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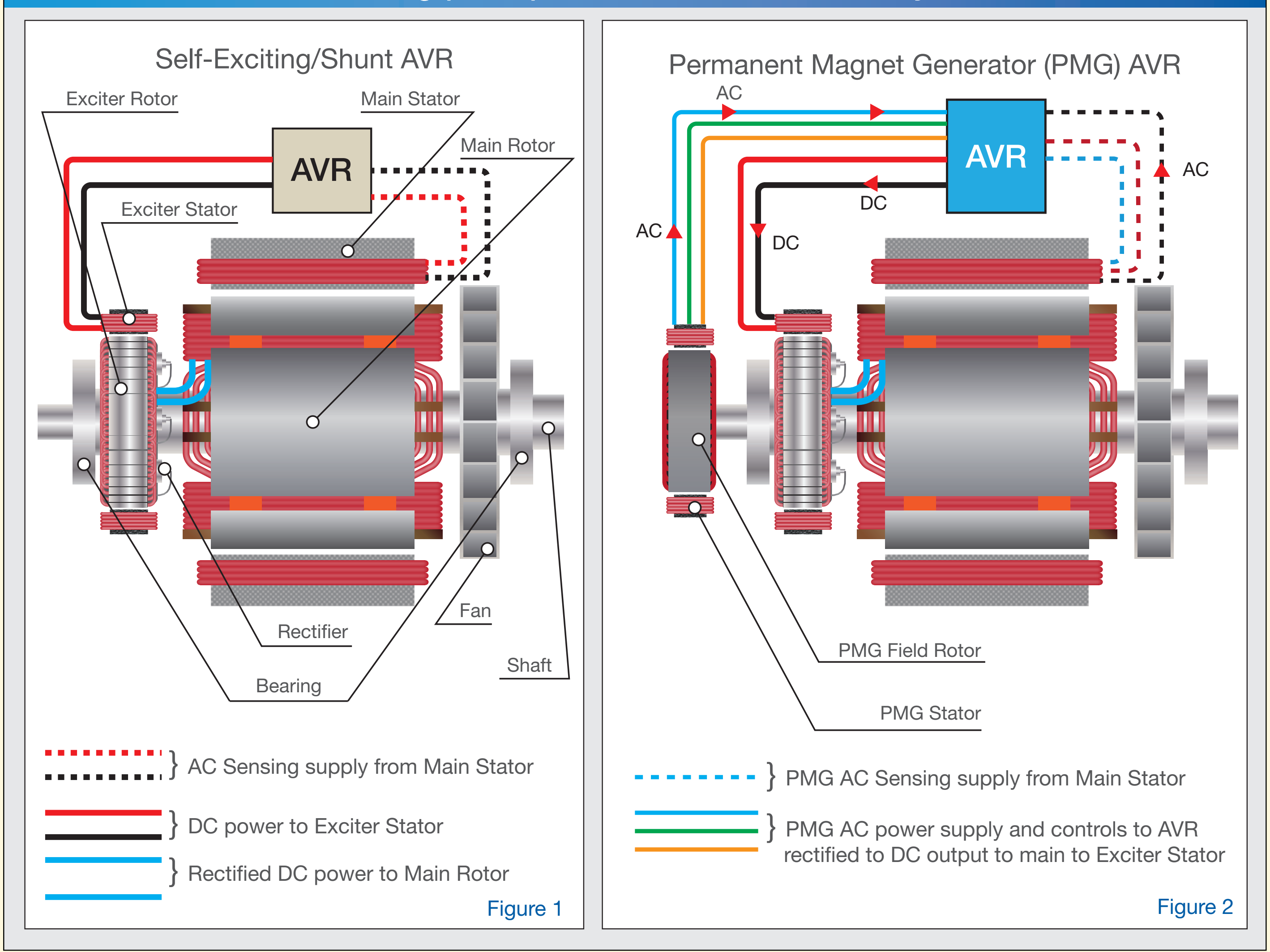
Automatic Voltage Regulators, commonly known as AVRs, are an essential component of an engine-driven generator system. Generator systems, whether used in prime or standby power applications, will be used to power electrical equipment designed and nameplate-rated for connection to a power source having voltage and frequency stabilization with a certain range. Most electrical equipment is designed to operate within the voltage and frequency provided by the Utility Grid. Generator Systems must provide at least the output voltage and frequency compatible with the Grid output. The sizing of a generator system, particularly when much of the load is electric motors, will depend on the engine's mechanical kWs and the system's ability to maintain voltage and frequency stabilization when the load is applied. This information sheet discusses the operation of an AVR, how it provides stable voltage through various loads, and different types of AVRs that are used for loads that demand a greater degree of voltage stabilization.

1.0 DEFINITION OF AN AVR:

An Automatic Voltage Regulator (AVR) is an electrical device fitted to a generator system, usually mounted to the generator. It maintains a constant stable voltage output to electrical equipment connected to the generator output terminals. The AVR ensures voltage variations the load can induce on a generator's output are countered to ensure constant rated voltage through all changes of the connected load. For example, when it starts, an electric motor pulls greater amps than running amps; the AVR function is to maintain voltage output by boosting excitation, even during the starting period of the motor.

To understand the importance of stable voltage output, refer to the information sheet titled: *"Automatic Voltage Regulator and the Need for Generator Voltage Stability".*

Self-Exciting (Shunt) and PMG AVR Excitation Systems



The installation information provided in this information sheet is informational in nature only, and should not be considered the advice of a properly licensed and qualified electrician or used in place of a detailed review of the applicable National Electric Codes and local codes. Specific questions about how this information may affect any particular situation should be addressed to a licensed and qualified electrician.

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2.0 GENERATOR SYSTEM VOLTAGE OUTPUT:

On an engine-driven generator system, the power output is a function of the engine-rated horsepower at a constant speed, usually in North America at 1800 rpm, and the size of the connected generator (alternator) being turned to produce an equivalent electrical kWe output compatible to engine's rated horsepower. The amount of horsepower to kWe generator output depends on the efficiency of the generator, usually between 88 and 92 percent. kW equals H.P. times 0.746.

Usually, generator systems have brushless alternators, with the power derived from the stator, the static component, and the rotor being the magnetic field. For further details, see the information sheet: "*Generator 101 Part 2 Generator Single and Three Phase Formulas*". Electrical power is produced as follows:

2.1 FARADAY'S LAW:

Faraday's law of generation states that when a wire is rotated in a magnetic field, an electromotive force (EMF) is induced into the wire. Therefore, the degree of power will depend on the strength of the magnetic field. Power is a function of amps (I) times volts (V). In a brushless generator, the EMF is induced into the stator, and the magnetic field is the rotor.

See the information sheet: "*Generator System 101 (Part 3) Advantages of a Brushless Generator*".

2.2 OUTPUT VOLTAGE:

Voltage output is dependent on the coil configuration wound into the stator. As per Faraday's law, the amount of electro-motive force induced into the stator coils is dependent on the strength of the magnetic field generated in the rotor.

3.0 ROTATING ELECTROMAGNETIC FIELD IN A BRUSHLESS GENERATOR:

To generate electricity, a magnetic field is required. A permanent magnet could be used, but manufacturers of brushless generators prefer to use an electromagnet with DC power energizing the magnetic field. This preference has two reasons:

1. The strength of permanent magnet decreases over time.
2. The strength of an electromagnet field can be varied by controlled changes in the DC input to the electromagnet.

The electromagnetic component of the rotor is made from steel laminations. As DC current travels through the rotor coils, a magnetic field is created around the core. As the magnetic rotating field rotates, an EMF is induced into the stator windings.

4.0 OPERATION OF AN AVR ON A SELF-EXCITED GENERATOR:

The AVR controls the voltage output on a rotating field generator by adjusting the magnetism, or excitation, within the rotor.

The AVR senses the AC voltage across the generator terminals. This voltage is then, by electronics, compared to a preset stable reference output voltage. The reference will be set in accordance with the nameplate rating of the generator.

When a variation between the actual terminal voltage and the predetermined reference voltage is detected, the AVR automatically adjusts the rotor's DC field current and the excitation level. Should the AC terminal voltage be too high, the DC field current will be reduced, and when it is too low, the DC field current is increased.

5.0 EXCITATION COMPONENT OF SELF-EXCITED GENERATOR:

In a self-excited generator, the AVR receives its AC input from the stator windings. As the generator runs up to speed, the AC input will increase, and the AVR will continue to feed DC power to the exciter until full voltage is reached.

The excitation component of a self-excited generator is additional AC generator windings on the rotor and additional energized DC magnetic coils fitted to the stator; the AVR feeds DC output to the exciter stator. An exciter is a generator within a generator; an AC current is induced into the exciter rotor coils as they rotate within the exciter stator. The exciter rotor AC output is converted to DC current using a rotating diode assembly. This DC current is fed into the main generator's rotating coils to create the rotating magnetic field. Excitation and strength of the magnetic field are dependent on the level of DC current fed into the field by the AVR.

As stated, the AVR controls output voltage by varying the DC power to the stator exciter coils, which induces AC power in the rotor exciter coils; this AC power is then rectified to DC and fed into the rotor magnetic field coils. ***See Figure 1.***

6.0 OTHER TYPES OF AVR FOR INDUCTIVE LOADS:

A shunt or Self-Excited AVR is the most straightforward and most economical solution. With pure linear or non-inductive loads, it is the best choice. However, with inductive loads, such as electric motors, as the load increases, the voltage starts to decrease, requiring the AVR to provide more current to the exciter to maintain the rated voltage. When electric motors start, they can push the Self-Excited AVR to its limits, which can result in a collapse of the excitation field. *See the information sheet on PMG AVRs*

The most common AVR solution for a high percentage of inductive loads is a Permanent Magnet Generator (PMG) AVR. A PMG permanent magnet is mounted on the driven end of the generator shaft. PMG supplies isolated power to the AVR when the generator shaft rotates. When the generator experiences a high demand as electric motors start or any other inductive load, the AVR utilizes the extra power generated by the PMG to avoid the collapse of the exciter field. ***See Figure 2.***

In addition to Self-Exciting and PMG, there are two other types of AVR. Some large Marine and Industrial generator applications have an additional single-phase winding in the stator, and as the rotor rotates, additional EMF voltage induced into the winding boosts the AVR. The other example is an Excitation Boost Generator (EBG) that, through an Excitation Boost Control (EBC) module and Excitation Boost Generator (EBG), is mounted like a PMG. The EBG supplies power to the EBC controller, which can boost excitation when required. It improves excitation for motor-starting, is not as versatile as PMG, but is less expensive.

To fulfill our commitment to be the leading supplier in the power generation industry, the Buckeye Power Sales team ensures they are always up-to-date with the current power industry standards as well as industry trends. As a service, our Information Sheets are circulated on a regular basis to existing and potential power customers to maintain their awareness of changes and developments in standards, codes and technology within the power industry.