A.C GENERATOR

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Introduction

- A.C. Generator means Alternating current generator.
- It is a device which is used to convert mechanical energy into electrical energy.
- A.C. generator forces electric current to flow through an external circuit.
- The source of mechanical energy may be a reciprocating or turbine steam engine, water falling through a turbine or waterwheel, an internal combustion engine, a wind turbine, a hand crank, compressed air ,or any other source of mechanical energy.

History

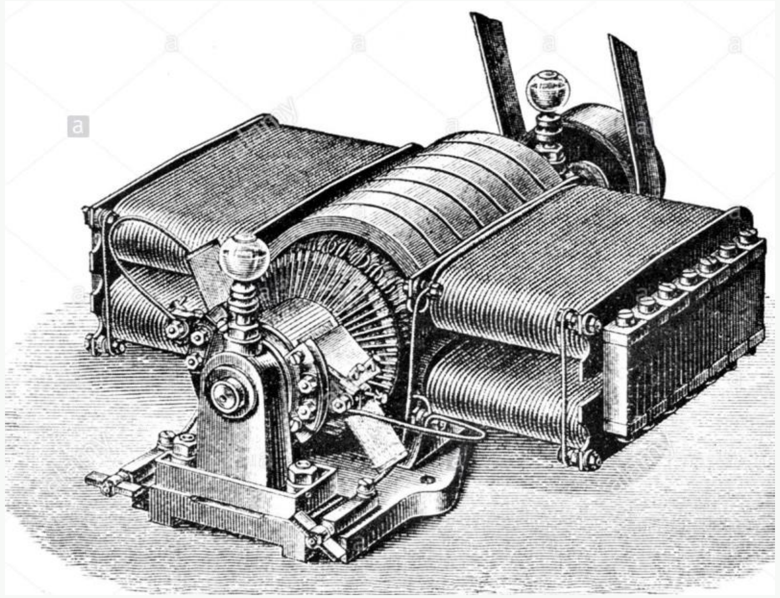
The history of AC generators is intertwined with the history of dynamos and DC electricity. The electric generator has its origins in the work of Michael Faraday and Joseph Henry, who discovered electromagnetic induction. The first AC generator was created accidentally by Hippolyte Pixii while he was inventing the first dynamo in 1832, which delivered pulses of DC electricity. After 1832, some important milestones in the development of generators included:

•**1860:** Antonio Pacinotti invented a dynamo that provided continuous DC power.

•**1867:** Werner Von Siemens and Charles Wheatstone invented a more powerful dynamo using a self-powered electromagnet.

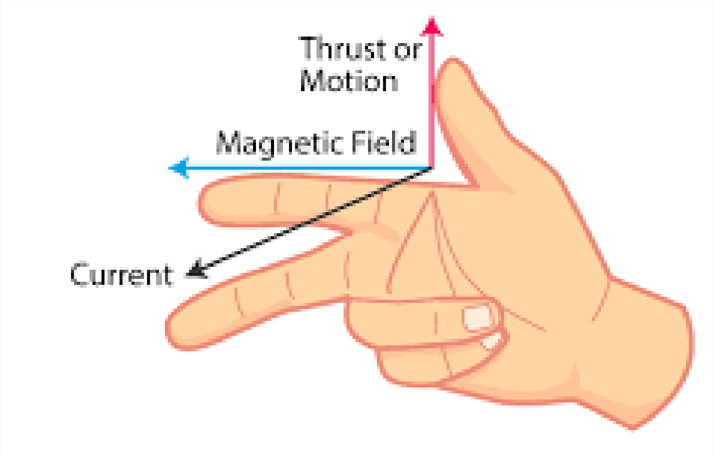
•**1871:** Zenobe Gramme created the first commercially feasible dynamo by placing an iron core in the magnetic field, vastly increasing the power output.

•**1878:** The Ganz company created the first AC generators to be used in commercial operations in Budapest.



Principle of AC generator

- An electric generator works under the principle of electromagnetic induction, which means that if an electrical conductor, such as a wire, is moved through a magnetic field, then an electric current will be generated in the conductor.
- The direction of the current is given by the right hand rule.
- The current is given by I = F / (b l Sin ø)



Construction of AC generator

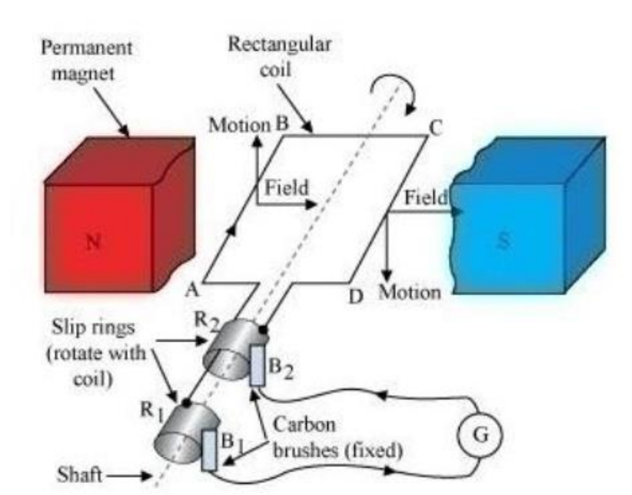
The A.C. Generator is consist of four main parts :

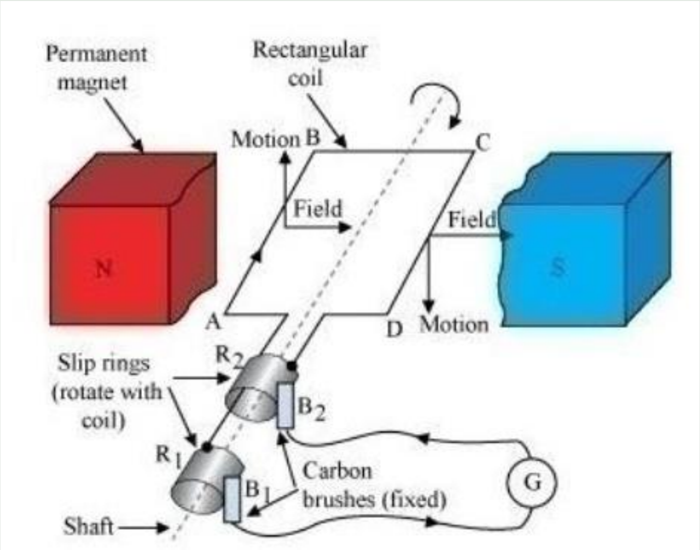
(1) THE COIL (ARMATURE) : A rectangular coil ABCD consist of a large number of turns of copper bound over a soft iron core is called armature. The soft iron core is used to increase the magnetic flux.

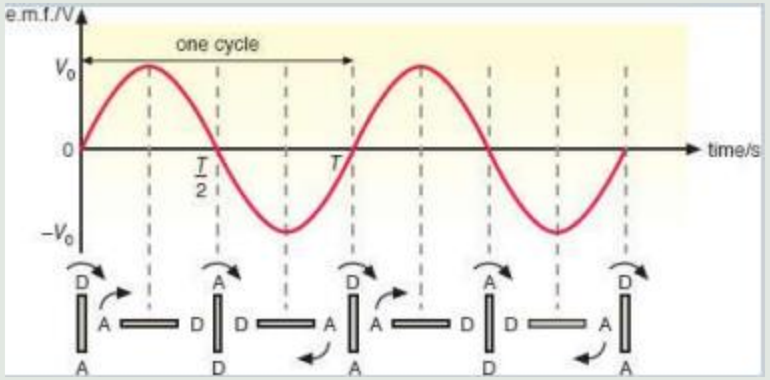
(2) MAGNETIC FIELD : It is usually a permanent sponge magnet having concave poles. The armature is rotated of a magnet so that axis of the armature is perpendicular to magnetic field lines.

(3) SLIP RINGS : Slip rings are the magnetic rings which are connected in the terminal of the armature. These rings are rotated with the coil and these are use to draw the current from the generator.

(4) BRUSHES : The brushes B1 & B2 are just touch the slip rings. They are not rotating with the coil and these brushes leads to the output of load resistance.







Working of AC generator

1. The strong magnetic field is produced by a current flow through the field coil of the rotor.

2. The field coil in the rotor receives excitation through the use of slip rings and brushes.

3. Two brushes are spring-held in contact with the slip rings to provide the continuous connection between the field coil and external circuit.

4. The armature is contained within the windings of the stator and is connected to the output.

5. Each time the rotor makes one complete revolution, one complete cycle of AC is developed.

6. A generator has many turns of wire wound into the slots of the rotor.

7. The magnitude of AC voltage generated by an AC generator is dependent on the field strength and speed of the rotor.

8. Most generators are operated at a constant speed; therefore, the generated voltage depends on field excitation, or strength.

INSTANTANEOUS EMF PRODUCED

The expression for instantaneous value of emf induced

Number of turns in coil = N

Area of the coil = A

Magnitude of magnetic field = B

Angle at any time $t = \theta$

Magnetic Flux would be

$$\phi = NBA\cos\theta \Rightarrow NBA\cos\omega t$$

So the induced emf is

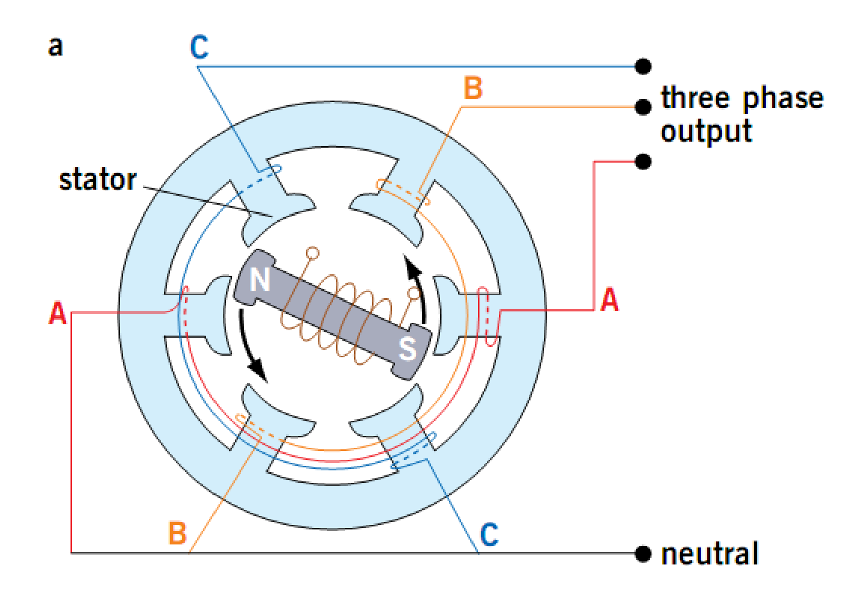
$$\varepsilon = \frac{-d\phi}{dt}$$

$$\Rightarrow \varepsilon = \frac{-d}{dt}(NBA\cos\omega t)$$

$$\Rightarrow \varepsilon = NBA\sin\omega t$$

And considering $NBA = \varepsilon_0$

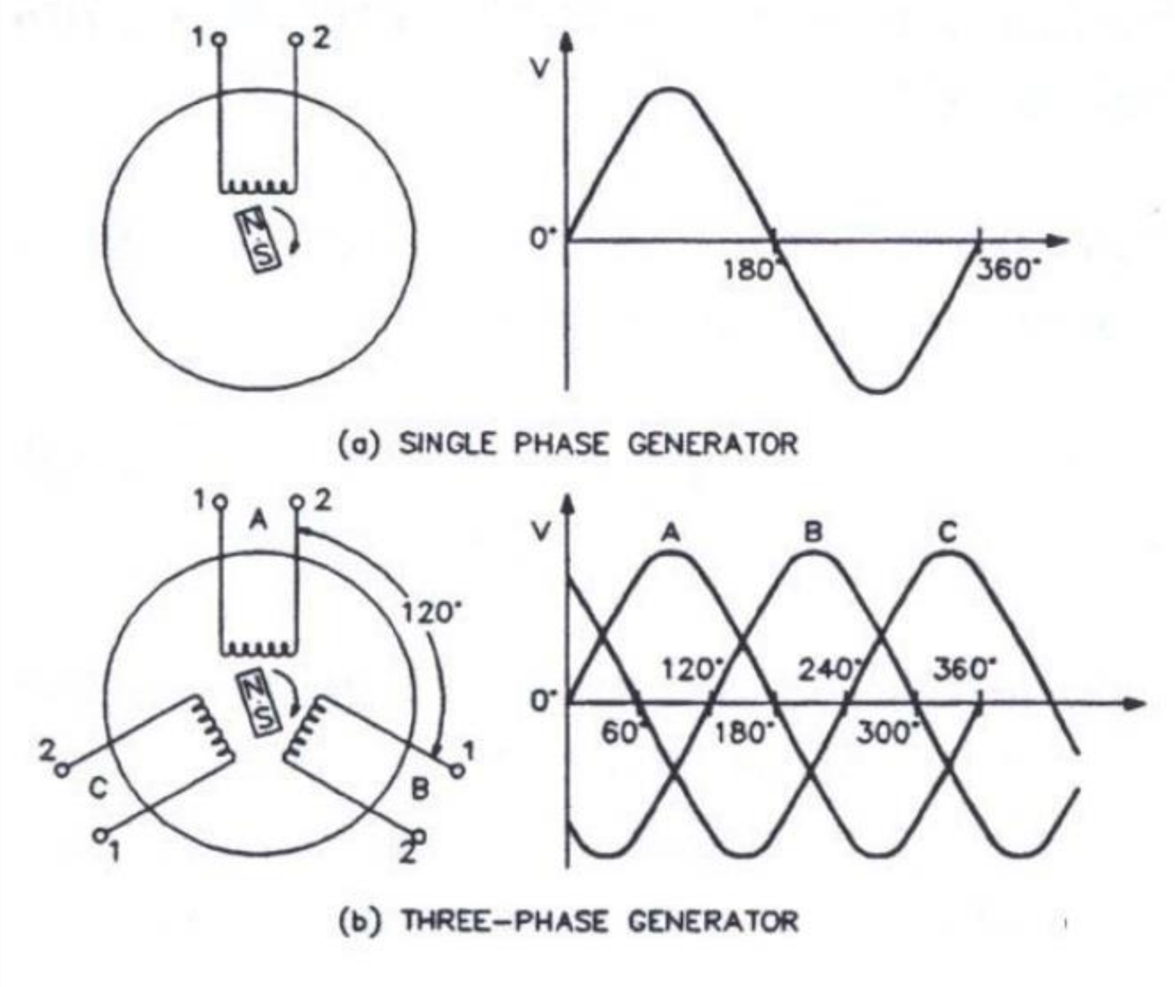
$$\Rightarrow \varepsilon = \varepsilon_0 \sin\omega t$$



3 Phase AC generator

According to Faraday's law of electromagnetic induction, when a conductor moves in a magnetic field, EMF gets induced across the conductor. If the closed circuit is provided to the conductor, induced emf causes current to flow in the circuit.
In a symmetric three-phase power supply system, three conductors each carry an alternating current of the same frequency and voltage amplitude relative to a common reference but with a phase difference of one third the period. The common reference is usually connected to ground and often to a current-carrying conductor called the neutral. Due to the phase difference, the voltage on any conductor reaches its peak at one third of a cycle after one of the other conductors and one third of a cycle before the remaining conductor. This phase delay gives constant power transfer to a balanced linear load. It also makes it possible to produce a rotating magnetic field in an electric motor and generate other phase arrangements using transformers.

DIFFERENCE BETWEEN SINGLE PHASE GENERATOR AND 3 PHASE GENERATOR



Voltage Output of a Three-Phase Generator

Application of AC Generator

Power Plants: These generators produce electricity for an entire region, including cities, towns, homes and businesses.

Agriculture: A power take-off generator uses a tractor's driveshaft as an input energy source. This is an example of a portable generator.

Aircraft: Large planes often use AC generators to provide power to onboard electrical systems. One type of system is called an aircraft ram air turbine generator, which harnesses air pressure created by the aircraft's flight to spin a turbine that is attached to a generator.

Airports: Aircraft starter generators and ground-support generators power aircraft when the engines shut down to operate onboard electrical systems.

Automotive Generators: Called alternators, these produce AC current that is transformed to DC current to run the vehicle's electronic systems. Vehicles with larger power requirements, like recreational vehicles, have larger generators.

Marine Generators: Using the ship's engines as an input energy source, these provide power to a ship's electrical systems.

Welding: Arc welding generators provide high output currents, measured in hundreds of amperes, to provide the electricity needed for arc welding equipment.

Numerical Problems

Question 1: Faraday's law:

A plane circular loop of conducting wire of radius r = 10 cm which possesses N = 15 turns is placed in a uniform magnetic field. The direction of the magnetic field makes an angle of 30 degrees with respect to the normal direction to the loop. The magnetic field-strength B is increased at a constant rate from *B1* = 1T to *B2* = 5T in a time interval of *Δt* = 10s. What is the emf generated around the loop? If the electrical resistance of the loop is R=15 ohm, what current flows around the loop as the magnetic field is increased?

Area of loop, $A = \pi r^2 = \pi (0.1)^2 = 0.0314\, m^2$

Component of magnetic fild perpendicular to loop is

$$B_\perp = B\cos\theta = B\cos 30^\circ = 0.866\, B$$

Initial Magnetic flux,

$$\phi_{B_1} = N A B_1 \cos\theta = 15 \times 0.0314 \times 1 \times 0.866 = 0.408\, Wb$$

Final Magnetic flux,

$$\phi_{B_2} = N A B_2 \cos\theta = 15 \times 0.0314 \times 5 \times 0.866 = 2.039\, Wb$$

Time rate of change of flux,

$$\frac{d\phi_B}{dt} = \frac{\phi_{B_2} - \phi_{B_1}}{\Delta t} = \frac{2.039 - 0.408}{10} = 0.163\, Wb\, s^{-1}$$

emf generated,

$$\mathcal{E} = \frac{d\phi_B}{dt} = 0.163\,V$$

Therefore, current which flows around the loop is

$$i = \frac{\mathcal{E}}{R} = \frac{0.163}{15} = 0.011\, A$$

Question 2: Lenz's law:

A long solenoid with an air core has *n1* = 400 turns per meter and a cross-sectional area of *A1* = 10 *cm2*. The current *I1* flowing around the solenoid increases from 0 to 50 A in 2.0 s. A plane loop of wire consisting of *N2* = 10 turns, which is of cross-sectional area *A2* = 100 *cm2* and resistance *R2* = 0.050 ohm, is placed around the solenoid close to its centre. The loop is orientated such that it lies in the plane perpendicular to the axis of the solenoid. What is the magnitude *E2* of the emf induced in the coil? What current *I2* does does this emf drive around the coil? Does this current circulate in the same direction as the current flowing in the solenoid, or in the opposite direction?

The magnetic flux Φ_B linking the whole coil is

$$\Phi_B = N_2 A_1 B$$

Magnitude of magnetic field generated by solenoid is

$$B = \mu_0 n_1 I_1$$

∴ Magnetic flux linking the coil is

$$\Phi_B = N_2 A_1 \mu_0 n_1 I_1$$

Time rate of change of magnetic flux is given by

$$\frac{d\Phi_B}{dt} = N_2 A_1 \mu_0 n_1 \frac{dI_1}{dt} = 10 \times 10 \times 10^{-4} \times 4\pi \times 10^{-7} \times 400 \times \frac{50}{2}$$

$$= 1.26 \times 10^{-4}\ \text{Wb s}^{-1}$$

EMF generated around the coil

$$\mathcal{E}_2 = -\frac{d\Phi_B}{dt} = -1.26 \times 10^{-4}\ \text{V}$$

Therefore, current induced is given by

$$I_2 = \frac{\mathcal{E}_2}{R_2} = \frac{-1.26 \times 10^{-4}}{0.05} = -2.6\ \text{mA}$$

i.e. I_2 flows in opposite direction of I_1

Question 3: AC generators:

A simple AC generator consists of an N = 10 turn coil of area A = 1200 cm^2 which rotates at a constant frequency of f = 60 Hz in a B = 0.40 T magnetic field. What is the peak emf of the device?

The peak emf $\mathcal{E}_{max}$ is given by $\mathcal{E}_{max} = NBA\omega$

$$\mathcal{E}_{max} = 2\pi NBA\nu = 6.283 \times 10 \times 0.4 \times 0.12 \times 60$$
$$= 180.95\,V \approx 181\,V$$

THANK YOU