VERTIV.

Powering the thermal chain

Supporting mechanical loads with Vertiv™ Liebert® APM2 UPS

Powering the thermal chain: Reliable UPS protection for mechanical loads including CDUs or pumps in AI data centers

Artificial intelligence (AI) and high-performance computing (HPC) are driving power densities to levels that challenge the limits of traditional air cooling in data centers. With graphics processing unit (GPU) racks consuming 30 to over hundreds of kilowatts per rack, airflow-based systems may struggle to maintain safe operating temperatures, especially when cooling is interrupted even briefly. Liquid cooling is now essential because it transfers heat more efficiently and facilitates sustained performance in highly dense compute environments. Its ability to remove heat directly from the chip makes it indispensable for modern AI workloads that demand continuous, high-throughput processing.

As liquid cooling becomes a core element of data center design, the reliability of its mechanical components, pumps, fans, and coolant distribution units (CDUs) is critical to maintain system performance and uptime. These systems are typically powered by motors controlled through variable frequency drives (VFDs) and are classified as inductive loads. Inductive loads (i.e., motors, compressors, pumps) behave very differently from standard IT loads: systems and components draw current in a non-linear fashion, often with high inrush and reactive power, and can introduce harmonic distortion into the power system. VFDs bring significant efficiency benefits to CDUs that enable precise flow control, reduce energy consumption, and extend equipment life. However, they also introduce power quality challenges that must be addressed to maintain stable operation. To mitigate these risks, Vertiv recommends isolating mechanical loads with a dedicated uninterruptible power supply (UPS).

This application brief tackles the challenges of VFD-based loads, outlines the Vertiv™ Liebert® APM2's design features that address them, and highlights the benefits of protecting critical cooling infrastructure alongside IT systems.

Power challenges from VFD-based mechanical loads

Harmonic distortion and noise:

VFDs draw pulsed current rather than smooth sine waves, introducing significant harmonic distortion into the electrical system. Standard 6-pulse VFDs generate 30–50% total harmonic distortion (THDi), with dominant 5th, 7th, and 11th harmonics (e.g., 60Hz in North America, the 5th harmonic = 300 Hz). These harmonics can distort upstream voltage, overheat transformers, strain connected equipment, and violate IEEE 519 standards, causing nuisance trips and instability, particularly for generators and utility feeds.

Undervoltage sensitivity:

Mechanical loads like pumps and fans with VFDs can have limited ride-through capability when under abnormal voltage range conditions, making them highly vulnerable to voltage sags. A 10–15% dip can trigger VFD faults or drop motor contactors, instantly interrupting cooling operations. Unlike IT equipment, which can buffer short disturbances, interruptions in mechanical systems can drive temperature increases by 10 °C in under 30 seconds, well before generators can respond. Even a brief cooling loss can jeopardize IT load stability.

Poor power factor (inductive loads):

Induction motors and VFDs often operate at a lagging power factor (PF) between 0.7–0.9, drawing significant reactive power. While VFDs can improve displacement PF (DPF), their harmonic currents degrade true PF and strain generators and switchgear, increasing overall energy loss, and potentially triggering utility penalties[1] or the need for corrective measures like capacitor banks.

High inrush and transients:

Motors can draw several times their rated current during startup or have rapid speed changes. Although VFDs reduce extreme inrush compared to direct-on-line (DOL) starts, they can still produce capacitor charging surges, typically in the range of 1.2–1.5 times the normal operating current. Simultaneous pump starts or fast fan ramp-ups may demand twice to three times the steady-state current, increasing the risk of overload trips or voltage flicker if the power source is not adequately sized or conditioned.

[1] A number of electric utilities charge extra fees when a facility's PF falls below a set threshold (typically 0.90–0.95, depending on operator and location demands, among other factors). Low PF increases reactive power demand, strains the grid, and requires additional infrastructure. Penalties may include surcharges per excess kVAR or adjusted demand charges, incentivizing PF correction measures like capacitor banks. Source: U.S. Department of Energy.

Vertiv™ Liebert® APM2 UPS design features for harmonic distortion mitigation and mechanical load support.

The Vertiv™ Liebert® APM2 UL UPS (20–600 kW, 400/480 V) is purpose-built for reliable power protection of IT and mechanical loads. Its modular, advanced three-level topology with silicon carbide (SiC) technology, transformer-less design, and high-performance power conditioning capabilities help maintain clean, continuous power in the most demanding conditions.Unlike traditional approaches that require oversizing the UPS, the high power density design of the Vertiv Liebert APM2 can be right-sized to match the power needs of cooling units such as the Vertiv™ CoolChip CDU reducing wasted capacity and supporting more efficient infrastructure planning.

Vertiv Liebert APM2 uses a double-conversion topology to deliver clean, uninterrupted power by isolating mechanical loads from upstream disturbances. Mechanical loads such as pumps and fans receive stable, regulated three-phase voltage and frequency during utility outages or generator transitions. This protection limits exposure to voltage sags, surges, and fluctuations, maintaining reliable operation.

The following sections explore key design features, including an active front-end rectifier for harmonic mitigation, unity power factor across load variations, high overload and crest factor handling, and rapid voltage regulation.

Active front-end rectifier: Vertiv Liebert APM2 uses a three-level topology coupled with silicon carbide (SiC) converters in place of traditional diode- or SCR-based designs. The active front-end shapes input current to remain sinusoidal and in phase with the input voltage, delivering < 3–5% THDi and an input power factor near 0.99, even under non-linear VFD loads. This functionality acts as an integrated harmonic filter and power factor correction device. It prevents distortion from propagating upstream and keeps the utility or generator connection clean while supporting compliance with IEEE 519 guidelines. The ~0.99 input PF means upstream sources operate without the strain of reactive power or harmonic interference, avoiding generator derating, transformer overheating, and the need for capacitor banks. This provides a stable, predictable load for system-wide efficiency and reliability.

Unity power factor and dynamic load handling:
Vertiv Liebert APM2 UPS delivers full, real power at unity output PF (kW=KVA) and supports 0.5 lagging to 0.5 leading without derating. This capability is critical because inductive loads typically have lagging PF. In practice, the power factor of mechanical loads depends on the VFD quality and configuration. Vertiv Liebert APM2 supplies reactive current internally, reducing upstream stress and eliminating the need for oversizing or adding capacitor banks. Its three-level inverter maintains stable voltage and handles crest factors up to 3:1 to accommodate sudden current peaks like VFD capacitor charging.

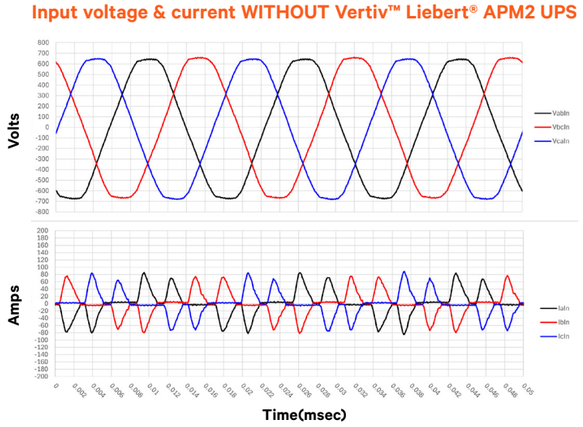

Figure 1. Input voltage and current waveforms WITHOUT Vertiv™ Liebert® APM2 UPS.
Source: Vertiv

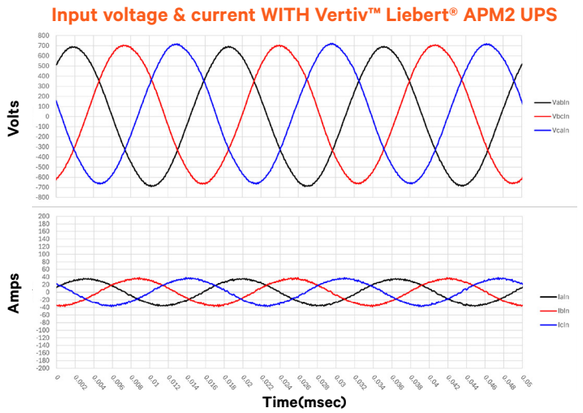

Figure 2. Input voltage and current waveforms WITH Vertiv™ Liebert® APM2 UPS.

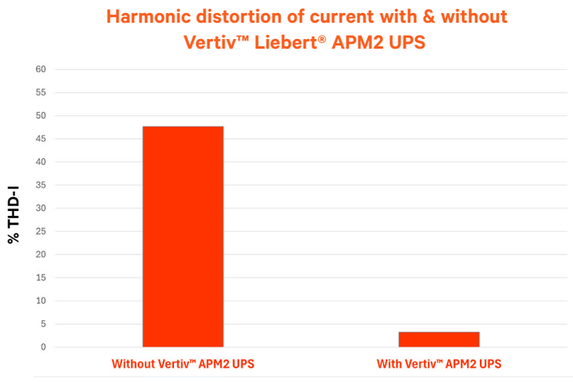

Figure 3. Harmonic distortion - THDi % with and without Vertiv™ Liebert® APM2 UPS.
Source: Vertiv

Overload capacity and fault tolerance: Mechanical loads can demand high surge currents during startup. Vertiv™ Liebert® APM2 UPS is designed to handle these conditions without compromising stability. It supports 125% load for up to 10 minutes, short-duration overloads up to 150%, and continuous operation at up to 105%. The inverter accommodates crest factor loads up to 3:1 for VFD capacitor charging or pump acceleration while maintaining voltage integrity. With a 65 kAIC short-circuit withstand rating, the Vertiv Liebert APM2 clears downstream faults effectively and protects equipment. This capability supports sequential pump starts after outages, avoiding simultaneous inrush spikes and enabling smooth recovery of cooling capacity without overload trips that could trigger a system fault.

Rapid response and voltage regulation:
Vertiv Liebert APM2 UPS combines a double-conversion design with a strong DC energy reserve and advanced control algorithms to correct voltage and frequency deviations in 4-5 milliseconds. This enables the UPS to maintain output voltages within ±1% and frequency within ±0.05 Hz. If input power is out of tolerance, batteries take over instantly with zero transfer time. This stable output keeps VFDs, motor bypass modules, and contactors in operation, preventing pumps or fans from shutting down during voltage dips, sags, swells, or generator transitions, and delivering performance comparable to an ideal utility source.

Key benefits for inductive and VFD-controlled loads

The Vertiv Liebert APM2 UPS improves reliability for CDUs, pumps, and fans by filtering harmonics, maintaining seamless power-event ride-through, and reducing infrastructure stress. These capabilities help maintain uninterrupted cooling in demanding AI environments.

- **Continuous cooling during power events:** The Vertiv Liebert APM2 UPS provides seamless power continuity for mechanical cooling systems such as CDUs, pumps, and fans, during power sags, surges, or outages. Unlike in traditional configurations, where grid disturbances can trigger VFD trips, Vertiv Liebert APM2 maintains continuous cooling in AI/HPC environments to prevent temperature spikes and degraded server performance while bridging the gap until generators come online.
- **Cleaner power quality:** Vertiv Liebert APM2 UPS filters VFD harmonics to keep THDi below 5% in alignment with IEEE 519 guidelines and corrects power factor to near unity. This protects upstream equipment, transformers, switchgear, and generators from overheating and supports overall electrical efficiency.
- **Optimized infrastructure sizing:** Without a dedicated UPS, facilities would need to oversize upstream equipment to handle unpredictable mechanical loads. Vertiv Liebert APM2 UPS stabilizes these loads and presents a clean, predictable power profile that allows generators, transformers, and breakers to be sized closer to actual cooling requirements. This approach helps reduce capital expenditures (CapEx) and simplifies electrical system design.
- **Seamless integration with cooling equipment:** Vertiv tested the Vertiv Liebert APM2 UPS with its CDUs, including the Vertiv™ CoolChip CDU across typical operating conditions such as start, stop, and inverters-to-bypass transitions with no alarms or disruptions. Vertiv Liebert APM2 absorbs peak currents during transfers, preventing faults and enabling reliable cooling without special adjustments.
- **Higher reliability with redundancy and fast recovery:** The Vertiv Liebert APM2 UPS modular design supports N+1 redundancy with hot-swappable power, control, and bypass modules that can be replaced in under 30 minutes. This minimizes downtime, eliminates single points of failure, and enables cooling UPS systems to remain electrically isolated from IT UPS systems, providing greater resilience.

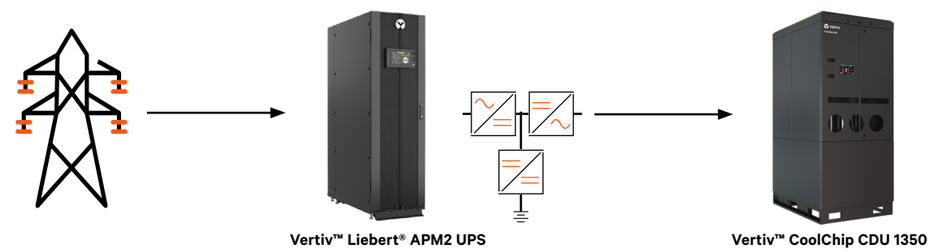

Figure 4. Vertiv™ Liebert® APM2 UPS with Vertiv™ CoolChip CDU setup.

Mechanical load challenge	Vertiv™ Liebert® APM2 UPS solution (design feature)	Outcome/benefit
Harmonic distortion	Active front-end; SiC converters	**THDi <5% clean input; IEEE 519** compliance: Clean input prevents transformer heating or generator issues
Undervoltage sensitivity	Tight voltage regulation ±1%; instant battery takeover	**No VFD trips on sags:** Supports continuous, uninterrupted cooling
Lagging power factor	Unity output PF design; ~0.99 input PF with active PFC	**No PF penalties or over-sizing:** Full kW delivery; efficient generator/switchgear loading
High inrush / transient current	125–150% overload; up to 3:1 crest factor	**Handles motor starts and load steps** without voltage drop; sequential CDU starts supported.
Shared load with IT UPS	Dedicated cooling UPS	**Isolated mechanical block;** prevents harmonic/surge interference; enables separate redundancy

Table 1. Vertiv™ Liebert® APM2 solutions for VFD-driven mechanical load challenges.

Vertiv reference designs and validation testing

Vertiv leverages decades of expertise in both power and cooling to develop a range of **reference architectures** for liquid cooling backup power. These architectures show various CDU configurations and demonstrate how Vertiv™ Liebert® APM2 UPS integrates with CDUs and other systems to meet diverse AI data center requirements.

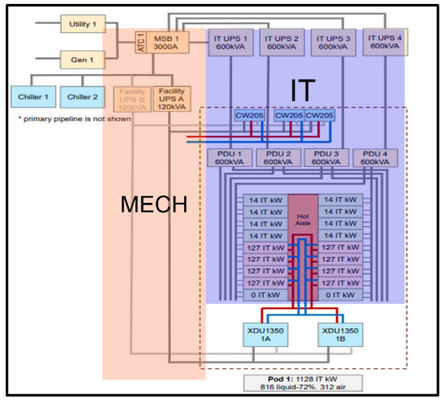

Figure 5. Vertiv™ 360AI Reference Design RD021.
Source: Vertiv
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Reference design A (4 MW cooling block):

A 90–120 kVA Vertiv™ Liebert ® APM2 UPS with ~13 kWh Lithium-ion (Li-ion) batteries (5-minute runtime, fire code compliant) supports ~4 MW cooling block using three Vertiv™ CoolChip CDU 1350 units. The system occupies a compact 35-inch footprint and includes an integrated 4-breaker bypass, sidecar distribution, and scalable UPS-to-CDU configurations ranging from 1:1 to 1:3. Vertiv validates reliable concurrent operation of all CDUs.

Reference design B (8 MW cooling block):

A 180–240 kVA Vertiv Liebert APM2 UPS supports up to ~8 MW of cooling with external Vertiv™ EnergyCore lithium battery cabinets (5-minute runtime). This configuration supports five to six Vertiv™ CoolChip CDU 1350 units. The system occupies a compact 59-inch footprint and includes an internal bypass, sidecar distribution, and scalable CDU pairing from 1:4 to 1:6. Vertiv validates this configuration for reliable and optimized system operation.

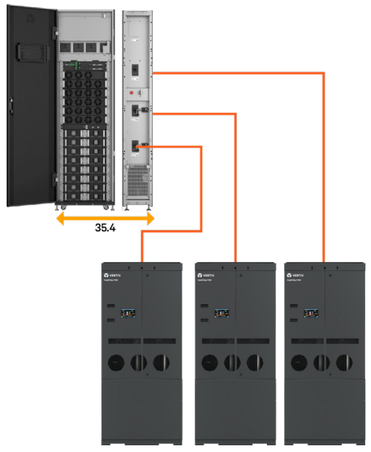

Figure 6. Reference design A: 4MW cooling system.
Source: Vertiv
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Proven system performance with Vertiv™ CoolChip CDUs

Extensive testing evaluated the Vertiv™ Liebert® APM2 UPS with the Vertiv™ CoolChip CDU 1350, and confirmed stable operation during start-and-stop cycles, inverter-to-bypass transfers, and full battery operation without triggering CDU alarms and faults. The UPS maintained continuous power under peak current conditions, proving capability to support cold starts, transient absorptions, and frequency stability.

This system-level integration gives operators the confidence in deploying Vertiv™ Liebert® APM2 UPS with Vertiv™ CoolChip CDUs (or other third-party CDUs) to support cooling continuity in AI environments.

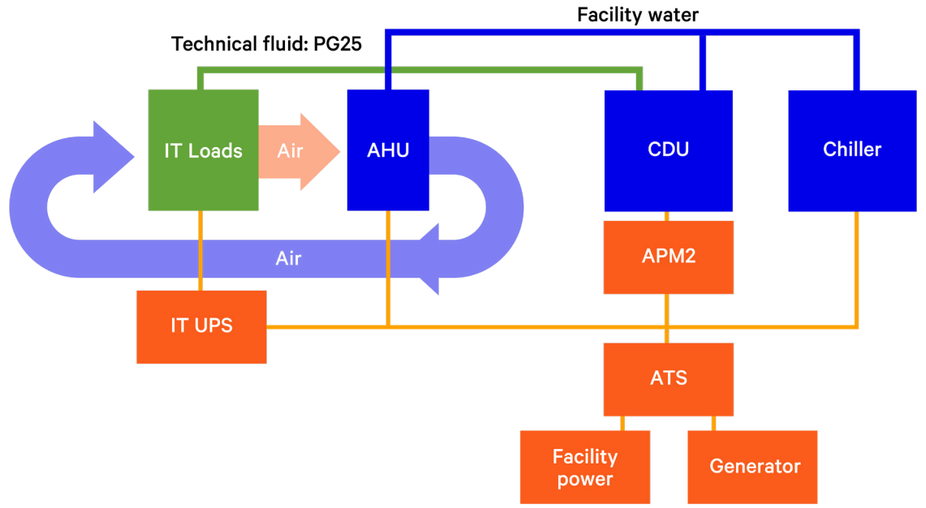

Figure 7. Schematic during laboratory testing.
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Operational benefits for AI cooling systems

- **Battery-backed cooling for IT protection:**
  Vertiv Liebert APM2 UPS bridges the gap between utility loss and generator startup, maintaining uninterrupted coolant flow and preventing thermal throttling or hardware damage.
- **Power conditioning for mechanical loads:**
  With active front-end and double-conversion isolation, Vertiv Liebert APM2 filters harmonics and stabilizes voltage and frequency, improving VFD performance and protecting upstream electrical infrastructure.
- **Resilience through redundancy and separation:**
  A modular N+1 design and <30-minute mean time to repair (MTTR) enable fault-tolerant cooling power independent of IT loads, reducing downtime risk and simplifying maintenance.
- **Verified performance and integration:**
  Lab-tested configurations confirm seamless CDU operation across all UPS modes, supporting reliable deployment and compatibility with Vertiv and third-party cooling systems.
- **Scalable and space-efficient:**
  Vertiv Liebert APM2's compact footprint and modular growth path support cooling loads from small HPC clusters to multi-megawatt AI deployments. Reference designs (e.g., 4 MW and 8 MW blocks) demonstrate space-saving solutions at scale.

Vertiv™ Liebert® APM2 delivers resilient, scalable, and validated power protection for liquid-cooled infrastructure, empowering data centers to meet the demands of AI with confidence, continuity, and efficiency.

Conclusion

In AI-driven, high-density data centers, cooling is as critical as IT power. The Vertiv™ Liebert® APM2 UPS expands power protection to mechanical loads such as CDUs, delivering clean, battery-backed power during voltage sags, surges, and outages—closing a key gap in data center resilience. By aligning power protection capacity with cooling load requirements, Vertiv Liebert APM2 eliminates oversizing for cooling loads, and supports a more scalable data center infrastructure. Its modular, right-sized design is built to support CDU requirements such as the Vertiv™ CoolChip CDU, enabling space efficiency and flexibility for future growth.

Contact a Vertiv representative today.

Vertiv™ Liebert® APM2 UPS

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