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### MADE EASY ELECTRICAL ENGINEERING Power System-2 By. Bhoopender Sir

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- Derivation
- Example
- Shortcuts
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# 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

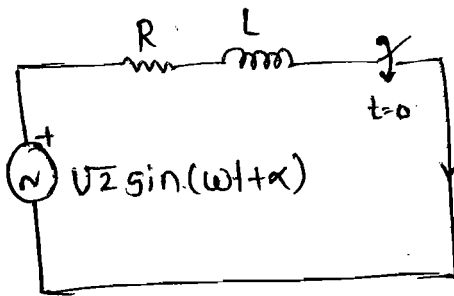
"No Selection, Without Revision"



# # Power Analysis of AC Circuit:

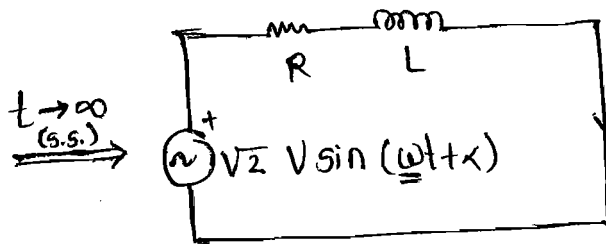
## o AC Circuit:

⇒ 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.



Response freq. is same as the source freq.

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

--- 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

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

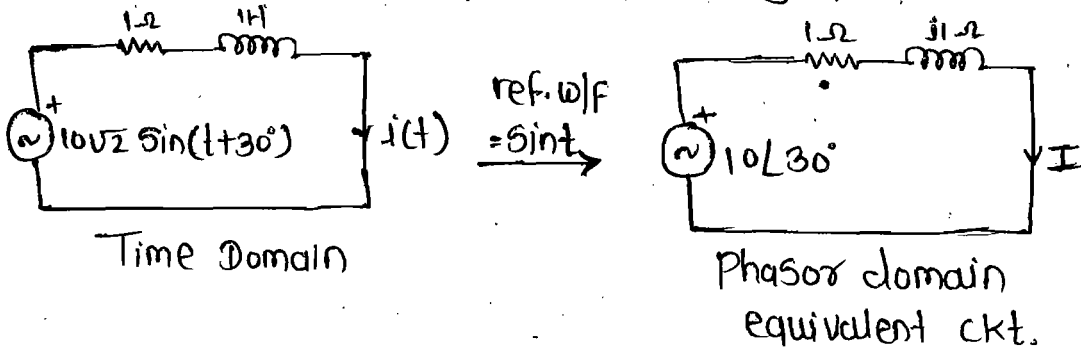
∴ Responses are Non-sinusoidal

•  $i(t) = \sqrt{2} \cdot I \sin(\omega t + \beta)$  ---- 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.



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

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

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.

$V_L(t) = 10 \sin(t + 75^\circ)$  ←  $V_L = \frac{10}{\sqrt{2}} \angle 75^\circ = \left[ \frac{j1}{1+j1} 10\angle 30^\circ \right]$

⊙ 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)

$\phi$  = 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. (VAR)

ckt / ckt. element absorbed Lagging VAR (VAR)

ckt. / ckt. element delivers Leading VAR

$\phi < 0$  : ckt. / ckt. element delivers reactive power (VAR)

ckt. / ckt. element delivers lagging VAR (VAR)

ckt. / ckt. element leading VAR (absorbed)

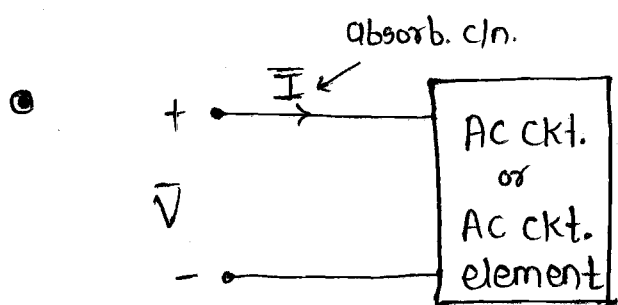


Fig (a)

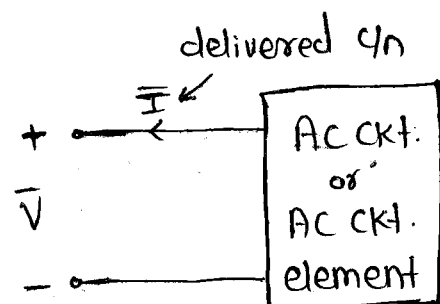


Fig (b)

$\Rightarrow$  Complex power delivered by AC ckt. / AC ckt. element :- (Fig (b))

$$S = V \bar{I}^* = P + jQ$$

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

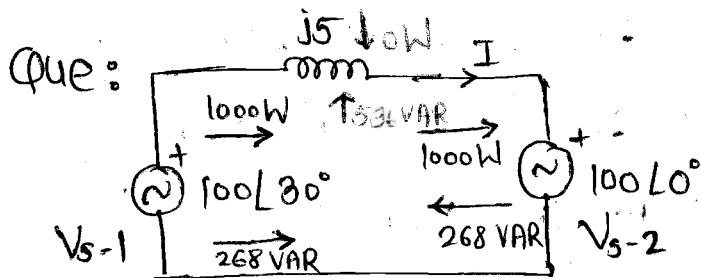
$P < 0$  : ckt. absorbs Active power.

$\phi > 0$  : ckt. delivers reactive power.

ckt. delivers lagging VAR / absorbed lead VAR.

$\phi < 0$  : ckt. absorbed reactive power.

ckt. deliver absorbed lagging VAR / delivered lead VAR.



• Pure L & C absorbs 0W  
in AC condition.

• L absorbs Reactive power

• C delivers Reactive power

Sol<sup>n</sup>:

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

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

• Complex power absorbed by  $V_s - 2$

$$S = VI^*$$

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

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

$$S = 1000 - j268$$

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



- Complex Power delivered by  $V_s - 1$

$$S = VI^*$$

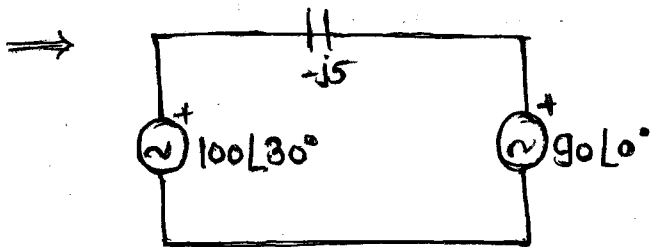
$$= (100 \angle 30^\circ) (10.35 \angle 75^\circ)^*$$

$$S = 1000 + j268$$

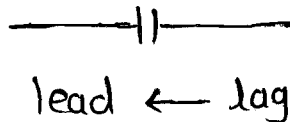
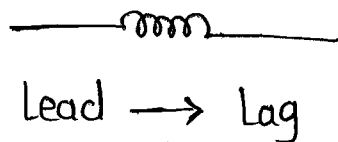
∴ Vtg. source - 1 delivers 1000W & delivers 268 VAR.

⊛ Note :

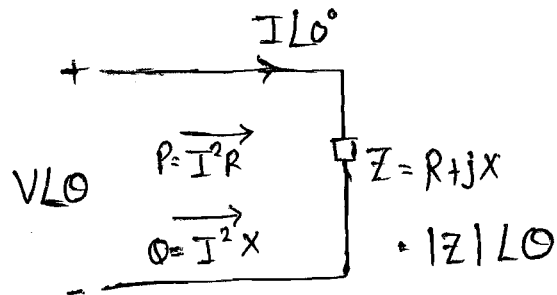
In power system, Active Power always flows from leading vtg. source towards lagging vtg. source, whereas, reactive power generally flows from high vtg. magnitude towards low vtg. magnitude.



In power sys. ckt. in series branch always inductor & in parallel branch always capacitor.



⊙



$$|Z| = \sqrt{R^2 + X^2}$$

$$\theta = \tan^{-1}(X/R)$$

$$Z = R + jX = \begin{matrix} X +ve = L \\ X -ve = C \end{matrix}$$

$$Y = G + jB = \begin{matrix} B +ve = C \\ B -ve = L \end{matrix}$$

⊙ Complex power abs. by  $Z = R + jX$

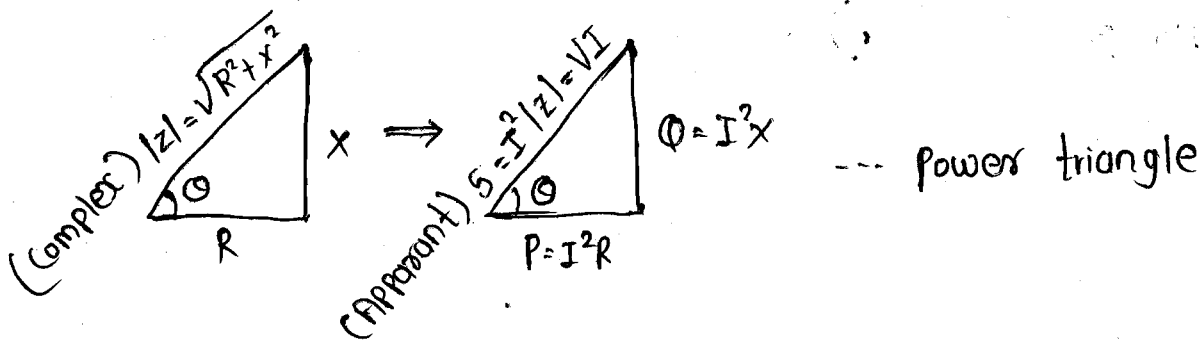
$$S = (V \angle \theta) (I \angle \theta)^* = P + jQ = VI \angle \theta$$

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

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

⊙ Apparent power:

$$S = I^2 |Z| = VI \text{ --- (magnitude of complex power)}$$



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

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

$\theta$  = angle bet<sup>n</sup> vtg. phasor & c/n phasor

- Resistance: It is the real part of impedance.

- Reactance: It is the imaginary part of impedance.

$R \geq 0 \rightarrow P \geq 0 \Rightarrow Z = R + jX$  : cant delivered  
Active power

⊙  $X > 0$  (Inductive Impedance)

- Inductive impedance absorbed Rea. power
- Inductive impedance absorbed Lag. VAR
- Inductive impedance del. lead. VAR.

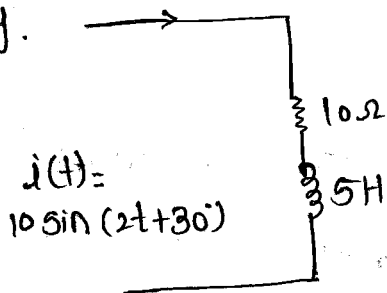
$X = 0$  (Resistive Impedance)

-  $\phi = 0$

$X < 0$  (Capacitive Impedance)

- capacitive impedance del. Reactive power
- capacitive impedance del. Lag. VAR
- capacitive impedance absorbed lead. VAR.

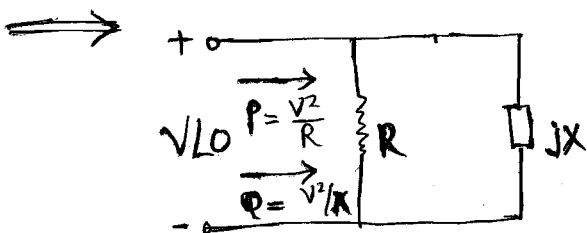
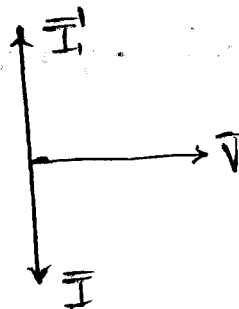
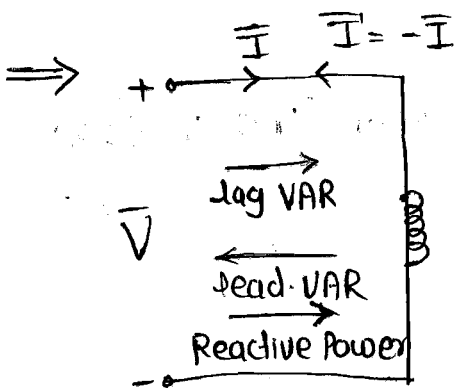
e.g.



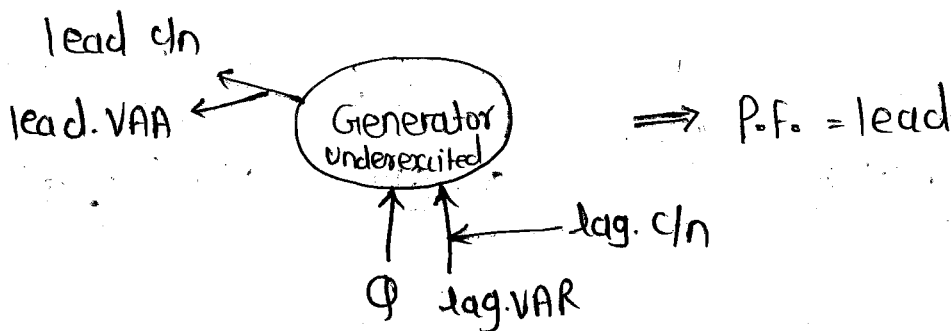
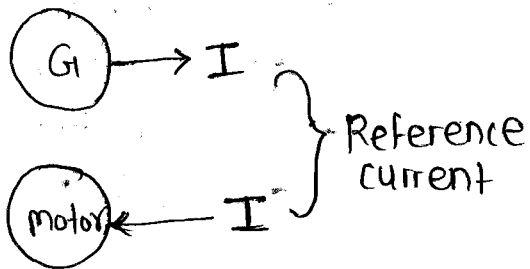
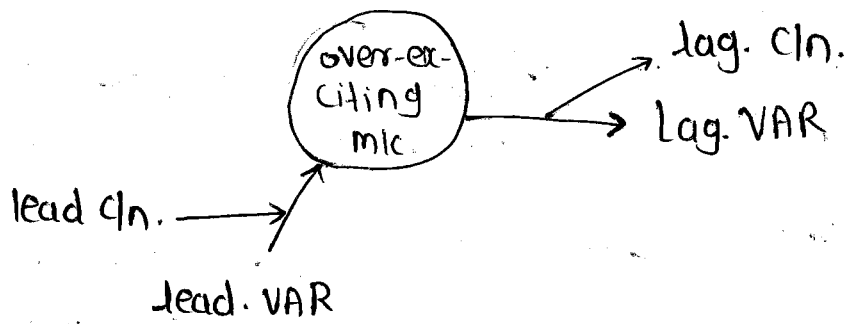
sol<sup>n</sup>:

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

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



• Significance of Reactive Power:



• Flux requirement depends upon operating voltage.

# # Balance 3- $\phi$ System |

9/06/2021  
lec-2

## Concept of phase Sequence

$\Rightarrow$  A polyphase system is said to be balance if

① The magn. of corresponding quantities are equal in each phase.

② The phase difference bet<sup>n</sup> the corresponding quantities is given by,

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

$$= 90 ; n = 2$$

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

Que. Current in two phases of two phase s/m is given below.

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

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

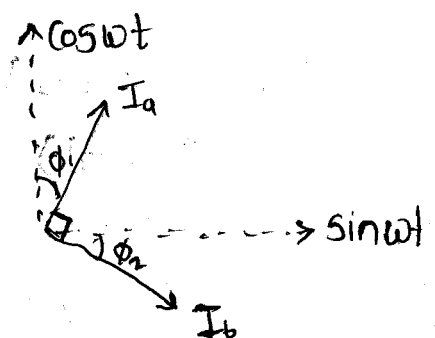
Find the relationship bet<sup>n</sup>  $\phi_1$  &  $\phi_2$ , so that the s/m is balance.

Sol<sup>n</sup>: leading  $\rightarrow$  +ve  $\Rightarrow$  Anticlockwise

$\cos \omega t$  leads  
 $\sin \omega t$  by  $90^\circ$ .

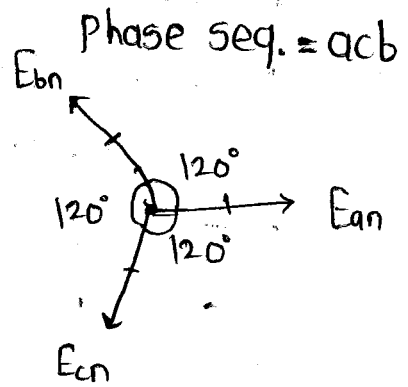
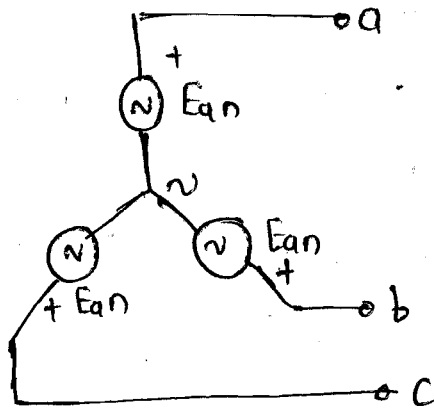
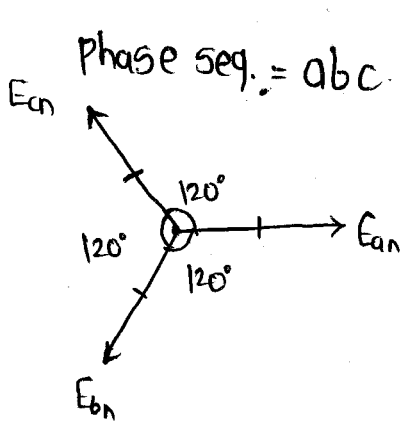
Lagging  $\rightarrow$  -ve  $\Rightarrow$  clockwise

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

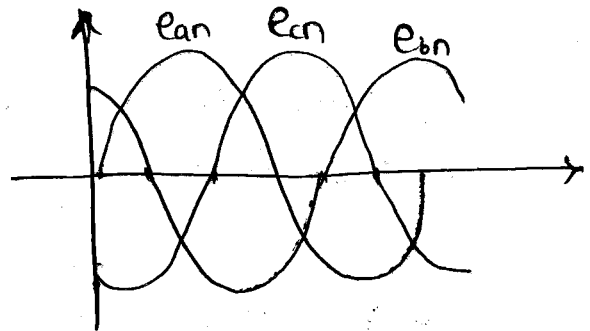
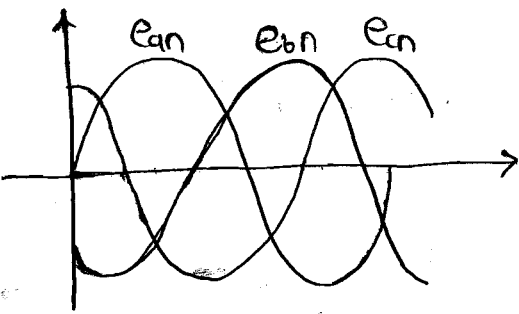


⊙ For 3- $\phi$  System:

Consider, a balance 3- $\phi$  (Ideal) Voltage Source. :  
 ↓  
 No impedance



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

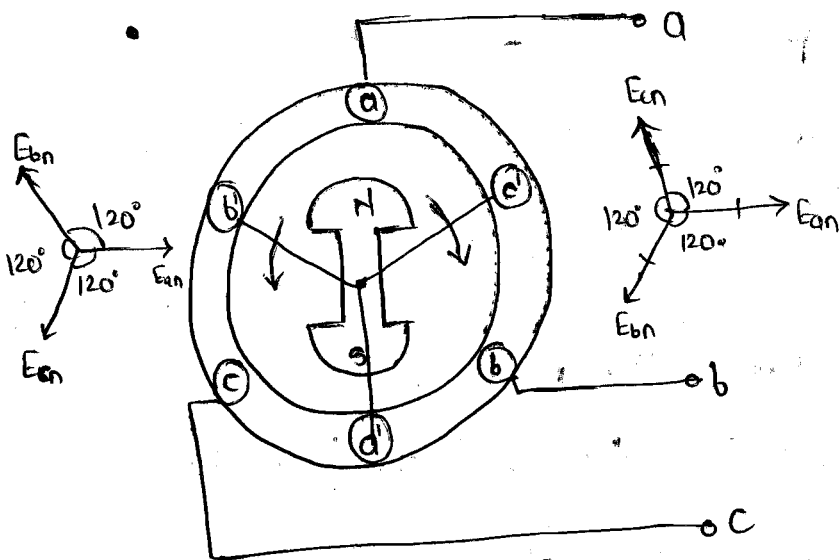
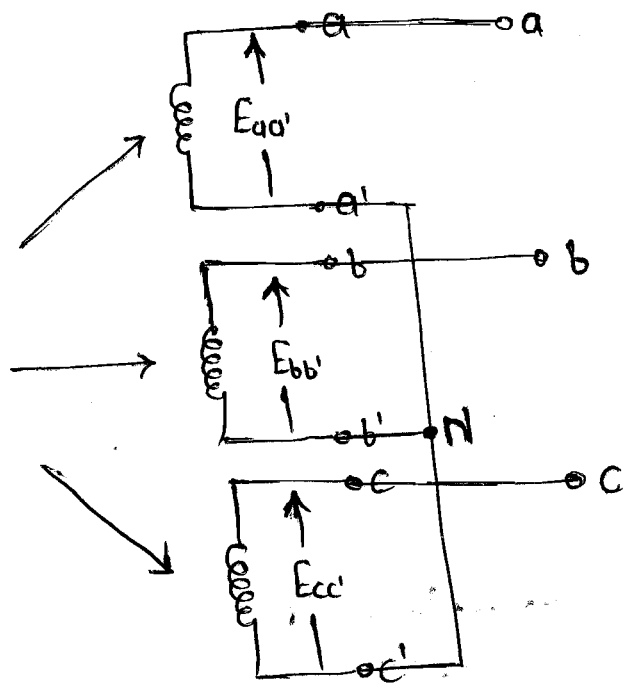


⊙ Phase sequence :

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

⇒ 3- $\phi$  (Ideal) voltage source is ckt. equivalent of a (Ideal) synchronous machine.

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



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

① Note:

- ① Only two type of phase sequence (abc & acb) is possible in a 3- $\phi$  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.