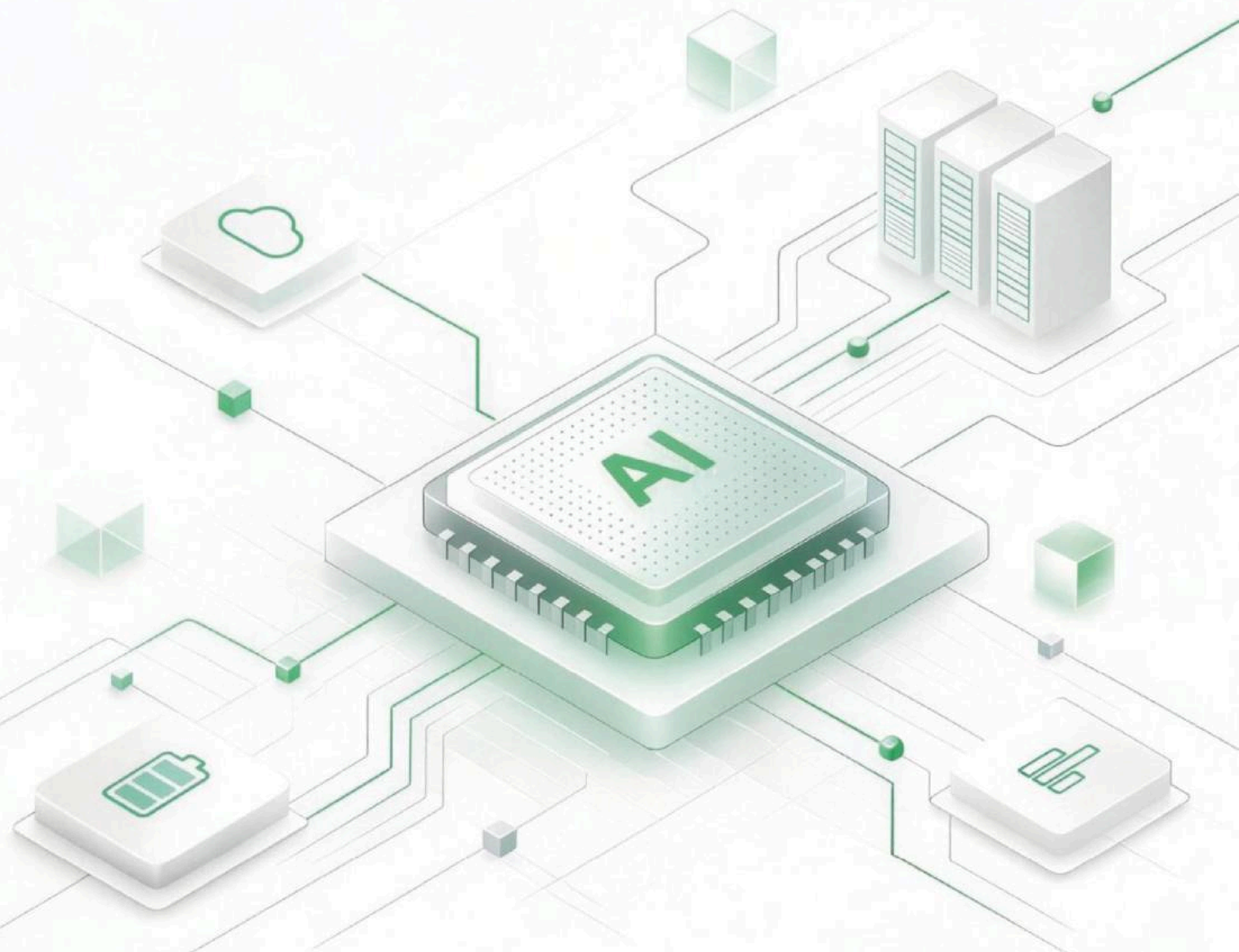
Ampace

AIDC Battery Solutions

White Paper



POWER YOUR LIFE

Executive Summary

I. The Era of Compute: How AIDC Is Reshaping the Data Center Landscape

The explosive growth of artificial intelligence is fundamentally restructuring the global data center industry. As demand for large model training and inference rises exponentially, AIDC (Artificial Intelligence Data Center) has emerged as the defining form of next-generation digital infrastructure. Compared with conventional data centers, AIDC exhibits distinctly different load characteristics: single-rack power density has surged to 100 kW and is expected to exceed 1,000 kW in the future. Cluster scale has grown from tens of megawatts (MW) in traditional facilities to several gigawatts (GW). GPU clusters generate severe instantaneous power fluctuations, shifting load profiles from "steady and continuous" to "high-frequency pulsed."

This transformation poses unprecedented challenges for data center power supply and distribution systems. Electricity has become the primary bottleneck constraining compute expansion—not only in terms of grid connection capacity, but at every stage of the power supply chain: from utility feed, transformation and distribution, to uninterruptible power supplies (UPS) and backup battery systems. In an era where AI training tasks routinely last weeks and a single interruption can cost millions, the reliability, response speed, and lifecycle performance of the power supply system directly determine an AIDC's commercial viability.

II. AIDC Multi-Tier Power Evolution: From UPS-Paired Energy Storage to BESS + Rack-Level Buffering

Surging demand for AI compute is driving continuous increases in power density within AIDCs, and GPU clusters now experience significant, frequent load swings. These fluctuations impose significant stress on power supply and distribution infrastructure, including UPS systems, diesel generators, and transformers—and have become an urgent challenge in large-scale AIDCs.

Given the constraints of rapid AIDC construction timelines and extremely high power supply reliability requirements, high-rate, high-safety, long-life lithium-ion batteries paired with UPS remain the most mature and reliable backup power solution available today. Traditional lead-acid batteries, with their shortcomings in energy density, cycle life, footprint, and maintenance costs, can no longer meet the demands of high-power-density AIDC applications. With a smaller footprint, longer lifespan, higher discharge rates, and superior total cost of ownership (TCO), high-performance lithium-ion batteries are rapidly displacing lead-acid batteries as the mainstream choice for AIDC backup power. Meanwhile, absorbing AI load fluctuations has become the primary challenge for AI data centers. Overall, for battery manufacturers, the three core capabilities of "high rate, high safety, and long life" have become table stakes for entering the AIDC market. Manufacturers able to deliver batteries with these capabilities are becoming the preferred partners of facility owners, CSPs, colo providers, and integrators.

Driven by NVIDIA's roadmap for future 800 V architectures, a hybrid architecture integrating Battery Energy Storage Systems (BESS) with rack-level energy storage is poised to define the way forward. Over the medium to long term, data center power supply systems will evolve from "passive backup" to "active energy management." BESS can assume multiple functions including peak shaving and load shifting, demand response, renewable energy absorption, and emergency backup, transforming power supply assets from "cost centers" into "revenue centers." Rack-level energy storage aligns with the trend toward modular compute, utilizing a distributed deployment model closer to the load, enabling on-site response to high-power fluctuations and more refined power delivery. Ampace believes that a multi-tiered power supply architecture—"From Battery-Backed UPS to BESS"—will define the evolution of AIDC energy infrastructure.

III. Ampace: Empowering the Computing Era with Green Energy Solutions

Ampace combines world-class technological capabilities with deep industrial resources. By directly addressing the real challenges of AIDC applications, Ampace is committed to defining the next generation of high-performance battery standards:

High Rate: High-rate discharge and millisecond-scale dynamic response meet the high-power-density and pulsed-load requirements of AIDC, enabling greater backup capacity in a constrained footprint.

High Safety: Building an intrinsically safe foundation with semi-solid-state lithium iron phosphate (LFP) cells, implementing end-to-end safety design from material systems and cell structures to system-level protection, complemented by intelligent BMS for millisecond-scale monitoring and early warning—embedding safety redundancy into the product's DNA.

Long Life: Designed for the high-frequency dynamic cycling and instantaneous high-power throughput demands of AI loads, with ultra-long cycle life and low degradation, enabling the battery to withstand the cumulative stress of continuous dynamic operation, significantly reducing replacement frequency and maintenance costs over the full lifecycle—so that battery service life matches the data center's operational lifespan.

From today's large-scale delivery of UPS backup batteries to the forward-looking deployment of BESS and rack-level storage, Ampace will leverage its full-stack battery technology capabilities to support the global AIDC industry through the transition from "backup power" to "intelligent power," providing dependable energy security for the computing backbone of the AI era.

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Chapter 1 Industry Insights: Analysis of Energy Challenges in the AIDC Era

Generative AI is reshaping the fundamentals of data centers: computing density is making order-of-magnitude leaps every year, with per-rack power consumption jumping from a few kilowatts in conventional data centers to the megawatt level; at the same time, training and inference workloads are exhibiting unprecedented instantaneous volatility, placing "zero-tolerance" demands on the response speed and reliability of power supply systems. Against this backdrop, the energy and industrial policies of major global economies are also undergoing rapid adjustment. Issues such as grid approval, power supply, supply chain security, and manufacturing localization are intertwined, and together they form the core challenges that energy infrastructure must confront head-on in the AIDC era.

1.1 AIDC Development Timeline: The Accelerating Evolution of the Computing Arms Race

Over the past three years, the refresh pace of global compute infrastructure has fundamentally changed. GPU manufacturers led by NVIDIA have compressed the product generation cycle from the traditional 3–5 years to roughly one update per year; meanwhile, cloud providers such as Google, AWS, Meta, and Microsoft are accelerating their in-house chip development, forming a "dual-track landscape" in which NVIDIA general-purpose GPUs and cloud providers' custom ASICs evolve in parallel. The Figure 1-1 below follows NVIDIA's technology roadmap to outline key milestones from major vendors between 2022 and 2027.

AI COMPUTING EVOLUTION: NVIDIA GPUs + CLOUD ASICs (2022–2027)

	2022	2023	2024	2025	2026	2027
NVIDIA General-purpose GPUs	H100 Hopper 80 GB HBM3 1,000-card clusters	H200 Hopper upgrade 141 GB HBM3e 4.8TB / s (Nov)	GB200 NVL72 Blackwell NVL72 rack ~132 kW / rack	B300 Blackwell Ultra 288GB HBM3e NVLink 5 (H2)	Vera Rubin Rubin FP4 inference: 50 PFLOPS NVL72: 190 – 230kW Mass production	Rubin Ultra NVL576 · Kyber ~600 kW / rack FP4 ~14× GB300 (H2)
Google TPU	TPU v4 Scaled deployment	v5e / v5p Aug: inference Dec: training	v6 Trillium Scaled deployment	v7 Ironwood 192GB HBM3e 4,614 TFLOPS	Next-gen TPU Training / inference split (roadmap)	Ongoing iteration —
AWS Trainium	Trainium1 / Inf2 Mass production / Inf2 release	Inferentia2 Scaled deployment	Trainium2 Rainier: 500,000 (Dec announcement)	Trainium3 3nm · 2.52 PF FP8 (Dec release)	Trainium4 Official preview 2026 rollout	Ongoing iteration —
Meta / Microsoft	In-house chips R&D stage	MTIA v1 · Maia 100 Sep: Meta Nov: Microsoft	MTIA v2 · Maia 100 Ramp-up / deployment	MTIA Scaled deployment	Next-gen chips Dual-vendor roadmap	Ongoing iteration —

Figure 1-1 Evolution of the "Dual-track Landscape" of AI Compute

Source: Compiled by Ampace from NVIDIA GTC and COMPUTEX keynotes, Google Cloud Next, AWS re: Invent, and disclosures from Meta and Microsoft, together with public industry research. 2027 values are industry estimates; specifications are subject to change.

1.2 Computing Density Challenge: Distribution and Instantaneous Power Supply Pressure from Kilowatts to Megawatts

The exponential increase in compute density is fundamentally changing how data center power supply and distribution systems are designed. Conventional data center single-rack power typically falls in the 5–10 kW range, while AI training and inference racks now demand ten to a hundred times more power (Table 1-1).

Year	Mainstream rack power	Corresponding cooling technology	Milestone
2024	~32 kW / rack	Air cooling dominant	Equivalent to the electricity load of about 4 households
2025	~100 kW / rack	Cold-plate liquid cooling becomes widespread	GB200 NVL72 measured peak reaches 132 kW
2026	200+ kW / rack	Immersion liquid cooling enters early stage of large-scale commercial deployment (high-density environments); cold-plate liquid cooling remains mainstream	Rubin VR200 NVL72 rack power of 190–230 kW; OCP 2025 showcases 1 MW rack designs
2028E	1+ MW / rack	Two-phase immersion liquid cooling matures	Single-rack load equivalent to about 150 households' electricity use

Table 1-1 Data Center Rack Power Evolution and Cooling Technology Roadmap

Source: Compiled by Ampace from OCP, NVIDIA, and major server OEM rack roadmaps and public industry research. Rack power and cooling data are indicative and subject to vendor release.

Dual pressure on rack cost and power supply / distribution architecture

At the power supply and distribution architecture level, traditional 48 V / 54 V DC solutions can no longer handle the current draw of megawatt-class racks. Take a 1 MW rack: if 54 V power distribution were retained, the copper cabling alone would weigh about 200 kg. If that design were extended to a 1 GW-class data center campus, total copper cabling would reach about 200 tons—unsustainable in both cost and weight. This contradiction is driving the 800 V high-voltage direct current (HVDC) architecture from pilot deployment toward large-scale application. Compared with traditional solutions, the 800 V architecture can cut copper cabling by more than 70% and centrally power hundreds of next-generation GPUs within a single rack, greatly improving space utilization. The technology is still in the early stages of adoption, with global penetration below 0.1%. Currently, the mainstream solution in China remains 240 V / 336 V HVDC, while overseas markets are advancing along two technical routes: ±400 V and 800 V.

Millisecond-scale load swings: an underestimated impact on the grid and equipment

A more severe challenge than steady-state power density is the extreme volatility of AI training loads. Large-model training synchronizes the workload of hundreds of thousands of GPUs, causing power draw to rise or fall within millisecond-scale windows. Some gigawatt-class data center campuses already consume as much power as a midsize city, and up to half of that load may switch states every few seconds. In extreme cases, AI loads can cause actual power draw to momentarily spike to 160% of design capacity. Fluctuations of this magnitude exceed the design parameters of most power equipment. The North American Electric Reliability Corporation (NERC) has repeatedly warned that data centers are among the largest risks to grid stability, noting that such loads may induce subsynchronous oscillations that can damage other equipment connected to the grid. Under the combined pressure of high-density deployment and millisecond-level load fluctuations, load variability may prevent data centers from maintaining the Tier 4 99.995% availability baseline, directly undermining the return on infrastructure investment.

1.3 Reliability and Continuity: "Zero Tolerance" Requirements for Power Interruptions

Unlike the relatively smooth load curves of conventional data centers, AIDCs face three compounding factors: high density, high volatility, and high value. A single large-model training run can carry a computational cost of tens or even hundreds of millions of dollars. Any millisecond-scale power interruption can erase training checkpoints and force jobs to restart, causing irreversible loss of time and investment. AIDC power continuity must therefore exceed existing IDC design standards, and it places far greater demands on the grid as well.

Taken together, the AIDC backup power application imposes four requirements on battery systems:

(1) Power rating: Backup systems have scaled from tens of kilowatts in traditional deployments to hundreds of kilowatts or even megawatts, with per-rack continuous output demand now reaching hundreds of kilowatts.

(2) Response speed: To address millisecond-scale load swings, batteries and power conversion systems require response speeds orders of magnitude faster than those in traditional backup power application.

(3) High-rate charge / discharge: Batteries must support instantaneous high-current charge and discharge at high C-rates to absorb the impact of synchronized GPU cluster power steps and compensate for ramp-up / ramp-down transients.

(4) Safety redundancy: Under sustained high-load, high-density deployment, battery thermal safety margins and cycle life requirements become more stringent.

Battery technology is also advancing rapidly. Owing to their superior thermal safety and longer cycle life, lithium iron phosphate (LFP) batteries are becoming the mainstream choice for AIDC applications.

1.4 Policy Environment: Multiple Dynamics in the Global Energy Governance Landscape

AIDC energy infrastructure build-out is increasingly shaped by policy variables, including grid approval efficiency, energy storage policy, supply chain security reviews, and manufacturing localization requirements. The U.S. market is a particularly instructive example.

1.4.1 Long Grid Approval Cycles Have Become a Practical Bottleneck for Compute Expansion

The United States currently has more than 4,000 data centers in operation, with about 3,000 more planned or under construction. Construction is clearly outpacing new power plant commissioning and grid interconnection approvals. Industry data from Sightline Climate shows that planned new U.S. data center capacity for 2026 totals about 16 GW, but constrained by shortages of key electrical components such as transformers, switchgear, and batteries, only about one-third of it actually enters construction. By project count, about half of the year's data center construction projects are delayed or canceled as a result. To alleviate this bottleneck, the U.S. Federal Energy Regulatory Commission (FERC) issued orders in June 2026 requiring the six FERC-jurisdictional regional grid operators (RTOs / ISOs) to submit resource adequacy assessment reports within 30 days and to demonstrate within 60 days that their existing interconnection and ratemaking rules are sufficient to support rapid connection of large loads, aiming to compress the large-load interconnection study process to 60–90 days. The orders also make clear that data centers must bear all upgrade costs associated with their grid interconnection.

1.4.2 Accelerating Requirements for Energy Storage Allocation and Ancillary Services, with the Role of Energy Storage Continuing to Strengthen

Facing grid stability pressures from load fluctuations, U.S. regulators are encouraging large-scale energy storage to participate deeply in ancillary services such as peak shaving and frequency regulation, with corresponding economic compensation. In regions with high wind and solar penetration such as Texas (ERCOT), installed energy storage capacity and project pipelines already rank among the largest in the United States, making these markets among the fastest to adopt the "direct green power supply + energy storage" model. This trend dovetails with data centers' own needs for backup power, peak shaving and load shifting, and renewable energy consumption, accelerating energy storage's evolution from a traditional "grid-side asset" into standard equipment for computing infrastructure.

1.4.3 Compliance Requirements for Specific Supply Chain Sources Continue to Tighten

The "One Big Beautiful Bill Act" (OBBBA), signed into law on July 4, 2025, significantly expanded the original "Foreign Entity of Concern" (FEOC) rules, extending their scope of application to the "Prohibited Foreign Entity" (PFE) framework, spanning key policy instruments such as the 45X Advanced Manufacturing Production Tax Credit, 45Y Clean Electricity Production Credit, and 48E Clean Electricity Investment Credit. The framework introduces multiple tests—equity and debt holding ratios, board appointment rights, actual control, and "material assistance." Any enterprise or related project identified as a PFE is ineligible for the above tax incentives. Because the global battery supply chain has long been dominated by Chinese companies, the energy storage industry is bearing the brunt of these rules. Starting in 2026, energy storage projects must meet the "Material Assistance Cost Ratio" requirement, and the compliance safe harbor ratio will tighten year by year—approximately 55% in 2026, rising to 75% by 2030—steadily narrowing the room for affected projects to rely on the Chinese supply chain.

1.4.4 Promoting Domestic Manufacturing, but Supply Chain Realities Constrain the Pace of Implementation

Alongside the FEOC restrictions, the United States employs the Section 45X Advanced Manufacturing Production Tax Credit as a key instrument for localizing the battery supply chain, requiring that covered products undergo "substantial transformation" within the United States to qualify for incentives. However, an underdeveloped domestic supply chain, lengthy construction timelines, and limited cost competitiveness have already led to delays or cancellations of multiple domestic battery capacity projects. The structural tension between policy incentives and supply chain realities will persist in the near term, creating a transitional market window for battery companies with a global manufacturing footprint and strong compliance capabilities.

1.4.5 Battery Passport: Full-Lifecycle Compliance Becomes a New Threshold for Overseas Expansion

Unlike the U.S. approach, which centers on tariffs and tax credits as instruments of industrial policy, the European Union is building a full-lifecycle compliance framework centered on data disclosure through the EU Batteries Regulation (EU 2023 / 1542). Under the regulation, as of February 18, 2027, industrial batteries and electric vehicle batteries with a capacity exceeding 2 kWh must carry a digital "Battery Passport" accessible via QR code. The passport records full-lifecycle data, including material composition, carbon footprint, supply chain due diligence, and recycling information, with all such data subject to third-party verification. Although the system applies directly only to the EU market, its disclosure framework and technical standards are becoming a global reference framework for battery sustainability compliance. For Chinese battery manufacturers seeking to expand their data center backup power and energy storage products into Europe and other global markets, building carbon footprint accounting, supply chain transparency, and digital traceability capabilities early has become a new prerequisite for competing in the global AIDC energy infrastructure market.

1.5 Regional Grid Differences: Market Access Conditions and Architecture Selection

Significant differences in grid systems and power supply architectures across major global markets directly determine the selection logic for AIDC power supply and backup solutions. North American grids are primarily 60 Hz with 480 V low-voltage distribution, with widespread medium-voltage access, fast diesel generator startup, and highly market-driven grid interconnection. Data centers generally adopt architectures with short-duration backup power and rapid diesel generator takeover. European grids have higher stability but high electricity prices, strict green power procurement (PPA) and carbon constraints, with power supply solutions placing greater emphasis on energy efficiency and green power coordination. Data centers in China generally adopt 10 kV medium-voltage access and 380 / 400 / 415 V low-voltage distribution, with ample grid capacity and relatively long diesel generator startup confirmation and synchronization times. Backup power design emphasizes long-duration fallback, with mature application of redundant architectures such as 2N and DR. Regional differences in grid frequency, voltage levels, approval processes, and reliability standards require battery and power supply system solutions to have flexible voltage platform adaptation and architecture compatibility capabilities.

1.6 Supply Chain Pressures: External Constraints on the Production Capacity of Key Components and Battery Cells

The rapid build-out of AIDC is putting pressure on the entire electrical equipment supply chain. Lead times for critical power equipment such as transformers and medium-voltage switchgear have stretched across the board, becoming a major bottleneck for data center grid connection and commissioning. The battery segment also faces structural shortages, as high-quality cell capacity is ramping more slowly than orders are growing. Leading manufacturers' production lines are running at high utilization for extended periods, and paying deposits to lock in capacity is becoming common practice among customers (see Section 5.1 "Delivery Assurance Management" for details). Meanwhile, U.S. FEOC / PFE restrictions and EU localization requirements are forcing battery companies to invest early in manufacturing footprint, raw material traceability, and compliance systems. Supply chain security has shifted from a cost issue to a delivery-certainty issue. Suppliers with vertical integration and a global manufacturing footprint will gain a significant edge.

1.7 Variations in Green Electricity Mix: The Impact of Clean Energy Proportions on Standby Power Strategies

Regional differences in green power penetration rates are reshaping the energy structure of data centers. In China, driven by the "dual carbon" goals and the build-out of large-scale renewable energy bases, green power direct connection and generation-grid-load-storage integration are being implemented at an accelerating pace. Inner

Mongolia, Gansu, Ningxia, and other regions rich in wind and solar resources generally impose green power usage requirements on new data centers, making large-capacity energy storage (utility-scale storage) a key enabling facility for smoothing wind and solar output and increasing green power consumption. In global markets, North America relies on green power purchase agreements (PPAs) and market-based renewable energy certificate (REC) systems to advance decarbonization, while Europe tightens full-lifecycle carbon constraints through the carbon market (EU ETS) and the Battery Passport. For battery companies, rising green power shares are blurring the boundary between backup batteries and energy storage systems: the same battery asset must provide emergency backup while also participating in green power consumption and grid interaction. This is precisely the industry foundation on which BESS moves from "cost center" to "revenue center."

In summary, AIDC-era energy infrastructure faces four simultaneous pressures: rapid technology refresh, an order-of-magnitude jump in power density, rising reliability requirements, and policy restructuring. The annual product cadence of NVIDIA and the cloud providers demands that power distribution systems be designed with far more forward-looking headroom than ever before. The shift in per-rack power density from kilowatts to megawatts, compounded by millisecond-scale load fluctuations, is forcing a fundamental redesign of power supply and distribution architectures. The high-value nature of training workloads has driven power supply reliability standards toward "zero tolerance," accelerating the evolution of battery technology toward higher safety, higher C-rates, and faster response. Meanwhile, U.S. grid approval efficiency, energy storage policy, supply chain restrictions on China, local manufacturing incentives, and international compliance regimes such as the EU Battery Passport are evolving together—collectively defining the regulatory boundaries within which global battery and energy storage companies must operate.

Chapter 2 AIDC Power Supply and Backup Architectures

Compared with conventional IDCs, AIDCs combine high power density with dramatic load fluctuations, placing far higher demands on the instantaneous response capability, operational stability, safety compliance, and low-carbon economics of power supply systems. Conventional lead-acid batteries and early lithium-ion battery products suffer from high O&M costs, poor power adaptability, and single-function designs that cover only basic outage backup, making them a poor fit for next-generation intelligent computing infrastructure. This chapter systematically reviews the technology paths from the conventional UPS baseline to newer power supply and backup architectures—Panama HVDC, medium-voltage UPS, and OCP Sidecar—and analyzes the distinct requirements each imposes on battery systems.

2.1 Characteristics of New AIDC AI Load Conditions and Core Requirements for Backup Power

As high-density computing workloads such as large model training, AI inference, and supercomputing clusters are deployed at scale, AIDC IT loads exhibit fundamentally different dynamics from those of conventional IDCs. Conventional steady-state backup power systems can no longer keep pace with AI compute operating patterns. Conventional data center loads are predominantly steady-state, with gentle power fluctuations and sustained load stability. Backup power systems only need to bridge short-term power after utility outages. In contrast, AIDC GPU computing loads exhibit typical dynamic characteristics of rapid ramp-up, high-frequency fluctuation, and instantaneous ramp-down, imposing entirely new, stringent requirements on power architectures, energy storage, and power smoothing.

From an operating-condition perspective, AI load dynamics fall into three core use cases—which are also the three hardest problems for current backup power solutions:

(1) Rapid load ramp-up conditions: During AI model startup, task initialization, and computing capacity expansion, GPU cluster loads can ramp from no-load to full load within seconds, with power ramp rates far exceeding conventional IT loads. Under such conditions, the grid and the utility feed cannot respond instantaneously to the rapid power increase, making grid voltage sag, input power lag, and momentary system overload highly likely. This places extremely high demands on the instantaneous power support capability and rapid response speed of the backup power system.

(2) High-frequency load fluctuation conditions: During scheduling of AI inference tasks, alternating operation of multiple models, and dynamic allocation of computing tasks, cluster power exhibits high-frequency fluctuations on a timescale of seconds, with no fixed steady-state range. Continuous power oscillation causes front-end UPS and rectifier equipment to frequently adjust operating states. Equipment spends extended periods in dynamic regulation under growing overload stress, and the constant adjustment can introduce small voltage and frequency deviations that affect the stability of computing equipment.

(3) Instantaneous load ramp-down conditions: When AI tasks terminate, model iterations conclude, or computing nodes go offline, cluster loads can instantaneously drop from full load to low load or even no load, creating significant instantaneous surplus power and bus voltage surge issues. Conventional backup power architectures lack efficient energy dissipation and energy storage buffering mechanisms, making them prone to overvoltage protection trips and equipment shutdowns that severely affect continuous data center operation.

Based on the above dynamic operating characteristics, the core requirements of AIDC backup power systems have evolved from the traditional "short-term backup during utility outages" to an integrated capability spanning backup, dynamic power smoothing, transient adaptation, and system efficiency optimization.

2.2 Mainstream Industry Solutions: Advantages and Adaptation Thresholds of the Conventional UPS and Lithium-ion Battery Overprovisioning Architecture

The vast majority of AIDC projects currently under construction or already in operation in China continue to rely on the conventional power supply and backup architecture of conventional data centers—namely, a standard configuration of line-frequency or high-frequency UPS paired with lead-acid or lithium-ion batteries. After adaptation and optimization, this architecture is used to address AI dynamic loads and remains the mainstream market solution today. This approach reuses mature UPS architectures and O&M systems directly, with no structural changes to existing power distribution. With a low implementation barrier and deep accumulated engineering and O&M experience, it is currently the most proven and cost-effective way to deploy AIDC backup power.

Figure 2-1 shows a typical AI load fluctuation curve. It is through the adaptation and optimization described above that this architecture is able to respond to such fluctuations.

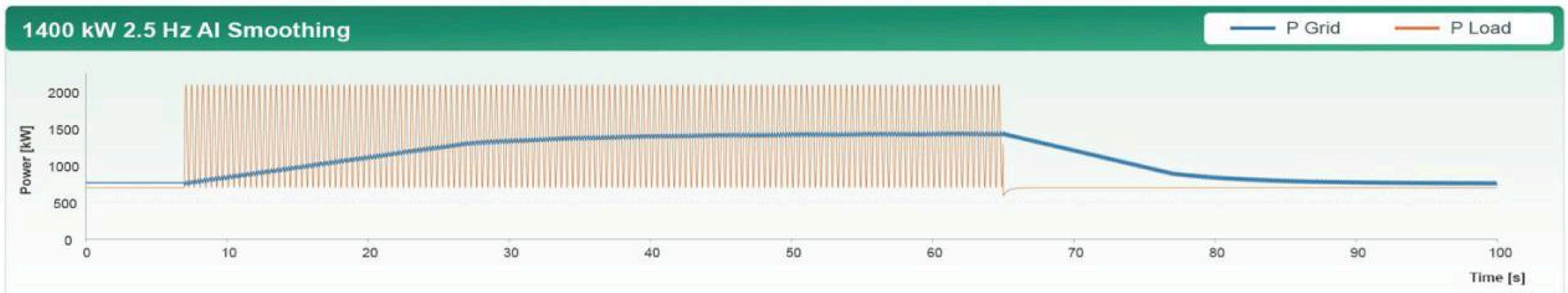


Figure 2-1 Load Fluctuation Curve

Figure 2-2 shows that, from an architectural design perspective, conventional UPS solutions employ centralized or modular UPS deployment, with utility power entering at the front end and IT equipment connected at the back end. Lithium-ion battery packs serve as the core backup power units. Compared with BESS and CBU solutions, this approach offers two distinct advantages:

First, it offers superior compatibility. Under conventional UPS architectures, CBU units are hard to integrate directly because of DC bus voltage platform and interface constraints. Assigning lithium-ion battery packs to handle both backup power and power buffering resolves the issue without any modification to the existing power architecture.

Second, it offers superior economics: investment cost per unit of available power is significantly lower than for standalone BESS or CBU storage, and the approach requires no additional transformation / distribution equipment or civil works.

Therefore, for existing AIDC projects, the "UPS and Lithium-ion Battery Overprovisioning" architecture remains the preferred backup power solution.

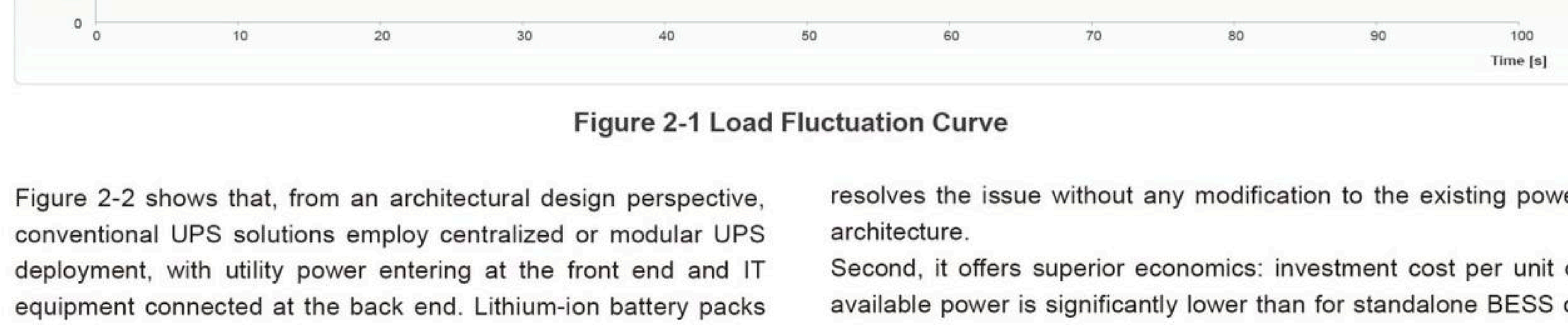


Figure 2-2 Conventional Low-voltage UPS + Lithium-ion Battery Architecture Topology

Topology description: A multi-stage AC / DC conversion architecture where batteries serve only as fault backup power, with normal float charging and fault discharging, and do not participate in dynamic power regulation—a typical steady-state backup topology.

It is worth noting that the real-world effectiveness of this solution depends heavily on battery-side capability—which is where the real technical barrier lies. In AIDC applications with rapid AI load ramps, conventional UPS systems rely on power headroom to stay clear of overload protection. However, abrupt load changes can also cause grid voltage sags, harmonics, and other issues. This requires lithium-ion batteries with higher C-rate dynamic response that can also preserve lifetime reliability and project economics under long-term, high-frequency charge / discharge cycling. Battery manufacturers with high-rate, high-cycle-tolerance, high-consistency cells—paired with dynamic management algorithms—can fully realize this solution's cost and engineering advantages within existing UPS architectures; without them, real-world performance under dynamic AI workloads is hard to guarantee. The solution path itself has been fully validated by the market; the real differentiation lies in whether the battery can adapt to these load profiles.

2.3 AIDC New Backup Architecture Overview

To address the structural shortcomings of conventional UPS architectures under AI dynamic loads, the industry has developed several mainstream power supply and backup architectures for different compute densities, refresh cadences, and mixed-load scenarios: Panama HVDC, medium-voltage centralized UPS, the UPS + Sidecar architecture with built-in Battery Backup Units (BBU) and Capacitor Backup Units (CBU), prefabricated containerized solutions, and future-oriented solid-state transformer (SST) architectures. Each improves on a different combination of dimensions—chain simplification, voltage level, compute refresh adaptability, and flexible regulation—addressing the dynamic challenges of rapid AI ramp-up, high-frequency fluctuation, and instantaneous ramp-down, and together forming a complete architecture matrix covering "existing retrofits, new construction, and future evolution." The rest of this chapter, together with Chapter 4, examines each architecture in turn—topology, operating-condition fit, battery requirements, deployment advantages, and application boundaries.

2.4 Panama Power Solution (Streamlined High-Voltage DC Power Architecture)

The Panama Power solution (Figure 2-3) is a radically simplified high-voltage DC backup power architecture for high-density computing environments. It abandons the conventional UPS AC / DC + DC / AC double conversion and multiple low-voltage power distribution stages, adopting high-voltage DC direct supply, which shortens the power chain and reduces conversion losses. Its core consists of high-voltage DC power modules, energy storage battery packs, and intelligent dispatch units. The backup batteries are directly connected to the DC bus, greatly improving response speed.

On voltage platforms, the current mainstream Panama Power deployment is a 400 V high-voltage DC architecture, and the industry is clearly moving toward an 800 V DC platform to further raise power density and transmission efficiency. This architecture relies on the strong voltage regulation and low-disturbance characteristics of front-end phase-shifted rectification and a high-voltage DC bus to smooth IT load power fluctuations from the power supply side, while the battery side primarily provides steady-state backup power as a fallback.

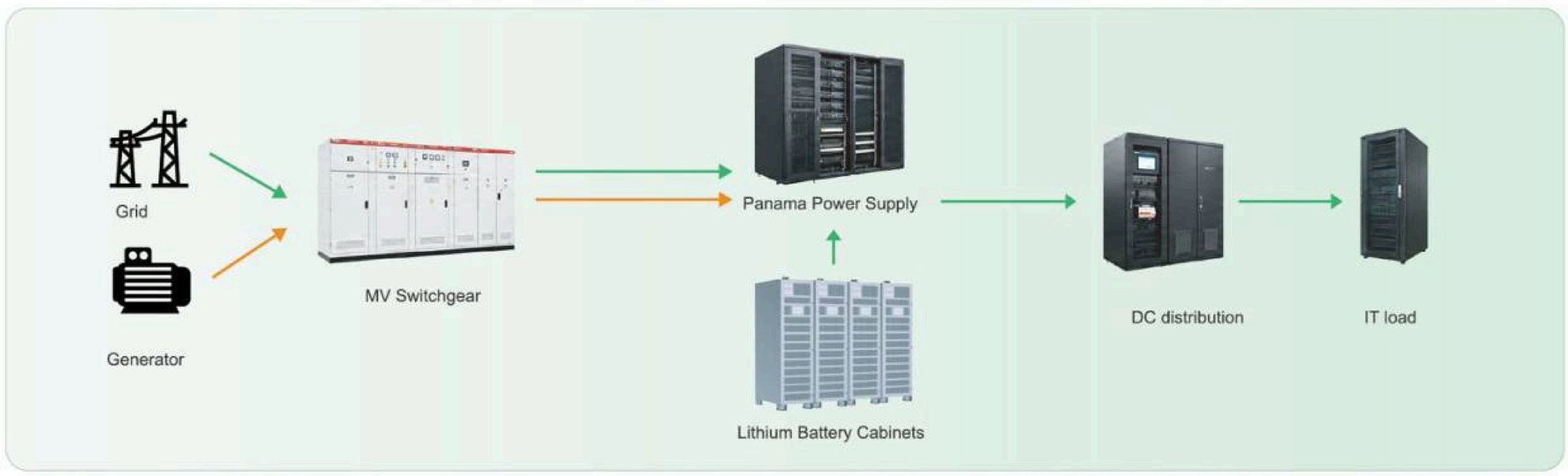


Figure 2-3 Panama Power (High-Voltage DC) Architecture Topology

Topology description: By eliminating the low-voltage transformation and secondary inversion stages, batteries are directly connected to the DC bus and participate throughout in dynamic charging / discharging and power smoothing, with no switching delay, an extremely simplified chain, and ultra-fast response.

2.5 Medium-Voltage UPS Solution (Medium-Voltage Centralized Large-Capacity Backup Architecture)

The medium-voltage UPS solution (Figure 2-4) adopts medium-voltage input, medium-voltage inversion, and a centralized large-capacity backup architecture. Unlike the distributed deployment of conventional low-voltage UPS, it uses a higher voltage level to greatly increase single-system capacity and supply stability, making it suitable for ultra-large-scale AIDC compute clusters. The energy storage system is centrally deployed and dispatched, providing stronger overall power support.

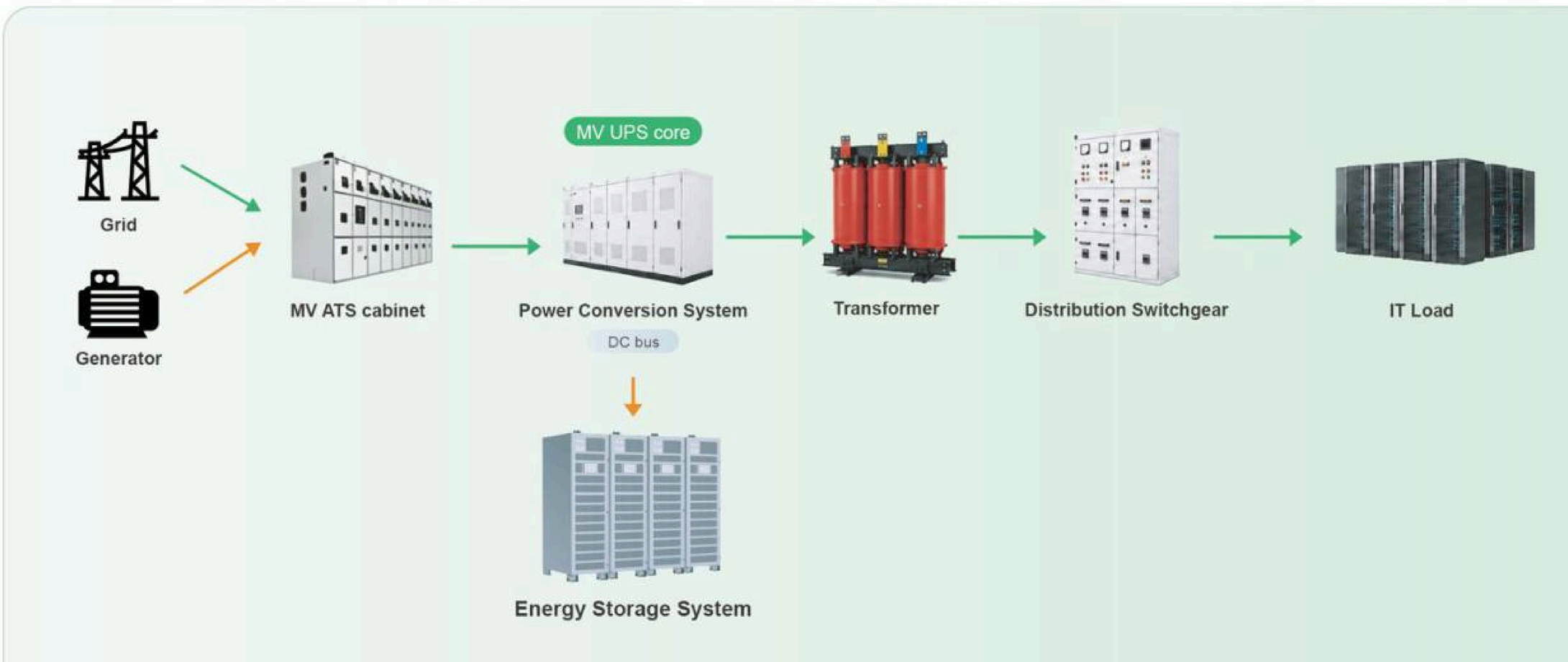


Figure 2-4 Medium-Voltage UPS Centralized Backup Architecture Topology

Topology description: The downstream side of the medium-voltage bus can flexibly adapt to multiple power supply architectures, facilitating data center expansion.

From a topological perspective, the medium-voltage UPS architecture is not bound to end-of-row cabinets or white-space topology. The front-end centralized energy storage cluster can flexibly adapt to future white-space architecture upgrades, rack power upgrades, and distributed retrofits. It is a stable, preferred power supply and backup solution for the transition period. At the same time, batteries paired with medium-voltage UPS must not only provide long-duration, last-resort backup after a utility outage but also continuously participate in global dynamic smoothing of AI loads and transient buffering. The current mainstream choice is 6C / 10C high-rate batteries, balancing steady-state large-capacity support with dynamic ultra-high-rate throughput. Currently, medium-voltage UPS systems generally operate on a 480–512 V DC platform, with a trend toward future adoption of a 1500 V DC higher-voltage platform. For the core challenges of medium-voltage scenarios—cluster parallel consistency, temperature rise under high current, and high-rate cycling stress—the battery system needs targeted optimization across high-rate cell selection, pack-level current-sharing processes, comprehensive thermal management, and dynamic cluster BMS strategies to support the long-term stable operation of ultra-large-scale AI computing clusters.

The medium-voltage UPS centralized large-capacity architecture is suited for ultra-large-scale AIDC cluster deployments. It is not bound to end-of-row cabinet topology and offers strong forward compatibility. The batteries must simultaneously provide high-current steady-state support and global dynamic buffering, with an emphasis on high rate, high consistency, and high reliability. It is the preferred solution for large-scale deployment during the industry transition period.

2.6 OCP Sidecar Solution (Mainstream Architecture for Computing Iteration with Built-in BBU and CBU)

OCP (Open Compute Project) introduced the Sidecar Power Rack (Figure 2-5), a power-decoupling architecture for high-density AI compute clusters. An independent, dedicated power rack sits adjacent to the IT cabinets, moving rectifier power modules, BBU+CBU energy storage units, power distribution busbars, and thermal management entirely out of the server cabinets. It centrally powers AI compute cabinets on one or both sides and is the core deployment form of the HPRv3 and Diablo 400 (±400 V / 800 V DC) high-voltage DC systems.



Figure 2-5 OCP Sidecar Power Rack

Topology description: The Sidecar Power Rack is deployed adjacent to and decoupled from IT compute cabinets. Rectifier power modules and BBU+CBU energy storage units are integrated into an independent power rack, dedicated to centrally supplying power to AI compute cabinets on one or both sides.

From the technical perspective of battery manufacturers, the Sidecar architecture's core design idea is to connect end-of-row batteries and supercapacitors directly to the busbar with no intervening conversion stages, so the energy storage side can handle backup power and power smoothing directly: the CBU handles small power oscillations on timescales of seconds to milliseconds. The BBU remains in a high state of charge for extended periods to handle grid outage applications. The built-in BBU in the Sidecar ensures full-time online backup power, while the CBU deeply participates in dynamic power regulation. Unlike centralized architectures such as Panama Power and medium-voltage UPS, Sidecar batteries are deployed at the rack end, close to the load. Space inside the rack is extremely valuable. This places stringent requirements on the BBU's volumetric power density: within a space-constrained compartment, the battery must balance ultra-high-rate discharge, high-temperature cycle life, and long calendar life.

The combined configuration of CBU supercapacitors and BBU lithium-ion batteries further requires systematic design of power allocation, SOC coordination, and thermal management zoning between the two types of energy storage. At the voltage platform level, the industry is moving rapidly from the 48 V low-voltage platform to the ±400 V (800 V DC pole-to-pole) high-voltage platform. High-voltage operation significantly reduces system current and line losses, while imposing entirely new requirements on BBU high-voltage cascading, insulation safety, and system-level consistency.

At the engineering deployment level, the Sidecar architecture has become the mainstream choice in this era of rapid compute refresh, thanks to the lifecycle decoupling of power supply and computing. Removing all power and backup power hardware from the IT rack greatly frees up rack unit (U) space, significantly improving compute density. The power fault domain is strictly limited to a single Sidecar rack. Power and BBU modules support online hot-swap replacement with zero interruption to compute services. Currently, small and medium-density AI clusters generally adopt mature mass-produced 48 V Sidecar solutions with standardized BBUs. Ultra-high-density clusters are accelerating the adoption of high-voltage Sidecar and high-voltage cascaded BBU / CBU combinations. The industry expects a gradual transition to the 800 V DC high-voltage system between 2027 and 2029. For battery manufacturers, this architecture elevates the battery from a "fault backup component" to a "core functional component of compute power delivery." High rate, high power density, high-frequency dynamic life, and system-level consistency become the decisive measures of competitiveness.

The OCP Sidecar architecture is a rack-level solution featuring "decoupling of computing and power supply, with end-of-row batteries deeply participating in dynamic regulation." The built-in BBU+CBU provides always-on backup and absorbs the dynamic stress of instantaneous AI load ramp-downs, with emphasis on high power density, high-rate response, and hot-swap maintainability. It suits new high-density AIDC projects with fast-iterating compute hardware, extreme compute density targets, and strict fault-domain isolation. It is also the core arena in which battery manufacturers compete on dynamic-condition product capability.

Chapter 3 Ampace AIDC Battery Solutions

Power architecture defines the skeleton of an AIDC backup system, and the battery is its "heart." In new architectures such as Panama HVDC, medium-voltage UPS, and OCP Sidecar, the battery has evolved from a static backup during utility outages into a core unit that participates in dynamic power regulation throughout operation.

3.1 Battery-Side Adaptation Thresholds for the Conventional UPS and Lithium-ion Battery Solution

For the three core operating conditions of AI loads, batteries must clear three capability thresholds to be viable in AIDC applications; batteries without these capabilities simply cannot handle the conditions.

Under rapid ramp-up conditions, GPU load power rises sharply within seconds, subjecting the battery to an instantaneous high-current surge (high C-rate discharge). If the cells lack sufficient high-rate discharge capability, DC bus voltage can sag suddenly, potentially tripping undervoltage protection and causing power outages. Therefore, batteries must possess high-rate discharge capability to stably support this condition while maintaining reasonable redundancy.

Under high-frequency fluctuation conditions, fragmented AI compute scheduling produces small power oscillations on millisecond-to-second timescales, driving UPS rectifier and inverter modules to constantly regulate voltage and current—and keeping the equipment away from its optimal efficiency point for long periods. Batteries must therefore meet demanding long-life requirements, degrading slowly and evenly in capacity and internal resistance under long-term high-frequency micro-cycling, so that consistency drift does not let the weakest cell limit the entire string.

Under ramp-down conditions, the battery must rapidly absorb the surplus energy released by an instantaneous load drop. Since the traditional UPS architecture lacks active power dissipation and energy recovery mechanisms, insufficient battery charge acceptance leaves this surplus energy nowhere to go, easily causing DC bus voltage surges and UPS overvoltage trips—and in severe cases, momentary interruption and restart of computing equipment. Therefore, batteries must possess high-rate charging capability for short durations and a sufficiently wide SOC buffer range.

From the perspective of battery integration, the UPS + lithium-ion battery over-provisioning path has been thoroughly validated by the market: it resolves CBU incompatibility under traditional UPS architectures at lower investment cost, while avoiding both the standalone footprint required by BESS and the high cost of CBU. The true variable lies on the battery side: if batteries are still specified with a steady-state mindset, cell micro-stress will accumulate and dynamic cycling degradation will intensify, turning the battery system into the weak link of the entire power supply and backup chain. A more pragmatic path, therefore, is not to wait for power architectures to be replaced, but to make batteries actively adapt to dynamic AI conditions: dedicated cells with high rate capability, high cycle endurance, and high consistency, coupled with dynamic current balancing and precise SOC / SOH algorithms, upgrade the battery from a "passively over-provisioned steady-state backup unit" into an "actively adaptive core unit for dynamic conditions." This approach closes the gap—reducing redundancy and O&M costs—without altering the customer's existing power supply architecture. This is precisely Ampace's core technical proposition for AIDC applications.

3.2 Characteristics and Reliability of AIDC Batteries

Conventional cells struggle with the high-frequency dynamics, mixed operating conditions, and long service cycles of AIDC. Drawing on deep accumulated expertise in cell materials, structural processes, and reliability engineering, Ampace has built a high-reliability cell system for these complex AIDC-specific conditions—addressing at the source the rapid degradation under dynamic stress, high rate-related temperature rise, and insufficient long-term reliability of conventional batteries. Core cell performance fully matches the dual demands of dynamic AI compute fluctuation and long-term backup power.

3.2.1 Key Characteristics of Cells

(1) Excellent high-frequency dynamic cycling stability, with resilience to AI condition switching on a seconds timescale: Conventional cells cannot withstand the typical 1 s / 1 s high-frequency charge / discharge micro-cycling of AIDC; long-term operation under such conditions is prone to capacity collapse, rapid life degradation, and consistency drift. Ampace's dedicated AIDC cells have been verified under stringent operating conditions. After more than 100 million 1 s / 1 s high-frequency charge / discharge micro-cycles, cell capacity degradation is essentially identical to conventional steady-state calendar life results (Figure 3-1)—breaking the traditional bottleneck in which dynamic cycle life falls far short of calendar life. Under hybrid conditions combining

dynamic AI load fluctuation and utility-outage backup, full-cycle capacity deviation is strictly controlled ≤0.2%, with no significant life degradation and no hidden stress accumulation. With precise life simulation models and condition-adapted design, the cells stably achieve an operating life of ≥10 years with end-of-life SOH (State of Health) ≥70%—matching the long service cycles of data centers and significantly reducing replacement and O&M costs.

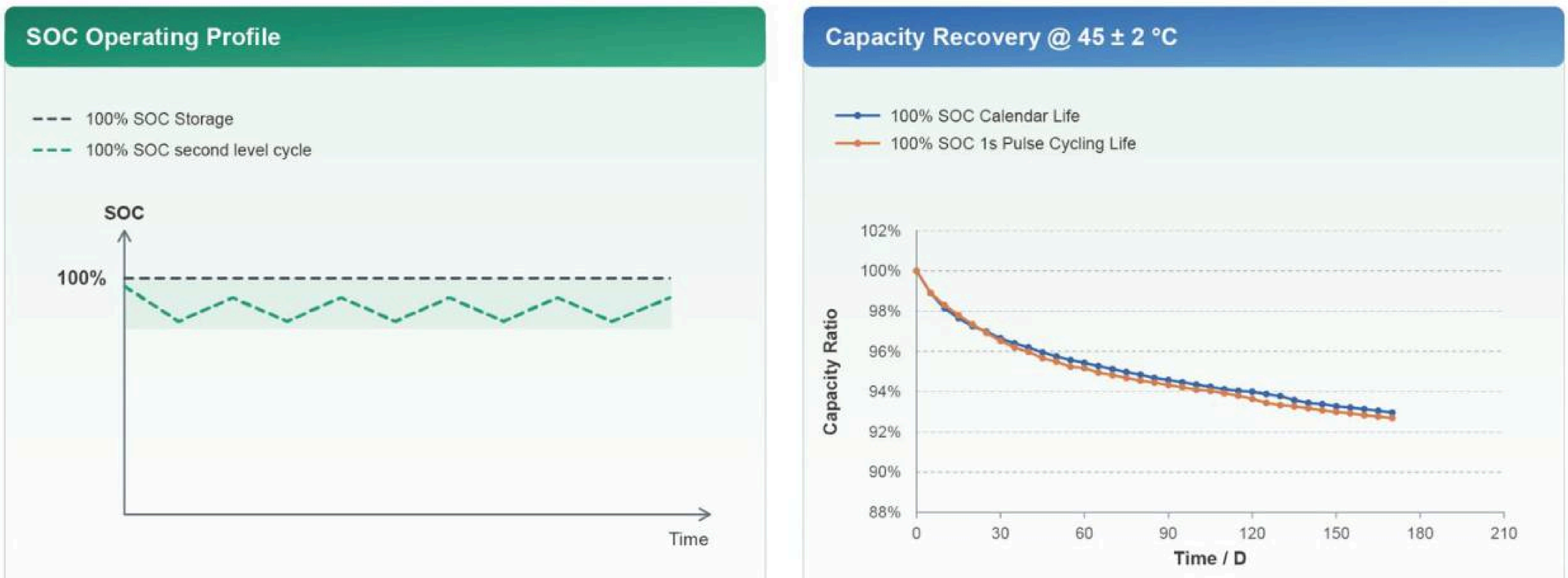


Figure 3-1 High Temperature Accelerated Test

(2) Low temperature rise under 6C ultra-high-rate discharge, designed for instantaneous AI power throughput: For extremely fast AI load ramping and instantaneous high-rate energy replenishment, Ampace high-rate cells feature specialized electrode optimization, an upgraded conductive network, and adapted thermal structures. Under continuous AI instantaneous power operation, the overall temperature rise is strictly controlled ≤10 °C. Extremely low rate-related temperature rise and balanced, full-coverage heat dissipation effectively prevent localized overheating, excessive temperature differentials, and heat-accumulation aging under highly dynamic conditions. The cells suit complex AIDC scenarios—multiple parallel cabinets, high-frequency load changes, instantaneous high-current throughput—balancing ultra-high power output with long-term thermal safety and stability.

(3) Optimized for the typical AI 6C discharge / 1C charge duty cycle, with excellent cycling performance and long-term RCC consistency: Everyday AI compute operation is inherently asymmetric—high-rate, high-current discharge followed by low-rate recharge. The mainstream industry duty cycle is 6C short-duration, high-power discharge with 1C normal-rate recharge. Long-term cycling under this profile can easily degrade active materials, drift contact resistance, and widen the dispersion of RCC (AC equivalent internal resistance)—producing voltage imbalance across battery cabinets, uneven internal resistance, and degraded dynamic load-carrying capability. Ampace cells are specifically optimized for asymmetric AI rate profiles in electrode structure, conductive network, and interface stability. Under high-frequency 6C discharge / 1C charge cycling, they maintain ultra-high cycle life and exceptional RCC consistency (Figure 3-2). Internal resistance grows slowly through cycling, dispersion stays extremely low, and there is no abnormal local impedance drift. This fundamentally prevents the current-sharing imbalance, load offset, and premature degradation of individual cabinets that inconsistent internal resistance causes in multi-cabinet parallel operation. The battery cluster maintains long-term uniformity in dynamic performance and electrical parameters under alternating high- and low-rate AI conditions—precisely matching the asymmetric, highly fluctuating loads of dedicated AIDC computing.

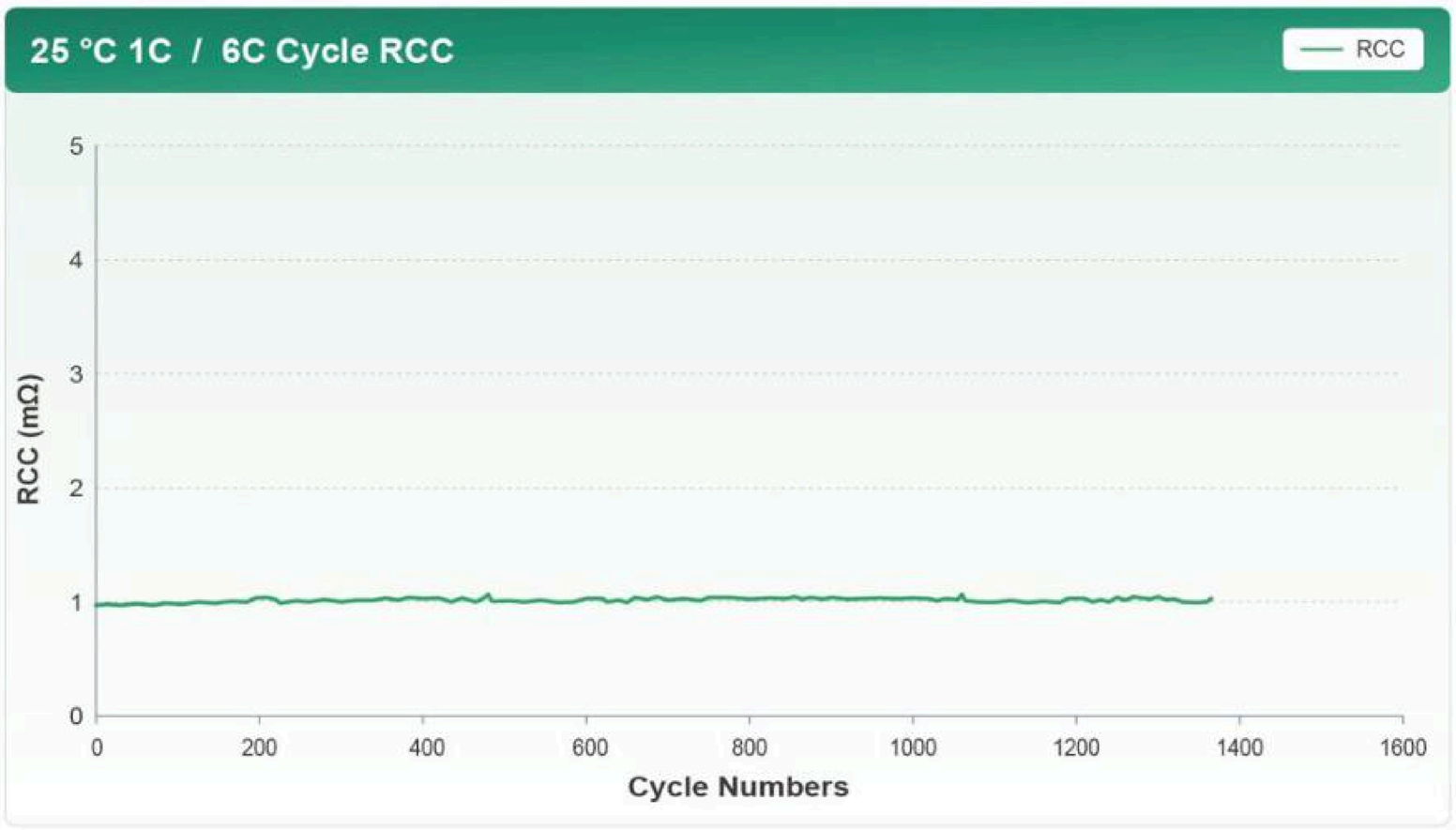


Figure 3-2 RCC Test

(4) Precise full-lifecycle electrolyte control builds a solid long-term reliability baseline: High C-rate cells in long-term dynamic operation are prone to electrolyte decomposition, free impurity accumulation, internal resistance growth, and reliability decline. Through customized electrolyte formulation, optimized interface passivation, and upgraded packaging structures, Ampace holds free electrolyte to ≤0.05 g / Ah (Figure 3-3) throughout the cell's lifecycle. This key indicator effectively suppresses the electrolyte side reactions and aging failures caused by long-term high-frequency cycling, rate switching, and temperature fluctuation, eliminating hidden failure modes such as swelling, internal resistance surge, and sudden capacity drop. Cells maintain stable electrochemical performance, safety, and reliability over more than 10 years of high-dynamic-stress AIDC operation—solving at the cell level the core inability of traditional backup batteries to handle dynamic AI conditions.



Figure 3-3 Ampace Semi-Solid Cell

3.2.2 Failure Mode Management and Reliability Verification

The cell is the smallest energy unit of the AIDC backup power system, and its intrinsic reliability directly determines the safety baseline of the entire power supply system. Based on the long-term high SOC float charge and standby-dominated service conditions of data centers, the industry treats failure mode management and validation as the final safeguard of solution design, and sets four core requirements for lithium-ion batteries: First, long service life: UPS systems typically last 10–15 years, so lithium-ion batteries must deliver a matching calendar life at 15–40 °C ambient temperature under long-term 100% SOC float charge. Second, high consistency: highly consistent cells effectively slow capacity loss and internal resistance growth, keeping backup duration dependable. Third, high C-rate: Backup duration has been shortened from 15 minutes to 10 minutes (6C) and 5 minutes (10C). BBU applications further require short-duration ultra-high-rate discharge capability of 90–120 seconds (30C level). Fourth, high safety and reliability: systematic intrinsic-safety requirements must span the entire lifecycle, from cell design and manufacturing through aging tests to field application.

Typical cell failure modes (Table 3-1) mainly include insulation failure, electrolyte leakage, swelling, abnormal life degradation, and thermal runaway:

Insulation failure and electrolyte leakage:

The main causes include conduction between tabs / terminals and the cover plate, damage to external insulation such as the casing's blue film, and electrolyte leakage from casing rupture or safety valve opening. In solidly grounded three-wire UPS applications, a single leak point can create a short-circuit loop, potentially shorting cells or even triggering thermal runaway. Design should minimize electrolyte leakage risk to the greatest extent possible. Semi-solid-state and other technologies offer effective pathways to this end.

Swelling:

Under abnormal service conditions, gas generated by the oxidative decomposition of the electrolyte causes the casing to swell, posing a risk of valve failure and explosion. Design should enhance the electrolyte's high-temperature stability and suppress gas generation.

Abnormal life degradation:

Data center cells remain in a high SOC float charge standby state for long periods, making calendar aging the dominant concern. A material system combining high-power LFP, low-BET (low specific surface area) graphite, and low-activity electrolyte improves float-charge life. Modeling cell life at 25 °C float charge against a 70% SOH end-of-life threshold supports a calendar life design target of more than 15 years.

Thermal runaway:

Thermal runaway is essentially a self-heating chain reaction triggered by abuse conditions. Design should adopt a highly stable material system and a thermally stable separator to raise the thermal runaway onset temperature. Intrinsic tolerance should be enhanced by optimizing the casing structure, N / P ratio, and current-carrying design, while module-level thermal barriers and directional venting should be employed to suppress thermal propagation.

Table 3-1 Typical Cell Failure Modes



Figure 3-4 Lifetime Simulation

Ampace has established a cell validation system covering both lifetime and safety dimensions. Without altering the failure mechanism, accelerated life testing establishes the relationship between battery life and accelerated stress conditions, then extrapolates high-stress life data to normal stress levels. The float-charge life model accounts for stress factors such as ambient temperature, charge / discharge rate, and float-charge SOC, combining 1C / 6C (or manufacturer-rated) charge / discharge, 1,000 cycles at 25 °C, and long-term 100% SOC float charge to assess the 10–15 year life requirement (Figure 3-4), bridging the gap between the cycling test methods of current standards such as GB / T 36276 and UL 1973 and the high-rate float-charge application of data centers. Safety verification covers four dimensions—electrical abuse, thermal abuse, mechanical abuse, and manufacturing defects—through 11 tests: external short circuit, internal short circuit, overcharge, overdischarge, rate charge / discharge, heating, thermal runaway trigger, drop, crush, temperature cycling, and CT scan. This verification system systematically evaluates intrinsic cell safety under complex AIDC conditions, providing the validation basis for high-reliability operation.

3.2.3 System Characteristics

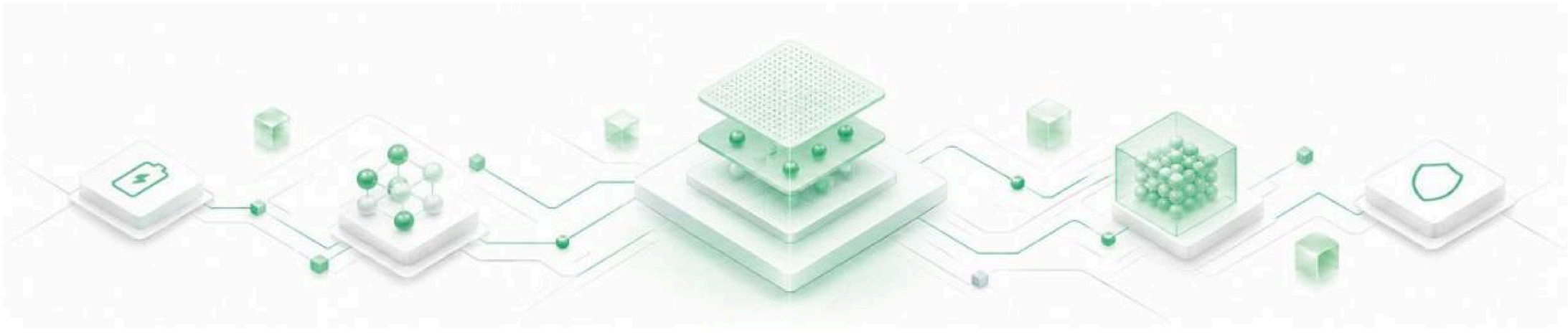
To match ultra-high-power AI compute clusters, AIDCs generally use over-provisioned designs with multiple battery cabinets in parallel. Under traditional UPS architectures, this creates three easily overlooked battery system problems: poor current-sharing consistency among multiple parallel cabinets, inaccurate SOC calibration under dynamic load profile, and excessive SOH calculation deviation under high-frequency disturbances. These have become key bottlenecks for system reliability and refined O&M. Conventional BMS and battery solutions cannot effectively address them. Ampace has developed dedicated solutions for these scenarios.

Inter-cabinet current-sharing imbalance under multi-cabinet parallel operation

Conventional IDCs (Internet Data Centers) run few parallel battery strings with little steady-state current-sharing stress, whereas AIDCs often connect dozens of battery cabinets in parallel on a single UPS system to meet power redundancy and dynamic ramping requirements. Under long-term AI high-frequency fluctuations and instantaneous high-rate throughput conditions, slight cell manufacturing variations, line impedance differences, and ambient temperature differences cause uneven inter-cabinet current sharing that progressively amplifies load imbalance. Some branches suffer long-term overcurrent and stress overload while others sit lightly loaded for long periods—ultimately leading to premature degradation of individual cabinets, sudden loss of overall available capacity, and heating from parallel circulating currents. Conventional passive balancing and fixed current-sharing strategies cannot adapt to dynamic load-change use cases.

SOC calibration failure under dynamic AI load profiles

Conventional SOC algorithms are built on steady-state float-charge and constant-current charge / discharge models, suited to stable conventional IDC conditions. In AIDC, however, continuous millisecond-to-second-scale shallow charge / discharge and instantaneous high-power ramps produce severe instantaneous jumps in voltage and current. The cumulative error of conventional coulomb-counting algorithms keeps amplifying, and static calibration mechanisms fail outright. The result is frequent inflated SOC, understated SOC, and erratic SOC jumps—true available capacity becomes impossible to determine. That either drives excessive redundancy and wasted investment, or underpredicts backup capacity and raises the risk of failure during a utility outage.



Distorted SOH estimation health calculation under high-frequency disturbances

Conventional SOH models evaluate battery health from fixed cycle counts, rest decay, and deep charge / discharge life models—completely unsuited to AI-specific dynamic conditions. Long-term micro-cycling, high-frequency disturbances, and instantaneous stress impacts of AI loads are non-standard damage mechanisms that cause hidden stress accumulation and shift battery aging pathways. Conventional SOH algorithms cannot identify dynamic micro-damage, so reported health looks fine while actual available capacity has already decayed—culminating in sudden fault shutdowns and greatly increased O&M risk and unplanned downtime.

3.3 Ampace Targeted Battery System Solutions

As a battery manufacturer, Ampace aligns closely with the market's core customization needs—especially those of high-end North American AIDC customers. Responding to the markedly different EOL (End of Life) backup power design philosophies of Chinese and U.S. data centers, Ampace has built a differentiated product strategy. In Chinese AIDC projects, diesel generators generally start slowly, so the mainstream design is 15-minute EOL long-duration backup: the battery must still deliver the full 15 minutes at end of life. Evaluation centers on battery capacity and long-duration backup capability. In North American AIDC, diesel generators start quickly—typically carrying the load within 2 minutes—so long-duration backup redundancy is unnecessary. The industry generally adopts a 5-minute EOL short-duration backup standard. It is worth emphasizing that the North American 5-minute EOL standard does not relax backup requirements; it shifts the evaluation focus from backup duration to short-duration, ultra-high-rate charge / discharge capability. Projects commonly select 6C–10C ultra-high-rate batteries to handle extreme AI load ramp-up, absorb instantaneous load-drop energy, and bridge diesel generator startup.

Around this differentiation, Ampace has built a dedicated lithium-ion battery solution system across five dimensions—cell formulation, rate performance, thermal management, lifespan management, and BMS dynamic algorithms—precisely matching the needs of North American AIDC high-rate short-duration operating conditions and Chinese long-duration backup operating conditions (the cell intrinsic reliability design and verification system is detailed in Section 3.2.2). Ampace's core design and optimization priorities target customers' real-world pain points:

(1) Optimized for North America's EOL 5-minute short-duration backup and ultra-high-rate core conditions: With local diesel generators starting within 2 minutes, North American AIDCs do not need batteries to carry long-duration backup. The core stress is concentrated in short-duration, ultra-high-rate throughput. The industry mainstream selects 6C / 10C high-rate batteries for rapid energy replenishment, dynamic power smoothing, and short-duration backup support for diesel generator startup. Ampace specifically optimizes cell high-rate discharge characteristics and high-current charge / discharge stability, ensuring the battery still meets the 5-minute full-rate discharge requirement at end of life—precisely matching North America's short-duration, high-stress, transient-first operating profile, as distinct from China's 15-minute, long-duration, capacity-first design philosophy.

(2) Built for short-duration, high C-rate AI charge / discharge profiles: For the extreme conditions of rapid AI load ramp-up and instantaneous drop, Ampace products strengthen short-duration, high-rate charge / discharge capability—delivering rapid high-current energy replenishment and fast absorption of surplus energy, matching the dynamic power throughput of multiple parallel UPS cabinets, and eliminating the stress overload, capacity cliff, and response lag of traditional batteries under high-rate conditions.

(3) Pack thermal management optimized to tightly control temperature rise under dynamic conditions: Continuous high-frequency charge / discharge and uneven current sharing across parallel cabinets can easily cause localized module temperature rise and excessive temperature differentials. Through refined pack structural design and uniform, full-coverage thermal management, Ampace effectively suppresses temperature rise and differential accumulation under high-rate dynamic conditions—keeping module temperatures consistent across parallel cabinets, preventing thermal runaway and localized heat aging, and meeting the high-reliability requirements of unmanned North American white space.

(4) Balancing high volumetric energy density with long-term reliability: Ampace maintains industry-leading volumetric energy density—meeting high-density equipment room deployment needs and saving cabinet space and infrastructure cost—without blindly cutting design margins. Through cell structure optimization and module assembly process upgrades, Ampace achieves high-density integration while significantly improving dynamic stress resistance—balancing high-density deployment needs with long-term stability under complex AI conditions, and resolving the conventional market dilemma of "high density with short life, long life with low density."

(5) Dynamically adaptive BMS algorithms that address traditional O&M pain points at the root: With active dynamic current sharing, high-frequency dynamic SOC fusion algorithms, and AI dynamic-stress SOH lifespan models, Ampace precisely solves multi-cabinet current-sharing imbalance, SOC calibration inaccuracy, and SOH distortion—achieving adaptive power distribution across parallel cabinets, accurate capacity measurement at all times, and early detection of hidden aging, significantly reducing O&M cost and downtime risk for North American AIDC projects.

Overall, Ampace's solution is built entirely around customer scenarios and the North American EOL 5-minute core standard, balancing five capabilities: high-rate dynamic condition adaptation, long-cycle lifespan, high energy density, thermal safety and reliability, and refined O&M. It handles both the dynamic fluctuation of AI compute loads and the stringent steady-state backup requirements of traditional UPS architectures—systematically closing, from the battery side, the gaps of traditional over-provisioned architectures, and meeting the deployment standards of high-end AIDC projects worldwide.

3.4 Product Portfolio and Evolution Roadmap

For AIDC's complex and diverse power demands, Ampace has built a product matrix of battery and system solutions covering application scenarios across white space, gray space, and green space—meeting needs from today's basic backup power to future high-power AI compute evolution (Figure 3-5).

In the current solution portfolio, Ampace provides a multi-timescale backup and energy storage matrix (Figure 3-6), covering 1–8-hour battery energy storage system (BESS) solutions and 5–7-minute, 10–15-minute UPS battery systems. Among these, BESS systems focus on AI load smoothing, grid fluctuation smoothing, and improved power quality for connected equipment; UPS batteries are evolving to support AI load smoothing, with semi-solid-state technology progressively adopted to deliver higher performance, withstand millions of micro-cycles, and handle rapid ramp-up / down.

For the future AIDC evolution from 2026 to 2030, Ampace has planned a roadmap aligned with high-power OCP platforms such as GB200 / GB300; the SP 25 and SP 35 series will launch in sequence, progressively raising operating temperature (up to 45 °C), service life (10 years), and power output. At the system product level, Ampace will introduce semi-solid-state cells and Kunlun technology cells, building complete full-scenario solutions from cell to system and from backup power to grid interaction.

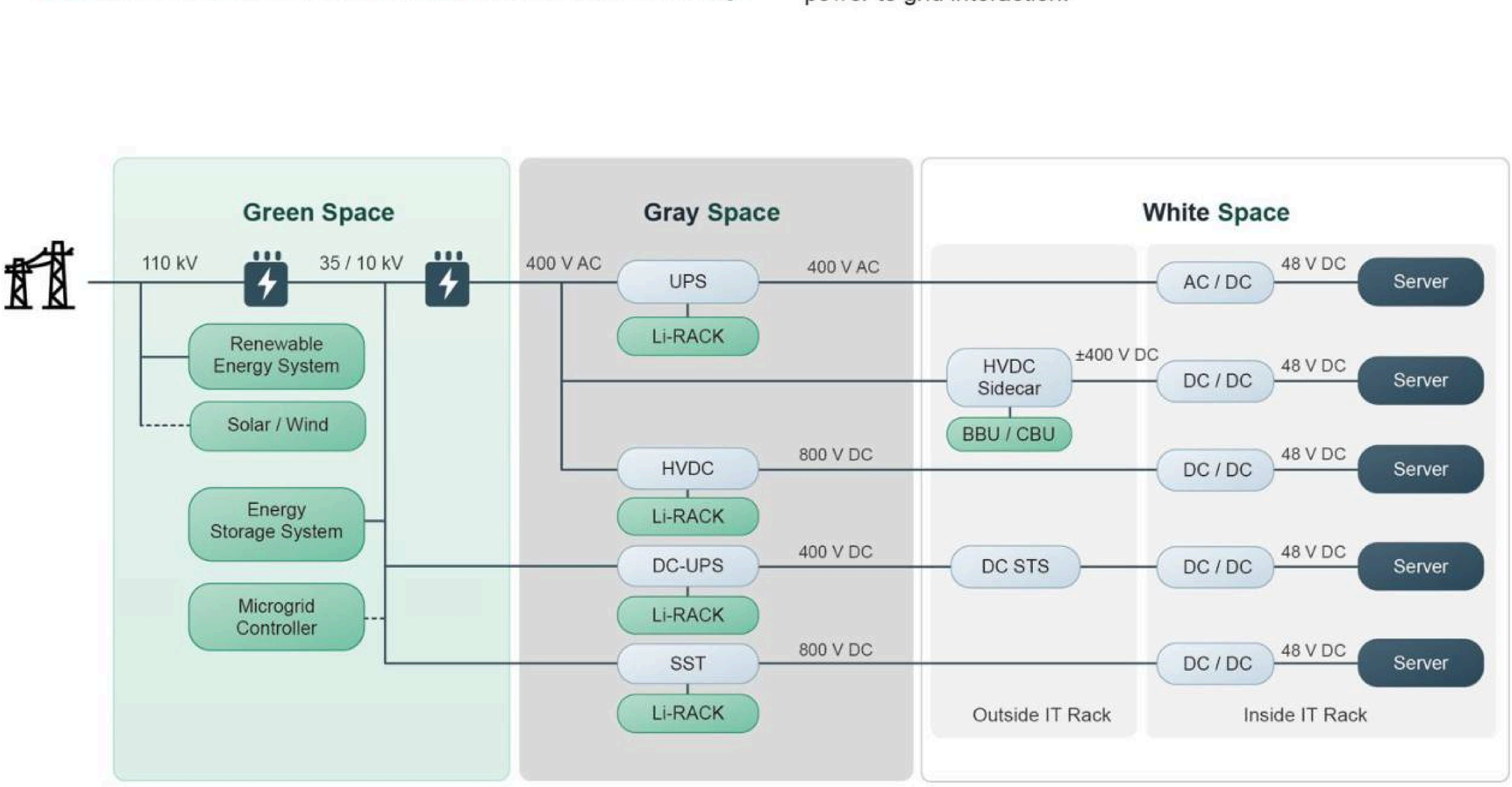


Figure 3-5 AIDC Solutions

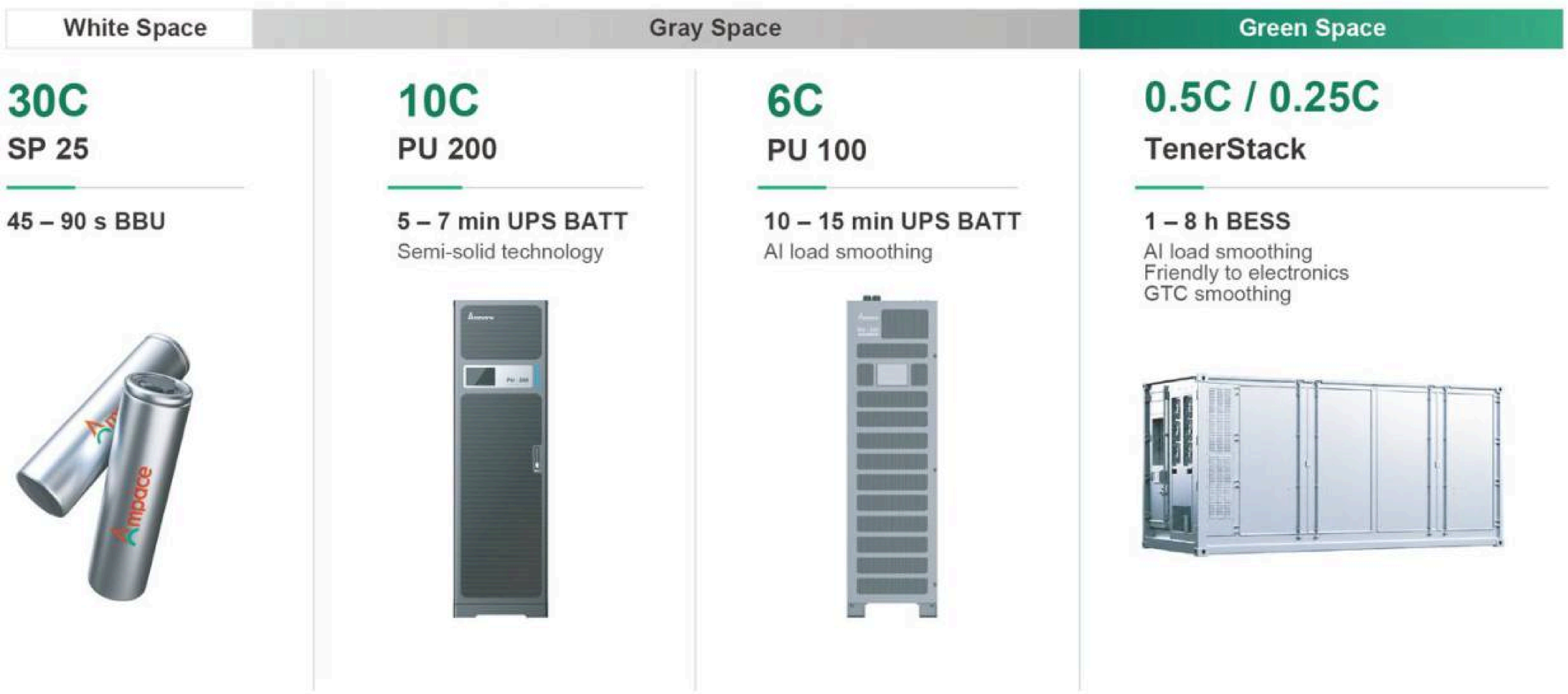


Figure 3-6 Product Matrix

Chapter 4 Future Technology Solutions and Compliance Trends

4.1 Prefabricated Containerized Integration Solutions (Preferred for Large-Scale Deployment Worldwide)

With demand accelerating for large-scale, fast-built AIDC compute clusters—and given the high civil engineering, on-site construction, and labor costs of overseas projects—prefabricated containerized integrated power supply solutions have become a mainstream deployment form for large-scale AIDC and overseas projects. This approach departs from the traditional equipment-room model of scattered on-site installation, on-site wiring, and step-by-step commissioning. It follows a "factory prefabrication, full-system integration, on-site plug-and-play" philosophy, significantly reducing on-site construction difficulty and deployment time. The industry currently has two mainstream forms—UPS + lithium-ion battery integrated containers and walk-in standard energy storage containers—suited to different compute deployment scenarios and construction requirements worldwide.

Type 1: UPS + Lithium-ion Battery Integrated Container (compact solution supporting computing stations)

This is a compact prefabricated solution designed specifically for compute scenarios. It integrates the complete UPS power equipment, lithium-ion battery energy storage system, power distribution PDUs, thermal management, fire protection, and monitoring BMS into a single container, so the entire power supply and backup system ships factory-prefabricated. The industry uses two standardized layouts. The first is an isolated battery compartment: the lithium-ion battery energy storage unit sits in an independent sealed compartment, physically separated from power distribution, with dedicated thermal management and fire protection. This offers a higher safety level, suiting high-end compute clusters and high-reliability overseas white-space requirements. The second places batteries and power distribution PDUs side by side for high space utilization, emphasizing lightweight, low-cost, rapid deployment—suited to volume new-build projects in China and small-to-medium compute node scenarios. Note that this solution integrates large battery quantities inside containers, which carries compliance risks associated with large-scale battery fires; proactive compartment isolation, fire protection, and compliance verification are therefore required.

Type 2: Walk-in Standard Energy Storage Container (mainstream solution for large overseas AIDC projects)

To address the long civil construction cycles, extremely high on-site installation labor costs, and difficult on-site commissioning of overseas AIDC projects, the industry has adopted standardized walk-in energy storage containers at scale. The container uses a spacious walk-in structure with ample internal maintenance access. The energy storage battery cluster, centralized power distribution system, thermal management and fire protection, and EMS are all factory-integrated and fully commissioned before shipment. The

delivered product is a complete, self-contained backup power unit that needs only utility and load connections on site to enter service. Centered on centralized large-capacity energy storage, it provides site-wide steady-state backup power, grid disturbance buffering, and diesel generator startup support for the entire compute cluster—suited to overseas ultra-large-scale AIDC deployments. In line with overseas O&M practice, battery evaluation focuses on short-duration, high-rate discharge, high instantaneous current output, and full-cycle capacity retention reliability. The industry mainstream adopts 6C / 10C high-rate batteries to meet the North American 5-minute EOL standardized assessment requirements. Centralized thermal management and full-coverage monitoring inside the container ensure the long-term consistency and safety of large parallel battery clusters, meeting overseas unattended, maintenance-free operation requirements.

From a construction model perspective, both solution types achieve "factory prefabrication and minimal on-site implementation," fully matching the need for rapid deployment of AI compute. Domestic projects focus on compact integration, high space utilization, and cost-effective batch deployment, while overseas projects focus on standardized complete-unit prefabrication, low on-site labor dependence, high safety redundancy, and long-term maintenance-free operation. From the perspective of battery manufacturer adaptation, the enclosed space of containers places higher demands on battery temperature rise control, thermal runaway protection, and cycling stability. Large-scale complete-unit deployment imposes stringent requirements on batch consistency, parallel current-sharing capability, and long-term accurate SOH management. This calls for refined pack thermal management, dynamic current sharing, and high-frequency, accurate SOC / SOH algorithms to keep entire containers—and entire batches—of battery clusters running stably over the long term.

4.2 The Next-Generation SST Architecture (Industry Evolution Direction)

The SST (solid-state transformer) is the future core power supply architecture for next-generation AIDC, delivering ultra-high density, ultra-low losses, and fully flexible control (Figure 4-1). Built on wide-bandgap power electronics, it abandons the traditional line-frequency transformer plus multi-stage passive conversion architecture, integrating voltage transformation, AC / DC conversion, flexible power routing, power quality management, and bidirectional energy storage coordination in a single device. It fundamentally resolves the multi-stage losses, response lag, and weak condition-regulation capability of traditional architectures, and is the ultimate evolutionary direction for fully dynamic AI loads and high-density compute refresh. Current industry SSTs fall into two mainstream topologies: single-port SST (with an independent DC / DC stage) and multi-port integrated SST. The two architectures differ fundamentally in conversion chain topology, power regulation mode, and energy storage coupling. Battery solutions can be flexibly matched to each customer's mix of steady-state IDC and dynamic AI loads, enabling on-demand selection.



Figure 4-1 SST Architecture Topology

Topology description: The single-port SST architecture requires an external independent DC / DC conversion unit to achieve energy storage and load adaptation; the multi-port SST is a magnetically integrated all-in-one architecture that natively integrates multiple independently controllable AC / DC ports, requiring no additional external conversion equipment and capable of directly coupling energy storage with multiple types of hybrid loads.

(1) Single-port SST + independent DC / DC architecture and battery adaptation logic

The single-port SST is a standardized single-channel power conversion architecture with a simple design, a low engineering barrier, and strong compatibility. It outputs a single DC bus and must be paired with an external DC / DC module for electrical isolation, voltage adaptation, and power regulation between the battery and the load. This architecture follows a standardized, general-purpose, steady-state-first design philosophy, suiting hybrid data centers where traditional steady-state IDC loads dominate and dynamic AI loads remain manageable. Battery duty is dominated by conventional steady-state backup and low-frequency energy buffering, with little high-frequency dynamic charge / discharge. For scenarios dominated by steady-state IDC business, high-capacity, long-cycle-life, high-consistency steady-state energy storage batteries are the right choice, with emphasis on long-term backup reliability and lifecycle economics. Only where the AI load share rises moderately should a general-purpose lithium-ion battery system with moderate dynamic response capability be used.

(2) Multi-port integrated SST architecture and battery adaptation logic

The multi-port SST uses a magnetically integrated all-in-one design built around a common magnetic core. It natively integrates multiple independently controllable power ports, enabling power decoupling, independent regulation, and dynamic energy routing across the grid, energy storage, steady-state IDC loads, and highly dynamic AI compute loads. The conversion chain is more streamlined, regulation accuracy is higher, and dynamic response speed is faster, making it the core topology for future fully dynamic AI compute centers. Under this architecture, the energy storage battery is no longer a single backup unit, but a core regulation unit participating in full-domain power smoothing, cross-port energy scheduling, and extreme condition buffering. The battery operates long-term under complex, high-frequency dynamic throughput: during ramp-up (rapid power increases), multiple ports release energy simultaneously and the battery provides high-power, seconds-scale energy supplementation; during high-frequency fluctuation, the relevant port fine-tunes independently to suppress oscillation without affecting steady-state loads across the facility; during ramp-down (instantaneous power drops), surplus energy is rapidly buffered and absorbed across ports, completely eliminating bus overvoltage.

As the ultimate next-generation power supply architecture, the SST covers all scenarios through its single-port and multi-port forms, enabling flexible power scheduling and tailored battery adaptation—precisely matching the evolution toward ultra-high-density, fully dynamic AI compute centers.

4.3 Sodium-Ion and Solid-State Batteries: Next-Generation Technology Pathways for AIDC Energy Storage

As AIDC computing clusters evolve toward ultra-high density and fully dynamic operation, single-rack power consumption exceeding 100 kW is gradually becoming the industry norm. Large model training and AI inference give GPU clusters dynamic load characteristics—rapid ramp-up, high-frequency fluctuation, and instantaneous drops (see Section 2.1). The requirements for AIDC backup power systems have evolved from traditional short-term outage backup to a comprehensive capability integrating the four functions described in Section 2.1.

Traditional UPS + LFP over-provisioned architectures rely on capacity redundancy to passively absorb compute power surges, which demands higher rate response from the batteries. Under long periods of frequent fluctuating charge / discharge, cell life, operational reliability, and project lifecycle economics all suffer significantly. Traditional lithium-ion battery systems are increasingly showing their limits in high-rate cycling, wide-temperature operation, and safety margins in enclosed spaces. Sodium-ion and solid-state batteries, each with distinct technical advantages, are entering the AIDC market at different paces of industrialization. Technology advances are reshaping how the market selects energy storage for computing power.

4.3.1 Sodium-Ion Batteries: Technical Characteristics Open Up Incremental Space for AIDC Power Energy Storage

The sodium-ion battery industry has moved beyond the early "wholesale replacement of lithium-ion batteries" narrative and no longer relies solely on lithium price cycles for its cost advantage. High-rate output, wide temperature range, and intrinsic safety have become its core competitive strengths. As leading enterprises continue to bring production capacity online, sodium batteries are moving from demonstration projects to large-scale delivery, and AIDC has become an important incremental market for them.

Several sodium battery performance characteristics map precisely onto AIDC's special operating conditions. First, high-rate capability and millisecond-scale response. Some power-type products can achieve 6C–20C high-rate discharge, with millisecond-scale load smoothing—effectively cushioning the impact of AIDC compute ramp-up on power distribution systems while avoiding the rapid life degradation that traditional LFP batteries suffer under frequent high-rate cycling. Second, outstanding wide-temperature adaptability. Cell-level operating temperature can span -40 °C to 60 °C. This can reduce data center air conditioning loads, improve PUE, and support outdoor prefabricated containers as well as compute projects in extremely cold regions. At the same time, sodium cells also have lower intrinsic chemical reactivity, an added safety advantage in

enclosed container scenarios.

Constrained by lower energy density, sodium-ion batteries will remain a power-type complement rather than a wholesale replacement for lithium-ion batteries. At the same time, with the release of large-scale production capacity and the gradual decline in costs, sodium battery penetration in AIDC-UPS and prefabricated container energy storage will steadily increase—particularly for 5-minute short-duration backup assessments and compute projects in extremely cold regions. On the market side, the evaluation criteria for AIDC energy storage are changing. End customers no longer focus solely on capacity; high-rate performance, temperature adaptability, and cycle stability under frequent fluctuation have become important evaluation dimensions—creating clear market opportunities for sodium-ion batteries.

4.3.2 Solid-State Batteries: Technological Breakthroughs Will Determine the Long-Term Development Direction of High-End AIDC

Solid-state batteries replace conventional liquid electrolytes with solid ones, fundamentally reducing the risks of leakage and combustion. Intrinsic safety is their defining feature, making them a key direction for the mid- to long-term technology upgrade of AIDC energy storage. Hybrid solid-liquid systems retain a small amount of liquid electrolyte, striking a balance between interface impedance and safety. Some products already pass nail-penetration tests without fire and overcharge tests without explosion, aligning closely with the stringent thermal-safety requirements of ultra-high-density equipment rooms. All-solid-state batteries eliminate liquid electrolytes entirely, combining high safety with high energy density, but remain technically harder to realize.

The rigors that dynamic AI loads impose on cells apply equally to solid-state batteries. Even with substantially better intrinsic safety, deployment in AIDC will still require validation of cycle life, reliability, and lifecycle economics under high-frequency, large-amplitude charge-discharge swings. Constrained by solid-solid interfaces and manufacturing processes, solid-state industrialization is proceeding at clearly different speeds by technology tier. Hybrid solid-liquid routes are closer to commercialization, while all-solid-state batteries remain in pilot and small-batch trial production, still some distance from large-scale deployment. Industry standards are catching up, with clear definitions for liquid, hybrid solid-liquid, and all-solid-state batteries plus supporting quantitative test methods—further standardizing product qualification and accelerating the migration of solid-state technology from automotive to energy storage applications.

In the short term, constrained by cost and mass-production capacity, solid-state batteries in AIDC will be limited mainly to pilot demonstrations and will be difficult to deploy at scale. Over the medium to long term, if key breakthroughs in materials and interface processes are achieved, solid-state batteries could simultaneously deliver high safety, usable rate capability, and high energy density—serving both power smoothing and long-duration backup. They could become the solution of choice for high-end AIDC at core computing nodes with extreme safety requirements. Advances in solid-state technology will also keep raising the battery safety bar for data centers, pushing the industry toward stricter requirements on thermal runaway and thermal propagation.

4.3.3 Technology-Driven Stratified Market Landscape for AIDC Energy Storage

The two emerging routes and lithium iron phosphate (LFP) are not simple substitutes; they occupy distinct niches defined by technical performance. LFP, backed by a mature supply chain and cost advantages, continues to serve baseload and long-duration backup. Sodium-ion batteries, with high-rate and wide-temperature-range capabilities, capture power-oriented incremental scenarios and enable a coordinated multi-timescale storage architecture. Solid-state batteries, with their ultimate safety, stand as the long-term technology reserve for high-end data centers.

Market evolution follows technology: AI computing has created entirely new load profiles that compel battery technology to iterate. Traditional over-provisioning has exposed trade-offs in cell life, reliability, and economics, while progress in sodium-ion and solid-state batteries has in turn expanded the boundaries of AIDC energy storage. In the short term (3–5 years), coordinated lithium–sodium, multi-timescale storage solutions will accelerate deployment, while solid-state remains largely in small-scale pilots. Over the medium to long term, as solid-state matures, the market will settle into a landscape of coexisting routes, with different products matched to AIDC sub-scenarios by power rating, backup duration, and safety level—together ensuring the energy security of ultra-high-density AI computing centers.

4.4 Safety and Data Dual Compliance: Architecture-Level Fire Protection and EU Battery Passport Solutions

Global deployment of AIDC energy storage equipment faces a systematic rise in compliance thresholds. On one hand, safety standards represented by the UL 9540A large-scale fire test continue to tighten, turning "fire non-propagation" from a differentiator into a mandate; on the other, the EU Batteries Regulation (EU 2023 / 1542) makes the Battery Passport a statutory market access condition, extending regulation from the product itself to full-lifecycle data. Safety compliance and data compliance have become the dual passports for energy storage equipment entering global markets, especially high-end markets in Europe and the United States.

4.4.1 Safety Compliance: Large-Scale Fire Testing Reshapes the Fire Protection Capability Baseline

On March 13, 2026, the 6th edition of UL 9540A was officially released and will take effect on January 1, 2027 (Figure 4-2). The new edition incorporates the Large-Scale Fire Test (LSFT) (Figure 4-3) into installation-level evaluation, aiming to verify that combustion of a single energy storage unit does not propagate to adjacent units and to raise the safety level of energy storage systems. Its large-scale fire test requirements will gradually become de facto mandatory as fire codes such as NFPA 855 (2026 edition) adopt them.

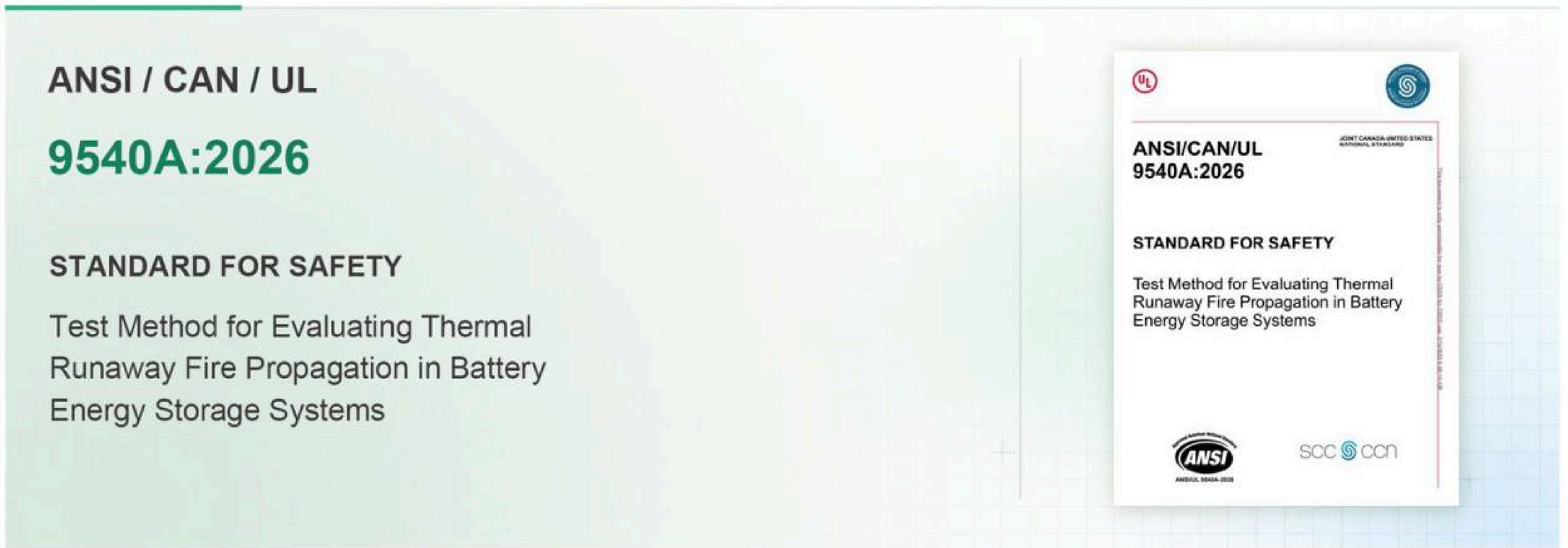


Figure 4-2 UL 9540A, 6th Edition (2026)

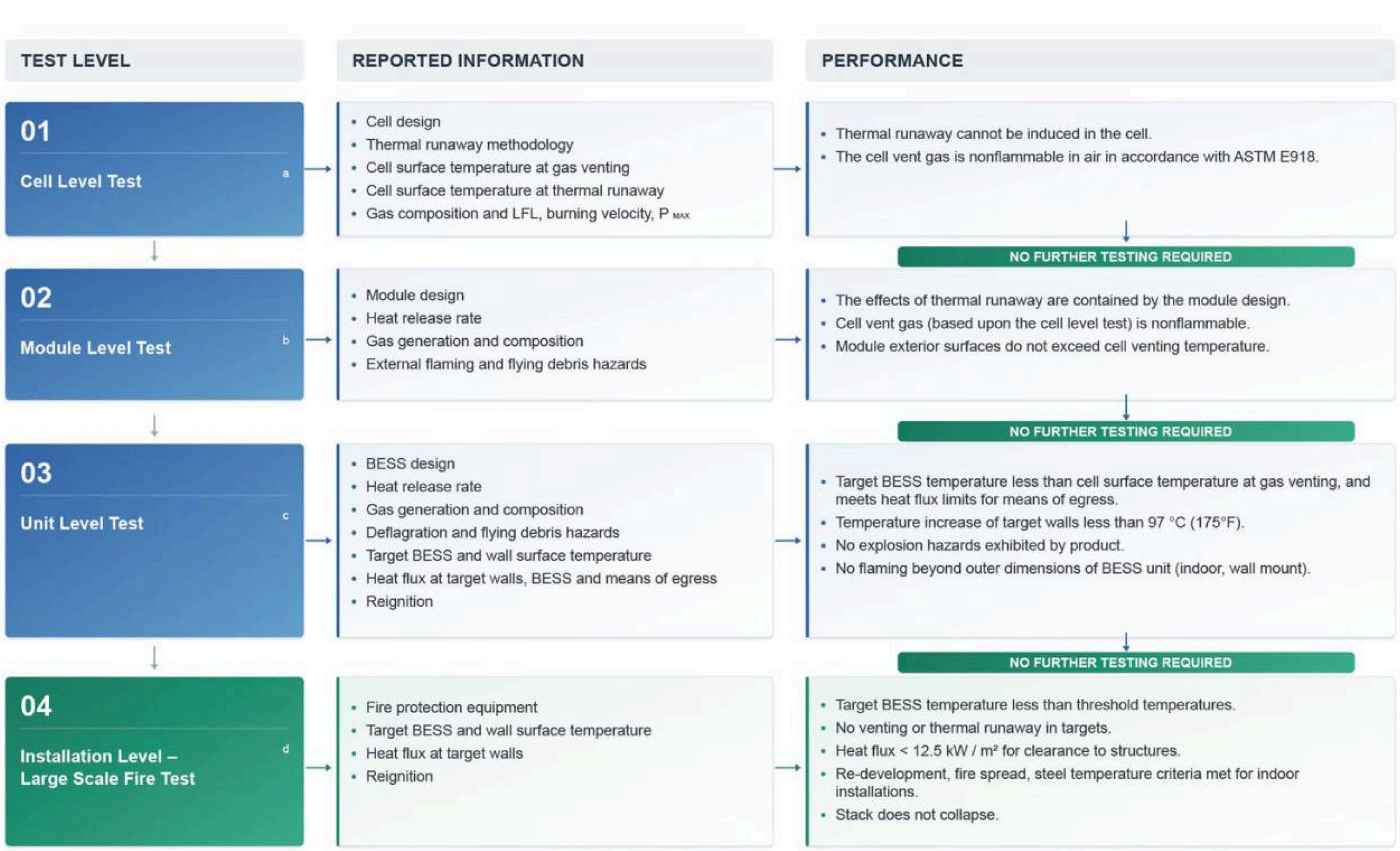


Figure 4-3 LSFT Requirements

For AIDC large-scale compute clusters, backup energy storage units in white space and gray space are located near critical power supply equipment and critical loads. A fire in one energy storage unit can directly interrupt power to part of the facility or even the entire site, halting the training and inference workloads of large-scale compute clusters. In today's era of rapid AI growth, the direct and indirect losses from business interruption are enormous. After an energy storage fire, the scope of cleanup and recovery is determined by how far the fire propagated and what it affected. The longer the recovery, the deeper the impact on end users.



Figure 4-4 Fire Monitoring and Protection System

Ampace strengthens energy storage fire safety across four dimensions (Figure 4-4): early warning, fire protection control, incipient-stage suppression, and propagation isolation. Fires are confined to individual modules within the cabinet—even if a single module burns, the fire does not propagate to neighboring modules—limiting its spread, minimizing disruption to customer operations, and accelerating recovery. Fire hazards are addressed in three stages:

Incipient-Stage Suppression: Through very early off-gas detection and thermal runaway warning algorithms, the system provides minute-scale advance warning of thermal runaway and fire. Once a warning is triggered, the fire protection controller electrically isolates the faulty unit from the rest of the power supply system within milliseconds, preventing it from affecting other units. This early intervention greatly reduces the probability of open flame.

Developing-Stage Control: The fire suppression unit inside the battery module releases a clean agent upon incipient ignition, effectively extinguishing early fires and significantly slowing flame spread driven by heat release. This mid-stage control greatly reduces the probability of sustained open-flame combustion.

Fully-Developed-Stage Containment: Module-level and cabinet-level fire-resistant insulation and isolation design block fire spread within and between cabinets, keeping the fire's impact strictly local. This late-stage containment minimizes the reach of any open flame.



Figure 4-5 On-site Photos of the LSFT

Building on this four-dimensional fire protection system, Ampace conducted a full-scale (1:1) verification test (Figure 4-5) in which thermal runaway was simultaneously triggered in every cell of a single module and the module was actively ignited, resulting in complete combustion of that module. The fire lasted for approximately 40 minutes. Throughout the test, the overhead sprinklers never activated, and the fire did not spread to adjacent modules or cabinets. This greatly reduces fire hazard and greatly simplifies emergency response and post-incident recovery.

4.4.2 EU Battery Passport Compliance Solution

The EU Batteries Regulation (EU 2023 / 1542) has officially entered into force, and the Battery Passport will become a mandatory market access requirement for energy storage and industrial lithium-ion batteries with a capacity exceeding 2 kWh from February 18, 2027. Centered on full-lifecycle digital traceability, verifiable carbon footprints, and auditable data security, the regulation requires companies to achieve end-to-end data connectivity spanning manufacturing, cross-border customs clearance, on-site operation, and end-of-life recycling, and subjects them to routine and unannounced inspections by EU regulators. At the same time, requirements for standardized compliance data collection, industrial cybersecurity management, and commercial data privacy protection have also taken effect, exposing energy storage companies exporting to the EU to overlapping, multi-dimensional compliance pressure.

Traditionally, building a compliance system from scratch requires coordinating multiple service providers, retrofitting hardware and software in stages, and rebuilding data linkages, which often results in high investment, long implementation cycles, compliance gaps, and difficult maintenance. To address this industry-wide pain point, Ampace offers a one-stop Battery Passport compliance solution (Figure 4-6) covering the full range of EU energy storage project export scenarios. With a standardized, integrated approach, it helps companies meet all of the regulation's mandatory market access and ongoing regulatory requirements at lower cost and with greater efficiency.

The solution establishes an end-to-end compliance loop spanning production registration, production-line coding, customs verification, on-site data collection, and long-term cloud-based management. This enables full-lifecycle traceability and auditability without the need for fragmented retrofitting. Natively aligned with the provisions of EU 2023 / 1542, the system fully consolidates product information, supply chain data, and carbon footprint records, and supports synchronized reporting of operational data—ensuring smooth customs inspections and routine regulatory oversight. In parallel, the solution places strong emphasis on clear data ownership and commercial privacy protection. Through an open architecture and standardized secure transmission, customers can freely choose their data hosting arrangements—satisfying EU industrial cybersecurity requirements while preventing core commercial data leakage and platform lock-in. Furthermore, the responsible compliance entity can also be flexibly configured to the company's overseas business structure, with no mandatory need to establish a new EU entity—further lowering the barrier to entry. Through its highly integrated and adaptable design, Ampace helps enterprises unlock access to the EU market with lower investment and greater speed, while supporting long-term compliance with the requirements of the EU Batteries Regulation.

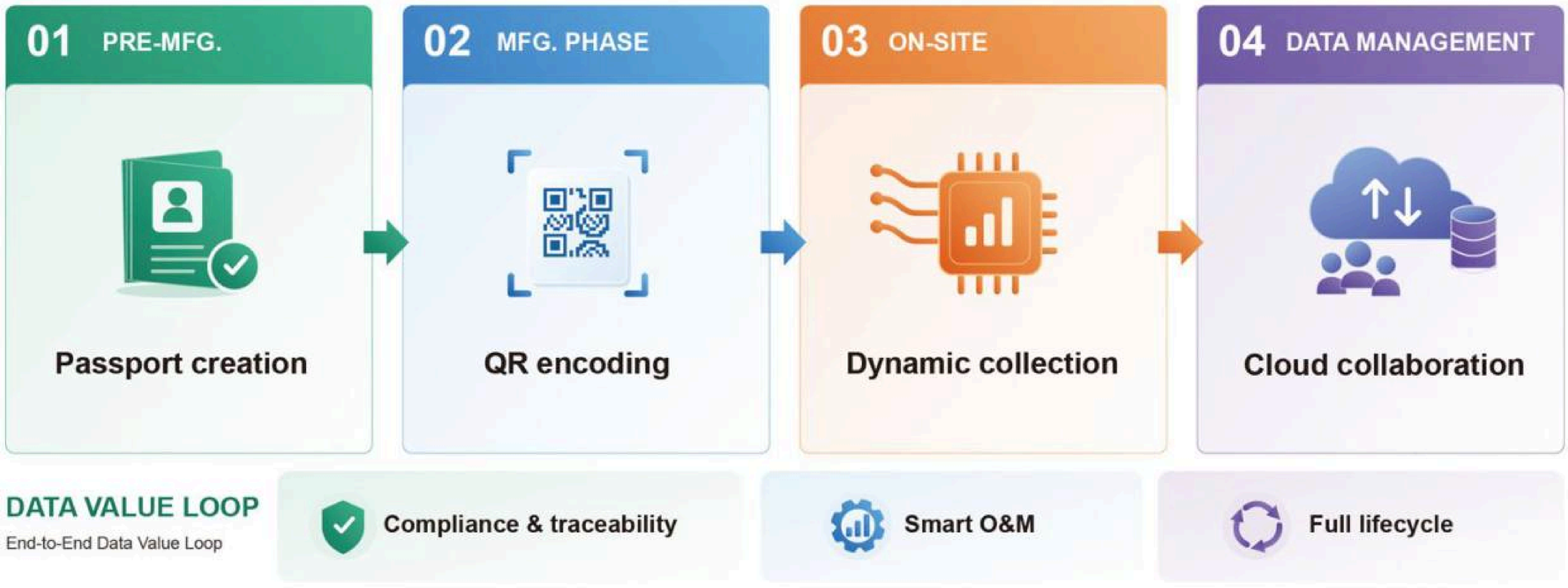


Figure 4-6 Full-Lifecycle Data Management for Battery Passport

Chapter 5 Ampace's Value Proposition

5.1 Delivery Assurance Management: Building Certainty in Delivery Through Systematic Capabilities

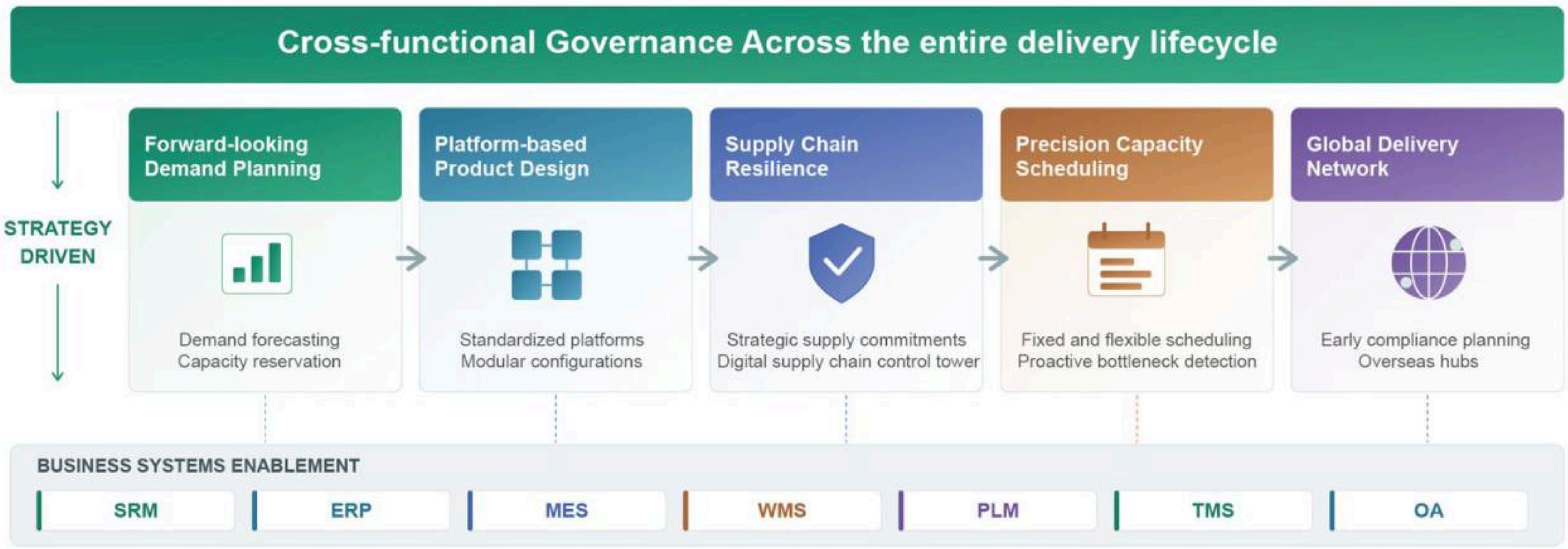


Figure 5-1 Ampace Delivery Management Chain

The explosive growth of global AIDC construction is reshaping how battery suppliers compete—delivery capability has become as decisive as product performance in partner selection. With delivery times tight across the industry, capacity reservations and long-term supply agreements are becoming standard market practice. In response, Ampace has elevated delivery assurance into a systematic engineering discipline: with "deterministic delivery" as the core objective, it has built an end-to-end assurance system (Figure 5-1) spanning demand foresight, platform-based design, supply chain collaboration, capacity scheduling, a global network, and organizational governance—converting volatile market demand into commitments that are executable, traceable, and deliverable.

Mechanistically, Ampace moves delivery management upstream of the order: capacity reservation assessments begin as soon as key customers signal bidding intent, demand guidance flows to the supply chain 3–6 months ahead, and a three-tier delivery priority matrix guarantees capacity for key projects even under high load. On design, Ampace engages early at the technical-agreement stage, converging non-standard requirements onto four standard platforms—cells, structure, BMS, and electrical interfaces—serving customer needs quickly through flexible combinations while strictly limiting new part numbers, cutting on-site installation time by roughly 70%.

At the supply chain level, a digital supply chain control tower orchestrates the end-to-end chain. Medium- and long-term strategic agreements for key raw materials lock in capacity with core suppliers to ensure continuous allocation; a combined rigid-flexible scheduling plan follows the delivery priority matrix; and capacity-bottleneck pre-checks for key processes are completed at order confirmation, with expansion or outsourcing plans triggered in advance.

For global markets such as Europe, the Americas, and Southeast Asia, Ampace has built a localized stocking and regional response network: market-access adaptation for UL, CE, IEC, and other standards begins at order confirmation to achieve "compliance at launch," while regional warehouses and local service teams safeguard end-to-end delivery timelines.

Cross-functionally, a joint governance mechanism ties supply completeness, schedule adherence, first-pass yield, and on-time logistics into a single delivery-cycle assessment—closing the loop from order confirmation to delivery, with full-chain information transparency and rapid issue resolution.

Delivery certainty is not a promise—it is a systematic capability spanning demand sensing, design convergence, supply chain layout, capacity scheduling, and global deployment. As the global AIDC industry shifts from "competing on capacity" to "competing on delivery," Ampace will keep providing customers worldwide with predictable, trustworthy long-term delivery commitments through this systematic capability.

5.2 ESG and Carbon Footprint: Supporting Data Center Carbon Neutrality Goals with Low-Carbon Battery Technology



Figure 5-2 Sustainable Development Management Strategies

The explosive growth of AI computing has made data center energy consumption and carbon emissions a focal point of the global ESG agenda. Under the combined pressure of China's carbon peaking and carbon neutrality goals, the EU Battery Regulation, and customer carbon disclosure requirements, carbon neutrality for data centers has shifted from a "nice-to-have" to a "must-have." As a key link in the power supply chain, the carbon footprint and lifecycle environmental performance of battery products are increasingly built into AIDC owners' procurement evaluations—choosing low-carbon batteries means choosing a lower carbon baseline for computing operations. Ampace embeds sustainability in its business management (Figure 5-2): guided by the UN Sustainable Development Goals (SDGs) and as a signatory to the UN Global Compact, Ampace earned an EcoVadis Gold Medal in 2026, receiving authoritative international recognition across all four assessment themes—environment, labor and human rights, ethics, and sustainable procurement. The rating confirms that Ampace not only runs low-carbon operations itself but also practices responsible sourcing across its supply chain, further strengthening value-chain management and building a sustainable computing ecosystem together with customers. Across product carbon footprint, green manufacturing, and circular recycling, Ampace turns its systematic zero-carbon capabilities into its customers' carbon-reduction assets.

At the product level, Ampace builds a full-lifecycle low-carbon system along four pathways—"zero-carbon design—zero-carbon manufacturing—zero-carbon supply—circular regeneration." Zero-carbon design cuts a product's carbon footprint at the R&D stage; at the same time, lithium-ion batteries' exceptionally long service life—compared with lead-acid solutions—significantly reduces replacement-related carbon emissions. For zero-carbon manufacturing, Ampace passed the TÜV SÜD audit in March 2026 and obtained ISO 14068-1:2023 carbon neutrality certification, achieving carbon neutrality in its own operations. On the zero-carbon supply side, dedicated LCA guidance is provided to suppliers of key raw materials such as cathode, anode, and electrolyte materials, securing products' low-carbon credentials at the source. For circular regeneration, Ampace collaborates with ecosystem partners to advance closed-loop resource utilization and reverse battery traceability management, reducing dependence on virgin minerals and addressing environmental responsibilities at the retirement stage.

In carbon data management, Ampace has established an institutionalized, digitalized support system. Three core procedural documents, formulated in accordance with ISO 14064-1:2018 and the GHG Protocol, ensure the global comparability and credibility of its carbon data. In 2026, Ampace will launch a battery passport and carbon footprint calculation system covering 100+ environmental data points across the entire lifecycle, giving customers ready-to-use product carbon footprint data. A dedicated task force on the EU's new Battery Regulation shields customers from international carbon-barrier risks. Ampace also continuously improves supply chain environmental data quality, guiding suppliers to build carbon accounting systems and identify emission-reduction potential.

For AIDC customers, choosing Ampace low-carbon batteries directly improves Scope 3 emissions data and provides substantive support for their carbon neutrality roadmaps; certified low-carbon products command green premiums in the global market and are an important credential for winning high-end computing customers and international orders. Ampace has set a third-party-verified target of value-chain carbon neutrality by 2035. Customers who choose Ampace are choosing a long-term decarbonization partner with clear goals and a credible pathway.

5.3 Helping Customers Maximize IT Output: Unlocking Computing Value Through Lithium-ion Battery Space Advantages

5.3.1 The "Zero-Sum Game" Between Power and Computing Space

In the investment logic of AIDC, every square meter of a data center has a clear value assignment: space used for IT equipment generates computing revenue, while space used for power and distribution infrastructure is a necessary cost with no direct return. As land, construction, and electromechanical costs keep rising, maximizing IT load within a given footprint has become a key variable in project return on investment (ROI).

Traditional lead-acid battery solutions are the "high space consumption" in this competition. Constrained by low energy density (typically 35–45 Wh / kg) and low discharge rates, the lead-acid bank needed for the same backup duration is enormous, often requiring a dedicated battery room plus extra spending on floor reinforcement, ventilation and cooling, and acid-fume protection. In high-power-density AIDC scenarios, this tension intensifies—backup power demand surges, and sticking with lead-acid would multiply the battery room footprint, directly squeezing out valuable space that could otherwise host IT racks.

5.3.2 Space Benefits of Lithium-ion Battery Solutions: From "Saving Space" to "Increasing Output"

With high energy density and high-rate discharge, Ampace's high-performance lithium-ion battery solutions deliver reliable space savings and output gains for customers. For the same backup power and duration, lithium-ion battery systems cut footprint by roughly 50%–70% versus traditional lead-acid: the battery room shrinks from a "large dedicated room" to a "compact battery zone" and can even share a room with the UPS. Lithium-ion systems also weigh only about a third as much as lead-acid systems, significantly lowering floor-loading requirements and allowing flexible placement on standard floors—no longer tied to ground floors or reinforced areas—which gives civil design and equipment room layout far greater freedom. The real value of this freed-up space is its conversion into IT capacity: in an

AIDC project with 10 MW-scale backup power, for example, the area saved by lithium-ion batteries can directly accommodate dozens of additional high-power racks—substantial computing rental revenue over the project's lifecycle. Choosing a battery solution is, in effect, choosing IT production capacity. In addition, the 8–15 year service life of lithium-ion batteries spans a data center's core operating cycle, avoiding the disruption of wholesale replacement every 3–5 years under lead-acid and further ensuring the continuity of IT output.

5.4 Standards Leadership: Building a Standards System to Safeguard the Stable and Long-Term Development of the AIDC Battery Industry

The delivery assurance, low-carbon value, and space benefits described above answer the question of "what kind of battery supplier AIDC needs"; whether the industry can develop sustainably over the long term ultimately depends on "what kind of battery counts as qualified and reliable." Standards are the institutional answer to that question. Today, AIDC battery applications are in a stage where "applications lead and standards lag": while current global standards essentially cover the safety baseline across cells, systems, and management, entirely new operating conditions—millisecond-scale pulse impacts from AI loads, high-frequency shallow charge / discharge micro-cycling, long-term high-SOC float charging, and 800 V high-voltage direct current (HVDC)—have clearly outgrown the assessment boundaries of existing standards. As a battery manufacturer deeply engaged in AIDC applications, Ampace strictly benchmarks its R&D and validation against current standards while actively advancing next-generation standards for AI operating conditions.

5.4.1 Current Battery and System Standards

The current standards system related to AIDC batteries can be divided into three levels: cell / module / pack, system, and BMS. At the cell level, IEC 62619, UL 1973, and UL 9540A form the cornerstone of safety market access in North America and globally, while in China, GB 44240, GB 40165, and GB/T 36276 establish comprehensive requirements across three dimensions: mandatory safety, stationary equipment specifications, and product performance. At the system level, IEC 62477-1 and IEC 62040-1 respectively specify safety requirements for power electronic conversion systems and UPS systems, and the thermal runaway assessment of UL 9540A also extends to the system level. At the BMS level, GB/T 34131-2023 and IEC 60730-1 respectively define the functional performance and electrical control safety baseline. Overall, current standards already cover the end-to-end safety baseline and can support basic market access for today's AIDC projects; what is still missing is targeted assessment of AI dynamic loads—precisely the core direction of next-generation standards.

IEC
International Electrotechnical Commission

UL
Underwriters Laboratories

GB
Chinese National Standards
国家标准

5.4.2 Future Standard Trends for AIDC Batteries

AIDC battery operating conditions differ fundamentally from traditional energy storage—millisecond-scale high-power pulses, long-term high-SOC float charging, high-frequency shallow micro-cycling, 800 V HVDC architectures, and compute-energy coordinated dispatch are driving accelerated standards evolution in four directions.

First, reconstruction of operating conditions and test methods. Future standards will shift from traditional constant-current, constant-power cycling to simulated real AI loads, adding tests such as millisecond-scale pulse impact, high-frequency shallow micro-cycling, and long-term high-SOC float-charge aging—expected to become mandatory type-test requirements. Products will be clearly differentiated into power-type and energy-type, with new metrics such as pulse rate, continuous rate, and pulse cycle life replacing the single deep-cycle-life assessment. For 800 V DC architectures, specialized tests—DC insulation, high-voltage BMS, DC-side fault ride-through, arc protection, and liquid-cooling coupling—will also be progressively refined.

Second, safety requirements will escalate from "no fire, no explosion" to full-chain risk management. Thermal runaway constraints will extend to thermal propagation suppression and vent-path control, with explicit requirements for cell spacing, thermal barriers, flame-retardant enclosures, and busbar temperature resistance in high-density stacked cabinets. BMS functional safety will center on verifying protection logic under high-frequency pulse conditions, preventing nuisance tripping and failure to trip in high-current pulse scenarios. As battery systems join compute dispatch, cybersecurity requirements—communication tamper-proofing, log retention, alarm traceability—will enter the standards. Evaluation methods for SOH, internal resistance, and thermal characteristics, along with AIDC-specific retirement thresholds, will also be standardized, accelerating the shift from periodic inspection to predictive maintenance.

Third, standardization of architecture, interfaces, and interoperability. The topology, grounding, insulation, and protection logic of HVDC-coupled architectures will be clearly defined, along with installation, transportation, and on-site verification specifications for prefabricated integrated battery cabinets. Unified standards will emerge for batteries' external telemetry data models (millisecond-scale voltage, current, SOC, SOH, and fault alarms), communication protocols, and sampling accuracy, supporting load buffering, black start, and source-grid-load-storage coordination. Battery passport and digital twin requirements will align with the EU Battery Regulation and China's energy storage digital traceability system, enabling full-chain data traceability from cell to module to system.

Fourth, upgraded evaluation systems for life, reliability, and environmental adaptability. Traditional deep cycling will no longer be the sole life criterion; float-charge aging life, pulse micro-cycle life, temperature-cycling life, and multi-factor accelerated aging methods will together form a new evaluation framework. With liquid cooling adoption accelerating, standards will distinguish air-cooled from liquid-cooled test conditions and strengthen environmental adaptability assessments such as cell temperature-difference control, condensation, and in-cabinet high temperatures.

The direction of standards evolution is essentially a preview of product competitiveness—companies whose products first meet the assessment logic of future operating conditions will gain first-mover advantage when those standards take effect. Ampace uses current standards as its R&D verification baseline and has proactively built a rigorous internal verification system around AI dynamic operating conditions—covering high-frequency micro-cycle life, high-SOC float-charge aging, and dynamic-condition consistency. These requirements generally exceed current industry standards and are consistent with the dynamic-condition testing capabilities described in Section 3.2.1. At the same time, we look forward to working with industry partners, standards organizations, and end customers to turn frontline engineering practice into industry consensus—moving AIDC batteries from "scenario innovation" to "standard maturity" and laying an institutional foundation for the safe, reliable, and sustainable development of global computing infrastructure.

Chapter 6 Case Studies

6.1 Case Study 1: Ningxia Zhongwei Zone D Project



Figure 6-1 Ningxia Zhongwei Zone D Project

The Zhongwei AIDC project (Figure 6-1) showcases the project owner's capabilities in both "speed" and "technology": a fully modular architecture compressed the delivery cycle from one year to roughly 100 days, while an HVDC, air-liquid-compatible design established a replicable, scalable, standardized foundation. The project adopted Panama Power for direct conversion from 10 kV AC to 400 V DC—a one-step power architecture that cut equipment construction workload by approximately 40% and floor space by approximately 50%, a benchmark implementation of the customer's self-developed power supply architecture.

The project deployed Ampace's high-performance semi-solid-state lithium-ion batteries. Compared with traditional lead-acid batteries and conventional LFP batteries, this solution is smaller and lighter. Combined with prefabricated, integrated delivery in containerized enclosures, it significantly shortened on-site construction time and aligned seamlessly with the project's 100-day delivery pace.

On safety, the containerized enclosure addresses the major challenges of large-capacity lithium-ion batteries in data centers: cell-level semi-solid-state intrinsic safety, module-level active fire suppression, container-level isolation, and water-based firefighting as a final safeguard together form an integrated protection system spanning electrical safety, thermal management, and fire suppression. This confines battery safety risks within the enclosure and mitigates at the source concerns such as thermal runaway, fire propagation, and personnel risks during operation and maintenance. The enclosure supports integrated lifting and independent deployment, enabling safety zoning and flexible capacity expansion—a safe, highly integrated, and scalable model for large-scale AIDC replication.

6.2 Case Study 2: Eaton Modular Prefabricated Data Center Solution

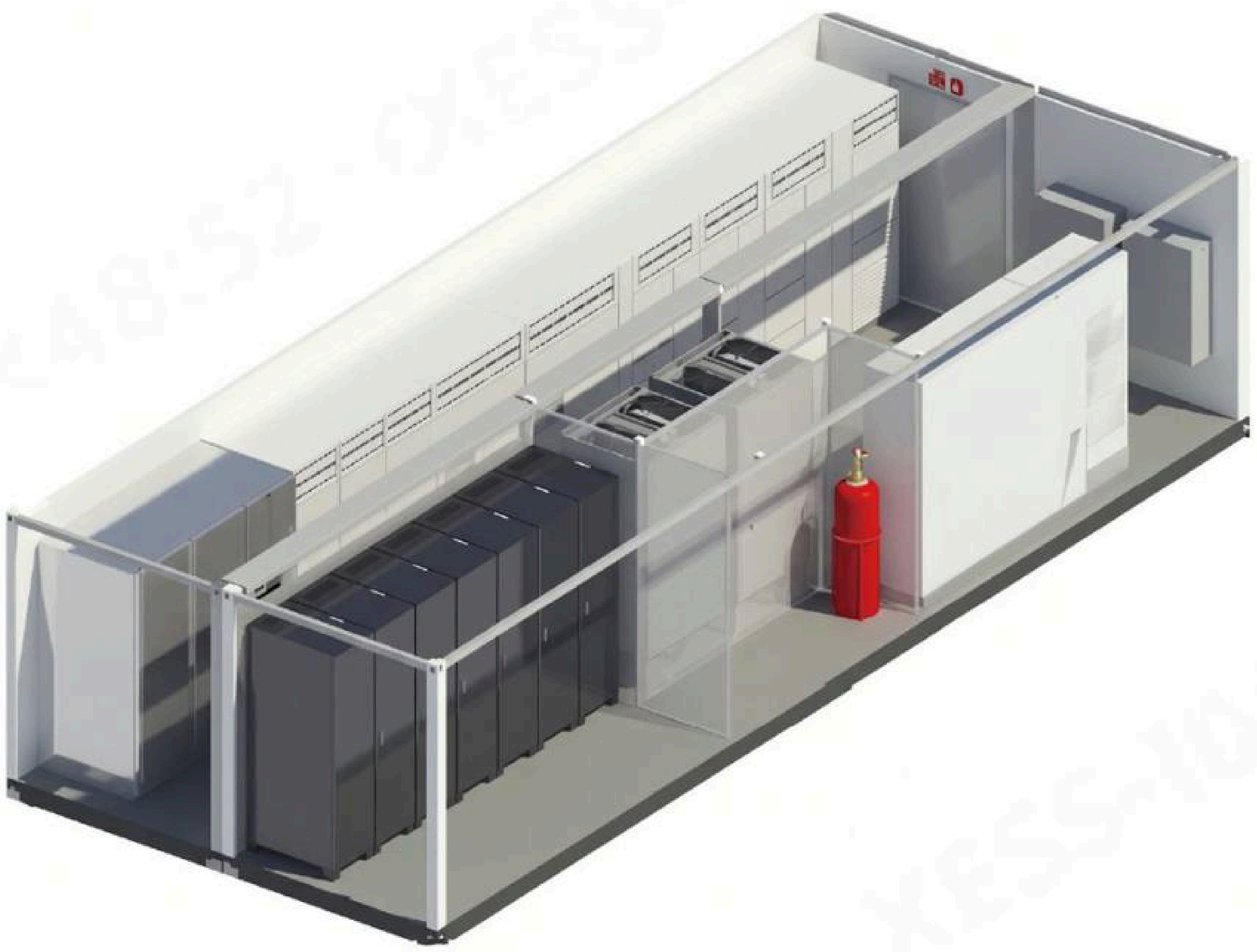


Figure 6-2 Power Train Unit (PTU)

With data center delivery timelines under severe compression, both backup power and AIDC applications face mounting pressure to meet tight deadlines. Targeting the prefabricated modular data center (PMDC) market, Eaton has advanced a strategic shift from "single products" to "modular solutions." Its core offering—the containerized Prefabricated Module Unit (Figure 6-2)—integrates key power supply and distribution components, including medium-voltage switchgear, dry-type transformers, low-voltage switchgear, 9395XR UPS units, lithium-ion battery backup units, cooling units, and intelligent monitoring systems, into standard prefabricated modules at the factory, enabling plug-and-play functionality and rapid delivery.

Eaton's prefabricated solution offers three key advantages. First, rapid deployment reduces delivery timelines by approximately 50 percent compared with traditional construction methods, helping customers capitalize on the window of opportunity created by the surge in AI computing power. Second, modular and flexible scalability enables power modules to be added as needed, supporting smooth data center expansion in line with business growth. Third, compact footprint and high reliability: a single PTU delivers 2.5 MW while meeting IP55, seismic, and fire resistance requirements, with a containerized design service life exceeding 25 years. In addition, Eaton's next-generation MW-class modular UPS platform ensures full-power support for sudden AI load fluctuations, significantly enhancing power availability and operational flexibility and delivering efficient, reliable, and scalable integrated power solutions for large-scale and AI data centers.

Chapter 7 Summary and Future Outlook

AIDC power supply architecture is evolving from a "steady-state IDC backup power system" toward a new hybrid architecture defined by highly dynamic loads, high power density, and the decoupling of compute and power lifecycles. Panama HVDC, medium-voltage centralized UPS, Sidecar + BBU distributed resilient backup, and prefabricated container solutions each address different scales, safety levels, and domestic and international compliance requirements—forming a layered, complementary technology spectrum that gives AI compute clusters diverse deployment paths.

In this evolution, rapid delivery, modular prefabrication, and factory-front-loaded integration are shifting from project "nice-to-haves" to non-negotiable industry requirements. Large overseas AIDC clusters commonly adopt prefabricated container models, completing pre-assembly and joint commissioning of batteries, BMS, power distribution, thermal management, and fire suppression in the factory. This compresses on-site construction and multi-vendor cross-commissioning to the minimum, avoiding the compounded risks of overseas labor, project timelines, and compliance acceptance. As competition in compute intensifies, speed to power will become a core competitive advantage, and prefabricated, modular, interface-standardized integration models will only gain further traction.

Over the long term, compute-side evolution will continue to reshape energy storage product definitions. NVIDIA's next-generation GPUs and full-rack architectures keep raising per-rack power, intensifying instantaneous load ramp-up and ramp-down stress. This imposes ever-stricter requirements on supporting energy storage: short-duration high-rate throughput, millisecond-scale dynamic response, high-frequency micro-cycle tolerance, and higher volumetric power density. Traditional lithium-ion batteries designed for long-duration backup and low-rate float charging will struggle to keep pace with next-generation compute workloads. High-power-density storage products for Sidecar end-of-row BBU and prefabricated skid / container applications will be the primary growth engine of the AIDC energy storage market.

Ampace continues to invest in high-power-density cells, product-level full-lifecycle traceability, intrinsic safety for white-space areas, and an open, interoperable battery passport compliance system—building product and solution reserves for NVIDIA's next-generation compute architectures. Ampace looks forward to working with ecosystem partners to advance standardized prefabricated integration, dynamic-condition battery management, and end-to-end EU battery compliance—supporting the efficient, stable, and predictable global deployment of next-generation large-scale AIDC clusters while holding the line on safety, cost, and compliance.

The multi-tier power supply architecture—"batteries paired with UPS as the backbone, complemented by BESS and rack-level storage"—will gradually materialize through the dual evolution of compute and energy: BESS will play a growing role in renewable integration, peak shaving and load shifting, and grid ancillary services, turning power supply assets from "cost centers" into "revenue centers." Rack-level energy storage, riding the proliferation of OCP architecture and HVDC, will evolve toward distributed forms closer to the load. The competitive frontier for battery companies will likewise expand from backup power performance alone to full-stack capabilities spanning "backup power + energy storage + energy management."



Appendix A: Ampace Technical Specification Overview

The following table summarizes the core product and technical specifications of Ampace referenced in the main body of this White Paper. For specific test conditions and statistical methodologies, please refer to the official product data sheets.

Specification Dimension	Key Parameter	Corresponding Section
Voltage Platform	UPS-coupled 480 V DC–512 V DC (planned evolution to 1500 V DC); Sidecar 48 V and ± 400 V (800 V DC between poles)	2.5 / 2.6
Dynamic Cycle Life	>100 million cycles under 1 s / 1 s high-frequency charge-discharge; degradation characteristics essentially comparable to conventional steady-state calendar life test results	3.2.1
Life & Capacity Retention	≥10-year operational life, end-of-life (EOL) SOH ≥70%; full-lifecycle capacity deviation ≤0.2%	3.2.1
Rate Capability & Temperature Rise	Overall temperature rise ≤10 °C under 6C high-rate discharge; excellent RCC consistency under 6C discharge / 1C charge asymmetric duty cycles	3.2.1
Electrolyte Control	Free electrolyte residue ≤0.05 g / Ah throughout full lifecycle	3.2.1
Reliability Validation	11 cell-level safety tests; floating-charge accelerated aging model; calendar life >15 years (70% SOH)	3.2.2
Backup Duration	North American EOL 5-minute (6C–10C high-rate options) and Chinese national-standard EOL 15-minute configurations	3.3
Fire Safety	Four-dimensional fire protection system; 1:1 empirical validation demonstrating single-module complete combustion without propagation across modules or cabinets	4.4.1
Compliance Capability	Turnkey EU Battery Passport compliance solution (EU 2023 / 1542); IEC 62443 industrial cybersecurity	4.4.2

Appendix B: Glossary of Terms

Term	Definition
AIDC	Artificial Intelligence Data Center
ASIC	Application-Specific Integrated Circuit
BBU	Battery Backup Unit - typically deployed at the rack side for end-point backup
BESS	Battery Energy Storage System
BMS	Battery Management System
Battery Pack	An integrated unit of battery cells / modules
CBU	Capacitor Backup Unit
DOD	Depth of Discharge
EOL	End of Life; EOL 5 min refers to the battery's ability to meet rated 5-minute backup discharge requirements at end-of-life
ERCOT	Electric Reliability Council of Texas
FEOC / PFE	Foreign Entity of Concern / Prohibited Foreign Entity
FERC	Federal Energy Regulatory Commission (U.S.)
GPU	Graphics Processing Unit
HVDC	High Voltage Direct Current
LCA	Life Cycle Assessment
LFP	Lithium Iron Phosphate
MACR	Material Assistance Cost Ratio
NERC	North American Electric Reliability Corporation
OBBBA	One Big Beautiful Bill Act
OCP	Open Compute Project
PPA	Power Purchase Agreement
PDU	Power Distribution Unit
PUE	Power Usage Effectiveness
RCC	AC Equivalent Internal Resistance
SOC	State of Charge
SOH	State of Health
SST	Solid-State Transformer
TCO	Total Cost of Ownership
Thermal Runaway	A phenomenon in which uncontrolled exothermic side reactions within a battery cause a rapid temperature rise, potentially leading to fire or even explosion
UPS	Uninterruptible Power Supply
VED	Volumetric Energy Density



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