14EE505

Hall Ticket Number:

III/IV B.Tech (Regular\Supplementary) DEGREE EXAMINATION

November, 2019 — **Electrical and Electronics Engineering**

Fifth Semester — **Synchronous Machines & Special Machines**

Time: Three Hours — **Maximum:** 60 Marks

Answer Question No.1 compulsorily. (1X12 = 12 Marks)

Answer ONE question from each unit. (4X12=48 Marks)

1. Answer all questions (1X12=12 Marks)
   a) Why three phase alternators are generally star connected?
   b) What do you mean by synchronous reactance of an alternator?
   c) Why are alternators rated in KVA?
   d) What happens if the load on an alternator connected to grid is increased beyond its limits?
   e) On what factor does the power factor of an alternator depend?
   f) What is the solution for reducing hunting in alternators?
   g) Why a synchronous motor is not self-starting?
   h) Draw the phasor diagram of synchronous motor for lagging power factor.
   i) What will happen if the synchronous motor is over excited?
   j) Why stepper motor is very robust and reliable?
   k) What are applications of hysteresis motor.
   l) What is universal motor?

UNIT I

2. a) Explain why stationary armature is preferred over rotating armature? 6M
   b) A 4 pole alternator has an armature with 24 slots and 10 conductors per slot. The flux per Pole is 0.08wb and machine rotates at 1500rpm. Calculate the EMF generated, if the winding factor is 0.98 and all the conductor in a phase are connected in series. 6M

(OR)

3. a) Derive the expression for winding factor (Kw). 6M
   b) Find the pitch factors for the following winding 6M
      i) 32 slots, 4 poles, coil span 7 slots ii) 72 slots, 8 poles, coil span 8 slots

UNIT II

4. a) Explain any one method of synchronization of alternators. 6M
   b) A 5 MVA,8-pole alternator runs at 1500 rpm in parallel with other machines on 6.6 KV bus bars. The synchronous reactance is 20%. Calculate the synchronizing power per one mechanical degree of displacement and the corresponding synchronizing torque. 6M

(OR)

5. a) Explain the effect of change in excitation on the parallel operation of two alternators. 6M
   b) Two identical 3MVA alternators are running in parallel. The frequency drops from no load to full load for the two alternators are 50Hz to 47 Hz and 50Hz to 48Hz respectively. 6M
      i. How will they share a load of 4000 KW?
      What is the maximum load they can share at unity power factor without overloading any alternator?

UNIT III

6. a) With neat diagram, explain the operation of synchronous motor with constant load and variable excitation. 6M
   b) An industrial load of 4MW is supplied at 11KV, the power factor being 0.8 lagging. A synchronous motor is required to meet an additional load of 1103.25 KW and at the same time to raise the resultant power factor to 0.95 lagging. Determine the KVA capacity of the motor and the power factor at which it must operate. The efficiency of motor is 80%. 6M

(OR)

7. a) A 3-phase, synchronous motor observing 60 kW is connected in parallel with a factory load of 240kW having lagging pf of 0.8. If the combined load has a pf of 0.9 lagging, what is the value of leading kVAR supplied by the motor and at what power factor it is working? 6M
   b) Explain the 'power factor v/s field current' & 'armature current v/s field current' characteristics of synchronous motor. 6M

UNIT IV

8. a) Explain in brief about the following. 6M
      i. AC series motor
      ii. Universal motor
   b) Explain the function of compensating winding in AC series motor. 6M

(OR)

9. a) With neat diagram, explain the construction and working of variable reluctance stepper motor. also,explain its static and dynamic characteristics. 6M
   b) Why small fractional horse power AC series motors are called universal motors? 6M

III/IV B.Tech (Regular/Supplementary) Degree Examination

November,2019 — Electrical and Electronics Engineering

Fifth Semester — Synchronous Machines & Special Machines

Time:Three hours — Maximum:60Marks

Answer Question No.1 compulsorily (1x12=12Marks)

Answer one question from each unit (4x12=48Marks)

1. Answer all questions (1x12=12 Marks)

a) STAR connection provides a neutral point. This neutral point is very important from the stability point of view of generator.Neutral grounding provides a path for the flow of circulating current during the unbalanced loading condition of generator.

b) Synchronous Reactance and Synchronous Impedance. The Synchronous Reactance (X_S) is the imaginary reactance employed to account for the voltage effects in the armature circuit produced by the actual armature leakage reactance and by the change in the air gap flux caused by the armature reaction.

c) The alternator conductors are calculated for a definite current and are designed for a definite voltage independent of p.f. (Cos φ) of the load. For this reason apparent power measured in kVA is regarded as the rated power of the alternator.

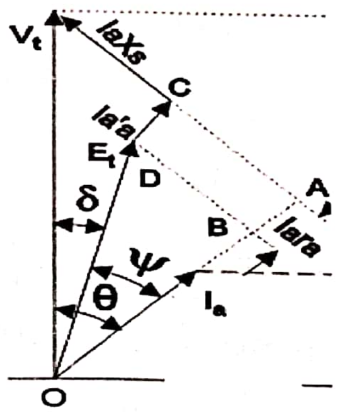
d) frequency will decrease with increased load.

e) The power factor of an alternator depends on Load.

f) Most of the alternators have their pole-shoes slotted for receiving copper bars of a grid or damper winding (also known as squirrel-cage winding). These dampers are useful in preventing the hunting (momentary speed fluctuations) in generators.

g) synchronous motors are not self-starting motors. This property is due to the inertia of the rotor; it cannot instantly follow the rotation of the magnetic field of the stator.

h)



i) An overexcited synchronous motor operates at leading power factor,

j) While having full control of rotation and speed, the simple structure of stepper motors is achieved without using electrical components, such as an encoder within the motor. For this reason, stepper motors are very robust and have high reliability with very few failures.

k) This type of motor is smoothest running, quietest single phase motor and is used for quality sound reproduction equipment like record players, tape recorders, etc.

l) A universal motor is a special type of motor which is designed to run on either DC or single phase AC supply. These motors are generally series wound (armature and field winding are in series), and hence produce high starting torque.

UNIT-I

2. A)

1. Rotating field is comparatively light and can run with high speed.
2. High voltage can be generated due to high speed and there is very little difficulty in providing high voltage on a stationary part than a moving part.
3. It is easier to insulate armature coils for high pressure usually generated (6.6 to 11 kV). Since the stator is outside the rotor, so more space is available for greater insulation required for armature winding.
4. Very little difficulty is experience in supplying the field magnet current as it is very low in comparison with the armature current.
5. Cooling of the winding is more efficient.
6. Only two slip rings are required to give DC supply to the field system.
7. Output current can be easily supplied to the load circuit. Slip-rings and brushes are not necessary.

2B) No of poles = 4

Total conductors $= 24 \times 10 = 240$

conductors/ph $= \frac{240}{3} = 80$

$\phi = 0.08$

$N = \frac{120f}{P} = 1500 \Rightarrow f = 50\,Hz$

$k_w = 0.98$ } 3M

$E_{ph} = 4.44\,\phi f N k_w$

$= 4.44 \times 0.08 \times 50 \times 80 \times 0.98$ } 3m

$= 1392.384$ V

(OR)

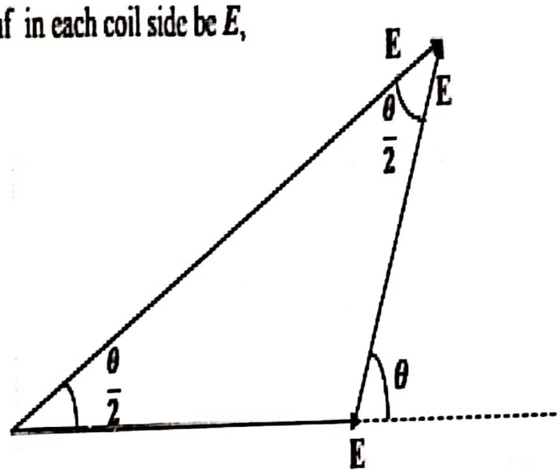
3A. **Winding Factor (Coil Pitch and Distributed Windings)**

3 M

Pitch Factor or Coil Pitch

The ratio of phasor (vector) sum of induced emfs per coil to the arithmetic sum of induced emfs per coil is known as ***pitch factor (K_p)*** or ***coil span factor (K_c)*** which is always less than unity.

Let the coil have a pitch short by angle θ electrical space degrees from full pitch and induced emf in each coil side be E,



- If the coil would have been full pitched, then total induced emf in the coil would have been $2E$.
- when the coil is short pitched by θ electrical space degrees the resultant induced emf, E_R in the coil is phasor sum of two voltages, θ apart

$$E_R = 2E\cos\frac{\theta}{2}$$

$$\text{Pitch factor, } K_p = \frac{\textit{Phasor sum of coil side emfs}}{\textit{Arithmetic sum of coil side emfs}} = \frac{2E\cos\frac{\theta}{2}}{2E} = \cos\frac{\theta}{2}$$

3M

Distribution Factor

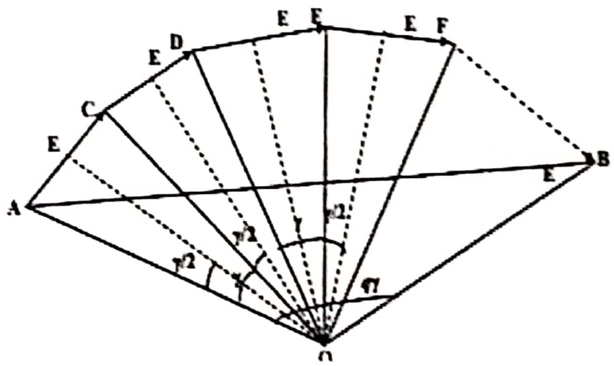
The ratio of the phasor sum of the emfs induced in all the coils distributed in a number of slots under one pole to the arithmetic sum of the emfs induced(or to the resultant of emfs induced in all coils concentrated in one slot under one pole) is known as ***breadth factor*** **(K_b)** or ***distribution factor*** **(K_d)**

$$K_d = \frac{EMF\ induced\ in\ distributed\ winding}{EMF\ induced\ if\ the\ winding\ would\ have\ been\ concentrated}$$

$$= \frac{Phasor\ sum\ of\ component\ emfs}{Arithmetic\ sum\ of\ component\ emfs}$$

- The distribution factor is always less than unity.

- Let no. of slots per pole = Q and no. of slots per pole per phase = q
  Induced emf in each coil side = E_c
  Angular displacement between the slots, $\gamma = \frac{180°}{Q}$
- The emf induced in different coils of one phase under one pole are represented by side AC, CD, DE, EF... Which are equal in magnitude (say each equal E_c) and differ in phase (say by $\gamma°$) from each other.



If bisectors are drawn on AC, CD, DE, EF... they would meet at common point *(O)*. The point *O* would be the circum center of the circle having AC, CD, DE, EF...as the chords and representing the emfs induced in the coils in different slots.

EMF induced in each coil side, $E_c = AC = 2OA \sin\frac{\gamma}{2}$

Arithmetic sum $= q \times 2 \times OA \sin\frac{\gamma}{2}$

∴ The resultant emf, $E_R = AB = 2 \times OA \sin\frac{AOB}{2} = 2 \times OA \sin\frac{q\gamma}{2}$

& distribution factor, $k_d = \frac{Phasor\ sum\ of\ components\ emfs}{Arithmetic\ sum\ of\ components\ emfs}$

$$= \frac{2 \times OA \sin\frac{q\gamma}{2}}{q \times 2 \times OA \sin\frac{\gamma}{2}} = \frac{\sin\frac{q\gamma}{2}}{q \sin\frac{\gamma}{2}}$$

3B) i) 32 slots, 4 pole, coil span 7 slots 3m

no. of slots/pole $= \frac{32}{4} = 8$

8 slots/pole $\rightarrow 180^\circ$

shorted by 1 slot

1 slot/pole $\rightarrow 22.5^\circ = \alpha$

$k_p = \cos\frac{\alpha}{2} = \cos\frac{22.5}{2} = 0.9844$

ii) no. of slots/pole $= \frac{72}{8} = 9$ 3m

9 slots/pole $\rightarrow 180^\circ$

shorted by 1 slot

1 slot/pole $\rightarrow 20^\circ = \alpha$

$k_p = \cos\frac{\alpha}{2} = \cos\frac{20^\circ}{2} = 0.9876$

UNIT-II

4.A) Conditions for Synchronization or Paralleling of Generators

There are certain requirements that must be met for successful paralleling of alternators. The following conditions must be met in order to synchronize a generator to the grid or with other generators. 2m

Phase Sequence

The phase sequence of the three phases of the alternator which is being connected to the power system bus must be same as the phase sequence of the three phases of the bus bar (or electric grid). This problem comes mainly in the event of initial installation or after maintenance.

Voltage Magnitude

The RMS voltage of the incoming alternator should be same as the RMS voltage of the bus bar or electric grid. If the incoming alternator voltage is more than the bus bar voltage, there will be a high reactive power that flows from the generator into the grid.

If the incoming alternator voltage is lower than the bus bar voltage, generator absorbs the high reactive power from the bus bar.

Frequency

The frequency of the incoming generator must be equal to the frequency of the bus bar. Improper matching of frequency results high acceleration and deceleration in the prime mover that increases the transient torque.

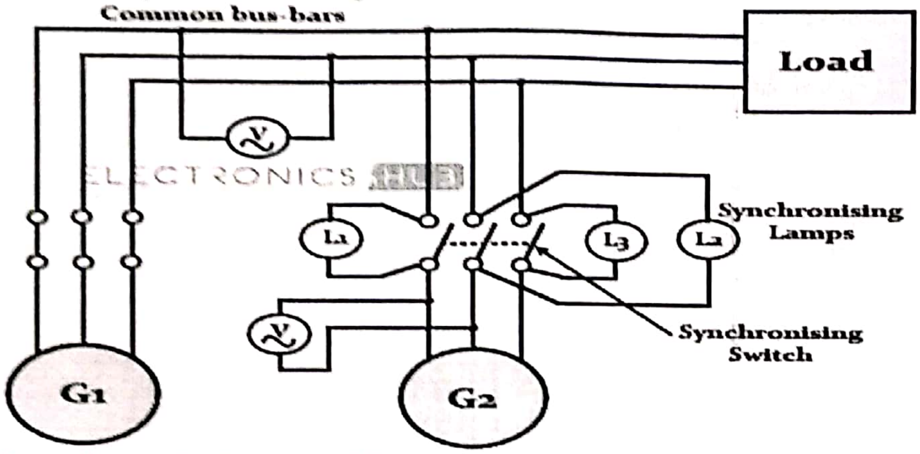
Phase Angle

The phase angle between the incoming generator voltage and voltage of the bus bar should be zero. This can be observed by comparing the occurrence of zero crossing or peaks of the voltage waveforms. 3m

Three Dark Lamps Method

The figure below shows the circuit for bright lamp method used to synchronize the alternators. Assume that alternator is connected to the load supplying rated voltage and frequency to it. Now the alternator-2 is to be connected in parallel with alternator-1.

Three lamps (each of which is rated for alternator terminal voltage) are connected across the switches of the alternator-2. From the figure it is clear that the moment when all the conditions of parallel operation are satisfied, the lamps should be more or less dark.
To synchronize the alternator-2 with bus bar, the prime mover of the alternator-2 is driven at speed close to the synchronous speed decided by the bus bar frequency and number of poles of the alternator.
Now the field current of the generator-2 is increased till voltage across the machine terminals is equal to the bus bar voltage (by observing the readings on voltmeters).
If lamps go ON and OFF concurrently , indicating that the phase sequence of alternator-2 matches with bus bar. On the other hand, if they ON and OFF one after another, it resembles the incorrect phase sequence.
By changing the connections of any two leads of alternator-2 after shutting down the machine, the phase sequence can be changed.



1m

Depending on the frequency difference between alternator-2 voltage and bus bar voltage, ON and OFF rate of these lamps is decided. Hence, the rate of flickering has to be reduced to match the frequency. This is possible by adjusting the speed of alternator by its prime mover control.
When all these parameters are set, the lamps become dark and then the synchronizing switch can be closed to synchronize alternator-2 with alternator-1.
The main disadvantage of this method is that rate of flickering only indicates the difference between the alternator-2 and the bus bar. But the information of alternator frequency in relation to bus bar frequency is not available in this method.
Suppose, if the bus bar frequency is 50Hz, the rate of flickering of lamps is same when the frequency of the alternator is either 51 or 49 Hz, as the difference in these two cases is 1Hz.

4.B)

$$\text{Voltage/ph} = \frac{6600}{\sqrt{3}} = 3810.51\ V$$

$$\text{F.L current } I = \frac{5\times10^6}{\sqrt{3}\times6600} = 437.38A$$

2m

$$IX_s = 20\% \text{ of } \frac{6600}{\sqrt{3}} = 762.102\ V$$

$$X_s = 1.742\ \Omega$$

$$P_{sy} = \frac{3\alpha E^2}{X_s}$$

$$\alpha = 1^\circ \text{mech} = 1^\circ \times \frac{8}{2} = 4^\circ \text{elec}$$

$$\alpha = 4\times\frac{\pi}{180} = \frac{\pi}{45} \text{ elec radian}$$

$$P_{sy} = 3 \times \frac{\pi}{45} \cdot \frac{(3810.51)^2}{1.742} = 1.745 \text{ kW}$$ 2m

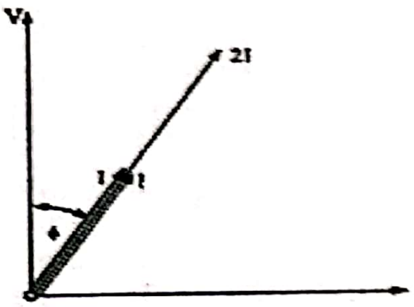
$$T_{sy} = 9.55 \frac{P_{sy}}{N_s} = 11.114 \text{ kN-m}$$ 2m

(OR)

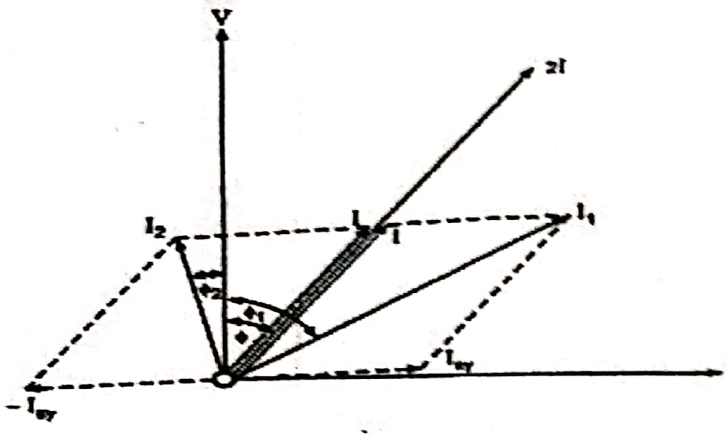
5.a) Effect of Increasing the Excitation of One of the Alternators:

For simplicity, let us consider two identical alternators sharing equally a load whose power factor is cos ϕ. If both machines have exactly the same excitation it will be found that their currents I_1 and I_2 are equal in magnitude (say I each) and in phase, since the conditions are identical for both machines. The phasor diagram for the total load, for one phase is given in Fig. below.

3m



(a)



Now, if the excitation of one of the alternators is increased, it will cause flow of synchronising current I_{sy} almost in quadrature with supply voltage V. Therefore, the load current of alternator 1, whose excitation has been increased, will be I_1, the phasor sum of I_{sy} and I and that of alternator 2 will be I_2, the phasor difference of I_{sy} and I.

Hence power factor cos ϕ, of alternator 1 decreases and that of the other improves. Because synchronising current I_{sy} is in quadrature with V, therefore, it does not change wattful (active) components but changes wattless (reactive) components. Hence by changing the excitation, the power factors of the alternators are changed.

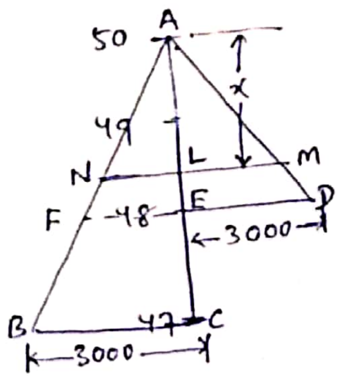
If the excitation of an alternator operating in parallel with other alternators is increased above its normal value of excitation, its power factor changes in the lagging direction and its current output increases with no appreciable change in its kW load. Likewise, if the generator is under excited its power factor becomes more leading and its current output increases with no change in kW output

This increase in current in either case is not supplied to the load but circulates between the alternators connected to the system, thereby increasing their losses and reducing their useful capacity. It is desirable in most cases, therefore, to operate each alternator at the same power factor (at or near the power factor of the load) keeping the circulating current to the minimum.

In general, the proper amount of field excitation for alternators operating in parallel is the amount of excitation each alternator would need if it were carrying its load alone at the same voltage and frequency.

} 3m

5.b)



NL+LM = 4000 kW

from ΔABC & ΔANL

$\frac{NL}{3000} = \frac{x}{3} \Rightarrow NL = 1000x$

$\frac{ML}{3000} = \frac{x}{2} \Rightarrow ML = 1500x$

$2500x = 4000 \Rightarrow x = \frac{8}{5}$

frequency $= 50 - \frac{8}{5} = \frac{242}{5}$ Hz

i) $NL = 1000 \times \frac{8}{5} = 1600$ kW

$ML = 1500 \times \frac{8}{5} = 2400$ kW

} 3m

ii) for getting max. load, DE is extended to cut AB at F.

max. load = DF

$\frac{EF}{2} = \frac{3000}{3} \Rightarrow EF = 2000$ kW

max. load DF = 3000 + 2000 = 5000 kW

} 3m

UNIT-III

6A)

Effect of Changing Excitation on Constant Load

As shown in Fig. 38.20 (*a*), suppose a synchronous motor is operating with normal excitation ($E_b = V$) at unity p.f. with a given load. If R_a is negligible as compared to X_S, then I_a lags E_R by 90° and is in phase with V because p.f. is unity. The armature is drawing a power of $V.I_a$ per phase which is enough to meet the mechanical load on the motor. Now, let us discuss the effect of decreasing or increasing the field excitation when the load applied to the motor ***remains constant***.

(a) Excitation Decreased 2m

As shown in Fig. 38.20 (*b*), suppose due to decrease in excitation, back e.m.f. is reduced to E_{b1} at the ***same load angle*** α_1. The resultant voltage E_{R1} causes a lagging armature current I_{a1} to flow. Even though I_{a1} is larger than I_a in magnitude it is incapable of producing necessary power $V I_a$ for carrying the **constant** load because $I_{a1} \cos \phi_1$ component is less than I_a so that $V I_{a1} \cos \phi_1 < V I_a$.

Hence, it becomes necessary for load angle to ***increase*** from α_1 to α_2. It increases back e.m.f. from E_{b1} to E_{b2} which, in turn, increases resultant voltage from E_{R1} to E_{R2}. Consequently, armature current increases to I_{a2} whose in-phase component produces enough power ($V I_{a2} \cos \phi_2$) to meet the constant load on the motor.

(b) Excitation Increased 2m

The effect of increasing field excitation is shown in Fig. 38.20 (*c*) where increased E_{b1} is shown at the original load angle α_1. The resultant voltage E_{R1} causes a ***leading*** current I_{a1} whose in-phase component is larger than I_a. Hence, armature develops more power than the load on the motor. Accordingly, load angle ***decreases*** from α_1 to α_2 which decreases resultant voltage from E_{R1} to E_{R2}. Consequently, armature current decreases from I_{a1} to I_{a2} whose in-phase component $I_{a2} \cos \phi_2 = I_a$. In that case, armature develops power sufficient to carry the constant load on the motor.

Hence, we find that variations in the excitation of a synchronous motor running with a ***given*** load produce variations in its ***load angle only***.

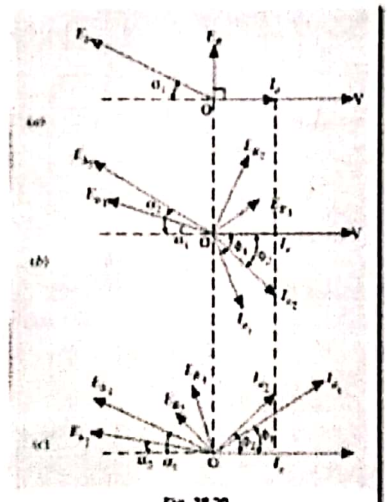


Fig 38.20

2m

6B) Ind. load $P_1 = 4000$ kW

$\cos\phi_1 = 0.8$ lag $\Rightarrow \phi_1 = 36.87°$

load kVAR $Q_1 = P_1 \tan\phi_1 = 4000 \times \tan 36.87 = 3000$ lag

motor i/p, $P_2 = \dfrac{1103.25}{0.8} = 1379.06$ kW

$P = P_1 + P_2 = 4000 + 1379.06 = 5379.06$ kW

combined p.f, $\cos\phi = 0.95 \Rightarrow \phi = 18.19°$

combined kVAR, $Q = P \tan\phi = 5379.06 \times \tan 18.19$

$= 1767.50$

2m

KVAR supplied by the motor, $Q_2 = Q - Q_1$
$= 3000 - 1767.5$
$= 1232.5$ leading } 2m

KVA rating of motor $S_2 = \sqrt{P_2^2 + Q_2^2}$
$= \sqrt{1379.06^2 + 1232.5^2}$
$= 1849.55$ KVA
$\cos\phi_2 = \frac{1379.06}{1849.55}$
$= 0.7456$ leading } 2m

(OR)

7.A)

Factory load, $P_L = 240$ kW
$\cos\phi_L = 0.8$ lag
$Q_L = 240 \tan(\cos^{-1} 0.8)$ } 2m
$= 180$ kVAR

Synch. motor load, $P_m = 60$ kW
Total load, $P = P_L + P_m = 240 + 60 = 300$ kW
combined P.f $\cos\phi = 0.9$ lag
$\phi = 25.84°$
combined kVAR, $Q = P \tan\phi = 145.3$ lag } 2m

leading kVAR supplied by the motor, $Q_m = Q_L - Q$
$= 180 - 145.3$
$= 34.7$ kVAR

KVA supplied by the motor, $S_m = \sqrt{P_m^2 + Q_m^2}$
$= \sqrt{60^2 + 34.7^2} = 69.3$

P.f of the motor, $\cos\phi = \frac{P_m}{S_m}$
$= \frac{60}{69.3}$
$= 0.866$ leading } 2m

7.B) **V-Curves and Inverted V-Curves**

It is clear that if excitation is varied from very low (under excitation) to very high (over excitation) value, then current Ia decreases, becomes minimum at unity p.f. and then again increases. But initial lagging current becomes unity and then becomes leading in nature. This can be shown as in the Fig: 2.26.

3m

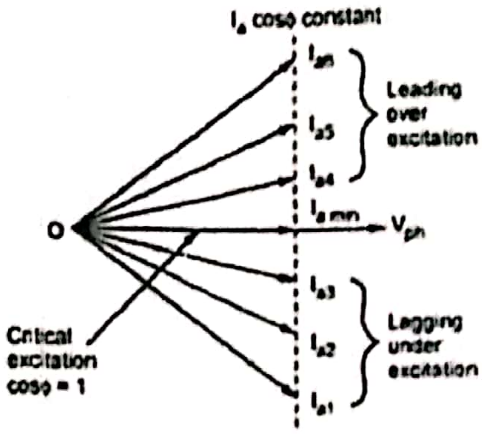


Fig: 2.26

Excitation can be increased by increasing the field current passing through the field winding of synchronous motor. If graph of armature current drawn by the motor (Ia) against field current (I_f) is plotted, then its shape looks like an english alphabet V. If such graphs are obtained at various load conditions we get family of curves, all looking like V. Such curves are called V-curves of synchronous motor. These are shown in the Fig: 2.27 (a).

As against this, if the power factor (cos ф) is plotted against field current (If), then the shape of the graph looks like an inverted V. Such curves obtained by plotting p.f. against If, at various load conditions are called Inverted V-curves of synchronous motor. These curves are shown in the Fig: 2.27 (b).

3m

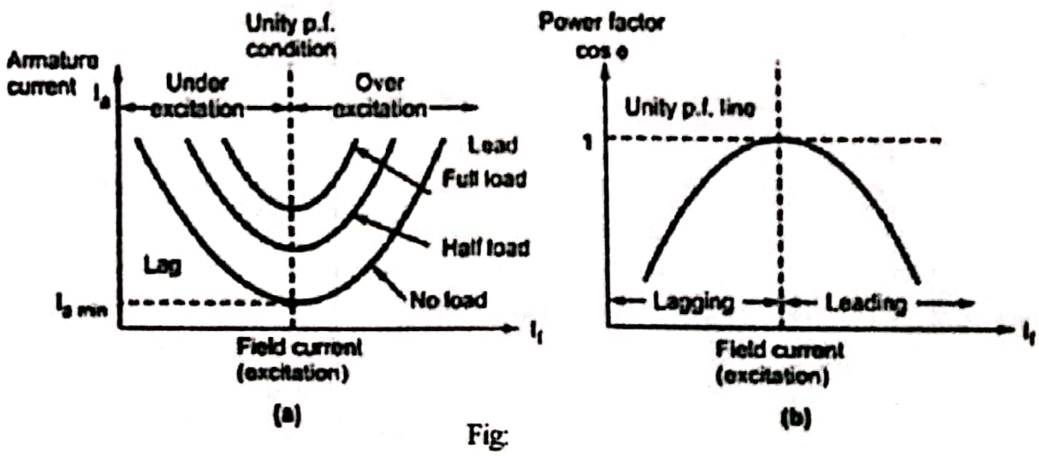


Fig:

Typically, the synchronous machine V-curves are provided by the manufacturer so that the user can determine the resulting operation under a given set of conditions.

UNIT-IV

8.A)

i) Single Phase Series Motor

The single-phase series motor is a commutator-type motor. If the polarity of the line terminals of a dc series motor is reversed, the motor will continue to run in the same direction. Thus, it might be expected that a dc series motor would operate on alternating current also. The direction of current through the armature[$T \propto \phi Ia$]. direction of the torque developed in a dc series motor is determined by both filed polarity. 3m

Operation

Let a dc series motor be connected across a single-phase ac supply. Since the same current flows through the field winding and the armature, it follows that ac reversals from positive to negative, or from negative to positive, will simultaneously affect both the field flux polarity and the current direction through the armature. This means that the direction of the developed torque will remain positive, and rotation will continue in the same direction. Thus, a series motor can run both on dc and ac.

However, a series motor which is specifically designed for dc operation suffers from the following drawbacks when it is used on single-phase ac supply:

1. Its efficiency is low due to hysteresis and eddy-current losses.
2. The power factor is low due to the large reactance of the field and the armature winding.
3. The sparking at the brushes is excessive.

In order to overcome these difficulties, the following modifications are made in a D.C. series motor that is to operate satisfactorily on alternating current:

1. The field core is constructed of a material having low hysteresis loss. It is laminated to reduce eddy-current loss.
2. The field winding is provided with small number of turns. The field-pole areas is increased so that the flux density is reduced. This reduces the iron loss and the reactive voltage drop.
3. The number of armature conductors is increased in order to get the required torque with the low flux.
4. In order to reduce the effect of armature reaction, thereby improving commutation and reducing armature reactance, a compensating winding is used.

The compensating winding is put in the stator slots. The axis of the compensating winding is 90 (electrical) with the main field axis. It may be connected in series with both the armature and field In such a case the motor is conductively compensated. The compensating winding may be short circuited on itself, in which case the motor is said to be inductively compensated. The characteristics of single-phase series motor are very much similar to those of D.C. series motors, but the series motor develops less torque when operating from an a.c. supply than when working from an equivalent D.C. supply. The direction of rotation can be changed by interchanging connections to the field with respect to the armature as in D.C. series motor.

ii) Universal motor: A **universal motor** is a special type of motor which is designed to run on either DC or single phase AC supply. These motors are generally series wound (armature and field winding are in series), and hence produce high starting torque.That is why, **universal motors** generally comes built into the device they are meant to drive. Most of the universal motors are designed to operate at higher speeds, exceeding 3500 RPM. They run at lower speed on AC supply than they run on DC supply of same voltage, due to the reactanc e voltage drop which is present in AC and not in DC. 3m
There are two **basic types of universal motor** : (i)compensated type and (ii) uncompensated type

Construction Of Universal Motor

Construction of a universal motor is very similar to the construction of a DC machine. It consists of a stator on which field poles are mounted. Field coils are wound on the field poles. However, the whole magnetic path (stator field circuit and also armature) is laminated. Lamination is necessary to minimize the eddy currents which induce while operating on AC. The rotary armature is of wound type having straight or skewed slots and commutator with brushes resting on it. The commutation on AC is poorer than that for DC. because of the current induced in the armature coils. For that reason brushes used are having high resistance.

Working of universal motor:
A universal motor works on either DC or single phase AC supply. When the universal motor is fed with a DC supply, it works as a DC series motor.. When current flows in the field winding, it produces an electromagnetic field. The same current also flows from the armature conductors. When fed with AC supply, it still produces unidirectional torque. Because, armature winding and field winding are connected in series, they are in same phase. Hence, as polarity of AC changes periodically, the direction of current in armature and field winding reverses at the sametime.Thus, direction of magnetic field and the direction of armature current reverses in such a way that the direction of force experienced by armature conductors remains same. Thus, regardless of AC or DC supply, universal motor works on the same principle that DC series motor works.

8.B) In A.C series motor in order to reduce the effect of armature reaction, thereby improving commutation and reducing armature reactance, a compensating winding is used. 2m

The compensating winding is put in the stator slots. The axis of the compensating winding is 90 (electrical) with the main field axis. It may be connected in series with both the armature and field In such a case the motor is conductively compensated. The compensating winding may be short circuited on itself, in which case the motor is said to be inductively compensated. The characteristics of single-phase series motor are very much similar to those of D.C. series motors, but the series motor develops less torque when operating from an a.c. supply than when working 4m from an equivalent D.C. supply. The direction of rotation can be changed by interchanging connections to the field with respect to the armature as in D.C. series motor.

(OR)

9.A)

Variable Reluctance type Step Motor: Variable reluctance type step motors do not require reversing of current through the coils, but at the same time do not have any holding torque. Compared to permanent magnet step motors, their step angles are also much smaller. Step angle as low as 1.8o can be achieved with this type of motors. Here the rotor is a cylindrical soft iron core with projected teeth. When a particular stator coil is excited, the rotor aligns itself such that one pair of teeth is along the energised stator coil, at the minimum reluctance path. The schematic arrangement of a three phase VR motor with 12 stator poles (teeth) and eight rotor teeth is shown in Fig.5. When phase-1 is energised, the rotor will align itself as shown in the figure. In the next step, if phase-1 is switched off and phase-2 is switched on, the rotor will rotate in CCW direction by an angle. 2m

Similar to the earlier case, we can also have half stepping where step angle of 7.5o can be achieved. Te switching sequence for rotation in the counter clockwise direction with half stepping would be 1-(1,2)-2-(2,3)-3-(3,1)-1.... Further reduction of step angle is possible by increasing the number of stator and rotor teeth. Besides, multi-stack stators are also used for achieving smaller step angle, where there are several stacks of stator windings skewed from each other by a certain angle. It has been already mentioned that the VR motors do not have any holding torque. It is natural because, when the stator coils are de-energised there is no magnetic force present and the rotor is free. Hybrid step motors are improved versions of single stack VR motors, where the basic constructions are modified slightly in order to achieve holding torque. However this part will not be discussed in this lesson. Interested readers may consult the books given in the reference

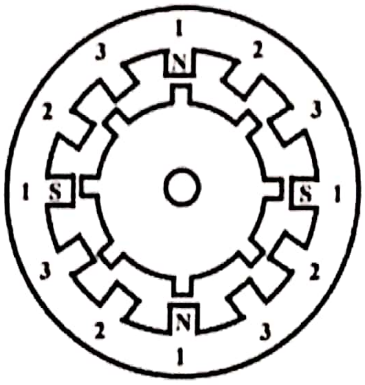


Fig. 5 Three-phase single-stack VR step motor with twelve stator poles (teeth) and eight rotor teeth.

The torque developed in a step motor is not constant and is position dependent. To understand the torque vs. displacement curve, consider a simple three-phase VR type motor with a rectangular rotor as shown in Fig. 7(a). Suppose Phase-1 is excited and the rotor is aligned with its axis ($\theta = 0$). At this position the rotor is not experiencing any torque (otherwise it should have moved, friction is neglected). With phase-1 remaining excited if we now rotate the rotor by hand through , it will experience torque as shown in Fig. 7(b). The torque is zero when . In between the torque direction will be +ve or –ve depending on the direction of angle , but the magnitude is not constant. However the zone of operation for phase-1 is limited to , since phase-2 or phase-3 takes up on either side. For clockwise operation, suppose the initial rotor position was −60 0 ±60 o . If phase-1 is excited, it will bring the rotor to the position θ = 0. If phase-2 is now excited the rotor will rotate clockwise by +60o and settle there.

2m

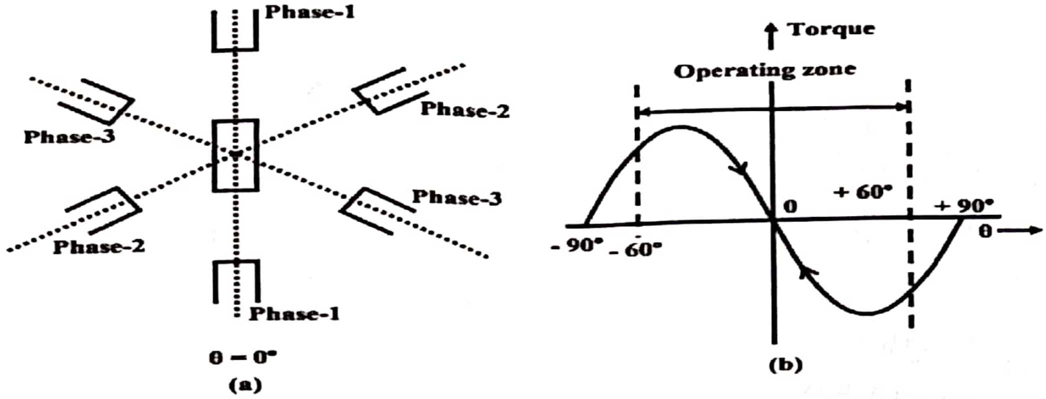


Fig. 7 (a) Three phase two pole VR-type step motor (b) Its torque vs displacement characteristics corresponding to phase-1.

Dynamic Response: So far we have discussed about the static performance of step motor. Now we examine how the motor behaves under dynamic condition. Ideally the rotor of a step motor should rotate by step angle once it receives a pulse and the rotation should occur instantaneously. But due to the inertia of the rotor, the rotor cannot settle down at its final position instantaneously and it undergoes through some oscillations as shown in Fig.10. Before settling down after some time. The overshoot increases if the inertia of the rotor is large. This will cause large settling time. In order to decrease the overshoot, additional damping arrangement is sometimes provided. The damping can be in the form of (a) viscous damping, (b) eddy current damping and (c) electronic damping. However the details of the damping arrangements are not discussed in this lesson.

2m

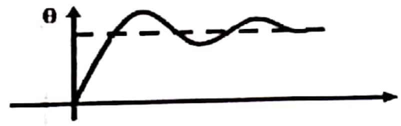


Fig. 10 Dynamic Response of a Step motor

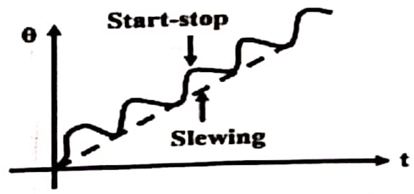


Fig. 11 Start-stop and slewing mode of operation

9.B)

Small fractional horse power AC series motors are called universal motors because they will run equally well on AC or DC power of the correct voltage. 2m

Universal motors are actually simply series DC motors. The interesting part is that, with DC power supplied, the commutator on the shaft "inverts" the DC into AC power at the correct frequency to keep the armature's North and South magnetic poles just a little offset from the field's N and S poles so the motor develops torque and the rotor spins. 4m

With AC power supplied, the commutator on the shaft "rectifies" the AC into DC power at the correct timing to keep the armature's North and South magnetic poles just a little offset from the field's rapidly switching N and S poles from the AC supply, so the motor develops torque and the rotor spins.

Scheme Prepared by

1. Dr K Ramesh
(K.R.)
9441172760

2. CH. SRIDHAR

3. T RAJU
(Dr T Raju)

Head of the Department

Head of the Department
Electrical & Electronics Engg
Bapatla Engineering College
BAPATLA - 522101