Grid-Forming Inverter Applications for Improved Reliability and Power Quality in AI Data Centers

Sam Maleki, Director of T&D consulting
RMS Energy

Introduction

Growth of AI

Increased reliance on data centers to host AI and internet-based technologies.

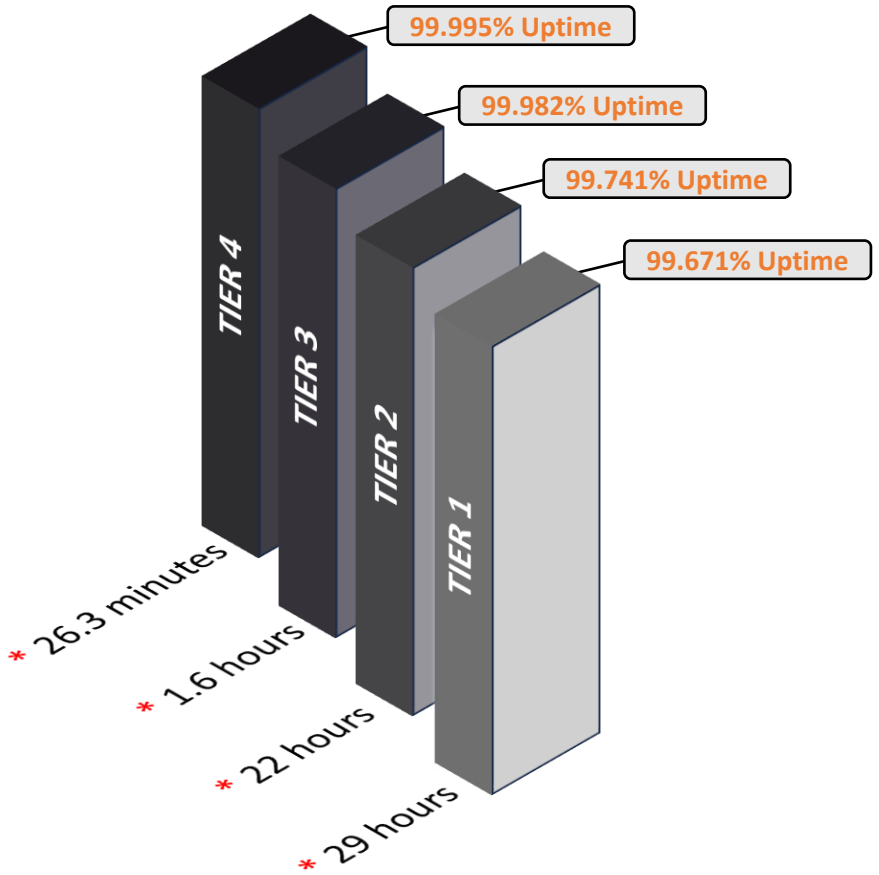
Power Quality

Data centers can create power quality issues, such as voltage sag and flicker.

GFM Solution

Grid-forming inverters offer a solution for stability and reliability improvements.

Uninterrupted Power: A Data Center Necessity



*: Annual potential offline time of up to

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Power Quality Challenges in Data Centers

1

High Energy Consumption

Voltage sags, harmonic distortion, and transients are common.

2

Sensitive Equipment

Minor fluctuations can cause data loss and equipment malfunction.

3

Financial Impact

Minor fluctuations can cause data loss and equipment malfunction.

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Grid Forming Inverters

Data Center Load	Co-Location with GFM
1. Unable to support a grid during faults or blackouts.	1. Voltage & frequency control
2. Can contribute to system instability in high renewable penetration scenarios.	2. Works in grid & islanded mode
	3. Supports black start (grid restoration)
	4. Provides system inertia & stability

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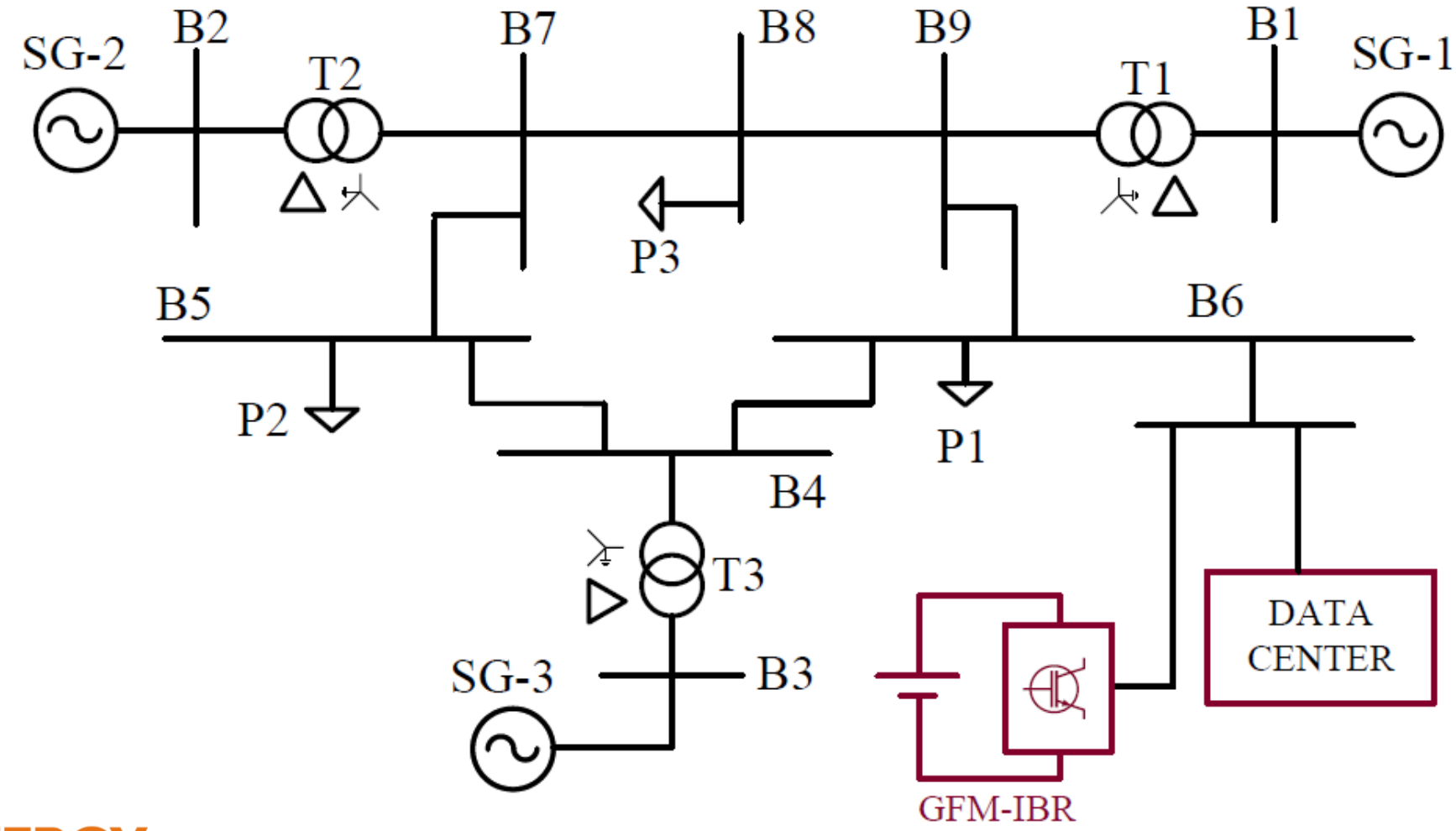
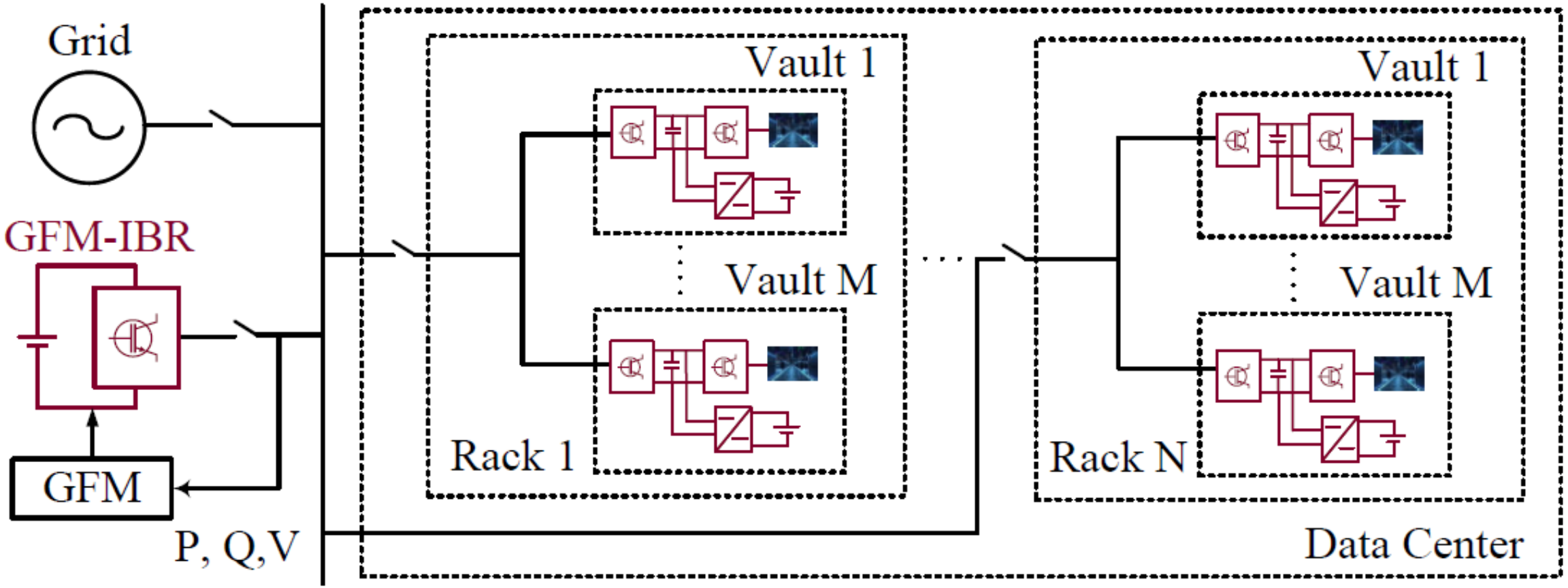
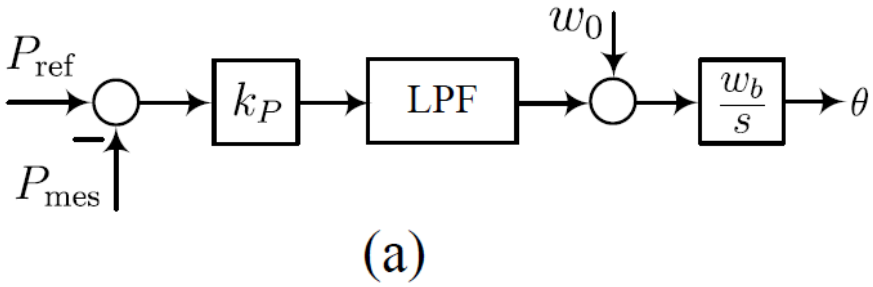
Study System Architecture (IEEE 9-Bus System)



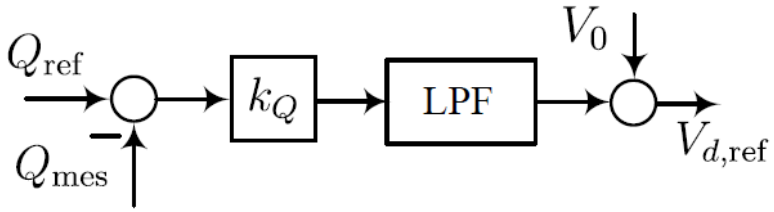
Data Center Load



GFM-BESS Control System



(a)



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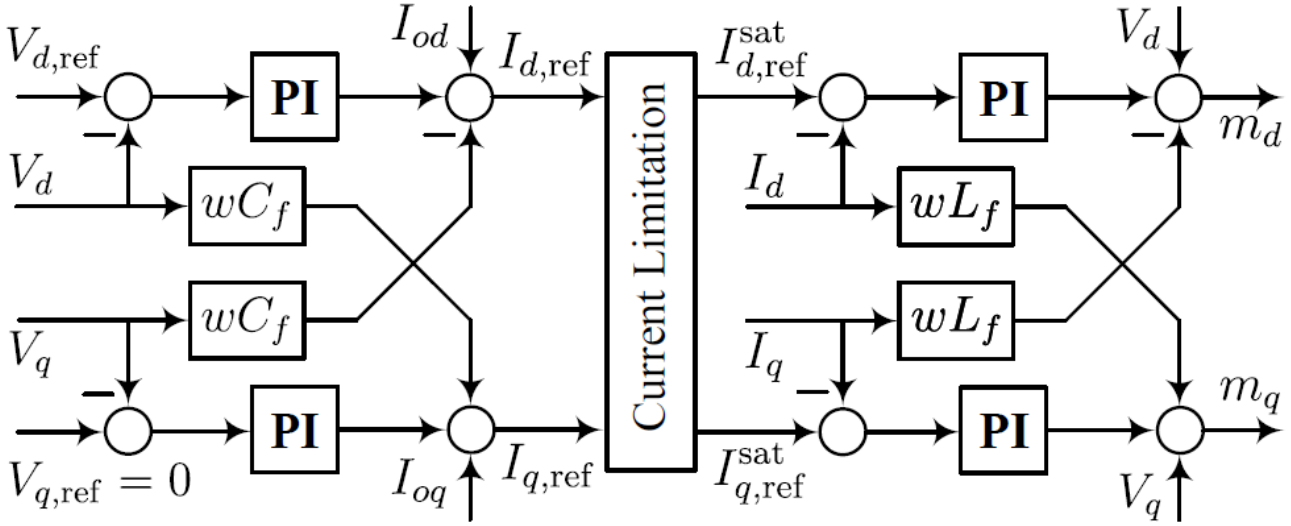


(c)

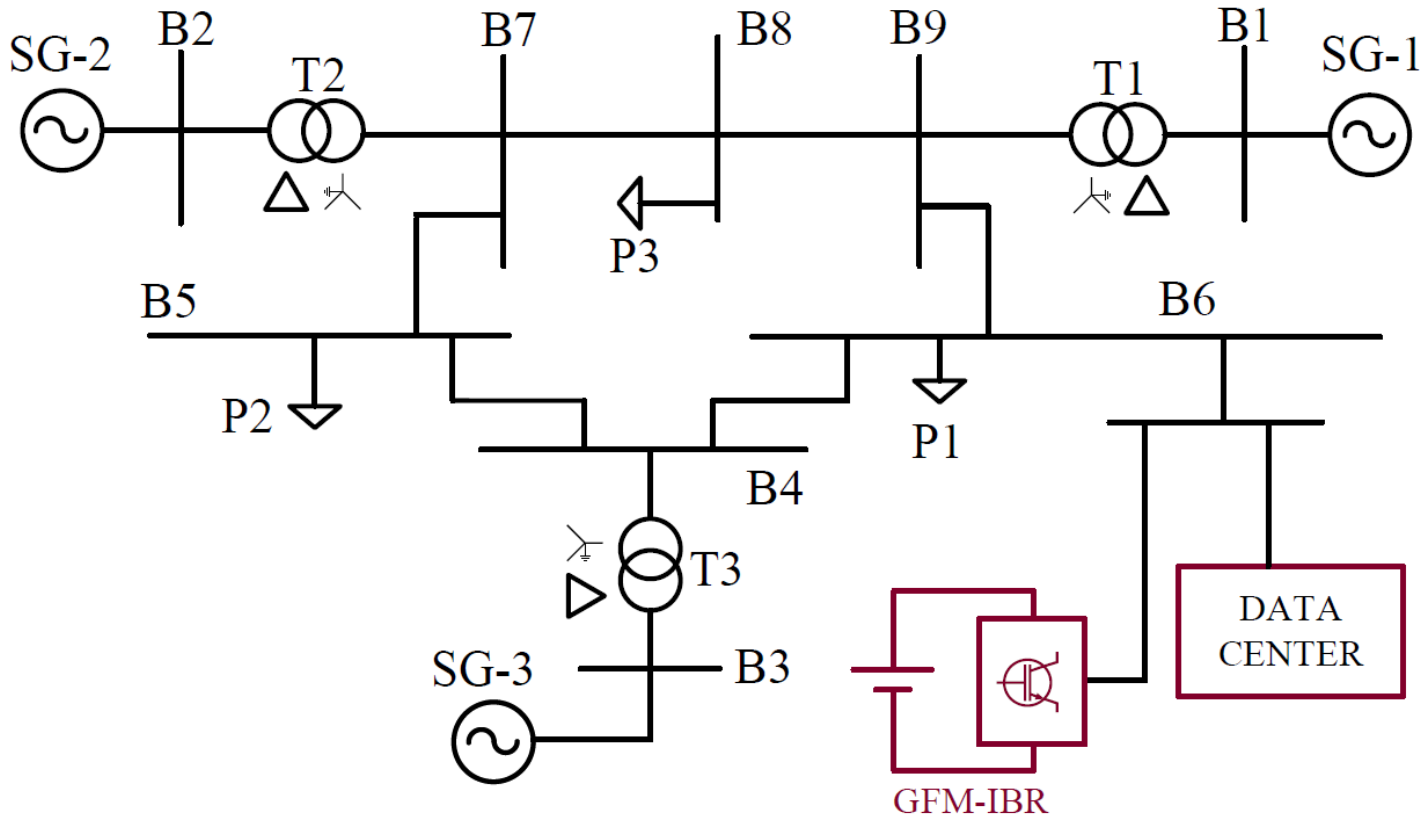
Voltage Sag Mitigation with GFM (PSCAD Simulation)

Study System Details

- ✓ 500 MW AI Data Center
- ✓ 200 MW Droop-Based BESS-GFM
- ✓ PSCAD Simulation on Modified IEEE 9-Bus System

Scenarios Analyzed

- ✓ Voltage Sag Mitigation with GFM
- ✓ Flicker Mitigation with GFM



Voltage Profile and Data Center Current During Fault (PSCAD Simulation)

Scenario Overview:

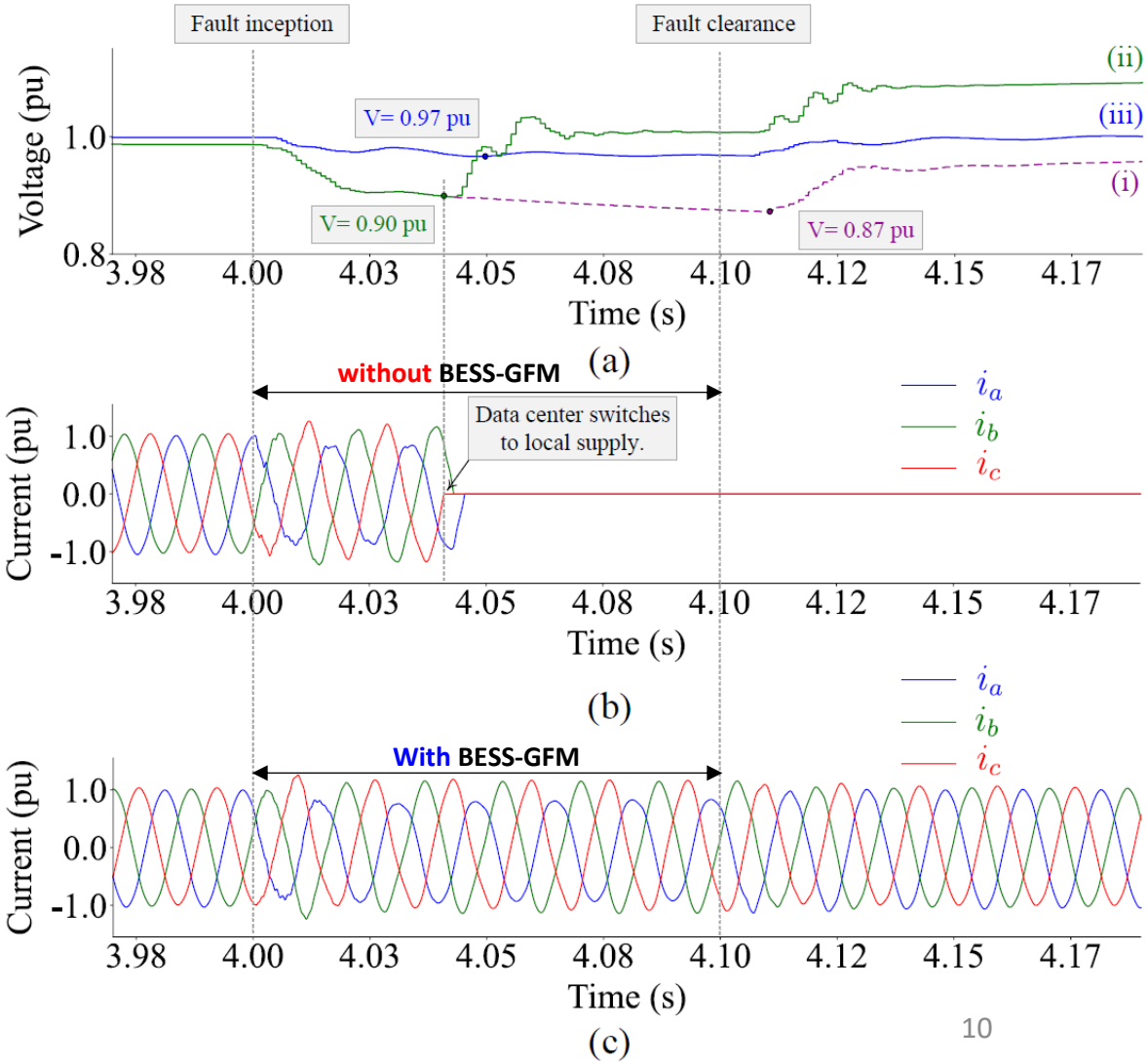
- ✓ Investigates the impact of fault event on the system **with** and **without** BESS-GFM.
- ✓ A single line-to-ground fault applied at t = 4 s, cleared after 6 cycles.

Voltage Profile at POI:

- ❑ **Purple dashed line (without BESS-GFM)**
  Voltage at the POI when the fault occurs, and the data center does not trip.

- ❑ **Green line (without BESS-GFM)**
  Voltage at the POI when the data center trips due to the fault.

- ❑ **Blue line (with BESS-GFM)**
  Voltage profile at the POI remains above 0.9 pu.



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Voltage Profile and Data Center Current During Fault (PSCAD Simulation)

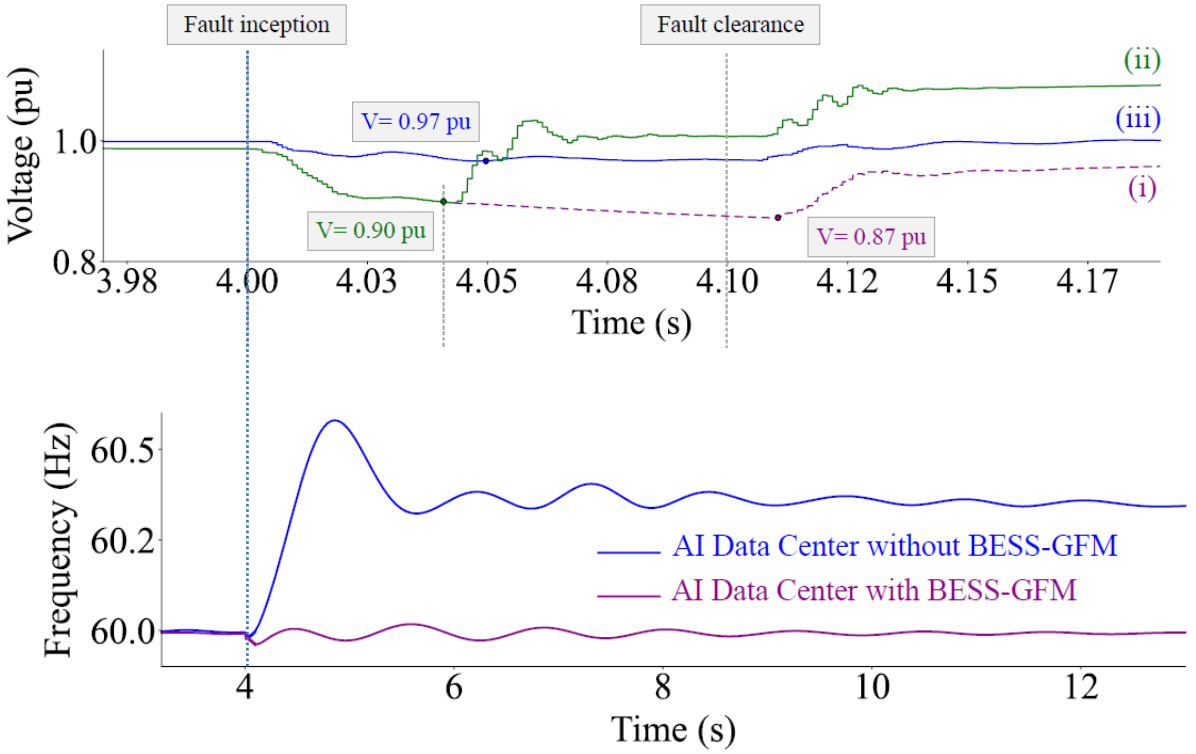
Scenario Overview:

- ✓ A single line-to-ground fault applied at t = 4 s, cleared after 6 cycles.

Frequency Profile at POI:

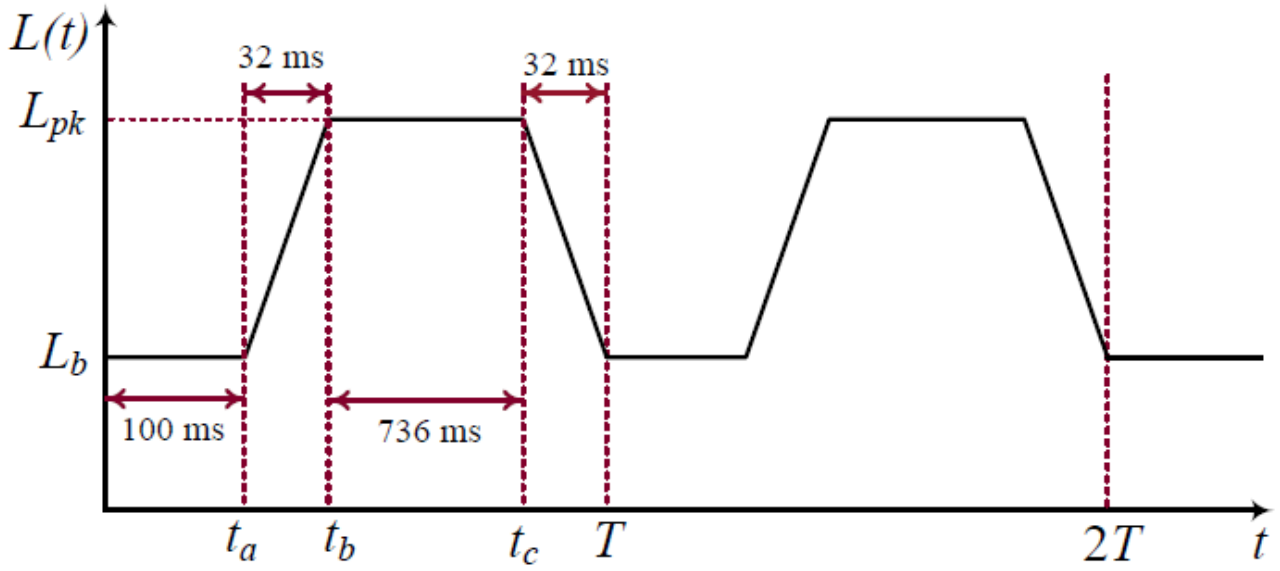
- ❑ **Blue line (without BESS-GFM)**
  Frequency at the POI increases due to data center load trip.

- ❑ **Purple line (with BESS-GFM)**
  Frequency at the POI remain in the acceptable range.

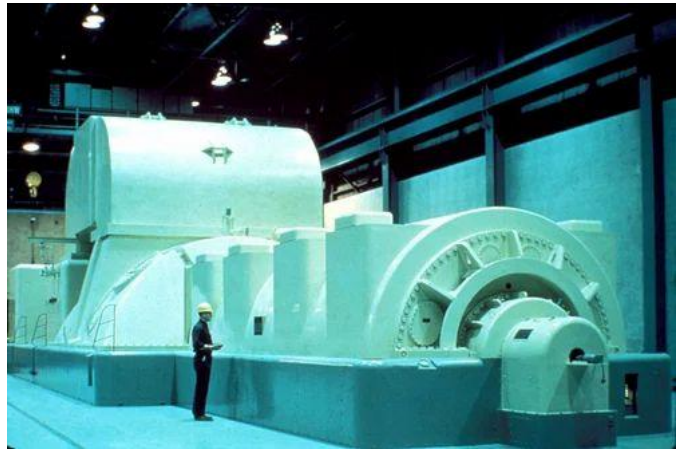


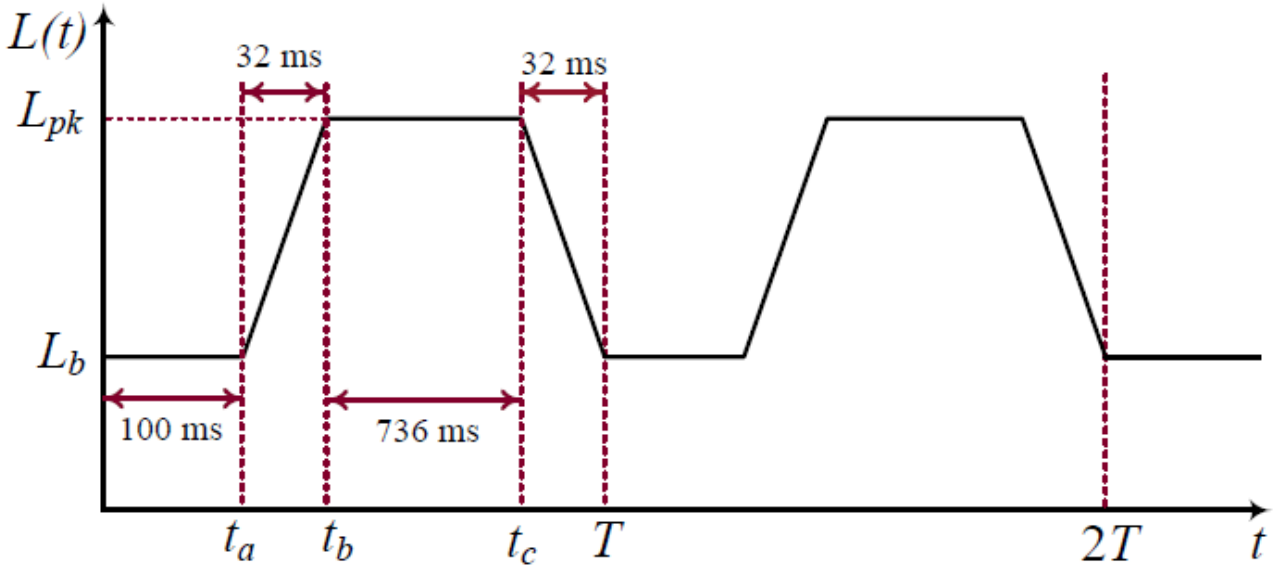
AI data center load profile

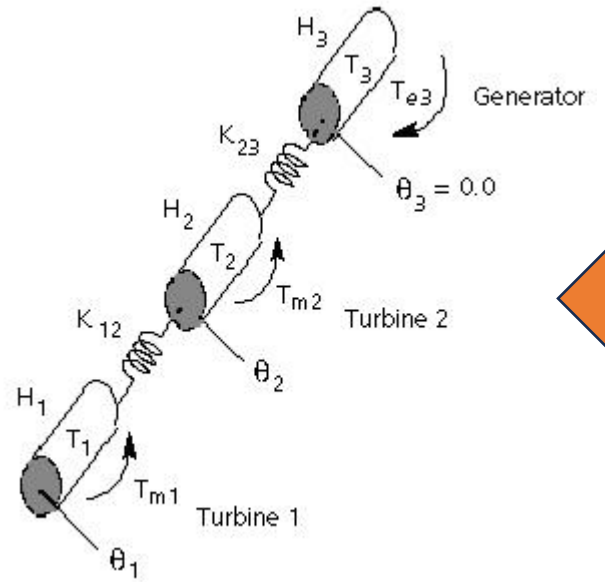
AI data centers cause voltage flicker due to nonlinear, fluctuating loads.



Co-location with conventional generator







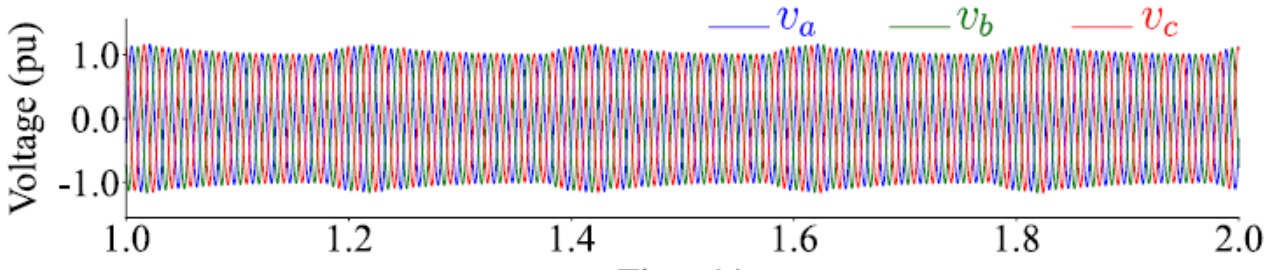
Energy goes to the generator shaft

Co-location with BESS-GFM

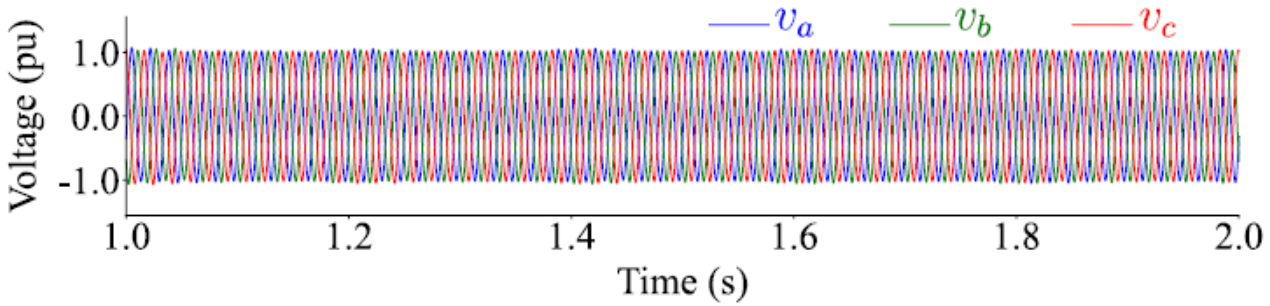
Without BESS-GFM: High variability causes significant flicker.

With BESS-GFM: Improved voltage stability, reduced flicker magnitude.

POI voltage without BESS-GFM



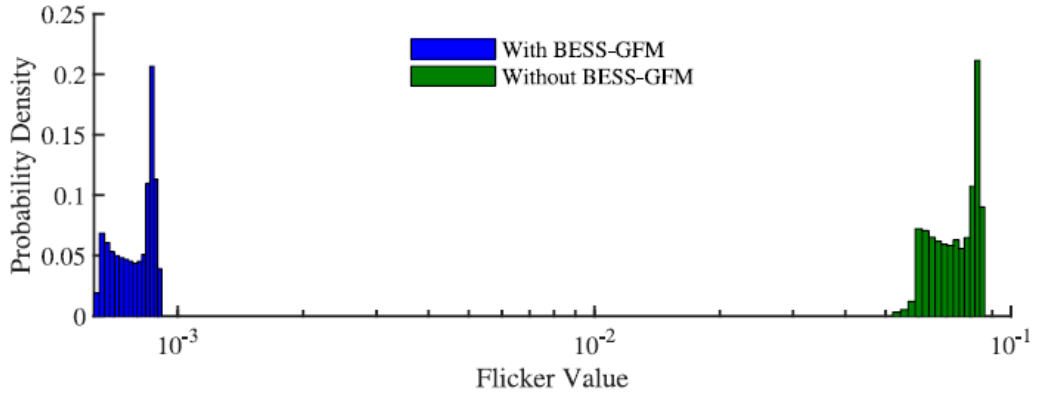
POI voltage with BESS-GFM

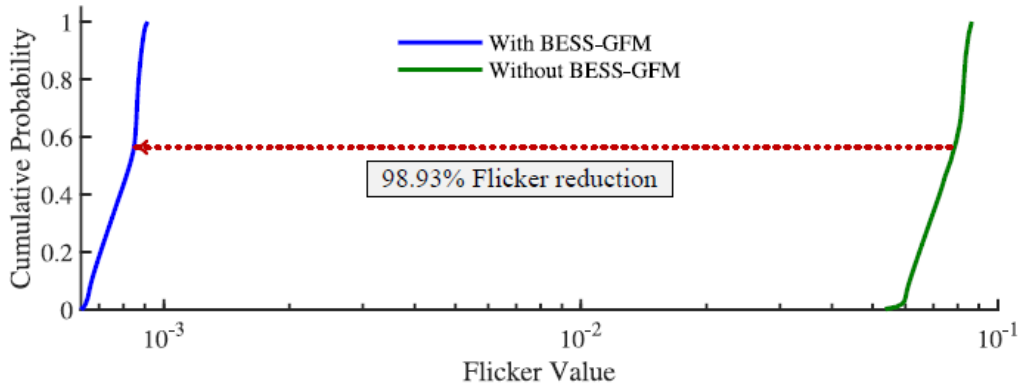


Flicker Value at the POI

Without BESS-GFM: High variability causes significant flicker.

With BESS-GFM: Improved voltage stability, reduced flicker magnitude.





SCR	P_{st} level without BESS-GFM	P_{st} level with BESS-GFM
High	0.2061	0.0212
Low	0.947	0.278

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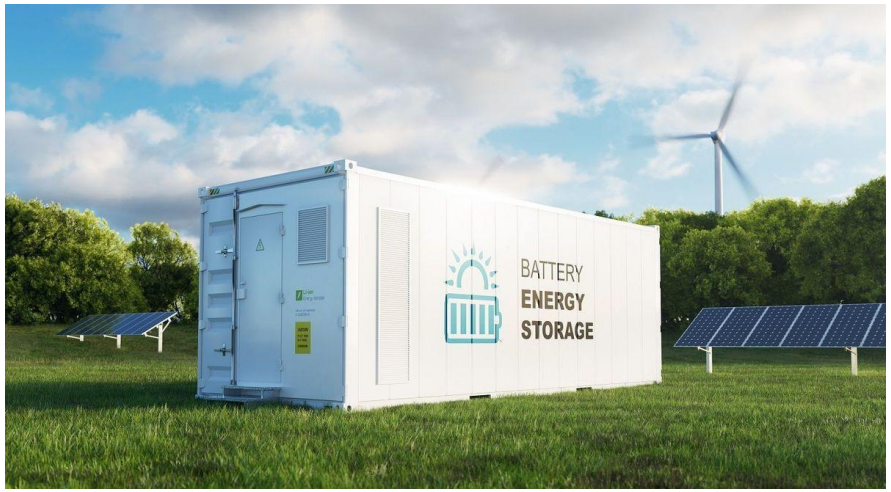
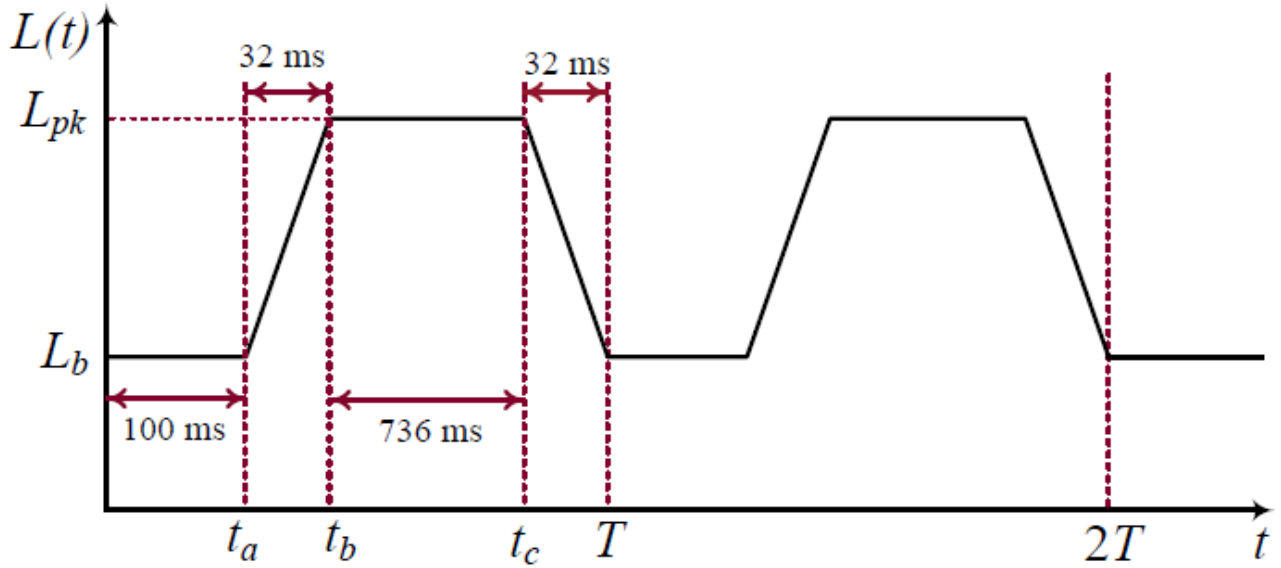
AI data center load profile



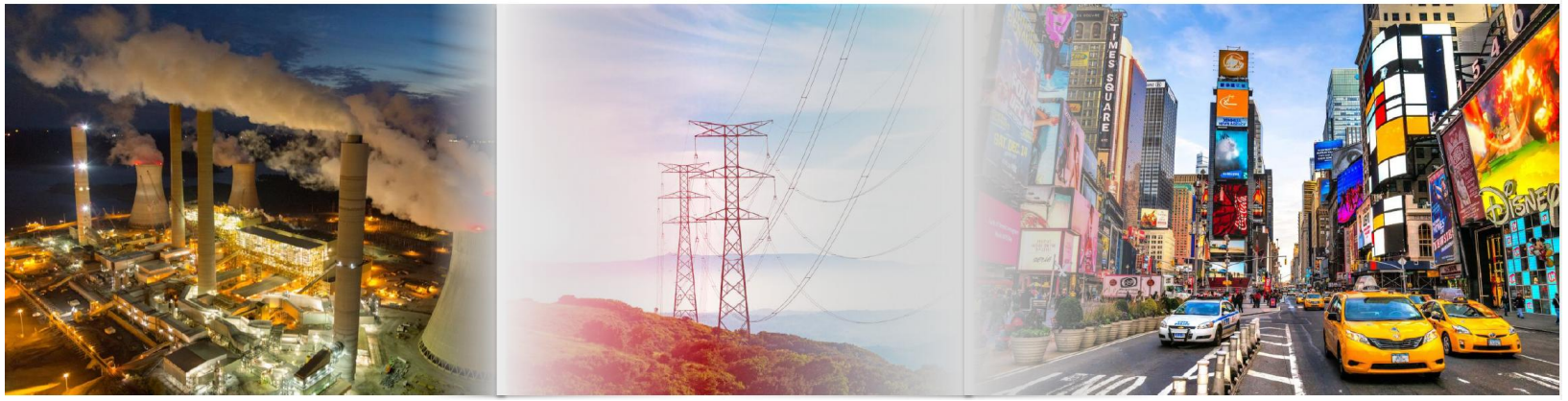


Significant BESS lifetime reduction

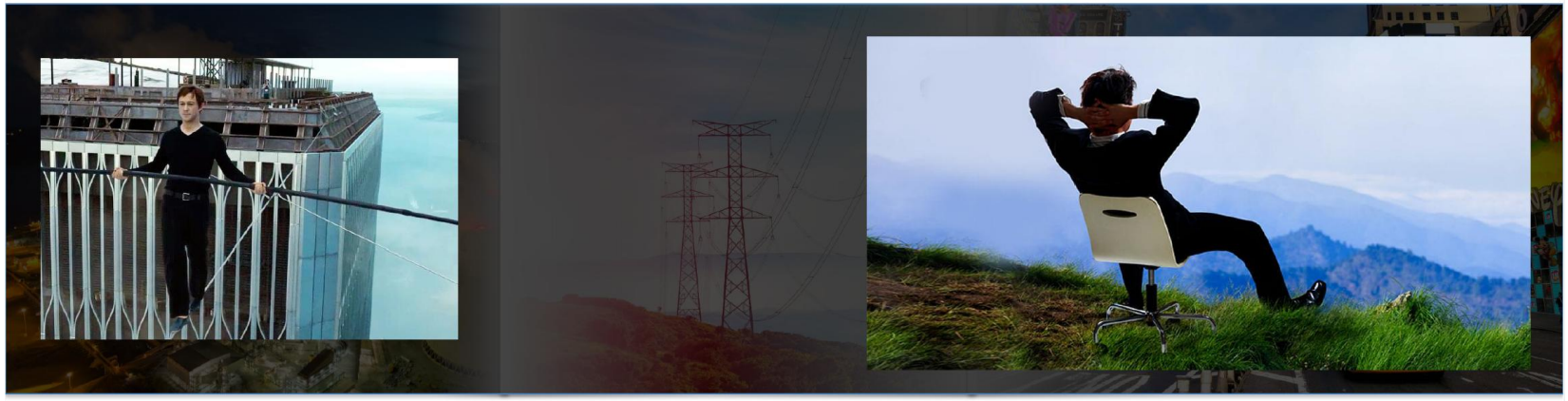
Energy goes to BESS with high ramp rate

Hyper-scaler Loads must provide grid services

Generation units | Transmission lines | Loads



Generation units | Loads



Conclusion

✓ **Key Takeaways**

- Improved Power Quality & System Reliability
- Mitigates Voltage Sags & Flicker in AI-driven data centers
- Ensures Stable Voltage & Frequency during low-voltage events
- Prevents Load Disconnections & provides reactive support
- Loads must provide grid support services

Thank you for your attention!