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Application Note

New Life for MGR Excitation Systems: Analog to Digital Conversion

Analog voltage regulating excitation systems evolved over a period of 30 years with various package designs offered by different manufacturers. The old analog technology peaked in the very early 1990s and remained popular until the end of the decade, when new digital technology became favored and new concepts in operating software made it user-friendly to manage.

The Westinghouse/Cutler Hammer MGR excitation system, now supported by Basler Electric, was one popular analog design of the 1990s. It was a robust voltage regulator that was applied to either the exciter field or main generator field, depending upon the application.

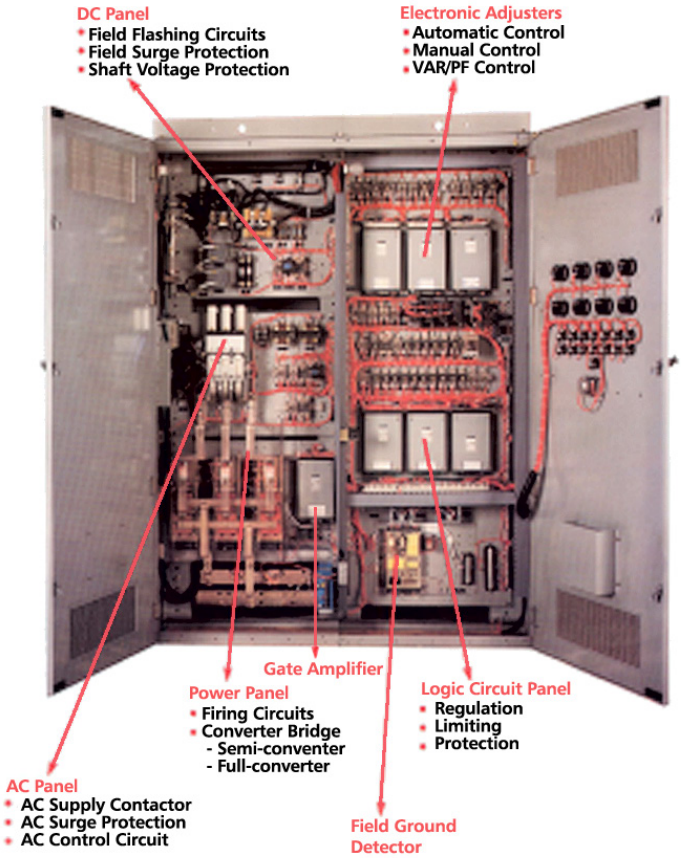

Figure 1: The inside compartment of a typical Westinghouse MGR Excitation System

Similar to many of the voltage excitation systems of the time, the MGR had discrete modules for each function. There were separate modules for the voltage regulator, manual control, individual reference adjusters for var control, the voltage regulator and manual control, and separate modules for under and over excitation limiters. An unfortunate trademark of these analog systems was substantial amounts of wiring, many control relays, and a high degree of wiring complexity inside the cubicle even for a simple system.

Figure 2: Retained Bridge Rectifier and current sharing reactor

Today, there is a need for technology to speed voltage regulator performance and an increasingly popular need for a power system stabilizer. Most importantly, modern digital excitation systems improve unit reliability.

Planning for equipment obsolescence and developing operating issues have become the primary justification for upgrading and replacing these analog systems. However, often where the analog excitation system has become flawed with age, the power rectifier bridge remains highly reliable and has provided proven uninterrupted operation.

The DECS-450 digital front-end kit offers the perfect solution for replacing only the components that need replacement - specifically, the analog portion of the MGR - and keeping the power rectifier bridge, power potential transformer, ac field breaker, dc field flash contactor, etc.

Table 1: Features in the MGR static exciter and the features of the DECS-450 that would be added

MGR Feature Description	Basler Electric DECS-450 Digital Controller
0.5% Voltage Regulation	0.1% Voltage Regulation
Manual Control	Field Current Regulator / Field Voltage Regulator
Var/PF Control	Var/PF Control
Reactive Droop Compensation	Reactive Droop / Line Drop Compensation / Network Load Sharing
Minimum Excitation Limiter	Five-Point Minimum Excitation
Maximum Excitation Limiter	Summing Point or Inverse Time MXL (Both Offline and Online MXL)
Instantaneous Limiting	Included in the MXL
Volts/Hertz Limiting	Two-Level Volts/Hertz Limiter
Overexcitation Protection	Overexcitation Protection (Field Overvoltage and Field Overcurrent)
Volts/Hertz Protection	Volts/Hertz Protection
Overvoltage Protection	Overvoltage and Undervoltage Protection
Loss of Field Protection	Loss of Field Protection
Electronic Adjusters (one per operating mode)	Remote Control and Autotracking of all modes
24 Vdc Power Supply	Retain or Option to Replace
Loss of Voltage Sensing	Loss of Voltage Sensing and Transfer to Manual
Field Flash Contactor with Resistor	Retain
SCR Overtemperature Protection	Retain
Bridge Blown Fuse Detector	Retain
Full Inverter Bridge	Retain
Field Ground Detection	Replace for new 64F
Firing Circuit and Gate Amplifier Board	Replace for New Digital Firing Circuit and Gate Amp

This approach offers many advantages:

- Eliminates the challenges and associated costs of removing the existing excitation cabinet.
- Takes advantage of reusing reliable yet otherwise costly components, including the power rectifier bridge and power transformer, thus reducing the overall cost of the overhaul.
- Easily integrates the new digital controller with new firing circuit and gate amplifier boards with the existing rectifier bridge, offering a simple solution to operational control.
- Minimizes the cost impact when a power system stabilizer is required, since it is an integrated feature and the built-in testing tools lower the effective cost of testing.
- Offers simplicity and increased reliability, since a single digital controller includes an integrated voltage regulator, manual control, excitation limiters, a data logger, etc.
- Allows for integration to the Distributive Control System for more flexible control and alarming via communications using Modbus®.

Application Solution

This Application Note describes the conversion of the analog portion of the MGR static exciter system using the DECS-450 digital controller as a front end replacement that provides firing pulses to the existing power rectifier bridges. The application involves a hydro generator in North Carolina rated for 41 MVA, 13.8 kV that required 250 Vdc at 861 amps. The age of the MGR analog components, modernization need and performance created the necessity to replace the controls while the power components, such as the PPT transformer, power rectifier bridges and contactors, demonstrated reliable performance. The MGR system was installed in 1992 with two 6 SCR power rectifier bridges each rated for 500 amps. The two 6 SCR bridges were connected in parallel, using current sharing reactors to balance currents between the bridges.

Since the analog portion of the MGR was the issue, the focus was to replace only that portion for a digital controller, the DECS-450, that could drive the power rectifier bridges. The new features in the digital controller provide many operational benefits, including improved voltage response to system disturbances and built-in data recording to capture disturbance information of the excitation system and the generator. See Table 1.

The DECS-450 offers an integrated design that consolidates all the functional features previously supplied in individual modules into a single digital controller that mounts on the front door of the existing cabinet. The fifteen (15) or more individual functions inside the cabinet were eliminated for a single drawout DECS-450 package

with shorting terminal blocks and instrument transformer disconnect to voltage sensing to make it drawout construction. As part of the retrofit package, a new digital firing circuit and gate amplifier board to drive the power SCRs were included. Since the MGR power rectifier can have bridges that are either a three (3) SCR and three (3) diode rectifier bridge or a six (6) SCR rectifier bridge type, the IFM-150 firing circuit is programmable for either rectifier bridge system configuration.

Figure 3 highlights the inside compartment of the original equipment package.

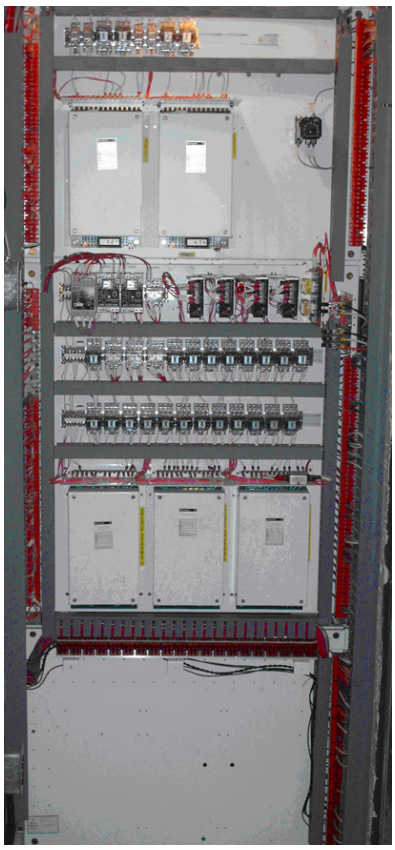

Figure 3: Existing MGR Modules

Individual modules of the MGR were decommissioned and replaced with a single new sub panel that included sequence relays, a field isolation module that measured field current from a shunt and voltage across the generator field, and a power module to convert ac to dc for the control relays to provide a reliable backup in the event of loss of control power, ac or dc.

A new gate amplifier chassis was provided, one for each rectifier bridge to shape the firing pulses delivered by the IFM-150 to ensure sufficient signal strength to gate on the power SCRs. The new gate amplifier chassis is shown in the upper right corner of Figure 4. Figure 5 highlights the interface between existing rectifier chassis and the new subpanel.

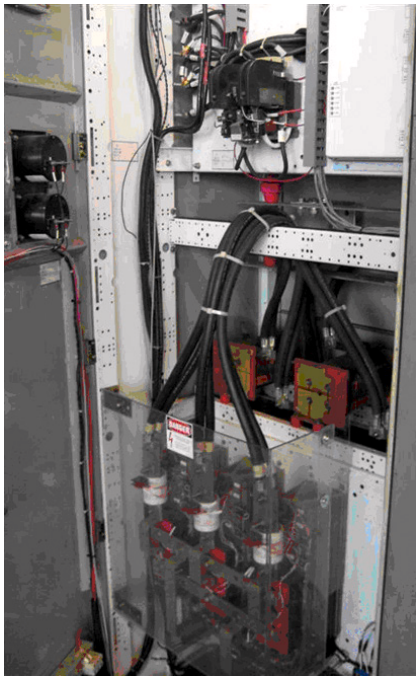

Figure 4: Original Bridge with New Gate Amplifier Chassis Shown in Upper Right Corner

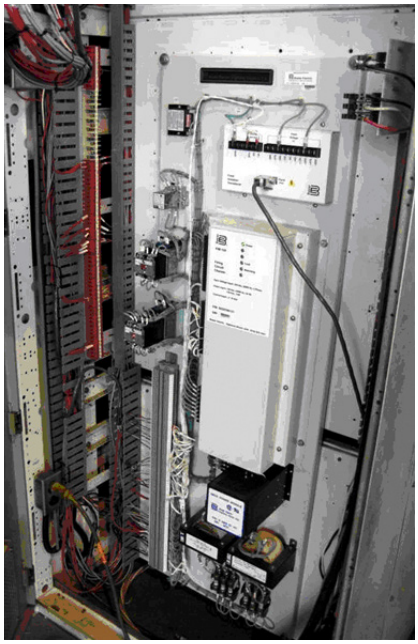

Figure 5: New subpanel to replace original MGR modules

The firing circuit voltage input matched the power potential transformer secondary voltage required for ensuring proper synchronizing signal inputs for firing the power SCRs. Interface of the raise/lower switches, start/

stop control, and voltage regulator/manual transfer were located in the powerhouse control room. After the install was complete, commissioning of the new equipment took place. The built-in BESTCOMS™ operating software tools in the DECS-450 provided real time data capture to monitor performance during the startup.

Figure 6 illustrates the voltage buildup of the generator. Notice the generator voltage comes up very smoothly with no voltage overshoot. The voltage rise time is programmed into the DECS-450 for the desired buildup and settling time. Here, the voltage buildup takes 15 seconds, the programmed value.

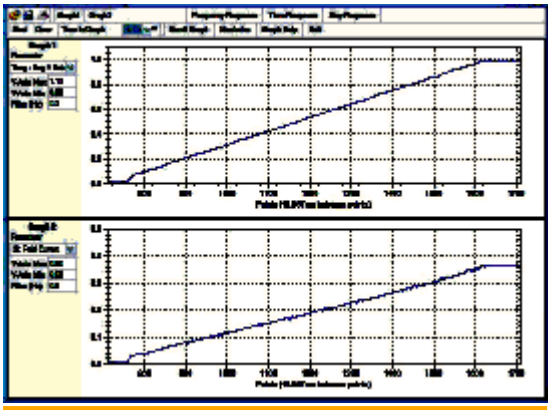

Figure 6: Voltage Buildup with new DECS-450: Top - Generator Voltage / Bottom - Field Current

The original MGR system always came up in manual control to avoid windup causing voltage overshoot. The new DECS-450 system comes up in voltage regulator mode.

Field voltage in Figure 7 highlights proper 6 SCR full wave output with the new equipment. Notice the time between the peaks is 2.8 ms.

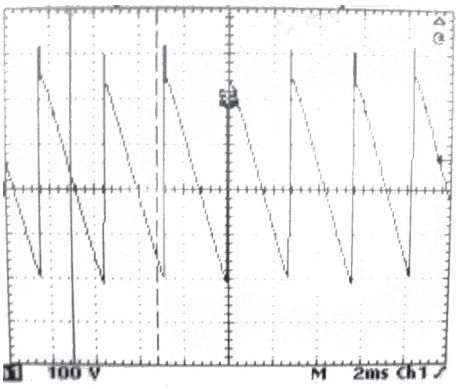

Figure 7: Six (6) SCR Output Waveform of the New System

Performance with the new DECS-450 interface is evaluated by executing a voltage step change to determine the voltage rise time, settling time. Voltage response is evaluated by applying a voltage step of 2% into the voltage regulator summing point. Figure 8 demonstrates a 0.16 second rise time with negligible voltage overshoot. It has been found that the replacement of the analog front end for a digital front end, while keeping the original SCR bridge, results in at least 2 to 3 times improved voltage speed of response.

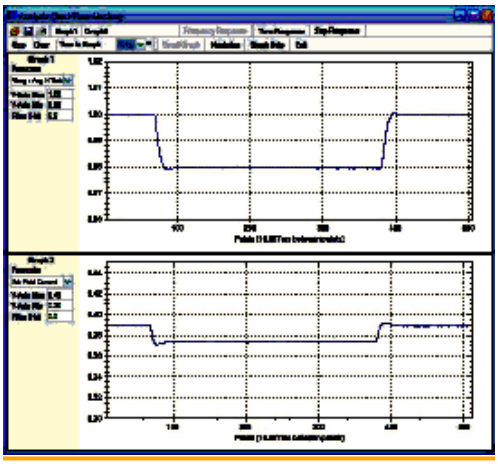

Figure 8: A 2% Voltage Step Change - 0.16 second rise time Top - Generator Voltage / Bottom - Field Current

Over and under excitation limiters were tested to ensure dynamic stability and stable performance when a disturbance has been initiated. Figure 9 illustrates the performance of the over excitation limiter during a step test. The top graph illustrates the field current and the lower graph illustrates reactive vars during the step test. Three current levels are demonstrated.

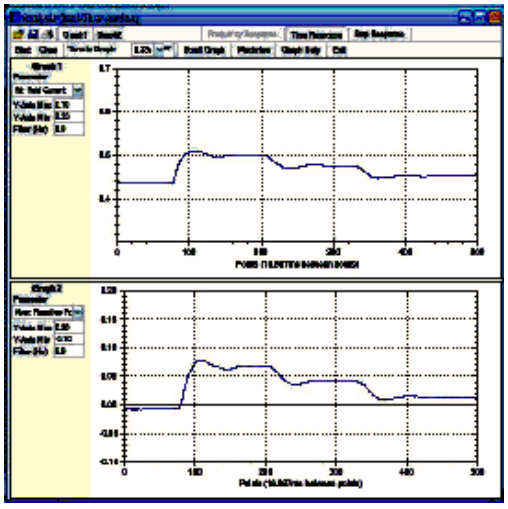

Figure 9: Over Excitation Limiter Disturbance Test Top - Field Current / Bottom - Reactive Current

Notice the over excitation limiter has three distinct limits with time delays - an instantaneous level limit, and intermediate level and low level limit. Stable operation is noted throughout the test. The over excitation limiter generally is tested at levels less than the nominal value, then shifted to the final limit after testing of limits has been demonstrated.

Figure 10 shows a two-bridge MGR excitation system updated with a DECS-450 for digital control.

Figure 10: Two Bridge MGR Excitation System Updated with DECS-450 for Digital Control

The Auto Tuning screen is shown in Figure 11. The Real Time Chart Recorder screen is shown in Figure 12. The BESTlogic™*Plus* screen is shown in Figure 13.

Summary

Today, options are available to recondition existing excitation system with modern improvements. These options include replacing the entire excitation system, keeping the power potential transformer and eliminating existing excitation cabinet or, as this Application Note describes, keeping the power transformer, rectifier bridge, large power handling devices and replacing only the analog portion of the excitation system into existing cabinet. This approach can be used on systems with single rectifier bridges and parallel bridges with current sharing reactors. Results indicate performance is substantially improved and with numerous additional control features can provide safer control of the generating system over its entire operating range.

For details on other spare parts and/or voltage regulator/ excitation system retrofits, consult the Basler factory at +1 618.654.2341 or visit www.basler.com.

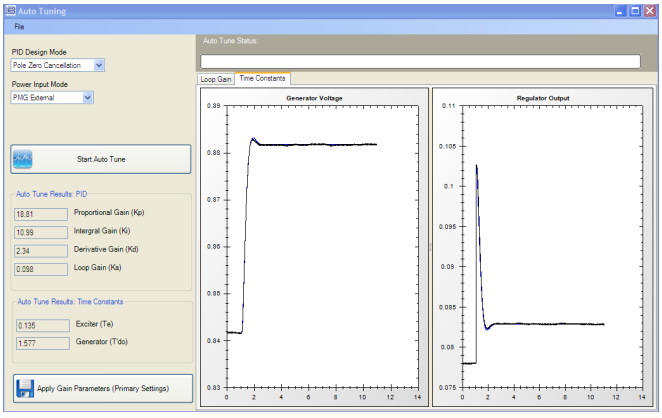

Figure 11: Auto Tuning Screen

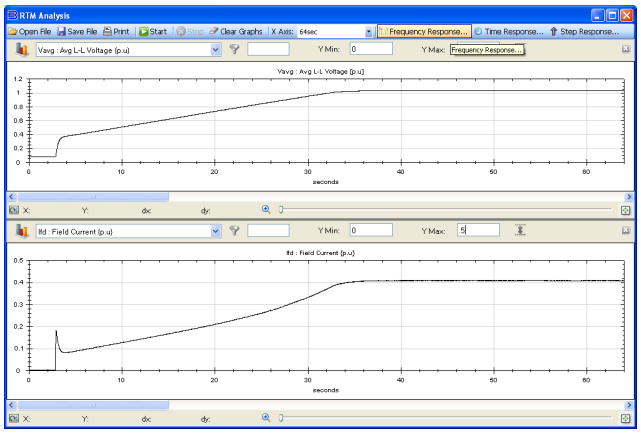

Figure 12: Real Time Chart Recorder

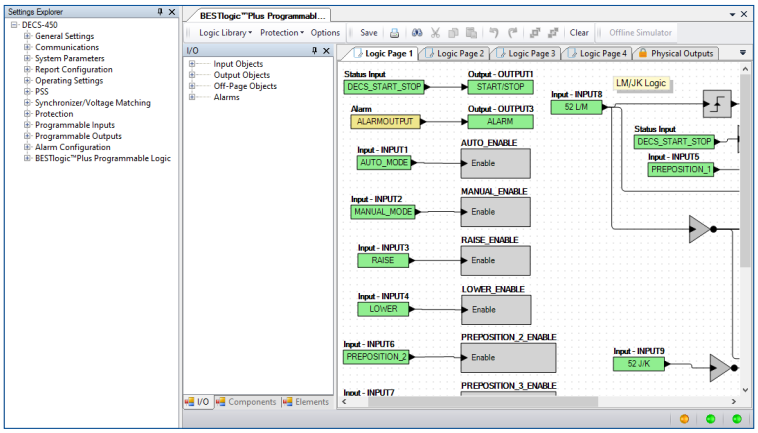

Figure 13: BESTlogic™*Plus* Programmable Logic Screen

Table 2: DECS-450 Features

- UL Recognized, CSA Qualified, CE Compliant
- Oscillography - 1,200 points, 6 programmable parameters, holds up to 6 records
- Meets ANSI C37.90.1 for Surge Withstand and Fast Transient
- Meets RFI (Radio Frequency Interference)
- Meets Conducted and Radiated Noise per IEC 60255-22-6 (Conducted) & 60255-22-3 (Radiated)
- Field current or field voltage regulator for standby mode and NERC testing
- Operating Temperature Range –40° to 60°C
- Voltage Regulation - 0.1% Accuracy for the DECS-450
- Var/Power Factor Controller
- Automatic Nulling - Nulling between operating modes and redundant DECS
- Selectable Underfrequency or Volts/Hertz Ratio Limiter
- Minimum Excitation Limiter - Flexible 5 point map on real/ reactive power axis or Internal generated UEL curve
- Maximum Excitation Limiter
- Var Limiter
- Stator Current Limiter
- Dual PID Setting Groups - Allows for programmed changes in PID gain settings for use with Power System Stabilizer or alternate transmission systems
- Auto Tuning of the Voltage Regulator PID gains (see Figure 11)
- Auto Voltage Matching - Automatically matches generator voltage to bus voltage
- Auto Synchronizing (Device 25A) option
- Autotracking for bumpless transfer between Automatic Voltage Regulator (AVR), manual control, and Redundant Controller when included
- 3 Preposition Set points - Programmable for AVR, Manual, Var/PF Controller
- Reactive Droop or Line Drop Compensation, Network Reactive line sharing via Ethernet communications for multiple machine on a single bus
- Loss of Voltage Sensing - Transfers to manual control automatically due to loss of voltage sensing at the voltage regulator
- Sequence of events - stores 2,047 records
- Real time chart recorder, data logging including oscillography and sequence of event information for data capture up to six channels (see Figure 12)
- Built-in Dynamic Analyzer for measuring frequency response of generator and excitation system using Signal Generator
- Protection
  - Generator Overvoltage
  - Generator Undervoltage
  - Loss of Voltage Sensing
  - Field Overvoltage with Dual Settings Groups
  - Field Overcurrent with Dual Settings
  - Generator Overfrequency
  - Generator Underfrequency
  - Generator Reverse Power
  - Generator Loss of Excitation
  - Synch Check when 25A is disabled
  - Exciter Diode Monitor for Brushless Exciters
  - Generator Below 10Hz
  - Volts per Hertz: coordinates with the V/Hz limiter function
  - Loss of Field Isolation Transducer
  - Control Power Input Failure
  - Crowbar Activated
  - Field Over Temperature
  - Watchdog Timer: monitors the microprocessors and provides a trip contact if a microprocessor fault occurs
- Redundant Controller
- Field overvoltage, generator over/ undervoltage, field overcurrent, and loss of field protections have dual set points selectable via programmable logic
- HMI Metering, Operating Screen - Metering, Control, Annunciation
- IRIG-B Time Synchronization stamp
- Generator Field Temperature Monitoring (Static Exciter)
- 5 Analog Transducers Outputs
- Optional Built-in Power System Stabilizer, Type 2A/2B/2C, Integral of Accelerating Power
- Phase Plot Compensator for Power System Stabilizer assisted tuning
- 6 SCR Bridge Rectifier
- RS-485
- Ethernet over Modbus® TCP
- BESTCOMS*Plus*® common operating software to Basler Electric product family
- BESTlogic™*Plus* programmable logic (see Figure 13)
- Expandable Inputs and Outputs via remote modules

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