CMR INSTITUTE OF TECHNOLOGY	USN										

Internal Assesment Test II – Aug-2022									
Sub:	BASIC ELECTRICAL ENGINEERING							Code:	21ELE13
Date:	10/8/2022	Duration:	90 mins	Max Marks:	50	Sem:	2nd	Section:	I,J,K,LM,N,O

Note: Answer any **FIVE FULL** Questions

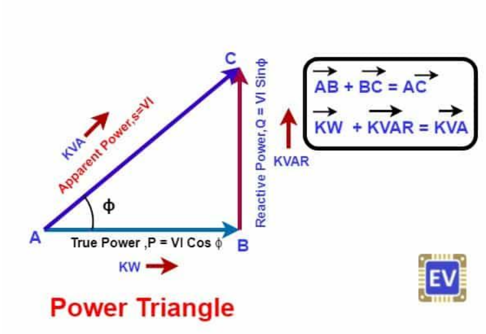
Sketch neat figures wherever necessary. Answer to the point. **Good luck!**

		Marks	OBE CO	OBE RBT
1(a)	Define (a)Active Power (b)Reactive Power (c)Apparent Power in AC circuits	[6]	CO1	L2
1(b)	Define power factor. Explain the Significance of power factor	[4]	CO1	L2
2(a)	Derive an expression for Power consumed in a series R-L Circuit and draw Voltage, Current and Power waveforms.	[5]	CO1	L2
2(b)	A circuit consists of a Resistance of 10 Ω, an Inductance of 16 mH and a Capacitance of 150 µF connected in series. A supply of 100 V at 50 Hz is given to the circuit. Find the impedance, current, pf and power consumed in the circuit	[5]	CO1	L3
3(a)	Derive the expression for Admittance in the case of Parallel R-L and R-C circuits with relevant phasor diagrams.	[5]	CO1	L2
3(b)	Two circuits A and B are connected in parallel across 200 V, 50 Hz AC supply. Circuit A consists of 10 Ω resistance and 0.12 H inductance in series while Circuit B consists of 20 Ω resistance and 40 µF capacitance in series. Calculate (a)current in each branch (b)Supply current (c)Total power (d)pf	[5]	CO1	L3
4(a)	Explain the generation of three phase voltage with suitable diagram.	[6]	CO2	L2
4 (b)	What are the Advantages of Three phase AC system over Single phase AC System	[4]	CO2	L2
5(a)	Derive the expression for Line voltage and phase voltage and Line current and phase current in a Balanced Delta connected Three phase system	[6]	CO2	L2
(b)	Three similar resistors are connected in Star across 400 V, 3 phase lines. The line current is 5 A. Calculate the value of each resistor. To what value should the line voltage be changed to obtain the same line current with the resistors Delta connected.	[4]	CO2	L3
6(a)	With the help of a neat circuit diagram and phasor diagram, demonstrate that, two wattmeters are sufficient to measure power in a three phase balanced star connected circuit.	[6]	CO2	L2
6(b)	Phase voltage and current of a Star connected inductive load are 150 V and 25A. Power factor of the load is 0.707 lag. Assuming that the system is three wire and power is measured by using two wattmeters, find the readings of the wattmeters	[4]	CO2	L3
7. (a)	Draw and explain the construction of a DC machine	[6]	CO2	L2
7.(b)	A 100 kW, 240 V DC Shunt Generator has a field resistance of 120 Ω and Armature Resistance of 0.05 Ω. Find the Generated Emf	[4]	CO2	L3

CI CCI HOD

Solution for BEE IAT2

1. (a)**Active Power** : The True or Real or Actual Power dissipated in the circuit is known as Active Power which is actually utilized or consumed. It is also known as useful or watt-full power).
Active Power = VICosφ
(b)**Reactive Power** : A Power which continuously bounces back and forth between source and load is known as Reactive Power.
Reactive Power = VISinφ
(c)**Apparent Power** : The total power flowing is known as the "apparent power" and is measured as the product of the voltage and current
Apparent Power = VI



(b)**Power factor**
The power factor of an AC power system is defined as the ratio of the real power absorbed by the load to the apparent power flowing in the circuit. Also power factor is the Cosine of the Angle between Voltage and current. It is the ratio of Resistance to Impedance of an AC Circuit.
Significance of Power factor
Power factor is the measure of the effectiveness in utilizing the Apparent power supplied to the circuit. Power factor is the measure of evaluating how effectively the incoming electrical power is used in an electrical system. If the power factor is high, then we can say that more effectively the electric power is being used in an electrical system. A load with power factor of 1 results most efficient loading of the system. But if the power factor is poor (say less than 0.8), then the effectiveness of usage of electrical power reduces which results in higher losses in the supply system and a higher bill for consumers. Power factor represents the fraction of the total power that is used to do the useful work. The other fraction of electrical power is stored in the form of magnetic energy in an inductor or electrostatic energy in the capacitor.

2(a)

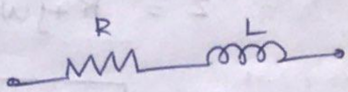
The average power consumed by the circuit is zero. Thus pure capacitor is lossless.

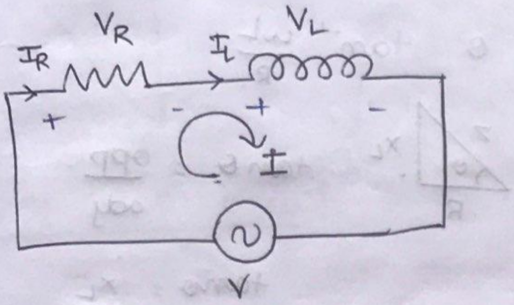
Power factor = $\cos\theta$

$= \cos 90° =$ zero leading (1M)

Series RL circuit

→ Practical inductor - not purely inductive - possesses inductance & resistance in series

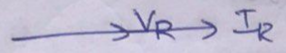




⇒ AC voltage source V connected to series RL circuit

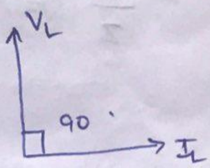
Applying KVL, $V = V_R + V_L$

1. Phasor diagram for resistor



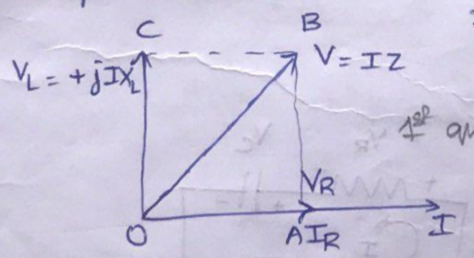
V_R & I_R - in phase with each other

2. Inductor



* I_L lags V_L by 90°

Complete phasor diagram



$I_R = I = I_L$

1st quadrant

$V_R = IR$

$V_L = jIX_L$

$V = I(R + jX_L)$

$V = V_R + V_L$

$OB = OA + OC$

Ratio of voltage phasor to current phasor is called complex impedance (Z)

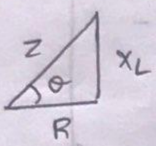
$$\frac{V}{I} = R + j\omega L = R + jX_L = Z$$

where R - resistance X_L - reactance

$$Z = R + j\omega L \Rightarrow Z\angle\theta$$

$$Z = \sqrt{R^2 + (\omega L)^2} \qquad \theta = \tan^{-1}\frac{\omega L}{R}$$

Impedance triangle



$$\tan\theta = \frac{opp}{adj}$$

$$\tan\theta = \frac{X_L}{R}$$

Now, assume

$$V = V_m \sin\omega t$$

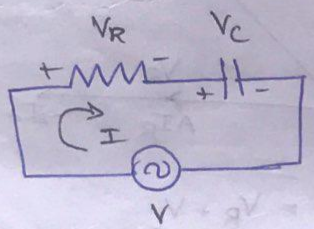
$$I = \frac{V}{Z} = \frac{V\angle 0^\circ}{Z\angle\theta} = \frac{V\angle -\theta}{\sqrt{R^2 + (\omega L)^2}}$$

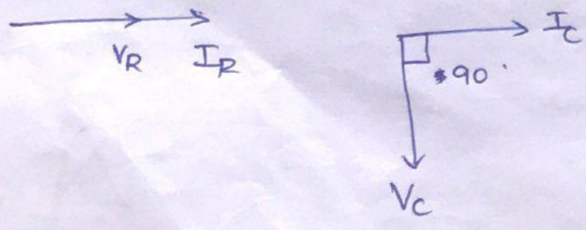
$$= \frac{V_m \sin(\omega t - \theta)}{\sqrt{R^2 + (\omega L)^2}}$$

$$i = \frac{V_m}{\sqrt{R^2 + (\omega L)^2}} \sin\left(\omega t - \tan^{-1}\frac{\omega L}{R}\right) \text{ Ampere}$$

Series RC circuit

$$V = V_R + V_C$$



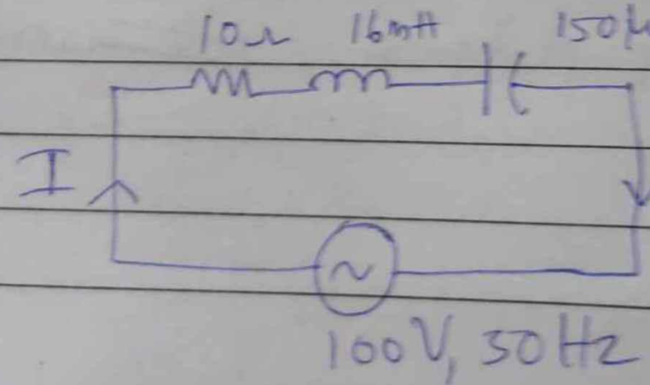


$$V_C = -jIX_C$$

$$V = V_R + V_C = IR - jIX_C$$

2(b)

2)(b) A circuit consists of a Resistance of 10Ω, an Inductance of 16 mH and a capacitance of 150μF connected in series. A supply of 100V at 50Hz is given to the circuit. Find the impedance, current, pf and power consumed in the circuit



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$R = 10\Omega$

$L = 16mH$

$C = 150\mu F$

$X_L = L\omega = 16\times10^{-3}\times2\pi\times50 = 5.027\Omega$

$X_c = \frac{1}{C\omega} = \frac{1}{150\times10^{-6}\times2\pi\times50} = 21.2$

$\bar{Z} = R + j[X_L - X_c] = 10 + j[5.027 -$

$= (10 - j16.193)$

$I = \frac{\bar{V}}{\bar{Z}} = \frac{100\angle 0^\circ}{10 - j16.193} = \frac{100\angle 0^\circ}{19.03\angle -5}$

$= 5.25\angle 58.3$

$pf = \cos\phi = \cos(58.30^\circ)$

$= 0.525$ lead

Power consumed, $P = VI\cos\phi$

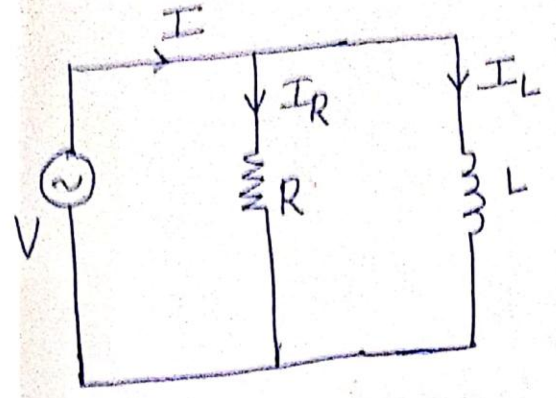
$= 100\times5.25\times0.525$

$= 275.625W$

3(a)

Parallel AC Circuits

R-L Circuit



From the circuit, $\bar{I}_R = \dfrac{\bar{V}}{R}$

$$\bar{I}_L = \frac{\bar{V}}{jX_L} = \frac{\bar{V}}{jLW}$$

By KCL, $\bar{I} = \bar{I}_R + \bar{I}_L$

$$\bar{I} = \bar{V}\left[\frac{1}{R} + \frac{1}{jwL}\right]$$

$$\therefore \bar{I} = \bar{V}\bar{Y}$$

where Y = Complex Admittance

$$Y = \frac{1}{R} + \frac{1}{jwL}$$

$$Y = \frac{1}{R} - j\cdot\frac{1}{LW}$$

$$\therefore Y = G - jB_L$$

Impedance, $Z = R + jX_L$

where $G = \dfrac{1}{R}$ = Conductance

$B_L = \dfrac{1}{LW} = \dfrac{1}{X_L}$ = Susceptance

Admittance = Conductance + j Susceptance

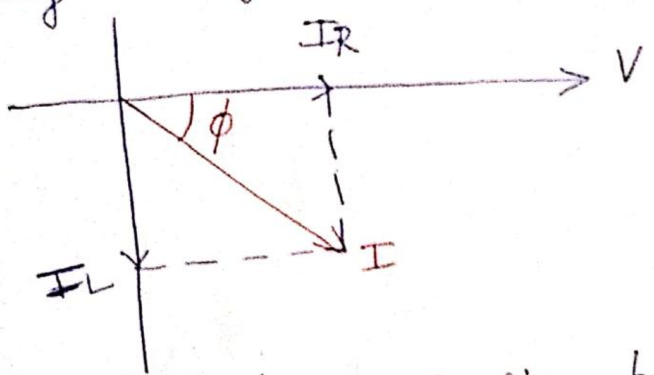
$$\bar{I} = \bar{I}_R + \bar{I}_L$$

$$\bar{I} = \bar{V}\left[\frac{1}{R} - \frac{j}{L\omega}\right] \rightarrow (1)$$

Phase angle, $\phi = \tan^{-1}\frac{\left(\frac{-1}{L\omega}\right)}{\left(\frac{1}{R}\right)}$

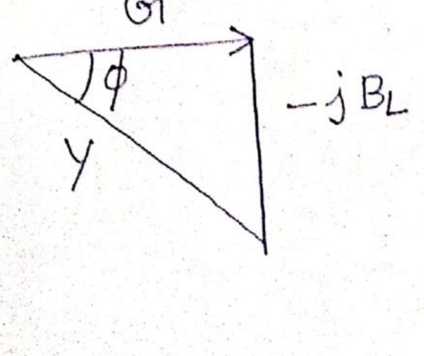
$$\therefore \phi = \tan^{-1}\left(\frac{-R}{L\omega}\right) \rightarrow (2)$$

Taking Voltage as Reference,

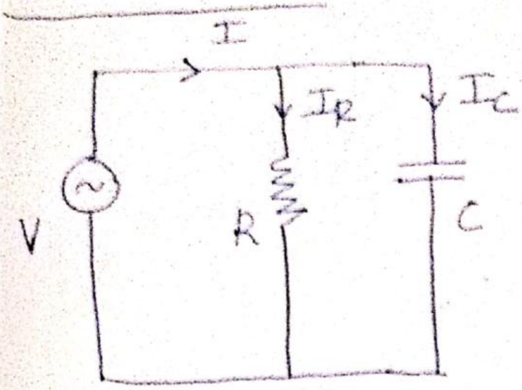


$\because$ Current I_L lags the voltage by 90°

Admittance Triangle



R-C Circuit



$\bar{I}_R = \frac{\bar{V}}{R}$

$\bar{I}_c = \frac{\bar{V}}{-jX_c} = \frac{\bar{V}}{-j(\frac{1}{cw})}$

$= jVCw$

By KCL, $\bar{I} = \bar{I}_R + \bar{I}_c$

$= \frac{\bar{V}}{R} + \bar{V}jwc$

$= \bar{V}\left[\frac{1}{R} + jwc\right]$

$\therefore \bar{I} = \bar{V}\bar{Y}$

$\bar{Y} = G + jB_c$

Impedance, $Z = R - jX_c$

Y = Admittance

G = conductance

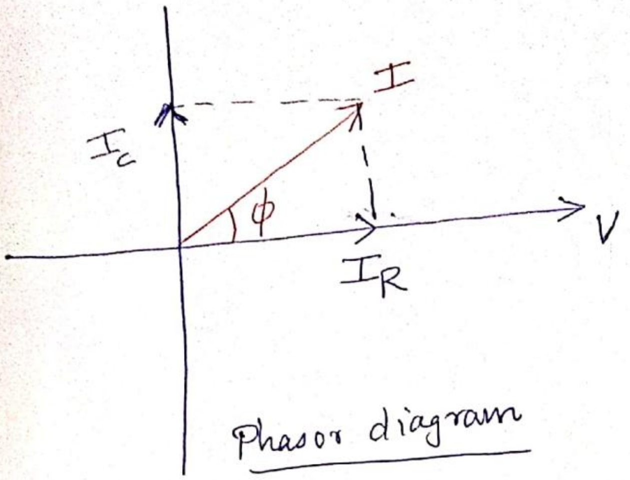
Here $G = \frac{1}{R}$

B_c = capacitive susceptance

$B_c = \frac{1}{X_c} = cw$

$\phi = \tan^{-1}\left(\frac{wc}{\frac{1}{R}}\right) = \tan^{-1}(wCR)$

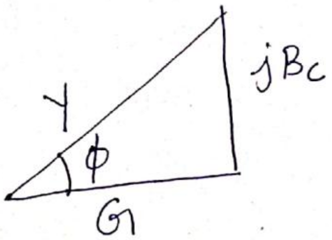
Taking voltage as reference,



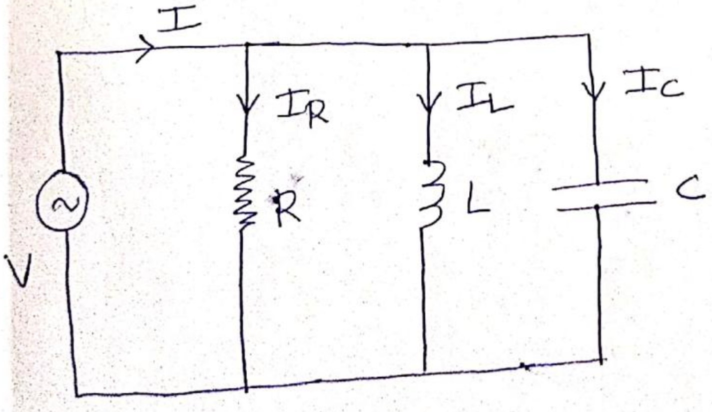
Here current I_c leads voltage by 90°

Phasor diagram

Admittance Triangle



R L C Parallel Circuit



3(b)

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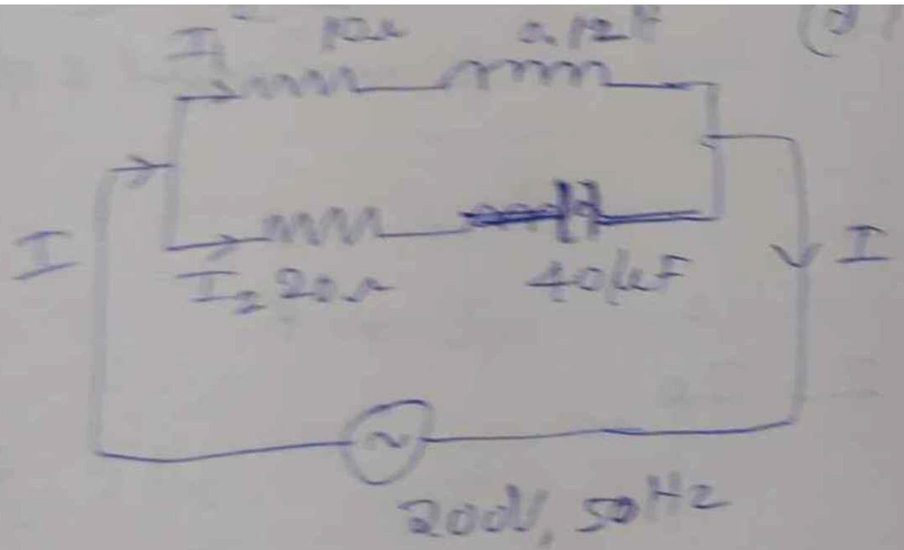


$V = 200V$

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

$\bar{Z} = Z_1 // Z_2$

$Z_1 = R_1 + jX_L$

$Z_2 = R_2 - jX_c$

$x_L = Lw = $

$Z_1 = (10 + 37.68j)\,\Omega$

$x_c = \frac{1}{cw} = \frac{1}{40\times10^{-6} \times 2\pi\times50}$

$= 79.62\,\Omega$

$Z_2 = (20 - 79.62j)\,\Omega$

$Z_{eq} = \frac{Z_1 Z_2}{Z_1 + Z_2}$

$Z_{eq} = \frac{(10+37.68j)(20-79.62j)}{10+37.68j+20-79.62j}$

$= 36.78 + 49.99j = 62.06\angle 53.66^\circ\,\Omega$

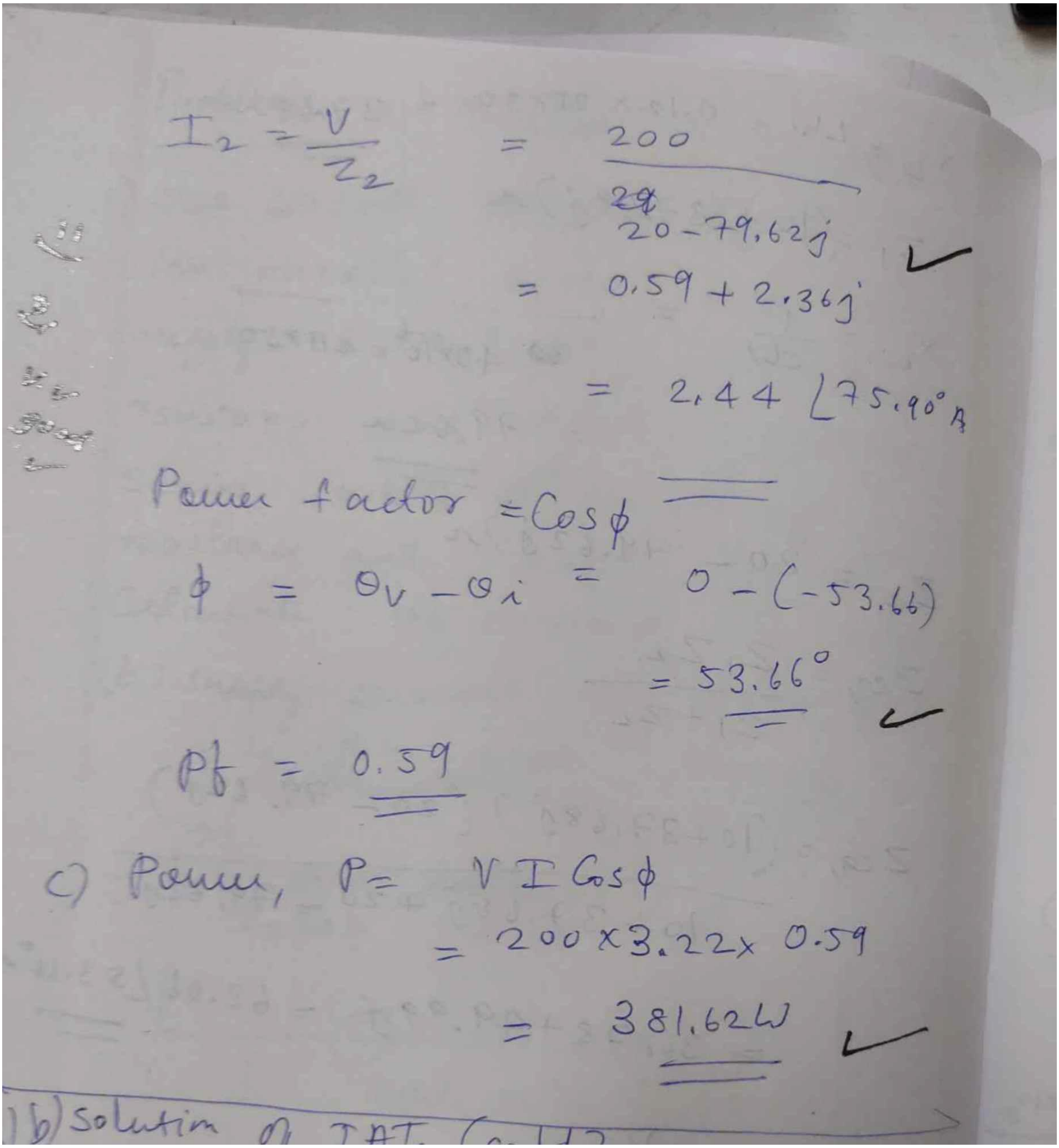
$V = 200V$

b) $\bar{I} = \frac{\bar{V}}{\bar{Z}_{eq}} = \frac{200}{62.06\angle 53.66}$

$= 3.22\angle -53.66^\circ$

a) $\bar{I}_1 = \frac{\bar{I}\times\bar{Z}_2}{\bar{Z}_1+\bar{Z}_2} = 5.14\angle -75.17^\circ A$

$= (1.31 - 4.97j)\,A$



$$I_2 = \frac{V}{Z_2} = \frac{200}{20 - 79.62j}$$

$$= 0.59 + 2.36j$$

$$= 2.44 \angle 75.90^\circ \text{ A}$$

Power factor $= \cos\phi$

$$\phi = \theta_v - \theta_i = 0 - (-53.66)$$

$$= 53.66^\circ$$

$$pf = 0.59$$

c) Power, $P = VI\cos\phi$

$$= 200 \times 3.22 \times 0.59$$

$$= 381.62\text{W}$$

1(b) solution of TAT. ...

4(a)**Generation of Three phase voltages**

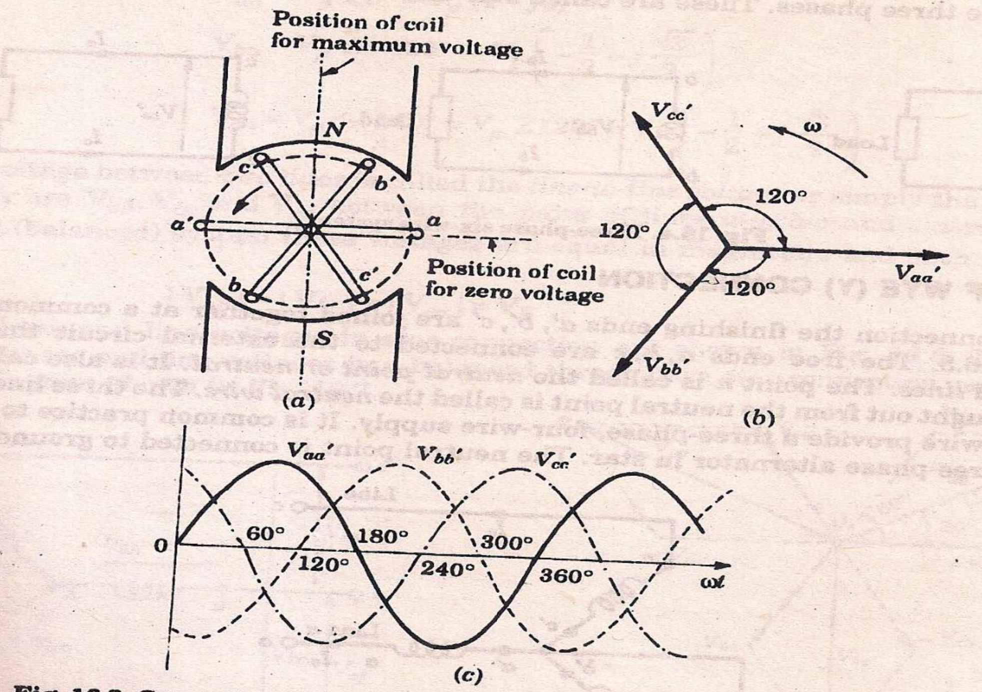


Fig. 16.3. Generation of three-phase supply : (*a*) three-phase two-pole alternator; (*b*) waveforms of voltages; (*c*) phasor diagram.

- When three identical coils are placed with their axes at 120^0 apart from each and rotated in a uniform magnetic field, a sinusoidal voltage is generated across each coil.
- Electrical displacement = 360^0/m = 360^0/3 = 120^0 where m = number of phases.

Consider a 3 phase, 2 Pole Alternator. It has three sets of coils aa', bb' and cc' symmetrically spaced such that their axes are 120 0 apart from each other. When the rotor is rotated in the anticlockwise direction at a constant angular velocity ω rad/sec at a sinusoidal voltage is generated across each coil. Generated emfs have the same frequency. The coils are identical, the generated voltages have the same magnitudes.

The generated voltages in the coils are given by

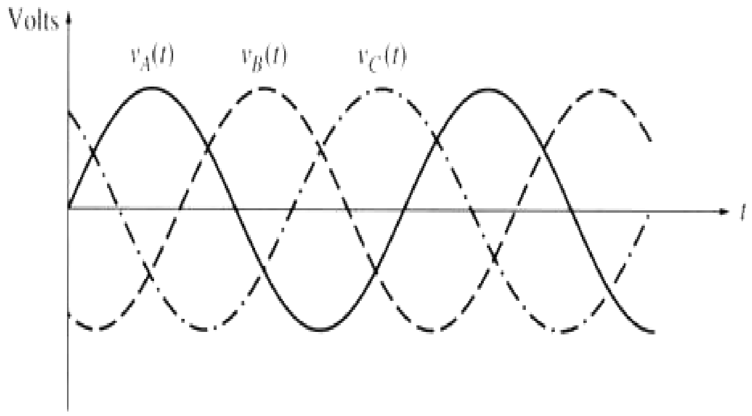
- Voltage vaa' = Vm Sinwt
- Voltage vbb' = Vm Sin(wt – 120 0)
- Voltage vcc'= Vm Sin(wt – 240 0)
- OR Voltage vcc' = Vm Sin(ωt + 120 0)

In a balanced 3 phase system, vaa'+vbb'+vcc'=0

In Polar form, Vaa' = V L0^0

Vbb' = V L-120^0

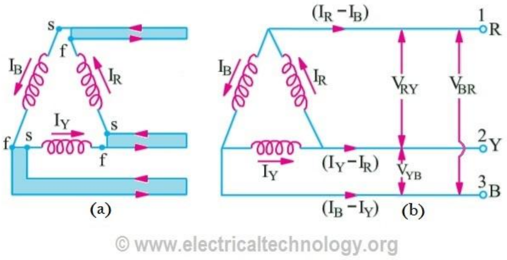
Vcc' = V L-240^0= V L120^0



From the waveforms, Vaa’ leads Vbb’ by 1200 . Also Vbb’ leads Vcc’ by 1200. Also the three voltages reach their positive maximum values in the order Vaa’, Vbb’, Vcc’. The order in which the phase voltages reach their maximum values is called the phase sequence. Phase rotation, or phase sequence, is the order in which the voltage waveforms of a polyphase AC source reach their respective peaks. For a three-phase system, there are only two possible phase sequences: a b c and c b a.

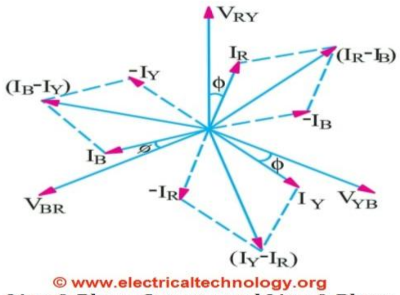
4(b)**Advantages of three phase system over single phase system**
- A three-phase AC system consists of three-phase generators, transmission lines, and loads
- It is also used to power large motors and other heavy loads.
- A three-wire three-phase circuit is usually more economical than an equivalent two-wire single-phase circuit
- This is because it uses less conductor material to transmit a given amount of electrical power.
- Almost all electric power generation and most of the power transmission in the world is in the form of three-phase AC circuits.

5(a)Delta connection



Delta Connection (Δ): 3 Phase Power, Voltage & Current Values

If the line voltage between;
Line 1 and Line 2 = V_{RY}
Line 2 and Line 3 = V_{YB}
Line 3 and Line 1 = V_{BR}
Then, we see that V_{RY} leads V_{YB} by 120° and V_{YB} leads V_{BR} by 120°.
Let’s suppose,
$V_{RY} = V_{YB} = V_{BR} = V_L$ …………… (Line Voltage)
Then $\mathbf{V_L = V_{PH}}$
The total current of each Line is equal to the vector difference between two phase currents flowing through that line. i.e.;
Current in Line 1= $I_1 = I_R – I_B$
Current in Line 2 =$I_2 = I_Y – I_R$
Current in Line 3 =$I_3 = I_B – I_Y$
{Vector Difference}



Line & Phase Current and Line & Phase Voltage in Delta (Δ) Connection

$I_R = I_Y = I_B = I_{PH}$ …. The phase currents
The current flowing in Line 1 would be
I_L or $I_1 = 2 \times I_{PH} \times \cos(60°/2) = 2 \times I_{PH} \times \cos 30°$
$= 2 \times I_{PH} \times (\sqrt{3}/2) = = \sqrt{3}\, I_{PH}$
(Since $\cos 30° = \sqrt{3}/2$)
i.e. In Delta Connection, The Line current is √3 times of Phase Current
Similarly, we can find the remaining two Line currents as same as above. i.e.,
$I_2 = I_Y – I_R$ … Vector Difference = $\sqrt{3}\, I_{PH}$
$I_3 = I_B – I_Y$ … Vector difference = $\sqrt{3}\, I_{PH}$
As, all the Line current are equal in magnitude
i.e. $I_1 = I_2 = I_3 = I_L$
Hence **IL = √3** $\mathbf{I_{PH}}$

5(b)**For Star connection**

IL = Iph = 5 A

VL = 400 V

Vph = 230.95 V

Rph = Vph/Iph = 230.95/5 = 46.19 Ω

For Delta connection

Here IL = 5 A

Rph = 46.19 Ω

Iph = 2.89 A

Vph = Iph Rph = 2.89 x 46.19 = 133.49 V

VL = Vph = 133.49 V

6(a)**Two wattmeter method**

... phase star connected load.

3.8.3. *Two-wattmeter method (Balanced load)*

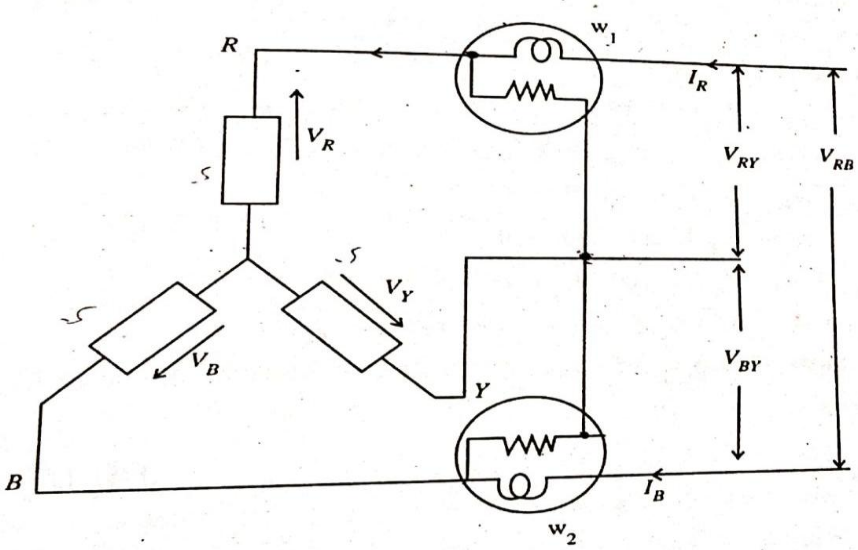


Fig 3.20. Two wattmeter method

Consider a 3-phase balanced load (lagging) of phase angle ϕ.

Let V_R, V_Y and V_B be the R.M.S values of phase voltages across the star connected load and I_R, I_Y and I_B be the phase currents (or line currents). Since the load is lagging, the phase currents lag their respective phase voltages by an angle ϕ. This is shown in phasor diagram (see Figs. 3.21 and 3.22).

The power in the circuit is measured by two wattmeters w_1 and w_2. Current coil of w_1 is connected in *R*-line and potential coil is connected between *R* and *Y*.

Similarly the current coil of w_2 is connected in B-line and the potential coil is connected between B and Y as shown in Fig. 3.20.

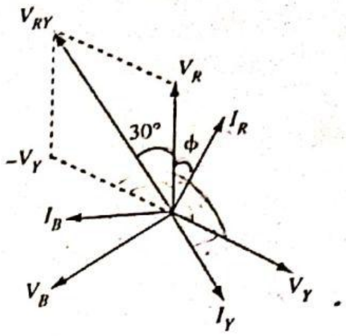


Fig. 3.21. Phasor representation of voltages and currents

Wattmeter reading w_1

Current through the current coil $= I_R$

Potential difference across potential coil $= V_{RY}$

Where V_{RY} is the phasor difference of V_R and V_Y

From the Phasor diagram (Fig. 3.20) the phase angle between V_{RY} and I_R is found to be $(30+\phi)$.

$\therefore$ Reading on w_1 is $= I_R V_{RY} \cos(30+\phi)$

Wattmeter reading w_2

Current through the current coil $= I_B$

Potential difference across potential coil $= V_{BY}$

V_{BY} is the phasor difference of V_B and V_Y. From the phasor diagram (Fig. 3.22) the phase angle between V_{BY} and I_B is found to be $(30-\phi)$.

$\therefore$ Reading on w_2 is $= I_B V_{BY} \cos(30-\phi)$

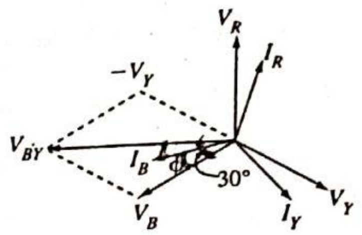


Fig. 3.22. Phasor representation of voltages and currents

Since the load is balanced

$$I_R = I_Y = I_B = I_L$$

$$V_{RY} = V_{BY} = V_{BR} = V_L$$

$$\therefore \quad w_1 = V_L I_L \cos(30+\phi)$$

$$w_2 = V_L I_L \cos(30-\phi)$$

$$w_1 + w_2 = V_L I_L \{\cos(30+\phi) + \cos(30-\phi)\}$$

$$w_1 + w_2 = \sqrt{3}\, V_L I_L \cos\phi$$ -> Activepower

Hence, the sum of two wattmeters gives the total active power in the circuit.

Power factor

We have $\quad w_1 = V_L I_L \cos(30+\phi)$

$$w_2 = V_L I_L \cos(30-\phi)$$

$$w_2 + w_1 = \sqrt{3}\, V_L I_L \cos\phi$$

$$w_2 - w_1 = V_L I_L \sin\phi$$

$$\frac{w_2 - w_1}{w_2 + w_1} = \frac{1}{\sqrt{3}} \tan\phi$$

$$\text{or } \phi = \tan^{-1}\left\{\sqrt{3}\left(\frac{w_2 - w_1}{w_2 + w_1}\right)\right\}$$

$\sqrt{3}(W_2 - W_1) =$ Reactive power $= \sqrt{3} V_L I_L \sin\phi$

Knowing ϕ from the wattmeter readings, the power factor of the load can be calculated.

pf = $\cos\phi$

6(b)Vph = 150 V

VL = 259.8 V

Iph = IL = 25 A

Cos Φ = 0.707 lag

$\Phi = 45^0$

Power = 3 Vph Iph Cos Φ = 3 x 150 x 25 x 0.707 = 7.954 kW

W1 = W2 = 7.954 kW

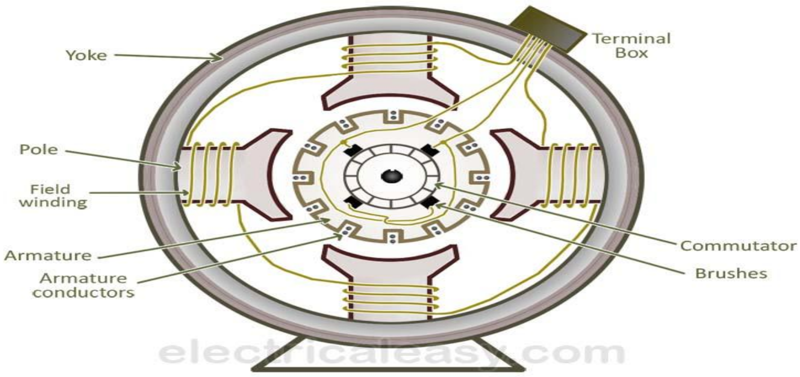
Tan Φ = tan 45 = 1

W2 – W1 = 4.592 kW

W1 = 1.684 kW

W2 = 6.27 kW

7(a)**Construction of a DC Machine**



Main components :

- Field system
- Armature core
- Armature winding
- Commutator
- Brushes
- Shaft & Bearings

Field System

The function of the field system is to produce uniform magnetic field within which the armature rotates

Yoke : forms the outer cover for the machine

Functions

- Giving mechanical protection
- Carrying the magnetic flux produced by the poles
- ➢ For small generators : cast iron
- ➢ For large generators : cast steel

Poles

- ➢ Main poles are made of an alloy steel of high relative permeability
- ➢ Pole core is laminated to reduce eddy current losses

Pole Shoes

Functions :

- It supports the field winding

- It spreads out the flux uniformly in the air gap
- It reduces the reluctance of the magnetic path

Field winding

- Field coils are mounted on the poles and carry the dc exciting current
- The connection of field coils is in such a way that adjacent poles have opposite polarity
- Field coils are made up of copper

Armature core

- A cylindrical drum like structure made up of Silicon steel laminations
- Each lamination is coated with a thin insulated film
- Core is laminated to reduce the eddy current loss
- Silicon steel material is used to reduce the hysteresis loss

Armature winding

- The conductors in the slots of the armature core forms the armature winding
- The armature conductors are in the form of coils
- The coils are connected in series through the commutator segments

Types of Armature winding

1. Lap winding
2. Wave winding

Lap winding

- Here the armature coils are connected in series
- The armature winding is divided into as many parallel paths
- The number of parallel paths = number of poles
- Each path has Z/P conductors in series
- Emf generated = Emf of any one of the parallel path
- Total armature current = sum of the currents in all the parallel paths

Wave winding

- Here the armature conductors are divided into two parallel paths irrespective of the number of poles
- Each parallel path will have Z/2 conductors in series
- Emf generated = Emf of any one of the parallel path
- Total armature current = sum of the currents in the two parallel paths

Commutator

- The function of the commutator is to convert alternating current induced in the armature to direct current
- The commutator is made up of copper segments insulated from each other by mica sheets

Brushes

- The function of the brushes is collect the rectified current from the commutator segments and supply it to the external circuit
- Brushes are made up of carbon or carbon graphite
- Carbon has good electrical conductivity and is a self lubricant
- Copper is added to improve the conductivity
- Brushes are placed in brush holders

Shaft and Bearings

- The rotation of the armature and commutator by the prime mover is done by mounting the former on a shaft using bearings
- This is done to reduce the frictional losses
- For small generators, ball bearings are used
- For large generators, roller bearings are used

7(b) $V = 240$ V

$P = 100$ kW

$R_{sh} = 120\ \Omega$

$R_a = 0.05\ \Omega$

$I_L = P/V = 100 \times 10^3 / 240 = 416.67$ A

$I_{sh} = V/R_{sh} = 240/120 = 2$ A

$I_a = I_L + I_{sh} = 418.67$ A

$E_g = V + I_a R_a = 240 + 418.67 \times 0.05 = 260.93$ V