Powering the AI Revolution: New Cost Effective and Efficient AI Data Center Power Architecture

Multi-Port Solid-State Transformer-Enabled Solutions by DG Matrix

Executive Summary

The rapid adoption of artificial intelligence (AI) and machine learning (ML) technologies requires equally rapid improvements in data center power infrastructure. Existing power conversion, distribution, UPS and AI dynamic power infrastructure is experiencing critical challenges for functionality and total cost of ownership. This paper introduces a new transformative data center power architecture with industry leading efficiency, power density, integrated energy storage, reliability, simplicity, future readiness, and cost savings potential for all AI data centers, which is aligned with key industry guidelines including for NVIDIA 800 VDC power architecture and Open Compute Project's Mount Diablo.

Figure 1: AI Factory

AI Data Center Power Challenges

The growth in AI-driven workloads fundamentally alters data center power consumption and presents unique and critical challenges:

1. **Ultra-high-power density:** AI intensive workloads combined with stringent proximity requirements drive rack-level power densities that exceed 100 kW per rack with roadmap power density requirements of 1.2+ MW per rack or greater starting as soon as in 2027.

2. **Response to unpredictable dynamic power demand:** Rapid and frequent load power transient peaks of 50-80% above baseline can occur in milliseconds and multiple times per second. This stresses data center power sources, power quality requirements, and infrastructure.

3. **Power reliability and uptime:** AI data centers demand near-perfect power quality and availability that limits outages to seconds per year. Traditional mechanically reliant power systems respond in milliseconds when microsecond reaction times are required.

4. **Need for efficiency:** Integration of multiple power sources like utility connections, batteries, fuel cells, solar cells, and generators necessitate numerous power conversions that can lower data center power efficiency to an unacceptable 92-95% level and increase the need for cooling.

5. **Need for scalability and flexibility:** Scaling of Legacy power architectures can require significant infrastructure redesign costs and prolonged downtime. Such systems struggle to adapt to evolving power requirements and create operational inefficiencies.

6. **Need for safety and low costs:** The need for rapid dynamic power response times and low cost of ownership require key power infrastructure, including batteries, to be located next to expensive AI loads. This requires safe power infrastructure with zero risk of damaging the AI loads.

DG Matrix: Solution Overview

DG Matrix
Power Router (LV SST)

- Integrated multi-port power conversion and controls
- Delivers up to 1.2 MW UPS power
- Handles AC (400-480 V) and DC (300-1,500 V) voltage ranges in single device
- Gray space or outdoor deployment
- Commercially deployed

DG Matrix
Power SideCar (LV SST)

- Integrated multi-port power conversion and controls (incl. dynamic power response)
- Delivers up to 1.6 MW UPS power with up to 2x surge
- Handles AC (400-480 V) and DC (300-1,500 V) voltage ranges in single device
- White space deployment

DG Matrix
Power Bridge (MV SST)

- Integrated multi-port power conversion and controls (incl. dynamic power response)
- Delivers up to 15 MW UPS power with up to 2x surge
- Handles MV AC (up to 34.5 kV) and DC (300-1,500 V) voltage ranges in single device
- Gray space or outdoor deployment

Figure 2: Key Specifications of DG Matrix Solution

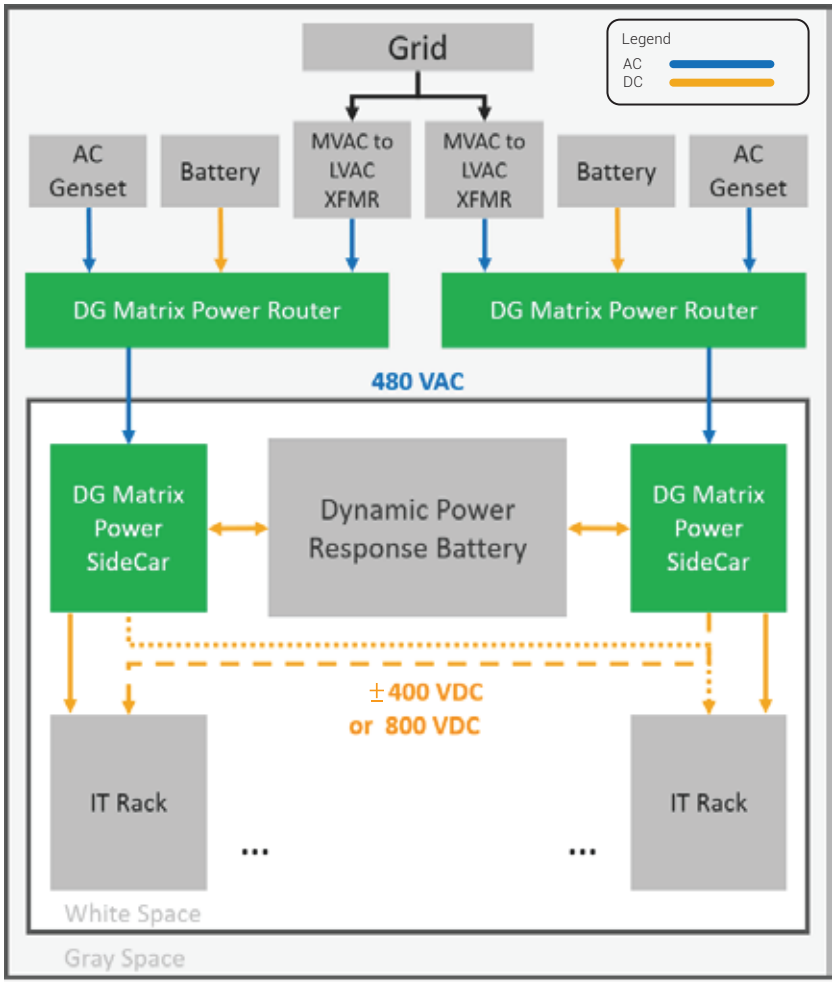

Figure 3: Box Diagram of DG Matrix Solution (Power Router + Power Sidecar)

The DG Matrix solution (see Figures 2 and 3) proves how DG Matrix Power Routers flexibly use multiple power sources to supply any combination of AC or DC power to IT racks. Power source selection is both flexible and dynamic based upon AC data center demand and power source availability. One special power source is the technology-agnostic adjacent battery rack which supplies backup UPS and dynamic power on demand.

Below details (summarized in Table 1) describe how the DG Matrix solution addresses the demands of existing and future AI data centers:

1. **Power density and load proximity enabling dynamic power demand:** At the core of the solution are a scalable power dense, and universally applicable multi-port solid-state transformer designed for outdoor operation called the “Power Router” and an ultra-dense solution designed to be located indoors next to the IT load called the “Power SideCar”.

The Power Router enables aggregation of all data center AC and DC energy solutions into a simplified solution with complete microgrid control of all energy sources outside the data center. An infinitely scalable, power dense, and universally applicable multi-port solid-state transformer (SST) called the DG Matrix "Power Router" with adjacent UPS and dynamic power batteries located next to IT loads. This addresses the need for a fast acting, safe, and low overall infrastructure cost AI data center solution.

2. **Managing unpredictable transient power demands:** DG Matrix's multi-port solution provides galvanic isolation at each port, ensuring transients can be selectively routed and managed. DG Matrix's Power SideCar solution seamlessly integrates with technology-agnostic infinitely scalable dual mode UPS and/or dynamic power mitigation batteries, providing instantaneous absorption of transient power peaks.

3. **Ensuring ultra-high reliability and continuous uptime:** DG Matrix's solution performs the same function as traditional UPS systems, enabling source switchover in a fast and reliable function. Leveraging an integrated UPS architecture with our partners' safe and power dense batteries, the DG Matrix solution achieves exceptional reliability significantly surpassing modern UPS inverters. The system's redundancy-compliant, IT-floor-safe, and hot-swappable maintenance design ensures continuous operation, achieving industry-leading availability (>99.999% uptime) necessary for sensitive AI workloads.

4. **Simplifying and enhancing power delivery system efficiency:** The DG Matrix solution combines multiple power electronics functions into one streamlined, multi-port system featuring robust voltage compatibility across AC and DC systems. With industry-leading DG Matrix conversion efficiency (up to 98.5%), the solution dramatically surpasses legacy systems (85-95% efficiency), significantly reducing heat generation and cooling infrastructure requirements.

5. **Providing unmatched scalability and flexibility:** The DG Matrix solution employs a modular and scalable infrastructure, allowing data centers to dynamically expand or reconfigure without costly redesigns or downtime. For example, DG Matrix offers programmable ports that enable data centers to initially operate at ±400 VDC and reprogram the ports up to 1,500 VDC, in the future, supporting the NVIDIA 800 VDC power architecture and Open Compute Project's Mount Diablo guidelines. This plug-and-play scalability dramatically reduces inefficiencies and retrofitting costs, ensuring data center infrastructure remains agile and future-proof as power requirements evolve.

6. **Unlocking new revenue through grid services:** The DG Matrix solution enables the participation in grid services such as frequency regulation, demand response, and peak shaving. With bi-directional, fast-response power conversion batteries, data centers can earn additional revenue or offset costs without compromising uptime. Millisecond-scale switching

allows seamless mode transitions, making the infrastructure a flexible, dispatchable grid asset. The Power Router also enables data center's greater control to unlock savings by utilizing the least-cost energy option.

AI Data Center Challenge	DG Matrix Solution	Data Center Benefits
Power Density	High-density power conversion	More power delivery, lower infrastructure costs, more room for expansion and upgrades
Dynamic Power Response	Microseconds for power conversion and single milliseconds for batteries	Eliminate AI load dynamic power challenges close to the source
Reliability and Uptime	Power conversion in partnership with technology-agnostic battery vendors	Long solution application life, modularity for easy maintenance and redundancy deployment
Efficiency	Up to 98.5% power conversion efficiency	High solution efficiency reduces energy consumption without compromising effectiveness
Scalability and Flexibility	Complete modularity for 200 kW to GW AI data center solutions	Grow in line with latest AI data center power demands for new-builds and retrofits
Safety	Reduced arc flash risk enabled by solid-state transformers	Ensure safety of data center technicians
Total Cost of Ownership (TCO)	Lower capex due to fewer components and reduced EPC work required; grid service revenues	Maximize capital available for AI compute equipment; boost data center profitability by offering grid services

Table 1: Benefits for Data Centers Using DG Matrix Solution

DG Matrix Energy Storage Partnerships for GPU Pulse Load Mitigation, UPS, and Long-Duration Energy Storage

DG Matrix is a technology-agnostic platform purpose-built to integrate seamlessly with a wide range of energy storage technologies — from ultra-fast, high-power batteries designed for GPU pulse load mitigation to multi-hour and even multi-day storage systems for UPS, resilience, and grid interaction. This flexibility allows DG Matrix to optimize data center power infrastructure across time scales, ensuring instantaneous power quality, continuous uptime, and long-duration sustainability.

Our open integration model enables compatibility with diverse energy storage chemistries and architectures, encompassing supercapacitors, advanced lithium-ion systems, nickel-zinc, zinc-air, and emerging long-duration chemical and thermal storage solutions. Through these partnerships, DG Matrix extends its SST-based ecosystem to deliver superior performance across the full spectrum of energy storage needs as outlined in Table 2.

	DG Matrix Energy Storage Partner	Technology Overview
Short-duration	MUSASHI	Musashi's Hybrid SuperCapacitor (HSC) technology excels in high-power and high-cycle applications. Delivering sub millisecond response, billions of cycles, and 360A continuous charge/discharge HSCs are perfectly suited for Gen AI load profiles
	nyobolt	Nyobolt's ultra fast batteries deliver exceptional power density and low internal resistance, providing superior transient suppression for GPU pulse load balancing while offering significantly greater energy capacity and extended hold-up times compared to supercapacitors.
	ZincFive	ZincFive's nickel-zinc battery systems offer safety in operation (no thermal runaway), long life, compact footprint, and industry leading power density, making them perfect for mission-critical UPS and AI applications requiring short duration battery back-up and rapid charge/discharge cycles.

	DG Matrix Energy Storage Partner	Technology Overview
Medium-duration	Ampace	Ampace's advanced high-energy lithium-ion battery packs are optimized for UPS and short-to-medium duration backup, offering strong energy density and cost efficiency.
	eos	Eos Energy's zinc hybrid cathode battery systems offer safe, 3–12 hour long-duration storage with low degradation and wide operating temperature range.
	Gotion	Gotion Inc is a tier 1 supplier for LFP based energy storage. With global supply chain and diverse manufacturing plants across the globe, Gotion Inc brings safe cost effective energy storage solutions to the global community.
Long-duration	EXOWATT	Exowatt's innovative thermal energy generation and storage systems convert and store excess renewable or off-peak energy as heat, enabling grid-interactive, dispatchable capacity for sustainable data centers.
	noon ENERGY	Noon Energy's next-generation reversible electrofuels battery technology deliver reliable power through intermittent renewable generation, extreme weather events, and seasonal fluctuations.

Table 2: DG Matrix Energy Storage Partners (Short-Duration to Long-Duration)

DG Matrix continues to actively expand its ecosystem of energy storage partnerships to deliver a unified, future-proof power platform. By maintaining technology neutrality and an open architecture, DG Matrix ensures that each deployment can integrate the best-fit energy storage technologies — whether for microsecond-scale AI power transients, mission-critical UPS, or multi-day energy resilience. We're excited to collaborate with additional innovative partners to further enhance grid-interactive data center architectures, drive sustainability, and unlock new operational and economic efficiencies across the global AI infrastructure landscape.

Strategic Value of DG Matrix Solution for Data Centers (Case Study: 60-MW AI Data Center Implementation)

The DG Matrix solution provides outsized strategic value compared to conventional solutions. For a typical 60-MW AI data center building block, our solution offers significant advantages for all key metrics as illustrated in Table 1:

- ½ to ⅔ of the cost
- ⅔ of the power losses
- ½ of the footprint compared to legacy systems for enabling highest GPU density

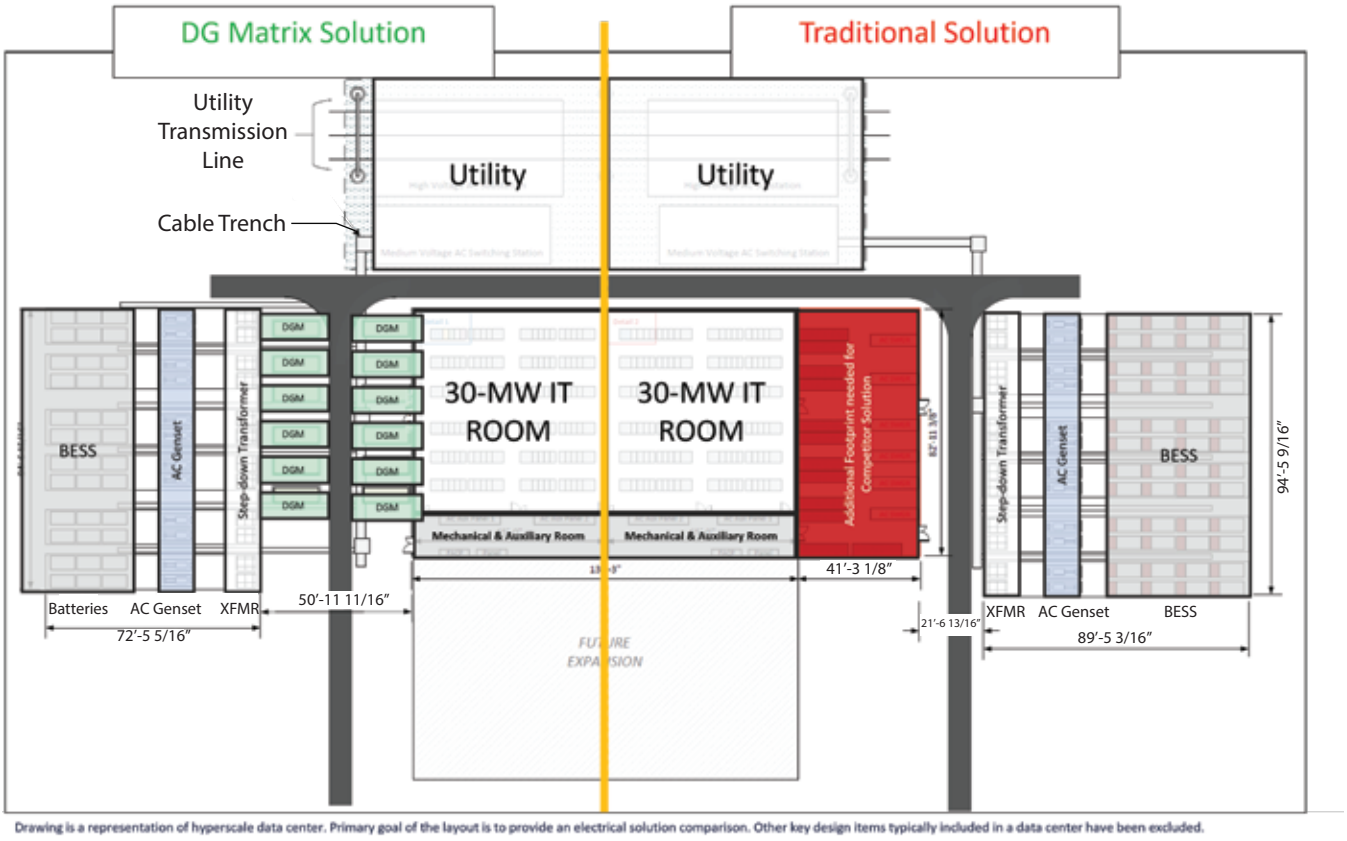

Figure 4: Concept of 60-MW Module Deployment of DG Matrix Solution

Conclusion

The DG Matrix solution represents a significant technological advancement, providing critical advantages in power density, pulse load mitigation capabilities, reliability, simplicity, future readiness, and substantial cost savings for large-scale cloud service provider ("hyperscalers", "neoclouds"), colocation, and enterprise data centers. This solution strategically positions data center companies for sustained growth and competitive advantage.

To learn more about the DG Matrix solution, please reach out to sales@dgmatrix.com. For energy generation, energy storage, and other partnership enquiries, please reach out to partnerships@dgmatrix.com.