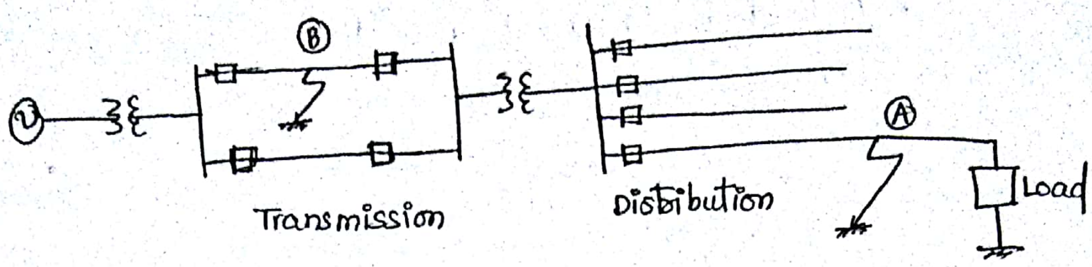
unit-2

(11) Sources of Sags and Interruptions:-

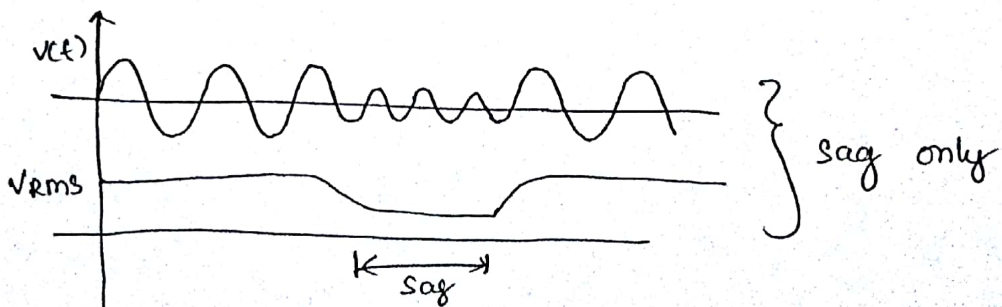


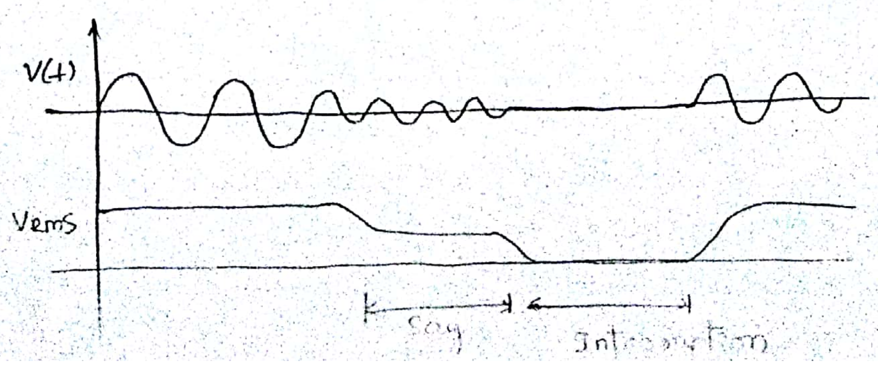
→ If there is a fault at point A (on the same feeder of load connected) the customer will experience a voltage sag during the fault and interruption when a breaker opens to clear the fault.

- If the fault is temporary in nature, a reclosing operation on the breaker should be successful and the interruption will only be temporary.
- CKT breaker require 5 or 6 cycles to open in this duration sag occurs.
- The breaker will remain open for typically a minimum of 12 cycles depends on utility reclosing.

→ suppose a fault happend on the parallel feeders the customer will experience a voltage sag during the period. ~~that the~~ as soon as breakers open to clear the fault, normal voltage will be restored at the customers.

•





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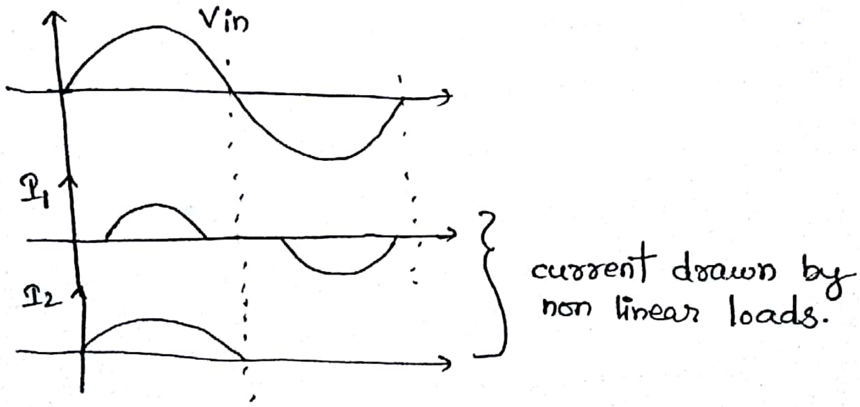
(12) **Non linear loads:-**

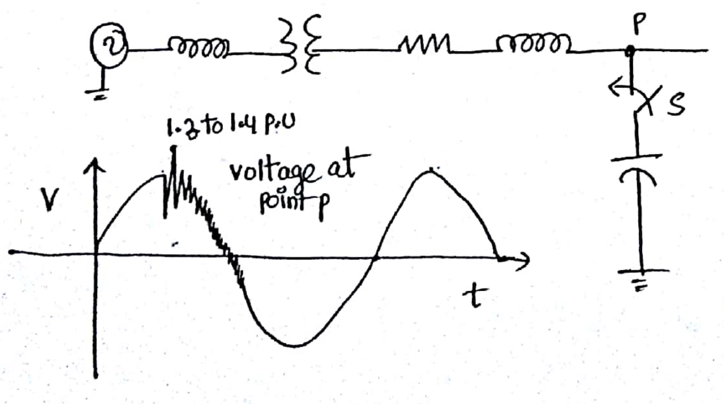
- A load is considered non-linear if its impedance changes with the applied voltage.
- The changing impedance means that the current drawn by the non linear load will not be sinusoidal even when it is connected to a sinusoidal voltage.
- These non linear sinusoidal currents contain harmonic currents that interact with the impedance of the power distribution system to create voltage distortion.
- Arc furnaces, variable frequency devices, rectifiers, are examps for non linear load
- 

① Sources of Transient over voltages:-

- There are main ~~sources~~ Reasons of Transient over voltages are
  - I. capacitor switching
  - II. magnification of capacitor switching Transients
  - III. Restrikes during capacitor de-energization
  - IV. Lightning
  - V. ferroresonance.

i) capacitor switching:-

- capacitors are to provide reactive power (VARs) to correct the powerfactor, which reduces the losses and supports the voltage on the system
- These are economically less cost than rotating machines, electronic var compensators
- But drawback of these are causing oscillatory transients when they switched.



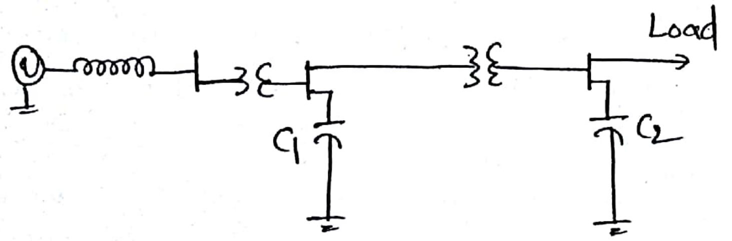
The peak point voltage ≃ 1.3 to 1.4 P.U

- consider capacitor voltage is zero initially and capacitor switch S contacts closed at a point near to peak
- Since the capacitor voltage cannot change instantaneously, the voltage ~~vol~~ across the capacitor will maintain zero
- The system voltage at the capacitor location is briefly pulled down to zero and rises as the capacitor begins to charge toward the system voltage

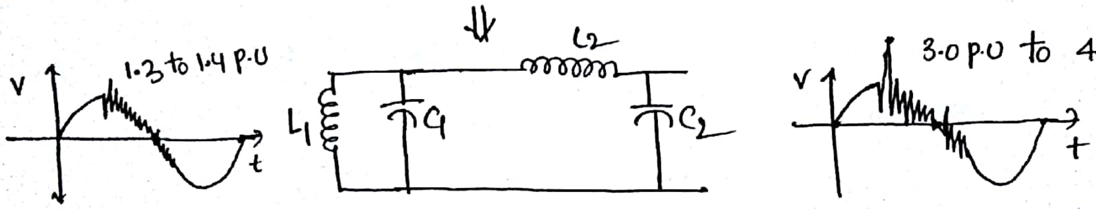
- Because the power system source is inductive, the capacitor voltage overshoots and rings at the natural frequency of the system.

ii) Magnification of capacitor switching Transients :—

- The effect of adding power-factor correction capacitors at the customer location is that they may increase the impact of utility capacitor switching transients on end user equipment.
- There is always a voltage Transient of at least 1.3 to 1.4 p.U when the utility capacitor banks are switched but load side capacitors magnify this transient over voltage to 3.0 p.U to 4.0 p.U at the load side.



$C_1 \rightarrow$ utility capacitor
$C_2 \rightarrow$ load side capacitor



Switching frequency $f_1 = \frac{1}{2\pi\sqrt{L_1C_1}}$

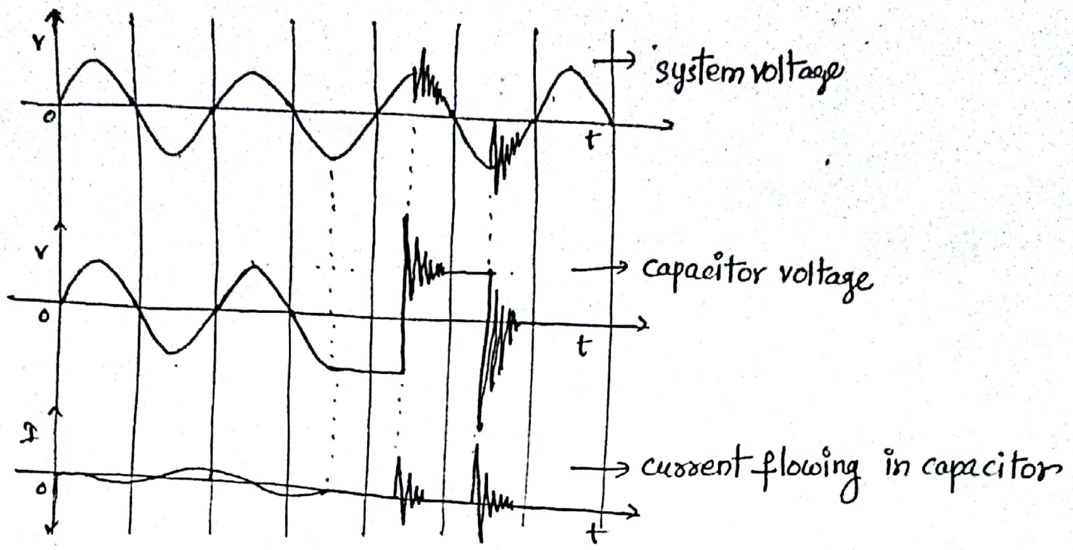
Natural frequency of customer resonant CKT $f_2 = \frac{1}{2\pi\sqrt{L_2C_2}}$

Voltage magnification $\Leftrightarrow f_1 \simeq f_2$

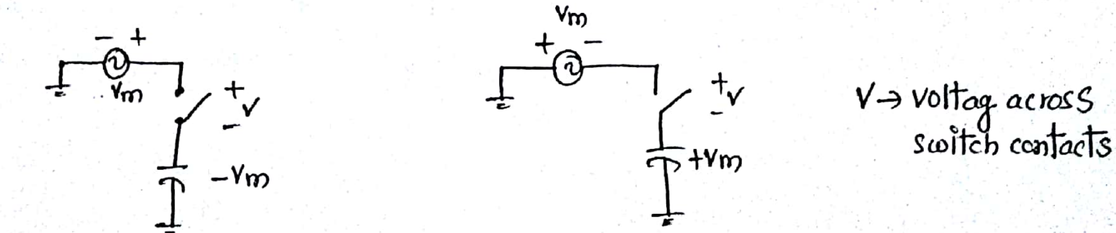
- voltage magnification occur when $f_1 \simeq f_2$.

iii) Restrikes during capacitor De-energigation:-

- consider a grounded capacitor being de-energiged. System and capacitor voltages along with current flowing in the capacitor are shown below.



- when the ~~capacitor~~ switch is opened at negative peak, the capacitor maintains a voltage of −1.0 p.u for sometime because of trapped charges (capacitor does n't allow sudden change of voltages)
- The first restrike occurs at the next immediate system peak voltage, causing system and capacitor voltages to overshoot above 2.0 p.u.



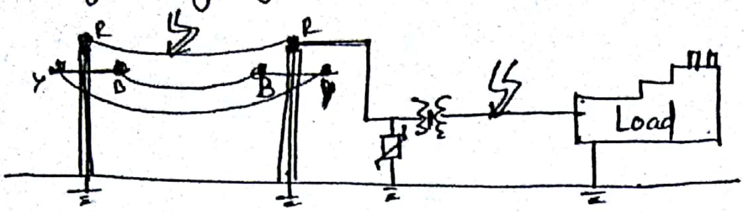
$-V_m + V - V_m = 0$
$V = 2V_m$

$V_m + V + V_m = 0$
$V = -2V_m$

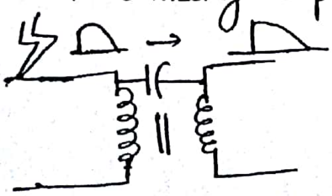
- The capacitor is reenergiged because the arc has been re-established between switch contacts even though they are apart.
- The second restrike has the potential of causing a higher voltage transient and capacitor charge de-energige completely through the switch contacts.
- Allthough worst case, ~~ad~~ restrikes occur at the system peak voltage, restrikes can occur anywhere between zero and peak voltages

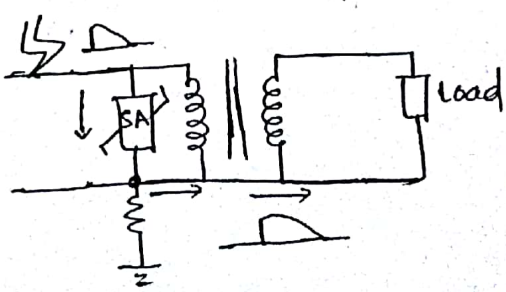
IV) Lightning:-

- Lightning is a potent source of impulse transients.
- Transient over voltages can be generated by lightning currents flowing along ground conductor paths



- strikes to the Transformer primary are conducted to the ground CKTS through the arresters.
- Ground conductors are never perfect conductors especially for impulses. while most of the surge current dissipates into nearest ground connection, there will be substantial surge currents flowing in other connected ground conductors in first few microseconds. Some of the currents may find its way to load apparatus.
- Lightning need not to strike on a conductor to inject impulses into the power system. Lightning may simply strike ~~the~~ near the line and induce an impulse.
- Lightning surges enter loads from the utility system through the interwinding capacitance of the transformers.

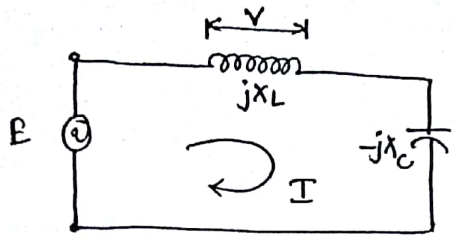




- Because of Non-idal ground conductors transients will move to load through ~~grou~~ Neutral wire.

V) Ferroresonance:-

- The term ferro resonance refers to a special kind of resonance that involves capacitance and iron core inductance.
- The most common condition when the magnetising impedance of a transformer is placed in series with a system capacitor.
- Resonance occurs in linear CKTS and results high currents of resonant frequency.
- Ferroresonance occurs in non-linear CKTS.



$$I = \frac{E}{j(X_L - X_C)} \longrightarrow ①$$

$$V = I(jX_L) \longrightarrow ②$$

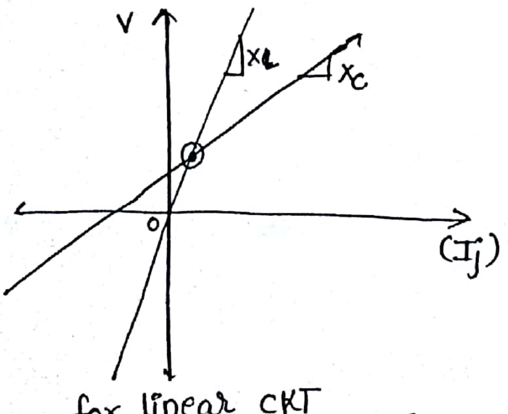
$$V = X_L(Ij) \quad [\, y = mx \,]$$

$$E = I(jX_L - jX_C)$$

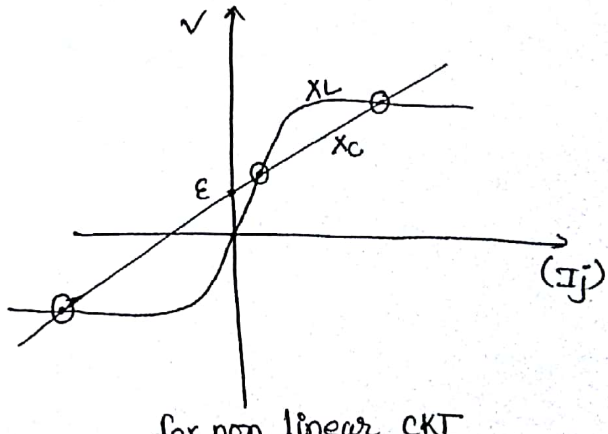
$$E = I(jX_L) - I(jX_C)$$

$$E = V - I(jX_C) \Rightarrow V = E + I(jX_C)$$

$$V = X_C(Ij) + E \quad (y = mx + c)$$

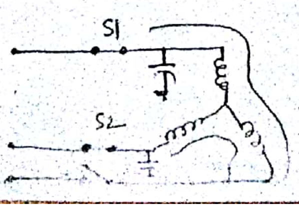


for linear CKT
[linear inductance]



for non linear CKT
[non linear inductance]

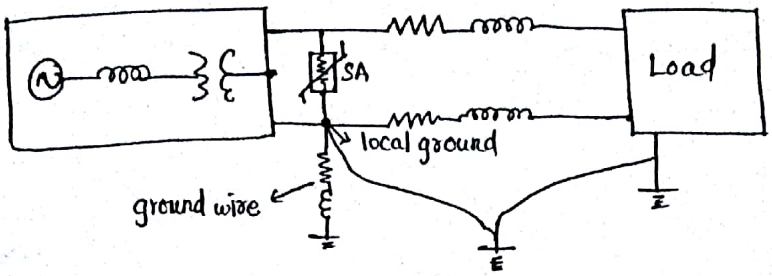
- I linear CKTS [Ex: series RLC] Resonance occur when $|X_L| = |X_C|$ results infinitely large current
- But in non-linear CKTS $|X_L|$ equals to $|X_C|$ number of times and results infinitely large current number of times



S_1, S_2 closed
S_3 open → ungrounded Transformer primary connections cause ferro resonance

② Principles of over voltage protection:-

- Limit the voltage across sensitive insulation
- Divert or Block the surge current away from the load
- Bond grounds together at the equipment to reduce or prevent surge current flowing between grounds.



- The local ground may not remain at zero potential during transient impulsive events. voltage at that point increase and cause flow of surge current though neutral. To avoid this all grounds reference conductors should be bonded together at the load equipment.
- If two grounds are not at same potential, will cause physical harm to operators or sensite equipment.

③ Devices for over voltage protection:-

i) Surge arresters and Transient voltage Surge Suppressors
ii) Isolation transformers
iii) Low pass filters
iv) Low impedance power conditioners
v) utility surge arresters.

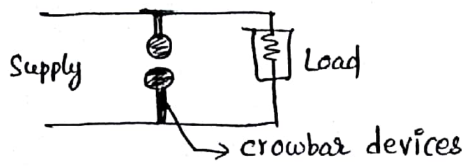
i) Surge arresters and TVSS:-

- SAs and TVSS are generally associated with devices used at the load equipment, to protect equipment from transient over voltages by limiting the maximum voltage.

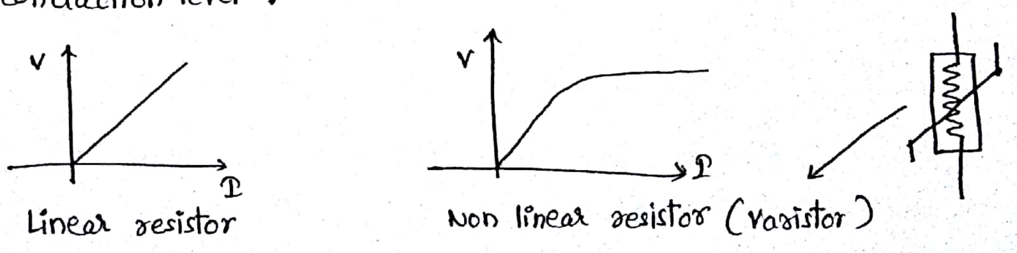
- SAs and TVSS are mostly MOV Blocks. MOVs blocks are normally non-linear resistors (varistors)
- The elements that make up these devices can be classified by two different modes of operation
    - crowbar devices
    - clamping devices

[∴ MOV – metal oxide varistors]

- crowbar devices are normally open devices (spark gaps) that conduct current during over voltage transients. once the device conducts the line voltage will drop to nearly zero due to short CKT. These devices are usually manufactured with a gap filled with air or gas.

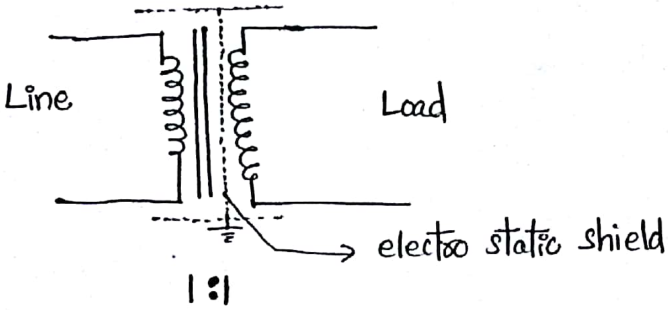


- clamping devices are commonly non-linear resistors (varistors) that conduct very low amounts of current until an over voltage occurs. Their impedance drops rapidly with increasing voltage. advantage of these devices are "line voltage is not reduced below the conduction level".



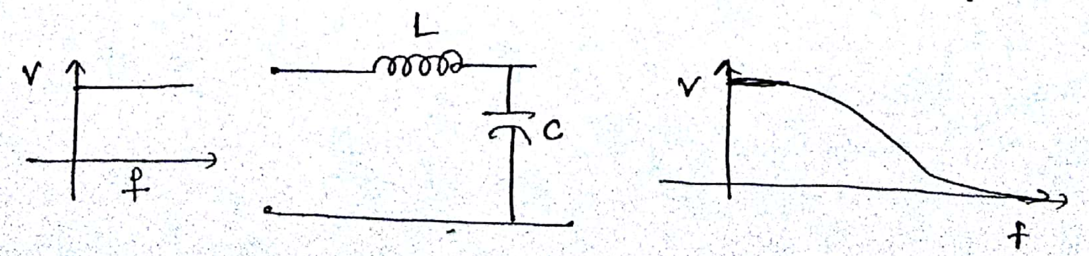
ii) Isolation transformers:-

- Isolation Transformers are used to attenuate high frequency noise and transients which are going to one side to another side
- Its leakage inductance is very less.
- additionally added Electrostatic shield between primary and secondary windings, electrically isolating the load from system
- Therefore high frequency noise in the primary are kept from the reaching the load.
- Also load generated transients will not allowed to primary side.
- can Eliminate voltage notching effect on the system.



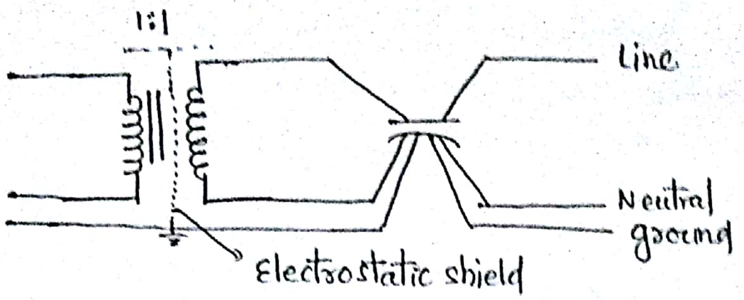
iii) Low pass filter:-

- Low pass filters are used to better protection for high frequency transient over voltages.
- Generally low pass filters are composed of series inductors and parallel capacitors.
- The inductor helps to block high frequency transients
- The capacitor limits the rate of rise of voltage



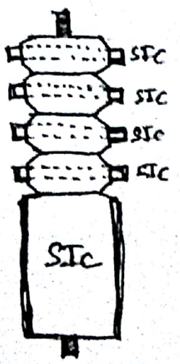
iv) Low impedance power conditioners (LIPCs):-

- LIPCs are normally combination of Isolation transformer plus filter
- LIPCs have a much lower impedance and have a filter as part of their design
- The filter is on the output side and protect against high frequency source side disturbances (noise & Impulses)

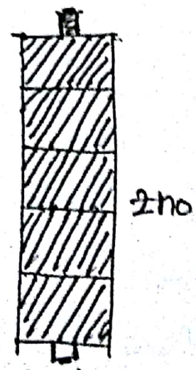


v) Utility surge arresters:-

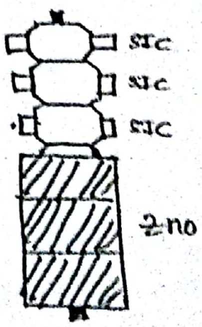
- The three most common surge arrester technologies employed by utilities are
    - Gapped silicon carbide (SIC)
    - Gapless MOV (ZnO)
    - Gapped MOV



Gapped silicon carbide



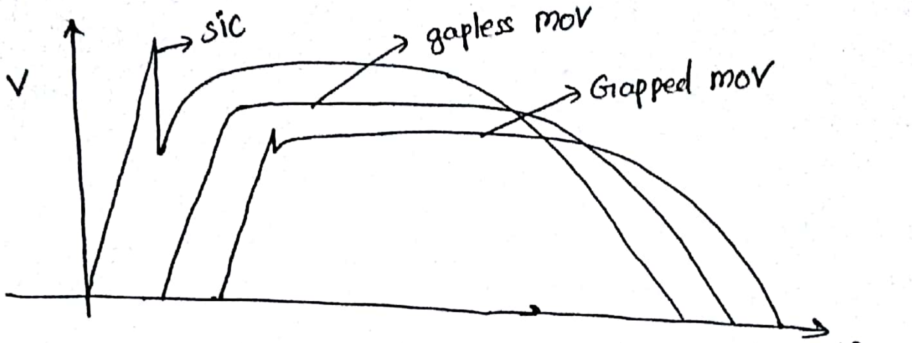
Gapless MOV



Gapped MOV Blocks

- Most arresters manufactured today use a MOV as the main voltage limiting element
- The older technology arresters used silicon carbide (SiC) as the non-linear resistance element in series with a spark gap.

- The voltage across the gap structure increases faster than the voltage across the material.
- Zno had a more favourable non-linear voltage current relationship than silicon carbide.
- So SIC replaced with Zno (MOV blocks) initially, next mov Blocks replaced with gapped mov arresters.
- The energy dissipated in the gapped mov blocks is less than gapless designs for the same lightning current.



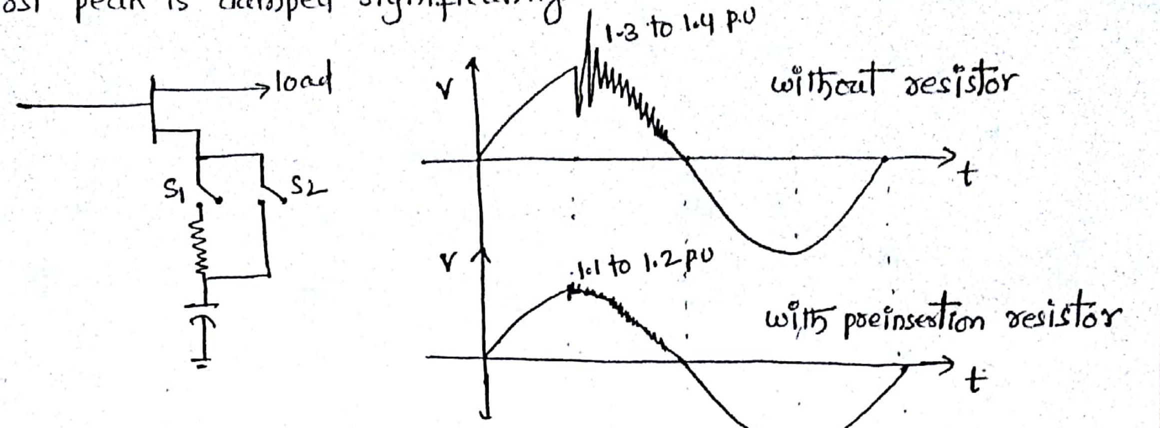
Lightning discharge voltage characteristics

④ Protection for utility capacitor switching transients:-

switching times:-

- Capacitor switching Transients are very common
- These transients may effect some sensitive loads
- If the loads picks up the same time each day, the utility may decide to switch the capacitor coincident with that load increase.
- So this coincidence causes several adjustable-speed drives to shut down shortly.
- It is better to switch-on the capacitor a few minutes before the begining of the load shift.

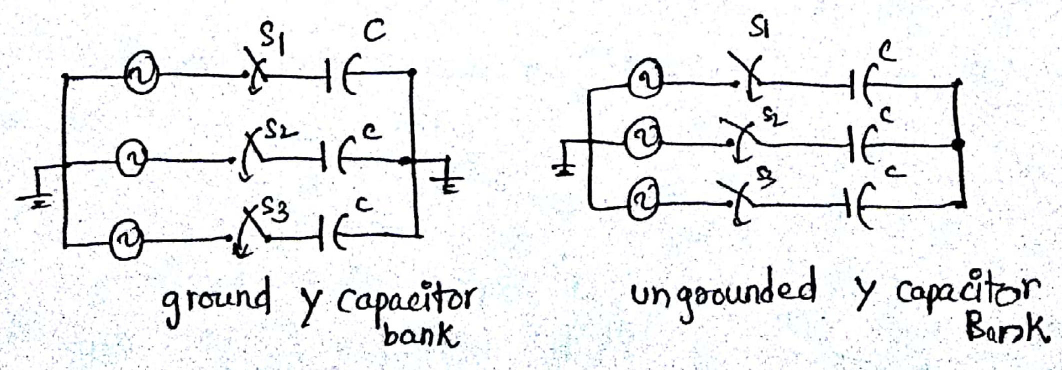
- Preinsertion resistors can reduce the capacitor switching transients
- The first peak of the transient is usually the most damaging so the idea is to insert a resistor into the CKT so the first peak is damped significantly.



- Initially resistor includes in the CKT (S_1 on, S_2 off). when the switch S_2 is closed automatically switch S_1 will open.
- Peak average values Expected : 1.3 to 1.4 p.u without resistors
  1.1 to 1.2 p.u with resistors
- a preinsertion resistor also reduce the capacitive inrush current during energiging.
- switching with preinsertion reactors have also been developed. It is helpful in limiting the high frequency components.

Synchronous closing:-

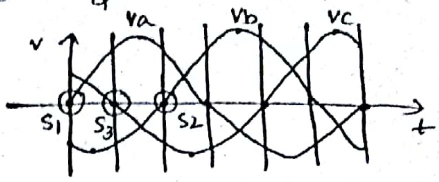
- Synchronous closing prevent transients by closing the switch at that time when the system voltage matches the capacitor voltage.



maintain sufficient di-electric strength to withstand the system voltage until its contacts touch.

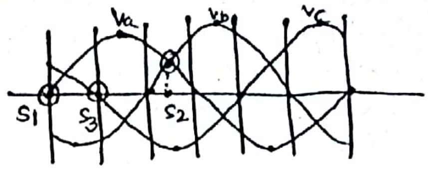
- For a grounded y capacitor every switch has to be closed when its corresponded phase voltage is zero

S_1 close at $V_a = 0$
S_2 close at $V_b = 0$
S_3 close at $V_c = 0$



- for a ungrounded y capacitor ~~every~~ switch's has to be closed when $V_a = 0$, S_2 will be closed at $V_a = V_b$ and S_3 at $V_c = 0$

S_1 close at $V_a = 0$
S_2 close at $V_b = V_a$
S_3 close at $V_c = 0$

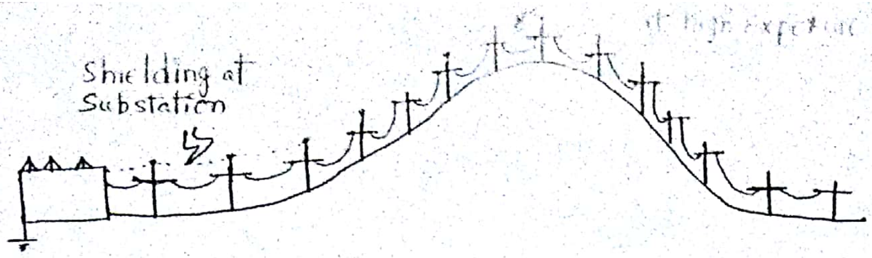


⑤ Utility system lightning protection:-

- shielding
- Line arresters

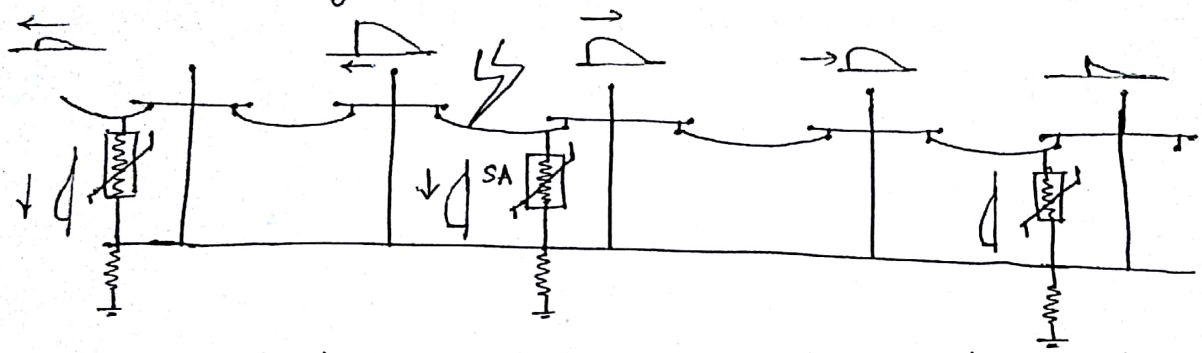
shielding:-

- shielding means providing a neutral wire over the phase lines on the towers.
- Neutral wire directly connect to ground in that tower.
- shielding will intercept most lighting strokes before they strike the phase wires.
- To minimize the back flashovers maintain adequate clearance betwen ground wire and phase wire.
- Also the grounding resistance plays an important role in the magnitude of the voltage and must be maintained as low as possible.
- In some places (hill areas) feeder may give unusual exposure to lightning. shielding in that area may be an effective way to reducing lightning induced faults.

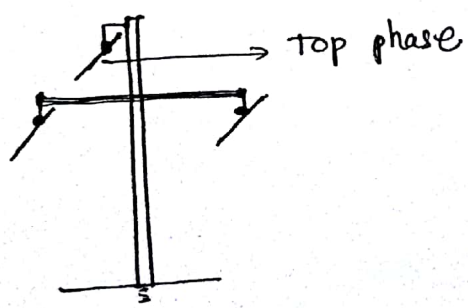


Line arresters:-

- Another strategy to reduce lighting fault is to apply arresters periodically along the phase wires
- Normally lines flash over first at the pole insulators. Therefore preventing flashover will reduce the interruption and sag rate significantiy.



- The amount of current that an arrester bleeds off depending on the ground resistance.
- Some utilities place line arresters only on the top phase when they connected like below but it will be necessary to put arrester on all three phases.



The most widely used computer programs for transient analysis of power systems are

1. Electro magnetic transient program (EMTP)

   - EMPT — RV
   - EMPT — ATP
   - EMPT — MT

2. PSCAD / EMTDC

   Power system computer aided design (PSCAD)

   Electro magnetic transient for DC

3. PSPICE

   Power system simulation program with integrated circuit emphasis.