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

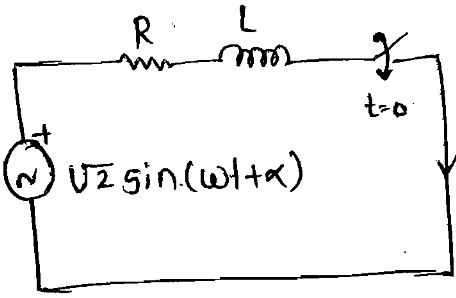
"No Selection, Without Revision"

8|06|2021
Lec-1

Power Analysis of AC Circuit:

AC Circuit:

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

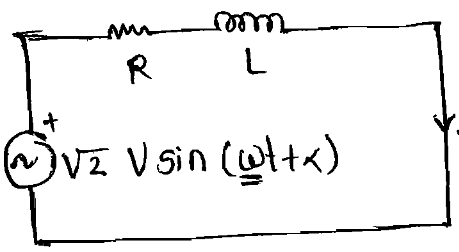


Sinusoidal exponential

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

--- Not an AC circuit.

$\xrightarrow[(s.s.)]{t\to\infty}$



Response freq. is same as the Source freq.

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

--- 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

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

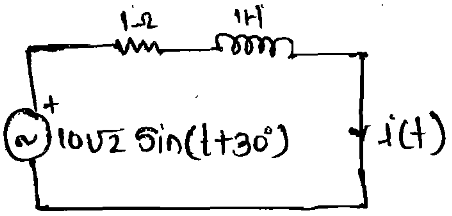
$\therefore$ Responses are Non-sinusoidal

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

$\therefore$ Response are sinusoidal.

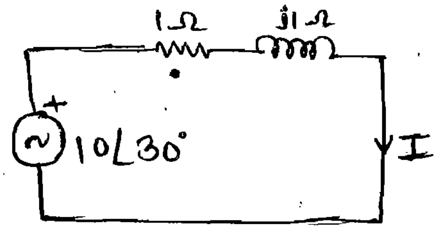
⇒ All the responses of an AC ckt. are sinusoids with freq. equal to the source freq.

⇒ 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.

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

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

⊙ 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)

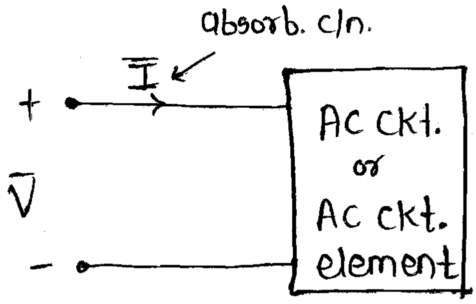


Fig (a)

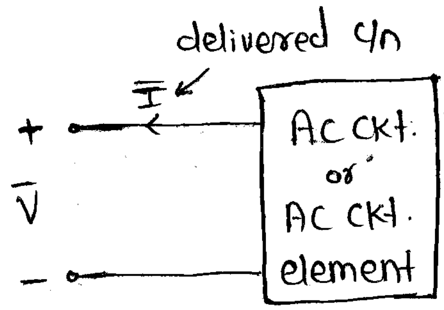


Fig (b)

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

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

where,

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

Q = Reactive power / laggig VAR delivered by Ac ckt. / Ac ckt. element.

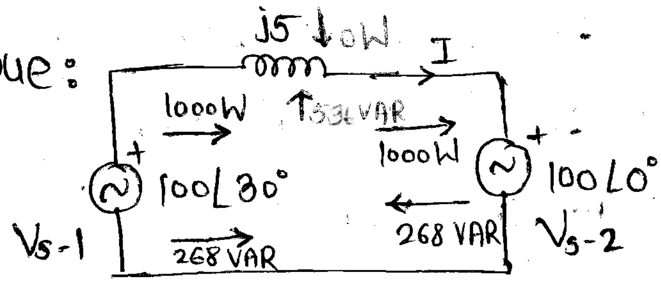
P>0 : Ckt. delivers active power

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:

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

$$I = 10.35\angle 15°$$

- Complex power absorbed by V_{s-2}

$$S = VI^*$$
$$= (100\angle 0°).(10.35\angle 15°)^*$$
$$= (100\angle 0°).(10.35\angle -15°)$$
$$S = 1000 - j268$$

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

- Complex power delivered by V_s - 1

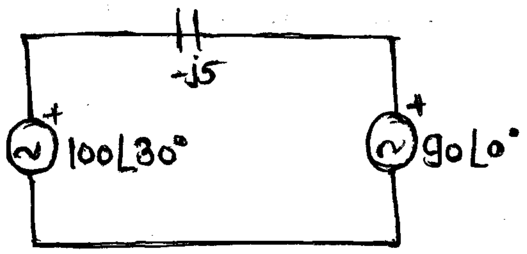
$$S = V I^*$$
$$= (100\angle 30^\circ)(10.35\angle 15)^*$$
$$S = 1000 + j268$$

$\therefore$ Vtg. source - 1 delivers 1000W & delivers 268 VAR.

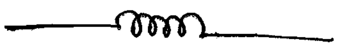
(*) Note :

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.

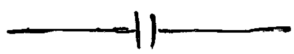
$\Rightarrow$



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



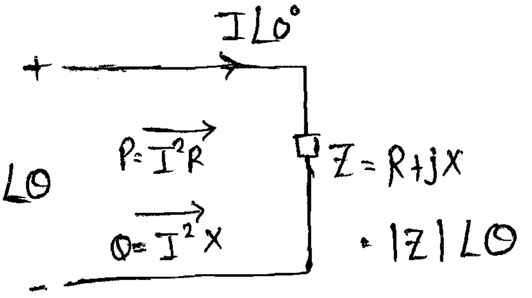
Lead $\rightarrow$ Lag



lead $\leftarrow$ lag

$Z = R + jX$: X +ve = L, X −ve = C

$Y = G + jB$: B +ve = C, B −ve = L



$$\boxed{\begin{aligned}|Z| &= \sqrt{R^2 + X^2} \\ \Theta &= \tan^{-1}(X/R)\end{aligned}}$$

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

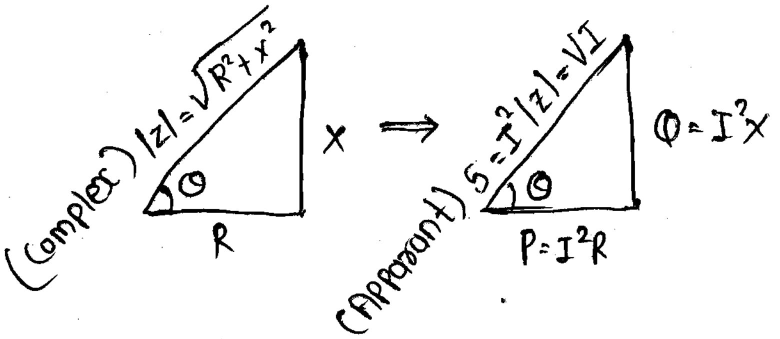
$$S = (V\angle\Theta)(I\angle 0^\circ)^* = P + jQ = VI\angle\Theta$$

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

(Reactive) $Q = VI\sin\Theta = VI\cdot\frac{X}{|Z|} = I^2X$ --- (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.

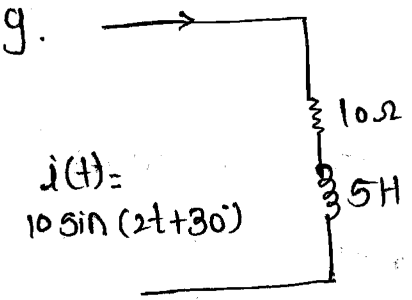
$R \geq 0 \longrightarrow P \geq 0 \Longrightarrow Z = R + jX$: cant delivered Active power

- $X > 0$ (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.

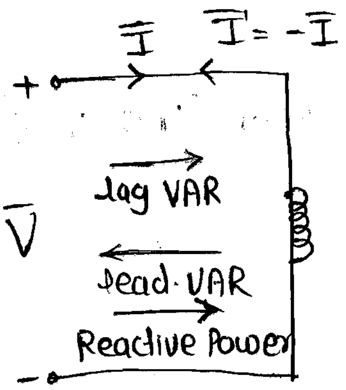


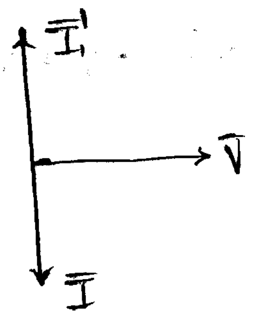
Sol^n:

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

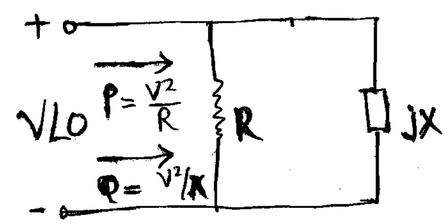
$\varphi = I^2 X = \left(\frac{10}{\sqrt{2}}\right)^2 \cdot (2 \times 5)$ VAR

$\Longrightarrow$



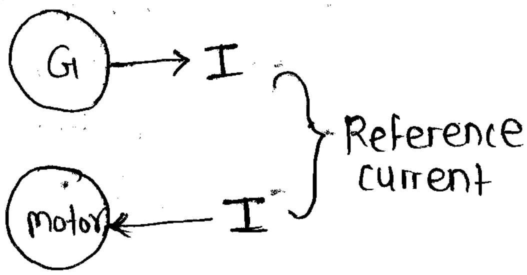


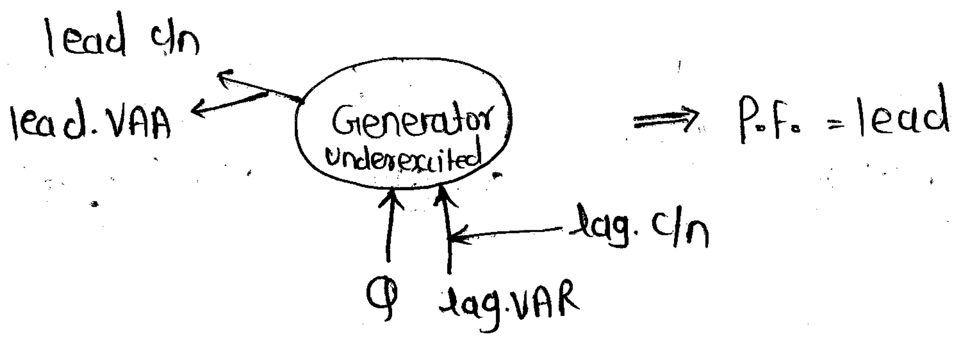
$\Longrightarrow$



- Significance of Reactive Power:

- 

- 

- 

- Flux requirement depends upon operating voltage.

Balance 3-ϕ System | Concept of phase Sequence

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Lec-2

$\Rightarrow$ 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. $i_a = \sqrt{2}\, I . \cos(\omega t - \phi_1)$

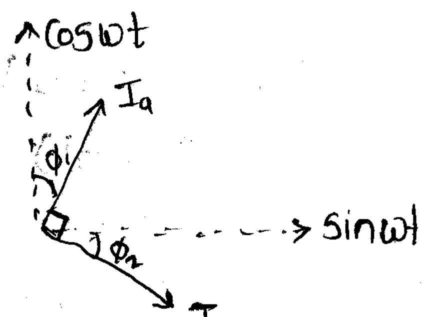
$i_b = \sqrt{2}\, I . \sin(\omega t - \phi_2)$.

Find the relationship betn ϕ_1 & ϕ_2, so that the s/m is balance.

Soln.: leading $\rightarrow$ +ve $\Rightarrow$ Anticlockwise

lagging $\rightarrow$ -ve $\Rightarrow$ Clockwise

cos ωt leads sin ωt by 90°.



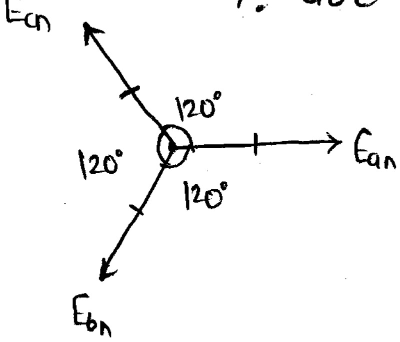
$$\boxed{\therefore \phi_1 = \phi_2}$$

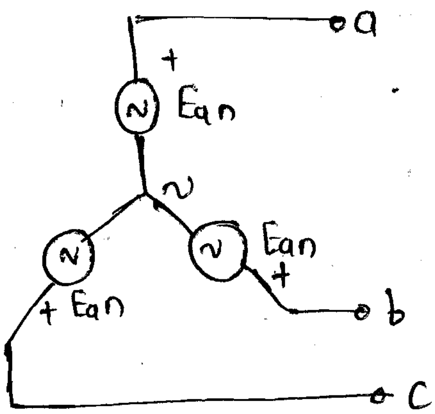
⊙ For 3-ϕ System:

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

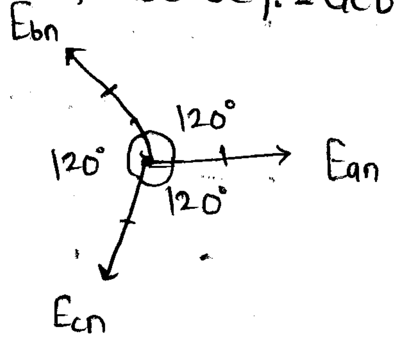
No impedance

Phase seq. = abc

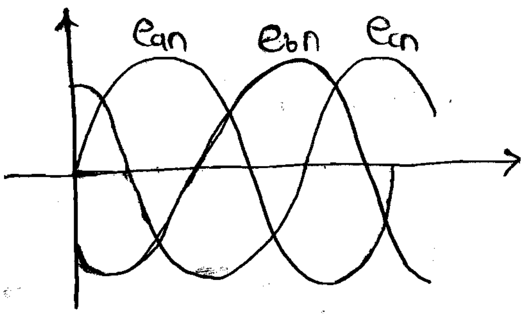


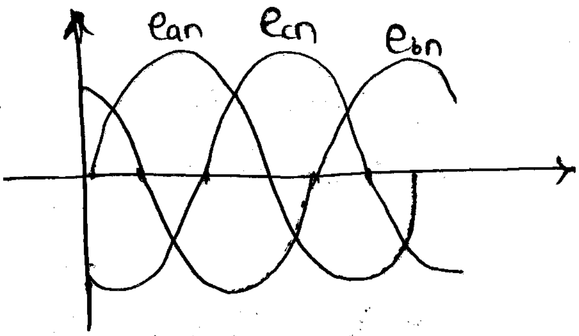


Phase seq. = acb



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



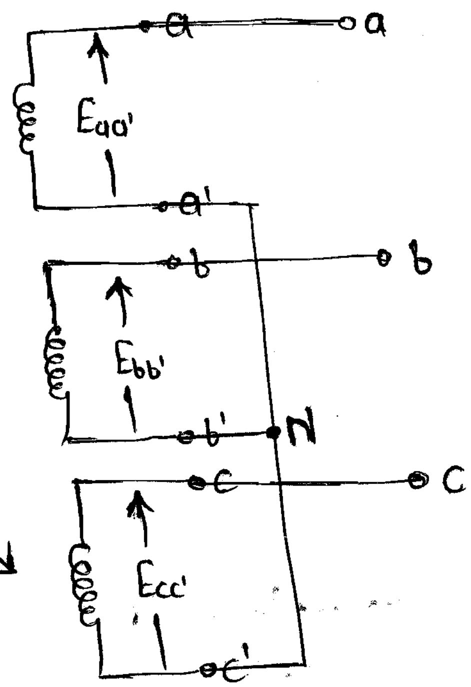


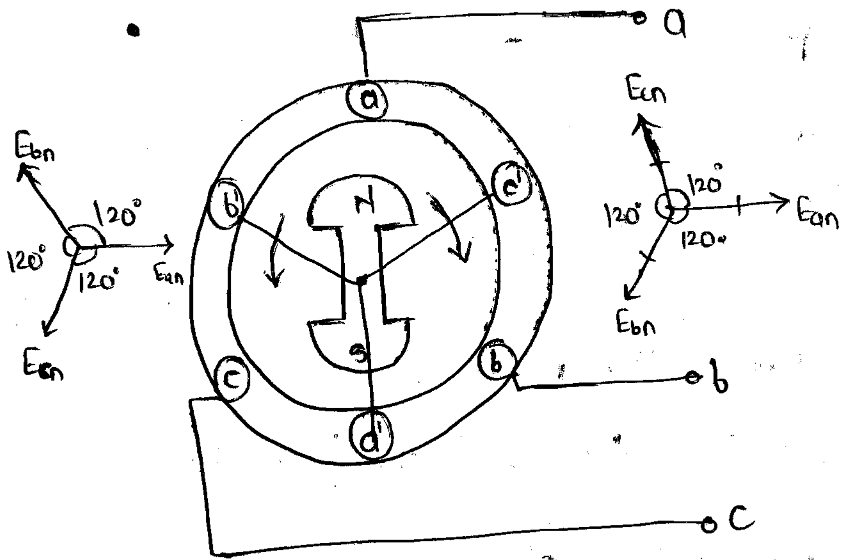
⊙ Phase sequence:

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.



- 

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

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.