COURSE : B.E (REG)-EEE SEM/YEAR : V/III

SUBJECT : INDUCTION AND SYNCHRONOUS MACHINES

SUBJECT CODE: BEEF185T40

COURSE PLAN

Topic No	Topic Name	No. of Periods	Proposed Date of Completion
	UNIT – I		
1	CONSTRUCTION(SF&RF)- TYPES(SALIENT&NON-SALIENT) --ALTERNATOR PARAMETERS- SYNCHRONOUS REACTANCE -CIRCUIT MODEL	2	**14/07/21**
2	ARMATURE REACTION AND VOLTAGE REGULATION OF ALTERNATOR	2	**16/07/21**
3	DETERMINATION OF VOLTAGE REGULATION - EMF, MMF	2	**21/07/21**
4	DETERMINATION OF VOLTAGE REGULATION - POTIER METHOD, ASAMETHOD	2	**23/07/21**
5	SYNCHRONIZING -METHODS OF PARALLEL OPERATION	2	**28/07/21**
	UNIT – III THREE PHASE INDUCTION MACHINES		
1	THREE PHASE INDUCTION MOTOR-CONSTRUCTION-TYPES- WORKING PRINCIPLE OF THREE PHASE INDUCTION MOTOR	2	**30/07/21**
2	TORQUE EQUATION AND RELATION SHIP BETWEEN VARIOUS TORQUE IN THREE PHASE INDUCTION MOTOR	2	**04/08/21**

3	PROBLEMS RELATED TO TORQUE EQUATION	2	**04/08/21**
4	POWER OUTPUT &LOSSES IN INDUCTION MOTOR- PROBLEMS RELATED TO POWER OUTPUT &LOSSES	2	**06/08/21**
5	EQUIVALENT CIRCUIT - TESTING OF THREE PHASE INDUCTION MOTOR	2	**11/08/21**
-6	EQUIVALENT CIRCUIT PROBLEMS-COGGING AND CRAWLING	2	**11/08/21**
7	STARTING METHODS OF THREE PHASE INDUCTION MOTOR- DOUBLE CAGE ROTOR	2	**13/08/21**
8	SPEED CONTROL OF THREE PHASE INDUCTION MOTOR	2	**13/08/21**
UNIT – IV SINGLE PHASE INDUCTION MACHINE			
1	SINGLE PHASE INDUCTION MOTOR – CONSTRUCTION& WORKING PRINCIPLE -DOUBLE REVOLVING FIELD THEORY	2	**25.08.21**
2	STARTING METHODS OF SINGLE PHASE INDUCTION MOTOR(TYPES)- LOAD CHARACTERISTICS	2	**27.08.21**
3	EQUIVALENT CIRCUIT - PERFORMANCE ANALYSIS	2	**01.09.21**
4	PROBLEMS RELATED TO EQUIVALENT CIRCUIT	2	**03.09.21**

UNIT – V : FRACTIONAL HORSE POWER MOTORS			
1	CONSTRUCTION AND WORKING PRINCIPLE SHADED - POLE INDUCTION MOTOR	2	**08.09.21**
2	CONSTRUCTION AND WORKING PRINCIPLE OF VARIOUS TYPES OF STEPPER MOTOR	2	**15.09.21**
3	CONSTRUCTION AND WORKING PRINCIPLE OF AC SERIES MOTOR	1	**17.09.21**
4	PERMANENT MAGNET DC AND AC MOTORS	1	**17.09.21**
UNIT – II SYNCHRONOUS MOTORS			
1	SYNCHRONOUS MOTOR- CONSTRUCTION AND WORKING PRINCIPLE- STARTING METHODS OF SYNCHRONOUS MOTOR	2	**29.09.21**
2	PHASOR DIAGRAMS	2	**01.10.21**
3	V & INVERTED V CURVES	2	**06.10.21**
4	PHASE MODIFIERS- HUNTING IN SYNCHRONOUS MOTOR	2	**08.10.21**
5	HUNTING PREVENTION IN SYNCHRONOUS MOTOR	2	**13.10.21**
6	APPLICATIONS OF SYNCHRONOUS MOTOR	2	**15.10.21**
7	REVISION OF SYNCHRONOUS GENERATOR&MOTOR(UNIT-I&II)	2	**22.10.21**
8	REVISION OF INDUCTION MOTOR(UNIT-III)	2	**27.10.21**
9	REVISION OF SINGLE PHASE INDUCTION MOTOR & SPECIAL MACHINES(UNIT-IV &V)	2	**29.10.21**

INDUCTION MACHINES

SINGLE PHASE INDUCTION MOTOR

1. Aim & objective:

1. **Introduction to single phase induction motor**

2. **To study the Construction of single phase induction motor.**

3. **To understand the Working of single phase induction motor.**

4. **To study the Various types of single phase induction motor**

5. **To deduce the equivalent circuit of single phase induction motor based on DRF& analyzing the performance.**

6. **To study the procedure for Testing of single phase induction motor for obtaining the equivalent circuit**

2. PRE TEST:

1. When the magnetic flux linking a conductor or coil changes

   a) It produces no flux   b) it produces sinusoidal flux

   C) It produce EMF   d) none of the above

2. The direction of induced EMF can be determined by

   a) LENZ   b) Flemings right hand rule   c) left hand rule   d) none of the above

3. The EMF induced in the coil due to change in own flux

   a) Self induced EMF   b) mutual induced EMF   c) Both a&b   d) none of the above

4. The EMF induced in the coil due to change in current in the other coil

a) Self induced EMF b) mutual induced EMF c) Both a&b d) none of the above

5. Factors affecting the inductance

   a) Number of turns b) permeability c) shape d) all of the above

6. Double revolving field theory formulated by

   a) Ferrari b) Lenz c) Maxwell d) none of the above

7. According to DRF single pulsating magnetic field resolved in to

   a) Two b) three c) four d) none of the above

8. The direction of rotation of single phase induction motor depends on

   a) Direction of starting torque b) current c) voltage d) none of the above

9. DRF explains why single phase induction motor is.

   a)self starting b) not self starting c) low torque d) none of the above.

10. A centrifugal switch is

    a) Force operated b) voltage c) current d) none of the above

3. PRE –REQUISITES:

1. FARADAYS LAW OF ELECTROMAGNTIC INDUCTION

2. DOUBLE REVOLVING FIELD THEORY

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SINGLE-PHASE INDUCTION MOTORS

4.1 INTRODUCTION:

There are two basic reasons for the use of single-phase motors rather than 3-phase motors.

1. For reason of economy, most houses, offices and also rural areas are supplied with single phase a.c, as power requirements of individual load items are rather small.

2.Single phase motors are simple in construction, reliable, easy to repair and comparatively cheaper in cost

Because of above reasons motors of comparatively small ratings (mostly in fractional KW ratings) are manufactured in large number to operate on single phase ac at standard frequencies.

TYPES OF SINGLE-PHASE MOTOR:

The Single phase motors may be of the following types:

1. Single-phase Induction Motors:

A. Split-phase motors
   - (i) Resistance-start motor
   - (ii) Capacitor-start motor
   - (iii) Permanent-split (single-value) capacitor motor
   - (iv) Two-value capacitor motor.

B. Shaded-pole induction motor.

C. Reluctance-start induction motor.

D. Repulsion-start induction motor.

2. Commutator-Type, Single-Phase Motors:

A. Repulsion motor.

B. Repulsion-induction motor.

C. A.C series motor.

D. Universal motor.

3. Single-phase Synchronous Motors:

A. Reluctance motor.

B. Hysteresis motor.

C. Sub-synchronous motor.

SINGLE-PHASE INDUCTION MOTORS

Applications and Disadvantages:

Applications:

- Single phase induction motors are in very wide use in industry especially in fractional horse-power field.

  They are extensively used for electrical drive for low power constant speed apparatus such as machine tools, domestic apparatus and agricultural machinery in circumstances where a three-phase supply is not readily available.
- Single phase induction motors sizes vary from 1/400 kw to 1/25 kw are used in toys, hair dryers, vending machines etc.
- Find wide use in fans, refrigerators, vacuum cleaners, washing machines, other kitchen equipment, tools, blowers, centrifugal pumps, small farming appliances etc.
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Disadvantages:

The main disadvantages of single-phase induction motors are:

1. Their output is only 50% of the three-phase motor, for a given frame size and temperature rise.

2. They have lower power factor.
3. Lower efficiency.
4. These motors do not have inherent starting torque.
5. More expensive than three-phase motors of the same output.
6. Low overload capacity.

4.2 CONSTRUCTION OF SINGLE PHASE INDUCTION MOTOR:

Single phase induction motor is very simple and robust in construction. The stator carries a distributed winding in the slots cut around the inner periphery. The stator conductors have low resistance and they are winding called Starting winding is also mounted on the stator. This winding has high resistance and its embedded deep inside the stator slots. The rotor is invariably of the squirrel cage type.. The auxiliary winding has a centrifugal switch in series with it. The function of the switch is to cut off the starting winding, when the rotor has accelerated to about 75% of its rated spe ed. In capacitor-start motors, an electrolytic capacitor of suitable capacitance value is also incorporated in the starting winding circuit.

The main stator winding and auxiliary (or starting) winding are joined in parallel, and the polarity of only the starting winding can be reversed. This is necessary for changing the direction of rotation of the rotor.

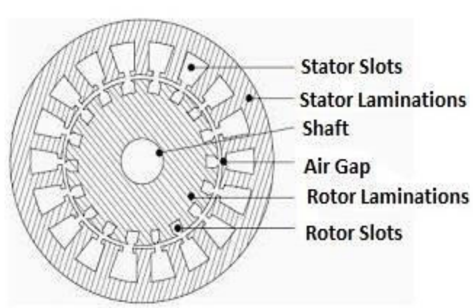

Fig: 1.41

A 1-phase induction motor is similar to a 3-phase squirrel cage induction motor in physical appearance. The rotor is same as that employed in 3-phase squirrel cage induction motor. There is uniform air gap between stator and rotor but no electrical connection between them.

Although single phase induction motor is more simple in construction and is cheaper than a 3-phase induction motor of the same frame size, it is less efficient and it operates at lower power factor.

4.3WORKING OF SINGLE-PHASE INDUCTION MOTOR:

A single phase induction motor is inherently not self-staring .

Consider a single phase induction motor whose rotor is at rest. Let a single phase a.c. source be connected to the stator winding. Let the stator be wound for two poles.

When power supply for the stator is switched on, an alternating current flows through the stator winding. This sets up an alternating flux. This flux crosses the air gap and links with the rotor conductors. By electromagnetic induction e.m.f.'s are induced in the rotor conductors. Since the rotor forms a closed circuit, currents are induced in the rotor bars. Due to interaction between the rotor induced currents and the stator flux, a torque is produced. It is readily seen that upper half come under a stator N pole, lower half come under a stator S pole. Hence the upper half of the rotor is subjected to a torque which tends to rotate it in one direction and the lower half of the rotor is acted upon by an equal torque which tends to rotate it in the opposite direction. The two equal and opposite torques cancel out, with the result that the net driving torque is zero. Hence the rotor remains stationary. Thus the single phase motor fails to develop starting torque.

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If, however, the rotor is in motion in any direction when supply is switched on, the rotor develops more torque in that direction. The net torque then would have non-zero value, and under its impact the rotor would speed up in its direction.

The analysis of the single phase motor can be made on the basis of two theories:

i. Double revolving field theory, and
ii. Cross field theory.

Each of the two component fluxes, while revolving round the stator, cuts the rotor, induces an e.m.f. and this produces its own torque. Obviously, the two torques (called forward and backward torques) are oppositely-directed, so that the net or resultant torques is equal to their difference as shown in fig: (g)

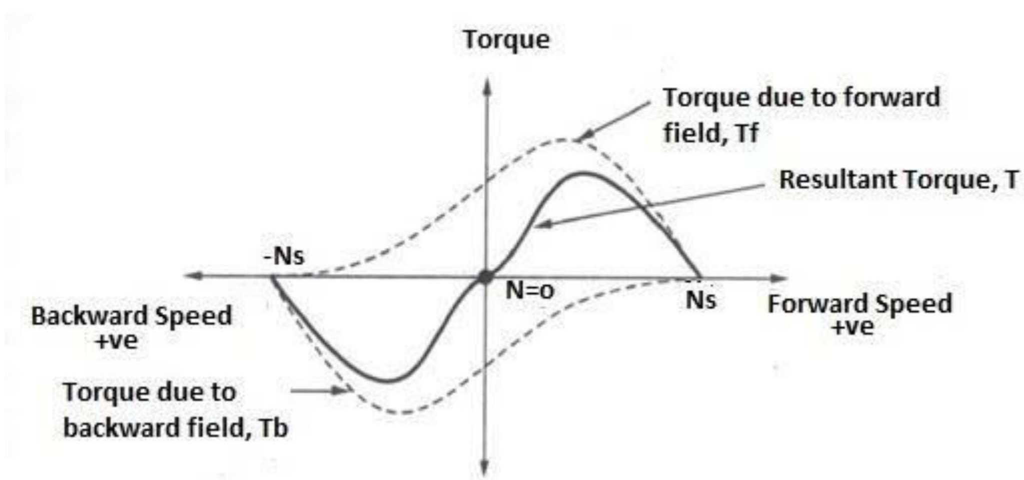


Fig:g Torque-Speed characteristics

Fig: (g) shows both torques and the resultant torque for slips between zero and +2. At standstill, S=1 and (2-S) =1. Hence, T_f and T_b are numerically equal but, being oppositely directed, produce no resultant torque. That explains why there is no starting torque in a single-phase induction motor.

However, if the rotor is started somehow, say, in the clockwise direction, the clockwise torque starts increasing and, at the same time, the anticlockwise torque starts decreasing. Hence, there is a certain amount of net torque in the clockwise direction which accelerates the motor to full speed.

4.4 .STARTING METHODS OF SINGLE-PHASE INDUCTION MOTORS:

A single-phase induction motor with main stator winding has no inherent starting torque, since main winding introduces only stationary, pulsating air-gap flux wave. For the development of starting torque, rotating air-gap field at starting must be introduced. Several methods which have been developed for the starting of single-phase induction motors may be classified as follows:

a) Split-phase starting.
b) Shaded-pole starting.
c) Repulsion-motor starting and
d) Reluctance starting.

A single-phase induction motor is commonly known by the method employed for its starting. The selection of a suitable induction motor and choice of its starting method, depend upon the following:

(i) Torque-speed characteristic of load from standstill to the normal operating speed.
(ii) The duty cycle and
(iii) The starting and running line-current limitations as imposed by the supply authorities.

(a) SPLIT-PHASE STARTING:

In this type of Single-phase induction motors have two stator windings, a main (or running) winding and an auxiliary (or starting) winding. Both these windings are connected in parallel but displaced by 90^0 electrical.

Rotating magnetic field is produced by varying the impedance of these windings, the currents may be made to differ in time phase, thereby producing a rotating field. This is the principle of phase splitting. Split phase motors are of following types.

1. Resistor-split phase motors
2. Capacitor split-phase motors
3. Capacitor start and run motors
4. Capacitor-run motors

4.4.1 RESISTOR SPLIT-PHASE MOTORS:

The stator of a split-phase induction motor is provided with an auxiliary or starting winding S in addition to the main or running winding M. The starting winding is located 90° electrical from the main winding [See figure: 4.4.1(a)]. Among The two windings , the starting winding S has a high resistance and relatively small reactance while the main winding M has relatively low resistance and large reactance Consequently, the currents flowing in the two windings have reasonable phase difference (25° to 30°)

Operation

(i) When the windings are energized from a single-phase supply, the main winding carries current I_m while the starting winding carries current I_s

(ii) Since main winding is made highly inductive while the starting winding highly resistive, the currents I_m and I_s have a reasonable phase angle a (25° to 30°) Consequently, a weak revolving field produced which starts the motor. The starting torque is given by;

$$Ts = k\, I_m\, I_s \sin\phi$$

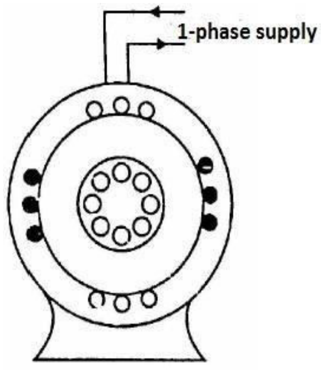
When the motor attains about 75% of synchronous speed, the centrifugal switch disconnect the circuit of the starting winding. The motor then operates as a single-phase induction motor and it reaches the normal speed.

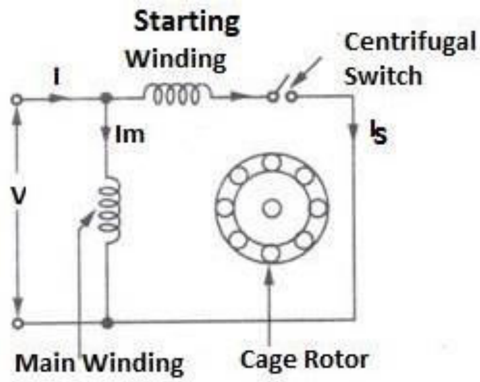
Characteristics:

(i) due to their low cost, split-phase induction motors are most popular

(ii) The current density is high and the winding heats up quickly. so This motor is, therefore, suitable where starting periods are not frequent.

(iii) An important characteristic of these motors is essentially constant-speed motors. The speed variation is 2-5% from no-load to full-load





Schematic Diagram of Resistor-split phase motor

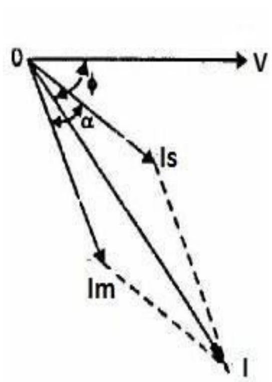
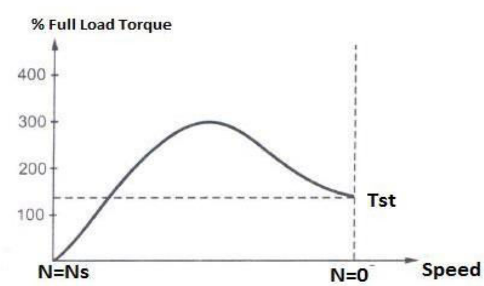


Fig: 4..4.1(a) **Fig:** 4.41(b) **Fig:** 4.41(c)



Applications:

These motors find the application where a moderate starting torque is required

a. Fans

b. washing machines

c. oil burners

d. Small machine tools etc.

The power rating of such motors lies between 60 W to 250 W .

4.4.2 Capacitor split-phase motors (or) Capacitor start motors:

It is similar to a resistor split-.phase motor except that the starting winding has as many turns as the main winding. Moreover, a capacitor C is connected in series with the starting winding The value of capacitor is so chosen that I_s leads I_m by about 80°.Consequently, starting torque is much more than that of a split-phase motor . The starting winding is opened by the centrifugal switch when the motor attains about 75% of synchronous speed.

Characteristics

(i) Although starting characteristics of a capacitor-start motor are better than those of a resistor split-phase motor, both machines possess the same running characteristics because the main windings are identical.

(ii) The phase angle between the two currents is about 80° compared to about 25° in a resistor split-phase motor.. Therefore, the starting winding of a capacitor start motor heats up less quickly and is well suited to applications involving either frequent or prolonged starting periods.

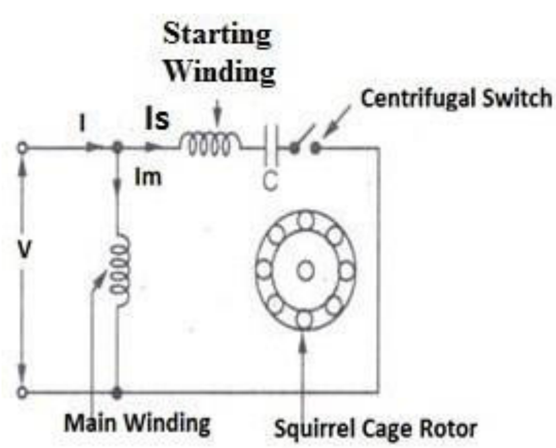


Fig: 4.4.2(a)

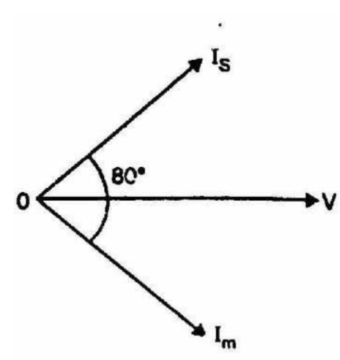
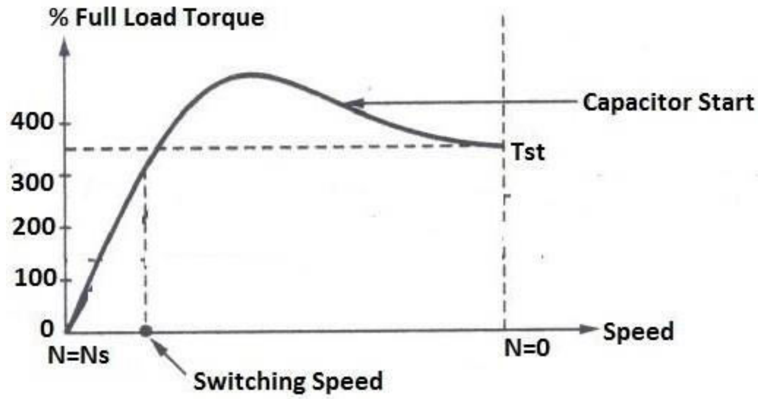


Fig: 4.4.2(b)



Applications:

These motors are used when high-starting torque is needed

a. Refrigerators
b. Air-conditioners
c. Compressors
d. Reciprocating pumps

The power rating of such motors lies between 120 W to 750W.

4.4.3Capacitor-Start and Capacitor-Run motors:

This motor is identical to a capacitor-start motor except that starting winding is not opened after starting. Two designs are generally used. In one design, a single capacitor C is used for both starting and running as shown in fig: 4.4.3(a).This design improves the power factor and efficiency of the motor. In the other design, two capacitors C1 and C2 are used in the starting winding as shown in fig: 4.4. (b) The smaller capacitor C1 permanently connected in series with the starting winding. The much larger capacitor C2 is connected in parallel with C1 for optimum starting and remains in the circuit during starting. The starting capacitor C1 is disconnected when the motor reaches about 75% of synchronous speed. The motor then runs as a single-phase induction motor.

Characteristics

(i) The motor then produces a constant torque and not a pulsating torque

(ii) Because of constant torque, the motor is free from vibration.

Applications:

a. Hospitals
b. Studios and

c. Other places where noiseless operation is important.

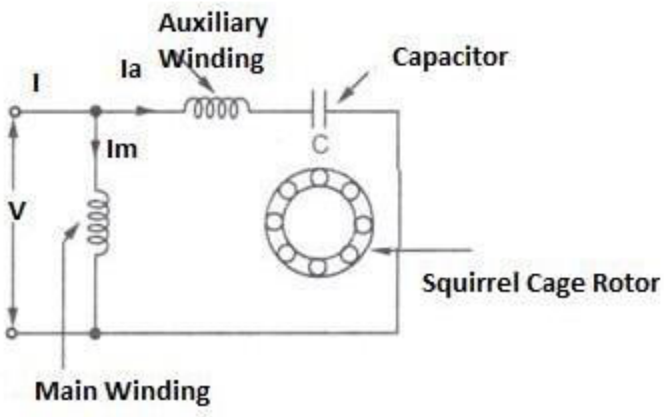


Fig: 4.4 3(a)

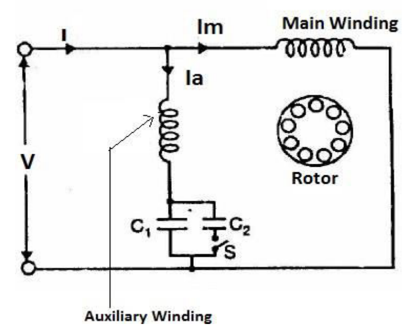
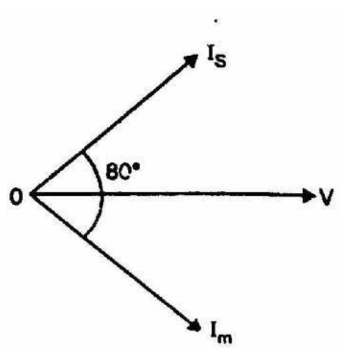
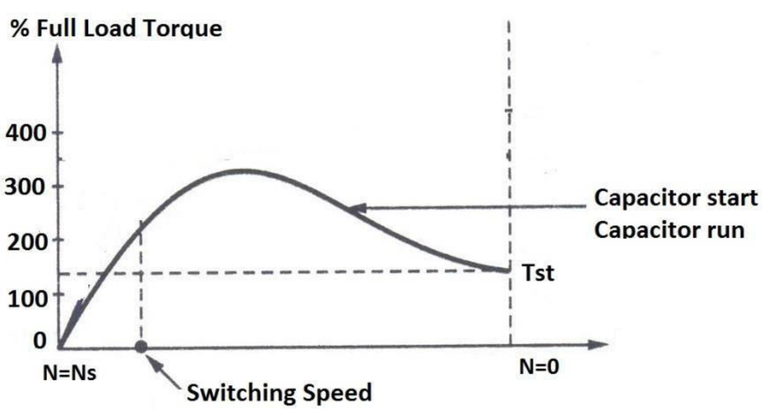


Fig: 4.4.3 (b)

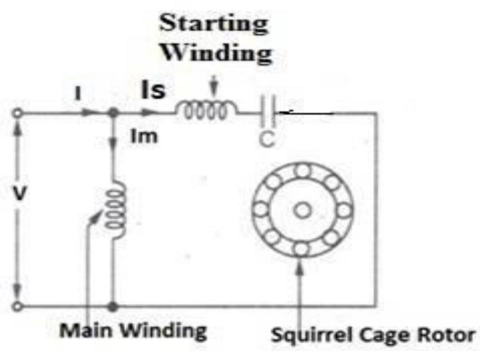




The power rating of such motors lies between 100 to 400 watts

4.4.4Capacitor-run motors:

This motor is also called permanent split capacitor motor. The same capacitor is kept permanently in series with auxiliary winding both at starting and under running conditions there is no centrifugal switch.



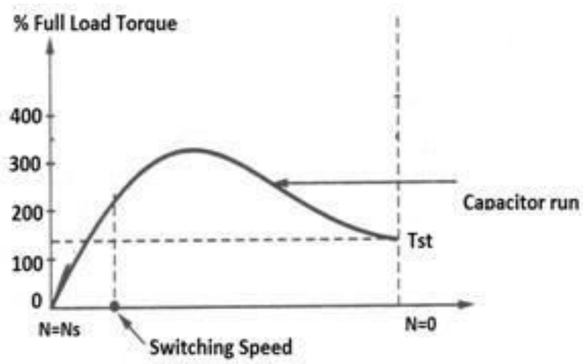


Fig: 4.4.4 (a) **Fig**: 4.4.4 (b)

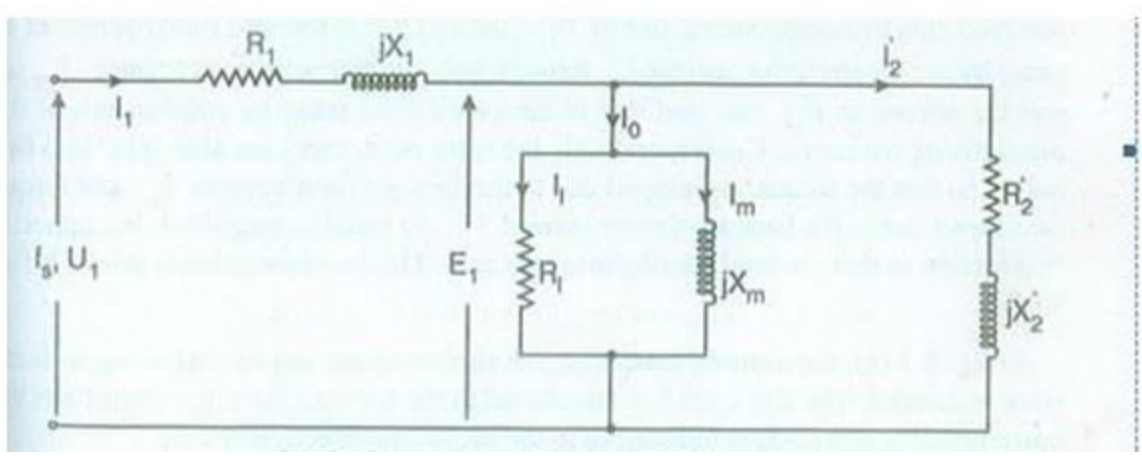
In these motors, the value of permanent capacitor is so chosen as to obtain a compromise between the best starting and running conditions. A typical torque-speed characteristic is shown in fig: 4.4.4 (b)

These motors are used where quiet operation is essential as in

a. Offices
b. Class rooms
c. Theaters
d. Ceiling fans, in which the value of capacitance varies from 2 to 3μF.

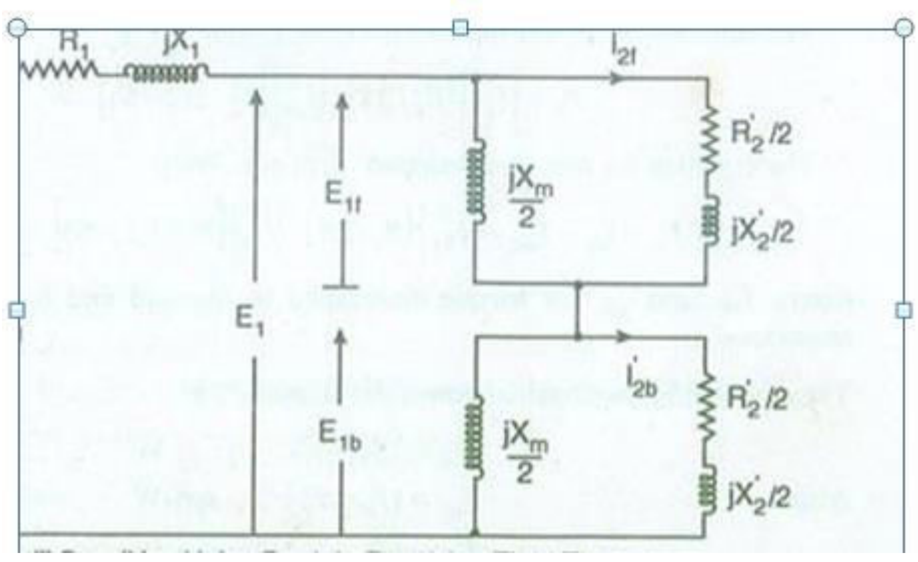
4.5. EQUIVALENT CIRCUIT OF SINGLE PHASE INDUCTION MOTOR:

EQUIVALENT CIRCUIT AT STAND STILL CONDITION:

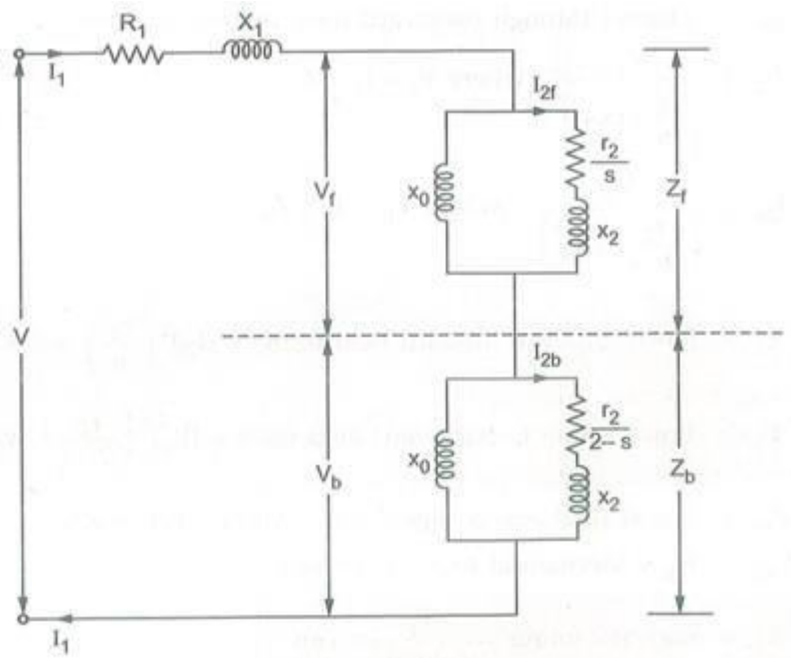


The double revolving field theory can be effectively used to obtain the equivalent circuit of a single phase induction motor

Stand still condition: (based on DRF)

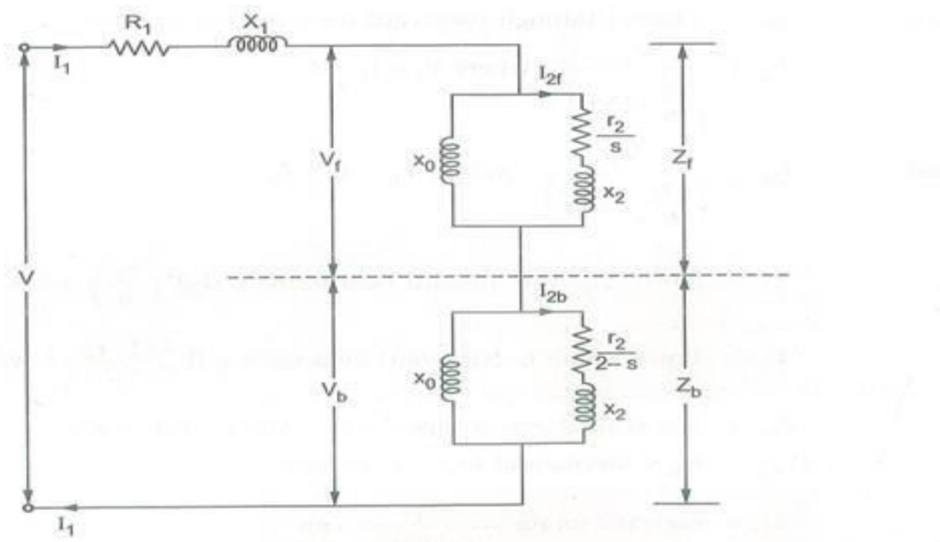


Running condition: (based on DRF without core loss)



Imagine that the single phase induction motor is made up of one stator windings and two imaginary rotor windings. one rotor is rotating in forward direction i.e.in the direction of rotating magnetic field with slip s while other is rotating in backward direction i.e.in direction of oppositely directed rotating magnetic field with slip 2-s.

Running condition: (based on DRF without core loss)



Performance analysis:

Without core loss

let the stator impedance be Z Ω

$$Z = R1 + j\, X1$$

Where R1 = stator resistance

X1 = stator reactance

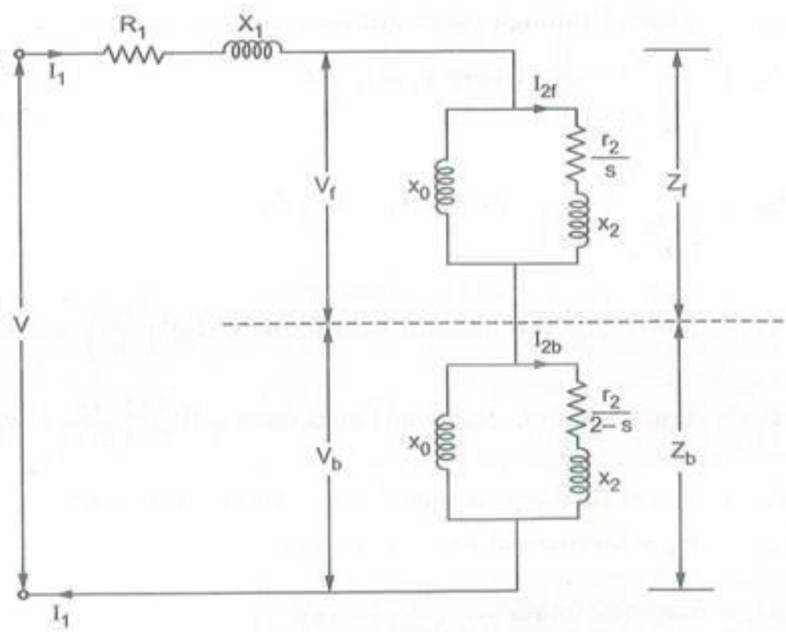
and X2 = rotor reactance referred to stator

R2 = rotor resistance referred to stator

Hence the impedance of each rotor is r2 + j x2 where

$$X2 = X2 /2$$

Running condition: (based on DRF without core loss)



Now the impedance of the forward field rotor is Zf which is parallel combination of (0+j x0) and (r2/s) + jx2.

$$Zf = \frac{jx0[(r2/s)+jx2]}{r2/s+j(x0+x2)}$$

While the impedance of the backward field rotor is Zb which is parallel combination of (0+jx0) and [r2/2-s]+jx2.

$$Zb = \frac{jx0[(r2/2-s)+jx2]}{r2/2-s+j(x0+x2)}$$

Under standstill condition, s=1 and 2 – s =1. Hence Zf =Zb and Vf = Vb. But in the running condition, Vf becomes almost 90 to 95% of the applied voltage.

Zeq = Z1 + Zf +Zb = Equivalent impedance

Let I2f = Current through forward rotor referred to stator

And I2b = Current through backward rotor referred to stator

$$I2f = \frac{Vf}{[\frac{r2}{s}+jx2]}$$ where Vf = I1 X Zf

And $I_{2b} = \frac{V_b}{[r_2/2-s+jx_2]}$ where $V_b = I_1 X Z_b$

Pf = Power input to forward field rotor = $(I2f)^2 [r2/s]$ watts

Pb = Power input to backward field rotor = $(I2b)^2 [r2/2-s]$ watts

$Pm = (1-s)$ [Net power input] $= (1-s)(Pf - Pb)$ watts

Pout = Pm – Mechanical loss – Core loss

Tf = Forward torque $= \frac{Pf}{[2¶N/60]}$ N-m

Tb = Backward torque $= \frac{Pb}{[2¶N/60]}$ N-m

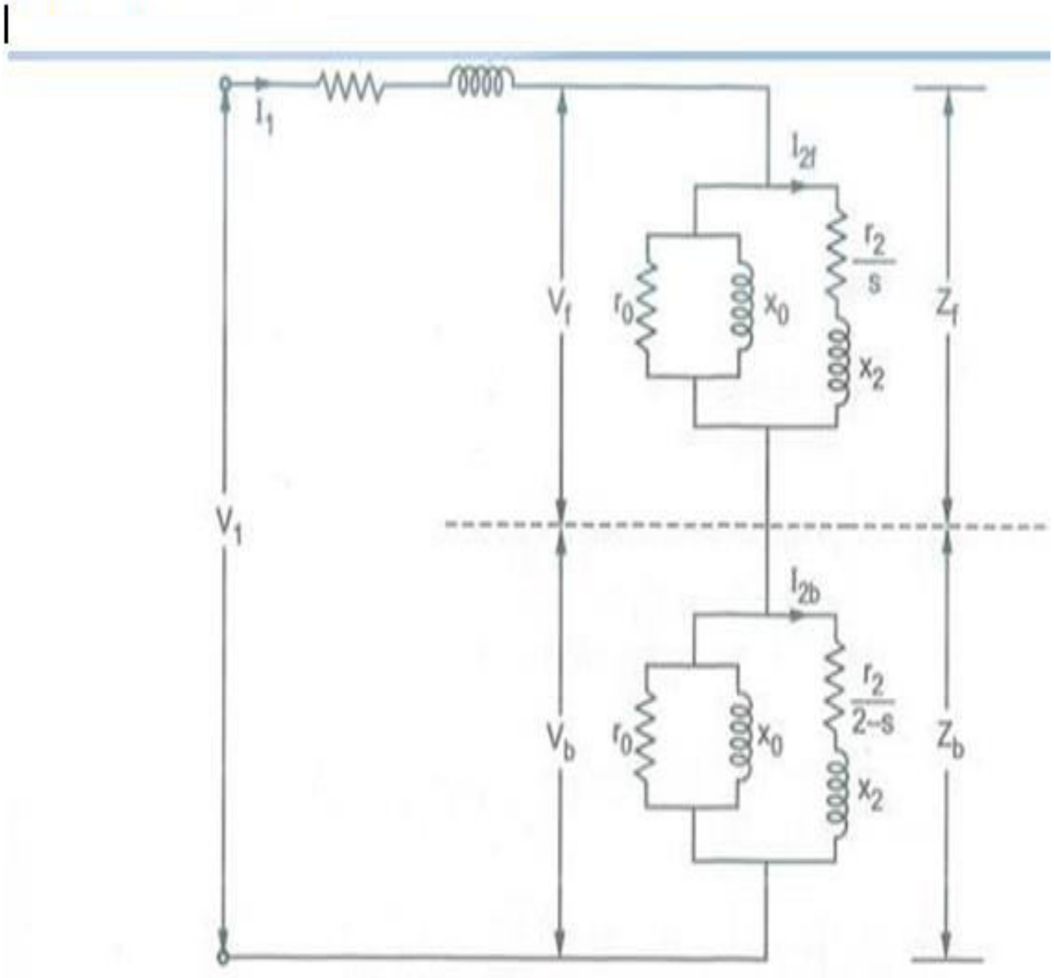
T = Net torque $= Tf - Tb$

While Tsh = Shaft torque $= \frac{Pout}{[2¶N/60]}$ N-m

$$\%\eta = \frac{Net\ output}{Net\ input} X\ 100$$

Equivalent circuit running condition: (based on DRF with core loss)

WITH CORE LOSSES:



Let Z_{of} = Equivalent impedance of exciting branch in forward rotor = $r_0 \| (jx_0)$

and Z_{ob} = Equivalent impedance of exciting branch in backward rotor = $r_0 \| (jx_0)$

$$Z_f = Z_{of} \| [\frac{r_2}{s} + jx_2]$$

All other expressions remain same as stated earlier in case of equivalent circuit without core loss.

4.6. Testing of single phase induction motor

TESTING NEED FOR ESTIMATING THE PERFORMANCE OF THE MACHINE.

IT CAN BE DONE BY TWO METHODS

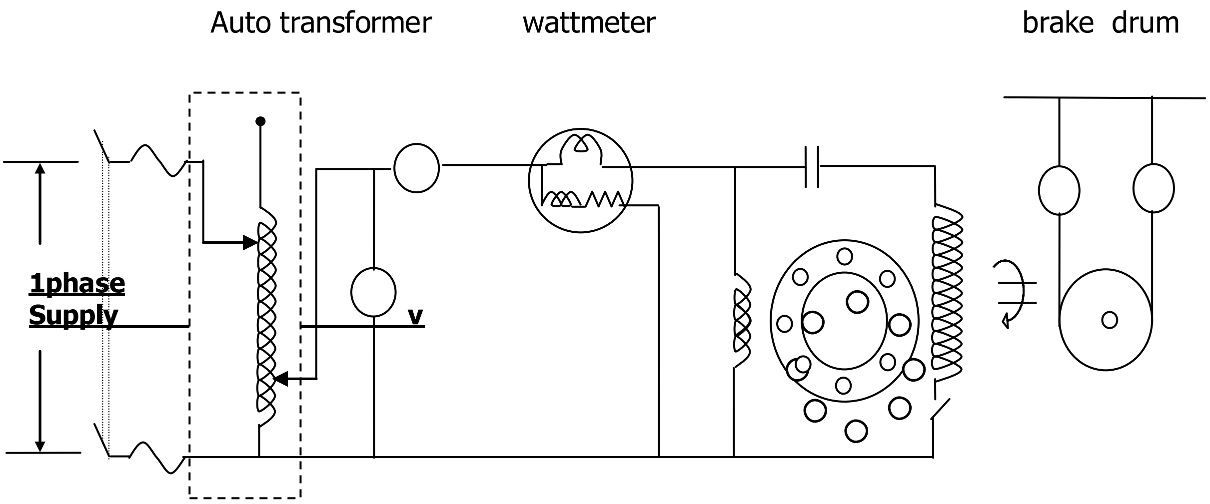
1. **DIERECT METHOD (FOR SMALLER RATED MACHINE)**
2. **INDIRECT METHOD (HIGHER RATED MACHINE)**

4.6.1 Direct method (LOAD TEST)

PROCEDURE:

The connections are made, as per the circuit diagram. With no mechanical loading on the motor, it is started by using the starter provided. The motor will be running with a small slip, very near to the synchronous speed. The readings of the ammeter IL, line voltage applied V_L, speed "N" in r.p.m., and power drawn from supply W_L are noted. The belt is slowly tightened against the brake drum. Now the readings of the spring balances, S1 and S2 in kg, are noted, in addition to the readings mentioned earlier. The loading is increased in convenient steps until 110% of rated current is reached. The readings taken for each loading are tabulated. Gradually decrease the load and after removing the entire load, stop the motor. The effective radius "R" of the brake drum is measured.

Load Test on Single-Phase Induction Motor



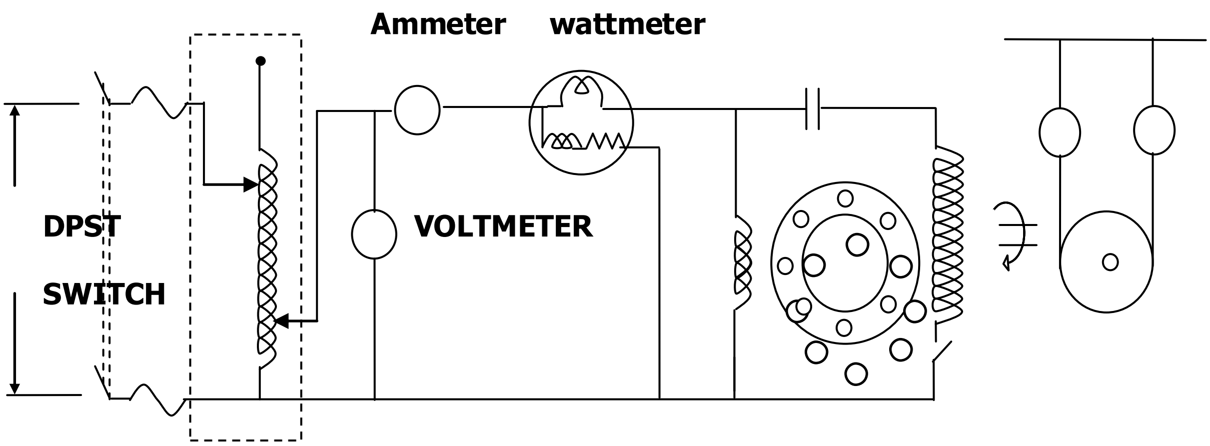
CALCULATION:

- Frequency = F = 50Hz
- Synchronous speed = Ns = ------------- rpm
- Speed at the load = N =------------rpm
- Per unit slip = S = (Ns - N) / Ns
- Radius of the brake drum = r =-------------meter
- Thickness of the belt = t = -----------meter
- Effective radius of the brake drum = R_{eff} = r + t/2 = --------------meter
- Torque Output of Motor = T = (S1 - S2) x (R_{eff}) x 9.81 NM
- Mechanical Power output = P_o = 2 π NT / 60 Watts.
- Electrical Power input to motor = P_i = W_L = --------------watt

4.6.2 INDIRECT METHOD OF TESTING:

IN INDIRECT METHOD, TWO SPECIAL TESTS WERE CONDUCTED, BASED ON THE TEST RESULT, EQUIVALENT CIRCUIT WAS CONSTRUCTED AND PERFORMANCE OF MOTOR WAS ANALYSED.

Blocked Rotor Test on Single-Phase Induction Motor



AUTO TRANSFORMER WATTMETER

BLOCKED ROTOR TEST:

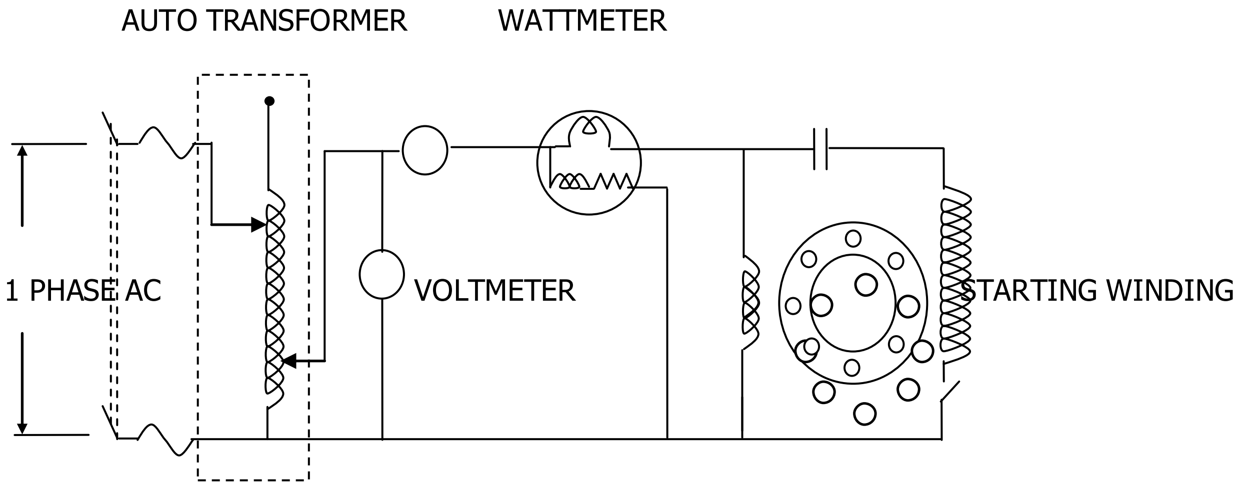
- Connections are given as per circuit diagram.
- The motor should not be allowed to run by tightening the belt around the break drum.
- Now using auto transformer apply single phase A.C supply is applied, until the ammeter shows the rated current

Note down the meter readings & tabulate

Blocked rotor test: **Wsc measured equal to copper losses**

Vsc	Isc	Wsc	Cosϕoc

No Load Test on Single-Phase Induction Motor



NO LOAD TEST:

- Connections are given as per circuit diagram.
- Dpst switch is closed and 1phase A.C supply is applied to the motor, through the variac rated voltage is applied
- Note down the meter reading and tabulate it.

No load test :

Woc measured equal to iron losses

Voc	Ioc	Woc	Cos ϕ_{oc}

BLOCKED ROTOR TEST

$W_{sc} = V_{sc} I_{sc} \cos \phi_{sc}$

$\cos \phi_{sc} = W_{sc} / V_{sc} I_{sc}$

$Z_{eq} = V_{sc} / I_{sc}$

$R_{eq} = W_{sc} / (I_{sc}^2)$

$R_{eq} = R1 + R2$

$R2 = R_{eq} - R1$

= rotor resistance referred to stator

$X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2}$

Assuming $X1 = X2$ we get

$X2 = X_{eq} / 2$ = rotor reactance referred to stator

FROM NO LOAD TEST:

Now the voltage across x_0 is V_{AB}

$$\therefore \quad V_{AB} = \bar{V}_0 - \bar{I}_0 \times \left[\left(R_1 + \frac{r_2}{2}\right) + j(x_1 + x_2)\right]$$

But $$V_{AB} = I_0 x_0$$

$$\therefore \quad x_0 = \frac{V_{AB}}{I_0}$$

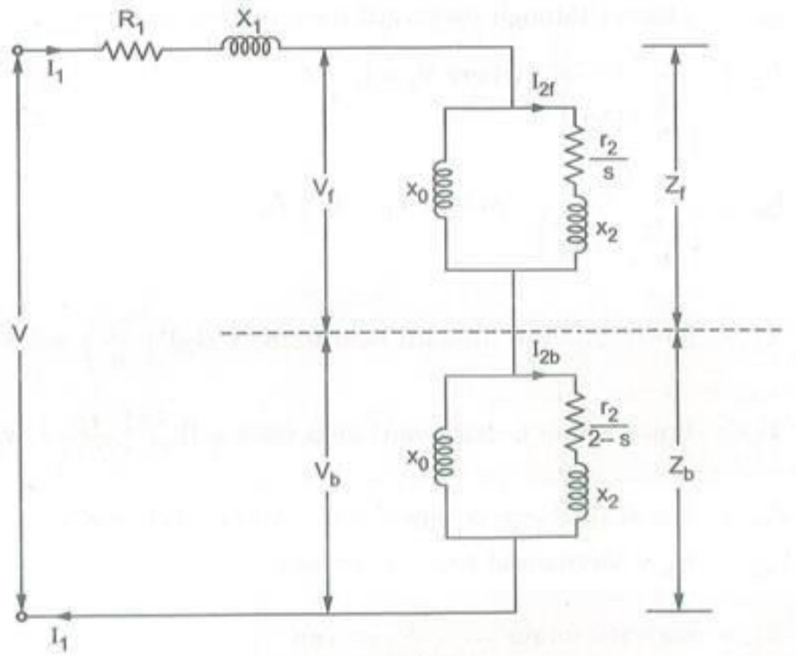
But $$x_0 = \frac{X_0}{2}$$

$$\therefore \quad X_0 = 2x_0 = \frac{2 V_{AB}}{I_0}$$

Thus magnetising reactance X_0 can be determined.

The no load power W_0 is nothing but the rotational losses.

EQUIVALENT CIRCUIT OF SINGLE PHASE INDUCTION MOTOR



5. POST MCQ

1. EQUIVALENT CIRCUIT OF INDUCTION MOTOR BASED ON

   1. DRF THEORY. 2. CROSS FIELD THEORY . 3. NONE OF THE ABOVE

2. EQUIVALENT CIRCUIT IS NEED FOR

   1. ESTIMATING EFFICIENCY. 2.POWER OUTPUT. 3. BOTH 1&2

3. NO LOAD TEST ESTIMATES

   1. IRON LOSSES. 2. COPPER LOSS. 3. BOTH 1&2.

4. BLOCKED ROTOR TEST ESTIMATES

   1. IRON LOSSES. 2. COPPER LOSS. 3. BOTH 1&2.

5. INDIRECT METHOD OF TESTING IS PREFERRED FOR

1. LOW CAPACITY MACHINE. 2. HIGH CAPCITY MACHINE 3.BOTH1&2

6. SINGLE PHASE MOTORS ARE NOT SELF STARTING BECAUSE

A) IT PRODUCES NO FLUX B) IT PRODUCES SINUSOIDAL FLUX

C) IT PRODUCE RMF D) NO WINDING ON ROTOR

7. TO PRODUCE TORQUE....... FLUX IS REQUIRED

A) PULSATING B) AXIAL C) CROSS D) STEADY

8. SPLIT PHASING PRODUCES

A) TWO FLUXES AT THE SAME PHASE B) TWO FLUXES AT THE PHASE DIFFERENT OF 90° (NEARER) C) TWO FLUXES AT THE PHASE DIFFERENT OF 120° (NEARER) D) TWO FLUXES AT THE PHASE DIFFERENT OF 180° (NEARER)

9. IN A SPLIT PHASE 1PHASE MOTOR, THE RUNNING WINDING IS MADE OF

A) HIGH " R " AND LOW "L" B) LOW " R " AND HIGH "L" C) LOW " R " AND LOW "L" D) HIGH "R "AND HIGH "L"

10. IN CAPACITIVE START, THE SPLIT-PHASE ANGLE WILL BE

A) 30° B) 60° C) 90° D) 120°

11. IN CAPACITOR START, SINGLE PHASE MOTORS THE CURRENT IN STARTING WINDING

A) LEADS APPLIED VOLTAGE B) LAGS APPLIED VOLTAGE C) IN PHASE WITH APPLIED VOLTAGE D) 90° LAGGING WITH VOLTAGE

12. WHICH TYPE OF MOTOR WILL BE GIVE, RELATIVELY HIGH STARTING TORQUE

A) CAPACITOR START B) RESISTOR START C) CAPACITOR RUN D) SHADED POLE

13. THE TYPE OF CAPACITOR USED FOR STARTING AND RUNNING

A) OILED FILLED PAPER B) ELECTROLYTIC C) CERAMIC D) POLISTER

14. THE FOLLOWING 1Ø MOTOR WILL HAVE RELATIVELY HIGH P.F.

A) CAPACITOR START B) CAPACITOR RUN C) SHADED POLE D) RESISTIVE START.

15. A CENTRIFUGAL SWITCH IS PLACED IN 1Ø MOTORS IN SERIES WITH

A) REGULATOR B) RUNNING WINDING C) STARTING WINDING D) LINE

6. CONCLUSION:

Thus, we learned how to deduce the equivalent circuit of induction motor and how to test the single phase induction machine for finding the performance either by direct method or indirect method.

7. References:

1. Electrical machines – BR.SHARMA.

2. Induction and synchronous machines –k.murgeshkumar.

3. Ac & Dc machines- B.L Therja& A.K Therja.

8. VIDEO:

1. **PROCEDURE FOR BLOCKED ROTOR TEST VIDEO(LINK)**
2. **PROCEDURE FOR NO LOAD TEST VIDEO(LINK)**

SPECIAL MACHINES

1. Aim & objective:

1. To Study the Construction and working of shaded pole single phase induction motor.

2. To Study the Construction and working of PMDC motor

3.To understand the Construction and working of PMAC motor.

4. To understand the construction and Working of single AC SERIES motor.

5. To learn the construction and working of Repulsion MOTOR

2. PRE TEST:

1. Single phase motors are not self starting because

a) It produces no flux b) it produces sinusoidal flux

C) It produce RMF d) no winding on rotor

2. To produce torque .... flux is required

a) Pulsating b) axial c) cross d) steady

3. Split phasing produces

a) Two fluxes at the same phase b) two fluxes at the phase different of $^{\circ}$ (nearer) c) two fluxes at the phase different of 120° (nearer) d) two fluxes at the phase different of 180° (nearer)

4. In a split phase 1phase motor, the running winding is made of

a) high “ R “ and low “L” b) low “ R “ and high “L” c) low “ R “ and low “L”

d) High “R “and high “L”

5. The split-phase angle will be

A) 30° b) 60° c) 90° d) 120°

6. The commutator and brushes are used to produce

a) Unidirectional torque b) Bi- directional torque c) Both a&b d) none of the above

7. Which type of motor will be give, relatively high starting torque

a) Series b) shunt c) compound d) both a&b

8. The type of material used brushes

A) Carbon b) copper c) both a&b d) none of the above

9. No lad operation is restricted in

a) Series b) shunt c) compound d) both a&b

10. The torque produced in dc machines restricted by

a) Commutation b) current c) voltage d) both a&b

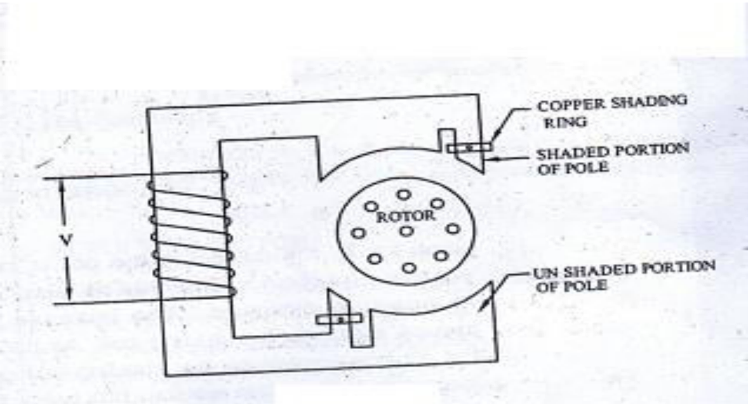
3. PRE –REQUISITES:

1. CONSTRUCTION AND WORKING OF DC MACHINES
2. CONSTRUCTION AND WORKING OF AC MACHINES

SPECIAL MACHINES

4.1. Shaded pole induction motor

This type of motor having projected pole on the stationary part. For forming alternate pole, each pole is provided with exciting coil and connected in series. The rotating part constructed with squirrel cage type construction. Approximately one third distances a slot is cut across each pole. In small part of the pole short circuited copper winding is placed and the left out portion of the pole is called unshaded portion.

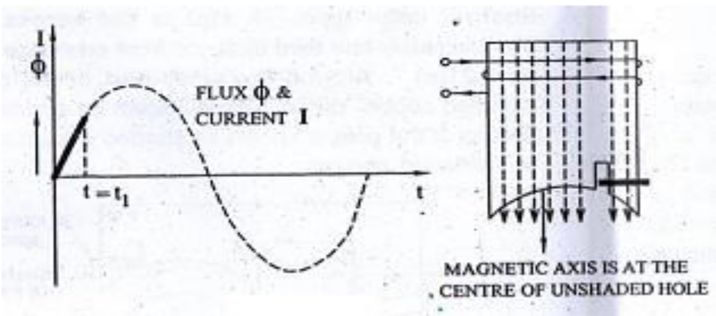


Shaded pole motor

Working

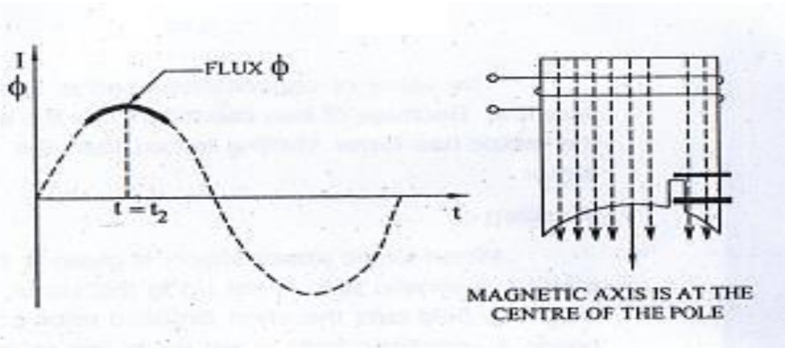
When an ac current is passed through the field winding, the magnetic axis of the pole shifts from the unshaded portion to shaded portion.It is, equivalent to the actual physical movement of the pole. Hence the rotor starts rotating in the direction from unshaded portion to the shaded portion. .

When single phase supply is applied the excitng winding an alternating field is generated. The flux created is sinusoidal and consider the three instances at time t_1,t_2,t_3.

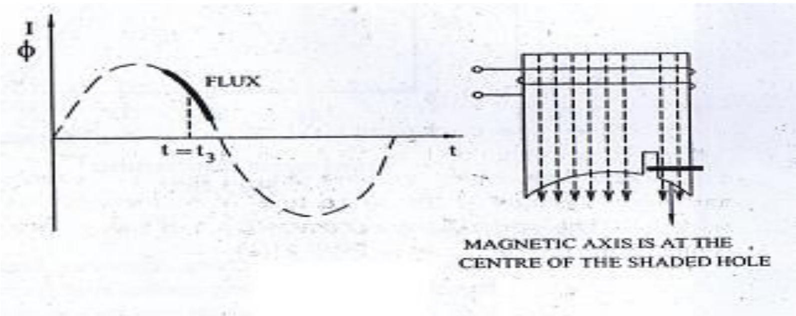


(i) when t = t_1, the current in the coil and The flux is also increasing in positive direction. The increase in flux will induce e.m.f. in the adding coil. As per lenz's law, the resultant flux below the shaded pole is reduced and hence the flux below the unshaded pole is high. So the resultant flux axis will be at the centre of the unshaded pole .

(ii) When time t = t2, rate of change of flux in minimum. The induced e.m.f. in the shading coil is very small; hence opposition of shading ring flux will be negligible. The flux distribution is uniform and the magneticaxis is at the centre of the pole

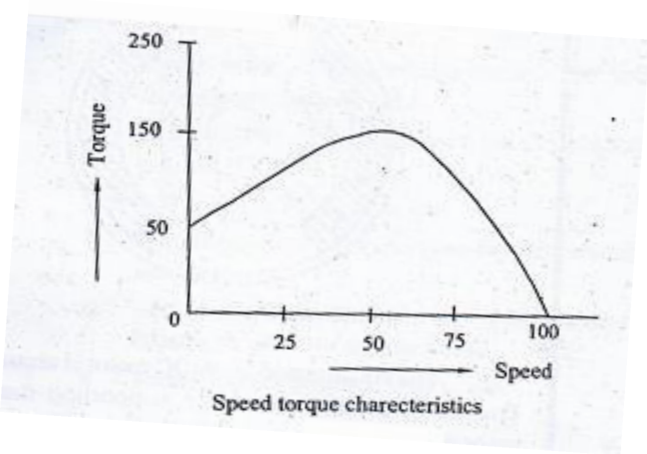


(iii) When time t = t3, gradually current falls in the field winding and hence flux is reduced. Hence the rate of change of flux is increasing and therefore emf induced in the shading ring increases there is rate of change of flux,



Hence the flux density will be more below the shaded part region. The magnetic axis is therefore shifted to the centre of the shaded pole as shown in fig.

From the above discussion, it is clear that the magnetic axis gets continuously altered from unshaded portion to shaded portion. This rotating magnetic field creates a torque in the cage rotor.



The direction of rotation in shaded pole induction motor is fixed. For reversing the direction of rotation two set of shading rings to be provided

Merits:

1. Simple in construction.

2. They are reliable

3. Cost is low

Demerits:

1. Very low starting torque.

2. Copper losses occur in the shading ring and hence the efficiency of the operation is reduced.

Applications:

Low starting torque needed places like small fans, toys , hair driers, ventilators and electric clock etc.

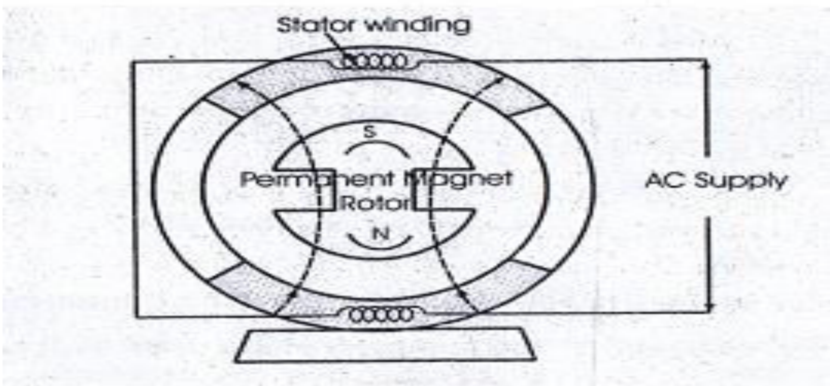
4.2. Permanent Magnet DC Motor Operated on AC Supply PMAC Motor

Construction and performance

This motor is known as permanent Magnet Synchronous Motors. This motors have a cage rotor having rare earth permanent magnets instead of a wound rotor.

This motor consists of a Stator winding wound on this stator and ac supply of normal frequency is aplled.

- Its starts like an induction motor from a fixed frequency supply.
- for exciting the rotor DC SUPPLY is not required, it can be made more robust and reliable.
- The motors have outputs ranging from about 100W to 100kW.
- The maximum synchronous torque is designed to be around150% of the rated torque.



If loaded beyond this point, the motor losses synchronism and will run either as an induction motor or stall.

These motors are designed for direct on line starting. The efficiency and power factor of the permanent magnet excited synchronous motors are each 5 to 10 percent better than the reluctance motor.

Advantages

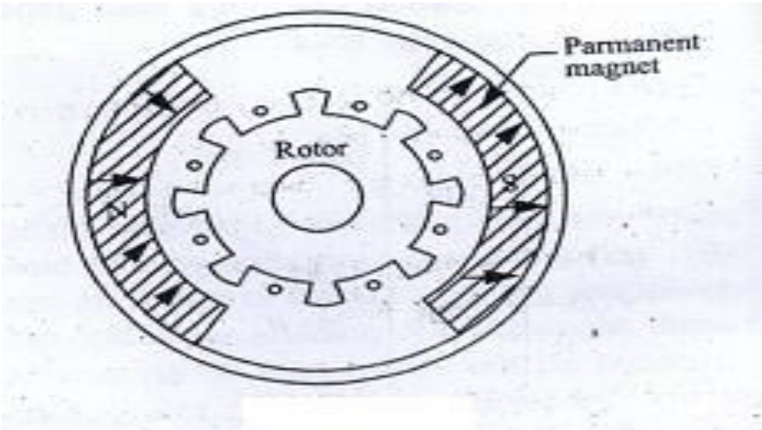
1. The motor maintains a constant speed
2. It runs at perfectly constant speed.
3. Absence of brushes or slip - rings there is no sparking.
4. Also brush maintenance is eliminated. .
5. Absence of slip rings and brushes leads to Maintains of the motor is easier.

Applications

1. for maintaining precise speed to ensure a consistent product.
2. Used in digital clock.
3. PMAC motors are used where constant speeds are absolutely essential.

4.3. Permanent Magnet D.C. Motor

The constructions of PMDC MOTORS are similar to the normal dc motor construction with only difference is permanent magnets in field windings instead of electromagnets for producing magnetic flux.



Construction

The permanent magnets are supported by cylindrical steel stator and provides the return path of magnetic flux

Like conventional D.C motor the rotor consists of armature winding, commutator and brushes. The high residual flux density and high coercivity material used for making permanent magnet.

Up to 150KW-ALINICO permanent magnets used. The Ferrite magnets are used in fractional KW motor. For small and large motors rare earth magnets are used.

Working

These motors constructed with 6V, 12V or 24V D.C. supply. This D.C supply can be obtained either by batteries or rectified A.C. The motor rotates, due to the interaction between two flux produced by permanent magnets and armature flux.

Advantages

1. Absence of external excitation for producing magnetic field.

2. The size of such motor is small (absence of field winding)

3. The motor cost is low.

4. The efficiency of the motors are high due to the absence of losses

5. These motors produce less noise.

Disadvantages

1. If the excessive current flows in the armature winding create demagnetize the permanent magnet.

2. The flux density produced in the air gap is limited.

Applications

1. Small PMDC motors are used for automobile heater, wind shield wipers, fans and radio antennas etc.

2. Its finds application in electrical fuels, pumps, marine engine starters, wheel chairs, cordless power tools etc.

3. It is also used in toy industries,food mixer, ice crusher, vacuum cleaner.

4.4 Single Phase Commutator Motors(AC SERIES MOTOR)

The d.c. motors having commutator. The a.c. motors having wound rotor with brushes and commutator is called commutator motors. . The commutator arrangement is similar to the armature of a d.c. motor. There are two types of single phase commutator motors namely a.c. series motors and the universal motor.

Single Phase A.C. Series Motor

When normal d.c. series motor is connected to an a.c. supply, both field and armature current get reversed and unidirectional torque gets produced in the motor hence motor can work on a.c. supply

But performance of motor is lag due to the following

(I) Eddy current losses in the yoke and field, which creates overheating

(ii) Operating power factor is very low due to high reactance to a.c

(iii) The sparking at brushes is very high.

Some changes are required to have the satisfactory performance of d.c series motor on a.c supply , when it is called a.c series motor.

The modifications are:

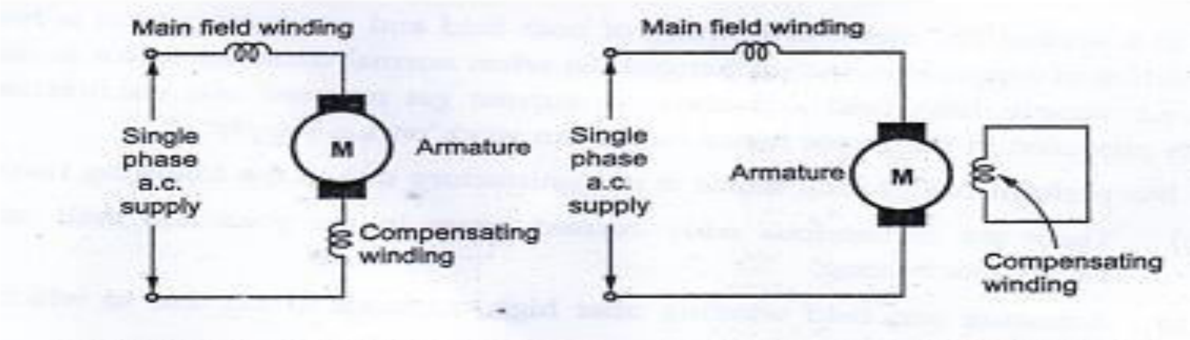
(I) Yoke and pole core construction is laminated

(ii) The power factor can be improved by reducing the magnitudes of field and armature reactance.

(III)Field reactance can be decreased by reducing the number of turns. But this reduces the field flux. To keep the torque same it is necessary to increase the armature turns proportionately. This further increase the armature inductance.

Now to compensate for increased armature flux , it is necessary to use compensating winding. The flux produced by this winding is effectively neutralizes the armature reaction.

Depending upon the connection, the motor is conductively compensated type(connected in series with armature)or inductively compensated(short circuit itself).in inductively compensated winding act as secondary. The ampere turns produced by compensating winding neutralize the armature ampere turns



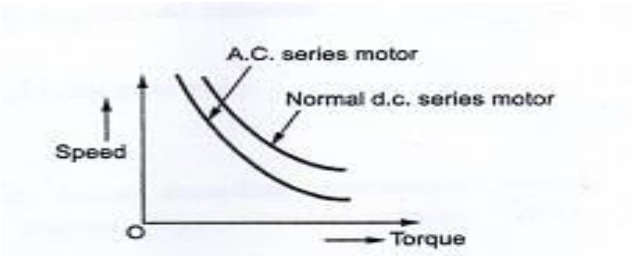
(a) Conductively compensated motor (b) Inductively compensated motor

To reduce the induced e.m.f. due to transformer action in the armature coils, the following measures are taken:

I) Number of poles are increased due to that flux per pole is reduced.

ii) By reducing the frequency of supply

iii) By constructing single turn armature coils



Speed-Torque characteristics of a.c. and d.c. series motor

The characteristics of ac series motor are similar to that of d.c. series motor. (The torque varies as square of the I_A and speed varies inversely as the I_A). Similar to dc series motor, no load operation is restricted. Hence it is always started with some load. Starting torque produced by the motor is 3 to 4 times the full load torque. .

Applications: high starting torque needed places like in electric traction, hoists, locomotives etc.

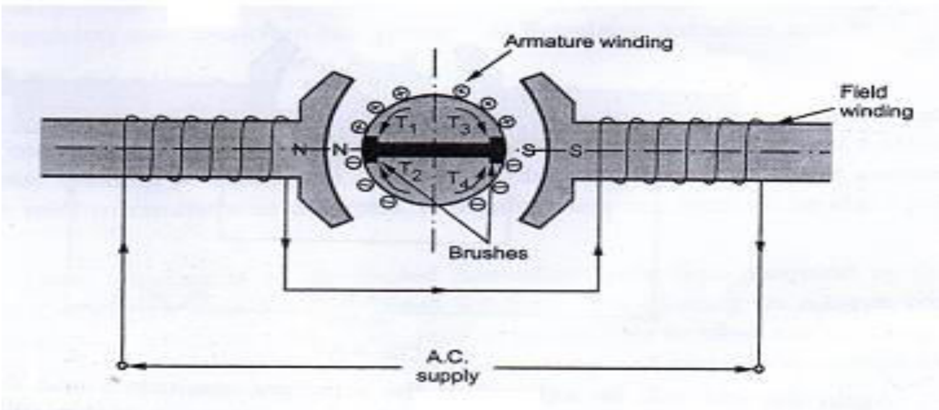
4.5. Repulsion Motor

Repulsion motors work on the principle of repulsion between two magnetic fields.

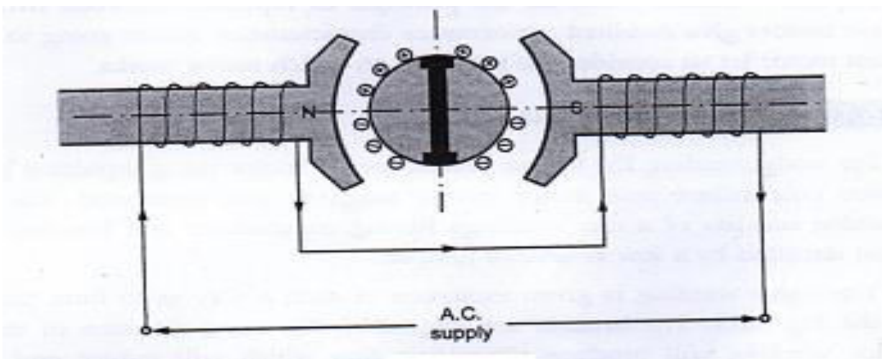
Repulsion Principle

Consider a two pole salient pole motor having magnetic axis horizontal. The machine consists of a d.c. windings with commutator and brushes. The brushes are short circuited by a low resistance jumper.

The stator winding is given excitation in such a way as to form the poles. The brushes are aligned in the same direction of the field axis. The stator winding will produce alternating flux which will induce emf in the armature conductors by transformer action. The direction of induced emf can be found by using Lenz's law. The direction of induced current will depend on position of brushes. These currents will lag behind the induced voltages by almost 90°. Because of the current flowing through the armature, it will produce its own magnetic field with the poles as shown in fig. Thus equal force of repulsion exists between like poles which will not produce any torque. .

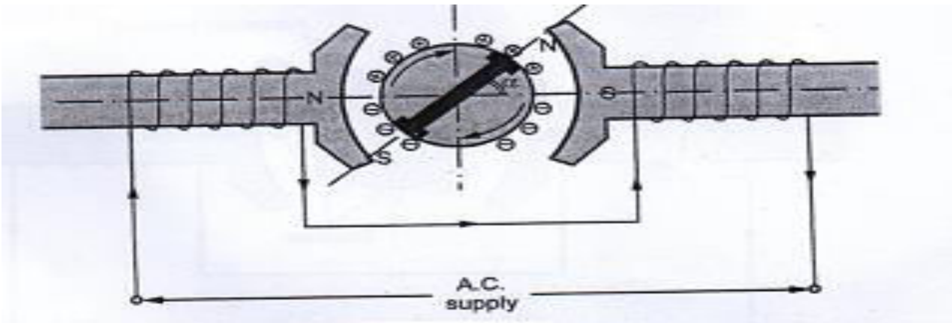


If brushes are shiffed by 90°, sothe conductors undergoing short circuit are also changed. The induced emf are in the same direction as before. The arrangement is shown in the fig.

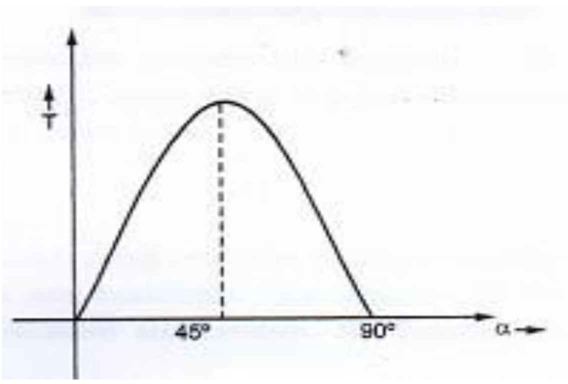


Apart from the coils undergoing short circuit, the remaining armature winding gets divided into two parallel paths. It can be seen that the induced emfs are balanced and the resultant emf is zero. Thus no current flows through the brushes and the resultant torque is also zero.

Now if the brushes are in the position shown in the fig. In this case, the brushes axis is not in the line of main field or at an angle of 90° to main field but it is at an angle of αwith the main field.



Again the emf will be induced in the armature conductors and there will be net voltage across brush terminals which will produce current in the armature. Thus the armature will also produce its own magnetic field with the poles as shown in the fig. The north and south poles of stator and rotor will attracvt each other and there will be net torque avilable which will run the motor in the clockwise direction. Alternatively we can say that the north pole formed by armature winding will be repelled by the north pole formed by the main field winding and similarly the south pole will be repelled by south pole formed by the main field winding and



the motor runs in clockwise direction. As the forces are of repulsion which contributes in the motion so the name of the motor is repulsion motor. If the brush is given shift in the opposite direction to that the shown in the fig. Then motor runs in anticlockwise direction which can also be explained on the similar lines. Hence the position of brushes decides the direction of rotation. The torque produced by the motor depends on the brush shift angle α.

6. POST MCQ

1. In a shaded pole motor, the pole shaded is done by ....ring

   A) Thick nicrome b) thick copper c) thick aluminum d) thick brass.

2. In shaded pole motor the rotating magnetic field is produced by

   a) Series inductor b) capacitor c) resistor d) shading ring.

3. Shaded pole motors are generally used for

   a) Toys b) hair dryers c) circulators d) any of the above

4. The motor which use highest starting torque is

   a) Stepper motor b) D.C. motor c) repulsion start motor d) universal motor

5. In repulsion motor, by shifting brush position ....controlled

   a) Only speed b) direction and speed c) speed, direction torque

   d) None

6. In repulsion motor, the speed.......

   a) Varies with load b) remains constant c) varies within 5% load. d) Varies with applied voltage

7. The following single phase motor has low starting torque

   a. universal b) capacitor type c)repulsion d) all

8. In shaded pole motor, the direction of rotation is

   a) Shaded to un-shaded b) un-shaded to shaded

C) depended on polarity of voltage   d) depended on p.f.

9. The approximate rating of ceiling fan is

A) 50-250W   b) 50-150W   c) 250-500W   d) 500-1000W

10. ALNICO magnet used in

A) PMDC   b) PMAC   c) UNIVERSAL   d) STEPPER

11. FERITES magnets used for

1. Fractional KW motor

2. High power rating 3.mediumpower rating 4.none of the above

12. Rare earth magnets used for

1. Fractional KW motor

2. High power rating 3.mediumpower rating 4.small and high

13. PMDC motor mostly used in

a) Toys   b) pumps   c) ceiling fan   d) grinders

14. PMAC motor uses PERMANENT magnets in

a) Stator   b) rotor   c) both a &b   d) none

15. PMDC motor y uses PERMANENT magnets in

a) Stator   b) rotor   c) both a &b   d) none

16. REPULSION start induction motor start as

a) Repulsion   b) induction   c) both a &b   d) none

17. REPULSION start induction motor, run as

a) Repulsion   b) induction   c) both a &b   d) none

18. Linear induction motor produces as

a) Linear synchronous speed b) Non-linear synchronous speed c) both a &b d) none

19. PMAC motor uses sine wave supply for,

a) Low power b) high-power c) both a &b d) none

20. PMAC motor uses square wave supply for,

a) Low power b) high-power c) both a &b d) none

7. CONCLUSION:

Thus, we learned in detail about various special machines construction and working with application, advantages and disadvantages.

8. References:

1. Electrical machines – BR.SHARMA.

2. Induction and synchronous machines –k.murgeshkumar.

3. Ac & Dc machines- B.L Therja& A.K Therja.

SYNCHRONOUS MACHINES

SYNHCRONOUS GENERATOR

1. Aim & objective:

7. **TO STUDY THE CONSTRUCTION OF SYNCHRONOUS GENERATOR**

8. **TO UNDERSTAND THE EFFECT OFALTERNATOR PARAMETERS.**

9. **TO DEDUCE THE EQUIVALENT CIRCIT OF ALTERNATOR.**

10. **TO STUDY THE VARIOUS METHODS FOR FINDING VOLTAGE REGULATION OF ALTERNATOR**

11. **TO STUDY THE NECESSITY CONDITIONS OF PARALLEL OPERATONSAND VARIOUS METHODS OF SYNCHRONISING**

2. PRE TEST:

1. Compared to dc system ac system is preferred due to
   a) Change in magnitude b) simple design of switch gear
   C) Both a&b d) none of the above

2. The generated voltage waveform in generator mostly
   A) Sine b) square c) rectangle d) trapezoidal

3. The EMF induced in the coil due to change in own flux
   a) Self induced EMF b) mutual induced EMF c) Both a&b d) none of the above

4. The EMF induced in the coil due to change in current in the other coil
   a) Self induced EMF b) mutual induced EMF c) Both a&b d) none of the above

5. The smoothest and efficient waveform

a) sine b) square c) rectangle d) none of the above

6. Step up and step down easier in

a) Ac b) dc c) both a&b d) none of the above

7. Electrical circuit representation of machine is called

a) Equivalent circuit b) load circuit c) no load circuit d) none of the above

8. The no-load operation is represented by

a) Shunt branch circuit b) series circuit c) parallel circuit d) none of the above

9. The voltage drop in ac machine is. Estimated by

A) Regulation b) efficiency c) slip d) none of the above.

10. The performance of ac machine estimated by

a) Regulation b) efficiency c) slip d) none of the above

3. PRE –REQUISITES:

1. ELECTROMAGNTIC INDUCTION
2. FUDAMENTAL OF AC GENERATION
3. CONCEPT OF EQUIVALENT CIRCUIT &VOLTAGE REGULTION

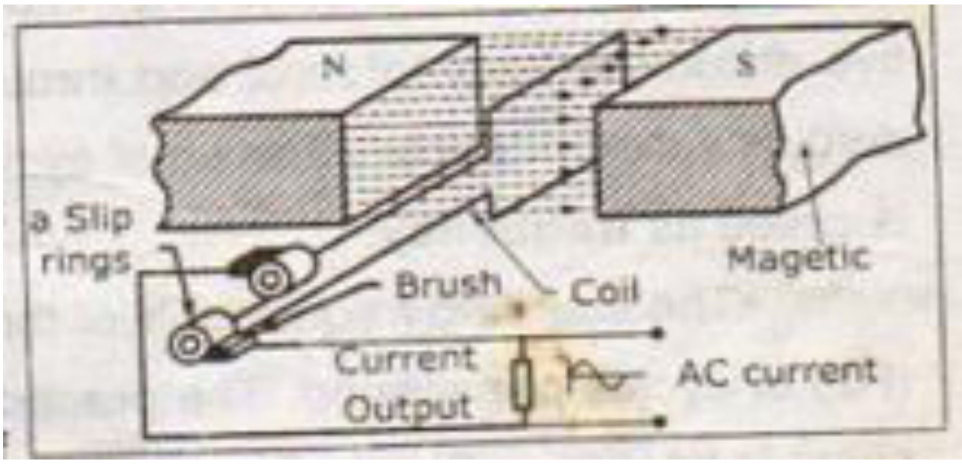
.

Synchronous machines

4.1construction and types of alternator

UNIT-1

4.1Working principle of alternator



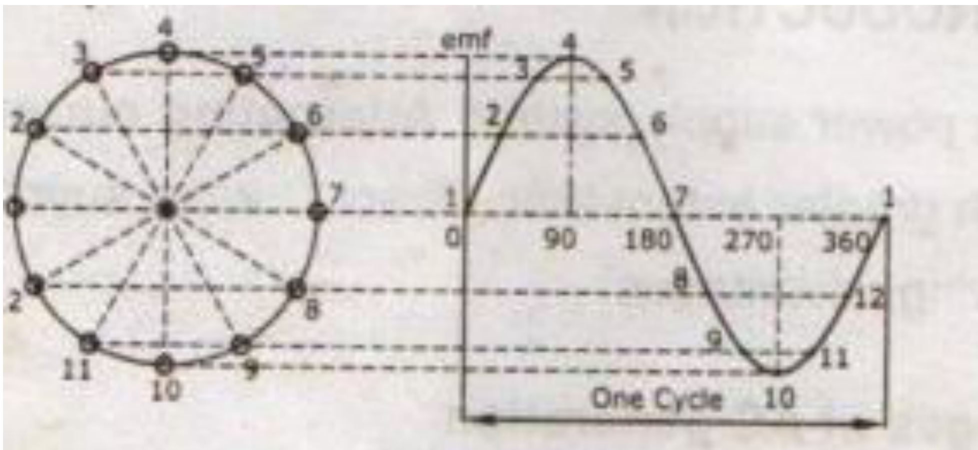


Figure1

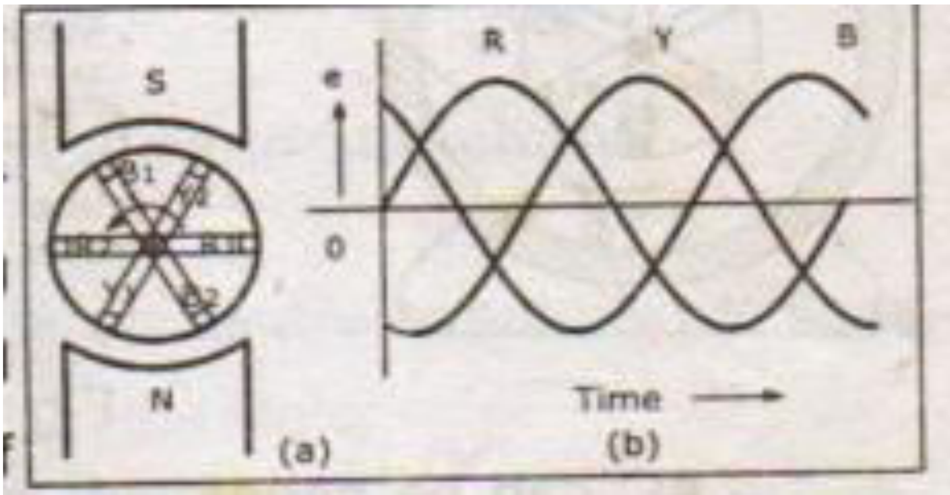
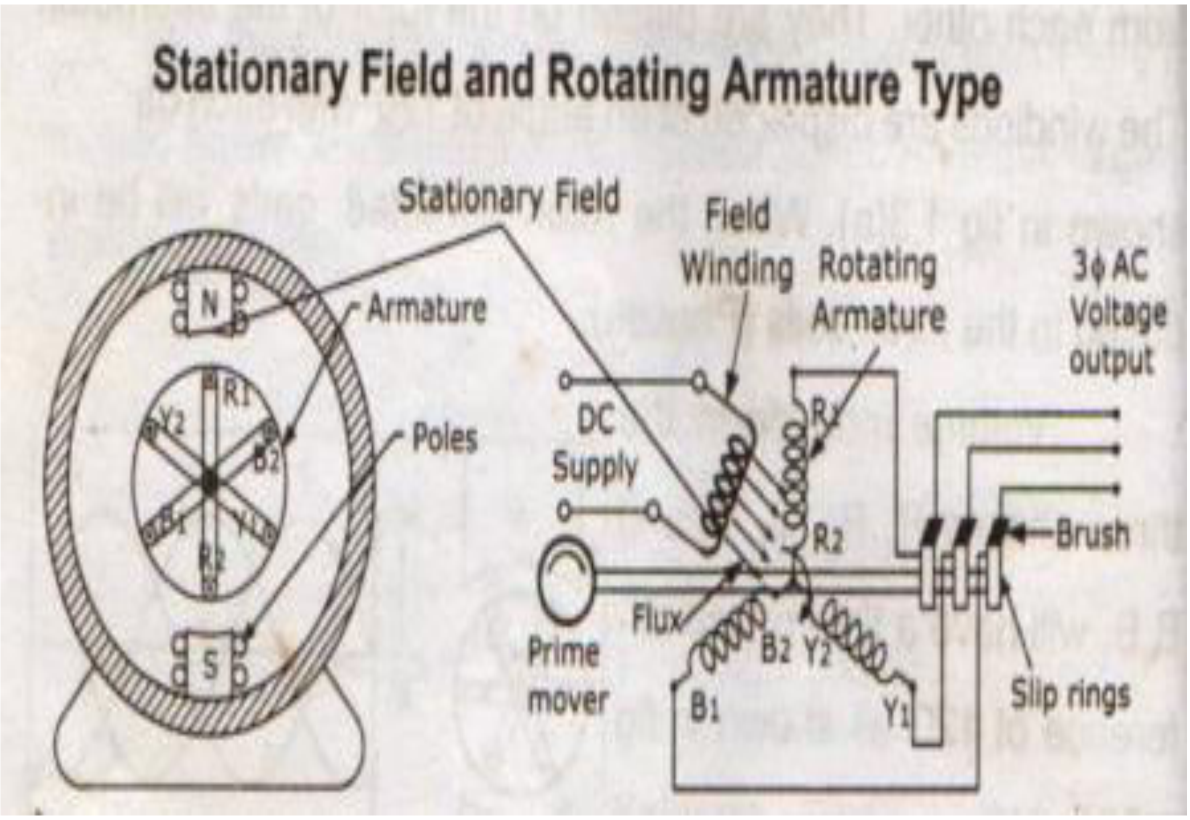


Figure2

Figure.1---GENERATION OF SINGLE PHASE EMF

Figure.2---GENERATION OF THREE PHASE EMF

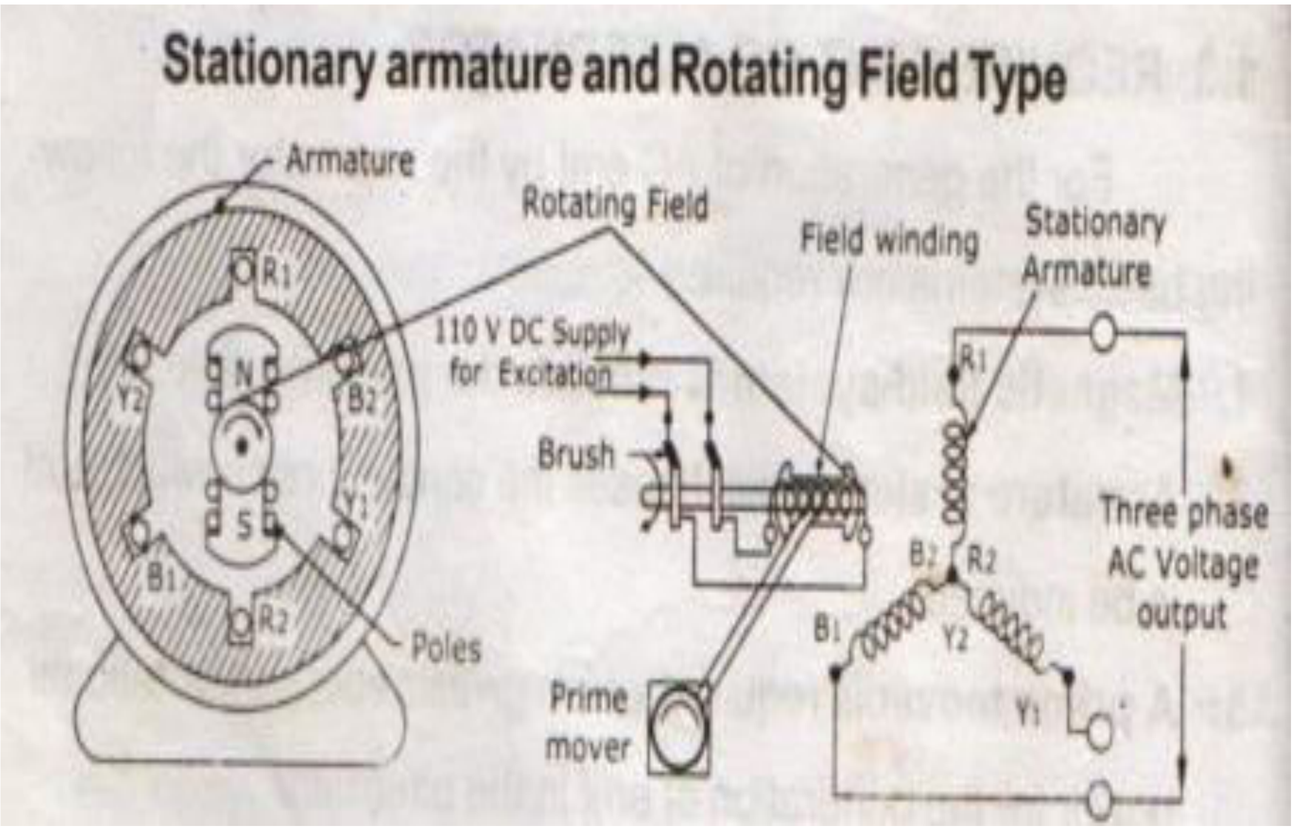
4.1.1Construction of alternator (SFRA):



ADVANTAGES OF ROTATING FIELD ALTERNATOR

Most alternators have the rotating field and the stationary armature.The rotating-field type alternator has several advantages over the rotationg-armature type alternator.

(1) A stationary armature is more easily insulated for the high yoltage for which the alternator is designed. This generated voltage may be as high as 33KV.
(2) The armature windings can be braced better mechanically against high electro-magnetic forces due to large short-circuit currents when the armature windings are in the stator.
(3) The armature windings, being stationary, are not subjected to vibration and centrifugal forces.


Stationary armature and Rotating Field Type
Armature
Rotating Field
Field winding
Stationary Armature
110 V DC Supply for Excitation
Brush
R1
R2
Y1
Y2
B1
B2
N
S
Poles
Prime mover
Three phase AC Voltage output

(4) The output current can be taken directly from fixed terminals on the stationary armature without using slip rings, brushes, etc.

(5) The rotating field is supplied with direct current. Usually the field voltage is between 100 to 500 volts. Only two slip rings are required to provide direct current for the rotating field while at least three slip rings would be required for a rotating armature. The insulation of the two relatively low voltage slip rings form the shaft can be provided easily.

(6) The bulk and weight of the armature windings are substantially greater than the windings of the field poles. The size of the machine is, therefore, reduced.

(7) Rotating field is comparatively light and can be constructed for high speed rotation. The armatures of large alternators are forced cooled with circulating gas or liquids.

(8) The stationary armature may be cooled more easily because the armature can be made large to provide a number of cooling ducts.

4.1.2SPEED AND FREQUENCY

The frequency of the generated voltage depends upon the number of field poles and on the speed at which the field poles are rotated. One compete cycle of voltage is generated in an armature coil when a pair of field poles (one north and one south pole) passes over the coil.

Let P =total number

of field poles

P= pair of field poles

N= speed of the field

poles in r.p.m. n=speed

of the field poles in

r.p.s.

f= frequency of the generated voltage in Hz

Obviously $\frac{N}{60}$ = n 1.1

and $\frac{P}{2}$ = p...1.2

one cycle is generated in an armature coil when a pair of field poles passes over the coil, the number of cycles generated in one revolution of the rotor will be equal to the number of pairs of poles. That is,

Number of cycles per

revolution = p

Also, number of revolutions

per second=n

Now frequency=number of cycles per second

$$= \frac{of\ cycles}{revolutons\ number} X \frac{revolutons}{seconds}$$

f= p x n 1.3

Since n =N/60 and p=p/2

$f=\frac{PN}{120}$.. 1.4

Equation(1.2) and (1.4) give the relationship between the number of poles, speed and frequency.

SYNCHRONOUS SPEED

From Eq.(1.4)

$$N_s = \frac{120\,f}{p} \quad \text{...} \quad (1.5)$$

Equation (1.5) shows that the rotor speed N bears a constant relationship with the field poles and the frequency of the generated voltage in the armature winding. The speed given by Eq. (1.5) us called synchronous speed N_s . A machine which runs at synchronous speed is called synchronous machine. Thus, a synchronous machine is an a.c. machine in which the rotor moves at a speed which bears a constant relationship to the frequency of the generated voltage in the armature winding and the number of poles of the machine .

Table 1.1

Number of poles	Synchronous speed N_s in r.p.m.
2	3000
4	1500
6	1000
8	750
10	600
12	500

(a) f= 50 Hz, p=2

$$N_S = \frac{120X50}{} = 3000\text{r.p.m.(Ans.)}$$

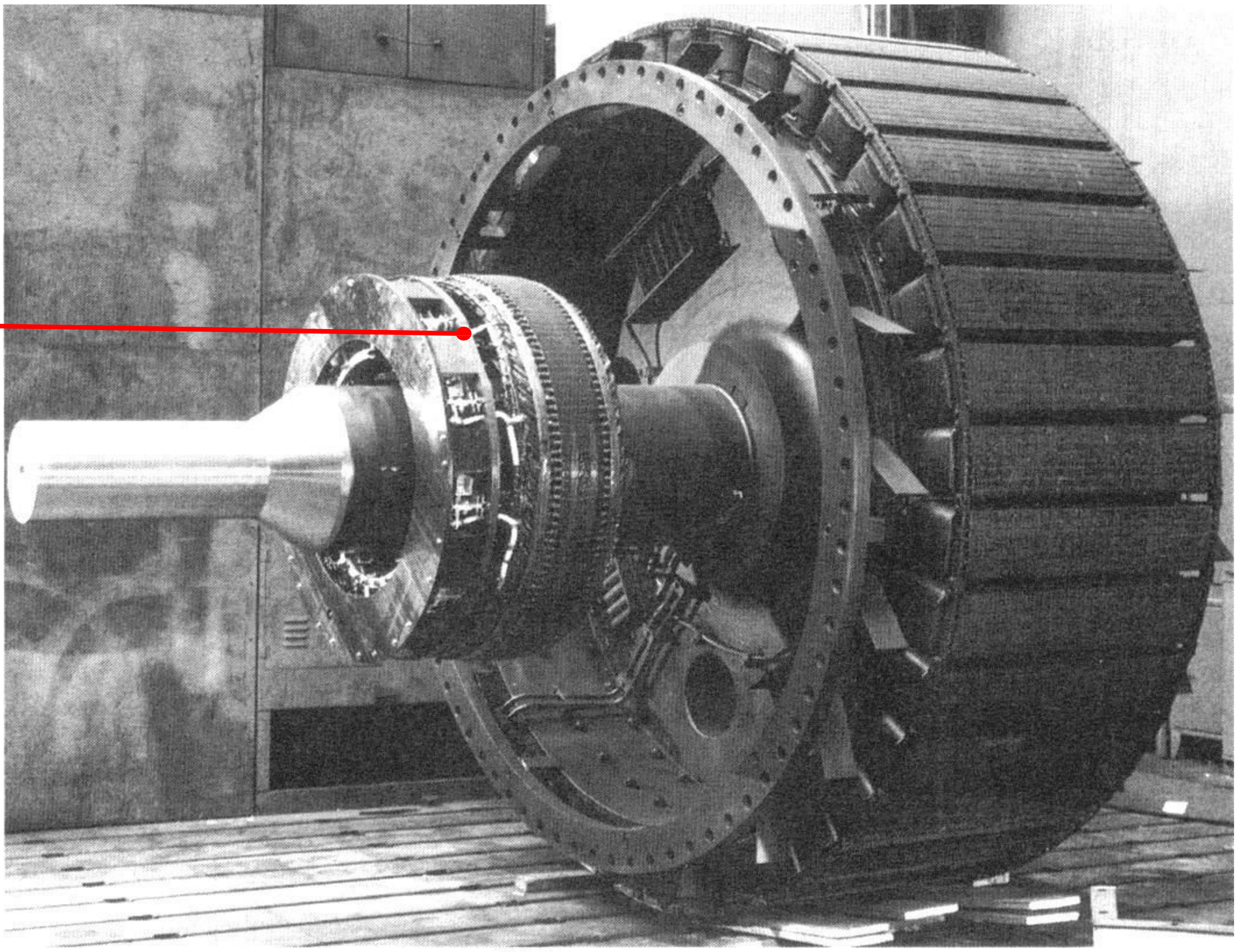
P=2

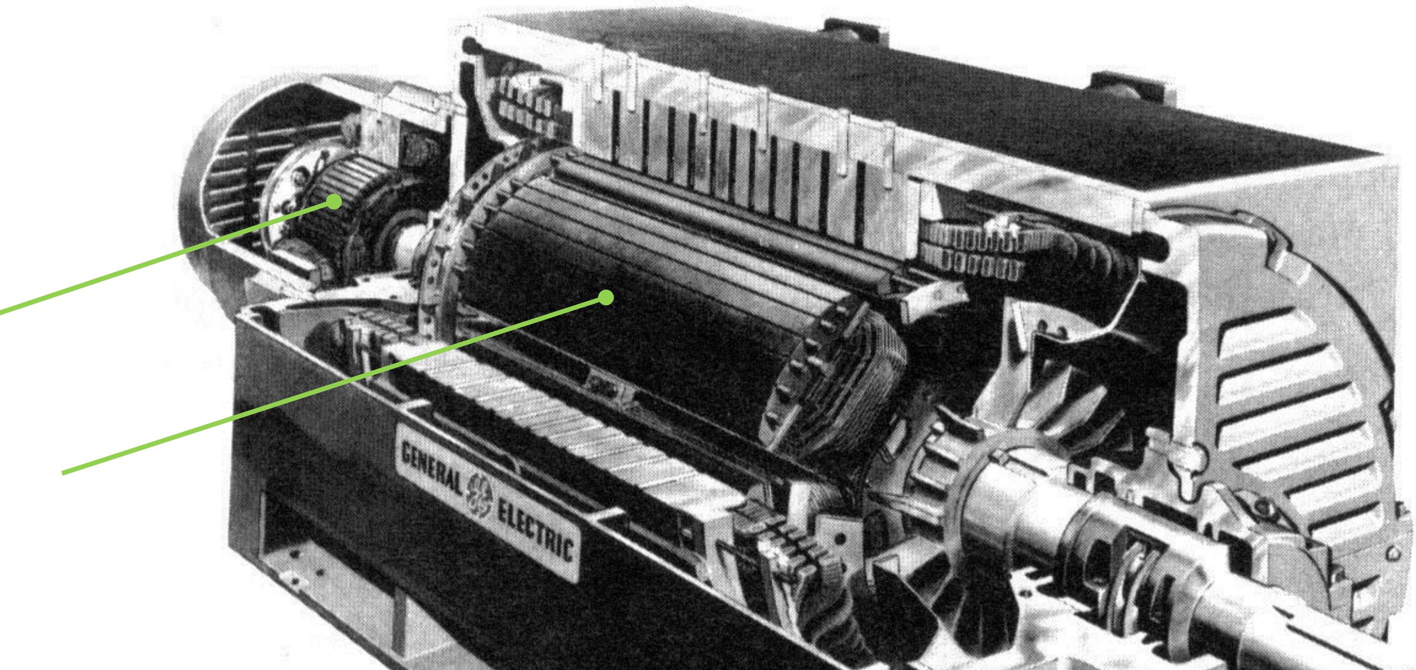
4.1.3COMPARISION BETWEEN ROTATING & STATIONARY FIELD SYSTEMS

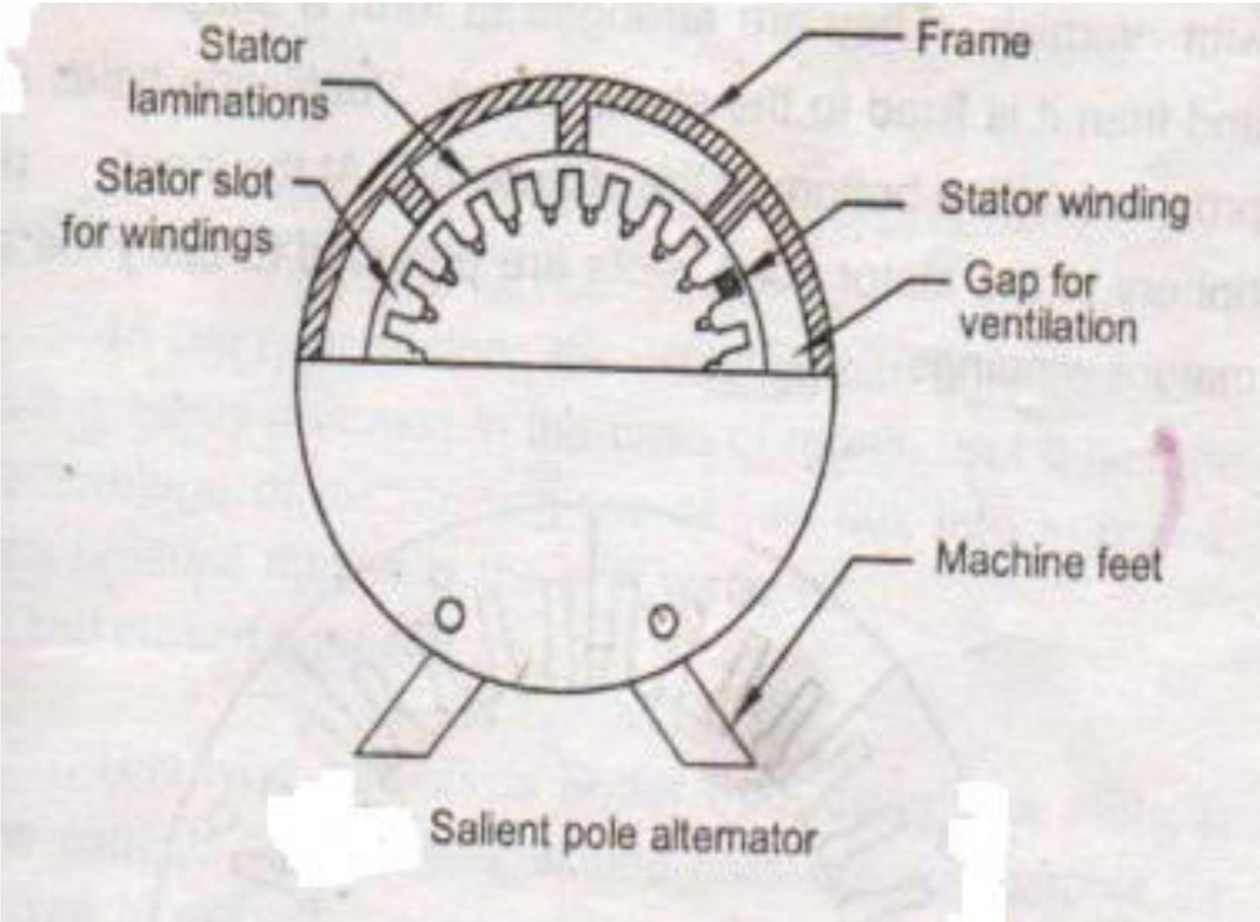
S. no	component	Rotating poles	Stationary poles
1	Construction	Rotating field stationary armature	stationary field rotating armature
2	Field system	Rotating	Stationary
3	Armature	Stationary	Rotating
4	No .of slip-rings	2	4
5	Current rating of slip-rings	5% of total current	95% of total current
6	Sparking	Very low	Very high
7	Brush friction	Very low	Very high
8	Brush drop	Not appreciable	Appreciable
9	Capacity	Above 25KVA	Below 25 KVA
10	Voltage	Above 6.6 KVie.6.6KV to 30KV	Below 6.6 KV ie.250Vto 600V
11	Efficiency	High	Low
12	Cost/KVA	Low	High
13	Size/KVA	Low	High
14	Cooling	Easy	Not easy
15	Providing insulation	Easy	Complex

16	Taking supply from armature	By fixed connection	Through slip-rings
17	Circulation of cooling water	Possible through stator frame	Not possible

Alternator types:







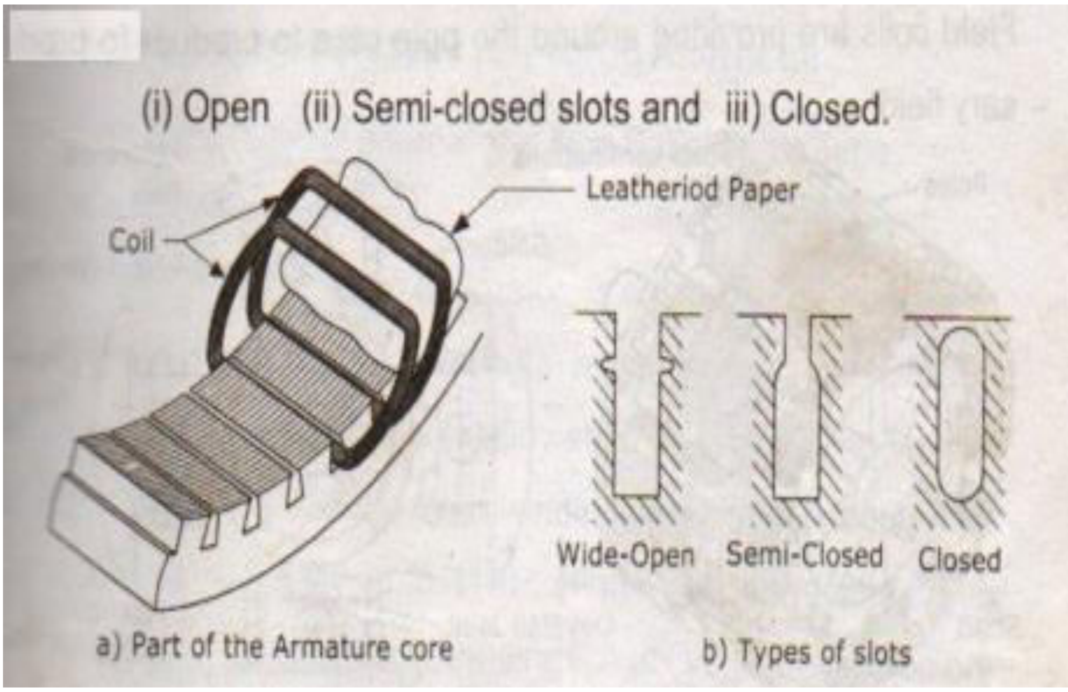
STATOR ARRANGEMENT OF ALTERNATOR(SALIENT & NON-SALIENT)

4.1.4TYPES OF (ROTATING FIELD) ALTERNATORS

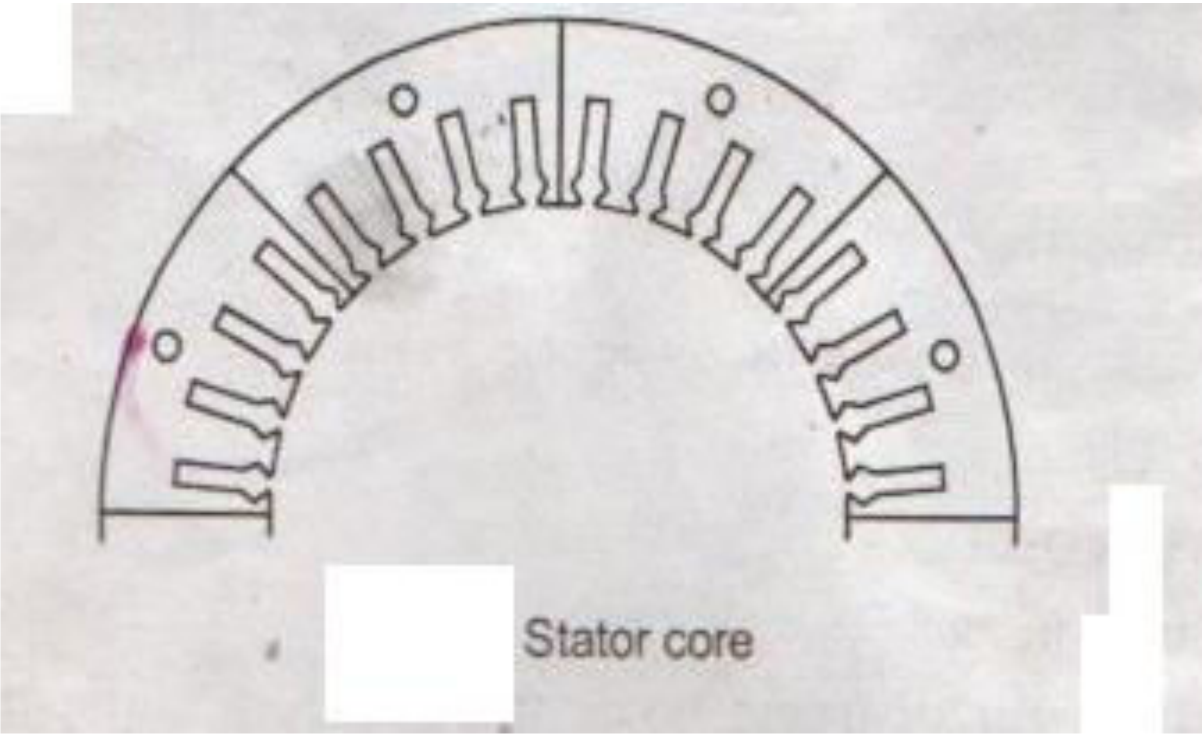
BASED ON POLE MOUNTING

According to arrangements of poles to the rotor, the rotating field alternators are further classified into

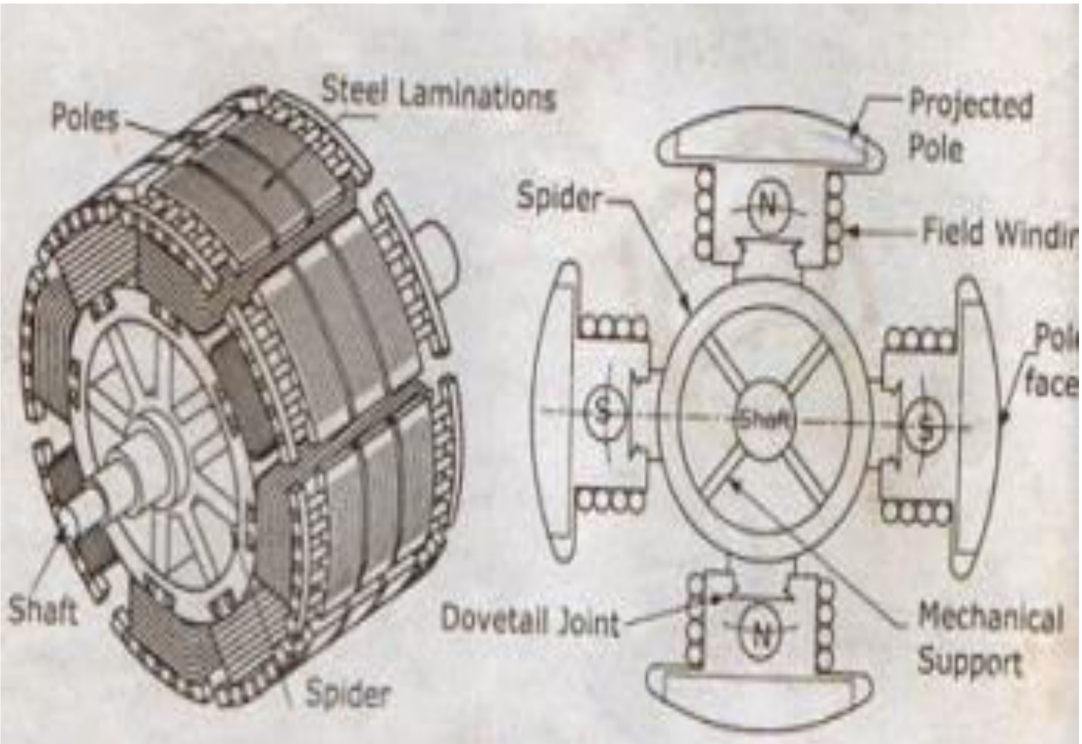
1. Salient or projected pole type
2. Non salient or smooth cylindrical type


(i) Open (ii) Semi-closed slots and iii) Closed.
Coil
Leatheriod Paper
Wide-Open
Semi-Closed
Closed
a) Part of the Armature core
b) Types of slots

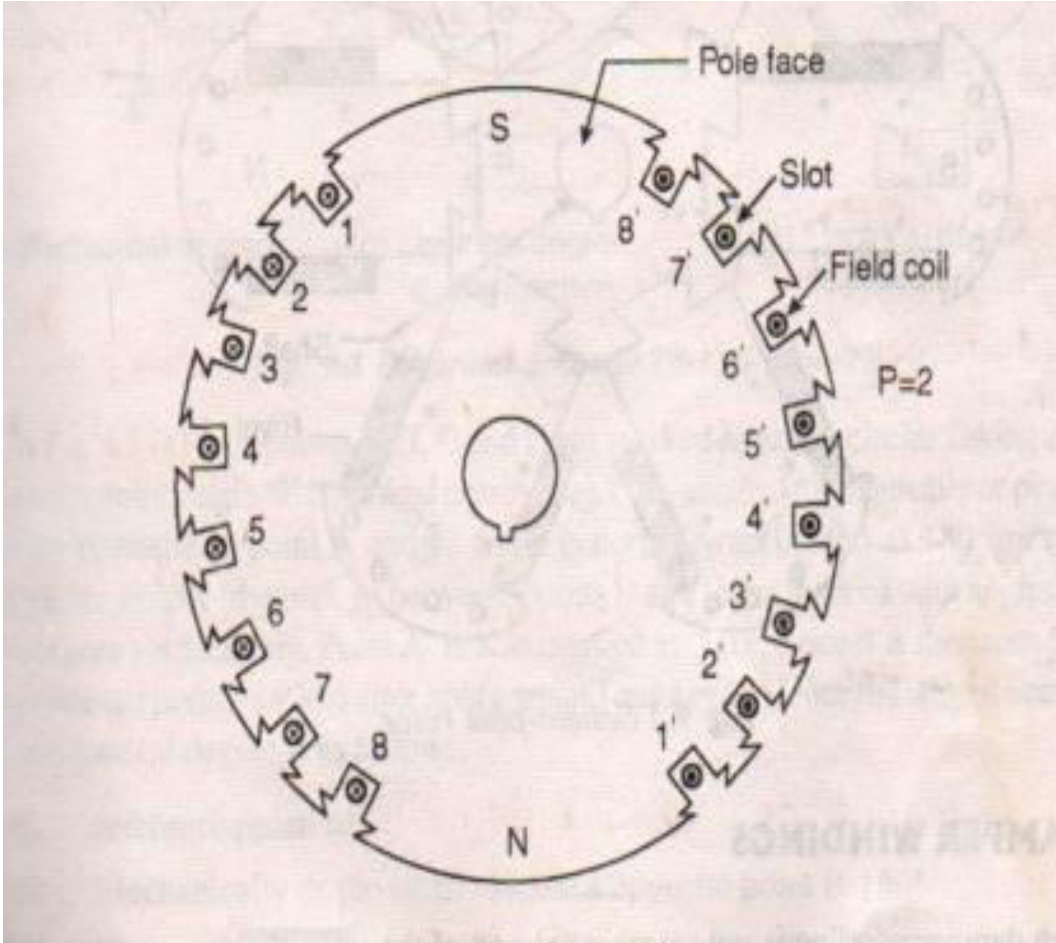
Stator core:


Stator core

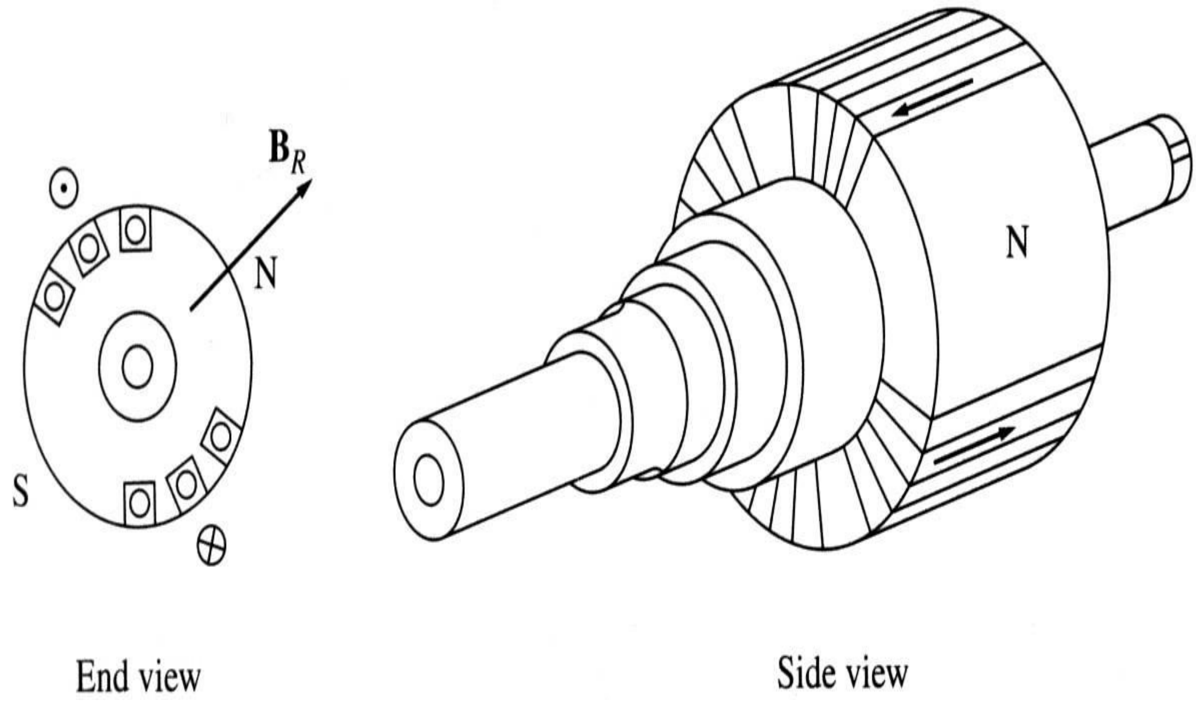
TYPES-ROTOR (SALIENT POLE)



TYPES-ROTOR(N0N-SALIENT POLE)



Smooth cylindrical type rotor



TYPES OF (ROTATING FIELD) ALTERNATORS

BASED ON POLE MOUNTING

According to arrangements of poles to the rotor, the rotating field alternators are further classified into

1. Salient or projected pole type
2. Non salient or smooth cylindrical type.

Difference between salient and non salient type alternators.

S. no	component	Non-salient	salient
1	Construction	Poles are not projected	Poles are projected
2	Damper windings	Not used	used
3	Rotor surface	smooth	Not smooth
4	Air friction	minimum	more
5	Air gap	uniform	Not uniform
6	Speed (rpm)	High 3000 or1500	Low from1500 to150
7	Efficiency	high	Less than non-salient
8	Armature reaction	simple	complex
9	Synchronous reactance	One x_o	Two (1)X_d =along D-axis (2) X_q =along q-axis
10	Application	Thermal & nuclear power station	Hydro ,diesel and non-conventional power stations
11	Voltage regulation	good	Better
14	Dimensions	Short diameter and large axial length	Large diameter and short axial length

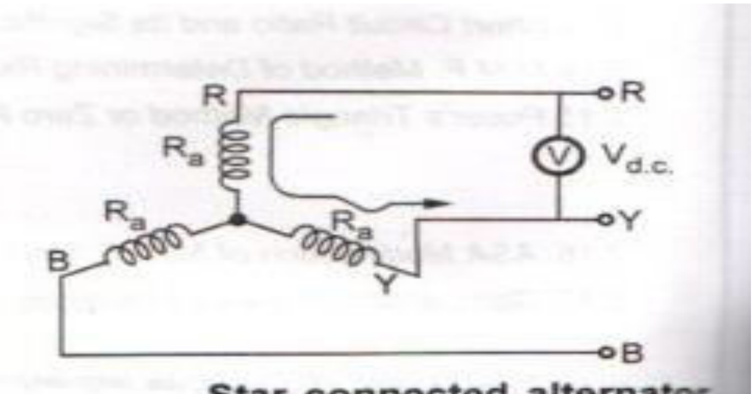
4.2 Parameters of Armature winding

There are three important parameters of an armature winding of an alternator. These are

1. Armature resistance R_a
2. Armature leakage reactance X_L
3. Reactance corresponding to armature reaction.

Let us discuss these three parameters in detail which will help us to draw an equivalent circuit of an alternate. The equivalent circuit and the concept of synchronous impedance plays an importance role in determining the regulation of an alternator.

Armature resistance



Star connected alternator

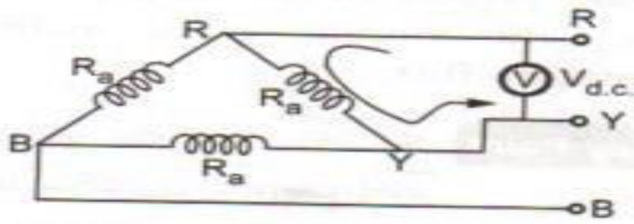
Every armature winding has its own resistance. The effective resistance of an armature winding per phase is denoted as R_{aph} Ω /ph or R_a Ω/ph.

Generally the armature resistance is measured by applying the known d.c. voltage and measuring the d.c. current through it. The ratio of applied voltage and measured current is the armature resistance. But due to the skin effect, the effective resistance under a.c. conditions is more than the d.c. resistance. Generally the effective armature resistance under a.c. conditions is taken 1.25 to1.75 times the d.c. resistance.

R_{ry} = resistance between R-Y terminals $=R_a+R_a = 2R_.$

Where R_a = armature resistance per phase.

$R_a = \frac{Rry}{2}$ Ω /ph



Delta connected alternator

Thus in star connected alternator, the armature resistance per phase is half of the resistance observed across any two line terminals.

Consider the delta connected alternator as shown in the fig.

When voltage is applied across any two terminals, then one phase winding appears in parallel with series combination of other two.

Hence the equivalent resistance across the terminals is parallel combination of the resistance R_a and $2R_a$

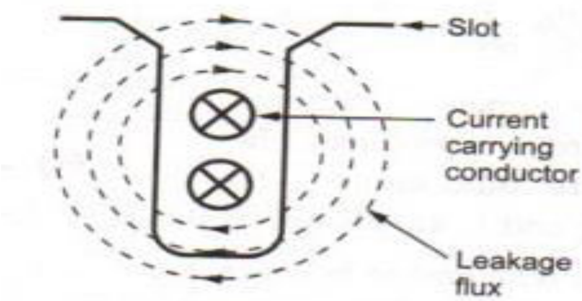
$R_{RY} = R_a \parallel 2R_a$ Ω/ph $= \frac{2}{3} R_a$

$R_a = \frac{3}{2} R_{RY}$

Thus in delta connected alternator, the armature resistance per phase is to be calculated from the equivalent resistance observed across any two line terminals.

Armature leakage reactance

When armature carries a current, it produces its own flux. Some part of the air around the conductors itself. Such a flux is called leakage flux. This is shown in the figure.



Armature leakage flux

Key point: this leakage flux makes the armature winding inductive in nature. So winding possesses a leakage reactance, in addition to the resistance.

So if L is the leakage inductance of the armature winding per phase, then leakage reactance per phase is given by XL = 2 π f L Ω / ph. The value of leakage reactance is much higher than the armature resistance. Similar to the d.c. machines, the value of armature resistance is very very small.

Armature reaction

When the load is connected to the alternator, the armature winding of the alternator carries a current. Every current carrying conductor produces its own flux so armature of the alternator also produces its own flux, when carrying a current.

So there are two fluxes present in the air gap. One due to armature current while second is produced by the field winding called main flux. The flux produced by the armature is called armature flux.

Key point : so effect of the armature flux on the main flux effecting its value and the distribution is called armature reaction.

The effect of the armature flux not only depends on the magnitude of the current flowing through the armature winding but also depends on the nature of the power factor of the load connected to the alternator.

Armature reaction reactance (X_{ar})

In all the conditions of the load power factors, there is change in the terminal voltage due to the armature reaction. Mainly the practical loads are inductive in nature, due to the demagnetising effect of armature reaction, there is reduction in the terminal voltage. Now this drop in the voltage is due to the interaction of armature and main flux. This drop is not across any physical element.

But to quantity the voltage drop due to the armature reaction, armature winding is assumed to have a fictitious reactance. This fictitious reactance of the armature is called armature reaction reactance as X_{ar} Ω /ph. And the drop due to armature reaction can be accounted as the voltage drop across this reactance as $L_a X_{ar}$.

Key point ; the value of this reactance changes as the load power factor changes, as armature reaction depends on the load power factor.

Concept of synchronous reactance and impedance

From the above discussion, it is clear that armature winding has one more parameter which is armature reaction reactance in addition to its resistance and the leakage reactance.

The sum of the fictitious armature reaction reactance accounted for considering armature reaction effect and the leakage reactance of the armature is called synchronous reactance of the alternator denoted as X_s.

So $X_s = X_L + X_{ar}$ Ω /ph

As both X_L and X_{ar} are ohmic values per phase, synchronous reactance is also specified as ohms phase.

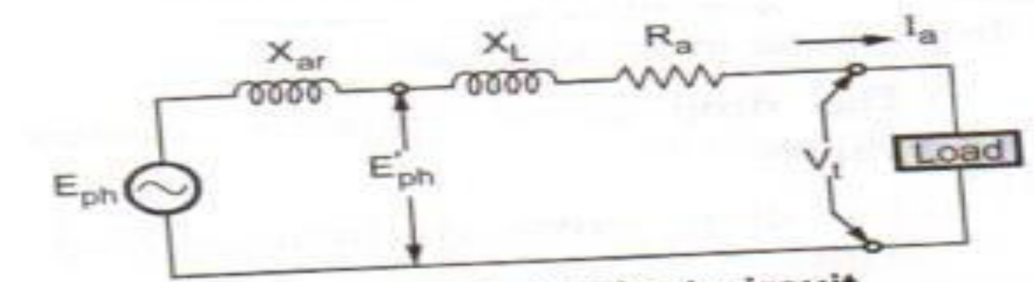
Now from this, it is possible to define an impedance of the armature winding, such an impedance obtained by combining per phase values of synchronous reactance and armature resistance is called synchronous impedance of the alternator denoted as Z_s

So $Z_s = R_a + j_{xs}$ Ω / ph

$| Z_s | = \sqrt{Ra^2 + Xs^2}$ Ω / ph

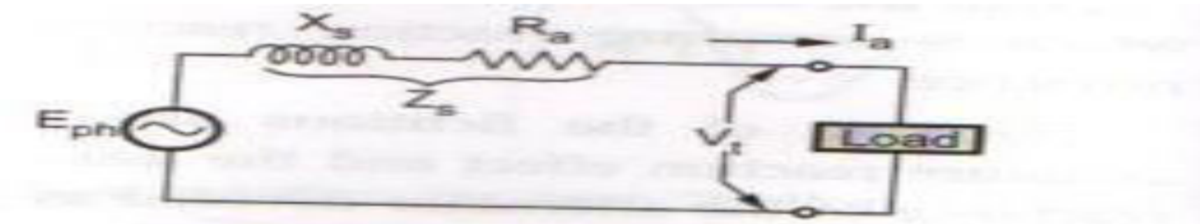
For getting a standard frequency, alternator is to be drivers at synchronous speed. So word synchronous used in specifying the reactance and impedance is referred to the working speed of the alternator. Generally impedance of the winding is constant but in case of alternator, synchronous reactance depends on the load and its power factor condition, hence synchronous impedance also varies with the load and its power factor conditions.

4.3 .Equivalent circuit of an alternator (circuit model):



Equivalent circuit

If E_{ph} is induced e.m.f. per phase on no load condition then on load it changes to E” due to armature reaction as shown in the equivalent circuit. As current I_a flows through the armature, there are two voltage drops across Ra and XL as I_a R_a and I_a X_L respectively. Hence finally terminal voltage V_t is less than E’ by the amount equal to the drops across R_a and X_L.



Equivalent circuit of an alternator

In practice, the voltage reactor X_L and the armature reaction reactor X_{ar} are combined to get synchronous reactors X_s.

Hence the equivalent circuit of an alternator gets modified as shown in the figure.

Thus in the equivalent circuit shown,

E_{ph} = induced e. m. f . per phase on no load.

V_{tph} = terminal voltage per phase on load

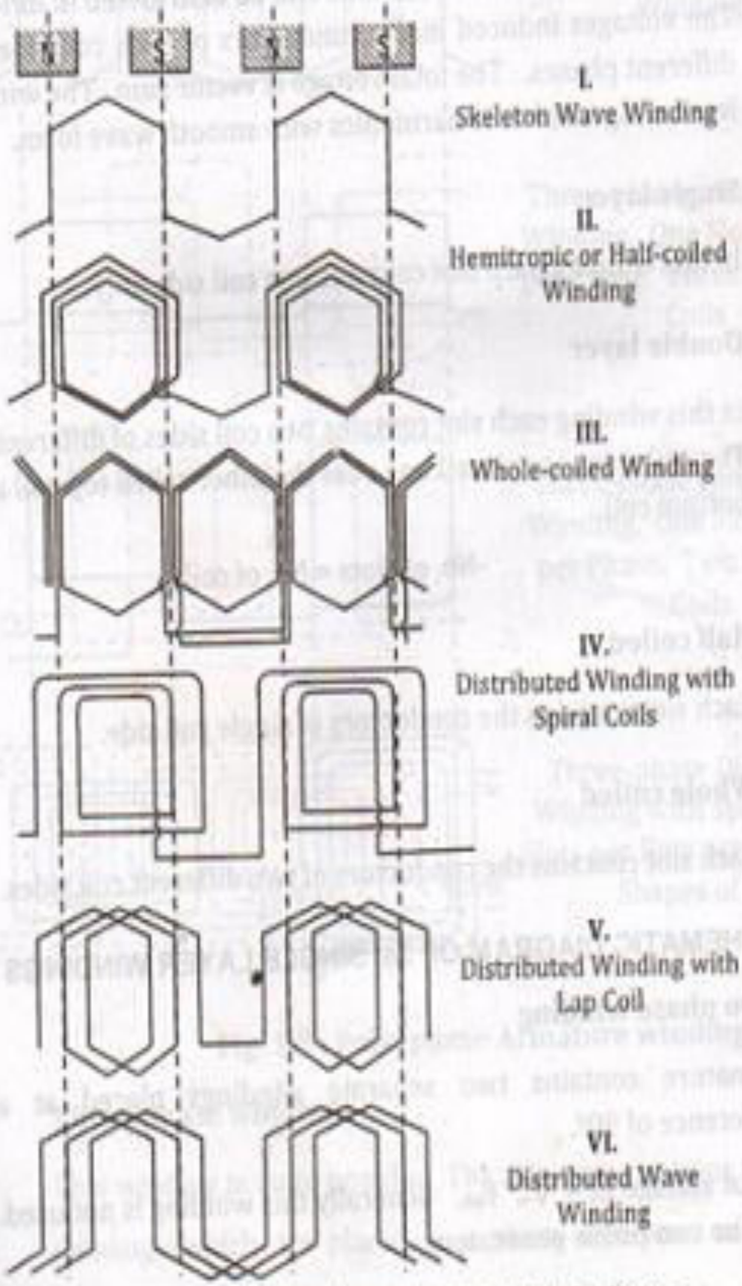
I_{aph} = armature resistance per phase

Z_s = synchronous impedance per phase.

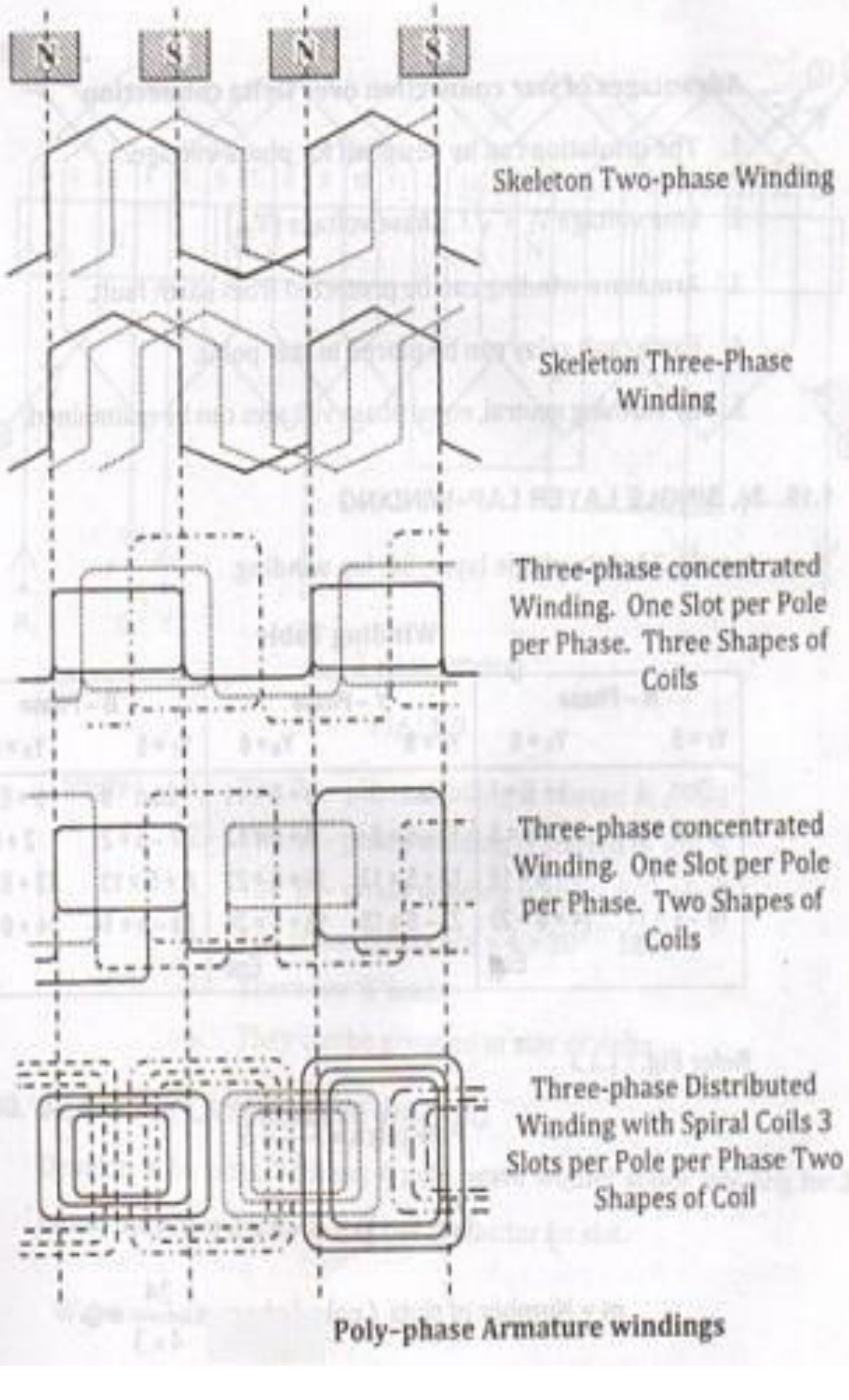
$\bar{E}_{ph} = \bar{V}_{tph} + \bar{I}_a \bar{Z}_s$.........(phasor sum)

Single phase windings:

Armature contains only one winding formed by number of coils.



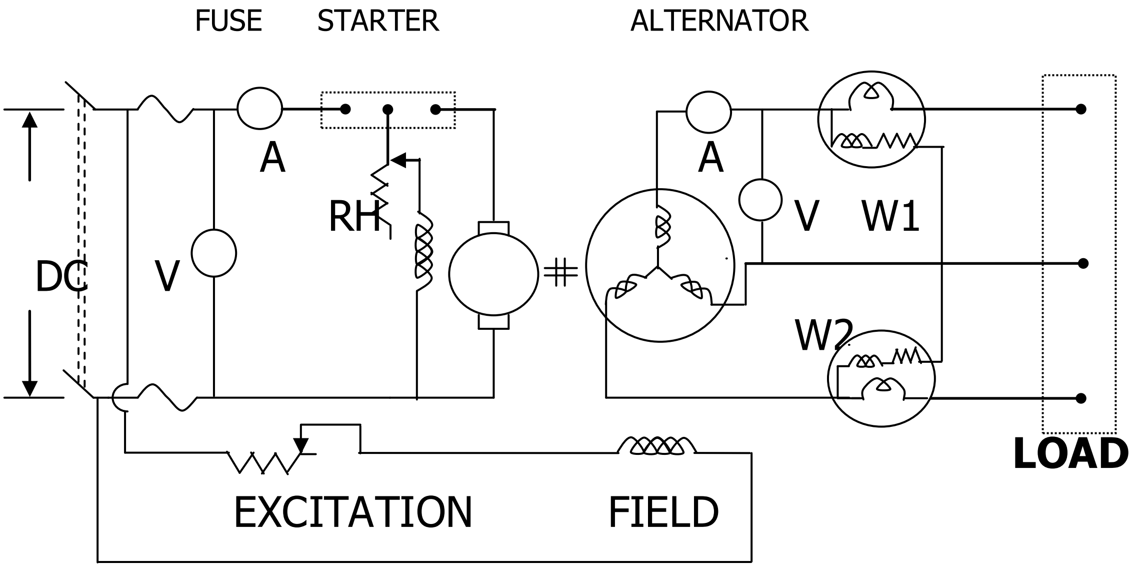
Single-phase Armature windings



Poly-phase Armature windings

4.4. DETERMINATION OF VOLTAGE REGULATION IN ALTERNATOR

DIRECT METHOD (LOAD TEST)



PROCEDURE:

1) Connections are made as per the circuit diagram.
2) Switch on DC Supply using DPST switch and start DC motor using 3 point Starter.
3) Motor was made to run at rated speed using motor filed rheostat.
4) The alternator field rheostat was varied till the voltmeter reads rated voltage.
5) For various values of Balanced loading (resistive load) the terminal voltage (Vdc and Vt), Wattmeters (W1 and W2) and current (Idc and IL) readings are tabulated.

TABULAR COLOUMN:

Sl. No	V_{dc}	I_{dc}	Input power (DC)	W_1 (Watts)	W_2 (Watts)	Output Power (AC)	$V_{T/ph}$	I_L	E/ph	Reg.	%Eff.
1.											
2.											
3.											
4.											
5.											
6.											
7.											
8.											

FORMULAE:

% Regulation = E - V / E × 100

Where, E = E/ph in no load condition

V = E/ph in Load condition

TO FIND EFFICIENCY:

% Efficiency of Alternator = Output Power / Input Power x 100

Assume efficiency of D.C Motor as 75 %

Input power = $0.75 \times V_{dc} \times I_{dc}$

Output power = W1+ W2 (Consider Actual Value of Wattmeter)

4.4.2 INDIRECT METHODS:

1. DETERMINATION OF VOLTAGE REGULATION - EMF

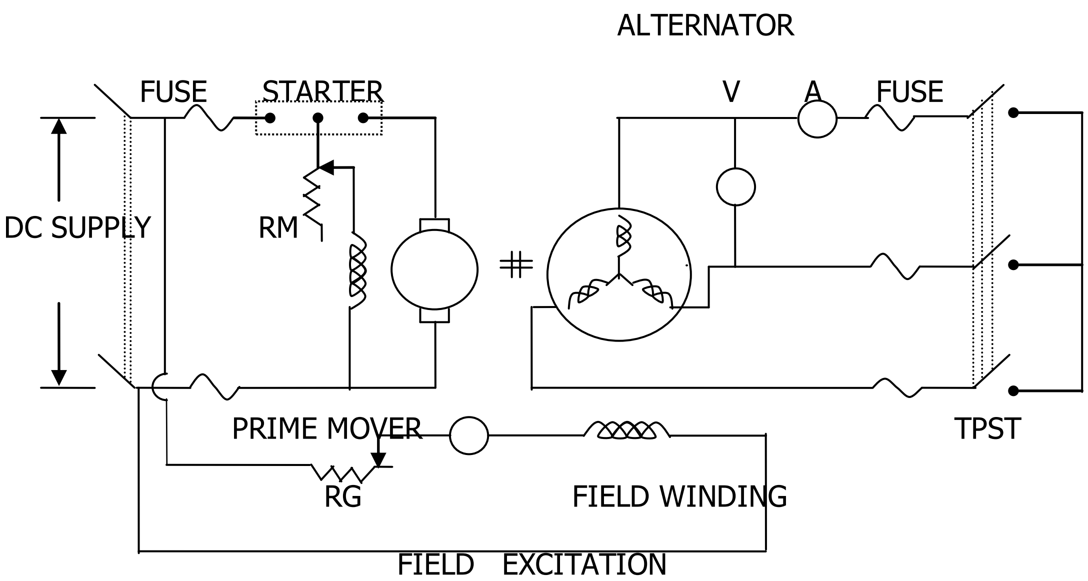
2. DETERMINATION OF VOLTAGE REGULATION - MMF

3. DETERMINATION OF VOLTAGE REGULATION - POTIER METHOD

4. DETERMINATION OF VOLTAGE REGULATION – ASA METHOD

VOLTAGE REGULATION

Predetermination of Regulation of Alternator by EMF and MMF Methods



TPST--- OPEN FOR OC TEST

TPST--- CLOSED FOR SC TEST

Open circuit test and short circuit test:

The circuit connections for the conduct of these two tests, were as shown. The T.P.S.T. switch S3, was to be kept open in the open circuit test, for measuring the open circuit (no load) voltage developed by the alternator. The rheostat in the field circuit of the motor (R_m) was initially set for minimum resistance position, while the R_g rheostat in the alternator field circuit were made, and supply to the d.c shunt motor was effected by closing the D.P.S.T. switch S1. The motor was started by means of the 3-point starter. It was brought to the rated speed of the alternator, (the speed being noted by the Tachometer) by adjustment (increase of resistance) of the field rheostat, R_{fm}. D.c supply was now given to the field of the alternator by closing the D.P.S.T. switch s2. The alternator line voltage under no load condition V_{oc}, and field current of the alternator I_{fo}, were noted. The field current I_{fo} was now increased by adjustment (decrease of resistance) of the alternator field rheostat. The increase in I_{fo} was carried cut in convenient steps of increments, until V_{oc} reaches a value of 125% of the rated line voltage of the alternator. For each setting of I_{fo}, the corresponding value of V_{oc}, was also noted. The sets of reading taken, I_{fo} and V_{oc} were tabulated .

After completion of the earlier open circuit test, the field current of the alternator I_f, was brought to the minimum value possible by increasing R_{fg}. The T.P.S.T. switch s3, was now closed on to the three phase short circuit provided, resulting in a line current I_{sc} (short circuit current). Under these condition, the value of the field current I_{fs}, and line (short circuit) current Isc, were tabulated.

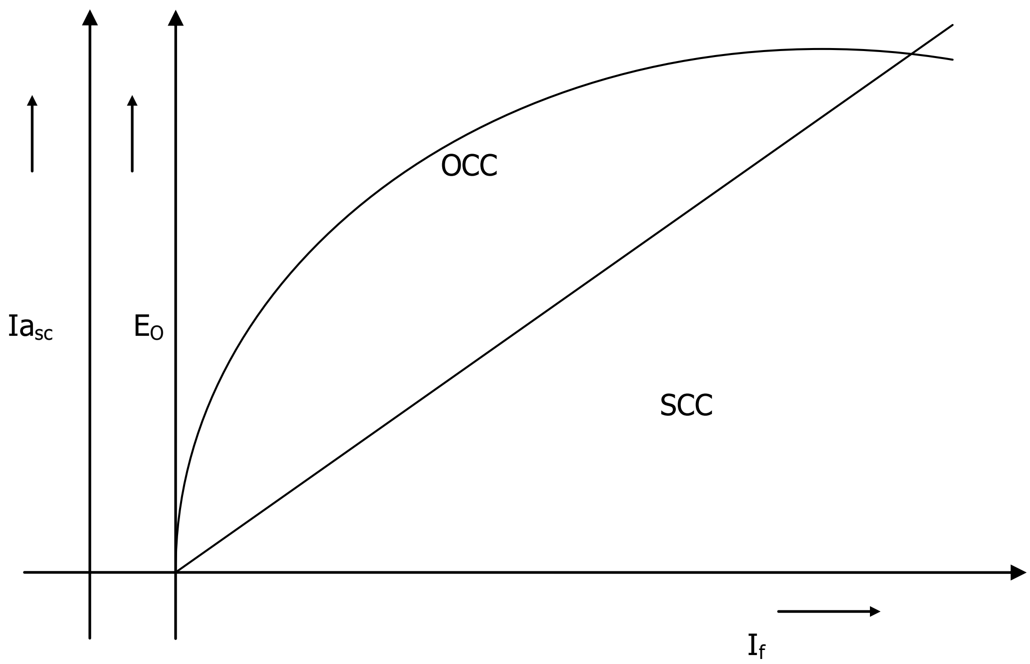
OC Test:

Sl.No.	E_g	I_f

SC Test:

Sl.No.	V_{sc}	I_f	I_{SC}

Model Graph:



CALCULATION:

For EMF method

From the O.C.C find the value of field current required to produce the rated line voltage. . Correspondingly to this field current, the short circuit current is found from S.C curve.

Synchronous impedance per phase $= V_{OC} / I_{SC}$

Synchronous impedance per phase $Z_S = R_a + j x_s$

Synchronous reactance $X_S = \sqrt{(Z_S)^2 - (R_A)^2}$

Induced emf (E) = $\sqrt{(V\cos\Phi + IR_A^2) + (V\sin\Phi \pm IX_S^2)}$ Volts

For lagging power factor **+**

For leading power factor -

% Percentage Regulation = $\frac{E - V}{E} \times 100$

4.4.3.FOR MMF METHOD:

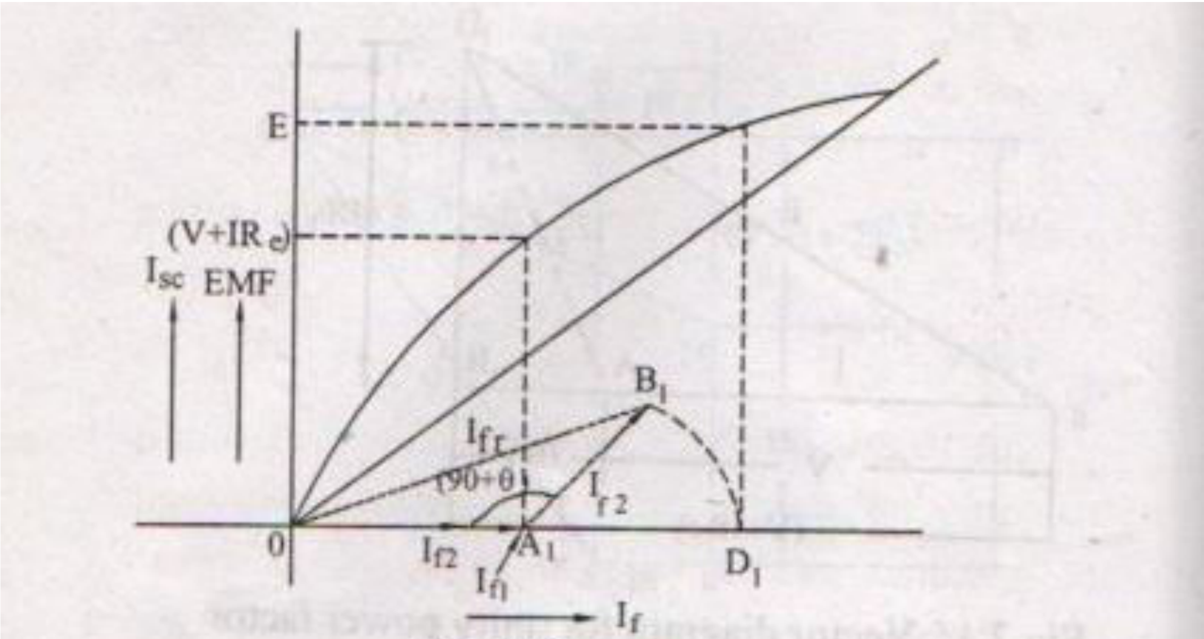


Fig 2.16
Open circuit and short circuit characteristics and vector diagram for lagging p.f load

From the O.C.C curve find out the field current (I_{F1}) with respect to rated terminal line voltage.

From the S.C.C curve find out the field current (I_{F2}) with respect to rated short circuit current Find out the resultant field current I_F

$$I_F = \sqrt{I_{F1}^2 + I_{F2}^2 - 2 * I_{F1} * I_{F2} * \cos(90 \pm \Phi)} \text{ amps}$$

For lagging power factor $90 + \phi$

For leading power factor 90 - ϕ

For this field current, find the corresponding voltage (E) from the O.C.C Curve and find out the regulation using the expression

% Percentage Regulation = $E - V \times 100 / E$

The following steps are followed in this method for calculating the regulation.

1. MMFs in terms of field currents are calculated

2. Field current (MMF) for the voltage of the vector sum of terminal voltage and I_{Re} drop is found out from the O.C.C. Let this field current be I_{f1}

3. Rated armature current is known. Then from the S.C.C, the value of field current is found out in order to produce the rated full load armature current on short circuit. Let this field current be I_{f2}.

4. This is the field current or MMF necessary to send the rated current against the effect of armature leakage reactance and the armature reaction.

5. The vector sum of the two field currents I_{f1} and I_{f2} are found out and let this value be I_{fr}

6. For this current I_{fr}, the corresponding e.m.f.on the open circuit characteristics is found out. This e.m.f. is the no load e.m.f. of the alternator E.

7. Knowing the no load EMF E, the regulation can be calculated as % Regulation =E-V/ V x100

Fig. has shown the OC and S.C characteristics and also the vector diagram for lagging P.f. load. For lagging p.f. load the I_{f2} is drawn from I_{f1} by an angle (90+Ø) as shown in fig. The vector sum of I_{f1} and I_{f2} is I_{fr}. For this current I_{fr}, the corresponding e.m.f. on the open circuit characteristics is found out. This emf is No load e.m.f(E).

Hence, % Regulation =E-V/ V x100 can be calculated for lagging p.f.

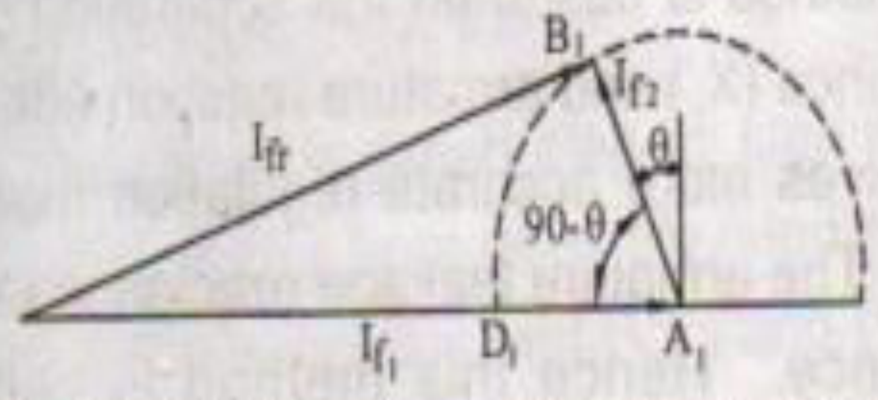
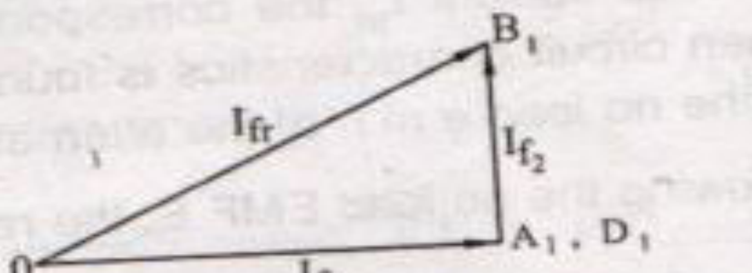


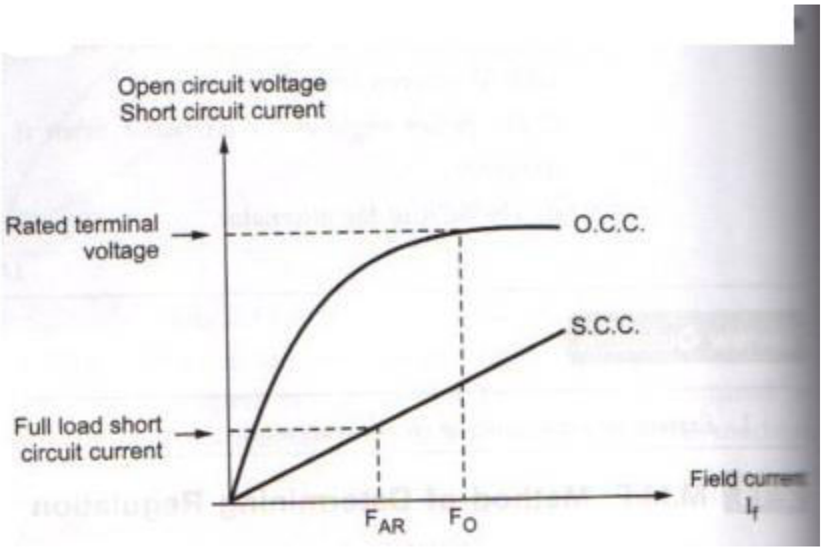
Fig 2.16(a) Vector diagram for leading p.f load

For leading p.f. load, I_{f2} is drawn from I_{f1} by an angle (90- Ø) as shown in fig. The vector sum of I_{f1} and I_{f2} is I_{fr}. For this current I_{fr}, the corresponding e.m.f. on open circuit characteristics is found out. This e.m.f. is no load e.m.f. (E). Then Regulation = E-V/ V x100 can be calculated for leading p.f.



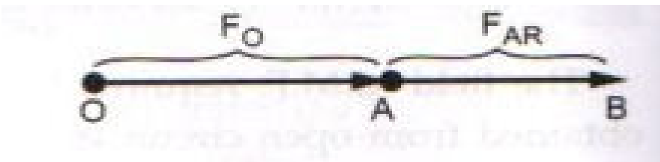
Vector diagram for unity p.f load

For unity p.f. load, I_{f2} is drawn 90 from I_{fi} as shown in fig. The vector sum of I_{f1} and If2 is I_{fr}. For this current I_{fr}, the corresponding e.m.f. on O.C.C. is found out. This e.m.f. is no load e.m.f.(E). Then regulation = E-V/ V x 100 can be calculated for unity p.f.



Zero lagging p. f. : As long as the power factor is zero lagging, the armature reaction is completely demagnetising. Hence the resultant F_R is the algebraic sum of the two components F_o and F_{ar}. Field M M F is not only required to produce rated terminal voltage but also required to overcome completely demagnetising armature reaction effect.

This is shown in the figure.



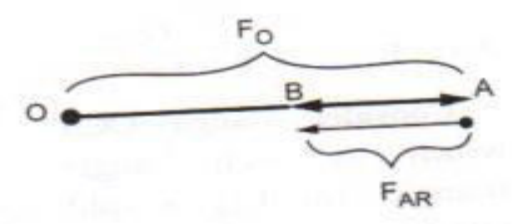
OA = F_O

AB = F_{AR} Demagnetising.

OB = F_R = $F_O + F_{AR}$

Total field M. M. F. Is greater than F_o .

Zero leading p.f : when the power factor is zero leading then the armature reaction is totally magnetising and helps main flux to induce rated terminal voltage. Hence net field M M F . required is less than that required to induce rated voltage normally, as part of its function is done by magnetising armature reaction component. The net field M M F. Is the algebraic difference between the two components F_o and F_{AR}. This is shown in the figure.



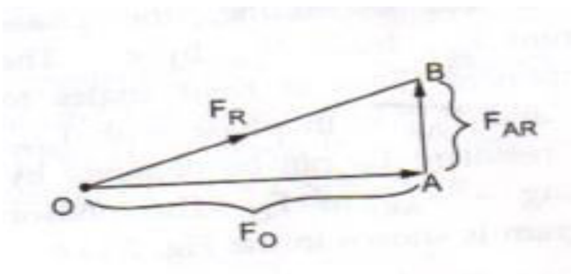
OA = F_o

AB = F_{AR} Magnetising

OB = $F_O - F_{AR} = F_R$

Total M M F is less than F_o

Unity p . f. : under unity power factor condition, the armature reaction is cross magnetising and its effect is to distort the main flux. Thus F_o and F_{AR} are at right angles to each other and hence resultant M M F . is the vector sum of F_o and F_{ar} this is shown in the figure.

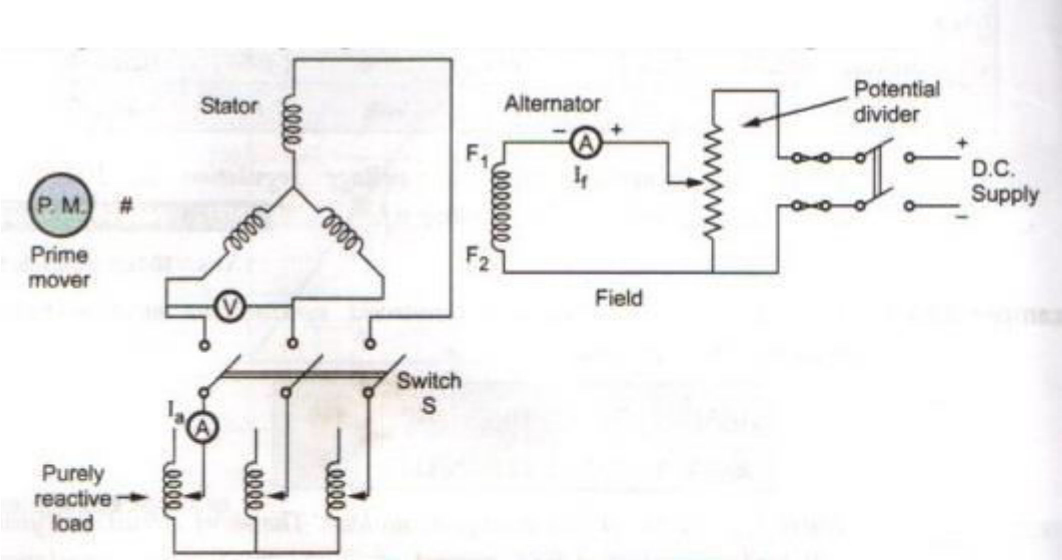


OA = F_o

AB = F_{AR} Cross magnetising

OB = $F_R = \bar{F}_o + \bar{F}_{AR}$

4.4.5 Zero power factor (ZPF METHOD)



Experimental setup for ZPF method

The steps to perform open circuit test are,

1. The switch S is kept open.
2. The alternator is driven by its prime mover at its synchronous speed and same is maintained constant throughout the text.
3. The excitation is varied with the help of potential divider, from zero up to rated value in definite number of steps. The open circuit e m f. Is measured with the help of voltmeter. The readings are tabulated.
4. A graph of If and Voc ph . i.e field current and open circuit voltage per phase is plotted to some scale. This is open circuit characteristics.

Zero power factor test

To conduct zero power factor test, the switch S is kept closed. Due to this, a purely load has power factor of cos 90° (i e) zero lagging hence the test is called zero power factor test.

The machine speed is maintained constant at its synchronous value. The load current delivered by an alternator to purely inductive load is maintained constant at its rated full load value by varying excitation and by adjusting variable inductance of the inductive load. Note that ,due to purely inductive load. An alternator will always operate at zero p. f lagging.

Key point : in this test, there is no need to obtain number of points to obtain the curve. Only two points are enough to construct a curve called zero power factor saturation curve.

This is the graph of terminal voltage against excitation when delivering full load zero power factor current.

One point for this curve is zero terminal voltage (short circuit condition) and the field current required to deliver full load short circuit armature current. While other point is the field current required to obtain rated terminal voltage while delivering rated full load armature current. With the help of these two points the zero p.f. saturation curve can be obtained .

Procedure:

1. Plot open circuit characteristics on graph paper as shown in the figure.

2. Lot the excitation corresponding to zero terminal voltage (i.e) short circuit full load zero p.f. armature current. This point is shown as A in the fig. Which is on the x axis. Another point is the rated voltage when alternator is delivering full load current at zero p.f. lagging. This point is p as shown in the fig.
3. Draw the tangent to O.C.C. Through origin which is line OB as shown dotted in fig. this is called air line.
4. Draw the horizontal line PQ parallel and equal to OA.

5. From point Q draw the line parallel to the air line which intersects O.C.C. At point R. Join RQ and join PR. The triangle PQR is called potier triangle.
6. From point R, drop a perpendicular on PQ to meet at point S.

7. The zero p.f. full load saturation curve is now be constructed by moving a triangle PQR so that R remains always on O.C.C. and line PQ always remains horizontal. The dotted

triangle is shown in the figure. It must be noted that the potier triangle once obtain is constant for a given armature current and hence can be transferred as it is.

8. Through point A, draw line parallel to PR meeting O.C.C. at point B. From B, draw perpendicular on OA to meet it at point C. Triangles OAB and PQR are similar triangles.

9. The perpendicular RS gives the voltage drop due to the armature leakage reactance i.e IX_{L}.

10. The length PS gives field current necessary to overcome demagnetising effect of armature reaction full load.

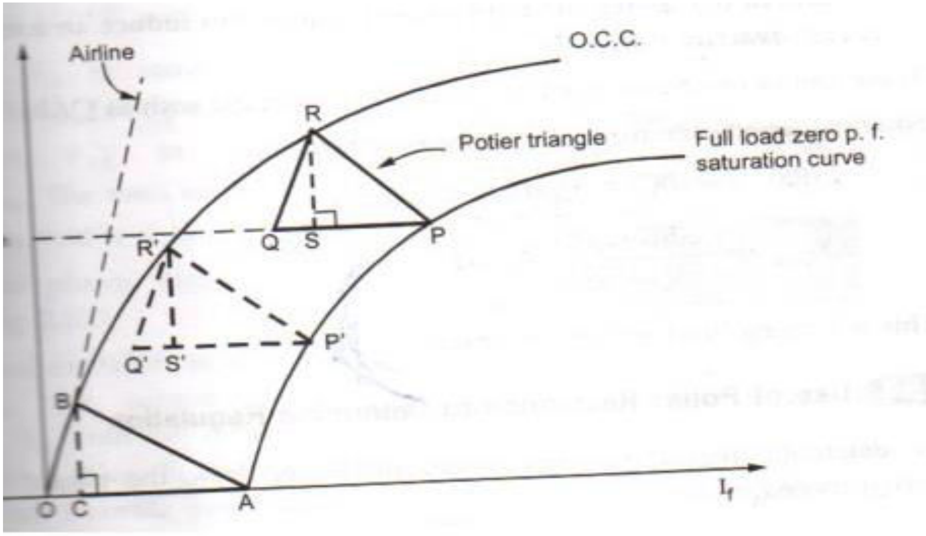
11. The Length SQ represents field current required to induce an e.m.f. for balancing leakage reactance drop RS.

These values can be obtained from any potier triangles such as OAB, PQR. And so on.

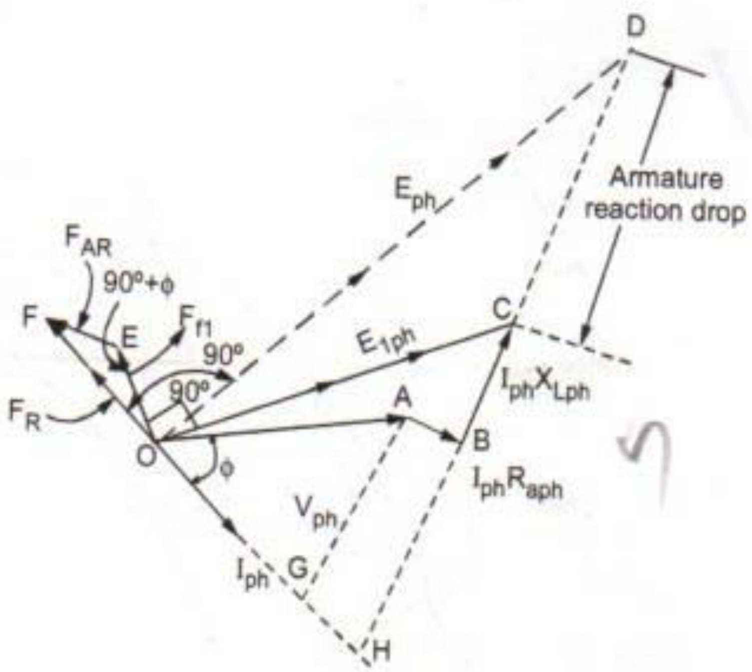
So armature leakage reactance can be obtained as,

$l(RS) = l(BC) = (I_{aph})$ F.L x X_L ph

$$X_{L\ ph} = \frac{l\,(RS)\ \text{or}\ l\,(BC)}{(I_{aph})\ F.L.}\ \Omega$$



VECTOR DIAGRAM(ZPF MTHOD)



4.5 Parallel Operation of Alternators

NECESSITY

(i) When the load demand on the alternator in the course of time increases beyond the capacity of the existing alternator. The demand of more power can be met either by replacing the existing alternator by a new one of greater capacity of by installing additional alternators and by making them share a portion of the load. The cost of adding and operating new alternators in parallel with the existing one is cheaper than replacing the existing alternator by new one of larger capacity.

(ii) If the amount of power to be generated is greater than the power with which one alternator can be built in two or more alternators are installed and operated in parallel.

(iii) Alternators are normally constructed to operate at maximum efficiency around full load. Therefore, if a single large capacity alternator is to meet the entire load, it will lead to inefficient operation during part-load periods. When more alternators are operated in parallel, only required number of alternators needs to be put into service to give efficient operation while others are shut down.

(iv) To ensure reliability of supply, it is customary to install a spare. Alternator with the capacity of the largest alternator operating in the plant. Hence the capacity and the cost of the spare alternator will be less if two or more alternators are operated in parallel.

4.5.2 CONDITIONS FOR SYNCHRONISING

The process of connecting an alternator is parallel with an existing operating alternator or with common supply bus-bars is called as synchronising.

The following are the three conditions to be satisfied before synchronising the additional alternator with the existing one or the common bus-bars.

(i) The terminal voltage magnitude of the incoming alternator must be made equal to the existing alternator or the bus-bar voltage magnitude.

(ii) The phase sequence of the incoming alternator voltage must be similar to the bus-bar voltage.

(iii) The frequency of the incoming alternator voltage must be the same as the bus-bar voltage.

4.5.3 SYNCHRONISING PROCEDURE

Among the three conditions listed above, condition

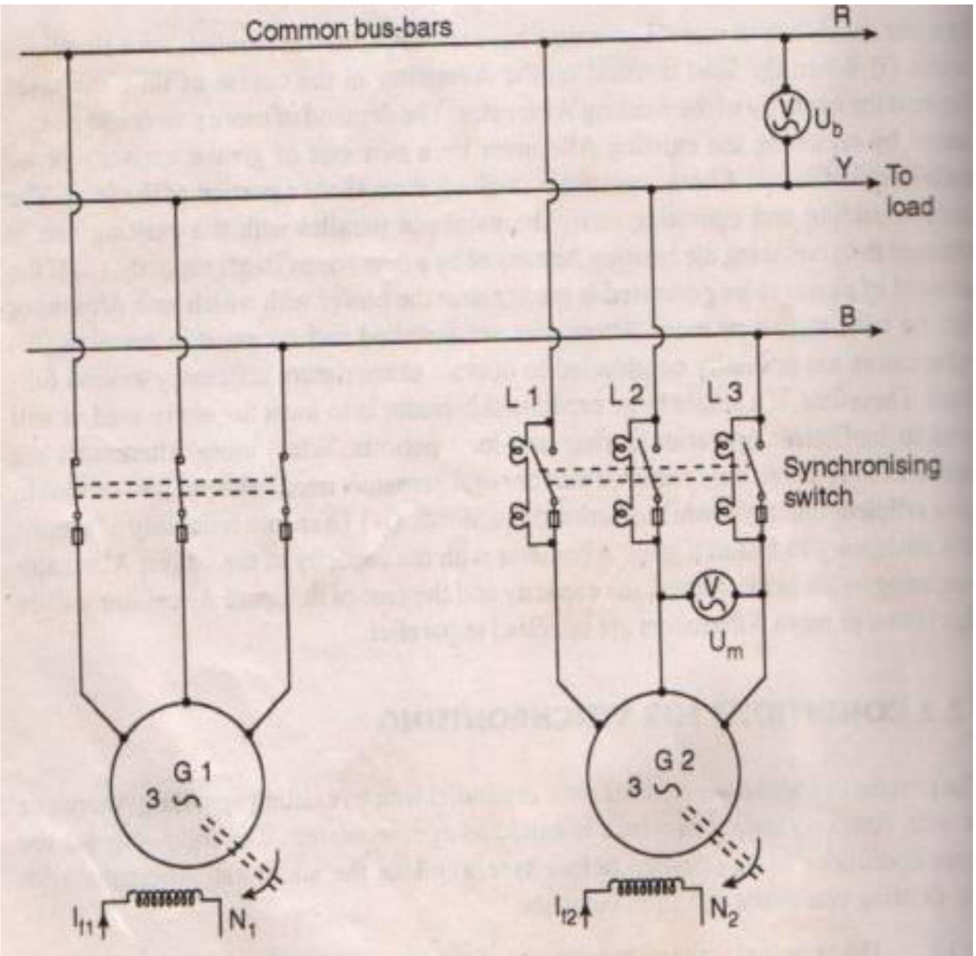
(i) Can be checked with the help of voltmeters.

(ii)can be checked either by using a phase sequence meter or synchronising lamps and

(iii) Can be inspected by either synchronising lamps or synchroscope.

4.5.4 Three Dark lamps method

In fig 1, the alternator marked as G_1 is the already existing one which is connected to the common bus-bars RYB. G_1 supplies power to the load. The alternator marked as G_2 is the new alternator which is connected to the common bus-bars through the synchronising switch. Across each pole of the synchronising switch L_1, L_2, And L_3 set of lamp are connected.



Three dark lamps method

To synchronise Alternator G_2 with the common bus-bars, it is driven by its prime mover at a speed very close to the synchronising speed decided by the bus-bar frequency and the number of poles in Alternator G_2. The field current of G_2 is increased so that the voltage across the machine terminals Um becomes equal to the bus-bar voltage U_b. Thus the first condition specified above is satisfied. Now the three sets of lamps glow bright and dark. Condition (ii) about the correctness of the phase sequence can be checked by looking at the three sets of lamps. If the lamps glow bright and dark in unison it is an indication of the correctness of the phase sequence. If on the other hand, they become bright and dark one after the other, connections to any two machine terminals has to be interchanged after shutting down the machine. This will correct the phase sequence. The machine is once again started and conditions (i) and (ii) are satisfied. Checking for condition (iii) the frequency, can be carried out by looking into the rate of flickering of the lamps. The rate of flickering accounts for the frequency difference between the bus-bar voltage and the incoming Alternator voltage. The rate of flickering then has to be reduced to as low as possible by adjusting the speed of the Alternator G_2 by its Prime-mover control. When all the three set of lamps become dark, the synchronising switch can be closed and thus the Alternator G_2 gets synchronised with Alternator G_1.

Advantages

The following are the advantages of using this method:

(i) The synchronising switch shown in fig 1 is inexpensive.
(ii)Checking for correctness of the phase sequence can be obtained in a simpler manner which is essential especially when the Alternator is connected for the first time or for fresh operation after disconnection.

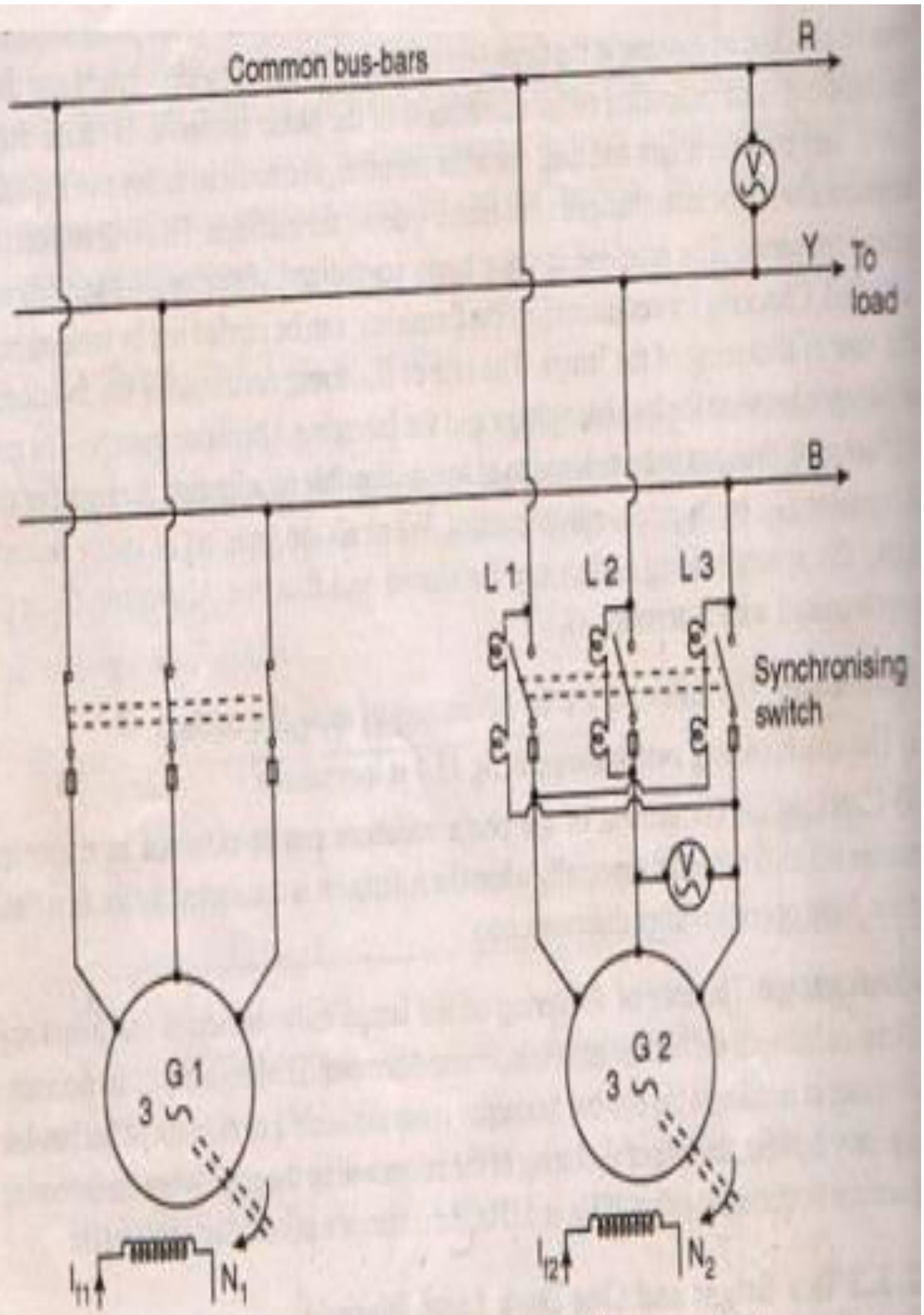
Disadvantage

The rate of flickering of the lamps only indicates the frequency difference between the bus-bar and the incoming Alternator. The frequency of the incoming Alternator in relation to the bus-bar frequency is not available. For example, if the bus-bar frequency is $50H_z$, the rate of flickering of the lamps will be the same when the incoming Alternator frequency is either $49H_z$ or $51H_z$, the difference in both cases being 1H

4.5.5. Two Bright and One Dark Lamp Method

This method again makes use of three sets of lamps and is useful in finding whether the incoming Alternator frequency is higher or lower than the bus-bar frequency. But the correctness of the phase sequence cannot be checked by this method. It is also unnecessary for permanently connected Alternators where phase sequence check is enough to be carried out for the first time of operation alone. Fig 2 shows the connection diagram of this method.

In the synchronising switch, lamps of L_2 are connected across the pole in the middle line, similar to the previous case, whereas lamps of L_1 and L_3 are connected in a transposed manner as suggested by Profs. Siemens and Halske. After condition (i),equal voltage magnitude, is satisfied, the three set of lamps L_1, L_2, and L_3 glow bright and dark one after the other. The sequence in which the three sets of lamps become bright and dark indicates whether the incoming generator frequency is higher or lower than the bus-bar frequency. The sequence of becoming bright and dark say. L_1 L_2 L_3 may be an indication that the incoming generator frequency is higher than the bus-bar frequency. Then the alternator speed can be reduced by its prime-mover control and the rate of flickering is to be brought down to as small as possible. On the other hand, if the sequence of flickering is reversed, i.e. L_1,L_2,L_3 then it is an indication that the incoming Alternator frequency is less than the bus-bar frequency and needs a speedcorrection in the increasing direction. After bringing down the rate of flickering to as small as possible, the synchronising switch is to be closed at the instant when lamp L_2 is dark and lamps L_1 and L_3 are equally bright.

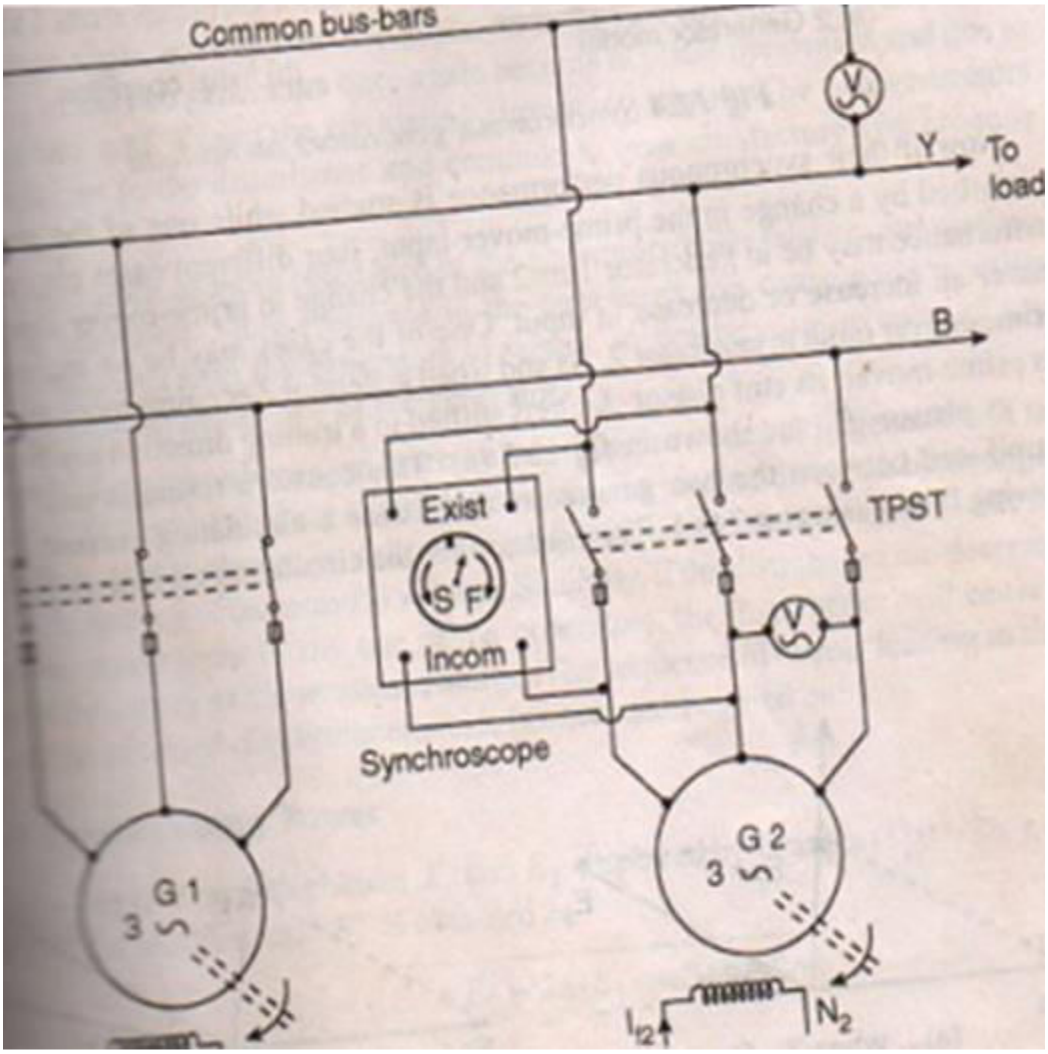


Two bright and one dark lamps method

4.5.6 Using Synchroscope

Using Synchroscope is similar in using two bright and one dark lamps method. It indicates whether the incoming Alternator frequency is higher or lower than the bus-bar frequency. It can also be used for permanently connected Alternator where the correctness of phase sequence is already checked by other means. Fig. 3 shows the connection diagram.

The Synchroscope has two pair of terminals. One pair marked as existing has to be connected to the existing Alternator or bus-bar terminals and the other pair with the marking ‘incoming’ has to be connected to the corresponding terminals of the Alternator as shown in the fig .3. The Synchroscope has a circular dial in which a thick line is marked at the top, a clockwise symbol with letter ‘F’ on one side and an anti-clockwise symbol with letter ‘S’ marked on the other side. The pointer is capable of rotating in both directions. After condition (i) is satisfied the operator has to look into the Synchroscope. The rate of rotation of the pointer indicates the amount of frequency difference between the Alternators. The direction of rotation indicates whether the incoming Alternator frequency is higher or lower than the existing Alternator, ie whether the incoming Alternator is fast or slow. Sutiable correction is then made in the speed of the Alternator and the rate of rotation is reduced to the smallest possible value. The TPST switch is closed to Synchronise the incoming Alternator when the pointer faces the top thick line marking.



SYNCHROSCOPE METHOD

5. POST MCQ

1. Alternator is called synchronous Generator because it,
   a) Runs at constant speed b) Runs at synchronous speed
   c) Produce synchronous. Voltage d)Produce constant voltage

2. Alternators are run at synchronous Speed to produce power at
   a) Constant frequency b) Constant voltage
   b) Constant power factor d) Leading power factor

3. The maximum speed of alternator producing power at 50Hz is
   a) 1500rpm b) 3000rpm c) 6000rpm d)4500rpm

4. In low voltage (4000v) & low capacity (50KVA) alternator, the following system is used
   a) Rotating field b) Salient pole c) Rotating armature

Non-salient

5. Advantages of using rotating field system
   a) Power at high voltage is generated b) No sparking
   c) High efficiency d) All the three above

6. The wave form of the a.c. voltage generated in alternator is
   a) Flat topped b) triangular c) Rectangular Sinusoidal

7. The wave form of the flux produced by the D.C. poles of alternator is
   a) Sinusoidal b) Rectangular c) Trapezoidal Square

8. In salient pole alternators, the air gap between poles and armature is
   a) Narrow and uniform b) Narrow but not uniform
   c) Not narrow but uniform d) None of the above

9. In non-salient pole alternators, the air gap between poles and armature is
   a) Narrow and uniform b) Narrow but not uniform
   c) Not narrow but uniform d) None of the above

10. Salient pole machines have

a) More poles and length to diameter ratio is small

b) Less poles and length to diameter ratio is small

c) More poles and length to diameter ratio is high

d) More poles and length to diameter ratio is high

11. Damper windings are placed on

a) Stator core b) Rotor poles c) in the slots on pole shoe

d) In the slots provided on stator.

12. Damper windings are not used in........ Alternators

a) Salient b) non- salient c) low speed d) normal speed

13. Leakage reactance is mainly due to

a) Pole leakage flux b) Armature leakage flux

c) Armature reaction flux d) Damper winding leakage flux

14. Leakage reactance is independent of

a) Load p f b) Air gap c) Slots d) End connections.

15. The effect of armature reaction mainly depends on

a) Load current b) load p.f c) load voltage d) load power

.16. Damper windings are not used in........... alternators

a) Salient b) non- salient c) low speed d) normal speed

17. Leakage reactance is independent of

a) Load p. f b) Air gap C) Slots D) End connections

.

18. At Zero lagging p,f . The armature reaction is ....

a) Cross magnetization b) Demagnetization

c) Magnetization d) (a) and (c)

19. At 0.8 leading p.f the armature reaction is...........

a) Cross magnetization b) Demagnetization

c) Magnetization d) (a) and (c)

20. The voltage regulation at lagging p.f is

a) Positive b) negative c) unity d) Zero

21. The voltage regulation at leading p.f is

a) Positive b) negative c) unity d) Zero

22. The voltage regulation of alternator is

A) $\frac{Eo - V}{Eo}$ b) $\frac{Eo - V}{V}$ c) $\frac{V - Eo}{Eo}$ d) $\frac{V - Eo}{V}$

23. The regulation obtained by Zs method is

a) Actual b) less than actual c) more than actual d) optimistic

24. The regulation obtained by ampere turns method is ....

a) Actual b) less than actual c) more than actual
d) pessimistic

25. The power factor of an alternator is determined by its

a) Speed b) load c) excitation d) prime mover

.

26 .The regulation obtained by ZPF method is

a) Actual b) less than actual c) more than actual d) none of the above

6. CONCLUSION:

Thus, we learned in detail about the construction of synchronous generator, effect of alternator parameters and how to deduce the equivalent circuit of synchronous machine. We also learned how to determine the regulation of alternator and various methods of synchronizing of alternator.

7. References:

1. Electrical machines – BR.SHARMA.

2. Induction and synchronous machines –k.murgeshkumar.

3. Ac & Dc machines- B.L Therja& A.K Therja.

8. VIDEO:

1. **PROCEDURE FOR FINDING VOLTAGE REGULATION OF ALTERNATOR (INDIRECT METHOD) TEST VIDEO(LINK)**

2. **SYNCHRONISING OF ALTERNATOR(DARK &SYNCROSCOPE METHOD) VIDEO(LINK)**