



GE VERNOVA

Stability and Operation Considerations for an Off-Grid Data Center

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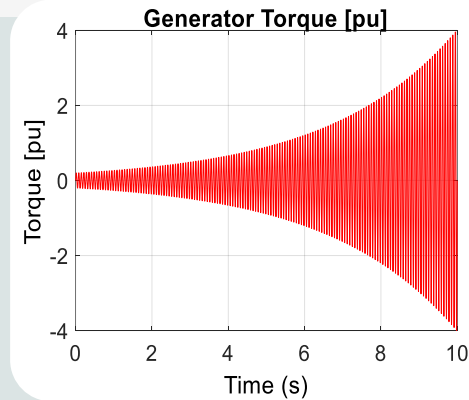
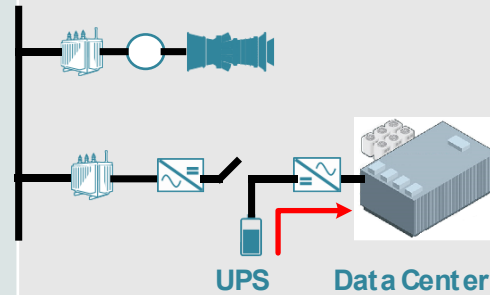
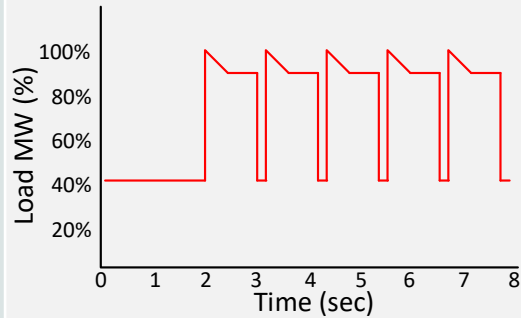
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ESIG 2025 Fall Technical Workshop

Outline

- Data center challenges
- Architecture for Islanded System
- Frequency Regulation in Islanded System
- Simulation Example
 - AI Load Profile
 - Fault
- Risks and Mitigation Summary
- Conclusion

Data Center Considerations & Challenges



Fast Load Fluctuation

- Frequency excursion & risk of generation trip
- Torsional stress on turbine shaft & risk of fatigue damage

UPS Operation

- Large load loss
- Over-frequency
- Risk of generation trip

Power electronic load

- Torsional interaction with adjacent generators
- Risk of generation trip

High Reliability

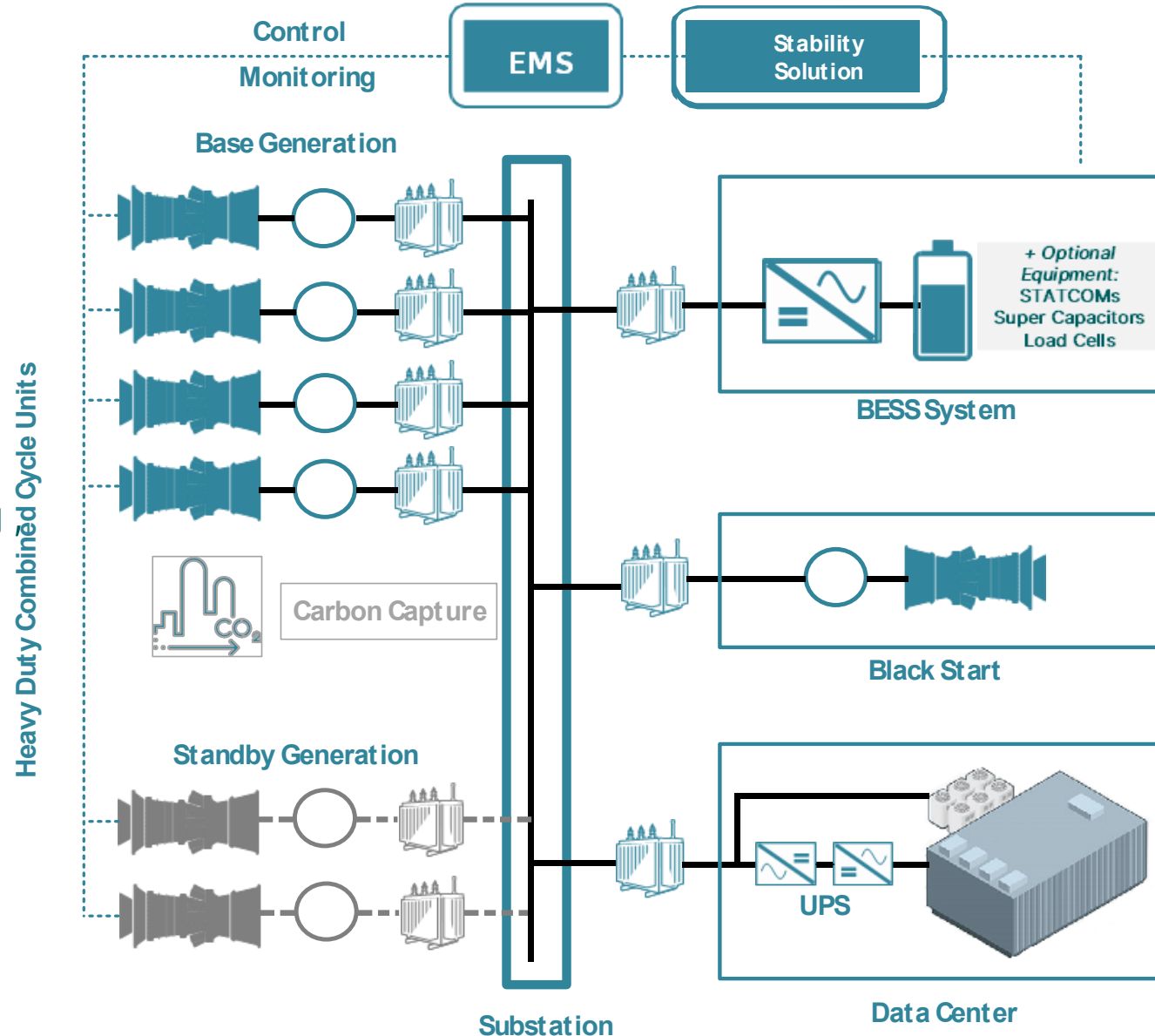
- >99.9% reliability
- Tight frequency and voltage tolerance
- Limitations to shed load to contain frequency excursions

System Solutions to mitigate project risks

Reference Architecture for Islanded Data Center

Heavy Duty GT Missions:

- Base power
- Standby power for reliability
- Inertia
- Droop
- Mix of large and small frame (or aero-derivatives) machines for load commissioning startup and minimum load consideration



EMS Missions:

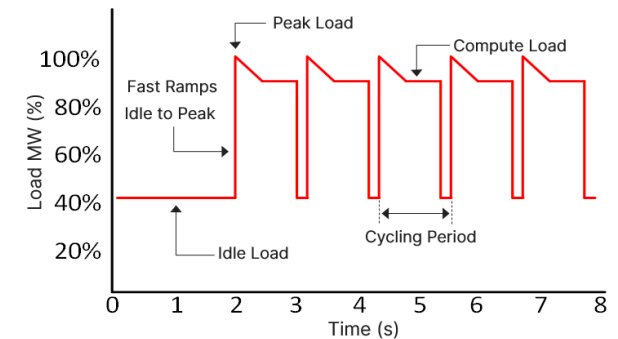
- Supervisory control
- Loading balancing across GTs and BESS
- BESS SOC Correction
- Generation shedding
- Load Shedding

BESS Missions:

- Synthetic inertia
- Torsional damping
- Frequency control
- Voltage regulation
- N+1 backup power

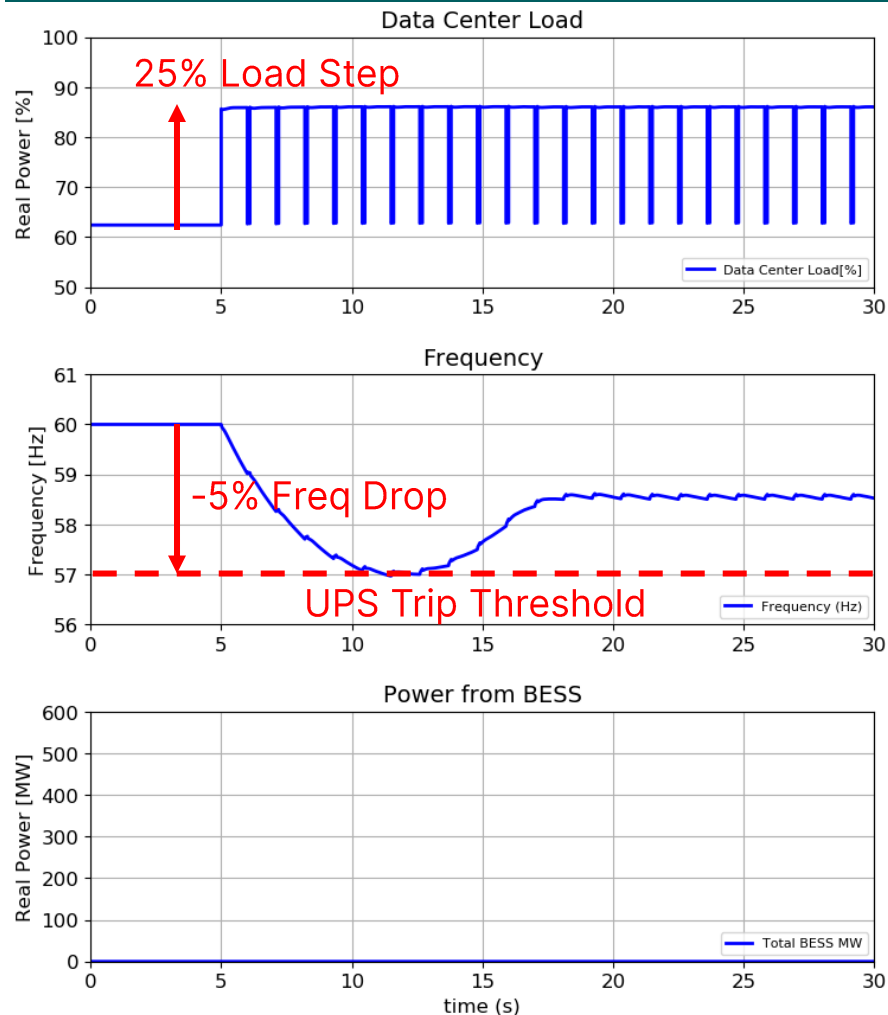
Frequency Regulation in Islanded System

- Imbalance between generation and load is reflected in frequency (or speed).
- Gas Turbines are used in Islanded systems of similar size (Oil & Gas, Mining, Smelters etc.)
- So, what is unique about data center?
 - Load characteristics (rapid and large amplitude load steps) – “underfrequency”
 - UPS operation (UPS are sensitive to power quality events) – “overfrequency”.
 - Load reliability (critical and non-critical loads)
- Understanding load characteristic is important for:
 - Design of resilient power supply solution for islanded system
 - Determination of additional equipment (BESS, STATCOM, Load banks etc.)
 - Load & generation shedding scheme for frequency control in extreme events.

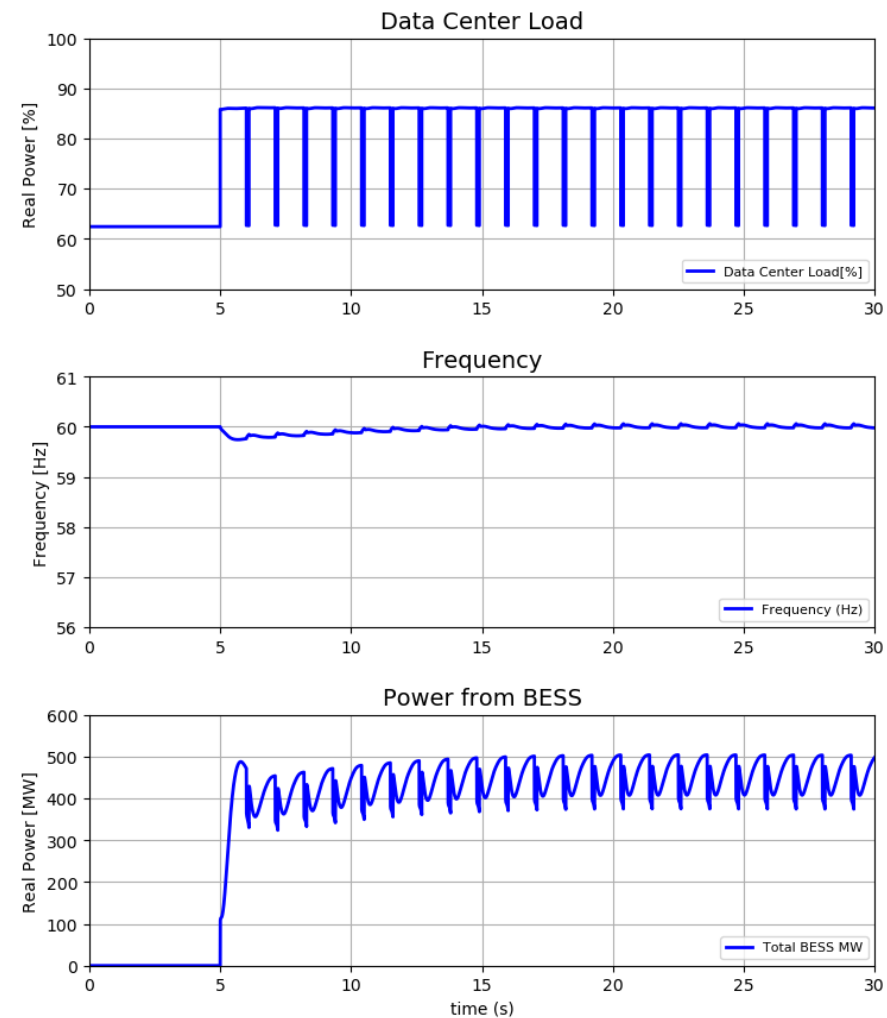


Impact of AI Load Profile on Island Frequency

Without BESS (2.1 GW Load, No BESS)

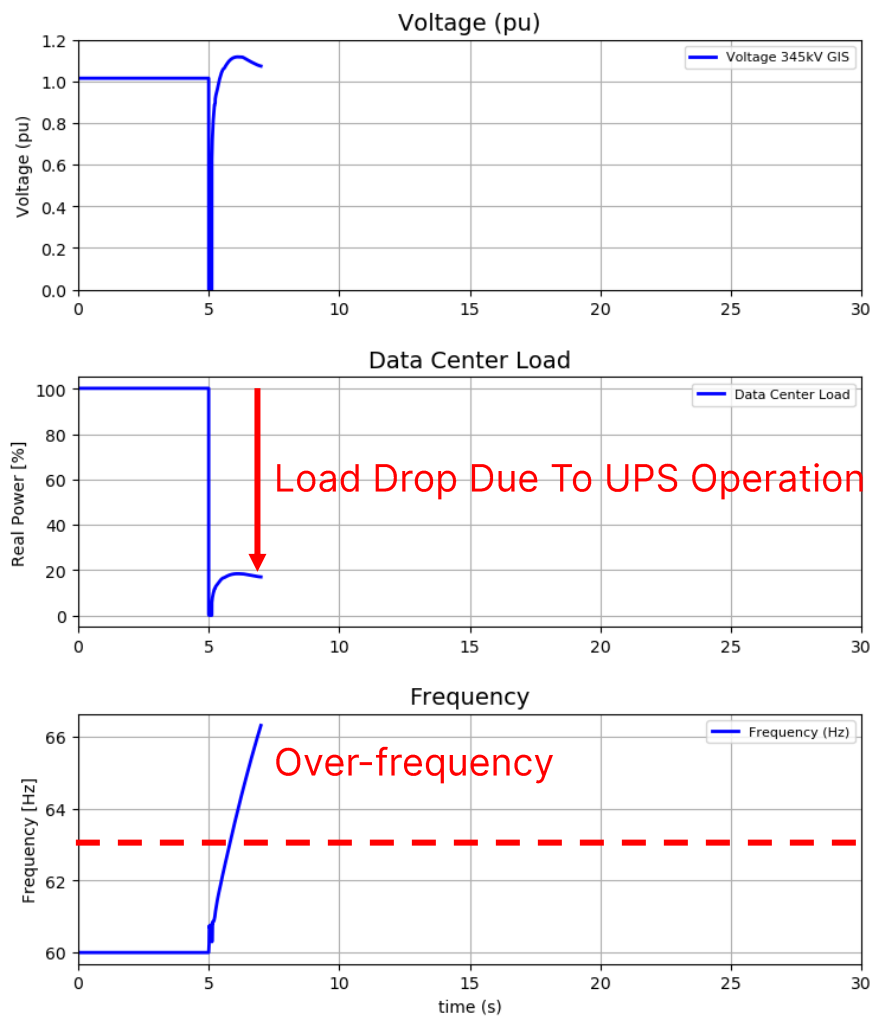


With BESS (2.1GW Load, 550MW BESS)

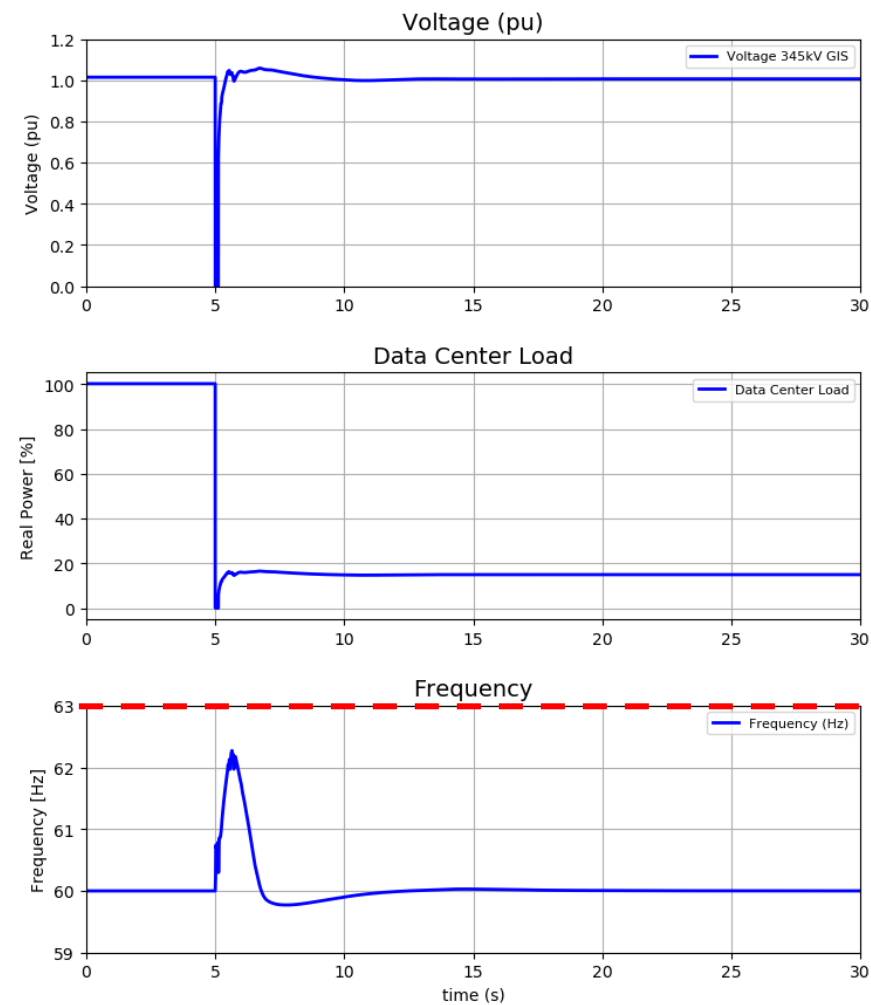


Impact of Fault On Island Frequency

Voltage induced over-frequency issue



Multiple Unit Trip to Contain Frequency



Stability Risks and Mitigation

Risk	Cause	Mitigation
Under-frequency	• Generation unit trip • Starting transient of AI load • Combination of both	• BESS with fast response to frequency deviation (grid forming) • Coordination with data center to minimize coincidental starting of AI load
Over-frequency	• UPS operation causing loss of large customer load • Ending transient of AI load	• Fast generation shedding from EMS • GT full load rejection capability • BESS acting like load (charging)
Voltage & frequency fluctuations	• AI load profile characteristics	• BESS with fast response to frequency deviation • BESS with fast voltage regulation in grid forming mode
Sub-optimal BESS size	• Uncertain load profile	• Scalable BESS deployment
Plant Operation & Control	• Operation and control with constantly varying load	• Coordinated control of BESS, GT and EMS • GT dispatched to serve the average of profile • BESS responds to transients and outages • EMS coordinate GT dispatch and BESS state of charge

Conclusion

- Stability study demonstrated feasible islanded operation & stability expectations under normal and severe operational conditions.
- GE Vernova integrated control (BESS, GT, and EMS) and operational strategies effectively manage frequency stability and voltage fluctuations
 - BESS control can manage fast variation in frequency and voltage associated with AI load
 - BESS can effectively manage large transients associated with 'starting' and 'ending' of AI load profile.
 - Appropriate BESS size is dependent on load profile, combination of disturbances to be withstand and coordination with data center load.



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