How Electric Motors and Generators Work

Learn How They Generate Power for Electric Cars & Hybrids

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Electric vehicles rely exclusively on electric motors for propulsion, and hybrids use electric motors to assist their internal combustion engines for locomotion. But that's not all. These very motors can be, and are, used to generate electricity (through the process of regenerative braking) for charging these vehicles' onboard batteries.

The most common question is: "How can that be ... how does that work?" Most folks understand that a motor is powered by electricity to do work—they see it every day in their household appliances (washing machines, vacuum cleaners, food processors).

But the idea that a motor can "run backward," actually generating electricity rather than consuming it seems almost like magic. But once the relationship between magnets and electricity (electromagnetism) and the concept of conservation of energyis understood, the mystery disappears.

Electromagnetism

Motor power and electricity generation begin with the property of electromagnetism—the physical relationship between a magnet and electricity. An electromagnet is a device that acts like a magnet, but its magnetic force is manifested and controlled by electricity.

When wire made of conducting material (copper, for example) moves through a magnetic field, current is created in the wire (a rudimentary generator). Conversely, when electricity is passed through a wire that is wound around an iron core, and this core is in the presence of a magnetic field, it will move and twist (a very basic motor).

Motor/Generators

Motor/generators are really one device that can run in two opposite modes. Contrary to what folks sometimes think, that does not mean that the two modes of the motor/generator run backward from each other (that as a motor the device turns in one direction and as a generator, it turns the opposite direction).

The shaft always spins the same way. The "change of direction" is in the flow of electricity. As a motor, it consumes electricity (flows in) to make mechanical power, and as a generator, it consumes mechanical power to produce electricity (flows out).

Electromechanical Rotation

Electric motor/generators are generally one of two types, either AC (Alternating Current) or DC (Direct Current) and those designations are indicative of the type of electricity that they consume and generate.

Without getting into too much detail and clouding the issue, this is the difference: AC current changes direction (alternates) as it flows through a circuit. DC currents flow uni-directionally (stays the same) as it goes through a circuit.

The type of current utilized is concerned mostly with the cost of the unit and its efficiency (An AC motor/generator is generally more expensive, but is also much more efficient). Suffice it to say that most hybrids and many larger all-electric vehicles use AC motor/generators—so that is the type we'll focus on in this explanation.

An AC Motor/Generator Consists of 4 Main Parts:

- A shaft-mounted wire wound armature (rotor)
- A field of magnets that induce electrical energy stacked side-by-side in a housing (stator)
- Slip rings that carry the AC current to/from the armature
- Brushes that contact the slip rings and transfer current to/from the electrical circuit

The AC Generator in Action

The armature is driven by a mechanical source of power (for example, in commercial electric power production it would be a steam turbine). As this wound rotor spins, its wire coil passes over the permanent magnets in the stator and an electric current is created in the wires of the armature.

But because each individual loop in the coil passes first the north pole then the south pole of each magnet sequentially as it rotates on its axis, the induced current continually, and rapidly, changes direction. Each change of direction is called a cycle, and it is measured in cycles-per-second or hertz (Hz).

In the United States, the cycle rate is 60 Hz (60 times per second), while in most other developed parts of the world it is 50 Hz. Individual slip rings are fitted to each of the two ends of the rotor's wire loop to provide a path for the current to leave the armature. Brushes (which are actually carbon contacts) ride against the slip rings and complete the path for the current into the circuit to which the generator is attached.

The AC Motor in Action

Motor action (supplying mechanical power) is, in essence, the reverse of generator action. Instead of spinning the armature to make electricity, current is fed by a circuit, through the brushes and slip rings and into the armature. This current flowing through the coil wound rotor (armature) turns it into an electromagnet. The permanent magnets in the stator repel this electromagnetic force causing the armature to spin. As long as electricity flows through the circuit, the motor will run.