

Alternators

Brushless

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The author prepares to repair a Dunlite BL, 2 KW wind generator that uses a brushless, 3-phase alternator.

Several different technologies are used in the generator portion of wind turbines (wind generators). One of the older, more reliable technologies is the brushless DC alternator. Its operation is often poorly understood by the owners, and in some cases, poorly described by the manufacturers. I'm not an expert on brushless alternators, but when I acquired some damaged Dunlite wind turbines, I became seriously interested in how they work.

Basic Theory

When an electric current is passed through a coil of wire, a magnetic field is produced (an electromagnet). Conversely, when a magnetic field is moved through a coil of wire, an electric current is produced in the wire. Both of these actions take place in alternators, motors, and generators or dynamos.

The stationary part of a motor or alternator is called the stator and the rotating part is called the rotor. The coils of wire that are used to produce a magnetic field are called the field, and the coils that produce electricity are called the armature. The coils of wire are sometimes referred to as the “windings.”

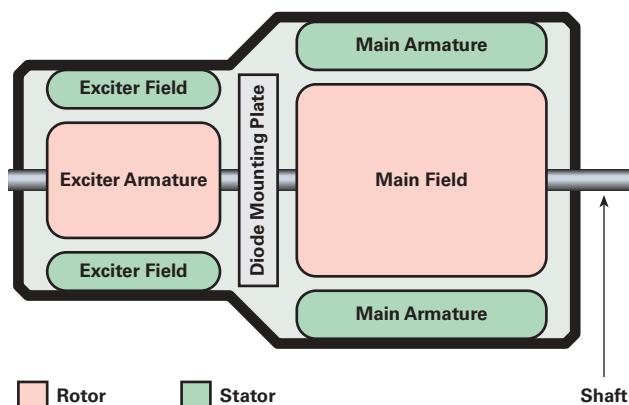
Electrical energy is generated when a coil of wire is moved through a magnetic field. It doesn't matter whether the coil is moving or the magnetic field is moving. Either configuration works equally well, and both are used separately or in combination depending on mechanical, electrical, and other objectives. The old DC generators (dynamos) used a stationary field and rotating armature. Automotive alternators use the opposite configuration—a rotating field and stationary armature. In a brushless alternator, both configurations are used in one machine.

Construction

A brushless alternator is composed of two alternators built end-to-end on one shaft. Smaller brushless alternators may look like one unit, but the two parts are readily identifiable on the large versions. The larger of the two sections is the main alternator and the smaller one is the exciter.

The exciter has stationary field coils and a rotating armature (power coils). The main alternator uses the opposite configuration with a rotating field and stationary armature. This configuration is required to implement brushless technology without using permanent magnets. Eliminating the brushes eliminates brush and slip ring wear and maintenance. The only moving parts subject to wear in the basic alternator are the bearings.

Brushless Alternator Configuration



Alternator Terminology

The parts of an alternator or related equipment can be expressed in either mechanical terms or electrical terms. These two sets of terminology are frequently used interchangeably or in combinations that include one mechanical term and one electrical term. This causes great confusion when working with compound machines such as a brushless alternator, or when conversing with people who are used to working on a machine that is configured differently than the machines that the speaker is used to.

Mechanical

Rotor: The rotating part of an alternator, generator, dynamo, or motor.

Stator: The stationary part of an alternator, generator, dynamo, or motor.

Electrical

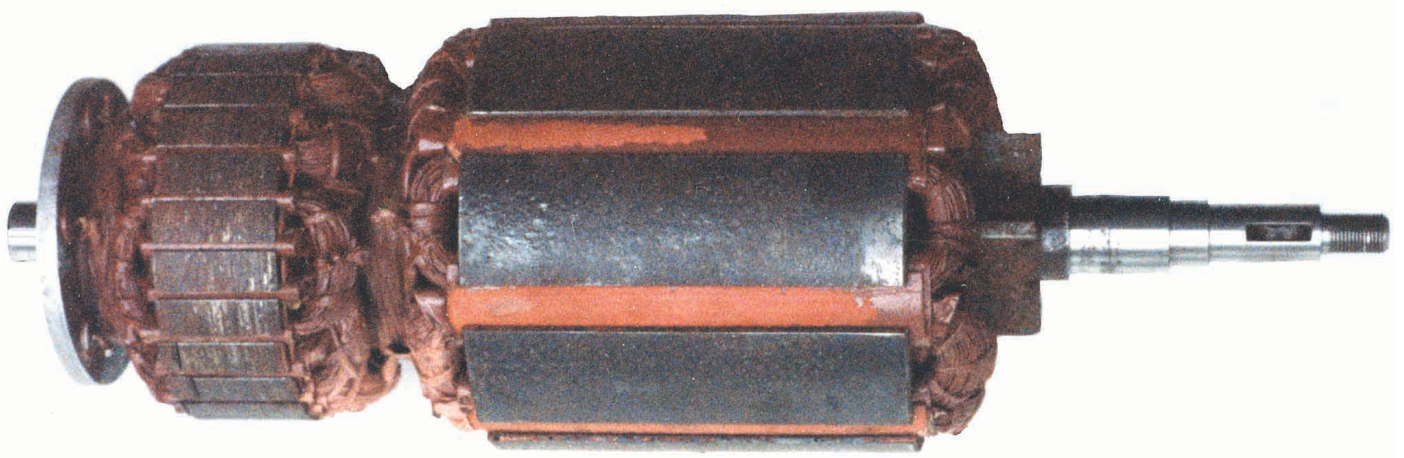
Armature: The power-producing component of an alternator, generator, dynamo, or motor. The armature can be on either the rotor or the stator.

Field: The magnetic field component of an alternator, generator, dynamo, or motor. The field can be on either the rotor or the stator, and can be either an electromagnet or a permanent magnet.

Although rugged and reliable, brushless alternators are expensive to manufacture and therefore were only used in premium quality wind turbines. The high cost of production puts them solidly in the industrial grade category. With the advent of powerful, cheap permanent magnets, the residential-sized wind industry has switched to the cheaper permanent magnet alternator (PMA) technology. Brushless alternators are also used extensively in large engine-driven power plants and in utility-sized power generation.

Exciter

The exciter field coils are on the stator, and its armature is on the rotor. The AC output from the exciter armature is fed through a set of diodes that are also mounted on the rotor to produce a DC voltage. This is fed directly to the field coils of the main alternator, which are also located on the rotor. With this arrangement, brushes and slip rings are not required to feed a current to the rotating field coils. This can be contrasted with a simple automotive alternator, where brushes and slip rings are used to supply a current to the rotating field.



The rotor of a brushless alternator: The smaller section at left is the exciter armature; the larger section at right is the main alternator field. The diodes are mounted on the aluminum disk at the left end.

Main Alternator

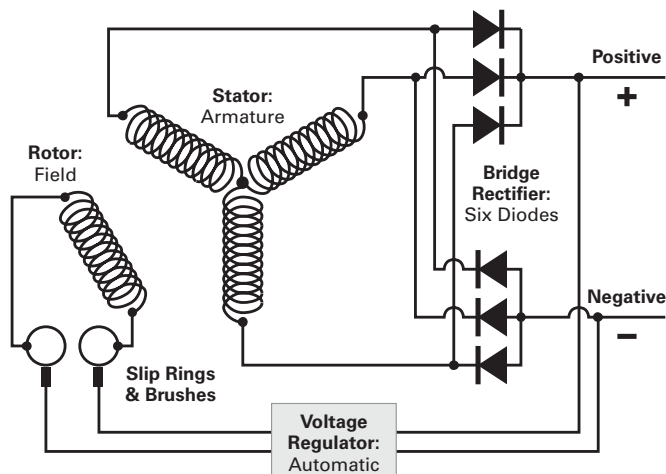
The main alternator has a rotating field as described above and a stationary armature (power generation windings). With the armature in the stationary portion of the alternator, the high current output does not have to go through brushes and slip rings. Although the electrical design is more complex, it results in a very reliable alternator because the only parts subject to wear are the bearings.

Control System

Varying the current through the stationary exciter field coils controls the strength of the magnetic field in the exciter. This in turn controls the output from the exciter. The exciter output is fed into the rotating field of the main alternator to supply the magnetic field for it. The strength of the magnetic field in the main alternator then controls its output.

The result of all this is that a small current in the field of the exciter indirectly controls the output of the main alternator, and none of it has to go through brushes and slip rings.

Automotive Alternator



In a wind generator, this means that the loading can be matched to the speed, unlike in a permanent magnet alternator. Although some of the wind generator's output is used to generate the magnetic field, there is no cogging effect, so low wind start-up characteristics are improved.

Automatic Voltage Regulator

An automatic voltage regulator (AVR) serves the same function as the voltage regulator in an automobile or the charge controller in a solar-electric system. It measures the battery voltage and uses that information to adjust the level of current fed into the field coil. As the battery voltage goes down, the AVR increases the current to the field coils to produce a stronger magnetic field.

The stronger magnetic field causes a higher output from the alternator to bring the battery voltage back up to the set point. Conversely, when the voltage rises too high, the field current is decreased, lowering the output from the alternator.

Variations

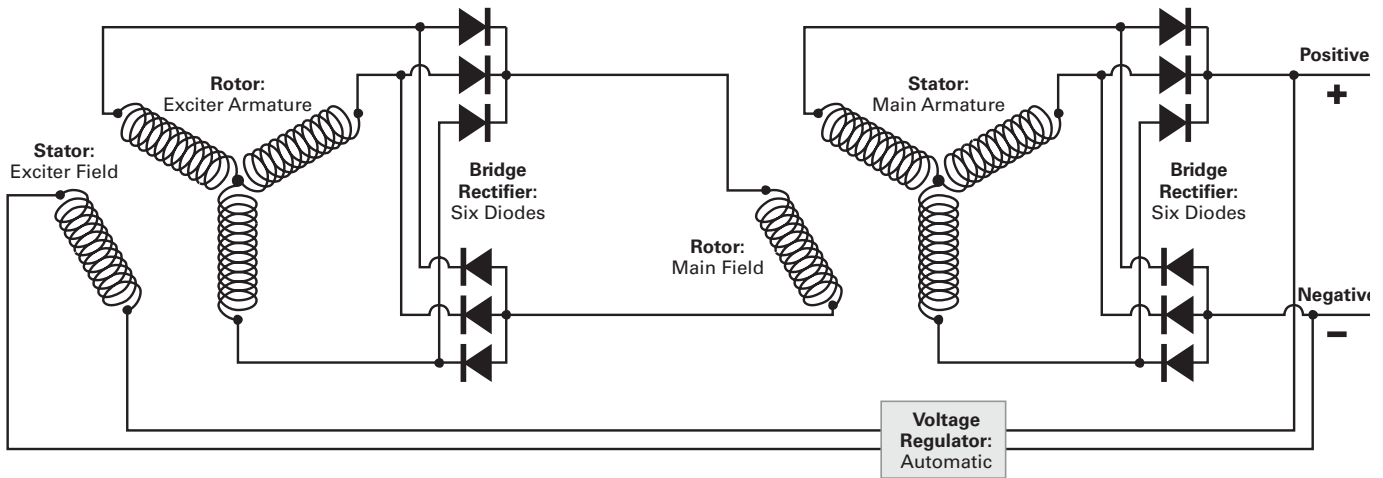
As with any other electronic or electrical device, there can be numerous variations in the design. The Dunlite 2 KW wind machines use an auxiliary winding on the main stator to generate the voltage for the exciter field. These machines rely on residual magnetism to excite the auxiliary winding, while some machines use permanent magnets for this purpose.

On the Dunlite machines, both the exciter and main field coils use eight poles. (Three phases, multiplied by eight poles, is twenty-four coils of wire.) The exciter armature is wound in a three-phase, four-wire wye (star) configuration, and the main armature is a three-phase, three-wire delta design.

Three-Phase Basics

A three-phase alternator has a minimum of three sets of windings, spaced 120 degrees apart around the stationary armature (stator). As a result, there are three outputs from

Brushless, 3-Phase Alternator



the alternator, and they are electrically spaced 120 degrees out of phase with each other. A multi-pole design will have multiple sets of three windings. The more poles there are, the slower the alternator turns for a given voltage and frequency.

More poles increase the complexity of the alternator, and that in part accounts for the higher price of slow speed versions. Other than in single-phase power plants, most alternators, including the automotive type, generate three-phase power. A three-phase AC alternator will not have any diodes in it.

If the output is DC, it will probably have six diodes to convert the output from the main alternator to DC. This is the configuration used in automotive alternators. A three-phase brushless alternator may have four or six diodes on the rotor for the exciter output in addition to the diodes that may be on the stator.

There are two ways that three-phase machines can be wired. One is the delta (triangle) configuration, with one

wire coming off each "point of the triangle." The other is the wye (Y) or star configuration. They have one wire from each branch of the Y and a fourth common wire is added from the center point of the Y (the common connection point between the windings). Multiple voltage machines will have additional wires to allow them to be configured for the desired system voltage.

If you ever have to service an old wind turbine with a brushless alternator, this brief description may help you to understand how it works, or at least let you talk the same language as the repair shop.

Access

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See "Yer Basic Alternator,"

Bob-O Schultze, *HP20*, available in print or on the *Solar2 CD*.



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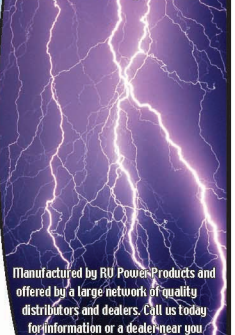


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