UNIT I
SYNCHRONOUS GENERATOR
PART A

1. Name the various types of alternators.

i. Turbo alternator ii. Salient pole alternator

2. Write the EMF equation of a three-phase alternator.

The emf equation of alternator is

$E = 4.44\ K_c\ K_d \Phi\ f\ T$ volts

Where

E = Induced emf per phase

Kc = Pitch factor

Kd = Distribution factor

T = No of turns connected in series in each phase

3. Why do cylindrical Alternators operate with steam turbines?

Steam turbines are found to operate at fairly good efficiency only at high speeds. The high speed operation of rotors tends to increase mechanical losses and so the rotors should have a 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.

4. Which type of Synchronous generators are used in Hydro-electric plants and why?

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

5. What are the advantages of salient pole type construction used for Synchronous machines?

 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

6. How does electrical degree differ from mechanical degree?

Mechanical degree is the unit for accounting the angle between two points based on their mechanical or physical placement. Electrical degree is used to account the angle between two points in rotating electrical machines. Since all electrical machines operate with the help of magnetic fields, the electrical degree is accounted with reference to the magnetic field. 180 electrical degree is accounted as the angle between adjacent North and South poles.

7. Why is short pitch winding preferred over full-pitch winding?

Advantages

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

8. Define winding factor.

The winding factor kw is defined as the ratio of phasor addition of emf induced in all the coils of each phase winding to their arithmetic addition of emf's.

9. Why are Alternators rated in kVA and not in kW?

The continuous power rating of any machine is generally defined as the power of 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 I2 R, 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 ratings in VA/kVA/MVA.

10. What do you mean by "single layer" and “double layer" winding?

In single layer winding, there- is only one coil side per slot- But in double layer winding, in each slot there are two coil sides namely upper coil side and lower coil side. Hence, in single layer winding, the number of coils is half the number of slots, but in double layer winding, the number of coils is equal to the number of slots.

11. Compare the salient pole rotor and cylindrical pole rotor on stability point of view.

Salient pole rotor is of large diameter and small axial length. It is used for low speed alternator.
Smooth cylindrical rotor is of smaller diameter and long axial length. Therefore it is used for high-speed turbo alternator.

12. Where the damper windings are located? What are their functions?

Damper windings are provided in the pole shoes of the salient pole rotor. Slots or holes are provided in the pole shoes. Copper bars are inserted in the slots and the ends of all the bars in both the sides are short circuited by copper end rings to have a closed circuit. These windings are useful in preventing the hunting in alternators; they are also needed, in synchronous motor to provide the starting torque.

13. What are the causes of changes in terminal voltage of Alternators when loaded?

Variations in terminal voltage in Alternators on load condition are due to the
following three causes:

- Voltage drop due to the resistance of the winding, IR.
- Voltage drop due to the leakage reactance of the winding, IXl.
- Voltage variation due to the armature reaction effect, IXa.

14. What is meant by armature reaction in Alternators?

The effect of armature flux on the flux produced by the field ampere turns is called as armature reaction.

15. What do you mean by synchronous reactance?

Synchronous reactance Xs= (Xl + Xa)

The value of leakage reactance Xl is constant for a machine based on its construction. Xl depends on saturating condition of the machine. Xa , which represent the armature reaction effect between two synchronously acting magnetic fields. The sum of leakage flux and armature reaction reactance makes the total reactance XS to be called synchronous reactance.

16. What is meant by synchronous impedance of an Alternator?

The complex addition of resistance, R and synchronous reactance, jXs can be represented together by a single complex impedance Zs called synchronous impedance.

In complex form Zs = (R + jXs)

17. What is meant by load angle of an Alternator?

The phase angle introduced between the induced emf phasor, E and terminal voltage phasor (V), during the load condition of an Alternator is called load angle.

18. Upon what factors does the load angle depend?

The magnitude of load angle δ increases with increase in load. Further the load angle is positive during generator operation and negative during motor operation.

19. Define the term voltage regulation of Alternator.

The voltage regulation of an Alternator is defined as the change in terminal voltage from no-load to load condition expressed as a fraction or percentage of terminal voltage at load condition; the speed and excitation conditions remaining same.

20. What is the necessity for predetermination of voltage regulation?

Most of the Alternators are manufactured with large power rating, hundreds of kW or MW, and also with large voltage rating up to 33kV. For Alternators of such power and voltage ratings conduction of load test is not possible. Hence other indirect methods of testing are used and then voltage regulation can be predetermined at any desired load currents and power factors.

21. Name the various methods for predetermining the voltage regulation of 3-phase Alternator.

The following are the three methods which are used to predetermine the voltage regulation of smooth cylindrical type Alternators

- Synchronous impedance / EMF method
- Ampere-turn / MMF method
- Potier / ZPF method

22. What are the advantages and disadvantages of estimating the voltage regulation of an Alternator by EMF method?

Advantages:

- Simple no load tests (for obtaining OCC and SCC) are to be conducted
- Calculation procedure is much simpler

Disadvantages:

- The value of voltage regulation obtained by this method is always higher than the actual value

23. Why is the synchronous impedance method of estimating voltage regulation considered as pessimistic method?

Compared to other methods, the value of voltage regulation obtained by the synchronous impedance method is always higher than the actual value and therefore this method is called the pessimistic method.

24. In what way does the ampere-turn method differ from synchronous impedance method?

The ampere-turn /MMF method is the converse of the EMF method in the sense that instead of having the phasor addition of various voltage drops/EMFs, here the phasor addition of MMF required for the voltage drops are carried out which more accurate compared to EMF method. Further the effect of saturation is also taken care in this method.

25. Why is the MMF method of estimating the voltage regulation considered as the optimistic method?

Compared to the EMF method, MMF method, involves more number of complex calculation steps. Further the OCC is referred twice and SCC is referred once while predetermining the voltage regulation for each load condition. Reference of OCC takes care of saturation effect. As this method require more effort, the final result is very close to the actual value. Hence this method is called optimistic method.

26. State the condition to be satisfied before connecting two alternators in parallel.

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

- The terminal voltage magnitude of the incoming Alternator must be made equal to the existing Alternator or the bus-bar voltage magnitude.
- The phase sequence of the incoming Alternator voltage must be similar to the bus-bar voltage.
- The frequency of the incoming Alternator voltage must be the same as the bus-bar voltage.

27. How do the synchronizing lamps indicate the correctness of phase sequence between existing and incoming Alternators?

The correctness of the phase sequence can be checked by looking at the three sets of lamps connected across the 3-pole of the synchronizing switch. If the lamps grow bright and dark in unison it is an indication of the correctness of the phase sequence. If on the other hand, ie. If phase sequence is not correct they become bright and dark one after the other, then connections of any two machine terminals have to be interchanged after shutting down the machine.

28. What are the advantages and disadvantages of three dark lamps method of synchronizing?

Advantages:

- The synchronous switch using lamps is inexpensive
- Checking for correctness of the phase sequence can be obtained in a simple manner which is essential especially when the Alternator is connected for the first time or for fresh operation after disconnection

Disadvantages:

The rate of flickering of the lamps only indicates the frequency difference between the bus-bar and the incoming Alternator. The frequency of the incoming Alternator in relation to the bus-bar frequency is not available.

29. How synchronoscope is used for synchronizing Alternators?

Synchronoscope can be used for permanently connected Alternators where the correctness of phase sequence is already checked by other means. Synchronoscope is capable of rotating in both directions. The rate of rotation of the pointer indicates the amount of frequency difference between the Alternators. The direction of rotation indicates whether incoming Alternator frequency is higher or lower than the existing Alternator. The TPST synchronizing switch is closed to synchronize the incoming Alternator when the pointer faces the top thick line marking.

30. Why synchronous generators are to be constructed with more synchronous reactance and negligible resistance?

The presence of more resistance in the Synchronous generators will resist or oppose their synchronous operation. More reactance in the generators can cause good reaction between the two and help the generators to remain in synchronism in spite of any disturbance occurring in any one of the generators.

31. List the factors that affect the load sharing in parallel operating generators?

The total active and reactive power delivered to the load, connected across the common bus-bars, are shared among Synchronous generators, operating in parallel, based on the following three factors

- Prime-mover characteristic/input
- Excitation level and
- Percentage synchronous impedance and its R/X ratio

32. How does the change in prime mover input affect the load sharing?

An increase in prime-mover input to a particular generator causes the active power shared by it to increase and a corresponding decrease in active-power shared by other generators. The change in reactive power sharing is less appreciable. The frequency of the bus-bar voltage will also subjected to slight increase in value.

33. How does change in excitation affects the load sharing?

The decrease in excitation in one generator causes the reactive power shared by it to decrease and a corresponding increase in reactive-power shared by other generators. The change in active-power sharing is less appreciable. There will be a slight decrease in terminal voltage magnitude also.

34. What is meant by infinite bus-bars?

The source or supply lines with non-variable voltage and frequency are called infinite bus-bars. The source lines are said to have zero source impedance and infinite rotational inertia.

35. How does increase in excitation of the Alternator connected to infinite bus-bars affect the operation?

Increase in excitation level of the synchronous generator will effectively increase the reactive component of the current supplied by the generator and hence the active power delivered.

36. What is meant by floating when the synchronous motor is connected to an infinite bus?

For starting a synchronous motor, a D.C motor is mechanically coupled with it. The D.C motor is started and its speed is adjusted to a value near about the syn speed of the synchronous motor. The excitation is gradually increased. The synchronous machine is now working as an alternator. The excitation is increased till the EMF induced is equal to the A.C bus bar voltage. If it is now synchronized with A.C supply, we will say the machine is 'floating' on the bus bar. The alternator will neither supply power nor take power from the bus bars.

37. What steps are to be taken before disconnecting one Alternator from parallel operation?

The following steps are to be taken before disconnecting one Alternator from parallel operation

- The prime-mover input of the outgoing generator has to be decreased and that of other generators has to be increased and by this the entire active-power delivered by the outgoing generator is transferred to other generators.
- The excitation of the outgoing generator has to be decreased and that of other generators have to be increased and by this the entire reactive-power delivered by the outgoing generator is transferred to other generators.
- After ensuring the current delivered by the outgoing generator is zero, it has to be disconnected from parallel operation.

38. Explain "phase Spread" in the armature winding.

In order to obtain the better-wave shape the coil are not concentrated or bunched in one slot, but are distributed in a number of slots to form polar groups under each pole. This is called phase spread. The winding so obtained is known as distributed winding.

39. What is an exciter?

The field windings of an alternator are excited by means of direct current from some external source. For this purpose D.C generator is used. This D.C generator is called as exciter.

40. What is a turbo-alternator?

Turbo-alternators are high-speed alternators. Therefore smooth cylindrical type rotor is used. To reduce the peripheral velocity, the diameter of the rotor is reduced and axial length is increased two or four poles are normally adopted for this type of alternators. Steam turbines are used as prime mover.

41. Why are the large capacity alternators made of revolving field type?

- Rotating field is comparatively light and can run with high speed:
- It is easier to insulate stationary armature winding for very high voltage.
- Load circuit can be connected directly with the fixed terminals for the stator without passing through slip rings and brushes
- Only two slip rings are required to give D.C supply to the field system. This voltage is 110V or 220V and hence the slip rings can be easily insulated.

42. What is meant by armature reaction?

The load currents flowing in the stator winding usually generate a magnetic field which opposes the magnetic field generated by the excitation (field) winding, reducing the total airgap field and the terminal voltage. In order to counteract this reaction effect from the stator currents, the field current has to be adjusted (usually increased).

43. Why is the field system of an alternator made as a rotor?

Number of brush, voltage drop across the brush, number of phases of windings in rotor and weight of rotor are reduced.

44. What is synchronizing power of an alternator?

When two alternators are operated parallel after synchronism, suppose due to change in input parameter of second alternator it act as motor, first alternator supplies power to second alternator. That power is called as synchronous power

PART –B

1. Describe the principle and construction of slow speed operation generator with neat diagram.
2. Derive the emf equation of alternator.
3. What are the methods of determining regulation of alternator? Discuss each briefly.
4. Explain the procedure for POTIER method to calculate voltage regulation of alternator.
5. For a salient pole synchronous machine, prove the d-axis synchronous reactance Xd, can be obtained from its OCC and SCC. Neglect armature resistance.
6. Explain the condition for parallel operation of 3 phase alternator with neat diagram.
7. Explain about the various methods of Synchronization.
8. Explain how you will determine the d and q axis reactance of a synchronous machine in your laboratory.
9. For the salient synchronous machine, derive the expression for power developed as a function of load angle.
10. Explain the EMF method of determining the regulation of an alternator.
11. Explain the phenomena of armature reaction in alternator for different load power factors.
12. What is synchronizing power of an alternator? Derive an expression for the synchronizing power between the two alternators connected in parallel.
13. List the methods used to predetermine the Voltage Regulation of Synchronous machine and explain the M.M.F Method.