PERFORMANCE STANDARD FOR

VOLTAGE REGULATORS USED ON ELECTRIC GENERATORS

EGSA 100R, 1992a

Electrical Generating Systems Association
1650 S. Dixie Highway, 4th Floor
Boca Raton, Florida 33432
Phone: (561) 750-5575 • Fax: (561) 395-8557

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1. SCOPE

This standard defines performance specifications for voltage regulators used with synchronous generators equipped with rotating exciters. Voltage regulators function as feedback control systems which monitor generator output voltage and adjust exciter field current to maintain output voltage at a constant level.

2. REFERENCE SPECIFICATIONS

EGSA GTD 4, 1981	Glossary of Standard Industry Terminology and Definitions
NEMA MG1-1978	Motors and Generators
ANSI/IEEE 100-1988	IEEE Standard Dictionary of Electrical and Electronic Terms

3. DEFINITIONS

Electromagnetic lnterference. Any electrical disturbance which causes an undesirable response or malfunction in a system. Can be man-made (radio transmitter); inherent (thermal agitation in components); natural (atmospheric disturbances - sun spots, cosmic radiation).

Rate of Change. The incremental change of a parameter in a given increment of time. Also known as the time derivative.

Response Time. Time required by the voltage regulator to initiate corrective output in response to a change in voltage.

Steady State. Operating point under any constant load when all fluctuations due to transients have been eliminated.

Temperature Range-Operating. This range defines the range of ambient temperatures in which the regulator will perform its function without damage.

Temperature Range-Storage. This range defines the range of ambient temperatures in which the regulator will not sustain damage when totally de-energized.

Thermal Drift. The change in regulated generator output voltage after a specified change in ambient operating temperature.

Transient. A momentary variation in system voltage or frequency during transition from one steady state operating condition to another.

Volts/Hertz. The relationship between voltage and frequency where the frequency decreases causing the voltage to decrease, and the frequency increases causing the voltage to increase in a proportional relationship.

4. RATINGS

4.1 **Power Output Rating.** The power output rating of the voltage regulator must be selected to match the requirements of the exciter field to produce generator rated output. The following parameters are required to select the proper power output rating of the voltage regulator:

4.1.1 **Continuous Voltage Rating.** Continuous voltage rating is selected by the regulator manufacturer to indicate the highest full load exciter field voltage with which the regulator should be used. Preferred regulator output voltage ratings are selected to match nominal exciter field voltage ratings of 32, 63, 125, and 250 volts dc.

4.1.2 **Forcing Voltage Rating.** This rating is the maximum regulator output voltage available to the exciter field when nominal voltage is available to the regulator. The forcing ratio shall be expressed as follows:

Forcing Voltage Rating = Forcing Ratio

4.1.3 **Maximum Continuous Current Rating.** The continuous current rating of the voltage regulator is the current that results from application of rated continuous voltage to the minimum rated exciter field resistance.

4.1.4 **Maximum Forcing Current Rating.** The forcing current rating is the maximum exciter field current available from the voltage regulator when forcing voltage is applied to minimum rated exciter field resistance. This rating may have a time limit due to thermal considerations of the voltage regulator.

4.1.5 **Exciter Field Resistance Rating.** The voltage regulator will perform properly when used with an exciter whose field resistance falls between rated minimum and maximum field resistance. This resistance shall be measured at or corrected for a winding temperature of 25º C.

4.2 **Sensing Voltage Rating.** The voltage regulator must monitor the ac output voltage of the generator and detect deviation of the voltage from some nominal value. The voltage regulator sensing circuit must be selected to match the requirements of the generator system. Three parameters are required to select the proper sensing voltage of the voltage regulator.

4.2.1 **Type of Sensing Circuit.** Single phase or three phase sensing is available. Single phase sensing may be used on single or three phase generators. Three phase sensing must only be selected for three phase generators. Three phase sensing may be selected when single phase loading will unbalance the phase voltages.

4.2.2 **Nominal Sensing Voltage.** The nominal sensing voltage of the regulator is selected to match the generator output voltage or the secondary rating of potential transformers used to step down generator output voltage. Preferred nominal sensing voltage ratings of voltage regulators for 50, 60 and 400 Hertz operation are:

60 and 400 Hz	**50 Hz**

120	100
208	190
240	220
416	380
480	400
600	415

4.3 **Voltage Regulator Accuracy.** Voltage regulation is the change in steady-state output voltage of the controlled generator system due to a specified change in generator load. Constant frequency and constant ambient temperature is assumed. The change in voltage is expressed as a percentage of generator voltage measured under load:

$$\frac{ENL - EFL}{EFL} \times 100 = \text{Regulator Accuracy (\%)}$$

EFL = Generator Terminal Voltage at Specified Load
ENL = Generator Terminal Voltage at No Load Note: Regulation accuracy has no bearing on transient voltage performance.

5. CLASSIFICATION

Voltage regulators are classified as Standard, High Performance, or Precision. See paragraph 8.0.

6. APPLICATION

6.1 **Generator Field Requirements.** To select a voltage regulator for particular generator application, the field excitation requirements must be known. Selection of the correct regulator type requires data describing the full load voltage and current required by the generator at rated load and rated power factor. The required field voltage at full load will place the exciter field voltage into one of the following standard ratings:

32 Vdc
63 Vdc
125 Vdc
250 Vdc

The standard rating selected must be the next higher voltage above the exciter field voltage at full load, rated power factor.

The cold value of exciter field resistance must be higher than the minimum field resistance rating for the voltage regulator.

Note: The selection may be verified as correct, based on the first two requirements by checking that regulator continuous current rating is greater than the exciter field current rating.

6.2 **Regulator Input Requirements.** Manufacturer's literature will advise the input requirements for the power and sensing circuits of the model selected. (check voltage, frequency, power or burden to make sure that input signals required by the regulator are provided).

6.3 **Regulator Performance Selection.** Unless the load dictates the regulation accuracy, a generator may use Standard regulator performance when it will only operate as a single unit. Paralleled generators require the High Performance regulator for good parallel operation. The Precision Regulator, is recommended for paralleled generators in unattended operation.

6.4 **Regulator Sensing Circuit Requirements.** Single phase sensing may be used for single or three phase generators when unbalanced loading is anticipated.

7. MINIMUM PERFORMANCE REQUIREMENTS

The voltage regulator must meet the following performance requirements.

7.1 **Voltage Regulation.** Generator output voltage shall not vary by more the ⇑2% as the load varies from zero to full load at rated power factor.

7.2 **Forcing Rating.** A regulator shall provide a forcing voltage of more the 1.2 times its continuous rating. The regulator shall be capable of maintaining forcing level for a least one minute at maximum rated ambient temperature, with minimum rated field resistance.

7.3 **Continuous Rating.** At rated input voltage, the regulator shall be capable of maintaining the continuous output voltage rating, driving the minimum rated field resistance at the maximum rated ambient temperature without time limit.

8. OPTIONAL PERFORMANCE REQUIREMENTS

For applications which require performance beyond the Standard, a High Performance or a Precision Voltage regulator may be specified.

PARAMETER	STANDARD	HIGH PERFORMANCE	PRECISION
Voltage Reg.	⇑2%	⇑1%	⇑1/2%
Forcing Ratio	1.2	1.3	1.4
Thermal Drift	+5% for 40º C change	+1% for 40º C change	+1/2 for 40º C change
Response Time	6 cycles	3 cycles	1 cycle
Operating Temp.	0º to 50º C	-40º to 60º C	-40º to 70º C

8.1 **Other Application Requirements.** The following items may be required for use with the voltage regulator.

8.1.1 **Frequency Compensated Voltage Regulators.** A voltage regulator without frequency compensation will maintain rated voltage without regard for frequency, within its capability. In general, this means increased exciter field current as speed decreases below synchronous speed.

Frequency compensation may be used to reduce the rising field excitation with decreasing speed or to provide coordination between frequency transient recovery and voltage transient recovery. This coordination of frequency and voltage recovery is often used when large blocks of load may be applied to a generator set, e.g. 75% of rated kW or more. The coordination occurs by reducing voltage when frequency is reduced causing the voltage recovery and frequency recovery to occur simultaneously.

Two general types of characteristics are available -- Volts per Hertz (V/Hz) and Voltage Limited Volts per Hertz (VLV/Hz).

V/Hz frequency compensation is a linear relationship between voltage and frequency. If frequency decreases, voltage also decreases. If voltage increases in direct proportion to frequency, the curve is described exactly as the 1.0 per-unit V/Hz curve, but common industry usage of this term is that the "1.0 per-unit" is understood.

8.1.2 **Paralleling Provisions.** A current transformer signal from one phase of the generator system is required for this option to allow two or more generators to serve a common load by paralleling their outputs.

8.1.3 **Three Phase Sensing.** Recommended when unbalanced loading of the generator is expected to be excessive. This option will not correct the unbalance, but will cause unbalanced voltages to be regulated at the average of the phase values.

8.1.4 **External Voltage Adjust Rheostat.** Sets generator voltage to exact value desired. Generally remotely mounted as an operator control on parallel applications. A minimum of 5% adjustment range shall be provided.

8.1.5 **Excitation SupportSystem.** A means of providing some exciter field current by means of current transformers connected to generator output. Offers a means to supply fault current to allow breaker selective tripping and fuse coordination during a short circuit condition. Also used to assist in starting motors whose inrush current is high compared to generator rated current.

8.1.6 **Underfrequency Protection.** Protects generator, exciter, and voltage regulator from high forcing currents possible when operating below synchronous speed. Use when prime mover is lugged or malfunctions, or startup and shutdown sequences could result in underspeed operation longer than 30 seconds.

8.1.7 **Excitation Limiting or Protection.** Detects abnormally high or low excitation and acts to control or shutdown the excitation system.

8.1.8 **Backup Excitation System.** This option may consist of a backup automatic voltage regulator or a device for manually adjusting the field current. Use manual control only when an operator will be available to continually monitor voltage and adjust excitation. Switching of the automatic or manual systems should follow the manufacturer's instructions to prevent opening the field and causing danger to personnel.

8.1.9 **Line Drop Compensation.** When good regulation is required at a point remote from the generator system, the voltage drop in the lines to that point can be compensated by sensing line current with a current transformer and raising generator voltage proportionally.

8.1.10 **VAR or Power Factor Control.** If a generator is paralleled with a system which has generating capacity and loads several times greater in size, the available reactive power capacity of the machine may be continuously supplied to the bus by adding a VAR or power factor controller. This controller causes the regulator to maintain constant VAR load or constant power factor load instead of providing voltage regulation. This type of control will allow better utilization of generator capacity under varying bus voltage conditions, without need for an operator.

8.1.11 **Motor Operated Potentiometer.** The voltage adjust rheostat for the regulator may be replaced by a type driven by an electrical "raise" or "lower" signal to a reversible motor. This device allows for remote adjustment from two or more locations, or control of voltage by other control devices, such as an automatic synchronizer.

8.1.12 **Transformers.** Current and potential transformers are used to adjust system levels to the levels needed by control and protection equipment. A comparison of equipment needs with voltage and current levels available from the system will identify transformer outputs and make certain the selected transformer power is adequate.

8.1.13 **Load Produced Waveform Distortion.** Some generator loads, such as silicon controlled rectifiers (SCR) can produce severe waveform distortion. The voltage regulator sensing circuit measures and regulates the average value of the waveform. For this reason, meters which respond to the average value (rectifier type, for example) are recommended. In severe cases voltage regulator operation may be adversely affected by such distortion. Filtering in the ac power input to the regulator is needed to alleviate the effect. Contact the regulator manufacturer for a recommendation.

9. INSTALLATION

The regulator shall be installed in an enclosure normally accessed only by maintenance personnel, with adequate precautions for protection of others from dangerous voltages.

The regulator shall be protected from exposure to weather and other environmental hazards. Consideration must be given to removal of heat fromthe regulator by convection. Wiring and connections to the regulator and other equipment must comply with applicable codes and standards and be done in a professional manner.

The regulator location should allow easy access for installation, wiring, adjustment, and replacement. The regulator should be mounted away from devices which generate large amounts of heat.

10. MAINTENANCE

The regulator should be kept free of dust, dirt, or contaminants which may restrict dissipation of heat by obstructing air flow or by insulating. Contaminants which are conductive may also cause leakage or short circuits. No other periodic maintenance is generally required.

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