

Increase the efficiency of power distribution in your high-density data center

Abstract

As power density in modern data centers increases, more focus has been placed on improving efficiency in the power distribution infrastructure.

Dramatic changes, such as switching to 400V or DC distribution systems, have been explored, but there are some practical and affordable options to significantly improve efficiency without making major changes to the existing power delivery infrastructure.

This paper shows how the latest advancements in power distribution products can reduce energy, cabling and cooling costs for your data center.

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Taming the power-hungry data center

Consolidation, blade centers, high-performance servers, Tier III and Tier IV redundancy... these trends and technologies have dramatically escalated power requirements in the modern data center. For example, an HP BladeSystem C3000 Blade Enclosure consumes 4.8 kW of power for its 6U footprint. The 9U IBM BladeCenter H Chassis draws 5.8 kW of power, and a Sun Blade 8000P Chassis (14U) pulls 9kW of power.

Distributing power to these high-density racks is no trivial matter, especially if efficiency is a concern. Data centers often spend more capital budget on power components than on the IT equipment to be served. The power infrastructure itself consumes power to do its work, accounting for about 10 percent of energy consumption modern data centers⁴.

In the quest to reduce this percentage and increase the efficiency in the power distribution system, data center leaders have proposed alternative architectures, such as higher-voltage AC and DC distribution systems. However, the equipment to support these architectures can be very expensive and is often incompatible with existing equipment.

The good news is that there are simple and affordable ways to increase data center efficiency—to make more efficient use of power, cabling, and floor space—without major infrastructure changes and while continuing to support existing equipment. As an added bonus, new power distribution schemes and products also make the data center more adaptable and easier to manage.

Let's take a look at how any data center can increase efficiency and adaptability simply by making smart choices in the major building blocks of power distribution:

- Uninterruptible power systems (UPSs)
- Power distribution racks (PDRs)
- Enclosure-based power distribution units (ePDUs)

The UPS—From behind the scenes to the data center floor

In traditional data center designs, a large, three-phase UPS stood alone in a separate room, providing conditioned power and battery backup for the whole data center, perhaps even the entire building. These UPSs fed PDUs on the data center floor.

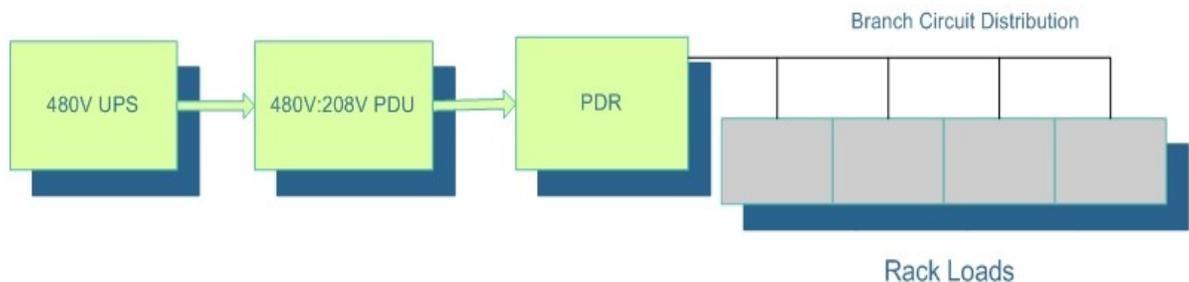


Figure 1. A typical data center relies on a large, centralized UPS system

Advances in UPS technologies have greatly improved the efficiency of these large UPS systems. In the 1980s, a state-of-the-art UPS was 75 to 80 percent efficient at best. With the advent of faster switching devices in the 1990s, efficiency jumped to 85 to 90 percent, and later to 90 to 94 percent.

Even higher efficiency is now possible. In 2007, Eaton® introduced the BladeUPS® power system for high-density computing environments. This modular UPS operates at an industry leading 97 percent efficiency in normal operation. Even at <30% load, where you would expect much lower efficiency, this UPS is more efficient than others' modular products at full load.

Even small increases in UPS efficiency can quickly translate into tens of thousands of dollars. For example, assuming a utility rate of 10 cents per kWh, a 60 kW N+1 redundant configuration would save more than \$30,000 in five years. The savings compound with data center size. High UPS efficiency also extends battery runtimes and produces cooler operating conditions.

The compact, modular BladeUPS opens up new options for efficient and adaptable power distribution. A single 6U UPS module delivers 12kW. Up to six modules can be paralleled to support up to 60kW in a single 19" rack, with N+1 redundancy. The BladeUPS delivers twice the backup power of other vendors' modular solutions, and requires much less floor space than traditional stand-alone three-phase UPSs of comparable power levels.

This flexible UPS can be deployed in a variety of system architectures for centralized, zone or distributed power protection, with Tier I to Tier IV redundancy. It can be installed alongside IT equipment in the same rack, or in its own rack, feeding either a PDR or rack-based power distribution device. In either case, the UPS receives 208V input power from downstream of the PDU.

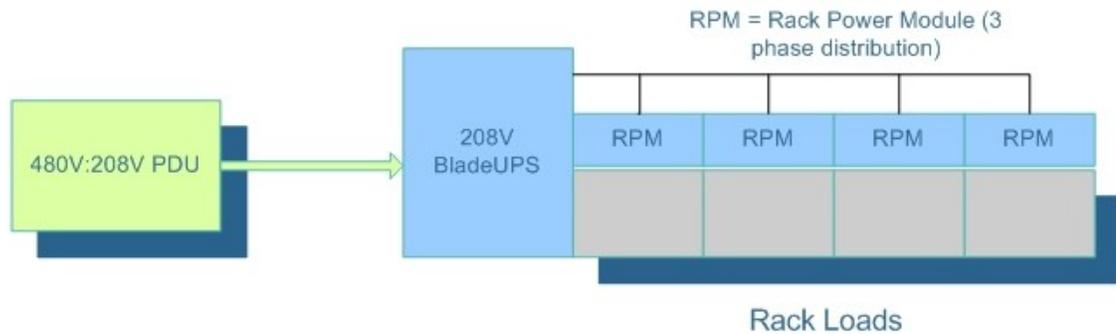


Figure 2. BladeUPS flexibly delivers power to rack power modules

A major search engine company has begun setting up its data centers as shown in Figure 2 to maintain a high level of modularity as it constantly increases capacity and density. As older servers are phased out and higher density ones are phased in, more BladeUPS modules can simply be added to the rack to accommodate the evolution. As the data center grows and more rows are added, the UPS and distribution structure for the row can be easily duplicated as many times as necessary.

Summary of BladeUPS benefits

Category	Advantage
Efficiency	97 percent, highest in the industry
Footprint	Smaller than traditional free-standing UPS of similar power range
Modularity	Easily add capacity or redundancy as needed
Metering	Remote monitoring available

Power distribution unit (PDU)—the backbone of efficient distribution

Power Distribution Units from Eaton provide efficient and flexible distribution for today’s data centers. These PDUs promote efficiency in two key ways:

Reduce the tangle of power drops to racks. In a traditional distribution scheme, the PDU feeds a panelboard, and separate branch circuits deliver power to racks, as shown in Figure 3.

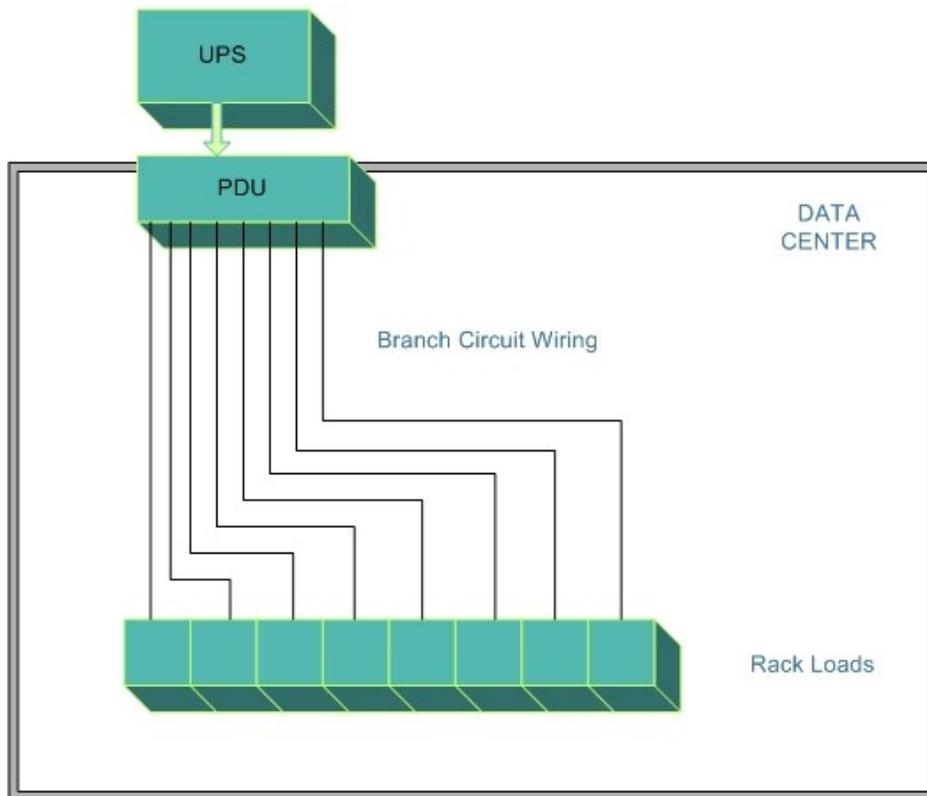
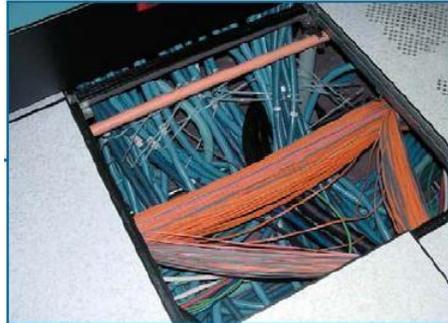


Figure 3. An inefficient cable strategy has branch circuits from the PDU to each rack

This is what the inefficient cabling arrangement can look like under the floor.



**Excessive Cabling Can Restrict
Airflow Under the Raised Floor**

PDUs from Eaton can dramatically streamline those cabling requirements by using subfeed breaker distribution rather than panelboard/branch circuit distribution. The subfeed distribution wiring can be connected to power distribution racks (PDRs) that sit at the end of rows, closer to rack loads. This arrangement has the added benefit of being able to handle moves, adds and changes (MACs) more easily, since branch circuit cables only have to be managed up to the PDR, not all the way back to the PDU.

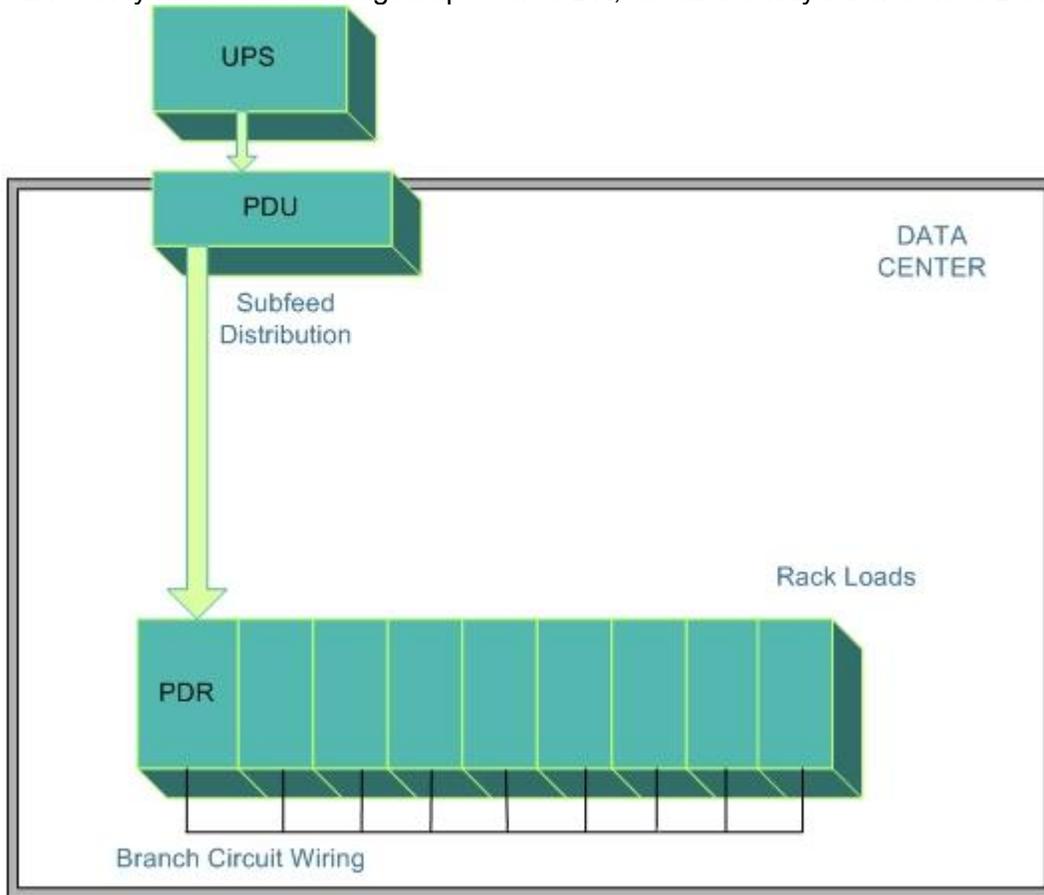


Figure 4. Simplify wiring to the row using subfeed distribution and a PDR

In addition to the obvious cost savings of less cabling, cooling efficiency is also increased by reducing airflow restrictions under the raised floor. Some data centers have been designed with four-foot raised floors (or taller) to compensate for excessive wiring. These higher raised floors add cost and compromise the structural integrity of the floor.

Use high-efficiency transformers. PDUs from Eaton can use energy-efficient TP-1-compliant transformers that meet the requirements of the Energy Policy Act of 2005. The TP-1 standard calls for distribution transformers to be one to two percent more efficient at their typical loading level (30 to 50 percent).

Although TP-1 transformers are more expensive, these transformers pay for themselves in five to six years by significantly reducing energy costs—and they continue to deliver cost savings for the remainder of their 20- to 30-year lifespan. Additionally, since TP-1 transformers are part of Eaton’s standard design our lead times may be shorter than other manufacturers.

Summary of Eaton PDU benefits

Category	Advantage
Efficiency	Energy-efficient TP-1 transformers available in the standard design
Footprint	Smallest in industry, conserving valuable data center space
Flexibility	Capable of both panelboard and subfeed distribution
Cabling	Subfeed distribution dramatically reduces number of cables to rows
MAC management	With subfeed distribution, branch circuits only have to be handled at the row level, not all the way back to the PDU
Thermal	Reduced cabling due to subfeed distribution can improve airflow under the raised floor
Metering	Most comprehensive metering package in industry, down to the branch circuit level; remote monitoring available via IP and support for common protocols (SNMP, ModbusTCP, etc.)
Maintenance	True front-only access; secondary connections to transformer are brazed, reducing maintenance

High-density PDRs—Optimizing three-phase distribution to the rack

As we saw earlier, PDRs located at the end (or middle) of a row can significantly reduce the amount of branch circuit wiring to serve racks—compared to running branch circuits directly from panelboards mounted on PDUs at the edges of the data center.

Further simplification can be achieved by using Eaton’s High-Density Power Distribution Racks (HD-PDRs), which can be optimized for pure three-phase distribution to the rack. The HD-PDR can contain up to eight panelboards, ranging from 12 to 42 pole positions. These panelboards are rated from 225A to up to 800A to support high-power three-phase distribution from the panel.

This three-phase distribution allows more power to the racks with less wiring. The smaller panelboards that are available (due to eliminating extraneous pole positions) allow more effective use of space in the unit for wiring and maintenance. By eliminating single and dual pole circuits, MACs once again become easier since these types of changes will now be handled solely at the rack level.

All Eaton PDRs can support separate input sources to feed dual-corded loads or rack-mounted static transfer switches. This can reduce the amount of cabling required. In the following diagrams, you can see how cabling for dual-corded loads was reduced using dual-source PDRs—about a 25 percent reduction in this example.

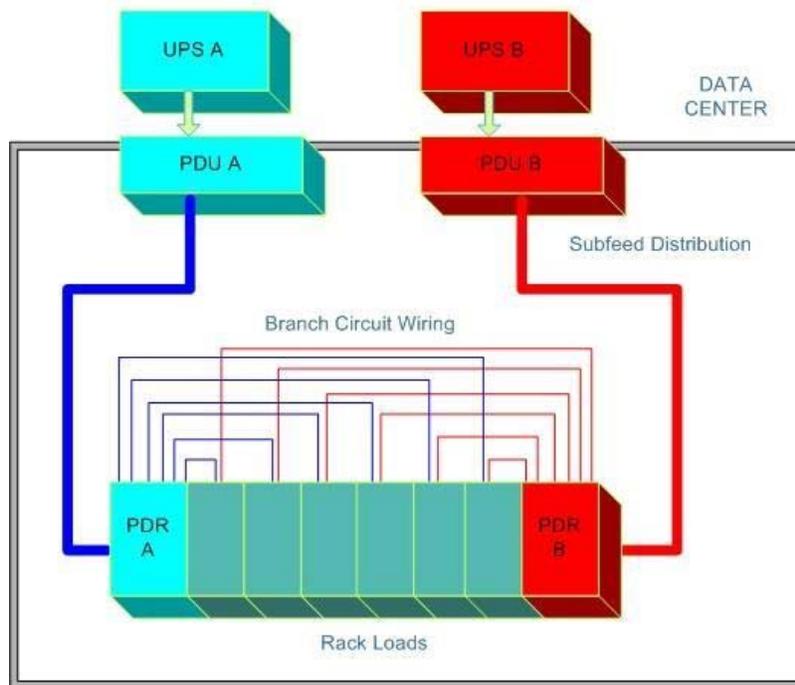


Figure 6. Inefficient cabling strategy for dual-corded loads

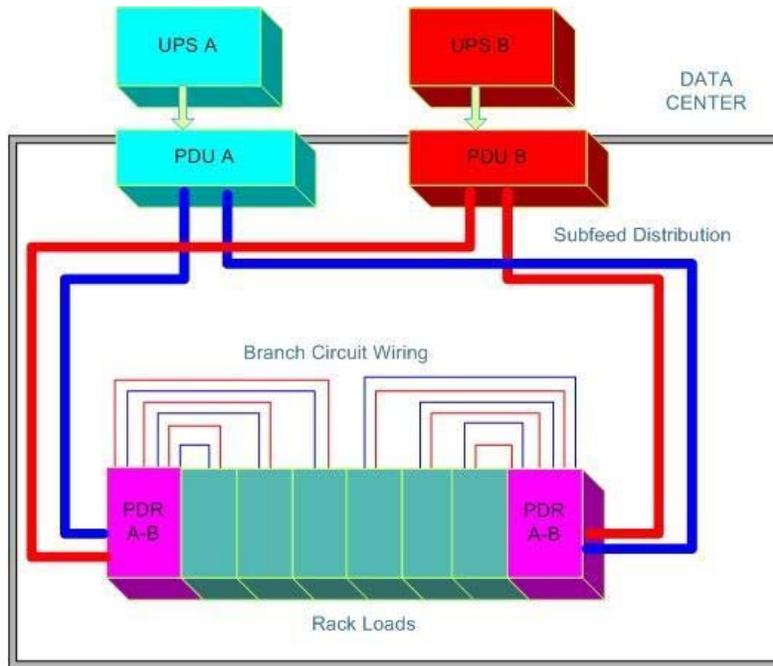


Figure 7. Total wiring used reduced by approximately 25 percent

As always, minimizing cabling along the rows and to the racks improves airflow and therefore thermal efficiency of the room and racks.

Summary of Eaton HD-PDR benefits

Category	Advantage
Power density	Most efficient use of space: higher amperage panels and fewer unused poles, optimizing three-phase distribution to the rack
Dual-source capable	Feed dual-corded loads from the same PDR, reducing cabling
Thermal	Simplified cabling improves airflow and thermal efficiency on the row and in the racks

Eaton ePDUs—Power distribution for the high-density rack

With data center devices smaller than ever—often served by dual or triple power supplies—a single rack of equipment might produce 80 or more power cords to manage. You want to minimize the number of expensive power drops to each rack, yet power consumption keeps rising.

Traditional power strips just don't deliver enough power or flexibility for these realities. That's why Eaton provides a complete suite of rackmount power distribution units (Eaton ePDUs). Eaton is unique in the industry for providing a tiered set of ePDU™ product families along two dimensions—tiered both in power capacity and in functionality. You choose the combination of features and power rating you need to best suit each application.

In high power density environments, Eaton's rack-mounted ePDUs are quickly being recognized as the optimal solution for rack power distribution. These ePDUs are the perfect complement to the PDR (although ePDUs are certainly compatible with standard remote power panels, and can even be directly connected all the way back to the PDU).

There are many advantages of using three-phase, 208V power down to the ePDU level, as opposed to just using a plethora of single-phase 120V rack power strips:

- Three-phase distribution can transfer almost twice as much power (1.73 x) as equivalent 120V, single-phase circuits over the same size conductors
- By switching from single-phase 208V to three-phase 208V distribution to the rack, 73 percent more power can be transmitted with only a 50 percent increase in copper and losses
- Using higher voltage (and power) ePDUs in the rack reduces the number of cables that need to be brought in and managed

A few high-power ePDUs replace an unwieldy web of cabling and a mass of low-power plug strips. The result is greatly simplified cable management, more space available in the rack, and improved air flow and thermal efficiency. Furthermore, many of our high-density ePDUs mount vertically at the rear of the rack, saving valuable rack space for other equipment.

Eaton offers ePDUs with four levels of power rating:

- A **Standard Power** ePDU (for applications less than 4 kW, 15 to 30A) will support up to six 1U/2U servers or peripherals, such as network switches, environmental monitors, KVM devices and rack accessories
- A **Mid-Range Power** ePDU (4 to 10 kW, 15A to 40A) supports up to 16 1U/2U servers or two blade server chassis, offering both ICE-320 and NEMA receptacles
- A **High-Range Power** ePDU (10 to 15 kW, 30A to 60A) for high-density applications can support up to 25 1U/2U servers or three blade server chassis, offering up to 45 receptacles in several form factors
- An **Ultra Power** ePDU (15 kW to 36 kW, 60A) is designed for a rack that will be loaded with up to four blade server chassis and other power-hungry pieces of IT equipment

The ePDU family includes a variety of power inputs and outputs to fit most power requirements. You can select from NEMA, IEC and hardwired inputs from 10A to 60A, 110 or 208V, single- or three-phase.

This flexibility is a necessity for the evolving data center. Although many blade centers can run directly off 208V power, many legacy servers still require 110V single-phase power. ePDUs can accommodate single-phase 120V receptacles and 208V receptacles on the same strip (such as 5-20R, C13 and C19 receptacles).

To make the transition to 208V in the rack even easier, many pieces of IT equipment have universal switching power supplies that can accept either 208V or 120V. It's worth mentioning that these switched-mode power supplies run noticeably more efficiently on 208V.

Summary of high-density ePDU benefits

Category	Advantage
Cabling	With only three-phase power being delivered to rack, fewer or smaller conductors are required than with single phase power
Thermal	With fewer/smaller cables coming into the rack, airflow through the rack improves.
Efficiency	Servers with switched-mode power supplies run more efficiently on 208V than 120V.
Flexibility	ePDUs can accommodate a variety of receptacles on the same strip, even 120V and 208V on the same unit.
Rack Space	Large selection of ZeroU-mounted ePDUs available, saving valuable rack space.
Metering	Advanced metering down to the receptacle level with remote monitoring available.
Security	Lock-out unused receptacles to prevent accidental overloads.

The complete solution—A simple case study

Depending on the UPS configuration in your data center, you have a choice of strategies for efficiently distributing three-phase power to your racks. Here we will compare options for two UPS topologies:

- A large, stand-alone UPS in a separate room,
- A rack-based modular UPS such as BladeUPS

In our example, we will consider a row of eight high-density racks, each with three full HP C-class BladeCenters, requiring about 15kW of power per rack. For either UPS topology, a single-feed or dual-feed arrangement could be designed.

You'll notice that we have specified ePDUs for both configurations. Here's why:

If we used traditional single-phase power strips...

Each 120V, 20A rack power strip would provide approximately 1900W of power.

Each rack would require at least **eight** power strips, for a total of **64** strips for the entire row. This means 64 cables would have to be routed from the PDR or PDU to the racks, not including the neutral.

If we used Eaton's high-density ePDUs instead...

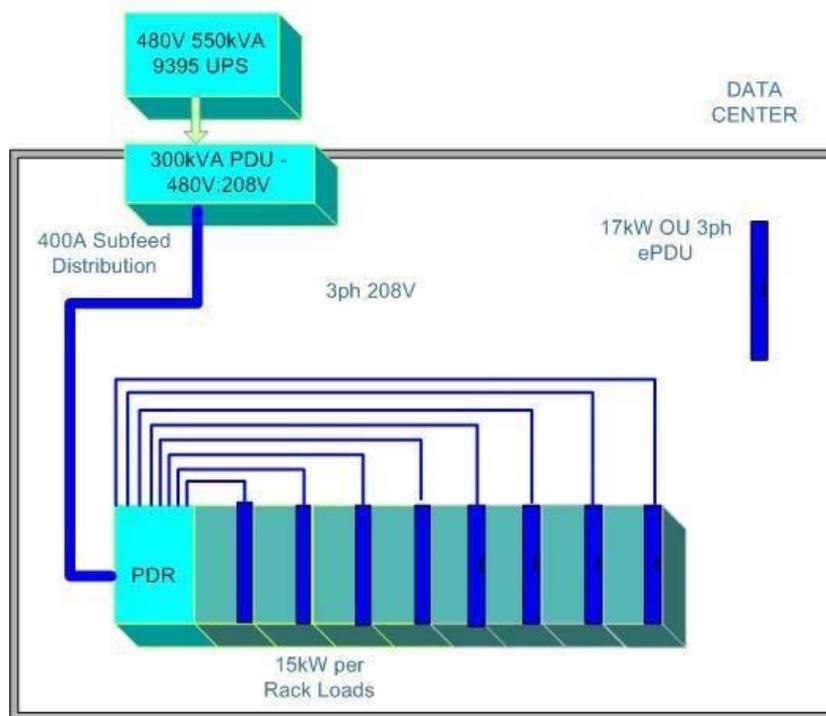
The same amount of power can be delivered with eight strips, requiring only 24 cables and panelboard poles.

The sample configurations on the following pages show how Eaton's high-density equipment reduces cabling and simplifies the power infrastructure, making the most efficient use of the data center's power resources.

Configuration 1. UPS ► PDU ► PDR ► ePDU

This traditional data center configuration is one of the most common in the industry. The easiest way to connect high power ePDUs to your distribution system is to simply wire them directly to the PDR at the end or center of your aisle.

An Eaton High-Density PDR is a perfect fit for this application, since it is designed for these higher power applications and optimized for three-phase circuit breakers specifically.



Equipment for this sample application

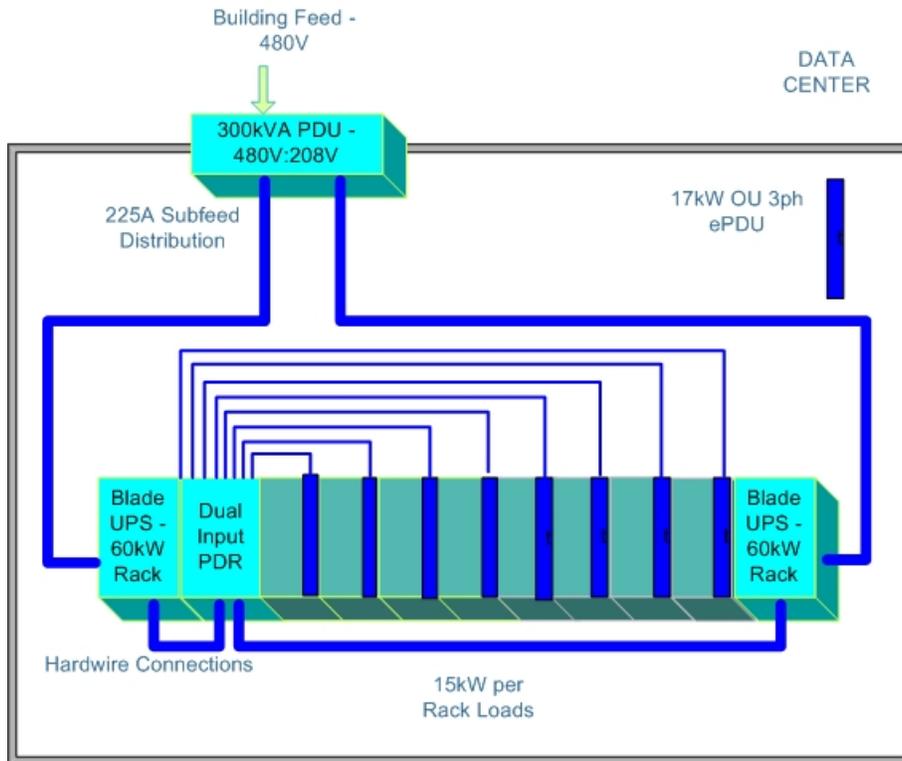
UPS	Eaton 9395 550 kVA
PDU	Eaton 300 kVA with (4) 400A subfeed distribution breakers
PDR	Eaton PDR with (4) 42-pole 400A panelboards and 60A 3-pole branch circuit breakers
ePDU	17 kW with (12) C19 receptacles hardwired to PDR panelboards

Configuration 2. PDU ► BladeUPS ► PDR ► ePDU

Another common configuration gaining popularity is using modular rackmount UPSs on the rows, such as BladeUPS.

Eaton 3U Rack Power Modules (RPMs) are easily connected to the output of a BladeUPS and can be configured with a variety of receptacles that can deliver 12 kW of three-phase power to the rack.

In higher-density applications such as this one, the parallel bus bar can be hardwired to a PDR to give more flexibility in distributing the 60 kW power from the BladeUPS rack.



Equipment for this sample application

PDU	Eaton 300 kVA with (2) 225A subfeed distribution
UPS	(6) BladeUPS configured in a 5+1 parallel redundant configuration
PDR	Dual Input Eaton PDR with (4) 42-pole 400A panelboards and 60A 3-pole branch circuit breakers; Input hardwired to BladeUPS parallel bus bar
ePDU	17 kW with (12) C19 receptacles hardwired to PDR panelboards

The importance of metering in three-phase distribution

Traditionally, data center managers could plan for about 60-100 watts of power consumption per U of rack space. A full rack of equipment averaged 5-8 kW of power. With today's blade servers, that figure has escalated to 600-1000 watts per U, and growing. Power consumption may soon reach up to 20 kW per rack.

Furthermore, power demands can easily double or triple during peak periods, and it fluctuates with every move, add or change. Adding a 1U or 2U server used to mean drawing 300 to 500 more watts from the branch circuit; now a new blade server consumes *10 times* as much current.

That means the power distribution system is more easily stressed by even the simplest changes in your data center. How much current are your servers drawing right now? Are electrical circuits approaching capacity, ready to trip a breaker if transaction processing rises or a new component is added? Would you be able to see trouble coming?

With the amount of power being drawn by high-density servers, accidental overload is easier than you might think.

To maximize the capacity of the feed without overloading one of the phases and risking a load drop due to a tripped breaker, it is important to be able to meter each of the phases. Eaton offers state-of-the-art metering from the PDU level all the way down to the rack ePDU receptacle level.

- ePDU ammeters monitor current on each circuit (or receptacle) on easy-to-read LED displays
- The RPM graphically displays loading on each phase right on the front of the unit
- Larger distribution units, such as the PDU and PDR, can be configured with Eaton's advanced Energy Management System, allowing monitoring of all branch circuits as well as system-level main feeds

Eaton's advanced metered products support remote monitoring via IP using common protocols, such as SNMP and Modbus TCP—and are compatible with most building management systems.

With advanced metering at every level of the power distribution tree, you can quickly determine the capacity of a phase about to be utilized, at all levels, to avoid accidental overloads.

Summary

While this is by no means an exhaustive list of ways to increase data center efficiency, this paper highlights some common efficiency considerations when selecting power distribution equipment. Eaton's power protection and distribution systems have been designed for the realities of modern data centers, with their escalating power demands and constant moves, adds and changes:

- BladeUPS, with the highest efficiency in the industry, reduces UPS footprint and allows more scalability than with traditional stand-alone three-phase UPSs
- Eaton PDUs incorporate energy-efficient transformers into the standard design and have the smallest footprint in the industry
- Eaton PDRs and ePDUs simplify three-phase distribution to high density racks

The sample configurations demonstrate how Eaton can provide a total power solution while improving efficiency—without requiring you to make drastic changes to the power infrastructure of the data center.

“Replacement of aging equipment with alternatives that consume less power may be more viable than you might think, when long-term energy pricing is factored into the total cost of ownership (TCO) evaluation.”

**Stephen Prentice, in *Why Cool Is Now 'Hot' for IT Planners*
Gartner RAS Core Research Note G00138041, May 2006**

About Eaton

Eaton is a global leader in electrical control, power distribution, power protection and industrial automation products and services. Eaton delivers a broad range of infrastructure solutions for your IT systems:

- UPS products—Rackmount and freestanding power protection systems for applications from the simplest desktop to the largest government, healthcare or industrial facilities
- Enclosures—Attractive, secure and functional enclosures for data centers, wiring closets, office environments and warehouse spaces
- Power distribution—Rackmount PDUs to streamline the distribution of power throughout a data center, rack or enclosure
- Power reliability—Generators and advanced battery technologies to provide backup power, paralleling gear to create redundant UPS configurations, power quality audits to assess and improve power conditions
- Services—Maintenance plans and extended warranties, 7x24 support, remote monitoring and diagnostic services, turnkey project management and electrical contracting and system integration—350+ customer support engineers in North America

- Power Xpert Architecture—Meters, switches, gateways and software transform your power system into an integrated, agile system that you can monitor, control and manage effectively and efficiently.

For more information about Eaton's data center solutions:

800.356.5794

www.Powerware.com/datacentersolutions

About the Author

Jonathan Rodriguez is a Senior Application Engineer in the Data Center Solutions group with six years of experience in the power protection industry, ranging from software design of three-phase UPSs to data center application support. He holds bachelors degrees in Computer and Electrical Engineering, as well as a Master's degree in computer engineering from North Carolina State University.

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Sun Blade 8000P Chassis Specifications -

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Mission Critical Magazine Webinar: US government initiatives to accelerate energy efficiency within data centers –

<https://event.on24.com/eventRegistration/EventLobbyServlet?target=registration.jsp&eventid=97025&sessionid=1&key=3A50E47C351516437863155D2DD75355&sourcepage=register>

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Energy-efficient transformers -

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