ALTERNATIVE POWER

fifteen lecture

Electrical engineering

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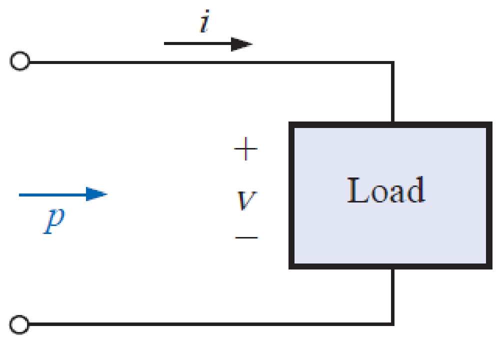
15.1Alternative power

Average Power and Power Factor The average power, or **real power** as it is sometimes called, is the power delivered to and dissipated by the load. It corresponds to the power calculations performed for dc networks.

$$p = vi$$



Since V and I are sinusoidal quantities, let us establish a general case where:

$$v = V_m \sin(\omega t + \theta)$$

$$i = I_m \sin \omega t$$

* The angle (ϴ) is the phase angle between v and I.

Substituting the above equations for V and I into the power equation will result in θ

$$p = V_m I_m \sin \omega t \sin(\omega t + \theta)$$

If we now apply a number of trigonometric identities, the following form for the power equation will result

$$\boxed{p = VI \cos \theta(1 - \cos 2\omega t) + VI \sin \theta(\sin 2\omega t)}$$

- where V and I are the rms values.

$$\boxed{V = \frac{Vm}{\sqrt{2}} \qquad and \qquad I = \frac{\text{Im}}{\sqrt{2}}}$$

So that the power is

$$p = \underbrace{VI\cos\theta}_{\text{Average}} - \underbrace{VI\cos\theta}_{\text{Peak}} \underbrace{\cos 2\omega t}_{2x} + \underbrace{VI\sin\theta}_{\text{Peak}} \underbrace{\sin 2\omega t}_{2x}$$

The average power equal

$$\boxed{P = VI\cos\theta}$$

The magnitude of average power delivered is independent of whether v leads i or I lead V.

- for resistor θ = 0 then **P = VI cos0 =VI**
- for Inductor V leads I by 90°, then **P = VI cos90 = 0**
- for Capacitor i leads v by 90°, then **P = VI cos90 = 0**

15.2 Power factor:

The power factor is the factor that has significant control over the delivered power level.

$$\boxed{\text{Power factor} = F_p = \cos\theta}$$

- Capacitive networks have leading امامي power factors,
- Inductive networks have lagging متاخر power factors.

15.2 Apparent Power

It is a power rating of significant usefulness فائدة in the description and analysis of sinusoidal ac networks and in the maximum rating of a number of electrical components and systems.

$$\boxed{S = VI} \qquad \text{(volt-amperes, VA)}$$

$$\boxed{S = I^2 Z} \qquad \text{(VA)}$$

$$\boxed{S = \frac{V^2}{Z}} \qquad \text{(VA)}$$

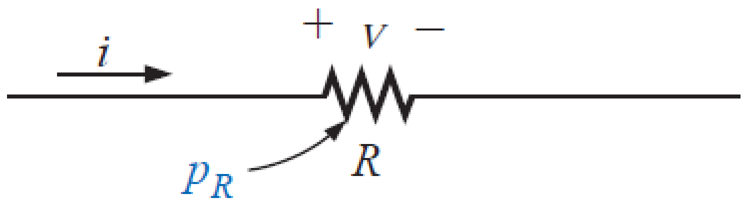
Therefore

$$\boxed{P = S\cos\theta} \qquad \text{(W)}$$

$$\boxed{F_p = \cos\theta = \frac{P}{S}}$$

1. Resistive Circuit:

For a purely resistive circuit, v and i are in phase, and θ= 0°,



$$p_R = VI\cos(0°)(1 - \cos 2\omega t) + VI\sin(0°)\sin 2\omega t$$
$$= VI(1 - \cos 2\omega t) + 0$$

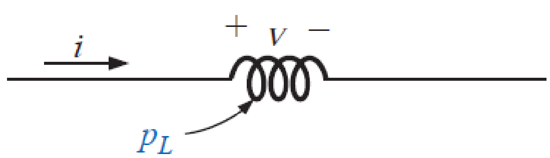
$$\boxed{p_R = VI - VI\cos 2\omega t}$$

The average (real) power is

$$\boxed{P = VI = \frac{V_m I_m}{2} = I^2R = \frac{V^2}{R}} \qquad \text{(watts, W)}$$

2. Inductive Circuit

For a purely inductive circuit, v leads i by 90°, = 90°. Θ



$$p_L = VI\cos(90°)(1 - \cos 2\omega t) + VI\sin(90°)(\sin 2\omega t)$$
$$= 0 + VI\sin 2\omega t$$

$$\boxed{p_L = VI\sin 2\omega t}$$

The reactive power is

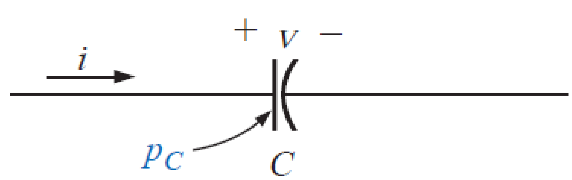
$$\boxed{Q = VI \sin \theta} \qquad \text{(volt-ampere reactive, VAR)}$$

$$\boxed{Q_L = I^2 X_L} \qquad \text{(VAR)}$$

$$\boxed{Q_L = \frac{V^2}{X_L}} \qquad \text{(VAR)}$$

3. **Capacitive Circuit**

For a purely capacitive circuit, I leads V by 90°, θ =-90°



$$\begin{aligned} p_C &= VI \cos(-90^\circ)(1 - \cos 2\omega t) + VI \sin(-90^\circ)(\sin 2\omega t) \\ &= 0 - VI \sin 2\omega t \end{aligned}$$

$$\boxed{p_C = -VI \sin 2\omega t}$$

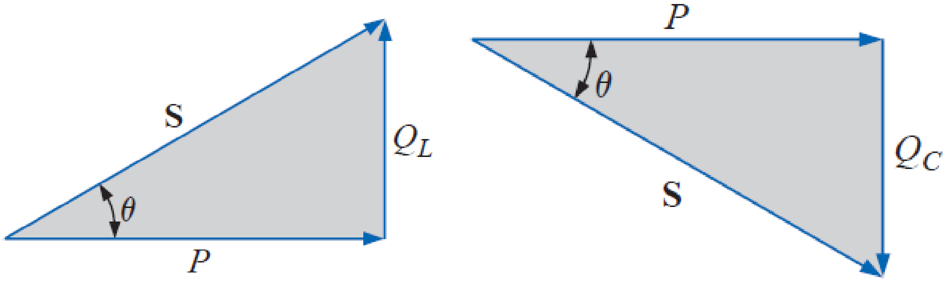
The reactive power is:

$$\boxed{Q = VI \sin \theta} \qquad \text{(volt-ampere reactive, VAR)}$$

$$\boxed{Q_C = I^2 X_C} \qquad \boxed{Q_C = \frac{V^2}{X_C}}$$

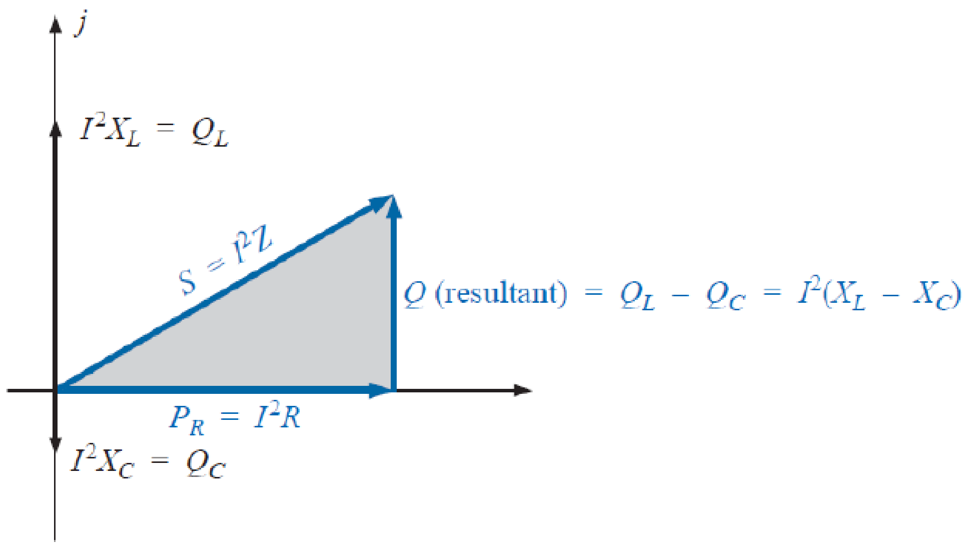
15.3 The Power Triangle

The three quantities average power (P), apparent power (S), and reactive power (Q) can be related in the vector domain by:



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

$$\boxed{\begin{array}{l} S = P + jQ \\ Q = Q_L - Q_C \end{array}}$$



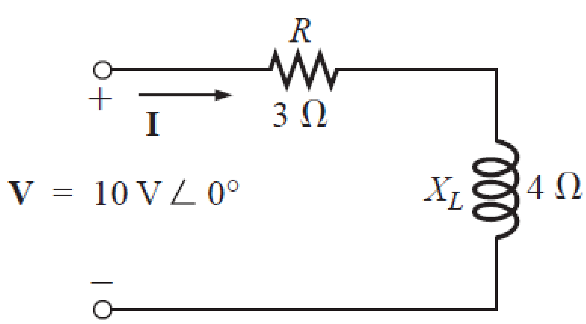
$$\boxed{S = \sqrt{P^2 + Q^2}}$$

$$\boxed{F_p = \cos\theta = \frac{P}{S}}$$

15.4 Steps for question answers:

1. Find the real power and reactive power for each branch of the circuit.
2. The total real power of the system (PT) is then the sum of the average power delivered to each branch.
3. The total reactive power (QT) is the difference between the reactive power of the inductive loads and that of the capacitive loads.
4. The total apparent power is $S_T = \sqrt{P_T + Q_T}$
5. The total power factor is TTSP. P_T / S_T

Example: Find the total number of watts, volt-amperes reactive, and volt-amperes for the network.



Solution:

$$\mathbf{I} = \frac{\mathbf{V}}{\mathbf{Z}_T} = \frac{10\text{ V}\angle 0^\circ}{3\ \Omega + j\,4\ \Omega} = \frac{10\text{ V}\angle 0^\circ}{5\ \Omega\angle 53.13^\circ} = 2\text{ A}\angle -53.13^\circ$$

$$P = I^2R = (2\text{ A})^2(3\ \Omega) = 12\text{ W}$$

$$Q_L = I^2 X_L = (2\ \text{A})^2(4\ \Omega) = 16\ \text{VAR}\ (L)$$

$$\mathbf{S} = P + j\,Q_L = 12\ \text{W} + j\ 16\ \text{VAR}\ (L) = 20\ \text{VA}\ \angle 53.13^\circ$$

Or

$$\mathbf{S} = \mathbf{V}\mathbf{I}^* = (10\ \text{V}\ \angle 0^\circ)(2\ \text{A}\ \angle +53.13^\circ) = 20\ \text{VA}\ \angle 53.13^\circ$$