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AmpSentry Overcurrent Protection and Arc Energy Reduction

White Paper

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In the interest of worker safety arc energy reduction has become a common requirement in emergency power systems. Manufacturers of circuit breakers and protective relays have responded by adding various arc energy reducing functions to their products. One of the most commonly used arc energy reduction methods is energy reducing maintenance switching or “maintenance mode”. When maintenance mode is enabled any time delays configured for selective coordination are bypassed in the event of a fault so the fault is cleared instantaneously. The logic behind this is that when a technician is working in the vicinity of live electrical equipment the high level of available arc flash energy allowed by the time delays in the overcurrent protective devices (OCPD) puts the worker at a significant risk if there is a fault in the system. Bypassing the time delay reduces the risk of injury due to arc flash to the worker. When the work is finished and the worker leaves the area the OCPD is taken out of maintenance mode which re-activates the time delays so that the system will be selectively coordinated.

Certain Cummins PowerCommand controls have an overcurrent protection and fault current regulating feature called AmpSentry, which is UL listed as a protective relay. In 2014 Cummins added a maintenance mode function to Ampsentry for PowerCommand 2.2, 2.3 and 3.3 controls. In this paper we will describe AmpSentry and its new maintenance mode, how to enable maintenance mode and how it meets NEC energy reduction requirements.

AmpSentry

When PowerCommand controls measure current in any phase as exceeding 110% of the generator set standby rating a current summing integral will be activated so that the generator will shut down based on the Ampsentry time current curve. The green line in Figure 1 is the AmpSentry trip curve. This allows AmpSentry to protect the alternator and also the feeder cables connected to the alternator provided they are rated for at least 100% of the full load current rating of the genset.

AmpSentry also has a fault current regulation feature. When the control measures current in any phase as exceeding 300% of the generator set standby rating the control recognizes that this is a fault condition and begins to regulate current in the phase with the highest level of current to 300% of rated current. The purpose of this is to allow a downstream OCPD to clear the fault, maintaining a coordinated system. AmpSentry's overcurrent protection function is in effect during a

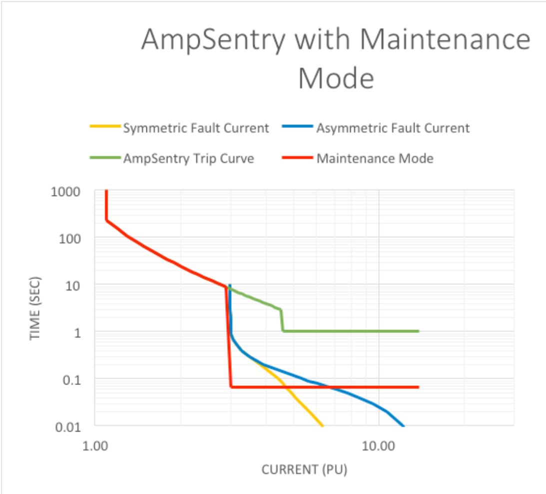

Figure 1. AmpSentry Time Over Current curve. Includes symmetric and asymmetric fault current decrement curves for a DQLD 2750 kW genset.

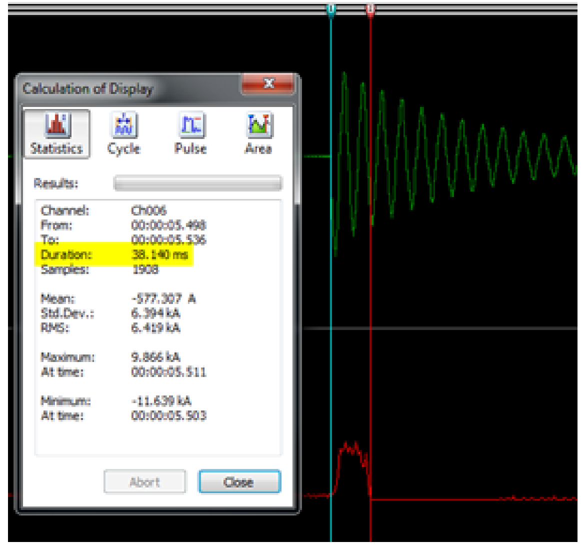

Figure 2. Control response and fault current decay resulting from a short circuit with AmpSentry Maintenance Mode active

fault and will shut down the generator set based on the time current curve if the fault is still active. Note that in Figure 1 as fault current decays to 300% of rated current AmpSentry holds the current constant at that level until the line crosses the AmpSentry trip curve.

AmpSentry Maintenance Mode

PowerCommand AmpSentry's Maintenance Mode function acts in the same manner as maintenance mode on a circuit breaker. When maintenance mode is enabled AmpSentry shuts down the generator set (by shutting off fuel and excitation) as soon as it recognizes that current on any phase has exceeded 300% of the generator set rating. The short circuit shutdown event can also be mapped to one of the customer configurable outputs of the control to shunt trip a breaker providing immediate isolation. Tests have shown that excitation is shut off within 50 msec of the occurrence of the fault. In Figure 1, the red line is activated as the trip curve when maintenance mode is enabled. Note that for current less than 300% of rated current the maintenance mode trip curve is the same as the standard AmpSentry trip curve.

Figure 2 displays a current trace created during a test of AmpSentry Maintenance Mode. Note that in this test the control recognized the fault within 38 msec of the fault occurrence and shut off the genset fuel and excitation. The current decayed exponentially according to the transient time constant.

Enabling AmpSentry Maintenance Mode

Maintenance Mode is enabled by either activating a configurable customer input while the control switch is in "Auto" or by plugging in the InPower Service tool.

There are several customer configurable inputs on the PowerCommand controls that can be configured as the Maintenance Mode enable switch by connecting a pair of dry contacts between two terminals on the control terminal block. InPower can be used to configure the input as the maintenance mode enable switch. The input can be configured to be either active closed or active open. Figure 3 displays an example of setting up a configurable input in InPower.

Fault code 5399 becomes active whenever Ampsentry maintenance mode is enabled. As a default this fault code is set up as an event only. By configuring this fault code to be a warning the control can log when maintenance mode is enabled and disabled. This log may be useful if the genset ever does sustain a short circuit. Figure 4 shows an example of how to use InPower to set up control to log the maintenance mode event.

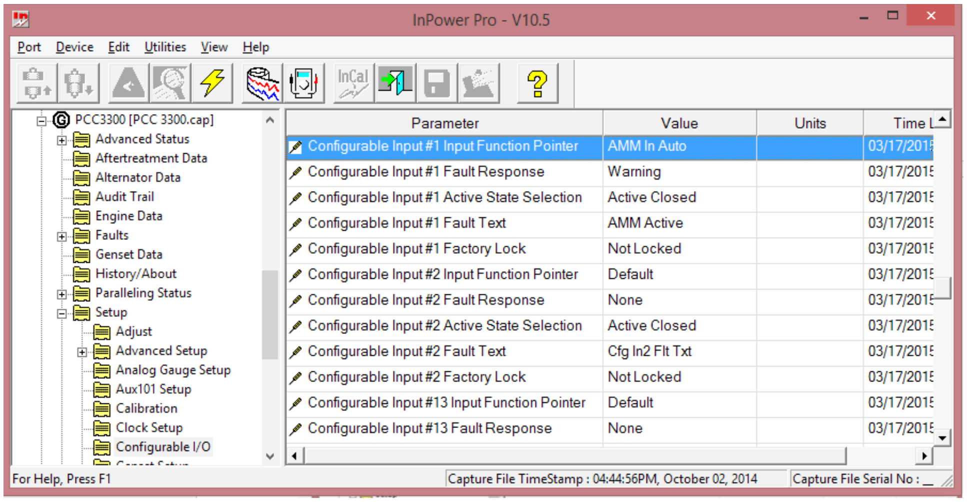

Figure 3. Setting up a configurable input to enable maintenance mode

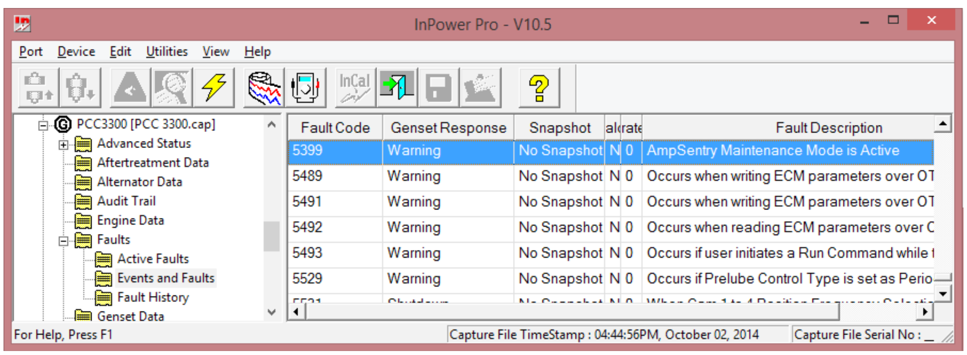

Figure 4. Ampsentry maintenance mode fault code

NEC Arc Energy Reduction requirements

The 2014 version of the NEC requires that OCPD's rated 1200 amps and higher have some type of arc energy reduction function. Relevant text from the 2014 NEC is printed below:

> ***240.87 Arc Energy Reduction***
> *Where the highest continuous current trip setting for which the actual overcurrent device installed in a circuit breaker is rated or can be adjusted is 1200 A or higher, 240.87 (A) and (B) shall apply.*
>
> ***(A) Documentation.*** *Documentation shall be available to those authorized to design, install, operate, or inspect the installation as to the location of the circuit breaker(s).*
>
> ***(B) Method to Reduce Clearing Time.*** *One of the following or approved equivalent means shall be provided:*
>
> 1. *Zone-selective interlocking*
> 2. *Differential relaying*
> 3. *Energy-reducing maintenance switching with local status indicator*
> 4. *Energy-reducing active arc flash mitigation system*
> 5. *An approved equivalent means*
>
> ***Informational Note No. 1:*** *An energy-reducing maintenance switch allows a worker to set a circuit breaker trip unit to "no intentional delay" to reduce the clearing time while the worker is working within an arc-flash boundary as defined in NFPA 70E-2012, Standard for Electrical Safety in the Workplace, and then to set the trip unit back to a normal setting after the potentially hazardous work is complete.*

AmpSentry Maintenance Mode provides “energy reducing maintenance switching” as enumerated in 240.87(B)(3). The informational note describes the energy reducing maintenance switch as allowing a worker to set a breaker trip unit to “no intentional delay” while working within the arc flash boundary and then to set the trip unit back to a normal setting after the work is complete.

AmpSentry clearly meets the requirement for arc energy reduction as defined in NEC 240.87. The fact that the text in the informational note refers to a circuit breaker does not mean that only a circuit breaker can be used to meet this requirement. The fact that the code allows for “an approved equivalent means” underscores the point that a circuit breaker is not the only means for meeting this requirement.

Arc Energy Calculation

NFPA 70E references the IEEE 1584 method for estimating Arc Flash energy. This method is also used by SKM Power Tools software as well as other power system analysis programs. In addition to available fault current and arc interrupting time arc energy depends on a number of site specific factors such as system voltage, grounding method, conductor gap and working distance. Because of this arc energy available from a genset is site specific and within a site the arc flash incident energy will vary throughout the electrical distribution system based on cable resistance between the sources and the fault and on other sources such as motors that could feed the fault.
To illustrate the arc energy reduction capabilities of maintenance mode we have done calculations of arc energy for a specific generator set, a 2750 kW, 480 volt DQLD model. Note that these calculation are for comparison purposes only. In Table 1 we have calculated theoretical arc flash energy at the output of the generator using the IEEE 1584 method and parameters for a 480 volt, solidly grounded system for arcs in a box in low voltage panel board class of equipment. This calculation is intended for illustrative purposes only. Actual arc flash calculations should be performed by a licensed Professional Engineer taking into account all of the characteristics of the site.

Arc Flash Incident Energy — cal/cm^2	
AmpSentry — current reduced to 300% of rated for 2 seconds	58.1
AmpSentry — maintenance mode — immediate shutdown	11.3
AmpSentry maintenance mode — breaker trip	3.57

Table 1. Arc Flash Energy Calculations – IEEE 1584 Method

Arc flash energy is calculated for three scenarios: One without maintenance mode enabled, one with maintenance mode enabled and one with maintenance mode enabled with a configurable output wired to shunt trip a breaker.

For a DQLD 2750 kW Genset without maintenance mode active we calculated an arc flash energy level of 58.1 cal/cm^2. In this scenario arcing current is not interrupted but the arc duration is 2 seconds. NFPA 70E (D.7.3) recognizes 2 seconds as a reasonable maximum time for calculations because a person will likely move away from the arc quickly if physically possible. In this scenario arc flash energy is calculated for both the transient period and the steady state period. This is how SKM calculates arc energy from a generator set in recognition that fault current from a synchronous generator decays rapidly. Three phase bolted fault current is used in the transient period calculation. 300% of rated current is used in the steady state calculation to correspond with AmpSentry’s fault current regulation function.

With AmpSentry Maintenance Mode enabled we calculated an arc flash energy level of 11.3 cal/cm^2. With Maintenance Mode enabled the control shuts off fuel and excitation immediately on recognizing the fault. The arc doesn’t necessarily immediately extinguish however due to energy stored in the windings. As can be seen in Figure 2 when excitation is shut off fault current decays exponentially based on the transient time constant. It takes 1 transient time constant (0.19 sec for this alternator) for the current to decay to a level that the arc extinguishes. (NFPA 70E D.5(1) states that the industry accepted minimum level for a sustaining arcing fault is 38 percent of available bolted fault current. 38 percent of initial current corresponds to 1 time constant.)

About the author

Rich Scroggins is a Technical Advisor in the Application Engineering group at Cummins Power Generation. Rich has been with Cummins for 18 years in a variety of engineering and product management roles. Rich has led product development and application work with transfer switches, switchgear controls and networking and remote monitoring products and has developed and conducted seminars and sales and service training internationally on several products. Rich received his bachelors degree in electrical engineering from the University of Minnesota and an MBA from the University of St. Thomas.

We calculated an arc flash energy level of 3.57 cal/cm^2 for the scenario in which a configurable output of the control is wired to shunt trip a breaker at the instant that the control recognizes the fault, isolating the working space from the energy stored in the alternator windings. Tests have shown that AmpSentry will recognize the fault within 50 msec. For this calculation we used 60 msec for the duration of the arc, allowing 10 msec for the breaker to clear.

Conclusion

Arc energy reduction requirements have been added to the National Electrical Code as a means for improving worker safety. Cummins Power Generation's AmpSentry protective relay with Maintenance Mode has the functionality to meet all of an onsite emergency generator's NEC requirements for overcurrent protection and arc energy reduction.

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