Southland

White Paper

A Comparison of Fault Managed Power (FMP) and Traditional AC Distribution in High Performance Data Centers

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Fortunately, there is a technology solution emerging to address the "perfect storm" around AI

The demands of Artificial Intelligence are continuing to put pressure on data center builders and operators, with some co-location customers seeing up to 30% price increases. There is consensus in the industry that server rack power requirements could reach 20–30kW near term and 50–100kW longer term.[1]

These demands along with demands for electric vehicle charging infrastructure and legislation by states to eliminate natural gas in new buildings, are putting unprecedented pressure on the supply chain for power distribution components such as transformers, where lead times can reach 100 weeks.[2]

Another challenge is a shrinking pool of skilled tradespeople. A recent article on the online career platform Indeed.com had the following statement about the availability of electrician labor: "The current state of the electrician labor shortage is shocking." [3] The article goes on to reference National Electrical Contractors Association (NECA) data showing that 10,000 electricians retire for every 7,000 that enter the workforce. So, there does not appear to be an immediate solution to the labor shortage even as demand skyrockets. The article points out a survey by Tallo where around 76.5% of young people preferred technology related careers as opposed to only 16.7% who were attracted to careers associated with construction.

Fortunately, there is a technology solution emerging to address the "perfect storm" around AI, decarbonization, supply chain, and the skilled labor shortage. It is called Fault Managed Power (FMP). The technology was recently adopted into the 2023 National Electric Code and has been branded by its inventor, VoltServer, as Digital Electricity™.[4] Although VoltServer has a 20kW pilot edge data center in operation since 2018, the company only started to pursue the data center market in earnest in 2023. This pursuit was initiated by the maturity of their technology that allows for larger density installations.

1 https://www.itpro.com/infrastructure/data-centres/soaring-demand-for-generative-ai-resources-is-pushing-data-centers-to-maximum-capacity

2 https://www.latitudemedia.com/news/catalyst-understanding-the-electric-transformer-shortage

3 https://www.indeed.com/career-advice/news/electrician-labor-shortage

4 *Digital ElectrictyTM is a trademark of VoltServer Inc.

Fig. 1 depicts the general FMP topology. Digital Electricity transmits high power electricity on communication cabling from a transmitter unit to a receiver unit in the form of digitally controlled energy "packets." The packets contain electrical energy and control data. Each packet has only a small amount of electrical energy and is checked for safety as it leaves a transmitter enroute 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 at 336VDC high power levels are achieved. In a data center application, the transmitter units are packaged in a common cabinet with batteries to form a Fault Managed Power Uninterruptible Power Supply (FMP UPS). The receiver unit is embedded with high voltage DC receptacles to form a server rack PDU.

This inherently safer form of electricity simplifies electrical construction and maintenance because it installs with the same practices as data cabling, using IT installation practices.

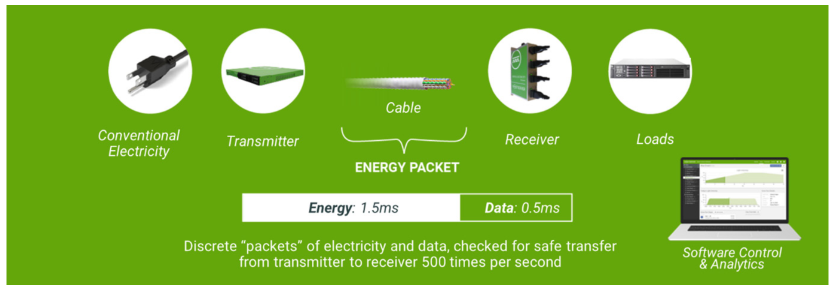

FIG. 1: *Digital ElectricityTM General Topology*

As server rack power densities increase, a denser and safer form of electricity is essential since IT personnel will be working in densely populated cabinets fed with unprecedented voltage/power levels. Already, data centers utilize 415VAC power feeds directly to server racks. One immediate concern is crossing from 110V/208V to 415VAC means that potentially lethal arc flash events will no longer self-extinguish.[5]

Because FMP has the unique capability of providing industrial power capabilities at safety levels comparable to low voltage (<50V) circuits, it has the potential to converge the separate worlds of electric power distribution and information technology. For example, overhead busway, floor PDUs, circuit breakers, and conduit in the data hall are no longer required outside of the electrical room or "gray space." During construction, server power and communications are both installed in data tray using limited-energy technicians[6] — further reducing labor costs and project delays. In other words, FMP could "digitize" the electrician skill set, replacing conduit bending with a mobile phone app interfaced to a converged energy/data network. This could bring those young people, who grew up with mobile phones, back to the trades.

One might jump to the conclusion that the disruptive nature of FMP technology would make electrical trade groups nervous, but today's electrical workforce is highly sophisticated, forward-looking, and seeking out new technologies that will pave the way into the next century. After all, many electricians are also business owners, seeking a competitive edge. According to Jeff Beavers, Executive Director of Network Integration and Services at the National Electrical Contractors Association representing 650,000 electrical workers, "NECA sees FMP as a revolutionary new tool for the electrical trades to help us keep up with the unprecedented workforce demand due to electrification, EV charging, 5G communications and the AI data centers. We are moving quickly to create a training program that will provide business tools to help our members take advantage of this important new technology."

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5 "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

6 https://nietc.org/applicants/apprenticeship-programs/limited-energy-a-technician/

COMPARATIVE ANALYSIS OF AC AND FMP ARCHITECTURES

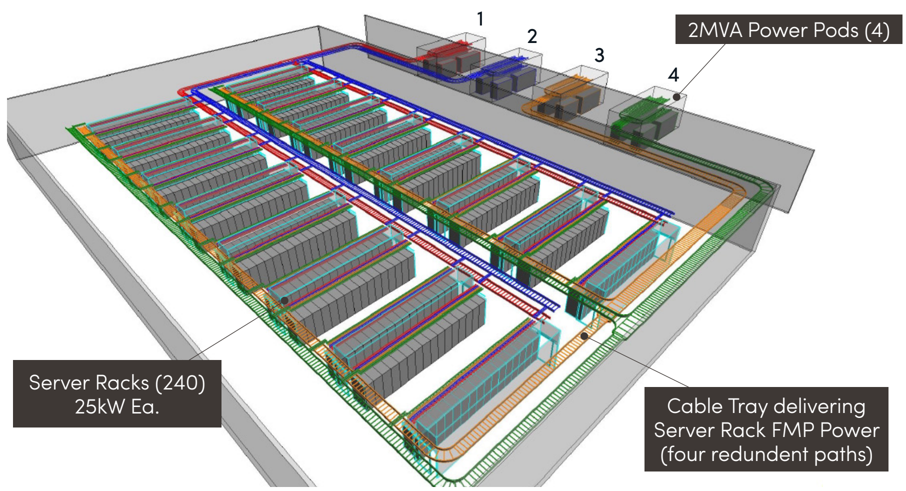

Fig. 2: *Data Center and Power Pods*

A dedicated section for Fault Managed Power in the National Electric Code was adopted in 2023 and installations have reached over 1,000 buildings globally. FMP has also 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, FMP's viability in data centers hasn't been analyzed by a firm experienced with data center design until now. Southland Industries is dedicated to exploring new technologies that could benefit our customers, and conducted the below analysis that compares FMP technology to AC distribution for a model data center. Established in 1949, Southland Industries is a leading mechanical, electrical, plumbing, and fire protection (MEPFP) design-build firm that has been the design and construction authority for over 20 years on hundreds of data centers ranging from 10MW–180MW critical load each.

The FMP design model incorporates four external "power pods" rated at 2MW critical load each, see *Fig. 2*. The pods operate in an N+1 configuration, so 8MW is installed to deliver 6MW to the data hall.

In both cases the analysis starts with the three-phase supply to the UPS cabinets. In the AC case, the UPS is followed by a series of distribution equipment that include an output switchboard, conduit, distribution panels, floor PDUs, and overhead busway as is depicted below in *Fig. 3*:

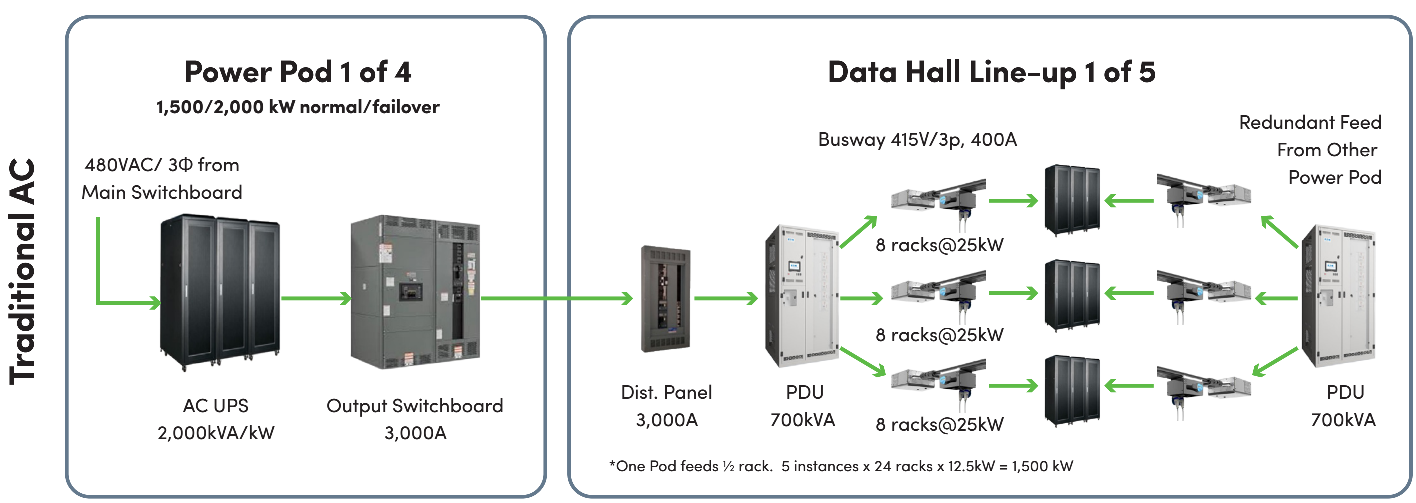

Fig. 3: *AC Distribution Line-up Diagram*

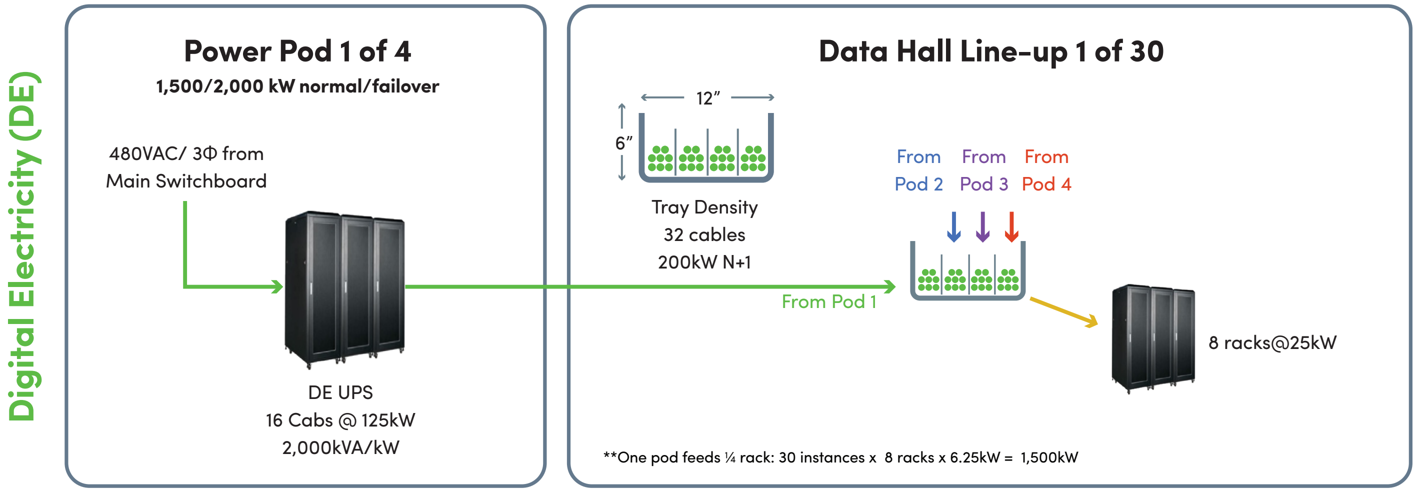

Fig. 4: *FMP Distribution Line-up Diagram*

As described earlier, the power pods are configured in an N+1 configuration in both the AC and FMP cases. However, within the data hall, the distribution becomes 2N for the AC case, where two separate power pods feed a server cabinet row on separate distribution pathways.

In *Fig. 4*, the FMP line-up is depicted. What is immediately apparent is the simplification of the distribution downstream of the UPS. In the case of FMP, the UPS and FMP transmitter functions are part of the same cabinet assembly. All intermediate distribution devices are eliminated, and the power is distributed on structured cabling, in cable tray, using IT-like, limited energy installation practices.

It is important to note in *Fig. 4* that in the FMP case, each server cabinet in the data hall is fed by an individual cable from each of the four power pods. The loss of a power pod or cable takes out only one of the four possible sources of power. The entire server rack is capable of operating on three power pods, allowing one pod failure for N+1 redundancy.

Each FMP UPS cabinet has approximately 125kW of power capacity and sixteen (16) 19" rack cabinets are needed per power pod for 2000kW capacity. If all of the pods are operational, the FMP UPS cabinets run at approximately 93.75kW per cabinet the power demand only rises to 125kW for the FMP UPS cabinet if one of the four power pod fails (failover condition).

The comparative AC equipment in the power pod comprise the 2,000kVA/kW UPS and 3,000 Amp output switchboard. These two components populate the equivalent of approximately twenty-three (23) 19" rack cabinets.

To provide some perspective on power density, the cables from all four pods are shown to be in the same tray in *Fig. 4*. *Fig. 5* depicts the cable design used for the study where 200kW is placed in a 6" x 12" data tray. However, the model analysis was performed as depicted in *Fig. 1* where the different Pod cables are placed in physically separated trays and approach the server cabinets from diverse directions to avoid the possibility that physical damage to a tray could interrupt server operation.

In the data hall, the model is based on 25kW server racks with redundant power feeds. In other words. 25kW is to be delivered to the servers even with a single point failure somewhere in the distribution system. Internal to the

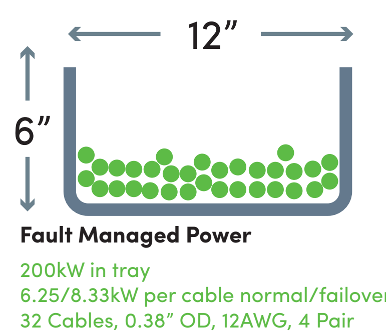

Fig. 5: *FMP in the Data Tray (200kW)*

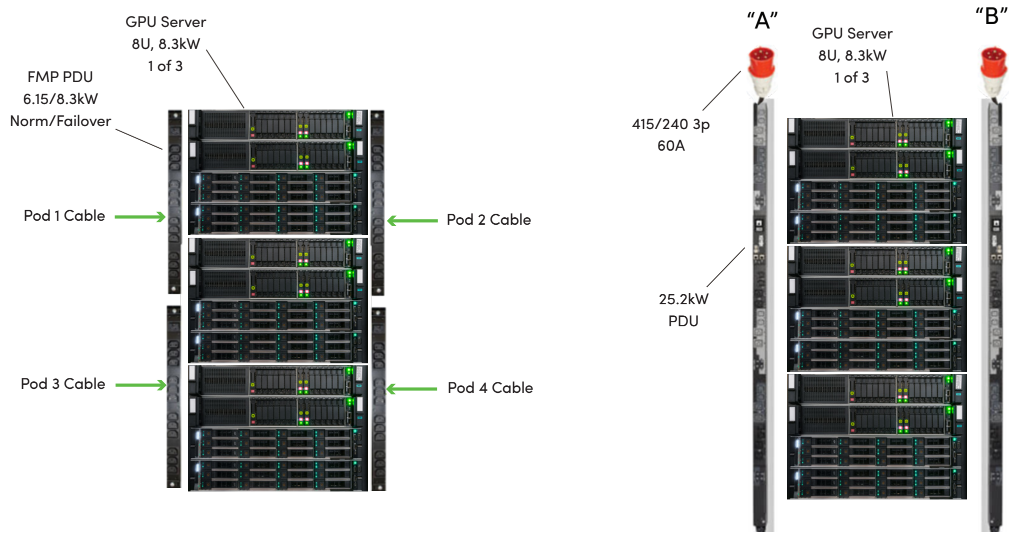

Fig. 6: *25kW Server Rack PDU Configuration: FMP (Left) AC (Right)*

server racks, distribution is accomplished with an N+1 design using FMP. Four PDUs containing embedded FMP receiver modules are utilized, but only three are necessary to supply 25kW to the servers. In the AC case, the architecture is 2N and each of the two rack PDUs can support 25kW, see *Fig. 6*. The two rack PDUs are always fed by different pods. The distribution is done in round-robin fashion to even the load on the pods across the rack population.

The reason why the FMP distribution can be accomplished in an N+1 configuration versus 2N is because the architecture is point to point. A cut or short circuit on an FMP cable affects only that cable and is completely isolated, as opposed to AC systems that are "multi-drop" where a short circuit or arc-over on an overhead busway can cause an outage for an entire row bus.

COMPARATIVE COST ANALYSIS OF AC AND FMP

Our analysis was performed based on vendor-quoted price data, shipping, G&A, taxes, and a contractor mark-up of 20%. A mixture of electrician, technician, and mechanical installation trades resulted in an average labor rate of $75/hour for both the AC and FMP cases. The result of the cost analysis is shown in *Table 1*. Based on the available data, an approximate 33% decrease in overall cost could be realized using FMP.

Table 1: *Installed Cost Comparison*

Item	DE Labor Hrs	DE Labor	DE Material	AC Labor Hrs	AC Labor	AC Material
UPS	384	$28,800	$7,059,072	1,200	$90,000	$4,744,893
Cable/Busway/Tray	20,215	$1,516,144	$2,886,011	29,198	$2,189,832	$5,698,181
Panels and Breakers	256	$19,200	$193,897	1,755	$131,639	$2,566,556
Floor PDUs	0	0	0	2,010	$150,743	$2,902,632
Rack PDUs	480	$36,000	$1,562,160	1,440	$108,000	$596,872
Power/Battery Monitoring	0	0	$100,000	0	$0	$800,000
Total	21,335	$1,600,144	$11,801,140	35,603	$2,670,214	$17,309,135
Total Labor+Material			$13,401,283			$19,979,349

Notes: Material costs include shipping, G&A, equip rental, tax, 20% markup

The FMP UPS and rack PDUs are the most technologically advanced components in the system and therefore carry the majority of the cost. However, in comparison to the AC solution, the higher cost of the FMP UPS and rack PDUs are more than compensated for by the labor cost reduction and the elimination of a host of traditional AC distribution equipment — switch-boards, floor PDUs, overhead busway, and large-gauge AC wire and conduit. The 14k+ fewer labor hours not only save initial project cost, but also yields a faster speed of data hall deployment. Couple that with 30–40% time savings in lead time of traditional AC equipment, and data hall deployments can occur months sooner than AC critical load topologies.

Another evident difference is a reduction in monitoring equipment costs. The packet energy transfer protocol at the heart of the Digital Electricity also includes inherent data capabilities. The FMP UPS and FMP rack PDUs are in constant communication to monitor and meter electrical energy and to check for faulty wiring or configuration. Batteries are integrated with the FMP transmitter units and monitored for status and performance. In other words, complete monitoring of the power distribution system within and downstream of the FMP UPS is achieved with the inherent data capabilities of Digital Electricity. At the March 2024 Data Center Dynamics conference in New York City, VoltServer, in cooperation with Planet Associates, a leading data center infrastructure monitoring (DCIM) company, demonstrated how the line-up can be monitored automatically for energy use and status and how disconnected, faulted, or even misconfigured wire pairs are automatically registered in DCIM and result in notification and automatic recalculation of line-up availability. This is demonstrated in *Fig. 7*, below:

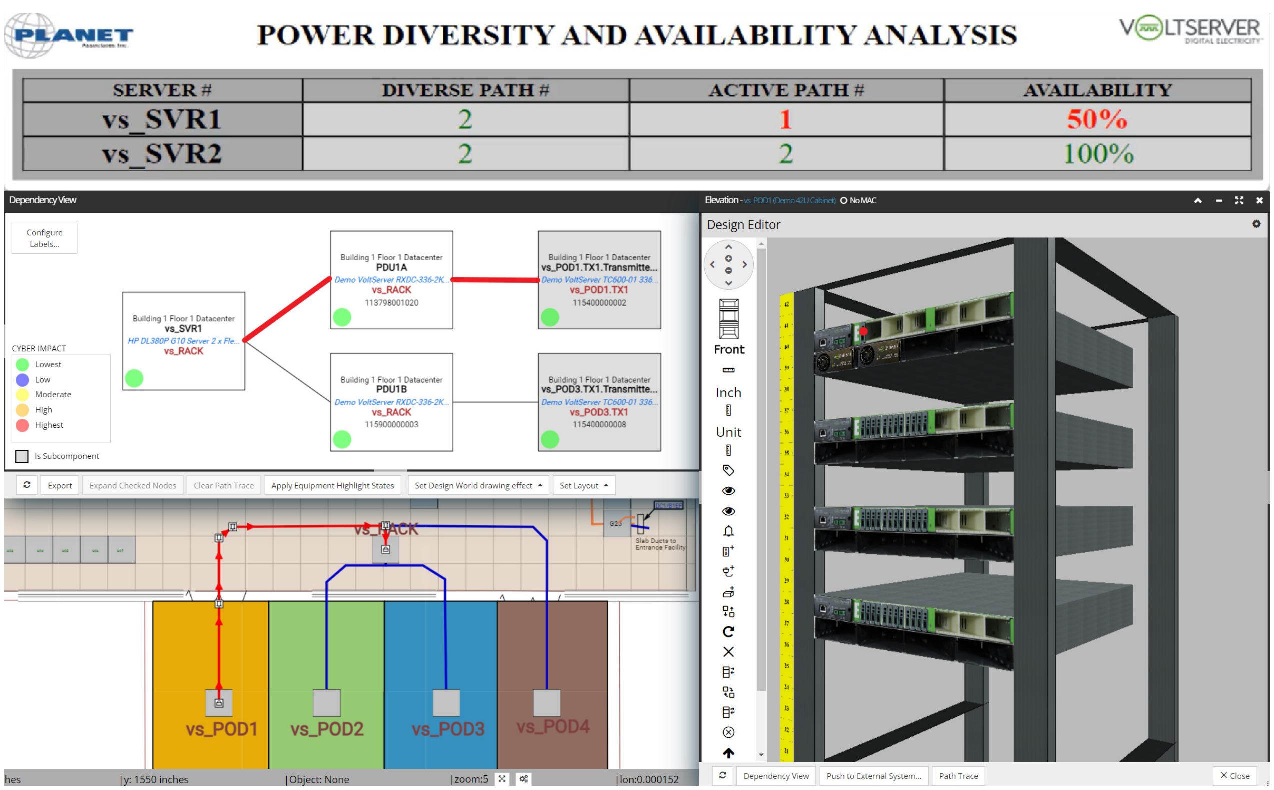

Fig. 7: *DCIM Status with loss of a power cable from one of four power pods (Planet Associates Inc.)*

Although the study focuses on initial cost, there will be long term maintenance benefits to the FMP topology. The first point to be made would be the great reduction in points of failure. One continuous FMP 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 of those

AC connections and equipment require continuous maintenance via monitoring, infrared imaging, and data logging. All of that laborious maintenance is replaced by the advanced digital system monitoring already built in the system. The inherent advanced monitoring of the FMP 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 will yield thousands of maintenance labor hours saved over the life of the system compared to the AC topology.

CONCLUSION

FMP is becoming mainstream and installed in over 1,000 facilities. FMP's minimum guidelines and installation practices are now specifically recognized and prescribed in the 2023 National Electric Code.

FMP's advancing technology and inherent characteristics are becoming a perfect match for data center owners' needs in a competitive market. This analysis studied the application of FMP technology in the large-scale data center market and illustrates the enormous potential of this disruptive technology to achieve:

- Electrically safe operation of a data hall.
- Potential initial cost savings of 33%.
- Faster speed to deployment.
- Space savings due to decreased equipment.
- Built-in electrical power monitoring system.
- Decreased points and failure.
- Reduced maintenance cost.

We see great potential in the advancement of FMP in the large data center market and look forward to this application evolution.

33%
potential cost savings

About the Authors

Michael Starego, PE, LEED AP, Southland Industries

As Principal Electrical Engineer, Michael is responsible for providing oversight on electrical design and analysis projects, developing department standards, maintaining quality control of electrical engineering projects, and managing electrical engineering personnel. With over 25 years of experience, Michael has been the Engineer of Record for many complex sites and building projects in the mission critical, industrial, education, healthcare, commercial, and government markets.

He also performs many building power system analyses including power quality studies, harmonic analyses, lifecycle analyses, and short circuit, coordination, and arc flash studies. Michael leverages his extensive design-build and integrated project delivery (IPD) project experience to enhance designs in constructability, cost and schedule practicality, and maintainability. He has a passion for working directly with owners and builders to develop unique and cutting-edge solutions for implementation into new electrical projects.

Michael has a Bachelor of Architectural Engineering from The Pennsylvania State University. He holds a PE license in over 15 states and is a member of the Institute of Electrical & Electronic Engineering, the Illuminating Engineering Society of North America, and the National Fire Protection Association.

Stephen S. Eaves, CEO, VoltServer, Co-Author

Stephen Eaves is the founder and CEO of VoltServer, and is the inventor of Digital Electricity, a new electricity format generically known as Fault Managed Power (FMP). FMP was adopted into the U.S. National Electric Code in 2023, and has deployed the technology in over 1,000 large venues worldwide.
With more than 30 years of experience innovating around electrical energy storage, distribution, and management, Stephen has authored and co-authored numerous industry and peer reviewed papers related to the energy industry. Additionally, he is an inventor on 35 patents.

About Southland

As an MEP building systems expert, Southland Industries provides integrated, full lifecycle solutions that optimize the design, construction, operation, and efficiency of buildings. Through collaborative partnerships with our clients and the collective expertise of our people, we create premier built environments and future-ready spaces where communities and businesses can thrive.

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