# Circuit Breakers – Are you protected?

Denser cabinets with high power devices are driving today's power distribution needs. As this high density trend continues 208 V power and 3-Phase 208 V power is being brought down to the cabinet level. Most organizations consider this equipment mission critical with downtime measured in thousands of dollars for each minute a system is unavailable. With so much at risk a better understanding of overcurrent protection and the differences between fuses and circuit breakers protection is key to maintaining uninterrupted service when implementing cabinet level power distribution units (PDU's).

There are several approaches to providing overcurrent protection. This paper focuses on the differences between using fuses and circuit breakers. To explore this topic further selective coordination, component protection, maintenance, resettability and other issues are discussed.

Overcurrent protection is driven by the standard UL60950-1, Clause 2.7 which states that "standard supply outlets and receptacles **shall** be protected by an overcurrent protective device in either the equipment or the branch circuit, rated not more than the outlet or receptacle. The overcurrent protective device shall be of a type that is suitable for branch circuit protection in accordance with the National Electrical Code (NEC®) ANSI/NFPA 70…"

Branch circuit protective devices typically fall into two categories, molded case circuit breakers listed to UL489, or fuses listed to UL248. By definition, a circuit breaker is a means of automatically opening a circuit at a specified level of overcurrent, on either an overload or a short circuit condition. Fuses are also designed to open the circuit at specified levels of overcurrent. Fuses are typically the less costly up-front solution, and are replaced after each occurrence. Breakers are typically the more costly upfront solution and if listed to UL489 are large,, bulky and do not fit into a 1U enclosure..

## *Selective Coordination*

Proper selective coordination eliminates unnecessary power outages and reduces costly downtime. Selective coordination is the act of isolating a faulted circuit from the remainder of the electrical system, while maintaining uninterrupted power to the unaffected circuits. The faulted circuit is isolated by the selective operation of only that Overcurrent Protection Device (OCPD) closest to the over current condition.

Fuses open the circuit when they 'see' a specific level of current passing through the fuse. Lower amperage rated fuses require less energy to open the circuit than higher amperage rated devices. This allows fuses to be very easy to selectively coordinate.

Circuit breakers require a coordination study to ensure selective coordination. Overlap of circuit breaker trip curves between the upstream and downstream devices often results in simultaneous operation of both devices. A circuit breaker system will

clear the fault condition and open the circuit, but it will also remove power to all of the remaining loads being served by the PDU.

### *Component Protection*

According to the NEC® 110.10, overcurrent protection devices shall be selected to permit the OCPD to clear a fault without damage to the electrical components of the circuit. By reducing the amount of energy that passes through to the protected device, you decrease the damage that reduces repair and downtime. In order to successfully protect sensitive equipment, the upstream overcurrent protective device needs to be able to operate in a very short amount of time, and consistently limit the amount of fault current/energy, which passes through to the downstream devices.

Fuse operation is based on a simple thermal principle; the internal fuse element will rapidly melt/vaporize, at a very specific level of energy. This amount of energy is well below the total amount of energy potential available during a faulted condition. The resultant clearing time and the subsequent let-through current is significantly reduced which results in less energy that a downstream component is required to withstand. Per UL248 listing, fuses are required to meet maximum allowable energy let through values under fault conditions, which allows for excellent protection of components.

Most thermal magnetic molded case circuit breakers are not listed and marked as current limiting. They do not interrupt short circuit currents in less than a ½ cycle, and typically require a full cycle to clear a fault condition. This means that the full peak current and energy of the first cycle of the fault will be let-through. Per UL489 listing, standard thermal magnetic molded case circuit breakers are not tested to limit the maximum amount of energy let-through to downstream components.

### *Maintenance*

Proper maintenance of overcurrent protection devices, as specified by the manufacturer, is critical to effectively and consistently operate within its manufacturing specifications in the event of an overcurrent condition. Fuses do not require maintenance. Molded case circuit breakers require periodic inspection and manual operation as part of their prescribed maintenance procedures. Failure to manually exercise the mechanism can cause the breaker to open slower than specified or not operate. The causes for this can be numerous, but one cause is the internal lubricants begin to thicken and harden. Most manufacturers recommend that if a molded case circuit breaker has not been operated, opened or closed, within six months time, it should be removed from service and manually exercise the mechanical operation and the tripping mechanism. “If operated outside of its ratings or without proper maintenance, catastrophic failure of the power system, circuit breaker, or switchgear can occur causing not only the destruction of the equipment but serious injury or even death of employees working in the area.” (Refer to Dennis Kneitzel’s white paper at http://www.bussmann.com/library/arcflash/PDMaintPaper.pdf)

Because of the highly engineered yet simple design, fuses ship from the factory calibrated to a very specific set of operating parameters. This ensures that the fuse will operate as specified without maintenance and upkeep concerns.

### *Interrupting Rating*

According to NEC® 110.9 "Equipment intended to interrupt current at fault levels shall have an interrupting rating sufficient for the nominal circuit voltage and the current that is available at the line terminals of the equipment." Failure to comply can result in catastrophic failure of the overcurrent protective device, which will require replacement of the entire PDU, and an immediate loss of power. Worst case examples could result in a fire and/or explosion. All modern current-limiting fuses listed to UL248 employ a simple and reliable method of current-limitation and are able to easily achieve interrupting ratings of 100,000 amps or higher. Standard UL489 Circuit Breakers typically tested to safely interrupt much lower levels of fault current, and are not inherently current limiting.

### *Venting*

When operating under a short circuit condition, as the contacts of a circuit breaker separate, an arc is created between the contacts. The circuit breaker utilizes arc-chutes to divide and dissipate the resulting arc. As a mechanical device, the breaker cannot internalize the resultant expansion of ionized gases. These must be vented 'safely' from the breaker into the surrounding equipment. These hot ionized gases can potentially damage other sensitive components. Fuses are required and listed under UL248 to contain any violence or fire that occurs during the internal arc that is created when the fuse opens under a short circuit condition. This includes maximum amounts of physical deformity, of which very little is allowed.

### *Physical Attributes*

The fuses utilized in many PDU's have a very specific physical footprint and rejection style fuse holder that prevents the wrong fuse from being installed. This prevents unqualified personnel from replacing an open fuse with a different fuse that may not provide the correct level of protection. PDU suppliers such as Server Technology utilize a Class G fuse, UL specifications file #E42730, which provides a very high degree of current limitation. Class G fuses have unique dimensions. Also, the dimensions are different based upon the continuous amperage rating of the fuse. After a fault occurs, fuses are replaced assuring the same level of protection that existed previous to the fault. This ensures a high level of protection and reliability, without concern for maintenance and potential mechanical damage inherent to re-settable OCPD's.

***Resettability***

There are several misconceptions concerning the suitability for using re-settable devices for reliable overcurrent protection. Per OSHA 1910.334(b)(2) after a circuit has been de-energized by the operation of a circuit protective device, the circuit may not be reenergized until it has been determined that the circuit can be safely energized. A qualified person is required to determine the cause of the overcurrent condition, and in the event of a short-circuit, fix the problem prior to reenergizing the circuit. Circuit breakers that have interrupted a fault approaching their listed ratings **shall** be inspected and tested to the manufacturers instructions according to NFPA70E 225.3. After a circuit breaker safely interrupts one short circuit fault, the breaker needs to be evaluated to determine if it can safely be put back into service, and it may need to be tested in order to determine if it will safely interrupt a short circuit in the required amount of time. This testing can involve taking the PDU out of service and taking the breaker out of the PDU. In some cases the breaker may need to be discarded and replaced.

***Environmental temperature concerns***

Fuses and many circuit breakers use thermal principles to sense overcurrents in a circuit. External temperature can affect the opening time of the OCPD, and could cause potential nuisance opening of the device. For applications in data centers, the environment is very carefully controlled and the temperature has not been a concern.

## ***Conclusion***

When making the selection of overcurrent protection devices for applications such as power distribution for critical circuits; selective coordination, component protection, and maintenance must be taken into consideration. Fuses offer easy and reliable selective coordination, superior component protection and zero maintenance. Fuses are a simple, proven and effective means of providing reliable overcurrent protection, and reducing the energy let-through to sensitive downstream equipment. This will improve safety, decrease downtime, and maintain company profitability.

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**Figure 1:**


**Figure 2:**

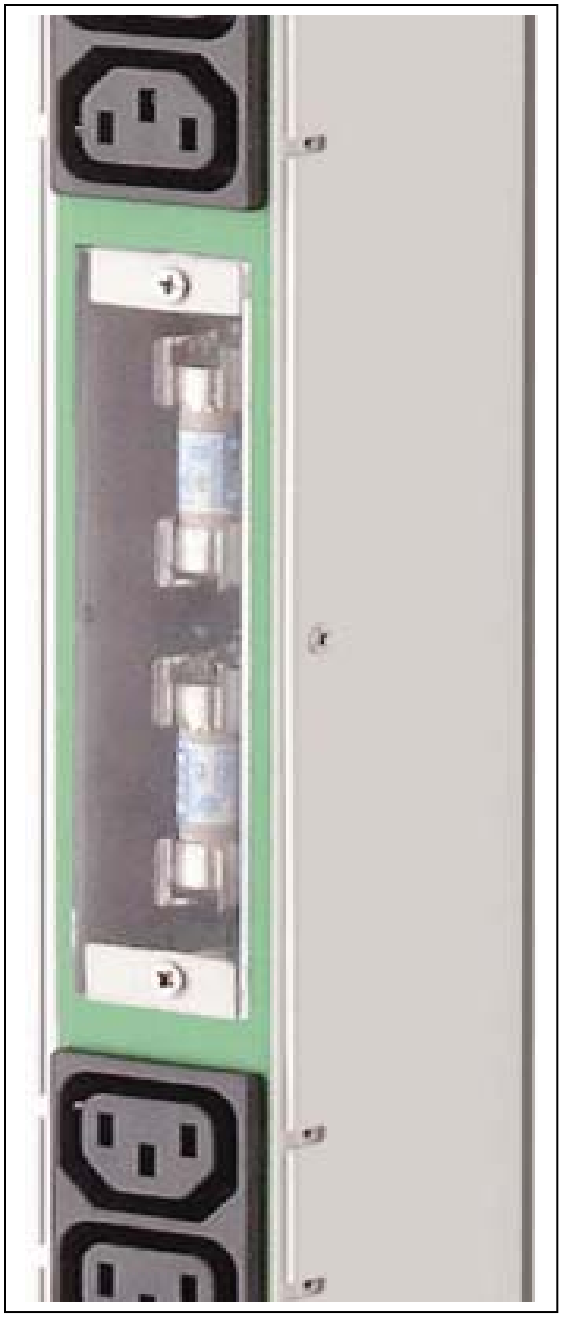

**Figure 1** is a PDU with circuit breaker protection to UL 489 and **Figure 2** is a PDU with fused protection to UL248.