B.TECH.

SECOND SEMESTER EXAMINATION, 2009-10

ELECTRICAL ENGINEERING

Time : 3 Hours] *[Total Marks : 100*

Note : *Attempt all the questions.*

SECTION - A

Q. 1. Attempt all parts : (20 × 1 = 20)

Q. 1. (a) Among following which conductor has highest conductivity ?

(i) Cu (ii) Al

(iii) Ag (iv) Mg

Ans. (i) Cu

Q. 1. (b) The mass of electron is ....

Ans. 9.1×10^{-31} Kg.

Q. 1. (c) Pure inductive circuit :

(i) consames 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. (i) consumes some power on average.

Q. 1. (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).

Q. 1. (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).

Q. 1. (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. (iv) infinite source resistance

Q. 1. (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. (ii) two wattmeters method only.

Q. 1. (h) At resonance power factor of series R-L-C circuit would be :

(i) 0 (ii) 1 (iii) – 1 (iv) 1.1

Ans.

Q. 1. (i) A transformer transforms :

(i) voltage (ii) current

(iii) voltage and current (iv) frequency.

Ans. (i) voltage.

Q. 1. (j) A transformer can be connected to DC :

(i) Yes (ii) No

Ans. (ii) No.

Q. 1. (k) Slip rings are made of aluminium :

(i) Yes (ii) No.

Ans. (ii) No.

Q. 1. (l) The form factor sinusoidal alternating current is :

(i) 1 (ii) 0 (iii) 1.11 (iv) 1.15

Ans. (iii) 1.11

Q. 1. (m) Three phase induction motor has a low efficiency :

(i) Yes (ii) No.

Ans. (i) Yes.

Q. 1. (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. (i) slip ring motors.

Q. 1. (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. (i) 1/V

Q. 1. (p) What will happen if the back emf of DC motor vanishes ?

Q. 1. (q) .... Motor has self load properties.

Ans. $3-\phi$ I.M Motor has self load properties.

Q. 1. (r) .... Motor will be preferred for elevators.

Ans. Synchronous.

Q. 1. (s) Synchronous motor can be used as power factor improving device.

(i) Yes (ii) No.

Ans. (ii) No.

Q. 1. (t) Ceiling fan is :

(i) three phase IM

(ii) single phase IM

(iii) single phase synchronous motor

(iv) none of these.

Ans. single phase IM.

SECTION-B

Q. 2. Attempt any three : (3 × 10 = 30)

(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.

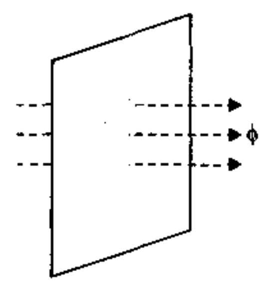
Ans. (i) Magnetic flux : The magnetic field cannot be detected by any of our personal senses but its effects can be observed in many ways. To identify the magnetic field quantitatively (*i.e.*, with numbers), we generally use the term magnetic flux.

The amount of magnetic field produced by a magnetic source is called **magnetic flux.**

Magnetic flux is denoted by Greek letter ϕ. If 10 magnetic lines come out of the north pole or enter the south pole of a magnet, then magnetic flux $\phi = 10$ lines or maxwells. The *SI* unit of magnetic flux is *weber.*

$$1 \text{ Wb} = 10^8 \text{ lines}$$

(ii) Magnetic Flux Density : The magnetic flux density is the flux per unit area at right angles to the flux (See. Fig. (a)) *i.e.*



Area 'A' normal to ϕ

Fig. (a)

Magnetic flux density, $B = \dfrac{\phi}{A}$ Wb/m^2

where ϕ = magnetic flux in Wb

A = area in m^2 normal to flux

The *SI* unit of magnetic flux density is Wb/m^2 or *tesla. Flux density is a measure of field concentration *i.e.*, amount of flux in each square metre of the field. In practice, it is much more important than the total amount of flux.

(i) Right-hand rule : *Hold the conductor in the right hand with the thumb pointing in the direction of current (See fig. (b)). Then the fingers will point in the direction of magnetic field around the conductor.*

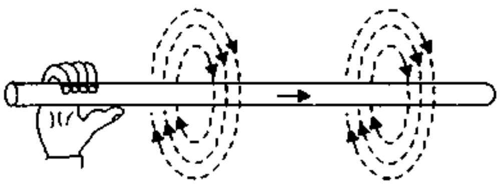


Fig. (b)

Applying this rule to Fig. (b) it is clear that when viewed from left hand side, the direction of magnetic lines of force will be clockwise.

(ii) Cork screw rule : *Hold the cork screw in your-right hand and rotate it in such a way that it advances in the direction of current.Then the direction in which the hand rotates will be the direction of magnetic lines of force.*

Referring to Fig(b) and applying cork screw rule, the direction of magnetic lines of force will be clockwise.

Right-hand rule for coil :The magnetic polarity of a coil of several turns or a * solenoid can be determined by right hand rule for coil stated below:

Grasp the whole coil with right hand so that the fingers are curled in the direction of current. The thumb stretched parallel to the axis of the coil will point towards the n-pole end of the coil (see Fig. (c))

It may be noted that both right-hand rules (for a conductor and for a coil) discussed so far can be applied in reverse. If we know the direction of magnetic field encircling a conductor or the magnetic polarity of a coil, we

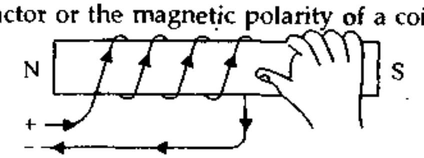


Fig. (c)

can determine the direction of current by applying appropriate right-hand rule.

Fleming's Left-hand Rule :*Stretch out the first finger, second finger and thumb of your left hand so that they are at right angles to one another. If the first finger points in the direction of magnetic field (North to South) and second finger (i.e. middle finger) points towards the direction of current, then the thumb will point in the direction of motion of the conductor.*

Applying Fleming's Left-Hand Rule to Fig(d) (i), it is clear that the force F on the conductor will act vertically upwards. Note that if direction of any two of F, B and I is known, the direction of the third can be found by this rule.

If the conductor and magnetic field make an angle θ as shown in Fig (*d*) (*ii*), then effective length (*i.e.* length presented normally to magnetic field) is $l\sin\theta$ and the force is given by;

$$F = Bil \sin \theta \text{ Newtons}$$

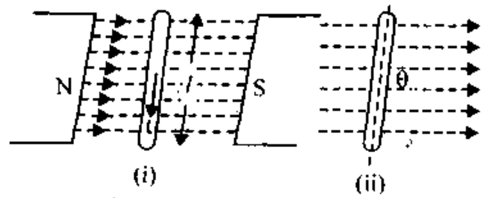


Fig. (d)

Q. 2. (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 expression for the resultant voltage. Check the result so obtained graphically.

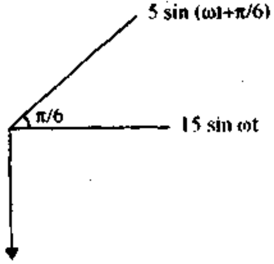
Ans. $e_1 = 15 \sin \omega t$

$e_2 = 5 \sin (\omega t + \pi/6)$

$e_3 = 10 \cos \omega t$

$= 10 \sin (\omega t - \pi/2)$

Phasor Diagram



In X direction

$= 15 \cos 0 + 5 \cos \pi/6 + 10 \cos\left(\frac{-\pi}{2}\right)$

$10 \sin\left(\omega t - \frac{\pi}{2}\right)$

= 19.33

In Y direction

= 15 sin 0 + 5 sin π/6 + 10 sin (– π/2)

= – 7.5

Resultant :

$= \sqrt{x^2 + y^2} = 373.65 + 56.25 = 20.73$

Phase angle $\tan^{-1} y/x$

= – 212°

Q. 2. (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. $N_S = \frac{120 f}{P}$

$\frac{960}{120 \times 50} = \frac{1}{P}$

Pole = P = 6.25 = 6 Pole

$N_r = \frac{120 \times f}{P} = 1000$

$S = \frac{N_S - N_r}{N_S} = \frac{960 - 1000}{960}$

Slip : $S \doteq 4\%$

$f_2 = Sf_1$

Frequency $f_2 = 2$ Hz

Q. 2. (d) List out main components of power supply system with a brief description. Also write the advantages of power factor improvement.

Ans. Main components are generator, wire for transmission, primery and secondary winding, Receiver terminal, transformer.

Adv. of p.f. improvement : It include the efficiency incrimnent in the given machine.

It give the long life to the instrument working function will improves.

Q. 2. (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. Resonance in R–L–C Circuit : A series circuit is said to be in resonance when circuit power factor is unity *i.e.* $X_L = X_C$. The frequency f_r at which it occurs is called the *resonant frequency.* At a certain frequency, called the resonant frequency f_r, X_L becomes equal to X_C and series resonance occurs.

At series resonance, $X_L = X_C$.

or $2\pi f_r L = \frac{1}{2\pi f_r C}$

∴ Resonant frequency, $f_r = \frac{1}{2\pi\sqrt{LC}}$

If L and C are measured in henry and farad respectively, then f will be in Hz.

Resonance in Parallel Circuits : A parallel circuit containing reactive elements (L and C) is said to be in resonance when the circuit p.f. is unity *i.e.*. the reactive component of line current is zero. The frequency at which it occurs is called the *resonant frequency* f_r.

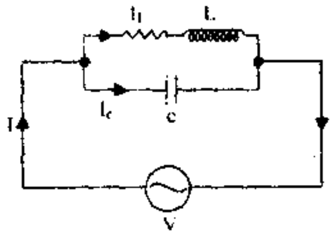
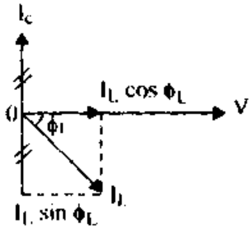


Fig. (a) (i)



(ii)

Consider the most common parallel circuit consisting of a coil shunted by a capacitor as shown in Fig. (a) (*i*). The phasor diagrm of this circuit in fig. (a) (ii). The circuit will be in resonance when the reactive component of line current is zero *i.e.* $I_C - I_L \sin \phi_I = 0$. This can be achieved by changing the supply frequency because both I_C and $I_L \sin \phi_L$ are frequency *dependent. At some frequency called resonant frequency f_r, the reactive component of line current will be zero and resonance takes place.

At parallel resonance, we have,

$$I_C - I_L \sin \phi_I = 0$$

or $$I_C = I_L \sin \phi_L$$

or $$\frac{V}{X_C} = \frac{V}{Z_L} \times \frac{X_L}{Z_L}$$

or $$X_L X_C = Z_L^2$$

or $$\omega L / \omega C = Z_L^2 \quad ...(i)$$

or $$L/C = R^2 + (2\pi f_r L)^2$$

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

or $$2\pi f_r L = \sqrt{\frac{L}{C} - R^2}$$

or $$f_r = \frac{1}{2\pi L}\sqrt{\frac{L}{C} - R^2}$$

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

If the coil resistance is small (as is generally the case), then

$$f_r = \frac{1}{2\pi\sqrt{LC}} \quad \textit{... as for series resonance}$$

The resonant frequency will be in *Hz* if *R*, *L* and *C* are measured in ohms, henry and farad respectively.

SECTION - C

Q. 3. Attempt any two parts : (2 × 5 = 10)

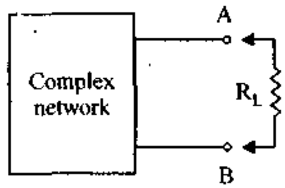
Q. 3. (a) State the Superposition and Norton's Theorem.

Ans. Superposition Theorem :The essence of superposition theorem is that an e.m.f. acting in a *linear network produces the same effect whether it acts alone or in conjunction with other e.m.f.s. The theorem may be stated as under:

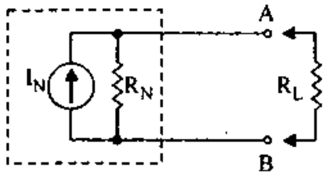
In a linear network containing more than one source of e.m.f., the resultant current in any branch is the algebraic sum of the currents that would be produced by each e.m.f., acting alone. all other sources of e.m.f. being replaced meanwhile by their respective internal resistances.

Norton's Theorem : Fig (a) (i) shows a network enclosed in a box with two terminals *A* and *B* brought out. The network in the box may contain any number of resistors and e.m.f. sources connected in any manner. But according to Norton, the entire circuit behind *AB* can be replaced by a current source I_N in parallel with a resistance R_N as shown in Fig. (a)(ii). The resistance R_N is the same as Thevenin resistance

$R_{Th.}$ The value of I_N is determined as mentioned in Norton's theorem. Once Norton's equivalent circuit is determined [See Fig. (a) (ii)], then current through any load R_L connected across AB can be readily obtained.

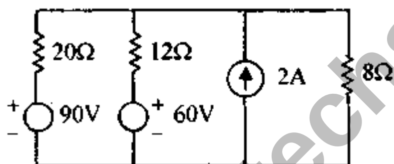


(i)



(ii)

Q. 3. (b) Using Superposition theorem find the current in 20 Ω resistor of the circuit shown in Figure.



Ans. Using superposition theorem

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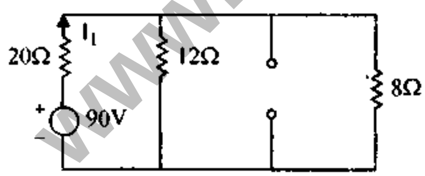

$$R + h_1 = 12118 + 20$$

$$= \frac{12 \times 8}{12 + 8} + 20$$

$$= \frac{96}{20} + 20 = 4.8 + 20 = 24.8\,\Omega$$

$$I_1 = \frac{90}{24.8} = 3.62 \text{ A}$$

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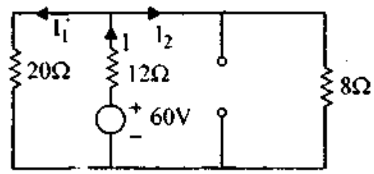


$$R + h = 20118 + 12$$

$$= \frac{20 \times 8}{20 + 8} + 12$$

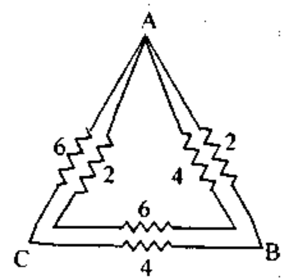
$$= \frac{160}{28} + 12$$

$$= 17.71\,\Omega$$

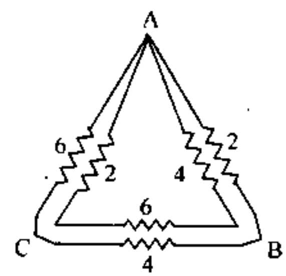
$$I = \frac{60}{17.17}$$

$$= 3.49$$

Q. 3. (c) In the given circuit shown in figure find the resistance between the points B and C.



Ans.



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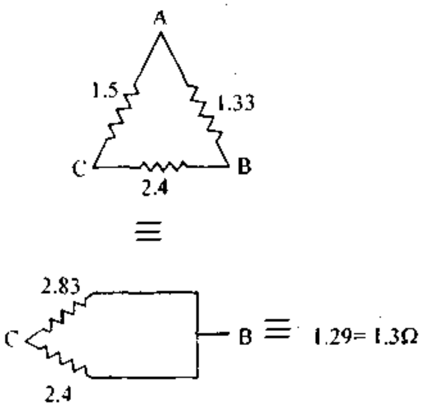


Q. 4. Attempt any two parts :

Q. 4. (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. $E_{b1} = V - I(R_a + R_{se})$

– brush contact drop

$= 140 - 40\,(0.2 + 70) - 3$

$= -423$ V

back emf when line current is 40 A

$E_{b2} = 140 - 20\,(.2 + 70) - 3$

$= 126$ V

$$\frac{\phi_2}{\phi_1} = \frac{I_2}{I_1}$$

$$= \frac{40}{20} = 2$$

$$N_2 = N_1 \times \frac{Eb_2}{Eb_1} \times \frac{\phi_1}{\phi_1}$$

$$= 1800 \times \frac{126}{423} \times \frac{1}{2}$$

$= 268$ rpm

Q. 4. (b) Sketch and explain the speed-load characteristics of following dc motor :

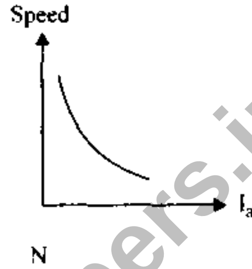
(i) Series motor

(ii) Shunt motor

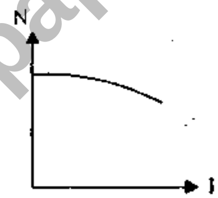
(iii) Cumulatively compounded motor

(iv) Differentially compound motor

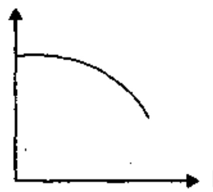
Ans. (i) Series :



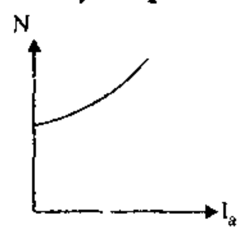
(ii) Shunt :



(iii) Cumulative compound:



(iv) Differentially compound :



Q. 4. (c) Discuss the principle of operation and deduce the emf equation for synchronous motor.

Ans. Operating Principle : The fact that a synchronous motor has no starting torque can be easily explained.

(*i*) Consider a 3-phase synchronous motor having two rotor poles N_R and S_R. Then the stator will also be wound for two poles N_S and S_S. The motor has direct voltage applied to the rotor winding and a 3-phase voltage applied to the stator winding . The direct (or zero frequency) current sets up a two-pole field which is stationary so long as the rotor is not turning. Thus we have a situation in which there exists a pair of revolving armature poles (*i.e.*, $N_S - S_S$) and a pair of stationary rotor poles (*i.e.*, $N_R - S_R$).

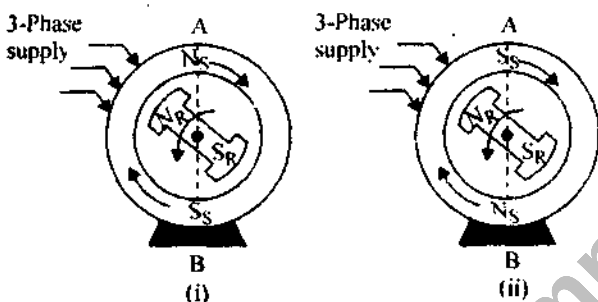


Fig. (a)

(ii) Suppose at any instant, the stator poles are at positions A and B as shown in Fig. a(i). It is clear that poles N_S and N_R repel each other and so do the poles S_S and S_R. Therefore the rotor tends to move in the anticlockwise direction.

Now S_S and N_R attract each other and so do N_S and S_R. Therefore, the rotor tends to move in the clockwise direction. Since the stator poles change their polarities rapidly, they tend to pull the rotor first in one direction and then after a period of half-cycle in the other.

Hence, a synchronous motor has no self starting torque i.e., a synchronous motor cannot start by itself.

EMf Equation : Since n revolutions are made in one second, one revolution will be made in 1/n second. Therefore the normal time for one revolution of the armature is $1/n$ second. The average voltage generated per conductor.

$$E_{av} / \text{Conductor} = \frac{P\Phi}{1/n} = nP\Phi \text{ volts} \quad ...(1)$$

We know that

$$f = \frac{PN}{120} = \frac{Pn}{2} \quad ...(2)$$

$$Pn = 2f$$

Substituting the value of Pn in Eq.(1) we get

$$E_{av} / \text{Conductor} = 2 f\Phi \quad ...(3)$$

Since there are Z_p conductors in series per phase, the average voltage generated per phase is given by

$$E_{av} / \text{phase} = 2 f\Phi Z_p \quad ...(4)$$

Since one turn or coil has two sides, $Z_p = 2T_p$ and the expression for the average generated voltage per phase can be written as

$$E_{av} / \text{phase} = 4 f\Phi T_p \quad ...(5)$$

For the voltage wave, the form factor is given by

$$k_f = \frac{\text{r. m. s. value}}{\text{average value}}$$

For a sinusoidal voltage, $k_f = 1.11$. Therefore, the r. m. s. value of the generated voltage per phase can be written as

$$E_{r.m.s.} / \text{phase} = k_f \times E_{av} / \text{phase}$$

$$= 1.11 \times 4 f\Phi T_p$$

$$= 4.44 f\Phi T_p$$

The suffix r. m. s. is usually deleted. The r. m. s. value of the generated voltage per phase is given by

$$E_p = 4.44 f\Phi T_p \quad ...(6)$$

Equation (6). has been derived with the following *assumptions* :

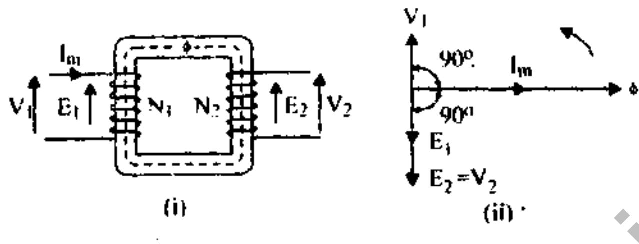
(*a*) Coils have got full pitch.

(*b*) All the conductors are concentrated in one stator slot.

Q. 5. Attempt any two parts : (2 × 5 = 10)

Q. 5. (a) Draw and explain the no-load and full-load phasor diagram for a single phase transformer.

Ans. Phasor Diagram at No Load :



Phasor Diagram at Full Load :

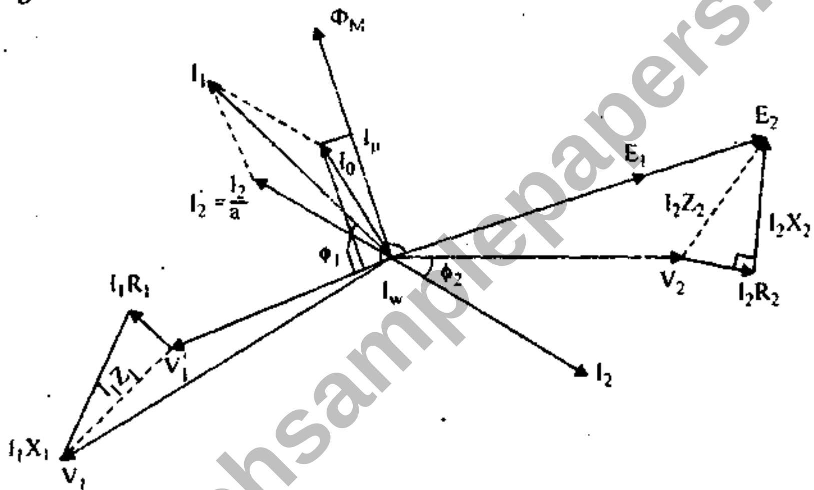


Fig. Phasor diagram for the exact equivalent circuit of real transformer

$$I_1' = \frac{8 \times 3.49}{20 + 8} = 0.997 \text{ A}$$

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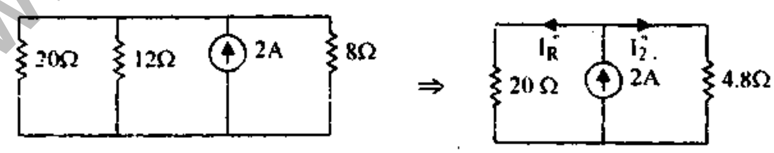


$$I_1'' = \frac{2 \times 4.8}{20 + 4.8} = 0.387 \text{ A}$$

The total I will $= I_1 - I_1' - I_1''$

$= 3.62 - 0.997 - 0.387$

$= 2.235$ A

Q. 5. (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. $\frac{N_1}{N_2} = \frac{I_1}{I_2} = \frac{V_2}{V_1}$

$\frac{4600}{150} = \frac{20}{60} = \frac{1}{4}$

No load Power = 75 W

Primary volt = 120 V

Primary resistance = 0.4 Ω

Copper loss in primary winding

$P_C = I_0^2 R_1 = (1.5)^2 \times 0.4 = 0.9$ W

No Load iron loss

$= P_i = P_0 - P_C = 75 - 0.9 = 74.1$ W

Iron loss current

$= I_c = I_0 \cos \phi_0$

$= \frac{700}{2400} = 0.292$ A.

Magnetizing component of no load current

$I_m = \sqrt{I_0^2 - I_c^2}$

$= \sqrt{(0.64)^2 - (0.292)^2}$

$= 0.57$ A

$R_0 = \frac{V_1}{I_c} = \frac{2400}{0.292}$

$= 8,220\ \Omega$ or 8.2 kΩ

$X_0 = \frac{V_1}{I_m} = \frac{2400}{0.57}$

$= 4210\ \Omega$ or 4.2 kΩ

Q. 5. (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. Separation of Hysteresis and Eddy-Current Losses : The transformer core loss P_i has two components namely hysteresis loss P and eddy-current loss P_e.

$$P_i = P_h + P_e$$

$$P_i = K_h f B_m^n + K_e f^2 B_m^2 \quad ...(1)$$

where K_n = a constant whose value depends upon the ferromagnetic material

B_m = maximum value of the flux density

f = supply frequency

The exponent n varies in the range 1.5 to 2.5 depending upon the material. For a given B_m the hysteresis loss varies directly as the frequency and the eddy-current loss varies as the square of the frequency. That is ,

$$P_h \propto f \text{ or } P_h = af$$

and $$P_e \propto f^2 \text{ or } P_e = bf^2$$

where a and b are constants.

$$P_i = af + bf^2 \quad ...(2)$$

For separation of these two losses the no-load test is performed on the transformer. However, the primary of the transformer is connected to a variable frequency and variable sinusoidal supply and the secondary is open circuited.

Now $V = E = 4.44 f \Phi_m T$

or $\frac{V}{f} = 4.44\ B_m A_i T$

For any transformer T and A_i are constants. Therefore B_m will remain constant if the test is conducted so that the ratio (V / f) is kept constant.

Dividing Eq. (2) by f, we get

$$P_i / f = bf + a \quad ...(3)$$

During this test, the applied voltage V and frequency f are varied together so that (V / f) is kept constant. The core loss is obtained at different frequencies. A graph of (P_i / f) versus frequency f is plotted. This graph is a straight line AB of the form $y = mx + c$, as shown in Fig (b).

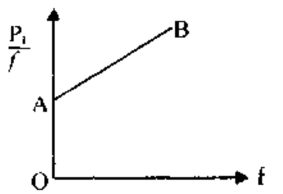


Fig. (b) m bariation of (P_i / f) with f

The intercept of the straight line on the vertical axis gives *a* and the slope of the line *AB* gives *b*.

Q. 6. Attempt any two parts : (2 × 5 = 10)

Q. 6. (a) Power measurement by two wattermeter explain the significance of (i) equal wattmeters readings (ii) zero reading on one wattmeters using suitable phasor diagram.

Ans. Deflecting torque : We shall now prove that deflecting torque is proportional to load power in a d.c. as well as a.c. circuit.

(*i*) Consider that the wattmeter is connected in a d.c. circuit to measure power as shown in Fig. (*ii*). The power taken by the load is VI_1.

Deflecting torque,

$$T_d \ \alpha \ I_1 I_2$$

Since I_2 is directly proportional to *V*.

∴Deflecting torque, T_d α VI_1 α load power

(*ii*) Consider that the wattmeter is connected in an a.c. circuit to measure power. Suppose at any instant, current through the load is *i* and voltage across the load is *v*. Let the load power factor be cos ϕ lagging. Then,

$$v = v_m \sin\theta$$

$$i = I_m \sin(\theta - \phi)$$

Instantaneous deflecting torque α *v i*

The pointer cannot follow the rapid changes in the instantaneous power owing to the large inertia of the moving system. Hence the instrument indicates the mean or average power.

∴ Average deflecting torque, T_d α Average of *v i* over a cycle

$$\alpha \ \frac{1}{2\pi}\int_0^{2\pi} V_m \ I_m \ \sin\theta \sin(\theta - \phi)\, d\theta$$

$$\alpha \ \frac{V_m I_m}{2} \cos\phi$$

$$\alpha \ V \ I \cos\phi$$

∴ T_d α load power

Thus whether the instrument is used to measure d.c. or a.c. power, deflecting torque is proportional to load power.

Since the instrument is spring -controlled, T_C α θ

In the steady position of deflection, $T_d = T_C$.

∴θ α load power

Hence such instruments have uniform scale.

Disadvantages :

(*i*) At low power factors, the inductance of the potential coil causes serious errors.

(*ii*) The readings of the instrument may be affected by stray magnetic fields. In order to prevent it, the instrument is shielded from the external magnetic fields by enclosing it in a soft-iron case.

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

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

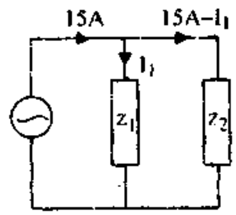
$$= \frac{180 + 10i}{(16 + 71°)}$$

$$= (9.67 - 3.6j)$$

given $I = 15$ A

$$P = I^2 Z$$

$$V = IR$$



$= 15\,(9.67 - 3.6\,j)$

$V = (145.05 - 54\,j)$ Volt

$V = I_1 Z_1$ ...(1)

$15\,Z_2 - I_1 Z_2 - I_1 Z_1 = 0$ ...(2)

from equation (1)

$145.05 - 54j = I_1(10 + 15j)$

$I_1 = 1.97 - 8.35\,j$

from equation (2)

$(90 - 120j) - I_1(6 - 8j) - I_1\,(10 + 15j) = 0$

$(90 - 120\,j) - (16 + 7j)\,I_1 = 0$

$$I_1 = \frac{90 - 120\,j}{16 + 7j}$$

$I_1 = 1.96 - 8.35$ J

Power in $Z_1 \Rightarrow P = I^2 R_1$

$= 1311 \angle -97° = P_1$

Power in Z_2

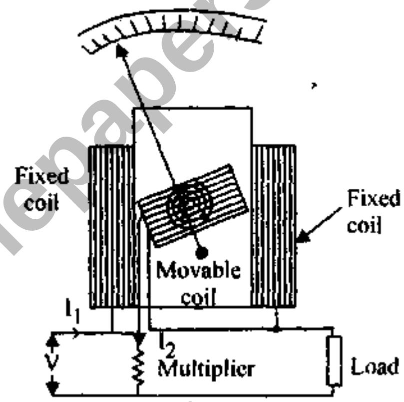
$P = (15 - I_1)^2 Z_2^{\,2} = (13 + 8.35j)^2\,(6 - 8j)$

$= 2392 \angle 12.2 = P_2$

Q. 6. (c) Show that the power intake by a three-phase circuit can be measured by two wattmeters connected properly in a circuit.

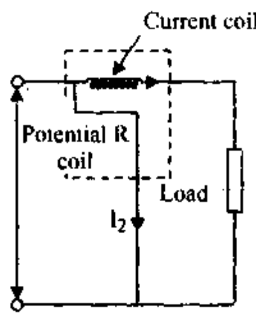
Ans. Dynamometer Wattmeter : A dynamometer wattmeter is almost universally used for the measurement of d.c. as well as a.c. power. It works on the dynamometer principle *i.e.* mechanical force exists between two current carrying conductors or coils.

Construction : When a dynamometer instruments is used as a wattmeter, the fixed coils are connected in series with the load and carry the load current (I_1) while the moving coil is connected across the load through a series multiplier R and carries a current (I_2) proportional to the load voltage as shown in Fig. (a). The fixed coil (or coils) is called the *current coil* and the movable coil is known as *potential coil*. The controlling torque is provided by two spiral springs which also serve the additional purpose of leading current into and out of the moving coil. Air friction damping is provided in such instruments. A pointer is attached to the movable coil.



(i)

Fig. (a)



(ii)

Working : When the wattmeter is connected in the circuit to measure power (See Fig.), the current coil carries the load current and potential coil carries current proportional to the load voltage. Due to currents in the coils, mechanical force exists between them. The result is that movable coil moves the pointer over the scale. The pointer comes to rest at a position where deflecting torque is equal to the controlling torque. Reversal of current reverses currents in both the fixed coils and the movable coil so that the direction of deflecting torque remains unchanged.

Hence, such instruments can be used for the measurement of d.c. as well as a.c. power.

Q. 7. Attempt any two parts : (2 × 5 = 10)

Q. 7. (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. Moving Iron Instruments : These instruments are widely used in laboratories and switchboards at commercial frequencies because these are cheaper in cost, robust in construction and can be manufactured with required accuracy.

There are two general types of such instruments *i.e.* (*i*) the *attraction type* and (*ii*) the *repulsion type*. The attraction type instruments operate on the principle of attraction of a single piece of soft iron into a magnetic field and repulsion type instruments operate on the principle of repulsion of two adjacent iron pieces magnetised by the same magnetic field. Repulsion type instruments are more sensitive as in these instruments large operating torque is developed by having two iron elements positioned close together inside the field coil where the magnetizing effect maximum is passed through a coil of wire. This current carrying coil sets up the necessary field. Depending on the magnitude of the current to be measured, the coil may be of a few turns of very heavy conductor or of many turns of fine wire.

(1) *Attraction Type Moving Iron Instruments* : The earliest and simplest form of attraction moving iron instruments uses a solenoid and moving oval shaped soft iron

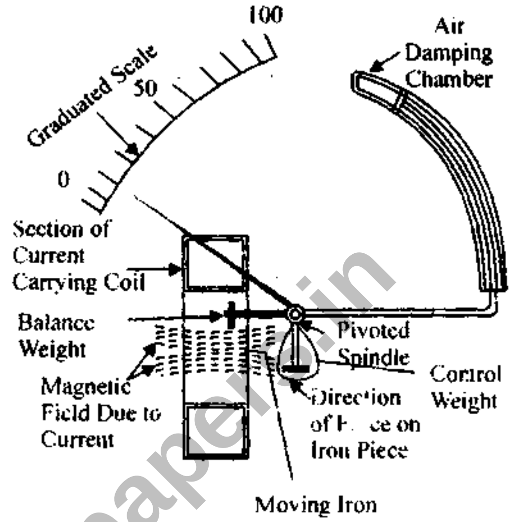


Fig. (a) Moving Iron Attraction Type Instrument

pivoted eccentrically as shown in Fig (a) To this iron a pointer is attached so that it may deflect along with the moving iron over a graduated scale .The iron is made of sheet metal specially shaped to give a scale as nearly uniform as possible. The moving iron is drawn into the field of solenoid when current flows through it. The movement of the iron is always from.

Merits And Demerits of PMMC instruments :

Merits : (i) Uniform Scale

(ii) Low power consumption (say from 25 microwatt to 200 microwatt) because of small driving power.

(iii) No hysteresis loss as the former is of copper or aluminium.

(iv) Very effective and reliable eddy current damping.

(v) High torque-weight ratio resulting in high accuracy (2-5% of full-scale reading).

(vi) Use of single instrument for measurement of currents and voltages by employing shunts and multipliers of different resistances.

(vii) No effect of stray magnetic fields because of use of intensive polarised or unidirectional field.

(viii) The instrument using core magnet is very suitable in air-craft and aerospace applications, where a multiplicity of instruments are mounted in close proximity to each other .This is because of self-shielding property of core magnets.

Demerits : (i) These instruments cannot be used for ac measurements.

(ii) These are costilier in comparison to moving iron instruments because of delicate construction and thé necessary accurate machining and assembly of various parts.

Merits and Demerits of Moving Iron Instruments :

Merits : (i) These instruments can be used both in dc as well as in circuits. This is due to the fact that the deflecting torque depends on the square of the current.

(ii) These instruments are robust, owing to the simple construction of the moving parts and the fact that there are no current leads to these parts.

(iii) The stationary parts of the instruments are also simple.

(iv) The simplicity of construction ,as described in *(ii)* and *(iii)* results in low cost.

(v) These instruments possess high operating torque.

(vi) These instruments can withstand over-load momentarily.

(vii) These instruments are capable of giving an accuracy within the limits of both precision and industrial grades. Instruments which are required to have industrial grade accuracy on both ac and dc require very considerable care in design.

Q. 7. (b) A moving-coil milli-ammeter having a resistance of 8 Ω 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) voltage up to 8 V.

Ans. Multiplying power of Shunt

$$= \frac{I}{I_m} = \frac{R_m + S}{S}$$

$$= \frac{8 + 0.228}{0.228} = 36.6$$

(i) $I = \frac{2}{36} = 5.5 \text{ mA}$

(ii) $I = \frac{8}{36} = 2.2 \text{ mA}$

Q. 7. (c) Give the construction and working of dynameter watt meter.

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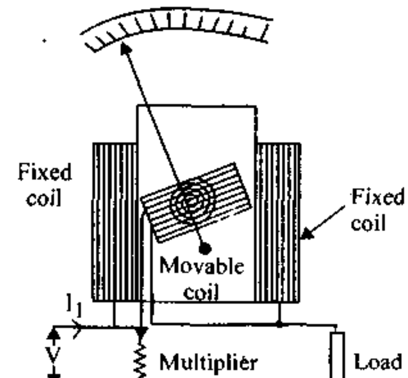
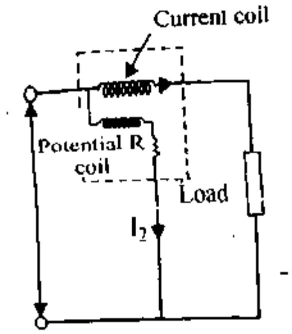


(i)



(ii)

Fig. (a)

coil. The controlling torque is provided by two spiral springs which also serve the additional purpose of leading current into and out of the moving coil. Air friction damping is provided in such instruments. A pointer is attached to the movable coil.

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