MADE EASY

ELECTRICAL ENGINEERING

Power System-2

By.Bhoopender Sir

- Theory
- Explanation
- Derivation
- Example
- Shortcuts
- Previous Years Question With Solution

Power System - 2

Book:- Steven son
- Nagrath Kothari

- Standard book solved examples.
- IES mains solved problem.
- W.B. | IES previous year
- Gate previous year

---- Bhupendra Singh sir

Topics:

For Gate 5 to 8

For ESE Mains (MImp)

① Fault

② E.D.

③ Load flow

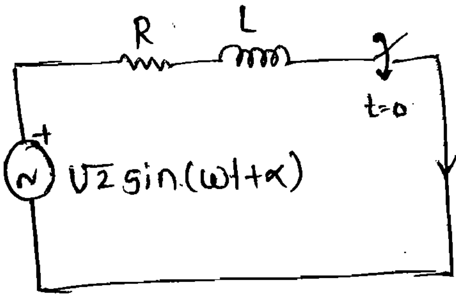
④ Stability

"No Selection, Without Revision"

Power Analysis of AC Circuit:

- **AC Circuit:**

⇒ A circuit which is in steady state corresponding to a given sinusoidal excitation is called AC circuit.

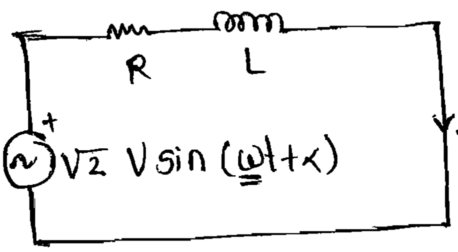


Sinusoidal exponential

$i(t) = i_{ss} + i_{TR}$

--- Not an AC circuit.

$t \to \infty$ (s.s.) ⟹



Response freq. is same as the Source freq.

$i(t) = \sqrt{2}\, I \sin(\underline{\omega} t + \beta)$

--- An AC Circuit

- Steady state response nature depends upon the source.
- Transient response nature depends upon circuit itself.
- $i(t) = i_{ss} + i_{TR}$ --- for Non-AC circuit

  $i(t) = \sqrt{2}\, I \sin(\omega t+\beta) + Ae^{-t/\tau}$

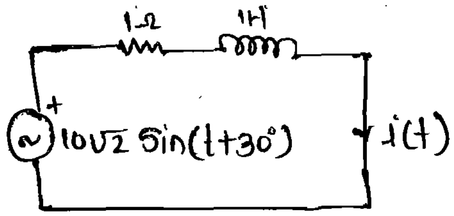
∴ Responses are Non-sinusoidal

- $i(t) = \sqrt{2}\,.\, I . \sin(\underline{\omega} t+\beta)$ ---- for AC circuit.

∴ Response are sinusoidal.

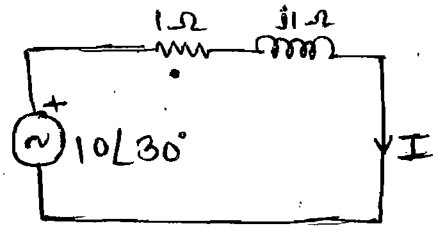
⇒ All the responses of an AC ckt. are sinusoids with freq. equal to the source freq.

⇒ The magnitude (RMS Value) and phase of a response in an AC circuit is computed using phasor technique.



Time Domain

ref. w/f = sin t →



Phasor domain equivalent ckt.

- $I = \dfrac{10\angle 30^\circ}{1+j1}$ ---phasor form

  $I = \dfrac{10}{\sqrt{2}} \angle -15^\circ$

Time domain	→	R	L	C
Phasor	→	R	$j\omega L$	$\frac{1}{j\omega C}$
Freq.	→	R	SL	$\frac{1}{SC}$

- $i(t) = 10 \sin(t - 15^\circ)$ --- time domain.

$v_L(t) = 10 \sin(t + 75^\circ)$ ← $V_L = \dfrac{10}{\sqrt{2}} \angle 75^\circ$

$= \left[\dfrac{j1}{1+j1} \, 10\angle 30^\circ\right]$

⊙ Power Calculation:

⇒ Complex power absorbed by AC ckt. | AC ckt. element:- (Fig @)

$$S = VI^* = P + jQ$$

where,

P = Active Power | Avg. Power | useful power Absorbed by AC ckt. | AC ckt. element (Watt)

Q = Reactive power | lagging VAR absorbed by AC circuit / AC ckt. element (VAR).

P>0 : ckt | ckt element absorbed Active power

P<0 : ckt | ckt. element delivers Active power.

Q>0 : ckt. | ckt. element absorbed Reactive power. (or)
ckt | ckt. element absorbed lagging VAR (or)
ckt. | ckt. element delivers Leading VAR

Q<0 : ckt. | ckt. element delivers reactive power (or)
ckt. | ckt. element delivers lagging VAR (or)
ckt. | ckt. element leading VAR (absorbed)

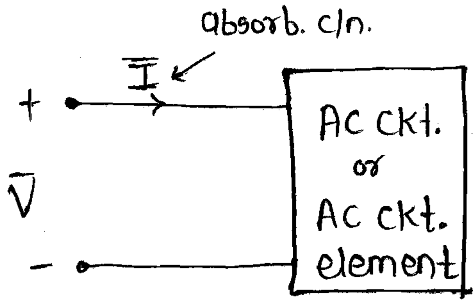


Fig (a)

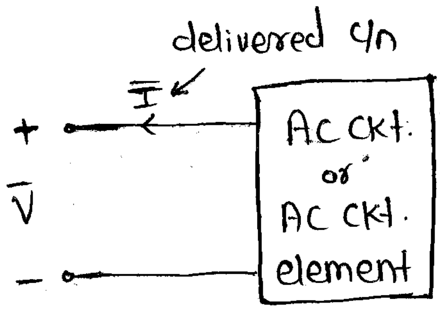


fig (b)

⟹ Complex power delivered by AC ckt. / AC ckt. element :- (fig (b))

$$S = V I^* = P + jQ$$

where,

P = Active power delivered by AC ckt. / AC ckt. element

Q = Reactive power | lagging VAR delivered by AC ckt. / AC ckt. element.

$P > 0$: Ckt. delivers active power

$P < 0$: Ckt. absorbs Active Power.

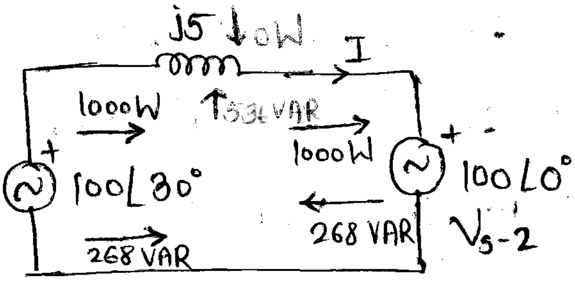
$Q > 0$: Ckt. delivers reactive power.

Ckt. delivers lagging VAR | absorbed lead. VAR.

$Q < 0$: Ckt. absorbed reactive power.

Ckt. ~~deliver~~ absorbed lagging VAR | delivered lead VAR.

Que:



- Pure L & C absorbs 0W in AC condition.
- L absorbs Reactive Power
- C delivers Reactive Power

Soln:

- $$I = \frac{100\angle 30^\circ - 100\angle 0^\circ}{j5}$$

$$I = 10.35\angle 15^\circ$$

- Complex power absorbed by $V_s - 2$

$$S = VI^*$$

$$= (100\angle 0^\circ).(10.35\angle 15^\circ)^*$$

$$= (100\angle 0^\circ).(10.35\angle -15^\circ)$$

$$S = 1000 - j268$$

∴ Vtg. source absorbs 1000W & delivers 268 VAR.

- Complex power delivered by V_s-1

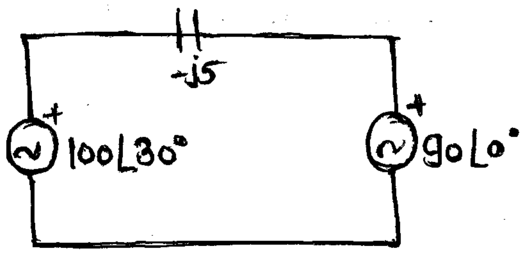
$$S = VI^*$$
$$= (100\angle 30^\circ)(10.35\angle 15)^*$$
$$S = 1000 + j268$$

∴ Vtg. source-1 delivers 1000W & delivers 268 VAR.

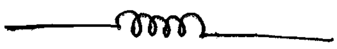
⊛ Note :

In power system, Active Power always flows from leading vtg. source towards lagging vtg. Source, whereas, reactive power generally flows from high vtg. magnitude towards low vtg. magnitude.

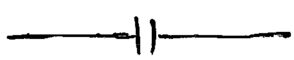
⇒



In power s/m. ckt. in series branch always inductor & in parallel branch alway capacitor.



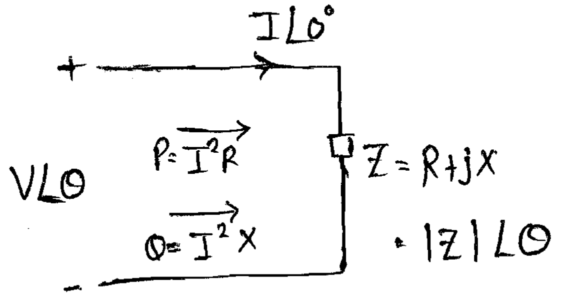
Lead → Lag



lead ← lag

$Z = R + jX$: X +ve = L, X −ve = C

$Y = G + jB$: B +ve = C, B −ve = L



$$|Z| = \sqrt{R^2 + X^2}$$
$$\theta = \tan^{-1}(X/R)$$

- Complex power abs. by $Z = R + jX$

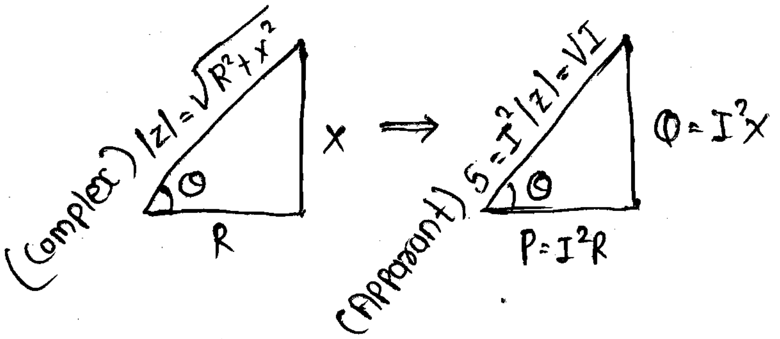
$$S = (V\angle\theta)(I\angle 0°)^* = P + jQ = VI\angle\theta$$

(Active) $P = VI\cos\theta = VI\frac{R}{|Z|} = I^2R$ --- (Real part of complex power)

(Reactive) $Q = VI\sin\theta = VI.\frac{X}{|Z|} = I^2X$ --- (Img. part of complex power)

- Apparant power:

$$S = I^2|Z| = VI$$ ... (magnitude of complex power)



--- power triangle

- Power factor: $\cos\theta = \frac{P}{S} = \frac{\text{Active Power}}{\text{Apparant Power}}$ --- P.S.

$$\cos\theta = \cos\tan^{-1}\left(\frac{Q}{P}\right)$$ --- m/c

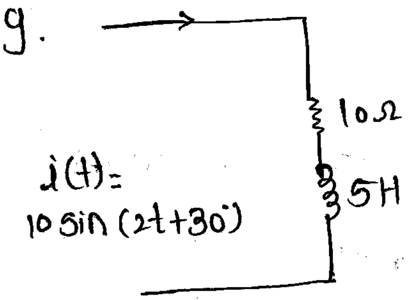
θ = angle betn vtg. phasor & c/n phasor

- Resistance: It is the real part of impedance.
- Reactance: It is the imaginary part of impedance.

$R \geq 0 \longrightarrow P \geq 0 \Longrightarrow Z = R + jX$: cant delivered Active power

- $X > 0$ (Inductive Impedance)
  - Inductive impedance absorbed Rea. power
  - Inductive impedance absorbed Lag. VAR
  - Inductive impedance del. lead. VAR.
- $X = 0$ (Resistive Impedance)
  - $\varphi = 0$
- $X < 0$ (Capacitive Impedance)
  - capacitive impedance del. Reactive power
  - capacitive impedance del. Lag. VAR
  - capacitive impedance absorbed lead. VAR.

e.g.

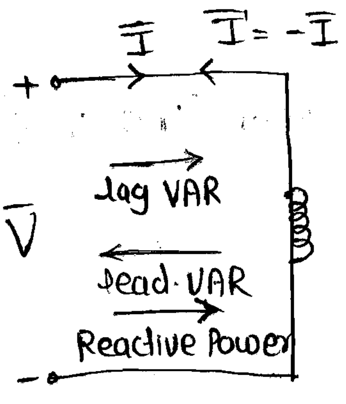


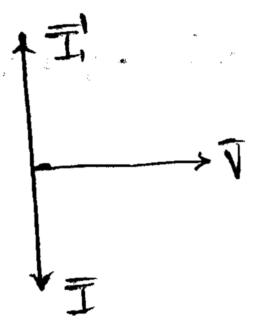
Sol^n:

$P = I^2 R = \left(\frac{10}{\sqrt{2}}\right)^2 \cdot 10$ Watt

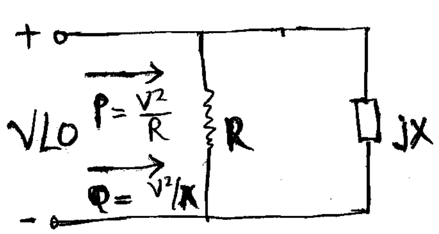
$Q = I^2 X = \left(\frac{10}{\sqrt{2}}\right)^2 \cdot (2 \times 5)$ VAR

$\Longrightarrow$



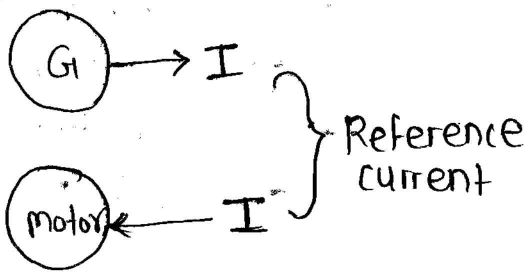


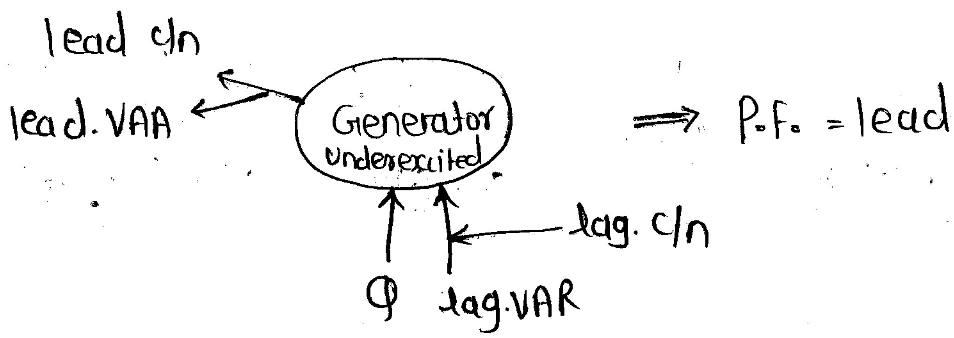
$\Longrightarrow$



- Significance of Reactive Power:

- 

- 

- 

- Flux requirement depends upon operating voltage.

Balance 3-ϕ System | Concept of phase Sequence

9/06/2021
Lec-2

⇒ A Polyphase system is said to be balance if
1. The magn. of corresponding quantities are equal in each phase.
2. The phase difference betn the corresponding Quantitive is given by.

$$\theta = \frac{360^\circ}{n} \; ; \; n \neq 2$$

$$= 90 \; ; \; n = 2$$

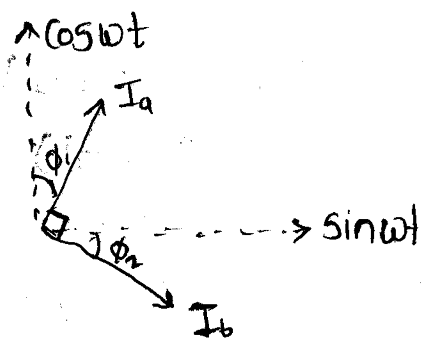
$$= \frac{360}{3} \; ; \; n = 3 \quad \text{--- for 3-}\phi \text{ s/m}$$

Que. Current in two phases of two phase s/m is given below. $i_a = \sqrt{2}\, I . \cos(\omega t - \phi_1)$
$i_b = \sqrt{2}\, I . \sin(\omega t - \phi_2)$.
Find the relationship betn ϕ_1 & ϕ_2, so that the s/m is balance.

Soln.: leading → +ve ⇒ Anti clockwise

lagging → -ve ⇒ Clockwise

cos ωt leads sin ωt by 90°.

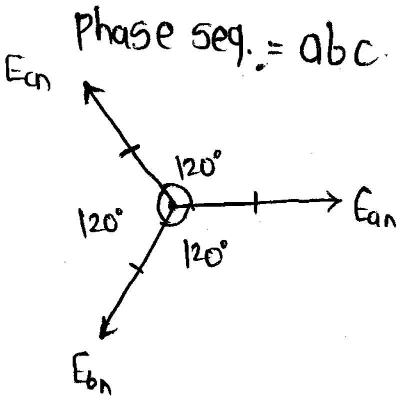


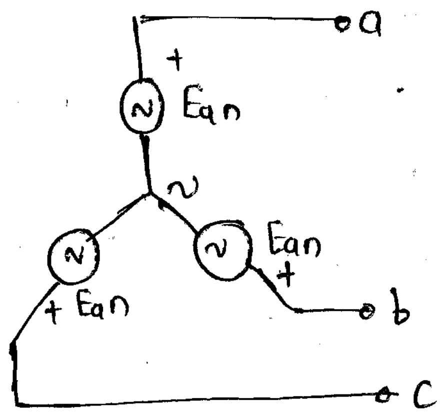
$$\therefore \phi_1 = \phi_2$$

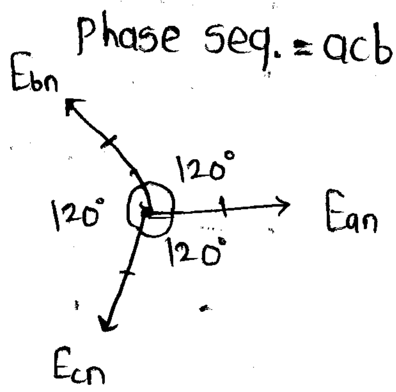
For 3-ϕ System:

Consider, a balance 3-ϕ (Ideal) Voltage Source. :

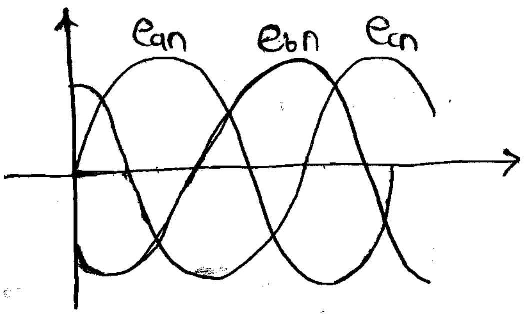
(Ideal ↓ No impedance)

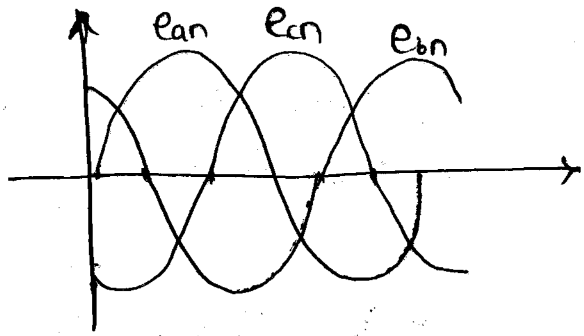






⟹ Both phasor dia. is represent balance condition but they do differ phase sequence.



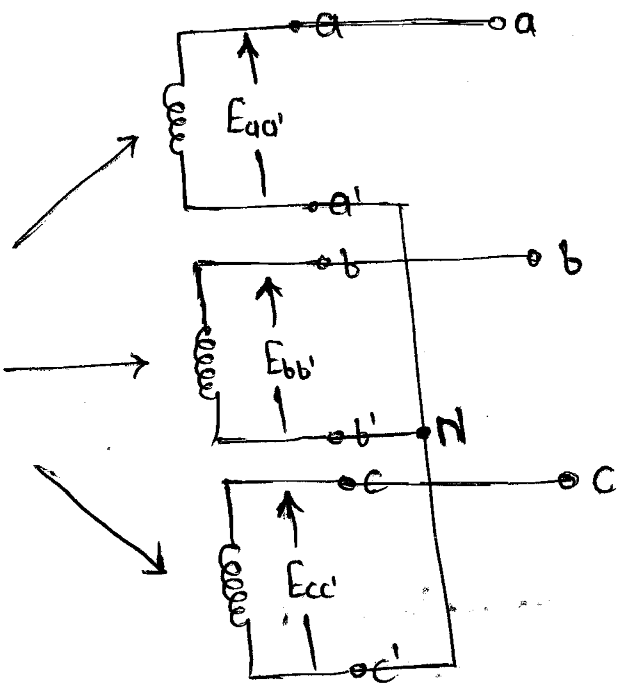


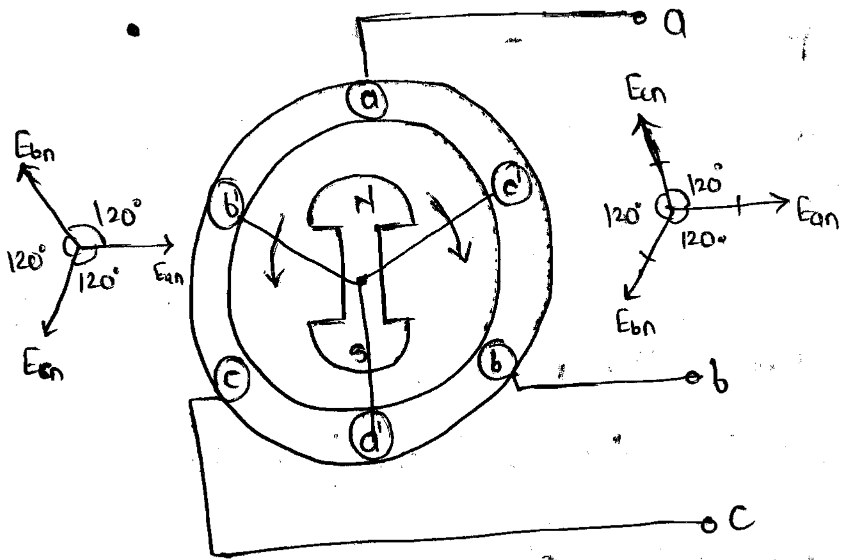
Phase sequence:

Phase sequence is defined as the order in which the phases attained their maximum value.

⟹ 3-ϕ (Ideal) Voltage Source is ckt. equivalent of a (Ideal) Synchronous machiehe.

- Identical winding in all three phases to produce equivalent magnitude of a voltage in all 3-ϕ's.



- 

$$\phi_e = \frac{P}{2}\,\phi_m$$

Note:

① only two type of phase sequence (abc & acb) is possible in a 3-ϕ system.

② The phase sequence can be reverse by reversing the rotation of rotor, but practically doing it is not possible.

③ phase sequence cannot be reverse by reversing the field excitation.