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EPUS

⇒ 1 unit = 1 kWh

price per unit.
tarrif difference :- 0 - 50 unit → BPL
for different range of unit consumption
51-100 "
101-150 "
unit rate will increase with increase of consumption

in resedential { flat tarrif :- not charged on when we use electricity like during days / nights

in industry { → variable tarrif :- charged based on when we use electricity like during peak hr.

⇒ per unit charge
⇒ service charges / fixed charges :- different for 1-ϕ, 3-ϕ
based on type of user and type of connection

⇒ Fuel Charges for power generation
(FPPA) = 2.5₹/unit.

⇒ Load :- 1kW & 5kW } voltage supply is same 230V r.m.s., 50 Hz
but current for each load will be different. It shows the amt. of current.

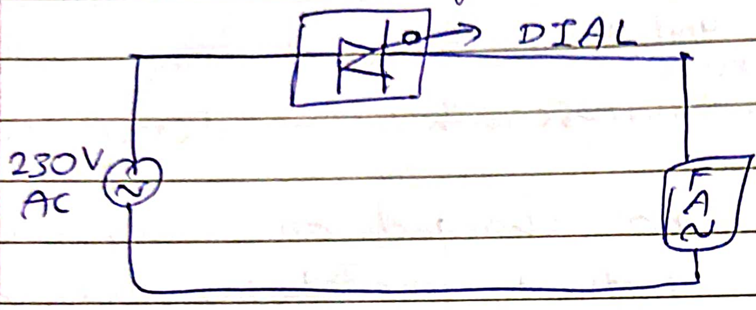
$P = VI\cos\phi$ neglecting

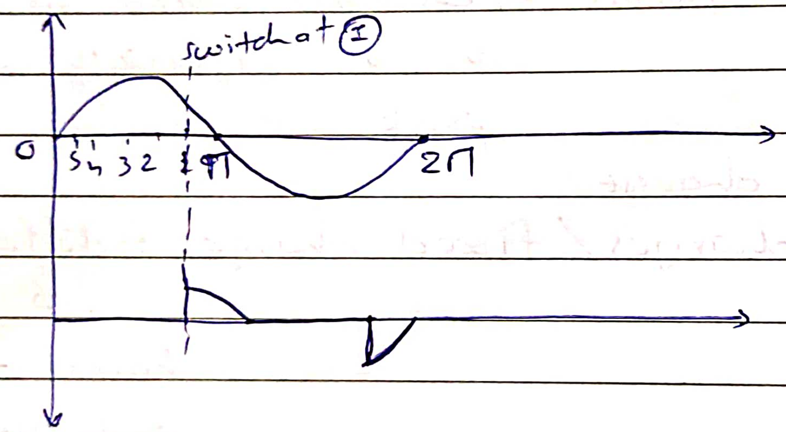
$\therefore P \approx VI$

⇒ Load capacity for 1 - ϕ :- 6 kW for resedential

⇒ TRIAC switch in fan regulator.
↳ Semiconductor.

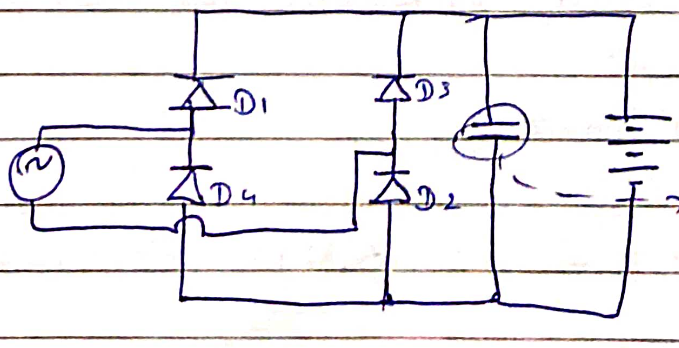
Fan Regulator.





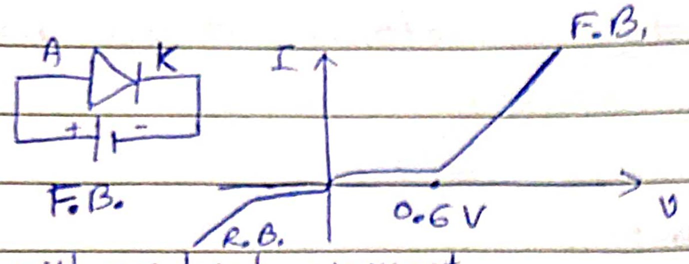
we control rms value of current

⇒ Basic elements in any electrical circuits:-
Resistance (R) : keep the current constant.
Inductors (L) : to oppose the change in current
Capacitor (C): to oppose change in voltage.

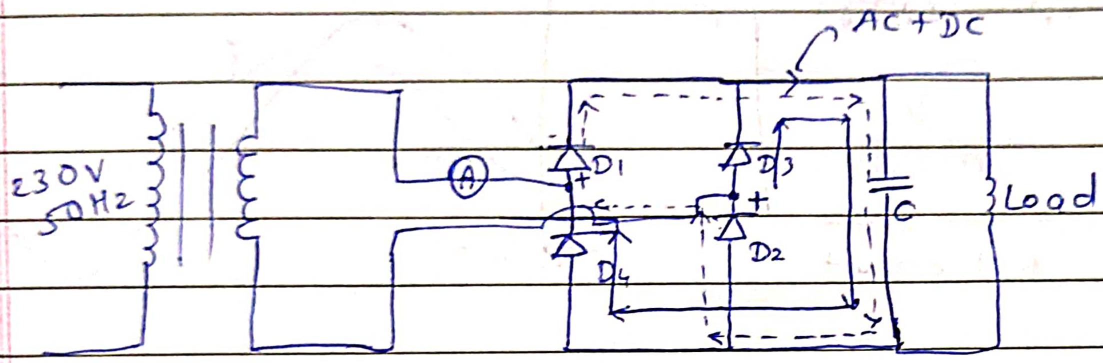


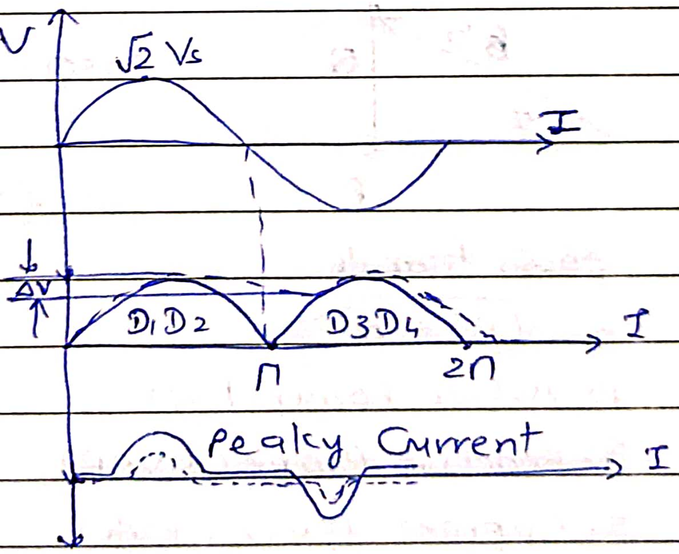
uncontrolled rectifier? (diod based)
→ why here capacitor.

⇒ Diode is P-N Junction.



It will conduct current





$x_c = \frac{1}{2\pi f c}$

in D.C. $f = 0$

$x_c \approx \infty$

So, capacitor will not allow D.C. to flow through capacitor and A.C. will flow through capacitor hence, constant DC will flow through load.

And we will start distructing the utility by

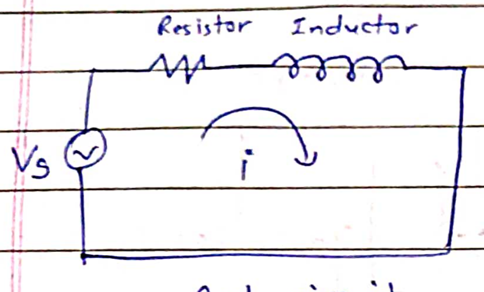
⇒ generating and transforming non-linear current this is known as classical power quality issue.

voltage will remain sin-suiodal but current will be peaky current, so power quality will reduce.

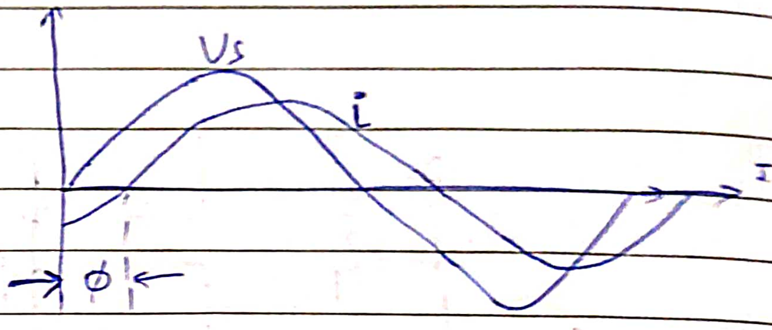
⇒ Power Quality Issue:-

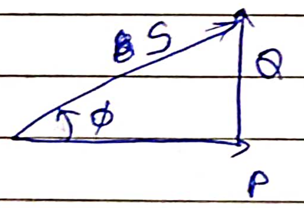
⇒ If ~~po~~ voltage ~~and~~ or current or both will deviate from sino-suidal waveform it will raise power quality issue.

⇒ Power Factor:-



R-L circuit





$$\cos\phi = \frac{P\ (\text{Active Power})}{S\ (\text{Apparent Power})} = \frac{kW}{KVA}$$

It is the cos of phase ~~gap~~ difference/angle betⁿ voltage & current.

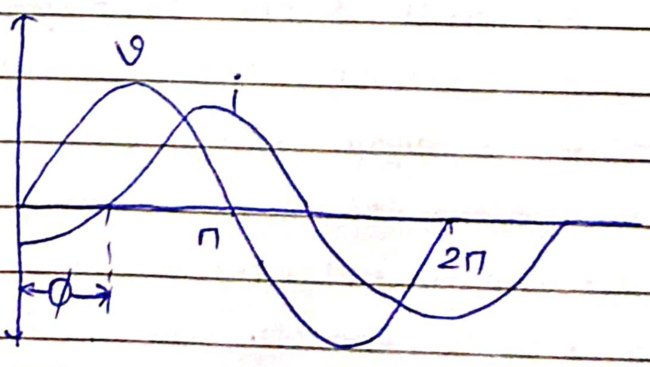
power triangle

$S = \sqrt{P^2 + Q^2}$

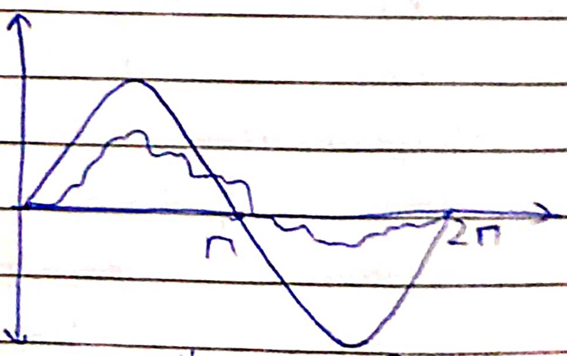
P: Active Power (kW)

Q: Reactive Power (KVAR)

S: Apprant Power (kVh).
or Total Power



P.F. = $\cos\phi$



$\cos\phi = 1 = P/S$

→ statcom

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→ Power Factor of whole system
① Power Factor
② Distortion Factor (other frequency component present in the element)

Total P.F. = $\cos\phi$ × D.F.

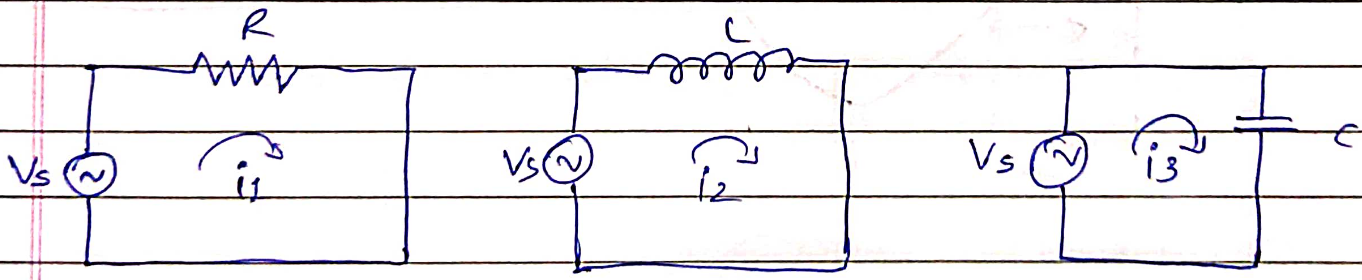
$\cos\phi$ ↓ displacement p.f. ↓ $\cos\phi$ (Fan)

D.F. ↓ Distortion p.f. → non-linear load ↓ deviation of sinwave (Adapter) or power semiconductor electronics of diode based IGBT

→ Many non-linear elements & inductive we use in house.

so both phase difference and distortion will be there; so it will create harmonic pollution.

→ electromagnetic devices tries to oppose Δcurrent.



(1) (2) (3)

Vs : supply voltage (sinosuidal waveform)

$i_1 = \frac{V_s}{R}$

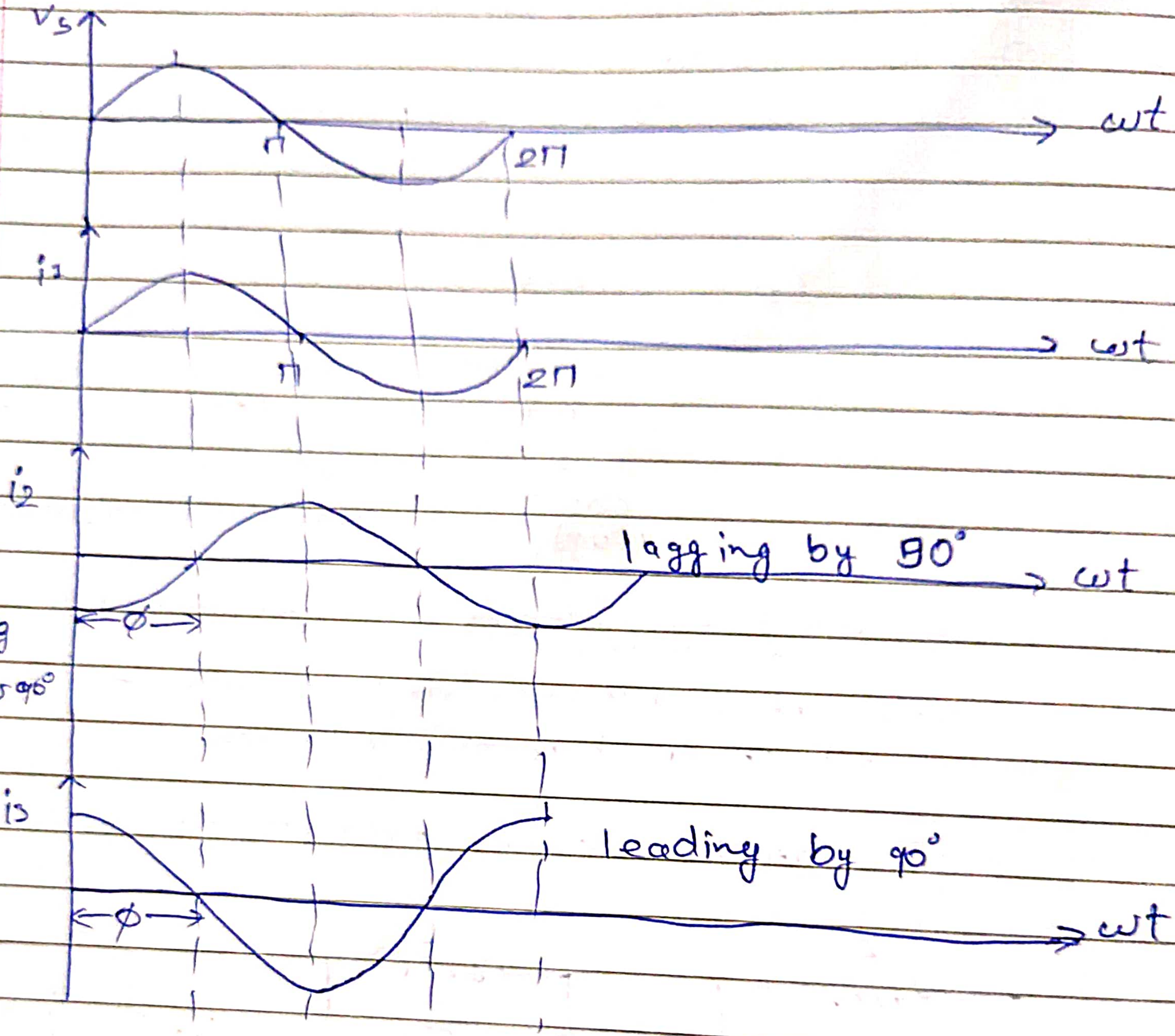
$i_2 = \frac{V_s}{(\omega L)}$ or $\frac{V_s}{(X_L)}$

ωL → $2\pi f L$

X_L → inductive reluctance

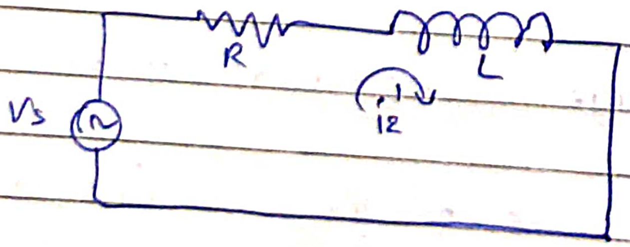
$i_3 = \frac{V_s}{X_c}$

$X_c = \frac{1}{2\pi f c}$



$\cos\phi$
$\Rightarrow$ lagging
power factor $= \cos 90° = 0$.

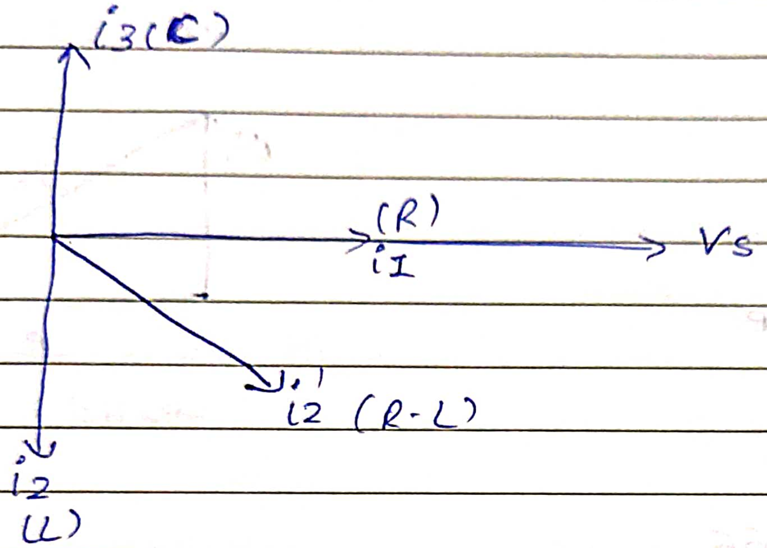
when, R - L circuit is there.



$$i_2' = \frac{V_s}{Z \text{ (impedence)}}$$

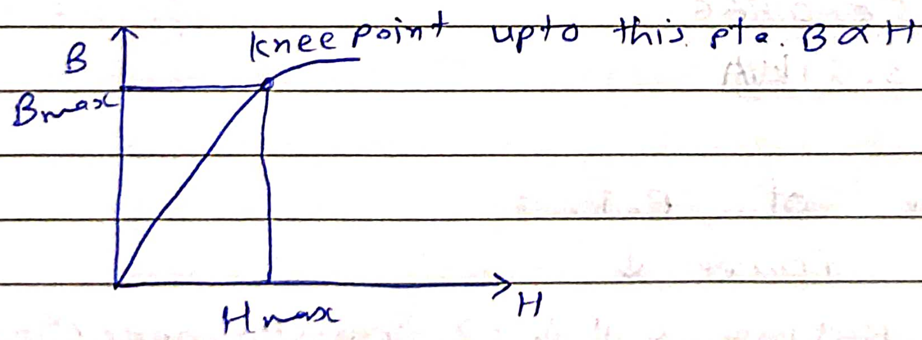
$$Z = \sqrt{R^2 + X_L^2}$$

→ phasor representation:-



→ Power Factor:-

→ B-H Curve:-



→ Linear:-
Capacitor,
Inductor
& Electro-magnetic
devices.

displacement p.f. depends on :- L, C, R.

($\cos\phi$) p.f. for L = 0° to 90° (lagging)

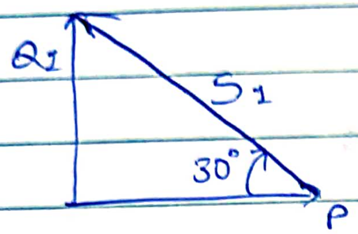
p.f. for C = 90° to 180° (leading)

Total P.F. = $\frac{P}{S}$

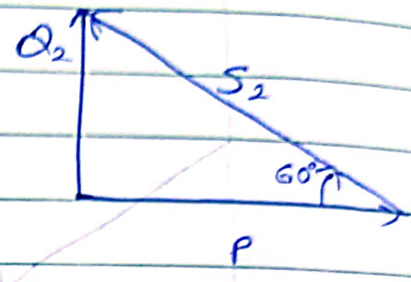
p.f. limit → industry :- 0.9 to 0.95
→ residential :- 0.98

⇒ Power Factor:-

$\phi_1 = 30^\circ$



$\phi_2 = 60^\circ$



$\cos 30^\circ = \frac{\sqrt{3}}{2}$

$= 0.866$

$\cos 60^\circ = \frac{1}{2} = 0.5$

if $P = 5\,kW$

$\cos\phi_1 = \frac{P}{S_1}$

$S_1 = 5/0.866$

$\boxed{S_1 = 5.81\,kVA}$

$\cos\phi_2 = P/S_2$

$0.5 = 5/S_2$

$\boxed{\therefore S_2 = 10\,kVA}$

⇒ Advantage of P.F. :-

→ Reactive Power ↓

→ System Rating will ↓ → Transformer/ Motor Rating will ↓

↓

→ Overall current of system will ↓.

→ I^2R Loss ↓

→ Temp. Rise ↓

→ Life Cycle equipments

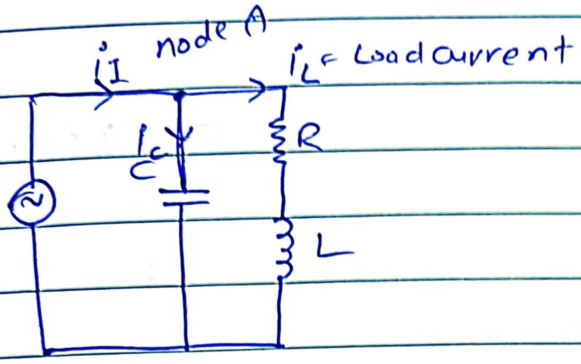
→ Stability of Grid ↑

→ False triggering of devices

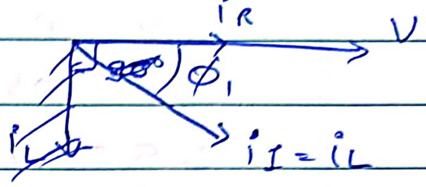
→ Reduce cost of energy or power bill

⇒ Mechanism to Improve P.F. :-

→ Capacitor Bank

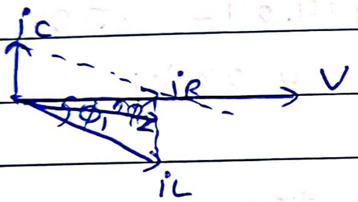


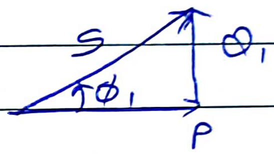
① for only R-L :-
(w/o capacitor)



phasor dia.

② with capacitor:-
R-L-C





power triangle

$\phi_2 < \phi_1$

$\cos\phi_2 > \cos\phi_1$

→ Limitation:-

→ It will lead to series resonance

→ current will be increase & loss to equipments nearby.

→ If parallel resonance occurs it will increase a lot of voltage.

Ex:① An alternator / generator is supplying of a load of 500kW at p.f. 0.7 lagging. If p.f. is raised to unity, how many more kW can alternate supply on the same kVA loading?

$P_1 = 500kW$

$pf_1 = 0.7$ (lag) $\qquad pf_2 = 1$

kVA = constant

$\cos\phi_1 = \frac{P_1}{S}$ $\qquad \cos\phi_2 = \frac{P_2}{S}$

$\therefore S = \frac{P}{\cos\phi}$ $\qquad 1 = \frac{P_2}{714.28}$

$\therefore S = 714.28 kVA$ $\qquad \therefore P_2 = 714.285 kW$

$\therefore$ Additional Power $= P_2 - P_1$

$= 714.29 - 500$

$= 214.29 \; kW$

Ex:- ② A single phase A.C. generator supplies ~~first~~ ① lighting load of 20kW @ p.f 1; ② Induction motor of 150kw @ p.f. 0.75 (lag); ③ synchronous generator having a load capacity of 50kW @ 0.9 p.f. leading. Find the total kw and kVA supplied by the generator Also represent it's phasor diagram.

① $\cos\phi_1 = \frac{P_1}{S_1}$

$\therefore S_1 = \frac{20}{1} = 20kVA$

$\therefore Q_1 = \sqrt{S_1^2 - P_1^2} = 0kVAR$

② $\cos\phi_2 = \frac{P_2}{S_2} \Rightarrow 0.75 = \frac{150kW}{S_2} \Rightarrow S_2 = 200kVA$

$\therefore Q_2 = \sqrt{S_2^2 - P_2^2} = \sqrt{(200)^2 - (150)^2} = 132.29 \; kVAR$

$\sin\phi = Q/S$

$\tan\phi = Q/P$

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(i) $\cos\phi_3 = \dfrac{P_3}{S_3} \Rightarrow 0.9 = \dfrac{50}{S_3} \Rightarrow S_3 = 55.56$ KVA

$\therefore Q_3 = \sqrt{S_3^2 - P_3^2} = \sqrt{(55.56)^2 - (50)^2} = 24.26$ KVAR

Total kW = 20 + 150 + 50 = 220 kW

Total KVAR = $Q_1 - Q_2 + Q_3$

lagging

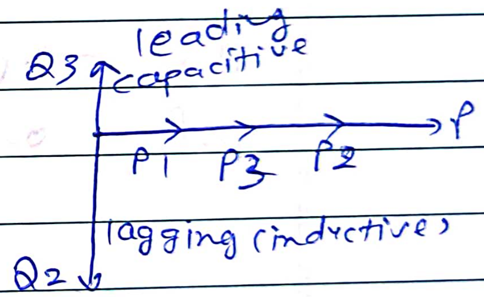
$= 0 - 132.29 + 24.26$

$= -108.03$ KVAR

$S = \sqrt{P^2 + Q^2}$

$= \sqrt{(220)^2 + (-108.03)^2}$

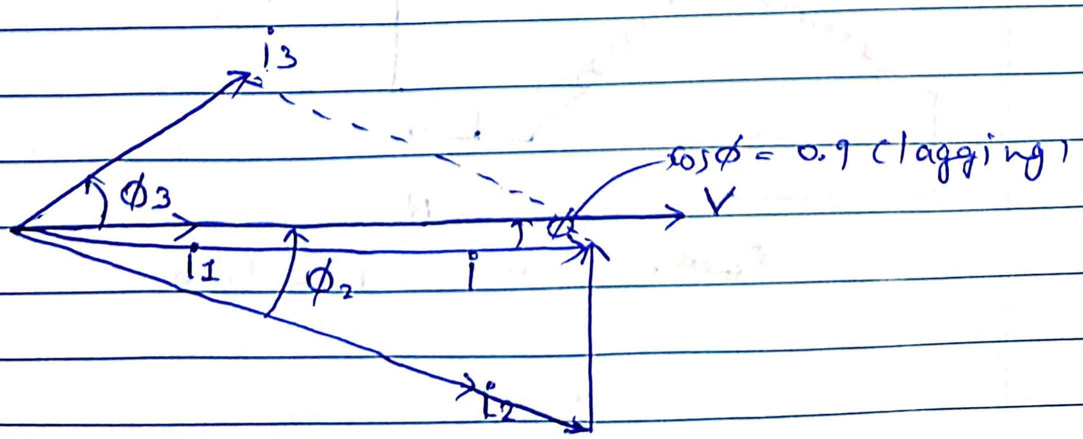
$\therefore S = 245.09$ KVA



Net p.f. of system $= \dfrac{P}{S} = \dfrac{220}{245.09}$

$= 0.897$ (lagging)

≈ 0.9 (lagging)



more.

if $V = 230\,V$

$P = VI\cos\phi$

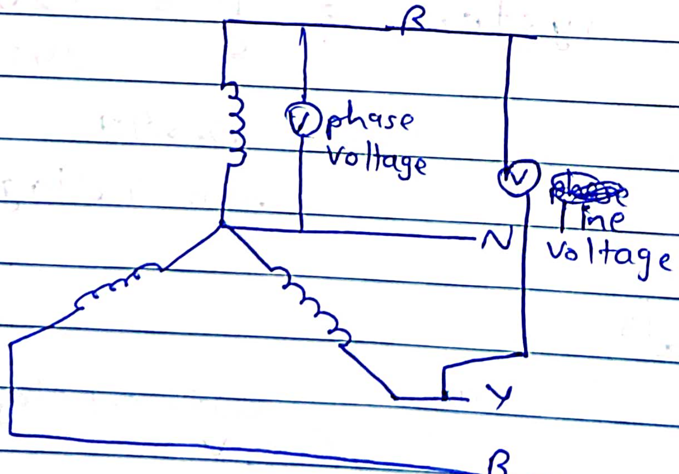
$220 \times 10^3 = 230 \times I \times 0.9$

$I = 1062.80$
$\hookrightarrow rms$

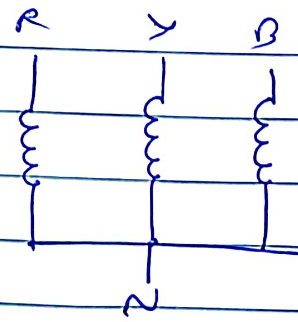
Ex:-③ A three-phase induction motor of 5kW has a p.f. of 0.75 lagging. A bank of capacitors is connected in delta across the supply terminal of motor and p.f. is raised to 0.9 lagging. Determine the KVAR rating of capacitor bank connected to each phase.

$P = 5\,kW$

p.f. = 0.75 (lag)



~~Delta~~ Star: Connection

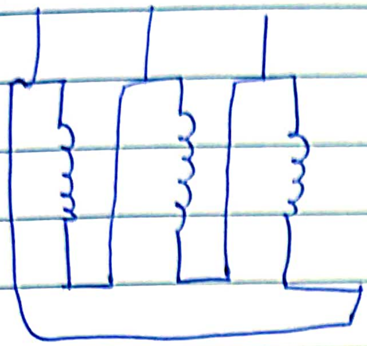


star (Y)

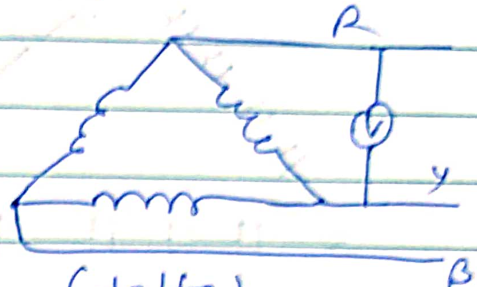
$V_L = \sqrt{3}\,V_{ph}$

$I_L = I_{ph}$

$1\,hp = 745$ Watt



delta (Δ)



(delta)

$V_{ph} = V_L$

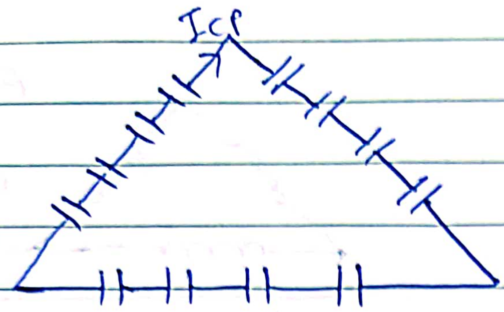
$I_L = \sqrt{3}\, I_{ph}$

Ex:- 4 A 3ϕ, 50 Hz, 415 V induction motor develop 100 hp power at 0.75 p.f. with the efficiency of 93%. A capacitor bank is connected in delta across supply terminal, to raise the p.f. 0.95 lagging. Each capacitor unit is build ~~up~~ of 4 similar 100 V capacitor connected in series. Determine capacitance of each capacitor. (KVAR)

$P = 100\,hp = 74.5\,kW$; $\eta = 93\%$; $f = 50\,Hz$; $V = 415\,V$ (line voltage)

p.f. $= 0.75$ lag $= \cos\phi_1 = 0.75 \Rightarrow 41.40^\circ$

$\cos\phi_2 = 0.95 \Rightarrow 18.19^\circ$



$\tan\phi = Q/P$

$Q_1 = P\tan\phi_1 = 74.5 \times \tan(41.4^\circ) = 65.68$ kVAR

$Q_2 = P\tan\phi_2 = 74.5 \times \tan(18.19^\circ) = 24.48$ kVAR

Injected ~~rea~~ power by capacitor bank $= Q_1 - Q_2$

$= 65.68 - 24.48$

$= +41.2$ kVAR

For entire unit $=$ 41.2 kVAR

Per phase KVAR Injecton by each capacitor bank $= \frac{41.19}{3} = 13.73$ kVAR

for Δ connection, $I_{line} = I_{phase}$

~~Vop~~ $I_{cp} = \frac{V_L}{X_c}$

$X_c = \frac{1}{2\pi fc} \Rightarrow I_{cp} = \frac{V_L}{1/2\pi fc}$

$\Rightarrow I_{cp} = V_L 2\pi f C$ — (1)

$\Rightarrow I_{cp} = 415 \times 2 \times \pi \times 50\, C$ A

$\therefore I_{cp} = 130.376 \times 10^3 C$ A

$$KVAR_p = \frac{V_L \times I_{CP}}{10^3}$$

10^3 → for (KVA)

$$13.73\ KVAR = \frac{415 \times 130.376 \times 10^3\ C}{10^3}$$

$$C = 253.76 \times 10^{-6}\ F$$

$\therefore \boxed{C = 253\ \mu F}$ ⇒ It is per phase

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4}$$

$$\frac{1}{253\mu F} = \frac{1}{C} + \frac{1}{C} + \frac{1}{C} + \frac{1}{C}$$

$$\frac{1}{253\mu F} = \frac{4}{C}$$

$$\therefore C = 4 \times 253\ \mu F$$

$$\boxed{\therefore C = 1012\ \mu F}$$

we need 12 capacitors of $1000\ \mu F$

Ex:- ⑤ A supply system ~~has~~ fits following load ① A lighting load of 700 kW, ② Industrial load of 1200 kW at 0.707 p.f. (lagging) ③ A load of 600 kW at 0.8 leading p.f. ④ A load of 500 kW at 0.6 lagging p.f. ⑤ A synchronous motor ~~of 600~~ which driving a 600 kW load having a overall efficiency of 95%. Calculate p.f. of motor so that distribution station is operating at unity p.f.

Sol^n:

⇒ lighting load means unity p.f.

① lighting load = 700 kW ⇒ $\cos\phi_1 = 1$
② industrial load = 1200 kW ⇒ $\cos\phi_2 = 0.707$
③ load = 600 kW ⇒ $\cos\phi_3 = 0.8$
④ load = 500 kW ⇒ $\cos\phi_4 = 0.6$
⑤ load (motor) = 600 kW ⇒ $\cos\phi_5 = ?$

$\cos\phi_1 = 1 \Rightarrow \phi_1 = 0°$
$\cos\phi_2 \Rightarrow \phi_2 \Rightarrow 45°$
$\cos\phi_3 \Rightarrow 0.8 \Rightarrow \phi_3 = 36.87°$
$\cos\phi_4 = 0.6 \Rightarrow \phi_4 = 53.13°$
$\cos\phi_5 = ?$

$Q_1 = P_1 \tan\phi_1 = 0$
$Q_2 = P_2 \tan\phi_2 = 1200 \times \tan(45°) = 1200$ kW (lagging)
$Q_3 = P_3 \tan\phi_3 = 600 \times \tan(36.87°) = 450$ kW (leading)
$Q_4 = P_4 \tan\phi_4 = 500 \times \tan(53.13°) =$ (lagging)
$= 666.66$ kW

Total lagging KVAR = 1200 + 666.66 ~~− 450~~
= ~~1416.66~~ KVAR (lagging)
= 1866.66 KVAR

Total leading KVAR = 450 KVAR

⇒ for unity of station,

Leading KVAR = lagging KVAR

$Q_5 = (Q_2 + Q_4) - Q_3$

$\therefore Q_5 = 1416.66$ KVAR

$$\tan\phi_5 = \frac{Q_5}{P_5}$$

$$\tan\phi_5 = \frac{1416.66}{600}$$

$$\phi_5 = 67.045$$

p.f. of motor $= \cos\phi_5 = 0.39 \approx 0.4$ (leading)

⇒ Types of Loads :-

① Domestic Load :- unity p.f.
lighting systems, Illumination System
- working voltage :- 230V, 50Hz, 1-ϕ
- current rating :- 5 to 10 A

② Commercial Load :-
- (Advertisement boarding)
- 230 V / 415 V, 50Hz
- (1-ϕ / 3-ϕ)
- Current < 15 A

③ Industrial Load :-
- Large scale - > 500kV, 11kV or 33kV line
- Medium scale - 100kV to 500kV, 11 kV Line
- Small Scale - 3ϕ, 415V, 50Hz
floor mill, show mill

④ Agricultural / Irrigation Load :-
Load :- 15 to 20hp
- 3ϕ motor used, 415V, 50Hz
- different territ
- good subsidies