Overcurrent Protection for Emergency & Standby GENERATOR SYSTEMS

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INTRODUCTION:

Power generation equipment must be protected from damage due to abnormal conditions that exceed output ratings. The coordination of protective devices in circuits fed by generators is required by the National Electric Code (NEC) for life safety loads. Coordination can be simplified using voltage regulation controls to apply full excitation to the generator field during fault conditions.

OVERCURRENT PROTECTION:

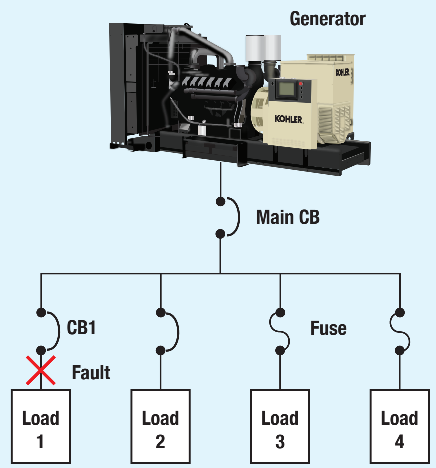
DEFINITION

Overcurrent protection is defined as any current above the generator rating. These conditions are typically caused by overloads, short circuits or ground fault events. Without overcurrent protection, the entire system is out of service, and important life safety circuits may be lost because of a fault elsewhere as shown in *Figure 1*. Types of protective devices used include fuses and circuit breakers.

FUSES

Fuses typically work faster and are less expensive, but they must be replaced after tripping blows the filament inside.

Figure 1



CIRCUIT BREAKERS

Circuit breakers can be reset after tripping, have many options to determine reaction time in a fault situation, and are much safer than fuses.

The best circuit breakers for this condition have inverse time trip characteristics. In other words, the greater the current, the shorter the time allowed before opening the circuit breaker. Except for comparatively small branch breakers, these systems will usually depend upon the thermal or electronic section of the breaker and not upon the magnetic (instantaneous) section.

These breakers will have an Amperes Interrupting Capacity (AIC) rating that is associated with the amount of tripping current it can handle prior to damage of the equipment.

EXCITATION SUPPORT:

EXCITATION FAULT CHARACTERISTICS

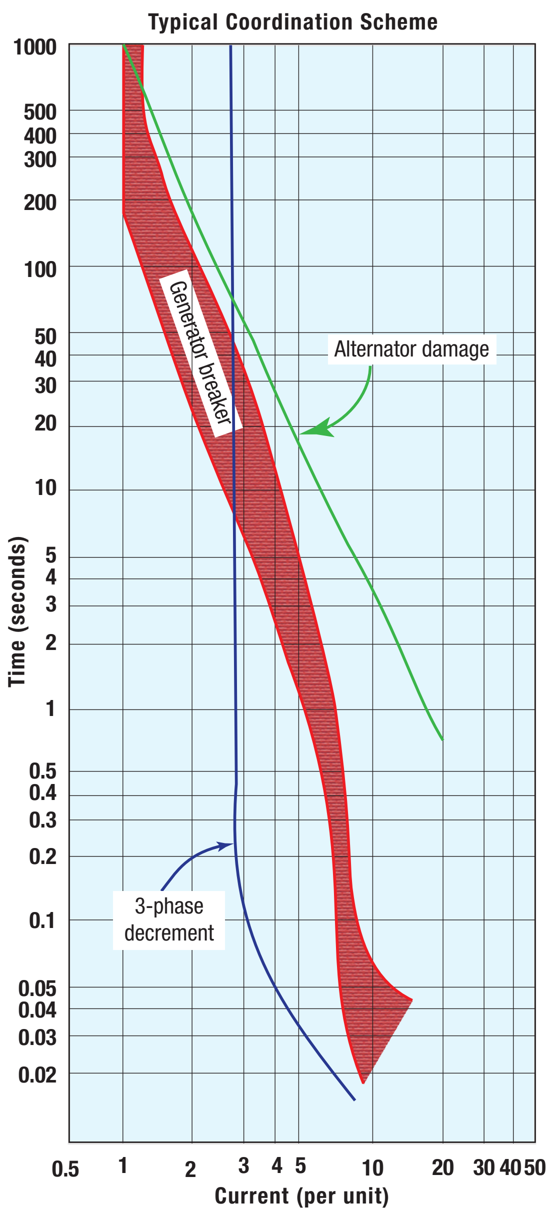
A standard generator set without special provisions to maintain field excitation will suffer a complete collapse of output if anything near a solid fault occurs.

The instantaneous section of generator line circuit breakers is unlikely to trip because, when short circuited, generators in actual applications usually will be less than five times rated current.

When generator voltage decreases because of a ground fault or short circuit on any load line, full excitation is applied to the generator field by the digital voltage regulator. This excitation is typically two to three times the full-load excitation.

Depending upon the fault location and severity, short-circuit currents up to 600% of rated will produce currents sufficient to open branch-circuit fuses or circuit breakers.

Figure 2



WITHOUT EXCITATION SUPPORT

Without excitation support, the short-circuit current will fall to zero within a fraction of a second or within a few seconds at the most.

A permanent magnet (PMG) or auxiliary winding design is used for enhanced field forcing, supplying current throughout a fault condition. This allows the voltage regulator to recover faster as a function of the internal reactances of the generator.

GENERATOR CIRCUIT BREAKER PROTECTION

The ability of the generator to supply large fault currents would damage the alternator without an overcurrent protection device. Therefore, a generator circuit breaker is provided to interrupt overload (including a fault condition) current after a predetermined time delay to permit downstream circuit overcurrent devices to operate or trip closest to the fault, but before generator damage occurred.

KOHLER® generator sets can sustain 300% of the rated current for 10s during a short circuit.

SELECTIVE COORDINATION STUDY

Figure 2 shows a typical coordination scheme which is current vs. time. For a complete coordination study, it is important to understand the relationship of these three curves:

- An alternator damage curve that coincides with alternator protection.
- A generator breaker curve shows the tripping window.
- An alternator decrement curve(s) for current generated.

Each overcurrent protection device time delay increases as the circuit moves upstream of the load to the source.

A selective coordination study must be done with all components in the power system to determine the correct time delays for each overcurrent device between the power source and the load.

ALTERNATOR DECREMENT CURVES:

STANDARD ALTERNATOR DECREMENT CURVE

Decrement curves show the generator current available with the short circuit made at the generator terminals. Thus, the curves show the maximum current available from the generator for developing a coordinated protection system.

Figure 3 shows a standard alternator decrement curve. Note that actual applications will not reach the maximum because of load line impedance. Also, in many cases, limited torque of the prime mover will reduce the speed of the generator, further reducing the maximum current.

Three curves are provided, one for a three-phase fault, one for a line-to-line fault and one for a line-to-neutral fault.

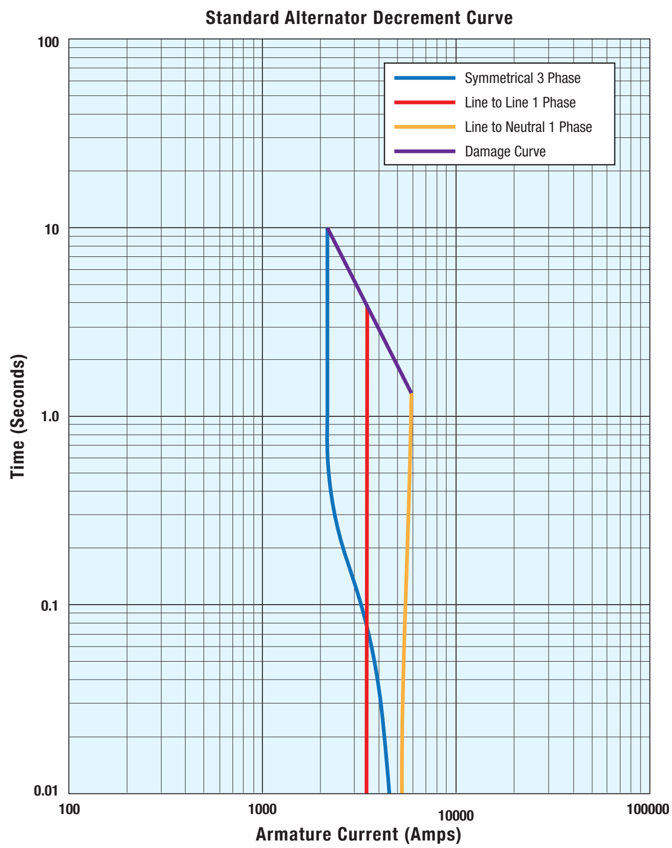


Figure 3

THREE PHASE CURVE

The three-phase curve is used by most engineers, representing conservative planning as far as selective coordination study calculations are concerned. However, line-to-line and line-to-ground are the types of faults commonly encountered in practical situations. The curves terminate at a line called the thermal capability limit (also known as the damage curve).

The protection system design must avoid any combination of current and time beyond this line, so the protection system must have an inverse- time characteristic. This defines the thermal limits of the alternator.

The amperes at time zero on the three-phase curve should theoretically be the same as obtained by dividing the full load amps (FLA) rating by the sub-transient reactance (X"d) pu value. In practice, there is no zero-impedance short-circuit condition due to system dynamics.

CONTROLLER PROTECTION:

KOHLER® GENERATOR CONTROLLERS

Kohler generator controllers have integral alternator thermal protection. The alternator protection built into KOHLER controllers limits the delivered current from exceeding the damage curve and the generator breaker protects downstream devices.

Figure 4 depicts the new APM603 controller. It has additional features that assist in the overcurrent protection efforts including current-limiting settings for alternator and fault protection.

With an integral voltage regulator, the APM603 can precisely control alternator excitation. The on-board configuration files have overload and short-circuit protection built in. This is a function of designed setpoints for maximum protection of the generator.

APM603 FEATURES

The APM603 includes the addition of energy reduction maintenance switching (ERMS) capability, so the controller can be classified as an overcurrent protective device according to NEC 240.87 Arc Energy Reduction.

Figure 4

MAINTENANCE MODE FUNCTION

The Maintenance Mode function is a flexible event subsystem that allows for creating an instantaneous current overload without changing the software.

The customer will set these limits based on their load profile permitting a warning present whenever the instantaneous trip or maintenance mode was enabled, which would prevent it from being in “system ready” mode.

FINAL THOUGHTS

In general, generators have very limited fault current ability compared to utility service. KOHLER provides the level of overcurrent protection support critical for generators to properly function. This is imperative when designing a safe and reliable backup power system.

Emergency systems require a selective coordination study per the NEC. Decrement current curves are a convenient tool for completing these studies. KOHLER generator circuit breakers and alternator decrement curve information are available on SKM Power Tools to assist engineers with their coordination studies.

ABOUT THE AUTHOR

Carson Bishop is a Senior Project Engineer at Kohler Co. He holds a bachelor of science in electrical engineering from Rose-Hulman Institute of Technology. Carson joined Kohler in 2018 and specializes in sustaining alternator design, large enclosure electrical design and National Electrical Code requirements.

A global force in power solutions since 1920, Kohler is committed to reliable, intelligent products; purposeful engineering and responsive after-sales support. Kohler-SDMO is among the world's largest manufacturers of industrial generators. The company has 100 years' experience in industrial power and benefits from global R&D, manufacturing, sales, service and distribution integration.

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