Using a Battery Energy Storage System to Enhance Stability in an Islanded Microgrid

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Overall Project Overview

- Validate the economic and system performance benefits of Battery Energy Storage Systems (BESS) in the distribution system
- Premium Power Corporation (Prime Contractor) is developing large-capacity flow battery and inverter systems

Premium Power

nationalgrid

U.S. DEPARTMENT OF ENERGY

WPI

galvin center for electricity innovation at ILLINOIS INSTITUTE OF TECHNOLOGY

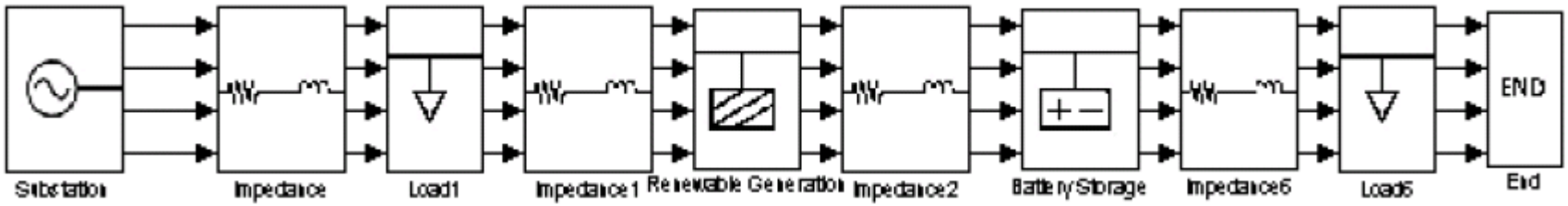
IEEE PES Power & Energy Society®

WPI Role

- Develop a modeling environment for distribution feeders including distributed generation and energy storage
- Develop Optimal Charge/Discharge Algorithms for use in the model
- Perform detailed investigation of economic benefits of:
  - Time shifting of energy purchases
  - Output leveling
  - Feeder upgrade deferral
  - Outage prevention

Power Flow Model Capabilities

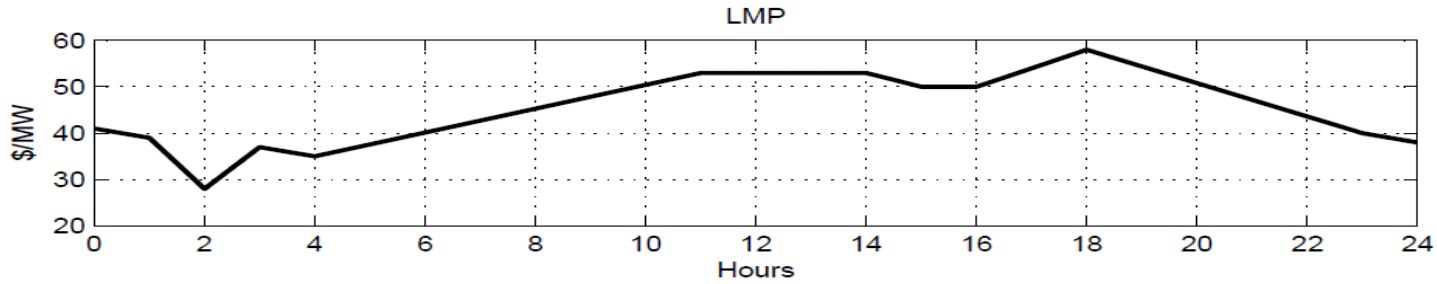
- Produces time profiles of output variables
- Performs electrical and economic calculations
- Implemented in MATLAB's Simulink
- Models real and reactive power, voltage, and voltage phase angle with substation as the reference
- Three phase, balanced/unbalanced
- Load and energy price profiles vs. time are inputs
- Series RL, symmetric geometry line model is used

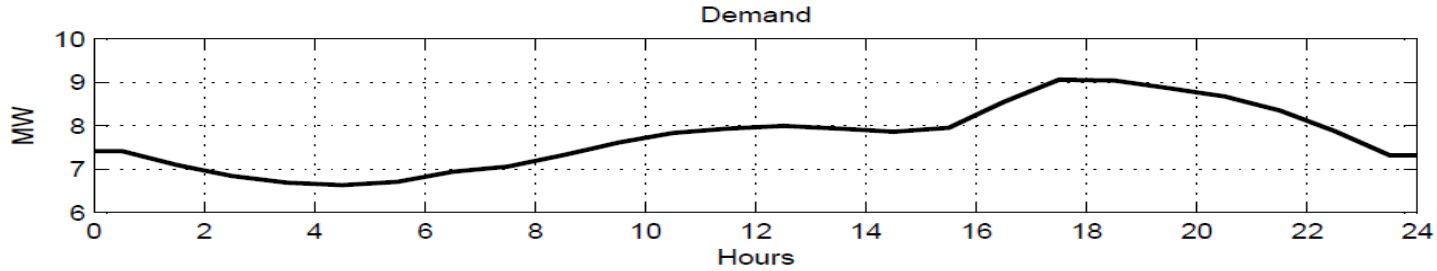


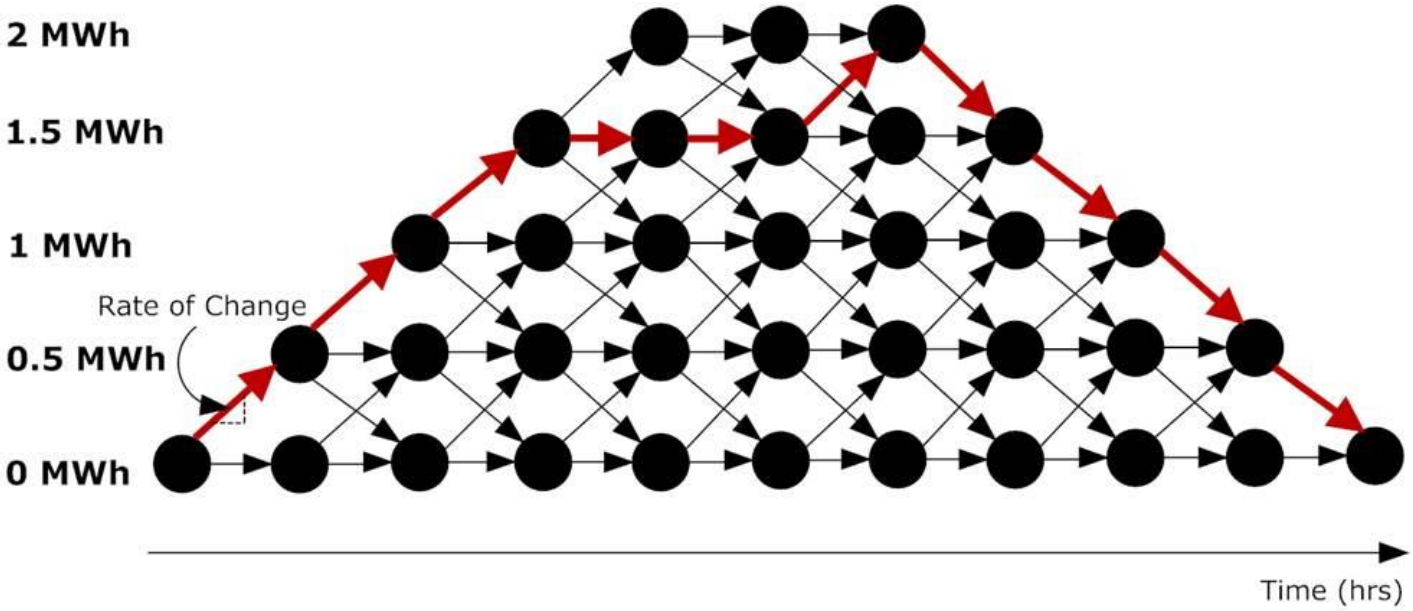
Application of the Modeling System

- Goal is to investigate BESS benefits
  - Energy arbitrage (buy low, sell high)
  - Voltage stabilization
  - Outage prevention
  - Peak shaving, load leveling
- Inputs to model
  - Distribution system design (substation transformer rating, wire gauge, geometry, load locations)
  - Time varying profile of each load (balanced/unbalanced, active/reactive)
  - Distributed generation location and output profile
  - BESS location, capacity, charge/disch rates, efficiency
- A BESS control algorithm is needed

Dynamic Programming Algorithm







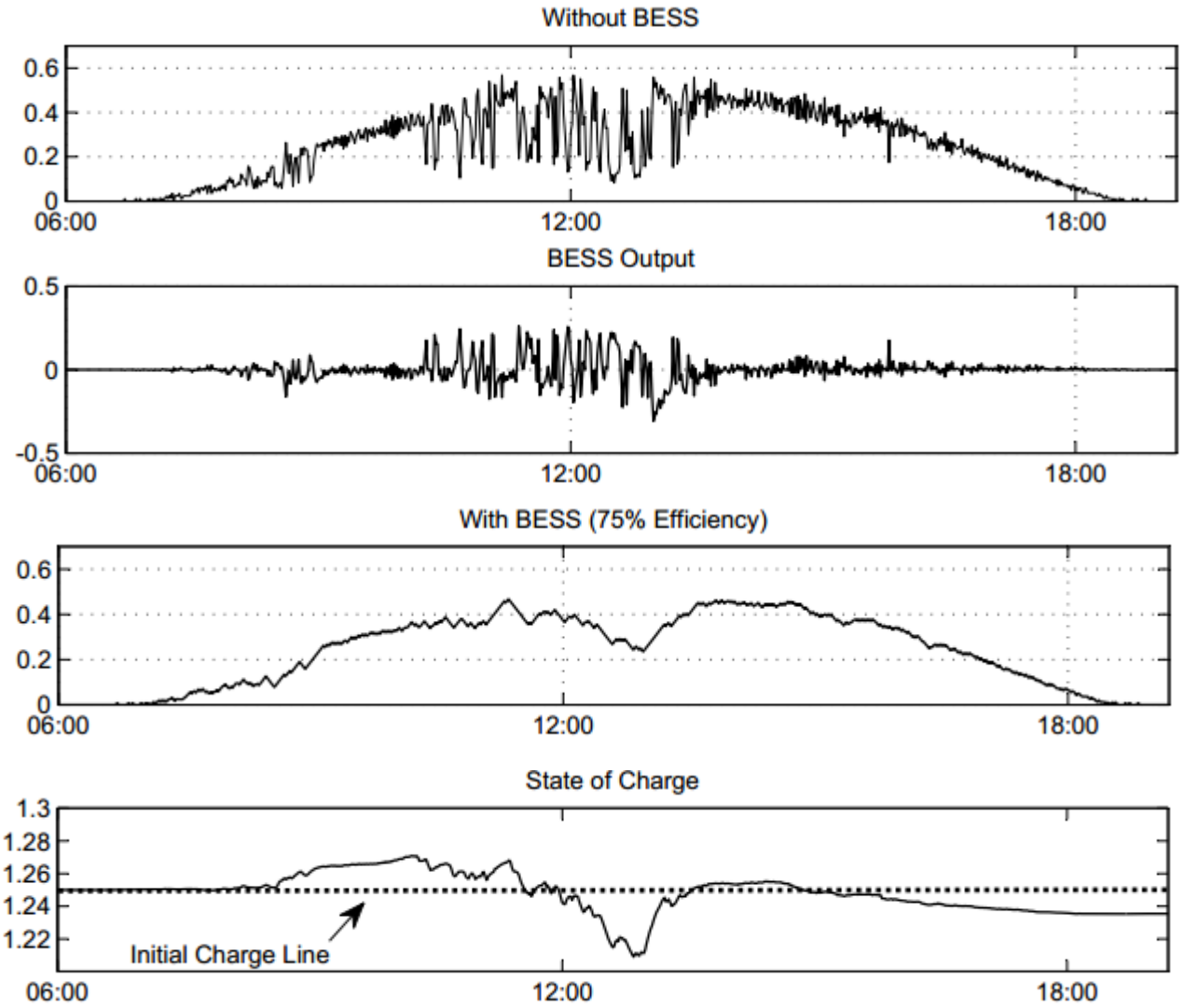
Renewable Energy Smoothing Example

Output from Solar

Output from BESS

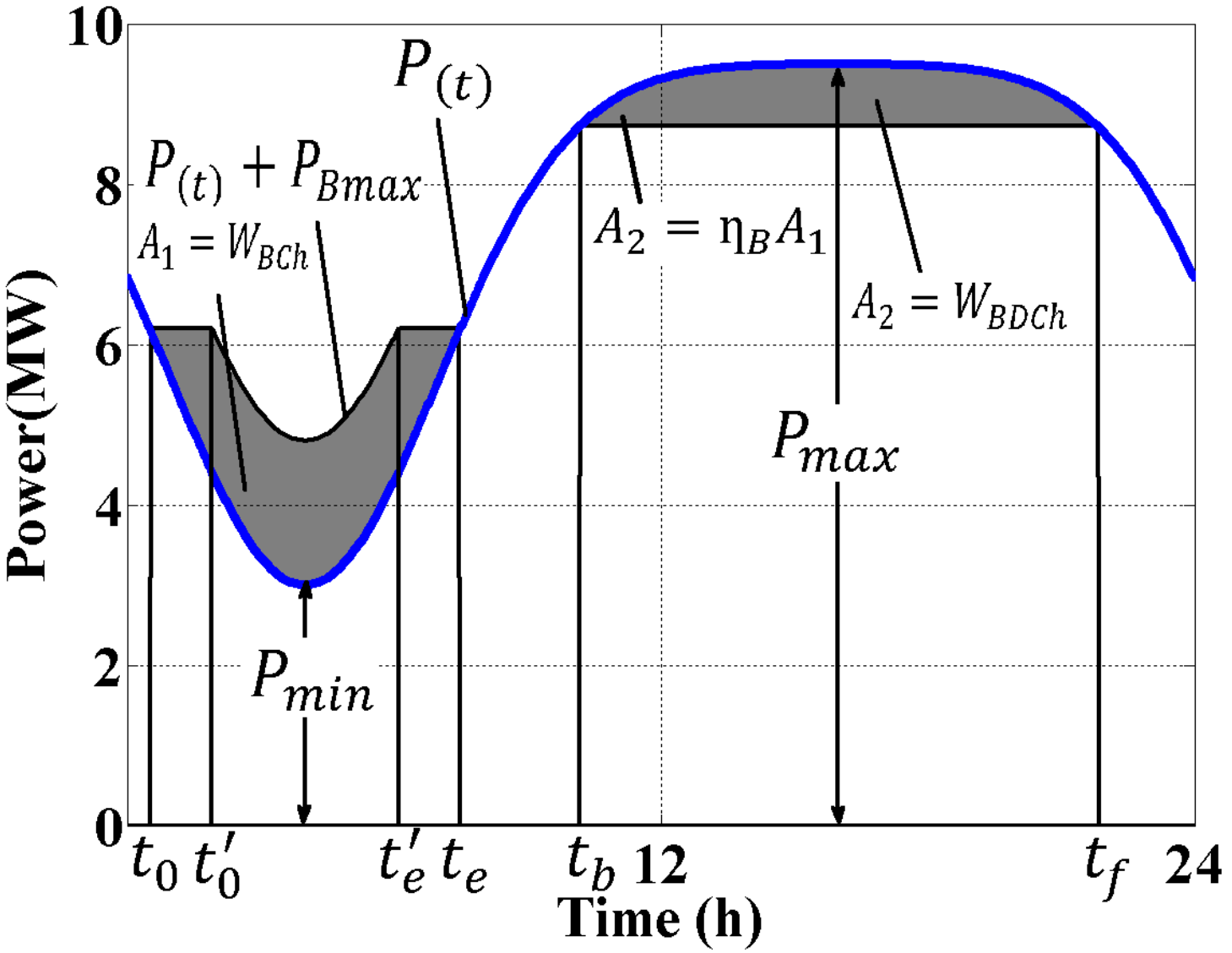
Net Site Power

Battery Charge



Energy Purchase Shifting

Differential Cost of Energy $\mathbf{DCE}=K_{WD}-K_{WC}$ **(\$)**



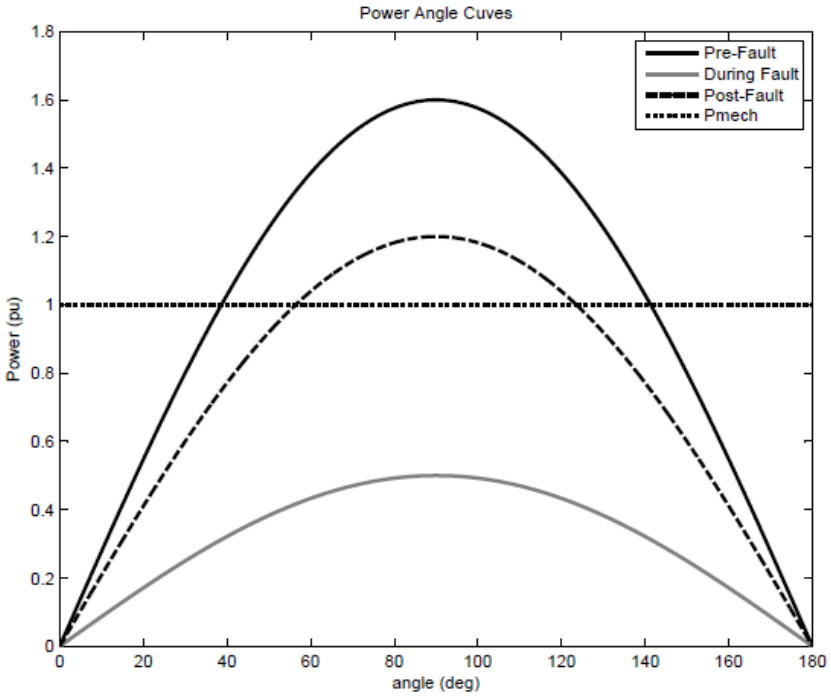
Multiple uses for a grid-located BESS may be required for economic viability

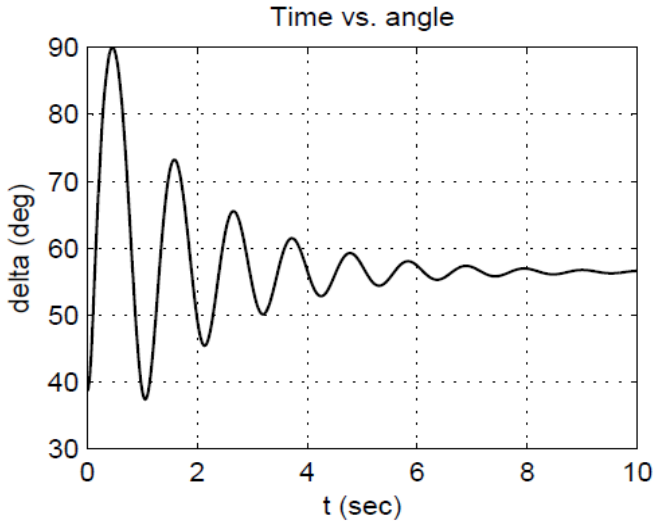
Using a Battery Energy Storage System to Enhance Stability in an Islanded Microgrid

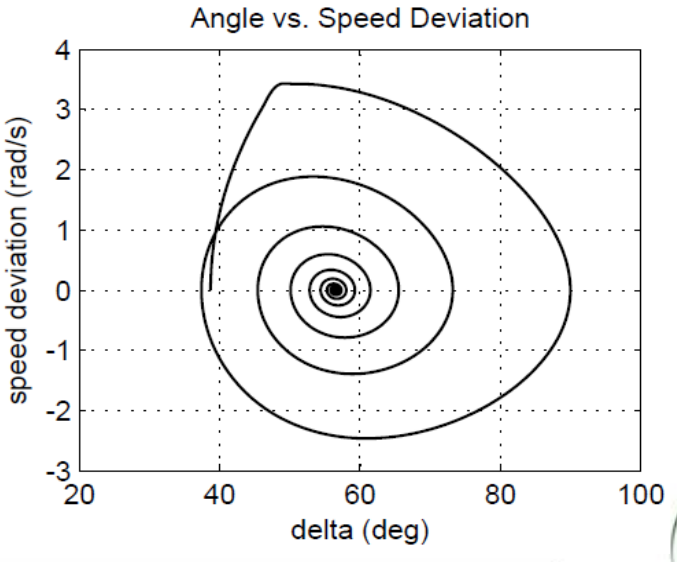
Microgrid Components

- Essential loads
- Controllable generation
  - Sized with a safety margin
  - Small amount of system inertia

Stability



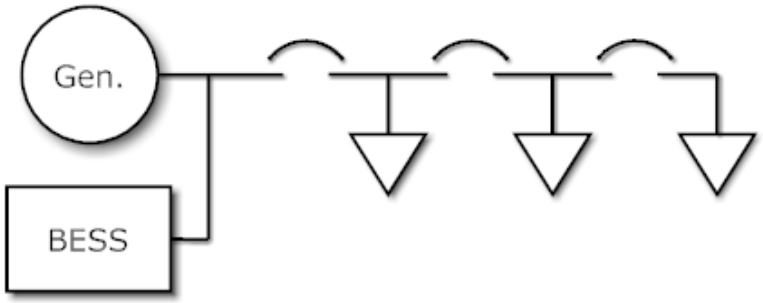


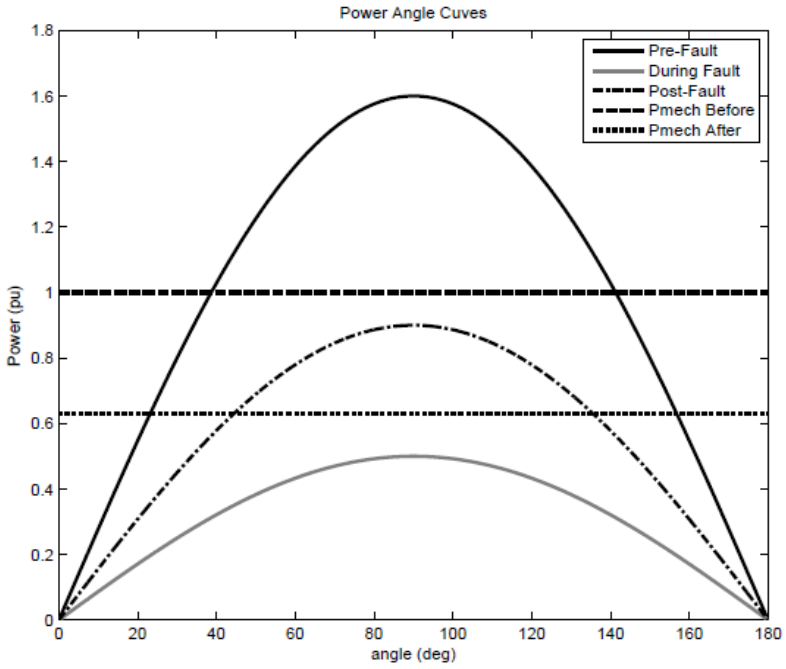


$$\frac{H}{\pi f_0}\frac{d^2\delta}{dt^2} = P_m - P_e - D\frac{d\delta}{dt}$$

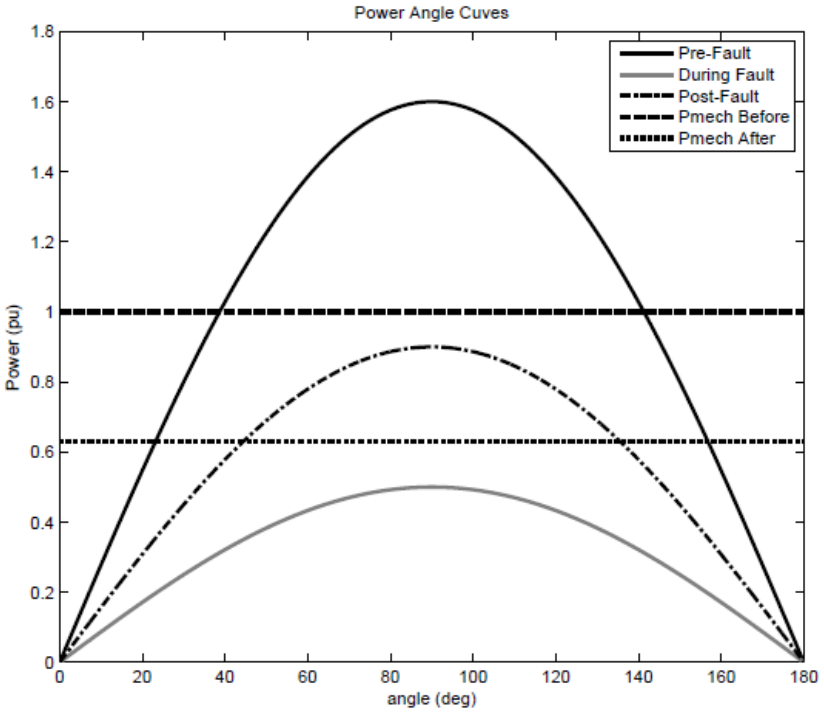
Adding a BESS

- BESS Can be used as temporary load during transient events

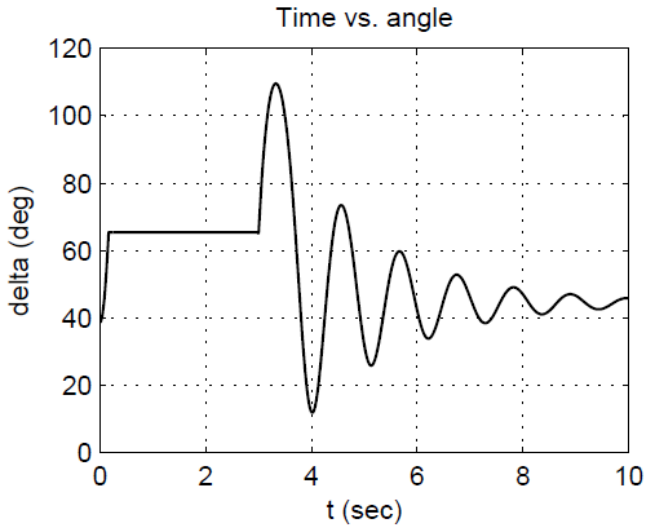


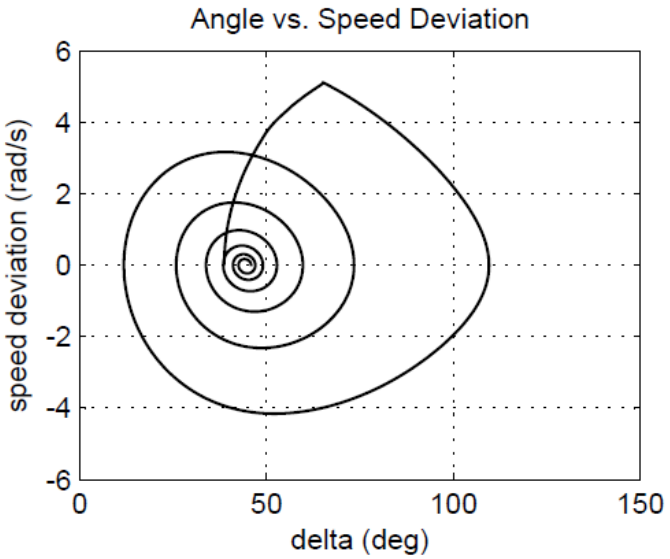


Stability with BESS



$$\frac{H}{\pi f_0}\frac{d^2\delta}{dt^2} = P_m - P_e - D\frac{d\delta}{dt}$$





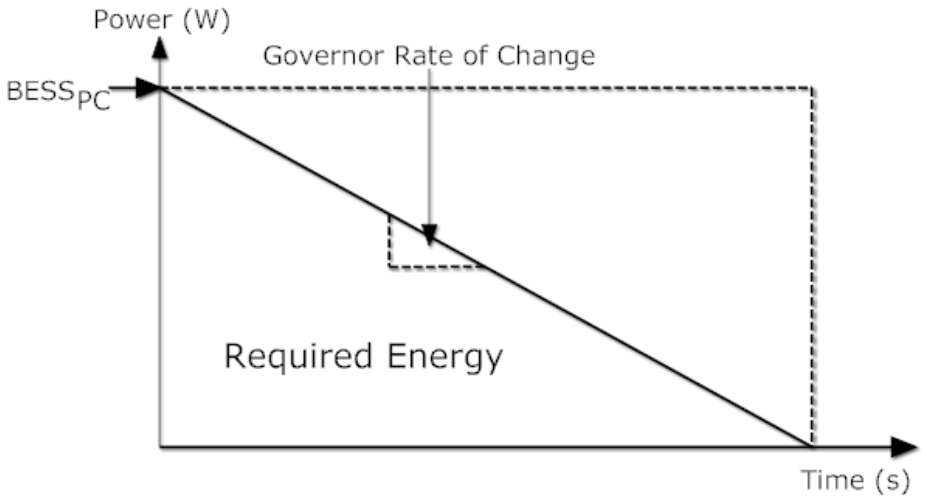
BESS Sizing

$$BESS_{PC} = P_{ML} - (P_{MLPF}) * (1 - S)$$

	Description
$BESS_{PC}$	Required BESS power capacity
P_{ML}	Maximum pre-fault load
P_{MLPF}	Maximum post-fault load
S	Safety margin

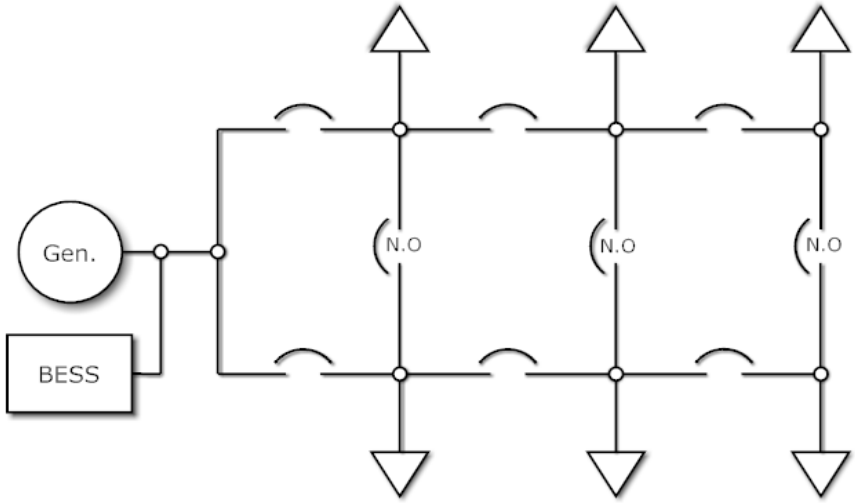
$$BESS_{EC} = \frac{BESS_{PC} t_d}{2} = \frac{BESS_{PC}^2}{2R_G}$$

	Description
$BESS_{EC}$	Required BESS energy capacity
t_d	Time the BESS must act as a load
R_G	Rate at which the generator changes power output



Microgrid Configurations

- Adding tie schemes can reduce the amount of load shedding



Conclusion

- BESS can be a useful addition to microgrids in order to improve stability
- The stability enhancement function may be combined with other BESS uses, improving economic viability