Comparing Data Center Power Distribution Architectures

White Paper 129

Revision 3

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Executive summary

Significant improvements in efficiency, power density, power monitoring, and reconfigurability have been achieved in data center power distribution, increasing the options available for data centers. This paper compares five power distribution approaches including panelboard distribution, field-wired PDU distribution, factory-configured PDU distribution, floor-mount modular power distribution, and modular busway, and describes their advantages and disadvantages. Guidance is provided on selecting the best approach for specific applications and constraints.

> Revision notice

This original version of this paper focused on the benefits of floor-mount modular distribution. This revision discusses the five common distribution approaches and provides guidance for selecting the best approach for a given application.

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Introduction

Many existing data centers utilize the same power distribution architecture to get power to their IT equipment that was developed for data centers approximately 40 years ago. There have been dramatic changes, however, in how power is utilized in data centers that have challenged this architecture, specifically driven by increasing power density, the increasing number of separate IT devices within the data center, and the need to add and remove IT devices on a continuous basis. Improved systems allow IT racks to be installed or changed without any new wiring, distribute power overhead, support rack densities up to 30 kW with a single flexible power feed, improve electrical efficiency, are instrumented for power at the branch circuit, and have a standard capacity management system.

This paper compares the five power distribution approaches seen in data centers today, including panelboard distribution, traditional field-wired PDUs (power distribution units), traditional factory-configured PDUs, floor-mount modular power distribution, and modular overhead (or underfloor) power busway (see **Figure 1**). The advantages and disadvantages of each approach are discussed, and guidance is provided on selecting the optimal approach for specific applications and constraints.

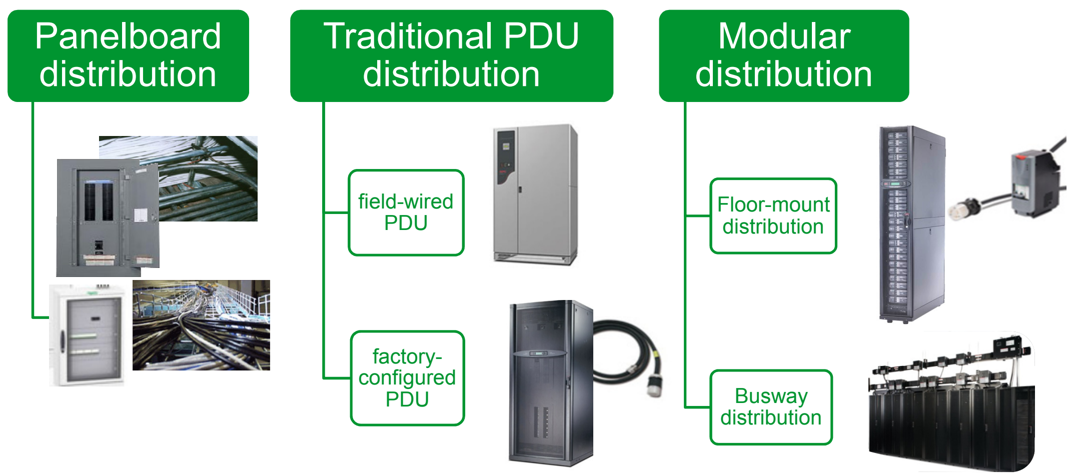


Figure 1

Five approaches to distributing power to IT racks

Data center IT characteristics

Traditional data centers consisted of a small number of large IT devices that were rarely changed except during the scheduled downtime of a major IT upgrade. The low power density of these facilities required a low volume of under-floor air, and typically less than one branch circuit for every three square meters of computer room. **Table 1**, on the other hand, summarizes the characteristics of the IT equipment in many data centers today.

Table 1

IT characteristics that impact power distribution selection

Characteristic	Description
Number of IT devices	Instead of a few large IT devices, data centers may contain thousands of plug-in devices with separate power cords, requiring many more power receptacles
Frequency of IT refreshes	IT devices are changed often within the lifetime of the data center, changing the power requirements or receptacle requirements at a rack location; New power circuits must frequently be added to a live data center without disturbing nearby existing IT loads
Power density of IT racks	The per-rack power density has increased greatly, often requiring multiple branch circuits per cabinet; The number of power feeds has clogged the under-floor air plenum with conduits, blocking the airflow and making changes very difficult
Type of IT devices	Dual power path systems are commonly implemented, requiring assurance that no circuit is loaded above 50%

Distribution voltage

In the majority of the world, power is distributed to IT loads at 400/230VAC. In North America, however, power is traditionally distributed at 208/120VAC, which results in deficiencies including greater cost, lower efficiency, and greater space consumed. Another operating voltage for North America offers advantages over 208/120VAC. Using 415/240VAC distribution enables higher density per rack without adding extra circuit breakers as would be the case with 208/120VAC distribution. White Paper 128*, High-Efficiency AC Power Distribution for Green Data Centers*, discusses the benefits of 415/240VAC over 208/120VAC.

Panelboard distribution

In panelboard distribution, the main data center power is distributed to multiple wall-mounted panelboards, such as those in **Figure 2**. Panelboards (typically rated from 1.5 kVA to 75 kVA) may come assembled by the vendor or they may be assembled in the field by the electrical contractor. Individual branch circuits or power cables are cut, terminated, and connected in the field by the contractor. The cables are run either overhead in cable trays (also called ladder trays), or they are run under the raised floor (sometimes in trays under the floor, and sometimes placed directly on the floor) to provide power close to the IT rack enclosures. Wall mount panelboards are a very low cost power distribution strategy, made up of parts that an electrician can acquire in days, not weeks, to implement quickly. This approach is very much custom engineered to meet the unique needs of a particular data center

Figure 2

Example panelboards

Advantages

- Lowest first cost, primarily driven by lower cost components
- Accommodates unusual physical room constraints
- Electrician has more flexibility in breaker and cable combinations, since they are not choosing from pre-configured assemblies
- Parts can be obtained very fast, i.e. from a local electrical supply

Disadvantages

- Increased risk of human error since installations are custom engineered and there is greater reliance on the quality of work and skill of the electrician
- If the plenum is used for distributing air, cabling restricts high volume air required by modern IT equipment (over time) which impacts effectiveness of cooling distribution
- Creates an environment that is not readily changeable
- Cable tracing & removing cables can be difficult because of the placement of the power cables under the floor or in trays

Usually used

- For smaller capacity installations and when lowest first cost is a top priority
- When IT changes are not likely or frequent
- When density per IT rack is low (if power cables are distributed in air plenum)

Traditional PDU distribution

In traditional power distribution systems, the main data center power is distributed to multiple power distribution units (PDUs), typically rated from 50kVA to 500kVA, throughout the IT space. Sometimes, PDUs without transformers are referred to as RPPs (see **side-bar**), but in this paper, the term PDU is used generically to include transformer-based and transformer-less distribution units. PDUs are fed from centralized subfeed breakers and are generally placed along the perimeter of the space, throughout the room. Some have an IT rack form factor that line up in a row of racks providing improved aesthetics for the space and bring the distribution closer to the load. Branch circuits are distributed from the PDUs to the IT equipment. Each IT rack enclosure uses one or more branch circuits. An example of this approach is illustrated in **Figure 3**.

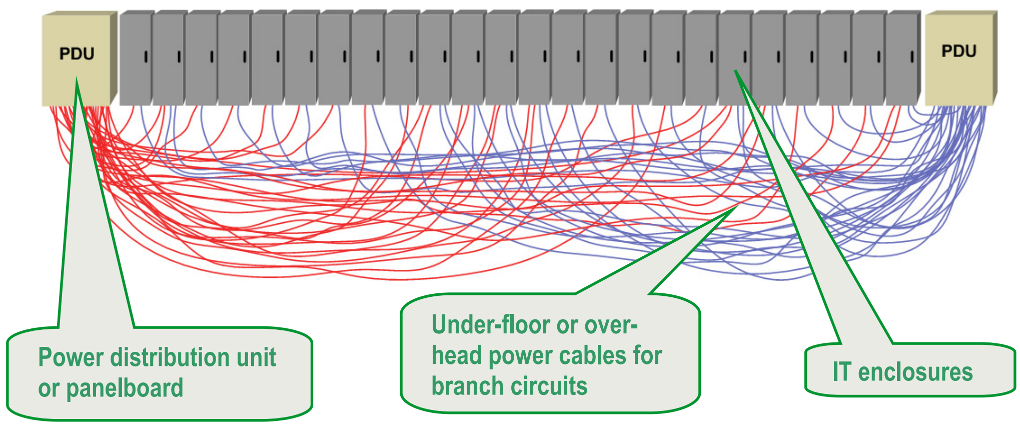


Figure 3

Wiring of a traditional data center power center distribution system

PDUs and RPPs

A **PDU** or power distribution unit is a component in the electrical infrastructure designed to distribute power from the upstream electrical path(s) to the downstream loads.

In some parts of the globe, the term PDU refers specifically to distribution systems that include a transformer to convert voltage or provide power conditioning; and those without transformers are referred to as **RPPs** or remote power panels.

Traditional methods often result in the following unfavorable conditions:

- Data center operators feel constrained to make circuit changes on energized wiring which is dangerous and violates codes
- PDUs take up a significant fraction of the floor space and the floor load weight capacity
- Large transformer-based PDUs typically run out of breaker positions before being fully loaded
- Large transformer based PDUs generate waste heat that must be cooled, decreasing data center efficiency

There are two main categories of traditional PDU systems:

- **Field-wired** using power cables in cable trays or in flexible or rigid conduit, distributed beneath the raised floor or overhead to the IT racks.
- **Factory-configured** using pre-installed breaker/power cable assemblies distributed from PDUs overhead in cable troughs to the IT racks.

Field-wired PDU distribution

Similar to the branch circuits fed from panelboard distribution, the power cables from field-wired PDUs to the IT enclosures may be run through flexible or rigid conduit or they may simply be placed in trays or underfloor. The approach selected often varies based on local code requirements**. Figure 4** illustrates a field-wired PDU as well as two methods of distributing the power cables – rigid conduit below the raised floor and cable trays overhead.

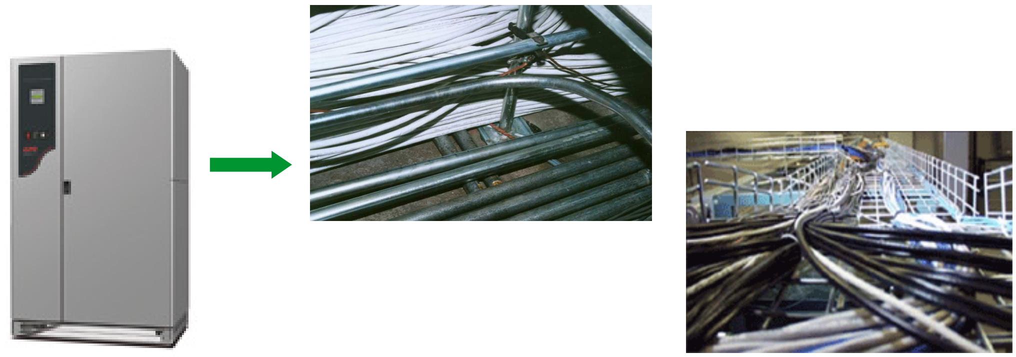


Figure 4

Field-wired PDU with under-floor power distribution in hard pipes and overhead cable trays

The electrical contractor plays a large role in engineering this type of solution and a significant amount of wiring work is done onsite, including cutting, terminating, and connecting each individual branch circuit, and routing them to the racks. In a raised floor installation, special under-floor mounting supports are engineered as well. For branch level metering, sensors are added and then programmed.

Advantages

- Higher degree of monitoring options than panelboard approach
- Low first cost, primarily driven by lower PDU cost than factory-configured or modular PDUs
- Accommodates unusual physical room constraints and allows for more strategic placement of the distribution when compared to wall-mounted panelboards.
- Electrician has more flexibility in breaker and cable combinations, since they are not choosing from pre-configured assemblies

Disadvantages

- Increased risk of human error since field-wired designs mean greater reliance on the quality of work and skill of the electrician (i.e. wire terminations done in the field may result in loose connections and other defects)
- Limited warranty of whole power distribution system, since components like breakers and power cables are installed in the field
- If the plenum is used for distributing air, cabling restricts high volume air required by modern IT equipment (over time) which impacts effectiveness of cooling distribution
- Cable tracing & removing cables can be difficult because of the placement of the power cables under the floor or in trays

Usually used

- When low first cost is a priority compared to a factory-configured & modular distribution
- When floor space is available but unique room constraints limit the use of factory-configured or modular designs
- When IT changes are not likely or frequent and growth of IT is done at the pod level
- When the IT layout is unknown at the time of the PDU specification, since exact branch breaker ratings and power cable lengths do not get specified until closer to installation

Factory-configured PDU distribution

With factory-configured distribution, much of the field-wiring work that is otherwise done on site is done in a controlled factory. The PDU is configured to the customer’s requirements with factory-assembled branch breakers with power cables pre-cut and terminated to the length and ampacities required by the IT racks. These cable /breaker assemblies are installed onto the PDU at the factory, so that the only onsite work involves running the conduit from a subfeed breaker to the PDU input, and then routing the pre-connected cables to the appropriate IT racks. By standardizing the power distribution solution, data center projects can eliminate costly and time-consuming one-time engineering. **Figure 5** illustrates a factory-configured distribution system, tightly integrated with the UPS and rows of racks.

Figure 5

Factory-configured traditional distribution integrated in row of racks

Advantages

- Pre-fabricated breaker / power cable assemblies improve reliability by minimizing field work
- Integrated design with integrated and pre-configured intelligence for better capacity and change management as load requirements change
- System-level warranty of whole power distribution system, since components are designed, tested, and integrated in a factory
- Accommodates unusual room constraints since PDUs can be rolled into any location on IT floor
- Lower first cost than modular distribution approaches

Disadvantages

- The IT room layout must be understood earlier in the planning cycle, since specific breakers and cable lengths are procured with the system; better coordination between IT and facilities is typically necessary
- Higher field cost to install new power cables and breakers as load requirements change compared to modular distribution approaches
- Cable tracing & removing cables can be difficult because of large volumes of cables overlayed in troughs
- Takes up space on the IT room floor
- Heavier shipping weight since it ships with all breakers and cables attached

Usually used

- When a data center plans to scale their future IT at the pod level
- When a data center requires portable equipment due to likelihood of future move
- When space is not constrained and low first cost is a priority

Modular power distribution systems

In order to meet the modern IT requirements shown in **Table 1**, alternative power distribution approaches are appearing in data centers. These approaches are more flexible, more manageable, more reliable, and more efficient. Specifically, they include the following attributes:

- **Integrated branch circuit power metering** – Capacity and redundancy are managed on every circuit
- **Flexible changeable power cords with tool-less expansion** – IT zones and associated power distribution can be deployed over time, by anyone
- **Reduced footprint** – Less floor space required than with traditional PDUs
- **High efficiency** – Transformerless options and minimized copper use

Two modular distribution systems can achieve these desired characteristics:

- **Overhead / underfloor modular distribution** using plug-in units powered by busway overhead or underfloor to feed IT enclosures
- **Floor-mount modular distribution** using branch circuit cables, distributed overhead in cable troughs to the IT enclosures, that are pre-terminated with breaker modules that plug into a finger-safe backplane of a modular PDU

In general, these approaches have a higher first cost per watt than traditional distribution. However, from a lifetime cost perspective, these approaches have lower TCO because of the ability to implement changes faster, avoid stranded capacity (oversizing) with better capacity management, improve efficiency, and reduce maintenance expense.

Overhead / underfloor modular distribution (busway)

Busway was the first alternative to traditional distribution that achieved a more flexible, reconfigurable distribution system. The power bus is generally installed over IT equipment rows. Installation onsite involves installing subfeed breakers, securing the busway in place by attaching it with threaded rod and Unistrut to the ceiling, running wire from the breakers to the busway feed units, and then inserting the plug-in units and routing them to the racks. This approach addresses many limitations with traditional distribution, such as making changes easier and removing under-floor cabling. In the busway system, the IT enclosures directly connect into the busway via plug-in units with breaker boxes as shown in **Figure 6**. These systems are generally installed upfront for the maximum expected load.

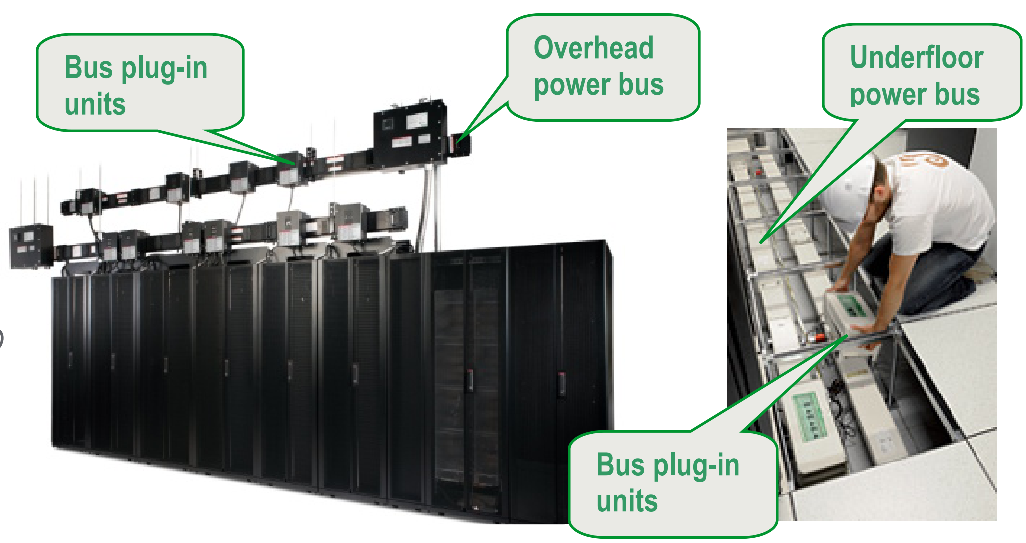


Figure 6

Busway to the rack showing power taps attached to an overhead power bus (left) and an underfloor power bus (right)

Advantages

- Zero footprint on IT room floor, making more space available for IT equipment
- Improved cable management and tracing, with distribution cable from plug-in unit located directly over or under IT racks

- Inventory of cables can be reduced dramatically with fixed distance from busway to each IT rack
- Tool-less pre-assembled plug in units improves the reliability by eliminating field wire cutting and terminating branch circuits
- System-level warranty of whole power distribution system, since components are designed, tested, and integrated in factory
- Broader range of capacities available in market to address greater capacity needs
- Simpler adds, moves, and changes because cables are not stacked on top of each other

Disadvantages

- Ceiling height could constrain overhead implementation of this approach, as space is required above the racks (approximately 25 inches or 0.6 m); raised floor used as air plenum constrains underfloor implementation
- Field installation of multiple bus sections and field-integrated management capabilities requires more time and expense and can create unique problems
- Can interfere with ducts and air containment systems when hung above IT enclosures
- Row placement and length need to be thought through in advance for busway placement since it is intrusive to install or move bus in a live IT environment
- Oversizing of bus is more likely since it is commonly built out on day one

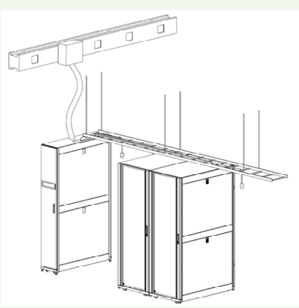
Usually used

- When floor space in the IT room is constrained
- In large facilities with an open floor plan with a very well defined IT row layout
- When there is a high degree of confidence in final IT load requirement
- When there is a high frequency of IT equipment turn-over requiring new circuits to be installed (i.e. lab environment)

Types of busway

This paper is focused on busway in the IT space for final distribution to the IT racks.

Busway solutions also exist to distribute power upstream in the electrical path. Installing "interconnect" busway upfront that traverses the planned IT rack layout (perpendicular to the rows) enables quick and easy scaling of the final IT distribution. When groups of IT racks are ready to be installed, PDUs (traditional or modular) can be added and powered by the main busway, as illustrated below.



Floor-mount modular power distribution

Instead of traditional circuit breaker panels with bolted wire terminations, modular PDUs have a backplane into which pre-terminated circuit breaker modules are installed. This arrangement eliminates on-site termination of wires. A new row of 24 IT enclosures, along with all of the associated branch circuit wiring and rack outlet strips, can be installed in an hour, without any wire cutting or terminations. Installation involves installing the subfeed breakers, placing the distribution units on the floor, running the wire from the subfeed breakers to the units, inserting the pre-assembled circuits, and routing them to the racks. Power monitoring is included in each branch circuit and automatically configures when plugged in. An example of a floor-mount modular distribution unit and its branch circuit modules is shown in **Figure 7**.

Figure 7

Example of a floor-mount modular PDU with a half-rack footprint. Shown with 24-branch circuit modules installed

A large number of data center projects involve the upgrade of an existing data center, with common projects being the addition of capacity or installation of a high-density zone. The floor-mount modular distribution system is particularly well suited to these types of retrofit projects, because installation is much less disruptive than installing a traditional PDU. As the data center evolves, modular PDUs can operate alongside existing traditional PDUs.

In smaller data centers, the modular PDU may be directly integrated with the UPS system into a compact arrangement that can be located in the IT room and integrated into an IT enclosure lineup. In this case, the need for a separate UPS room is eliminated.

In some cases there may be one or more zones within a data center where only a small number of branch circuits are needed. This can occur when there is a cluster of very high density racks, or when a small group of racks is isolated by room shape or other constraints. In these cases, there are smaller versions of modular PDUs that directly mount into an IT rack, consuming zero floor footprint, as illustrated in **Figure 8**.

Figure 8

Smaller-scale modular distribution that mounts directly into an IT enclosure that can provide power to 6 IT enclosures (door closed and door open views)

Advantages

- Pre-fabricated backplane and branch circuit modules ensures a well integrated, reliable system
- Quicker installation time due to roll-in form factor and pre-assembled modules which require minimal field work
- Integrated design with plug and play intelligence for better capacity and change management as load requirements change
- System-level warranty of whole power distribution system, since components are designed, tested, and integrated in factory
- Improved aesthetics, with IT rack form factor for lining up in a row of racks, closer to the load
- Ease of scaling additional PDUs as new IT demand is identified
- Accommodates unusual room constraints since PDUs can be rolled into any location on IT floor

Disadvantages

- Greater number of cables to inventory since distances from PDUs to IT racks vary
- Cable tracing as well as adds and changes can be difficult, especially for high density applications, due to volume and size of cables located in troughs
- Takes up floor space in IT room

Usually used

- When data center has uncertain growth plan and locations are not precisely defined in advance, requiring flexibility to add/move distribution
- When the room is constrained in shape or ceiling height or has obstructions
- When IT personnel want to re-configure the breakers and branch circuits without involvement of third parties
- When speed of deployment is a high priority
- When retrofitting an existing data center with additional capacity or installation of a high-density zone

Rack-level power distribution

For equipment that requires a dedicated branch circuit, such as most blade servers, a single cable from the power distribution system carries one, two, or three branch circuits that plug directly into the blade server, with no additional rack PDU (i.e. power strip) required. When mixed equipment exists in the rack, rack PDUs are available that provide various receptacle and current ratings.

Comparison of architectures

Five architectures have been described in this paper. This section takes a closer look at how they compare from a reliability, cost, and agility perspective. In all cases, this comparison assumes the transformers are upstream in the distribution infrastructure (i.e. not located in individual distribution units).

Reliability comparison

The likelihood for downtime from human error is increased when a system is custom-engineered since custom designs often result in custom (or unique) problems. A standardized pre-fabricated system reduces field work and moves it to a controlled factory setting. Systems that are uniquely engineered also have limited system-level warranties compared to pre-fabricated and integrated systems. Safety of personnel working on the systems is also an important factor. Systems that limit exposure to live conductors are preferred. **Table 2** compares the five architectures from a reliability and safety viewpoint.

Table 2

Reliability comparison of five power distribution architectures

Attribute	Panelboard distribution	Field-wired PDU distribution	Factory-configured PDU distribution	Busway modular distribution	Floor-mount modular distribution
Reliability	System is custom engineered and manufactured onsite resulting in increased potential for human error. No system-level warranty.	System is field-wired onsite resulting in increased potential for human error. Reduced system-level warranty.	System is pre-fabricated in a factory setting with pre-connected breaker/cable assemblies and pre-configured intelligence, for increased reliability and predictability.	System has pre-fabricated plug-in units resulting in increased reliability and predictability. Management system, however, typically requires more field-configuration.	System has pre-fabricated backplane & breaker/cable modules with wiring terminations pre-made in a factory environment, for increased reliability and predictability.
Safety	Installation, adds & changes of branch circuits involve exposure to live electrical wiring.	Installation, adds & changes of branch circuits involve exposure to live electrical wiring.	Adds & changes of branch circuits involve exposure to live electrical wiring.	Installation, adds, & changes of plug-in units with ceiling mounted busway requires ladder access and sometimes chain or other actuators.	All branch circuit protectors are behind a lockable door and are easily accessible location. The plug-in installation requires no field wiring.

Cost Comparison

The final power distribution (i.e. downstream of transformers to the IT racks) accounts for less than 5% of the total capital cost of a data center's physical infrastructure. Although this represents a small percentage of the total, it's important to understand the differences in system cost, installation cost, and TCO for the five architectures in order to select the optimal approach for a particular need.

On a *per watt* basis, there is not a significant difference in the installed cost; however, data centers aren't typically built upfront for a known final capacity, and when growth plans are factored in, the upfront cost delta among the architectures is greater. Some approaches are highly scalable, which means significant capital expense can be deferred to future years or avoided altogether. Others incur a significant expense on day one, for an uncertain future capacity need.

From an operating cost standpoint, cooling inefficiency can result when running power beneath a raised floor that is also being used as an air plenum for distributing cool air to the IT equipment. These under-floor cables, as well as the floor openings for the wire, interfere with the airflow resulting in an inefficient cooling distribution system that must be oversized to adequately cool the load. Distribution schemes that run circuits overhead avoid this issue. See White Paper 159, *How Overhead Cabling Saves Energy in Data Centers*, for more information.

Table 3 compares these architectures from a cost perspective.

Table 3

Cost comparison of five power distribution architectures

Attribute	Panelboard distribution	Field-wired PDU distribution	Factory-configured PDU distribution	Busway modular distribution	Floor-mount modular distribution
Capital Cost	Lowest cost approach at $0.15 – $0.30/ watt* System is typically installed up front for maximum expected capacity, resulting in increased first cost; Installation labor is nearly half of total cost, which results in greater variation in total cost.	Low cost approach at $0.20 – $0.40 / watt* System is scalable at pod level; Installation labor is greater percent of total cost, which results in greater variation in total first cost.	Low cost at $0.30 - $0.50 / watt* System is highly scalable so costs can be deferred until capacity need exists; Installation labor is approximately 20% of total cost.	$0.40 - $0.60 / watt* Busway is generally installed up front for maximum expected capacity, resulting in increased first cost; Installation labor is approximately 20% of total cost.	$0.40 - $0.70 / watt* System is highly scalable so costs can be deferred until capacity need exists; Installation labor is approximately 20% of total cost.
Operating Cost	Underfloor cabling causes interference with underfloor airflow that reduces cooling efficiency and capacity; changes involve more costly field-work.	Underfloor cabling causes interference with under-floor airflow that reduces cooling efficiency and capacity; changes involve more costly field-work.	Cabling is generally overhead so no interference with airflow and no leakage from wire openings in floor; changes to breakers / cables involve more costly field-work than modular distribution.	Busway, when run overhead, results in no interference with airflow and no leakage from wire openings in floor; changes to breakers / cables involve less field-work.	Cabling is generally overhead so no interference with airflow and no leakage from wire openings in floor; changes to breakers / cables involve less field-work.

** Approximate cost range for 1N distribution, varies by density and labor rate*

Agility Comparison

Agility, or the ability of the system to adapt to change, is a critical attribute for consideration based on the frequency of IT refreshes and changes to IT demands that most data centers experience today. This includes the ease of configuring / planning, the speed of deployment when a new need is identified, flexibility with placement within the IT space, and the ability to scale or make changes as capacity and density needs change. **Table 4** compares the agility of the five architectures.

Table 4

Agility comparison of five power distribution architectures

Attribute	Panelboard distribution	Field-wired PDU distribution	Factory-configured PDU distribution	Busway modular distribution	Floor-mount modular distribution
Ease of configuring & planning	Number and location of panelboards established early in the design; number, location, length of cables can be deferred.	Number and location of panels established early in the design, before the final power density is known.	Number and location of distribution units can be deferred to later phases without special preparation.	Sized for maximum final load on day 1, but the number, location, and type of plug-in-units can be deferred to later phases.	Number and location of distribution units can be deferred to later phases without special preparation.
Installation speed	Highest degree of electrician field work during installation with custom panel & circuits.	High degree of electrician field work during installation with field-wired circuits.	Low degree of field work during installation with pre-installed circuits	High degree of field work during installation to mount busway	Low degree of field work during installation with modular plug-in circuits
IT space consumed	Minimal IT floor space is consumed since system is wall-mounted.	Consumes roughly 4 m^2 of IT space for every 100 kW of IT load, or roughly 9% of computer room space.	Consumes roughly 2.5 m^2 of IT space for every 100 kW of IT load, or roughly 7% of computer room space.	No IT floor space is consumed since system is mounted above or under floor.	Consumes roughly 0.7 m^2 of IT space for every 100 kW of IT load, or roughly 2% of computer room space.
Flexibility with room constraints	Accommodates most room constraints since system is field-engineered to meet unique specifications of room.	Accommodates most room constraints since system is field-wired to meet unique specifica-tions of room and placement of PDUs is flexible.	Accommodates unusual room constraints with line-up and match design and flexibility to install cable trays to the tops of the IT racks, or under-floor.	Accommodates space-constrained rooms best, but height requirements, interference with ducts or containment, or unusual shaped rooms may limit deployment.	Accommodates unusual room constraints with line-up and match design and flexibility to install cable trays to the tops of the IT racks, or under-floor.
Inventory of breakers / cables	Not constrained or limited by pre-engineered assemblies of breakers/cables; electrician custom builds to suit needs.	Not constrained or limited by pre-engineered assemblies of breakers/cables; electrician custom builds to suit needs.	More whips to inventory since the distance to IT racks vary, requiring different length cables.	Busway is same distance to each IT enclosure so all cable drops are the same length, simplifying spares inventory.	More whips to inventory since the distance to IT enclosures vary, requiring different length cables.
Ability to scale capacity	Electrician may feel constrained to work on energized wires to add circuits which is dangerous and may violate codes.	Electrician may feel constrained to work on energized wires to add circuits which is dangerous and may violate codes.	Electrician may feel constrained to work on energized wires to add circuits which is dangerous and may violate codes.	Plug-in units easily scale; bus is installed day 1 over all expected enclosure locations & oversized to maximum power density.	Simple to scale capacity with plug-in, pre-made branch circuits; can also easily scale at pod level.
Ability to make changes	Electrician may need to work on exposed wiring. Conduit needs to be extracted from complex network of under-floor wiring or overhead cable trays.	Electrician may need to work on exposed wiring. Conduit needs to be extracted from complex network of under-floor wiring.	Electrician may need to work on exposed wiring. Cable management & tracing can be challenging making adds, moves, changes difficult, especially high density circuits.	Easy access to circuits for cable tracing & management; enables high density adds, moves, changes.	Cable management & tracing can be challenging in troughs making adds, moves, changes difficult, especially high density circuits; pod-level changes are simplified.

Conclusion

This paper described the five common power distribution approaches in data centers, including their advantages and disadvantages, and provided guidelines for when each is optimal.

Panelboard distribution and field-wired traditional PDU distribution systems are shown to be the best approach when low first cost is the highest priority, when the IT space has unique room constraints, and when IT changes are not likely. Factory-configured traditional distribution systems are shown to be the best approach when a data center requires portability of its equipment, when additional pods may be added in the future, and when low first cost is still a priority.

Modular distribution approaches allow for more flexibility, more manageability, increased reliability, and increased efficiency, to better address the IT needs of many data centers today. Busway is optimal when floor space is a constraint, when there is a large open floor plan with a well defined IT equipment layout, and when there is a high confidence in the final capacity need. It's also ideal when there is a high frequency of IT equipment turn-over requiring new circuits. Floor-mount modular distribution, on the other hand, is optimal when the data center has an uncertain growth plan and locations are not precisely defined in advance, because it offers flexibility to place units in specific locations when the need arises. It's also best for data centers that are being retrofit with additional capacity (i.e. addition of a high-density zone).

About the author

Neil Rasmussen is a Senior VP of Innovation for Schneider Electric. He establishes the technology direction for the world's largest R&D budget devoted to power, cooling, and rack infrastructure for critical networks.

Neil holds 25 patents related to high-efficiency and high-density data center power and cooling infrastructure, and has published over 50 white papers related to power and cooling systems, many published in more than 10 languages, most recently with a focus on the improvement of energy efficiency. He is an internationally recognized keynote speaker on the subject of high-efficiency data centers. Neil is currently working to advance the science of high-efficiency, high-density, scalable data center infrastructure solutions and is a principal architect of the APC InfraStruXure system.

Prior to founding APC in 1981, Neil received his bachelors and masters degrees from MIT in electrical engineering, where he did his thesis on the analysis of a 200MW power supply for a tokamak fusion reactor. From 1979 to 1981 he worked at MIT Lincoln Laboratories on flywheel energy storage systems and solar electric power systems.

Wendy Torell is a Senior Research Analyst at Schneider Electric's Data Center Science Center. In this role, she researches best practices in data center design and operation, publishes white papers & articles, and develops TradeOff Tools to help clients optimize the availability, efficiency, and cost of their data center environments. She also consults with clients on availability science approaches and design practices to help them meet their data center performance objectives. She received her Bachelor's of Mechanical Engineering degree from Union College in Schenectady, NY and her MBA from University of Rhode Island. Wendy is an ASQ Certified Reliability Engineer.

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