Impact of the AI datacenter on the nearby generation plant

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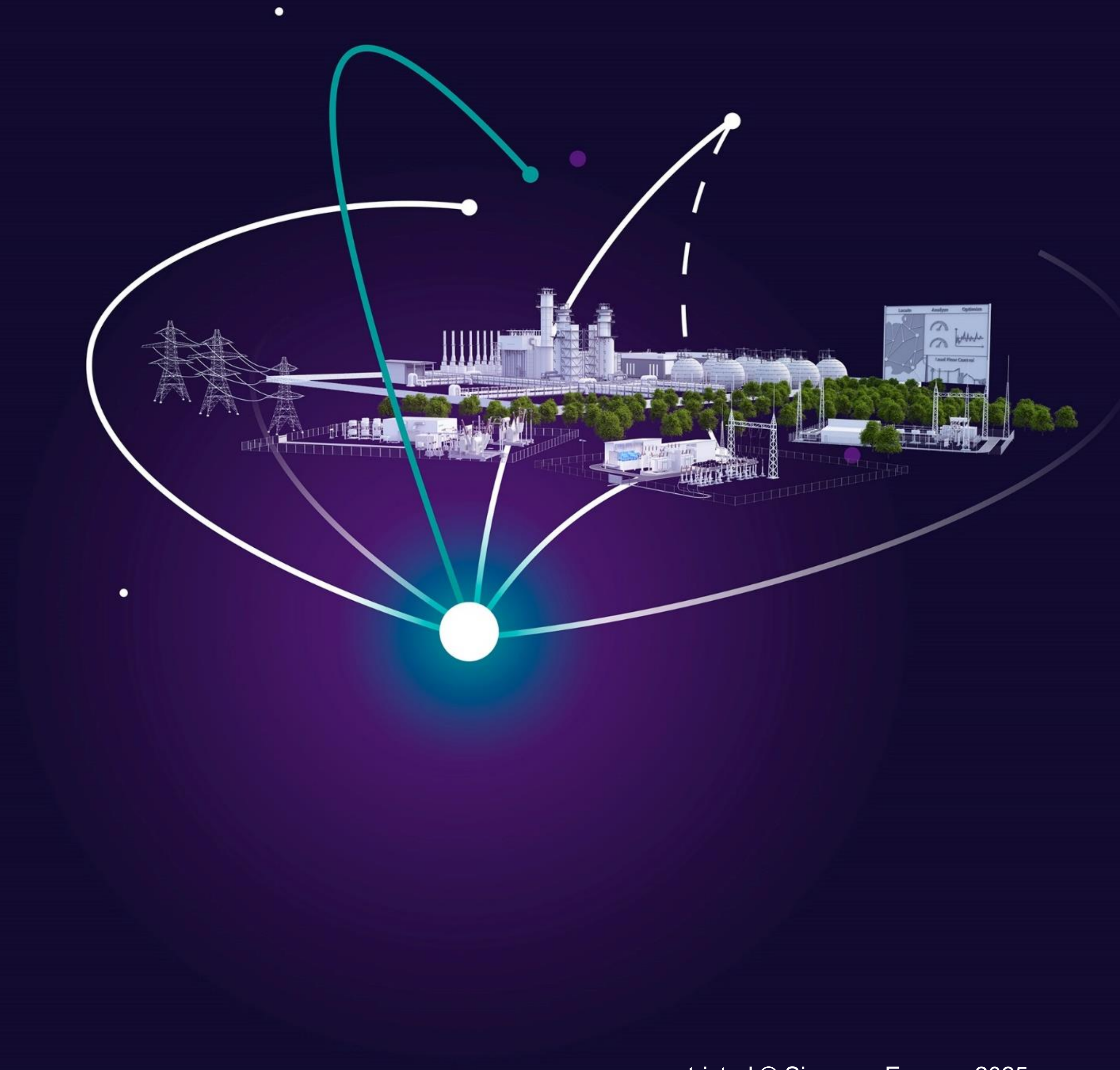
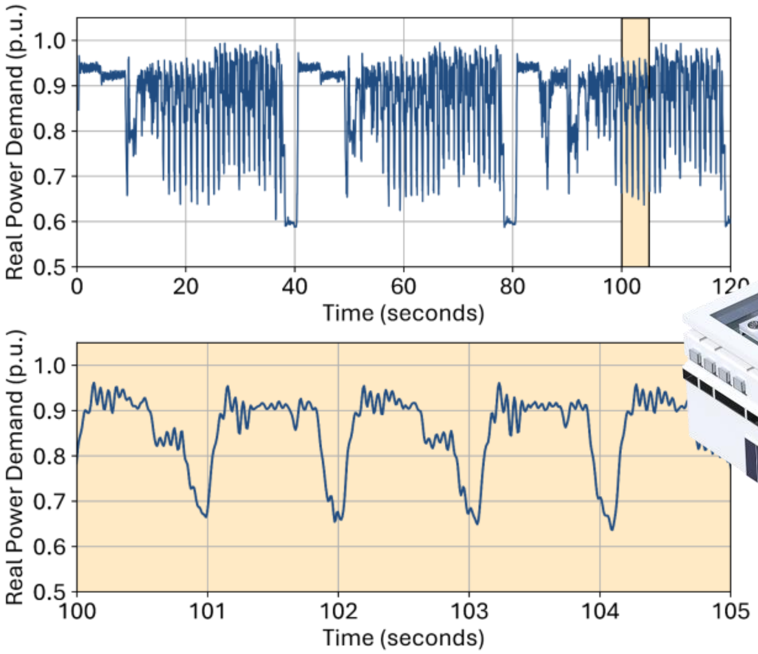


AI-training datacenter load pattern

If no mitigation measures put in place such load might damage the nearby electrical equipment (such as generators and turbines at the power plant)

Negative concerns on the nearby generators:
•Torsional resonance
•Local mode oscillations
•Might lead to unavailability due to poor operational behavior
•Premature Component damage

AI datacenters exhibit unique power consumption patterns, with rapid load transitions—shifting from idle (~40%) to full load (100%) and back within fractions of a second.
This is a behavior that no other load has done before.



AI Data Center

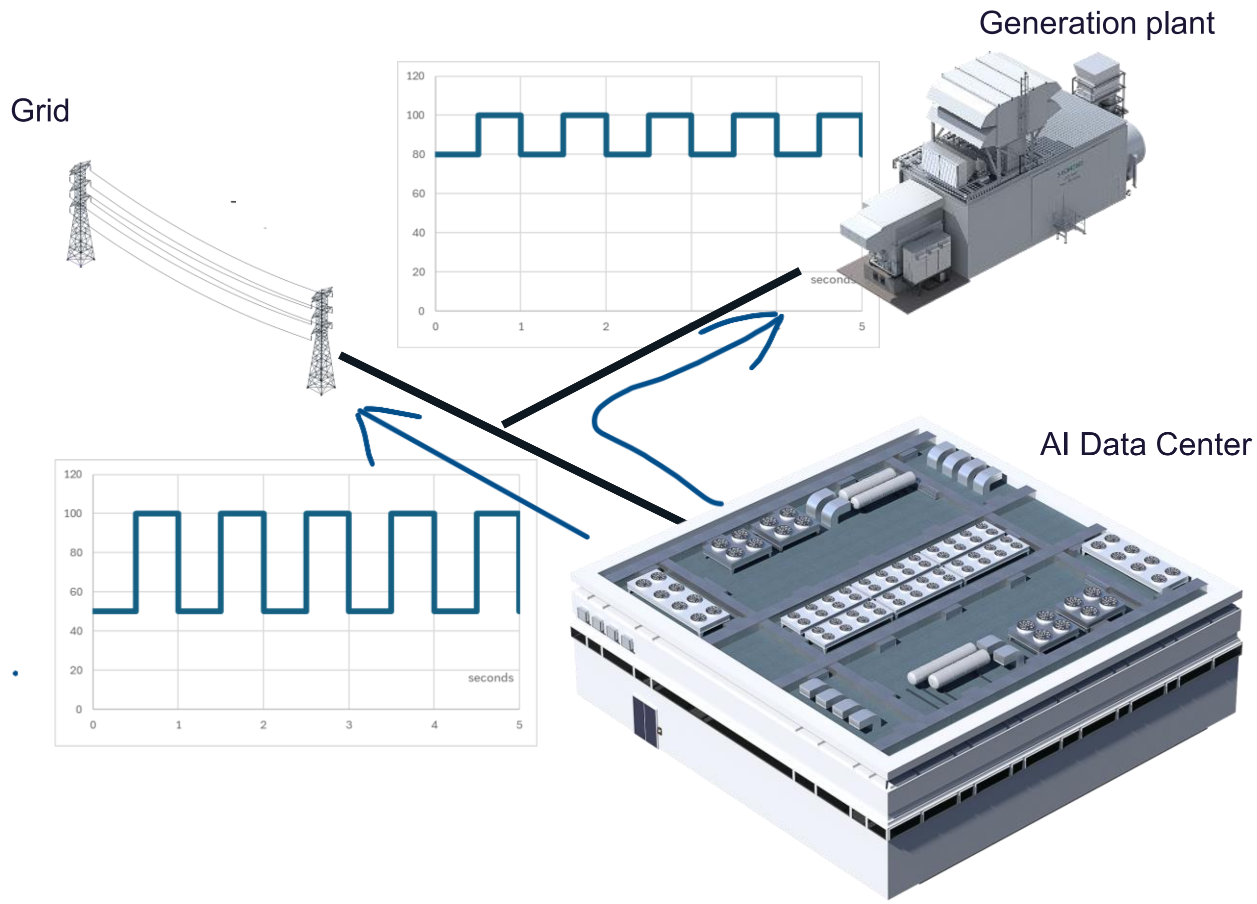
Source: NERC White Paper: Characteristics and Risks of Emerging Large Loads

How fluctuating load impacts nearby plant?

If not addressed load fluctuation will enter the gen-set.

Depending on the magnitude and frequency of the fluctuation it might cause control malfunctioning, frequent unintended trips, and ultimately damage to critical components, and significantly reduce the expected life-time

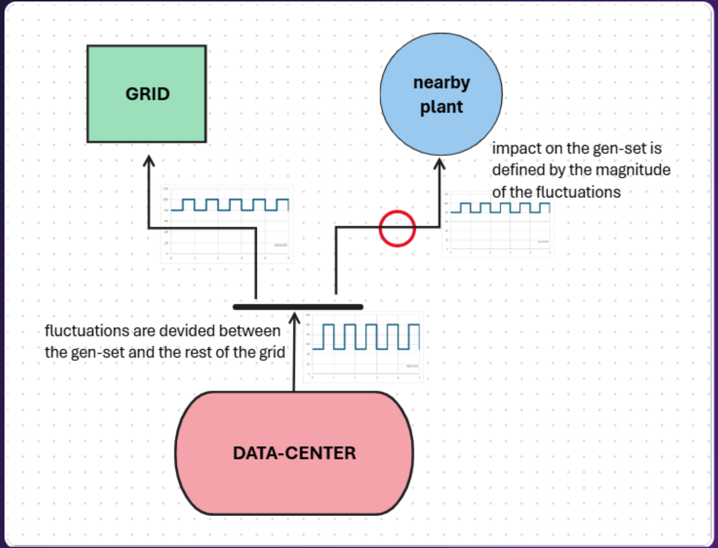
Consistent fluctuations are significant risk to the gen-set

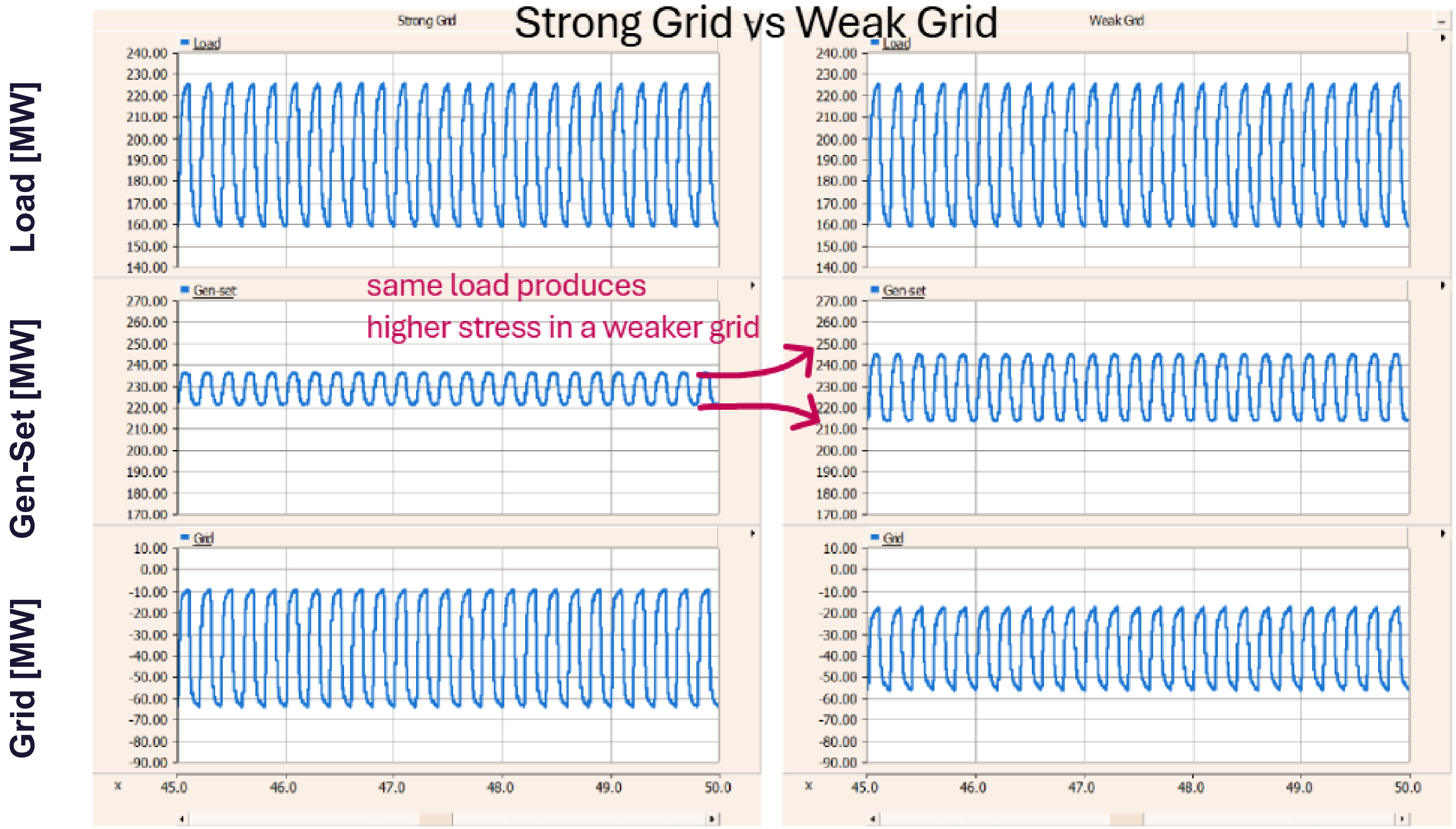


Major factors:
1. Strength of the grid

The fraction of a fast load disturbance ΔP that appears at the generator terminals depends on the grid configuration.

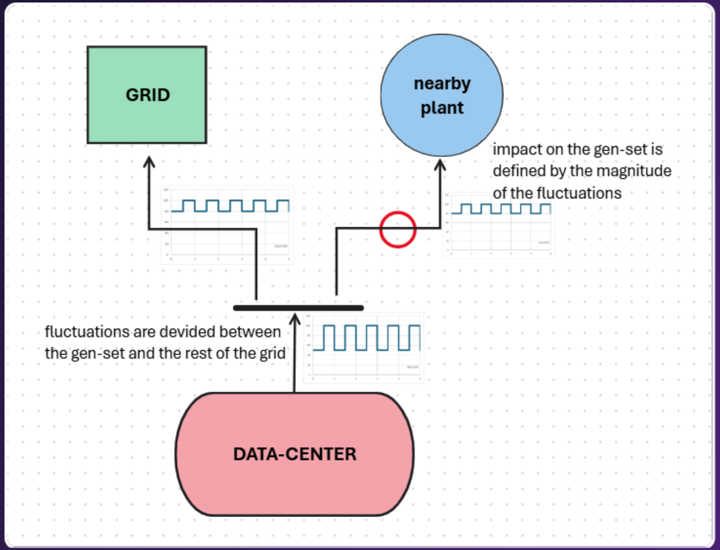
Hence a generator tied to a weak grid can see up to 2-3 times of the data-center fluctuation compared to the same unit on a strong grid.

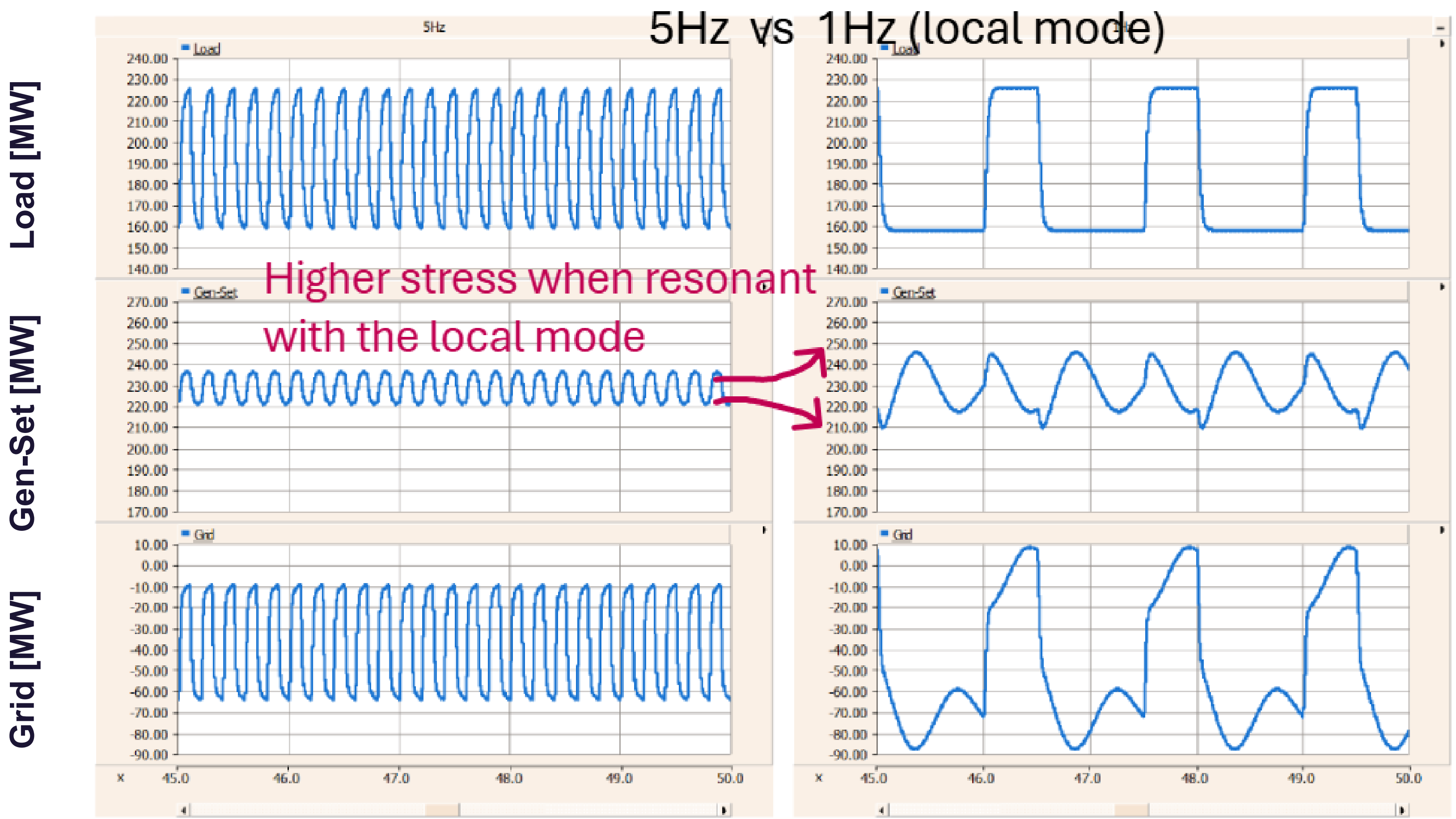




Major factors:
2. Frequence of the disturbance

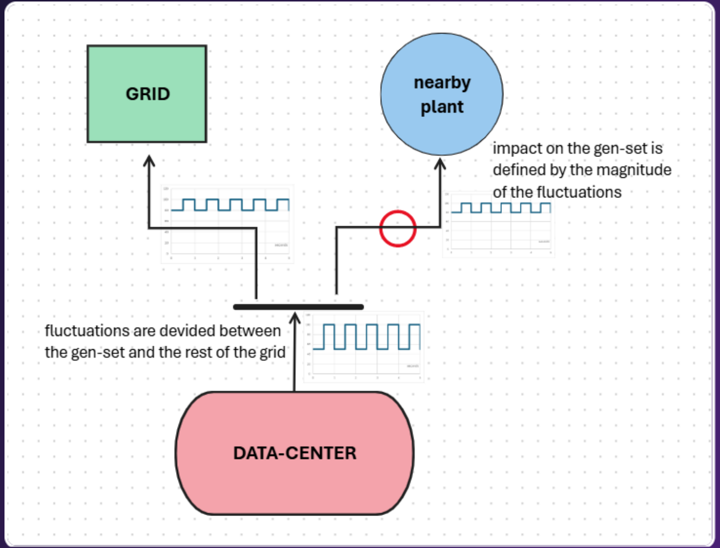
If the forcing frequency coincides with local mode (typically 0.5-2Hz), the generator can resonate with the grid, magnifying the oscillation by up to 50 % even when the external SCR is high.

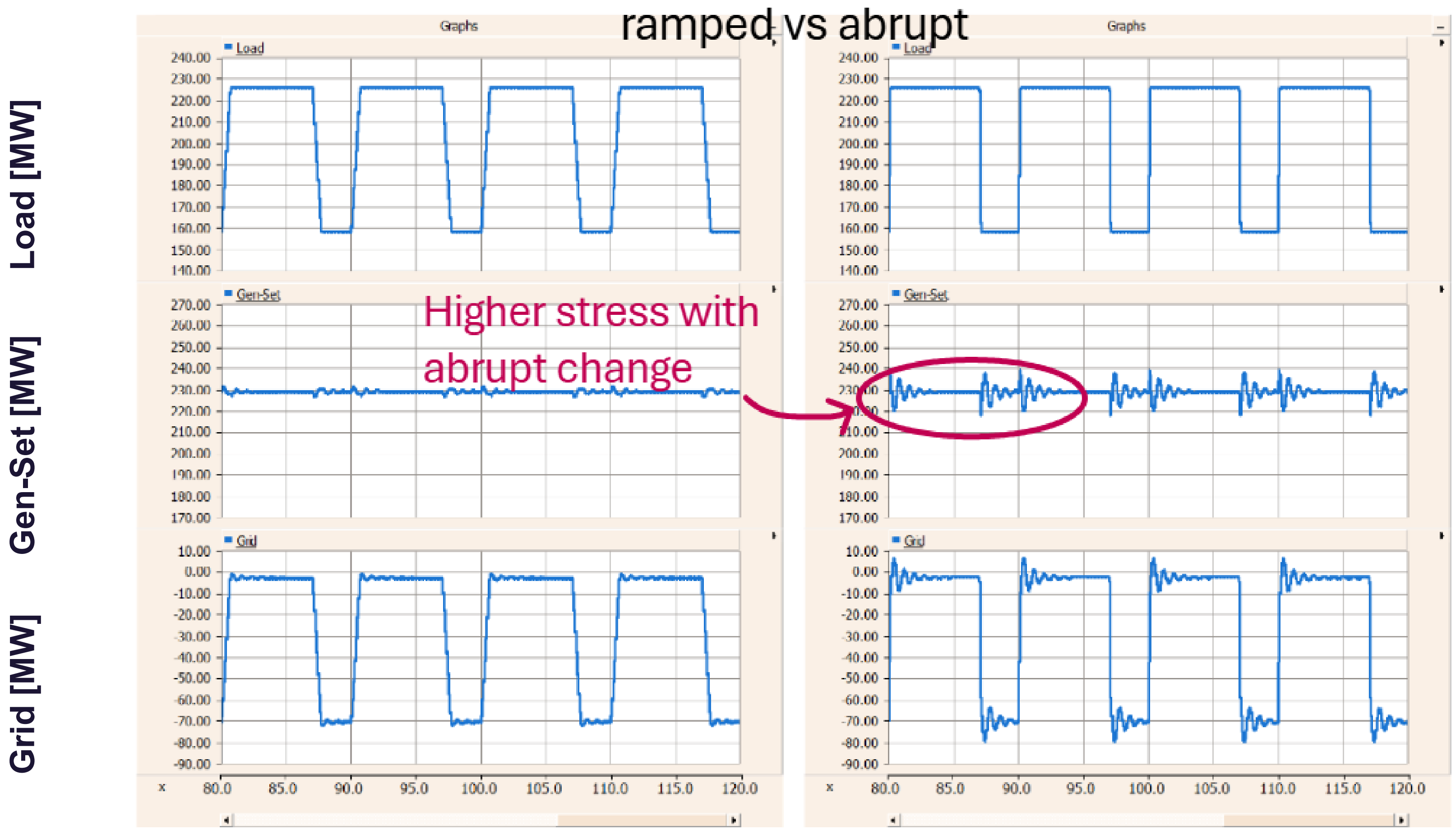




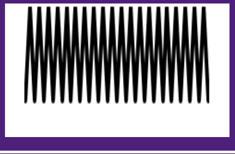
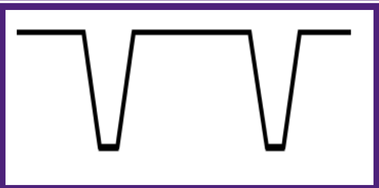
Major factors:
3. Ramp of the change

A step change forces large sub-transient currents; the same load change delivered as a ramp (e.g. dP/dt ≤ ~10 %/sec) produces only small additional current and torque, since the machine impedance can now be represented by the larger synchronous reactance Xd.





Operational Risks of Gen-set

Frequence of the load change	Risk to the nearby plant
5-55 Hz 	risk of torsional resonance, shaft and turbine damage
0.5-5 Hz 	risk of local swing-mode resonance, control mal-operation
<0.5 Hz,  or any multiple events per day	risk of high-cycle mechanical / thermal fatigue

E-STATCOM for AI datacenters

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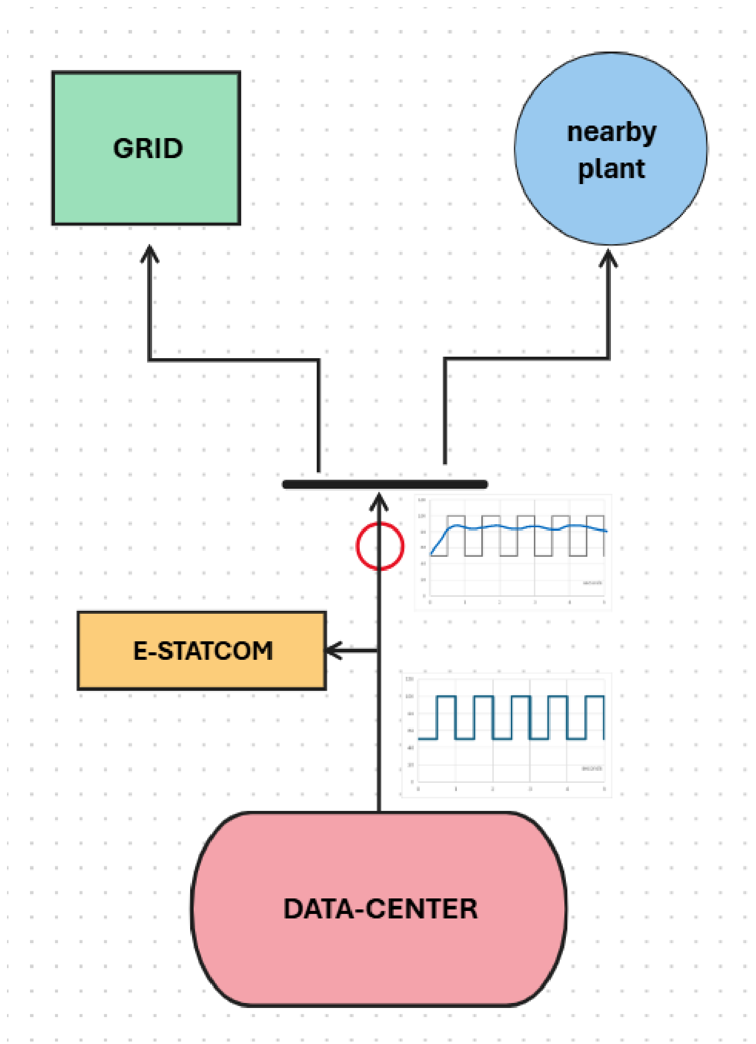


How to mitigate the risk to the nearby plant

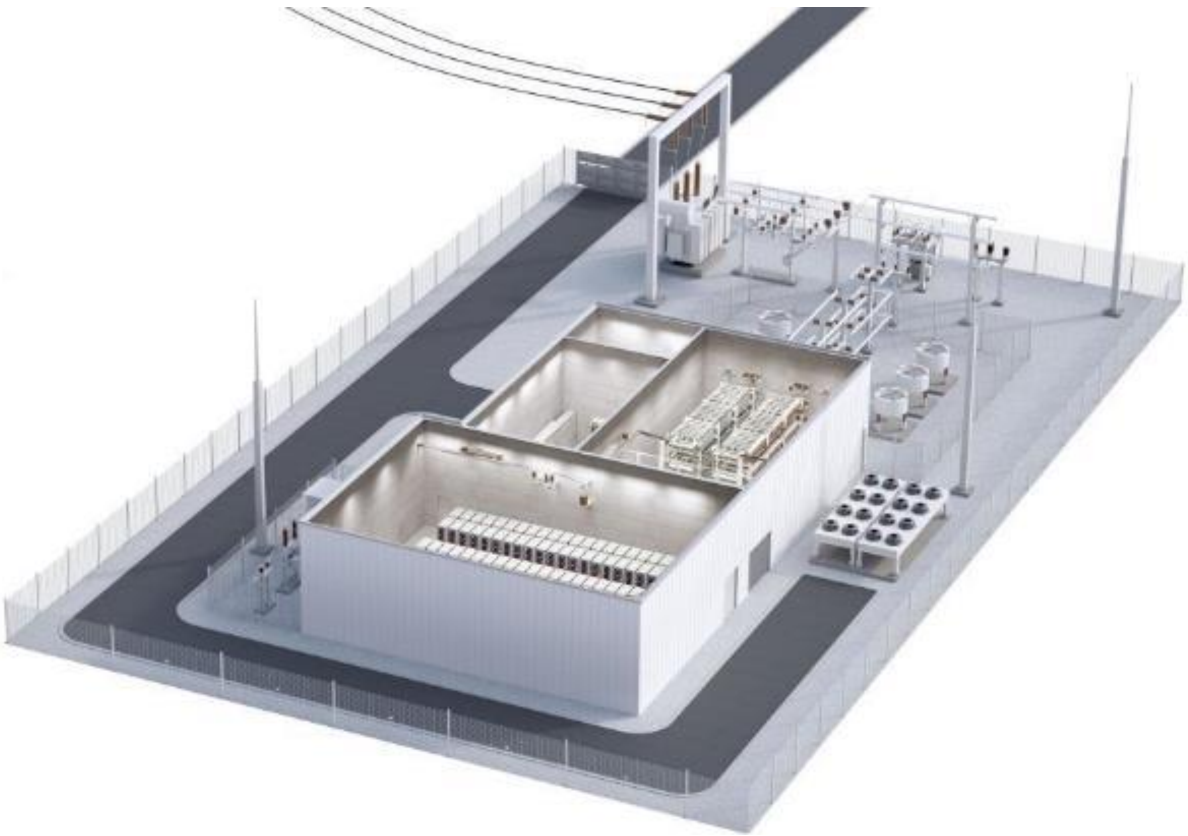
The most effective way to mitigate the risk is to reduce the fluctuation **at its source** – adding an E-STATCOM at data center facility

The source of the fluctuation must be reduced, such that the impact on the generator is neglectable, for example magnitude of the fluctuations are <1-2% * at the machine terminals

** 1-2% is a suggestive figure and can depend on individual shaft train's design and configuration and can vary by application*

E-STATCOM for AI Datacenter load fluctuation

SIEMENS energy



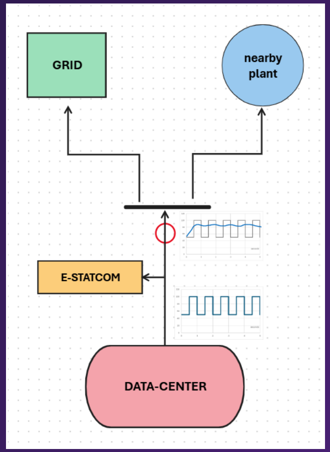
Product	SVC PLUS FS (Siemens Energy)
Active power	+/-75MW
Reactive Power	+/-75MVAR
System Voltage	34.5kV or higher
Response time	- <5ms
Special Features	- Variable Load Compensation - Fault-ride through support - Reactive Power Compensation - Voltage control

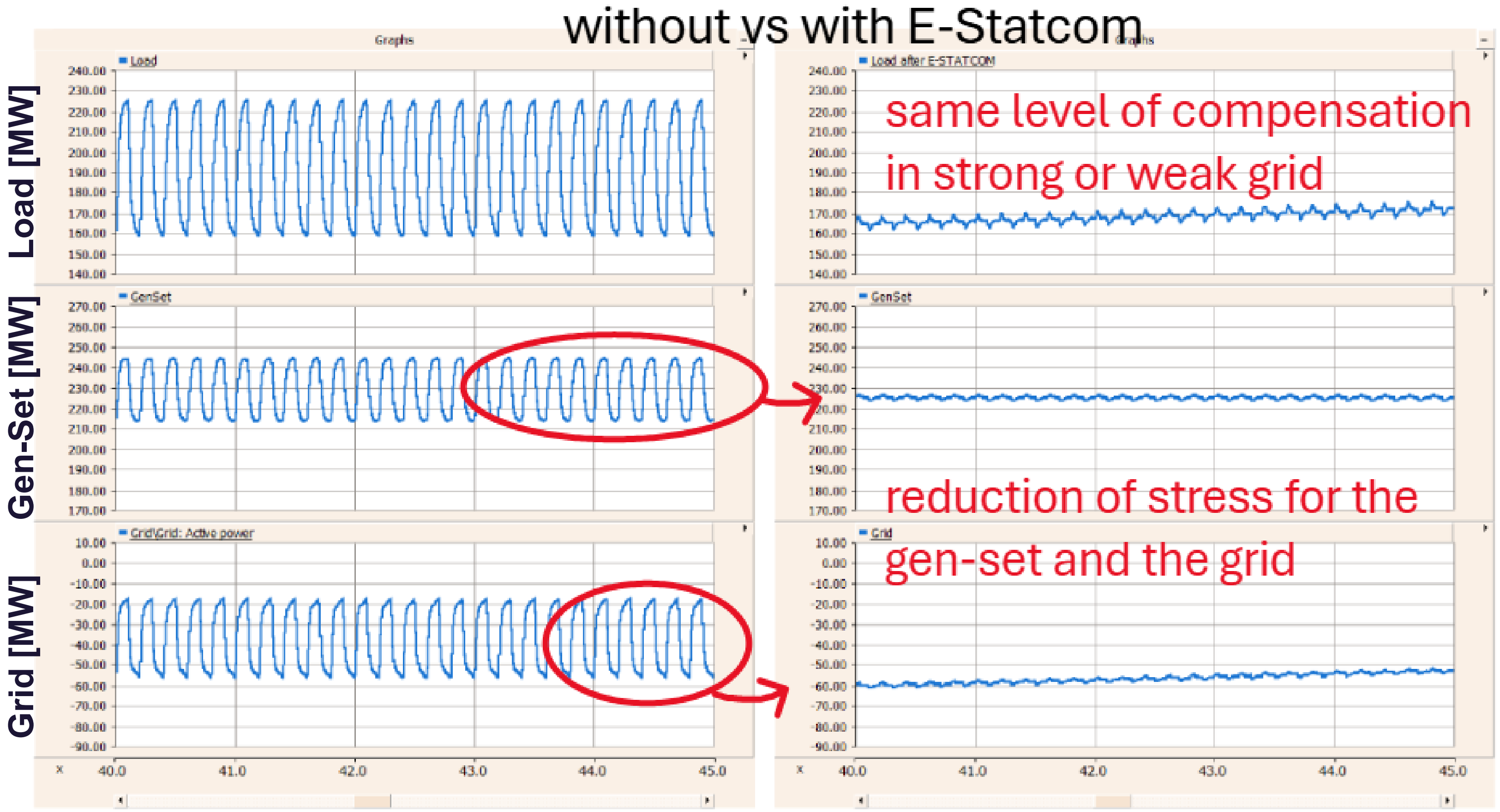
Very fast response time is critical for load compensation

E-STATCOM as a mitigation measure Example1: 5Hz oscillation

E-STATCOM effectively absorbs sub-synchronous oscillations, thereby protecting the grid and nearby rotating equipment.

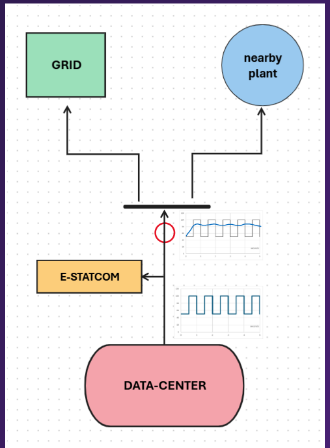
It achieves the same degree of compensation regardless of whether it is connected to a strong or weak grid.

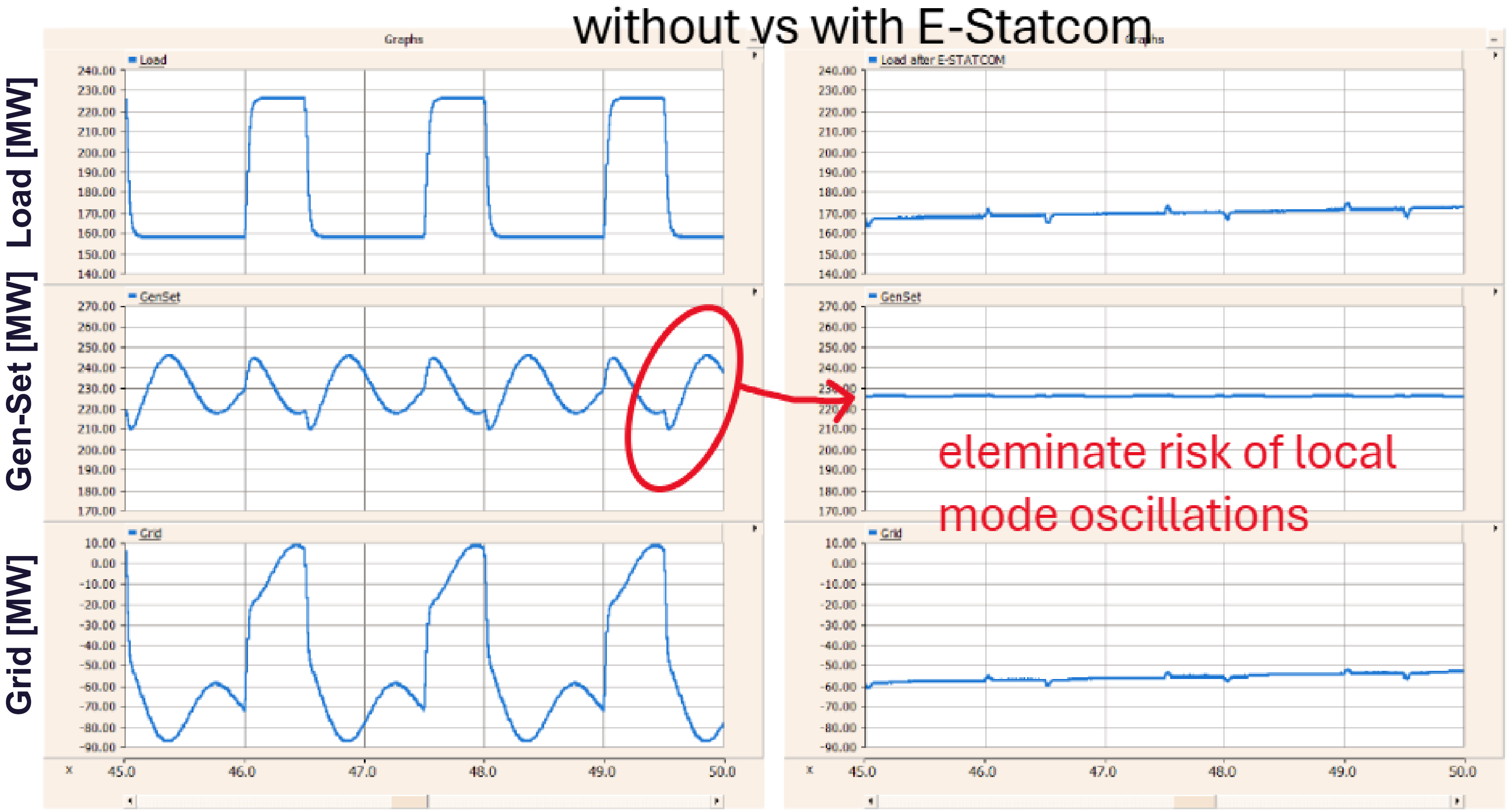




E-STATCOM as a mitigation measure
Example 2: 1Hz oscillation

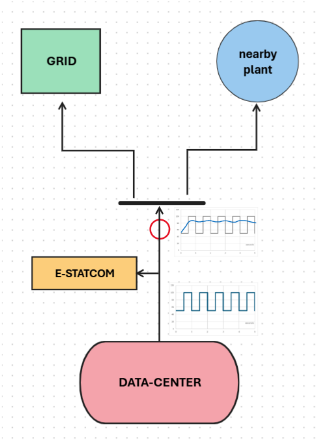
E-STATCOM can reduce load fluctuations by up to 99% in critical local and interarea mode regions (0.1-2 Hz)

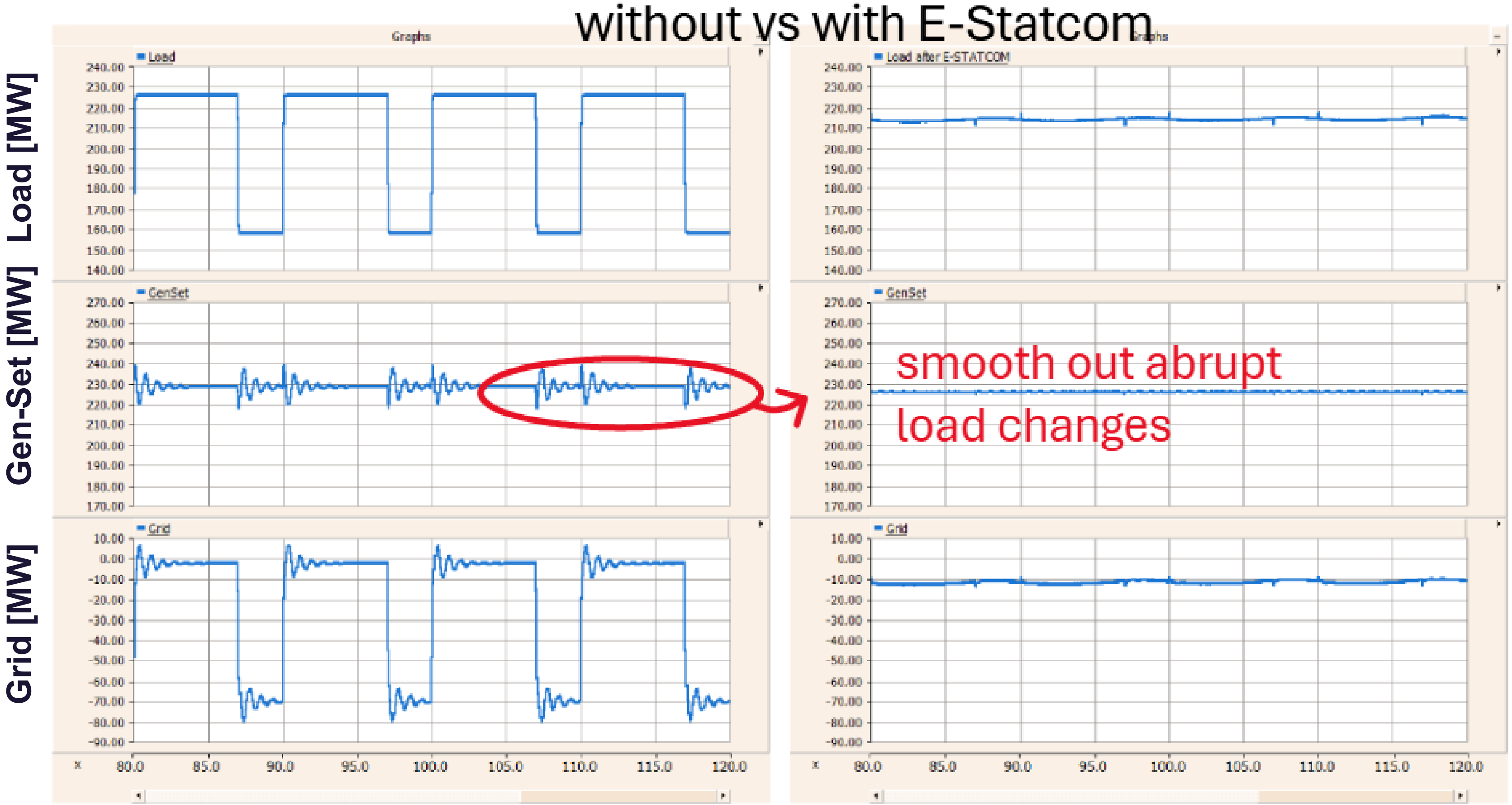




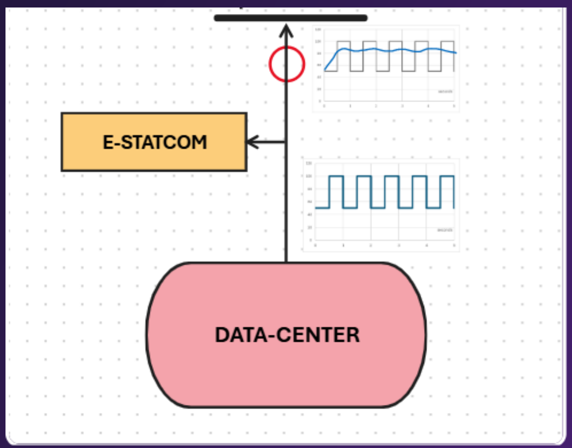
E-STATCOM as a mitigation measure
Example3: 0.1Hz load change

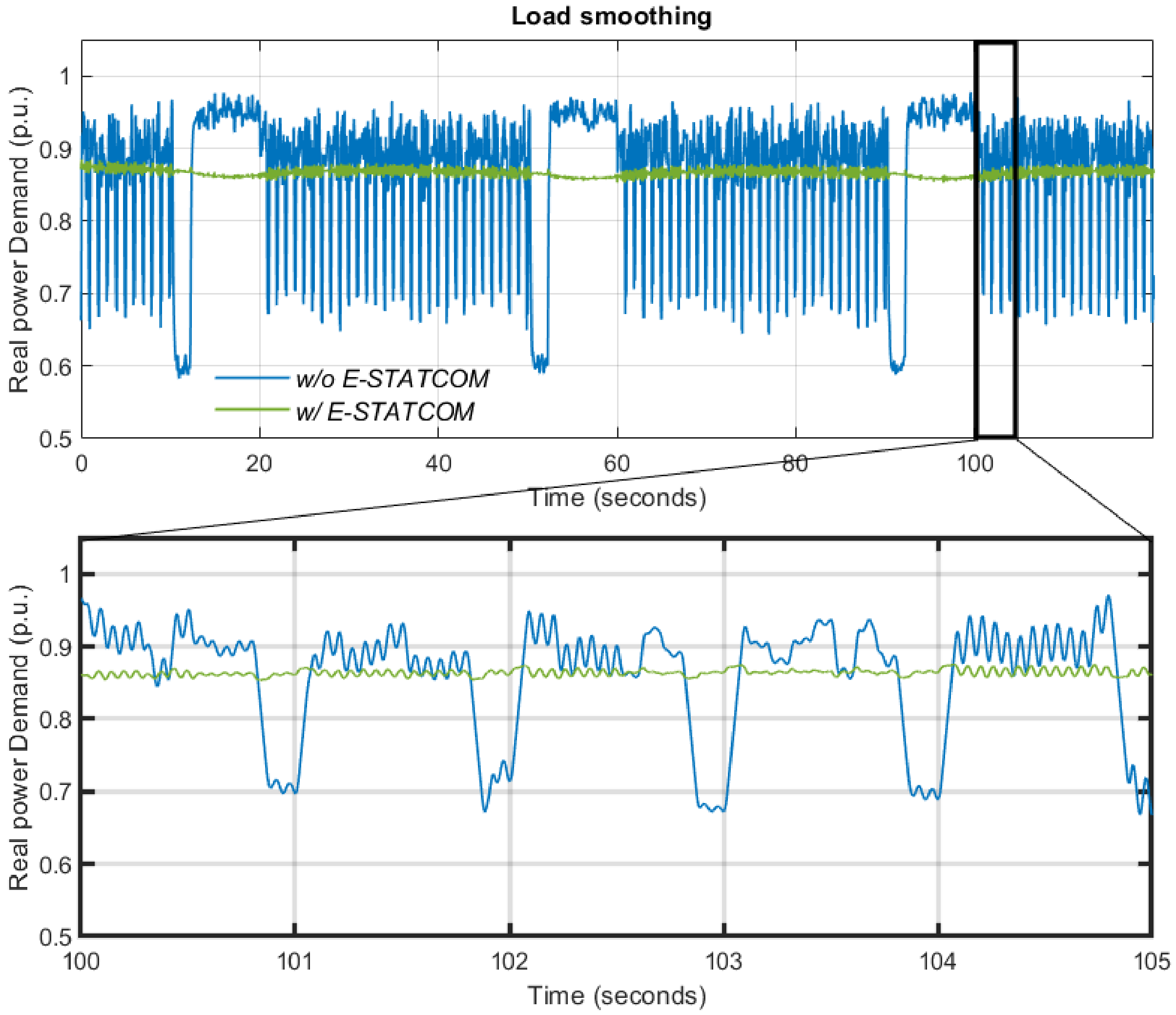
E-STATCOM smooths out abrupt changes in the load, resulting in a more gradual and stable load transition





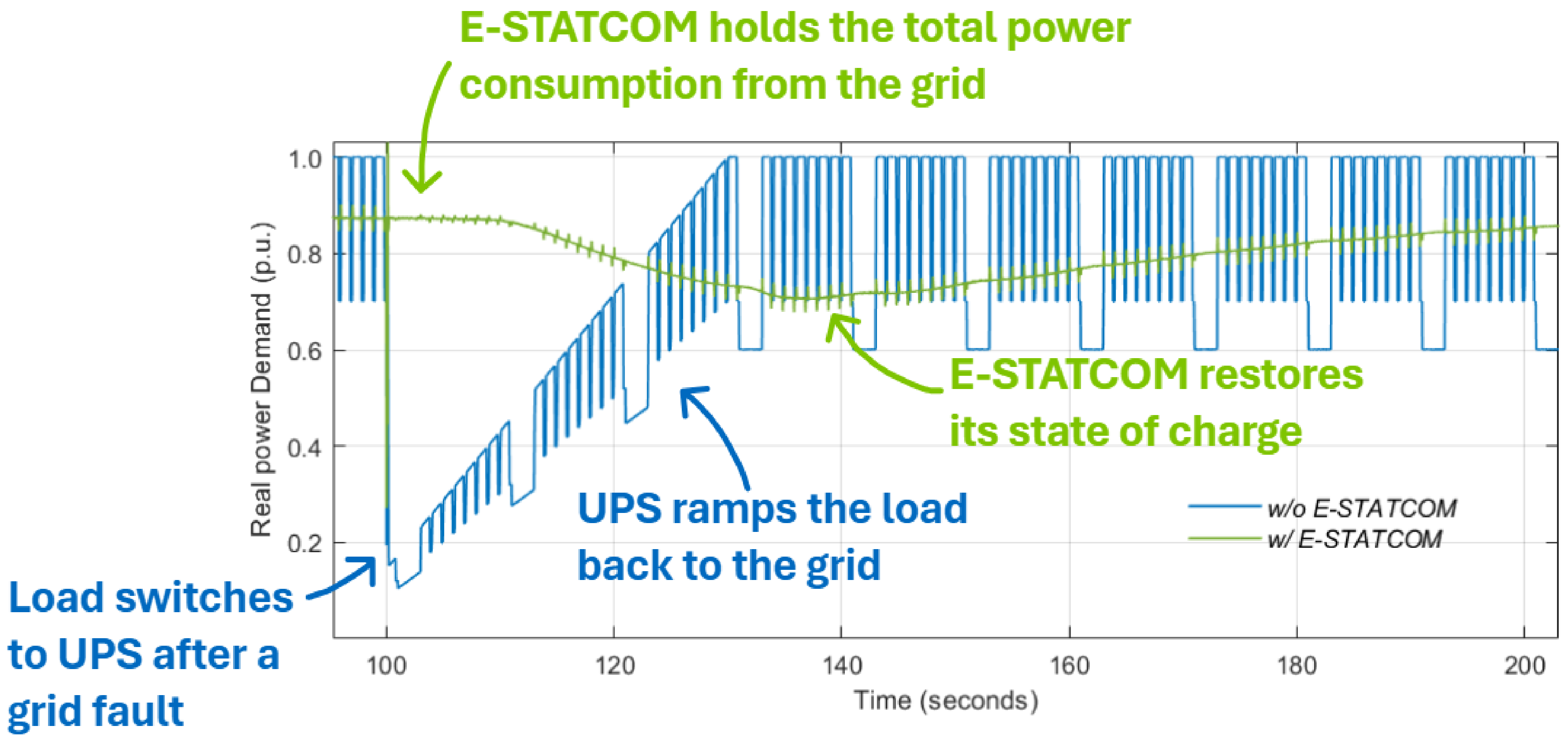
Example. Based on NERC Report





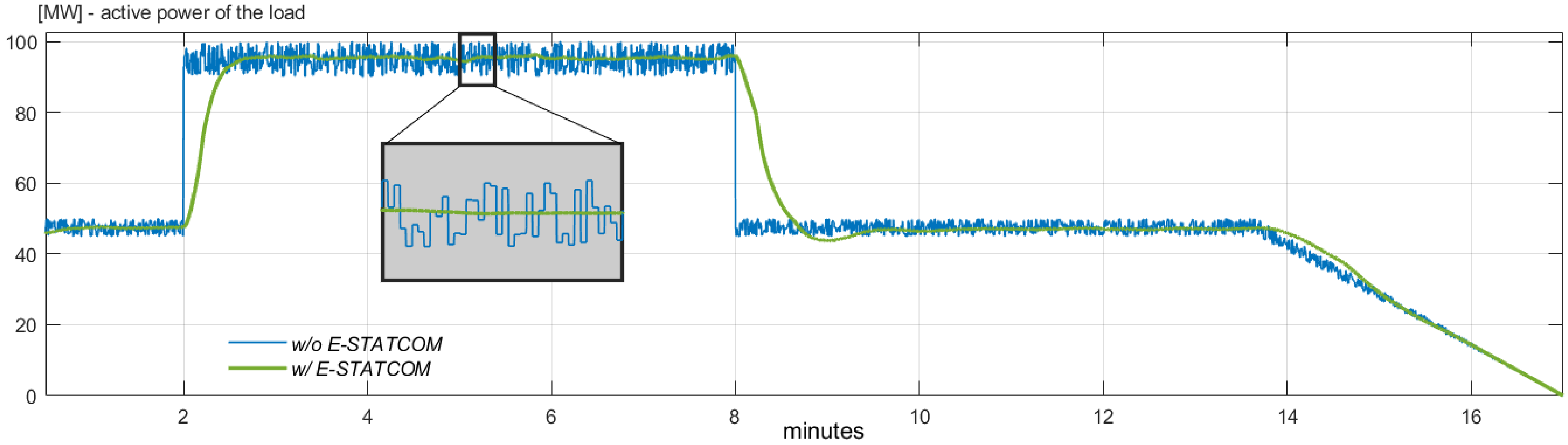
An approximation inspired by the load pattern in : NERC White Paper: Characteristics and Risks of Emerging Large Loads

E-STATCOM during Voltage-Sensitive Load Reduction[1]



1:: NERC Incident Review: Considering Simultaneous Voltage-Sensitive Load Reductions

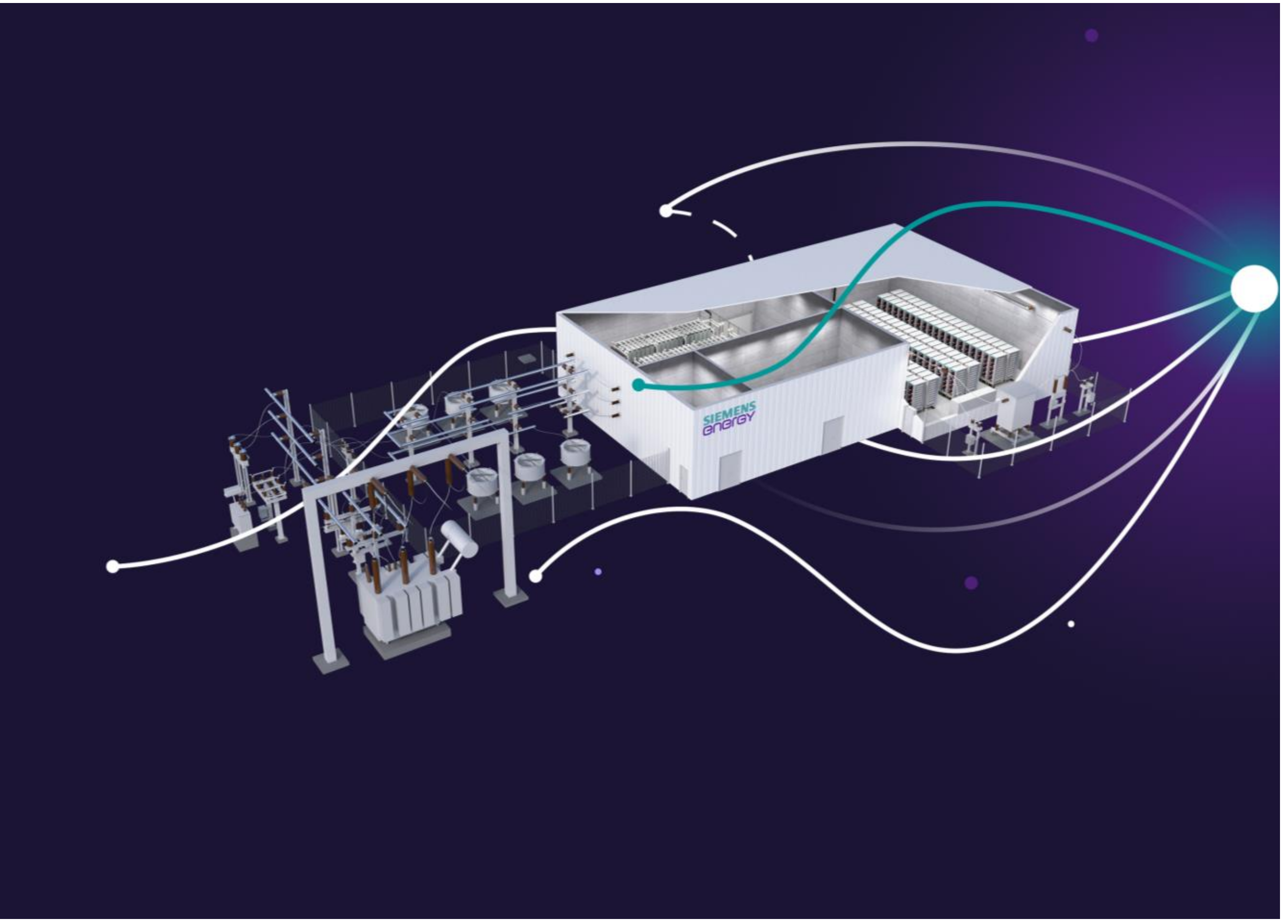
Zoom out: Minutes timescale



AI Workload concerns
E-Statcom as a mitigation measure

Type of load changes	Concerns	Effect of E-STATCOM
5-55 Hz **(any abrupt load change contains these high frequence components)**	Torsional resonance, shaft, and turbine damage High-cycle mechanical/thermal fatigue	effectively damps in the entire range of the sub-synchronous oscillations. slows down the millisecond ramps into minute ramps
0.1-2 Hz	local swing-mode resonance, control mal-operation inter-area oscillation, grid instability	eliminates oscillations in critical regions for local and interarea mode.
Load reduction after LVRT	angular or frequence instability, Potential over-voltages	compensates load dip up to its MW and energy capability provides voltage control by reactive power
Large power ramps (in minutes range)	Resource balancing and dispatch Voltage control might be a challenge	does not resist slow, minute-scale ramps. provides voltage control by reactive power

Contact information



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