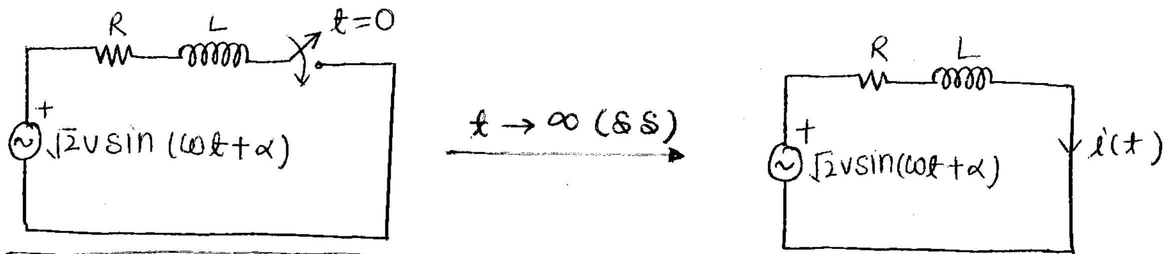
MADE EASY
ELECTRICAL ENGINEERING
Power System-2
By.Bhoopender Sir

Power Analysis of AC circuit :—

(i) A circuit which is in steady state corresponding to a given sinusoidal excitation is called an AC circuit.



Not an AC circuit

because it is in transient state

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

i_{ss} = steady state response depends upon the source

i_{TR} = Transient response depends upon the circuit itself

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

$\therefore$ **Responses are non-sinusoidal**

An AC circuit

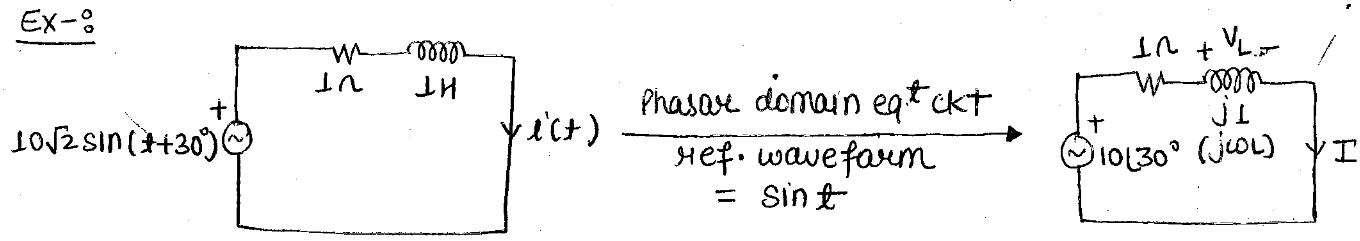
$i(t) = \sqrt{2} I \sin(\omega t + \beta)$

Responses are sinusoidal and having same freq.

(ii) All the **responses** of an **An ac circuit** are **sinusoidal** with frequence **equal to** the **source frequency**.

(iii) The **magnitude (RMS value)** and **phase of a response** in an AC circu is computed **using phasor technique**.

Ex-:



Reference waveform is selected such that frequency of ref. waveform should be equal to the frequency of source.

In phasor diagram equivalent ckt we have to take rms value.

$$V_m = 10\sqrt{2} \Rightarrow V_{RMS} = 10$$

	Time domain	Phasor domain	Frequency domain
Inductor	Henery (H)	jX or $j\omega L$	sL
Capacitor	Farad (F)	$1/(j\omega C)$	$1/sC$
Resistance	R	R	R

$$I(t) = \frac{10\angle 30^\circ}{1+j1} = \frac{10}{\sqrt{2}}\angle -15^\circ = 10\sin(t-15^\circ)$$

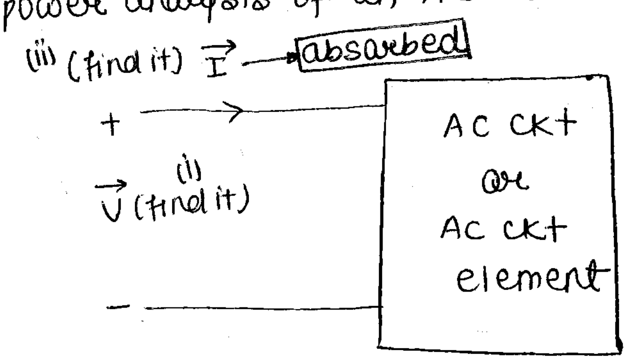
$\frac{10}{\sqrt{2}}$ → RMS value

$10\sin(t-15^\circ)$ → Maximum value

By applying voltage division rule

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

Now power analysis of an AC circuit



complex power absorbed by AC ckt or element

(ii)

$S = \vec{V}\,\vec{I}^*$ [find it]

$= P + jQ$

(iv) Then;

P = Active power / useful power / Avg. Power / Power absorbed by AC ckt or AC ckt element (watt)

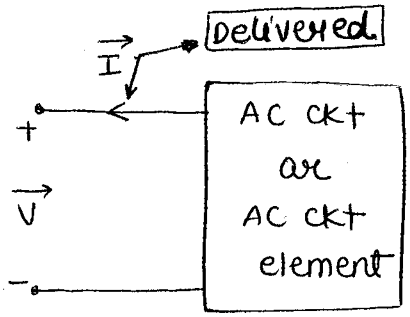
Q = Reactive power / lagging VAR absorbed by the AC ckt element or AC ckt. (VAR)

By default Active power

$P > 0$ →	ckt absorbed active power
$P < 0$ →	ckt delivers active power

$Q > 0$ → ckt. absorbed Reactive power / lagging VAR
or
ckt delivers leading VAR

$Q<0 \rightarrow$ ckt delivers Reactive power / lagging VAr
or
ckt absorbs leading VAr.



complex power delivered by AC ckt or AC ckt element

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

P = Active power / useful power / Average Power / Power delivered by AC ckt or AC ckt element

Q = Reactive power / lagging VAr delivered by the AC ckt element or AC ckt.

$P > 0$ = ckt delivers active power
$P < 0$ = ckt absorbs active power

$Q > 0$ = ckt delivers Reactive power / lagging VAr
or
ckt absorbes leading VAr

$Q < 0$ = ckt absorbs Reactive power / lagging VAr
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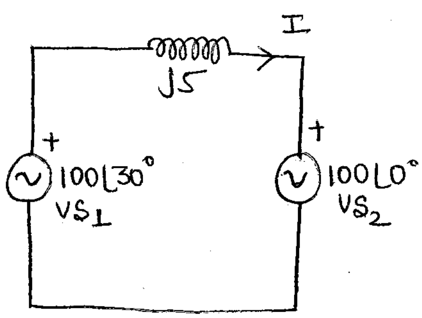
Ex-:



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

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

complex power absorbs by VS-2

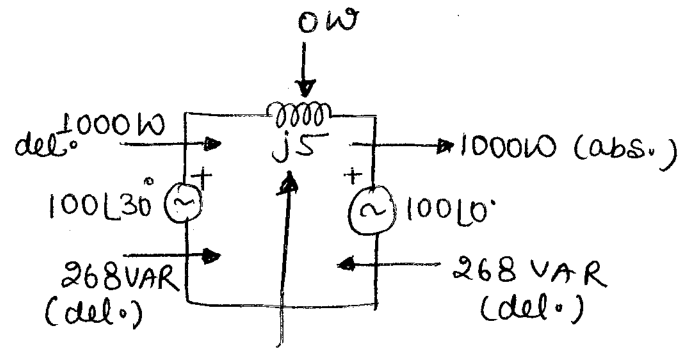
$$S = (100\angle 0^\circ)(10.35\angle 15^\circ)^{*} = 1000 - j268$$

VS_2: absorbs 1000W and delivers 268 VAr

complex power delivered by VS-1

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

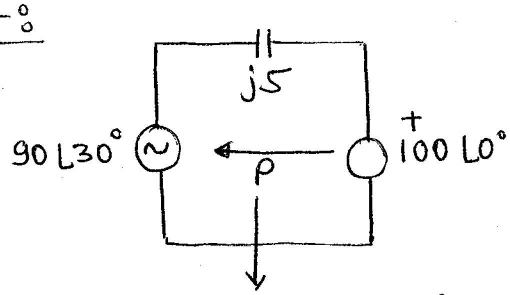
VS_1: delivered 1000W and delivers 268 VAr

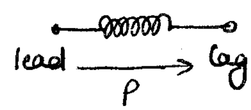


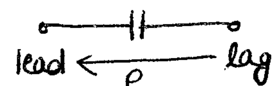
536 VAr (abs.)
= 268 VAr + 268 VAr & [Active power = 0 (always)]

<u>NOTE</u>:- In power system active power always flows from leading voltage source towards the lagging voltage source where as reactive power generally flow from voltage of high magnitude towards voltage of low magnitude.

<u>EX</u>:-



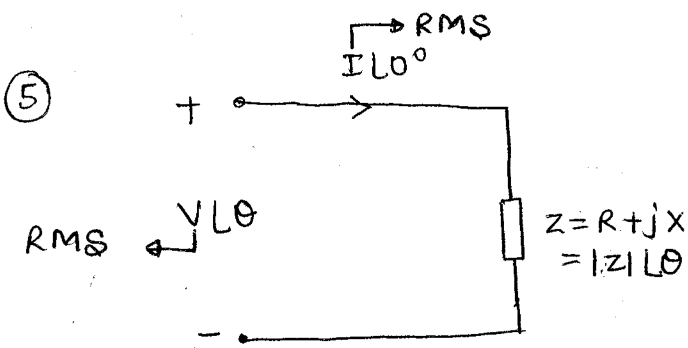




But in power system in series capacitor is not present i.e; not power system ckt.

i.e; flowing from lagging to leading voltage source because it is not power system ckt. b.c. the series branch of power system is always inductive in nature.

(5)



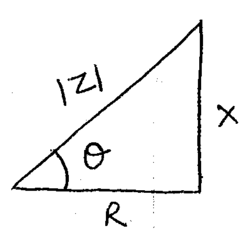
X = +ve ⟶ inductance
X = −ve ⟶ capacitance

$Y = \frac{1}{Z} = G + jB$

B = −ve ⟶ inductance
B = +ve ⟶ capacitance

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

$\theta = \tan^{-1}\frac{X}{R}$



$\cos\theta = \frac{R}{|Z|}$

$\sin\theta = \frac{X}{|Z|}$

$\vec{V} = \vec{I}\,\vec{Z}$

$= I\angle 0^\circ \; Z\angle\theta$

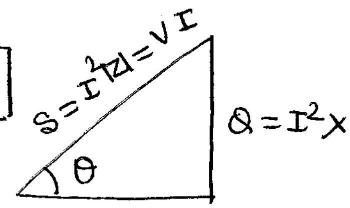
$= IZ\angle\theta = V\angle\theta$

so, complex power absorbs by $Z = R + jX$

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

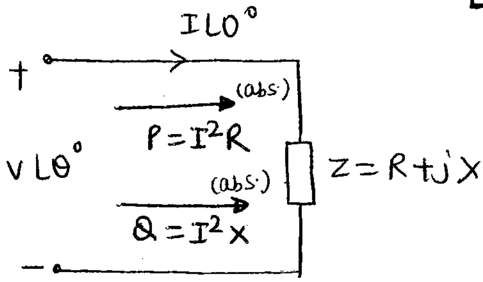
$$\boxed{P} = VI\cos\theta = VI\frac{R}{|Z|} = \boxed{I^2R}$$ → RMS value

$$\boxed{Q} = VI\sin\theta = VI\cdot\frac{X}{|Z|} = \boxed{I^2X}$$ → RMS value



$P = I^2R$

:- power triangle :-



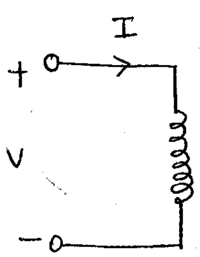
$$p.f. = \cos\theta = \frac{P}{S}$$

| $R \geq 0 \longrightarrow P \geq 0$ so, $Z = R + jX$ can't deliver active power. |

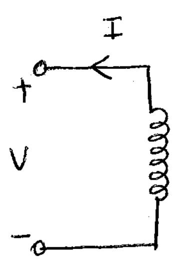
| $X > 0$ (inductive) | → | $Q > 0$ i.e.; inductive Impedance absorbs Reactive power / lagging VAR (or) inductive Impedance delivers leading VAR |

| $X = 0$ (Resistive) $\longrightarrow Q = 0$ |

| $X < 0$ (capacitive) | → | $Q < 0$ i.e.; capacitive impedance delivers Reactive power / lagging VAR (or) capacitive Impedance absorbs leading VAR |



I laggs V by 90°



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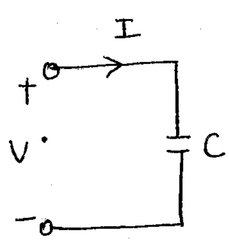

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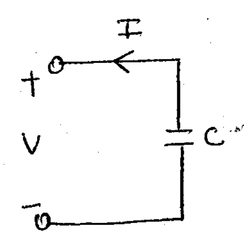
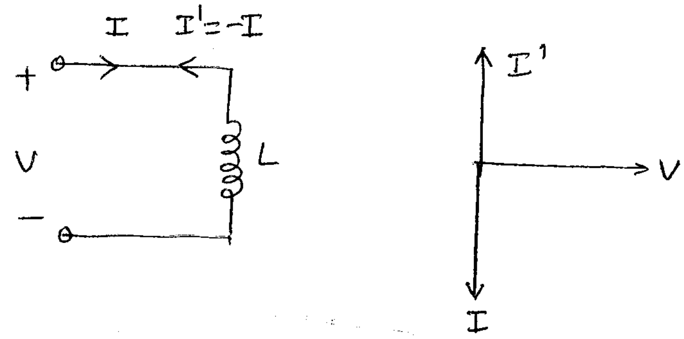


I lags V by 90°

(By default we take absorb current always)

Ex-:



For I (अन्दर आने वाली) current is lagging then it always absorbs lagging VAR.

For I' which is leads by V then it always delivers leading VAR.

NOTE-:

(i) Overexcited Synchronous M/C → delivers reactive power / lagging VAR i.e; lagging current (or) absorbs leading VAR i.e; leading current [Always]

(requirement of flux get excess in m/c then it will deliver reactive power)

(ii) Underexcited Synchronous M/C → absorbs reactive power / lagging VAR i.e; lagging current (or) delivers leading VAR i.e; leading current [Always]

Now; Motor → absorb the current & current may be leading or lagging in nature

Generator → delivers the current & current may be leading or lagging in nature

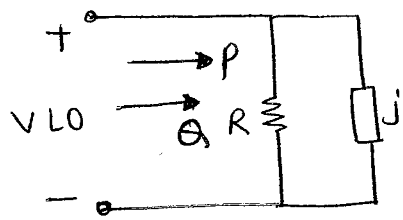
Overexcited syn. motor → motor absorbs the current i.e; absorbs leading VAR

we can say that pf ≡ leading

Over excited Sync. Generator ⟶ Generator delivers the current i.e; delivered lagging VAr i.e lagging current

we can say that p.f ≡ lagging

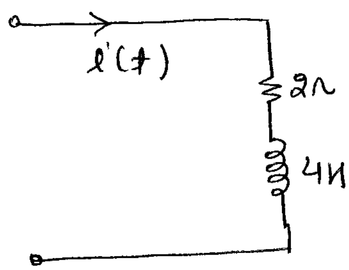
#



$P = \frac{V^2}{R}$ → RMS value

$Q = \frac{V^2}{X}$ → RMS value

Ex-:



$i(t) = 10\sin(2t + 30^\circ)$ (ω = 2)

$P = ?$ $Q = ?$

$P = I^2R = \left(\frac{10}{\sqrt{2}}\right)^2 \times 2 = 100\,W$

$[X = \omega L]$
$\omega = 2,\ L = 4$

$Q = I^2X = \left(\frac{10}{\sqrt{2}}\right)^2 \times (2\times 4) = 400\ VAr$

I = RMS value

Balance 3-φ system / concept of phase sequence :-

A polyphase system is said to be balance if

(i) The magnitude of corresponding quantity are equal in each phase.

(ii) The phase difference b/w the corresponding quantities is given by

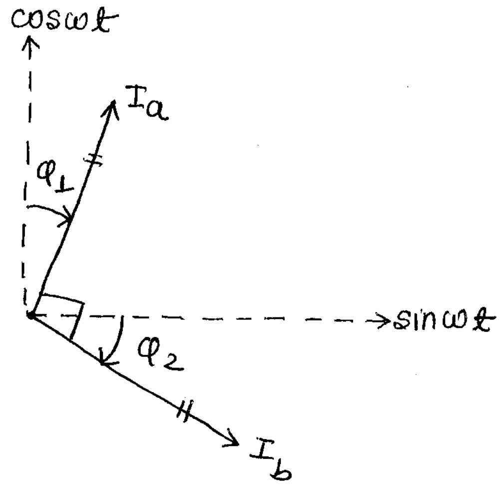
$\theta = \frac{360^\circ}{n}$	; $n \neq 2$
$\theta = 90^\circ$	; $n = 2$

Q.N:- The current in 2-phases of a two phase system is given below

$i_a = \sqrt{2} I \cos(\omega t - \varphi_1)$ $i_b = \sqrt{2} I \sin(\omega t - \varphi_2)$

Find the relationship b/w φ_1 and φ_2 so that the two phase system is balance system.

Solution :- magnitude same i.e; rms value $= I$ & $\theta = 90^\circ$ between I_a & I_b



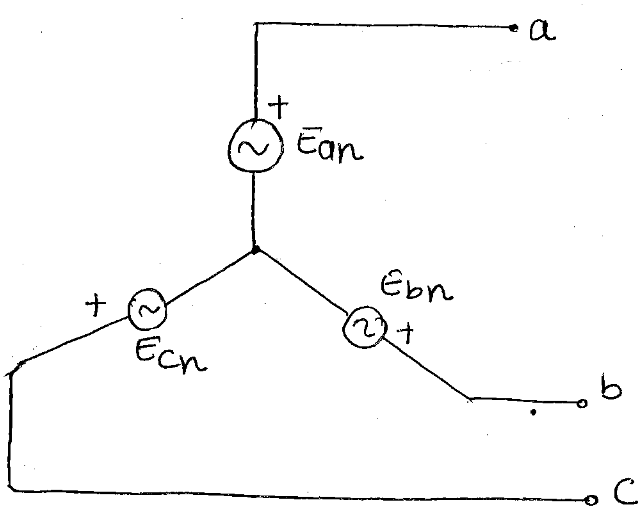
To maintaine the angle b/w I_a & I_b. $= 90^\circ$ Then $\boxed{\varphi_1 = \varphi_2}$

lead →	+ve →	Anticlockwise
lag →	−ve →	clockwise

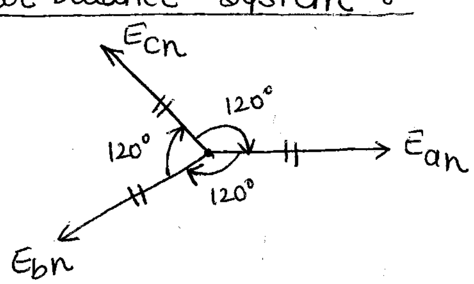
3φ Balance System :-

consider an (ideal) balance 3φ voltage source —

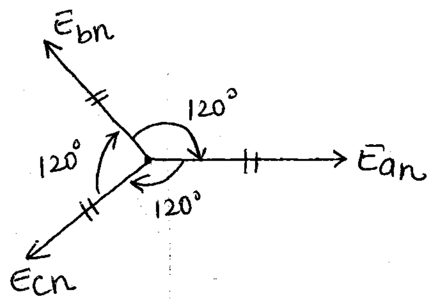
By default we have to take star connection



for balance system :-



Phase sequence : abc



Phase sequence : acb