B.TECH. EEE–101/EEE–201

SECOND SEMESTER EXAMINATION, 2009-10

ELECRICAL ENGINEERING

Time : 3 Hours Total Marks : 100

Note : Attempt all questions.

SECTION-A

1. Attempt all parts :

(a) Among following which conductor has highest conductivity?

(i) Cu

(ii) Al

(iii) Ag

(iv) Mg

Ans. (iii) Ag

(b) The mass of electron is--------.

Ans. 9.1×10^{-31} KG

(c) Pure inductive circuit :

(i) consumes some power on average

(ii) does not consume power

(iii) take power form the line during some part of the cycle and then returns back during other part of cycle

(iv) none of these

Ans. (ii) does not consume power

(d) Autotransformer can do the following :

(i) Step up Voltage

(ii) Step down Voltage

(iii) both (i) and (ii)

(iv) none of these

Ans. (iii) both (i) and (ii)

(e) Power factor of the following circuit will be zero :

(i) Resistive

(ii) Inductive

(iii) Capacitive

(iv) Both (ii) and (iii)

Ans. (iv) Both (ii) and (iii)

(f) An ideal voltage source should have :

(i) large value of emf

(ii) small value of emf

(iii) zero source resistance

(iv) infinite source resistance

Ans. (iii) zero source resistance

(g) The power measurement in balanced 3-phase circuit can be done by :

(i) one wattmeter method only

(ii) two wattmeters method only

(iii) three wattmeters method only

(iv) any one of the above

Ans. (iv) any one of the above

(h) At resonance power factor of series R-L-C circuit would be :

(i) 0 **(ii) 1**

(iii) –1 **(iv) 1.1**

Ans. (ii) 1

(i) A transformer transforms :

(i) voltage

(ii) current

(iii) voltage and current

(iv) frequency

Ans. (iii) voltage and current

(j) A transformer can be connected to DC:

(i) Yes **(ii) No**

Ans. (ii) No

(k) Slip rings are made of aluminium :

(i) Yes **(ii) No**

Ans. (ii) No

(l) The form factor sinusoidal alternating current is :

(i) 1

(ii) 0

(iii) 1.11

(iv) 1.15

Ans. (iii) 1.11

(m) Three phase induction motor has a low efficiency :

(i) Yes **(ii) No**

Ans. (ii) No

(n) Open circuit test is usually conducted on :

(i) slip ring motors

(ii) wound rotor motor

(iii) either of (i) and (ii)

(iv) none of above

Ans. (iii) either of (i) and (ii)

(o) The torque developed in an induction motor is nearly proportional to :

(i) 1/V

(ii) V

(iii) V^2

(iv) none of these

Ans. (iii) V^2

(p) What will happen if the back emf of DC motor vanishes ?

Ans. Current will be very high which will damage the DC motor, also speed may shoot up.

(q) .... Motor has self load properties.

Ans. 3-phase induction motor

(r) .... Motor will be preferred for elevators.

Ans. Wound rotor induction motor

(s) Synchronous motor can be used as power factor improving device :

(i) Yes

(ii) No

Ans. (i) Yes

(t) Ceiling fan is :

(i) three phase IM

(ii) single phase IM

(iii) single phase synchronous motor

(iv) none of these

Ans. (ii) single phase IM

SECTION-B

2. Attempt any three parts :

(a) State the following :

(i) Magnetic flux and its properties

(ii) Flux density

(iii) Fleming's right hand rule

(iv) Fleming's left hand rule

(v) Len's law

Ans 2 (a) (i) Magnetic flux : The total number of lines of force existing in a particular magnetic field is called magnetic flux. Lines of force can be called lines of magnetic flux. The unit of flux is weber and flux is denoted by symbol (ϕ). The unit weber is denoted as Wb.

$$1 \text{ weber} = 10^8 \text{ lines of force.}$$

Properties of magnetic flux : Though the lines of force are imaginary, with the help of them various magnetic effects can be explained very conveniently. Let us see the various properties of these lines of force.

1. Lines of force are always originating on a N-pole and terminating on a S-pole, external to the magnet.
2. Each line forms a closed loop as shown in the Fig.

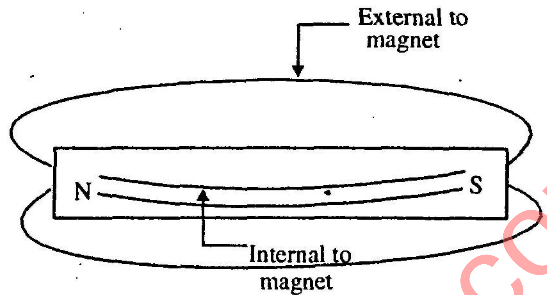


Fig. Lines of force complete the closed path

> **Key point :** This means that a line emerging from N-pole, continues upto S-pole external to the magnet while it is assumed to continue from S-pole to N-pole internal to the magnet completing a closed loop. Such lines internal to the magnet are called as lines of induction.

3. Lines of force never intersect each other.
4. The lines of force, are like stretched rubberbands and always try to contract in length.
5. The lines of force, which are parallel and travelling in the same direction repel each other.
6. Magnetic lines of force always prefer a path offering least opposition.

Ans. (ii) Flux density : It can be defined as, "The flux per unit area (a) in a plane at right angles to the flux is known as 'flux density'." Mathematically,

$$B = \frac{\phi}{a} \frac{Wb}{M^2} \text{ or Tesla}$$

It is shown in the fig.

Flux density
$B = \frac{\phi}{a}$

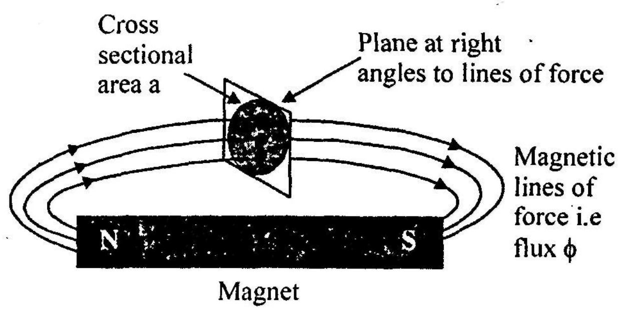
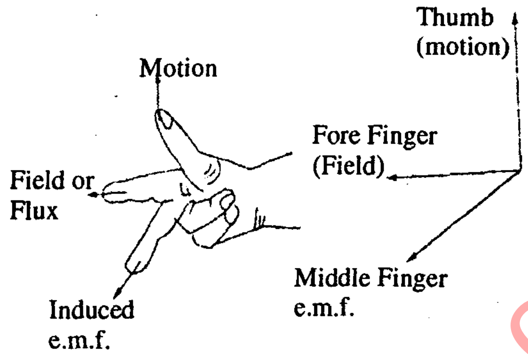


Fig. Concept of magnetic flux density

Ans. (iii) Flemming's right hand rule : The thumb, fore finger and the middle finger of the right hand are held mutually at right couples as shown Fig. If the forefinger points in the direction of the magnetic flux the thumb points in the direction of motion of the conductor relative to the magnetic field. Then the middle finger represents the direction of the induced e.m.f.



Ans. (iv) Flemming's left hand rule : The direction of the force experienced by the current carrying conductor placed in magnetic field can be determined by a rule called 'Flemming's Left Hand Rule'. The rule states that, 'Outstretch the three fingers of the left hand namely the first finger, middle finger and thumb such that they are mutually perpendicular to each other. Now point the first finger in the direction of magnetic field and the middle finger in the direction of the current then the thumb gives the direction of the force experienced by the conductor'.

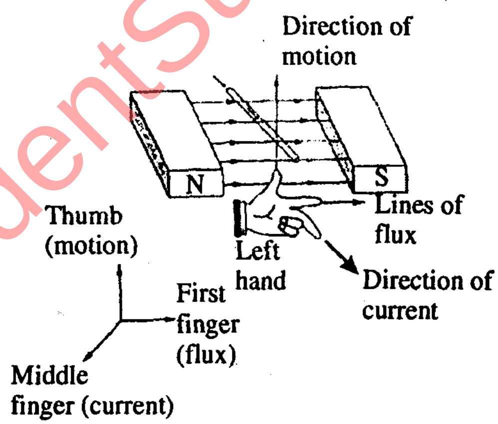
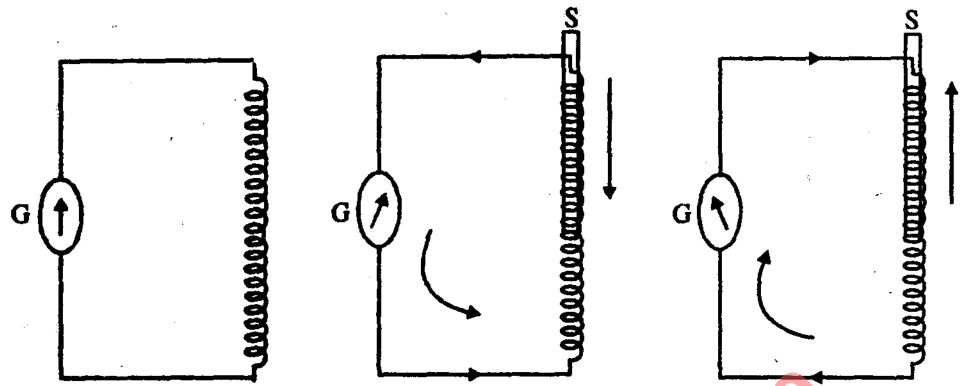


Fig. Flemming's left hand rule

The rule is explained in the diagrammatic form in the Fig.

Ans. (v) Lenz's law : The direction of statically induced e.m.f can be obtained with the help of Lenz's law, which states: "The direction of the induced e.m.f. always such that it tends to setup a current opposing the change of flux responsible for producing that e.m.f."



(b) Three voltages represented by the following equations,
$e_1 = 15\sin \omega t$, $e_2 = 5\sin(\omega t + \pi/6)$, $e_3 = 10\cos\omega t$ together in an ac circuit. Represent these voltages by Phasor and calculate an expresssion for the resultant voltage. Check the result so obtained graphically.

Ans. $e_1 = 15\sin\omega t = \frac{15}{\sqrt{2}}\angle 0°$

$$e_2 = 5\sin(\omega t + 30°) = \frac{5}{\sqrt{2}}\angle 30°$$

$$e_3 = 10\sin(\omega t + 90°) = \frac{10}{\sqrt{2}}\angle 90°$$

$$H = \frac{15}{\sqrt{2}}\cos 0° + \frac{5}{\sqrt{2}}\cos 30° + \frac{10}{\sqrt{2}}\cos 90°$$

$$= \frac{15}{\sqrt{2}} + \frac{5}{\sqrt{2}} \times \frac{\sqrt{3}}{2} + \frac{10}{\sqrt{2}} \times 0 = \frac{15}{\sqrt{2}} + \frac{5\sqrt{3}}{2\sqrt{2}}$$

$$V = \frac{15}{\sqrt{2}}\sin 0° + \frac{5}{\sqrt{2}}\sin 30° + \frac{10}{\sqrt{2}}\sin 90°$$

$$= \frac{15}{\sqrt{2}} \times 0 + \frac{5}{\sqrt{2}} \times \frac{1}{2} + \frac{10}{\sqrt{2}} \times 1 = \frac{5}{2\sqrt{2}} + \frac{10}{\sqrt{2}}$$

$$E^2 = \sqrt{H^2 + V^2}$$

$$\phi = \tan^{-1}\frac{V}{H}$$

(c) A three phase, 50 Hz induction motor has a full load speed of 960 rpm. Calculate :

(i) slip

(ii) frequency of rotor induced emf

(iii) Number of poles

(iv) Speed of rotor field with respect to rotor structure

(v) Speed of rotor field with respect to stator field.

Ans. $N_s = \frac{120 \times 50}{6} = 1000\,\text{RPM},$

(i) Slip = $(N_s - N_r)/N_s$ = (1000 – 960)/ 1000 = 0.04

(ii) $F_r = s_f = 0.04*50 = 2\text{Hz}$

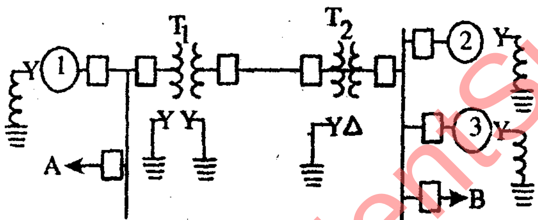
(iii) P = 6

(iv) 40 RPM

(v) Zero

(d) List out main components of power supply system with a brief description. Also write the advantages of power factor improvement.

Ans. Main components of power supply system: A one-line diagram of a power system shows the main connections and arrangements of components. Any particular component may or may not be shown depending on the information required in a system study, e.g. circuit breakers need not be shown in a load flow study but are a must for a protection study. Power system networks are represented by one-line diagrams using suitable symbols for generators, motors, transformers and loads. It is a convenient practical way of network representation rather than drawing the actual three-phase diagram which may indeed be quite cumbersome and confusing for a practical size power network. Generator and transformer connections–star, delta, and neutral grounding are indicated by symbols drawn by the side of the representation of these elements. Circuit breakers are represented as rectangular blocks. Figure shows the one-line diagram of a simple power system.

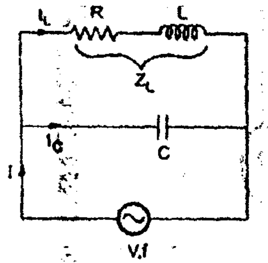


Advantages of power factor improvement

- Increased plant capacity
- Reduced power factor "penalty" charges from the electric utility
- Improvement of voltage supply
- Less power losses in feeders, transformers and distribution equipment.

(e) **Show that the condition for resonance in a parallel R-L-C circuit is same as that in a series R-L-C circuit. State the application of Series as well as Parallel resonance.**

Ans. Circuit for resonance in parallel RLC circuit



At resonance $I_C = I_L \sin\phi_L$

$$\therefore \frac{V}{X_C} = \frac{V}{Z_L}\frac{X_L}{X_L} = \frac{VX_L}{Z_L^2}$$

$$\therefore Z_L^2 = X_L X_C$$

$$\therefore R^2 + (2\pi f_r L)^2 = (2\pi f_r L) \times \frac{1}{2\pi f_r C} \; as \; f = f_r$$

$$\therefore R^2 + (2\pi f_r L)^2 = \frac{L}{C}$$

$$\therefore (2\pi f_r L)^2 = \frac{L}{C} - R^2$$

$$\therefore (2\pi f_r)^2 = \frac{1}{LC} - \frac{R^2}{L^2}$$

$$\therefore \boxed{f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - 1\frac{R^2}{L^2}}}$$

Thus if R is very small compared to L and C,

$$\frac{R^2}{L^2} << \frac{1}{LC}$$

$$\therefore \boxed{f_r = \frac{1}{2\pi\sqrt{LC}}}$$

$\therefore$ This is same as that for series resonance.

Applications of resonance effect

1. Most common application is tuning. For example, when we tune a radio to a particular station, the LC circuits are set at resonance for that particular carrier frequency.
2. A series resonant circuit provides voltage magnification.
3. A parallel resonant circuit provides current magnification.
4. A parallel resonant circuit can be used as load impedance in output circuits of RF amplifiers. Due to high impedance, the gain of amplifier is maximum at resonant frequency.
5. Both parallel and series resonant circuits are used in induction heating.

SECTION-C

3. Attempt any two parts :

(a) State the Superposition and Norton's Theorem.

Ans. Superposition theorem : Statement : In any multisource complex network consisting of linear bilateral elements, the voltage across or current through any given element of the network is equal to the algebraic sum of the individual voltages or currents, produced independently across or in that element by each source acting independently, when all the remaining sources are replaced by their respective internal resistances.

Norton's theorem : Statement : Any combination of linear bilateral circuit elements and active sources, regardless of the connection or complexity, connected to a given load R_L can be replaced by a simple two terminal network, consisting of a single current source of I_N amperes and a single impedance R_{eq} in parallel with it, across the two terminals of the load R_L. The I_N is the short circuit current flowing through the short circuited path, replaced instead of R_L. It is also called Norton's current. The R_{eq} is the equivalent impedance of the given network as viewed through the load terminals, with R_L removed and all the active sources are replaced by their internal impedances. If the internal impedances are unknown then the independent voltage sources must be replaced by short circuit while the independent current sources must be replaced by open circuit, while calculating R_{eq}.

(b) Using Superposition theorem, find the current in 20 Ω resistor of the circuit shown in figure. 1.

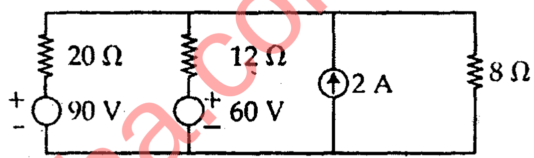


Fig. 1

Considering 90V source

$R_{eq} = (12 \| 8) + 20 = 24.8$ Ohm

$I' = 90/24.8 = 3.63$ A (upwards)

Considering 60V source

$R_{eq} = (20 \| 8) + 12 = 17.71$ Ohm,

$$\text{Current from 60 V source} = \frac{60}{17.71} = 3.38A$$

So $I'' = 3.38 * 8/28 = 0.96$ A (Downwards)

Considering 2A source, current in the parallel combination of 20Ω & 12Ω

$$= 2 \times \frac{8}{15.5} = 1.03A$$

$I''' = 12/32 * 1.03 = 0.386$ A (Downwards)

$I = I' + I'' + I''' = 3.63 - 0.96 - 0.386 = 2.284$ A (Upwards)

(c) In the given circuit shown in figure-2, find the resistance between the points B and C.

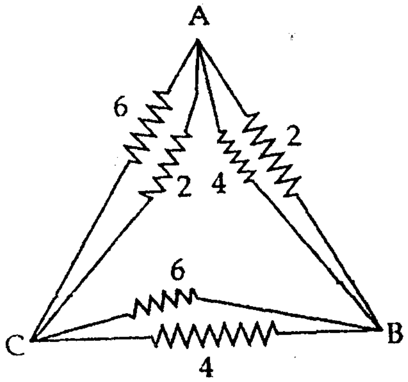


Fig. 2

Ans. Calculating equivalent resistances of all the three parallel branches

$$R_{ac} = 1.5 \text{ Ohm } = \frac{6 \times 2}{6+2}$$

$$R_{bc} = 2.4 \text{ Ohm } = \frac{6 \times 4}{6+4}$$

$$R_{ab} = 1.33 \text{ Ohm } = \frac{4 \times 2}{4+2}$$

Equivalent resistance between B & C

$R_{BC} = (2.4!! \, 2.83) = 1.3$ Ohm

4. Attempt any two parts :

(a) A 140 V DC shunt motor has an armature resistance of 0.2 ohm and a field resistance 70 ohm. The full load line current is 40 A and the full load speed is 1800 rpm. If the brush contact drop is 3 V, find the speed of the motor at half load.

Ans. V = 140V, Ra = 0.2 Ohm, Rsh = 70 Ohm, I_L = 40A, N_{FL} = 1800 rpm, V brush = 3V

$N_{FL}/N_{HL} = E_{FL}/E_{HL}$

Ish = 140/70 = 2A

Ia = 40 − 2 = 38A

Ia (half load) = 20 − 2 = 18A

$1800/N_{HL} = (140 - 38 * 0.2 - 3)/(140 - 18*0.2 - 3)$

$N_{HL} = 1800 * 133.4/129.4 = 1855.64$ RPM

(b) Sketch and explain the speed-load characteristics of following dc motor :

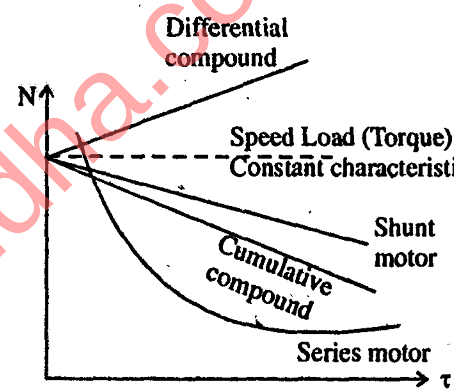
(i) Series motor

(ii) Shunt motor

(iii) Cumulatively compounded motor

(iv) Differentially compound motor

Ans. Speed load characteristic of DC motor : Compound motor characteristics basically depends on the whether the motor is cumulatively compound or differential compound. All the characteristics of the compound motor are the combination of the shunt and series characteristic.



Cumulative compound motor is capable of developing large amount of torque at low speeds just like series motor. However, it is not having a disadvantage of series motor even at light or no load. The shunt field winding produces the definite flux and series flux helps the shunt field flux to increase the total flux level.

So comulative compound motor run at a reasonable speed and will not run with dangerously high speed like series motor, on light or no load condition.

In differential compound motor, as two fluxes oppose each other, the resultant flux decreases as load increases, thus the machine runs at a higher speed with increase in the load. This property is dangerous as on full load, the motor may try to run with dangerously high speed. So differential compound motor is generally not used in practice. The exact shape of these characteristics depends on the relative contribution of series and shunt field windings. If the shunt field winding is more dominant then the characteristics take the shape of the shunt motor characteristics. While if the series field winding is more dominant then the characteristics take the shape of the series characteristics.

(c) Discuss the principle of operation and deduce the emf equation for synchronous motor.

Ans. Principle of operation of synchronous motor : Synchronous motor works on the principle of the magnetic locking. When two unlike poles are brought near each other, if the magnets are strong, there exists a tremendous force of attraction between those two poles. In such condition, the two magnets are said to be magnetically locked. If now one of the two magnets is rotated, the other also rotates in the same direction, with the same speed due to the force of attraction i.e. due to magnetic locking condition. The principle is shown schematically in the Fig.

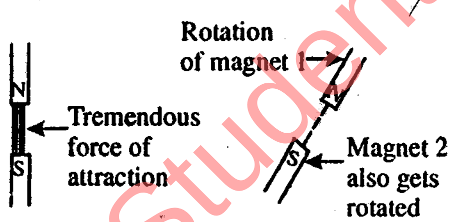


Fig. Principle of magnetic locking

So to have the magnetic locking condition, there must exist two unlike poles and magnetic axes of two must be brought very close to each other.

EMF equation for synchronous generator

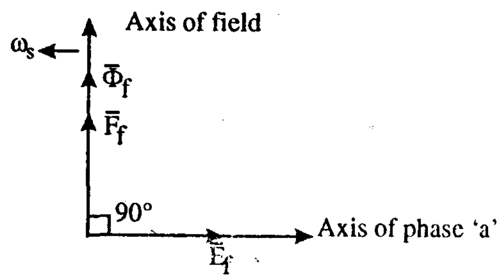
Consider now the space vector $\vec{F}_f$ as seen from the axis of coil aa′ on the stator. As $\vec{F}_f$ rotates at synchronous speed, it appears to be sinusoidally time-varying at $\omega_s = 2\pi f$ elect. rad/s as is evident from the developed diagram of Fig. Furthermore, when the maximum positive value of F_f space wave is directed along the axis of coil aa′, the flux linkage of the coil has maximum positive value. It may, therefore, be considered that the rotating space vector $\vec{F}_f$ as seen from the stator is a time phasor $\bar{F}_f$ which is in phase with the flux phasor $\bar{\varphi}_f$ as shown in Fig. The magnitude relationship between $\bar{\varphi}_f$ and $\bar{F}_f$ will be governed by the magnetization curve; this will be linear if the iron is assumed to be infinitely permeable in which case

$$\varphi_f = \varphi F_f$$

Where φ = permeance per pole

The emf induced in the coil aa′ of N turns is given by Faraday's law,

$$e_{af} = -N\frac{d\lambda}{dt}$$



$$= -N\frac{d}{dt}\left(\varphi_f \cos\omega_s t\right)$$

$$= N\omega_s\varphi_f \sin\omega_s t$$

It immediately follows from above eq. that the rms value of the emf induced in coil aa′ is

$$E_f = \sqrt{2}\,\pi f\, N\varphi_f$$

Wherein $\varphi_f = \varphi_f'(F_f)$ or $\varphi_f(I_f)$ flux/pole

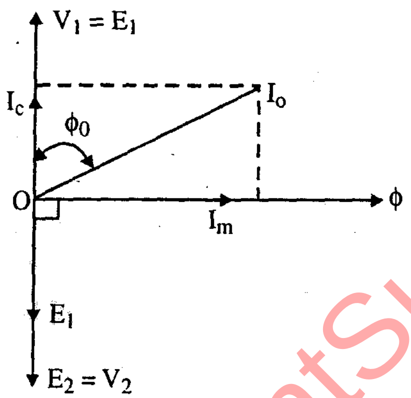
I_f being the direct current in the rotor field. Equation between the flux/pole and field current is indeed the magnetization characteristic. Equation suitably modified for a distributed (and also possibly short-pitched) stator winding is

$$E_f = \sqrt{2}\,\pi K_w f N_{ph} \varphi_f$$

5. Attempt any two parts :

(a) Draw and explain the no-load and full-load phasor diagram for a single phase transformer.

Ans. Phasor diagram of transformer at no load



When transformer is loaded, the primary current I_1 has two components :

1. The no load current I_0 which lags V_1 by angle ϕ_0. It has two components I_m and I_e.
2. The load component I'_2 which is in antiphase with I_2. And phase of I_2 is decided by the load.

Hence primary current I_1 is vector sum of I_0 and I'_2.

$$\therefore\ \bar{I}_1 = \bar{I}_0 + \bar{I}'_2$$

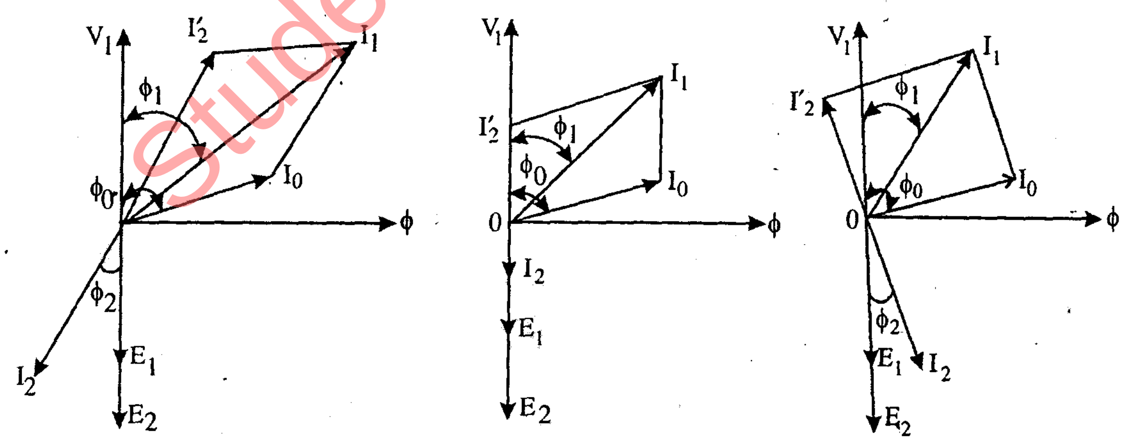
Assume inductive load, I_2 lags E_2 by ϕ_2, the phasor diagram is shown in the Fig. (a)

Assume purely resistive load, I_2 in phase with E_2, the phasor diagram is shown in the Fig. (b).

Assume capacitive load, I_2 leads E_2 by ϕ_2, the phasor diagram is shown in the Fig.(c).

Note that I'_2 is always in antiphase with I_2.

Actually the phase of I_2 is with respect to V_2 i.e. angle ϕ_2 is angle between I_2 and V_2. For the ideal case, E_2 is assumed equal to V_2 neglecting various drops.



(a) Inductive load **(b) Resistive load** **(c) Capacitive load**

(b) **A transformer has a primary winding of 600 turns and a secondary winding of 150 turns. When the load current on the secondary is 60 A at 0.8 power factor lagging, the primary current is 20 A at 0.707 power factor lagging. Determine the no-load current of the transformer and its phase with respect to the voltage.**

Ans. $N_1 = 600$ turns

$N_2 = 150$ turns

$I_2 = 60A \;\; \cos\phi_2 = 0.8, \; \phi_2 = 36.9°$

$I_1 = 20A \;\; \cos\phi_1 = 0.707, \; \phi_1 = 45°$

$$K = 0.25 = \frac{N_2}{N_1}$$

$I_1' = K\,I_2 = 0.25 * 60 = 15$ A

$I_0 \cos\phi_0 = 20\cos45 - 15\cos36.9 = 14.14 - 12 = 2.14$ A

$I_0 \sin\phi_0 = 20\sin45 - 15\sin36.9 = 14.14 - 9 = 5.14$ A

$\tan\phi_0 = 5.14/2.14 = 2.4$

$\phi_0 = 67.39°$

$I_0 = 2.14/0.38 = 5.63$ A

(c) **Explain why the hysteresis and eddy current losses occur in the transformer. How does change in frequency affect the operation of given transformer?**

Ans. Hysteresis loss occurring in the magnetic frame of the transformer depends upon the following.

(i) Area of the hysteresis loop of magnetic material used for magnetic frame, which again depends upon the flux density at which the material is being worked.

(ii) Volume of the core.

(iii) Frequency of magnetic flux reversal.

Dr. Charles Steinmetz suggested an empirical formula based on a series of tests for calculating the hysteresis loss and is given by

$$\text{Hysteresis loss} = \eta V f (B_{max})^{\eta} \text{ watt}$$

Where η varies from 1.6 to 2.1 depending upon the material of magnetic frame and η is a constant for a particular material and is commonly known as Steinmetz's coefficient.

Eddy current loss is due to the flow of eddy current in the magnetic core and yoke of the transformer, caused by small emf induced in the magnetic frame. Eddy current loss depends upon the following factors.

(i) Thickness of lamination of magnetic core and yoke, t.

(ii) Frequency of flux reversal, f.

(iii) Maximum value of flux density in core and yoke, B_{max}.

(iv) Volume of core and yoke, V.

(v) Quality of magnetic material used for the magnetic frame.

Hence, eddy current losses in core and yoke of a transformer are given by,

$$\text{Eddy current loss} = k\,V\,B_{max}^2\,f^2\,t^2 \text{ watts}$$

Thus, eddy current losses are directly proportional to the square of maximum value of flux density, frequency of flux reversal and thickness of lamination of magnetic frame. Eddy current losses are reduced by decreasing the thickness of lamination and also by adding a certain percentage (3 to 4 per cent) of silicon to steel. Addition of silicon to steel increases the electrical resistivity there by decreasing the eddy current loss.

6. Attempt any two parts :

(a) Power measurement by two wattmeter explain the significance of (i) equal wattmeters readings (ii) zero reading on one wattmeters using suitable phasor diagram.

Ans. Reading of wattmeter W_2 is zero, when the load power factor is 0.5 lagging, i.e. $\phi = 60°$.

Both the wattmeters will indicate the same readings, when the power factor of the load is unity, i.e $\phi = 0$.

(b) Two impedances $Z_1 = (10 + j15)$ ohms and $Z_2 = (6 - j8)$ ohms are connected in parallel. The total current supplied is 15A. What is the power taken by each impedance?

Ans.

$Z_1 = (10 + j15)$ Ohm $= 18.03 \angle 56.31°\Omega$

$Z_2 = (06 - j8)$ Ohm $= 10 \angle -53.13°\Omega$

$Zeq = Z_1 !! Z_2$

$Zeq = 10.31 \angle -20.39$ Ohm

$V = 15 * 10.31 \angle -20.39 = 154.65 \angle -20.39$ V

$I_1 = 154.65 \angle -20.39/18.02 \angle 56.3 = 8.58 \angle -76.69$ A

$I_2 = 154.65 \angle -20.39/10 \angle -53.13 = 15.46 \angle -32.74$ A

Power consumed by Z_1

$= I_1^2\,R_1 = (8.58)^2 * 10 = 736$ Watt

Power consumed by Z_2

$= I_2^2\,R_2 = (15.46)^2 * 6 = 1434$ Watt

(c) Show that the power intake by a three-phase circuit can be measured by two wattmeters connected properly in a circuit.

Ans. Power measurement by two wattmeter method: Power in a 3-phase three-wire system, with balanced or unbalanced load can be measured by using two wattmeters. The load may be star or delta connected. The current coils of the two wattmeters are connected in any of the two lines and the pressure coils are connected between these lines and the third line, as shown in Fig. Let e_{RN}, e_{YN} and e_{BN} be the voltages across the three phases of the load and i_R, i_Y and i_B the currents flowing in the three lines.

Total instantaneous power in the load

$= e_{RN} i_R + e_{YN} i_Y + e_{BN} i_B$

Instantaneous current through the current coil of wattmeter $W_1 = i_R$

Instantaneous voltage across the pressure coil of wattmeter W_1

$e_{RB} = e_{RN} - e_{BN}$

Instantaneous power measured by wattmeter $W_1 = i_R \times (e_{RN} - e_{BN}) = i_R \times e_{RB}$

Instantaneous current through current coil of wattmeter $W_2 = i_Y$

Instantaneous voltage across the pressure coil of wattmeter W_2

$e_{YB} = e_{YN} - e_{BN}$

Instantaneous power measured by

$W_2 = i_Y \times (e_{YN} - e_{BN}) = i_Y \times e_{YB}$

Total instantaneous power $= e_{RN} i_R + e_{YN} i_Y + e_{BN} i_B$

Moreover, for 3-phase, 3-wire system,

$i_R + i_Y + i_B = 0$

$\therefore \quad iB = -(i_R + i_Y)$

Substituting the value of i_B in Eq (1)

Total instantaneous power

$= e_{RN} i_R + e_{YN} i_Y + e_{BN} (-i_R - i_Y)$

$= i_R (e_{RN} - e_{BN}) + i_Y (e_{YN} - e_{BN})$

= Power measured by W_1 + Power measured by W_2

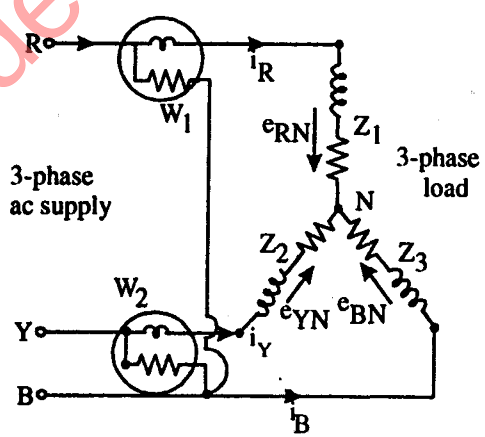


Fig. Measurement of power in 3-phase, three-wire system

7. **Attempt any two parts :**

(a) **Explain why moving Iron type of instrument is suitable both on DC and AC. Also differentiate between moving iron type instrument and moving coil permanent magnet instrument.**

Ans. The various advantages of moving iron instruments are

1. The instruments can be used for both a.c. and d.c. measurements.
2. As the torque to weight ratio is high, errors due to the friction are very less.
3. A single type of moving element can cover the wide range hence these instruments are cheaper than other types of instruments.
4. There are no current carrying parts in the moving system hence these meters are extermely rugged and reliable.
5. These are capable of giving good accuracy. Modern moving iron instruments have a d.c. error of 2% or less.
6. These can withstand large loads and are not damaged even under severe overload conditions.
7. The range of instruments can be extended.

Since $Q \propto I^2$ in these instruments, so moving non-instruments are suitable for both DC and AC.

Q = deflection of pointer, I = current through instrument

The variuos advantages of PMMC instruments are,

1. It has uniform scale.
2. With a powerful magnet, its torque to weight ratio is very high. So operating current is small.
3. The sensitivity is high.
4. The eddy currents induced in the metallic former over which coil is wound, provide effective damping.
5. It consumes low power, of the order of 25 W to 200 μW.
6. It has high accuracy.
7. Instrument is free from hysteresis error.
8. Extension of instrument range is possible.
9. Not affected by external magnetic fields called stray magnetic fields.

Here $Q \propto I$, So these instruments are suitable only for DC.

(b) **A moving-coil milli-ammeter having a resistance of 8Ω gives full scale deflection when a current of 5 mA is passed through it. Explain how this instrument can be used for measurement of (i) current up to 2 A (ii) voltages up to 8 V.**

Ans. Rm = 8 ohm

Im = 5 mA

(i) $m = \frac{2}{5 \times 10^{-3}} = 400$

$$R_{sh} = \frac{R_m}{m-1} = \frac{8}{400-1} = 0.02\ \Omega$$

(ii) $R_{se} = \frac{8}{5 \times 10^{-3}} - 8 = 1600 - 8 = 1592\ \Omega$

(c) Give the construction and working of dynamometer watt meter.

Ans. Electrodynamometer Wattmeter : The wattmeter is a device which is used to measure power as it has to sense cos ϕ and just voltmeter and ammeter are sufficient to measure power.

An electrodynamometer type wattmeter is used to measure power. It has two coils, fixed coil which is current coil and moving coil which is pressure coil or voltage coil. The current coil carries the current of the circuit while pressure coil carries current proportional to the voltage in the circuit. This is achieved by connecting a series resistance in voltage circuit.

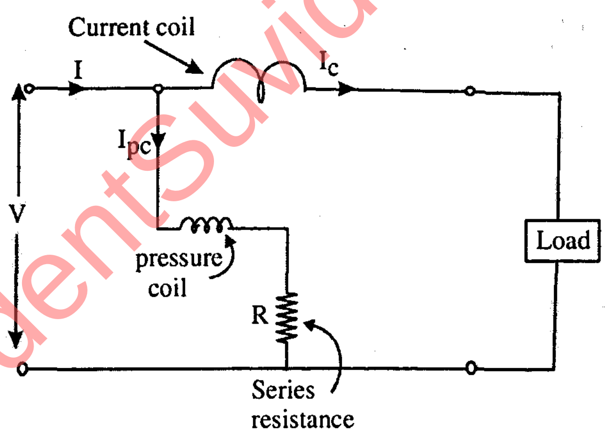


Fig. Electrodynamometer wattmeter

Reading on Wattmeter : The Fig. shows symbolic representation of wattmeter.

Thus if, I_c = Current through current coil

V_{pc} = Voltage across pressure coil

Then wattmeter reading is,

$$\boxed{W = V_{pc} I_c \cos (V_{pc} \wedge I_{pc})}$$

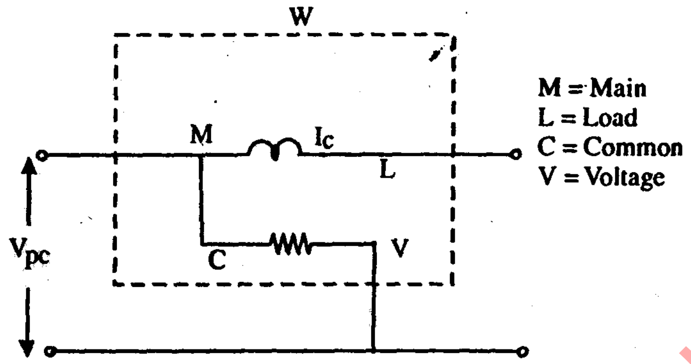


Fig. Symbolic representation of wattmeter

Key point : The angle between V_{pc} and I_{pc} may or may not be power factor angle ϕ. It depends on the wattmeter connection in the circuit.

Thus, if wattmeter is connected in a three phase circuit such that $I_C = I_{ph}$ and $V_{pc} = V_{ph}$ then only V_{pc} ^ I_{pc} $= \phi$

Key point : In a three phase circuit, angle V_{pc} and I_{pc} is to be obtained from the corresponding phasor diagram.