Data Center

Mission Critical/Data Center Electrical Distribution Systems

Data center electrical distribution designs are rapidly evolving, driven by needs such as increasing power densities, energy efficiency, more flexibility for making changes after the initial install, increased uptime, adhering to safe electrical work practices, and minimizing maintenance while retaining reliability. Many of these design advances result in higher distribution voltages, high available fault currents, and greater potential arc flash hazard. Current-limiting fuses provide excellent overcurrent protection for the challenging needs of modern data centers. The following section will discuss some of these trends and challenges facing designers and users along with the solutions that current-limiting fuses can provide. This section will discuss:

1. Products for data center overcurrent protection
2. Fusible solutions for two broad architectures: PDU architecture and busway architecture
3. Highlight the benefits of fusible data center distribution systems
4. Trend to higher distribution voltages

1. Data Center Distribution Architectures

PDU Architecture:

See Figure 1 for power distribution unit (PDU) architecture. The line side of the UPS system can consist of a normal source and alternate source utilizing standard fusible power distribution panels or fusible switchboards. PDU manufacturers are now incorporating the new Cooper Bussmann Quik-Spec™ Coordination Panelboard (QSCP) in their PDU and RPP (remote power panel) offerings. The new QSCP panelboard utilizes the innovative 600Vac rated Compact Circuit Protector (15A to 100A) integrated with the 1 to 100A UL Class CF CUBEFuse. The width of the standard enclosed QSCP panelboard for general construction branch panels is the same as standard 20” circuit breaker panelboards. The single pole Compact Circuit Protector (CCP) with CUBEFuse is 1” wide and is available in one, two, or three pole versions. At the cabinet, a fusible cabinet power distribution unit (CDU) (or often referred to as rack PDU) provides another level of current-limiting fuse protection. Fusible solutions offer many benefits which will be discussed later in this section.

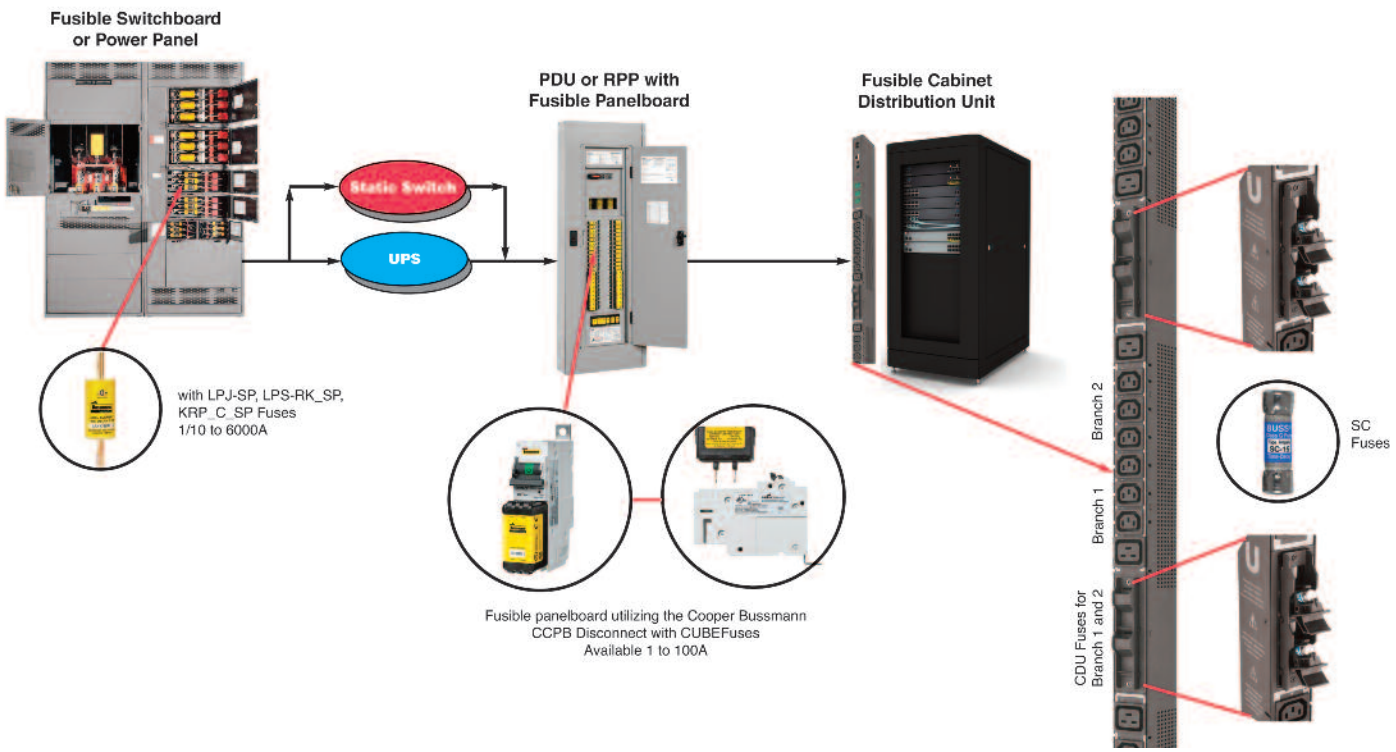

Figure 1. The fusible solution PDU architecture utilizes standard available fusible distribution panels/switchboards, PDUs/RPPs with the new QSCP panelboards incorporating the CCP disconnects and CUBEFuse, and cabinet power distribution systems with fuse protection.

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Busway Architecture:
See Figure 2 for busway architecture which utilizes a plug-in busway to distribute power on the loadside of the UPS to the cabinets. The plug-in busway is suspended above server cabinets. The bus plug-in unit can utilize the 30A, 60A, or 100A Compact Circuit Protector integrated with 1 to 100A CUBEFuse. The fusible bus plug-in unit is attached to the cabinet power distribution unit (CDU) via cable. At the cabinet, a fusible CDU provides another level of current-limiting fuse protection. The fusible solution offers many benefits which will be discussed later in this section.

With bus plug-in units utilizing the CCP disconnect and CUBEFuse, the plug-in unit does not have to be changed out for ampacity changes to rack, if proper foresight and work practices are followed. Instead the disconnect can be switched to off. Then the CUBEFuse can be changed to the amp rating that is necessary for the cabinet or server change. See the discussion under Data Center Products.

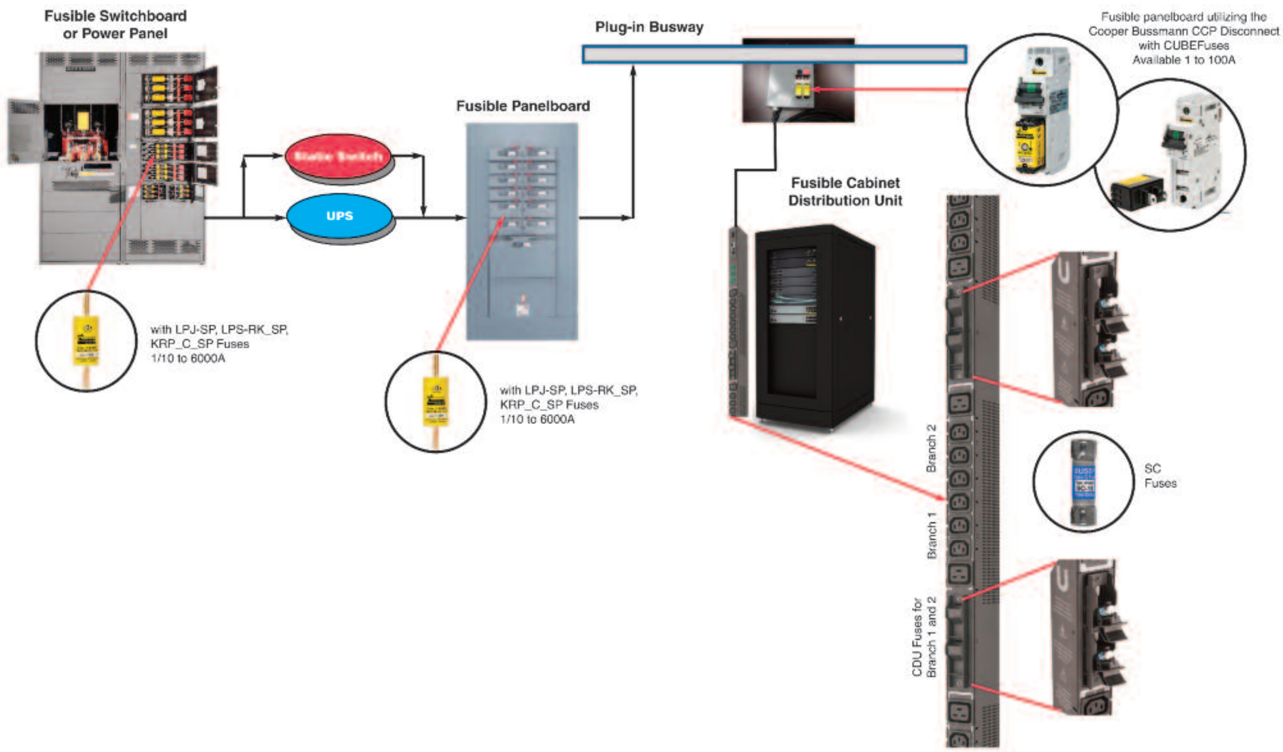

Figure 2. The fusible solution plug-in busway architecture utilizes standard available fusible distribution panels/switchboards, fusible bus plug-in units incorporating the CCP/CUBEFuse fusible disconnects, and fusible cabinet power distribution systems.

2. Trend to Higher Distribution Voltage

The majority of the installed data center distribution systems are 208/120Vac. However, there is a major trend to utilizing higher electrical distribution voltages with the most prominent being 415/240Vac and with some 480/277Vac and 600/347Vac.

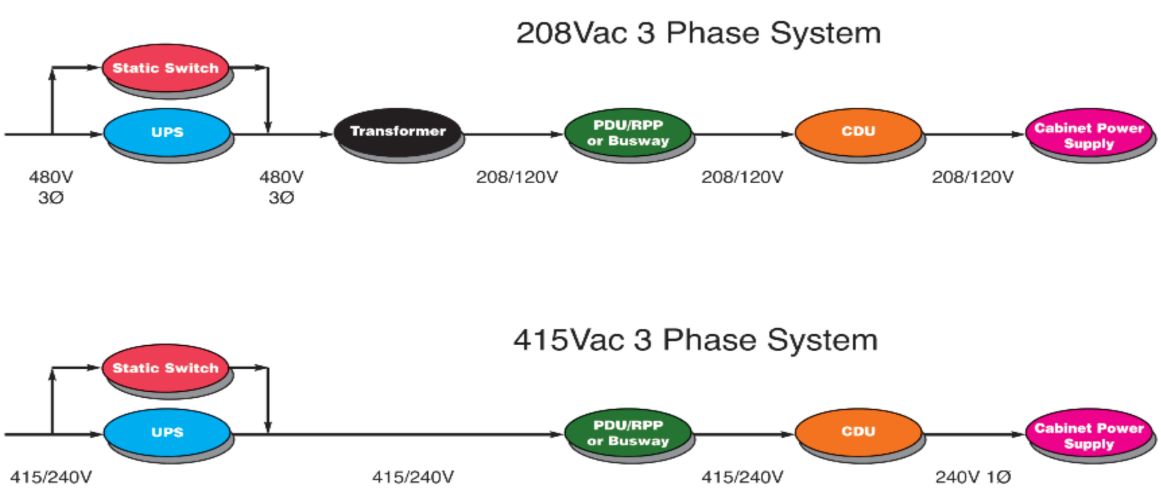

Figure 3. 208/120Vac and 415/240Vac data center distribution centers. In the 208V system the PDU includes the transformer. In the 415V system configuration, the 415V is transformed from a higher voltage prior to the data center and as a result there are no transformers in the data center. For either system the circuits to the cabinets could be from a panelboard or busway with plug-in fusible disconnect.

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See the 208/120Vac 3 phase system example in Figure 3. The three phase UPS output supplies a transformer from which the downstream distribution can be via a PDU architecture or busway architecture. With the PDU architecture, the transformer PDU may distribute 208V to a number of other panels (referred to as remote power panels or RPP) located throughout the data center which then distributes power to cabinet distribution units (CDUs) at the server cabinets. The cabinet power supplies are connected to the CDU.

See the 415/240Vac 3 phase system example in Figure 3. Industry experts have found that data center distribution at higher voltage can increase energy efficiency and reliability within a data center. There are many ways to configure 415Vac data center electrical systems. This 415Vac example illustrates a "transformerless" data center, where the transformation to 415Vac from a higher voltage is outside the data center. Moving to 415/240Vac data centers accommodates the typically available cabinet power supplies. The typical cabinet power supplies operate within a voltage range of 200Vac to 240Vac with some of the lower wattage power supplies operating within a voltage range of 100 VAC to 240 Vac. Commonly, 415/240Vac three phase is brought to the CDU and the CDU distributes single phase 240Vac to the cabinet power supplies. This is a significant advantage since higher efficiency is achieved while using existing power supplies.

The drivers moving to 415Vac data centers include increased mean time between failure (MTBF), double the power to the rack in the same footprint, double the power for a given conductor size, and reduction in components with a result of less space utilization and lower cost. However, there is the resulting increase in voltage and available short-circuit currents. It is important to consider the OCPD type, ratings, and characteristic best suited to meet the desired design criteria and the operational practices while complying with the NEC and OSHA.

3. Benefits of Fusible Designs

Current-limiting fuses offer many benefits to the data center designer and owners. These advantages are more pronounced with the challenges posed by the trend to higher voltage, higher energy efficiency and greater power density data centers. As a consequence, the overcurrent protective devices in the PDUs, RPPs, busway plug-in units, and cabinet CDUs must have higher interrupting ratings at higher voltage ratings. In addition, this electrical equipment must also have higher short-circuit current ratings.

With higher fault currents, ensuring selective coordination becomes even more essential to avoid cascading overcurrent protective devices causing unnecessary outages. Similarly, higher fault currents typically result in higher arc flash incident energy unless mitigated by current-limiting overcurrent protective devices.

Interrupting Rating:

Interrupting rating is the maximum short-circuit current that an overcurrent protective device can safely interrupt under standard test conditions. IR is an abbreviation for the term interrupting rating. Interrupting capacity with an abbreviation of IC is an older synonymous term carried over from years past. The National Electrical Code, UL Standards, and markings on fuses and circuit breakers now use the term interrupting rating and markings such as "IR 200KA" or "200kA IR." The term AIC or KAIC, such as in "200k AIC," is no longer used for product markings nor in the NEC or UL Standards.

All overcurrent protective devices must have interrupting ratings equal to or greater than the available fault current at their lineside terminals per NEC 110.9 and OSHA 1910.303(b)(4). In addition to fault currents trending up in new data centers, existing data centers can be expanded, increasing fault current beyond the interrupting ratings of existing OCPDs. Current-limiting fuses typically have interrupting ratings of 100,000A, 200,000A or 300,000A for 600Vac or less. With higher voltage distribution to the cabinet (i.e., 415Vac or greater), it is not uncommon to have 50kA or greater short circuit current available at a RPP or server cabinet busway plug-in unit. Even the cabinet power distribution unit can have high fault currents. Therefore, the 5kA IR or 10kA IR overcurrent protective devices often used in CDUs may be inadequate for many installations.

Circuit breaker solutions for higher available short-circuit currents either (a) use fully rated circuit breakers (each circuit breaker has an individual interrupting rating equal or greater than the available fault current at its lineside terminals) or (b) use series combination rated circuit breakers (a circuit breaker is permitted to have an interrupting rating less than the available fault current at its lineside terminals if installed in a panelboard that is tested, listed, and marked with a specific line side circuit breaker or fuse). Fully rated circuit breakers with higher interrupting ratings cost more and may have a larger footprint. In either case with fully rated or series rated circuit breaker systems, reliability is sacrificed since selective coordination is usually more difficult to achieve when using standard molded case circuit breakers; this is more pronounced as the fault currents increase.

Fuses inherently provide fully rated high interrupting ratings for systems with fault currents up to 200kA without any price premium or footprint increase. The high interrupting rated fuses are all current-limiting making it simple to achieve selective coordination and easy to provide excellent protection of circuit components.

Component Protection and Short-Circuit Current Rating of Equipment:

One of the principal advantages to fusing data center circuits is the current-limiting ability of fuses which can greatly reduce the let-through energy during faults. Per the fuse product standard UL 248, current-limiting fuses are not permitted to exceed maximum allowable energy let-through values under fault conditions. This provides excellent protection for components. The most current-limiting fuses (UL fuse Classes CF, J, RK1, T, CC, G, and L) provide superior short-circuit current protection. All equipment and components in the data center electrical system are required per NEC 110.10 and OSHA 1910.303(b)(5) to have a short-circuit current rating equal to or greater than the available short-circuit current. This includes the transfer switches, UPSs, PDUs, CDUs, RPPs, busway, bus plug-in units, and power supplies. The trend is that systems are capable of delivering more fault current as a result of the higher voltage and higher power density designs being used in data centers.

A current limiting device is needed to quickly drive the short-circuit current down to zero and keep the let-through energy below the damage levels of the equipment.

For instance, most fusible panelboards and enclosed disconnects can be tested, listed, and marked with a 200,000A short-circuit current rating. If busway is tested, listed, and labeled with current-limiting fuses as the short-circuit protection, 200,000A short-circuit current rating is typically achievable.

Selective Coordination:

The ability of a system to prevent an unnecessary blackout, has been a design consideration in data centers and mission critical systems long before it was a code requirement in the NEC® for systems supplying life safety loads. Mission critical system designers understand the added reliability that selective coordination of overcurrent protective devices brings to system reliability. The use of properly selected fuses in data centers alleviates the design hassle of trying to achieve selectively coordinated circuit breakers at the cabinet and busway (or PDU) levels as well as further upstream. Fuses simply need to maintain a 2:1* amp rating ratio for Cooper Bussmann Low-Peak fuses from the lineside fuse to the loadside fuse in order to achieve selective coordination. This eliminates the possibility of cascading multiple levels of overcurrent protective devices under fault conditions.

When overcurrent protective devices are not selectively coordinated multiple levels of overcurrent protective devices can cascade open on a fault condition. An example of a non selectively coordinated system: a fault in a power supply or CDU results not only in one of the CDU overcurrent protective devices opening as it should, but the RPP or busway plug-in overcurrent protective device opens unnecessarily resulting in the unnecessary power outage to the entire CDU. Even worse is if the feeder overcurrent protective device would open for a fault in the CDU resulting in an unnecessary power outage to an entire PDU/RPP or busway run.

See the clarifying Note under the section Fusible Cabinet Power Distribution Unit for selective coordination on 415/240V systems between SC 20A fuse to CUBEFuse 40A or larger.

*Where fuses are in same case size the 2:1 ratio may not apply, consult Cooper Bussmann.

Reliability:

Fuse operation is based on a simple thermal principle; the internal fuse element will rapidly melt, at a very specific level of energy. Users can be assured that a fuse's precise thermal element will always operate when called upon to remove a fault and protect valuable equipment. It's a matter of physics. In contrast, a circuit breaker is a mechanical device that requires periodic exercise, testing, and maintenance. In addition, after interrupting a fault, a mechanical overcurrent protective device should be inspected and tested to ensure it is safe to reclose and provide the level of protection as originally specified (2012 NFPA 70E 225.3). As a result of the design differences, the ongoing maintenance costs of a fusible system are less.

Renewability:

OSHA 1910.334(b)(2) is the law when an overcurrent protective device opens due to an overcurrent. If an overload caused the opening, then fuses can be replaced or circuit breakers reset. However, if a faulted circuited caused the opening, then fuses cannot be replaced or circuit breakers reset “until it has been determined that the equipment and circuit can be safely energized.” To avoid possible catastrophic damage to equipment or danger for workers, it is important to identify the source of the fault and repair the faulted circuit. In addition, the conductors and electrical components on the faulted circuit path should be tested and verified suitable to be placed back in service. When a fuse opens an overcurrent, it is replaced with a new factory calibrated fuse and the same level of protection is assured. In contrast, if it is determined that a circuit breaker opened due to a fault the breaker must be inspected and tested before it can be put back into service per 2012 NFPA 70E 225.3. Even if a circuit breaker is still operable it may be out of calibration and result in increased opening time and let-through energy. Additionally, see 2012 NFPA 70E 130.5,130.6(L), 205.4, and 210.5.

Arc Flash Mitigation:

Arc Flash is a frequent concern in today’s data centers. With minimizing downtime as a priority, it is important to have current-limiting overcurrent protective devices mitigating the arc flash hazard where possible. By limiting the energy let-through and quickly bringing the current down to zero, fuses can reduce the arc flash hazard experienced during most arc flash events.

In addition, arc flash hazard mitigation is dependent on the “design and condition of maintenance” of the overcurrent protective device per 2012 NFPA 70E 130.5. If overcurrent protective devices that require maintenance are not maintained an actual arc flash event can be more severe than that determined by the arc flash hazard analysis. 2012 NFPA 70E 205.4 requires overcurrent protective devices to be maintained and the “maintenance, tests, and inspections to be documented.” Fuses are inherently reliable for fault conditions. There is no need to maintain the internal parts of fuses. All that is necessary is to maintain the external connections and proper environmental conditions.

Flexibility

There are data center operation flexibility and inventory advantages for some applications with the CCP/CUBEFuse. These are described in the next section Compact Circuit Protector and CUBEFuse.

4. Data Center Products

Compact Circuit Protector and CUBEFuse™ (CCP/TCF):

The innovative CUBEFuse™ with 300kA interrupting rating is available in amp ratings from 1A to 100A. These fuses have been on the market for more than a decade and offer many advantages including smallest footprint and finger-safe. The CUBEFuse is available in a time-delay version (TCF) which has a 600Vac/300Vdc rating and fast-acting version (non-time-delay) (FCF) which has a 600Vac/600Vdc rating. See Figure 4. Both CUBEFuse versions are very current-limiting, resulting in excellent equipment short-circuit current protection and arc flash incident energy mitigation. The TCF is available in an on-board indicating version and a non-indicating version. The FCF is available in a non-indicating version.

100A, 60A, & 30A TCF - with and without optional indication

View showing blades

100A, 60A, & 30A FCF - non-indicating

View showing blades

Figure 4. *CUBEFuse™ TCF and FCF versions*

For datacenter applications, the CUBEFuse in conjunction with the Compact Circuit Protector, which is a small UL 98 fused disconnect, offer great advantages. The amp ratings of the Compact Circuit Protector range up through 100A. This combination of Compact Circuit Protector disconnect and CUBEFuse provides excellent overcurrent protection solutions. The Quik-Spec Coordination Panelboard (QSCP) incorporates the Compact Circuit Protector/CUBEFuse and provides the means for fusible PDUs/RPPs. For the busway data center architecture the Compact Circuit Protector with CUBEFuse™ is incorporated into busway plug-in units.

These products offer excellent switch/fuse combinations for data center applications. There are two versions of the Compact Circuit Protector using the CUBEFuse™. See Figure 5.

1. CCP: DIN-Rail mount version, which allows small fusible switch applications such as the plug-in busway unit up to 100A.
2. CCPB: bolt mount version used in the QSCP panelboard, which allows fusible panelboards having up to 100 amp rated branch circuits with panel width and depth the same as traditional circuit breaker panelboards.

Bolt mounted 30A versions

60A DIN-Rail version

Figure 5. *Bolt mounted Compact Circuit Protector Base (CCPB) with non-indicating CUBEFuse, and DIN-Rail mount Compact Circuit Protector with indicating CUBEFuse.*

A CCP or CCPB has a disconnect amp rating and horsepower rating. A CCP or CCPB of a specific amp rating can accept any CUBEFuse amp rating equal or less than the CCP or CCPB amp rating.

There is a notable difference in the bolt mounted version versus the DIN-Rail mount version. The DIN-Rail mount version CCP disconnect is available in 30A, 60A, and 100A ratings. So the 30A CCP will accept 1A to 30A CUBEFuse. The CCP 60A will accept the 1A to 60A CUBEFuse and the CCP 100A will accept the 1A to 100A CUBEFuse. The bolt-on CCPB is available in the NEC standard branch circuit amp ratings of 15, 20, 30, 40, 50, 60, 70, 90, and 100 amperes. Each bolt mounted CCPB will accept any CUBEFuse amp rating equal or less than the CCPB amp rating.

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This feature of a given Compact Circuit Protector accepting CUBEFuse amp ratings equal or less than its amp rating provides some important flexibility options for data center management. For instance, if a plug-in busway unit uses a CCP 60A and the cable whip is rated 60A, then any CUBEFuse from 1A to 60A can be installed.

For example, assume on the initial installation, a 15A CUBEFuse is needed so a 15A CUBEFuse is inserted in the plug-in busway unit CCP. Then modifications are required to the cabinet changing the load so that a 35A CUBEFuse is needed. All that is necessary is to switch the 60A CCP disconnect to “off,” remove the 15A CUBEFuses and insert the 35A CUBEFuses. Then switch the CCP to “on.” This can save time and reduce inventory of busway plug-in units since the entire plug-in busway unit does not have to be removed and replaced with a larger amp rating unit.

1-pole version

2-pole version

3-pole version

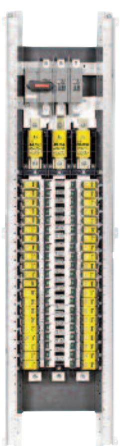
Figure 6. *Both CCP and CCPB are available in 1-, 2-, or 3-pole versions. Shown are CCPs.*

Quik-Spec Coordination Panelboard (QSCP):

The QSCP is rated 600Vac and can be utilized for either 208Vac or 415Vac data centers applications (or up to 600Vac). The left image of Figure 7 shows the QSCP as a complete panelboard and the right image of Figure 7 shows a QSCP chassis or interior only version which other manufacturers integrate into their PDU/RPP equipment. Examples of QSCP chassis versions in other manufacturers’ RPPs are shown in Figures 8 and 9.

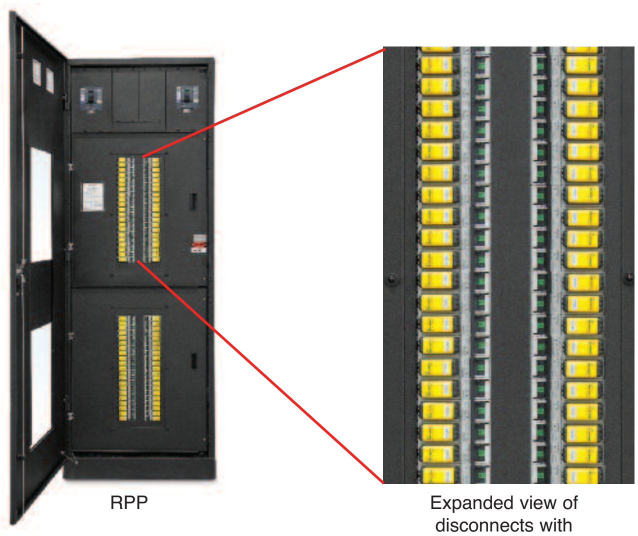
The complete panelboard version QSCP with high SCCR, 300kA IR CUBEFuses, ease in achieving selective coordination, and excellent arc flash hazard mitigation is also an excellent panelboard for electrical distribution system supplying non-IT equipment loads in a data center such as the computer room air conditioners/air handlers (CRAC/CRAH).

Complete panelboard version



Chassis version

Figure 7. *Quik-Spec Coordination Panelboard (QSCP).*



RPP

Expanded view of disconnects with CUBEFuses

Figure 8. *Remote power panel incorporating chassis QSCP with CCPB/CUBEFuse. Courtesy Cyberex, Thomas & Betts Power Solutions.*

Figure 9. *Remote power panel incorporating chassis QSCP with CCPB/CUBEFuse as well as spare CUBEFuses in holders. Courtesy Liebert® FDC™ power distribution cabinet from Emerson Network Power™.*

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Plug-In Busway Fusible Disconnect:

A plug-in busway utilizing the DIN-Rail mount version CCP/CUBEFuse is suitable for any voltage up to 600Vac. The cable whip connects the busway unit to the cabinet distribution unit. See Figure 10.

Figure 10. *Plug-in busway fusible disconnects using the DIN-rail mount CCP with CUBEFuse.*
Courtesy of Universal Electric Corporation (UEC).

Fusible Cabinet Power Distribution Unit:

By using fuses in cabinet power distribution units (CDU) or rack PDU, the CDU IT and circuits can be properly protected in systems even with high available fault levels. In addition, this scheme can isolate a faulted subsection of the CDU, thereby keeping the power supplies fed by the remainder of the energized CDU (when CDU fuses are selectively coordinated with upstream RPP fuses or busway plug-in fuses see Note on Selective Coordination for CDU below). See Figure 11. If a fault or overload were to occur on branch 1, the branch 1 fuse would open and remove the overcurrent from the circuit. The rest of the CDU would remain in normal operation. CDU manufacturers provide options for local and remote notification if a fuse opens. Remote notification includes both SNMP traps (simple network management protocol traps) and email alerts.

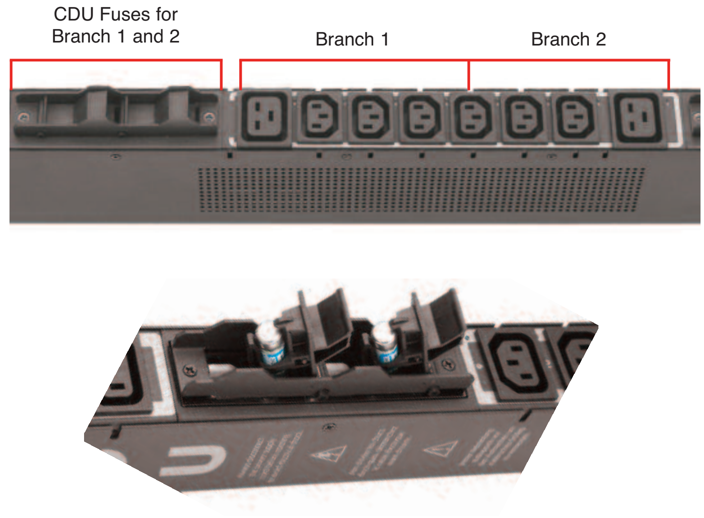

Figure 11. *Partial views of fused cabinet power distribution unit (CDU). SC fuses are used in this CDU to protect the receptacles and circuit to the power supplies.*
Courtesy of Server Technology, Inc.

Note on selective coordination for CDU fuses with upstream fuses: the easiest way to achieve selective coordination with fuses is to adhere to the published Fuse Selectivity Ratio Guide (see this section in SPD publication). 20 amp SC fuses are commonly used in the CDU as shown in Figure 11. CUBEFuses, either TCF or FCF, are often used in the supply circuit to the CDU via the RPP or busway plug-in disconnect. The published selectivity ratio for a TCF fuse supplying a SC fuse is 4:1(for a 600 volt system), which means for a CDU using a SC20 fuse the minimum upstream TCF fuse would need to be 80 amps to ensure selective coordination. However, tests have demonstrated that either TCF40 or FCF40 fuses (or larger) will selectively coordinate with downstream SC 20 fuses for 415/240V systems up to 100,000 available short-circuit amperes (the SC fuse interrupting rating). The deviation from the published ratio for these specific type fuses and amp ratings is due to the characteristics of these specific fuses being used at the lower application voltage of 415/240V.