EXPLANATION OF SELF-EXCITATION IN BRUSHLESS GENERATOR SYSTEMS

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Most generator system manufacturers use brushless rotating field generators in their engine-driven generator systems. The advantages of a rotating generator are covered in our information sheet, Generator System 101 (Part 3) Advantages of a Brushless Generator. However, this sheet covers why self-excited brushless generators have become the industry standard. The other term for self-excited generators is shunt excitation. A generator system has to produce power to match the frequency and voltage output of the electrical grid system. Generators must also provide their connected electrical loads with the same frequency and voltage stability they were designed to receive from the grid. Automatic Voltage Regulators (AVRs) are used to achieve voltage stability between loads. This information sheet discusses AVR systems that receive their reference voltage directly from the brushless generator's main stator, a system referred to as "Self-Excitation" or "Shunt Excitation." It also covers the advantages and disadvantages of this system.

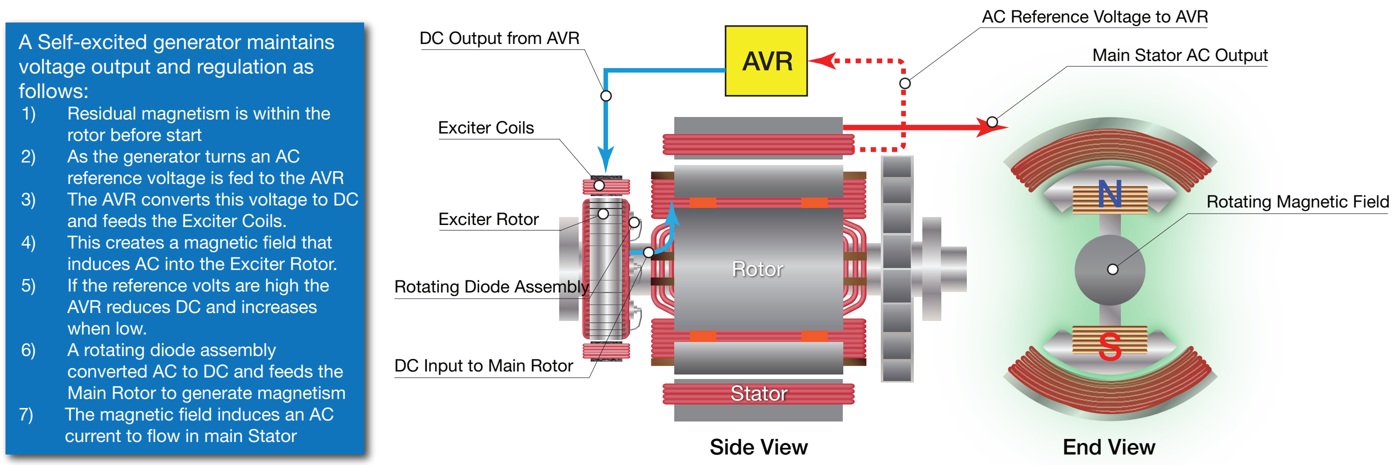
1.0 RECAP ON AVR OPERATION AND EXCITATION:

The information sheet *"Generator Series 101 (Part 5) Principals of Excitation and Electro-Magnetism"* covers how generator output voltage is regulated by an Automatic Voltage Regulator (AVR) and how excitation in a brushless generator is the process of creating a magnetic field in the rotor coils that, per Faraday's law, induces an Electro Magnetic Force (EMF) to flow in the stator windings *(Continued over)*

Self-Excited Brushless Generator and Voltage Drop When Electric Motors Start

Figure 1

Self-excited (Shunt) Excitation System for a Brushless Generator



Within Range Normal Voltage Drop on Start

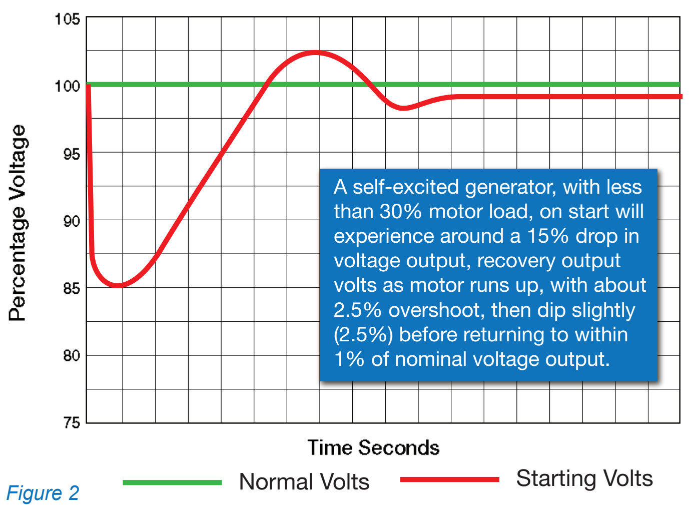


Figure 2

Excessive Voltage Drop & Excitation Collapse

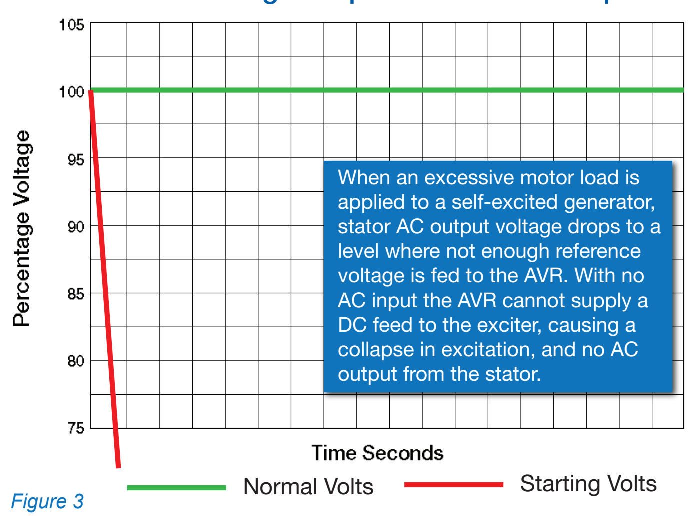


Figure 3

1.0 RECAP ON AVR OPERATION AND EXCITATION (CONTINUED):

As covered in the previous sheet, the AVR receives a reference voltage from the generator's AC output; this is compared with the alternator's specified nominal AC output. Using the reference voltage input, the AVR controls the stator's AC voltage output by varying the voltage to the exciter coils. When the reference voltage is above nominal, the AVR reduces the voltage sent to the exciter to reduce the magnetic field and AC output. When the reference voltage is lower than nominal, the AVR increases the voltage to the exciter to boost the magnetic field, increasing stator AC voltage output. It's like an electrical governor. *(Continued over)*

2.0 EXPLANATION OF A SELF-EXCITING GENERATOR SYSTEM:

As covered, the AVR requires a reference voltage to regulate the field windings' excitation by constantly comparing its value to a set nominal voltage output. The stator's AC output is the most straightforward source for a reference voltage. Utilizing an AC feed from the generator's stator AC output gives the term self-excitation because the generator is regulating its output voltage by monitoring its own output voltage; there are no other sources of AC input to the AVR. This method of excitation is also called "Shunt Excitation." See ***Figure 1*** depicting the Self-Excited Generator

3.0 PROS OF A SELF-EXCITING GENERATOR SYSTEM:

Self-excitation is the most basic of excitation systems and by far the most commonly employed on generators for power generation. While there are disadvantages that will be covered, the following pros are why this system is very common:

3.1 SIMPLICITY:

A simple tap to the stator's AC output provides the reference voltage. No other components or moving parts are required.

3.2 LOW COST:

Other forms of excitation, covered in other information sheets, require more components and complexity.

3.3 COMPACT:

Only an internal tap to provide a feed from the stator. No extra components to increase the generator envelope.

3.4 EASE OF SERVICE:

With no moving components, there is nothing to service; just verify electrical connections.

3.5 CLOSE VOLTAGE REGULATION:

Steady-state voltage regulation is better with self-excitation over other forms of voltage regulation.

4.0 CONS OF A SELF-EXCITING GENERATOR SYSTEM:

Using the generator's voltage output for the reference voltage is the biggest weakness of self-excitation when connected to loads that can significantly reduce the main stator AC voltage output:

4.1 EXCESSIVE VOLTAGE DROOP:

When the connected load has a high content of inductive loads, such as electric motors, when the load is connected to a generator instead of the grid, which has enormous capacity behind it, the power required to bring the inductive load to full power can considerably reduce stator AC voltage output, termed voltage droop. A self-excited generator only has one source of voltage to feed the AVR. Should this feed fall too much, the AVR will have difficulty regulating it.

4.2 COLLAPSE OF EXCITATION:

When a high inductive load is connected to a self-excited generator, the main stator output can be pulled down to a level that produces a very low reference voltage to the AVR. When the AVR's input AC power is too low, there are insufficient AC volts to rectify to feed the main rotor field coils, resulting in a collapse of the magnetic field and no excitation to the stator windings, resulting in a loss of AC voltage output. See ***Figure 2*** for normal voltage drop and ***Figure 3*** for excessive.

5.0 WHY SELF-EXCITING GENERATOR SYSTEMS ARE NOT SUITABLE FOR HIGH INDUCTIVE LOADS:

As stated, the AVR requires a reference voltage to regulate the AC output from the main stator. In a self-excited voltage regulation system, the stator-generated AC generator reference voltage input to the AVR is converted to DC to feed the generator exciter coils. The following can occur when a high percentage of inductive load, such as electric motors, is applied:

5.1 INRUSH CURRENT:

When an inductive load (such as an Electric Motor) is connected to a generator, the motor draws a very high current (relative to the running current) in the initial startup phase. This starting current can be many times higher than the running current. The initial rush of current when the motor is first connected to the generator is termed the Inrush current.

5.2 CAUSE FOR INRUSH CURRENT:

When a motor starts from a stationary position, it requires a lot of current to overcome the torque required to accelerate up to speed. If one large motor or several smaller motors are started simultaneously, this can create an inrush amps draw 3 to 7 times the rated operating current of the motor.

5.3 HOW INRUSH CURRENT EFFECTS GENERATOR OUTPUT:

Power watts are a function of volts time amps. A generator is rated at so many watts. On starting the generator, it has to draw many more amps to overcome starting torque and internal motor resistance. Therefore, for the given power available, more amps means fewer volts. In a self-excited generator, when excessive motor loads pull down the stator volts, the reference voltage taken from the generator stator is too low for the AVR to convert enough DC current to the excitation coils. This leads to a collapse of excitation and no AC output from the stator. See ***Figure 3*** voltage droop.

5.4 SOLUTION TO HIGH INRUSH CURRENT FROM MOTOR LOADS:

Solutions range from having a larger generator, motor starting aids that stagger the inrush amps through the starting phase, or an alternative form of excitation to self-excitation. See the *information sheet on PMG excitation*, which provides an additional voltage source for excitation independent of the main stator reference voltage.

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.

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