WHITE PAPER

How Digital Electricity® Enables Low-Disruption Installation of AI Server Racks in Operational Data Centers

Digital Electricity can be a viable method to add AI compute resources to an existing data center with minimal cost and disruption.

AI adoption in data centers is surging. This increase in demand drives the need for scalable, efficient electrical infrastructure that can keep pace with escalating compute workloads. Digital Electricity (DE) stands out as an innovative solution, enabling swift installation of high-powered AI server racks with minimal operational disruption. By merging ease of deployment with robust power density and safety, DE marks a transformational shift for data center modernization at a time when speed and safety are paramount.

DE installs with the same rapid, low-cost practices as a USB or Ethernet cable, but it eclipses those technologies in terms of power delivery:

- **DE's power density** exceeds the 415VAC, 3-phase power distribution commonly used in data centers, while being touch-safe and free from the dreaded arc flash hazards known to operators.
- **DE circuits can coexist in the same tray**, be installed in separate trays or even exist within the same cable jacket as communication or data circuits.
- **Monitoring, metering and control** are made possible with the digital data contained in every wire pair.

The development of Fault-Managed Power represents another giant leap in power distribution across multiple environments.

— Denise Lee, Vice President of Engineering, Cisco

[1] https://fmpalliance.org/

[2] https://online.flippingbook.com/view/906766654/

[3] https://iaeimagazine.org/standards/the-next-edition-of-the-nec-a-transformational-change-in-electrical-safety/

Digital Electricity is the most widely adopted and field-proven form of Fault-Managed Power (FMP), setting the benchmark for the industry. The National Fire Protection Association (NFPA) assigned a new power class to FMP (Class 4) when it was formally adopted as part of the National Electrical Code (NEC) in 2023. This was the first time in half a century that a new power class was created.

A new industry group, the FMP Alliance[1], encourages market cooperation and education. Out of the more than 1,000 large buildings and venues implementing FMP, the format developed by VoltServer captured by its Digital Electricity brand represents more than 99% of the installed base.

FMP's potential to power the digital world is described in a recent Cisco e-book[2]. Cisco is a strong technology and standards advocate for FMP and is a founding member of the growing FMP Alliance.

From a safety and methods perspective, an article in *IAEI Magazine*[3], the publication representing electrical enforcement authorities, describes the inclusion of FMP in the National Electrical Code:

[The 2023] edition of the National Electrical Code introduces a wiring method that has the potential to fundamentally change electrical installations, upend electrical safety, revive DC distribution and reduce emissions. Quite a wiring method. Quite a new Article.

— Kevin Smith, Senior Technologist, CSA Group

Today, multiple manufacturers deliver:

- **FMP equipment,** including Panduit and EnerSys
- **FMP-certified cable**, including Belden, CommScope, Remee, Southwire and Prysmian

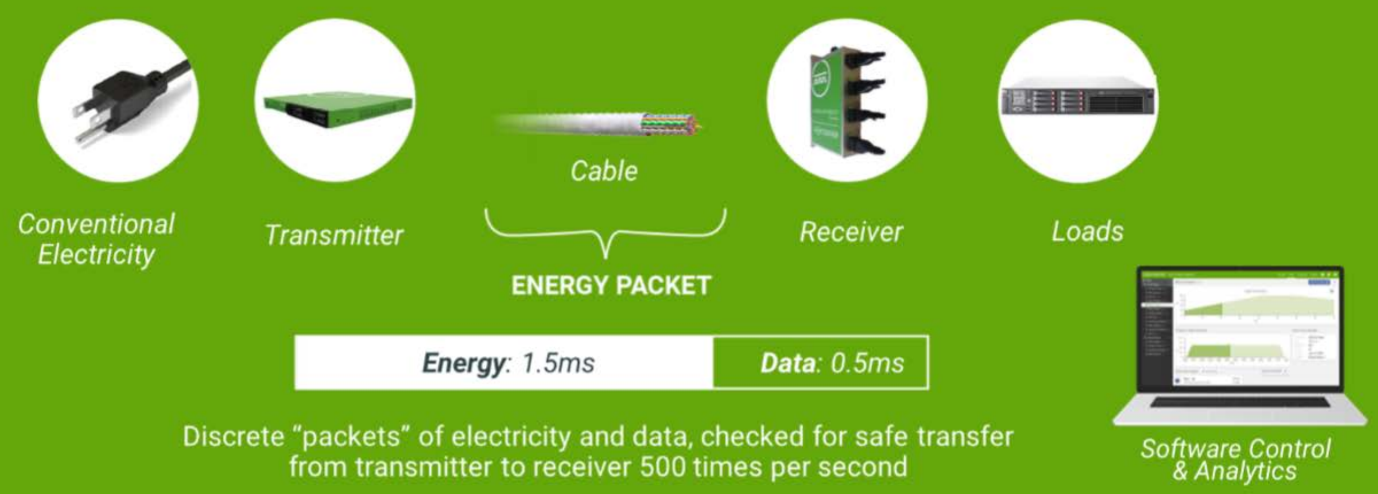


FIG. 1: Digital Electricity general topology

Delivering Safe, High-Power Transmission Over Communication Cables

Digital Electricity equipment transmits high-power electricity on structured (communication) cable from a transmitter to a receiver in the form of energy "packets." These packets contain electrical energy and control data. Each one has only a small amount of electrical energy and is checked for safety as it leaves a transmitter en route to a receiver.

The safety check tests all fault modes, including human touch, short circuit, ground and arc fault. By sending 500 packets per second, high power levels are achieved.

In a data center application, the transmitter units are packaged in a common cabinet with batteries to form a transmitter/uninterruptible power supply (TX-UPS). The receiver unit is embedded with high-voltage DC receptacles to form a server rack power distribution unit (PDU).

Meeting the Challenges of High-Density, High-Safety AI Rack Power Distribution

As server rack power demands increase, a denser and safer form of electricity is essential for IT personnel who work in densely populated cabinets fed at unprecedented power levels. The difficulty is even greater when adding high-density racks to an existing data center, where operators fear that major infrastructure changes and contractors in the data room might trigger an outage.

From a safety perspective, most U.S. data centers utilize 415VAC, 3-phase power to server racks. Already at the 415VAC level, potentially lethal arc-flash events will no longer self-extinguish[4]. But the demands of high-performance computing are driving a conversation around even higher voltage levels.

Safety aspects are further complicated by the addition of liquid cooling in the same spaces as electrical distribution. The point is often missed that the size and weight of electrical distribution in a data center is not driven as much by the cross-sectional area of the copper conductors (which decrease with voltage) as it is by the accompanying devices and structure to protect people and buildings from electrical hazards.

Increasing conductor voltage reduces conductor size but increases the size of the protective space and enclosures around conductors. In addition, power converters like PSUs and VRMs that are responsible for converting the rack power at hundreds of volts to the sub 1V level for CPUs and GPUs get larger, not smaller, at higher voltages, because the internal separation of the components increases. In other words, doubling the voltage of power distribution in the data room should not be assumed to halve its size in the overhead space. It may actually increase space requirements inside and around the server racks.

[4] "Arc Flash Safety in 400V Data Centers", Dave G. Loucks, Eaton Corp, https://www.eaton.com/content/dam/eaton/markets/data-center/Arc-flash-safety-in-400V-DCs.pdf

DE offers large reductions in the volume of power distribution components because most of the volume of electrical infrastructure is related to separating its hazards from people or buildings. Moreover, DE uses a nominal operating voltage of 350VDC, which is already compatible with many off-the-shelf server power supplies.

Why Reducing the Footprint of Electrical Equipment Matters

In today's AI data centers, GPUs are often linked to other GPUs within the rack using high-speed connections. In this case, the groups of linked GPUs are referred to as "superclusters" because they perform almost as if they were a single, super-powered processor.

For example, NVIDIA's Blackwell NVL72 rack system is a 72 GPU supercluster linked using NVLINK™. NVLINK represents a short-distance active electrical cable (AEC) communication system operating at extreme bandwidths: 1.8 Tb/s at around 2 meters[5]. Communication delays of just nanoseconds within a supercluster can have serious effects on overall performance because all GPUs run in parallel, like race cars side by side on a track. The race is not complete until the slowest car reaches the finish line, meaning that one straggler wastes the advantage of all the others that arrive first.

It's extremely important that GPUs be grouped close together since no signal can travel faster than the speed of light. This has resulted in GPUs being so tightly packed that a single rack can cost between $2 million and $3 million[6].

Data center infrastructure has been traditionally separated into two worlds:

- **Information technology (IT)**, also known as white space, where servers and communication equipment reside
- **Operational technology (OT)**, also known as grey space, which is responsible for electrical supply and cooling

This creates a tendency to perceive clean-cut boundaries between white space and grey space, where very expensive real estate within the server rack suddenly drops to lower-cost real estate just outside the rack sheet metal.

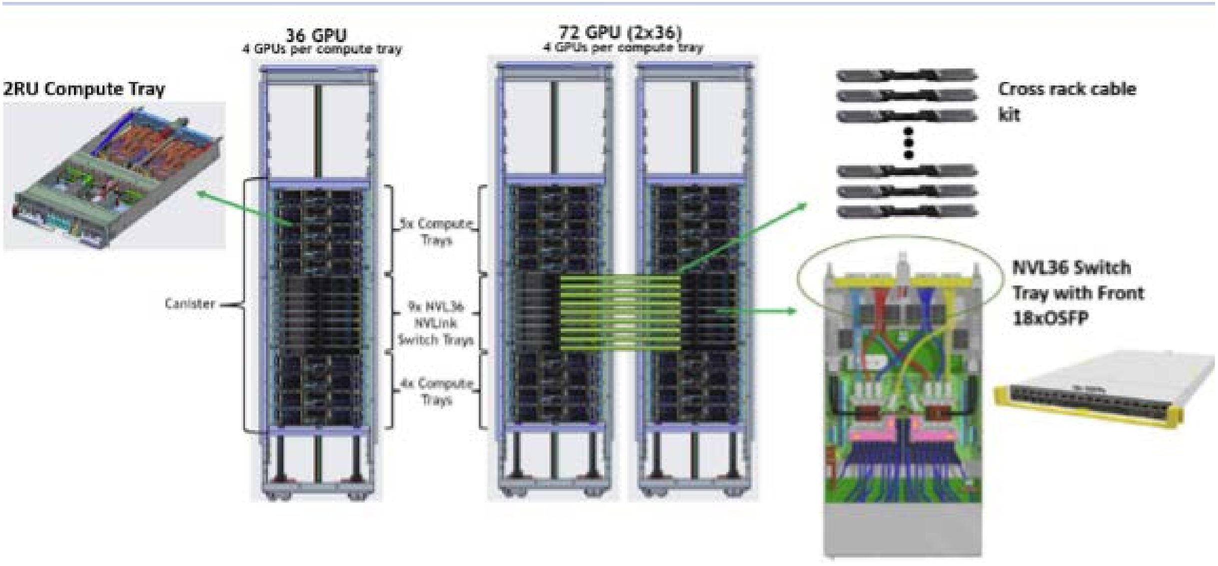


FIG. 2: Cross-rack High-Speed Link within a supercluster (NVIDIA)

[5] https://www.diskmfr.com/nvidia-gpu-copper-cable-interconnect-technology-explained/

[6] ASP estimate by HSBC analyst Frank Lee, May 30, 2024

But the supercluster is not driven by such arbitrary boundaries, as illustrated in the diagram below from NVIDIA, depicting server connections reaching left or right to another rack to form a cluster.[7] The reach of superclusters upward is evident in the trend to higher racks reaching 52U and higher.

Imagine a luxury hotel where the owner makes money by renting rooms. Would the hotel operator be happy if the architect allocated the top 10 floors of the hotel to electrical distribution?

So, it is misleading to assume that a sidecar can easily be placed next to a server rack, or that electrical and cooling infrastructure can easily occupy overhead space. Operators would much rather use that room to expand their revenue-producing superclusters.

Digital Electricity has a tradition of converging the boundaries of OT and IT. In this case, that means combining separate infrastructure for power and data into one layer. The elimination of overhead busway, transformers circuit breakers and lots of metal results in a massive decrease in the required space for electricity near servers.

Comparative Analysis of AC and DE Architectures

DE has been deployed in factories, hotels, offices, airports, conference centers and large indoor agriculture facilities. Many of the installations support critical power infrastructure. Despite that track record, DE is only in the pilot stage in data centers.

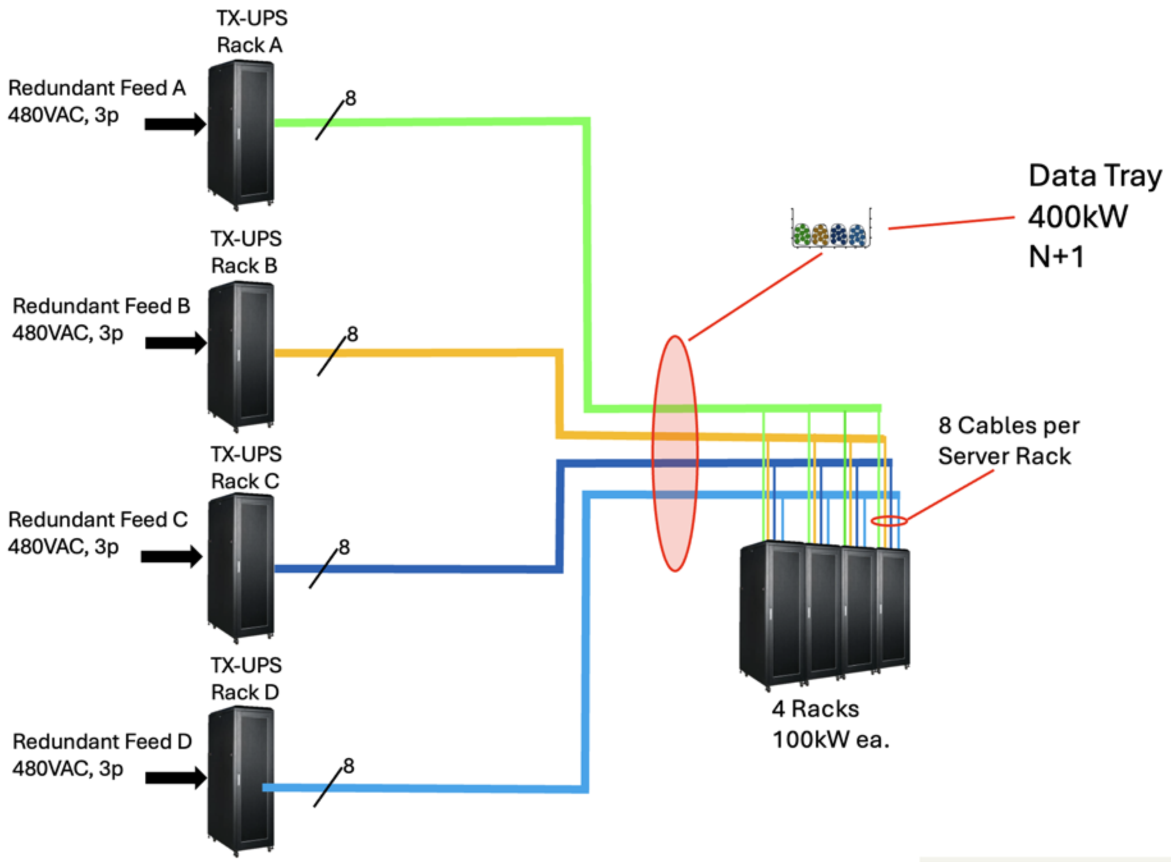


FIG. 3: Digital Electricity powering four 100kW server racks

[7] https://docs.nvidia.com/multi-node-nvlink-systems/imex-guide/overview.html

How does DE compete with the 415VAC, 3-phase distribution commonly used in data centers when applied to 100kW server rack power densities?

To install power for four 100kW server racks, DE architecture incorporates a total of four DE TX-UPS racks in one electrical room or separate electrical rooms, as shown in Figure 3. The TX-UPS cabinets are 19-inch racks, 52U, 48-inch depth. Only three of the four transmitter-UPS racks are needed to maintain 100kW server-rack operation.

DE is a point-to-point architecture, where the failure of a single rack, cable or other component is isolated to a small group of equipment, allowing the N+1 architecture to provide the same availability as a 2N architecture in the AC case.

Eight DE cables leave each of the four TX-UPS racks (A-D) and travel in overhead data trays or even J-hooks to the server racks. An individual server rack receives two cables from each of the four TX-UPS racks, for a total of eight DE cables per server rack.

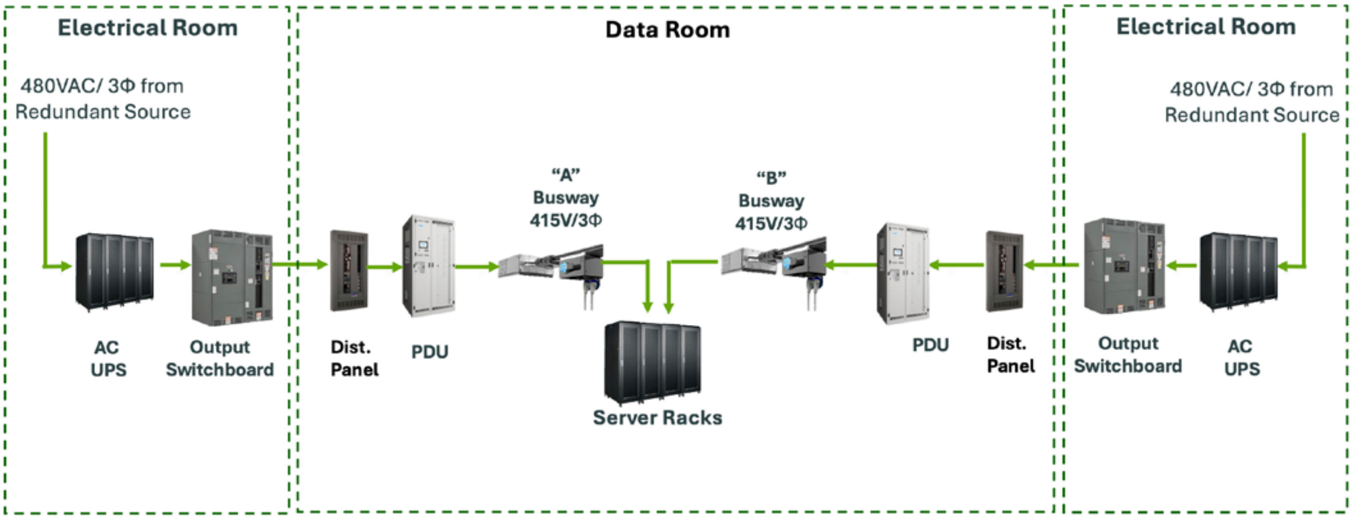


FIG. 4: AC distribution diagram

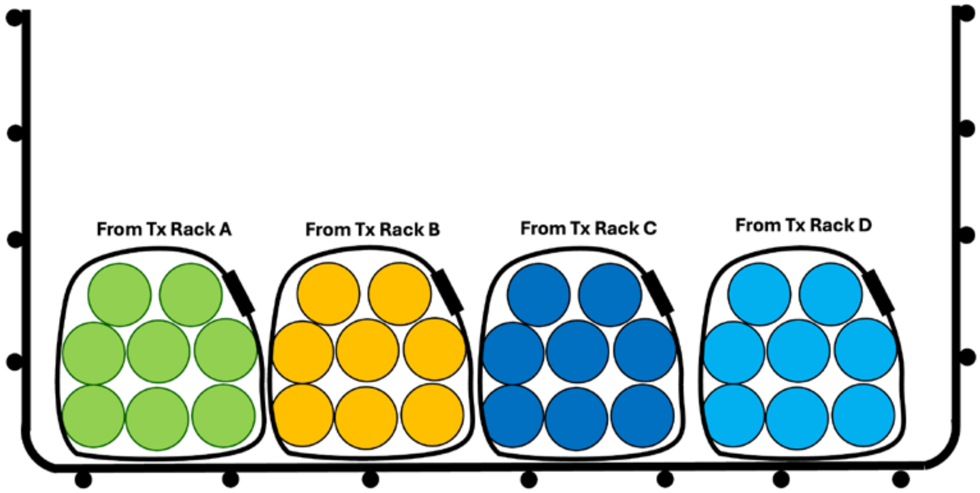


FIG. 5: DE cables in a 6” x 12” cable tray (400 kW N+1)

In the AC case, the UPS is followed by distribution equipment that includes:

- An output switchboard
- Conduit
- Distribution panels
- Floor PDUs
- Overhead busway

The AC implementation utilizes a 2N architecture, so there are two copies of the distribution equipment (A and B). The configuration is depicted in Figure 4 (on the previous page).

The first thing that jumps out when the two architectures are compared is that all the intermediate distribution devices are eliminated with DE. Power is delivered from the TX-UPS racks all the way to the server cabinets on communication cabling.

To provide perspective on power density for the DE case, all the cables for the 400kW row of server racks, including N+1 redundancy, are shown in a single 6-inch by 12-inch data tray in Figure 5 (on the previous page). The figure is a cross-sectional

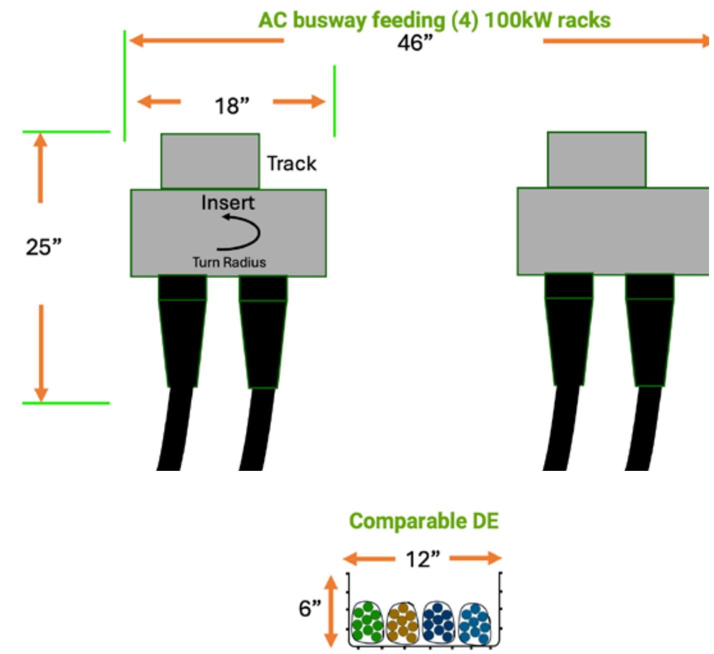


FIG. 6: AC busway and DE cross-section comparison

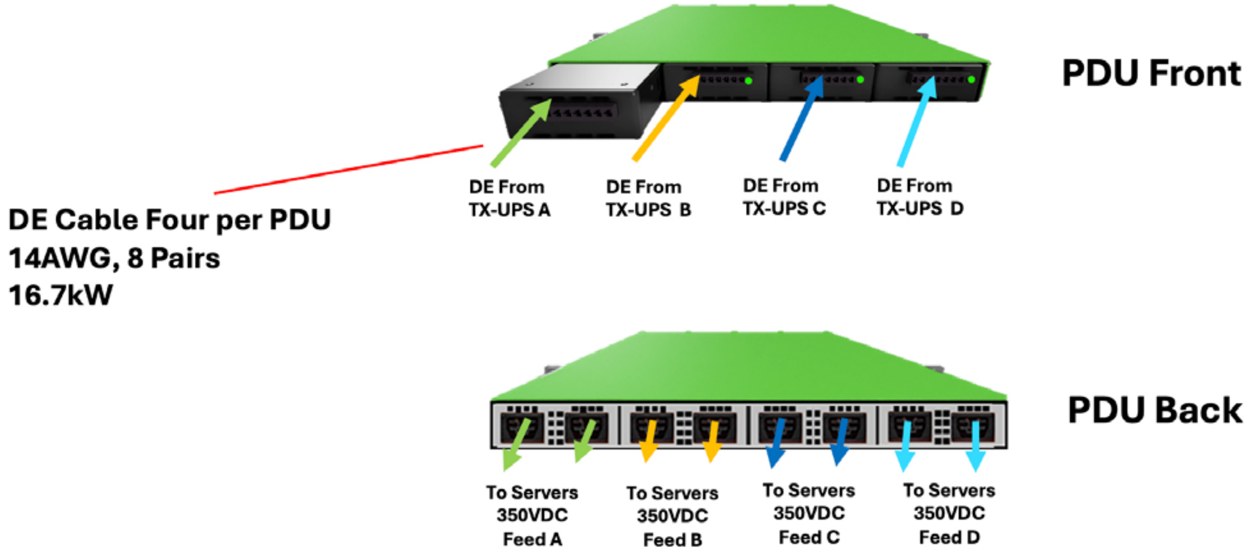


FIG. 7: DE PDU, 50kW N+1

view of the tray and cable. The packing density of the cable is 21%, and the conductor current is 35% of its nominal rating, conforming to NEC requirements[8].

In the AC case, two redundant busways are employed to provide 400kW in a 2N configuration. The cable tray for the DE solution is shown in the lower right of Figure 6 (on the previous page) for a size comparison.

The result is an 80% reduction in space requirements in the area above the server racks.

Within the server racks, DE PDUs consolidate and convert multiple channels of Digital Electricity back to conventional DC at 350VDC. The PDU provides 50kW of N+1 power in a 32-inch-deep, 1RU package, as shown in Figure 7 (on the previous page).

The PDUs have four removable modules. Each module receives an 8-pair cable from a separate TX-UPS rack located in the electrical room. At the back of each PDU module are two Anderson Saf-d-grid® high-voltage DC (HVDC) connectors to provide HVDC to the server power

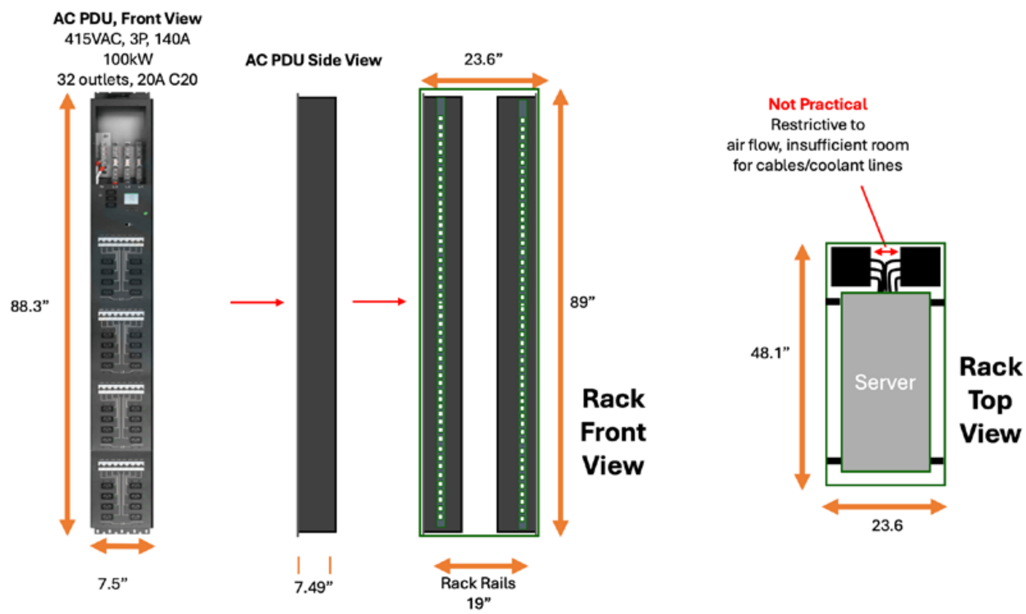


FIG. 8: AC PDUs in server rack

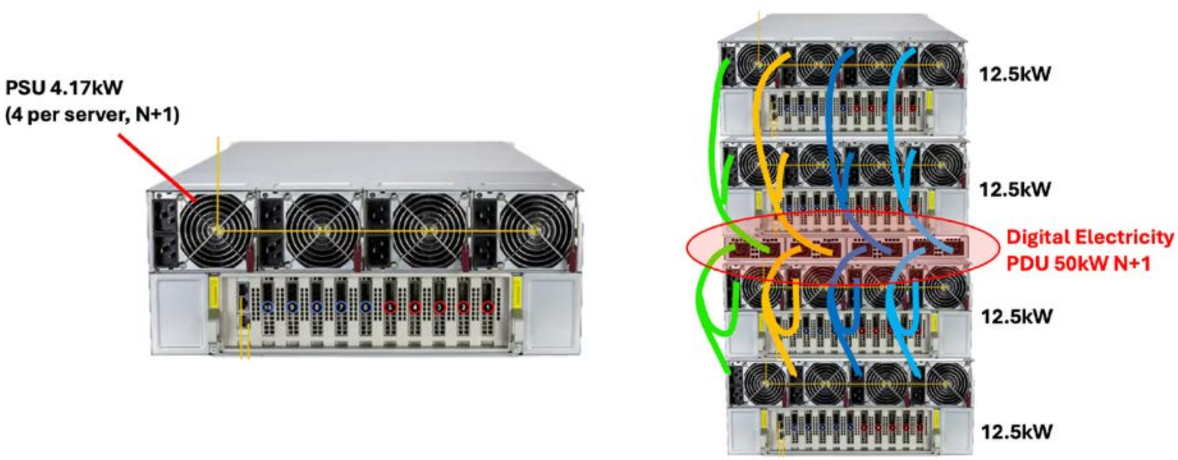


FIG. 9: 50kW server building block powered by DE PDU

[8]NEC Chapter 9, Table 1 and Table 310.15(B)(3)(a)

supply units (PSUs). The connectors are rated at 30A each. Two DE PDUs are required to power a 100kW server rack.

In the AC case, 100kW, 3-phase, 415VAC PDUs are utilized for in-rack distribution of AC to servers. Each AC PDU provides 32 20A 240V receptacles, as shown in Figure 8. To provide 2N redundancy, two of the AC PDUs are needed within the rack. The space left between the two redundant AC PDUs, particularly when power cords and cooling lines are installed, is questionable from the perspective of allowing cool air to flow front to back in the rack. This would make access for maintenance and configuration nearly impossible.

In the DE case, two rack units are required for the two DE PDUs to deliver 100kW to a server rack. The fact that an N+1 vs. 2N architecture can be employed with DE makes it easier for PDUs and servers to fit in the rack.

First, as shown in Figure 9 (on the previous page), a 50kW server "building block" can be constructed by combining a 50kW DE PDU with four GPU servers, each drawing 12.5kW.

Finally, in Figure 10, a complete 100kW rack is depicted by combining two of the 50kW building blocks of Figure 9 in a 48RU-high by 48-inch-deep server rack. The space allocation includes:

- 3RU for switching
- 4RU for a 200kW CDU
- 4RU for the FMP PDUs
- 32RU for eight servers

Another differentiator between Digital Electricity and traditional AC systems is a reduction in monitoring equipment costs. Digital Electricity packets contain energy *and* monitoring data. DE TX-UPS and server PDUs are in constant communication to monitor and meter electrical energy and check for faulty wiring or configuration.

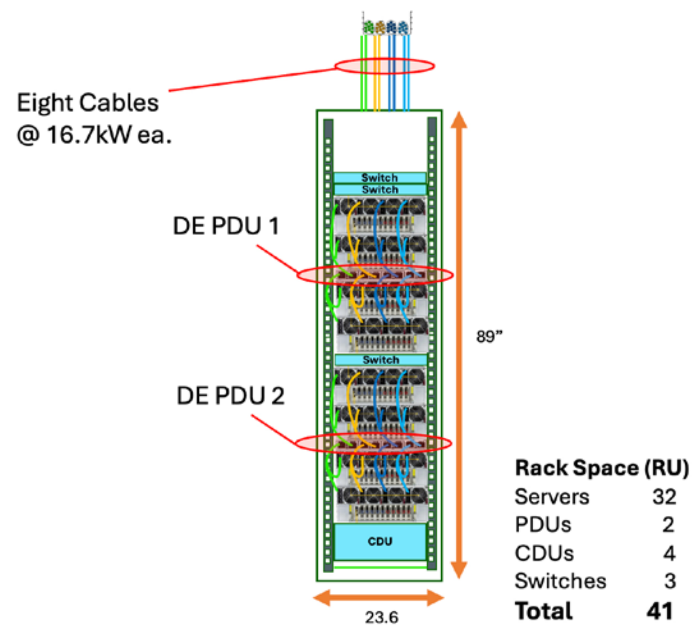


FIG. 10: 100kW Server Rack powered by Digital Electricity

Batteries and UPS functions are integrated with the DE transmitter and monitored for status and performance. In other words, complete monitoring of the power distribution system within and downstream of the TX-UPS is achieved with the inherent data capabilities of Digital Electricity.

As illustrated in an earlier study led by Southland Industries[9], a leading data center design-build firm, more than 30% in installed system savings can be realized with Digital Electricity.

[9] https://southlandind.com/article/utilizing-fault-managed-power-systems-fmps-data-center-power-distribution

The cost of the Digital Electricity TX-UPS racks and PDUs are more than compensated for by reductions in labor costs and the elimination of a host of traditional AC distribution equipment: switchboards, floor PDUs, overhead busway, and large-gauge AC wire and conduit. Fewer labor hours not only save initial project costs but also yield faster deployment.

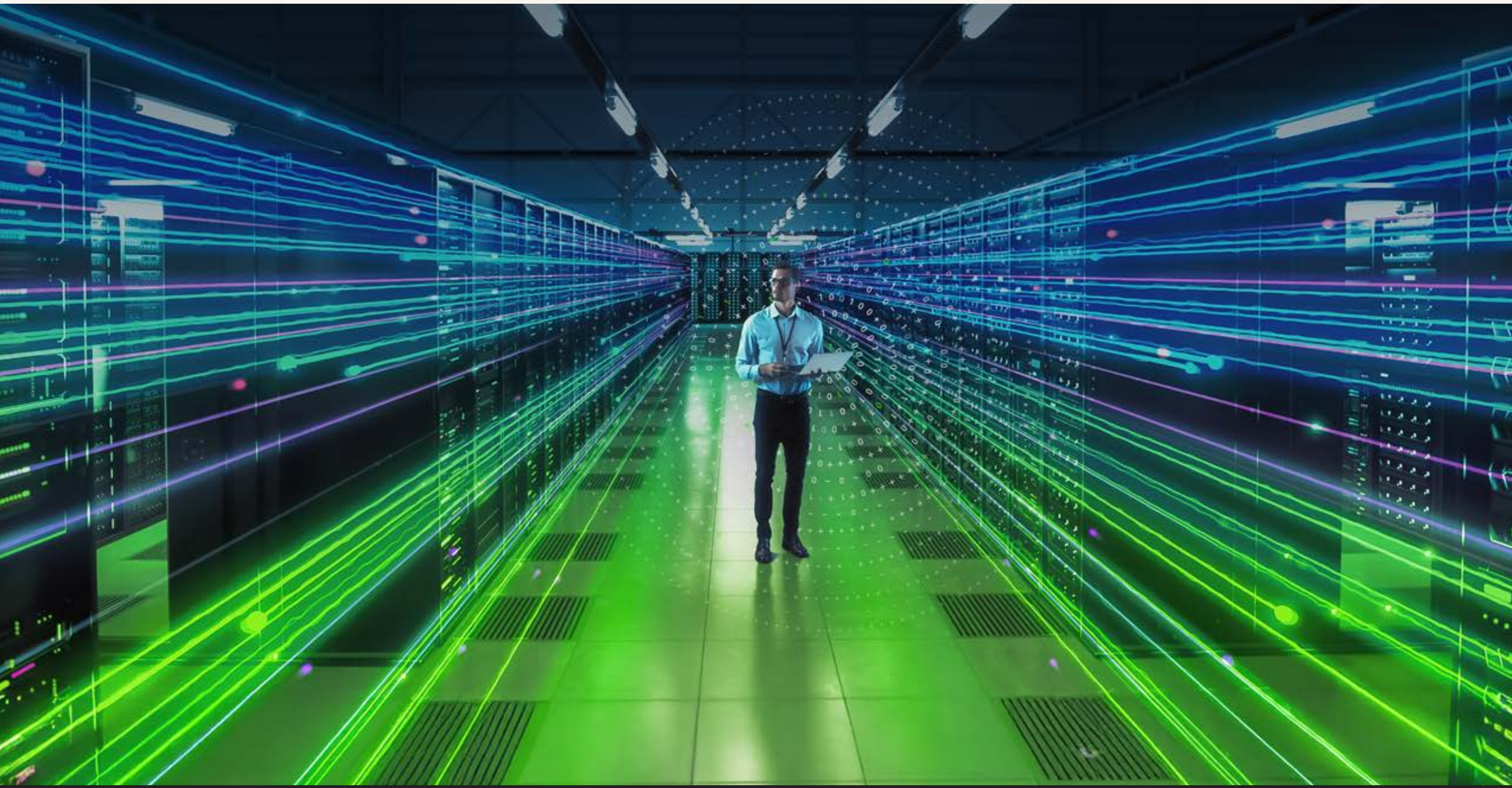
Although the Southland study focuses on initial cost, additional long-term maintenance benefits are noted. At the top of that list is the great reduction in points of failure. One continuous DE cable “bypasses” many connections and different types of equipment in comparison to the AC topology. These connections and various equipment components are prime failure points in AC systems, where continuous cable lengths remain the most reliable part of the system.

All these AC connections and equipment require continuous maintenance via monitoring, infrared imaging and data logging. This laborious maintenance is replaced by the advanced digital system monitoring already built into the system. The inherent advanced monitoring of the DE system not only detects all types of faults but also detects loose end connections and even monitors dielectric degradation of the insulation over time. This yields thousands of maintenance hours saved over the life of the system compared to AC topology.

Setting New Standards for Modern Data Center Operations

Digital Electricity, the leading implementation of Fault-Managed Power, is becoming mainstream, installed in more than 1,000 facilities. Guidelines and installation practices are now specifically recognized and prescribed in the 2023 National Electrical Code, Article 726, for Class 4 power systems.

Digital Electricity’s advanced technology and inherent monitoring characteristics closely match the needs of data center owners, particularly when adding new racks to an operational facility. As a leading form



of Fault-Managed Power, Digital Electricity offers enormous potential to achieve:

- Low disruption in an operational data center
- Electrically safe operation
- Potential initial cost savings of more than 30%
- Faster speed to deployment
- Space savings
- Built-in electrical power monitoring
- Decreased points of failure
- Reduced maintenance costs

Digital Electricity is redefining data center power strategies, merging streamlined installation, built-in monitoring and enhanced safety. Its adoption removes many traditional barriers while offering reliability and agility for next-generation AI workloads. As data center owners futureproof their operations, DE is a low-disruption, high-performance power-delivery solution.

Low disruption in an operating data center

Electrically safe operation

Potential initial cost savings of more than 30%

Faster speed to deployment

Space savings

Built-in electrical power monitoring

Decreased points of failure

Reduced maintenance costs

VoltServer's Digital Electricity® solutions for data centers allow operators to optimize space and reduce material use, resulting in more efficient power and data distribution.

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