B.Tech 2nd Semester Exam, 2021
BASIC ELECTRICAL ENGINEERING

Time : 3 Hours

Full Marks : 70

Instructions:

(i) The marks are indicated in the right-hand margin.

(ii) There are **NINE** questions in this paper.

(iii) Attempt **FIVE** questions in all.

(iv) Question No. **1** is compulsory.

1. Choose the correct answer of the following (any seven) : $2\times7=14$

(a) Lamps in street lighting are all connected in

(i) series

(ii) parallel

(iii) series-parallel

(iv) end-end

(b) The rotor slots in a 3-phase induction motor are kept inclined. This phenomenon is known as

(i) skewing

(ii) crawling

(iii) cogging

(iv) hardening

(c) An alternator with higher value of SCR has

(i) poor voltage regulation and lower stability limit

(ii) better voltage regulation and higher stability limit

(iii) poor voltage regulation and higher stability limit

(iv) better voltage regulation and lower stability limit

(d) If the flux of a DC motor approaches zero, its speed will

(i) approach infinity

(ii) approach zero

(iii) remain unchanged

(iv) betwen zero and infinity

(e) The core flux of a practical transformet with a resistive load

(i) is strictly constant with load changes

(ii) increases linearly with load

(iii) increases as the square roor of the load

(iv) decreases with increases in load

(f) A transformer has a percentage resistance of 2% and percentage reactance of 4%. What are its voltage regulation at 0.8 lagging and 0.8 leading respectively?

(i) 4.8% and –0.6%

(ii) 3.2% and –1.6%

(iii) 1.6% and –3.2%

(iv) 4% and –0.8%

(g) Higher the Q of a series circuit, narrower its

(i) pass band

(ii) resonance curve

(iii) bandwidth

(iv) All of the above

(h) A 10 mH inductor carries a sinusoidal current of 1 A r.m.s. at a frequency of 50 Hz. The average power dissipated by the inductor is

(i) 0 W

(ii) 0.25 W

(iii) 0.5 W

(iv) 1 W

(i) Which of the following statements is incorrect?

(i) Resistance is a passive element.

(ii) Inductor is a passive element.

(iii) Current source is a passive element

(iv) Voltage source is an active element.

(j) Which of the following is not bilateral element?

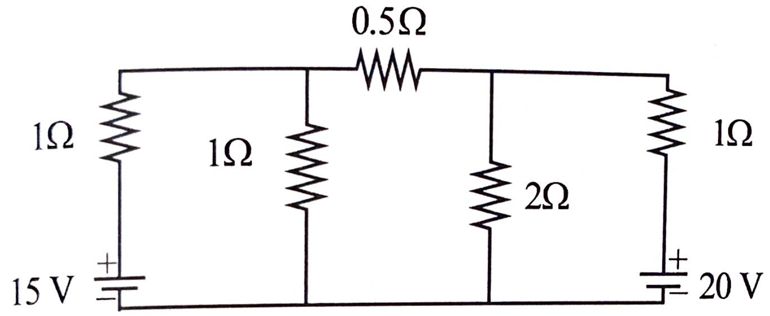
(i) Constant current source

(ii) Resistor

(iii) Inductor

(iv) Capacitor

2.(a) Find the current through each resistor of the following circuit using nodal analysis: 4



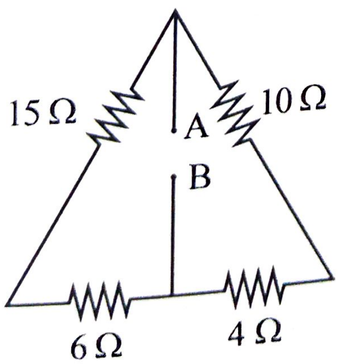
(b) Explain the concept of superposition theorem applied to the electric circuit by taking a 3-element T-network and two batteries. 6

(c) Find the equivalent resistance between points A and B in the following circuit: 4

3.(a) An iron cored coil draws 2 A at 0.5 p.f. lag against a 50 Hz, 100V supply. Iron core being then removed, the voltage applied being 50 V, the current rises to 5A at 0.78 lag. Find the inductance of each case. 6

(b) A resistance of 10W, an inductance of 150mH and a capacitor of 10mF are connected across a 50 V, 50 Hz source. Find the branch currents and total current. Draw the phasor diagram. 4

(c) Discuss the effect of resistance of RLC series circuit on the frequency response curve. 4



4. (a) An iron ring 8 cm mean diameter is made up of round iron diameter 1 cm and permeability of 900 has an air gap of 2mm wide. It consists of winding with 400 turns carrying a current of 3.5A. Determine-

(i) MMF

(ii) Total reluctance

(iii) The flux

(iv) Flux density in ring 4

(b) Give the comparison between electric circuit and magnetic circuit. 4

(c) Explain the experimental method of obtaining hysteresis loop of magnetic circuit. 6

5. (a) The open-circuit and short- circuit tests on a 10kVA, 125/250 V, 50 Hz single phase transformer gave the following results: 8

OC test :	125V, 0.6A, 50 W on LV side
SC test :	15V, 30A, 100W on HV side
Calculate :	(i) copper loss on full load
	(ii) full-load efficiency at 0.8 leading p.f.
	(iii) half-load efficiency at 0.8 leading p.f. and
	(iv) voltage regulation at full load, 0.9 leading p.f.

(b) Explain the various three-phase transformer connections with neat circuit and phasor diagrams. 6

6. (a) Draw the speed-torque characteristics of D shunt motor and series motors. 4

(b) Explain the constructional details of alternators. 4

(c) The lap wound armature of a 4 pole DC shunt motor has 600 armature turns and it take 100 Amps when running at 600 r.p.m. The flux per pole is 100m Wb. Calculate the gross mechanical torque developed lost in friction, windage and core losses is 60 N-m. 6

7. (a) A 4-pole, 50Hz, 3-phase induction motor running on full load develops a useful torque of 200 N-m when the rotor e.m.f. makes 120 complete cycles per minute., If the mechanical torque lost in friction and rotor core loss is 15 N-m calculate the- 4

(i) Shaft power output

(ii) Rotor copper losses

(iii) Motor efficiency

(b) Differentiate the principle of operation of induction and synchronous motors. 4

(c) Draw the speed- torque characteristics of an induction motor. 3

(d) List the various types of Dc generators and draw their electrical circuits. 3

8.(a) Define cold ranking ampere and specific power in batteries. 6

(b) Describe the various devices used to improve the system power factor. 4

(c) Explain the various type of earthing system. 4

9.(a) Explain maximum power transfer theorem applied in a DC network. 7

(b) Why a DC series motor cannot be started on no load? Explain your answer with the help of basic speed torque equation and necessary diagrams. 7

Answer

1.(a) ii

1.(b) i

1.(c) ii

1.(d) i

1.(e) i

1.(f) iv

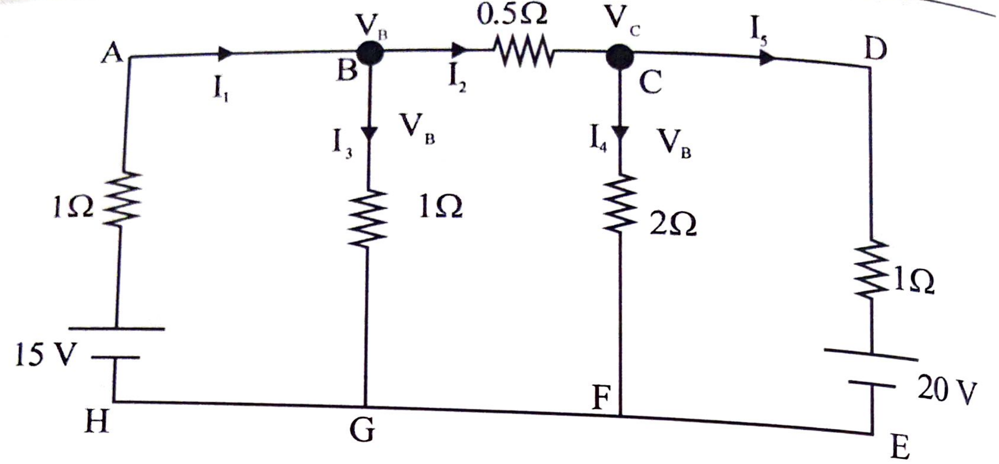
1.(g) i

1.(h) i

1.(i) iii

1.(j) i

2.(a)



→ Here there is 2 node & 1 reference node.

→ & there is 2 nod equation.

→ Writing the KCL equation of node:-

$$I_1 = I_2 + I_3$$

$$\Rightarrow \frac{V_{B-}V_{15}}{2} = \frac{V_{C-}V_B}{0.5} + \frac{V_{B-}V_G}{1}$$

$$\Rightarrow V_B\text{-}15 = \frac{V_C}{0.5} - \frac{V_B}{0.5} + V_B$$

$$\Rightarrow \frac{V_B}{0.5} - \frac{V_C}{0.6} = 15 \qquad \text{.....(i)}$$

Writing KCL equation of node 2 :-

$$I_2 = I_4 + I_5$$

$$\Rightarrow \frac{V_{C-}V_B}{0.5} = \frac{V_C}{2} + \frac{V_{0-}V_C}{1}$$

$$\Rightarrow 2V_C\text{-}\frac{V_C}{2} + V_C - 2V_B = 20 \qquad (\because V_0 = 20)$$

$$\Rightarrow 3V_C\text{-}\frac{V_C}{2} - 2V_B = 20$$

$$\Rightarrow \frac{6V_C - V_C - 4V_B}{2} = 20$$

$$\Rightarrow \quad 5V_C - 4V_B = 40 \quad \text{....(ii)}$$

equation (i) + equation (ii)

$$\cancel{4V_B} - 4V_C = 30$$

$$\cancel{4V_B} + 5V_C = 20$$

$$V_C = 50$$

From equation (i)

$$2V_B - 2 \times 50 = 15$$

$$2V_B - 100 = 15$$

$$2V_B = 115$$

$$V_B = 57.5 \text{ volts}$$

$$I_1 = \frac{57.5 - 15}{1} = 42.5\,A$$

$$I_2 = \frac{50 - 57.5}{0.5} = -15A$$

$$I_3 = \frac{57.5 - 0}{1} = 57.5A$$

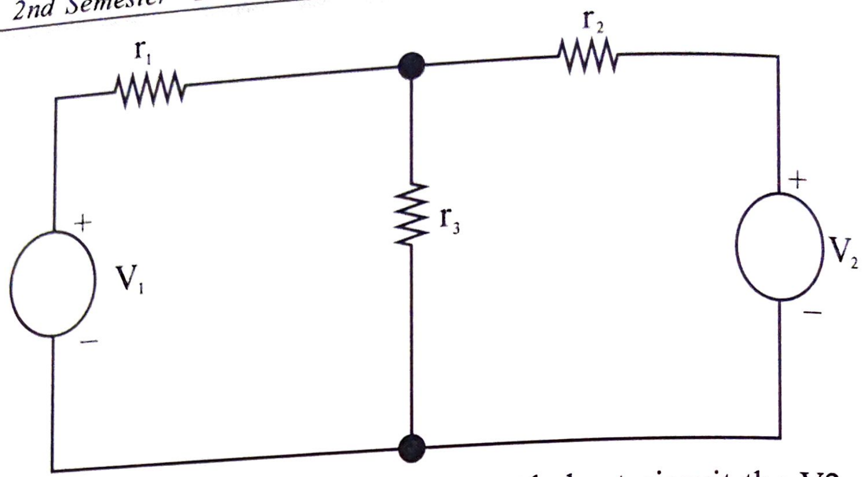
$$I_4 = \frac{50}{2} = 25\,A$$

$$I_5 = \frac{20 - 50}{2} = 30A$$

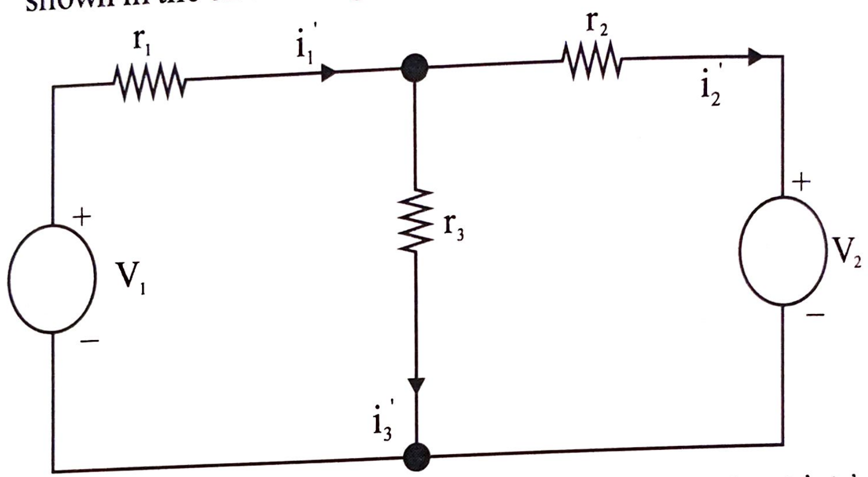
(b) Superposition theorem states that in any linear, active, bilateral network having more than one source, the response across any element is the sum of the responses obtained from each source considered separately and all other sources are replaced by their internal resistance.

Explanation of Superposition Theorem

Let us understand the superposition theorem with the help of an example. The circuit diagram is shown below consists of two voltage sources V_1 and V_2.



First take the source V1 alone and short circuit the V2 source as shown in the circuit diagram below:



Here the value of current flowing in each branch i.e. i_1', i_2' and i_3' is calculated by the following equations.

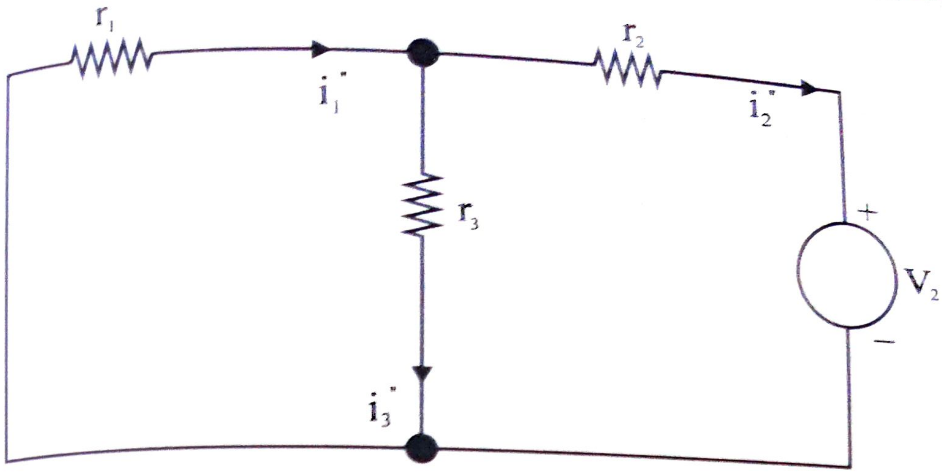
$$i_1' = \frac{V_1}{\frac{r_2 r_3}{r_2 + r_3} + r_1} \quad \text{.... (1)}$$

$$i_2' = i_1' \frac{r_3}{r_2 + r_3} \quad \text{.... (2)}$$

The difference between the above two equations gives the value of the current $1_3'$

$$1_3' = i_1' - i_2'$$

Now, activating the voltage source V2 and deactivating the voltage source V, by short-circuiting it, find the various currents, i.e. i_1', i_2' and i_3' flowing in the circuit diagram shown below:



Here

$$i_2'' = \frac{V_2}{\frac{r_1 r_3}{r_1 + r_3} + r_2} \quad \text{and} \quad i_1'' = i_2' \frac{r_3}{r_1 + r_3}$$

And the value of the current i3'' will be calculated by the equation shown below:

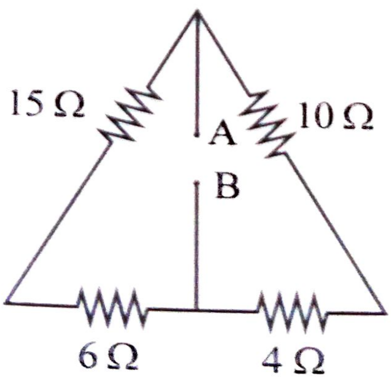
$$i_3'' = i_2'' - i_1''$$

As per the superposition theorem, the value of current i_1', i_2' and i_3' is now calculate as:

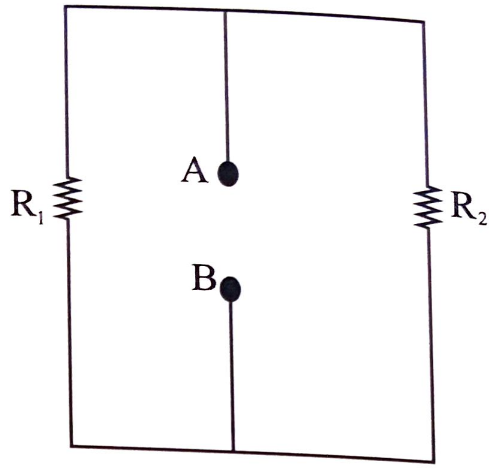
$$i_3 = i_3' + i_3''$$
$$i_2 = i_2' - 1_2''$$
$$i_1 = i_1' - i_2''$$

The direction of the current should be taken care of while finding the current in the various branches.

(C)



Here 15Ω & 6 Ω are in series and 10Ω & 4Ω are also in series.



$R_1 = 15\Omega + 6\Omega = 21\,\Omega$
$R_2 = 10\Omega + 4\,\Omega = 14\,\Omega$

$$R_{A-B} = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{21 \times 14}{21 + 14}$$

$$= \frac{294}{35} = 8.4\Omega \text{ Ans.}$$

3.(a) Solution:

1st case (core within the coil)

$$Z(\text{impedance}) = \frac{V}{1} = \frac{100}{2} = 50\,\Omega$$

$$R(\text{Resistance}) = \frac{watt}{I^2} = \frac{VI\cos\phi}{I^2}$$

$$= \frac{100 \times 2 \times 0.5}{2^2} = 25\Omega$$

$$\therefore \quad X = \sqrt{Z^2 - R^2}$$

$$= \sqrt{50^2 - 25^2} = 43.3\Omega$$

$$\text{and } L(\text{inductance}) = \frac{X}{2\pi f} = \frac{43.3}{314} = 138\text{mH}$$

2nd case (coil without the core)

$$Z = \frac{50V}{5A} = 10\Omega$$

and

$$R = \frac{VICos\phi}{I^2} = \frac{50\times5\times0.78}{5^2} = 7.8\Omega;$$

Now,

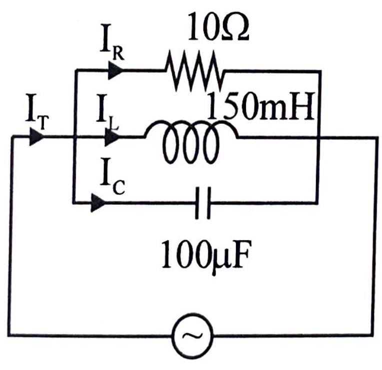
$$\therefore \quad X = \sqrt{Z^2 - R^2} = \sqrt{10^2 - 7.8^2} = 6.25\Omega$$

Again,

$$\therefore \quad \text{L(inductance)} = \frac{6.25}{2\pi f}$$

$$= \frac{6.25}{314} = 20\text{mH}$$

(b) given



find :- $I_R, I_L, I_C = ?\ I_T = ?$

$$I_R = \frac{V_s}{R} = \frac{50}{10} = 5\text{A}$$

$$I_L = \frac{V_s}{X_L} = \frac{50}{47.12} = 1.06\text{A}$$

$$[X_L = 2\pi fL = 2\pi \times 50 \times 150 \times 10^{-3} = 47.12\Omega]$$

$$I_C = \frac{V_C}{X_C} = \frac{50}{31.33} = 1.57\text{A}$$

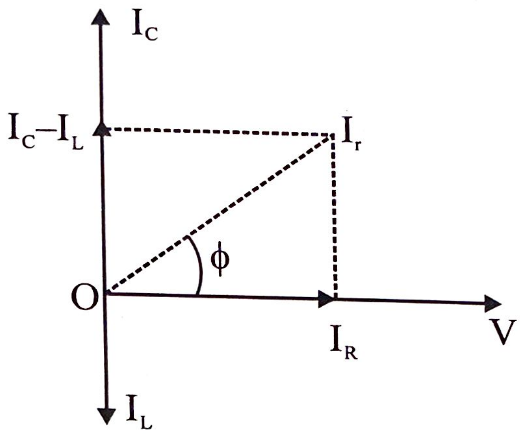
$$\left[X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi \times 50 \times 100 \times 10^{-6}} = 31.83\Omega\right]$$

$$I_T = \sqrt{I_R^2 + (I_C - I_L)^2}$$

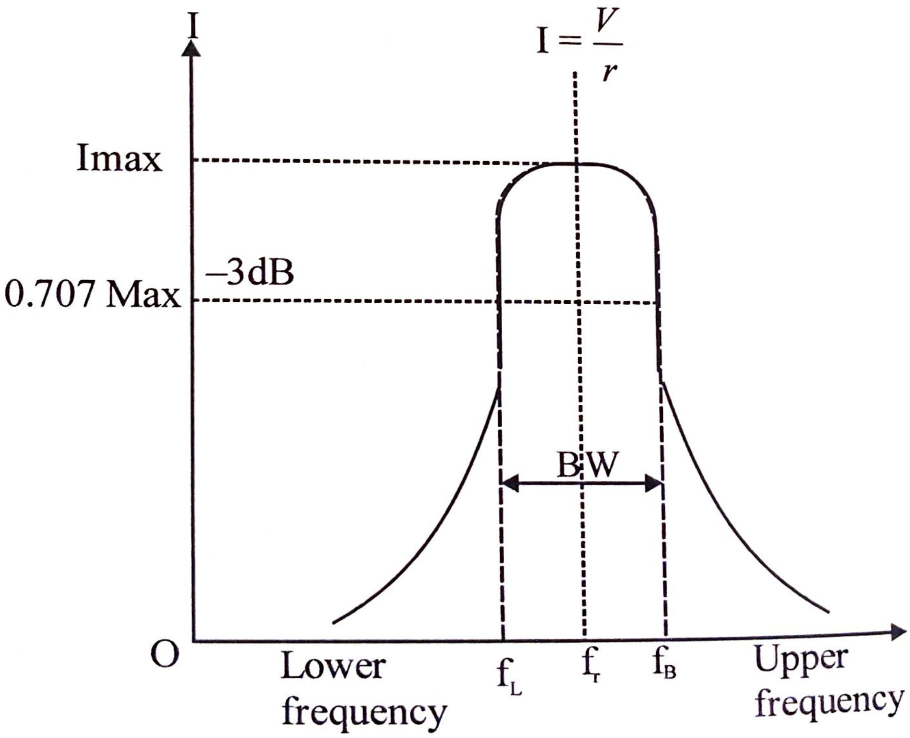
$$= \sqrt{(5)^2 + (1.57 - 1.06)^2}$$

$$= 5.02 \text{ A}$$

Phaser diagram



(c)

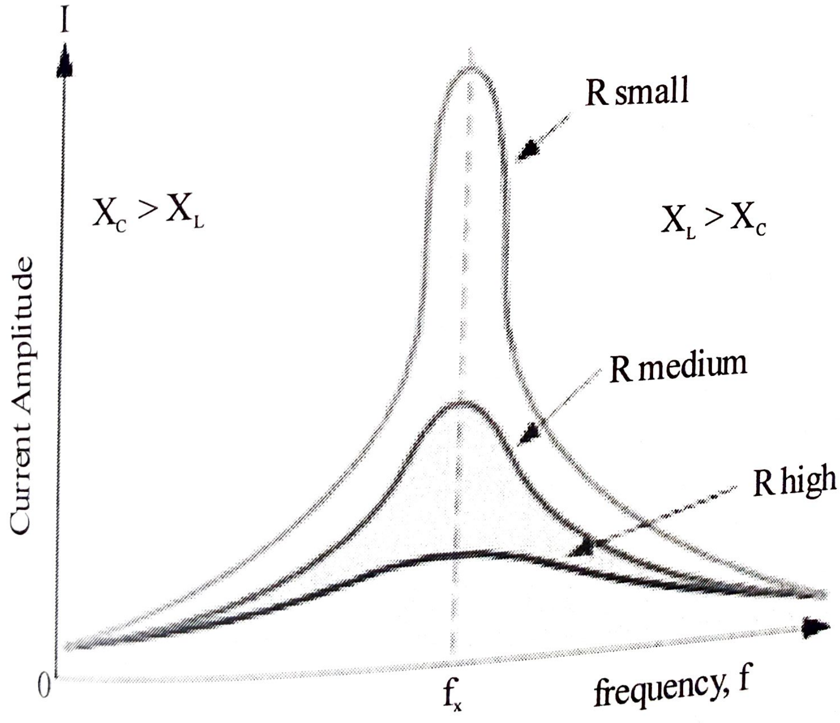


The frequency response of the circuits current magnitude above, relates to the "sharpness" of the resonance in a series resonance circuit. The sharpness of the peak is measured quantitatively and is called the Quantity factor, Q of the circuit.

The quality factor relates the maximum or peak energy stored in the circuit (the reactance) to the energy dissipated (the resistance) during each cycle of oscillation meaning that it is a ratio of resonant frequency to bandwidth and the higher the circuit Q,the smaller the bandwidth, $Q = f_r/BW$.

As the bandwidth is taken between the two-3dB Points, the selectivity of the circuit is a measure of its ability to reject any frequencies either side of these points. A more selective circuit will have a narrower bandwidth where as a less selective circiut will have a wider bandwidth.

The selectivity of a series resonance circuit can be controlled by adjusting the value of the resistance only, keeping all the other components the same , since $Q = (X_L \text{ or } X_C)/R$



4.(a)

Given

diameter of ring	=	8cm	=	8×10^{-2} m
diameter of iron	=	1 cm	=	1×10^{-2} m
permeability	=	900		
length of air gap	=	2mm	=	2×10^{-3} m

No. of turn $= 400$

I $= 3.5\,A$

(i) M.M. f. $= N.I$

$$= 400 \times \frac{3.5}{10} = 1400\ AT$$

M.M.F. $= 1400AT$

(ii) Total relucatnce $= ?$

(a) formula $= S_T = S_j + S_g$

S_j = reluctance of iron core

S_g = reluctance of air gap

$$S_T = \frac{lr}{\mu r A} + \frac{lg}{\mu 0 A} = \frac{1}{\mu 0 A}\left(\frac{lr}{\mu r / \mu 0} + lg\right)$$

$$S_T = \frac{1}{\mu 0 A}\left(\frac{lr}{\mu r} + lg\right)$$

l_r = length of ring

l_g = length of air gap

length of ring (lr) $= \pi d -$ length of air gap

$$= \pi \times (8 \times 10^{-2}) - 2 \times 10^{-3}$$

$l_r t_r = 0.2493\,m$

Diameter of iron = 1 cm

Area of cross section = area of iron $= \pi \times \left(\frac{1 \times 10^{-2}}{2}\right)^2$

$$A = 7.85 \times 10^{-5}\ m^2$$

Now

Total relutance $= \frac{1}{\mu_0 A}\left(\frac{l_r}{\mu_r} + l_g\right)$

$$\frac{1}{10^{-5} \times 7.85 \times 4n \times 10^{-7}}\left(\frac{0.24963}{900} + 2 \times 10^{-3}\right)$$

$S_T = 23094243.17$

(iii). Flux

resistance $= \frac{MMF}{flux}$

flux $= \frac{MMF}{reduc\tan ce} = 6.06 \times 10^{-5}$ wb

ϕ $= 6.06 \times 10^{-5}$w

(iv). flux density $=$ $B = \frac{\phi}{A}$ $= B = 0.7722$wb/m^2

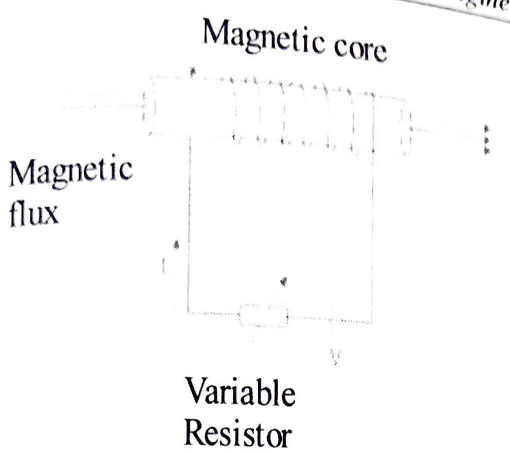
(b) Similarities between electric and magnetic circuits are listed below:

Sr. No.	Electric Circuit	Magnetic Circuit
1.	Path traced by the current is called electric circuit	Path traced by the magnetic flux is defined as magnetic circuit
2.	E.M.F. is the driving force in electric circuit, the unit is volts	M.M.F. is the driving force I the magnetic circuit, the unit of which is ampere turns.
3.	There is current I in the electric circuit measured in amperes.	There is flux f in the magnetic circuit measured in webers.
4.	The flow of electrons decides the current in conductor	The number of magnetic lines of force decides the flux.
5.	Resistance oppose the flow of the current, Unit is ohm.	Reluctance is opposed by magnetic path to the flux. Unit is ampere turn/weber.
6.	R = $p\frac{i}{a}$ directly proportional to I. Inversely proportional to 'a' Depends on nature of material.	$S = \frac{i}{\mu_0\mu_r a}$ Directly proportional to $\mu = \mu_0 \mu_r$ Inversely proportional to are 'a'
7.	The current I = $\frac{e.m.f.}{resis\tan ce}$	The flux $\phi = \frac{m.m.f.}{reluc\tan ce}$
8.	The current density d = $\delta = \frac{1}{a} A/m^2$	The flux density B = $\frac{\phi}{a} wb/m^2$
9.	Conductivity is reciprocal of the resistivity	Permeance is reciprocal of the reluctance
10	Kirchhoffs current and voltage law is applicable to the electric circuit	Krichoffs m.m.f. law and flux law is applicable to the magnetic circuit

There are few dissimilarities between the two which are listed below:

SL No.	Electric Circuit	Magnetic Circuit
1.	In the electric circuit the current actually flows i.e. there is movement of electrons	Due to M.M.F. flux gets established and does not flow in the sense in which current flows.
2.	There are many materials which can be used as insulators i.e. air, P.V.C. synthetic resin etc. from which current cannot pass	There is no magnetic insulator as flux can pass through all the materials, even through the air as well.
3.	Energy must be supplied to the electric circuit to maintain the flow of current.	Energy is requires to create the magnetic flux, but is not requires to maintain it.
4.	The resistance and the conductivity are independent of current density (δ) under constant temperature. But may change due to the temperature.	The reluctance, permeance and permeability are dependent on the flux density.
5.	Electric lines of flux are not closed. They start from positive charge and end on negative charge.	Magnetic lines of flux are closed lines. They flow from N pole to S pole externally while S pole to N pole internally.
6.	There is continuous consumption of electrical energy	Energy is required to create the magnetic flux and not to maintain it.

(c) A hysteresis loop(also known as a hysteresis curve) is a four-quadrant graph that shows the relationship between the induced magnetic flux density B and the magnetizing force H. It is often reffered to as the B-H loop.



Now, let us proceed step by step to make a clear idea about hysteresis loop.

Step 1:

When supply current I = 0, so no existence of flux density (B_0 and magnetizing force (H). The corresponding point is 'O' in the graph above.

Step 2:

When current is increased from zero value to a certain value, magnetizing force (H) and flux density (B) both are set up and increased following the path o - a .

Step 3 :

For a certain value of current flux density (B) becomes maximum (B_{max}). The point indicates the magnetic saturation or maximum flix density of this core material. All element of core material get aligned perfectly. Hence Hmax is marked on H axis. So no change of value of B with further increment of H occurs beyond point 'a'

Step 4 :

When the value of current is decreased from its value of magnetic flux saturation, H is decreased along with decrement of B not following the previous path rather following the curve a - b.

Step 5:

The point'b' indicates H = 0 for I = 0 with a certain value of B. This lagging of B behind H is called hysteresis. The point 'b' explains that after removing magnetizing force (H). magnetism property with little value remains in this magnetic material it is known as residual magnetism (B). Here o - b is the value of residual flux denstiv due to retentivity of the material.

Step 6 :

If the direction of the current I is reversed, the direction of H also gets reversed. The increment of H in reverses direction following path b- c decreases the value of residual magnetism (B.) that gets zero at point 'C' with certain negative value of H. This negative value of H is called coercive force (H).

Step 7:

H is increased more in negative direction further, B gets reverses following path c- d. At point 'd' again magnetics saturation takes place but in opposite direction with respect to previous case. At point'd' B and H get maximum values in reverse direction, i..e. ($-B_m$ and $-H_m$)

Step 8:

If we decrease the value of H in this direction, again B decreases following the path de. At point 'e' H gets zero-valued but B is with finite value. The point'e' stands for residual magnetism (-B) of the magnetic core material in opposite direction with respect ot previous case.

Step 9 :

If tje direction of H again reversed by reversing the current I, then residual magnetism or residual flux density (-B) again decreases and gets zero at point'f' following the path e -f. Again further increment of H, the value of B increases from zero to its maximum value or saturation level at point a following path f-a.

The path a - b - c - d - e - f - a forms hysteresis loop.

5. (a) From O.C. test we can write,

Wo - Pi = 50 W = Iron loss

From S.C. test we can find the parameters of equivalent circuit. Now S.C. test is conducted on H.V. side i.e. meters are on H.V. side which is transformer secondary. Hence parameters from S.C. test results will be referred to secondary

Vsc = 15 V, Isc = 30 A, Wsc = 100 W

$\therefore \quad R_2e = W_{sc}/(I_{sc})^2 = 10/(30)^2 = 0.111\Omega$

$Z_1e = V_{sc}/I_{sc} = 15/30 = 0.5\Omega$

$\therefore \quad X_2e = \surd(Z_2e^2 - R_2e^2) = 0.4875\ \Omega$

(i) Copper loss on full load

$(I)F.L. = VA\ rating/V_2 = (10 \times 10^3)/250 = 40\ A$

In short circuit test, $I_{sc} = 30$ A and not equal to full load value 40A

Hence W_{sc} does not give copper loss on full load

$\therefore\ W_{sc} = P_{cu}$ at 30 A = 100 W

Now $P_{cu} \alpha I^2$

$(P_{cu}$ at 30 A$)/(P_{cu}$ at 40 A$) = (30/40)^2$

$100/(P_{cu}$ at 40 A$) = 900/1600$

P_{cu} at 40 A = 177.78 W

$\therefore\ (P_{cu})F.L. = 177.78$

(ii) Full load h, $\cos\phi_2 = 0.8$

% η on full load

$$= \frac{V_2(I_2)F.L.Cos\phi_2}{V_2(I_2)F.L.Cos\phi_2 + p_1 + (p_{cu})F.L.} \times 100$$

$$= \frac{250 \times 40 \times 0.8}{250 \times 40 \times 0.8 + 50 + 177.78} \times 100 = 97.23\%$$

(iii) Halfload η, $\cos\phi_2 = 0.8$

n = 0.5 as halfload

$(I_2)H.L. = 0.5 \times 40 = 20.$

$\therefore$ % η on halfload

$$= \frac{V_2(I_2)HL.Cos\phi_2}{V_2(f_2)H.LCos\phi_2 + P_i + n_2(P_{cu}m)F.L} \times 100$$

$$= \frac{n(VA\,rating)\cos\phi_2}{n(VA\,rating)\cos\phi_2 + P_i + n^2(P_{cu})F.L.} \times 100$$

$$= \frac{0.5 \times 10 \times 10^3 \times 0.8}{0.5 \times 10 \times 10^3 \times 0.8 + 50 + (0.5)^2 \times 177.78} \times 100$$

= 97.69%

(iv) Regulation at full load, $Cos\phi = 0.9$ leading

$$\%R = \frac{(I_2)F.L.R_{2e}Cos\phi - (i_2)F.L.X_{2e}\sin\phi}{V_2} \times 100$$

$$= \frac{40\times0.111\times0.9-40\times0.4875\times0.4358}{250}\times100$$

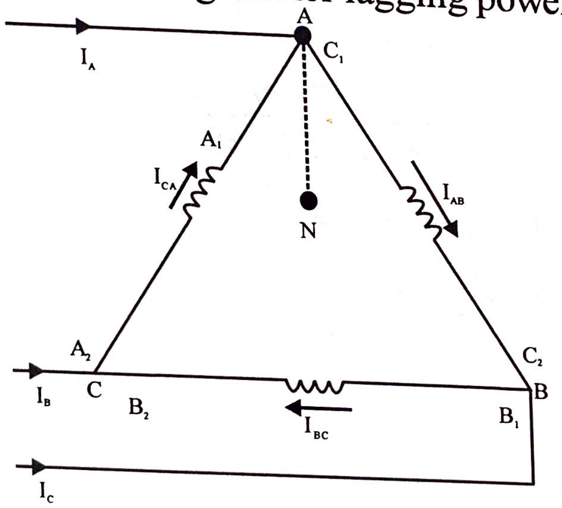
$$= -1.8015\%$$

(b) There are four possible connections for a 3-phase transformer

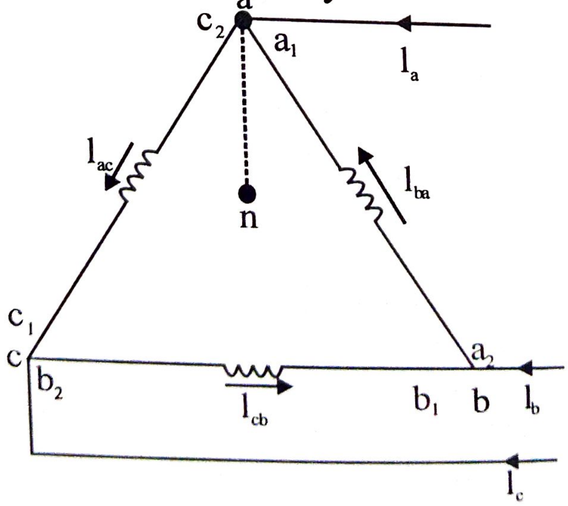
1. Δ - Δ (Delta – Delta) Connection
2. Y - Y (Star – Star) Connection
3. Δ - Y (Delta – Star) Connection
4. Y – Δ (Star – Delta) Connection

Delta-Delta (D - D) Connection

The delta-delta connection of three identical single phase transformer is shown in the figure below. The secondary winding a_1a_2 is corresponding to the primary winding A_1A_2, and they have the same polarity. The polarity of the terminal a connecting a_1, and C_2 is same as that connecting A_1, and C_2. The figure below shows the phasor diagram for lagging power factor cosϕ.

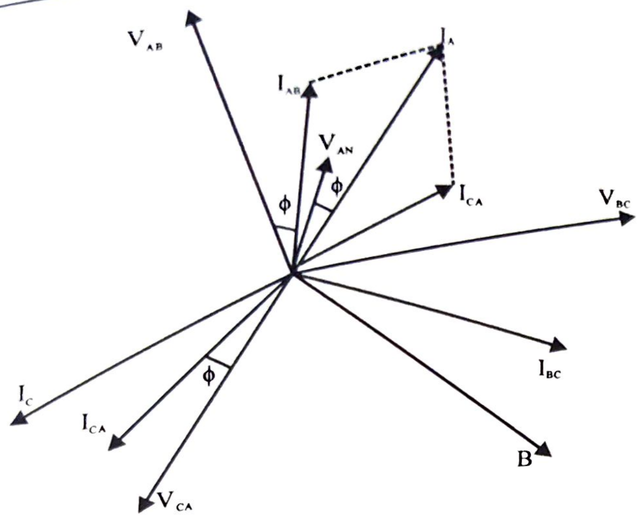


Primary

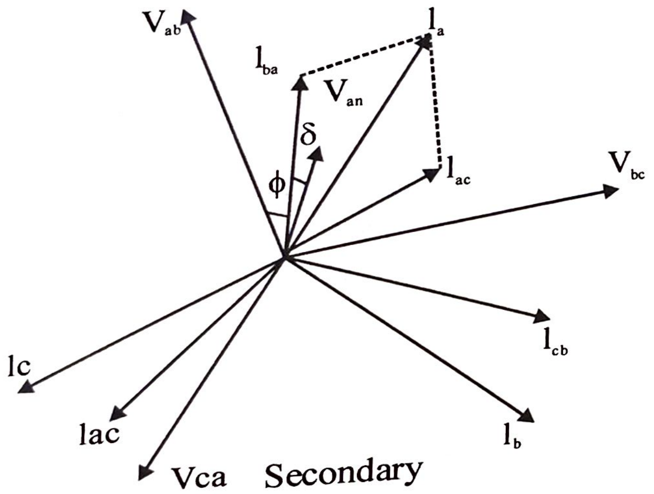


Secondary

Delta-Delta connection to transformer

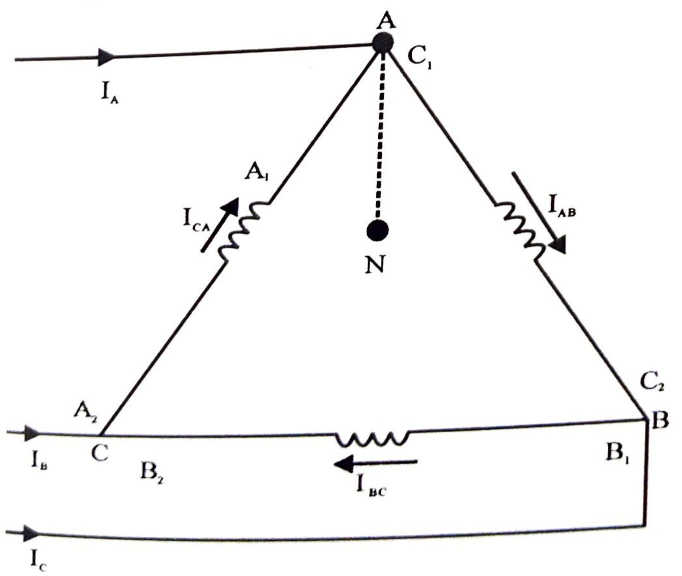


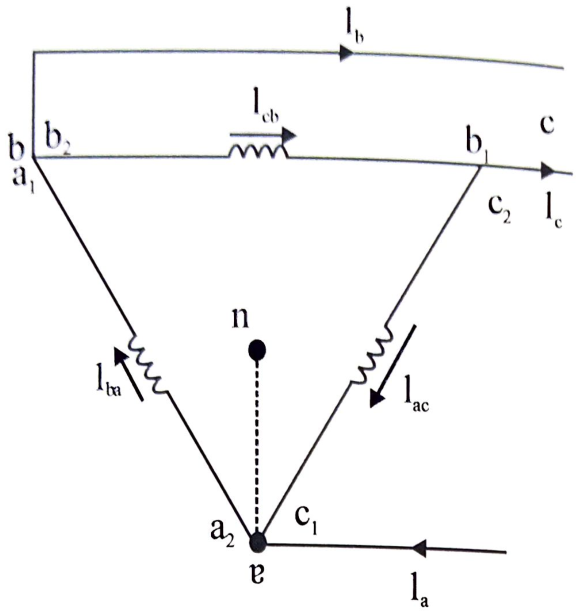
Primary



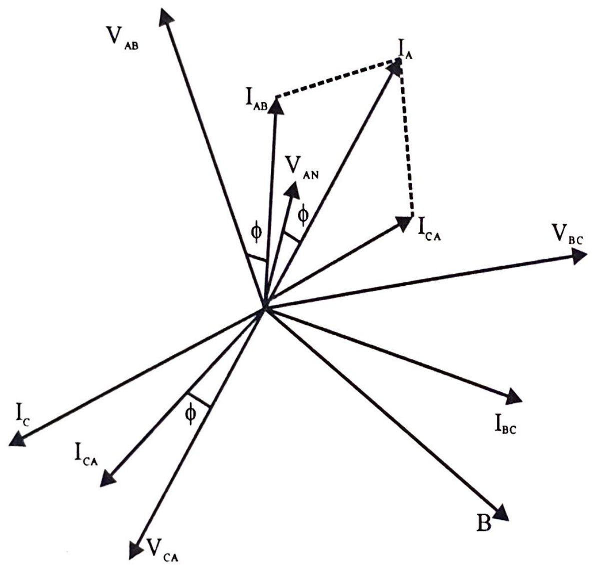
Secondary

The delta-delta connection with 180° phase shift is shown in the figure below. The phasor diagram of a three phase transformer shown that the secondary voltage is in phase opposition with the primary voltage.

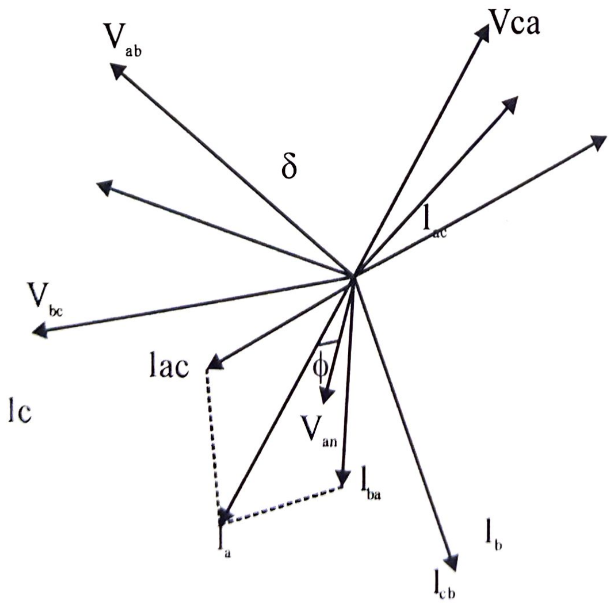




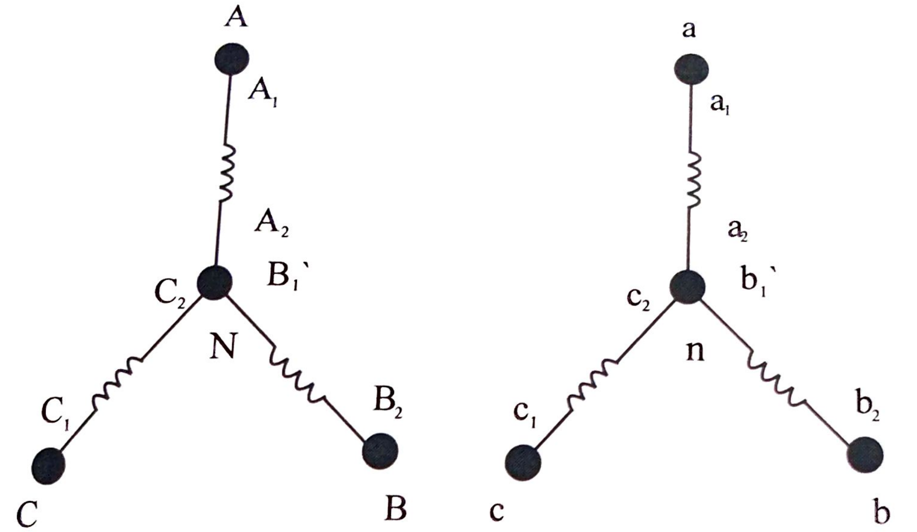
180° Phase shift of Delta-Delta Connection of Transformer



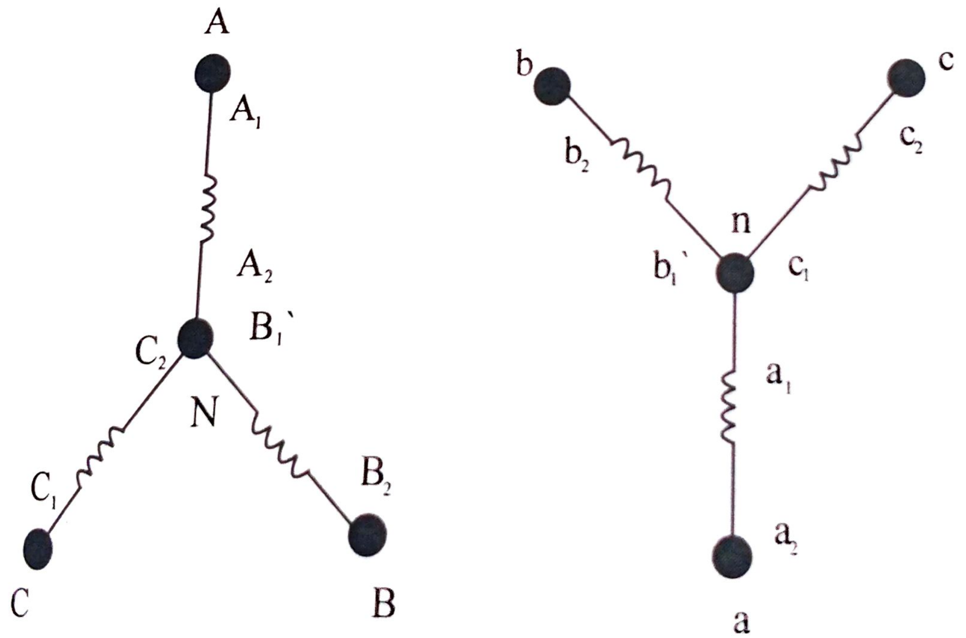
Primary



The star-star connection of three identical single phase transformer on each of the primary and secondary of the transformer is shown in the figure below. The phasor diagram is similar as in delta-delta connection.



0° Phase shift



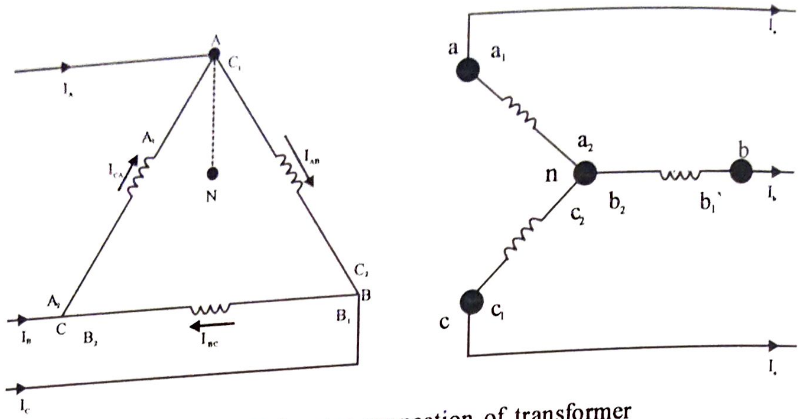
180° Phase shift

Star- Star Connection of transformer

The phase current is equal to the line current, and they are in phase. The line voltage is three times the phase voltage. There is a phase separation of 30° between the line and phase voltage. The 180° phase shift between the primary and secondary of the transformer is shown in the figure above.

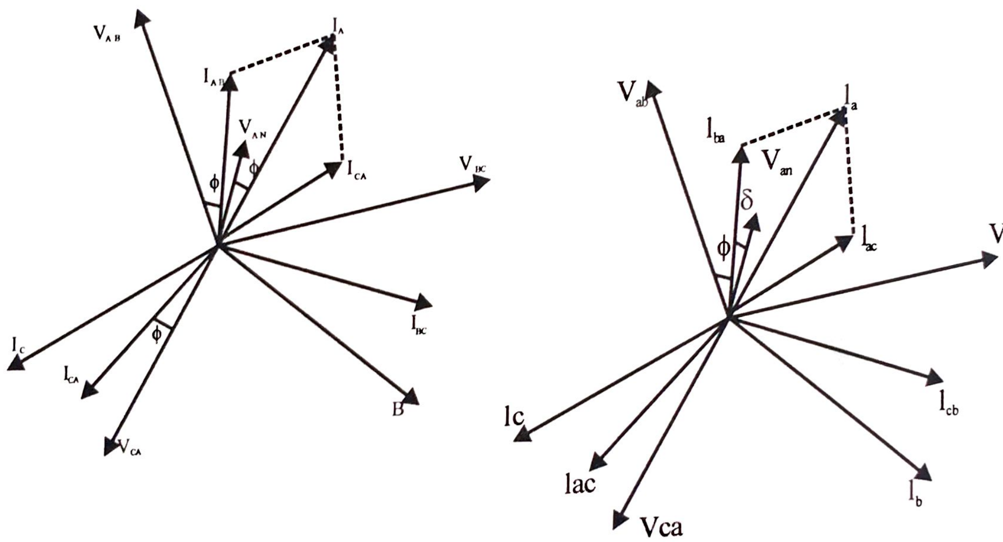
Delta-Star (Δ - Y) Connection

The Δ -Y connection of the three winding transformer is shown in the figure below. The primary line voltage is equal to the secondary phase voltage. The relation between the secondary voltages is $V_{LS} = \sqrt{3}\ V_{PS}$.



Delta star connection of transformer

It is seen from the phasor diagram that the secondary phase voltage V_{an} leads the primary phase voltage V_{AN} by 30°. Similarly, V_{bn} leads V_{BN} by 30° and V_{cn} leads V_{cn} by 30°. This connection is also called +30° connection.

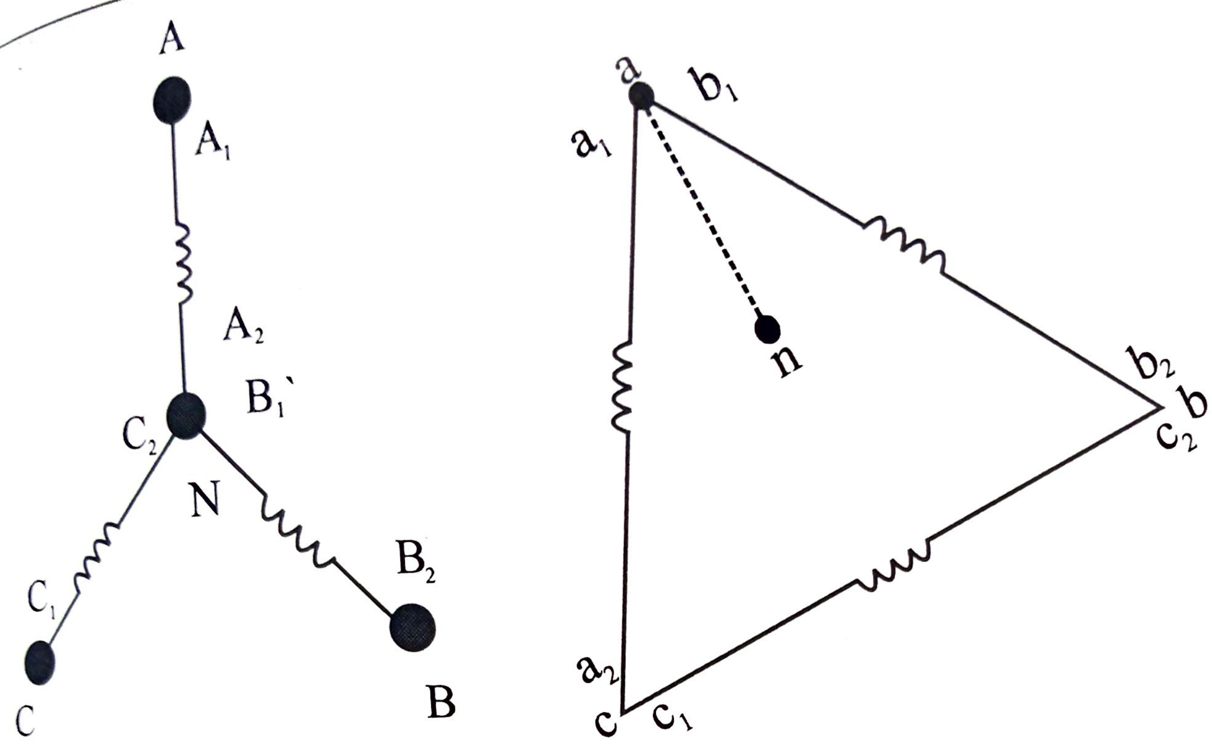


By reversing the connection on either side, the secondary system voltage can be made to lag the primary system by 30°. Thus, the connection is called -30° connection.

Star-Delta (Y-A) Connection

The primary line voltage is $\sqrt{3}$ times the primary phase voltage. The secondary line voltage is equal to the secondary phase voltage. The voltage ratio of each phase is

$$\frac{V_P P}{V_P S} = a$$



Star-delta Connection of Transformer

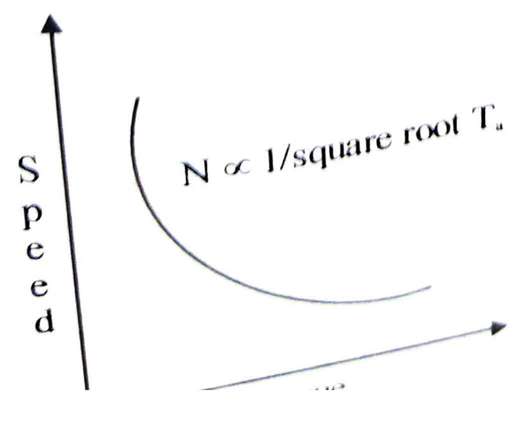
Therefore line -to line voltage ratio of Y - Δ connection is

$$\frac{V_{IP}}{V_{IS}} = \frac{\sqrt{3}V_{PP}}{V_{PS}} = \sqrt{3}a$$

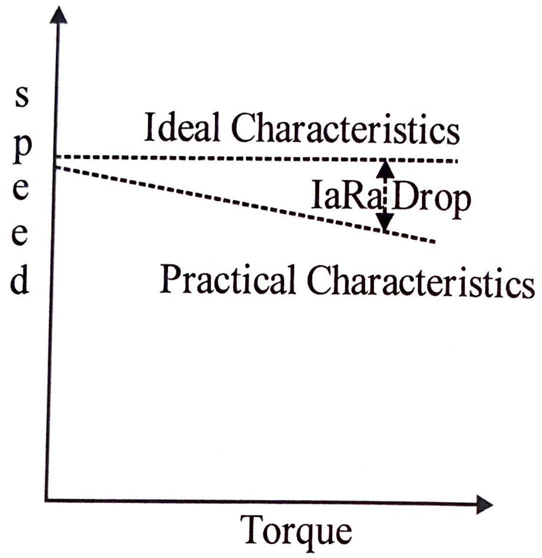
The phasor diagram of the configuration is shown in the figure above. There is a phase shift of 30 lead exists between respective phase voltage. Similarly, 30° leads exist between respective phase voltage. Thus the connection is called +30° connection.

6.(a)

Torque Vs Speed Characteristic ($T_a V_s N$): Torque is proportional to square of the armature current, $T_a \propto Ia^2$. The speed of DC series motor is $N \propto Eb/\phi$. Hence if the torque on the DC series motor increased the armature current also increases, thus flux increases and speed will be dropped as $N \propto$ 1/square root Ta.



Torque Vs Speed Characteristic (Ta Vs N): In DC shunt motor the flux is assumed to be constant hence to armature current, $T_a \propto I_a$. The speed of DC shunt motor is $N \propto E_b/\phi \propto$ (Vt-IaRa-Brush drop) ϕ. Hence as the torque on the DC shunt motor increases the armature current increases and speed will be dropped by some value. But the characteristic is slightly dropping,



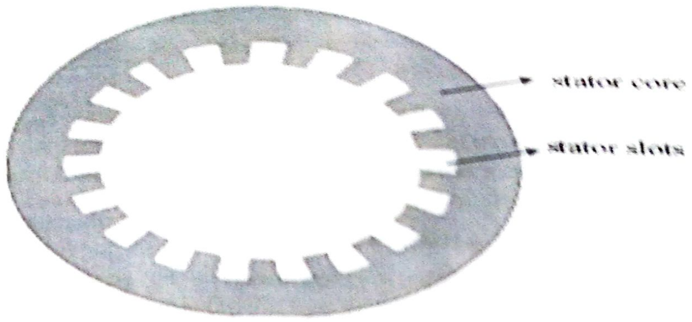
(b) Rotor and Stator are two main parts in the construction of an alternator

Stator

The stator of the synchronous generator consists of a stator frame and stator core. The stator frame is used for holding the armature stampings and windings in position. Ventilation is maintained with the help of holes cast in the frame itself, which assist in cooling the alternator.

The armature core is supported by the stator frame and is built up of laminations of steel alloys or magnetic iron. The core is laminated to minimize the eddy current loss.

The laminations are insulated from each other and have spaces in between them for allowing the cooling air to pass through. The stator is made up of a number of slots on its inner periphery, as shown in the below figure. The slots are used for holding the armature winding.



Cross Section of stator

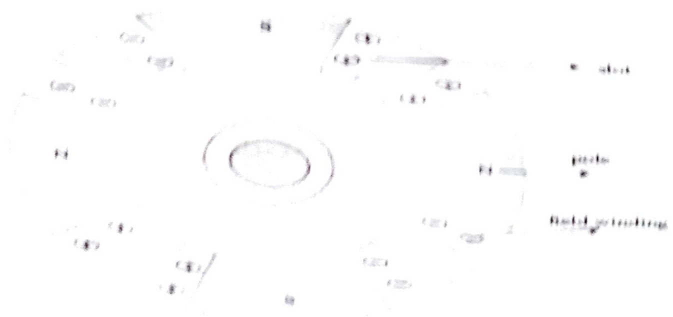
Rotor

There are two types of rotor, smooth cylindrical type and salient pole type.

Smooth Cylindrical type alternator

The rotor consists of a smooth solid steel cylinder, having a number of slots along its outer periphery for hosting the field coils. They do not have projected poles, instead, it has a uniform length in all directions, giving a cylindrical shape to the rotor.

The pole areas are un-slotted, as shown in the figure below. Here, the rotor has 4 poles. The pole areas are surrounded by field windings placed in slots.



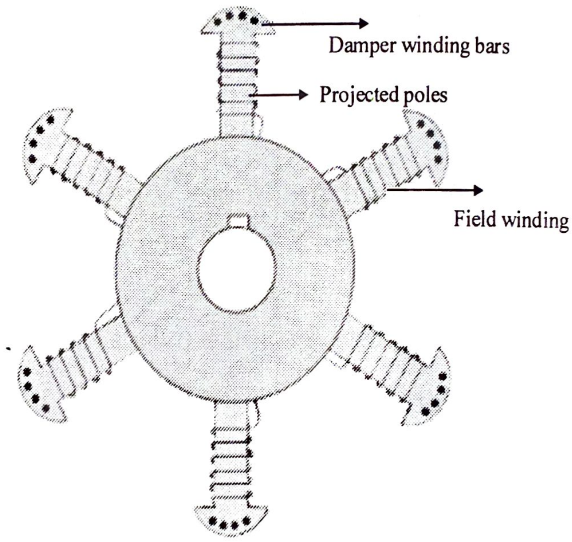
The windings are placed so that the flux density will be maximum on the polar central line and gradually falls away on either side. It has a very long axial length but small diameters. The construction of the rotor gives better balance, quieter operation and less windage loss.

This type of rotor is generally used for very high-speed operation (at 3600 rpm) and hence called turbo-generators, which are employed in alternators driven by a steam turbine. The machine is built with ratings from 10 MVA to over 1500 MVA.

Salient pole type alternator

The term salient means protruding or projecting. The poles are made of thick laminated steel sections pivoted together.

The poles are also laminated to minimize the eddy current losses. The salient pole type of rotors is characterized by their large diameters and relatively short axial lengths.



It is generally used for low and medium-speed operations, mainly employed in engine-driven alternators.

(c).

Solution : Given data

For dc shunt motor with lap winding

∴ No.of turns = 600

No.. of conductors (z) = 600 × 2 = 1200

Armature current (Ia) = 100amp

Speed (N) = 600 rpm,

No. of pole(P) = 4

Flux per pole(0) = 100 mWb = 100×10^{-3} wMb then $T_A - T_{SH} = 60\ N-M$

Gross mechanical torque (Ta) = ?

and Output power (Pwt) = ?

Now,. We know that

$$Ta = 0.159 \times \frac{PZ\phi}{A} \times Ia$$

Here Al = P (due to lap winding)

$$Ta = \frac{0.159 \times (4 \times 1200 \times 100) \times 10^{-3} \times 100)}{4}$$

$\therefore$ Ta = 1908 N-m

$\therefore$ Given that

Ta – Tsh = 60 N.m.

Tsh = Ta –60

Tsh = 1908 - 60 = 1948 N.m.

We know that,

$$Tsh = 9.55 \times \frac{P_{out}}{N}$$

$$P_{out} = \frac{N.T_{sh}}{9.55}$$

$$= \frac{600 \times 1848}{9.55}$$

= 116104.71 watt

= 116.10 Kw.

7.(a) Solution

Lets assume stator loss (Psc) = 500W

$$Ns = \frac{120 f_1}{P} = \frac{120 \times 50}{4} = 1500\text{ rpm}$$

$$f_2 = \frac{120}{60} = 2$$

$$S = \frac{f_2}{f_1} = \frac{2}{50} = 0.04 \text{ or } 4\%$$

$$Nr = (1-S)\,Ns = (1-0.04)1500$$
$$= 1440 \text{ rpm}$$

$$Wr = 2\pi n_r = \frac{2\pi \times 1440}{60} = 150.79 \text{ rad/s}$$

(i) Shaft power output $(P_o) = T_{shaft} \times W_r$

$$= 200 \times 150.79$$
$$= 30.15 \text{ kw}$$

also mechanicl lpower developed

$$(200+15) \times 150.79$$
$$= 32.42 \text{ kw}$$

(ii) rotor copper loss (Pre) $= \left(\frac{s}{1-c}\right)P_{md}$

$$= \left(\frac{0.04}{1-0.04}\right)32421$$
$$= 1.35 \text{ kw}$$

(iii) stator input $(p1) = Pmd + Pre + Psc$

$$= 32.42 + 1.35 + 0.5$$
$$= 34.27\text{kw}$$

(iv) Efficiency$= \frac{P_o}{P_i} = \frac{30.15}{34.27} = 0.8727Pu = 87.974$

(b)

The fundamental difference between these two motors is that the speed of the rotor relative to the speed of the stator is equal for synchronous motors, while the rotor speed in induction motors is less than its synchronous speed. This is why induction motors are also known as asynchronous motors.

The asynchronous nature of induction motors creates slip-the difference between the rotating speed of the shaft and the speed of the motor's magnetic field—which allows for increased torque. These motors are powered at the stator, while the rotor induces current-hence the name "induction" motor. Synchronous motors experience no slip because the stator and rotor are in sync and require an external AC power source.

Synchronous motors include two electrical inputs, making them doubly excited machines. In three-phase synchronous motors typically three-phase AC or another input will supply the stator winding required to facilitate torque generation. The rotor supply used is often DC, which either starts or excites the rotor. When the stator and rotor fields lock together, the motor is now synchronous. These motors are used in applications such as power stations, manufacturing facilities, and voltage control in transmission lines.

Unlike synchronous motors, induction motors can start when they supply power to the stator, eliminating the need for a power source to excite or start the rotor. These motors also feature a squirrel cage or wound design, which has led to the development of motor types such as capacitor start induction run motors, squirrel cage induction motors, and double squirrel cage motors. Induction motors see use in centrifugal fans and compressors, conveyors, lathe machines, and lifts.

(c)

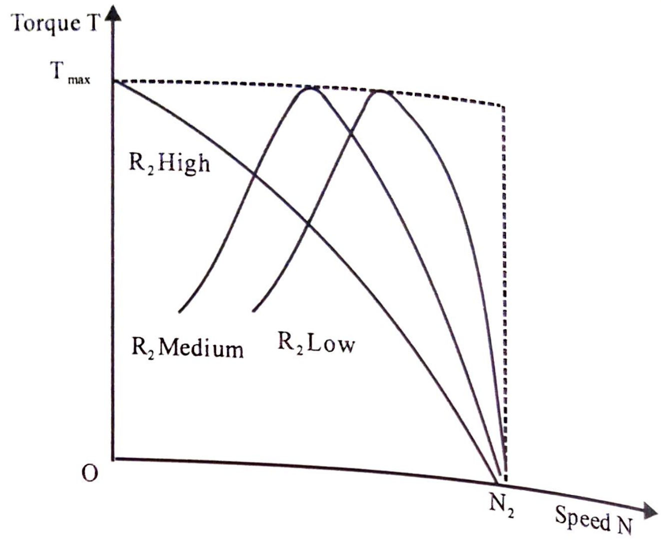
Torque Speed Characteristic is the curve plotted between the torque and the speed of the induction motor. We have already discussed the torque of the induction motor in the topic Torque Equation of an Induction motor. The equation of the torque is given as shown below:

$$T = \frac{ksR^2E^2{}_{20}}{R^2{}_2 + (sX_{20})^2} \qquad \text{......(1)}$$

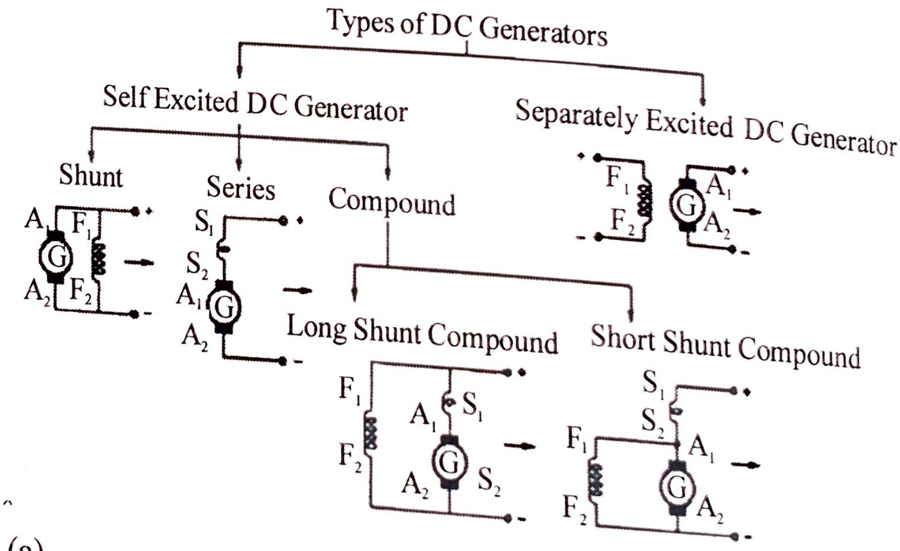
At the maxmium torque the speed of the rotor is expressed by the equation shown below:

$$N_M = N_s(1 - S_m) \qquad \text{..... (2)}$$

The curve below shows the Torque speed characteristic:



The maximum torque is independent of the rotor resistance. But the exact location of the maximum torque T_{max} is dependent on it. The greater, the value of the R_z, the greater is the value of the slip at which maximum torque occurs. As the rotor resistance increases, the pullout speed of the motor decreases. In this condition, the maximum torque remains constant.



8. (a)

CCA is a rating that defines a battery's ability to start an engine in cold temperatures. The rating refers to the number of amps a 12-volt battery can deliver at 0°F for 30 seconds while maintaining a voltage of at least 7.2 volts per cell. The higher the CCA rating, the greater the starting power in the battery.

Measuring cold cranking amps gives someone a good idea of what they can expect from their battery in some of the worst conditions possible for starting a vehicle. Generally speaking, it is easier to start an engine in a warm environment than in a cold one. If you live in a cold climate, the CCA rating is becomes an important consideration in selecting a new replacement battery for your vehicle. Battery starting power deteriorates as the battery ages, so a battery with higher starting power should give you more confidence over time. Replacement batteries should equal or exceed the original battery in ratings. Replacing a battery with a battery that has a lower CCA than the original equipment may result in poor performance.

Specific power, or gravimetric power density, indicates loading capability. Batteries for power tools are made for high specific power and come with reduced specific energy (capacity). Figure 1 illustrates the relationship between specific energy (water in bottle) and specific power (spout opening).

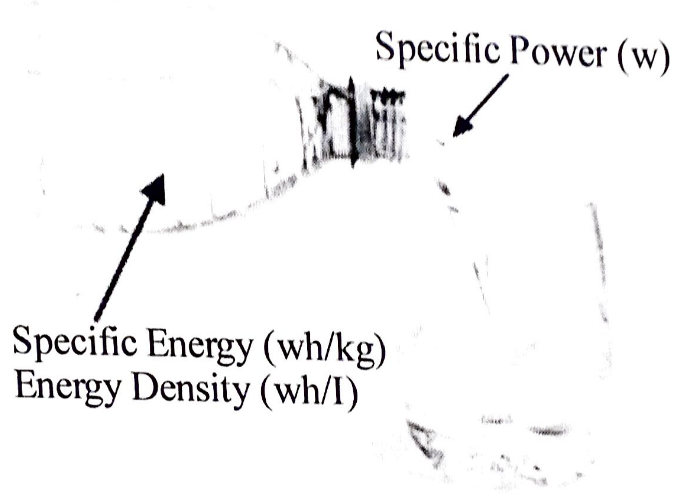


Figure 1: Relationship between specific energy and specific power.

The water in the bottle represents specific energy (capacity); the spout pouring the water govern specific power (loading).

AA battery can have high specific energy but poor specific power as is the case with the alkaline battery, or low specific energy but high specific power as with the super capacitor.

(b)

There are mainly three types of power factor improvement devices:

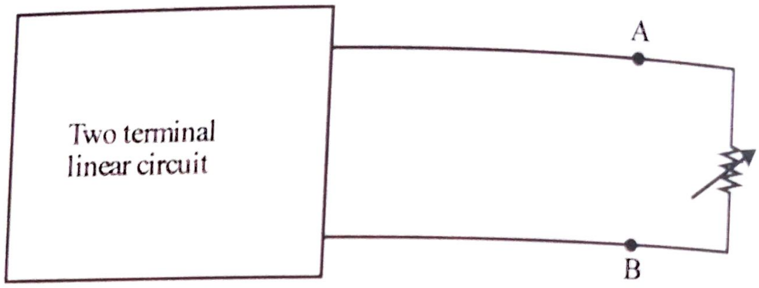
1. Static Capacitor
2. Synchronous Condenser
3. Phase Advancer

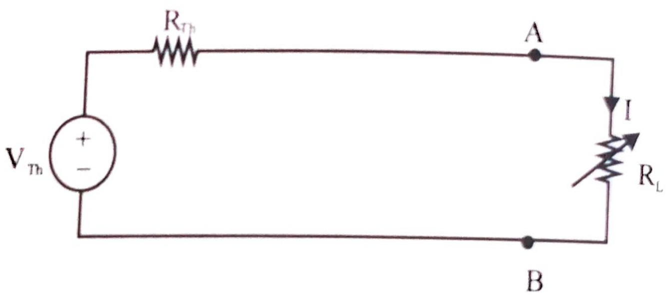
9. (a)

Maximum Power Transfer Theorem explains that to generate maximum external power through a finite internal resistance (DC network), the resistance of the given load must be equal to the resistance of the available source In other words, the resistance of the load must be the same as Thevenin's equivalent resistance

Maximum Power Transfer Formula

As shown in the figure, a dc source network is connected with variable resistance R.





The fundamental Maximum Power Transfer Formula is

$$P_{max} = \frac{V^2{}_{Th}}{4R_{Th}}$$

Maximum Power Transfer Theorem Proof

The Maximum Power Transfer Theorem aims to figure out the value

RL

such that it consumes maximum power from the source.

$$I = \frac{V_{Th}}{R_{Th} + R_L}$$

The total power connected to the resistive load

$$P_L = I^2R_L = \left(\frac{V_{Th}}{R_{Th}+R_L}\right)^2 \times RL$$

$$P_L = \left(\frac{V_{Th}}{R_{Th}+R_L}\right)^2$$

can be maximized by adjusting

RL

therefore highest power can be generated when

$(dP_L/R_L) = 0$

But,

$$\frac{dP_L}{dR_L} =$$

$$\frac{1}{\left[(R_{Th}+R_L)^2\right]^2}\left[R_{Th}+R_L\right]^2 \frac{d}{dR_L}\left(V2_{Th}R_L\right) - V2_{Th}R_L\frac{d}{d_{RL}}\left[R_{Th}+R_L\right]^2$$

$$= \frac{1}{\left(R_{Th}+R_L\right)^4}\left[R_{Th}+R_L\right]^2 V^2{}_{Th} - V^2{}_{Th}R_L \times 2\left(R_{Th}+R_L\right)$$

$$= \frac{V^2{}_{Th}(R_{Th}+R_L-2R_L)}{(R_{Th}+R_L)^3} = \frac{V^2{}_{Th}(R_{Th}-R_L)}{(R_{Th}+R_L)}$$

$$\frac{dP_L}{dR_L} = 0$$

$$\frac{V^2{}_{Th}(R_{Th}-R_L)}{(R_{Th}+R_L)} = 0$$

$(R_{th} - R_L) = 0$

$R_{th} = R_L$

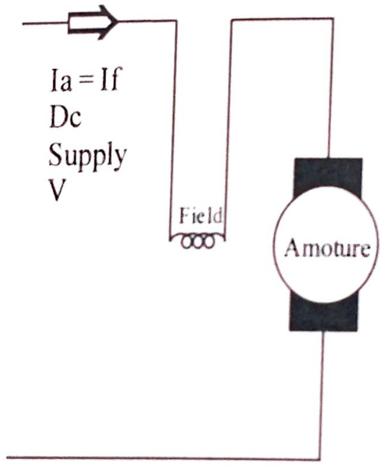
So, the highest power transmitted ot the load resistance is,

$$P_{max} = \frac{V^2{}_{Th}}{4R_{Th}}$$

(b)

The DC series motor attains dangerously high speed when we run it on no load. The main reason of over speeding is that at no load the flux produced by the field winding is very less and the reduced flux cause over speeding of the motor. The speed of the motor is inversely proportional to the flux. In DC series motor, the field and armature winding is connected in the series and, both winding carries the same amount of current. The field winding has to carry the full rated armature current, therefore the field coil has few turns of thicker wire.

The speed of the DC motor is proportional to the back EMF(Eb) and inversely proportional to the flux. The flux is proportional to the field current.



Series Excited DC Motor

In the DC series motor the field current and the armature current is same. Therefore, the flux in the motor is proportional to the armature current(Ia).

N=K1×Eb/ϕ .....(1)

N= Speed of the motor

Eb= Back EMF of the armature

O=Flux

K= constant

When the armature current flows, the armature inductance opposes the flow of the current. The voltage of the opposite polarity to applied voltage(V) is induced in the armature to impede the armature current. The voltage induced in the armature is known as the back EMF(Eb).

According to the Kirchoff's current law, the algebraic sum of all the voltage around any closed loop in a circuit is zero.

$V + Ia(Ra + Rf) + Eb = 0$ ......(2)

Ra= The armature resistance

Rf= The field resistance

V= Applied Voltage

$Eb = V - Ia(Ra + Rf)$ .....(3)

$N = K1 \times Eb/\phi$

$Eb = N\phi$ .....(4)

Putting the value of Eb of equation(4) in equation (3)

$K1 \times N\phi = V - Ia(Ra + Rf)$

$N = [V - Ia(Ra + Rf)]/K1 \times \phi$

$N - [V - Ia(Ra + Rf)]/K1 \times K2 1a$

($\phi \propto If$, or $\phi \propto Ia$ as Ia =if) K2- Constant

$N = [V - Ia(Ra + Rf)]/K1K2 \times Ia$

$N = (V/K1K2 \times 1/la - (Ra + Rf)]/K1K2$

$N = (V/K1K2) \times 1/Ia - (Ra + Rf)]/K1K2$

$N = K3 * 1/la - K4$

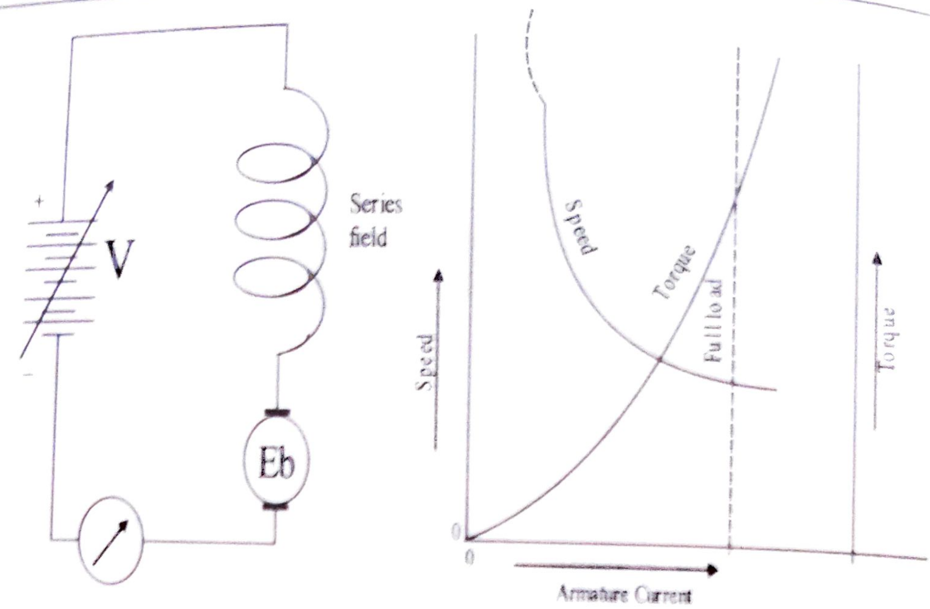
Where K3(constant) = (V/K1K2)

K4(constant) = (Ra + Rf)]/K1K2

$N = K3/la\text{-}K4$ ....(5)

From equation (5) it is clear that the speed of the dc series motor is inversely proportional to the armature current.

The armature current v/s speed characteristics of the DC series motor is as given below.



At no load, the armature current of the DC series motor is very low. If the motor is operated at no load, the motor will attain the enormously high speed that can physically damage the rocker arm assembly and the motor parts. This is like the same case when the separately excited DC motor is started without switching on the filed supply.

When the DC series motor is connected to the load at the time of starting of the motor, the motor draws the more armature current compared to the starting current with motor operation at no load and the speed of the motor increases in the controlled way. The DC series motor must not be tested on no load condition.

In view of the above reasons, the DC series motor should not be started at no load.