

Modeling of BESS for Blackstart System Restoration Studies

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Overview

- 1 Blackstart Study Process
- 2 Battery Storage Technology as a Blackstart Resource
- 3 BESS Inverter Modeling
- 4 Sample Simulation
- 5 Summary

Blackstart Study Process

- Transmission operators are required to have restoration plan for restoring their system following a disturbance as per NERC EOP-005-3 (System Restoration from Blackstart Resources)
- Combustion turbines are typically used as Blackstart generators
- With increasing renewable penetration, Inverter based generation may require to have Blackstart capability
- Battery Energy Storage System (BESS) has a capability to work as a Blackstart resource
- Studies are usually performed to demonstrate the capability of a Blackstart resource to start the largest load of the next larger generating unit(s)

Blackstart Study Process

Typical system restoration study

Steady state analysis

- Steady state voltages following line energization(s)
- Capability to produce/absorb reactive power following the energization of overhead and cable transmission system
- Blackstart generator capacity adequacy to supply system restoration load

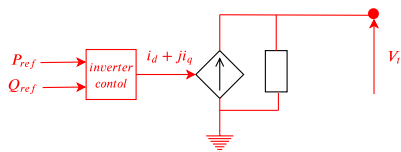
Dynamic analysis

- Load-frequency control
- Voltage control
- Largest induction motor starting capability of the next resource
- System Stability
- Switching transient overvoltages

Battery Storage Technology as a Blackstart Resource

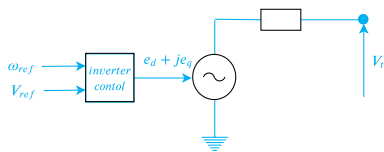
Two types of Inverter control strategy:

Grid following invertors



- Controls current and phase angle (PQ bus)
- Inverter is synchronized through PLL
- Cannot be used for islanded microgrid operation

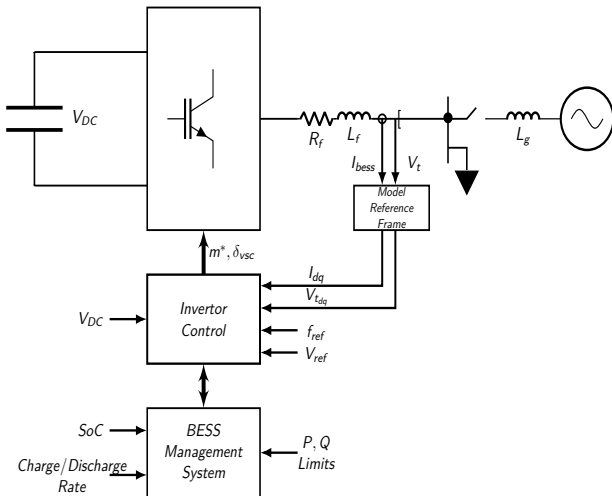
Grid forming invertors



- Internal voltage and frequency reference is used to form the grid (PV bus)
- Crucial for islanded microgrid operation

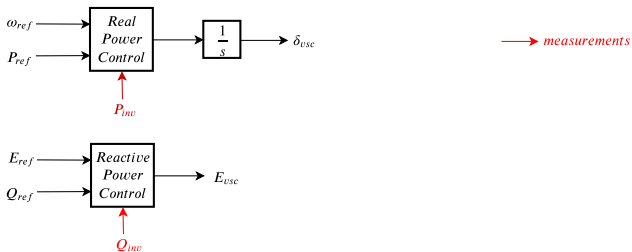
Battery Storage Technology as a Blackstart Resource

BESS Inverter in islanded mode of operation

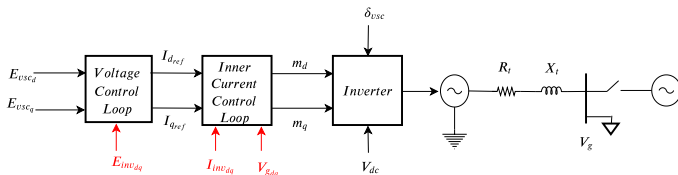


BESS Inverter Modeling

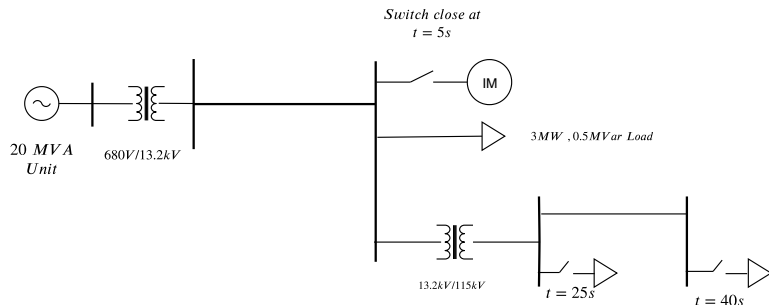
Voltage and Frequency Control



Voltage source representation of BESS Inverter



Sample Simulation

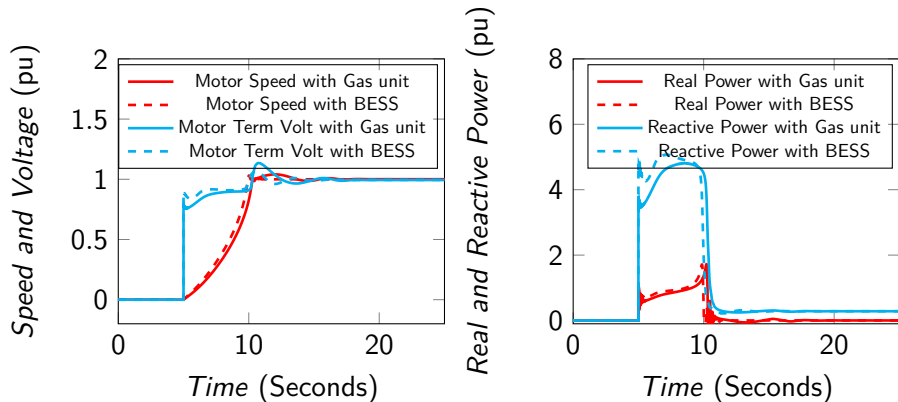


Restoration sequence:

- 1 Blackstart BESS started and stabilized
- 2 Switch in auxiliary load associated with generator start-up
- 3 Start the largest induction motor such as Induced Draft Fan
- 4 Energize EHV transformer
- 5 Supply some critical loads

Sample Simulation

Motor response comparison with Gas unit and BESS

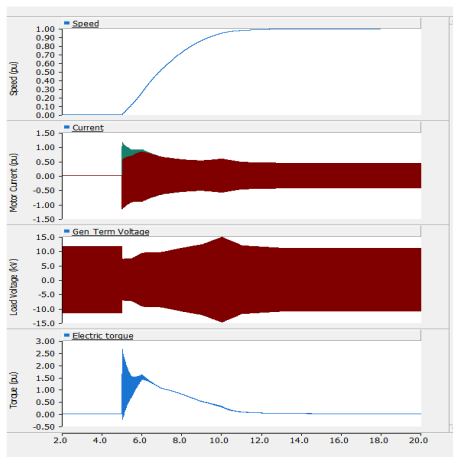


(a) Motor Speed and Terminal Voltage

(b) Motor Real and Reactive Power

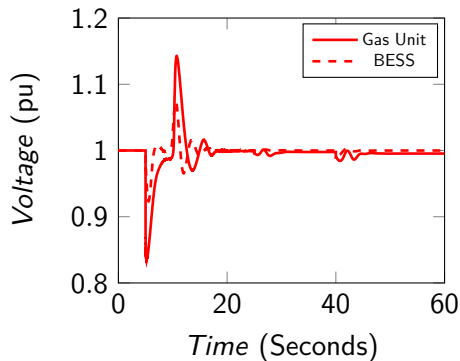
Sample Simulation

Validation with EMT simulation

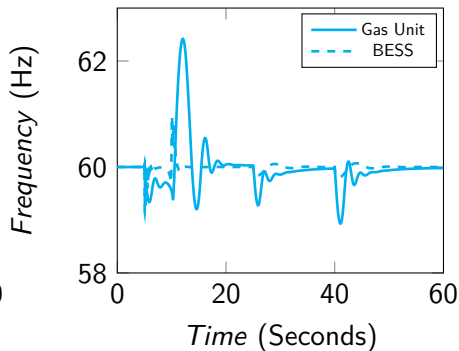


Sample Simulation

Generator terminal voltage and frequency comparison



(a) Generator Terminal Voltage



(b) Generator Bus Frequency

Summary

- BESS can act as a Blackstart resource provided grid forming controls are used
- Provides Blackstart resource during grid restoration and ancillary services during grid connected mode
- Starting current of the largest induction motor dictates the size of BESS

Questions?