Technical and Economical Impact of Energy Storage Devices on Electric Grid

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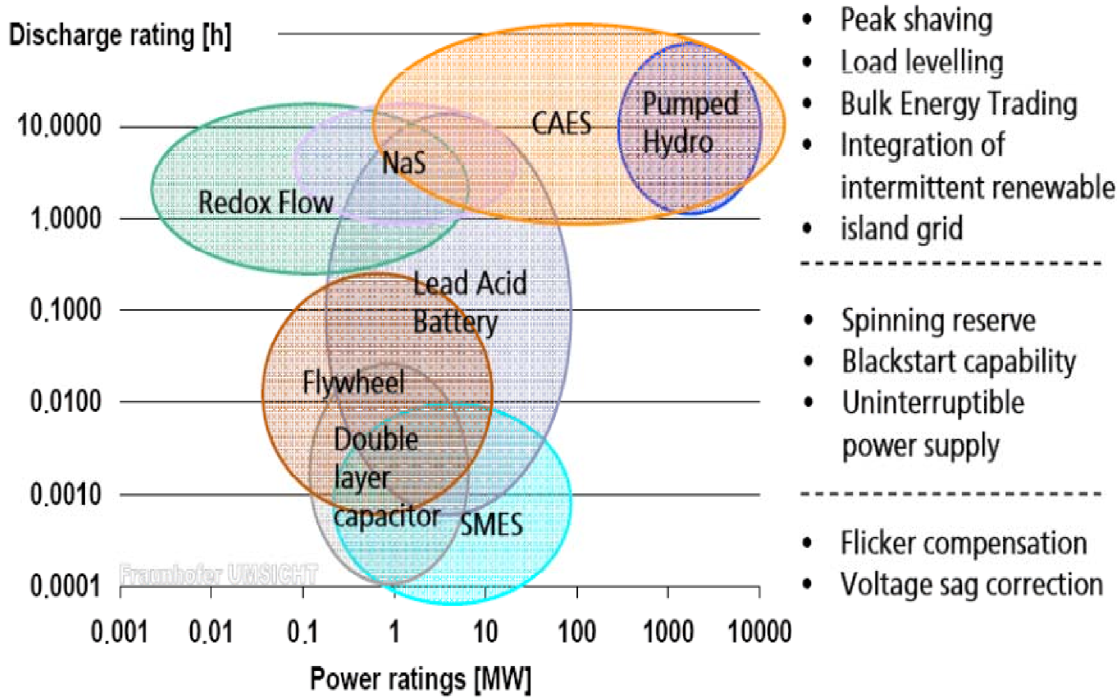
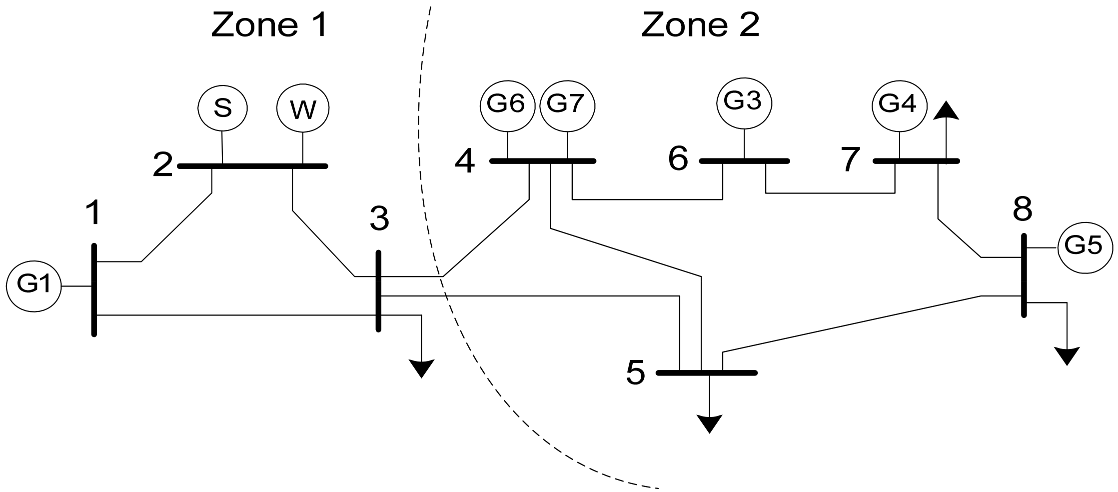
Energy Storage Applications

- ✓ **Load management**
- ✓ **Ancillary services**
- ✓ **Transmission enhancement**
- ✓ **Wind Generation matching**
- ✓ **Environmental**
- ✓ **Economy**



SCUC (Example: 8-bus system)

Test case with six thermal units, one wind, one battery storage, and two control zones



- **Case 1**

  Base case without BES unit. The example includes six thermal units and a wind at bus 2.

- **Case 2**

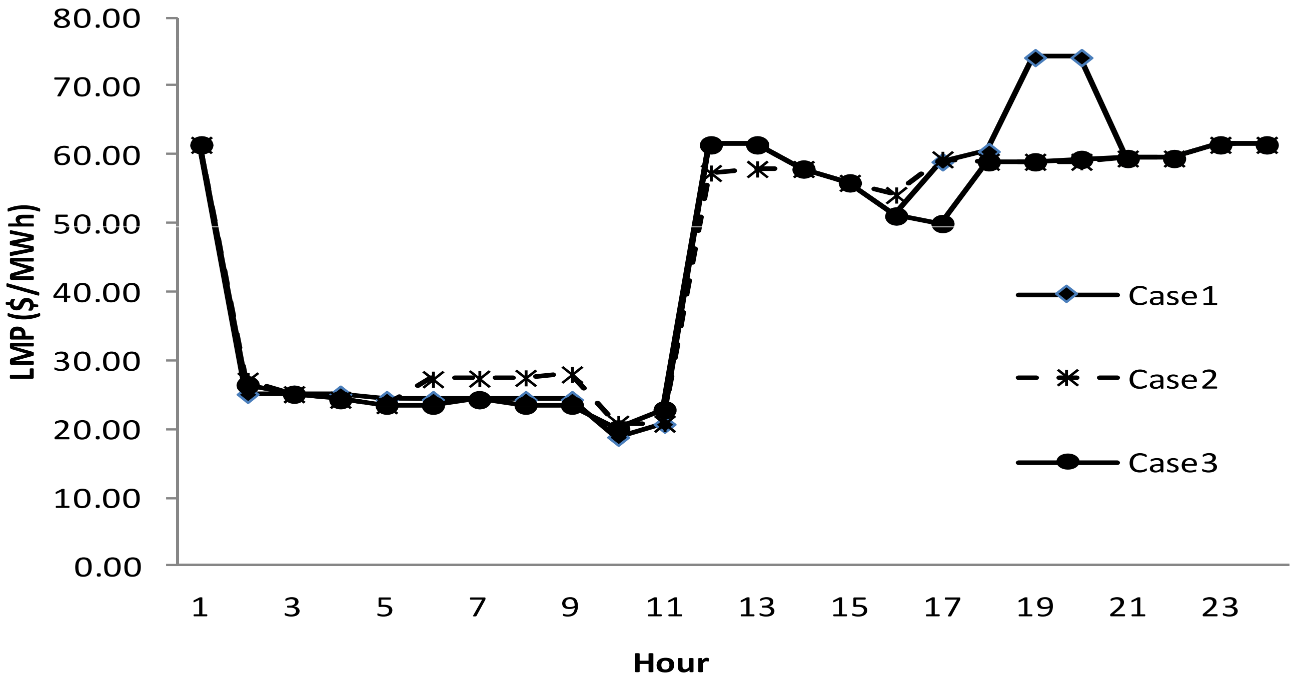
  A BES is installed on Bus 2 close to the wind resource.

- **Case 3**

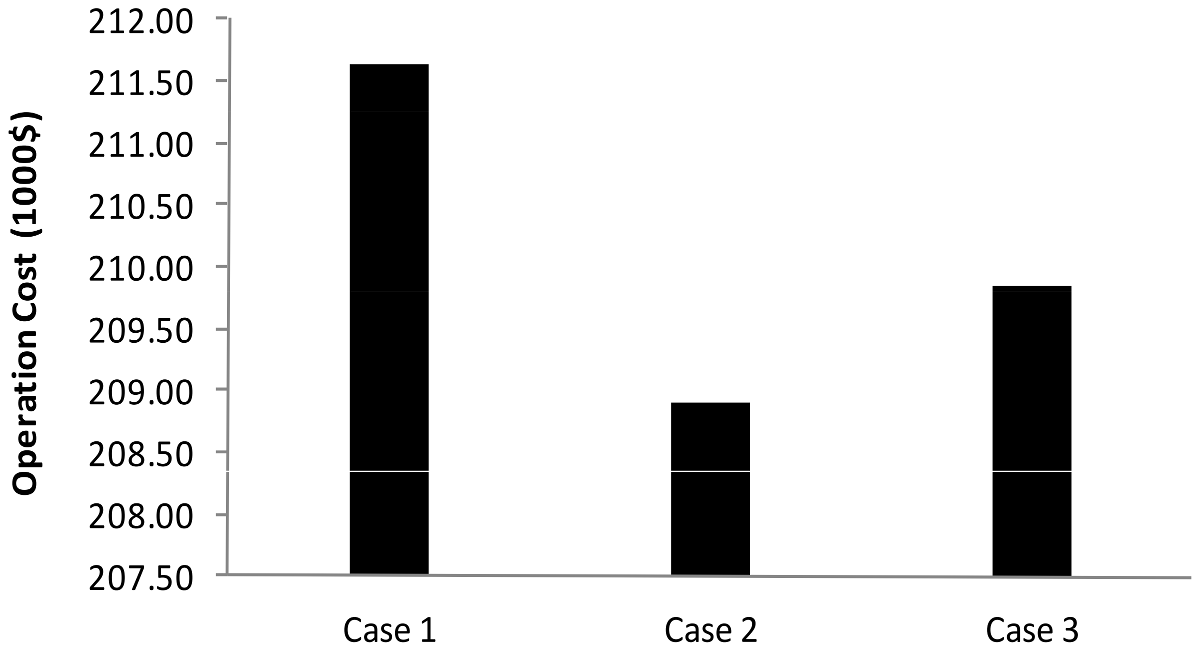
  We also analyze the impact of BES by relocating it from Bus 2 to Bus 8, close to load center.

Locational Marginal Price (LMP)

✓ Hourly LMP ($/MWh) at bus 5 (Zone 2)



System operation cost (1000$)



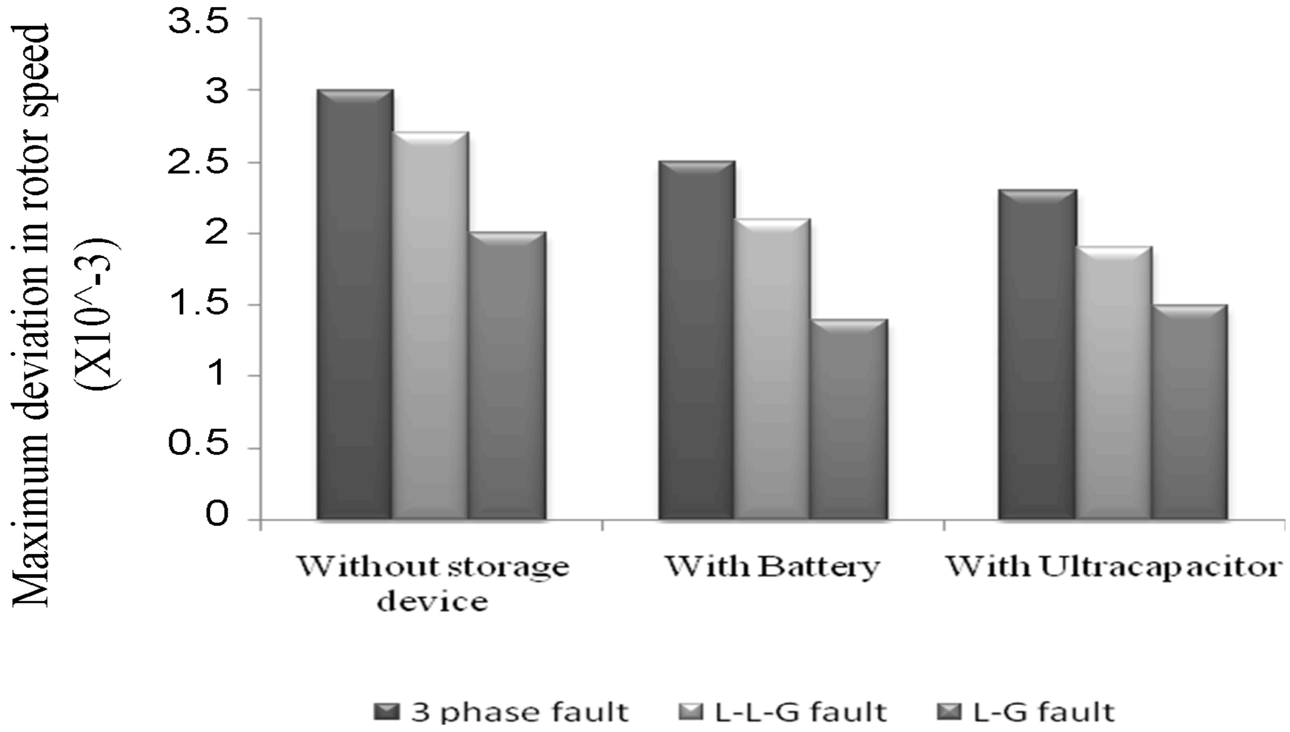
✓ **Impact of BES**

- Provides operational flexibility to the system and enhances reliability
- Reduces production cost
- Reduces transmission congestion and also nodal price (LMP)

Impact of DG and Storage on Stability

- Simulated system
  - 8-bus test case
  - 3-phase fault at bus 4
  - 3 scenarios: without any storage device, with a battery, and with an ultracapacitor
  - observed the stability of the system changes with the addition of the energy storage devices

Impact of DG and Storage on Stability



Comparison of impacts of storage devices on rotor speed deviation

Impact of DG and Storage on Stability

Simulation results

- addition of an energy storage device decreases the maximum deviation in rotor speed deviation
- adding an ultracapacitor to the system improves the stability in terms of rotor speed deviation more than the addition of a battery
- adding a battery to the system improves the stability in terms of oscillation duration more than the addition of a ultracapacitor
- the ideal penetration level of the DG for the 8-bus test system is 45%-50%.

Impact of Wind and Battery on Stability

- The simulated power system
  - an IEEE test system developed for power system transient stability study testing purposes
  - contains 17 generators and 162 buses with voltages from 69 to 345 kV
  - simulation platform: PSS/E version 30.3

Impact of Wind and Battery on Stability

Voltage Response Improvements with Battery

Fault Type	Configuration		Pre-Fault Voltage (p.u.)	Voltage at Fault Iniation (p.u.)	Voltage at Fault Conclusion (p.u.)	Voltage at Fault Clearing (p.u.)
Fault and no topology change	1	Synch Gen	1.0	0.904	0.901	0.988
	2	Synch Gen with Battery	1.0	0.904	0.938	1.015
	3	SCIG	1.0	0.897	0.866	0.958
	4	SCIG with Battery	1.0	0.905	0.928	1.014
Fault and Loss of Gen	5	Synch Gen	1.0	0.906	0.901	0.987
	6	Synch Gen with Battery	1.0	0.906	0.927	1.013
	7	SCIG	1.0	0.895	0.867	0.961
	8	SCIG with Battery	1.0	0.906	0.928	1.013
Fault and Loss of Bus	9	Synch Gen	1.0	0.906	0.902	0.984
	10	Synch Gen with Battery	1.0	0.906	0.928	1.010
	11	SCIG	1.0	0.896	0.869	0.958
	12	SCIG with Battery	1.0	0.906	0.927	1.010

Summary

Focuses: analyzing the steady state and transient impact of energy storage

Scenarios: Storage location, different types and locations of faults

Results:

- Provides operational flexibility to the system and enhances reliability
- Reduces production cost
- Reduces transmission congestion and also nodal price (LMP)
- energy storage devices can improve the transient stability of the system
- the impact on transient stability is system specific and depends on the location and type of disturbances