## UNIT – II

## SWITCHING TRANSIENTS

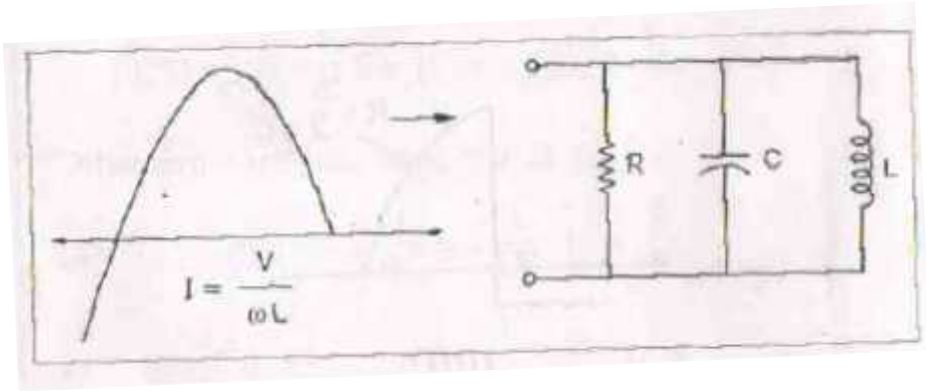
1. **What are classes of power system transients?**
   The transients in a power system can be grouped into three categories depending on the speed of the transients.
   (a) Class A – Ultra Fast transients
   (b) Class B – Medium Fast transients
   (c) Class C – Slow transients
2. **What is meant by resistance switching?**(May/June 2011, 2012)
   A deliberate connection of a resistance in parallel with the contact space (arc) is made to overcome the effect of transient recovery voltage. This is known as resistance switching.
3. **What are the objectives of resistive switching?**
   (a) To reduce switching surges and over-voltages
   (b) For potential control across multi breakers per phase in the high voltage breakers
   (c) To reduce natural frequencies effects and breaker recovery voltage.
4. **Define switching transients**
   The switching transient is initiated whenever there is a sudden change of circuit conditions. This transient is most frequently developed due to switching operations such as,
   a) The closing of a switch (or) circuit breaker to energies a load.
   b) The opening of a circuit breaker to clear a fault
5. **Give the relation between time constant of parallel and series circuit**
   Time constant of parallel circuit Tp = RC
   Time constant of series circuit Ts = L/R
   The product of the time constants is the square of the angular period of the un-damped circuit which is given by, $T_pT_s = LC = T^2$
6. **What is the need for resistance switching?**(Nov/Dec 2011)
   The shunt resistors connected across circuit breaker have to perform the following functions.
   a) To reduce the rate of rise of re-striking voltage and the peak value of re-striking voltage.
   b) To reduce the voltage surges due to current chopping and capacitive current breaking.
   c) To ensure even sharing of re-striking voltage transient across the various breaks in multi break circuit breakers.
7. **Why the circuit breakers are more sensitive to re-striking voltage transient?**
   In air blast circuit breaker it is observed that the rate at which dielectric strength of the gap increases is lower than the oil circuit breaker. Since air has a much lower dielectric strength than the gases at same temperature and pressure in oil CB. The dielectric strength of a gas increases with pressure. Thus the air blast CB is more sensitive to the re-striking voltage transient.
8. **Define Load switching**
   The frequent functions performed by switching devices are to switch on and switch off load (i.e) load switching which is represented by a parallel RL circuit.
   Low power factor loads are inductive and high power factor loads are resistive.
   When a high pf load is switched off, the effective capacitance of load becomes important in determining the form of transient produced.

9. **What is meant by current chopping?** (Nov/Dec 2011, 2012, 2013) (May/June 2012)
   When breaking low currents (i.e) unloaded transformer or reactor magnetizing current, the powerful deionizing effect of air blast circuit breaker (CB) causes the current abruptly to zero well before the natural current zero is reached. This phenomenon is called current chopping and it produces high voltage transients across the breaker contacts. The transient over voltages due to current chopping is prevented by resistance switching.
10. **Define capacitance switching**
    The shunt capacitors are employed to correct a lagging power factor, or in some cases, to provide voltage support for the system. In some applications they are switched in and out quite frequently as the system load varies and the system voltage fluctuates. The switching operations are nontrivial and should be carefully considered when designing capacitor banks and their associated switching equipment. This is called as capacitance switching.
11. **What is meant by abnormal switching transients?**(Nov/Dec 2011)
    Due to some other circumstances like transients the voltage and current magnitude may rise high. The transients occur due to trapping of energy and its subsequent release somewhere in the circuit. Such transients are referred as abnormal current and voltage transients.
12. **Define ferroresonance condition.**(Nov/Dec 2011) (April/May 2011)
    Resonance causes high transient voltage in the power system. In usual transmission lines the capacitance is very small so that resonance rarely occurred in power system at normal frequency. However if generator emf wave is distorted, the trouble of resonance may occur due to $5^{th}$ or higher harmonics. This phenomenon is referred as Ferro resonance, since the inductance involved is usually iron cored.
13. **Define Basic Impulse Level (BIL).**
    It is defined as the minimum insulation impulsive withstands voltage of any power equipment or apparatus. The BIL of a power system is usually chosen as 25% to 30% more than the protective level offered by protective devices.
14. **What is power swing?**
    During switching of lines or wrong synchronization surges of real and reactive power flowing in transmission line causes severe oscillation in the voltage and current vectors. It is represented by curves originating in load regions and travelling towards relay characteristics.
15. **What are the methods of capacitive switching?**
    (a) Opening of single capacitor bank
    (b) Closing of one capacitor bank against another
16. **What is Arc voltage?**
    It is the voltage that appears across the contacts of the circuit breaker during the acing period.
17. **What is re-striking voltage?**(Nov/Dec 2012, 2013)
    It is the transient voltage that appears across the contacts at or near current zero during arcing period.
18. **What is recovery voltage?**
    It is the normal frequency (50Hz) 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.
19. **What is Rate of rise of re-striking voltage (RRRV)?**
    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/µs.

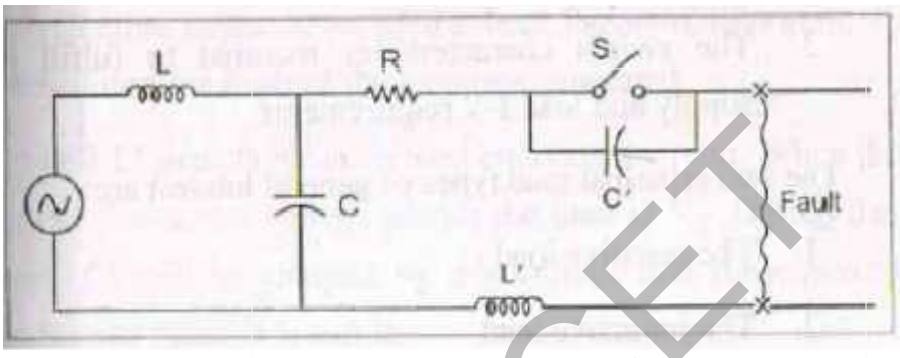
**20. What are the causes for ferroresonance?**(May/June 2011)

Ferroresonance or nonlinear resonance is a type of resonance in electric circuits which occurs when a circuit containing a nonlinear inductance is fed from a source that has series capacitance, and the circuit is subjected to a disturbance such as opening of a switch.

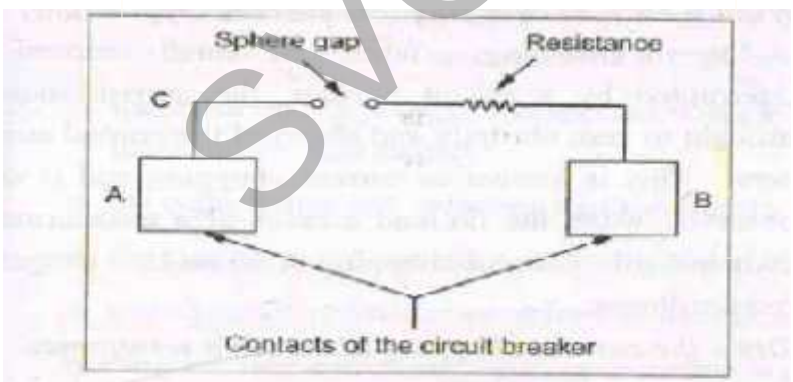
**21. Draw the equivalent circuit of resistance switching.** (Nov/Dec 2010)



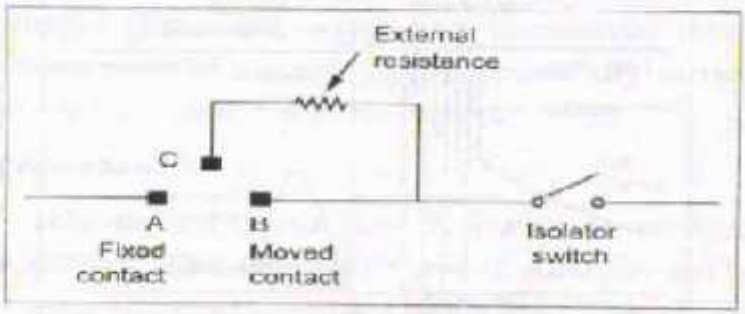

**22. Draw the equivalent circuit for interrupting the resistor current.**




**23. Draw the conceptual circuit of resistance switching.**

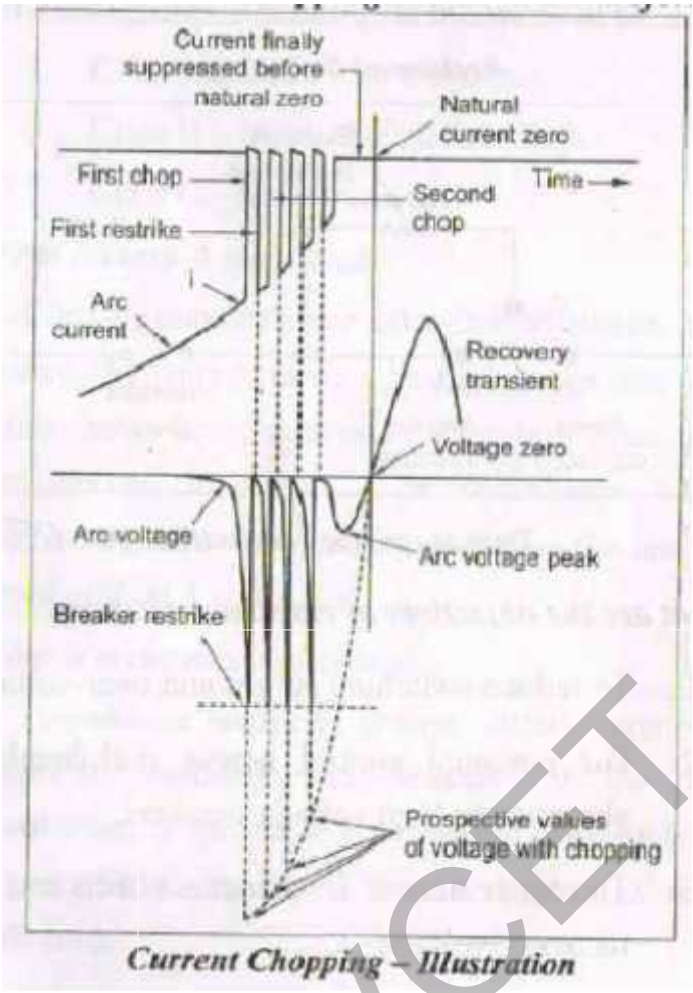



*Resistance Switching*




*Typical resistor connection*

**24. Draw the current chopping illustration waveform.**



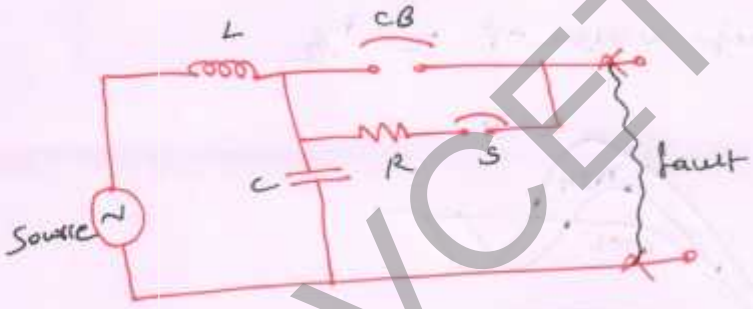

*Current Chopping – Illustration*

## UNIT -II

① Explain in detail about resistance switching & equivalent circuit

A deliberate connection of a resistance in parallel with the contact space (arc) is made to overcome the effect of transient recovery voltage.

This is known as Resistance Switching.




Shunt resistor across capacitor. C.B have two function

(i) To distribute transient recovery voltage equally uniformly across breaker

(ii) To reduce the oscillatory recovery voltage

R is equal to (or) less than $\frac{1}{2}\sqrt{L/C}$

for critical damping

$R = \frac{1}{2}\sqrt{L/C}$

$$V/S = (RLCs^2 + Ls + R)\bar{I}_2(s)$$

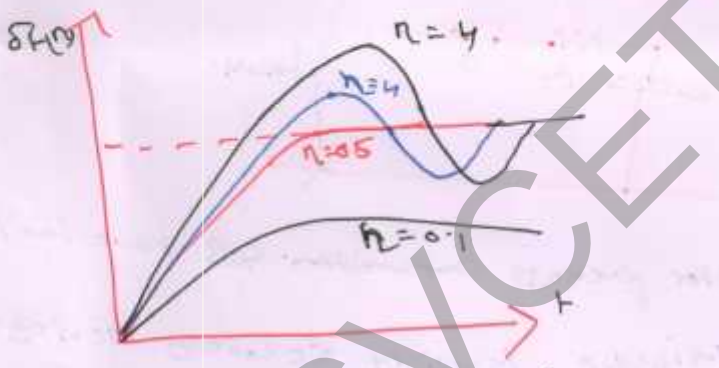
$$\bar{I}_{2(s)} = \frac{V}{s(RLCs^2 + Ls + R)}$$

$$i_{2(t)} = V/R \left[1 - e^{-\alpha t}\left(\cos\sqrt{\gamma}t + \frac{\alpha}{\gamma}\sin\sqrt{\gamma}t\right)\right]$$

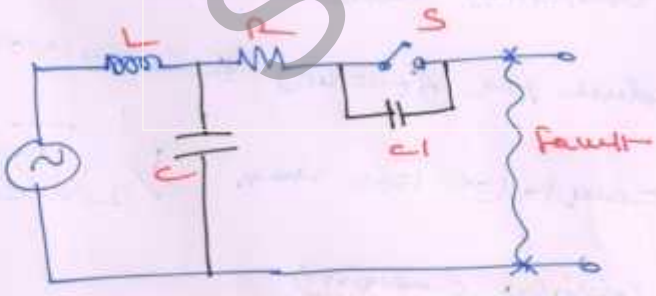
natural frequency of oscillation

$$f_n = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{1}{4C^2R^2}}$$

different value of $n = R/2$




The equivalent circuits



(2) Derive the equivalent circuit of load switching and also its waveform

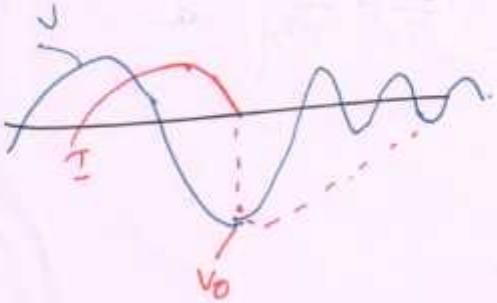
The transient function performed by switching devices are to switch on and switch off load load switching which is represented by a parallel RL circuit.

Low power factor loads are inductive

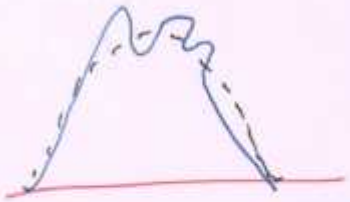
High power factor loads are resistive

when high P.f load is switched off, the effective capacitance load becomes important in determining the form of transient produced.


equivalent circuit

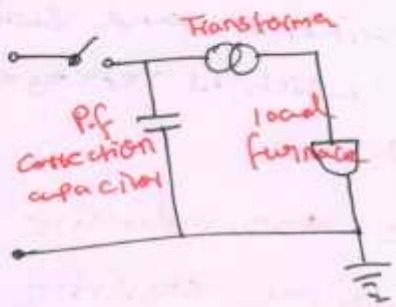



Transient voltage across load

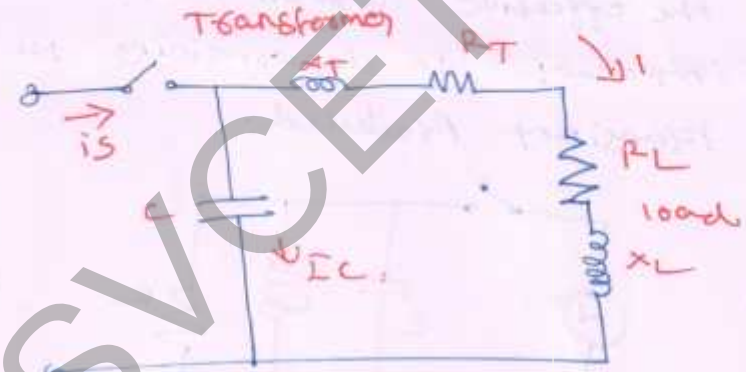


Transient voltage across switch.

Arc furnace in industries operate at a low voltage and high current and consequently fed by step down furnace transformer.




Schematic ~~representation~~ of arc furnace




$$V_{c(s)} = \left[ \frac{1}{s^2 + \frac{s}{T_s} + \frac{1}{T^2}} \right] \frac{I_0}{C}$$

(3) Briefly explain about normal & abnormal switching transients

- when the switch opens in single phase circuits. It is possible for the recovery voltage to reach a value twice as high as normal peak voltage of the system.

- when a switch close, then the current can reach a value a twice that of the everyday steady-state current.

Practically this theoretical magnitude of current and voltage are not achieved because of circuit damping

The transient occur due to trapping of energy and its subsequent release in the circuit. Such transient are referred as abnormal current and voltage transients.

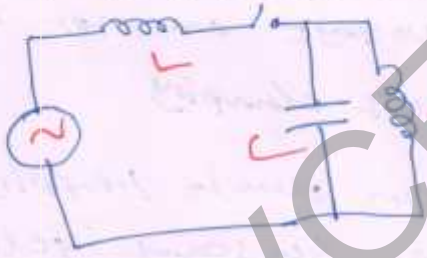
It is also caused due to change on a capacitor (or) line and current in an inductor. a circuit is completely quiescent when a transient is initiated it is called normal transient

4 write short notes on current chopping

- necessity of interrupting small inductive current arises while disconnecting transformer on no load.

when breaking low current, the powerful deionizing effect of air blast circuit breaker causes the current abruptly to zero.

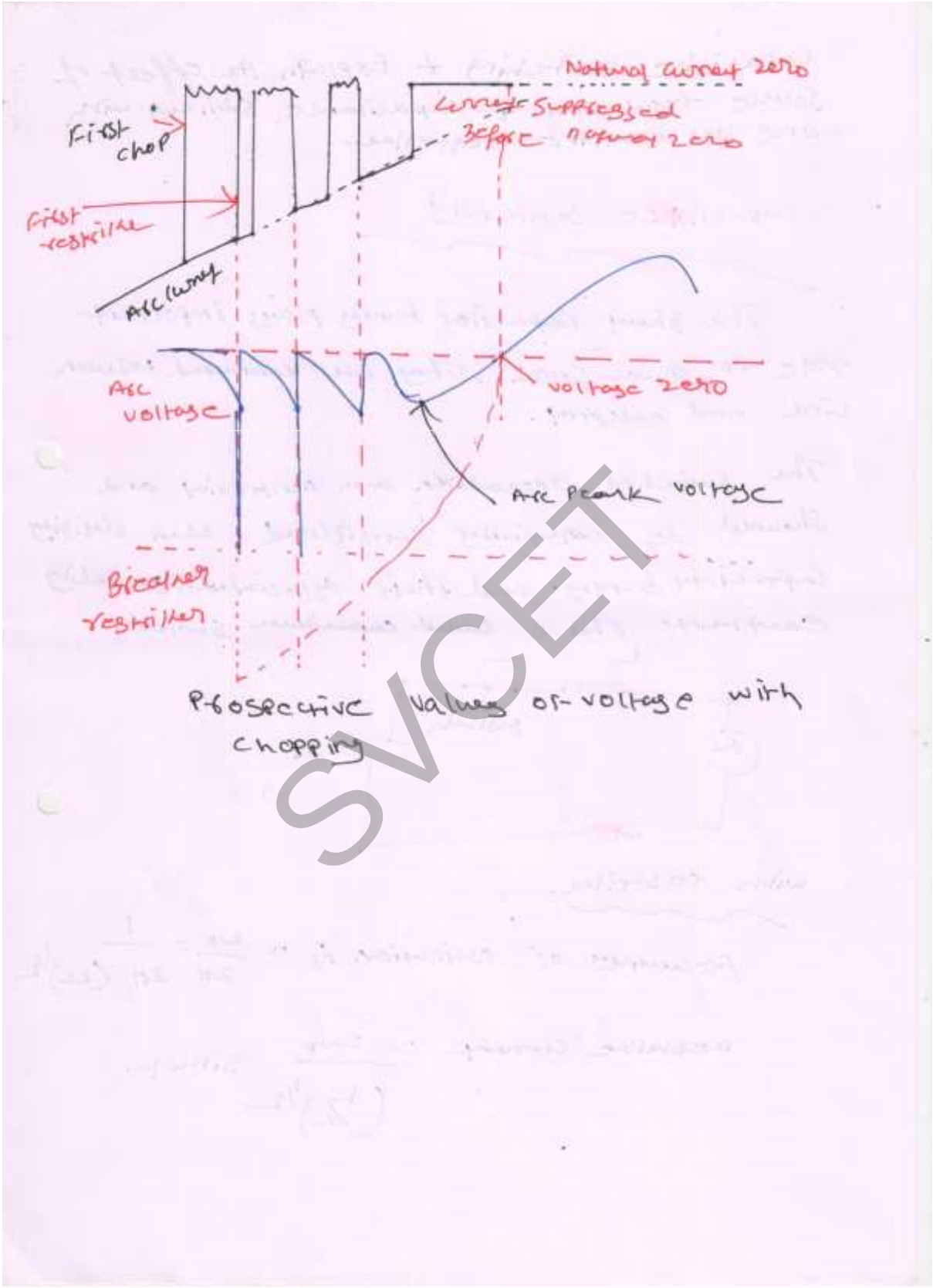
For breaking low magnetising current the CB need to perform 'severe' duty.




$\frac{1}{2} Li^2 = \frac{1}{2} CV^2$

$V = i\sqrt{L/C}$ $f_n = \frac{1}{2\pi\sqrt{LC}}$

$L_0 = \frac{X_0}{2\pi f}$


Natural current zero
Current suppressed
before natural zero
First chop
First restrike
Arc current
Arc voltage
voltage zero
Arc peak voltage
Breaker restriker
Prospective values of voltage with chopping

capacitive switching & Explain the effect of source regulation & capacitance switching with one (or) multiple restrike.

## Capacitance Switching

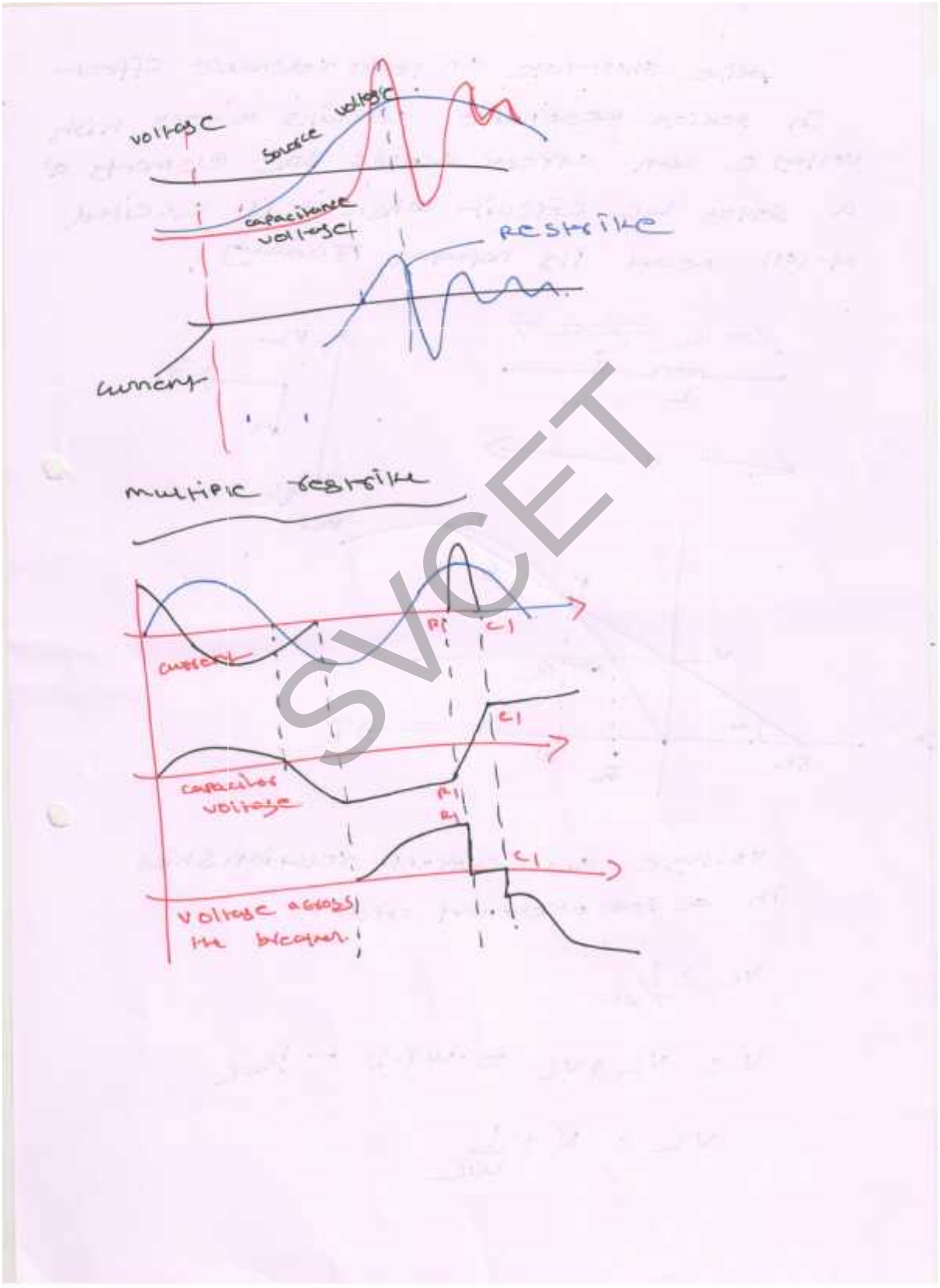
The Shunt capacitor banks plays important role in Power System. They are connected between line and neutral.

The switching operation are nontrivial and should be carefully considered, when designing capacitor banks and their associated switching equipment. This is called capacitance switching.


with restrike.

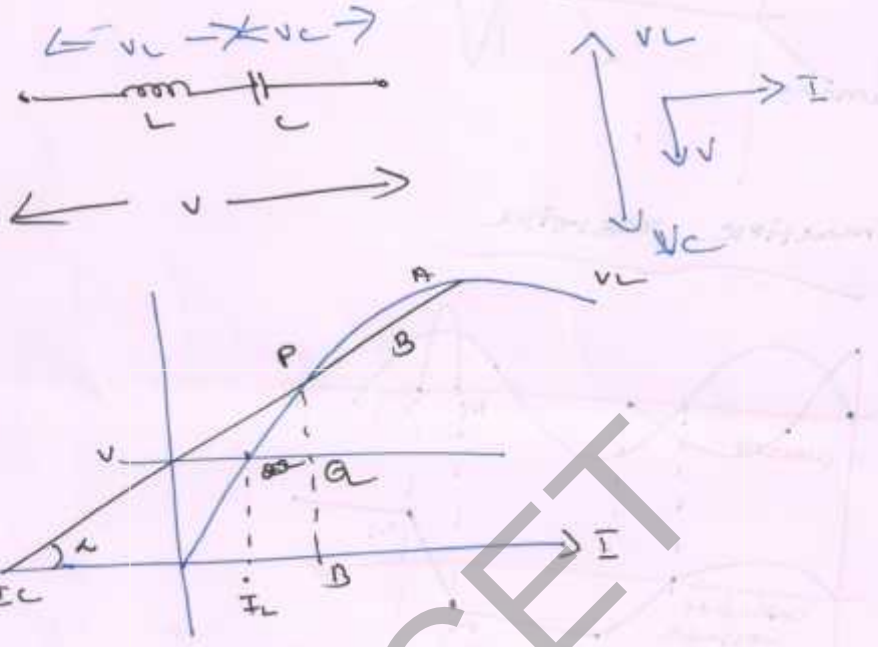
frequency of oscillation $f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi (LC)^{1/2}}$

Restrike current $= \frac{2v_p}{(L/C)^{1/2}}$ sin ωt.


voltage
source
voltage
capacitance
voltage
restrike
current
multiple restrike
current
capacitor
voltage
voltage across
the breaker.

write short note on ferro resonance effect.

In series Resonance circuits a very high voltage can appear across LC elements of a series LC circuit when it is excited at (or) near its natural frequency.




voltage and current relationships in a ferro resonant circuit.

$$V_C = \frac{1}{\omega C}$$

$$V = V_L + V_C = \omega f(i) - 1/\omega C$$

$$V_L = V + \frac{1}{\omega C}$$