Buckeye Power Sales
Reliable Power Professionals Since 1947

Most standby and prime power generator systems utilize an engine/prime-mover (usually diesel, gasoline or gaseous powered) to drive an AC generator to produce electric power with a voltage that matches the utility grid. To ensure the voltage produced is stable and constant, AC generators are equipped with an Automatic Voltage Regulators (AVR). Frequently the term Permanent Magnet Generator (PMG) Excitation AVR is used when referring to generators that are supplying loads with a high percentage of electric motor loads and/or Silicon Controlled Rectifier (SCR) loads. When selecting a generator you will need to take into account that some loads can adversely effect voltage regulation, when it is recommended to specify PMG excitation, and how a PMG voltage regulator operates.

1.0 BASICS OF ELECTRICAL POWER GENERATION:

When a wire, usually copper due to its high level of conductivity, is moved through a magnetic field an electric current is induced into the wire. A generator is principally a series of wire coils that are rotated at a given speed within a magnetic field. In the case of a brushless generator, the outside stator wires are stationary and the internal wires in the rotor generate a magnetic field. In this case the wires in which the electric current is induced remain stationary and the magnetic field rotates. This follows the same electrical principal, but by inducing the electrical current into the stator instead of the rotor, the need for brushes to pick up the power via a commutator is eliminated. (See diagram one)

2.0 PURPOSE AND OPERATION OF AN AVR:

The AVR senses and controls AC voltage output by varying the DC voltage input to the exciter powering the magnetic field. In a brushless generator, the rotor windings are the magnetic field and the stator windings generate the AC power. In a brushless rotating field generator, as the magnetism increases, more electric power will be induced into the stator winding, and as the magnetism decreases the voltage induced into the stator will reduce. When the AVR senses AC voltage output is below nominal, via thyristors, the AVR increases DC power to the magnetic field to increase magnetism and intern AC output from the stator windings, and alternatively reduces DC power when it senses AC generator voltage is above nominal. (See diagram one).

Diagram One

PMG Providing a Separate Power Supply to AVR

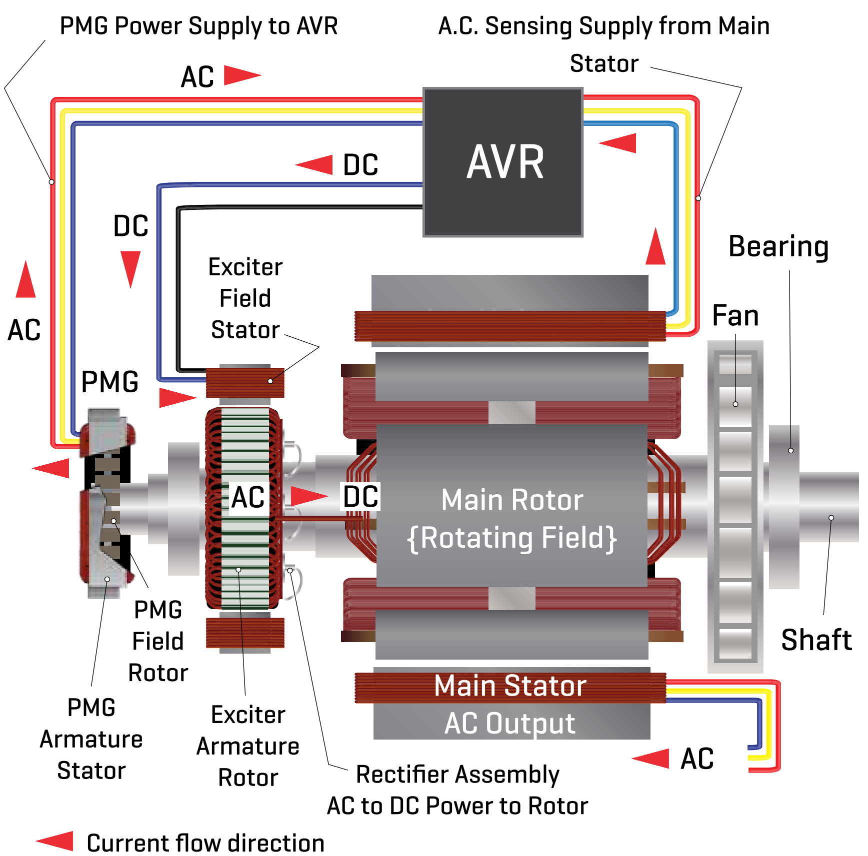
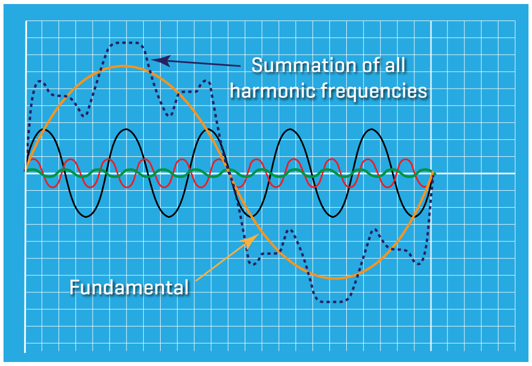


Diagram Two

Harmonic Distortion



Loads causing Harmonic Distortion	
Load Type	Description
Inductive	Electric motors, power transformers, solenoids
SCR	UPS systems, Thyristor drive equipment, rectifiers
LED Lighting	Concerts, displays
Generator Applications to consider PMG	
Rental	Unknown varying loads
Data Centers	UPS, rectifiers
Telecom	UPS, SCR switching loads
Agriculture	Large pump & fan motor loads
Construction	Welders and large motors

3.0 ADVANTAGES OF AN AVR POWERED BY THE OUTPUT OF THE GENERATOR - SHUNT EXCITED GENERATOR:

A common method to power an AVR is to use the AC output from the generator. This is the simplest design, lowest cost solution, and adequate for many applications. To generate a magnetic field the magnetic coils require a direct current (DC) input. To convert AC to DC power, the AC power input is fed through thyristors. This type of arrangement is termed a shunt excited generator.

4.0 DISADVANTAGES OF AN AVR POWERED BY THE OUTPUT OF THE GENERATOR:

When the AVR is powered by AC power connected to loads that produce adverse feed back, the quality of voltage to the AVR is reduced which impacts the AVR's ability to sense and maintain a stable generator output voltage. The specifier of a generator system has to consider the following connected load characteristics when determining the voltage regulator required.

4.1 Non-linear loads: These loads, unlike purely resistive loads, include Variable Frequency Drives (VFDs), LED Lighting Systems, Welders and Uninterrrupted Power Systems (UPS). The feed-back harmonics created by non-linear loads can severely effect the generator output waveform. (See diagram two)

Frequently non-linear loads are referred to as SCR loads. SCR means silicon controlled rectifier, and includes diodes and/or thyristors used to convert AC to DC and DC to AC output. As these loads switch on and off, they can impact the wave form of the AC voltage being generated. Similarly the harmonics of non-linear loads will effect the AVR's ability to accurately sense generator terminal voltage which will also result in voltage instability.

4.2 Failure to Excite the Magnetic Field: When the generator is supplying a load that experiences a downstream fault at the generator terminals, the output voltage can drop to zero. A shunt excited generator will then experience zero input to the AVR. In such a fault event the generator may be unable to force current long enough for downstream circuit interrupters to clear the fault and fail to excite the magnetic field, with subsequent loss of AC generator output.

4.3 High Percentage of Electric Motor Starting Loads: Starting many, or one large electric motor, can place a high starting load on the generator. Large starting loads reduce generator AC voltage output, the voltage input to the AVR, and the voltage it senses. These factors impact the AVR's ability to regulate voltage output during an electric motor starting phase.

5.0 ALTERNATIVE POWER SOURCES TO THE AVR:

When the generator is connected to a high percentage of non-linear and electric motor loads it is best to provide an alternative source of power to the AVR than the generator main AC output windings. There are two other solutions to consider:

5.1 Auxiliary Winding AUX: Some generators have auxiliary windings within the main AC windings. In the case of brushless rotating field generators, wound within the stator windings is an auxiliary second set of windings to feed the AVR. However, AUX windings are still magnetically coupled to the main stator windings resulting in the AUX windings waveform still being negatively effected by the harmonics of non-linear loads. Therefore, AUX input to the AVR can still adversely impact its ability to sense and control generator terminal AC voltage.

5.2 Permanent Magnet Generator PMG: With non-linear loads, the optimum solution is to have an AVR power source isolated from both the main generator windings and the magnetic field influencing them. This is accomplished by mounting at the end of the generator shaft a PMG. (See diagram one)

6.0 ADVANTAGES OF PMG OVER AUX:

PMG excitation provides the generator system specifier with a system that fully isolates the AVR power input from adverse harmonics generated by connected non-linear loads. While AUX windings can be an improvement on an AVR powered directly from the main generator AC winding terminals, the chart below details the advantages of PMG over AUX.

PMG	AUX Winding	Advantage
300% short circuit support.	300% short circuit support.	-
100% isolated AVR power supply fully supports non-linear loads resulting in better voltage regulation.	AUX winding is magnetically coupled to main stator may result in voltage instability under non-linear loading.	PMG
PMG assures voltage build-up.	Relies on residual magnetism for voltage build-up. May require field flashing.	PMG
Highly reliable PMG design is modular. Can be serviced in the field. PMG can be retrofitted in the field to address application issues.	A failure in the light duty aux winding is not field repairable and may also damage main stator windings. Replacing the AUX winding requires a complete main stator rewind or generator replacement.	PMG
Depending on generator design, PMG may result in additional length.	Light duty AUX winding incorporated in main stator slots. May result in shorter generator length for a more compact generator.	AUX

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.