EE6504 – ELECTRICAL MACHINES - II

UNIT I

SYNCHRONOUS GENERATOR

PART A

1. **What are the advantages of salient pole type construction used for synchronous machines? [A/M 2018]**

Advantages of salient-pole type construction are:

- They allow better ventilation
- The pole faces are so shaped that the radial air gap length increases from the pole center to the pole tips so that the flux distribution in the air-gap is sinusoidal in shape which will help the machine to generate sinusoidal emf.
- Due to the variable reluctance the machine develops additional reluctance power which is independent of excitation

2. **Two reaction theory is applied only to salient pole machines. State the reasons**. **[A/M 2018][N/ D 2007]**

A multipolar machine with cylindrical rotor has a uniform airgap and therefore, its reactance remains the same, irrespective of the special positions of the rotor but in case of salient pole machines, the airgap is not uniform and its reactance varies with the rotor positions. Because of nonunifomity of the reluctance of the magnetic paths, the mmf of the armature is divided into two components viz, (i) one component is located along the axis of salient pole rotor known as direct axis component. (ii) the other component is located perpendicular to the axis of salient pole rotor known as quadrature axis component. This makes the concept of two reaction theory.

3. **What is the necessity of chording in the armature winding of a synchronous machine? [N/D 2017]**

The armature winding is chorded in order to

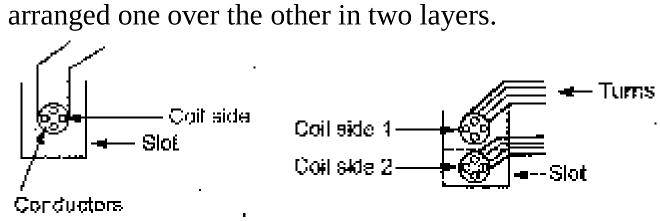
- Improve the wave form of induced emf .
- Save copper in the coil ends due to less span.
- Reduced inductance of the winding.

4. **Distinguish between transient and sub-transient reactance. [N/D 2017]**

Sub transient Reactance X''_d, is the reactance used to determine the current during the first cycle after the occurrence of the fault. In about 0.1 second this reactance increases to the level known as Transient Reactance X'_d, and after 0.5 to 2 seconds it increases to the level known as Synchronous Reactance X_d, and this determines the fault current after a steady condition is reached.

5. **What do you mean by single layer and double layer winding? (A/M 2017)**

In a single layer winding, a slot consists of only one coil side while in double layer it consists of two coil sides arranged one over the other in two layers.



(a) Single layer (b) Double layer

6. **Define Voltage Regulation. (Apr/may 2017) (M/J 2016)**

The voltage regulation of an alternator is defined as the change in its terminal voltage when full load is removed, keeping field excitation and speed constant, divided by the rated terminal voltage.

So if V_{ph} = Rated terminal voltage and E_{ph} = No load induced e.m.f.

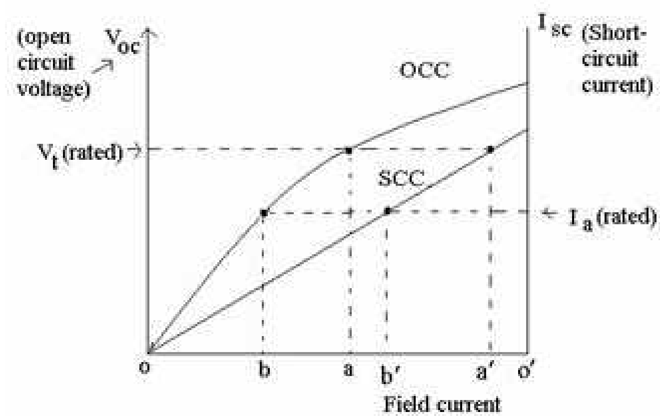
then voltage regulation is defined as,

$$\% \text{ Regulation} = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100$$

7. **Distinguish the use of salient pole and round rotor synchronous machines. (N/D 2016)**

Salient pole types are used for low speed alternators with speeds ranging from 125 to 500 r.p.m. The non salient pole types are used for high speed alternators called turbo alternators with speeds ranging from 1500 to 3000 r.p.m.

8. **Draw typical open circuit and short circuit characteristics of synchronous machine. (N/D 2016)**



9. **How can you distinguish between the two types of large synchronous generator from their appearance? (M/J 2016)**

S.No	Salient Pole Type	Smooth Cylindrical Type
10.	Poles are projecting out from the surface	Poles are non projecting
11.	Air gap is non uniform	Air gap is uniform
12.	Large diameter and small axial length	Small diameter and large axial length
13.	Mechanically weak	Mechanically strong
14.	Preferred for low speed alternators	Preferred for high speed alternators

15. **Define armature reaction. (N/D 2015)**

The interaction between flux set up by the current carrying armature conductors and the main field flux is defined as the armature reaction.

16. **What are all the various methods to determine the voltage regulation? (N/D 2015)**

(i) Synchronous Impedance method or EMF method
(ii) Ampere Turns method or MMF method
(iii) Zero Power Factor method or Potier Triangle method
(iv) ASA modified form of MMF method
(v) Two Reaction Theory

17. Why are Alternators rated in kVA and not in kW? [N/D 2011]

The continuous power rating of any machine is generally defined as the power the machine or apparatus can deliver for a continuous period so that the losses incurred in the machine gives rise to a steady temperature rise not exceeding the limit prescribed by the insulation class. Apart from the constant loss incurred in Alternators is the copper loss, occurring in the 3 –phase winding which depends on I^2R, the square of the current delivered by the generator. As the current is directly related to apparent power delivered by the generator, the Alternators have only their apparent power in VA/kVA/MVA as their power rating.

18. **Why is short pitch winding preferred over full-pitch winding? [N/D 2011]**

Advantages

i. Waveform of the emf can be approximately made to a sine wave and distorting harmonics can be reduced or totally eliminated.
ii. Conductor material, copper, is saved in the back and front end connections due to less coil-span.
iii. Fractional slot winding with fractional number of slots/phase can be used which in turn reduces the tooth ripples.
iv. Mechanical strength of the coil is increased.

19. What do you mean by synchronous reactance? [N/D 2011]

Synchronous reactance X s= (X_L + Xa). The value of leakage reactance X_L is constant for a machine based on its construction. Xa depends on saturating condition of the machine. It is the addition of Xa , which represents the armature reaction effect between two synchronously acting magnetic fields that makes the total reactance Xa to be called synchronous reactance.

20. Define distribution factor. [A/ M 2009]

The ratio of the vector sum of the emfs induced in all the coils distributed in a no. of slots under one pole to the arithmetic sum of the emfs induced is known as distribution factor.

$$K_d = \frac{E\ \ w\ \ \ c\ \ \ a\ \ d}{E\ \ w\ \ \ c\ \ \ a\ \ c} = \frac{s\ \ (\frac{m\beta}{2})}{m\,s\ \ (\frac{\beta}{2})}$$

21. What are the conditions for parallel operation of an alternator? [N/ D 2009], [June 2009]

i. The terminal voltage of the incoming alternator must be the same as that of bus bars.
ii. The frequency of incoming alternator must be same as that of bus bars.
iii. The phase sequence of the incoming machine voltage must be same as that of bus bar voltage .

22. Why is EMF method called pessimistic method? [A/ M 2007]

The value of voltage regulation obtained by emf method is always more than the actual value and therefore it is called pessimistic method.

23. What are the causes of changes in voltage of alternators when loaded? [A/ M 2006] [N/ D 2011]

i. Voltage drop due to resistance of winding
ii. Voltage drop due to leakage reactance
iii. Voltage drop due to armature reaction

24. Write down the equation for frequency of emf induced in an Altenator. [June 2009]

Frequency of emf induced in an Alternator,(f) ,expressed in cycles per second or Hz, is given by the following equation f = (PN)/120: Hz, Where P- Number of poles N-Speed in rpm.

25. What is the purpose of conducting slip test? [N/ D 2009]

The slip test is performed on an alternator to determine X_d and $X_{q.}$

26. State factors responsible for a change in synchronous generator terminal voltage while feeding isolated load. [A/ M 2008]

i. Armature resistance
ii. Armature leakage reactance
iii. Armature reaction

27. What are the functions of damping winding provided with alternator? [N/D 2011] [A/ M 2006]

i. Reduce the hunting
ii. To make rotor speed equal to synchronous speed.

28. Why alternators are synchronized in power plant? [N/D 2006]

i. The total load requirement can not be met by a single alternator.
ii. Parallel operation increases reliability of electric supply. An outage of one alternator will not cause total power loss to the load.
iii. If the alternators are operating in parallel, one or more of them can be shut down for preventive maintenance in turn.
iv. Parallel operation of alternators leads to economy in operating costs. The less efficient machines can be shut down when the load requirement is less.

29. **What are the principal advantages of rotating field system type of construction of synchronous machines?**

1) For stationary armature large space can be provided to accommodate large number of conductors and the insulation to obtain large e.m.f.

2) It is always better to protect high voltage winding from the centrifugal forces caused due to the rotation. This avoids the interaction of mechanical and electrical stresses.

3) It is easier to collect larger currents at very high voltages from a stationary member than from the slip ring and brush assembly.

4) The problem of sparking at the slip rings can be avoided by keeping field rotating which is low voltage circuit and high voltage armature as stationary.

5) Due to low voltage level on the field side, the insulation required is less and hence field system has very low inertia. It is always better to rotate low inertia system than high inertia, as efforts required to rotate low inertia system are always less.

30. **Why do cylindrical rotor alternators operate with steam turbines?**

Steam turbines are found to operate at fairly good efficiency only at high speeds. The high-speed operation of rotor tends to increase mechanical losses, so the rotors should have smooth external surface. Hence smooth cylindrical type rotors with less diameter and large axial length are used for synchronous generators driven by steam turbines with either 2 or 4 poles.

31. Which type of synchronous generators are used in Hydroelectric plants and why?

As the speed of operation is low, for hydro turbines used in hydroelectric plants, salient pole type synchronous generators are used. These allow better ventilation and also have other advantages over smooth cylindrical type rotor.

PART B & C

1. Explain the procedure for POTIER method to calculate voltage regulation of alternator. (13) [A/M 2018]
2. Describe the principle and construction of slow speed operation generator with neat diagram. (13) [A/M 2018]
3. (i) Derive the EMF equation of a 3 phase synchronous machine. (6)
   (ii) Describe how the direct and quadrature-axis reactances of a salient pole machine can be estimated by means of slip test. (7) [N/D 2017]
4. (i) What is meant by synchronizing? State the conditions for paralleling alternators with infinite bus bars. (5)
   (ii) Explain the Ampere-Turn method of finding voltage regulation of an alternator. (8) [N/D 2017]
5. (i) Explain the step by step method of Potier triangle method of determining the regulation of an alternator. (8)
   (ii) A 30 MVA, 15 kV, 60 Hz AC generator has a synchronous reactance of 1.2 pu and a resistance of 0.02 pu. Calculate
   (1) The base voltage, base power and base impedance of the generator.
   (2) The actual value of the synchronous reactance.
   (3) The actual winding resistance per phase
   (4) The total full load copper losses (8) (A/M 2017)
6. A 3 phase Y connected, 1000 kVA, 2000 V, 50 Hz alternator gave the following open circuit and short circuit test readings:

Field current (A):	10	20	25	30	40	50
O.C. Voltage (V):	800	1500	1760	2000	2350	2600

S.C. armature current (A) :	-	200	250	300	-	-

The armature effective resistance per phase is 0.2 Ω. Draw the characteristic curves and determine the full load percentage regulation at

(i) 0.8 p.f lagging (ii) 0.8 p.f leading by MMF method. (16) (A/M 2017)

7. (i) Explain the EMF and MMF method of evaluating the synchronous reactance. (4)

   (ii) A 220 V, 50 Hz, 6-pole star connected alternator with ohmic resistance of 0.06 ohm per phase, gave the following data for open circuit, short-circuit and full load zero-power-factor characteristics. Find the percentage voltage regulation at full-load current of 40A at power factor of 0.8 lag by (1) emf method (2) mmf method and (3) zpf method. Compare the results so obtained.

Field current, A	0.20	0.40	0.60	0.80	1.00	1.20
Open-circuit voltage, emf in V	29.0	58.0	87.0	116	146	172
Short-circuit current, Isc in A	6.6	13.2	20.0	26.5	32.4	40.0
Z.p.f. terminal voltage in V	-	-	-	-	-	0
Field current, A	1.40	1.80	2.20	2.60	3.00	3.40
Open-circuit voltage, Emf in V	194	232	261.5	284	300	310
Short-circuit current, Isc in A	46.3	59.0	-	-	-	-
Z p.f terminal voltage in V	29	88	140	177	208	230

(10) (N/D 2016)

8. (i) Derive an expression for real and reactive power outputs of asynchronous generator. (10)

   (ii) Illustrate a method for determining the direct and quadrate axis reactances of a salient pole synchronous generator. (6) (N/D 2016)

9. (i) Explain the concept of armature reaction and mention the methods to reduce this effect. (8)

   (ii) In a 50-KVA, Y-connected, 440-V, 3-phase, 50 Hz alternator, the effective armature resistance is 0.25 Ω / phase. The synchronous reactance is 3.2 Ω / phase and leakage reactance is 0.5 Ω / phase. Determine at rated load at unity power factor : (a) Internal e.m.f E_a (b) no-load e.m.f, E_0, (c) percentage regulation on full load, (d) value of synchronous reactance which replaces armature reaction. (8) (A/M 2016)

10. The following data were obtained for the 0CC of a 10 MVA, 13 KV, 3-phase, 50 Hz, Y-connected synchronous generator.

Field current (A):	50	75	100	125	150	162.5	200	250	300
0.C. Voltage (KV):	6.2	8.7	10.5	11.8	12.8	13.2	14.2	15.2	15.9

An excitation of 100 A causes the full-load current to flow during the short- circuit test. The excitation required to give the rated current at zero pf and rated voltage is 290 A.

(i) Calculate the adjusted synchronous reactance of the machine.

(ii) Calculate the leakage reactance of the machine assuming, the resistance to be negligible.

(iii) Determine the excitation required when the machine supplies full-load at 0.8 pf lagging by using the leakage reactance and drawing the mmf phasor diagram. What is the voltage regulation of the machine? Also calculate the voltage regulation for this loading using the adjusted synchronous reactance. Compare and comment upon the two results. (16) (A/M 2016)

11. A 3-phase, 11 kV star connected alternator delivers a current of 80A at

    (i) 0.8 power factor leading,

    (ii) Unity power factor and

    (Iii) 0.75 power factor lagging. Full load current of 80A is produced on short circuit by a field excitation of 2.8A. An EMF of 400V per phase is produced on open circuit by the same excitation. The armature resistance is 0.7 ohm per phase. Determine the voltage regulation in each phase. (16)

    (N/D 2015)

12. Explain the two reaction theory of salient pole alternator. (16) (N/D 2015)
13. Derive the EMF equation of an alternator. Explain pitch factor and distribution factor.
14. List the methods used to predetermine the voltage regulation of synchronous machine and explain any one method.
15. Explain blondel's two reaction theory of synchronous machines. How can X_d and X_q be determined from slip test?
16. Describe the construction and working of alternator with a neat sketch.
17. Explain the phenomena of armature reaction in alternator for different power factors.
18. Discuss the parallel operation of two alternators with identical speed/load characteristics.

19. State and explain the conditions for parallel operation.
20. Write short notes on (i) dark lamp method (ii) synchroscope method.
21. Elaborate the discussion on capability curve with its boundaries of synchronous machine.
22. Explain the effect of change in excitation on the load sharing of two alternators running in parallel.

PART C

1. A 1.1 MVA, 2.2 kV, 3 phase, star connected alternator gave the following test result during OC and SC tests:

Field current (A)	:	10	20	30	40	50
Open Circuit Voltage (kV)	:	0.88	1.65	2.20	2.585	2.86
Short Circuit current (A)	:	200	400	--	--	--

The effective resistance of the 3 phase winding is 0.22 Ω/ph. Estimate the full load voltage regulation at 0.8 p.f. lagging
   (i) By synchronous impedance method and
   (ii) Ampere Turn method. (15) [A/M 2018]

UNIT II
SYNCHRONOUS MOTOR
PART A

1. **How does a change of excitation affect its power factor? (A/M 2018)**
   Under Excitation: $E_b < V_{ph}$, Armature current increases, more lagging power factor
   Over Excitation: $E_b > V_{ph}$, Armature current increases, leading power factor
   Critical Excitation: $E_b = V_{ph}$, Armature current is minimum, unity power factor
2. **A 3 phase synchronous motor driving a constant load torque draws power from infinite bus at leading power factor. How power angle and power factor will change, if excitation is increased? (N/D 2017)**
   If the excitation is increased, the power angle decreases and the power factor angle increases, that is power factor is more leading in nature.
3. **What is the role of damper winding in synchronous motor? (N/D 2017)**
   When the load is changed the synchronous motor oscillates about the final position before setting down. This is called hunting. The damper winding is short circuited winding provided in synchronous motor and when motor oscillates there is relative motion between damper winding and the rotating magnetic field due to which emf is induced in the damper winding. According to Lenz's law this emf circulates the current so as to oppose the cause producing it which is hunting. Thus the damper winding opposes the hunting and minimizes the hunting effect. Damper winding also helps to start the motor as an induction motor.
4. **What are V curves? (A/M 2017)**
   The graph of armature current drawn by the synchronous motor plotted against field current for various excitations at constant load gives a shape like alphabet V. If such graphs are plotted at different load conditions we get a family of such curves all looking like V called V curves.
5. **What is synchronous condenser? (A/M 2017) (or) How the synchronous motor can be used as synchronous condenser? [A/M 2018]**
   An over-excited synchronous motor under no load, used for the improvement of power factor is called as synchronous condenser because, like a capacitor it takes a leading current.
6. **What is meant by hunting of a synchronous motor? (N/D 2016)**
   When the load applied to the synchronous motor is suddenly increased or decreased, the rotor oscillates about its synchronous position with respect to the stator field. This action is called hunting.
7. **What are the uses of damper winding in synchronous motor? (N/D 2016)**
   (i) To develop necessary starting torque
   (ii) To reduce hunting
8. **List the inherent disadvantages of synchronous motor. (M/J 2016)**
   (i) Higher cost (ii) Frequent maintenance required

(ii) Not self starting (iv) Separate DC excitation required

9. How can we change the operating speed of synchronous motor? (M/J 2016)

The only way to change its speed is to change its supply frequency. (As Ns = 120f / P)

10. What are the methods of starting a synchronous motor? (N/D 2015)

(i) Using pony motor (ii) Using damper winding (iii) As a slip ring induction motor (iv) using small DC machine coupled to it.

11. What are the applications of synchronous motor? (N/D 2015)

a. Used for power factor improvement in sub-stations and in industries.
b. Used in industries for power applications.
c. Used for constant speed drives such as motor-generator set, pumps and compressors.

12. **What could be the reasons if a 3-phase synchronous motor fails to start?**

It is usually due to the following reasons

a. Voltage may be too low.
b. Too much starting load.
c. Open circuit in one phase or short circuit.
d. Field excitation may be excessive

13. A synchronous motor starts as usual but fails to develop its full torque. What could it be due to?

a. Exciter voltage may be too low.
b. Field spool may be reversed.

14. What is an inverted 'V' curve?

For a constant load, if the power factor is plotted against various values of field exciting current, the curve formed is inverted V Shape and called as inverted 'V' curve.

15. Why synchronous motor is a constant speed motor? (M/J 2012)

Because of the magnetic locking between stator and rotor poles it is said to be constant speed motor.

16. List any two characteristics features of synchronous motor? (M/J 2011)

i. The power factor can be easily varied by varying its field current.
ii. It is used for constant speed operation.

17. How a synchronous machine is different from induction machine?(June 2009)

S.no	**Synchronous machine**	**Induction machine**
1	Speed is constant	Speed is not constant
2	DC excitation is required	Not required
3	Not self-starting	Self-starting
4	High cost	Low cost

18. Define pull in torque in synchronous motor.(Apr 2007)

It pertains to the ability of the machine to pull into synchronism when changing from induction to synchronous motor operation

19. Enlist the advantages and disadvantages of synchronous motor. (Dec 2005)

Advantages:

i. The speed is constant and independent of load.
ii. These motors are usually operated at higher efficiency

Disadvantages:

i. It cannot be started under load
ii. Collector rings and brushes are required**.**

20. Why is synchronous motor not self-starting? (Dec 2009)

If a three phase supply is given to the stator of stationary synchronous motor with the rotor exciter, no steady starting torque will be developed. Instead, a sinusoidally time varying torque is developed, the average value of which is zero and that is why synchronous motor is not self-starting.

21. What does synchronous phase modifier mean? (Dec 2009)

Synchronous condensers are sometimes operated at power factors ranging from lagging through unity to leading for voltage control. When operated in this way, a synchronous condenser is called a synchronous phase modifier.

22. When does a synchronous motor get over excited?

If the field excitation of the motor is increased, the field flux will become strong and E_b will increase. As a result E_b will exceed V and the motor will be called an over excited motor.

23. . What is the role of synchronous motor in a transmission line? How?

Synchronous motor acts as a voltage regulator load,

When line voltage decreases due to inductive load, motor excitation increases thereby increasing its power factor which compensate for the line voltage drop.

When the line voltage increases due to line capacitive effect, synchronous motor excitation is decreased, thereby making its power factor lagging which helps to the maintain the transmission line voltage at its normal value.

24. **Give the expression for the mechanical power developed by synchronous motor.**

$$Pm = \frac{E\ V}{Z} \cos(\theta - \delta) - \frac{E^2}{Z} \cos\theta$$

Where E_b= Excitation emf, V_{ph} = phase Voltage, θ=internal machine angle, δ=Load angle.

PART B & C

1. A 5 kW, 3 phase, Y connected 50 Hz, 440V, cylindrical rotor synchronous motor operates at rated condition with 0.8 pf leading. The motor efficiency excluding field and stator losses is 95% and X_s = 2.5 Ω. Calculate:
   - (iii) Mechanical power developed
   - (iv) Armature current
   - (v) Back emf
   - (vi) Power angle
   - (vii) Maximum or pull out torque of the motor (13) [A/M 2018]
2. Explain the working of synchronous motor with different excitations. (13) [A/M 2018]
3. (i) Describe the principle of operation of synchronous motor. (5)
   (ii) What are the methods of starting of a synchronous motor? Explain any one of them with a circuit diagram. (8) [N/D 2017]
4. (i) What are 'constant excitation circles and constant power circle' for a synchronous motor? How are they derived? (8)
   (ii) Explain briefly how a synchronous motor can be operated as a synchronous condenser. (5) [N/D 2017]
5. (i) Explain V – curve and inverted V curve. (8)
   (iii) A 500 hp, 720 rpm synchronous motor connected to a 3980 V, 3 phase line generates an excitation voltage E_0 of 1790 V (line to neutral) when the dc exciting current is 25 A. the synchronous reactance is 22 Ω and the torque angle between E_0 and E is 30^0, calculate
   (1) The value of E_x
   (2) The ac line current
   (3) The power factor of the motor
   (4) The approximate horse power developed by the motor
   (5) The approximate torque developed at the shaft (8) (A/M 2017)
6. (i) A 1000 kVA, 11000 V, 3 phase star connected synchronous motor has an armature resistance and reactance per phase of 3.5 Ω and 40 Ω respectively. Determine the induced emf and angular retardation of the rotor when fully loaded at 0.8 p.f lagging and0.8 p.f leading. (8)
   (ii) Derive the expression for power delivered by a synchronous motor in terms of load angle (α) (8) (A/M 2017)
7. The synchronous reactance per phase of a 3-phase, star connected 6600 V synchronous motor is 20 Ω. For a certain load the input is 900 kW at normal voltage and the induced line emf is 8500 V. Determine the line current and power factor. (16) (N/D 2016)
8. (i) Explain V curves and inverted V curves of a synchronous motor. (8)
   (ii) Draw and explain the equivalent circuit and phasor diagram of a cylindrical rotor synchronous motor operating at different power factors. (8) (N/D 2016)
9. (i) Explain in detail V and inverted V curves of a synchronous motor. (8)
   (ii) Explain in detail the method of starting of synchronous motor. (8) (May 2016)

10. (i) A 3300 V, delta connected motor has a synchronous reactance per phase of 18 Ω. It operates at a leading power factor of 0.707 when drawing 800 kW from the mains. Calculate its excitation emf. (8)
(ii) Enumerate in detail the effect of varying excitation on armature current and power factor of synchronous motor. (8) (May 2016)
11. Draw the simplified equivalent circuit of synchronous motor and explain the effect of loading in synchronous motor at various power factors with help of phasor diagrams. (16) (N/D 2015)
12. Write a brief note on the following:
    (i) Operation of synchronous motor at variable excitation. (10)
    (ii) Method of starting of synchronous motor. (6) (N/D 2015)
13. Show that the synchronous motor is a variable power factor motor.
14. Write short notes on (i) Hunting (ii) Synchronous condenser
15. Explain the principle of operation of synchronous motor (or) Show that synchronous motor is not a self starting motor.
16. Give short notes on the features of a synchronous motor.
17. Define the various torques associated with a synchronous motor.
18. Derive the expression for power developed in a synchronous motor. Also find the condition for maximum power developed.

UNIT III
THREE PHASE INDUCTION MOTOR
PART A

1. Why an induction motor will never run at its synchronous speed? [A/M 2018]

- If rotor & stator have same speed, no relative motion
- slip zero, no voltage induce in rotor
- current zero, torque zero

Thus induction motor never runs at synchronous speed

2. Explain why an induction motor, at no load, operates at very low power factor. [A/M 2018]

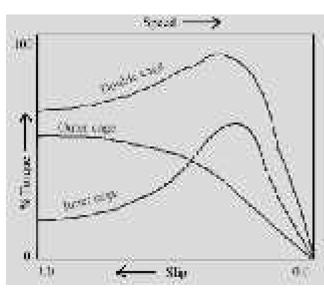
$\text{Cos}\ \phi_{2r} = \frac{R2}{Z2r} = \frac{R2}{\sqrt{R2^2+(s\ \ 2)^2}}$

During starting, reactance of rotor is maximum, $sX_2 = X_2$ since slip, s=1.As load increases, slip decreases and so does the reactance. Therefore it is obvious from above that during starting the impedance offered by rotor is more inductive as that during loading conditions and hence power factor at start is low compared to loading conditions.

3. What measure can be taken for minimizing the effect of crawling in a 3 phase induction motor? [N/D 2017]

Crawling effect can be reduced by taking proper care during the design. It can be reduced by proper choice of coil span and by skewing the stator or rotor slots.

4. Draw the torque slip characteristics of double cage induction motor. [N/D 2017]



5. **Why are the slots on the cage rotor of induction motor usually skewed? (A/M 2017) (A/M 2016) (or) Why the rotor slots are made skewed by a small angle to the shaft axis? (Nov 2015)**
   - (i) To make the motor run quietly by reducing the magnetic hum.
   - (ii) To reduce the locking tendency of the rotor.
6. **A 3 phase, 4 pole induction motor operates from a supply whose frequency is 50 Hz. Calculate the frequency of the rotor current at standstill and the speed at which the magnetic field of the stator is rotating. (A/M 2017)**

   $N_s = \frac{1 \quad f}{P} = \frac{1 \quad x5}{4} = 1500$ rpm

   Frequency of rotor current, $f_r = sf$

   At standstill, s = 1

   Therefore fr = f = 50 Hz
7. **How the direction of rotation of a three phase induction motor can be reversed? (N/D 2016)**

   The direction of the rotation of the three phase induction motor can be changed by inter changing any two terminal of the input supply. The direction of the synchronous rotating field reverses and hence the direction rotor reverses. By changing the supply sequence (R, Y, B) the rotation can be reversed.
8. **What is an induction generator? (Nov 2016)**

In general the induction motor connected to a constant frequency supply is able to run only at sub-synchronous speeds. Suppose the rotor is to be driven by another machine at above synchronous speed (slip is negative), the induction motor runs as a generator. Such arrangement of the machine is called an induction generator.

9. **Write down the condition to get maximum torque under running condition. (A/M 2016)**

   The condition for maximum torque is

   $$s_m = \frac{R2}{X2}$$

   Where R_2 is the rotor resistance per phase and X_2 is the rotor reactance per phase
10. **What is the difference between squirrel cage type rotor and phase wound rotor? (Nov 2015)**

S.No	Slip Ring (Phase wound)	Squirrel Cage
1.	Rotor consists of a three phase winding similar to stator winding	Rotor consists of bars which are shorted at the ends with end rings
2.	Construction is complicated	Construction is simple
3.	Resistance can be added externally	External resistance cannot be added as it is permanently shorted
4.	High starting torque	Moderate starting torque

11. **Define slip of a three-phase induction motor. (N/D 2012)**

    The slip of the induction motor is defined as the ratio the difference between synchronous speed (Ns) and the rotor speed(N) to the synchronous speed.

    s = (Ns-N)/Ns, % slip = [(Ns-N) / Ns]*100
12. **What are the merits of inner cage and outer cage of double cage induction motor? (N/D 2012)**
    1. Outer cage produces high starting torque.
    2. Inner cage gives good running performance
13. **A 50 Hz, 6 pole, 3–phase induction motor runs at 970 rpm. Find slip (A/M 2011)**

    s = (Ns-N)/Ns

    Where Ns=120f/P = 120 x 50 / 6 = 1000 rpm

    N=970 rpm

    Therefore s = (1000 – 970)/ 1000 = 0.03

14. Under what condition, the slip in an induction motor is (a) negative, (b) greater than one. (N/D 2010)

a) Slip negative → generator

b) Slip is greater than one → braking operation

15. Define slip speed in an induction motor.

The slip speed is defined as the difference in the speed between the rotating magnetic field produced by the stator(Ns)and the rotor speed(N).

16. Write down the advantages of slip ring induction motor?

i) High starting torque with low starting current

ii) No abnormal heating during starting condition

iii) The motor speed can be easily varied by varying the rotor resistance

iv) Smooth acceleration under heavy load condition

v) The running characteristics are good after external rotor resistances are cut out.

17. Define synchronous speed in a three phase induction motor?

The speed at which the revolving flux rotates is called synchronous speed and Ns and is the given by

$Ns=120f/p$

Where, f=supply frequency

P=number of the a poles on the stator

18. Enlist four application of wound rotor induction motor?

The slip ring induction motors are employed only when high level is starting toque required. eg are lifts, hoists, cranes, elevator and compressors

19. Which of the two ac motor has more efficient? Name the types of rotors induction motor?

Squirrel cage induction motor has more efficiency.

Types

1. Cage rotor
2. Slip ring (or) wound rotor

20. From the equivalent circuit of an induction motor, represent which component is the electrical equivalent of the mechanical load on the motor?

R_2 (1-s) /s. It represents electrical equivalent of the mechanical load on the motor.

21. What is cogging in the induction motor? How can it be overcome?

When the number of rotor slots is equal to the stator slot precisely the same order harmonics are strongly produced all rotating at corresponding speed in both stator and rotor. Thus harmonics of every order would try to exert synchronous torques at their corresponding synchronous speed and their motor would refuse to start.

22. List out the salient characteristic features of double scroll cage motor.

i) Good starting torque ii) Good running performance

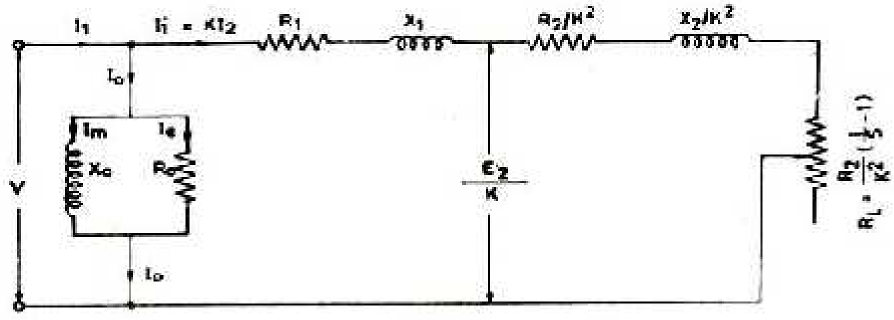
23. Mention the losses that occur in an induction motor.

1. Stator losses
   - i) Stator core loss ii) stator copper loss
2. Rotor loss
   - i) Rotor copper loss
3. Mechanical losses

24. Mention some of the applications of 3-phase induction motor.

1.Laths 2. Fans 3. Blows 4. Lifts 5. Cranes

25. . Draw the equivalent circuit of an induction motor. (A/M 2007)



26. What are the purposes that could be served by external resistors connected in the rotor circuit of phase wound induction motor? (A/M 2006)

Smooth and wide range of speed control
Starting torque can be improved
High line power factor
Availability of full rated torque at starting.

27. Why an induction motor is called asynchronous motor? (A/M 2011)

Induction motor is called asynchronous motor because the rotor does not run in synchronous with the rotating field developed by the stator current.

28. What is crawling? (N/D 2010)

The tendency of the motor to run stably at speeds as low as one-seventh of its synchronous speed with a low pitched howling sound is called crawling.

29. What are the tests to be performed on induction motor to obtain data necessary to draw the circle diagram? (N/D 2006)

No load test
Blocked rotor test
Stator resistance test

PART B & C

1. Explain the construction and working of 3 phase induction motor. (13) [A/M 2018]
2. Develop an equivalent circuit for 3 phase induction motor. State the difference between exact and approximate equivalent circuit. (13) [A/M 2018]
3. (i) Describe the working principle of a 3 phase induction motor. (7)
   (ii) An induction motor has an efficiency of 0.9 when the shaft load is 45 kW. At this load, stator ohmic loss and rotor ohmic loss each is equal to the iron loss. The mechanical loss is one third of the no load losses. Neglect ohmic losses at no load. Calculate the slip. (6) [N/D 2017]
4. (i) Derive the expression for torque under running condition of a 3 phase induction motor and obtain the condition for maximum torque. (8)
   (ii) Write short notes on induction generator. (5) [N/D 2017]
5. Explain in detail the construction of circle diagram of an induction motor. (16) (April 2017)
6. (i) Sketch and explain the torque slip characteristics of the 3 phase cage and slip ring induction motors. Show the stable region in the graph. (8)
   (ii) A 3 phase, 25 kW, 400V, 50 Hz, 8 pole induction motor has rotor resistance of 0.08 ohm and standstill reactance of 0.4 ohm. The effective stator / rotor turn ratio is 2.5/1. The motor is to drive a constant torque load of 250 N-m. Neglect stator impedance.
   (1) Calculate the minimum resistance to be added in rotor circuit for the motor to start up on load.
   (2) At what speed would the motor run, if the added rotor resistance is (a) left in the circuit (b) subsequently short circuited . (8) (April 2017)

3. (i) Deduce and discuss the equivalent circuit of 3 Φ induction motor. (8)
   (ii) Explain with neat diagram, the constructional features and working principle of a 3 Φ induction motor. (8) (Nov 2016)
4. Sketch and explain the torque slip characteristics of the 3 Φ cage and slip-ring induction motors. Show the stable region in the graph. (16) (Nov 2016)
5. (i) Derive the expression for torque, slip and draw speed-torque characteristics of 3-phase induction motor. (8)
   (ii) Explain in detail the construction of circle diagram of an induction motor. (8) (May 2016)

32. (i) Explain in detail the equivalent circuit of 3-phase induction motor. (8)
   (ii) A 40kW, 3-phase, slip-ring induction motor of negligible stator impedance runs at a speed of 0.96 times synchronous speed at rated torque. The slip at maximum torque is four times the full-load value. If the rotor resistance of the motor is increased by 5 times, determine:
   (a) The speed, power output and rotor copper loss at rated torque.
   (b) The speed corresponding to maximum torque. (8) (May 2016)

33. Develop and explain the equivalent circuit of three phase induction motor. (16) (Nov 2015)
34. The test readings of a three phase 14.71 kW, 400V, 50Hz, star connected induction motor is given below :
    No load test : 400V, 9A, Cos φ = 0.2
    Short circuit test : 200V, 50A, Cos φ = 0.4
    From the circle diagram find
    (i) line current
    (ii) power factor
    (iii) slip
    (iv) efficiency at full load. Also find the maximum power output. (16) (Nov 2015)
35. Sketch and explain the torque slip characteristics of the 3-phase cage and slip ring induction motors. Also derive the expression for torque and condition for maximum torque.
36. Describe how 3-phase supply produces a rotating magnetic field of constant value of constant speed with vector diagram.
37. Write short notes on
    (i) Double cage rotors (ii) Induction generator (iii) Synchronous induction motor.
38. Discuss the different power stages of an induction motor with losses.
39. Explain the tests required to be performed to obtain the data for the circle diagram.

PART C

1. A 415V, 11 kW, 50 Hz, delta connected, three phase energy efficient induction motor gave the following test results:
   No load test: 415V, 5.8 A, 488 W
   Blocked rotor test: 40V, 18.4 A, 510 W
   Stator resistance per phase = 0.7 Ω
   For full load condition, find (i) line current (ii) power factor (iii) input power (iv) slip and (v) efficiency. (15) [A/M 2018]

UNIT IV

STARTING AND SPEED CONTROL OF THREE PHASE INDUCTION MOTOR

PART A

1. What are the advantages of slip power scheme? [A/M 2018]

(i) The slip power can be recovered and fed back to the supply.
(ii) The overall efficiency also improved.

2. Why is rotor rheostat starter unsuited for a squirrel cage motor? [N/D 2017]

In squirrel cage motor, the rotor conductors are short circuited permanently at end rings and external resistance cannot be connected across it.

3. What are the conditions for regenerative braking of an induction motor to be possible? [N/D 2017]

The input power of the induction motor drive is given by the formula shown below

$$P_{in} = 3VI_s cos\emptyset_s$$

Where φ_s is the phase angle between stator phase voltage and the stator phase current I_s.

- When the φ_s is greater than the 90º, then the power flow to reverse and gives the regenerative braking.
- When the supply frequency is fixed, the regenerative braking is possible only for speeds greater than synchronous speed.

4. What is the effect of change in input voltage on starting torque of induction motor? (April 2017) (April 2016) (Nov 2015)

Starting Torque, T_{st} α V^2. Therefore starting torque increase when input voltage is increased and decreases when input voltage is decreased.

5. State any two advantages of speed control of induction motor by injecting an emf in the rotor circuit. (April 2017)

(i) The main advantage of this method is that any speed, within the working range, can be obtained.

(ii) If the rotor converter over excited, it will take a leading current which compensates for the lagging current drawn by SRIM and hence improves the power factor of the system

6. What is the effect of increasing the rotor resistance on starting current and torque? (Nov 2016)

The starting torque is proportional to the rotor resistance. Hence increase in rotor resistance increases the starting torque.

As rotor resistance increases, the rotor impedance increases and hence limits the starting current.

7. List out the methods of speed control of cage type 3 Φ induction motor. (Nov 2016)

a) By changing supply frequency
b) By changing the number of poles
c) By operating two motors in cascade

8. **What are the different methods of speed control of three phase induction motor? (Nov 2015)**

From stator side

b. Supply frequency control to control N_s, called V/f.
c. Supply voltage control
d. Controlling number of stator poles to control N_s
e. Adding rheostats in stator circuit

From rotor side,

a. Adding external resistance in the rotor circuit
b. Cascade control
c. Injecting slip frequency voltage into the rotor circuit

9. Why starter is necessary for the induction motor? (M/ J 2012)
What is the need of starter for induction motor? [A/M 2018]

Starter is used to reduce starting current. Starting current is usually large because of inertia-characteristics of motor winding (at starting slip=1, rotor resistance low implies less back emf).So at starting we use starter.

10. Mention the various methods of starting of a 3-phase induction motor (May / June 2009)

- Auto transformer starter
- Star-delta starter
- DOL starter
- Primary resistance starter
- Rotor resistance starter

11. State the effect of rotor resistance on starting torque. (Nov / Dec 2011)

The additional external resistance reduces the rotor current and hence the current drawn from the supply. It improves the starting torque developed by improving the power factor in high proportion to the decrease in rotor current.

12. State the drawback of star-delta starter. (May / June 2011)

The main disadvantage of this method, the starting torque is low.

13. What are the advantages of rotor resistance speed control method? (May / June 2011)

- Smooth and wide range of speed control
- High line power factor
- Starting torque can be improved
- Absence of in rush starting current

14. What are the disadvantages of rotor rheostat speed control method? (may 2010)

i) Large power losses due to large I^2R losses
ii) Efficiency is very low
iii) Cannot be used for cage type
iv) Large speed changes not possible

15. What is the function of rotary converter? Where it is used?

Rotary converter converts low slip ac power. It is used in Kramer system, which is for the speed control of three-phase induction motor.

16. What are the advantages of Kramer system of speed control?

(a) Any speed within the working range can be obtained

(b) When rotary converter is overexcited, it will take leading current, compensates with the lagging current drawn by the motor, thus improving power factor.

17. Write the expression for concatenated speed of the set.

Cumulative mode (N) = 120f / (Pa + Pb)

Differential mode (N) = 120f / (Pa – Pb)

Pa no of poles of motor A

Pb no of poles of motor B

18. What are the methods of speed control preferred for large motors?

a. Kramer system

b. Scherbius system

19. How is speed control achieved by changing the number of stator poles?

Here change in stator poles is achieved by having two or more independent stator windings in the same slot. Each winding gives different number of poles and different speeds. At a time only one winding is used and other is closed

20. **How can varying supply frequency control speed?**

We know that

Ns = 120f /P

From the equation it is clear that by varying frequency speed can be varied. It is very rarely.

21. What is plugging?

The reversal of direction of rotation of motor is the main principle of plugging. In induction motor, it can be quickly stopped by interchanging any two stator leads. Due to this, the direction of rotating magnetic field gets reversed suddenly, producing torque in the reverse direction.

22. What is dynamic braking?

In dynamic or rheostatic braking, one supply line out of R, Y or B is disconnected from the supply.

23. What is DC dynamic braking?

A quick stopping of an induction motor and its high inertia load can be achieved by connecting stator terminal to a dc supply. Any two terminals can be connected to a dc supply and the third terminal may be kept open or may be connected directly to other stator terminal.

24. What is regenerative braking?

If the rotor speed is increased greater than the synchronous speed with the help of external device, it acts as an induction generator. It converts the input mechanical energy to an electrical energy which is given back to supply. It delivers active power to the 3 phase line. The φ becomes greater than 90^0. The power flow reverses hence rotor induced emf and rotor current also reverse. So rotor produces torque in opposite direction to achieve the braking. As the electrical energy is given back to the line while braking, it is called regenerative braking.

25. What is slip power recovery scheme? (Dec 2013)

In the rotor resistance speed control, the slip power in the rotor circuit is wasted as I_2^2R losses. It is possible to recover the slip power from the rotor and feed back to the supply using static devices. Such a scheme of recovering slip power from rotor is called slip power recovery scheme.

PART B & C

1. Explain with neat diagram, the working of any two types of starters used for squirrel cage type 3 phase induction motor. {13) [A/M 2018]
2. Explain briefly various speed control schemes of induction motor. (13) [A/M 2018]
3. (i) With a neat diagram, explain the working of a star-delta starter for a 3 phase induction motor. (8)
   (ii) Describe the method of speed control of a 3 phase squirrel cage induction motor by changing the number of stator poles and state the applications of this method. (5) [N/D 2017]
4. (i) Draw and explain the schematic diagram of a static Kramer variable speed drive system for a slip ring induction motor. (7)
   (ii) Explain he DC dynamic braking of a 3 phase induction motor. (6) [N/D 2017]
5. The results of the no load and blocked rotor tests on a 3 phase, Y connected 10 kW, 400 V, 17 A, 50 Hz, 8 pole induction motor with a squirrel cage rotor are given below

   No load test: line voltage = 400V

	Total input power	=	467 W
	Line current	=	6.8 A
Blocked rotor test:	Line-line voltage	=	180V
	Total input power	=	1200W
	Line current	=	17 A

The dc resistance of the stator measured immediately after the blocked rotor is found to have an average value of 0.68 ohm/phase. Calculate the parameters of the circuit model of the induction motor. Draw circuit model. Calculate (i) torque (net) (ii) stator current (iii) power factor (iv) Efficiency (16) **(April 2017)**

6. Explain the speed control of a 3 phase induction motor with slip power recovery scheme. (16) **(April 2017)**
7. (i) State the different methods of starting of 3 phase induction motor and discuss in detail any two methods. (8)
   (ii) With aid of diagrams explain the principle of the following methods of speed control of a 3 phase induction motor.
   (1) variable Frequency (2) cascade connection (8) (Nov 2016)

8. (i) Describe a starter suitable for a 3 phase slip ring induction motor. (6)
   (ii) Determine approximately the starting torque of an induction, motor in terms of full load torque when. started by
   (1) Star—delta starter and
   (2) Auto—starter with 50% tapping. The short circuit current of the motor at normal voltage is 5 times the full load current and the full load slip is 4%. (10) (Nov 2016)

9. (i) Explain in detail the speed control methods of induction motor. (8)
   (ii) Explain in detail the scherbius system of speed control. (8) (April 2016)
10. (i) Describe a starter available for a 3-phase slip ring induction motor. (8)
    (ii) A small squirrel-cage induction motor has a starting current of six times the full load current and a full-load slip of 0.05. Find in pu of full-load values, the current (line) and starting torque with the following methods of starting ((a) to (d)).
    (a) Direct switching, (b) Stator-resistance starting with motor current limited to 2p.u, (c) auto-transformer starting with motor current limited to 2p.u, and (d) Y-delta starting. (e) What auto transformer ratio would give 1 p.u starting torque? (8) (April 2016)

11. Explain the various method of starting of three phase squirrel cage type Induction motor. (16) (Nov 2015)
12. Explain the different methods by which speed control of induction motor is achieved (16) (Nov 2015)
13. Why starters are necessary for starting 3-phase induction motors? What are the various types of starters? Explain any two in detail.
14. Explain the speed control of 3-phase induction motor by slip power recovery scheme with neat sketches.
15. Explain plugging and regenerative braking in 3-phase induction motor.

PART C

1. Explain the V/F control technique in 3 phase induction motor. (15) [N/D 2017]

UNIT V

SINGLE PHASE INDUCTION MOTORS AND SPECIAL MACHINES

PART A

1. **What are the various methods available for making a single phase motor self starting? [A/M 2018]**
   List the various types of single phase induction motors. (A/ M 2009)
   - Split phase induction motor
   - Capacitor – start induction motor
   - Capacitor – run induction motor
   - Capacitor – start Capacitor – run induction motor
2. **What is the principle of reluctance motor? [A/M 2018][N/D 2014]**

   The reluctance motor starts as a single phase induction motor when single phase ac supply is given. Once speed reaches 70 to 80 % of synchronous speed, the rotor aligns itself with the axis of magnetic field in a minimum reluctance position and gets magnetically locked. Thus rotor pulls into synchronism due to reluctance torque and keeps rotating at synchronous speed.

3. **How is the direction of rotation of a single phase induction motor reversed? [N/D 2017][N/D 2015] [N/D 2011]**

The direction of rotation of an AC motor depends on the magnetic polarity of the start winding. Reversing the polarity of the "Start" winding, in relationship to the "Run" winding, reverses the direction of rotation of all single-phase alternating current (AC) motors.

4. **What is the principle of operation of a linear induction motor? [N/D 2017]**

When the primary of an LIM is excited by a balanced three phase power supply, a traveling flux is induced in the primary instead of rotating 3 φ flux, which will travel along the entire length of the primary. Electric current is induced into the aluminum conductors or the secondary due to the relative motion between the traveling flux and the conductors. This induced current interacts with the traveling flux wave to produce linear force or thrust F. If the secondary is fixed and the primary is free to move, the force will move the primary in the direction of the force, resulting in the required rectilinear motion.

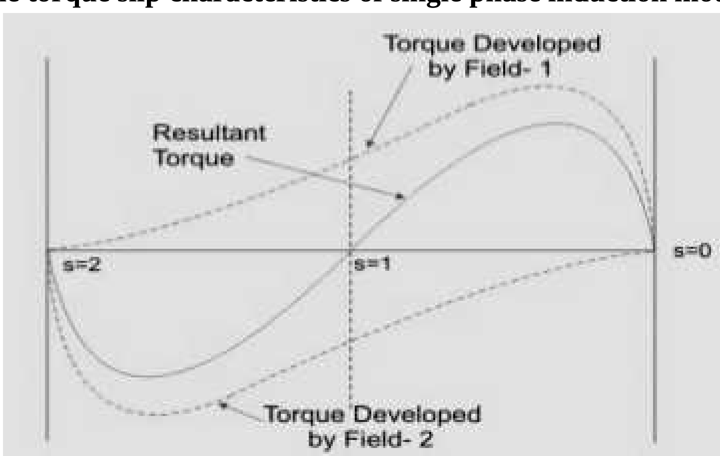
5. **Define double field revolving theory. (April 2017)**

According to double field revolving theory, any alternating quantity can be resolved into two rotating components which rotate in opposite directions and each having magnitude as half of the maximum magnitude of the alternating quantity.

6. **Why single phase induction motor is not self starting? Mention any one method of starting. (April 2017) (April 2016)**

When a single phase supply is fed to the stator winding, it produces only an alternating flux only i.e., one which alternates along one space axis only. Due to this, starting torque will be zero. Hence the motor does not rotate.

7. **Draw the torque slip characteristics of single phase induction motor. (Nov 2016)**



8. **What will be the direction of rotation of a shaded pole single phase induction motor? (Nov 2016)**

The direction of shaded pole single phase induction motor is in the direction specified by the non shaded part of the pole face to the shaded part of the pole face.

9. **Name the motor being used in ceiling fans. (April 2016)**

Ceiling fan – Capacitor start and capacitor run single phase induction motor.

10. **What is a linear induction motor? (Nov 2015)**

The linear induction motor works on the same principle as that of normal induction motor with the difference that instead of rotational movement, the rotor moves linearly. If the stator and rotor of the induction motor are made flat then it forms the linear induction motor.

11. Why are centrifugal switches provided on many single phase induction motors? (May / June 2012)

The centrifugal switches are provided on many single phase induction motors, because, when the motor is running at 75% of the synchronous speed, the centrifugal switch connected in the auxiliary circuit operates and disconnects the auxiliary winding from the supply.

12. What is the advantage of capacitor start induction motor over split-phase induction motor? (May / June 2012)

- High starting torque
- High efficiency
- High power factor

13. State the application of shaded pole motor. (Nov / Dec 2011)

- Fan
- Blowers
- Turn tables hair driers

14. Define step angle. (Nov / Dec 2011)

It is defined as angle through which the stepper motor shaft rotates for each command pulse. It is denoted as β

15. Why is the single phase induction motor having two windings in the stator? (Nov / Dec 2011)

Basically single phase induction motor is not self- starting. So in order to have a starting torque the single phase induction motor having two windings in the stator

16. State any two applications of capacitor start – run induction motors. (Nov / Dec 2011)

- Compressors
- Pumps
- Conveyors
- Refrigerators

17. Mention the applications of stepper motor. (Nov / Dec 2011,)

- Robotics
- Computer peripherals
- Facsimile machine
- Aerospace

18. Write down any two applications of single phase induction motors. (May / June 2011)

- Fans
- Washing machines
- Drillers
- Record player

19. Mention the working principle of hysteresis motor. (Nov / Dec 2010)

Operation depends upon the hysteresis effect and on the presence of continuously revolving magnetic flux.

20. Mention any two applications of hysteresis motor. (May / June 2010)

- Electric clocks
- Timing devices
- Tape decks
- Turn tables

21. State the applications of shaded pole 1-phase induction motor. (Apr / May 2010)

- Turn tables
- Hair driers

22. What are the different types of repulsion motor? (Nov / Dec 2009)

- Compensated repulsion motor
- Repulsion induction motor

23. What are the features of universal motor? (Nov / Dec 2009)

- Operates on either DC or AC supply
- High starting torque
- High no-load speed

PART B & C

1. Give the classification of single phase motors. Explain any two types of single phase induction motor. (13) [A/M 2018]
2. What is the principle and working of hysteresis motor and AC series motor? Explain briefly. (13) [A/M 2018]
3. (i) Explain the two field revolving theory for single phase induction motors. (8)
   (ii) Describe the principle of operation of Hysteresis motor. (5) [N/D 2017]
4. (i) Explain the no load and blocked rotor tests on a single phase induction motor. (7)
   (iv) Describe the working principle of any one type of stepper motor.(6) [N/D 2017]
5. Using double field revolving theory, explain why a single phase induction motor is not self starting. Also obtain the equivalent circuit of single phase induction motor with necessary equations. (16) (April 2017)
6. Describe the constructional features and principle of operation of hysteresis motor and AC series motor. (16) (April 2017)
7. (i) Using double revolving field theory explain why a single phase induction motor is not self starting. (8)
   (ii) The equivalent impedances of the main and auxiliary windings in a capacitor motor are (15 + j 22.5) Ω and (50 + j 120) Ω respectively, while the capacitance of the capacitor is 12 μF. Determine the line current at starting on a 230 V, 50Hz supply. (8) (Nov 2016)
8. Explain the operation and constructional features of
   (v) Capacitor start single phase induction motor
   (ii) AC series motor. (16) (Nov 2016)
9. (i) Explain in detail the operation of capacitor start and run induction motor. (8)
   (ii) Discuss in detail the operation of hysteresis motor. (8) (April 2016)
10. Write short notes on the following:
    (i) Linear Induction motor and (8)
    (ii) AC series motor (8) (April 2016)
11. Explain, why single phase induction motor is not self starting? Also explain about the Double revolving field theory. (16) (Nov 2015)
12. Write the brief note about the following
    (i) Repulsion motor (5)
    (ii) Hysteresis motor (5)
    (iii) AC Series motor. (6) (Nov 2016)
13. What are the types of single phase induction motor? Explain any two in detail.
14. Explain the construction and working of Hysteresis motor
15. Discuss briefly the operation and characteristics of (i) Repulsion motor.(ii) Linear induction motor.
16. What is stepper motor? Explain the operation of the types of stepping motors. Compare them. State four applications of stepper motors.
17. Draw the equivalent circuit of single phase induction motor and discuss the experimental procedure to obtain it's parameters.(no load and blocked rotor test)
18. Explain in detail about DC and AC servo motor.

PART C

1. With neat diagram, explain the construction and operation of shaded pole induction motor. (15) [N/D 2017]