PC-FLEX-GENPROT • April, 2024
Published for the Basler Electric Power Systems Group

Application Note

Loss of Prime Mover: Generator Reverse Power Protection (32) Replacement Opportunities (GE Type GGP-53C and ABB Type CW)

Generator Protection-Loss of Prime Mover

The condition of motoring is particularly critical for steam turbine generators and hydroelectric generators. For steam turbines, it causes overheating and potential damage to the turbine and turbine blades. For hydro units, low water flow can cause cavitations of the blades of the turbine. Protection during motoring conditions is required to maintain good protection practices and to prevent damage to equipment. Generally, this protection is provided using Reverse Power (32R) relay elements, detecting power flow into the generator. Typical values of reverse power required to spin a generator at synchronous speed with no prime mover input, in percentage of the nameplate kilowatts, are as follows:

- Steam Turbine, Condensing Types: 1 to 3%
- Steam Turbine, Non-condensing Types: 3+%
- Hydro Turbines: 0.2 to 2+%
- Diesel Engines: ±25%
- Gas Turbine: 50%

Generator motoring can also occur when closing the steam or water flow valves too rapidly during a load reduction phase or by tripping the turbine but not the corresponding tripping of the generator breaker. These conditions normally happen when a unit is being removed from service.

Loss of Prime Mover-Undetected by Conventional Relays

A past instance documented a potential deficiency with conventional 32R element protection. This involved a steam turbine at a distributed generation site, operating in parallel with the utility grid. The prime mover steam supply was suddenly removed while the generator was connected to the utility electric power system with the field excited. The existing protection failed to recognize the motoring condition, which resulted in the generator operating as a synchronous motor for an extended period of time. The thermal turbine scheme of the generator also failed to detect the motoring condition.

The condition was finally removed when a power plant operator noticed the real power output at nearly zero and manually tripped the breaker between the Industrial Electric Power System and the Utility Electric Power System.

The failure of the existing protection was traced to the fact that the generator was providing voltage support to the Utility Power System, which led to heavy Var loading on the generator prior to loss of prime mover (very low power factor angle). This problem can occur any time the motoring generator sees a relatively small amount of real power in comparison to the amount or reactive power (i.e., the resulting power factor is very small). Under these conditions, traditional electromechanical reverse power relays cannot detect the motoring and the generator may continue motoring indefinitely. If not manually detected, reverse power may continue long enough to damage the generator. Other utility and cogeneration power plant operators have reported similar unexplained 32R failures to trip when high reactive loads were being supplied by the machine when a system disturbance occurred, resulting in a plant load rejection operation. The sequential tripping schemes rely on the 32 devices to detect a motoring condition so that proper control action can complete the sequential shutdown of the boiler and steam turbine is completed safely.

Electromechanical 32R devices are difficult to calibrate and, in some cases, fail to operate. Basler Electric's BE1-FLEX Protection, Automation and Control System improves performance and provides successful tripping for real power at measured power factors much lower than electromechanical relays could measure. This makes the BE1-FLEX a suitable replacement for obsolete electromechanical 32R devices. The BE1-FLEX can reliably detect generator motoring at power factors as low as 0.025 or 88.6 degrees.

Typical Generator Protection Systems Reverse Power Protection Applications

As previously noted, real power will flow into the generator if the generator loses its prime-mover input. Preferred protection for this condition is provided with a reverse-power relay (32R), as shown in Figure 1.

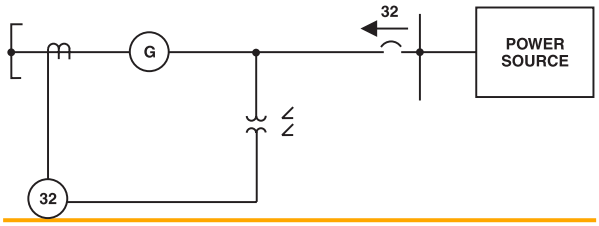


Figure 1 - Anti-Motoring (32) Protection

Since motoring can occur during a large reactive power flow, the real power component needs to be measured at low power factors. Basler's solid state relay, the BE1-32R, measures real power down to 0.5 pf. Basler's BE1-FLEX digital relay system reliably measures real power as low as 0.025 pf (88.6 degrees).

Figure 2 shows the use of two reverse-power relays: 32-1 and 32-2. The 32-1 relay supervises the generator tripping of devices that can wait until the unit begins to motor. Overspeeding on large steam turbine units can be prevented by delaying main and field breaker tripping until motoring occurs for nonelectrical and selected electrical conditions (e.g., loss-of-field and overtemperature). Relay 32-1 should be delayed by approximately 3 seconds, while relay 32-2 should be delayed by approximately 20 seconds. Time delay would be based on generator response during generator power swings. Relay 32-2 trips directly for cases of motoring that were not initiated by lockout relay 86NE — e.g., governor control malfunction.

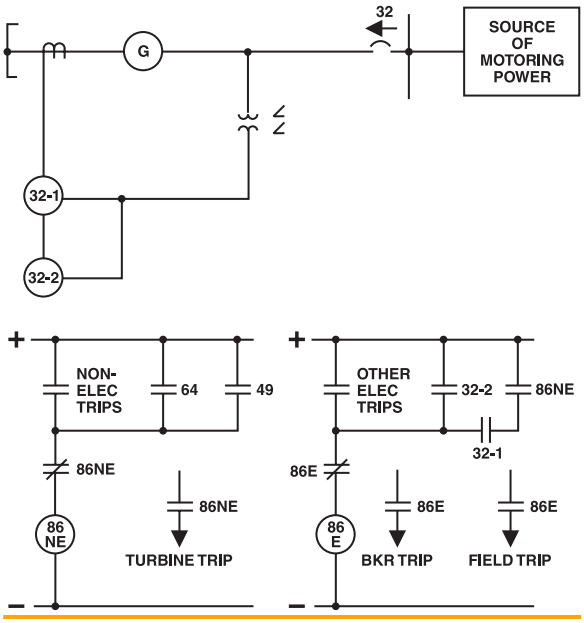


Figure 2 - Reverse-Power Relay 32-1 prevents load rejection before prime mover shutdown for selected trips; Relay 32-2 operates if motoring is not accompanied by an 86NE operation. (Reference: Basler Electric Generator Protection Application Guide)

Existing Electromechanical Reverse Power Protection

The historically used electromechanical (GE and ABB/Westinghouse) relays typically in service are usually tested when the steam turbine generator is manually reducing load and coming off line under controlled conditions by the sequential tripping of the other turbine and steam supply system schemes when a reverse power condition is detected. Typically, the measured power is set to trip when the power factor is at unity. Solid state relays work in a similar manner.

The potential problem occurs when a unit is tripped by shutdown initiated by loss of prime mover at some non-unity power factor load level. The Var loading is at some level and must run back to near zero to correctly trip the 32R device. Typically, those power factor values are measured down to 0.5 pf.

Why Retrofit with the BE1-FLEX?

To extend the tripping range of existing generator reverse power installations to 0.025 pf, the Basler BE1-FLEX is a potential candidate for these retrofit projects.

Retrofitting with the Basler Electric BE1-FLEX is a superior solution for power plant reverse power protection systems. The BE1-FLEX provides dramatically improved reverse power protection, performance of the 32R function is an order of magnitude better than the existing previous-technology relays. The digital protection system's 32R function is capable of tripping correctly for real power at measured power factors as low as 0.025 pf or 88.6 degrees.

A Sequence of Events (SOE) function (with resulting oscillography) can record any reverse power protection event. This recording capability may give additional information about electric power system performance during an event. Therefore, troubleshooting is enhanced by applying the BE1-FLEX.

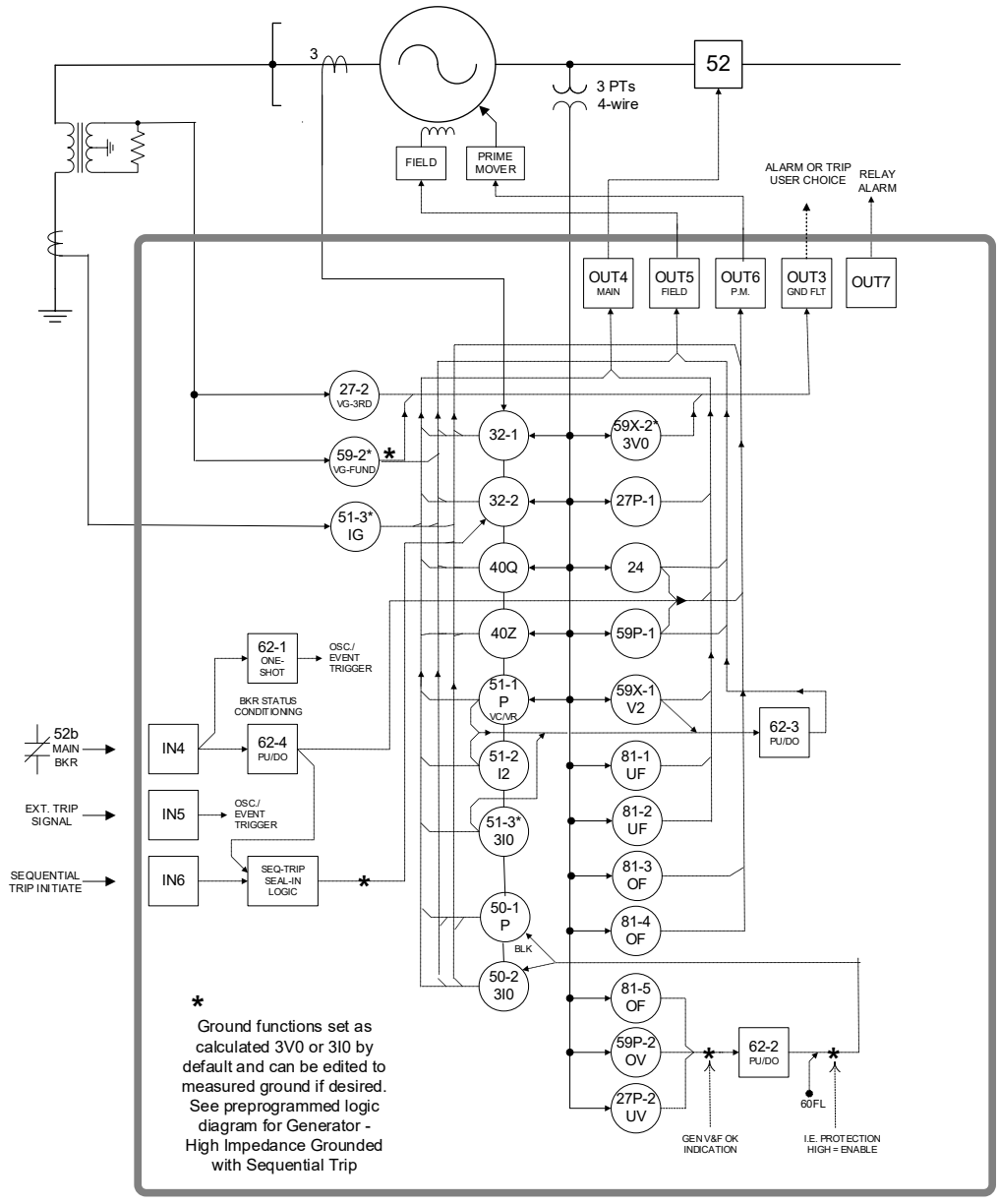
The Basler K-type (S1 size) case makes it an attractive cost solution to replace old reverse power relays, because they are typically in larger cases. The K-type (S1 size) can mount in existing panel cutouts. Additionally,

the digital protection system provides more protective elements such as overcurrent, loss of field, and voltage protection while consuming no extra panel space.

The typical existing ABB/Westinghouse 32R relay in a generator protection panel is shown in Figure 5.

Figure 3 - BE1-FLEX

To retrofit this 32R Generator Protection device requires rewiring the sensing and trip circuits as well as a power supply connection. A typical retrofit project one-line diagram with the BE1-FLEX is shown in Figure 4, including all of the protective elements of the BE1-FLEX. The panel cutout after the removal of the old device requires an adapter plate, part number 9108551021, to mount the BE1-FLEX.



High Impedance Grounded Generator Protection with Sequential Trip One-Line

Figure 4 - BE1-FLEX Applied to High Z Grounded Generator with Sequential Trip (K Case)

Figure 5 - Typical ABB/Westinghouse 32R Installation

The typical existing GE GGP53 installation in the generator protection panels is shown in Figure 6.

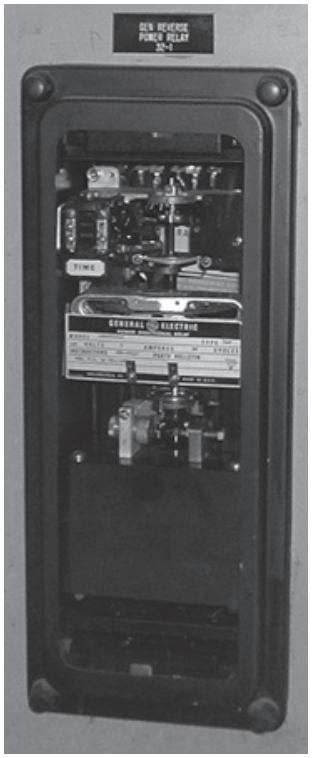


Figure 6 - Typical GE GGP53 Installation

To retrofit this 32R generator protection device will also require rewiring and an adapter plate, part number 9108551029, to mount the BE1-FLEX.

One of the advantages of using a digital protection system is the recording and monitoring capability when the settings detect an event. These recordings can be analyzed to ensure that the anti-motoring scheme is working as designed. If it is not, adjustments can be made with the information supplied by these protection systems.

Once the digital Basler multifunction Protection System is in place, other relay elements, such as 50/51 and 27/59, can be enabled. Then, the existing single function relays can be retired in place.

Summary and Conclusions

1. The use of Basler multifunction Digital Protection Systems can be a powerful tool for improving the Generator Protection Schemes as outlined in C37.102, the IEEE Guide for AC Generator Protection.
2. Improved accuracy and stable calibration features are provided, enhanced by retrofitting with Digital Protection Systems.
3. The addition of monitoring and recording of event records provides information to rapidly analyze an event and can speed up the restoration of power.
4. Basler Protection Systems provide a flexible way to retrofit without panel cutout modifications. Filler plates can be purchased or custom designed to fit existing mechanical configurations.
5. The use of Basler features is cost-effective in the O&M or capital budget when upgrading Generation Protection schemes.

For More Information

For more information about Basler BE1-FLEX Systems, visit www.basler.com or contact Basler Electric Technical Support at +1 618.654.2341.

Basler Electric®

Highland, Illinois USA
Tel +1 618.654.2341
Fax +1 618.654.2351
email: info@basler.com

Suzhou, P.R. China
Tel +86 512.8227.2888
Fax +86 512.8227.2887
email: chinainfo@basler.com

Quality System Certification
Basler
ISO 9001:2015