ENERGY CONVERSION-II

[TH-2]

5TH SEM ELECTRICAL ENGG.

Under SCTE&VT, Odisha

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CHAPTER -1

ALTERNATOR

Introduction

An alternator is an electromechanical device that converts mechanical energy to electrical energy in the form of alternating current. Synchronous generators are also called as alternators.

A.C. generators are used in to generate electricity in hydroelectric and thermal plants. Alternators are also used in automobiles to generate electricity.

Like a D.C. generator, an alternator also has an armature winding and a field winding.
But there is one important difference between the two.

- In D.C. generators, the field poles are stationary and the armature conductors rotate. The voltage generated in the armature conductors is of alternating nature. This generated alternating voltage is converted to a direct voltage at the brushes with the help of the commutator.
- But in the synchronous generator it is convenient and advantageous to place the field winding on the rotating part (i.e., rotor) and armature winding on the stationary part (i.e., stator). No commutator is required in an alternator

Advantages of Stationary Armature:

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

1. A stationary armature is more easily insulated for the high voltage for which the alternator is designed. This generated voltage may be as high as 33K V.
2. The armature windings can be fixed better mechanically against high electro-magnetic forces due to large short-circuit currents when the armature windings are in the stator.
3. The armature windings, being stationary, are not subjected to vibration and centrifugal forces.
4. The output current can be taken directly from fixed terminals on the stationary armature without using slip rings, brushes, etc.
5. Only two slip rings are required for d.c. supply to the field winding on the rotor.
6. The stationary armature may be cooled more easily because the armature can be made large to provide a number of cooling ducts.

Types of synchronous machines:

According to the arrangement of armature and field winding, the synchronous machines are classified as **rotating armature type** or **rotating field type**.

- In **rotating armature type** the armature winding is on the rotor and the field winding is on the stator. The generated EMF or current is brought to the load via the slip rings. These type of generators are built only in small units.
- In case of **rotating field type** generators field windings are on the rotor and the armature windings are on the stator. Here the field current is supplied through a pair of slip rings and the induced EMF or current is supplied to the load via the stationary terminals.

Based on the type of the prime movers employed the synchronous generators are classified as

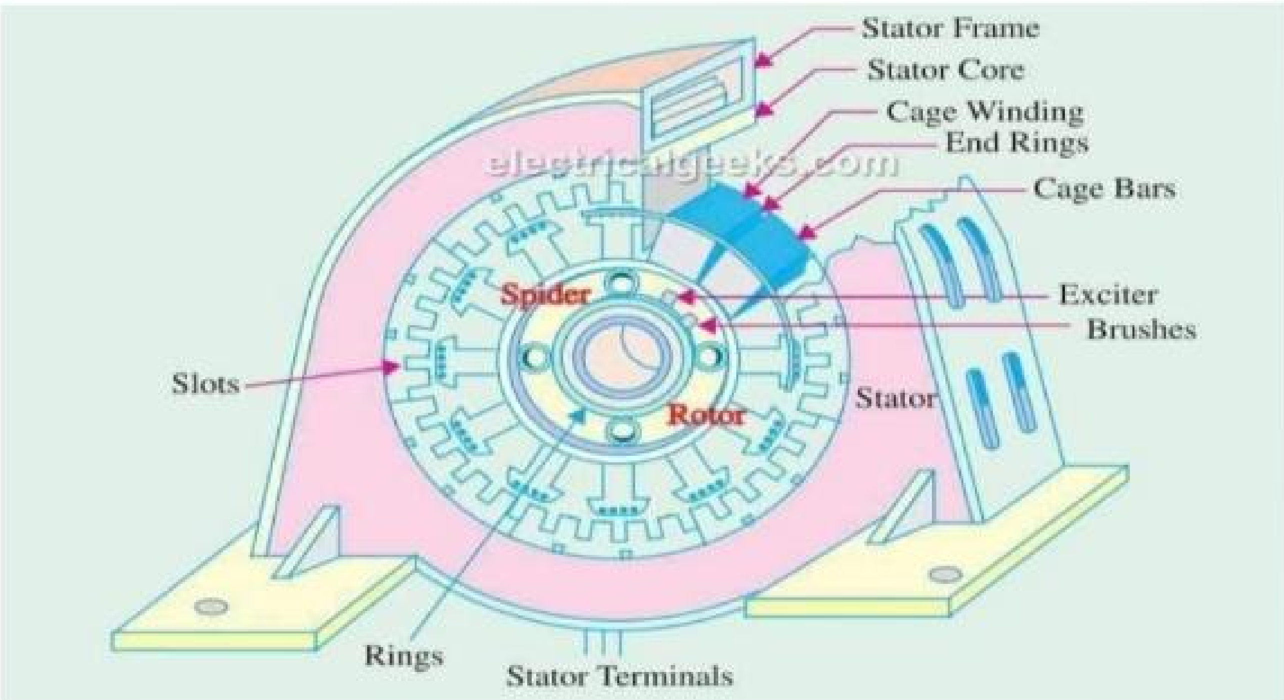
1. **Hydro generators:** The generators which are driven by hydraulic turbines are called hydro generators. These are run at lower speeds less than 1000 rpm.
2. **Turbo generators:** These are the generators driven by steam turbines. These generators are run at very high speed of 1500rpm or above.
3. **Engine driven Generators:** These are driven by IC engines. These are run at aspeed less than 1500 rpm.

Construction of Alternator:

An alternator consists of two main parts namely, the

i. stator
ii. rotor

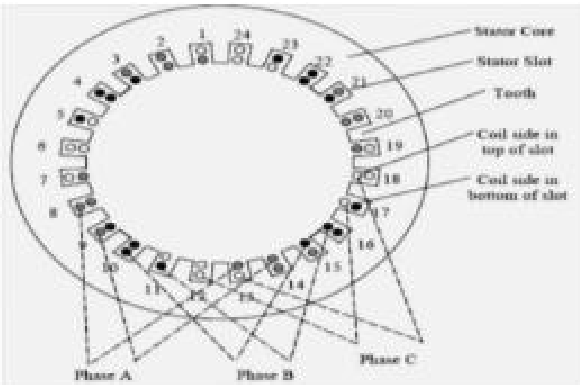
The stator is the stationary part of the machine. It carries the armature winding in which the voltage is generated. The output of the machine is taken from the stator.The rotor is the rotating part of the machine. The rotor produces the main field flux.



Stator Construction:

The Stationary part of the alternator is known as stator. It provides housing and support for the rotor. Statoris built up of sheet-steel laminations having slots on its inner periphery. A 3-phase winding is placed in these slots and serves as the armature winding of the alternator. The armature winding is always connected in star and the neutral is connected to ground.
The stator is the outer stationary part of the machine, which consists of

- The outer cylindrical frame called yoke, which is made either of welded sheet steel, cast iron.
- The magnetic path, which comprises a set of slotted steel laminations called stator core pressed into the cylindrical space inside the outer frame. The magnetic path is laminated to reduce eddy currents, reducing losses and heating.



Rotor Construction:

The rotor carries a field winding which is supplied with direct current through two slip rings by a separate d.c. source. This d.c. source (called exciter) is generally a small d.c. shunt or compound generator mounted on the shaft of the alternator.
There are two types of rotor constructions namely,

i. Salient(or projecting) pole type
ii. Non salient (or Cylindrical) pole type.

Salient (or projected) pole type.

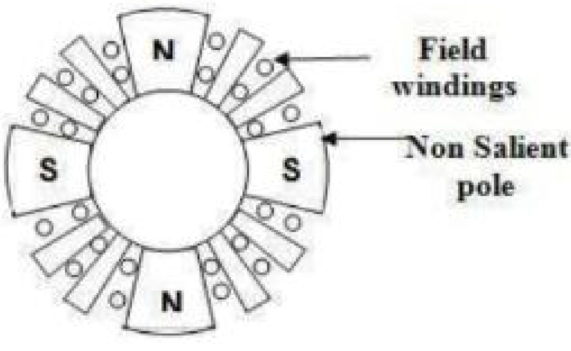
- The pole is made of steel or cast iron and the pole winding is excited by a D.C. generator driven by the shaft of alternator.
- These type of machines have salient pole or projecting poles with concentrated field windings. This type of construction is for the machines which are driven by hydraulic turbines or Diesel engines.
- The salient pole type of rotor is used for low to medium speed/rpm alternators, where more number of poles are required may be 20 or 30 poles.
- A salient pole alternator can be identified by large diameter and short axial length. The large diameter accommodates a large number of poles.
- A salient-pole synchronous machine has a non-uniform air gap. The air gap is minimum under the pole centres and it is maximum in between the poles.
- Salient-pole alternators driven by water turbines are called hydro-alternators or hydro-generators.

Damper windings are provided in the pole faces of salient pole alternators. Damper windings are nothing but the copper or aluminium bars housed in the slots of the pole faces. These damper windings are serving the function of providing mechanical balance; provide damping effect, reduce the effect of over voltages and damp out hunting in case of alternators.

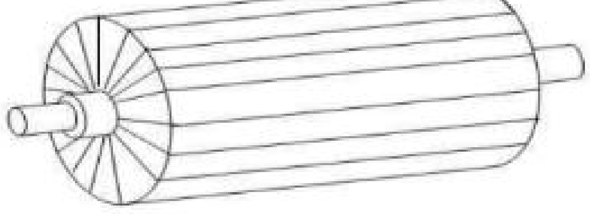
Salient pole type rotor

Non salient (or cylindrical or Round) pole type:

- The rotor is made of steel cylinder with number of slots cut on the periphery of the cylinder. The field windings are placed in the slots.
- These machines are having cylindrical smooth rotor construction with distributed field winding in slots.
- Cylindrical pole type of rotor construction is employed for the machine driven by steam turbines.
- These cylindrical pole type alternators have large axial length and smaller diameter.
- Cylindrical rotors are particularly useful in high-speed machines. The cylindrical rotor type alternator has two or four poles on the rotor. Such a construction provides a greater mechanical strength and permits more accurate dynamic balancing.
- The cylindrical rotor machine makes less windage losses and the operation is less noisy because of uniform air gap.



Smooth cylindrical or non salient type rotor



3D view of smooth cylindrical or non-salient type rotor

Working Principle of Alternator:

An alternator operates on the same fundamental principle of *electromagnetic Induction* as a D.C. generator i.e., when the flux linking a conductor changes, an e.m.f. is induced in the conductor.

Field windings are the windings producing the main magnetic field (rotor windings for synchronous machines); armature windings are the windings where the main voltage is induced (stator windings for synchronous machines).

The rotor winding is energized from the d.c. exciter to produce a rotor magnetic field and alternate N and S poles are developed on the rotor. When the rotor is rotated in anti-clockwise direction by a prime mover, the stator or armature conductors are cut by the magnetic flux of rotor poles. Consequently, e.m.f. is induced in the armature conductors due to electromagnetic induction. The induced e.m.f. is alternating since N and S poles of rotor alternately pass the armature conductors. The direction of induced e.m.f. can be found by Fleming's right hand rule and frequency is given by;

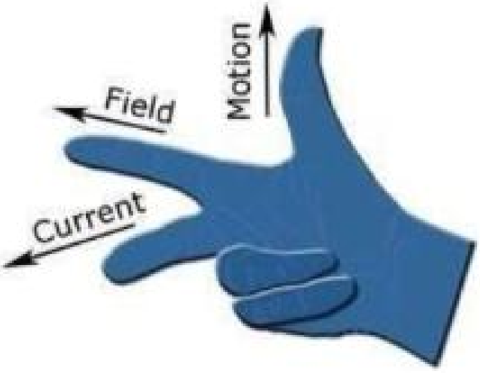
$$f = \frac{PN}{120}$$ where N=speed of rotor in r.p.m

P=number of rotor poles

When the rotor is rotated, a 3-phase voltage is induced in the armature winding. The magnitude of induced e.m.f. depends upon the speed of rotation and the d.c.exciting current. The magnitude of e.m.f. in each phases of the armature windingis the same.

Fleming's Right hand rule:

Statement: The thumb, fore finger and middle finger of the right hand are stretched to be perpendicular to each other and if the thumb represents the direction of the movement of conductor, fore-finger represents direction of the magnetic field,then the middle finger represents direction of the induced emf.



Relation between speed and frequency:

The frequency of induced e.m.f in the armature conductors depends upon speed &the number of poles.

Let N=rotor speed in r.p.m

P= number of rotor poles

f =frequency of emf in HZ

- Armature (stator) conductor successively swept by N &S poles of the rotor. If a positive voltage is induced when a N-pole sweeps across the conductor, similarly negative voltage is induced when a S-pole sweeps by.

That is one complete cycle of e.m.f is generated in the conductor as a pair of poles passes it i.e., one N-pole and the adjacent following S-pole.

No of cycles/revolution = No. of pair of poles = P/2

No of revolution/second =N/60

No. of cycles/second = (P/2)(N/60)

But no. of cycles of e.m.f per second is its frequency.

So $f = \frac{PN}{120}$ where N=speed of rotor in r.p.m

P =number of rotor poles

For a given alternator,P is fixed, therefore, the alternator must be run at synchronous speed to give an output of desired frequency. For this reason the alternator is also called as *synchronous generator*.

Terminology in Armature Winding:

Conductor: Each individual length of wire lying in the magnetic field is called conductor.

Turn: When the two conductors lying in the magnetic field are connected in series, so that the emf induced in them help each other or the resultant induced emf becomes double of that due to one conductor is called turn.

Coil: When one or more turns are connected in series and two ends of it are connected to the adjacent commutator segments it is called a coil.