Deploying effective power protection in data centers
The following document was written to serve as an informational resource for data center system owners, operators and engineers. Its focus is on electrical system design within a data center; presenting solutions to stay in front of growing IT demands, by deploying efficient, reliable, and safe electrical infrastructure for a flexible, manageable data center system.
Deploying effective power protection in data centers

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Mission critical systems designed for uptime

Data centers are powered by some of the world’s most complex electrical distribution systems. This complexity is driven by the data center industry’s intolerance to system downtime. In mission critical data center designs multiple incoming utility sources and multiple back up power sources such as paralleled engine generators, battery systems and redundant uninterruptible power supplies (UPS) are the norm. In order to keep power flowing to precious Information Technology (IT) loads careful thought must go into each piece of the vast electrical distribution network. Engineers and system designers utilize redundant distribution paths along with diverse power switching techniques to eliminate single points of failure, allow for concurrent maintainability and do whatever is possible to assure the continuity of power. Along with the demanding requirements for ‘uptime,’ data center system owners and designers have other challenges to overcome. Two of the most commonly mentioned objectives for data center design and operations are: (1) reducing the power consumption in a data center and the costs associated with it, and (2) managing the constantly growing demand for IT capacity through flexibility and future proofing.

Energy efficiency
Increasing energy efficiency is one of the primary objectives of data center designers and operators today. Nearly all of the power consumed by a data center can be attributed to one of three major categories: IT equipment, cooling the data center, or the data center’s electrical power distribution losses, which are the losses associated with delivering power from the source to the IT equipment. A small amount of power is also consumed by the facility infrastructure, other than the cooling, such as lighting and other general usage electrical loads. One of the most frequently used metrics to determine the energy efficiency of a data center is power usage effectiveness, or PUE. PUE is defined by a ratio of the total power entering a data center divided by the power used by the IT equipment.

\[
PUE = \frac{\text{Total Facility Power}}{\text{IT Equipment Power}}
\]

The lower the PUE of a data center, the more efficient it is. The ideal PUE value is 1.0. This would be a data center where all of the electrical utility power supplied to the data center is consumed by the IT equipment and no power is consumed for cooling or through power distribution losses. The average data center in the US has a PUE of around 2.0. A PUE of 2.0 indicates that for every watt of IT power, an additional watt is consumed to operate the data center this includes cooling, power losses and other electrical loads. In other words, the typical data center is only 50% efficient. It is for that reason there are significant initiatives to enhance the efficiency of data centers. Engineers, owners and data center equipment manufacturers are working together to create more efficient data centers, several industry solutions will be discussed in a later section.
Designing for the future
As the demand for IT continues to increase exponentially in all facets of life, so too will the need for new servers and more data centers. Studies show the number of data centers in the U.S. more than doubled between the years 2000–2006 and then doubled again from 2007 to 2011, with no end to growth in sight. Internet companies, collocation providers and corporations of all types need to be constantly planning their next move to stay ahead of the growing demand. As soon as one data center is built some companies are already working on the design of their next facility. For other companies that may not have that luxury it is imperative that current data center designs are created to meet future needs. The average lifespan of a piece of electrical distribution equipment may be twenty years however the average lifespan of an IT server is three to five years. As servers become smaller and more powerful, will your current electrical infrastructure support these changes? For example, day one power demands in your new data center may be 7kW per rack, however after multiple IT refreshes, and the addition of new blade servers, power demands are now 30kW per rack (or more). Will your standard PDUs, RPPs, or busway support these high density loads? These are the type of questions that must be considered when specifying and procuring new electrical distribution equipment for a data center. Cyberex® PDUs and RPPs are designed to support high density loads, and can accommodate multiple IT refreshes with minimal downtime or disruption to the system.
Key considerations

Interrupting rating

Interrupting rating (IR) is the maximum short-circuit current that an overcurrent protective device can safely interrupt. An overcurrent protective device must have an interrupting rating greater than or equal to the available fault current at its line side terminals per NEC 110.9 and OSHA 1910.303(b)(4). This is an extremely important rule to follow. Not only could noncompliance result in fines or shutdown from OSHA, but if a fault event was to occur and an overcurrent device with an inadequate interrupting rating was called upon to act, the results could be catastrophic. In order to ensure overcurrent devices and all electrical equipment are used appropriately it is necessary to have an understanding of the available fault current at all levels of the electrical distribution system – even the whitespace. As changes are made on the floor, servers are added or removed, or RPPs are moved from one area of the data center to the other, precautions must be taken to ensure the equipment has the proper interrupting rating for its new placement in the system.

Series ratings for circuit breakers

The NEC does make an exception to the rule for interrupting rating in 240.86. When certain test criteria have been met, upstream overcurrent devices may protect downstream circuit breakers where the available short circuit current exceeds the downstream circuit breakers’ IR. This is referred to as a series rated combination. The use of series ratings mean that a main circuit breaker must operate along with the branch breaker in order to protect the branch breaker from damage. Cyberex® FaultGuard™ RPPs have been tested and manufactured with a unique series coordinated design. The RPPs branch circuit breakers are provided with an increased series rating to open faults up to 28.6kA @ 240VAC or 14kA @ 480/277VAC. When higher fault currents exist, or more power is needed on the data center floor, the Cyberex® Fused HPP can provide fully rated, fully coordinated, protection from faults up to 200kA.

Short circuit current rating

Short circuit current rating (SCCR) is the amount of fault current that a component or piece of equipment in an electrical system can safely withstand without being damaged. (NEC 110.10) Equipment placed in a system must have a SCCR greater than the amount of fault current available at that point in the system. It is worth noting that just because a piece of equipment has circuit breakers with a given interrupting rating that does not mean that equipment is SCCR rated to a similar value. The SCCR of that device can be lower due to ‘weaker links’ within the equipment.
Selective coordination
Selective coordination was a recent addition to the NEC for life safety emergency systems and will now be a requirement in 2014 NEC 645.27 critical operations data systems. However long before it was a code requirement the practice of overcurrent device coordination has been used in critical data center systems. Selective coordination defines a system's ability to isolate a fault and increase system reliability. If a fault was to occur in a selectively coordinated system the overcurrent protective device closest to the fault will clear the fault and leave the rest of the system undisturbed. If the system was not selectively coordinated the breaker closest to the fault may or may not clear the fault before upstream devices start to open causing unnecessary loss of power to critical loads.

As discussed in previous sections many manufacturers of data center equipment rely on series ratings to protect the branch breakers in their RPPs and PDUs. Traditional series ratings require the main overcurrent device protecting a panelboard to operate along with the branch device in order to clear a downstream fault. This eliminates coordination in a system.

The amount of fault current available at the data center floor distribution plays a significant role on how selective coordination can be achieved. When higher fault currents are present, average main and branch breaker combinations of RPPs, PDUs, and busway will require main circuit breakers to act in order to protect 'branch' breakers with lower interrupting ratings. This lack of coordination and shutdown of an entire panelboard or busway run to clear an overcurrent on one circuit, will result in unnecessary downtime to critical server loads.

At ABB we understand the importance of coordinating overcurrent protection in a data center and have designed our RPPs with inherent selective coordination of main and branch devices. For fault conditions of up to 28.6kA at 240V (or less), the current limiting branch circuit breakers of the Cyberex® FaultGuard™ RPP will operate independently of the main circuit breaker and isolate fault conditions at the branch level without disrupting the rest of the panel circuits. For high density data center systems the Cyberex® Fused HPP offers selective coordination for the full range of fault currents up to 200kA at up to 600V. Providing this level of overcurrent protective device coordination within a data center could prove to be the difference between removing one server rack vs losing a whole row of critical loads if a fault was to occur in the system.
**Current limitation**

Cyberex® FaultGuard™ products utilize current limiting circuit breakers that bring a whole new level of protection and peace of mind to the distribution of electrical power on the data center floor. In 240.2 the NEC defines a current limiting breaker as a device that, “when interrupting currents in its current-limiting range, reduces the current flowing in the faulted circuit to a magnitude substantially less than obtainable in the same circuit if the device were replaced with a solid conductor having comparable impedance.” (1- from NEC) In order to list a current limiting breaker under the UL standard the breaker must interrupt and isolate a fault within the first half of an AC cycle, 8ms. It is important to note for a breaker to be defined as current limiting it must be UL listed, and labeled “current limiting breaker” on the device.

Current limiting overcurrent protection provides a number of invaluable benefits to a critical system such as a data center. Two of the most notable benefits of current limitation are increased protection for downstream system components and the mitigation of arc flash hazard for workers. Current limitation reduces the hazardous effects of a fault on downstream system components. Without a current limiting device the energy released during a fault is directly proportional to the amount of fault current available at that point in the system. When a current limiting device is used the energy released during a fault is proportional to the let through of the upstream overcurrent device. Both mechanical and thermal forces are drastically reduced through current limitation, which in a data center, means less potential damage or strain on the sensitive and expensive IT equipment. This heightened protection helps remove worries of extended downtime due to repairs or replacement of damaged equipment.

**Safety and flexibility**

Working on live electrical equipment is never recommended, however sometimes becomes a ‘necessary’ task due to the criticality of system loads in a data center. The Cyberex® FaultGuard™ RPP significantly enhances worker safety due to its touch safe panelboard chassis and plug in current limiting branch breakers. The Fused HPP can allow for circuit amp sizes to be changed without the need to de-energize the panel. When wired per switch size, simply turn off the branch switch and replace with a new fuse of a desired amp size. Fuses can be utilized from 1 Amp up to the switch size, rejection features prevent over-fusing. This allows your protection to grow along with your load demand and provides RPP infrastructure for multiple IT refreshes, including increases in current or voltage. Along with drastically reducing the shock hazard, the use of current limiting overcurrent devices significantly reduces the arc flash potential to which a worker could be exposed. At a high level, arc flash calculations depend on two main factors, first the time it takes for the upstream overcurrent device to clear the fault, and the second the magnitude to which the fault can reach before it is extinguished. Current limitation is the driving factor to reducing the energy released during an arc flash event.
Employing high density solutions in modern data centers safely

Data center owners and system designers are constantly faced with challenges as they try to keep pace with the exponential growth of the data storage industry. This demand to increase data center efficiency and push the limits of power density at the rack has introduced new design trends. One proposed solution to help meet these demands is raising the distribution voltage in the whitespace to 400V, 415V or 480V. Utilizing this higher distribution voltage on the data center floor allows system designers to bring twice the power to the same rack footprint as traditional 208/120V distribution. This can provide system owners with a significant advantage due to the premium cost of data center real estate in the whitespace. See the table below outlining the increased power delivery for a given current as the voltage increases.

<table>
<thead>
<tr>
<th>Circuit Current</th>
<th>80% De-Rated Value</th>
<th>208VAC</th>
<th>415VAC</th>
<th>480VAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>20A</td>
<td>16A</td>
<td>5.22kVA</td>
<td>10.35kVA</td>
<td>11.97kVA</td>
</tr>
<tr>
<td>30A</td>
<td>24A</td>
<td>7.74kVA</td>
<td>15.57kVA</td>
<td>17.91kVA</td>
</tr>
<tr>
<td>40A</td>
<td>32A</td>
<td>10.35kVA</td>
<td>20.7kVA</td>
<td>23.94kVA</td>
</tr>
<tr>
<td>50A</td>
<td>40A</td>
<td>12.96kVA</td>
<td>25.92kVA</td>
<td>29.88kVA</td>
</tr>
<tr>
<td>60A</td>
<td>48A</td>
<td>15.57kVA</td>
<td>31.14kVA</td>
<td>35.91kVA</td>
</tr>
</tbody>
</table>

400V design also provides notable efficiency increases versus traditional data center design. On average, upstream transformation and removing a traditional 480 to 208V PDU transformer can result in efficiency gains of 2–4%. The other option, upgrading transformation downstream to a 480 to 415V ultra-efficient Cyberex® TP1 transformer can also increase efficiency by 2–3% and still provide isolation benefits along with greater flexibility of using multiple voltages on the data center floor.

Efficiencies will also be realized in the IT device’s power supply. Most standard IT equipment can accept a range from 120 to 240VAC. Running devices at 240V vs. standard 120V will provide an increase in efficiency of approximately another 2–4%. This higher efficiency will directly lower a data center’s power bills, and indirectly reduce data center cooling cost and overheating issues.

There a multiple distribution architectures a designer can choose from, the following describe three typical design options:

01. Shows a tradition U.S. data center distribution system. 480V UPS system to a PDU with a step down transformer to 120/208V then distributed through RPP’s to server racks and IT loads.

02. Shows a design traditional to Europe. Transformation to 415/240V is done upstream of the data center sometimes from medium voltage or from 480V (in the U.S.) 415V UPS are used and then 415/240V is distributed through RPP’s to the server racks and IT Loads.

03. Shows a flexible and efficient design choice for 415V in U.S. Performing the transformation to 415V downstream closer to the server racks provides multiple advantages, including the use of standard 480V upstream equipment, such as the UPS, and also allowing lower wiring costs, from smaller conductors and elimination of neutral conductor from UPS to PDU. The configuration in figure 5 also provides the flexibility of having multiple voltages available in a data center. Many data centers are not ready to fully commit to high density distribution and still require 120/208V power for some legacy server loads. Downstream transformation provides this advantage, by simply installing a standard Cyberex® PDU when 120/208V is needed.
Challenges with high density
While helping to meet these demands, data center systems designed at higher voltages (400, 415, 480V), provide system owners and designers with a new set of challenges and concerns to overcome. Selective coordination, increased arc flash potential, protecting sensitive IT equipment and complying with SCCR and IR code requirements take center stage. These heightened concerns are mainly driven by the removal of a transformer and the potential increase in available fault current when compared to traditional 208V designs.

Cyberex® RPPs help remove the electrical concerns that come along with high density data centers. The use of current limiting overcurrent protection in Cyberex® products helps lessen the potential hazard of arc flash events and also increases protection for IT equipment. The use of touch safe components reduces the shock hazard and increases flexibility after installation. Cyberex® RPPs also are designed with built in selective coordination between main and branch overcurrent devices. Solutions are available for the full range of voltages and available fault currents.
Understanding the impact of busway systems on fault current

A growing trend for 400V data center design is the use of busway to distribute power to server loads. When designing a 400V system with busway, one of the principal challenges that must be overcome is dealing with higher fault currents on the busway and at the server racks. When the transformer is removed from the data center floor, and step down transformation is performed upstream from higher voltages, higher fault current is introduced into the system and is distributed to downstream loads. Along with higher fault currents comes additional concerns such as safety, selective coordination, compliance, and of course cost. Busway provides less fault current impedance than traditional cable distribution, requiring the need for larger more expensive circuit breakers or fuses throughout the data center.

The following examples compare fault current on Busway vs RPP distribution in a data center.

Provides a high level set of calculations comparing available fault currents in a data center using busway vs using RPP architecture. When upstream medium voltage is transformed to 415V and distributed throughout the data center floor via busway, it is likely that high fault currents will be available throughout the system and near sensitive IT equipment. When removing PDU transformers from a distribution system traditional cable methods reduce available fault potential, help ensure selective coordination, and allow for the use of more cost efficient overcurrent protection.

Again provides two sets of calculations comparing available fault currents in a data center using busway vs using RPP architecture. In this example medium voltage is transformed to 480V. 480V power is distributed upstream and 480V UPSs are utilized. Transformation to 415V is provided by PDUs on or near the data center floor. This method significantly reduces fault current for both busway and RPP power distribution. However fault current still remains higher when busway is used. This may force the use of more expensive circuit breakers in Rack PDUs in order to meet IR and SCCR requirements. Selectively coordinating your data center with standard molded case circuit breakers may also be more challenging and require the use of electronic trip LSI circuit breakers due to the higher voltage and fault current present on busway systems.
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