8.5.4: Generator

Figure 19.4.1

These large machines are electric generators. This particular row of generators is installed in a hydroelectric power station. The insides of these generators are coils of wire spinning in a magnetic field. The relative motion between the wire and the magnetic field is what generates electric current. In all generators, some mechanical energy is used to spin the coil of wire in the generator. In the case of hydroelectric power, the coil of wire is spun by water falling from higher PE to lower PE. Windmills and steam turbines are used in other types of power generators to spin the coil.

Electric Generators

Electric generators convert mechanical energy to electric energy. The generator consists of some number of wire loops wrapped around an iron core and placed in a strong magnetic field. The loops of wire and the iron core are called the **armature**. The armature is mounted so that it can rotate freely inside the magnetic field. Mechanical energy is used to spin the armature in the field so that the wire loops cut across the field and produce electric current. The EMF of this current is calculated by $EMF = Blv$.

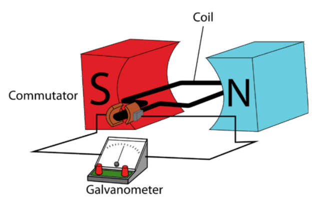


Figure 19.4.2

Consider the coil and magnetic field sketched above. When the right hand side of the coil moves up through the field, the left hand rule indicates that the electron flow will be from the front to the back in that side of the coil. The current generated will have the greatest EMF as the wire is cutting perpendicularly across the field. When the wire reaches the top of its arc, it is moving parallel to the field and therefore, not cutting across the field at all. The EMF at this point will be zero. As that same wire then cuts down through the field as it continues to spin, the left hand rule indicates that the electron flow will be from the back to the front in that side of the coil. In this second half of the arc, the direction of the electron flow has reversed. The magnitude of the EMF will reach maximum again as the wire cuts perpendicularly down through the field and the EMF will become zero again as the wire passes through the bottom of the arc. The current produced as the armature goes around will resemble a sine wave where the EMF reaches a maximum in one direction, then goes to zero, then goes to a maximum in the other direction. This type of current is called **alternating current**. By having more and more loops of wire on the armature, the crests and troughs overlap and fill in until a constant current is produced.

Diagram of a periodic wave

Figure 19.4.3

A **direct current** is one that always flows in the same direction rather than alternating back and forth. Batteries produce direct currents. A generator can also produce direct current by using a split ring commutator that changes external connections every half turn of the armature so that even though the current in the coil changes direction, every time the current in the coil changes direction, the external connection switches so that the external current always goes in the same direction.

Generators and motors are almost identical in construction but convert energy in opposite directions. Generators convert mechanical energy to electrical energy and motors convert electrical energy to mechanical.

Because of the alternating direction in alternating current, the average value is less than the power supplied by a direct current. In fact, the average power of an AC current is one-half its maximum power and one-half the power of an equivalent DC current. The effective current of an AC generator is 0.707 times its maximum current. The same is true for the effective voltage of an AC generator.

$$I_{eff}=0.707\ I_{max}$$

$$V_{eff}=0.707\ V_{max}$$

Example 19.4.1

An AC generator develops a maximum voltage of 34.0 V and delivers a maximum current of 0.170 A.

1. What is the effective voltage of the generator?
2. What is the effective current delivered by the generator?
3. What is the resistance in the circuit?

Solution

1. $V_{eff}=0.707\ V_{max}=(0.707)(34.0\ V)=24.0\ V$
2. $I_{eff}=0.707\ I_{max}=(0.707)(0.17\ A)=0.120\ A$
3. $R=V/I=24.0\ V/0.120\ A=200.\ \Omega$

Summary

- Electric generators convert mechanical energy to electric energy.
- The generator consists of some number of wire loops wrapped around an iron core and placed in a strong magnetic field.
- The loops of wire and the iron core are called the armature.
- The armature is mounted so that it can rotate freely inside the magnetic field.
- Mechanical energy is used to spin the armature in the field so that the wire loops cut across the field and produce electric current.
- The current produced as the armature goes around will resemble a sine wave where the EMF reaches a maximum in one direction, then goes to zero, then goes to a maximum in the other direction. This type of current is called alternating current.
- A generator can also produce direct current by using a split ring commutator that changes external connections every half turn of the armature so that even though the current in the coil changes direction, every time the current in the coil changes direction, the external connection switches so that the external current always goes in the same direction.
- The effective current of an AC generator is 0.707 times its maximum current.
- The effective voltage of an AC generator is 0.707 times its maximum voltage.

Review

1. What three things are necessary to produce EMF mechanically?
    1. magnet, force lines, and magnetic field
    2. EMF, conductor, and magnetic field
    3. conducting wire, magnetic field, and relative motion
    4. conducting wire, electrical field, and relative motion
    5. none of these will produce EMF mechanically
2. Increasing which of the following will increase the output of a generator?
    1. EMF
    2. strength of the magnetic field
    3. resistance of the conductor
    4. load on the meter
    5. none of these
3. The current in the rotating coil of all generators is
    1. AC

    2. DC
    3. pulsating AC
    4. pulsating DC
4. A generator in a power plant develops a maximum voltage of 170. V.
    1. What is the effective voltage?
    2. A 60.0 W light bulb is placed across the generator. A maximum current of 0.70 A flows through the bulb. What effective current flows through the bulb?
    3. What is the resistance of the light bulb when it is working?
5. The effective voltage of a particular AC household outlet is 117 V.
    1. What is the maximum voltage across a lamp connected to the outlet?
    2. The effective current through the lamp is 5.50 A. What is the maximum current in the lamp?

Explore More

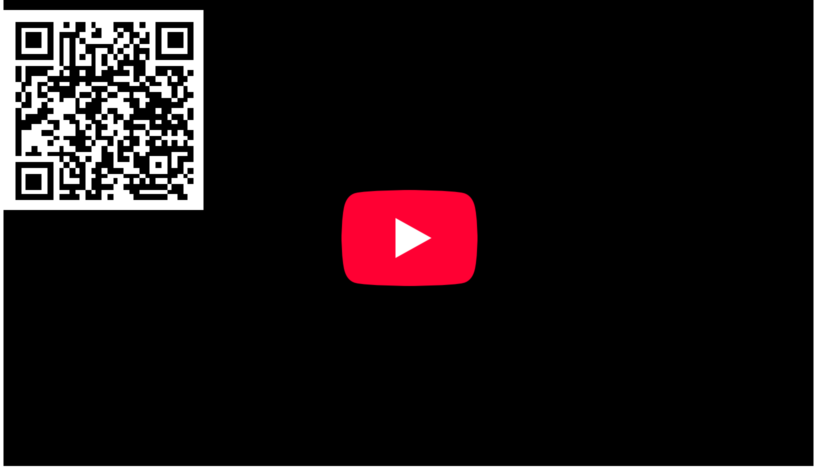
Use this resource to answer the questions that follow.

1. Which of the two generators in the video (an AC generator and a DC generator) involves a magnetic field?
2. Which of the two generators in the video involves a wire-wrapped armature?
3. What is the difference between the DC generator and the AC generator?

Additional Resources

Real World Application: Faraday Flashlight

Videos:



Study Guide: Magnetism Study Guide