BEE SOLUTION OF QUESTION PAPER REV 2019'C SCHEME (DEC-2022)

Q1. Attempt any four

A) Derive the emf equation of DC machine **(5)**

Solution:

Let,

P= Number of poles of generator
Φ = Flux produced by each pole in weber (Wb)
A=Number of parallel paths in which the total number of conductors are divided.
N=Speed of armature in rpm
Z=Total number of armature conductors

For lap type of winding, A=P
For wave type of winding, A=2
According to Faraday's law of electromagnetic induction,

Average value of emf induced in single conductor = $\frac{d\Phi}{dt}$.... (hence N=1)

Now, consider one revolution of a conductor. In one revolution, the conductor will cut the total flux produced by all the poles (=PΦ).
Flux cut by the conductor in one revolution, dΦ = PΦ weber

Time required to complete one revolution, dt =$\frac{60}{N}$ sec

Hence, average value of emf induced in single conductor= $\frac{d\Phi}{dt}=\frac{P\Phi}{60/N}=\frac{P\Phi N}{60}$ volt

This is the emf induced in one conductor. Now, the conductors in one parallel path are always in series. There are Z conductors with A parallel paths. Hence, $\frac{Z}{A}$ number of conductors are always in series and emf remains same across all the parallel paths.
So, total emf can be expressed as

$$E_g = \frac{P\Phi N}{60} \quad \frac{Z}{A} \text{ VOLT}$$

This equation is called emf equation of the dc generator.

We can also write $E_g=\frac{\Phi ZN}{60} \quad \frac{P}{A}$ volt

Where, A=P for lap winding
A=2 for wave winding

b) Calculate the total power and readings of two wattmeter connected to measure power in three phase balanced load if the apparent power is 15KVA & load pf is 0.8 lag.

(5)

Given:

S=15 KVA

$\cos \emptyset$= 0.8 lag

To find :

P, W and W_2

Solution:

$\cos \emptyset = \frac{P}{S}$

P= S x $\cos \emptyset$

P = $15 \times 10^3 \times 0.8$ = 12KW

$S=\sqrt{P^2 + Q^2}$

$Q=\sqrt{S^2 - P^2}$

Q=19.21×10^3 KVA

$P=W_1+W_2$…… $W_1+W_2=12 \times 10^3$

$Q=\sqrt{3}(W_1 - W_2)$ …..$\sqrt{3}(W_1 - W_2)= 19.21 \times 10^3$

$W_1+W_2=12 \times 10^3$…………….(1)

$W_1 - W_2= 11.09 \times 10^3$………………(2)

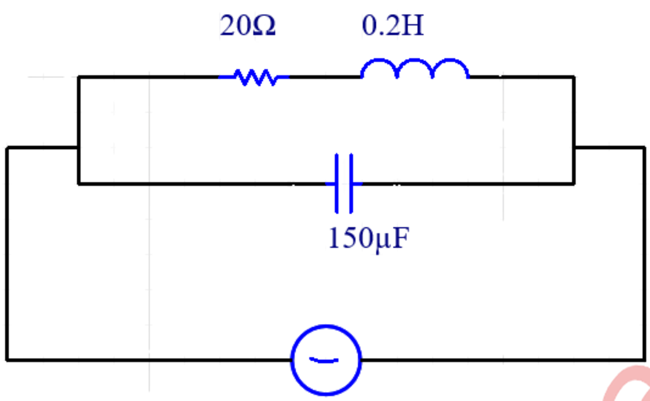
Solving equation (1) and (2) we get,

W_1=11545 W

W_2=455 W .

c) **In inductive coil containing resistance 20Ω and inductance of 0.2H is connected in parallel with a capacitor of 150µF. Find resonant frequency of the circuit, dynamic impedance of the circuit and current in the circuit.**

(5)



Given:
R=20Ω
L=0.2H
C=150µF = 150×10^{-6} F

To find :
f_r ,Z and I

SOLUTION:

$$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R_L^2}{L^2}}$$

From the above formula we get,
f_r =24.3 Hz

Now,

$Z = \frac{L}{CR}$

$Z=(0.2)/150x10^{-6}x20$

$Z=66.67\Omega$

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

$I=\frac{200}{66.67}$

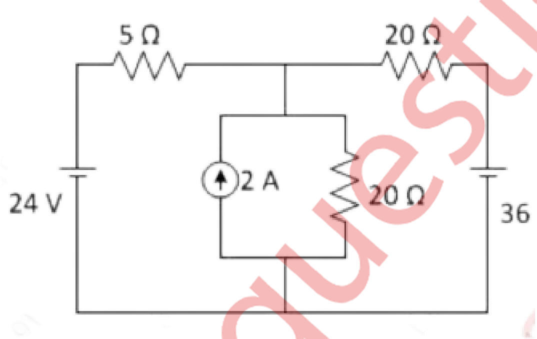
$I= 2.99\ A$

d) Find I current in 50Ω by nodal I analysis

(5)

To find:

$I_{5\Omega}$ Using nodal analysis.



SOLUTION:

By applying KCL at node A

$I_1+I_2+I_3=2$

$\frac{V_A-24}{5}+\frac{V_A}{20}+\frac{V_A-36}{20}$=2

$V_A[\ \frac{1}{5}+\frac{1}{20}+\frac{1}{20}\ ]$ =2+$\frac{24}{5}+\frac{36}{20}$

V_A=28.67

$I_{5\Omega}=\frac{V_A-24}{5}$

$I_{5\Omega}$ = 0.934 A

e) Three currents are meeting at a point. Find the resultant current
i1 = 50 Sin(wt)A, i2= 25 Cos($\omega t-\frac{\pi}{6}$) A,
i3 = -10 Sin(ωt+$\frac{\pi}{4}$) A.

(5)

SOLUTION:

To find resultant current I
$I_1=\frac{50}{\sqrt{2}}\angle 0$

i_2= 25 $\sin(\omega t-\frac{\pi}{6}+\frac{\pi}{2})$
i_2= 25 $\sin(\omega t-60)$

$I_2=\frac{25}{\sqrt{2}}\angle -6$

i_3= -10 Sin(ωt+$\frac{\pi}{4}$)

i_3= 10 Sin($\omega t+\frac{\pi}{4}+180°$)

i_3= 10 Sin($\omega t+225°$)

$I_2=\frac{10}{\sqrt{2}}\angle 225°$

I= $I_1+I_2+I_3$

I = $\frac{50}{\sqrt{2}}\angle 0 + \frac{25}{\sqrt{2}}\angle -6 + \frac{10}{\sqrt{2}}\angle 225°$

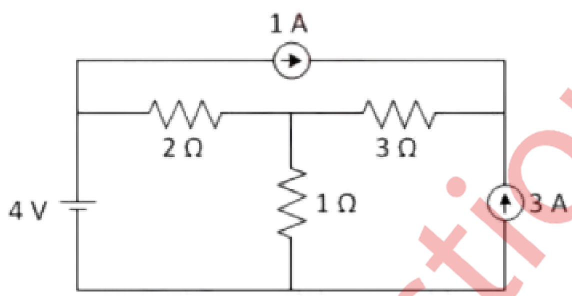
I = $44.17 \angle -27$

i = $62.42\sin(\omega t - 27°)$

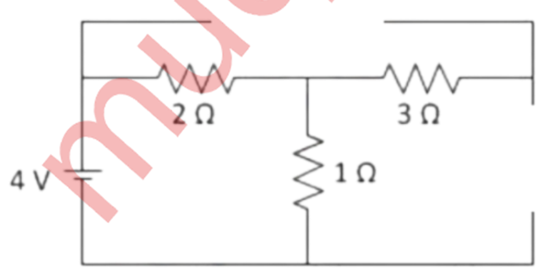
Q2.

a) Find current in 1Ω resistance by superposition theorem

(10)



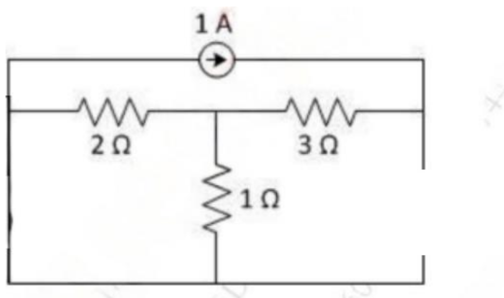
Consider 4V acting alone, replace 1A and 3A by OC



Applying KVL on mesh we get,

$I_1' = \frac{4}{3}$ A (↓)

Consider 1A acting alone, replace 4V by SC and 3A by OC

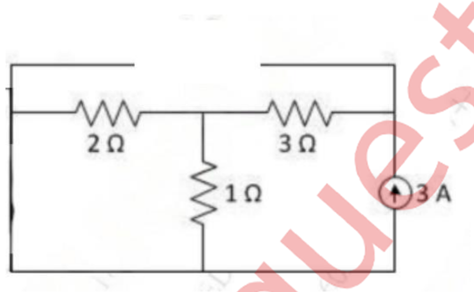


By current division rule,

$I'' = \frac{1\times2}{1+2}$

$I'' = \frac{2}{3}$ A (↓)

Consider 3A acting alone, replace 4V by SC 1A by OC



By current division rule,

$I''' = \frac{3\times2}{1+2} = \frac{6}{3}$

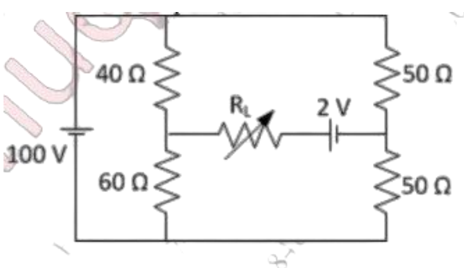
$I''' = 2$ A(↓)

$I_{1\Omega} = I_1' + I'' + I'''$

$I_{1\Omega} = \frac{4}{3} + \frac{2}{3} + 2$

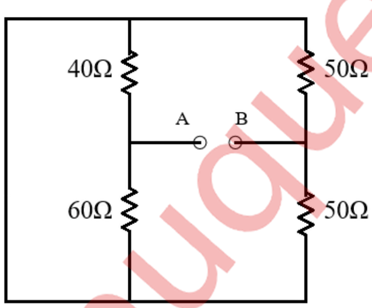
$I_{1\Omega} = 4\ A\ (\downarrow)$

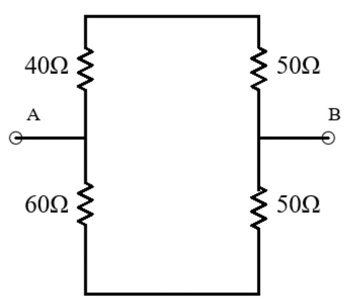
b) Find maximum power in RL. **(10)**

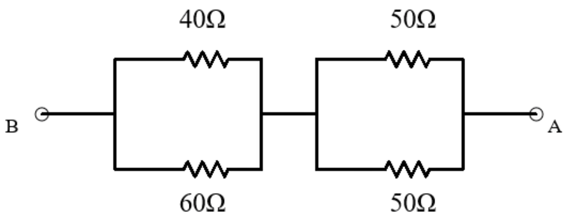


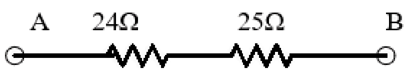
SOLUTON:

To find R_{TH}, Remove R_L and replace it by A B terminal



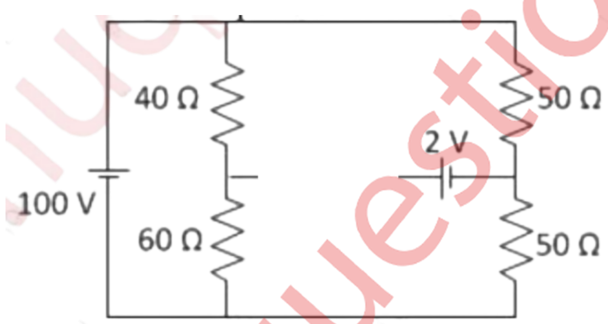






Hence R_{th}= 49Ω

To find V_{TH}, Remove R_L



By using mesh analysis

Apply KVL in mesh 1

$100-40\,(I_1-I_2)-60\,(I_1-I_2)=0$

$-100I_1+100I_2= -100$……………(1)

KVL in mesh 2

$-100(I_2-I_1)-100I_2=0$

$100I_1-200I_2=0$…………(2).

Solving Equation 1 and 2 we get,

$I_1= 2$ A

$I_2=1$ A

$V_{TH}=V_{AB}= -2-50I_2+60(I_2-I_1)$

$V_{TH}=-2-50+60$

$V_{TH}=-8$ V

$P_{MAX}=V_{th}^2/4R_{TH}$

$P_{MAX}=8^2/(4x49)$

$P_{MAX}=0.327$ W.

Q3.

a) **Find the equivalent resistance between A and B in the network shown.**

(10)

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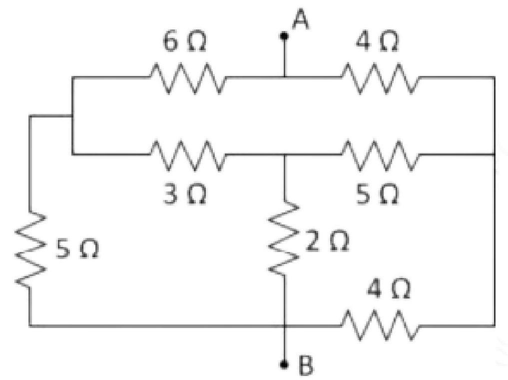
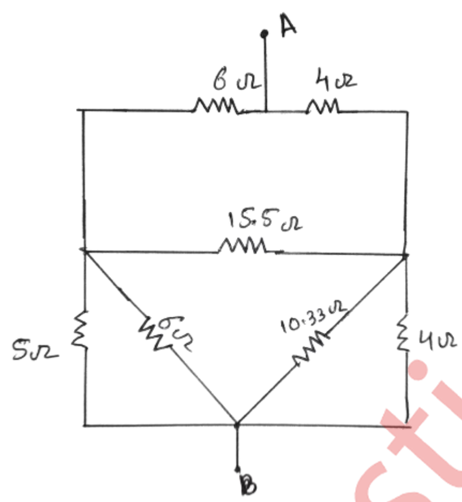
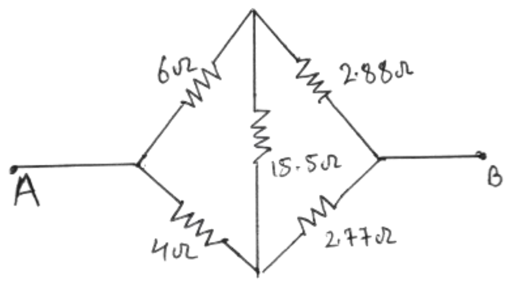
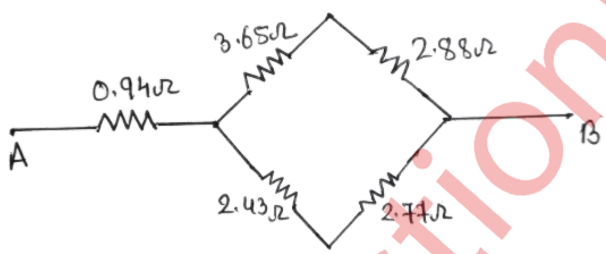


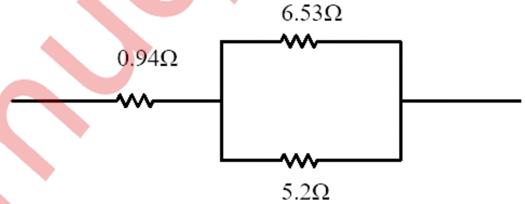
To find R_{AB}

SOLUTON:




6Ω
2.88Ω
15.5Ω
A
B
4Ω
2.77Ω


3.65Ω
2.88Ω
0.94Ω
A
B
2.43Ω
2.77Ω

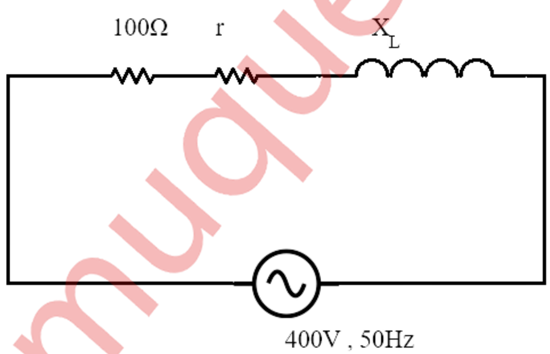

6.53Ω
0.94Ω
5.2Ω

Hence,

$R_{AB}=3.83\Omega$

b) A 100 resistance is connected in series with a choke coil. A voltage of 400V, 50Hz is applied across this combination. The voltage across resistance and coil is 200V and 300V respectively. Find resistance and reactance of a coil, power factor of a coil and complete circuit complete circuit, power absorbed by resistor, coil and complete circuit.

(10)



Given:

V_R= 200V
V_{COIL}=300V

To find:

R_r , X_L ,PF_{COIL},PF_T,P_R ,P_{COIL}, P.

SOLUTION:

V_R=200V

$I = \frac{V_R}{R}$

$I = \frac{200}{100}$

I = 2 A

Now,

$Z_{COIL} = \frac{V_{COIL}}{I}$

$Z_{COIL} = \frac{300}{2}$

Z_{COIL} =150Ω

$Z_T=(R+r)+jX_L$

$(Z_T)^2 = (R+r)^2+ (X_L)^2$

$200^2=100^2+(2x100r)+r^2+X_L^2$

As we know,
$Z_{COIL}^2=r^2+X_L^2$

Hence,

$200^2 = 100^2 + 200r + 150^2$

$r = 37.5\Omega$

$r^2 + X_L^2 = 150^2$

$X_L^2 = 150^2 - 37.5^2$

$X_L = 145.27\Omega$

$X_L = 2\pi f L$

$X_L = 145.24\Omega$

$L = \frac{145.24}{2\pi\times 50}$

$L = 0.46H$

$\cos \emptyset_{COIL} = \frac{r}{Z_{COIL}}$

$\cos \emptyset_{COIL} = \frac{37.5}{150}$

$\cos \emptyset_{COIL} = 0.25$ LAG

$\cos \emptyset = \frac{R+r}{Z}$

$\cos \emptyset = \frac{100+37.5}{200}$

$\cos \emptyset = 0.6875$ lag

$P_R = I^2R$

$P_R = 2^2 \times 100$

$P_R = 400W$

$P_{COIL} = I^2R$

$P_{COIL} = 2^2 x100$

$P_{COIL} = 150W$

$P = VIcos\,\emptyset$

P=400x200x0.6875

P=550W

Q4.

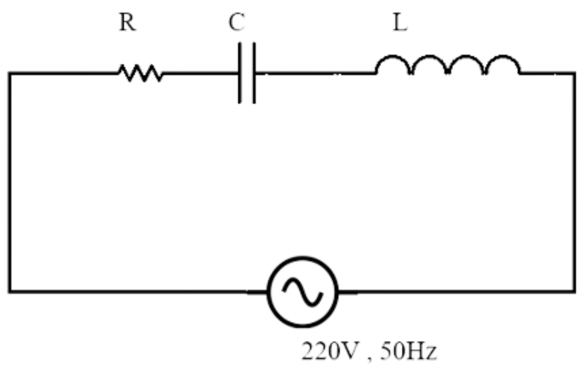
a) A resistor and a capacitor are in series with a variable inductor. When the circuit is connected to a 220V, 50Hz supply, the maximum current obtainable by varying the inductance is 0.314A. The voltage across capacitor is then 800V, find R, L and C.

(10)

To find R,L,C

I= 0.314 A

V_C=800V



SOLUTION:

$Z_T = \frac{V}{I}$

$Z_T = \frac{220}{0.314}$

$Z_T = R = 700.64\ \Omega$

$V_C = I\ X_C$

$X_C = \frac{800}{0.314}$

$X_C = 2547.77\Omega$

$X_C = \frac{1}{2\pi f c}$

$C = \frac{1}{2\pi \times 2547.77 \times 50}$

$C = 1.25 \mu f$

$Z_T = R = 700.64\ \Omega$………………(FOR RESONANCE CONDITION)

Also, $X_L = X_C = 2547.77\ \Omega$

$X_L = 2\pi f l$

$X_L = 2547.77\Omega$

$L = \frac{2547.77}{2\pi\times50}$

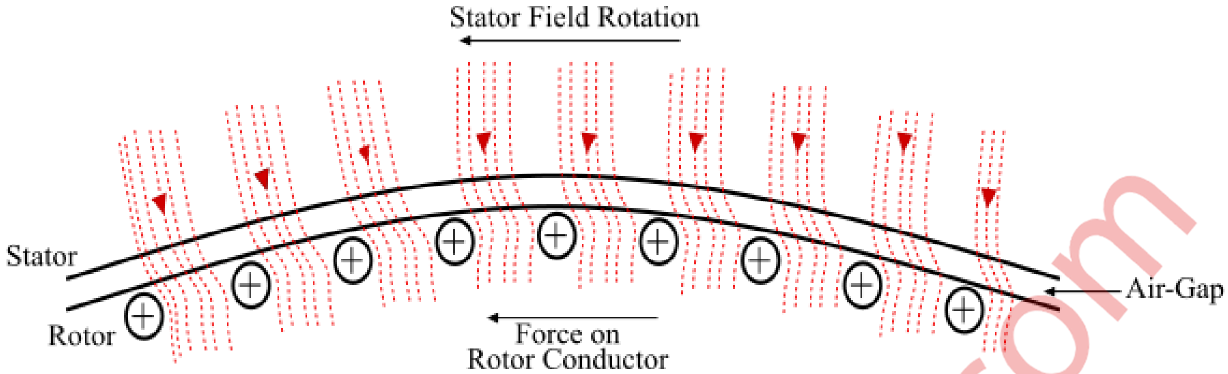
L=8.1H

b) Explain working principle of three phase induction motor and mention its types.

(5)

A *three phase induction motor* has a stator and a rotor. The stator carries a 3-phase winding called as *stator winding* while the rotor carries a short circuited winding called as *rotor winding*. The stator winding is fed from 3-phase supply and the rotor winding derives its voltage and power from the stator winding through *electromagnetic induction*. Therefore, the working principle of a 3-phase induction motor is fundamentally based on *electromagnetic induction*.

Consider a portion of a three phase induction motor (see the figure). Therefore, the working of a three phase induction motor can be explained as follows



- When the stator winding is connected to a balanced three phase supply, a rotating magnetic field (RMF) is setup which rotates around the stator at synchronous speed (N_s). Where, $N_S = \frac{120f}{P}$.

- The RMF passes through air gap and cuts the rotor conductors, which are stationary at start. Due to relative motion between RMF and the stationary rotor, an EMF is induced in the rotor conductors. Since the rotor circuit is short-circuited, a current starts flowing in the rotor conductors.
- Now, the current carrying rotor conductors are in a magnetic field created by the stator. As a result of this, mechanical force acts on the rotor conductors. The sum of mechanical forces on all the rotor conductors produces a torque which tries to move the rotor in the same direction as the RMF.
- Hence, the induction motor starts to rotate. From, the above discussion, it can be seen that the three phase induction motor is self-starting motor.
- The three induction motor accelerates till the speed reached to a speed just below the synchronous speed.

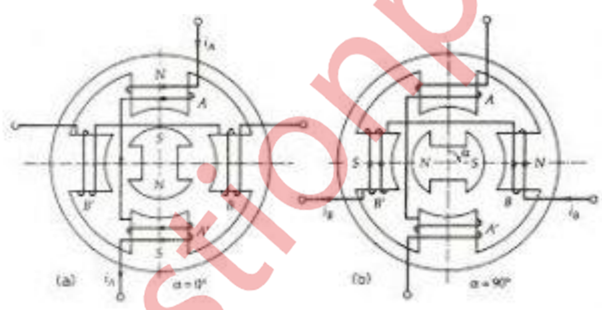
Types of Three Phase Induction Motors

- Squirrel Cage Induction Motor
- Slip-ring or Wound Rotor Induction Motor

c) Explain working of permanent magnet stepper motor.

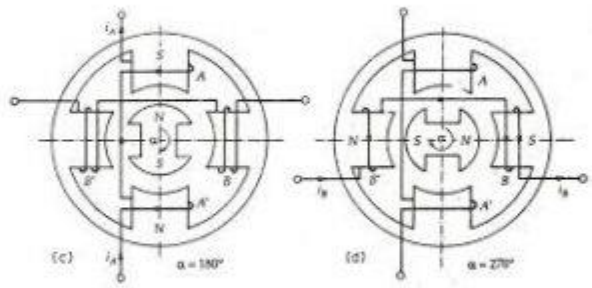
(5)

The working permanent magnet stepper motor can be explained in the following modes.



Mode 1– In this mode, the A phase of the stator poles are excited together with series winding to create two pairs of magnetic poles. It may be noted that, in this mode, the B phase is not excited at all. When the A phase is excited, it forms the North and South pole. At this moment, the rotor magnetic poles are attracted to the stator magnetic poles.

Mode 2 – In this mode, the B phase of the stator poles are excited together with series winding to create two pairs of magnetic poles. It may be noted that, in this mode, the A phase is not excited at all. When the B phase is excited, it forms the North and South pole. At this moment, the rotor magnetic poles are attracted to the stator magnetic poles. Which makes the rotor rotate in the clockwise direction from Mode 1.



Mode 3 – Again In this mode, the A phase of the stator poles are excited together with series winding to create two pairs of magnetic poles. It may be noted that, in this mode, the B phase is not excited at all. When the A phase is excited, it forms the North and South pole. At this moment, the rotor magnetic poles are attracted to the stator magnetic poles. It makes the rotor rotate in the clockwise direction from mode 2.

Mode 4– Again In this mode, the B phase of the stator poles are excited together with series winding to create two pairs of magnetic poles. It may be noted that, in this mode, the A phase is not excited at all. When the B phase is excited, it forms the North and South pole. At this moment, the rotor magnetic poles are attracted to the stator magnetic poles. Which makes the rotor rotate in the clockwise direction from Mode 3.

In this manner, the rotor makes one complete revolution from mode 1 to mode 4.

Q5.a) Derive relation between line & phase voltage and line & phase current in three phase STAR connected circuit. Also derive equation of active, reactive and apparent power.

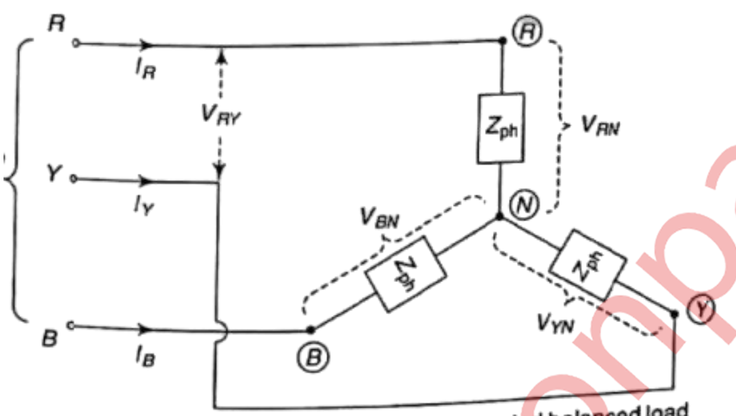
(10)

SOLUTION:

Relationship between line voltage and phase voltage:

The figure shows a balanced three phase Y-connected system.
As load is balanced, all the three phase voltages V_{RN}, V_{YN} and V_{BN} are equal in magnitude and 120° apart.
By phase sequence, V_{YN} Lags behind that of V_{RN} BY 120° and V_{BN} lags behind that of V_{RN} by 240°. The magnitude of each phase voltage id denoted by V_{PH}. Thus,

$V_{PH}=V_{RN}=V_{YN}= V_{BN}$



Three-phase, Y-connected balanced load

The three line voltages are V_{RY}, V_{YB} and V_{BR}.
From the circuit diagram it is clear that line voltage is not same as phase voltage.

However, for balanced system all three line voltages must be equal and the magnitude of each line voltage is denoted by V_L. Thus,

$V_L= V_{RY}=V_{YB}= V_{BR}$.

From the circuit diagram , the line voltage V_{RY} can be written in terms of the phase voltages as,

$\bar{V}_{RY}= \bar{V}_{RN} + \bar{V}_{NY}$

Similarly, $\bar{V}_{YB}= \bar{V}_{YN} + \bar{V}_{NB}$

$\bar{V}_{BR} = \bar{V}_{BN} + \bar{V}_{NR}$

But V_{RY} is the line voltage and V_{RN} and V_{NY} are the phase voltages. So, we have

$V_L^2 = V_{PH}^2 + V_{PH}^2 + 2V_{PH} \times V_{PH} \times \cos 60° = 3V_{ph}^2$

$V_L = \sqrt{3}\, V_{PH}$.

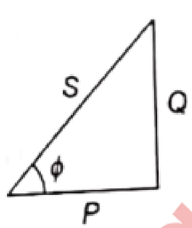
Relationship between line current and phase current:

In a star connection, each line conductor is connected in series to a separate phase as shown in the above diagram. Therefore, current in the line conductor is same as that in the phase to which the line conductor is connected.

Line current , $I_L = I_{PH}$

Equation of Active, Reactive and apparent power.

$S = \sqrt{P^2 + Q^2}$



$\cos\emptyset = \frac{P}{S}$

POWER TRIANGLE : In terms of circuit components

$\text{Cos } \emptyset = \frac{R}{Z}$

And

V = IZ

P= VI cosØ
$P= I^2R$

Q= VI sinØ
$Q= I^2X_L$

S= VI
$S= I^2Z$

b) A balanced three phase star connected load of 100 kW takes a leading current of 80A when connected across 3 phase 1100V, 50Hz supply. Find the circuit constants of the load per phase, power factor of the load.

(10)

Given : (for star connected condition)

$P=100Kw = 100 \times 10^3$ w
$I_{PH}=80$ A
$V_L= 1100$ V

To find :
Z_{PH} and power factor

Solution:

$V_L= \sqrt{3}\, V_{PH}$

$I_L= I_{PH}$

$V_{PH} = \frac{V_L}{\sqrt{3}}$

$V_{PH} = \frac{1100}{\sqrt{3}}$

V_{PH}= 635.09 V

$Z_{PH} = \frac{Z_{PH}}{I_{ph}}$

$Z_{PH} = \frac{635.09}{80}$

$Z_{PH} = 7.94\ \Omega$

$P = \sqrt{3}\ V_L\ I_L \cos\emptyset$

$\cos\emptyset = \frac{100}{\sqrt{3}\ \times 1100} \times 10^3$

$\cos\emptyset = 0.656$ leading

Q6.

a) A pure resistor R, a choke coil and a pure capacitor of 15.91 microfarad are connected in series across a supply of V volts and carries a current of 0.25A. The voltage across the choke coil is 40V, the voltage across the capacitor is 50V and the voltage across the resistor is 20V. The voltage across the combination of R and the choke coil is 45V.

i) supply voltage

ii) frequency

iii) the power in choke coil

(10)

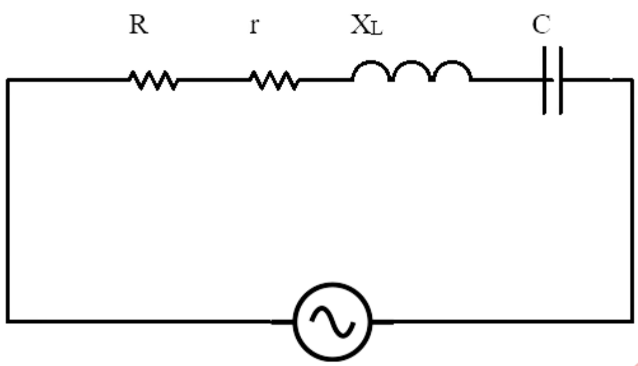
Given:

C = 15.91 μf = 15 $\times 10^{-6}$ f

I = 0.25 A

V_{COIL} = 40 V

Solution:



$R = \frac{V_R}{I} = \frac{20}{0.25}$

R = 80 Ω

Impedance across coil,

$Z_{COIL} = \frac{V_{COIL}}{I} = \frac{40}{0.25}$

Z_{COIL} = 160 Ω

Hence,

$Z_{COIL}^2 = r^2 + X_L^2$

$160^2 = r^2 + X_L^2$ ....(1)

$V_C = I X_C$

$X_C = \frac{V_C}{I} = \frac{50}{0.25}$

$X_C = 200\ \Omega$

$X_C = \frac{1}{2\pi f C}$

$f = \frac{1}{2\pi \times 200 \times 15.9 \times 10^{-6}}$

f = 50.02 Hz

Impedance across circuit,

$Z_T = (R+r) + j(X_L - X_C)$

$Z_T = \sqrt{(R+r)^2 + (X_L - X_C)^2}$

Impedance across resistance and coil,

$Z_{R+COIL} = (R + r) + jX_L$

$Z_{R+COIL} = \frac{V_{R+COIL}}{I} = \frac{45}{0.25}$

$Z_{R+COIL} = 180\ \Omega$

$Z_{R+COIL}^2 = (R+r)^2 + X_L^2$

$180^2 = R^2 + 2Rr + r^2 + X_L^2$

$180^2 = 80^2 + 160r + r^2 + X_L^2$

$180^2 = 80^2 + 160r + 160^2$ .....from (1)

r = 2.5Ω

Also,

$r^2 + X_L^2 = 160^2$

$X_L = 160^2 - 2.5^2$

$X_L = 159.98\ \Omega$

$X_L = 2\pi f L$

$L = \frac{X_L}{2\pi f}$

$L = \frac{159.98}{2\pi \times 50.02}$

L = 0.51 H

$Z_T = \sqrt{(R + r)^2 + (X_L - X_C)^2}$

$Z_T = \sqrt{(80 + 2.5)^2 + (159.98 - 200)^2}$

$Z_T = 91.69\ \Omega$

$V_T = I\ Z_T = 0.25 \times 91.69$

$V_T = 22.93\ V$

$P_{COIL} = I^2R = 0.25^2\ 2.5$

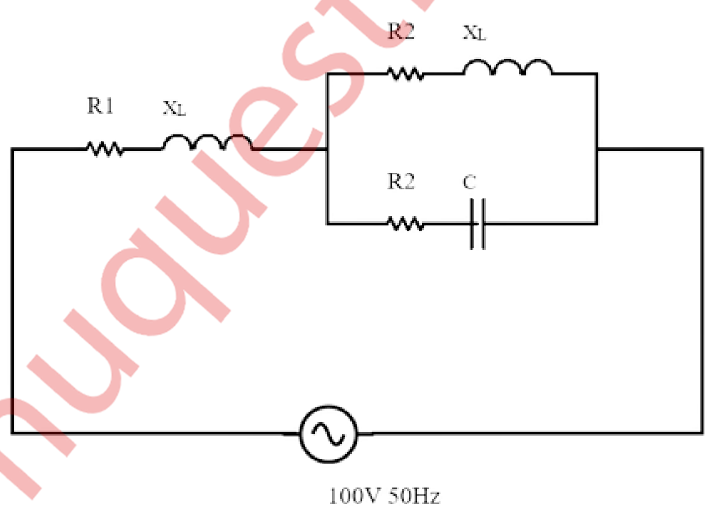
$P_{COIL} = 0.156\ W$

b) An impedance Z1 is connected in series with two parallel impedances Z2 and Z3. Z1 consists of a resistance of 6 ohm in series with an inductor of 0.01H. Z2 consists of a resistance of 6ohm in series with an inductor of 0.02H Z3 consist of resistance of 2 ohm in series with a capacitor of 200 microfarad. A voltage of 100V at 50Hz frequency is applied across complete circuit.

Find,

- **impedance of the circuit.**
- **current drawn by the circuit.**
- **power absorbed by all the three impedances and by complete circuit.**

(10)



Given:

Impedance 1 (Z_1)
$R_1 = 6\Omega$
$L_1 = 0.01H$

Impedance 2 (Z_2)
$R_2 = 4\Omega$
$L_2 = 0.02H$

Impedance 3 (Z_3)
$R_3 = 2\Omega$
$C = 20 \times 10^{-6}$ f

$V_T = 100V$
f= 50Hz

Solution:

For impedance 1,
$\bar{Z}_1 = R_1 + jX_{L1}$

$X_{L1} = 2\pi f L$
$X_{L1} = 2\pi \times 50 \times 0.01$

$X_{L1} = 3.14\ \Omega$.
$\bar{Z}_1 = 6 + j3.14$
$\bar{Z}_1 = 6.77\angle 27.62$

For impedance 2,
$\bar{Z}_2 = R_2 + jX_{L2}$

$X_{L2} = 2\pi f L$
$X_{L2} = 2\pi \times 50 \times 0.02$
$X_{L2} = 6.28\ \Omega$

$\bar{Z}_2 = 4 + j6.28$
$\bar{Z}_2 = 7.45 \angle 57.51$

For impedance 3,

$\bar{Z}_3$ = R_3 - jX_C

$X_C = \frac{1}{2\pi f c}$

$X_C = \frac{1}{2\pi \times 50 \times 200 \times 10^{-6}}$

X_C = 15.92 Ω

$\bar{Z}_3$ = 2 – j15.92

$\bar{Z}_3$ = 16.05 ∠ -82.84

Total impedance,

$Z_T = \bar{Z}_1 + \left[\frac{\bar{Z}_2 \bar{Z}_3}{\bar{Z}_2 + \bar{Z}_3}\right]$

We get,

$\bar{Z}_T$ = 17.28 ∠ 30.75

Z_T = 17.28 Ω

Now, current in every branch

$I = \frac{V_T}{Z_T} = \frac{100}{17.25}$

I = 5.79 A

$I_1 = \frac{100}{6.77}$

I_1 = 14.77

$I_2 = \frac{100}{7.45}$

I_2 = 13.42

$I_3 = \frac{100}{16.05}$

$I_3 = 6.23$ A

Power in every branch,

$P_1 = I_1^2R$

$P_1 = 14.77^26$

$P_1 = 1308.92$ w

$P_2 = 13.42^24$

$P_2 = 720.39$ w

$P_3 = 6.23^22$

$P_3 = 77.63$ w

$P_T = VI\cos\emptyset$

$P_T = VI\cos(30.75)$

$P_T = 467.6$ w