AI OPEN
DATA CENTER

Augmenting critical powertrains for fault ride-through (FRT) and load smoothing



Moving towards 800VDC solutions with lessons learned from AC UPS systems

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OCP PLATINUM Member

AGENDA

Moving towards 800VDC solutions with lessons learned from AC UPS systems

From stakeholder needs to prospective solutions and SE experience

01

Stakeholder power and energy needs

Establishing needs for data center power systems, supporting both load and source-side stakeholders

02

Prospective energy storage solutions for LVDC powertrains

Translating stakeholder needs and use cases into energy prospective 800 Vdc energy storage solutions

03

Transferrable SE industry experience and next steps

Validating approaches with lessons learned with AC powertrains

Building from DCF LVDC Whitepaper 1.1 → **Applying SE perspective**

01

Stakeholder energy storage needs and use cases

Introducing the basic stakeholders and associated needs generally identified in the Power Distribution Sub-Project whitepaper-
DATA_CENTER_FACILITY_–_LOW_VOLTAGE DIRECT_CURRENT_POWER_DISTRIBUTION





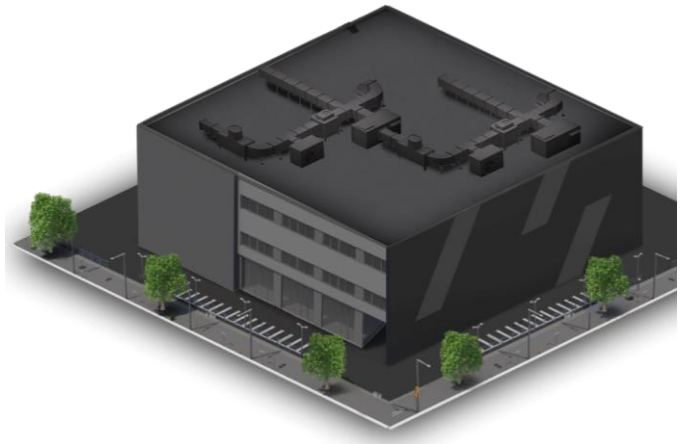
General

New workloads are shaping needs for data center energy storage and power

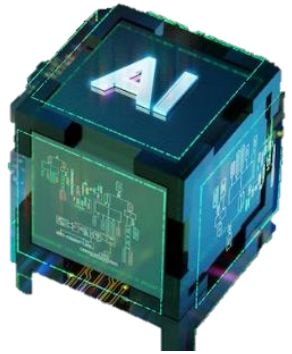
Power/Energy Sources



Data Center Power System



I.T.



Load Needs

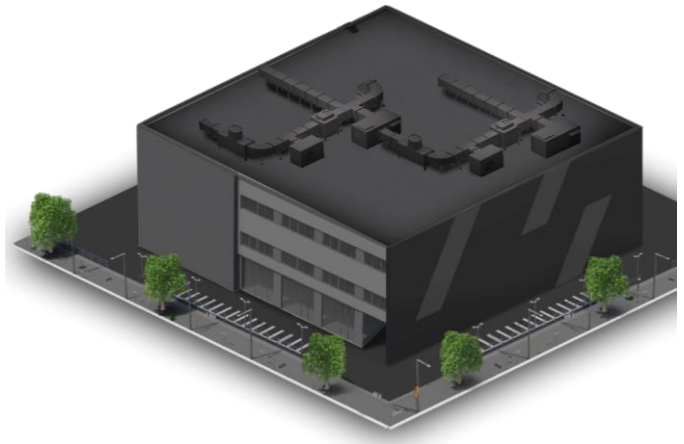
- High power and new nominal voltage with TBD voltage band
- Burst power and very high slew rate
- Persisting critical power needs (availability, UPS, and long-duration backup)

With new source-side constraints becoming mandatory considerations

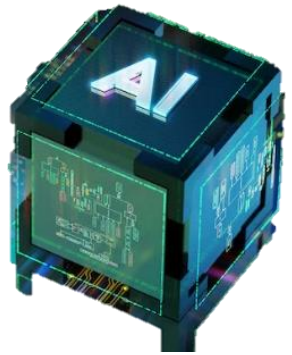
Power/Energy Sources



Data Center Power System



I.T.



Source Constraints

- Stability constraints with fault ride-through (FRT), power ramp, and sub-synchronous oscillation (SSO) needs
- Capacity constraints with peak mitigation and demand response needs

Load Needs

- High power and new nominal voltage with TBD voltage band
- Burst power and very high slew rate
- Persisting critical power needs (availability, UPS, and long-duration backup)

And increased emphasis on classical design considerations

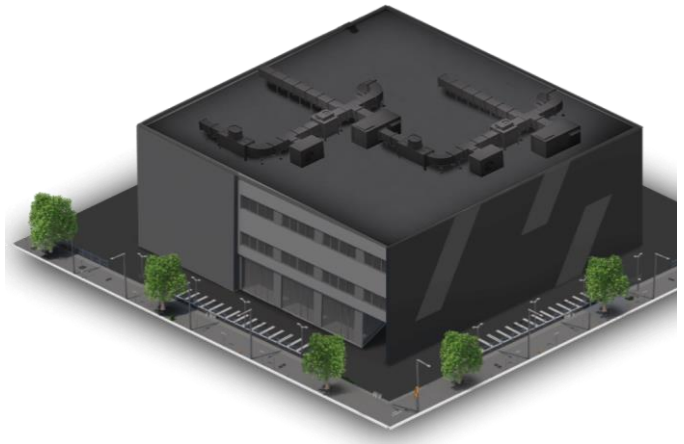
Power/Energy Sources



Source Constraints

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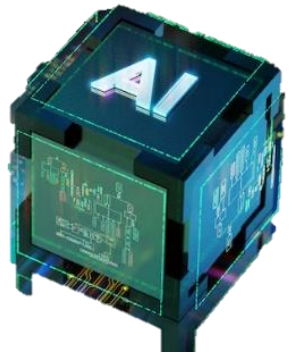
Data Center Power System



Infrastructure Optimizations

- Increase efficiency
- Lower footprint
- Manage CapEx
- Increase speed to deploy

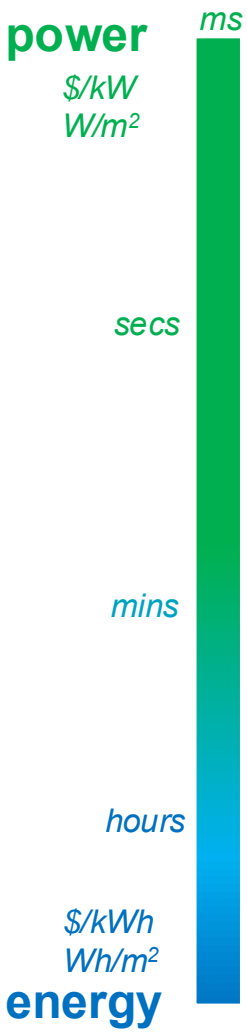
I.T.



Load Needs

- High power and new nominal voltage with TBD voltage band
- Burst power and very high slew rate
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Critical use cases can be articulated through the lens of energy storage mission profile

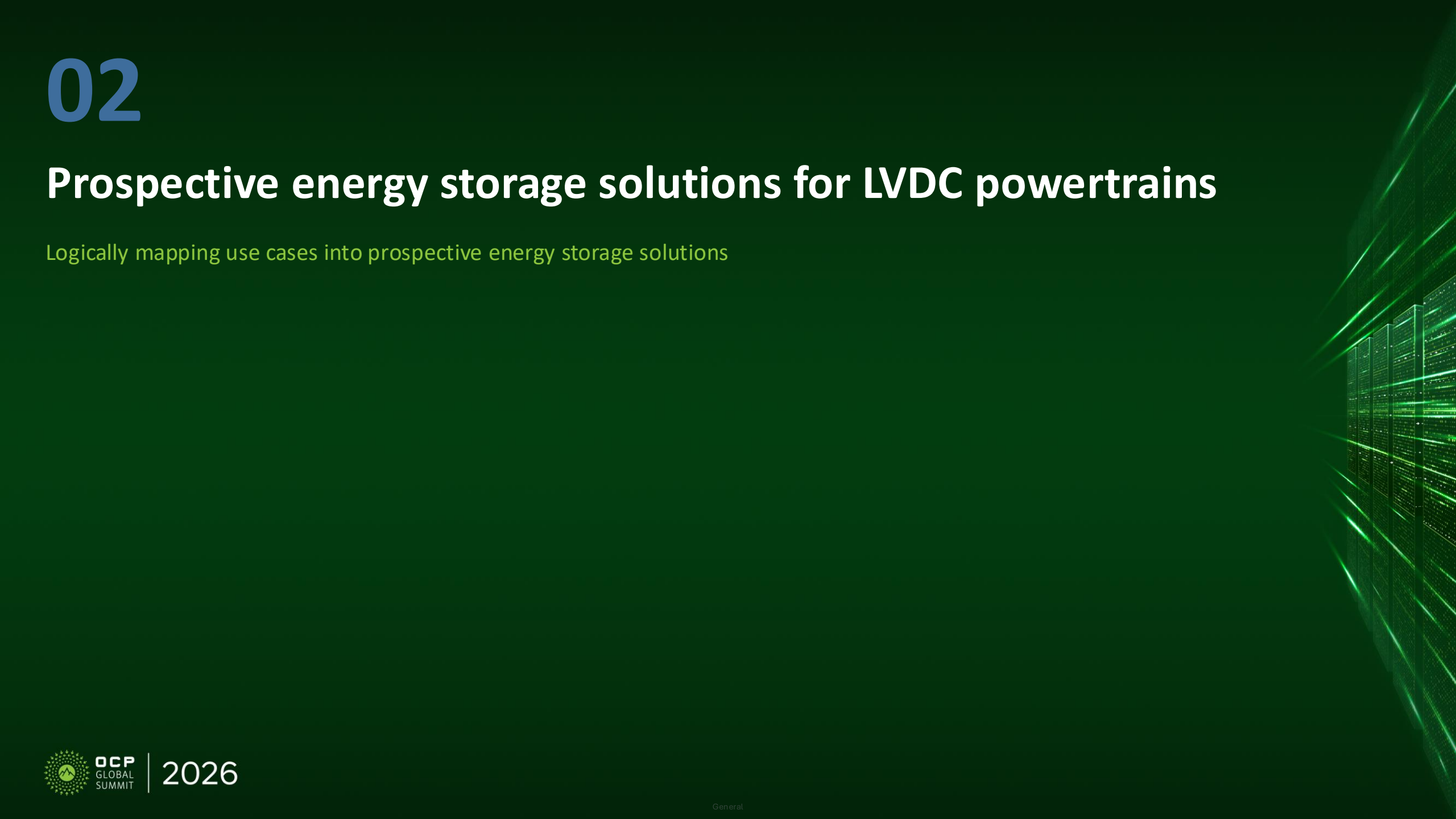


Stakeholder		Use Case	Type	Typical Duration	Dispatch Frequency
	Load & Dist. Equip.	AI Load Buffering	Power	ms to seconds	Constant use
	Grid	Grid fault-ride-through	Power	100+ ms ride through	Infrequent few events per year
G	Site Backup Gen.	Load smoothing	Power	Seconds to minutes for ramp support	Infrequent few events per year
G	Grid	Ramp limitations and SSO	Power	Seconds to minutes for ramp support and SSO mitigation	Frequent to correct AI power profile
G	Site Prime Gen.	Load following	Power	Seconds to minutes for ramp support	Frequent to correct AI power profile
	Load	UPS Backup	Power	1-15 minutes of backup	Infrequent few events per year
G	Grid	Demand response and contingency	Energy	Hours of dispatch	Infrequent few events per year/month
	Load	Site back-up	Energy	Hours to days of backup	Infrequent few events per year

02

Prospective energy storage solutions for LVDC powertrains

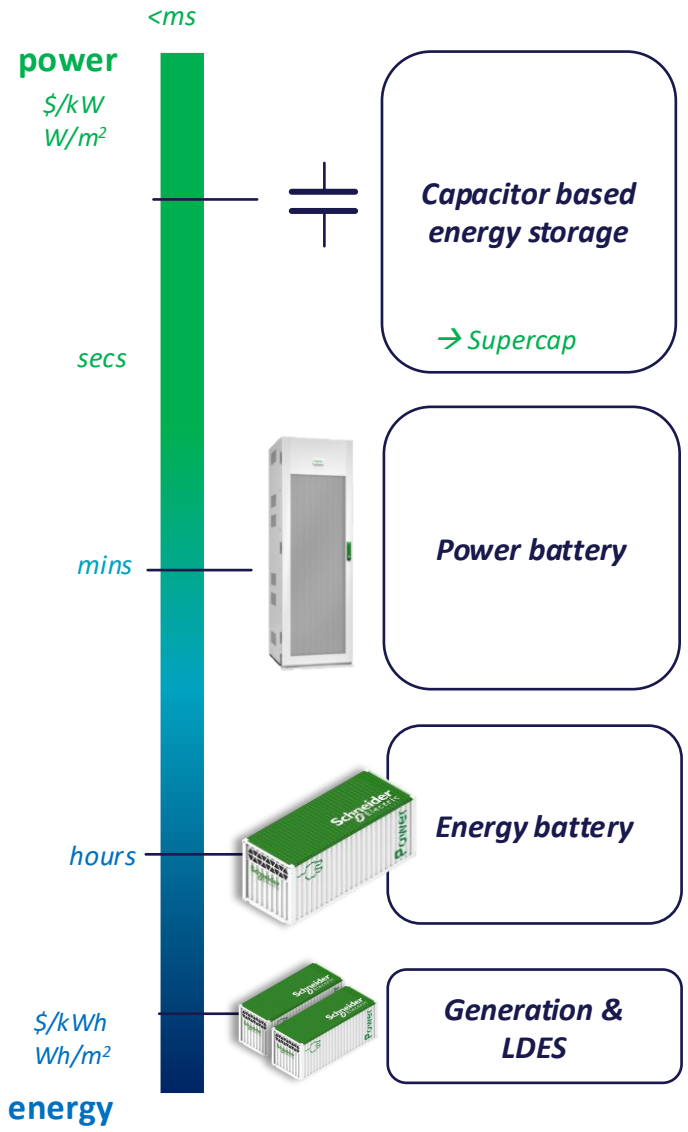
Logically mapping use cases into prospective energy storage solutions



General

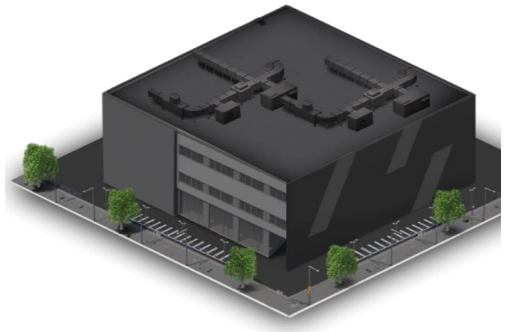
Energy storage attributes are key to solution discussions

From WP Table 8.5



Typical Duration	Form factors	Example Chemistries	Power Density	Energy Density	Cycle Life
• **µs to secs (Supercap)**	• Embedded PSU/PDB Capacitance • Capacitor shelves	• Electrolytic Caps • Film caps • Supercaps (EDLC/Hybrid)	Extremely High to High	Very Low to Low	Extremely High to High
• **Secs to minutes**	• BBU Shelves • Battery Cabinet	• Li-Ion (LFP, NMC, LMO, LTO) • NA-Ion	Very High to Medium High	Low to Medium(NMC)	Extremely High (Battery Cap) to Medium High
• **Minutes to hours**	• Battery Cabinet • Outdoor "Enclosure"	• NMC • Na-Ion • LFP	Medium	Medium to Very High (NMC)	Medium-high to High
• **Hours (8+) to days**	• Outdoor "Enclosure"	• Metal-Air • Thermal & CAES • Fuel Cell • Recip. Engine • Turbine	Medium to Low	Very High (→ separate energy from power scaling)	Continuous duty to Low (Meatal-Air)

Each architectural “level” provides different opportunities



Site/Campus Level

Typ. MV



Strengths: Close to Point of Common Coupling (PCC), covers all site loads, and less constrained on space and size (MW & footprint)

Limitations: additional power conversion needed, no mitigation for downstream equipment, and larger critical load domain

AC/DC

Powertrain Level

LV(DC)



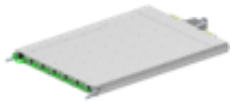
Strengths: reasonable space availability (electrical room or yard/skid), LVDC Integration (power conversion optimized), and mitigates impact to whole MV level

Limitations: limited chunk size, farther from utility interface, and needs standardization and deployability

DC/DC

Rack/Whitespace Level

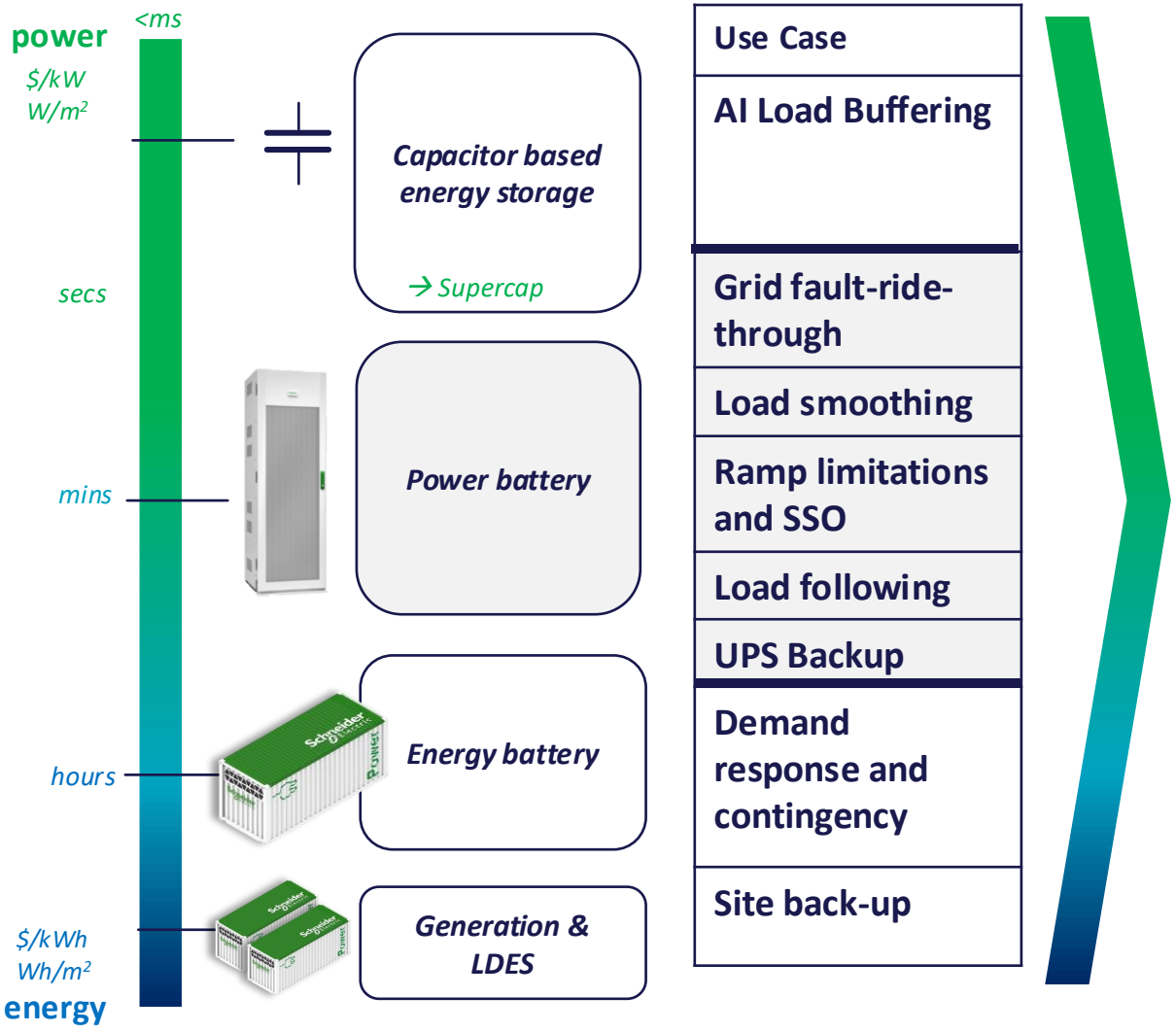
(E)LVDC



Strengths: Closest to load provides most benefit for power dynamics, and mitigates swings for upstream infrastructure

Limitations: limits on energy/duration due to limited volume for non-IT, fire-risk limits for ESS/technology choice, and operational and deployment challenges

There is no single magic bullet: a layered approach is needed with core UPS and power compliance proposed at powertrain level



1 **Whitespace capacitance(~ms) minimally sized to support system dynamics locally**

High frequency decoupling, extreme di/dt mitigation for LVDC dynamic performance. Preserve as much space as possible for IT.

2 **LVDC powertrain power battery integration secures core power compliance use cases: load continuity, FRT, smoothing stakeholders (~mins)**

Core use cases present in most data center installations, warranting standardization within the powertrain to secure critical loads and value stack power compliance

3 **Campus level solutions right-sized for non-critical load coverage and energy intensive use cases**

Campus level and utility specific coverage for longer duration use cases and coverage of non-critical powertrain components

LVDC storage solutions are not just defined by location and chemistry

There are multiple energy storage integration approaches

- Storage should be converter coupled for fault current, voltage compatibility, operations and maintenance

Droop

Pros:

- Decentralized control
- Limited need for fast real-time communication
- Flexible integration of heterogeneous power sources
- Simple system extension and high scalability

Cons:

- Intentional DC-bus voltage deviation for power sharing
- Smaller voltage margin available for regulation, transients, and cable voltage drops
- Stability constraints linking DC-link capacitance and droop band

Active Loadsharing

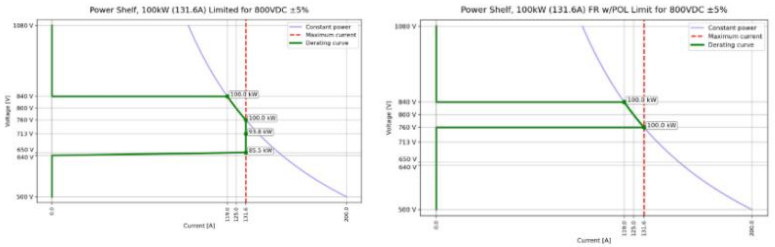
Pros:

- Tightly regulated 800 VDC bus under all load and power-sharing conditions
- Coordinated power sharing between the AC/DC and BESS DC/DC converters
- Reuses proven AC UPS control loops and communication architecture

Cons:

- Integration constraints-- dedicated protocols and buses
- Close coupling constraints and module paralleling limit inter-vendor integrations

Voltage bands must be considered in LVDC storage integration approach



Wide Band:

Traditionally DC Microgrids have utilized wider voltage bands to facilitate source/system operability and operating with power limiting converter type loads.

Narrow Band:

Modern IT solutions are targeting optimal power density and efficiency by leveraging narrow input bands

Current rack specs from Nvidia and OCP SST specs more aligned with narrow band approaches leaving less voltage band for droop

03

Transferrable SE industry experience

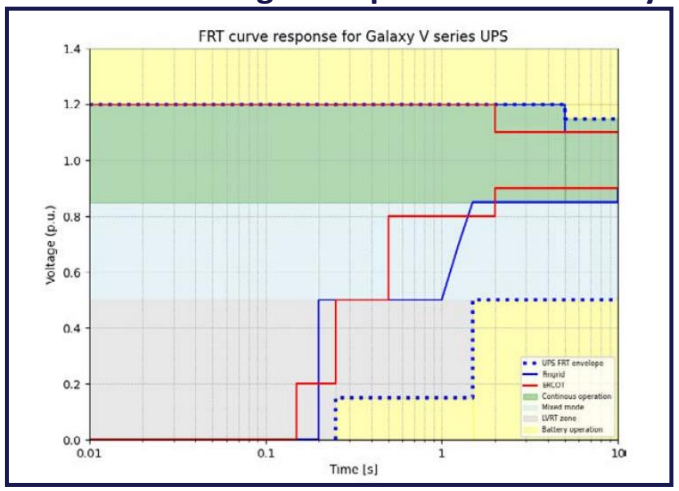
Learnings from development and deployment of critical powertrains with source power compliance augmentation



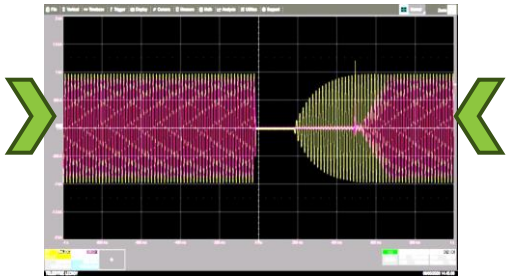
General

Coordination between storage and AC input sources for fault ride-through (FRT) and smoothing is being deployed in UPS products

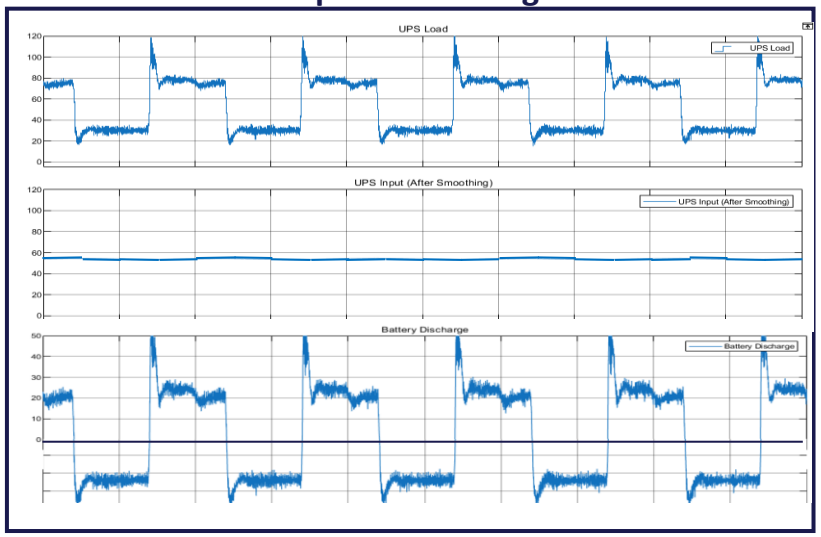
Fault ride through and post fault recovery



Being deployed in current gen UPS



Input smoothing



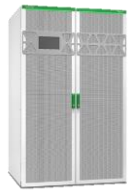
UPS Output

UPS Input

Battery

AI Load Smoothing Example (120% 100ms, 80% 0.5s, 30% 0.5s)

Area	Voltage limits	Behavior
Green area Continuous operation	1.15pu < V < 1.20pu	UPS operates in normal operation for minimum 5 seconds, taking all power from grid. *Note: GVX will support 1.25pu up to 60s.*
	0.85pu < V < 1.15pu	UPS operates in normal operation taking all power from grid.
Light blue area Mixed mode	0.5pu < V < 0.85pu	UPS operates in a mixed mode where power is taken from both grid and battery.
Grey area FRT zone	0.15pu < V < 0.5pu	UPS powers the load fully from battery but does not disconnect from the grid and will recover fast (<300 ms)
	0pu < V < 0.15pu	In this range the time limit is decreased to 250ms
Yellow area Battery operation		In this area the UPS transfers fully to battery operation and awaits a stable grid for 1 second, before transitioning back to grid operation



Galaxy UPS w/ Smoothing:
1%/sec ramp-up/down rate



Galaxy LiB Cabinet

Current power battery storage solutions can work, but future optimization is targeted

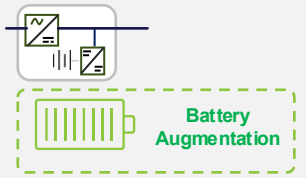
	Add batteries for power needs?	Battery lifetime impacts?
UPS Backup (~5 mins)	Baseline	Baseline (12+ years)
+ Fault Ride Through (FRT)	None	None
+ Smoothing (back-up only)	Depends on load profile and needed smoothing level	Minimal
+ Smoothing (continuous)	Depends on load profile and needed smoothing level	Typ. 5-10 years. Depends on profile, smoothing level, and cabinet quantity.

Full smoothing: 30%-75%, 1 hz		
LMO	50% duty cycle, 0.6C chrg	**12** cabinets/MW, **10 yrs**
LMO	50% duty cycle, 0.8C chrg	**9** cabinets/MW, **7 yrs**
LFP	50% duty cycle, 0.8C chrg	**7** cabinets/MW, **10 yrs**
LFP	50% duty cycle, 1.6C chrg	**4** cabinets/MW, **7 yrs**

Optimized power cabinets will be released with longer life and more charge power

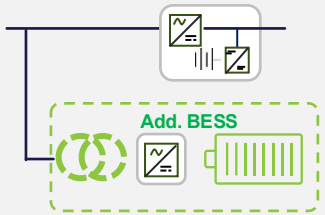
Value stacking FRT & Smoothing on critical powertrains is compelling vs new MV BESS

1



$ ~0.1-0.15 $/W Add.
~1.5-2 MW/m² Add.

2



$ ~0.3-0.6 $/W Add.
~5-15 MW/m² Add.

**UPS battery augmentation @ 0.13 $/W, BESS + PCS based on 0.5CTesla Megapack. Wider range provided to account for solution variability in augmentation approaches and BESS configurations*

Key Takeaways and Calls to Action

Storage integration is critical for load AND source side use cases

Source constraints and load needs require energy storage functions, with LVDC architectures introducing new possibilities

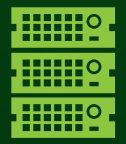
Power battery integration is compelling at powertrain level for critical power and core power compliance use cases

Power batteries at LVDC powertrain minimize whitespace penalties while allowing value stacking with UPS/critical power

Calls to action: Stakeholder architectural alignment



Standardize source side constraints to simplify storage optimization and deployment



Align IT and powertrain architectures to optimize voltage bands, energy storage selection, and load shaping capability.

Relevant Links

Power Distribution Sub-Project page

Data Center Facility – Low Voltage Direct Current Power Distribution

Energy Sub-Project page


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GLOBAL
SUMMIT
October 12-15, 2026
San Jose, California
General