Ch#11:- AC Power Analysis (Pg# 450)

11.1: Introduction:-

i) Yet now, we have calculated voltage & current.
ii) in This chapter, our major concern is Power.
iii) Power is most important quantity in:-

a) Utilities (Electricity)
b) Electronic & communication.
c) Home Appliance.
- Pressing iron,
- Bulbs,
- Fans,
- Motors,
- Charger, TV etc.

→ We prefer AC over DC bcz generation and transmission of AC is easy and we can step-up / down it (AC power).

$P = VI = \frac{V^2}{R} = I^2R$

11.2 Instantaneous Power:-

Instantaneous power (in watts) is power at any instant of time.

$$\boxed{p(t) = v(t) \cdot i(t)} \quad \text{— (1)}$$

→ Power we got normally is average power that is 220V, actually it is 310V.

→ Product of voltage & current at an instant is instantaneous power.

$$v(t) = V_m \cos(\omega t + \theta_v)$$
$$i(t) = I_m \cos(\omega t + \theta_i)$$
⟹ put in (1).

(1) ⟹ $p(t) = (V_m \cos(\omega t + \theta_v))(I_m \cos(\omega t + \theta_i))$

$$p(t) = V_m I_m \cdot \cos(\underbrace{\omega t + \theta_v}_{A}) \cdot \cos(\underbrace{\omega t + \theta_i}_{B})$$

$$2CC = C + C \rightarrow CC = \frac{1}{2}(C + C)$$

So,

$$\cos A \cos B = \frac{1}{2}[\cos(A-B) + \cos(A+B)]$$

So, $p(t)$ will be:

$$\boxed{p(t) = \frac{1}{2} V_m I_m \cos(\underbrace{\theta_v - \theta_i}_{A-B}) + \frac{1}{2} V_m I_m \cos(\underbrace{2\omega t + \theta_v + \theta_i}_{A+B})}$$

or $p(t) = V_m I_m \cdot \frac{1}{2}[\cos(\omega t + \theta_v + \omega t + \theta_i) + \cos(\cancel{\omega t} + \theta_v - \cancel{\omega t} - \theta_i)]$

$$p(t) = V_m I_m \cdot \frac{1}{2}[\cos(2\omega t + \theta_v + \theta_i) + \cos(\theta_v - \theta_i)]$$

or ∵ $f = \frac{1}{T}$

$\omega = 2\pi f$

$\omega = \frac{2\pi}{T}$

$$\boxed{p(t) = \underbrace{\frac{1}{2} V_m I_m \cos(\theta_v - \theta_i)}_{1st} + \underbrace{\frac{1}{2} V_m I_m \cos(2\omega t + \theta_v + \theta_i)}_{2nd}}$$

$T = \frac{2\pi}{\omega}$

pg# 11 → ch# 1 ref

1st → time independent

2nd → time-dependent

→ As instantaneous power is changing at every instant, we can't measure easily. Hence, we measure average power.

↳ average power (in watts) is average of instantaneous power over one period.

Thus, average power is:-

$$P = \frac{1}{T}\int_0^T p(t)\,dt$$

put p(t) value

$$P = \frac{1}{T}\int_0^T \left[\frac{1}{2}V_m I_m \cos(\theta_v-\theta_i) + \frac{1}{2}V_m I_m \cos(2\omega t + \theta_v+\theta_i)\right]dt$$

or separate :-

$$P = \frac{1}{T}\int_0^T \frac{1}{2}V_m I_m \cos(\theta_v-\theta_i)\,dt + \frac{1}{T}\int_0^T \frac{1}{2}V_m I_m \cos(2\omega t + \theta_v+\theta_i)\,dt$$

$t|_0^T = T$

$$P = \frac{1}{2}V_m I_m \cos(\theta_v-\theta_i)\frac{1}{\cancel{T}}\int_0^T 1\cdot dt + \frac{1}{2}V_m I_m \cdot \frac{1}{T}\int_0^T \underbrace{\cos(2\omega t+\theta_v+\theta_i)}_{0}dt$$

sin over a complete cycle is zero.

$$\int_0^{2\pi} \sin\omega t\,dt$$

$(\sin 2\pi - \sin 0)$

$0 - 0 = 0$

$$P = \frac{1}{2}V_m I_m \cos(\theta_v-\theta_i) + 0$$

So,

$$\boxed{P = \frac{1}{2}V_m I_m \cos(\theta_v-\theta_i)}$$

or

phasor → $\boxed{P = \frac{1}{2}V_m I_m \angle \theta_v-\theta_i}$

in-phase case (R)

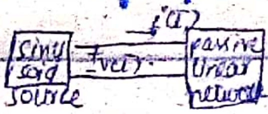
→ ① $\theta_v = \theta_i \Rightarrow P = \frac{1}{2}V_m I_m \cos(0°) \Rightarrow \boxed{P = \frac{1}{2}V_m I_m}$ (resistive ckt) → in-phase

lag or leads case (L or C)

→ ② $\pm 90° \Rightarrow P = \frac{1}{2}V_m I_m \cos(\pm 90°) \Rightarrow \boxed{P = 0}$ → no power absorbed.

→ A resistive load (R) absorbs power all the time, while reactive load (L or C) absorbs zero power.

Ex# 11.1:- if: $v(t) = 120\cos(377t + 45^\circ)\,V$ &
$i(t) = 10\cos(377t - 10^\circ)\,A$; find inst. power $p(t)$ and average power absorbed by passive linear network below (11.1)



$\rightarrow$ $p(t) = v(t) \cdot i(t)$

$p(t) = 120\cos(377t + 45^\circ) \cdot 10\cos(377t - 10^\circ)$

$p(t) = 1200\left[\cos(377t + 45^\circ) \cdot \cos(377t - 10^\circ)\right]$

$2CC = C + C \rightarrow CC = \frac{1}{2}(C + C)$

So,

$p(t) = \overset{600}{\cancel{1200}} \cdot \frac{1}{2}\left[\cos(\cancel{377t} + 45 - \cancel{377t} + 10) + \cos(377t + 45 + 377t - 10)\right]$

$= 600\left[\cos(55^\circ) + \cos(754t + 35^\circ)\right]$

$p(t) = 600 \times 0.57 + 600\cos(754t + 35^\circ)$

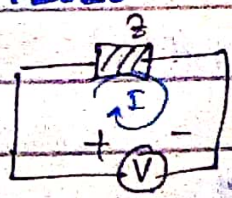
$\boxed{p(t) = 344.2 + 600\cos(754t + 35^\circ)\,W}$ $\rightarrow$ inst. power.

$\rightarrow$ $P = \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i)$

$P = \frac{1}{2}(\overset{60}{\cancel{120}})(10)\cos(45^\circ - (-10^\circ))$

$P = 600\cos 55 = \boxed{344.2\,W}$

Ex# 11.2:- Calculate avg. power absorbed by impedance $Z = 30 - j70\,\Omega$ when voltage $V = 120\angle 0^\circ$ is applied.



as: $I = \frac{V}{Z} = \frac{120\angle 0^\circ}{30 - j70}$ $\therefore \theta_v = 0^\circ$ $\therefore \theta_i = 66.8^\circ$

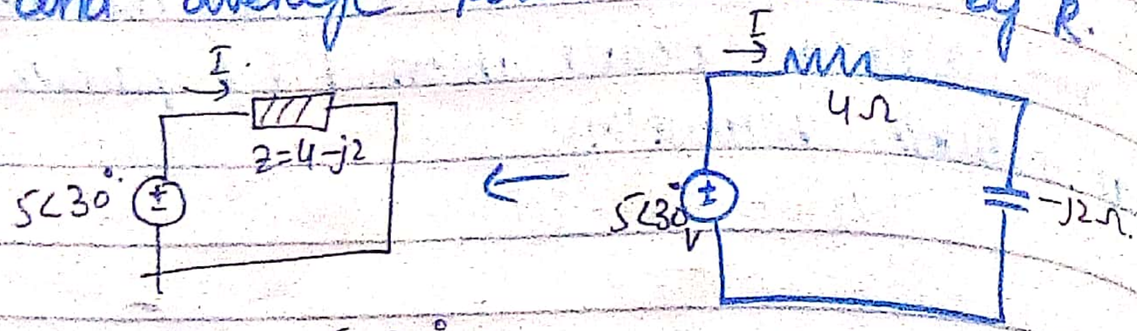
$\boxed{I = 1.57\angle 66.8^\circ A}$

$\rightarrow$ $P = \frac{1}{2} V_m I_m \angle \theta_v - \theta_i$

$P = \frac{1}{2}(120)(1.57)\angle 0^\circ - 66.8^\circ = 37.2 - 86.5j$

$\boxed{P = 94.2\angle -66.8^\circ\,W}$

Ex#11.3 :- Find avg. power supplied by source and average power absorbed by R.



$\rightarrow I = \dfrac{V}{Z} = \dfrac{5\angle 30^\circ}{4-j2}$

$\boxed{I = 1.11\angle 56.5\,A}$

avg. power supplied by voltage source

$\rightarrow P = \frac{1}{2}(5)(1.11)(\angle 30 - 56.5^\circ)$

$\boxed{P = 2.77\angle -26.5^\circ\,W}$

$\rightarrow V_R = \dfrac{4}{4-j2}(5\angle 30^\circ)$

$\boxed{V_R = 4.47\angle 56.56^\circ\,V}$

avg. power absorbed by R

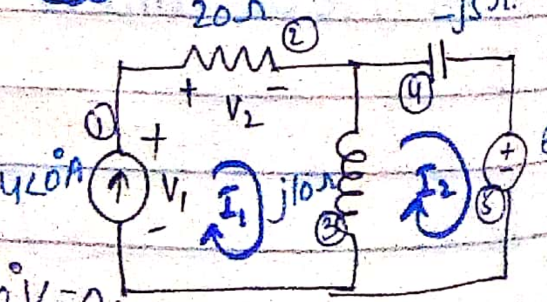
$P = \frac{1}{2} V_m I_m \cancel{(\theta_v - \theta_i)}$

$= \frac{1}{2}(\cancel{4.47})(\cancel{1.11})\cancel{(\angle 30^\circ - 56.5^\circ)}$

$P = \frac{1}{2}(4.47)(1.11)(56.56 - 56.56)$ 0°

$\boxed{P = 2.48\,W}$

Ex#11.4 :- Determine avg. power generated by each source & avg. power absorbed by each passive element in ckt.



mesh#1 :-

$\boxed{I_1 = 4A}$

mesh#2 :-

$j10(I_2 - I_1) - j5 I_2 + 60\angle 30^\circ V = 0$

$\because I_1 = 4$

$(j10 - j5)I_2 + j10(4) + 60\angle 30^\circ = 0$

$j5 I_2 = -60\angle 30^\circ + j40$

$I_2 = -12\angle -60^\circ + 8 = \boxed{10.58\angle 79.10^\circ A}$

for voltage source :-

$P_s = \frac{1}{2} V_m I_m \angle \theta_v - \theta_i$

$P_s = \frac{1}{2}(60)(10.58) \angle 30 - 79.10°.$

Absorbed by the source

$\boxed{P_s = 283 \angle 33.9° W}$ → contd.

for current source :-

$\boxed{I_1 = 4\angle 0° A}$;

$V_1 = 20 I_1 + j10(I_1 - I_2) = 20(4) + j10(4) - j10 I_2$

$V_1 = 80 + j40 - j10(2 + j10.31)$

$V_1 = 183.1 + j20 = \boxed{184.2 \angle 6.23° V}$

→ $P_1 = -\frac{1}{2}(184.2)(4) \angle 6.21° - 0$

$P_1 = -367.2 + j39.8 W$

or $\boxed{P_1 = -368.4 \angle 6.21° W}$

→ passive sign convention → I-source supplies power to ckt.

for resistor :-

$I_1 = 4\angle 0° A$, $V_2 = 20 I_1 = 20(4) = 80\angle 0°$.

So, $P_2 = \frac{1}{2}(80)(4) \angle 0 - 0°$

$\boxed{P_2 = 160 W}$

for capacitor :- $I_2 = 10.58 \angle 79.10° A$, $V = (-j5) I_2 = (-j5)(10.58 \angle 79.1)$

$V = 52.9 \angle -10.9° V.$

So, $P_4 = \frac{1}{2}(52.9)(10.58)(\angle -10.9° - 79.10°)$

$P_4 = \frac{1}{2}(52.9)(10.58) \angle -90°.$

$\boxed{P_4 = 0}$

for inductor :- $I_1 - I_2 = (4) - (2 + 10.31j) = 2 - 10.31j\ A = 10.51 \angle -79.$

$V = j10(I_1 - I_2) = 105.02 \angle 10.9 V.$

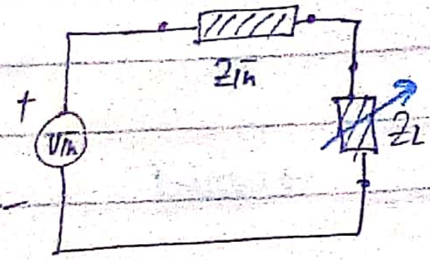
So, $P_3 = \frac{1}{2}(10.51)(105.2) \angle -79.1 - 10.9$

$\boxed{P_3 = 0}$

→ L & C absorbs zero avg. power & power suplied by I-source is equal to power absorbed by V & R

Monday 09-03-2020

11.3 Maximum Average Power Transfer:-



$$Z_{Th} = R_{Th} + jX_{Th} \quad \text{—— ①}$$

$$Z_L = R_L + jX_L \quad \text{—— ②}$$

To prove:-

$$Z_{Th} = Z_L$$

$$I = \frac{V}{R} = \frac{V_{Th}}{Z_{Th} + Z_L} \quad \text{—— ③}$$

putting values from ① & ② in ③.

so,

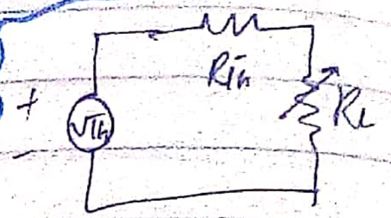
$$I = \frac{V_{Th}}{(R_{Th} + jX_{Th}) + (R_L + jX_L)}$$

Real $= R_{Th} + R_L$

Imaginary $= j X_{Th} + X_L$

Hence;

$$\boxed{P = \frac{1}{2} I^2 \cdot R_L} \rightarrow \text{power across Load.}$$



at: $R_{Th} = R_L$

$$I = \frac{V_{Th}}{R_{Th} + R_L}$$

$$P = I^2 R_L$$

$$P = \frac{V_{Th}^2}{(2R_{Th})^2} \times R_{Th}$$

$$P = \frac{V_{Th}^2}{4R_{Th}} \rightarrow DC$$

$$P = \frac{1}{2} \cdot \frac{V_{Th}^2}{4R_{Th}} \rightarrow AC$$

as: $\rightarrow$ $\because P = \frac{1}{2} V_m I_m$

$\because P = \frac{1}{2} I_m^2 R_o$

$\therefore P = \frac{1}{2} \cdot \frac{V_m^2}{R_o}$.

put value of I in above eqn.

$$P = \frac{1}{2}\left[\frac{V_{Th}}{(R_{Th} + jX_{Th}) + (R_L + jX_L)}\right]^2 \cdot R_L$$

or

$$P = \frac{V_{Th}^2 \cdot R_L/2}{(R_{Th} + R_L)^2 + (X_{Th} + X_L)^2} \quad \text{—— ④} \;|\; 11.15$$

i) $\frac{\delta P}{\delta R_L}$ ii) $\frac{\delta P}{\delta X_L}$ $\rightarrow$ partial derivatives.

Take $\frac{\delta P}{\delta R_L}$ of eqn. (4):- (partial derivative w.r.t R_L)

$$\frac{\delta P}{\delta R_L} = \frac{(R_{Th}+R_L)^2+(X_{Th}+X_L)^2 \cdot \frac{\delta}{\delta R_L}\left(\frac{V_{Th}^2 \cdot R_L}{2}\right) - \left(\frac{V_{Th}^2 \cdot R_L}{2}\right)\frac{\delta}{\delta R_L}\left((R_{Th}+R_L)^2+(X_{Th}+X_L)^2\right)}{\left[(R_{Th}+R_L)^2+(X_{Th}+X_L)^2\right]^2}$$

Put $\frac{\delta P}{\delta R_L} = 0$:-

$$0 = \frac{(R_{Th}+R_L)^2+(X_{Th}+X_L)^2 \cdot \frac{\delta}{\delta R_L}\left(\frac{V_{Th}^2 \cdot R_L}{2}\right) - \left(\frac{V_{Th}^2 \cdot R_L}{2}\right)\frac{\delta}{\delta R_L}\left((R_{Th}+R_L)^2+(X_{Th}+X_L)^2\right)}{\left[(R_{Th}+R_L)^2+(X_{Th}+X_L)^2\right]^2}$$

cross multiply.

So,

$$= (R_{Th}+R_L)^2+(X_{Th}+X_L)^2 \cdot \frac{\delta}{\delta R_L}\left(\frac{V_{Th}^2 \cdot R_L}{2}\right) - \left(\frac{V_{Th}^2 \cdot R_L}{2}\right)\frac{\delta}{\delta R_L}\left[(R_{Th}+R_L)^2+\underbrace{(X_{Th}+X_L)^2}_{\text{const. w.r.t } R_L}\right]$$

$$0 = \frac{V_{Th}^2}{2}\cdot\left((R_{Th}+R_L)^2+(X_{Th}+X_L)^2\right) - \frac{V_{Th}^2 \cdot R_L}{2}\left[2(R_{Th}+R_L)\underbrace{\frac{\delta}{\delta R_L}(R_{Th}+R_L)}_{1}+0\right]$$

Taking $V_{Th}^2/2$ common:-

$$0 = (R_{Th}+R_L)^2+(X_{Th}+X_L)^2 - R_L 2(R_{Th}+R_L)$$

$$R_{Th}^2+R_L^2+\cancel{2R_{Th}R_L}+(X_{Th}+X_L)^2-\cancel{2R_{Th}R_L}-2R_L^2=0$$

$$R_{Th}^2-R_L^2+(X_{Th}+X_L)^2=0$$

$$R_L^2 = R_{Th}^2+(X_{Th}+X_L)^2$$

or $$R_L = \sqrt{R_{Th}^2+(X_{Th}+X_L)^2} \quad \text{— 11·18 / (5)}$$

$$\left\{\begin{array}{l} \text{let } X_{Th} = -X_L \\ \text{So, } R_L = \sqrt{R_{Th}^2+0} \\ \boxed{R_L = R_{Th}} \end{array}\right\}$$

from 11.18 | - 11.5 :-

11.5 $\rightarrow$ $$P = \frac{V_{th}^2 \cdot R_L/2}{(R_{th}+R_L)^2+(X_{th}+X_L)^2}$$

Now partial derivative w.r.t $\delta P/\delta X_L$:-

$$\frac{\delta P}{\delta X_L} = \frac{V_{th}^2 \cdot R_L/2}{(R_{th}+R_L)^2+(X_{th}+X_L)^2}$$

$$= \frac{(R_{th}+R_L)^2+(X_{th}+X_L)^2 \frac{\delta}{\delta X_L}\underbrace{(V_{th}^2 \cdot R_L/2)}_{0} - (V_{th}^2 R_L/2)\frac{\delta}{\delta X_L}[(R_{th}+R_L)^2+(X_{th}+X_L)^2]}{[(R_{th}+R_L)^2+(X_{th}+X_L)^2]^2}$$

put $\frac{\delta P}{\delta X_L}=0$

$$0 = \frac{0 - \frac{V_{th}^2 R_L}{2} \cdot \delta/\delta X_L[(R_{th}+R_L)^2+(X_{th}+X_L)^2]}{[(R_{th}+R_L)^2+(X_{th}+X_L)^2]^2}$$

cross. multiply

$$0 = -\frac{V_{th}^2 \cdot R_L}{2} \cdot \left[\frac{\delta}{\delta X_L}(R_{th}+R_L)^2 + \frac{\delta}{\delta X_L}(X_{th}+X_L)^2\right]$$

$$0 = \frac{1}{2} \cdot 2(X_{th}+X_L)(1)$$

$$\boxed{0 = X_{th}+X_L} \rightarrow \text{condition.}$$

$$\boxed{X_{th} = -X_L}$$

$Z_L = R_L + jX_L$; $Z_{th} = R_{th} - jX_{th}$

So, $Z_{th} = Z_L^*$ (conjugate)

put $R_L = R_{th}$ & $X_{th} = -X_L$ in eq. 11.15.

$$P = \frac{V_{th}^2 \cdot R_{th}/2}{(2R_{th})^2 + (0)}$$

$$P = \frac{1}{2} \cdot \frac{V_{Th}^2 \cdot \cancel{R_{Th}}}{4 R_{Th}^{\cancel{2}}}$$

$$\boxed{P = \frac{V_{Th}^2}{8 R_{Th}}} \rightarrow \text{max. average power transfer}$$

Ex# 11.5, 11.6 → solve.

Section 11.4

Wednesday.
11-03-2020

$$\cos^2\theta = \frac{1+\cos 2\theta}{2}$$

$$\cos^2\theta - \sin^2\theta = \cos 2\theta$$

$$\cos^2\theta - (1-\cos^2\theta) = \cos 2\theta$$

$$2\cos^2\theta - 1 = \cos 2\theta$$

$$2\cos^2\theta = 1+\cos 2\theta$$

$$\cos^2\theta = \frac{1+\cos 2\theta}{2} \; ; \; \sin^2\theta = \frac{1-\cos 2\theta}{2}$$

Pg# 468, section 11.4 → from book.

→ Avg. Power $= P = \frac{1}{2} V_{max} \cdot I_{max} \cdot \cos(\theta_v - \theta_i)$

or $P = \frac{1}{\sqrt{2}} \cdot \frac{1}{\sqrt{2}} \cdot V_{max} \cdot I_{max} \cdot \cos(\theta_v - \theta_i)$

or $P = \frac{V_{max}}{\sqrt{2}} \cdot \frac{I_{max}}{\sqrt{2}} \cdot \cos(\theta_v - \theta_i)$ $\quad \because S = V_{rms} \cdot I_{rms}$ (VA) unit

$P = V_{rms} \cdot I_{rms} \cdot \cos(\theta_v - \theta_i)$ $\quad \because V_{rms} = \frac{V_{max}}{\sqrt{2}}$

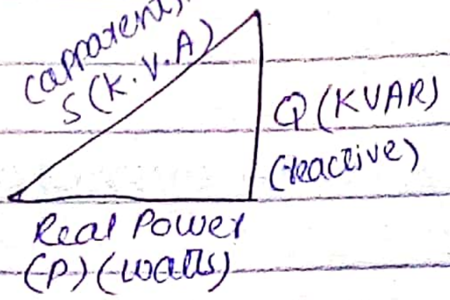
$P = S \cos(\theta_v - \theta_i)$ $\quad I_{rms} = \frac{I_{max}}{\sqrt{2}}$

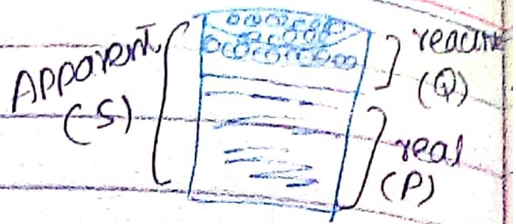
$\frac{P}{S} = \cos(\theta_v - \theta_i)$

if $\theta_v - \theta_i = 0 \Rightarrow \theta_v = \theta_i$

So, Power-factor $= P.F = \frac{P}{S} = \cos(0) = 1$ (unity).

Section : 11.5



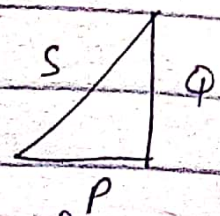


Power-factor:-

"P.F is cosine of phase difference voltage"

or "Ratio of Real Power/ to Apparent Power".
True / active.

S = VI (Proof):-



$$S^2 = P^2 + Q^2$$

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

$$S = \sqrt{(VI\cos\theta)^2 + (VI\sin\theta)^2}$$

$$S = \sqrt{V^2I^2\cos^2\theta + V^2I^2\sin^2\theta}$$

$$S = \sqrt{V^2I^2(\cos^2\theta + \sin^2\theta)}$$

$$S = \sqrt{V^2I^2(1)}$$

$$\boxed{S = VI}$$

$P = S\cos\theta$ or $P = VI\cos\theta$ ← $\cos\theta = \frac{P}{S}$

$\sin\theta = \frac{Q}{S}$

$Q = S\cdot\sin\theta$ $\because S = VI$

$\boxed{Q = VI\sin\theta}$

→ That is used to do work → P (watt) **Active / True / real power.**

→ That is sum of active & reactive power } S (KVA) **apparent**

→ Power which flows back & forth (move in both directions in cct.) Q → **reactive power.** (KVAR)

- $Q = 0$ → P.F = 1 (ideal) → resistive cct.
- $Q > 1$ → P.F lags → needs condensor/capacitor/ capacitor bank.
- $Q < 1$ → P.F leads → needs capacitor

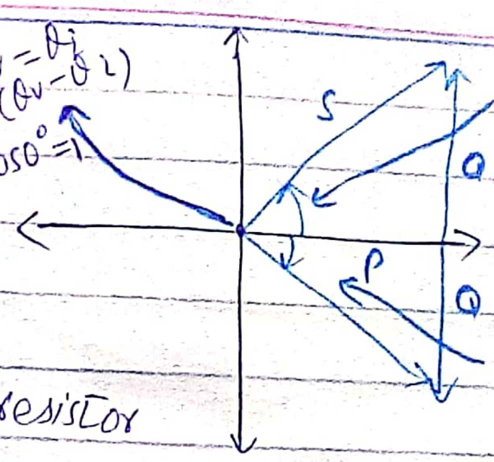
} to improve power factor.

→ Power-factor is unit-less.

$\theta_v = \theta_i$

$= \cos(\theta_v - \theta_i)$

$= \cos 0^\circ = 1$



inductive

$\boxed{\begin{array}{c}\cos(\theta_v - \theta_i) \\ \phi = \theta_v - \theta_i \\ \phi > 0\end{array}}$

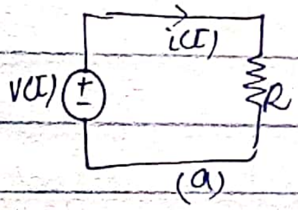
$\boxed{\begin{array}{c}\cos(\theta_v - \theta_i) \\ \phi = \theta_v - \theta_i \\ \phi < 0\end{array}}$

capacitive.

$\boxed{\text{Sec\# 11.4}}$ from start:-

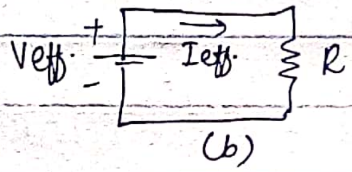
power absorbed by resistor in ac cct. is:-

$$P = \frac{1}{T}\int_0^T i^2 R\,dt = \frac{R}{T}\int_0^T i^2\,dt \quad —①$$



Power absorbed by R in dc cct:-

$$P = I_{eff}^2 \cdot R \quad —②$$



put ① in ② for I_{eff}:-

$$I_{eff}^2 = \frac{\cancel{R}/T \int_0^T i^2\,dt}{\cancel{R}}$$

$$I_{eff} = \sqrt{\frac{1}{T}\int_0^T i^2\,dt} \quad —③$$

∵ $I_{rms} = I_{eff}$

$V_{rms} = V_{eff}$

& V_{eff} is also as:-

$$V_{eff} = \frac{1}{T}\int_0^T v^2\,dt \quad —④$$

for any periodic function $x(t)$; rms value is:-

$$X_{rms} = \sqrt{\frac{1}{T}\int_0^T x^2\,dt} \quad —⑤$$

∵ $i(t) = I_m \cos\omega t$ → put in ③.

$$I_{eff} = I_{rms} = \sqrt{\frac{1}{T}\int_0^T I_m^2 \cos^2\omega t\,dt}$$

$$= \frac{I_m^2}{T}\int$$

$$= \frac{I_m}{\sqrt{2}}$$

& $V_{rms} = \frac{V_m}{\sqrt{2}}$

Thursday.
12-03-2020

11.8 Power factor Correction:-

"The process of increasing the power factor without changing voltage & current is Power factor correction."

Three methods:-

1 → capacitors bank installed parallel. → here, we deal. (voltage same & I ↑) (to load.)

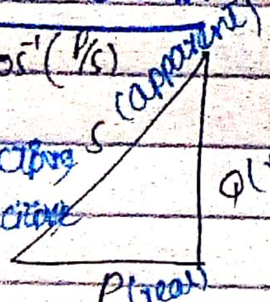
2 → Phase advancer

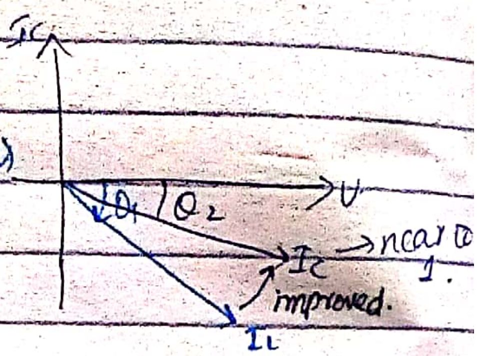
3 → synchronous condensor.

* Core losses depends upon supply voltages &
* Copper losses depends upon current (due to load)

1 → Using capacitor bank:-

→ $\cos\theta_1 = \frac{P}{S} \Rightarrow \theta_1 = \cos^{-1}(P/S)$





$P_1 = S_1\cos\theta_1$ (inductive)

new → $P_2 = S\cos\theta_2$ (capacitive) (after taking the capacitor bank).

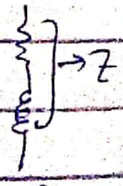
→ $\sin\theta_1 = Q/S$; → $\tan\theta = Q/P$

$Q_1 = S_1\sin\theta_1$ $\qquad Q_1 = P\tan\theta_1$

new → $Q_2 = S\sin\theta_2$ $\qquad$ new → $Q_2 = P\tan\theta_2$.

$\Big] \; Q_c = Q_1 - Q_2$

Q. If we have to increase P.F; what value of capacitor must be used?



→ $Q_c = Q_1 - Q_2$

$$\boxed{Q_c = P(\tan\theta_1 - \tan\theta_2)}$$

losses ⇒ $P = I^2R$ $\qquad Q = I_{rms}^2 \cdot Z$.

if : $Q_c = I_{rms}^2 \cdot Z_c$ (losses) $\qquad \because I_{rms}^2 = \frac{V_{rms}^2}{Z_x}$

$$\boxed{Q_c = \frac{V_{rms}^2}{Z_c}} \qquad Q_c. \qquad \because Z_c = \frac{1}{2\pi f C} = \frac{1}{\omega C}$$

or $\quad Q_c = \frac{V_{rms}^2}{(1/\omega C)} = \boxed{V_{rms}^2 \cdot \omega C}$

$$\boxed{C = \frac{Q_c}{V_{rms}^2 \cdot \omega}}$$

→ $Q_c = (\tan\theta_1 - \tan\theta_2)\,P$

net $Q_c = V_{rms}^2 \cdot \omega C$:-

$V_{rms}^2 \cdot \omega \cdot C = P\{\tan\theta_1 - \tan\theta_2\}$

$$\theta_1 = \cos^{-1}\left(\frac{P_1}{S}\right) \leftarrow \boxed{C = \frac{P[\tan\theta_1 - \tan\theta_2]}{V_{rms}^2 \cdot \underset{or}{\underline{\omega / 2\pi f}}}} \qquad \because \omega = 2\pi f$$

This value of capacitor must be used to increase power factor (P.F).

Ch#11.

→ Max. power Transfer (Ex# & PP) ; Power factor correction (Imp.)

→ why P.F includes cos with it? → sin is 0 at real-axis. ↳ cos is 1 at real-axis.

$P = \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i)$

$P_{avg.} = \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i) = \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \cos(\theta_v - \theta_i) = \underbrace{V_{rms} \cdot I_{rms}}_{S} \cos(\theta_v - \theta_i)$

$P = S\cos(\theta_v - \theta_i)$

$\frac{P}{S} = \cos(\theta_v - \theta_i)$ $\qquad \because P.F = \frac{P\,(\text{real})}{S\,(\text{apparent})}$

$P.F = \frac{P}{S} = \cos(\theta_v - \theta_i)$

at $\theta_v = \theta_i$:-

$P.F = \cos(0) = 1$ (unity)

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

So;

$$P.F = \frac{\frac{1}{2} \cdot V_m \cdot I_m \cos(\theta_v - \theta_i)}{V_{rms} \cdot I_{rms} \,/\, \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}}} = \frac{\frac{1}{2} \cancel{V_m I_m} \cos(\theta_v - \theta_i)}{\frac{1}{2} \cdot \cancel{V_m I_m}}$$

$\boxed{P.F = \cos(\theta_v - \theta_i)}$

Ex# 11.15 :- When connected to a 120V(rms); 60Hz power line; a load absorbed real 4kW at a lagging power factor of $\cos\theta_1$ 0.8. Find value of capacitance necessary to raise P.F to 0.95 $\rightarrow \cos\theta_2$ lead.

Solution :- $\rightarrow$ inductive load.

$\rightarrow$ If P.F $= 0.8 \Rightarrow \cos\theta_1 = 0.8 \Rightarrow \theta_1 = \cos^{-1}(0.8)$

$\boxed{\theta_1 = 36.87°}$

$S_1 = \dfrac{P}{\cos\theta_1} = \dfrac{4000}{0.8} = \boxed{5000\ VA}$

$Q_1 = S_1 \sin\theta_1 = 5000 \sin 36.87° = \boxed{3000\ VAR}$

$\rightarrow \cos\theta_2 = 0.95 \rightarrow$ capacitive load.

$\theta_2 = \cos^{-1}(0.95) \rightarrow \boxed{\theta_2 = 18.19°}$

$\omega = 2\pi f = 2\pi(60) = 376.99 \cong \boxed{377}$

So,

$S_2 = \dfrac{P}{\cos\theta_2} = \dfrac{4000}{0.95} = \boxed{4210.5\ VA}$

$Q_2 = S_2 \sin\theta_2 = (4210.5) \sin 18.19 = \boxed{1314.4\ VAR}$

$Q_c = Q_1 - Q_2$

$Q_c = 3000 - 1314.4$

$\boxed{Q_c = 1685.6\ VAR}$ or $C = \dfrac{P(\tan\theta_1 - \tan\theta_2)}{V_{rms}^2 \cdot 2\pi f}$

$C = \dfrac{Q_c}{\omega \cdot V_{rms}^2} = \dfrac{1685.6}{(377)(120)^2}$; $\boxed{C = 310\,\mu F}$

$C = 3.10 \times 10^{-4}$

or $\boxed{C = 310\,\mu F} \rightarrow$ must used.