BESS Test Systems & Applications to System Resilience and Reliability

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Objective

The project aims to address this gap/industry need by developing some simple use cases with different operating conditions that can be used effectively to understand the role for energy storage to improve system reliability and resilience. The utilities or ISOs can utilize the test systems, battery energy storage systems (BESS) models and use cases to test and validate BESS model parameters and study the sensitivities of the parameters in different use cases and different operating conditions.

Deliverables

The project deliverables are three-fold:

1. Test systems and models for transmission and distribution systems interconnected storage.
2. Test systems to capture T&D interactions when BESS is connected in distribution v/s transmission systems.
3. Insights on BESS use cases in short-term and long-term operations including dynamics and stability applications.

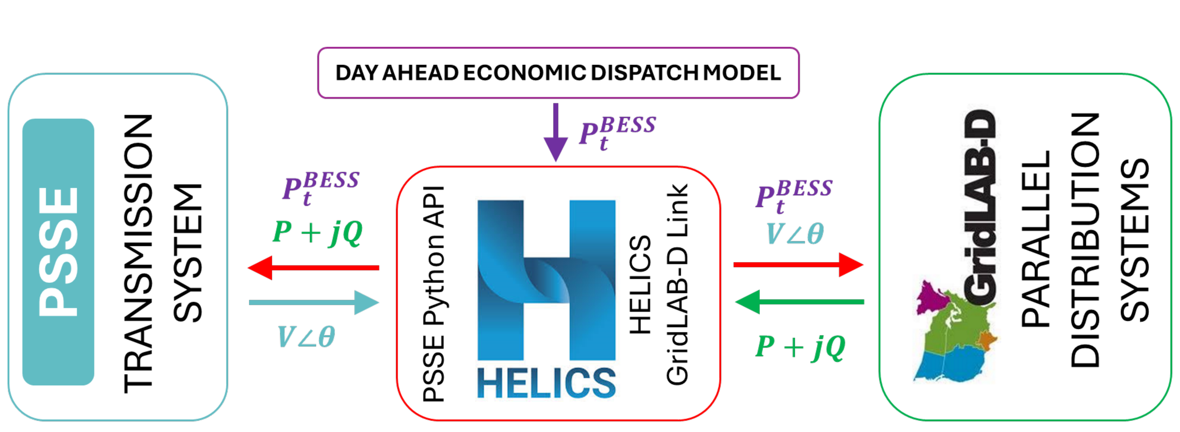
BESS Use Cases

The key BESS use cases being explored for test cases are:

1. Utilizing BESS to alleviate transmission system congestion under stressed operation.
2. Demonstrating reactive power control for voltage performance improvement with BESS under stressed operation.
3. Utilizing BESS to complement variable output generation.
4. Demonstrating the use of BESS with onsite generation to meet certain demand in the distribution systems.
5. Evaluate the dynamic performance with IEEE 1547 compliant distributed storage and IEEE 2800 compliant utility scale storage.

Background

- Most of the IEEE test systems have conventional generators and do not have models for BESS or other advanced technologies that are integrated to the grid.
- Smaller utilities do not have experience with BESS and its use cases and do not have test systems and tools to evaluate the different use cases of BESS.
- The test systems developed through this project can be utilized by the small utilities, rural coops, municipalities, etc. to understand the various applications of BESS.
- The project is utilizing existing tools like PSS/E,, GridLAB-D for modeling and simulations.
  - The co-simulation case-studies utilize these tools in combination with HELICS



Scalable Multi Timescale T&D Co-Simulation Framework

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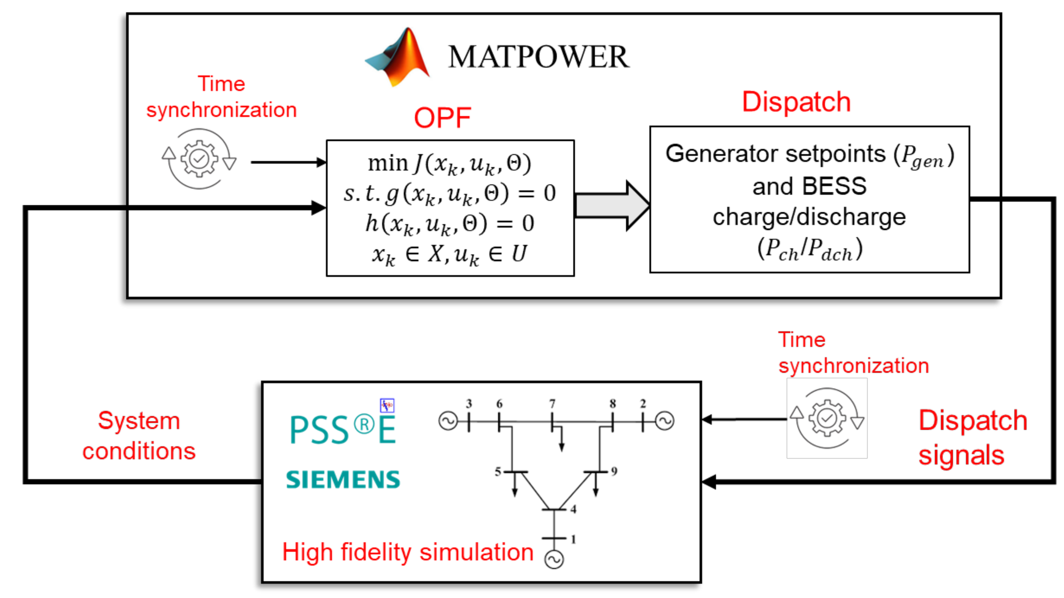
Transmission System Use cases



Developed an Integrated Control and Grid Simulations Framework to Evaluate BESS Capabilities in Mitigating Transmission System Stress

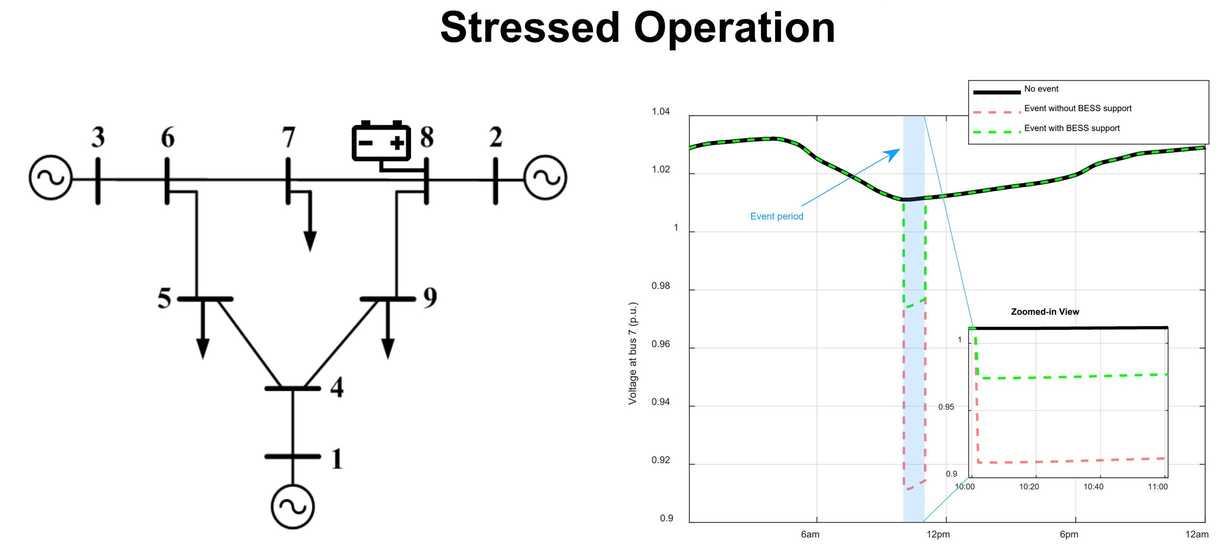
The testbed enables evaluation of multiple grid services, including reactive power support (voltage regulation) via converter-based BESS. Demonstrated effectiveness of voltage support on an IEEE 9-bus system under a 60-minute disturbance scenario involving:

•Increased reactive load at Bus 7 in event period (10am-11am) – voltage profile dips to < 0.95 p.u. at bus 7.

• 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.

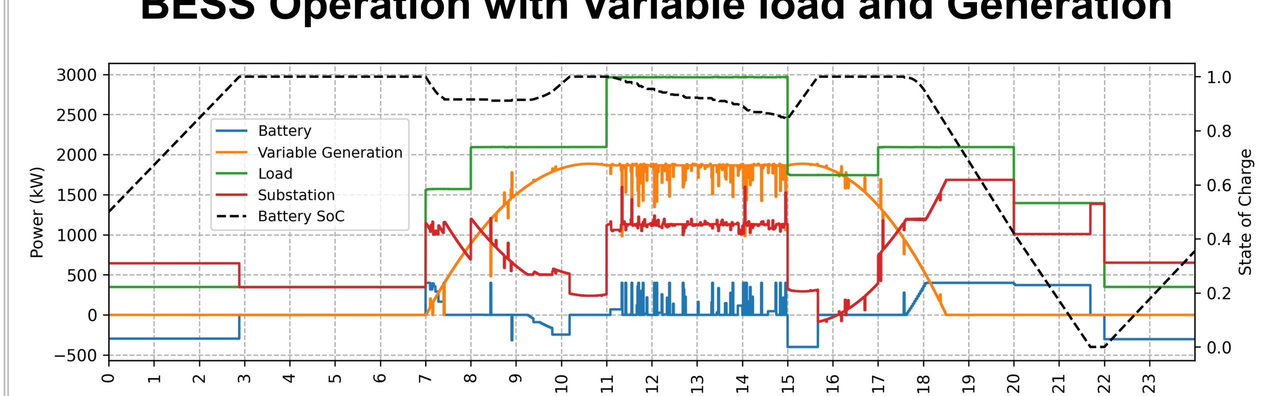
BESS used for Reactive Power Management under Stressed Operation



Distribution System Use cases

- The case study is based on IEEE 13 node test system.
- 2 MW variable generation is distributed proportional to loads across loads buses. It has 2 200kW 4 hr batteries
- The test system is connected to a grid via substation transformer.
- Batteries charge during
  - the low load hours or low supply from the substation (midnight to 7 AM, 10 PM to midnight, 4 PM-5 PM).
  - The hours when variable output generation exceeds the load (3 PM- 4 PM).
- Battery inverters are operated in load following mode, which enables the batteries to address the fluctuations in generation output that are within the battery rated capacity.

BESS Operation with Variable load and Generation



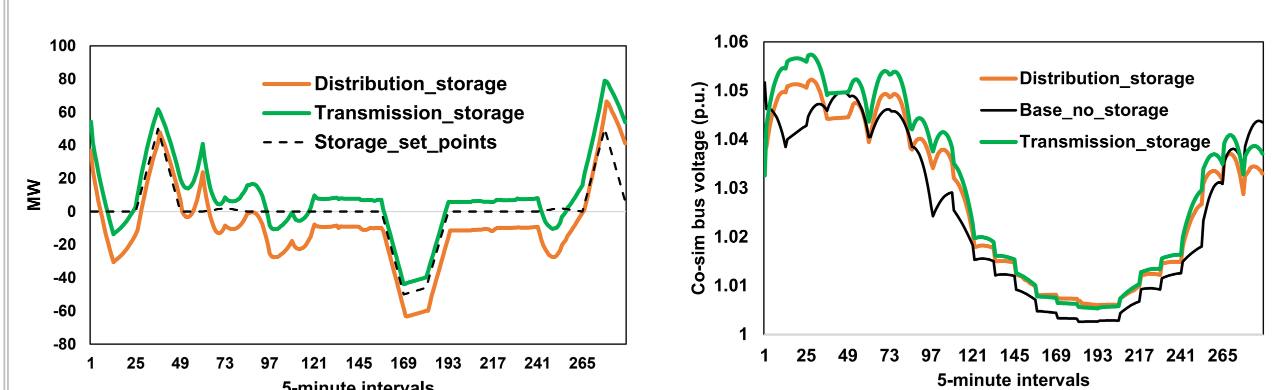
Active power of variable loads and generation, battery, and substation and average state-of-charge (SoC) of the batteries.

BESS Driven T&D Interactions – Steady State

- Aim: Compare the impact of BESS using T&D co-simulation with day-ahead schedules.
- Models: IEEE 39-bus (transmission) and IEEE 123-bus (distribution)

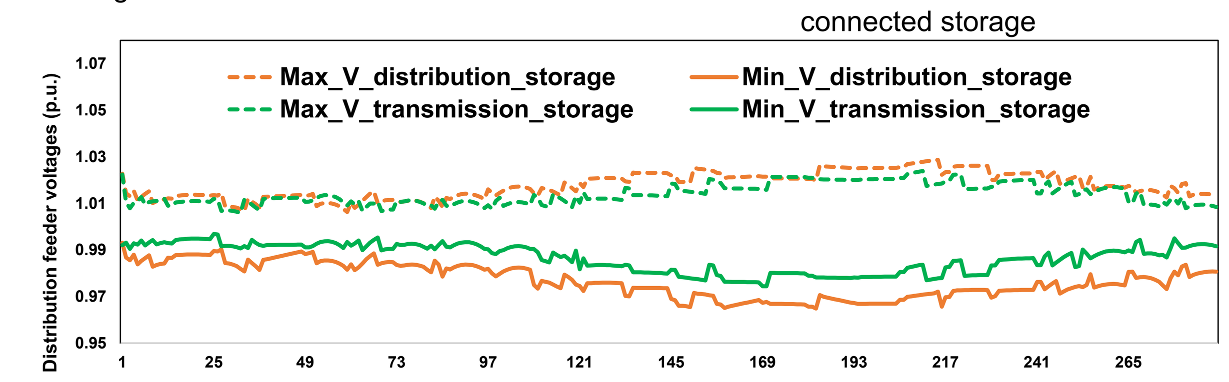
Case 1: 50MW BESS at transmission bus.
Case 2: 50MW was distributed at various locations of the feeder.

Transmission network receives day-ahead schedules and runs the 24 hours real-time market. It interacts with distribution feeder through co-simulation bus (bus 4). The actual load demand recorded throughout the day will be sent to day-ahead model to calculate schedules for Day 2.
Base Case: No storage.
distribution feeder.



Differences in net generation from the no storage case observed in PSS/E

Differences in PSS/E bus voltages of the co-simulation bus with distribution vs transmission connected storage



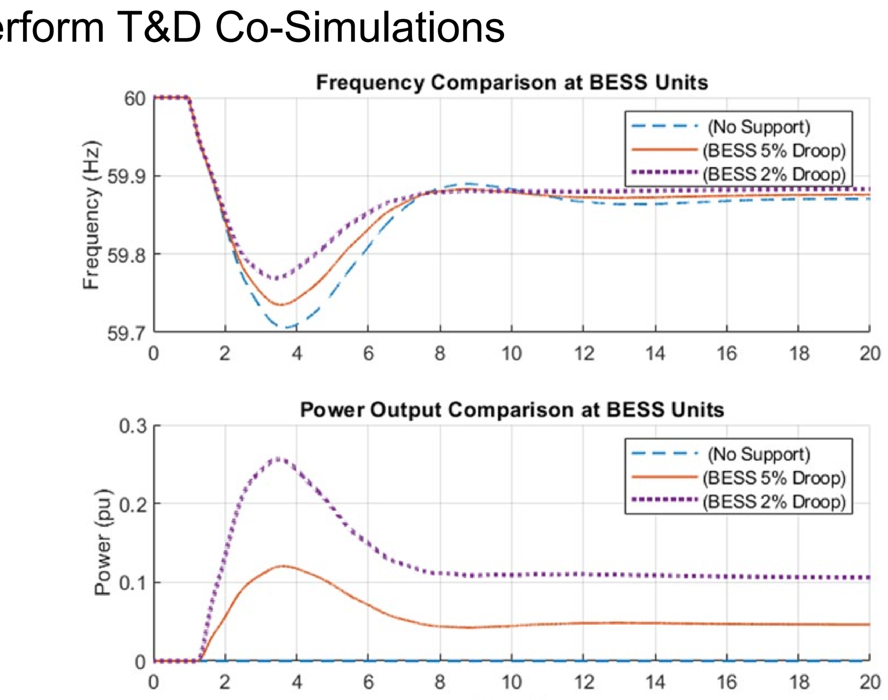
Differences in distribution feeder maximum and minimum voltages observed in GridLAB-D with distribution vs transmission connected storage

BESS Driven T&D Interactions – Dynamics (Preliminary Results)

- A modified IEEE 39-bus system is used
- Four BESS units has been implemented in PSS/e using generic models REGCA1, REECC1, and REPCA1
- Grid forming based BESS will also be used for comparison
- Frequency and Voltage protection relays are implemented in the model and tested with IEEE 1547 for now.
- A comparison of IEEE 1547 and IEEE 2800 standards has been conducted to determine relay setting in transmission and distribution systems

Next Steps:

- PSS/e Composite load model has been implemented to test the system during a motor stalling state
- Performance of the two standards at the transmission and distribution systems will be studied through different simulation scenarios
- Perform T&D Co-Simulations



BESS frequency response to the largest generator trip at Bus 31 using 5% and 2% droop control.

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