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BESS Applications to Enhance Transmission and Distribution System Performance

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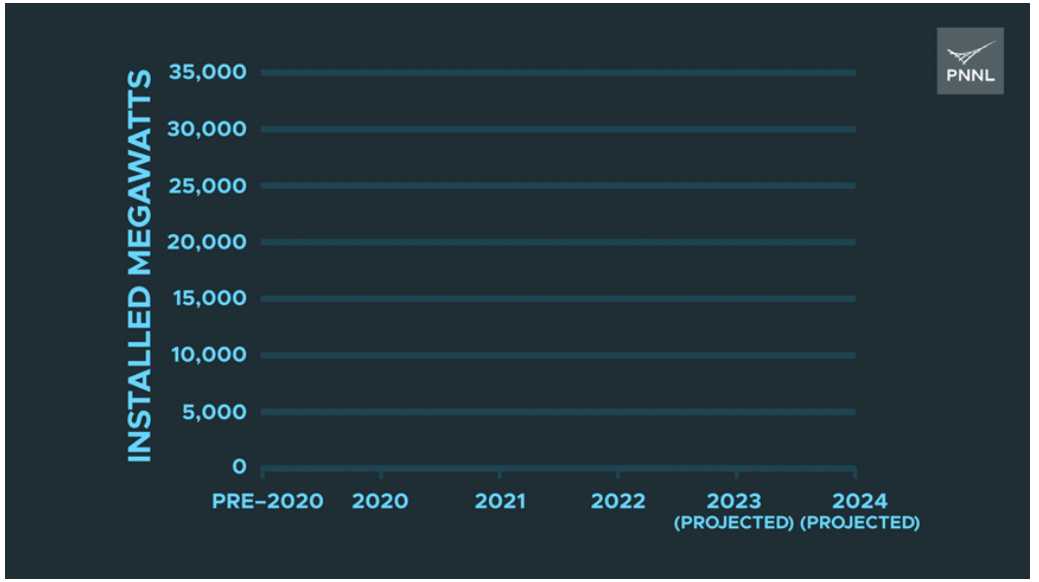
Project Overview

- **Project Goal:** Develop transmission and distribution test systems with BESS models to enable rural utilities to understand and evaluate the use of BESS for resilience and reliability enhancement applications.
- **Current Practice:** Most rural and/or small utilities do not have a good understanding how they could use BESS due to low engineering staff and high consulting costs.
- **Why PNNL?:** PNNL has deep expertise on modeling, simulation and tools development that are key blocks to develop these test systems and support the rural and small utilities.
- **Innovation:** We are utilizing commonly used IEEE test feeder models with open source/ commonly used tools by the industry to enable an easier transition to practice.
- **Impact:** The rural utilities we have talked to (through the ES4RR project) have all expressed a need for tools and material to equip them to take informed decisions. Currently, they depend heavily on consultants for simple analyses which can be done on their own with these test systems.
- **Alignment:** These test systems and use cases will enable affordable and reliable electric energy by allowing small utilities to explore BESS as a core resource for energy security.

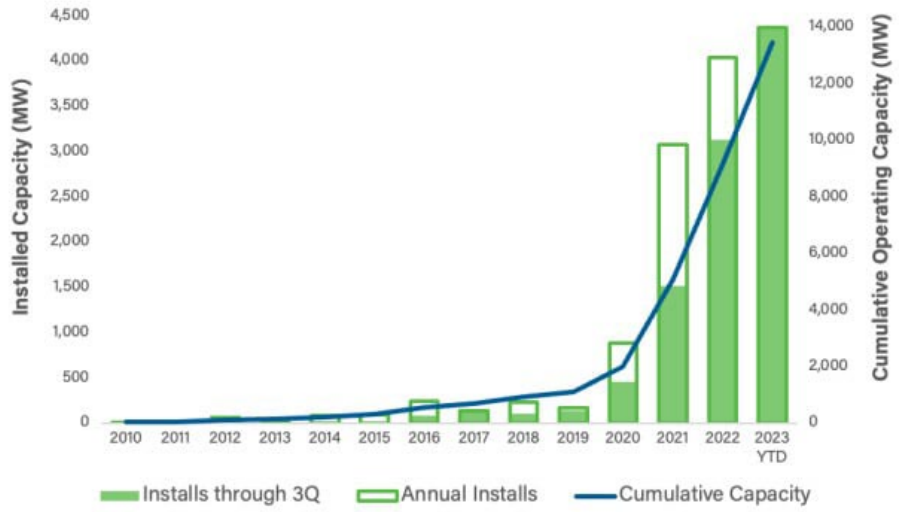
BESS Applications

- Large amounts of BESS capacity is being added to the grid
- Typical BESS use cases in the transmission and distribution systems
  - Resilience and energy security applications have been key – e.g., Puerto Rico.
  - Grid Reliability Improvement - Enhance grid stability through fast responding inverter technology.
  - Peak shaving for cost reduction
  - Microgrids and emergency response applications.



Source: PNNL - https://www.pnnl.gov/news-media/battery-energy-storage-systems-are-here-your-community-ready, 2022

Trend is similar (actual installed MW is about 2000 MW behind the projections), but more BESS is coming.



Source: Energy Storage News - https://www.energy-storage.news/us-large-scale-bess-installations-in-2023-already-exceed-whole-of-2022/, Nov 2023

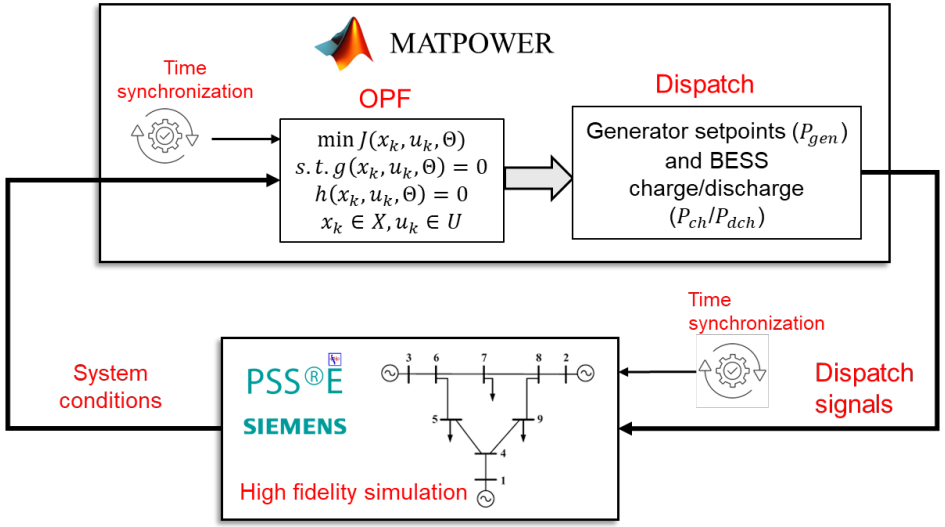
Challenge Experienced by Smaller Utilities, Coops, Municipalities

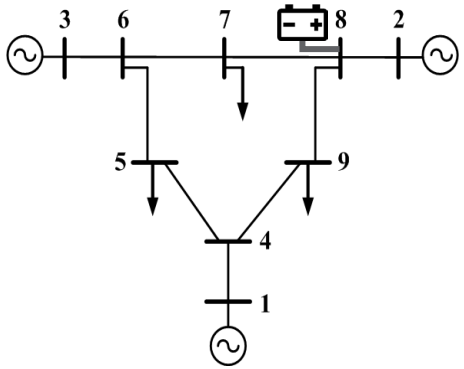
- Limited staff with inhouse engineering resources to do in depth analysis with development of a models and tools.
- Limited experience of exploring the role of BESS in their system operations.
- Lack of models and tools to run some simple analyses to evaluate the different BESS use cases.
- Through different projects and other allied efforts at PNNL we are
  - Supporting the smaller utilities with models and tools that can evaluate the different BESS use cases.
  - Providing technical assistance through projects like ES4RR (Energy Storage for Rural Resilience).
  - Developing whitepapers, reports and education modules from the Grid Storage Launchpad (GSL).

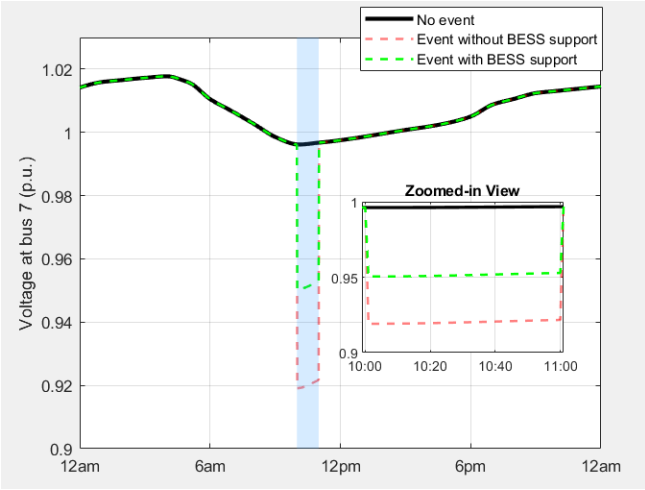
BESS for Transmission System

- The transmission system use cases will be focused on developing a small and medium test cases with BESS models for showing the application of BESS for:
  - Congestion management under stressed operating conditions.
  - Reactive power support with BESS for supporting the grid voltage under a stressed operating condition.
- The models being developed are in PSS/E format
  - Widely used transmission system modeling and simulation tool – free version can simulate systems upto 50 buses.
  - Models will include BESS models along with the BESS dispatch codes.
  - Can be easily translated to other simulation tool models

BESS Transmission System – Preliminary Results







- The testbed enables evaluation of multiple grid services, including reactive power support (voltage regulation) via converter-based BESS Demonstrated effectiveness of voltage support on an IEEE 9-bus system under a 30-minute disturbance scenario involving:
  - Sudden increase in load at Bus 7 is the stress.
- A 120 MW /480 MWh utility-scale BESS located at Bus 8 successfully provided voltage support during the event.
- Ongoing work includes extending the evaluation to IEEE 39-bus and 118-bus systems and incorporating additional stressors such as transmission line contingencies.

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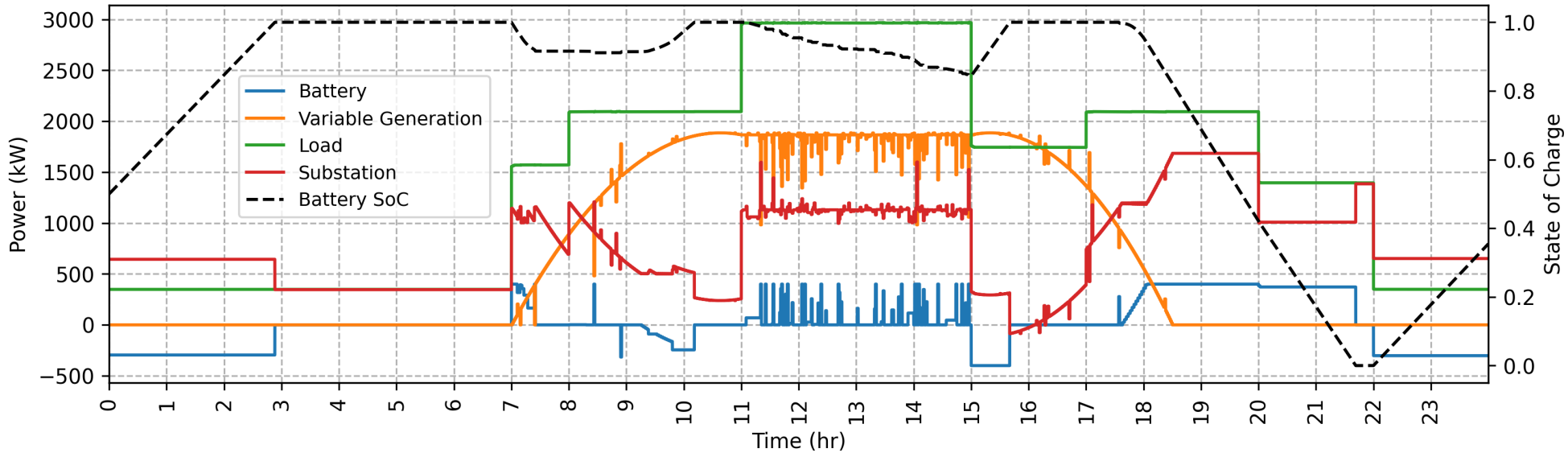
BESS for Distribution System Use cases

- The distribution system use cases are focused on developing small and medium size test systems with BESS models demonstrating the use of BESS systems for:
  - Effectively improving the power quality of the grid under variable output generation.
  - Energy arbitrage and peak shaving applications.
- The distribution system use cases are modeled and simulated using the GridLAB-D software (open source , developed by PNNL).
- GridLAB-D is strategically chosen to enable use of some multi-timescale T&D co-simulation between PSS/E and GridLAB-D that is of essence even for bigger utilities and ISOs to capture the recently increasing T&D interactions.

BESS Distribution System – Preliminary Results

- IEEE 13-node system is modified with variable output generation, BESS and variable loads.
- Day long simulation shows various phases of the BESS and its operation along with complementing the variable output generation.

BESS Operation with Variable load and Generation



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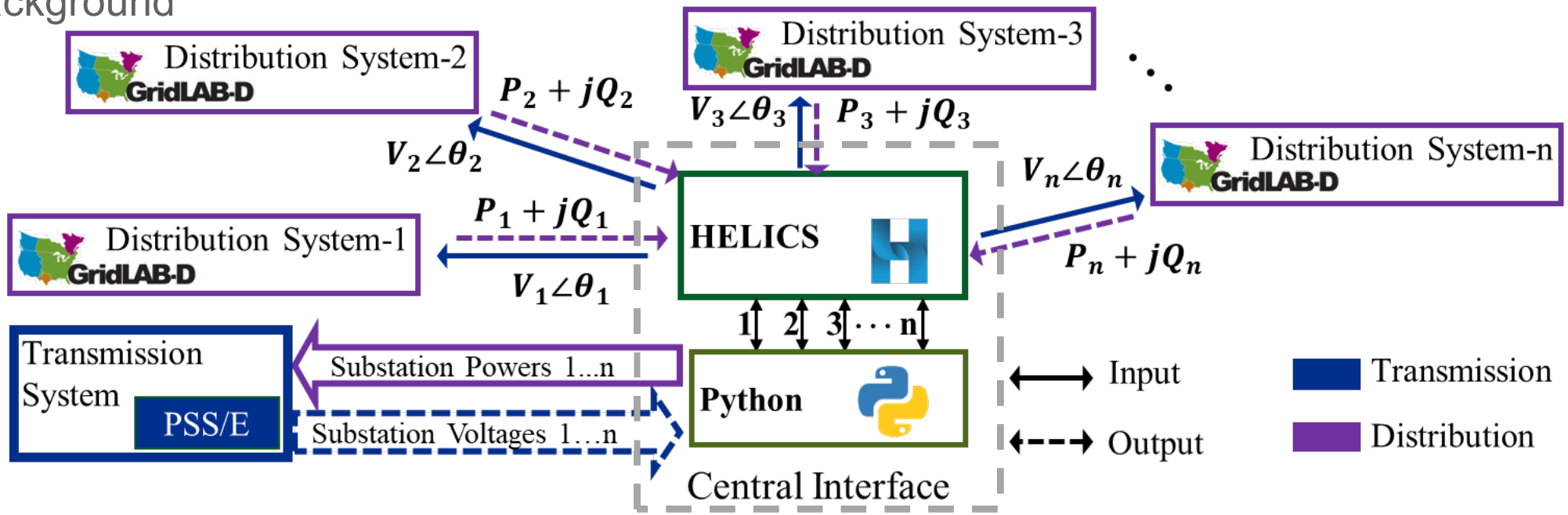
BESS in real world applications

- CAISO: “Electricity storage has the potential to provide significant flexibility in balancing the grid. The ISO has three participation models that provide opportunities for storage technologies to participate in the wholesale ancillary services market and energy market: pump storage, non-generator resource, and proxy demand resource - load shift resource.”
- BESS can effectively provide positive and negative power variations to manage the balancing functions in the bulk grid operations.
- CAISO is exploring the dispatch of BESS in AGC for frequency regulation.
- FERC 2222 provides mechanisms for aggregated resources like distributed energy storage units to participate in the energy and capacity markets

BESS and T&D Interactions

- Background

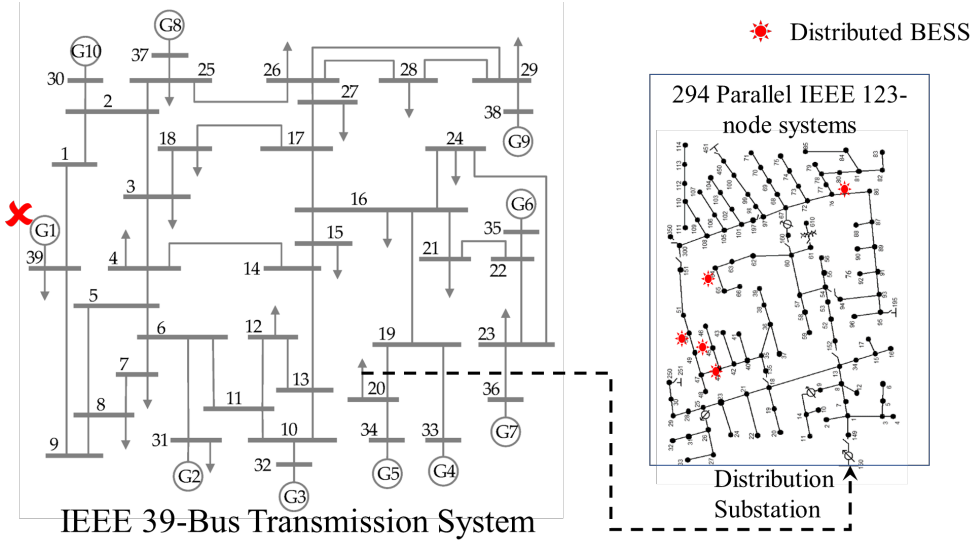


- **Key Blocks of the SMTD Co-Simulation Framework**
- Transmission Solver – PSS/E
- Distribution Solver – GridLAB-D
- Central Interface – Python + HELICS

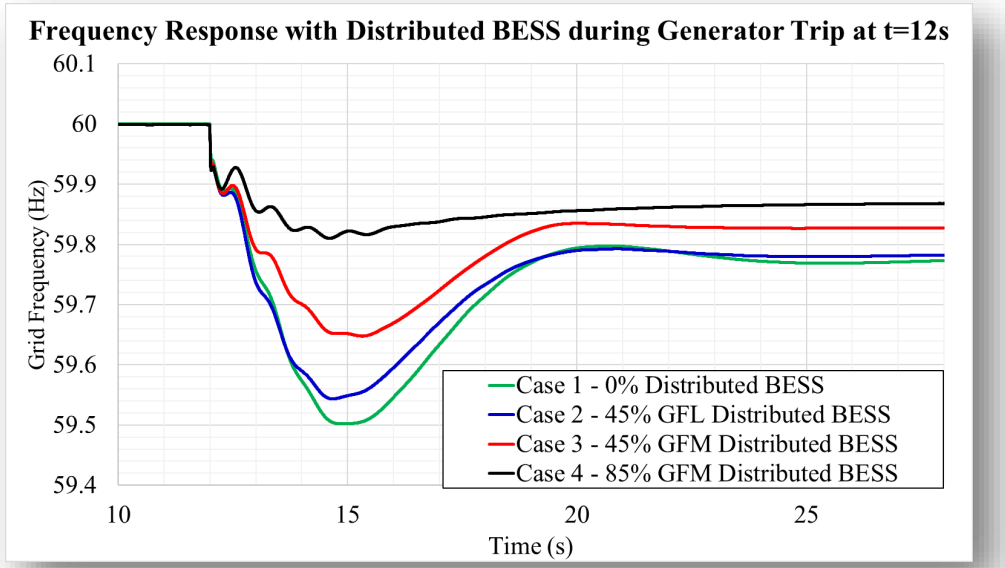
A. K. Bharati and V. Ajjarapu, "SMTD Co-Simulation Framework With HELICS for Future-Grid Analysis and Synthetic Measurement-Data Generation," in *IEEE Transactions on Industry Applications*, vol. 58, no. 1, pp. 131-141, Jan.-Feb. 2022,

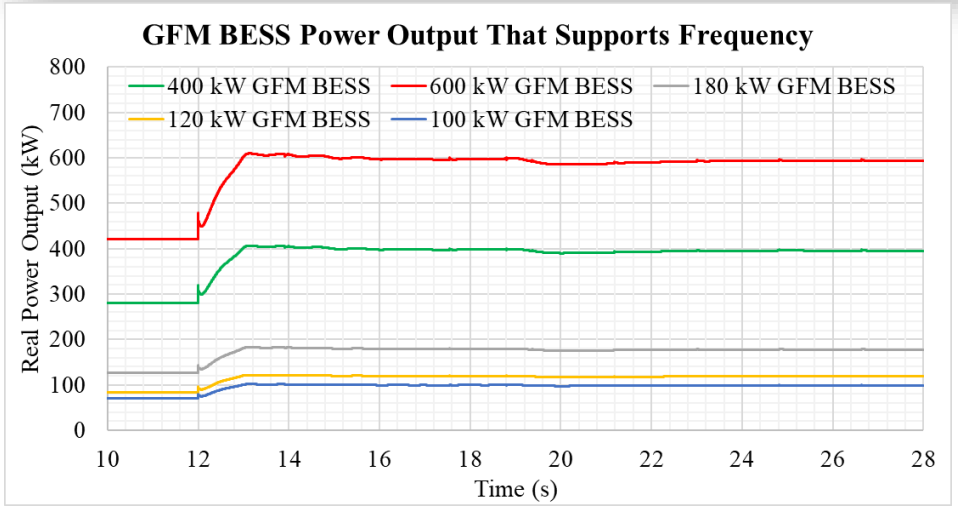
Role of Distributed BESS in Primary Frequency Support

- Applied to Primary Frequency Response



Case	Frequency Nadir (Hz)	Settling Frequency (Hz)
Case 1	59.50194	59.77309
Case 2	59.54337	59.78232
Case 3	59.64767	59.82723
Case 4	59.8102	59.86797





A. K. Bharati, V. Ajjarapu, W. Du and Y. Liu, "Role of Distributed Inverter-Based-Resources in Bulk Grid Primary Frequency Response Through HELICS Based SMTD Co-Simulation," in *IEEE Systems Journal*, vol. 17, no. 1, pp. 1071-1082, March 2023

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Conclusions and Takeaway

- Battery Energy Storage Systems (BESS) are extremely versatile to support the grid under various operating conditions to enhance its performance in steady state, quasi steady state and dynamic operations.
- A sufficient headroom on BESS is essential to ensure they can participate to support the grid under stressed conditions.
- BESS is interfaced with power electronics that have very quick response times enabling them to arrest disturbances preventing system instability that can otherwise lead to load shedding, cascading outages, etc..
- BESS can enhance system performance in distribution systems and transmission systems and can positively influence the T&D interactions to enable bulk grid support.
- The test systems for these use cases will enable the various stakeholders to evaluate various BESS applications on their systems.

Acknowledgment

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Questions?

Thank you

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