Application Note

Basler BE1-11m Motor Relay System Protects Synchronous Motors Used for Power Factor Correction

Uses and Advantages of Synchronous Motors

Synchronous motors supply a constant speed with varying loads, are highly efficient and have low inrush current. Engineers specify synchronous motors because these motors supply power system power factor protection, as well as performing other useful work. Typical uses are as drivers for large ball mills in iron mines and cement plants, compressors, pumps, blowers and for motor-generator (MG) sets that convert electrical power frequency, voltage and phase.

Figure 1 - BE1-11m (left) and Remote RTD Module (right)

Protecting Synchronous Motors

Synchronous motors are much like induction motors, because both produce a rotating magnetic field with stator windings connected to the power system. However, a synchronous motor receives dc excitation current through a wire-wound rotor to attain synchronous-speed operation.

One method of getting excitation current flowing in the synchronous motor is to use brushes on rotor shaft-mounted slip rings. Alternately, these motors can be supplied with brushless excitation systems that supply field current at the correct angle to maintain synchronous speed.

The Basler BE1-11m has all the motor elements needed to protect the synchronous motor, including out-of-bounds

power factor (55) operation. In addition, the relay can serve as backup for exciter systems with power factor correction or provide an analog correction signal to change the load power factor with the Remote RTD (resistance temperature detector) module.

Also, the relay can detect missing field excitation via the Remote RTD, serving as a backup to the main excitation system.

Starting and Synchronous Speed

A synchronous motor is started by a prime mover, "pony motor", induction motor methods (shorted field windings, squirrel cage type construction—amortisseur or damper winding) or other means to achieve near synchronous speed. The BE1-11m monitors starting for any abnormal conditions. Analog inputs from a rotor speed detector can serve as one way to check that rotor speed has reached the proper value for applying the field current. Once at induction-motor speed, applying external rotor excitation locks the rotor speed with the rotating stator magnetic field. Now, the motor shaft is rotating at synchronous speed and the machine produces usable motor torque. The motor power factor is at unity (1.0). If too much load is applied to the motor, the power factor begins to drift from unity. Adding more load causes the rotor to go out of step with the rotating magnetic field and no shaft torque is developed (if no further excitation is applied). At this point the synchronous motor, and consequently production, stops.

Power Factor Correction (var Support)

A unique capability of a synchronous motor is that it can provide var support and improve the power system total power factor; this operation mode is also known as a synchronous condenser (much like adding capacitors to improve power factor and save utility system billing charges). In fact, it can be operated with variable excitation to produce a leading power factor (overexcited is a variable capacitor and underexcited is a variable inductor), further stabilizing the power system power factor while performing usable work with an attached load.

In most cases, it is good practice to size the synchronous motor with more capability than the load. In this manner, the synchronous motor operates at a lower leading power factor and performs plant operations while supplying var support for a given excitation. This practice is particularly good for cyclical loads. The BE1-11*m* has a power factor (55) element for keeping the synchronous motor running correctly.

Operating a Synchronous Motor

An important aspect of the synchronous motor is maintaining operation over the rated load and power factor. Unlike other electrical machines, the synchronous motor has a set of "V curves" that describe motor operation, as show in Figure 2.
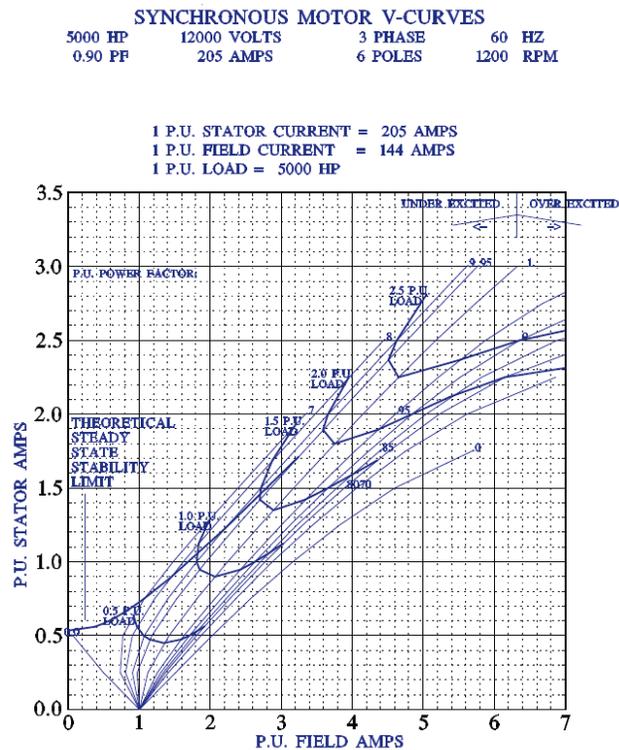

Figure 2 - Synchronous Motor Operation V Curves

As shown, the motor theoretical steady-state limits exist between 0.6 p.u. and 1.45 p.u. stator amps. This region corresponds to a portion of the 1.5 p.u. load, all of the 1.0 p.u. load or most of the 0.5 p.u. load depending on the excitation field current (P.U. FIELD AMPS) supplied. Therefore, the synchronous motor must be operated with a combination of machine loading, power factor and the correct rotor field excitation for continuous operation.

Synchronous Motor Protection Elements

To properly protect a synchronous motor, the BE1-11m features all of the standard induction motor protection, including:

- 49TC Thermal Capacity Model
- Stator, Bearing, and Rotor RTDs
- Incomplete Start (48)
- Overload
- Jam
- Load Loss
- Unbalance Trip and Alarm
- Undervoltage
- Overvoltage
- Short Circuit
- Ground Fault

For a synchronous motor, the power factor (55) element monitors whether the motor is operating within the manufacturer's limits set by the V curves. As shown in Figure 2, the load lines represent different excitation points on the V curves designated by power factor. For example, continuous operation at 1.0 p.u. load can have a power factor from ± 0.8 pf. However, these are the absolute limits for this load; operation outside this power factor will cause enough motor heating to eventually trip the motor via the thermal 49TC element if not previously tripped on the 55 element. As specified by the manufacturer, the lagging limit should be 0.90 pf, and close examination of the V curves indicates a leading pf of 0.85 as a reasonable limit. The power factor (55) element should be set to these levels, leaving an appropriate delay for events such as reaching pull-out torque, cyclic loading (load shedding and increasing) and reluctance torque synchronizing.

Better Programming via Easy Graphical Interface

A national reliability study shows that nearly all multifunction relay misoperations are caused by incorrect programming. Basler's intuitive settings software helps solve this problem. All models of BE1-11 can be programmed using any Boolean function with drag-and-drop elements, inputs, outputs and many other elements from the BESTlogic™*Plus* programmable logic (a part of BESTCOMS*Plus*®, included with each relay at no charge), shown in Figure 3. Further, Basler provides prebuilt settings and logic application templates for many protection applications. These views or templates can be customized and saved according to your company's standard. Logic documentation is provided, as well as logic printing, settings export capabilities and settings difference analysis.

Figure 3 is part of the default logic that comes with the BE1-11m. At the bottom of Figure 3, the BE1-11m notifies the excitation system that the motor is ready for synchronous mode by using the running mode detector to close relay output OUT6 dry contacts. Running and output OUT6 elements are chosen from the BESTlogic*Plus* toolbox by dragging and dropping these elements onto the programming page. Click and hold to connect a line between the two elements. Users can use the Comment Box located in the Toolbox to add a comment. The new logic can be saved as an integral part of the BESTCOMS*Plus* file, and it can be saved in the logic library for later use in similar applications. Also, power factor was ORed in the TRIP circuit in the same drag-and-drop manner. When complete, upload the new logic and settings to the BE1-11m via the BESTCOMS*Plus* program.

BE1-11 Series Settings Check

All BE1-11 models have summary pages that quickly show if the GUI programming logic has elements connected but not set, or elements set but not connected in logic. Figure 4 shows an example where there is more work to be done before uploading the final programming to the relay.
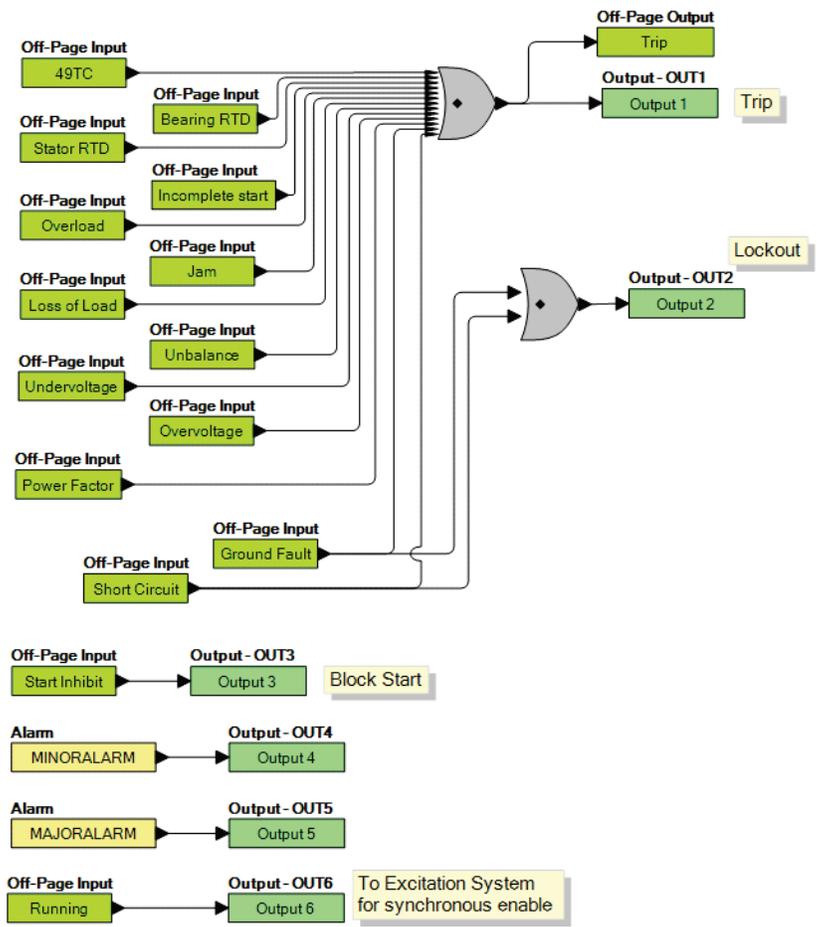

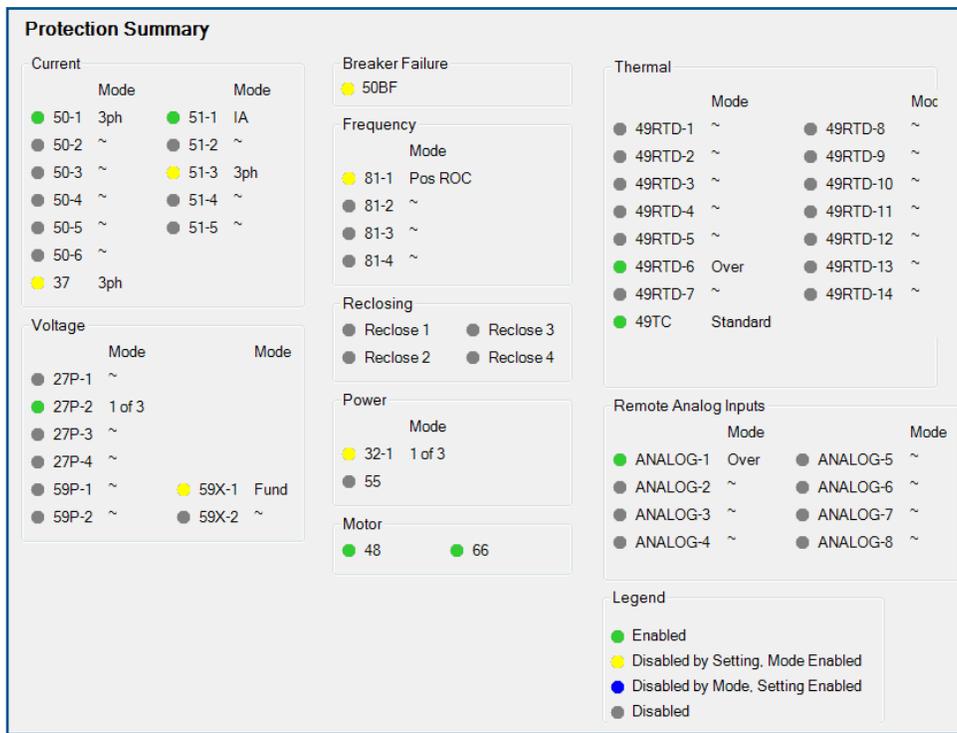**Figure 3 - Drag-and-Drop Graphical Relay Programming**

Figure 4 - Protection Summary for Program Checking

Upgrade in Place

The form factor of the BE1-11m Motor Protection System is the popular S1 case. With a panel cutout of 8.63-in. (219.1 mm) height and 5.69-in. (144.5 mm) width, screw mounting cutouts are exactly the same as any S1 case.

Thus, the relay is a slide-in solution for older products. The Remote RTD module can be mounted on the switchgear near the relay or at the synchronous motor. The module requires no calibration or maintenance, makes short runs of RTD and analog wiring and is connected via fiber-optic cables, RJ45 cable or RS-485 connections.

The process for upgrading your motor protection, whether synchronous or induction motors, is the following:

- Secure the tripping circuit, CTs, (and excitation) circuits
- Disconnect existing wiring (label if necessary)
- Remove the old device by taking off the four nuts
- Mount the new BE1-11m in the same cutout and screw-hole placements
- Connect existing wiring
- Mount and connect the Remote RTD module, if used
- Program the BE1-11m with BESTCOMS*Plus* (use graphical logic and be sure to use the BESTCOMS*Plus* Protection Summary pages)
- Test
- Enable the BE1-11m Motor relay for service

More Information

For more information on Basler BE1-11 Protective Relay System, see www.basler.com or contact Technical Support at 618-654-2341.