

Application Note

Digital Excitation Optimizes Synchronous Motor Controls

To take full advantage of a synchronous motor, shown in Figure 1, it is necessary to have an excitation system that maintains constant power factor or var regulation regardless of load and ac supply voltage variations to the excitation controller.

This Application Note discusses how today's excitation systems are designed with features that help improve the quality of machine control in an industrial facility.

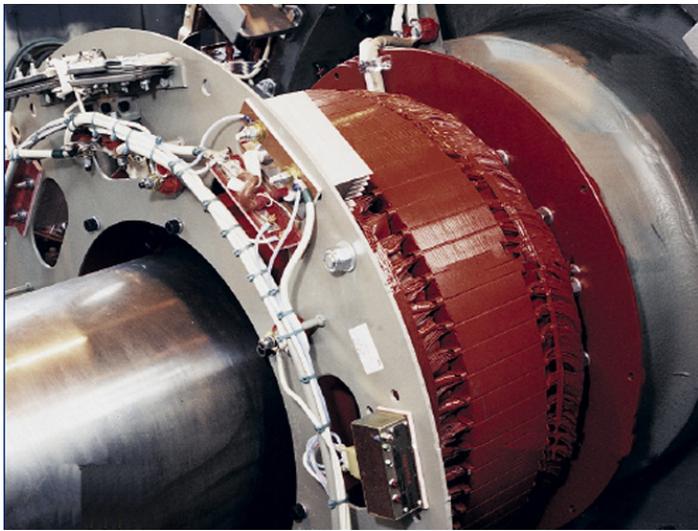


Figure 1: Typical Brushless Excited Synchronous Motor

Synchronous motor excitation systems from the past used a fixed ac-to-dc rectifier bridge control or an analog control unit that was subject to ac input voltage variations that could cause lagging power factor on the motor if ac input voltage dropped significantly. See Figure 2. Because of this, a pole slip could occur, resulting in loss of synchronization of the motor. New digital excitation systems offer enhance control features and provide reliable feedback to the system.

Today, the digital controller includes:

- Power Factor Control
- Underexcitation Limiting
- Overexcitation Limiting
- Logic Control

The digital controller also includes functions to provide added value to the plant and maintenance personnel who are responsible for the system, including:

- Loss of Voltage Sensing and automatic transfer to manual control to prevent a machine trip caused by loss of PT fuse at the controller input.
- Autotracking between power factor mode and manual control to avoid bumps and a system disturbance during a unit transfer.
- Oscillography, a diagnostic tool to evaluate plant issues such as a machine trip to help determine and locate the problem.
- Sequence of Events that tabulates all events occurring from the time the motor is started to the time the machine is shutdown.

Today's digital excitation controllers also include features that might otherwise have been neglected or provided by other discreet devices.



Figure 2: Analog Controller for Synchronous Motor

Automatic Power Factor Control

The digital controller is designed to maintain a specific cosine angle power factor by measuring the real power into the motor and adjusting the excitation into the field to provide the correct amount of kvars to maintain the cosine angle. Figure 3 illustrates the constant angle as a function of kW into the machine versus kvars out of the machine. Any voltage variation to the system or load change that would affect the power factor is immediately modified via the excitation system to restore the cosine angle and power factor of the machine.

The automatic control eliminates the concern with an ac supply variation to the excitation system that could otherwise result in pole slip due to too little excitation for the motor field. Additionally, digital systems are equipped with new safeguards to prevent pole slip from occurring. These include:

- Field Forcing Margins
- Underexcitation Limiting
- Overexcitation Limiting

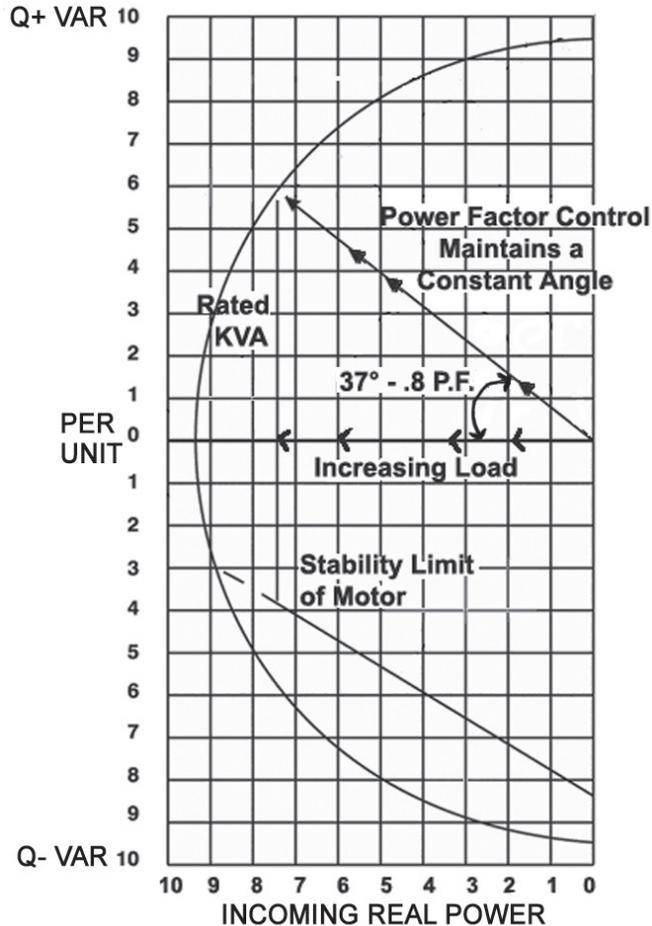


Figure 3: Motor Capability Curve

Field Forcing

Field forcing provides a means to maintain constant voltage into the field even when the ac supply voltage drops as much as 30–40%. Hence if the field voltage required by the motor were 100 Vdc at 0.9 power factor lead and the digital controller were selected to provide 150 Vdc maximum ceiling voltage, The digital controller would be able to provide 100 Vdc to the field even if the supply voltage into the controller were to drop 50%. The additional margin could mean the difference between continued process control or a machine trip and plant outage.

Underexcitation Limiter (UEL)

Digital controllers are also equipped with UELs. These have always been popular for generators, but they are also very practical for synchronous motors using digital controllers. The UEL compares the kW into the synchronous machine to the kvars being supplied. Should the kvars drop below the level needed to maintain synchronism, the UEL causes an increase in excitation to prevent a machine trip. Figure 4 illustrates an apparent drop in machine vars. Notice how the kvar drops to a level but is limited to any further reduction because of the UEL.

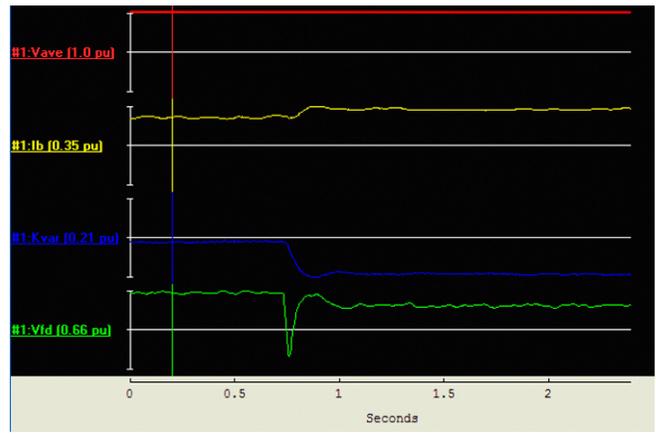


Figure 4: Underexcitation Limiter Operation for Synchronous Motor

Overexcitation Limiter (OEL)

To ensure that too much excitation is not applied into the rotor for extended periods of time, the excitation system is equipped with an OEL. The OEL monitors the field current and if it remains too high for extended periods, the excitation limiter reacts by restricting any further increased field current and restore the level within a safe operating region for the machine. Figure 5 illustrates how a transient on the system has occurred and kvars are controlled because the OEL restricts any further increases. The OEL operates at three levels to allow short time var boosting that could benefit the system.

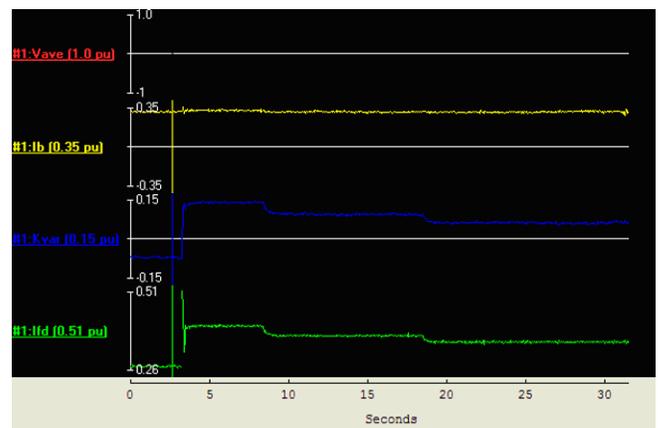


Figure 5: Overexcitation Limiter Operation on Synchronous Motor

Other Features

Additional features include field overvoltage and field overcurrent, as well as, over and under terminal voltage monitoring. Since brushless motors use diodes to rectify the ac to dc from the exciter output, failure of these diodes can lead to a faulted exciter phase, and subsequent overload and excessive vibration of the exciter. See Figure 6. New digital controllers are equipped with diode failure detectors for the brushless exciter that will alarm should failure occur and allow for a timely shutdown to repair faulted devices.

It also is important to note that if a momentary voltage sag occurs due to a system fault or machine overload, the voltage regulator primary control loop action in the DECS-250 Digital Excitation Control System, will respond first to provide voltage recovery. This will be followed by var or power factor control that is a supplementary control loop to bring the system back to regulating constant vars.

Often, industrial plants can use var support to help improve plant power factor. In Var Control Mode, a Synchronous Motor Controller (SMC-150 or SMC-250) that utilizes a Digital Excitation Control System (DECS-150 or DECS-250) for excitation control and the BEI-11m for motor protection, to boost vars by overexciting the synchronous motor to reduce reactive current demand from the electric utility. Boosting vars by overexciting the synchronous motor also affects the sizing of transformers and cabling and avoids power factor penalties.

Excitation System Interconnection

Unlike constant voltage supplies that require only an ac voltage source to provide a fixed dc into the field, the automatic control system requires inputs from instrument PTs for measuring motor line voltage and a current

transformer signal input for measuring the reactive current out of the motor. See Figure 6.

The SMC will start in FCR (Field Current Regulation) mode. The excitation start sequence will begin when the system receives a contact signal when the motor start command is initiated. The SMC will begin sensing the motor ac current from a current transformer. When the SMC determines that the motor has reached normal running current, an output relay contact will close to cause the SMC to automatically switch into power factor control mode (or var control mode). The DECS-250 will then regulate at a specific power factor (or var) level predefined by an adjustable setpoint.

Output contacts are available to monitor any operation of the excitation limiters and general annunciation for any protection alarms.

Testing and Evaluating

During testing, "V curve checks" are performed to evaluate motor characteristics. Historically, the V curve was obtained by installing chart recorders and appropriate transducers to measure watts and vars. In the digital excitation system, curves can be obtained using the oscillography that can speed commissioning time and provide permanent records of the motor's history. Figure 7 illustrates kvars and ac line current when field excitation is changed forming a V curve of the synchronous machine. Notice how the kvars increase with increasing excitation. As the motor line current valleys between the two ac line current peaks, the kvars are zero. A further reduction in field current now causes the kvars to further decrease, causing a lagging ac line current and lagging power factor in the system.

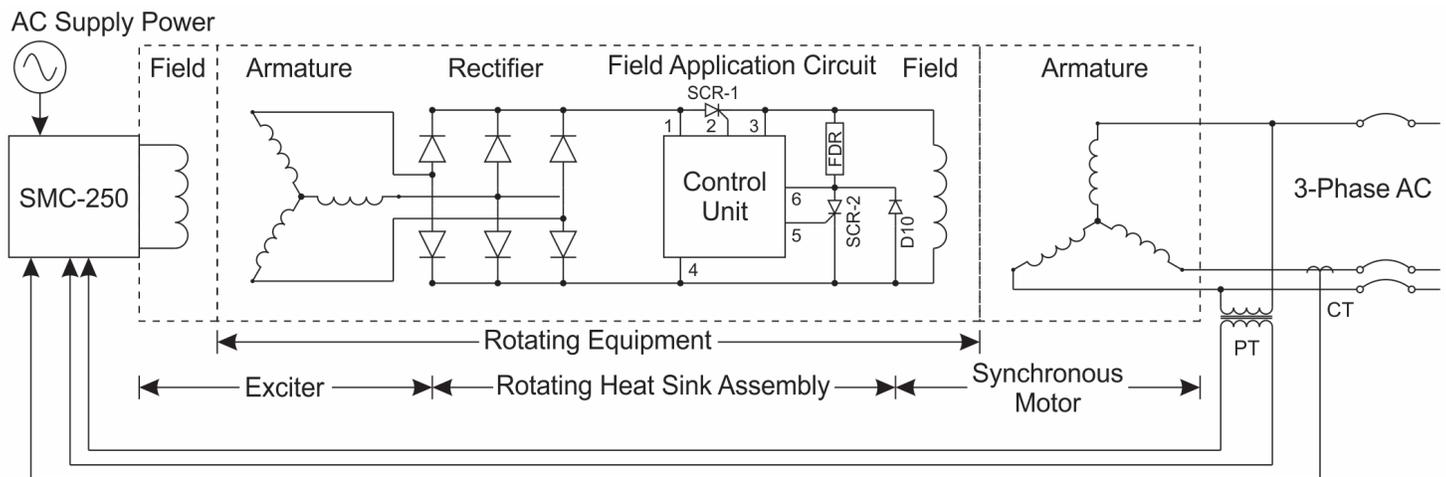


Figure 6: System One Line Interconnect

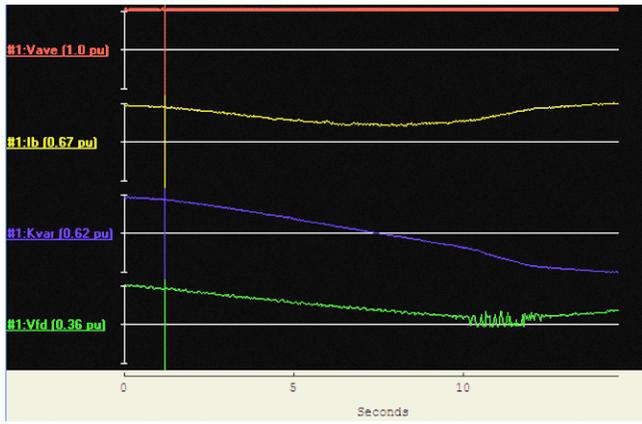


Figure 7: Testing the Synchronous Motor Operation using "V Curve Checks"

Synchronous Motor Controller

The Basler SMC-150 and SMC-250 are designed to fit into new or existing switchgear cubicles. The main components of the SMC package includes:

SMC-150

- DECS-150 Digital Excitation Control System
- 120/240 Vac input Single- or Three-Phase 50/60 Hz; 63/125 Vdc continual output; up to 10 Adc

SMC-250

- DECS-250 Digital Excitation Control System
- 120/240 Vac input Single- or Three-Phase 50/60 Hz; 63/125 Vdc continual output; up to 15 Adc

Common items for the SMC-150 and SMC-250:

- ES-55 Power Factor Protection Relay
- ES-74S Independent Field Under/Over Current Monitoring Relay
- ICRM Inrush Current Reduction Module
- Logic Control
- Pre-wired and tested on a mounting plate
- Terminal block for customer interface connections
- Control Power 24 Vdc or 120 Vac Single Phase

Other available system options include:

- IDP-801 Interactive Display Panel (SMC-250 only)
- BE1-11m Motor Protection System (SMC-250 only)
- Power Potential Transformer
- Field Ammeter
- Field Voltmeter
- New cubicle with custom feature and dimensions

Conclusion

For low speed applications and power factor concerns, the benefits offered by the synchronous motor can provide long term improvements that can represent cost savings to the plant. The brushless exciter favors a more streamlined control via a solid-state device to apply excitation to the field with increased reliability and economic benefits. Accurate control of the synchronous motor power factor as implemented by a digital excitation system offers more efficient control of the machine to help avoid potential machine trips due to low ac power supply variations to the excitation system. Features included in the excitation system also provide more complete monitoring of the synchronous machine to safeguard the unit under abnormal operating conditions. The SMC family contains Basler Electric's top-of-the-line products for your synchronous motor control and protection needs.

For More Information

Basler Electric offers retrofit options for a variety of existing applications. For details on other voltage regulator/ excitation system retrofits, consult the Basler factory at +1 618.654.2341 or visit www.basler.com.

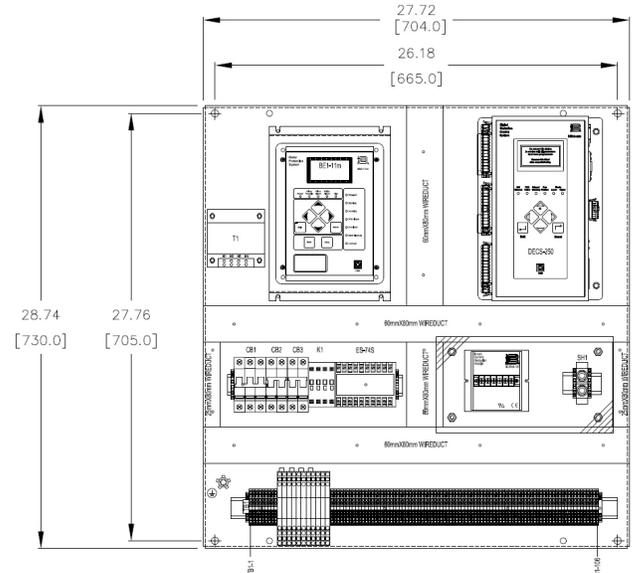


Figure 8: Typical SMC-250 Mounted on Pan Chassis

SMC Features and Functions	SMC-150	SMC-250
Control Features		
±0.25% Voltage Regulation	•	•
Field Current Regulation (manual)	•	•
Var / Power Factor Regulation (Auto)	•	•
Overexcitation Limiter (Based on field current)	•	•
Underexcitation Limiter (Based on Vars)	•	•
Automatic Tracking of Control Modes for Bumpless Transfer	•	•
Setpoint Pre-Position	•	•
Output Capabilities		
Up to 125 Vdc at 10 Adc Max Operating 50°C	•	
Up to 125 Vdc at 15 Adc Max Operating 50°C		•
Protection		
AC Overvoltage/Undervoltage	•	•
Loss of Voltage Sensing Detection and Transfer to Manual Control	•	•
Overfrequency/Underfrequency	•	•
Field Overvoltage	•	•
Field Overcurrent	•	•
Brushless Exciter Diode Monitoring	•	•
Loss of Excitation (based on var level)		•
Configurable Protection	•	•
Power Factor via ES-55	Standard	Standard
Enhanced Motor Protection with Integrated BEI-11m	N/A	Optional
Event Recording		
Sequence of Events	•	•
Data Logging Oscillography	•	•
Real-Time Monitoring	•	•
Trending		•
Communication Provisions		
USB for PC Interface	•	•
RS-485 Serial Communication MODBUS®		•
Ethernet RJ-45 MODBUS TCP/IP	•	•
Software Interface Program	BESTCOMSPlus®	BESTCOMSPlus®
Programmable Logic	•	•