum value of RRRV	[6]	CO5	L3
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5.b	Explain the construction and working of 'Klydonograph'.	[5]	CO6	L2
6	What is insulation coordination? Explain its volt-time curve.	[10]	CO6	L2

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PSP-IAT III – SOLUTION

Q.1

Recovery Rate Theory

The arc is a column of ionised gases. To extinguish the arc, the electrons and ions are to be removed from the gap immediately after the current reaches a natural zero. Ions and electrons can be removed either by recombining them into neutral molecules or by sweeping them away by inserting insulating medium (gas or liquid) into the gap. The arc is interrupted if ions are removed from the gap at a rate faster than the rate of ionisation. In this method, the rate at which the gap recovers its dielectric strength is compared with the rate at which the gap recovers its dielectric strength is compared with the rate at which the restriking voltage (transient voltage) across the gap rises. If the dielectric strength increases more rapidly than the restriking voltage, the arc is extinguished. If the restriking voltage rises more rapidly than the dielectric strength, the ionisation persists and breakdown of the gap occurs, resulting in an arc for another half cycle. Figure 14.5 explains the principle of recovery rate theory.

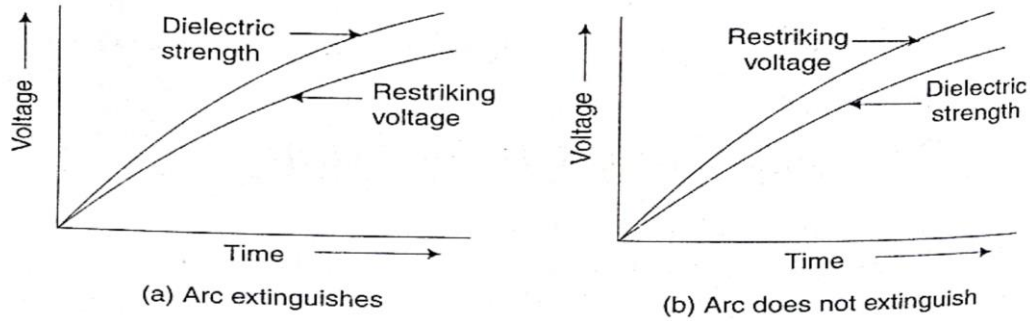


Fig. 14.5 *Recovery rate theory*

Energy Balance Theory

The space between the contacts contains some ionised gas immediately after current zero and hence, it has a finite post-zero resistance. At the current zero moment, power is zero because restricking voltage is zero. When the arc is finally extinguished, the power again becomes zero, the gap is fully de-ionised and its resistance is infinitely high. In between these two limits, first the power increases, reaches a maximum value, then decreases and finally reaches zero value as shown in Fig. 14.6. Due to the rise of restriking voltage and associated current, energy is generated in the space between the contacts. The energy appears in the form of heat. The circuit breaker is designed to remove this generated heat as early as possible by cooling the gap, giving a blast of air or flow of oil at high velocity and pressure. If the rate of removal of heat is faster than the rate of heat generation the arc is extinguished. If the rate of heat generation is more than the rate of heat dissipation, the space breaks down again resulting in an arc for another half cycle.

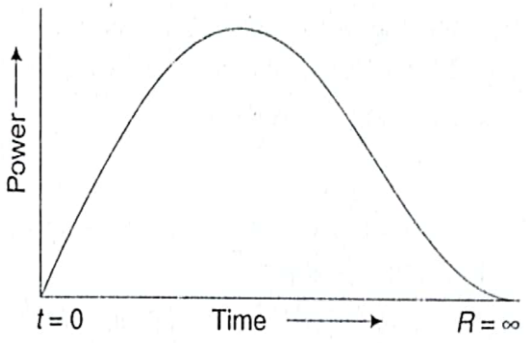
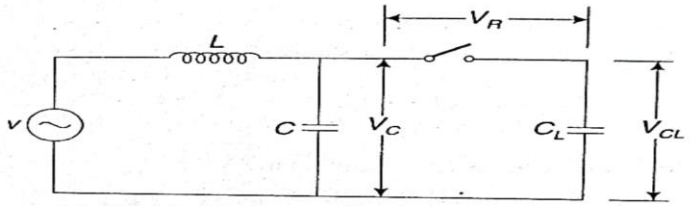
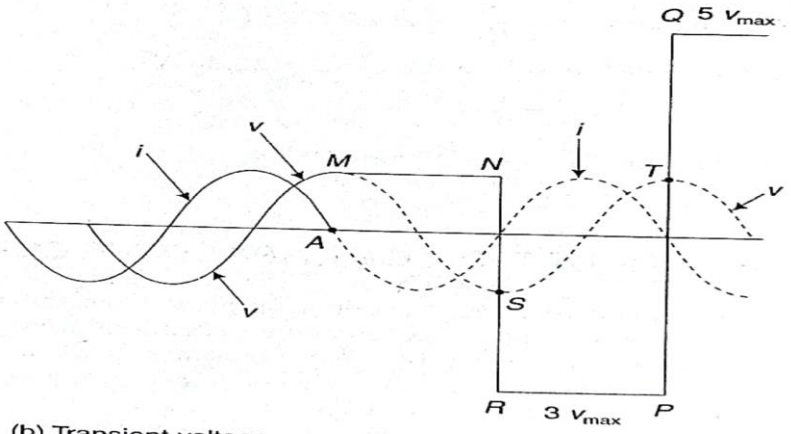


Fig. 14.6 *Energy balance theory*

Q.2



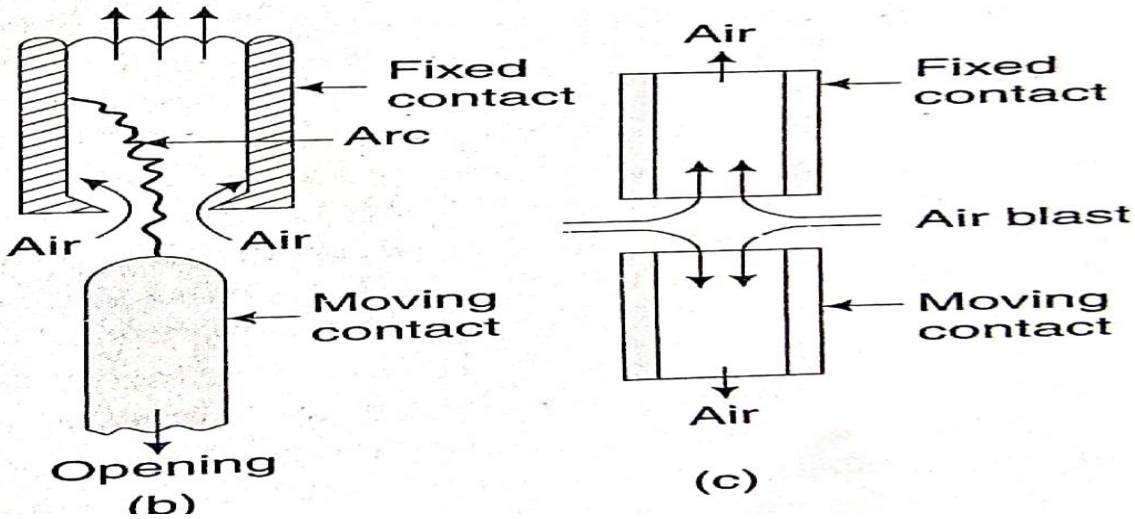
(a) Electrical circuit of a simple power system



(b) Transient voltage across the gap of the circuit breaker

Fig. 14.13 *Interruption of capacitive current*

Q.3



type circuit breakers. Figure 9.18(b) shows a single blast type. Whereas Fig. 9.18 (c) shows a double blast type or radial blast type. Axial blast circuit breakers are suitable for EHV and super high voltage application. This is because interrupting chambers can be fully enclosed in porcelain tubes. Resistance switching is employed to reduce the transient overvoltages. The number of breaks depends upon the system voltage, for example, 4 at 220 kV and 8 at 750 kV. Air-blast circuit breakers have also been commissioned for 1100 kV system.

Q.4.a

14.13.4 Advantages of SF_6 Circuit Breakers

(i) Low gas velocities and pressures employed in the SF_6 circuit breakers prevent current chopping and capacitive currents are interrupted without restriking.

(ii) These circuit breakers are compact, and have smaller overall dimensions and shorter contact gaps. They have less number of interrupters and require less mantenance.

(iii) Since the gas is non-inflammable, and chemically stable and the products of decomposition are not explosive, there is no danger of fire or explosion.

(iv) Since the same gas is recirculated in the circuit, the requirement of SF_6 gas is small.

(v) The operation of the circuit breaker is noiseless because there is no exhaust to atmosphere as in case of air blast circuit breakers

(vi) Because of excellent arc quenching properties of SF_6, the arcing time is very short and hence the contact erosion is less. The contacts can be run at higher temperatures without deterioration.

(vii) Because of inertness of the SF_6 gas, the contact corrosion is very small. Hence contacts do not suffer oxidation.

(viii) The sealed construction of the circuit breaker avoids the contamination by moisture, dust, sand etc. Hence the performance of the circuit breaker is not affected by the atmospheric conditions.

(ix) Tracking or insulation breakdown is eliminated, because there are no carbon deposits following an arcing inside the system.

(x) Because of the excellent insulating properties of the SF_6, contact gap is drastically reduced.

(xi) As these circuit breakers are totally enclosed and sealed from atmosphere, they are particularly suitable for use in such environments where explosion hazards exist.

14.13.5 Disadvantages of SF_6 Circuit Breakers

(i) Problems of perfect sealing. There may be leakage of SF_6 gas because of imperfect joints.

(ii) SF_6 gas is suffocating to some extent. In case of leakage in the breaker tank, SF_6 gas may lead to suffocation of the operating personnel.

(iii) Arced SF_6 gas is poisonous and should not be inhaled or let out.

(iv) Influx of moisture in the breaker is very harmful to SF_6 circuit breaker. There are several cases of failures because of it.

(v) There is necessity of mechanism of higher energy level for puffer-types SF_6 circuit breakers. Lower speeds due to friction, misalignment can cause failure of the breaker.

(vi) Internal parts should be cleaned thoroughly during periodic maintenance under clean and dry environment.

(vii) Special facilities are required for transporting the gas, transferring the gas and maintaining the quality of the gas. The performance and reliability of the SF_6 circuit breaker is affected due to deterioration of quality of the gas.

Q.4 b

(a) The frequency of transient oscillation

$$L = \frac{3}{2\pi 50}, \quad f = 50, \text{ the system frequency}$$

$$= \frac{3}{100\pi} = 0.00954 \text{ H}$$

$$f_n = \frac{1}{2\pi\sqrt{LC}}$$

$$= \frac{1}{2\pi\sqrt{0.00954 \times 0.015 \times 10^{-6}}}$$

$$= \frac{10^5}{2\pi \times 1.1962} = \frac{10^5}{7.5241} = 13.291 \text{ kHz}$$

(b) The restriking voltage

$$v_c = E\,[1 - \cos w_n t]$$

The maximum value of the restriking voltage $= 2\,E_{peak}$

$$= 2 \times \frac{132}{\sqrt{3}}\sqrt{2} = 215.56 \text{ kV}$$

(c) The maximum value of RRRV $= w_n E_{peak}$

$$= 2\pi f_n \times \frac{132}{\sqrt{3}} \times \sqrt{2} \times 1000$$

$$= 2\pi \times 13.291 \times 1000 \times \frac{132}{\sqrt{3}} \times \sqrt{2} \times 1000 \text{ V/s}$$

$$= 9010.45 \times 10^6 \text{ V/s} = 9.01045 \text{ kV/}\mu\text{s}$$

Q.5.a

16.2 LIGHTNING PHENOMENA

The discharge of the charged cloud to the ground is called lightning phenomenon. A lightning discharge through air occurs when a cloud is raised to such a high potential with respect to the ground (or to a nearby cloud) that the air breaks down and the insulating property of the surrounding air is destroyed. This raising of potential is caused by frictional effects due to atmospheric disturbances (e.g., thunderstorms) acting on the particles forming the cloud. The cloud and the ground form two plates of a gigantic capacitor whose dielectric medium is air. During thunderstorms, positive and negative charges are separated by the movement of air currents forming ice crystals in the upper layer of cloud and rain in the lower part. The cloud becomes negatively charged and has a larger layer of positive charge at its top. As the separation of charge proceeds in the cloud, the potential difference between concentrations of charges increases and the vertical electric field along the cloud also increases. The

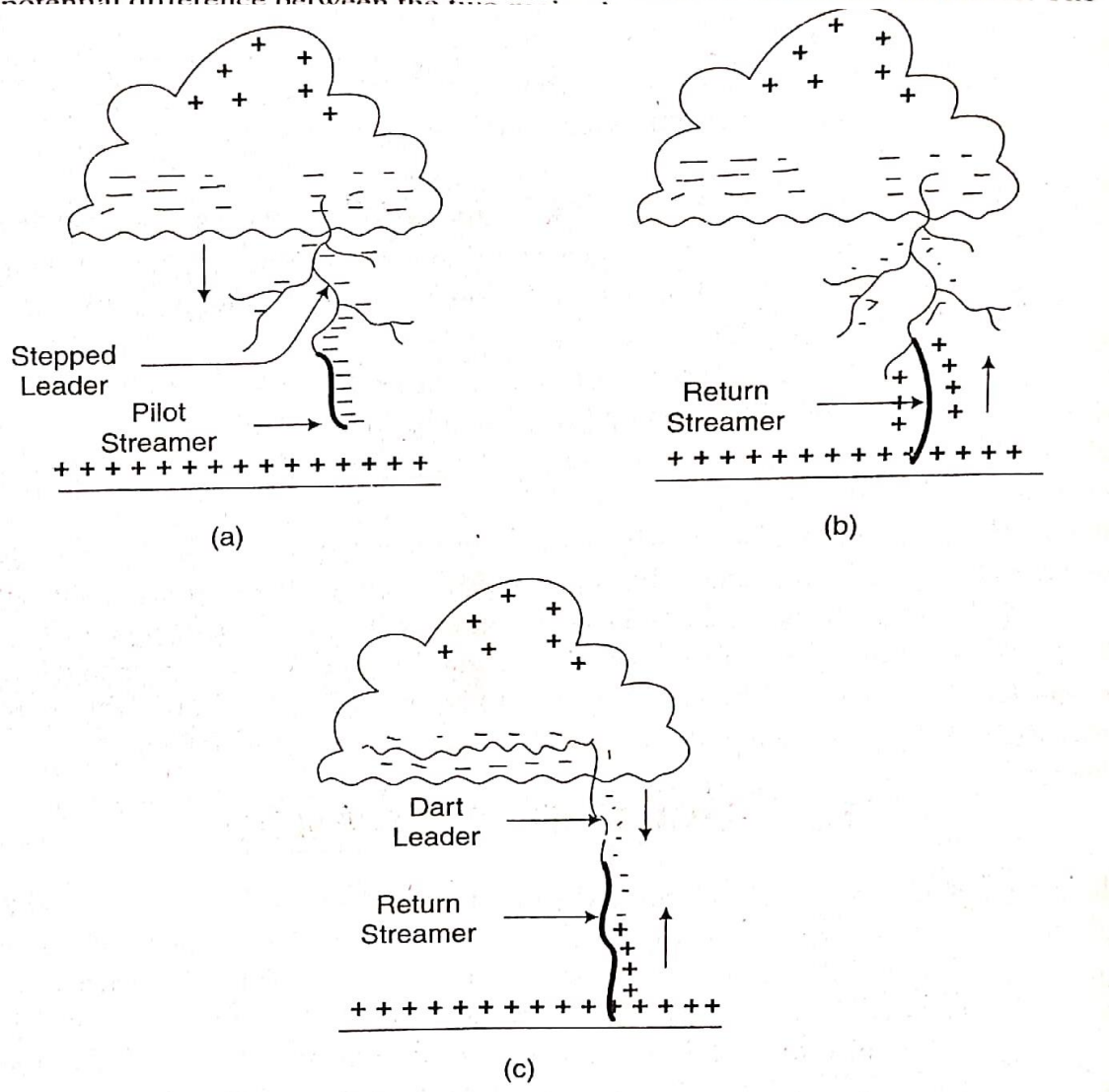


Fig. 16.1 *Lightning mechanism*

- The lightning is initiated with a flow of electrons from the base of the cloud towards the ground (stepped leader)
- When the leader gets close to the ground a flow of positive charges surges upwards.
- When they meet a strong current (return stroke) transfers a charge between the cloud and the ground.
- The process can be repeated several times in the same channel (dart leader, return stroke…)

Q.5.b

16.5.1 Klydonograph

The klydonograph is an instrument for the measurement of surge voltage on transmission lines caused by lightning. It measures voltage by means of Lichtenberg figures, when suitably coupled to the line whose surge voltage is to be measured. The klydonograph contains a rounded electrode connected to the line whose surge voltage is to be measured. The electrode rests on the emulsion side of a photographic film or plate, which in turn rests on the smooth surface of an insulating plate made of homogeneous insulating material, backed by a metal plate electrode as shown in Fig. 16.4.

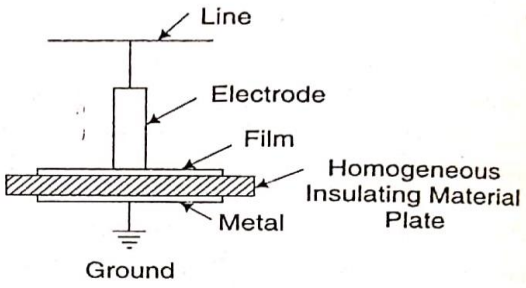


Fig. 16.4 *Klydonograph*

The photographic plate or the film is turned or moved by a clockwork mechanism for bringing in the element of time. Three assemblies are generally placed in the same box, for simultaneously measuring the voltages on the three phases of a transmission line.

With this arrangement, a positive Lichtenberg figure is produced by a positive surge, and a negative Lichtenberg figure by a negative surge, as illustrated in Fig.16.5. Positive Lichtenberg figures are found to be superior to the negative ones for voltage measurement purpose, since they are much larger than the negative figures for the same voltage, as shown in Fig. 16.5. Diameter of positive Lichtenberg figure is a

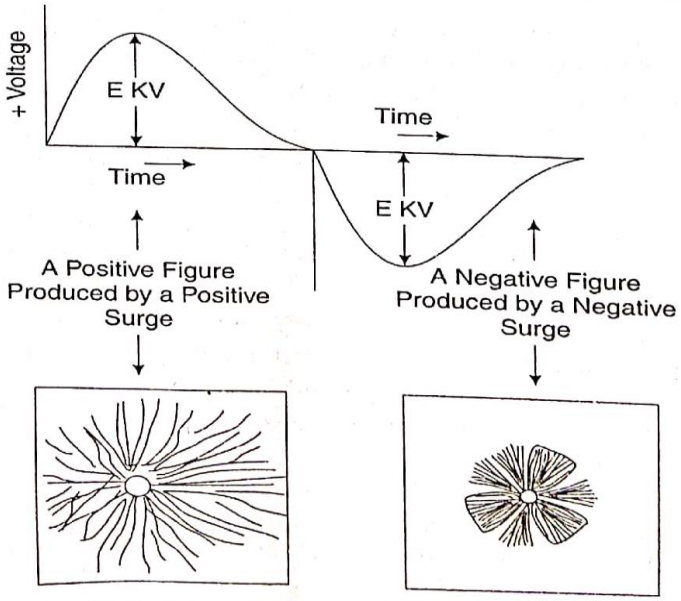


Fig. 16.5 *Positive and negative Lichtenberg figures produces by positive and negative surge voltages of same magnitude and wave shape*

Q.6

Insulation coordination is the correlation of the insulation of electrical equipment and lines with the characteristics of protective devices.

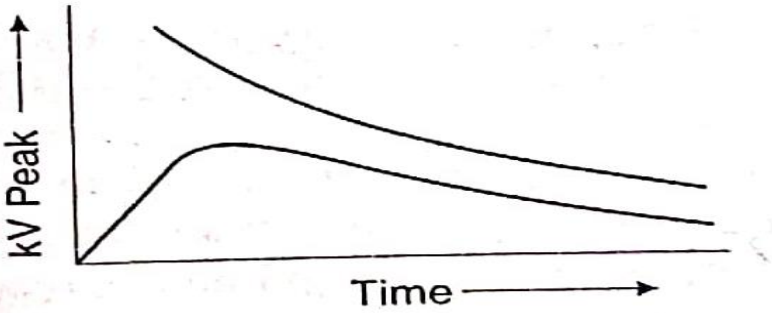


Fig. 16.24 *Volt-time curves of protective device and the equipment to be protected*

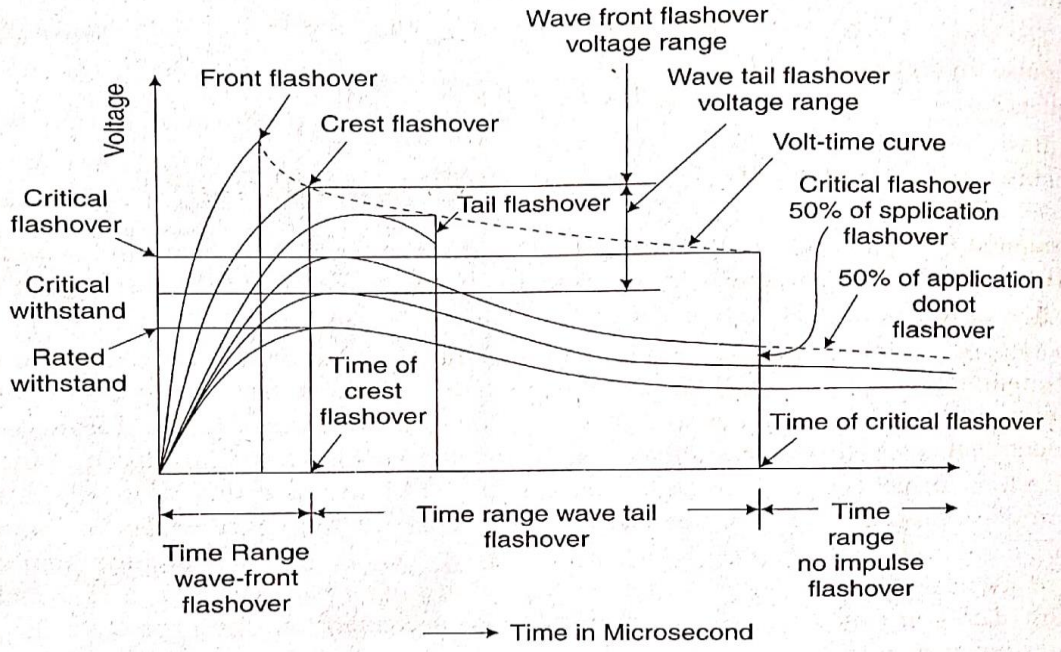


Fig. 16.25 *Construction of volt-time curve and the terminology associated with impluse testing*