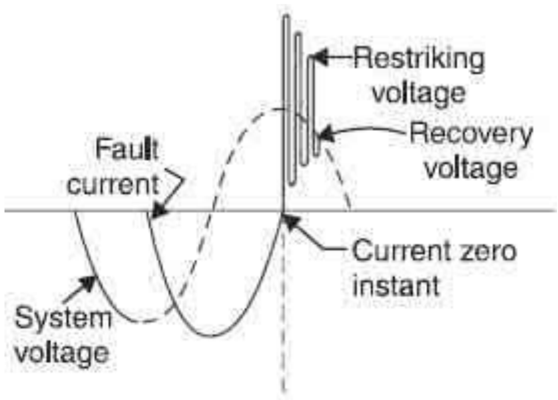
<u>5.1.</u> <u>Re-striking voltage and Recovery voltage</u>

<u>5.4.1Definition</u>

<u>Restriking voltage.</u>

It is the transient voltage that appears across the contacts at or nearcurrent zero during arcing period.At current zero, a high-frequency transient voltage appearsacross the contacts and is caused by the rapid distributionof energy between the magnetic and electric fields associatedwith the plant and transmission lines of the system. Thistransient voltage is known as restriking voltage. The current interruption in the circuit depends upon this voltage.If the restriking voltage rises more rapidly than the dielectricstrength of the medium between the contacts, the arcwill persist for another half-cycle. On the other hand, if thedielectric strength of the medium builds up more rapidly thanthe restriking voltage, the arc fails to restrike and the current will be interrupted



<u>Recovery voltage.</u>

It is the normal frequency (50 Hz) r.m.s. voltage that appears across the contacts of the circuit breaker after final arc extinction. It is approximately equal to the system voltage.When contacts of circuit breaker are opened, current drops to zero after every half cycle. Atsome current zero, the contacts are separated sufficiently apart and dielectric strength of the mediumbetween the contacts attains a high value due to the removal of ionisedparticles. At such an instant,the medium between the contacts is strong enough to prevent the breakdown by the restriking voltage.Consequently, the final arc extinction takes place and circuit current is interrupted. Immediately afterfinal current interruption, the voltage that appears across the contacts has a transient part. However, these transient oscillations subside rapidly due to the damping effect of systemresistance and normal circuit voltage appears across the contacts. The voltage across the contacts isof normal frequency and is known as recovery voltage.

5.4.2 Factros

The active recovery voltage depends upon the following factors(i)Effect of power factor
(ii)Effect of armature reaction
(iii)Effect of circuit conditions

5.4.3 Transient recovery voltage

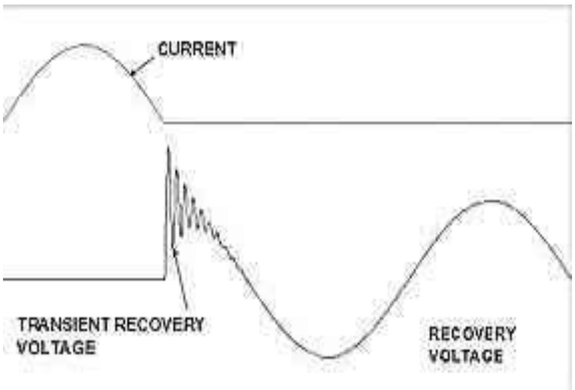
A transient recovery voltage (or TRV) for high-voltage circuit breakers is the voltage that appears across the terminals after current interruption. It is a critical parameter for faultinterruption by a high-voltage circuit breaker; its characteristics (amplitude, rate of rise) can lead either to a successful current interruption or to a failure (called reignition or restrike).

The TRV is dependent on the characteristics of the system connected on both terminals of the circuit-breaker, and on the type of fault that this circuit breaker has to interrupt (single, double or three-phase faults, grounded or ungrounded fault).

Characteristics of the system include:

- type of neutral (effectively grounded, ungrounded, solidly grounded ..)
- type of load (capacitive, inductive, resistive)
- type of connection: cable connected, line connected..

The most severe TRV is applied on the first pole of a circuit-breaker that interrupts current(called the first-pole-to-clear in a three-phase system).

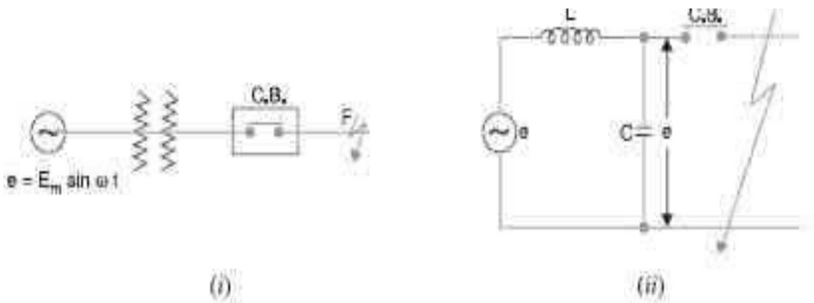


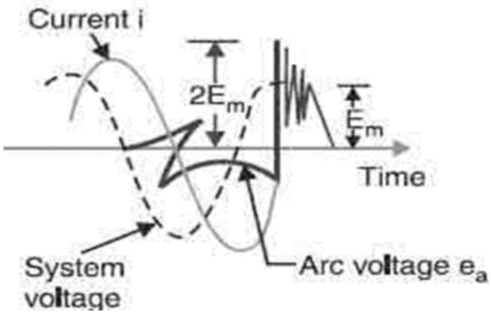
A terminal fault is a fault that occurs at the circuit breaker terminals. The circuit breaker interrupts a short-circuit at current zero, at this instant the supply voltage is maximum and the recovery voltage tends to reach the supply voltage with a high frequency transient. The normalized value of the overshoot or amplitude factor is 1.4.

5.2. Rate of rise of recovery voltage

When a fault occurs, the energy stored in the system can be considerable. Interruption of faultcurrent by a circuit breaker will result in most of the stored energy dissipated within the circuit breaker, the remainder being dissipated during oscillatory surges in the system. The oscillatory surges are undesirable and, therefore, the circuit breaker must be designed to dissipate as much of the stored energy as possible. Equivalent circuit where *L* is the inductance per phase of the system upto the point of fault and *C* is the capacitance per phase of the system. The resistance of the system is neglected as it is generally small. It is the rate of increase of re-striking voltage and is abbreviated by R.R.R.V. usually; the voltage is in kV and time in microseconds so that R.R.R.V. is in kV/μ sec.

Consider the opening of a circuit breaker under fault conditions shown in simplified form in Fig.





Before current interruption, the capacitance *C* is short-circuited by the fault and the short-circuit current through the breaker is limited by inductance *L* of the system only. Consequently, the short-circuit current will lag the voltage by 90º as shown in Fig., where *I* represents the short-circuit current and *ea* represents the arc volt- age. It may be seen that in this condition, the entire generator voltage appears across inductance *L*. When the contacts are opened and the arc finally extinguishes at some current zero, the generator voltage *e* is suddenly applied to the inductance and capacitance in series. This

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

L–*C* combination forms an oscillatory circuit and produces a transient of frequency:

Which appears across the capacitor *C* and hence across the contacts of the circuit breaker. This transient voltage, as already noted, is known as re-striking voltage and may reach an instantaneous peak value twice the peak phase-neutral voltage *i.e.* 2 *Em*. The system losses cause the oscillations to decay fairly rapidly but the initial overshoot increases the possibility of re-striking the arc. It is the rate of rise of re-striking voltage (R.R.R.V.) which decides whether the arc will re-strike or not. If R.R.R.V. is greater than the rate of rise of dielectric strength between the contacts, the arc will re-strike. However, the arc will fail to re-strike if R.R.R.V. is less than the rate of increase of dielectric strength between the contactsof the breaker. The value of R.R.R.V. depends upon:

(a) Recovery voltage

(b) Natural frequency of oscillations

For a short-circuit occurring near the power station bus-bars, *C* being small, the naturalfrequency