UNIT: IV

AC GENERATOR &ELECTRICAL INSTALLATION

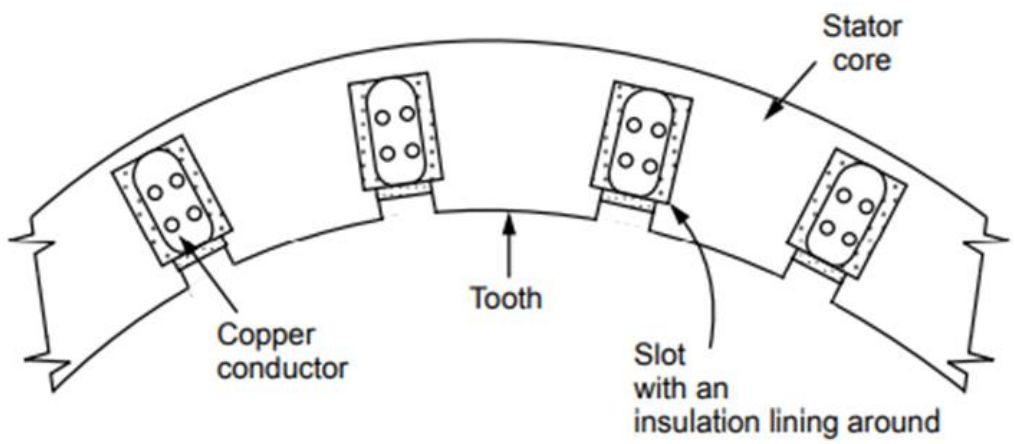
AC GENERATOR: Construction, principle of operation of synchronous generator, EMF equation.

ELECTRICAL INSTALLATION: Fuse, circuit breakers, difference between fuse and circuit breaker, Types of batteries, battery backup.

AC GENERATOR or ALTERNATOR or SYNCHRONOUS GENERATOR

5.1 Construction: Stator:

The stator is a stationary armature. This consists of a core and the slots to hold the armature winding similar to the armature of a d.c. generator. The stator core uses a laminated construction. It is built up of special steel stampings insulated from each other with varnish or paper. The laminated construction is basically to keep down eddy current losses. Generally, choice of material is steel to keep down hysteresis losses. The entire core is fabricated in a frame made of steel plates. The core has slots on its periphery for housing the armature conductors. Frame does not carry any flux and serves as the support to the core. Ventilation is maintained with the help of holes cast in the frame. The section of an alternator stator is shown in the Fig.



Section of an alternator stator

Rotor:

There are two types of rotors used in alternators

1) Salient pole type

2) Smooth cylindrical type.

1. Salient Pole Type

This is also called **projected pole type as all the poles are projected out from the surface of the rotor.**

The poles are built up of thick steel laminations. The poles are bolted to the rotor as shown in the Fig.

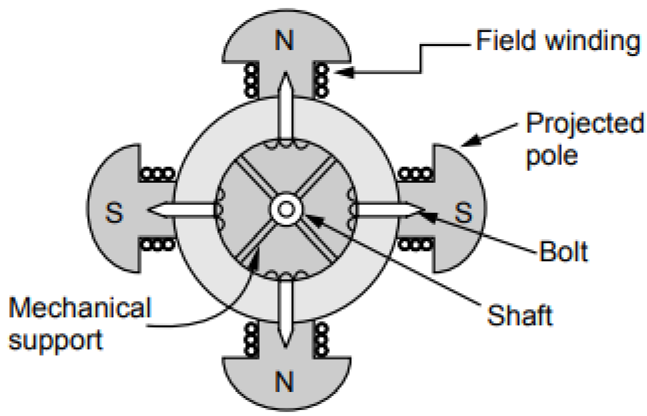


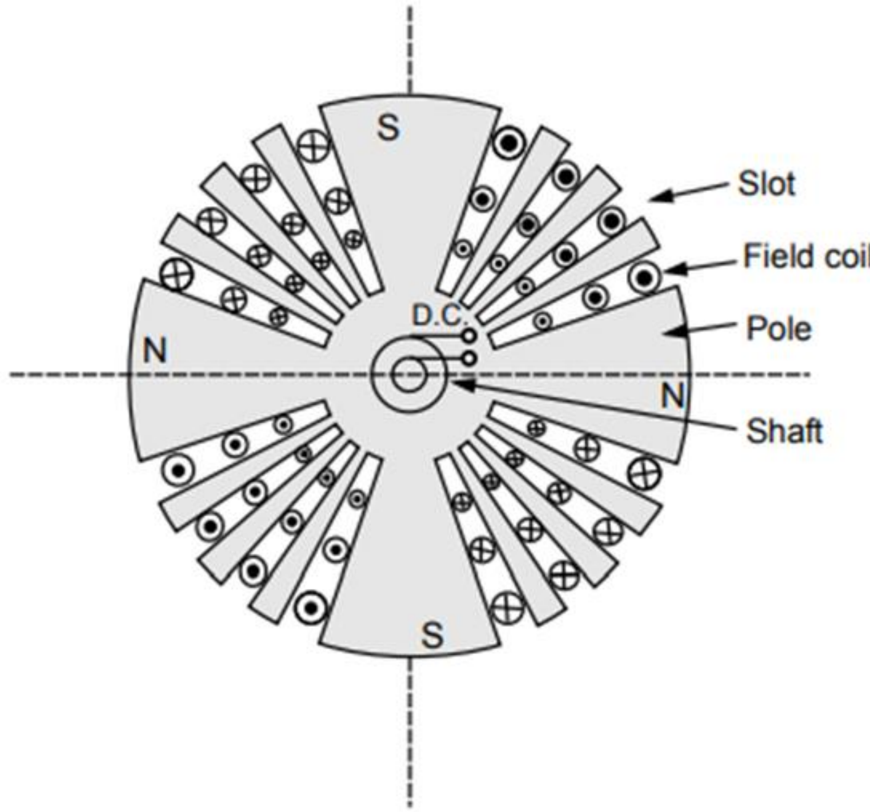
Fig. 1.6.1 Salient pole type rotor

The pole face has been given a specific shape. The field winding is provided on the pole shoe. These rotors have large diameters and small axial lengths. The limiting factor for the size of the rotor is the centrifugal force acting on the rotating member of the machine. As mechanical strength of salient pole type is less, this is preferred for low speed alternators ranging from 125 r.p.m. to 500 r.p.m. The prime movers used to drive such rotor are generally water turbines and I.C. engines.

2. Smooth Cylindrical Type

This is also called non salient type or non-projected pole type of rotor.

The rotor consists of smooth solid steel cylinder, having number of slots to accommodate the field coil. The slots are covered at the top with the help of steel or manganese wedges. The unslotted portions of the cylinder itself act as the poles. The poles are not projecting out and the surface of the rotor is smooth which maintains uniform air gap between stator and the rotor. These rotors have small diameters and large axial lengths. This is to keep peripheral speed within limits. The main advantage of this type is that these are mechanically very strong and thus preferred for high speed alternators ranging between 1500 to 3000 r.p.m. Such high speed alternators are called 'turboaltemators'. The prime movers used to drive such type of rotors are generally steam turbines, electric motors.



Smooth cylindrical rotor

5.2 Difference between Salient and Cylindrical Type of Rotor:

Salient Pole Type

1. Poles are projecting out from the surface.

2. Air gap is non uniform.

3. Diameter is high and axial length is small.

4. Mechanically weak.

5. Preferred for low speed alternators.

6. Prime mover used are water turbines, I.C. engines.

7. For same size, the rating is smaller than cylindrical type.

8. Separate damper winding is provided.

Smooth Cylindrical Type

1. portion of the cylinder acts as poles hence poles are non projecting.

2. Air gap is uniform due to smooth cylindrical periphery.

Small diameter and large axial length is the feature.

4. Mechanically robust.

5. Preferred for high speed alternators .e. for turboaltemators.

6. Prime movers used are steam turbines, electric motors.

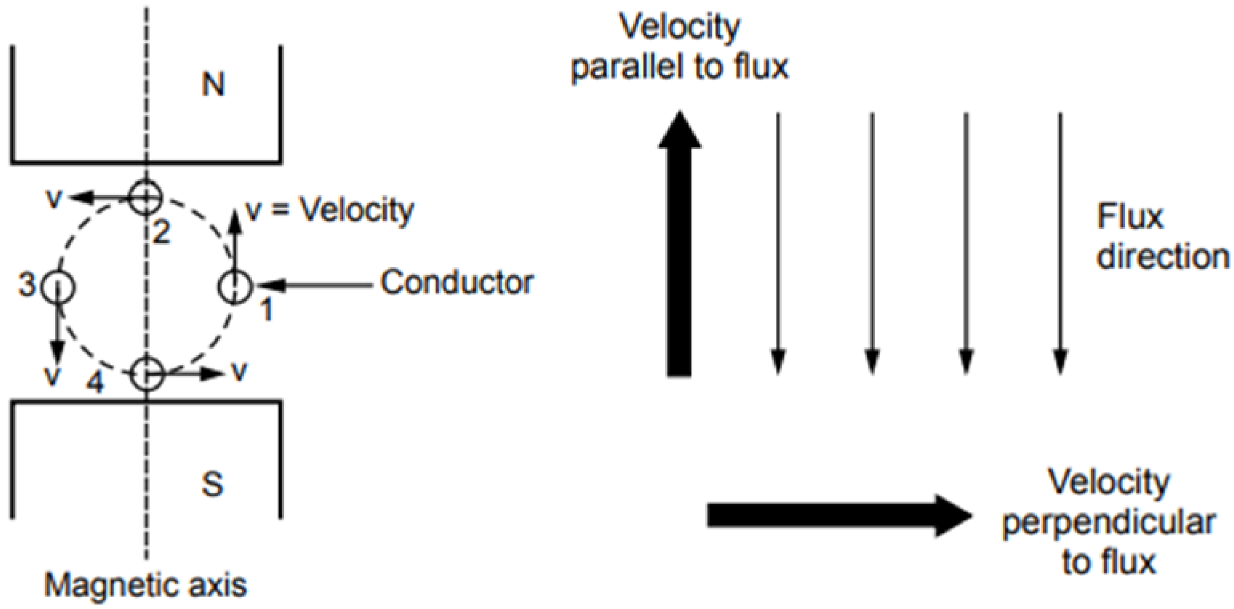
7. For same size, rating is higher than salient pole type.

8. Separate damper winding is not necessary.

5.3 Working Principle and operation of Alternator:

The alternators work on the principle of electromagnetic induction. When there is a relative motion between the conductors and the flux, e.m.f. gets induced in the conductors. The d.c. generators also work on the same principle. The only difference in practical alternator and a d.c. generator is that in an alternator the conductors are stationery and field is rotating. But for understanding purpose we can always consider relative motion of conductors with respect to the flux produced by the field winding.

Consider a relative motion of a single conductor under the magnetic field produced by two stationary poles. The magnetic axis of the two poles produced by field is vertical, shown dotted in the Fig.



Two pole alternator

Let conductor starts rotating from position 1. At this instant, the entire velocity component is parallel to the flux lines. Hence there is no cutting of flux lines by the conductor. So $d\phi/dt$ at this instant is zero and hence induced e.m.f. in the conductor is also zero.

As the conductor moves from position 1 towards position 2, the part of the velocity component becomes perpendicular to the flux lines and proportional to that, e.m.f. gets induced in the conductor. The magnitude of such an induced e.m.f. increases as the conductor moves from position 1 towards 2.

At position 2, the entire velocity component is perpendicular to the flux lines. Hence there exists maximum cutting of the flux lines. And at this instant, the induced e.m.f. in the conductor is at its maximum.

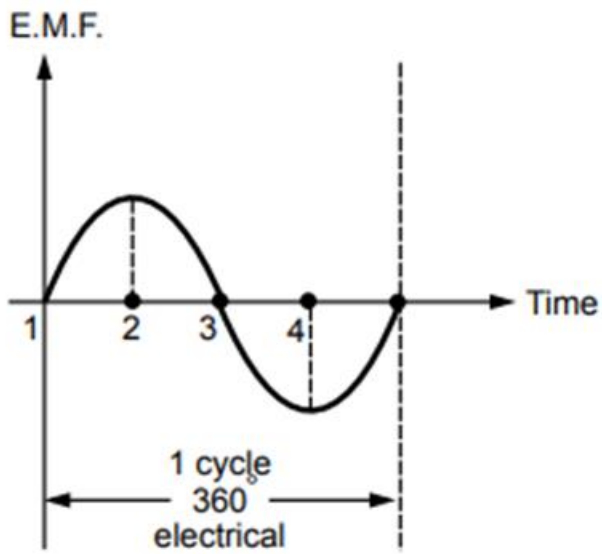
As the position of conductor changes from 2 towards 3, the velocity component perpendicular to the flux starts decreasing and hence induced e.m.f. magnitude also starts decreasing. At position 3, again the entire velocity component is parallel to the flux lines and hence at this instant induced e.m.f. in the conductor is zero.

As the conductor moves from position 3 towards 4, the velocity component perpendicular to the flux lines again starts increasing. But the direction of velocity component now is opposite to the direction of velocity component exsisting during the movement of the conductor from position 1 to 2. Hence an induced e.m.f. in the conductor increases but in the opposite direction.

At position 4, it achieves maxima in the opposite direction, as the entire velocity component becomes **perpendicular** to the flux lines.

Again from position 4 to 1, induced e.m.f. decreases and finally at position 1, again becomes zero. This cycle continues as conductor rotates at a certain speed.

So if we plot the magnitudes of the induced e.m.f. against the time, we get an alternating nature of the induced e.m.f. as shown in the Fig.



Alternating nature of the induced e.m.f.

5.4 Advantages of Rotating Field Over Rotating Armature:

1) As everywhere a.c. is used, the generation level of a.c. voltage may be higher as 11 kV to 33 kV. This gets induced in the armature. For stationary armature large space can be provided to accommodate large number of conductors and the insulation.

2) It is always better to protect high voltage winding from the centrifugal forces caused due to the rotation. So high voltage armature is generally kept stationary. 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. The voltage required to be supplied to the field is very low (110 V to 220 V d.c.) and hence can be easily supplied with the help of slip ring and brush assembly by keeping it rotating.

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.

6) Rotating field makes the overall construction very simple. With simple, robust mechanical construction and low inertia of rotor, it can be driven at high speeds. So greater output can be obtained from an alternator of given size.

7) If field is rotating, to excite it by an external d.c. supply two slip rings are enough. One each for positive and negative terminals. As against this, in three phase rotating armature the minimum number of slip rings required are three and can not be easily insulated due to high voltage levels.

8) The ventilation arrangement for high voltage side can be improved if it is kept stationary.

5.5 E.M.F. Equation of an Alternator:

Let ϕ = Flux per pole, in Wb, P = Number of poles

N_s = Synchronous speed in r.p.m., f = Frequency of induced e.m.f. in Hz

Z = Total number of conductors

Z_{ph} = Conductors per phase connected in series

$Z_{ph} = Z/3$

Consider a single conductor placed in a slot. The average value of e.m.f. induced in a conductor = $d\phi / dt$

For one revolution of a conductor, e_{avg} per conductor = Flux cut in one revolution / Time taken one revolution

Total flux cut in one revolution = $\phi \times P$

Time taken for one revolution = $60/N_S$ seconds.

e_{avg} per conductor = $\phi P/(60/N_S) = \phi\, PN_S/60$

But $f = PN_S/120$

Hence $PN_S/60 = 2f$

E avg per conductor = $2f\,\phi$ volts

If there are Z conductors in series/phase, then the average emf/phase in = $2f\,\phi\,Z$ volts

If $Z = 2T$ (T is no of coils or turns/phase),

Then, the average induced EMF in an alternator = $4\,f\,\phi\,T_{ph}$

But in a.c. circuits R.M.S. value of an alternating quantity is used for the analysis. The form factor is 1.11 of sinusoidal e.m.f.

K_f = R.M.S. value / Average value = 1.11

R.M.S. value of $E_{ph} = K_f \times$ Average value

$E_{ph} = 1.11 \times 4\,f\,\phi\,T_{ph}$

$$\boxed{\mathbf{E_{ph} = 4.44\, f\, \phi\, T_{ph}\ volts}}$$

ELECTRICAL INSTALLATION:

5.6 Fuse:

An electrical fuse is a safety device designed to protect electrical circuits from overcurrent or short-circuit conditions. It consists of a thin wire or strip of metal that melts when the current flowing through it exceeds a specific threshold, thereby interrupting the flow of electricity and preventing damage to the circuit.

5.7 Circuit breakers:

A circuit breaker is an electrical safety device designed to protect electrical circuits from damage caused by overcurrent, overloads, or short circuits. Unlike a fuse, a circuit breaker can be reset manually or automatically after the fault condition has been resolved, making it reusable.

5.8 Difference between Fuse and Circuit Breaker:

Fuse	**Circuit Breaker**
Works on the thermal and electrical properties of the conducting materials	Works on the switching principle and electromagnetism
It doesn’t give any indication of overloads	It gives an indication of overloads
Fuse can only be used once	A circuit breaker can be used many numbers of times
Provides protection against power overloads	Provides protection against power overloads and short circuits
It detects and interrupts faulty circuit conditions	It performs the interruption process only. Faults are detected by a relay system.
Low breaking capacity compared to the circuit breaker	High breaking capacity
Automatic operation	Can either be automatic or manually operated
Operating time of fuse is 0.002 seconds	Operating time of the circuit breaker is 0.02 – 0.05 seconds
Low Cost	High Cost

5.9 Types of Batteries:

Batteries can be classified into various types based on different categories such as the size, chemical composition, and form factor. But all in all, they fall under two main battery types, which are:

- Primary Batteries
- Secondary Batteries

Primary Batteries:

The primary battery is made for only single use. Once it is used, it cannot be recharged and is thrown away. For example:- disposable batteries.

- The common AA and AAA batteries found in wall clocks, television remotes, and other electrical devices are examples of these disposable batteries.
- Primary cells include the Daniell cell, Dry cell, and Mercury cell.

Types of Primary Batteries:

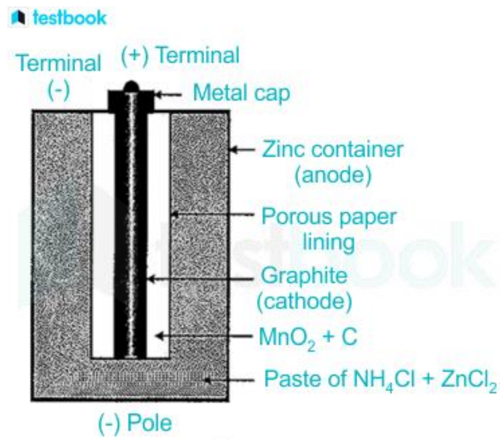
Alkaline Battery:

An alkaline battery gets its name due to the presence of an alkaline electrolyte mostly made up of potassium hydroxide (KOH). The image above represents a general diagram of an alkaline battery.

- The outside coating or the container is made up of steel, which serves as a current collector.
- The cathode is generally made up of manganese dioxide and carbon, which is in the shape of a hollow cylinder in the can, also known as the separator ring.
- The anode is present inside the separator rings.
- To control the polarity of the battery, it is covered with a metal or a plastic jacket.

Alkaline batteries are generally used in remotes, digital cameras, toys, flashlights etc.

Dry Cell



Dry Cell

Carl Gassner patented a variant of a Leclanche cell, which came to be known as the dry cell because it does not have a free liquid electrolyte.

Let us take an overview of the dry cell battery:

- The outermost part is a Zinc cylinder which acts as the anode.
- This anode is filled inside with a moist paste of NH4Cl & ZnCl2NH4Cl & ZnCl2
- The graphite rod inside acts as a cathode.
- A paste of manganese dioxide and carbon powder surrounds the cathode.
- The voltage range of a dry cell is between 1.2V to 1.5V.

These are generally used in hearing aid applications, watches, calculators, etc.

Secondary Batteries:

Secondary batteries are the ones which can be recharged if it is over or they can be recharged and used simultaneously. These are charged by using electric current. For example, batteries used in phones, laptops, etc.

The secondary batteries are further classified as follows:

- Lead Acid Battery
- Lithium Battery
- Nickel Cadmium Battery
- Sealed Maintenance-Free Battery

Lead Acid Battery

These kinds of batteries require proper care and maintenance for lasting longer. These are used in inverters, automobiles, and in backup power systems. It has to be charged for a longer duration and performs well when maintained properly at regular intervals. These provide the best value for power and energy per kilowatt-hour.

Lithium Battery

This battery is used in portable devices such as phones, music players etc and has capacities depending upon the size of the battery. These are of high density and have a potential for higher capacities. Therefore, it can also be used to provide a high current in power tool appliances.

Nickel Cadmium Battery

This battery can be recharged many times and has a more physical and electrical withstanding capacity. It has nickel oxide as the cathode and cadmium as the anode with potassium hydroxide as the electrolyte. These batteries are used in portable computers, cam recorders and other small battery-operated instruments.

Sealed Maintenance-Free Battery

This battery requires minimum maintenance and can be used in supplying consistent and low power such as in UPS applications. These are used to deliver instant power are used in power deficit areas such as rural areas. These are used with appliances when you need to store important information when the power goes out.

5.10 Battery Backup:

A **battery backup** (or uninterruptible power supply, UPS) is a device that supplies temporary power during electrical outages or fluctuations. It ensures continuity of operation for connected devices and protects them from damage caused by sudden power loss or unstable voltage conditions.

Types of Battery Backup Systems

1. **Standby UPS**
   - Activates during a power outage.
   - Provides basic protection for less-critical systems.
2. **Line-Interactive UPS**
   - Regulates voltage fluctuations without switching to battery power.
   - Ideal for environments with frequent voltage sags or surges.
3. **Online UPS**
   - Continuously powers devices from the battery.
   - Offers maximum protection and zero transfer time.