Megapack for Data Centers
Powering the Growth of AI Infrastructure

October 2025

TESLA

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Megapack 2 XL overview

01
AC battery modules (x24)

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Grid-tied inverter (x24)

03
Thermal cabinet

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Customer interface (AC breaker)

05
Thermal roof

06
IP66 enclosure

Megapack use cases at data centers

01

Power load smoothing, AI training

Smooth AI training power demands and ramp rates to meet utility and generator requirements

02

Low-voltage ride through

Meet emerging utility requirements

03

Flexible interconnection

Accelerate speed to power in partnership with utilities

04

Backup power

Emissions-free back up power

“Today’s problem is dealing with extreme power jitter…

…We are having some power fluctuation issues, when you do synchronized training it’s like having an orchestra and it can go loud to quiet very quickly, at the sub-second level. The electrical system freak out about that—with 10–20 MW shifts several times per second.”

Elon Musk
August 2024, in conversation with Lex Fridman about xAI Memphis data center

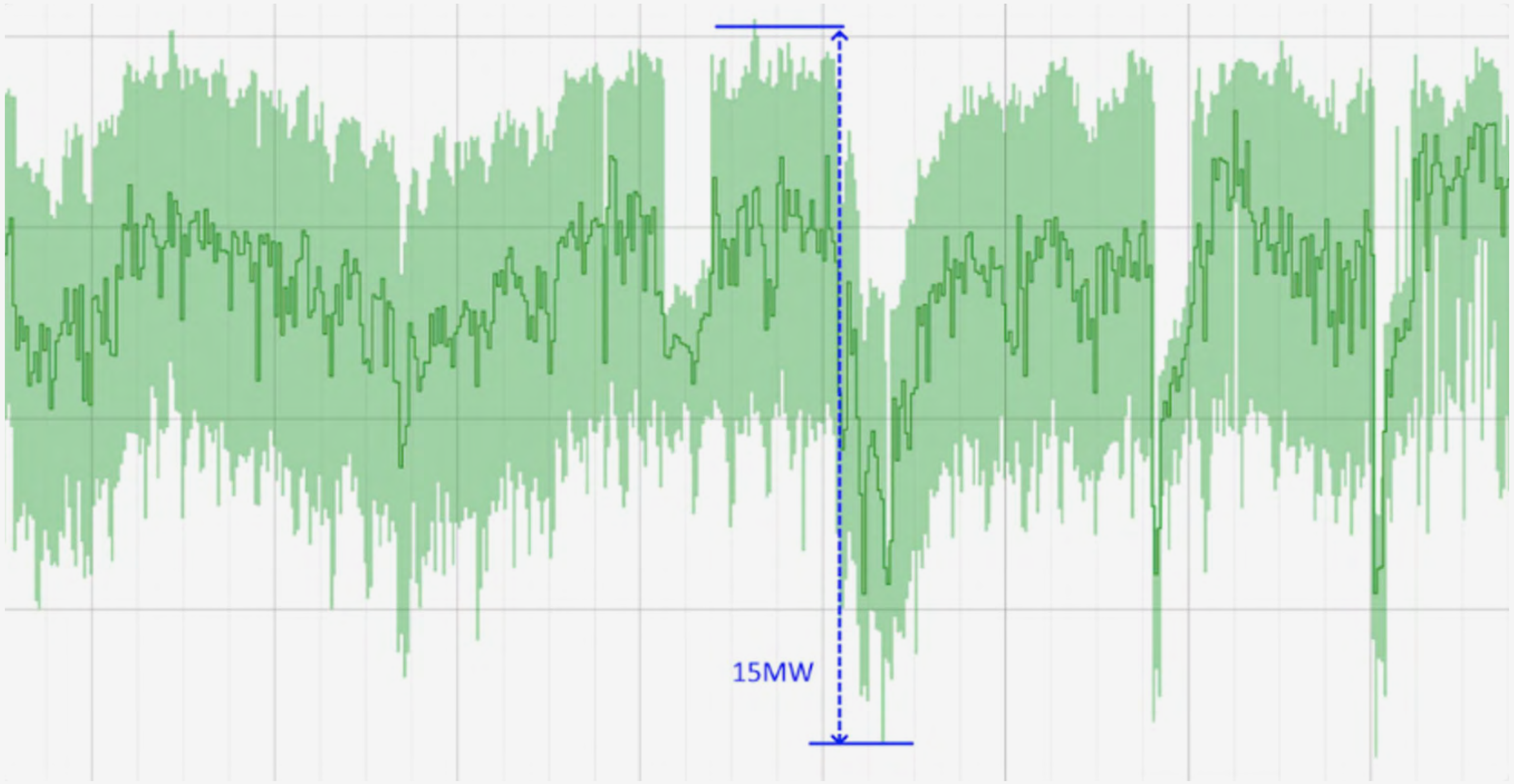


Fig. 1. Large power fluctuations observed on cluster level with large-scale synchronized machine learning (ML) workloads

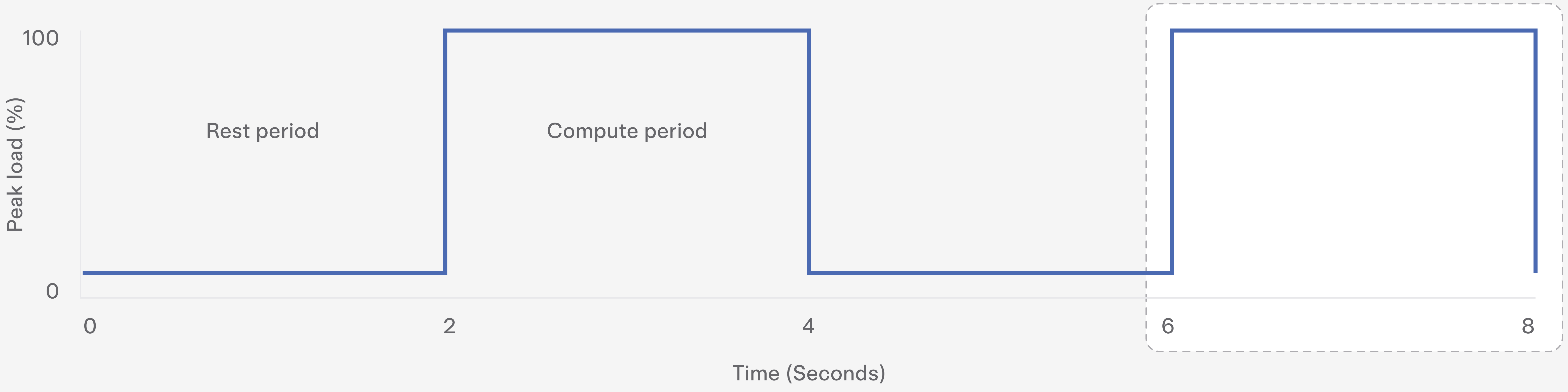
“In our latest batch-synchronous ML workloads running on dedicated ML clusters, we observed power fluctuations in the tens of megawatts”

Google Technical Lead Manager and VP, Engineering
Google "Balance of power: A full-stack approach to power and thermal fluctuations in ML infrastructure", February 2025

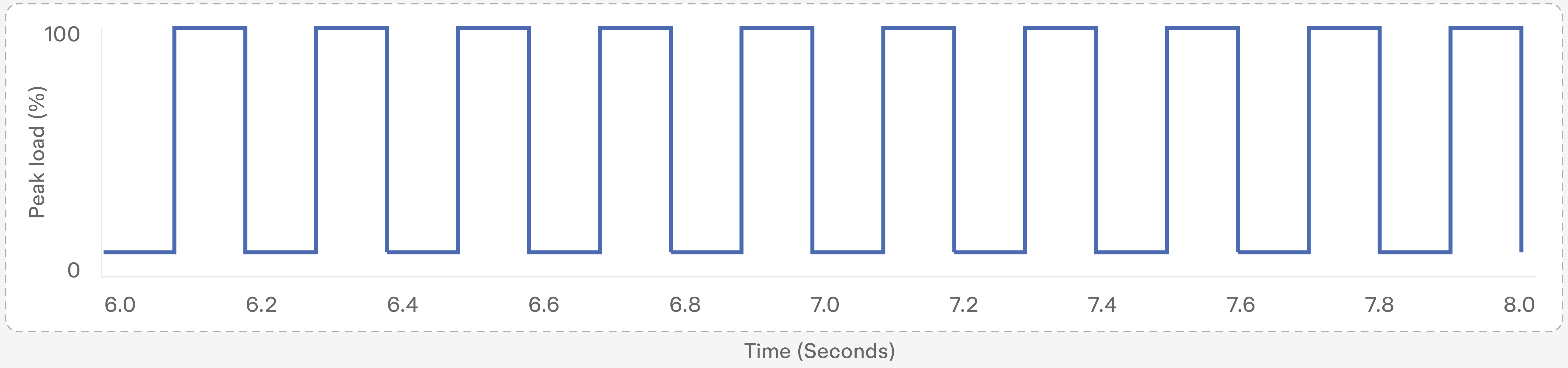
Challenge

Power load fluctuations at AI training data centers

01 Measuring AI loads at ~second scale



02 Measuring "compute" periods at millisecond scale



Common characteristics of reported AI training power loads include:

01

"Slow" seconds scale variations (0.1–1 Hz)

02

"Fast" millisecond scale variations (5–30 Hz)

Up to 90% power demand fluctuations (100% → 10%)

Impact of load variation

Off-Grid/backup (onsite generators)

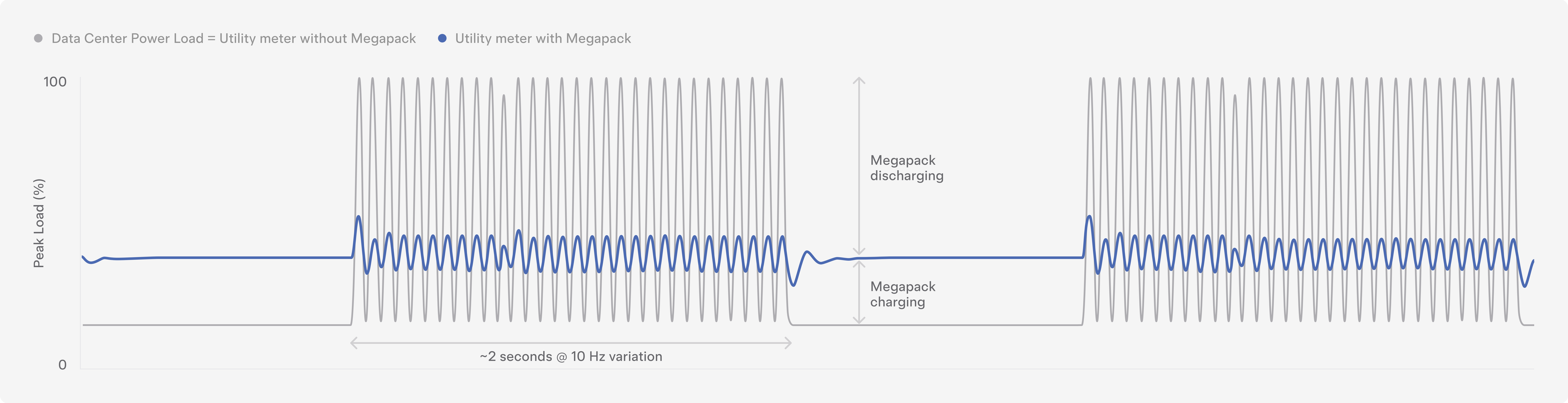
- Generator oscillations beyond specification

On-Grid

- Voltage flicker
- Nearby generator interactions
- Frequency regulation challenges and inter-area oscillation excitation

Solution

Load smoothing with Megapack can reduce 70%+ of variability

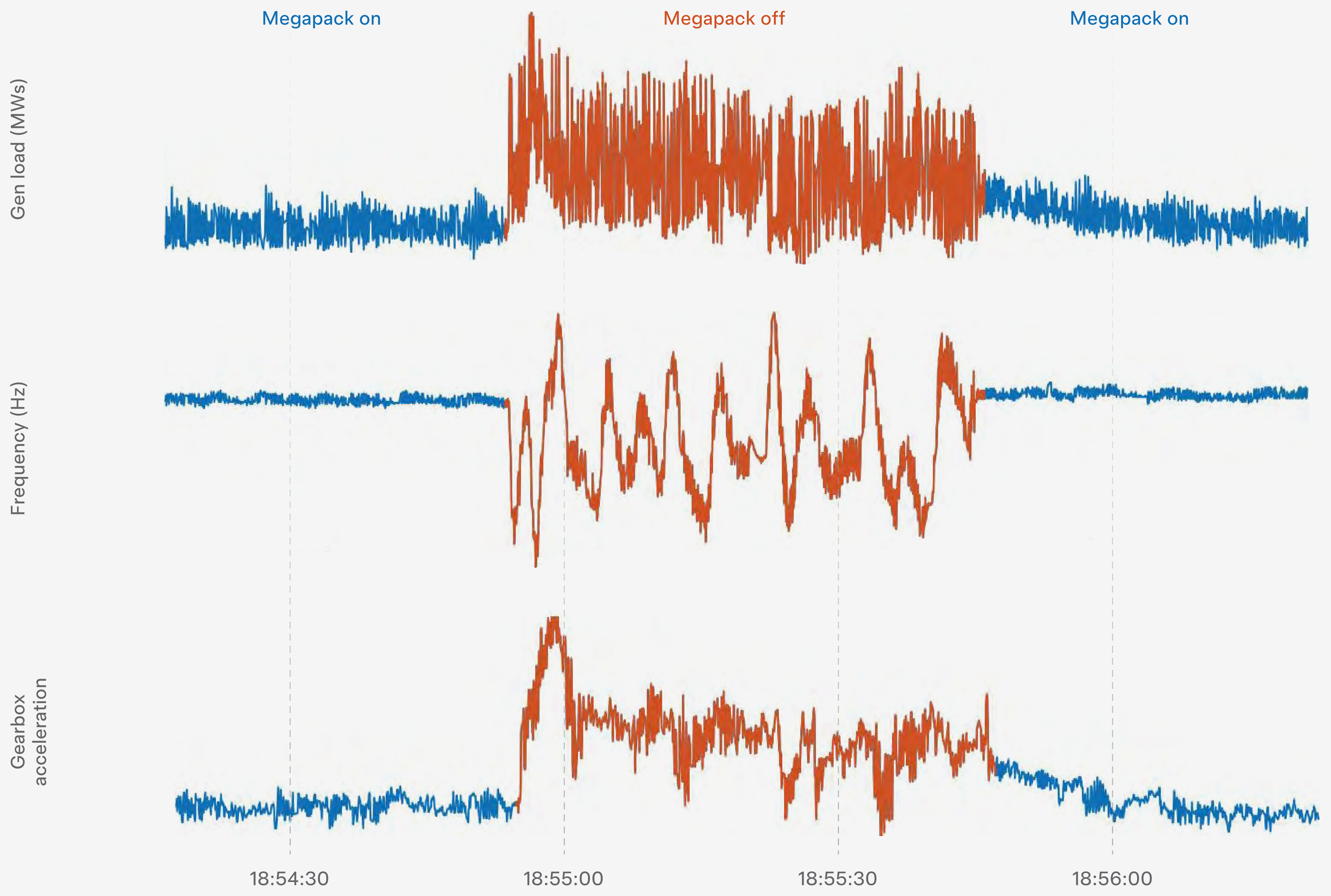


Connecting Megapack in parallel to the load helps reduce variability and improves grid reliability and power quality

20 year lifetime warranty and energy throughput modeling proven

24/7 operation: Charging and discharging are balanced such that Battery Energy Storage System (BESS) State-of-Charge (SOC) is maintained for continuous operation

Real-world results
of AI training power load smoothing tested beyond 25 MWs



Power

Power from generator highly variable without Megapack

Frequency

Generator controls too slow to compensate accurately for power variability

Mechanical

Generator bearing displacement – mechanical damage to equipment when high

Control options of load smoothing

Measurement-based

- Measures the load variations and commands storage to respond
- Effective for low-frequency variations
- Not effective for high-frequency variations due to control delays

Low frequency — High frequency

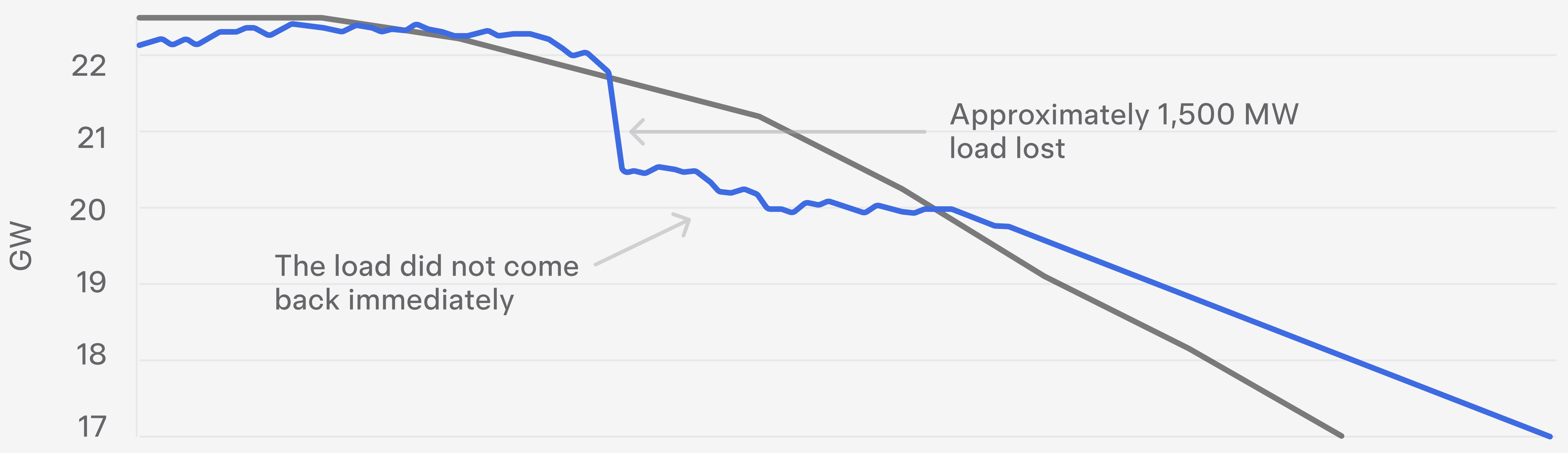
Tesla solution
Measurement + grid-forming controls

- Effective for low-frequency variations
- Reduces high-frequency variations (70%+) based on impedance split with grid-forming controls
- Can provide multiple services simultaneously

Low frequency — High frequency (Grid-forming)

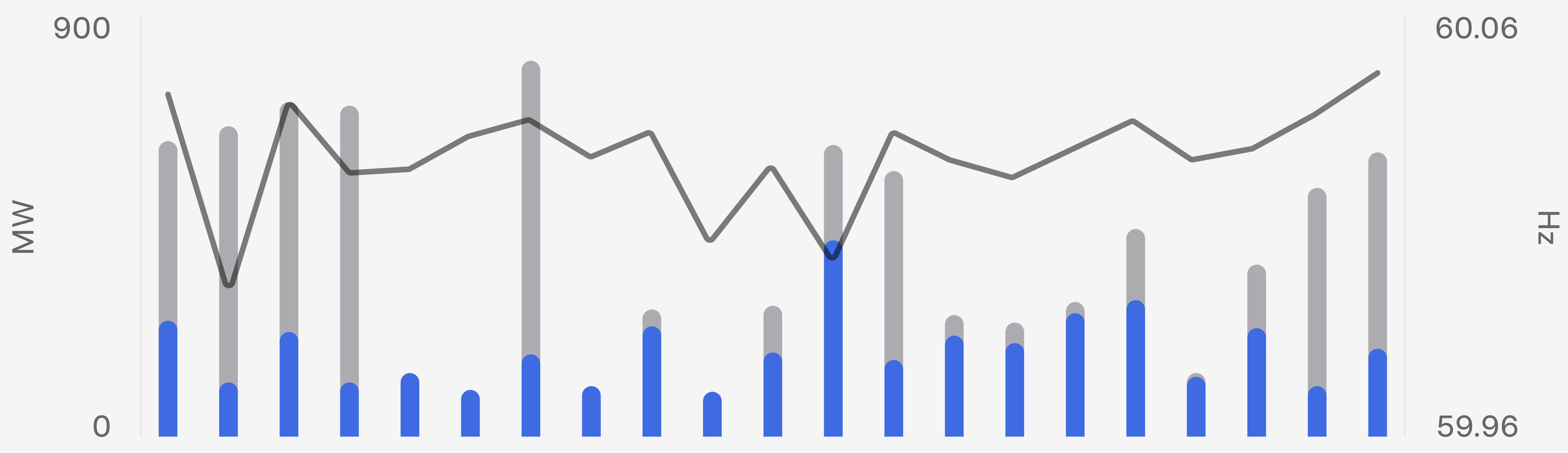
Challenge

Data centers lack low-voltage ride through (LVRT) capabilities



Dominion July 2024

Simultaneous trip of 1.5 GWs across 60 data centers, due to reclosing attempts on faulted 230 kV system



ERCOT Nov 2023–Nov 2024

Many events of 100s of MWs of loads tripping, with impact on grid stability

MW Reduction of affected loads
Total pre-disturbance consumption of affected loads
High frequency

Grid operator perspective

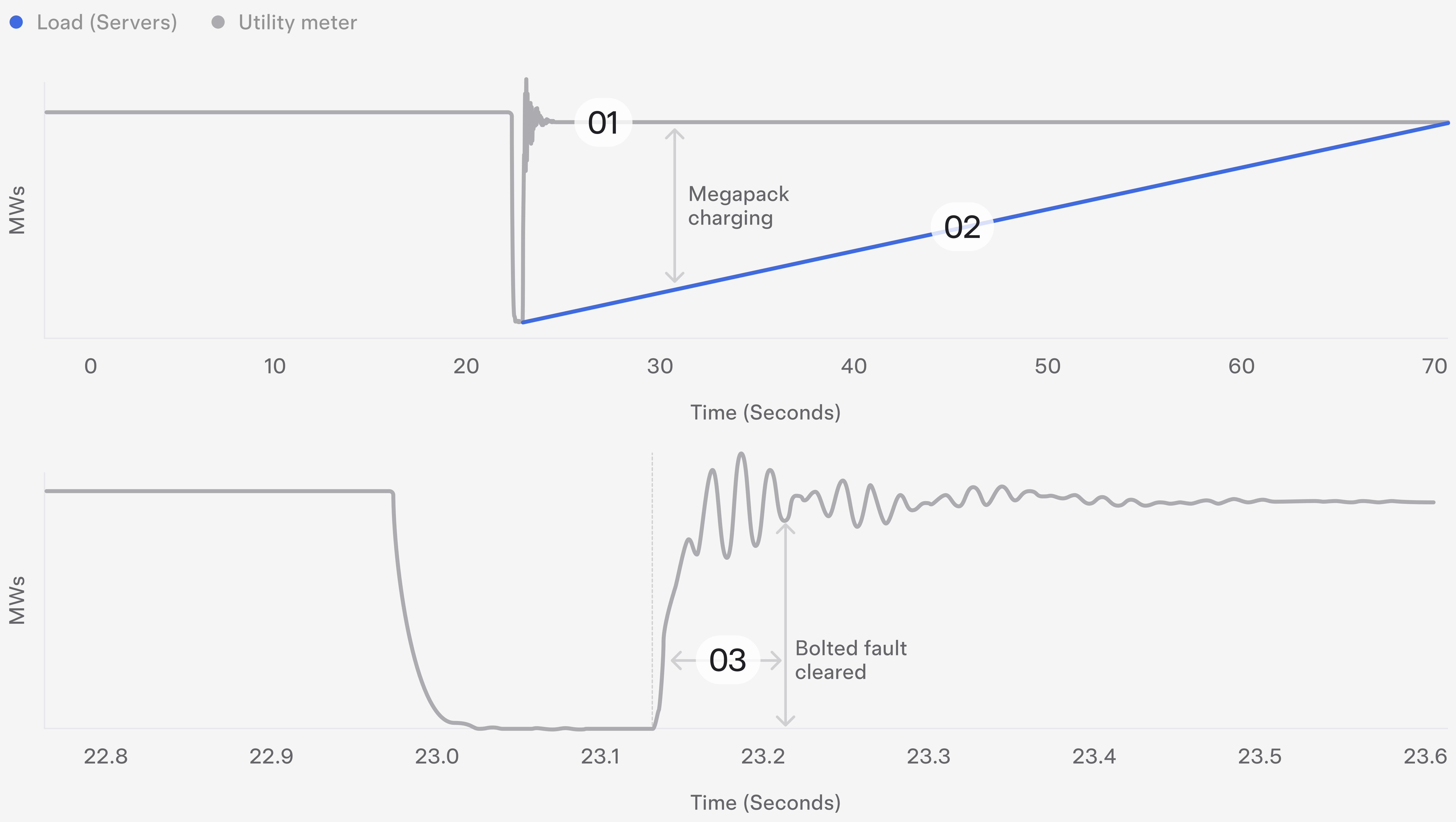
- Challenging to manage load drops at this scale
- Over frequency and voltage concerns

Data center perspective

- UPS systems working as intended
- Protecting our expensive and reliability critical equipment from utility system faults

Solution

Megapack charging after UPS systems trip to improve LVRT behavior



Notes

Assuming 150ms bolted fault at POI, voltage drops to 0 pu. Megapack system is capable of ride through IEEE2800 requirements.

Megapack can "mimic" load, enabling adherence to VRT grid codes

01

Utility load stays constant via Megapack charging

02

Utility load remains stable as UPS loads "step in"

Flexible solution to variety of controls and strategies

03

Utility draw rapidly returned to nominal following fault

As fast as ~30 ms when using grid-forming

Challenge

Data centers need power fast. Serving them requires system upgrades.

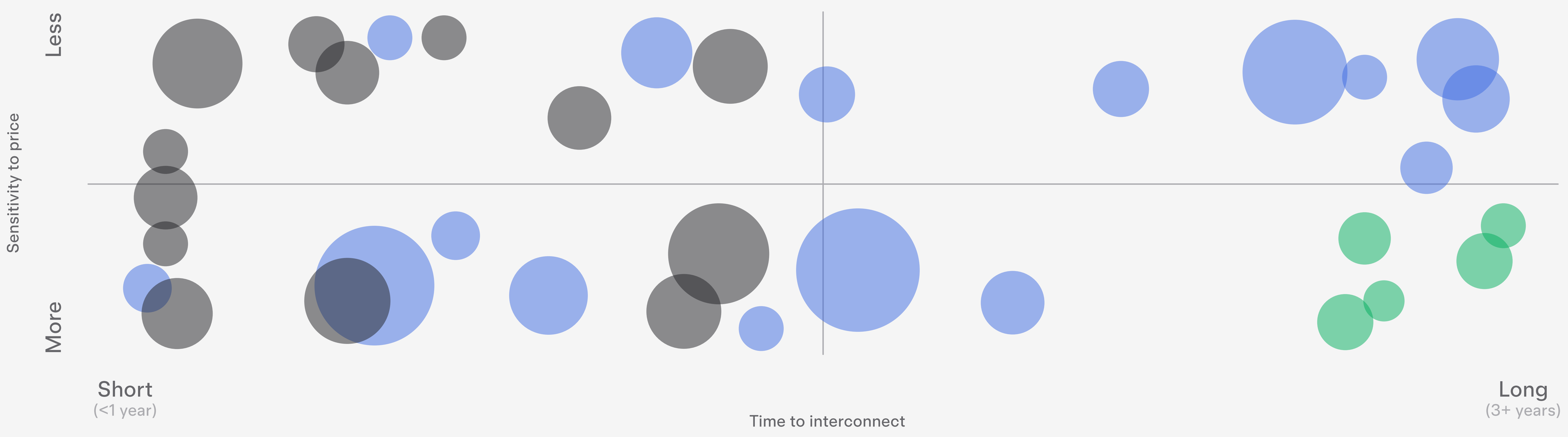
Data centers

Want reliable power fast
Load sizes are getting bigger—GW scale

Power sector

Has multi-year lead times for expansion projects
Supply chain crunches on key components

Changing characteristics of large loads coming to ERCOT



NERC "Large Loads Task Force kickoff meeting", October 2024

Historical large loads

Typically industrial facilities
Long timelines to interconnect can be studied by traditional planning processes
Little price-sensitive behavior in real-time

Current wave of large loads

Mostly cryptomining, data centers (traditional and AI), some oil field Load
Much shorter timeline to interconnect (months rather than years)
Some Loads are extremely sensitive to price

Projected future large loads

Hydrogen/electrofuel production, AI data centers, some cryptomining
Range of interconnection timelines and price sensitivity

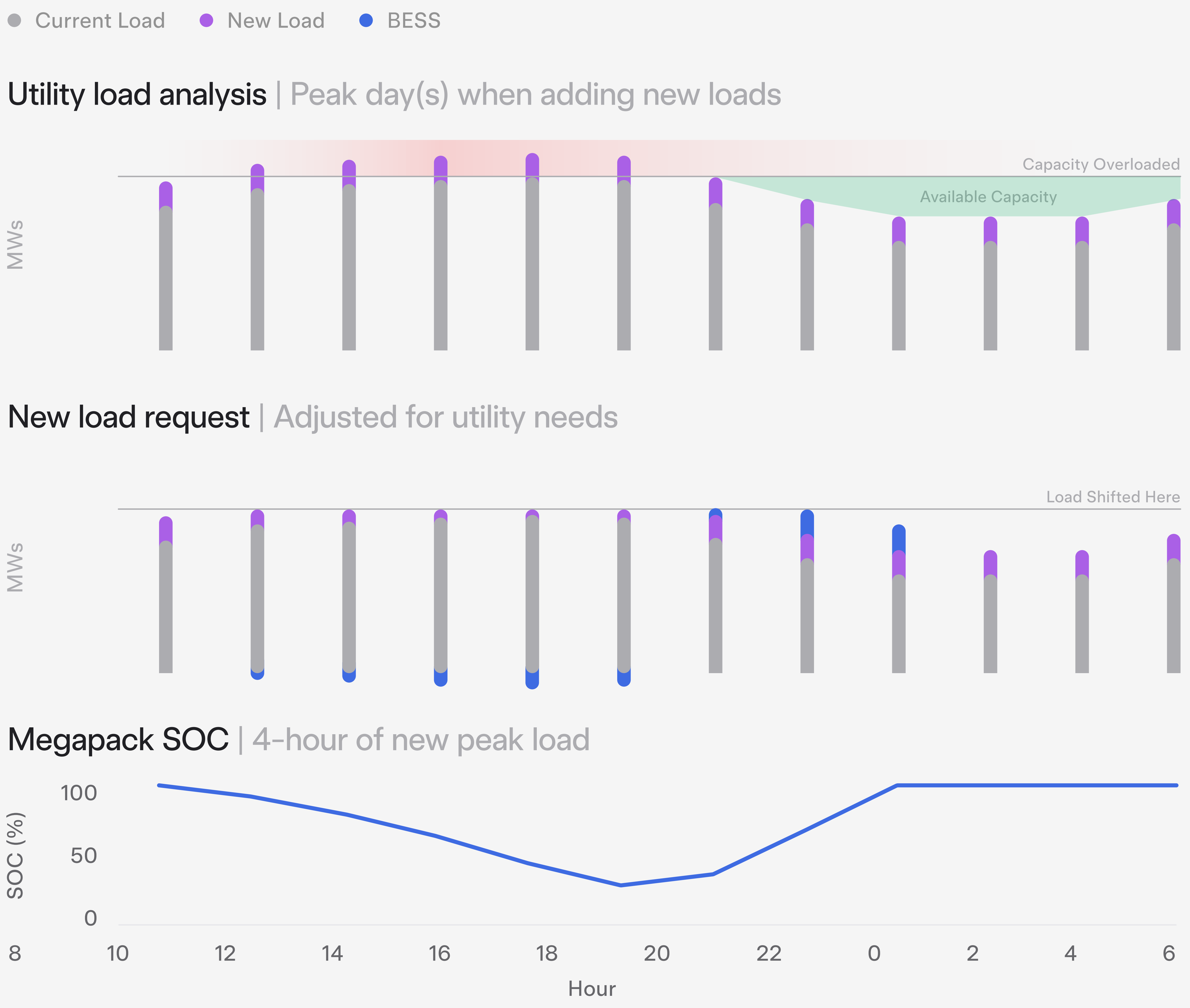
Data centers face seven-year wait for Dominion power hookups
Bloomberg | August 29, 2024

Biden executive order to fast-track AI data centers and energy infrastructure on federal lands
Morgan Lewis | January 22, 2025

Trump plans to use emergency powers to fast-track generation co-located with AI
Utility Dive | January 24, 2025

Solution

Megapack can help shape load to grid's needs



Load as-is

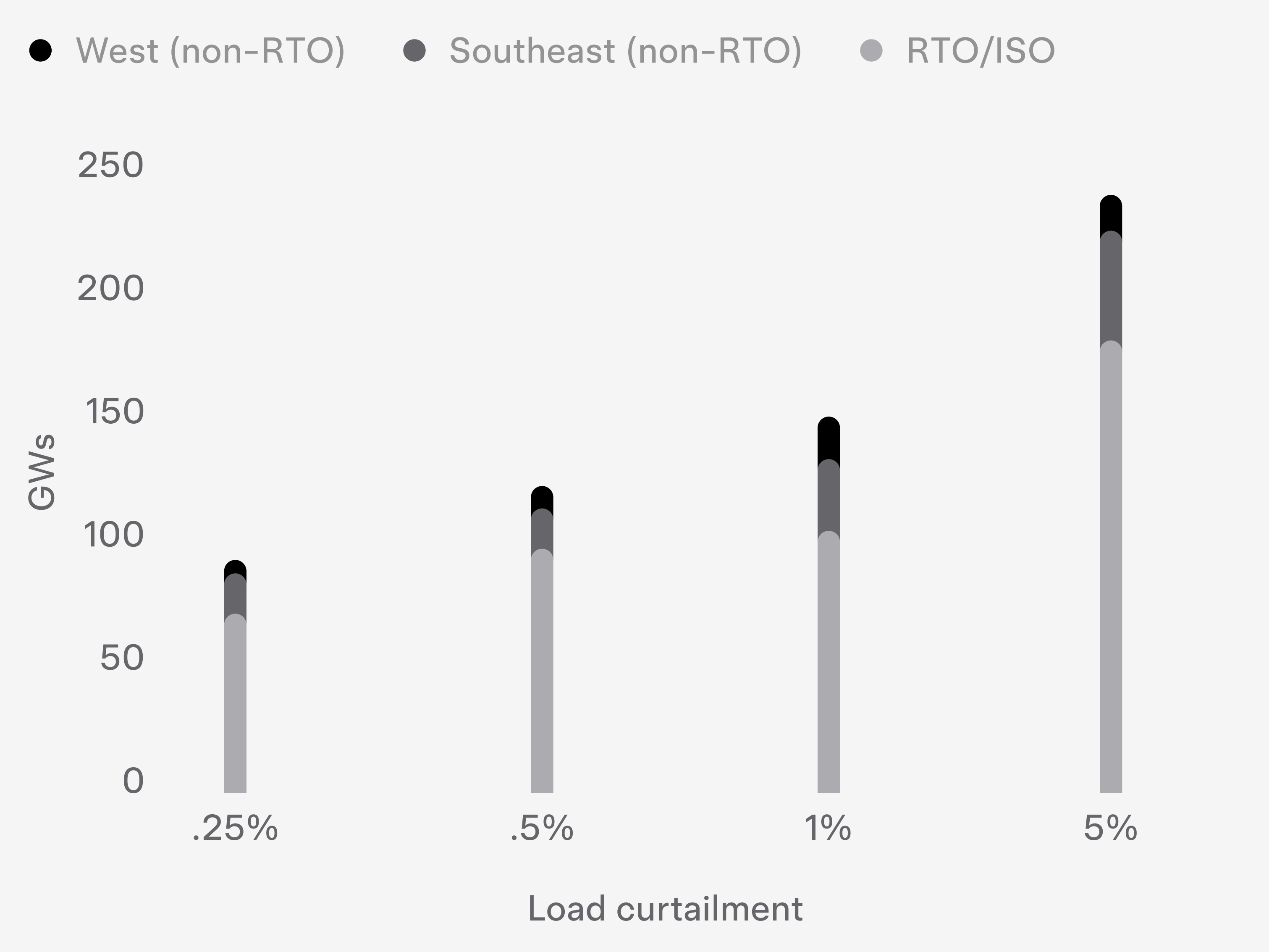
Can not support with existing infrastructure
Likely delays in energizing new load

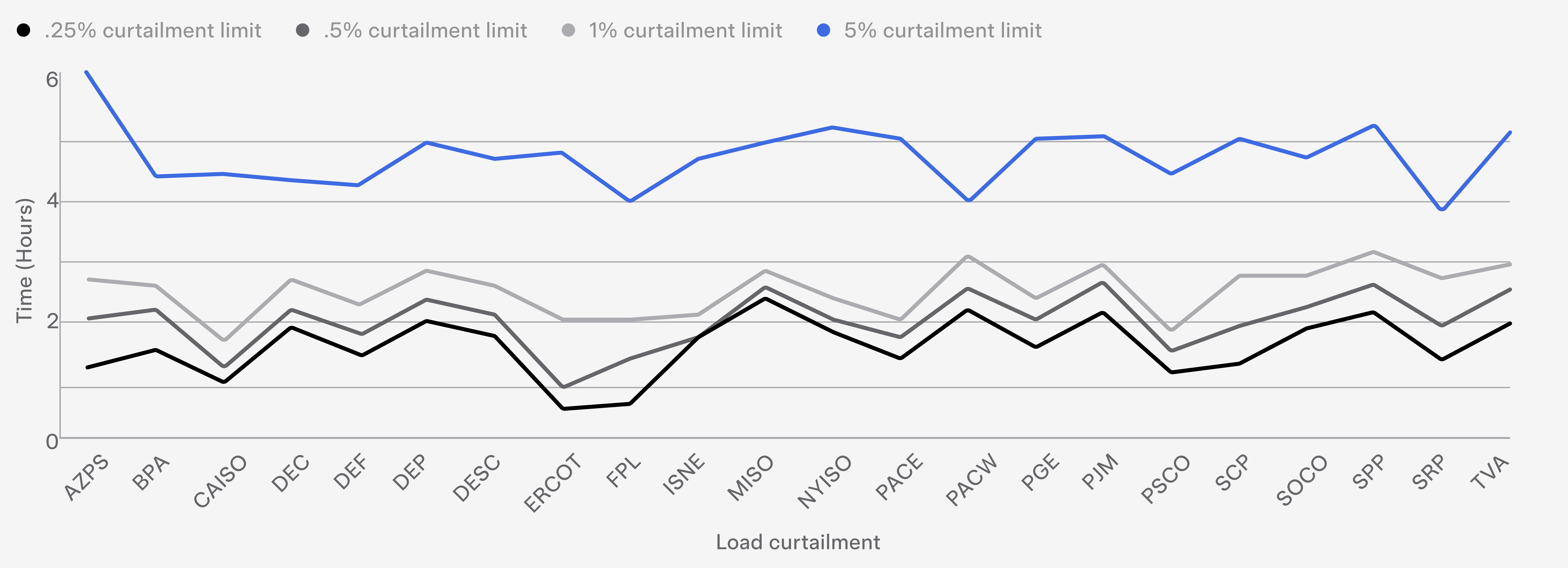
Adjusted Load (with BESS)

Can support with existing infrastructure
Shaping possible with 4-hour BESS

How much capacity can be unlocked?

Duke study shows 100+ GWs capacity unlock possible with 2–5 hrs of load shifting





Duke study summary

Analyzed 22 balancing authorities serving 95% of US's peak load

Capacity equivalent to 10% of US's peak load can be unlocked with 0.25% curtailment of new load

Required 2–5 hour curtailment can be enabled through BESS storage on-site

Duke University "Rethinking load growth", 2025

Grid operator:
What is your choice?

Connect in 5 years
when upgrades are done

Connect now
reduce load 5% of the time

- Megapack can make "no impact" on facility

Formal programs

- PG&E "FlexConnect"
- Dominion "CapFlex"
- SPP "CHILL"
- SCE "LCMS" pilot
- Black Hills "Blockchain Interruptible Service"
- National Grid (UK) "Flexible Connections"

Tesla experience

- Supercharger + Megapack in PG&E "FlexConnect"
- Semi Charging + Megapack in PG&E "FlexConnect"

PGE example (Real world example of potential benefits)

Hour of day

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	71%	71%	71%	20%	20%	20%	20%	20%	20%	20%	71%	71%
	71%	71%	71%	20%	20%	20%	20%	20%	20%	20%	71%	71%
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	71%	71%	71%	20%	20%	20%	20%	20%	20%	20%	71%	71%
23	71%	71%	71%	20%	20%	20%	20%	20%	20%	20%	71%	71%

Status Quo

Planning limits for 3.8MW EV charging station

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
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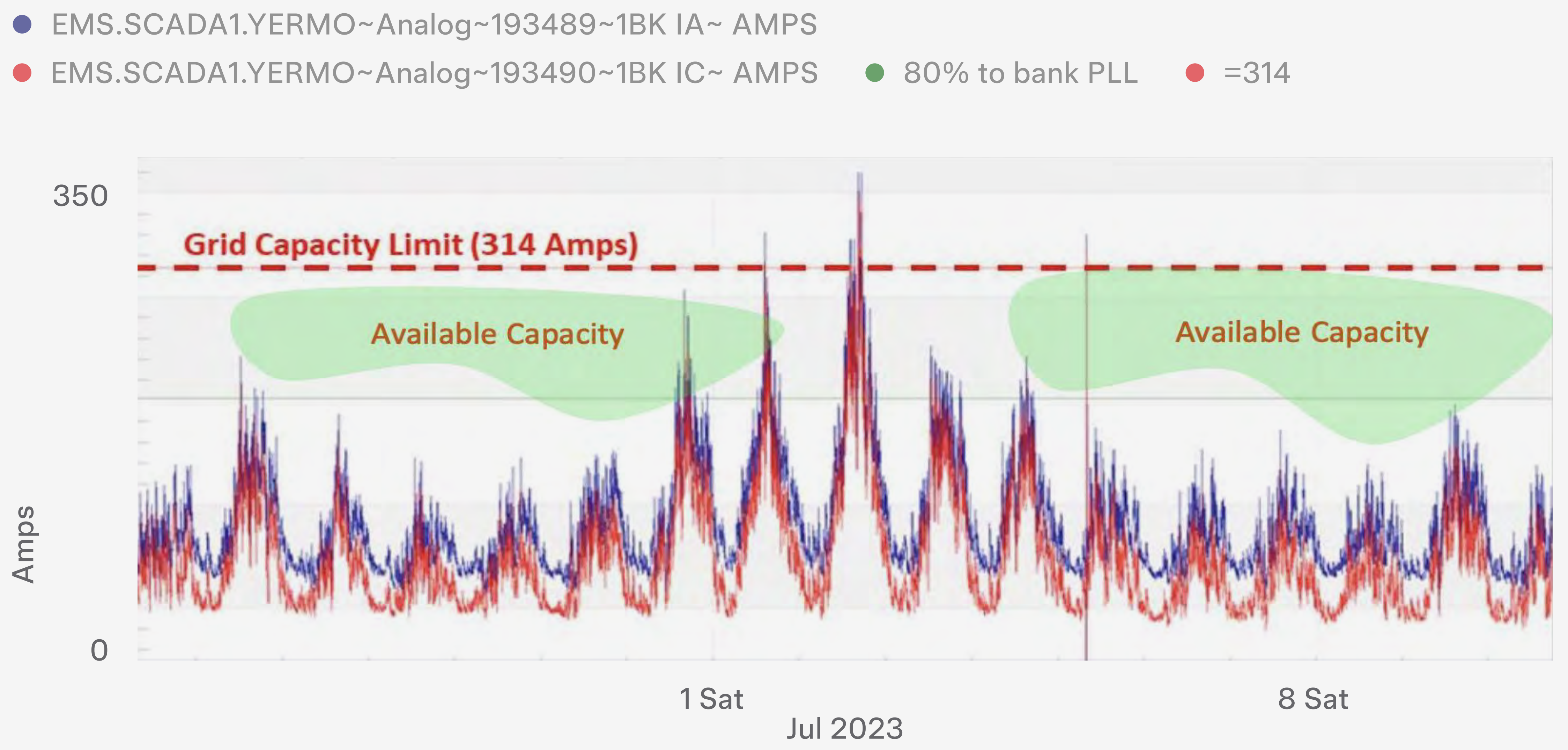
100%	100%	100%	100%	100%	100%	85%	87%	84%	100%	100%	100%
100%	100%	100%	100%	100%	100%	85%	94%	88%	100%	100%	100%

Flex Connect

Can support full request ~90% of the time on average

If a customer can reduce consumption for 3 months during 3–11 PM we can serve their full load request

SCE example



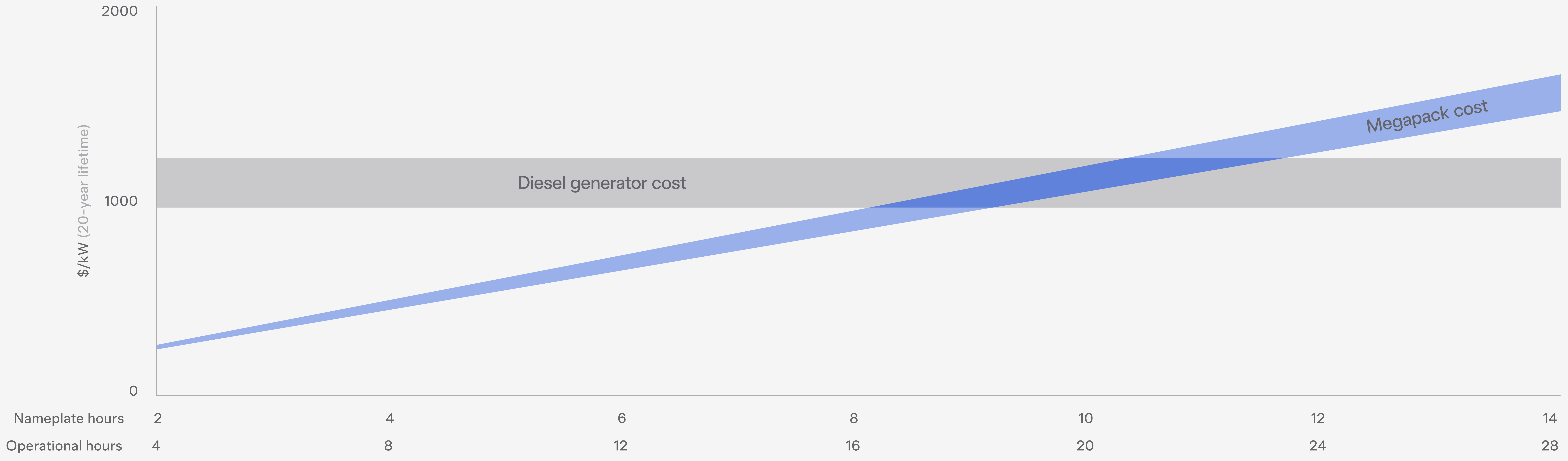
An LCMS can be used to allow the flexible load (e.g., charging station) to use more capacity outside the peak period

CPUC "Vehicle-grid integration forum", March 2024

Backup power

Fewer hassles without the emissions

Megapack cost competitiveness vs. diesel generators for ~20 hours of back up



Megapack operational hours assumes 50% nameplate loading

Megapack cost assumes:

- 40–50% ITC (30% base, +10% “domestic adder”, +10% “Energy Community” adder that many major metros qualify for) netted from CapEx expense. Please consult your tax advisor on all tax-related matters.
- Nominal installation expense which may vary dependent on site conditions, etc.
- Includes nominal operations and maintenance cost for 20 years, per standard services agreement.

Generator cost assumes:

- CapEx of $800–$1,000/kW installed.
- Maintenance cost at 2.5% of capex annually for cost of service agreement and fuel swaps.

Applications and considerations of various solutions

	AI load smoothing	LVRT support	Flexible grid connection	Lifetime (with smoothing)	Space (Acres/100 MW DC)
On-site generation (UPS)	Maybe	Maybe Objective conflicted	No Duration limited	~1 Year Cycling limited	N/A Existing equipment
On-site generation (Diesel generator)	No	No	Maybe Air permit limits use	N/A Can't load smooth	N/A Existing equipment
Capacitors (E-statcom)	Partially Fast = Yes Slow = Unlikely	No Duration limited	No Duration limited	20 Years	~0.5
2-Hour BESS (Megapack)	Yes	Yes	Yes	20 Years	~0.5

Megapacks at large loads

Tesla Gigafactory Texas 130 MW data center

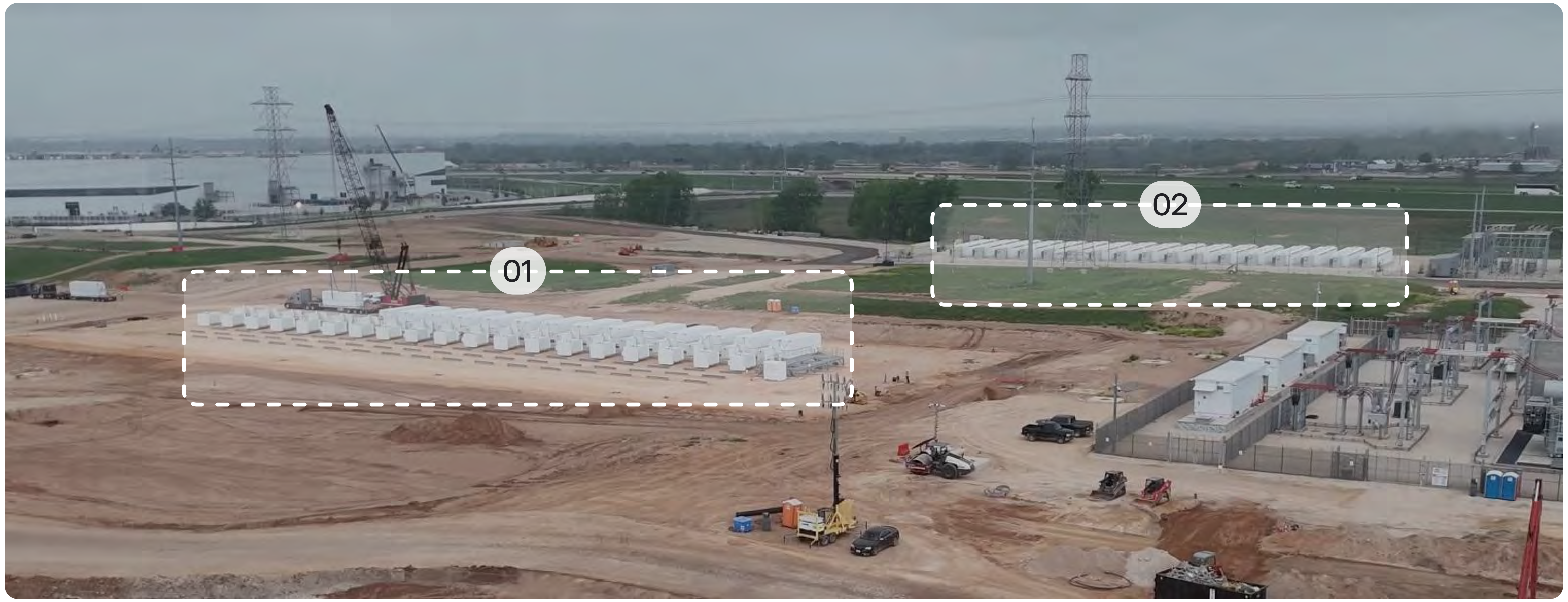
xAI Colossus 250 MW data center

Tesla Gigafactory Texas

Large load and Megapack overview

Facility is a large load 2-in-1 located in Austin, Texas

- Large manufacturing plant (largest building in world: 10M sqft).
- 130 MW data center.



Two Megapack installations at the facility

01 Data center Megapack system
130 MW/260 MWh

Installed “behind the meter”.

Backup power use case.

02 ERCOT-participating system
125 MW/250 MWh

Installed “front of the meter”.

Can provide back up power in a grid outage with unique configuration (ERCOT NPRR 1100).

xAI Colossus

Large load and Megapack overview

xAI's Colossus

200k GPU cluster — ~250 MWs

Phase 1
100k GPUs fully training synchronously in 122 days

Phase 2
Expansion to 200k GPUs in 92 days

AI load smoothing and demand response use cases