circuits 2

20/1/2019 sunday

absent _ D

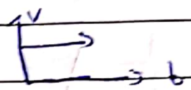
22/1/2019 tuesday

absent _ D

24/1/2019 Thursday

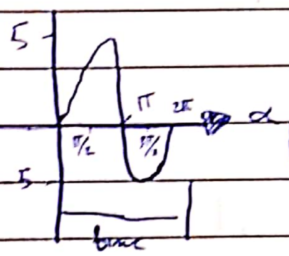
AC sources

DC ← ثابت ← زي ← البطارية



$V = 5\sin\alpha$

Periodic function ← Square / cos / sin ← AC



α ↳ angle

period = 2π → VCA

Assume α = (constant) × t

Angle = α = ωt

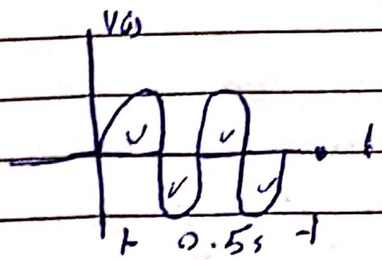
so $2\pi = \omega T$ → $\omega = \frac{2\pi}{T}$ rad/sec

angular velocity

Frequency → # of periods / 1 sec

$f = \frac{1}{T} = \frac{1}{s}$ = Hz (Hertz)

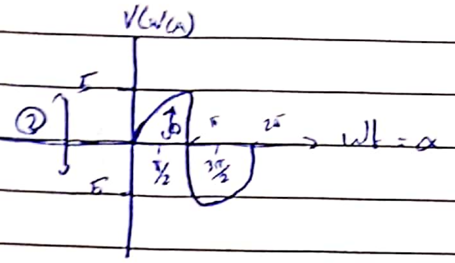
Example



2 periods so $f = 2Hz$

$\omega = \frac{2\pi}{T} = 2\pi f = 4\pi$ is the angular velocity (angular frequency)

24/1/2019 Thursday



① Peak → zero to max = 5

② Peak to peak → min to max = 10

③ amplitude → Distance between avg and max

- Avg for periodic function is $= \frac{1}{T}\int_0^T v(t)\,dt$.

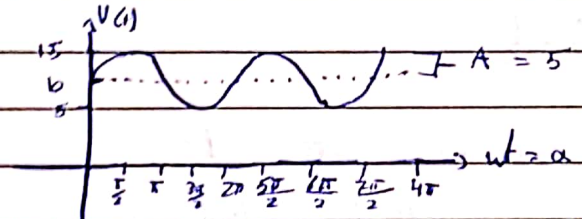
to find amplitude

$$\rightarrow \frac{1}{T}\int_0^T 5\sin wt\,dt = \frac{1}{T}\cdot 5\left[\frac{T}{2\pi}\left[\cos 0 - \cos\left(\frac{2\pi}{T}\cdot T\right)\right]\right] = 0$$

so A = Avg = 5

DC value

Ex: $V(t) = 10 + 5\sin wt$, find P to P, A



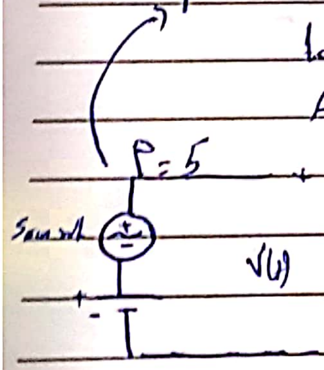
Peak = 15V

Peak to Peak = 10V

to find A, $V_{avg} = \frac{1}{T}\int_0^T 10 + 5\sin wt\,dt = \frac{1}{T}\cdot 10T + 0 = 10$

A = 5V.

P = 5



for example 1: find V(t) where Peak = 5

f = 50Hz

$V(t) = 5\sin(2\pi \times 50t) = 5\sin(100\pi t)$

2. if P = 5, A = 3, f = 50Hz

$\therefore V(t) = 2 + 3\sin wt$

Thursday 24/1/2019

Example : A Generator rotates at speed of 300°/sec, how long does it take to complete 360°?

1- find T

300 → 1s

360 → Xs

$Xs = \frac{360}{300} = 1.2$ seconds $= T$

$f = \frac{1}{T} = \frac{5}{6}$ Hz

$W = 2\pi f = \frac{10\pi}{6}$

Example: sinusoidal current with an A of 10A, and T = 0.12s. Determine the time at which ~~I~~ = 5A.

Solution:

$i(t) = 10 \sin wt + \cancel{B}$ ← assume no outside DC source

$w = \frac{2\pi}{T} = \frac{2\pi}{0.12}$ rad/s

$5 = 10 \sin(\frac{2\pi}{0.12} t)$, $t = \frac{0.12}{2\pi} \cdot \sin^{-1}(0.5)$

$t = 0.01$ sec

Thus when $t = 10$ ms

no H.W

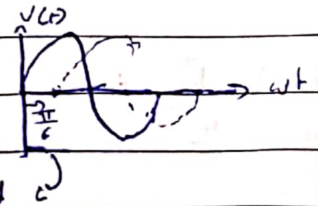
sunday 27/1/2019 circuits 102

Ex: if a Gen is rotating at speed 300°/sec, how long does it take to complete 360°.

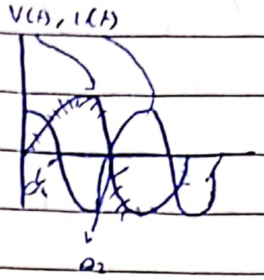
- phase shift

$v(t) = A \cdot \sin(wt \pm \phi) + B$, ϕ phase shift

$v(t) = A \sin(wt + \phi) + B$



Sunday 27/1/2019



① cross zero

② [illegible]

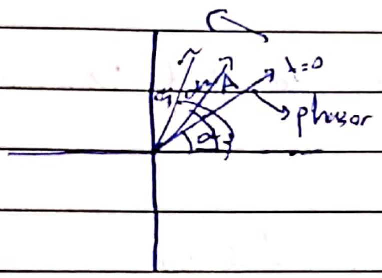
ϕ = Phase = $\phi_2 - \phi_1$

يسبق i leads v

يتأخر v lags i

to Differentiate
① same Freq
② same w

phasors: forget rid of time domain
make them all frequency domain



w = constant

$\alpha = wt$

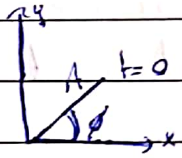
x-axis $= A\cos\alpha = A\cos wt$

y-axis $= A\sin\alpha = A\sin wt$

$A\cos(wt+\phi) = A\angle\phi$

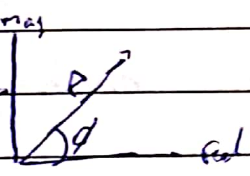
T.D P.D

Polar form



Convention always proj on x axis cos

Phasor diagram



$= A\cos\phi + jA\sin\phi$

so if $\phi = 30$, $A = 5$

$= 5(\cos 30) + j5\sin 30 = \underbrace{2.5\sqrt{3} + j2.5}$ Rectangular form

to go from Rec to Polar

Real $a + jb$

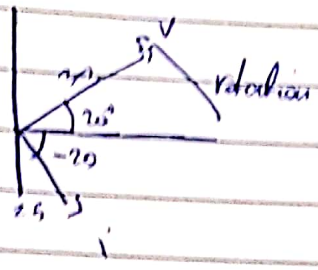
$|A| = \sqrt{a^2+b^2}$

$\phi = \tan^{-1}\frac{b}{a}$

tuesday - D

Thursday 31 / 1 / 2019 circuits 102

Ex :- Determine phase angle between
$v(t) = 30 \cos(wt + 20)$
$i(t) = 25 \sin(wt - 70)$,
go to phasor $\cos(wt - 70 - 10)$



$V(t) = 30 \measuredangle 20°$
$i(t) = 25 \measuredangle -20$

V leads i by 40°

AC $\Rightarrow$ sinusoidal signal

to get rid of differential
we go to phasor

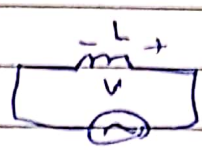
source say to phasor

$V_L = L\frac{di}{dt}$

$i_c = C\frac{dv}{dt}$

R
C → impedance (Z) ohm
L

$Z_L = Z = \frac{V}{I}$



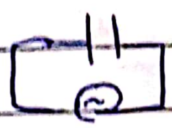
$\int di = \int \frac{1}{L} v_L \, dt$

$A\cos wt \Rightarrow A \measuredangle 0$

$i = \frac{1}{L}\int_0^t v_L(t)\,dt = \frac{A}{wL}\sin wt = \frac{A}{wL} \measuredangle -90$

$Z_L = \frac{A\measuredangle 0}{\frac{A}{wL}\measuredangle -90} = wL \measuredangle 90 \neq jwL \,\Omega$

Same for C



$i_c = -C A w \sin wt = C A w \cos(wt + 90)$
$= CAw \measuredangle 90$

$A\cos(wt) \Rightarrow A\measuredangle 0$

Five Apple

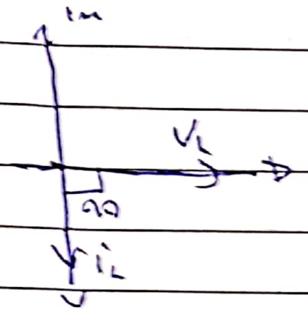
thursday 31/1/2019 circuits 102

to graph C and L

for L

$V = A \angle 0$

$i = \frac{A}{wL} \angle -90^\circ$

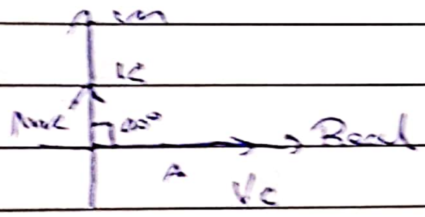


i_L lags V_L by 90

for C

$V_C = A \angle 90$

$i_C = AwC \angle +90^\circ$



i_C leads V_C by 90°

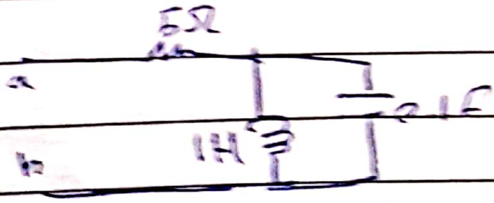
series impedance

$Z = Z_1 + Z_2 \ \Omega$

parallel impedance

$Z = \frac{Z_1 Z_2}{Z_1 + Z_2}$

Ex



$w = 100$ rad/sec

Zeq = ?

$Z_L = jwL \Rightarrow j100 \times 1 = j100\ \Omega$

$Z_C = \frac{-1}{wC} \Rightarrow \frac{-1}{100 \cdot 0.1} = -j0.1$

$Z_{eq} = (Z_L \parallel Z_C) + Z_r$

$\frac{j100 \cdot (-0.1j)}{j100 - j0.1} \approx -j0.1\ \Omega + 5 = \underbrace{5}_{Real} - \underbrace{j0.1}_{im}\ \Omega$

$= 5 \angle -1.15^\circ$

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31/1/2019 Thursday

1- Real part in impedance is called Resistive part

2- Imaginary part " " " " Reactant Part (Reactance)

$$Z = R \pm jx = |Z| \angle \theta$$

if + then Z is an inductive load (V leads i by θ)

if − then Z is an capacitive load (i leads V by θ)

How to get $\frac{V}{I} = \frac{|V| \angle \theta_1}{|i| \angle \theta_2} = \frac{|V|}{|I|} \angle \theta_1 - \theta_2$

$\frac{1}{R} \Rightarrow G$ (conductivity) (S)

$\frac{1}{Z} \Rightarrow Y$ (admittance) (S)

if $Z = R + jx$

$$y = \frac{1}{R+jx} \cdot \frac{R-jx}{R-jx} \Rightarrow \frac{R-jx}{R^2+x^2} = \underbrace{\frac{R}{R^2+x^2}}_{\text{Real part (Conductance)}} - j \underbrace{\frac{x}{R^2+x^2}}_{\text{img part (Susceptance)}}$$

S

So $y = G \pm jB$

the + sign is ~~conductor~~ capacitive

and − sign inductive

5/2/2019 tuesday

CH 11

phasor

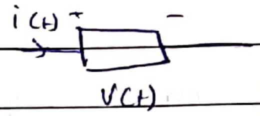
AC , sinusoidal source

$|I| \angle \theta_i$

$|V| \angle \theta_v$

$Z = |Z| \angle \theta_z$

AC power



$v(t) = V_m \cos(\omega t + \theta_v)$

$i(t) = I_m \cos(\omega t + \theta_i)$

$p(t) = V_m . I_m \cos(\omega t + \theta_i) \cdot \cos(\omega t + \theta_v)$

$p(t) = v(t)\, i(t) \Rightarrow$ watt

↳ instantaneous power

trig id

$\cos x . \cos y = \frac{1}{2}[\cos(x+y) + \cos(x-y)]$

$$P(t) = \frac{V_m I_m}{2}\Big[\underbrace{\cos(2\omega t + \theta_v + \theta_i)}_{\text{freq}} + \underbrace{\cos(\theta_v - \theta_i)}_{\text{constant (fixed power)}}\Big]$$

so $\frac{V_m I_m}{2} \cos(\theta_v - \theta_i) = P_{avg}$

$$P_{avg} = \frac{1}{T}\int_0^T p(t).\,dt = \frac{1}{T}\int_0^T \frac{V_m I_m}{2}\Big[\overset{\text{zero}}{\cancel{\cos(2\omega t + \theta_v + \theta_i)}} + \cos(\theta_v - \theta_i)\Big] dt$$

$$= \frac{1}{\cancel{T}} \frac{V_m I_m}{2} \cos(\theta_v - \theta_i) . \cancel{T} = \frac{V_m I_m}{2} \cos(\theta_v - \theta_i)$$

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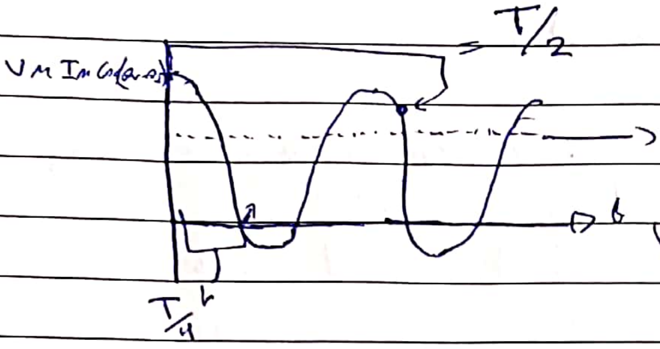
p(t) if $\theta v = 0$

graphically



$\frac{V_m I_m}{2} \cos(\theta v - \theta i)$

cos graph with A of

$$P(t) = \frac{V_m I_m}{2} \cos(2wt + \theta_1) + \frac{V_m I_m}{2} \cos(\theta t)$$

at $wt = 0 \Rightarrow P(0) = V_m I_m \cos(\theta_i)$

to find P_{max} when $2wt + \theta_1 = 2\pi$

$$t = \frac{2\pi - \theta_1}{2 \times \frac{2\pi}{T}} = T - \frac{\theta_1}{2T}$$

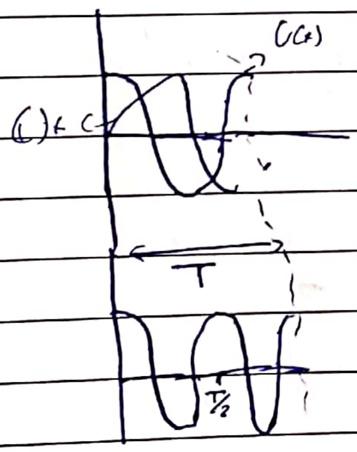
to find P_{lowest} when $\cos(2wt + \theta_1) = -\cos(\theta_i)$

$\cos(2wt + \theta_1) = \cos(\theta_1 + 180)$

$\therefore 2wt + \theta_1 = \theta_1 + \pi$

$$t = \frac{\pi}{2w} = \frac{\cancel{\pi} \cdot T}{2 \cdot 2\cancel{\pi}}$$

$$t = \frac{T}{4}$$



P takes half the time to (of the V or I) complete

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$$p = \frac{V_m I_m}{2}\cos(2\omega t + \theta_v + \theta_i) + \cos(\theta_v - \theta_i)$$

$$\cos(2\omega t + \theta_v + \theta_i + \theta_v - \theta_v) = \cos(\underbrace{2\omega t + 2\theta_v}_{x} - (\underbrace{\theta_v - \theta_i}_{y}))$$

apply trig ide

$\cos(x-y) = \cos x \cos y + \sin x \sin y$

$$\cos(2(\omega t + \theta_v))\cos(\theta_v - \theta_i) + \sin(2(\omega t + \theta_v))\sin(\theta_v - \theta_i)$$

$$p(t) = \frac{V_m I_m}{2}\Big[\cos(\theta_v - \theta_i) + \underbrace{(\cos(\theta_v - \theta_i)\cos 2(\omega t + \theta_v)}_{p_1(t)}$$
$$+ \underbrace{\sin(\theta_v - \theta_i)\sin 2(\omega t + \theta_i)}_{p_2(t)}$$

$$p_1(t) = \frac{V_m I_m}{2}\cos(\theta_v - \theta_i)\Big[1 + \cos 2(\omega t + \theta_v)$$

$1 + (-1 \to 1)$

≥ 0

$-90 < \theta_v - \theta_i < 90$

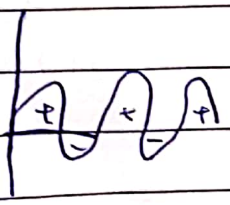
$p_1(t) \geq 0$ = real power active power

$$p_2(t) = \frac{V_m I_m}{2}\sin(\theta_v - \theta_i)\sin 2(\omega t + \theta_v)$$

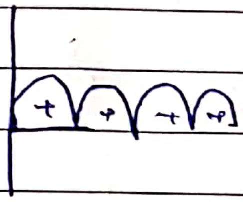
$-90 < \theta_v - \theta_i < 90$

reactive power

Q => VAr reactive



reactive



real power active

KVAr

KWh

Thursday 7/2 /2019 Circuit Ins.

A.C. Power

$$① \; P(t) = \frac{V_m I_m}{2}\left[\cos(\theta_v-\theta_i) + \cos(2\omega t + \theta_v + \theta_i)\right]$$

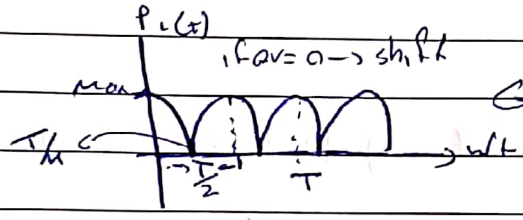
$P_1(t)$:- Real power

$\underbrace{\quad x \quad}$ Power average

$② \; P(t) = P_1(t) + P_2(t)$

$$P_1(t) = R.P = \frac{V_m I_m}{2}\cos(\theta_v-\theta_i)\left[1 + \cos 2(\omega t + \theta_v)\right]$$

$-90^\circ \leq \theta_v - \theta_i \leq 90^\circ \Rightarrow P_1(t) \geq 0$



Generator $\rightarrow$ load

$P_{1\,max}$ happens when

$\cos(2\omega t + 2\theta_v) = -1$

$2(\omega t + \theta_v) = 180$

$t = \frac{\pi}{2\omega} = \frac{\pi}{2(\frac{2\pi}{T})} = \frac{T}{4}$

$P_{1\,max} = V_m I_m (\cos \theta_v - \theta_i)$

$P_2(t)$ = reactive power $\Rightarrow$ VAr

$\sim Q(t)$ $P_2(t)$

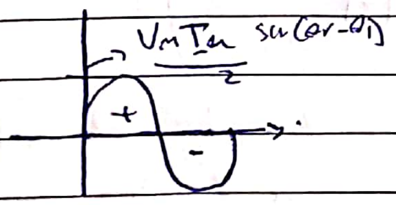
$$= \frac{V_m I_m}{2}\sin(\theta_v-\theta_i)\sin 2(\omega t + \theta_v)$$

if $-90^\circ \leq \theta_v - \theta_i \leq 90^\circ$

if $0 \leq \theta_v - \theta_i \leq 90$

$$P_2(t) = \frac{V_m I_m}{2}\sin(\theta_v-\theta_i) \geq 0$$ (inductive load)

because i lags V



+ Generator $\rightarrow$ load

− load $\rightarrow$ Generator

if $90 > (\theta_v - \theta_i) > 0$

$Q(t) \geq 0$

$Q_{avg} = 0$

(no power consumption)

Five Apple

7/3/2019 Thursday

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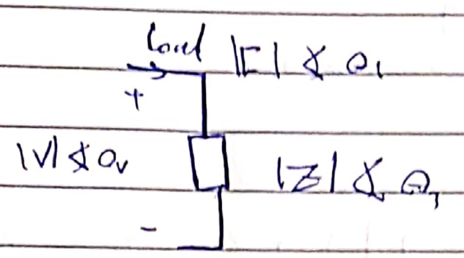
$$P_{avg} = \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i)$$

$$|Q| = \frac{1}{2} V_m I_m \sin(\theta_v - \theta_i)$$



so $|Z| = \frac{|V|}{|I|} = \frac{V_m}{I_m}$

$\theta_z = \theta_v - \theta_i$

$$V_z = IZ = (|I| \angle \theta_i)(|Z| \angle \theta_z) \qquad \theta_z = \theta_v - \theta_i$$
$$= |I||Z| \angle \theta_v$$

$$P(t) = V(t) I(t) = |I||Z| \cos(\omega t + \theta_v) \, |I| \cos(\omega t + \theta_i)$$

$$= \frac{|I|^2}{2} |Z| \left[\cos(2\omega t + \theta_v + \theta_i) + \cos(\theta_v - \theta_i) \right]$$

$$P_{avg} = \frac{I_m^2}{2} |Z| \cos(\theta_v - \theta_i)$$

$$|Z| \cos(\theta_z) = R$$
$$Z = R \pm jX$$

$P_{avg} = \frac{I_m^2}{2} R \rightarrow$ on a load (use on circuits component)

$Q = \frac{V_m I_m}{2} \sin(\theta_v - \theta_i)$ ∴ , $V_m = I_m |Z|$

$|Q| = \frac{I_m^2 |Z| \sin(\theta_z)}{2} = \frac{I_m^2}{2} X$ — X can be ωL if L or $X = \frac{1}{\omega C}$ if capacitor

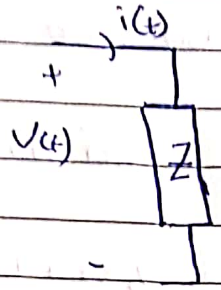
$X_C = \frac{1}{\omega C}$
$X_L = \omega L$

$Z = R + jX \Rightarrow$ inductor, i lags v, $Q > 0$

$Z = R - jX \Rightarrow$ capacitor, v lags i, $Q < 0$

7/2/2016 Thursday Circuits 102

Ex



if $V(t) = 100\sqrt{2}\cos(\omega t)$

$i(t) = \sqrt{2}\cos(\omega t - \theta_i)$

(a) avg. real power — 3 cases

(b) reactive power — $\theta_i = 0$

(c) peak to peak power — $\theta_i = 60$

$\theta_i = 80$

1-case $\theta_i = 0$ (R load)

(a) $P_{avg} = \frac{1}{2} V_m I_m \cancel{\cos(\theta_v - \theta_i)}^{=1}$

$= \sqrt{2} \cdot 100\sqrt{2} \cdot \frac{1}{2} = 100$ watt

(b) Reactive P $= 0$ (Resistive load)

(c) Peak to peak, $P_{max} = V_m I_m \frac{1}{2}(\cancel{\cos\theta v}\ 1 + \cos 2\omega t)$

$= 200$

$= V_m I_m \cdot 2 \cdot \frac{1}{2} = 200$ Watt

P_{lowest}

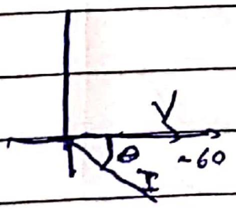
$= \frac{V_m I_m}{2}\left[\cos(\theta_v - \theta_i) + \cos(2\omega t + \theta_v - \theta_i)\right]$

$= 0$

$P_{to}P = P_H - P_L = 200 - 0$

$= 200$ watt

case 2 $\theta_i = 60$



i lags V

(a) $P_{avg} = \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i)$

$= \frac{1}{2}\sqrt{2}\sqrt{2}\,100 \cos 60$

$= 50$ watt

(b) R power $= Q(t) = \frac{V_m I_m}{2}\sin(\theta_v - \theta_i) \cdot \sin(2\omega t)$

$= \frac{100\sqrt{2}\sqrt{2}}{2}\sin(60)\sin(2\omega t)$

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thursday 7/2/2010

(c) P to P power $\quad p(t) = 50 + 100\cos(2\omega t - 60)$

$P_{min} = 50 - 100 = -50$

AC Power

$P(t) = V(t)\, I(t)$

(1) $P(t) = \underbrace{\frac{V_m I_m}{2}\cos(\theta_v - \theta_i)}_{P_{avg}}$

$+ \frac{V_m I_m}{2}\cos(2\omega t + \theta_v + \theta_i)$

$P_{avg} = \frac{1}{2} I_m^2 . R$

Z

$P_{max} = 50 + 100 = 150$

$P_{toP} = 150 - (-50) = 200$ watt

$P_{to}P$ power Doesn't Depend on phase shift

(2) $P(t) = \underbrace{\frac{V_m I_m}{2}\cos(\theta_v - \theta_i)\left[1 + \cos 2(\omega t + \theta_v)\right]}_{\text{Real Power}}$

$\underbrace{+ \frac{V_m I_m}{2}\sin(\theta_v - \theta_i)\ \sin 2(\omega t + \theta_v)}_{\text{Reactive},\ Q(t)}$

Ex :- $V(t) = 80\cos(10t + 20^\circ)$

$i(t) = 15\sin(10t + 60^\circ) = 15\cos(10t - 30)$ $\quad -90$

(a) instantaneous Power $P(t)$

(b) Avg Power

(c) Reactive

(a) $P(t) = \frac{80 \times 15}{2}\cos(20 - (-30)) + \frac{80 \times 15}{2}\cos(2 \times 10t + 20^\circ - 30^\circ)$

$= \underbrace{600\cos(50)}_{\text{Avg power} = 385.67\text{ watt}} + 600\cos(20t - 10^\circ)$

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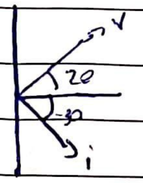
(c) Reactive Power (Q(t))

$$Z = \frac{V}{I} = \frac{80\angle 20}{15\angle -30}$$

$$= 80/15 \angle(+50)$$

$= 600 \angle \sin(20) \sin 2(\omega t + 20)$

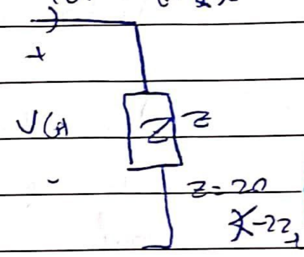
$+$ so its an inductive



(i lags v) inductive

Ex 2

$i(t) = 10\angle 30$



Pavg consumed by Z

(1) $P_{avg} = \frac{1}{2} I_m V_m (\cos(\theta_v - \theta_i))$ $\theta_z = \theta_v - \theta_i$

to get R

(2) $P_{avg} = \frac{1}{2} I_m^2 R$ or (3) $\frac{1}{2} V_m^2 / R$ $Z = \underbrace{20\cos(-22)}_{R} + j\, 20\sin(-22)$ $\Rightarrow$ capacitive

$R = |Z| \cos\theta_z$

(1) sol $V = IZ = (10\angle 30)(20\angle -22)$

$= 200\angle 8^{\circ}$

$P_{avg} = \frac{1}{2} \times 200 \times 10 \cos(8 - 30) = 1000 \cos(-22) = 927 \text{ watt}$

(2) $P_{avg} = \frac{1}{2}(10)^2 \times 20 \cos(-22) =$

find $Q(t)$ — (1) $\underbrace{V_m I_m \sin(\theta_v - \theta_i)}_{\text{Amp of } Q(t)} \sin 2(\omega t - 2\theta_v)$

$\frac{1}{2} I_m^2 X$, $X = |Z| \sin\theta_z = 20\sin(-22) = -7.49213$

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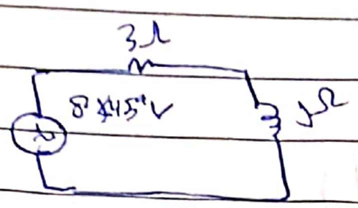
Ex



ⓐ Find Avg power on R, L
ⓑ " " " by the source
ⓒ Find reactive power " "
ⓓ Find P(t) source

ⓐ 1- P_{avg} on L = Zero , 2- P_{avg} on R = $\frac{1}{2} I_m^2 R$

$I = \frac{8\angle 45}{3+j} = 2.53\angle 26.5$

$= \frac{1}{2}(2.53)^2(3)$

$= 9.6$ watt

ⓑ its the same as P_{avg} on R

but

$P_{avg} = \frac{1}{2} V_m I_m \cos(\theta v - \theta i)$

$= \frac{1}{2} 8(2.53) \cos(45 - 26.5) = 9.6$ watt

ⓒ $Q(t) = \frac{1}{2} V_m I_m \sin(\theta v - \theta i) \sin(2wt + 2\theta v)$

$= \frac{1}{2}(8)(2.53) \sin(45 - 26.56°) \sin(wt + 45)$

$Q_R = 0$

$= \frac{1}{2} I_m^2 X$

$= \frac{1}{2}(2.53)^2 \times j$ $= j$

ⓓ $P(t) = P_1(t) + P_2(t)$

$P_1(t) = 9.6 [1 + \cos 2[wt + 45]]$

$P_2(t) = Q(t)$

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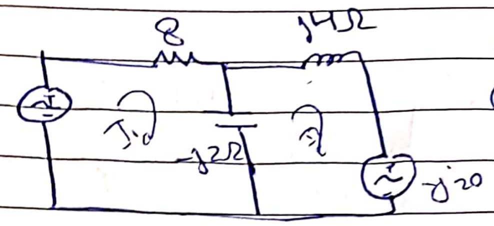
Ex



(a) Find avg power on each element

(b) Find Q(t) on each element

(a) P avg on C and I = 0

$P_{on\,8\Omega} = \frac{1}{2} I_m V_m \cos(\theta)$

$= \frac{1}{2} I_m^2 . R$

$= \frac{1}{2} 5^2 . 8 = 100$ watt

$P_{on\,j4\Omega} = Q(t) = \frac{1}{2} I_m^2 X . \sin(2wt + \theta v)$

mesh analysis

$(8 - j2) I_1 - I_2(-j2) = 40\angle 0$

$-I_1(-j2) + I_2(-j2 + j4) = -j20$

$I_1(8 - j2) + I_2(j2) = 40\angle 0$ ... (1)

$I_1(j2) + I_2(j2) = -j20$ ... (2)

using Kramers

$AX = B$

$A = \begin{bmatrix} 8-j2 & j2 \\ j2 & j2 \end{bmatrix}$

$X = \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = A^{-1}B \quad B = \begin{bmatrix} 40 \\ -j2 \end{bmatrix}$

$A^{-1} = \frac{1}{\Delta}\begin{bmatrix} - & \\ & - \end{bmatrix}$

$\Delta = (8 - j2)(j2) - j2(j2)$

$= 16j + 4 + 4 - 8 + j16$

$I_1 = \frac{1}{8 + j16}[(-8 + j2)40 + j2(-j20)]$

$I_2 = \frac{1}{8 + j16}[j2(40) - j2(-j20)]$

$X = A^{-1}B = \frac{1}{8 + j16}\begin{bmatrix} -8+j2 & j2 \\ +j2 & j2 \end{bmatrix}\begin{bmatrix} 40 \\ -j20 \end{bmatrix} \leftarrow A^{-1} = \frac{1}{8+j16}\begin{bmatrix} -8+j2 & j2 \\ -j2 & -j2 \end{bmatrix}$

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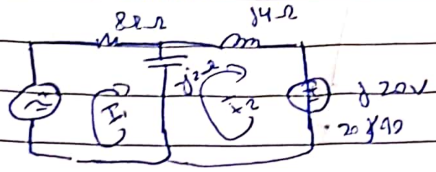
Ex continue previous



$40 = I_1(8-j2) + j2 I_2$

$-j20 = j2 I_1 - j2 I_2$

$I_1 = 5\angle 53.14$

$I_2 = 13.6\angle -163°$

$P_{avg\,C,L} = 0$

$P_{avg\,R} = \frac{1}{2}(5^2) \times 8 = \frac{400}{4}$ watt

$P_{avg} = -\frac{1}{2} V_m I_m \cos(\theta_v - \theta_i)$

$= -\frac{1}{2}(40)(5)\cos(0-53.14) = -60$ watt

$P_{avg} = +\frac{1}{2}(13.6)(20)\cos(90-(-163))$

$= -40$ watt

b) $Q_{40V} = -\frac{1}{2}(40)(6)\sin(0-53)$

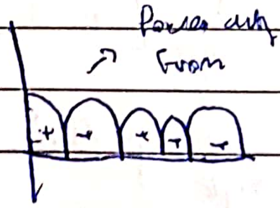
$Q_{-j2} = \frac{1}{2} I^2 X = \frac{1}{2}|(I_1 - I_2)|^2(-2)$

$Q_{j20} = +\frac{1}{2}(20)(13.6)\sin(90+162)$

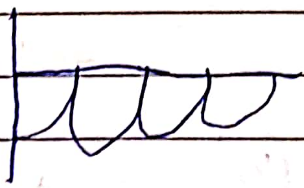
$Q_{j4} = \frac{1}{2}(13.6)^2 \times 4$

Power Avg can be 2 cases

Case 1



Case 2



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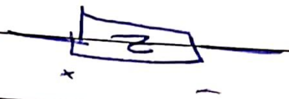
differand (f) Hz



$V(t) = 3\cos(10t) + 5\cos(20t)$

$P_{avg} = P_{avg_1} + P_{avg_2} + P \ldots$

$$= \frac{1}{2R}\left[V_{m_1}^2 + V_2^2 + \ldots\right]$$

if $R = 4$

$$P_{avg} = \frac{1}{2\times 4}\left[(3)^2 + (5)^2\right]$$

Ex $V(t) = 3\cos(10t) + 4\cos(10t - 30^\circ) + 5\cos(20t)$

$= 3\angle 0 + 4\angle -30$

$= 6.7\angle -17$

$$P_{avg} = \frac{1}{2\times 4}\left[(6.7)^2 + (5)^2\right]$$