Introduction to Electrical & Electronics Circuits

Course Code: EE 101

Department: Electrical Engineering

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Sub-Topics:

- Maximum power transfer theorem

Review

- Instantaneous power in 1-φ circuit pulsates at 2F
- Single phase motors require special resilient mountings
- Complex power, $S = VI^* = P + jQ$

$P \longrightarrow$ active power = $VI\cos\theta$ W = I^2R

$$\theta = \angle_V^I$$

$Q \longrightarrow$ $VI\sin\theta$ VAr = I^2X

$S = VI^*$ VA

- In DC, if P & V are known, I can be determined
- However in AC, P, V & cosΘ or V & S should be known to determine I

For a given P

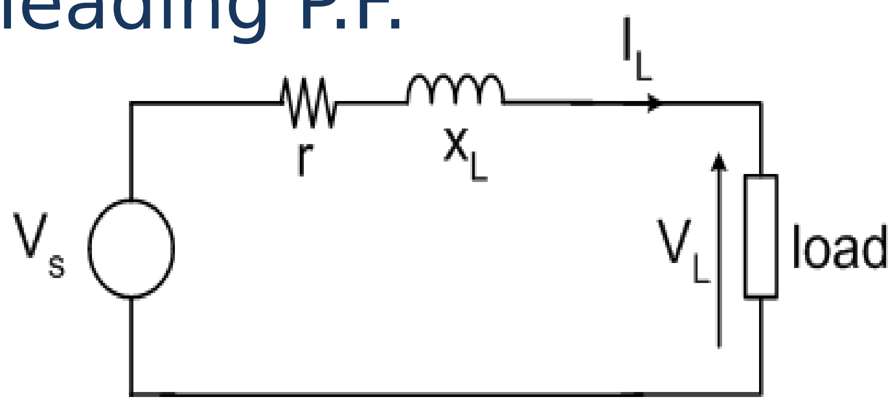
- I drawn by load $\uparrow$ as cos θ $\downarrow$ (P.F.)

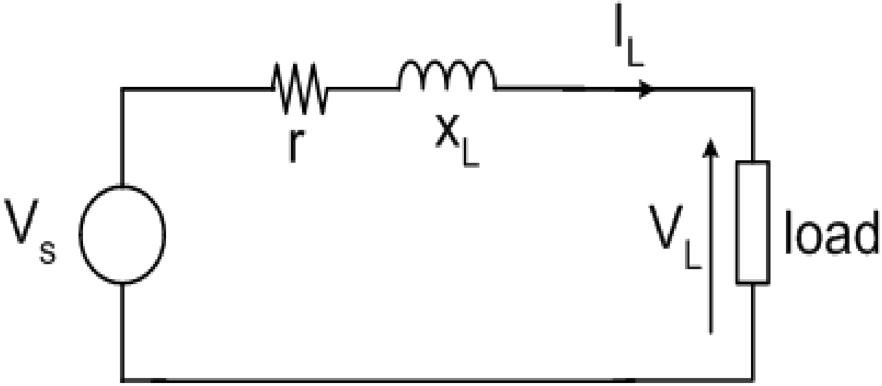
$\Rightarrow$ Drop in the line $\uparrow$

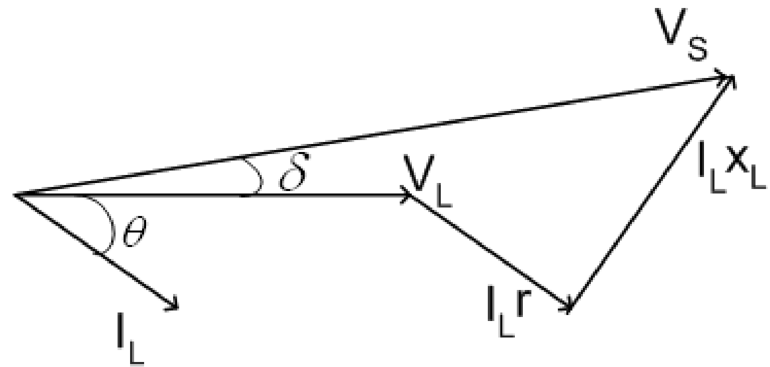
$\Rightarrow$ I^2R , I^2X in the line $\uparrow$ and therefore ‘S’ $\uparrow$ of source

$\Rightarrow$ I^2R loss in source also increases

- $V_L < V_s$ for lagging & unity P.F.
- $V_L \le V_s$ or $V_L > V_S$ for leading P.F.

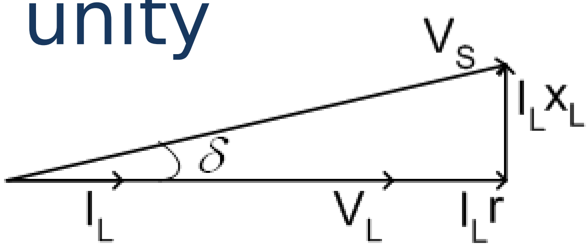






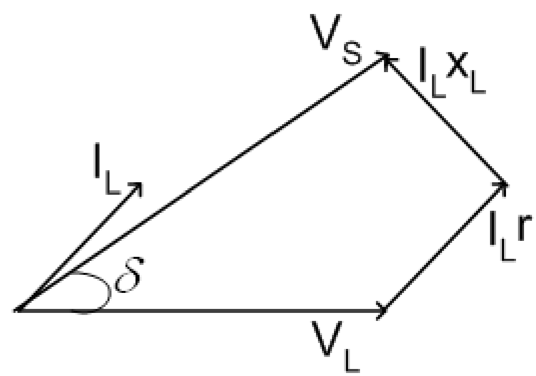
$$|V_s| > |V_L| \qquad \text{Source P.F.} = \cos\angle_{V_S}^{I_s = I_L}$$

If the P.F. is unity



$$|V_s| > |V_L|$$

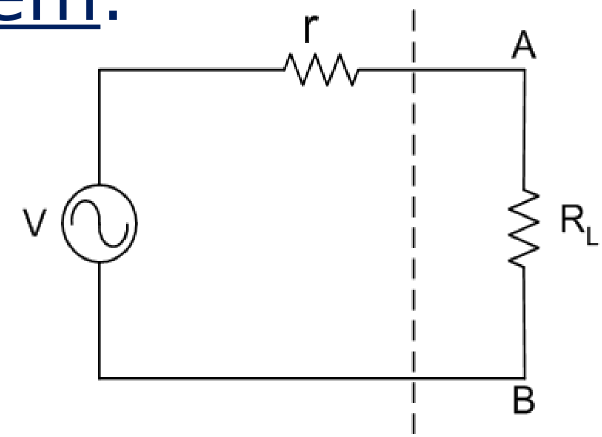
If P.F. is leading



$$|V_s| \geq |V_L| \text{ or } |V_s| \leq |V_L|$$

Maximum Power Transfer Theorem:

'P' transferred to the load is maximum when 'r = 0'

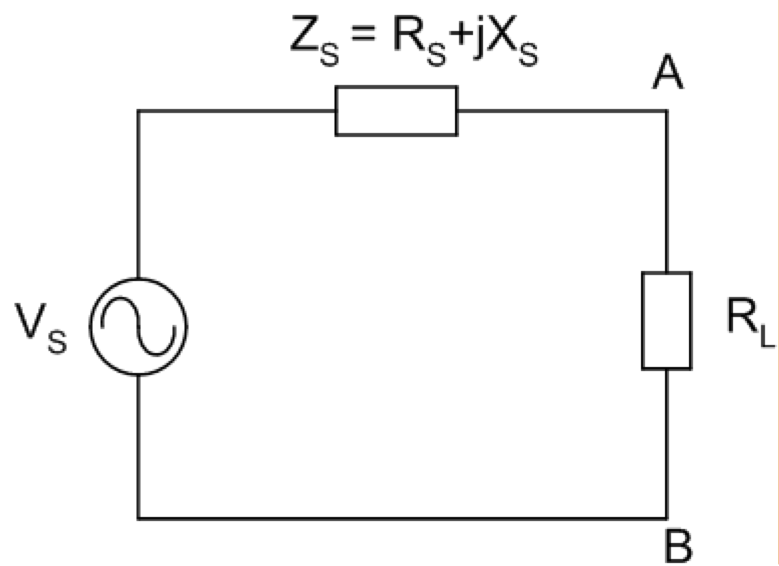


Generally load is variable .

What is the value of load which results in maximum power transfer ?

Case i: Load = R_L

$$I = \frac{V_S}{\sqrt{(R_S + R_L)^2 + X_S^{\,2}}}$$



$$P = I^2 R_L = \frac{V_S^{\,2} R_L}{(R_S + R_L)^2 + X_S^{\,2}}$$

$$P = P_{max} \quad \text{when} \quad \frac{dP}{dR_L} = 0$$

$$R_L^{\,2} = R_S^{\,2} + X_S^{\,2} \quad \text{or} \quad R_L = |Z_S|$$

$$X_S = 0, \quad P = P_{max} \quad \text{when} \quad R_L = R_S$$

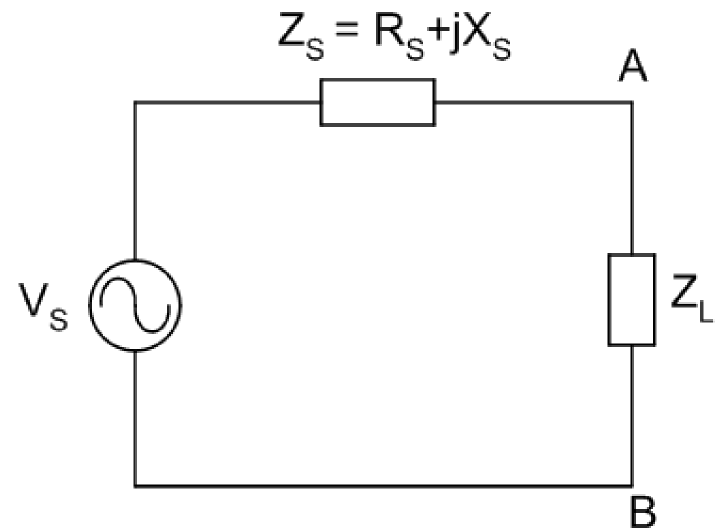
If

Case $Z_L = R_L + jX_L$

ii:

$$I = \frac{V_S}{(R_S + R_L) + j(X_S + X_L)}$$

$$\therefore P = I^2 R_L = \frac{V_S^{\,2} R_L}{(R_s + R_L)^2 + (X_S + X_L)^2}$$

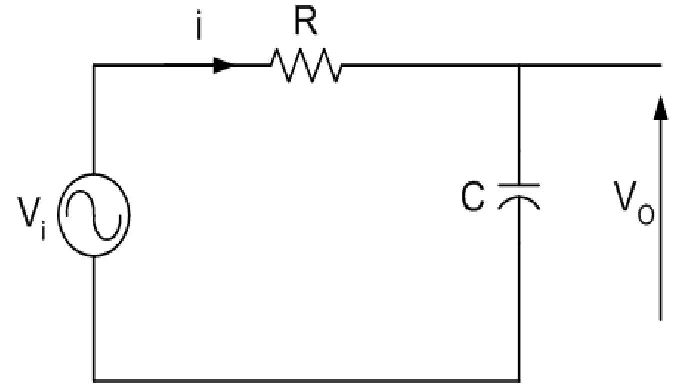


If R_L is held constant $P = P_{max}$ when $X_S = -X_L$

If R_L is variable $P = P_{max}$ when $R_L = R_s$

$\therefore$ If $R_L = R_S$ & $X_L = -X_S$ $Z_L = Z_S^*$

Frequency response of R-C and R-L circuits:



$$i = \frac{v_i}{R + \frac{1}{j\omega c}}$$

$$v_o = \frac{1}{j\omega c}\left(\frac{v_i}{R + \frac{1}{j\omega c}}\right) = \frac{v_i}{1 + j\omega RC}$$

$$\therefore \frac{v_o}{v_i} = \frac{1}{1 + j\omega RC} = A \Rightarrow \; Gain \; \Rightarrow$$ Transfer function

$$\therefore |A| = \frac{1}{\sqrt{1 + (\omega RC)^2}} \quad \& \; \theta = -tan^{-1}\omega RC$$

$$\omega = 0; \qquad \frac{v_0}{v_i} = 1 \quad \& \quad \theta = 0$$

For low values of ω, $\frac{v_0}{v_i} ; 1$ & $\theta ; 0$

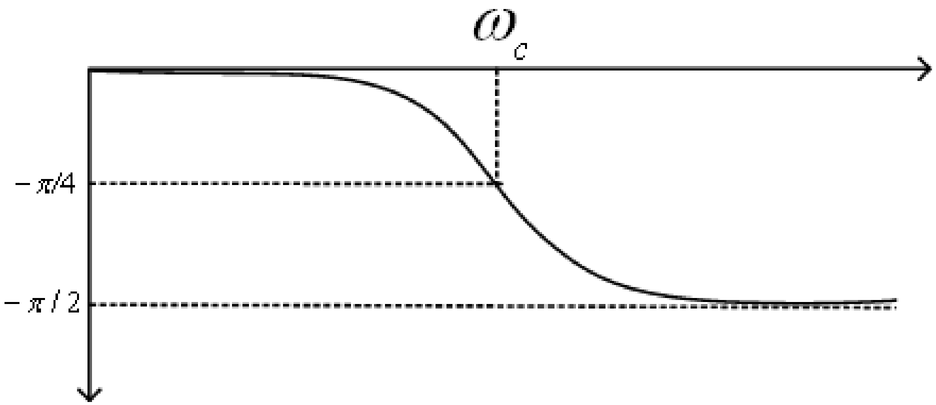
As $\omega \uparrow$, $\frac{v_0}{v_i} \downarrow$

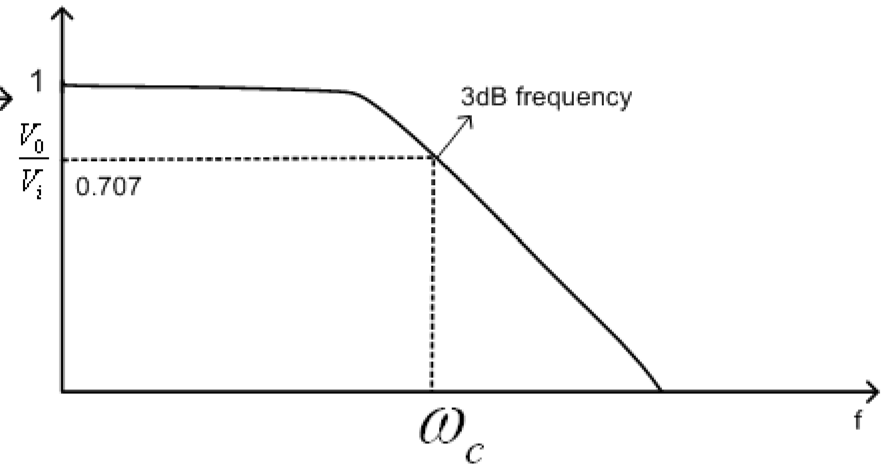
At $\omega = \omega_C = \frac{1}{RC}$, $\frac{v_0}{v_i} = 0.707$, $\theta = -45^0$

As $\omega \uparrow$ above ω_C, $\frac{v_0}{v_i} \downarrow$ rapidly & $\theta \uparrow$ towards $\frac{-\pi}{2}$

(Q for $\omega > \omega_C$, $\frac{v_0}{v_i} = \frac{1}{j\omega RC}$ if $\omega \uparrow$ by 10 times

$\frac{v_0}{v_i} \downarrow$ by 10 times)





$\Longrightarrow$ o/p always lags the i/p

$\Rightarrow$ Lag Network

$$\frac{V_o}{V_i} = \text{Voltage gain} = A$$

Gain in dB=20log A

$$\text{At } \omega = \omega_c \text{ Gain in dB = -20log}\left(\sqrt{2}\right) = -3db$$

$$\text{At } \omega = 0, \quad v_0 = v_i$$

$\Rightarrow$ Power transfer to the output terminal α V^2

At $\omega = \omega_c \quad |V_0| \downarrow$ to $\dfrac{1}{\sqrt{2}}$

$\therefore$ Power reduces to $\dfrac{1}{2}$

$\Rightarrow \omega_c \rightarrow$ Half power frequency

Observations:

⇒ The signal does not get attenuated if $f << f_c$

⇒ The signal gets attenuated if it's f>>fc

$$v_i = A\sin\omega_1 t + B\sin(7\omega t + \theta_1) + C\sin\left(9\omega t + \theta_2\right)$$

$$\omega_c = 3\omega_1 t$$

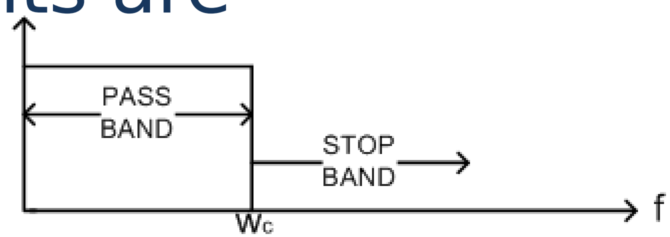
$$v_0 \; ; \; A\sin\omega_1 t$$

⇒ Only low f components are available at o/p

⇒ Allows low frequency components

⇒ High frequency components are filtered out

⇒ LOW PASS FILTER



⇒ FILTER: frequency selector circuit used to pass a certain band of frequencies & to stop or attenuate remaining band of frequencies

Active(Gain could be>1)

⇒ There are two types

Passive(Max gain<1 , only passive elements)

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