

ELECTRIC MOTOR



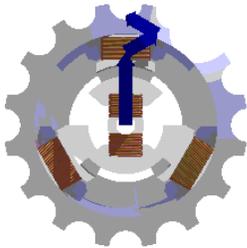
Electric motors of various sizes.

An electric motor converts electrical energy into mechanical motion.

Device references

The reverse task, that of converting mechanical motion into electrical energy, is accomplished by a generator or dynamo. In many cases the two devices differ only in their application and minor construction details, and some applications use a single device to fill both roles. For example, traction motors used on locomotives often perform both tasks if the locomotive is equipped with dynamic brakes.

Principle of operation



Rotating magnetic field as a sum of magnetic vectors from 3 phase coils.

Most electric motors work by electromagnetism, but motors based on other electromechanical phenomena, such as electrostatic forces and the piezoelectric effect, also exist. The fundamental principle upon which electromagnetic motors are based is that there is a mechanical force on any wire when it is conducting electricity while contained within a magnetic field. The force is described by the Lorentz force law and is perpendicular to both the wire and the magnetic field.

Most magnetic motors are rotary, but linear types also exist. In a rotary motor, the rotating part (usually on the inside) is called the rotor, and the stationary part is called the stator. The rotor rotates because the wires and magnetic field are arranged so that a torque is developed about the rotor's axis. The motor contains electromagnets that are wound on a frame. Though this frame is often called the armature, that term is often erroneously applied. Correctly, the armature is that part of the motor across which the input voltage is supplied. Depending upon the design of the machine, either the rotor or the stator can serve as the armature.

DC motors

One of the first electromagnetic rotary motors was invented by Michael Faraday [[1]] in 1821 and consisted of a free-hanging wire dipping into a pool of mercury.

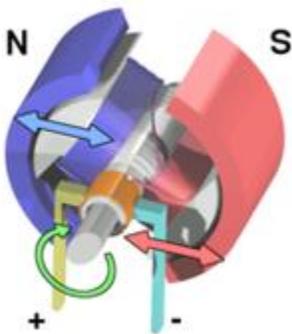
A permanent magnet was placed in the middle of the pool. When a current was passed through the wire, the wire rotated around the magnet, showing that the current gave rise to a circular magnetic field around the wire. This motor is often demonstrated in school physics classes, but brine is sometimes used in place of the toxic mercury. This is the simplest form of a class of electric motors called homopolar motors. A later refinement is the Barlow's Wheel [[2]].

Another early electric motor design used a reciprocating plunger inside a switched solenoid; conceptually it could be viewed as an electromagnetic version of a two stroke internal combustion engine.

The modern DC motor was invented by accident in 1873, when Zénobe Gramme [[3]] connected a spinning dynamo to a second similar unit, driving it as a motor.

The classic DC motor has a rotating legature in the form of an electromagnet.

A rotary switch called a commutator reverses the direction of the electric current twice every cycle, to flow through the armature so that the poles of the electromagnet push and pull against the permanent magnets on the outside of the motor. As the poles of the armature electromagnet pass the poles of the permanent magnets, the commutator reverses the polarity of the armature electromagnet. During that instant of switching polarity, inertia keeps the classical motor going in the proper direction. (See the diagrams below.)



A simple DC electric motor. When the coil is powered, a magnetic field is generated around the armature. The left side of the armature is pushed away from the left magnet and drawn toward the right, causing rotation.

The armature continues to rotate.

When the armature becomes horizontally aligned, the commutator reverses the direction of current through the coil, reversing the magnetic field. The process then repeats.

Wound field DC motor

The permanent magnets on the outside (stator) of a DC motor may be replaced by electromagnets. By varying the field current it is possible to alter the speed/torque ratio of the motor. Typically the field winding will be placed in series (series wound) with the armature winding to get a high torque low speed motor, in parallel (shunt wound) with the armature to get a high speed low torque motor, or to have a winding partly in parallel, and partly in series (compound wound) for a balance that gives steady speed over a range of loads. Further reductions in field current are possible to gain even higher speed but correspondingly lower torque, called "weak field" operation.

Speed control

Generally speaking the rotational speed of a DC motor is proportional to the voltage applied to it, and the torque is proportional to the current. Speed control can be achieved by variable battery tapplings, variable supply voltage, resistors or electronic controls. The direction of a wound field DC motor can be changed by reversing either

the field or armature connections but not both, this is commonly done with a special set of contactors (direction contactors).

Effective voltage can be varied by inserting a series resistor or by an electronically-controlled switching device made of thyristors, transistors, or, historically, mercury arc rectifiers. In a circuit known as a chopper, the average voltage applied to the motor is varied by switching the supply voltage very rapidly. As the "on" to "off" ratio is varied to alter the average applied voltage, the speed of the motor varies. The rapid switching wastes less energy than series resistors. Output filters smooth the average voltage applied to the motor and reduce motor noise.

Since the series-wound DC motor develops its highest torque at low speed, it is often used in traction applications such as electric locomotives, and trams.

Universal motors

A variant of the wound field DC motor is the universal motor. The name derives from the fact that it may use AC or DC supply current, although in practice they are nearly always used with AC supplies. The principle is that in a wound field DC motor the current in both the field and the armature (and hence the resultant magnetic fields) will alternate (reverse polarity) at the same time, and hence the mechanical force generated is always the same. In practice the motor must be specially designed to cope with the AC current (impedance must be taken into account), and the resultant motor is generally less efficient than an equivalent pure DC motor. The maximum output of universal motors is limited, and motors exceeding one kilowatt are rarely operated on commercial power frequency.

The advantage of the universal motor is that AC supplies may be used on motors which have the typical characteristics of DC motors, specifically high starting torque and very compact design if high running speeds are used. The negative aspect is the maintenance and short life problems caused by the commutator. As a result such motors are usually used in AC devices such as food mixers and power tools which are only used intermittently. Continuous speed control of a universal motor running on AC is very easily accomplished using a thyristor circuit while stepped speed control can be accomplished using multiple taps on the field coil. Household blenders that

advertise many speeds frequently combine a field coil with several taps and a diode that can be inserted in series with the motor (causing the motor to run on half-wave DC with half the RMS voltage of the AC power line).

Unlike AC motors, universal motors can easily exceed one revolution per cycle of the mains current. This makes them useful for appliances such as blenders, vacuum cleaners, and hair dryers where high-speed operation is desired. Many vacuum cleaner and weed trimmer motors will exceed 10,000 RPM, Dremel and other similar miniature grinders will often exceed 30,000 RPM. A universal motor allowed to operate with no mechanical load will overspeed, which may damage it.

With the very low cost of semiconductor rectifiers, some applications that would have previously used a universal motor now use a pure DC motor, usually with a permanent magnet field. This is especially true if the semiconductor circuit is also used for variable-speed control.

The advantages of the universal motor and alternating-current distribution made installation of a low-frequency traction current distribution system economical for some railway installations.

AC motors