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Application Note

Replacing RG3 Installations with the DECS-250N

For Siemens generators, the RG3 voltage regulator (Figure 1) was the OEM-standard. These voltage regulators were used on machines with ratings over 250 MW. The RG3 can be found on single-turbine generators as well as combined-cycle turbine generators where waste heat recovery from the combustion turbines is used to spin the turbine of the steam turbine generator. One or two combustion turbine generators and a steam turbine generator are combined to create one package. Brushless exciters are the standard for most new machines today. In a brushless exciter, the brushes and commutators have been replaced with power semiconductors to rectify the ac power from the rotating exciter output into a dc for the main field of the generator.

Figure 1 - Siemens RG3 Voltage Regulator

The RG3 voltage regulator (Figure 1) is found on most Siemens generator brushless exciter applications, and the Basler DECS-250N Digital Excitation Control System (Figure 2) offers the best replacement solution for obsolete products and retrofits where performance is an issue on exciter fields up to 20 Adc. For generators over 25 MVA and located in regions requiring a power system stabilizer (PSS), the DECS-250N utilizes the Integral-of-Accelerating-Power PSS type as the ideal retrofit solution.

Figure 2 - Basler DECS-250N Digital Excitation Control System

Negative Field Forcing

Generators with significant MW ratings can have sizable exciter and generator field time constants which affect the overall generator voltage response. The DECS-250N provides both positive and negative "exciter field forcing" to affect fast changes in generator field flux. This improves the reaction time of the generator voltage and provides the needed reactive power support during a system fault when the generator voltage becomes severely depressed. When the PSS is used, positive and negative field forcing dampens power modulations quickly, aiding in system recovery.

Power System Stabilizers

Power system stabilizers are required by NERC (North American Electric Reliability Corporation) on machines in certain geographical areas. The criteria for PSS application is as follows:

- Generator rating of 25 MVA or greater
- Power plant has a total aggregate power of 75 MVA or more
- Machine is one transformer removed from the transmission line
- Operating transmission voltage is 100 kV or higher

In the past, there have been various types of power system stabilizers including speed based, frequency based, and power based. Each of these PSS types are limited in their effectiveness due to the methods for deriving speed, frequency, or power deviations depending upon the type of PSS used.

Today, the Integral-of-Accelerating-Power PSS design is the preferred stabilizer for power system damping as a supplementary control of the voltage regulator. This PSS type has two inputs: one for the compensated frequency and one for measuring the change of power. The compensated frequency is obtained by measuring a changing parameter derived from the quadrature reactance (Xq) of the machine while the change of power is determined by the inertia of the machine shaft.

A Comparison of PSS Performance

To demonstrate the performance advantage of the two-input PSS, the DECS-250N was compared with the performance of a power-based PSS of the RG3 voltage regulator. This case data was obtained on a brushless 250 MW generator where the RG3 was replaced with a DECS-250N. Generator frequency response of the voltage regulator was measured and voltage step changes were performed to determine the voltage regulator frequency bandwidth used to obtain the lead/lag filter blocks needed for the PSS tuning.

RG3 Performance

Figure 3 demonstrates the RG3 voltage response to a 2% voltage step change with the generator open circuit. In Figure 3, the dark blue plot represents the actual voltage regulator performance while the light blue and red plots illustrate different computer simulations. Note the slow voltage recovery time of 3.3 seconds.

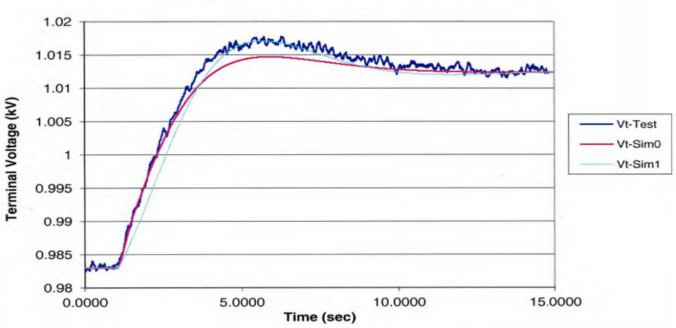

Figure 3 - RG3 voltage response: 2% open circuit voltage step

The PSS lead/lag filter time constants were determined and applied based on the generator frequency response. Then, small signal 2% voltage steps were applied to compare performance with the PSS off and PSS on.

RG3 PSS Disabled

Figure 4 illustrates RG3 performance with the PSS disabled. There was one initial rotor swing that reached 169 MW and then was damped after approximately 3 seconds.

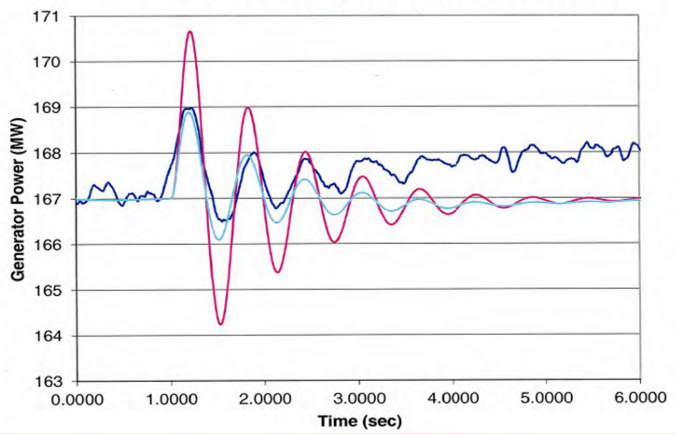

Figure 4 - Step change with RG3 PSS disabled

RG3 PSS Enabled

Figure 5 illustrates the application of a small signal step with the RG3 PSS enabled. By comparing Figure 4 (PSS disabled) with Figure 5 (PSS enabled), the effectiveness of the PSS is questioned. Figure 4 shows the power oscillation of about 1.5 Hz which is difficult to dampen with the RG3 voltage response of 3.3 seconds. Even with the RG3 PSS enabled, there was unsettled damping that continued after 5 seconds.

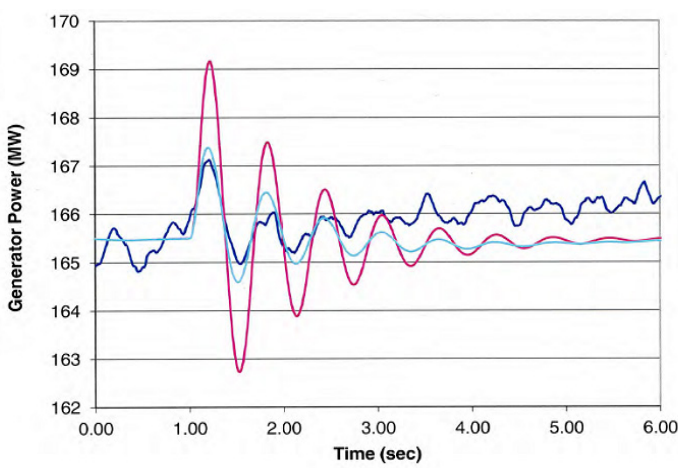

Figure 5 - Step change with RG3 PSS enabled

DECS-250N Performance

After replacing the RG3 voltage regulator with the DECS-250N, identical PSS tests were conducted.

Figure 6 illustrates the result of a 2% voltage step change with the generator open circuit. Note that, compared with the RG3 response shown in Figure 3, the DECS-250N responded much faster due to its PID gain tuning. Within 1 second, the generator reached its setpoint and was stable. To enhance generator performance, the DECS-250N was slightly underdamped initially. Gains were selected based upon the “pole-zero cancellation” technique which uses high proportional gains and significantly lower integral gain for the best generator voltage performance.

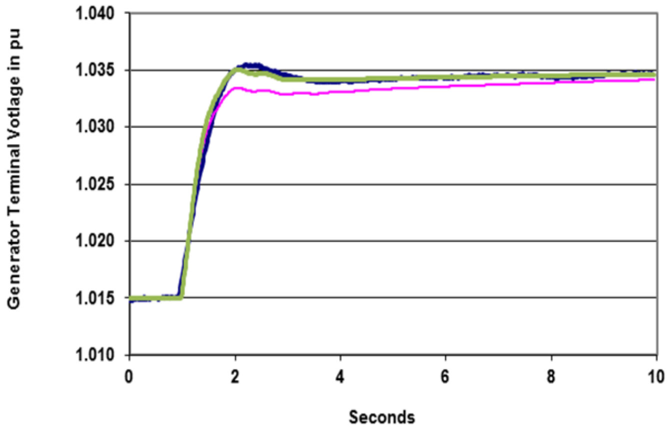

Figure 6 - DECS-250N voltage response: 2% open circuit voltage step

When the PSS is applied, aggressive voltage regulator PID gains should be used to optimize the needed synchronizing torques during a fault. With aggressive PID gains, less filtering is needed in the PSS lead/lag blocks because of the wide frequency bandwidth of the DECS-250N.

PID Setting Groups

The DECS-250N has two PID setting groups. One setting group is used when the PSS is disabled. This setting group uses slow, less aggressive PID gains to ensure system stability. The second PID setting group is used when the PSS is enabled and when the generator is operating above a predetermined power threshold the second PID group is utilized. This setting group uses a much faster, more aggressive PID gains that complements the increased performance of the DECS-250N's two-input PSS. The result of this combination is greatly improved damping of power system disturbances and fast AVR response.

DECS-250N PSS Disabled

As before with the RG3 regulator, the DECS-250N was tested with its PSS disabled and the generator operating at approximately 50% MW load. Figure 7 illustrates the DECS-250N's performance with the PSS disabled.

DECS-250N PSS Enabled

As illustrated in Figure 8, performance is greatly improved when the DECS-250N's two-input PSS is enabled. One initial rotor swing occurs and the PSS dampens the power swing within 1.5 seconds.

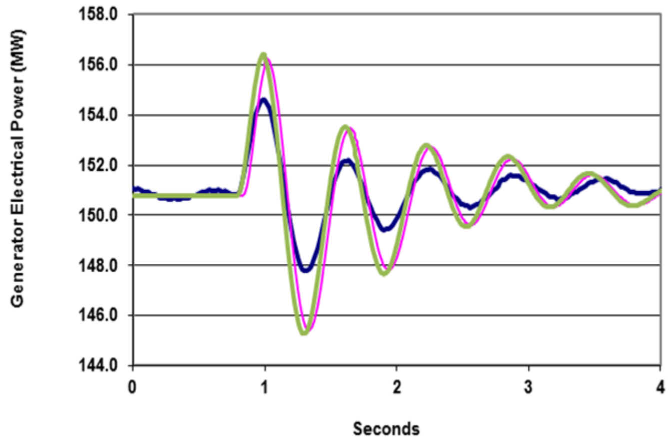

Figure 7 - Step change with DECS-250N PSS disabled

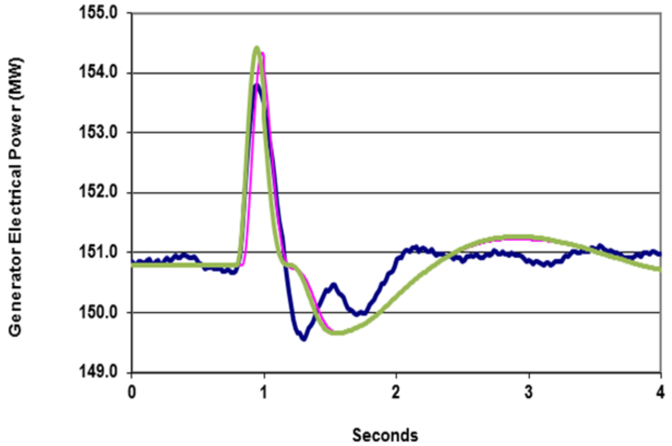

Figure 8 - Step change with DECS-250N PSS enabled

DECS-250N features include:

- True rms sensing, single-phase or three-phase voltage and current
- Full generator metering capabilities
- Auto tuning feature with two PID stability groups for optimum voltage response when the PSS is enable or disabled.
- Reactive load sharing over communication
- AVR, FCR, FVR, power factor and var modes of operation
- Overexcitation limiting (with temperature compensation)
- Underexcitation limiting
- Stator current limiting (with temperature compensation)
- Var limiting
- Underfrequency limiting or V/Hz limiting
- Exciter diode monitoring for brushless exciters
- Trending, oscillography, and sequence of events recording, real-time recording
- Power system stabilizer with phase plot compensator to assist PSS tuning

- Test analysis screens:
  - Voltage step response screen for each control mode
  - Dynamic system analyzer for performing frequency response testing
- Power input rated for up to 420 Hz with de-rating capability for higher PMG frequencies (contact Basler Electric for more information)
- Optional AEM-2020 Analog Expansion Module provides additional I/O

An excitation system can be equipped with a single DECS-250N or two DECS-250N controller for redundancy. Flexible installation options include door mounting in an existing enclosure with a DECS-250N and an auxiliary chassis with supporting components for internal cabinet mounting or the system can be mounted in a new, built-to-order cabinet.

Basler offers a wide range of retrofit solutions for obsolete voltage regulators across the industry. Excitation packages are designed to offer the best solution for new system designs as well as vintage systems where easing the change-out of outdated technology is paramount.

Conclusion

As demonstrated above, the Basler DECS-250N is an ideal retrofit solution for the aging, obsolete RG3 voltage regulator. The two-input power system stabilizer, negative forcing capability, and dual PID setting groups work together to provide optimum damping of power system oscillations that is far superior to older-technology controllers with single-input power system stabilizers.

For additional information about PSS tuning, request the following technical papers from Basler Electric:

- *Elements of Tuning a Power System Stabilizer for NERC Compliance*
- *Auto-Tuning Speeds Up Commissioning of the Generator Excitation System*
- *Voltage Regulator with Dual PID Controllers Enhances Power System Stability*

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