2012 DOE Energy Storage Program Peer Review

OFFICE OF ELECTRICITY DELIVERY & ENERGY RELIABILITY

Second Generation Emissions Study

Sandia National Laboratories

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KEMA DNV

Original KEMA Study on Emission Benefits

- Study was conducted in 2007 and compared a flywheel to traditional technologies
  - Study highlights
    - Showed emission savings from utilization of storage
    - Study provided a simple “snapshot” of potential trends
    - Compared a flywheel to natural gas, coal, and pumped hydro systems
  - Methodology “vetted” at 2007 EESAT Conference
  - Next steps called for a “deeper dive into actual performance numbers
    - Actual simulations of specific ISO

- Today, study is still cited as the main “Emission “ Study for such applications
  - Results referenced in many cases as a secondary benefit of storage systems
    - But model simply lacked the granularity such roles require

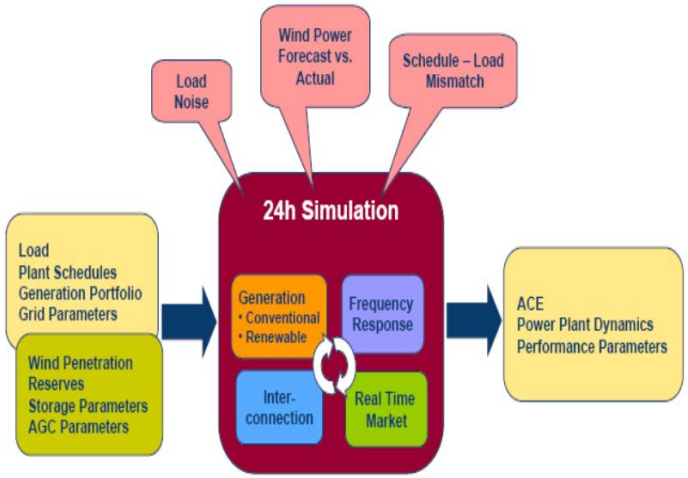
2nd Generation Study on Emission Benefits

- Goal was to update the study using tools that have been developed since the time of the first study
  - Actual ISO territories were modeled instead of the original “snapshot” approach
  - Used emission models of actual generators instead of a “generic” plant
  - Coordinated with actual ISOs to collect the data for the study
    - CAISO model included 590 power plants and 14 control areas
    - PJM Model included 600 power plants and 19 control areas

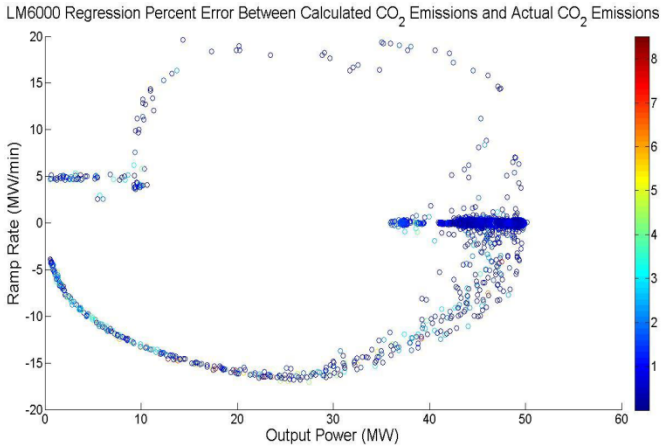
- Results provided a more accurate assessment of the potential emissions savings to utilizing advanced storage systems vs. traditional power plants
  - Study substituted specific plants with Lithium and flywheel devices from a 25% penetration of regulation supplied up to 100% of the regulation

Tools Used for the Study

- DNV KEMA KERMIT Model
  - Designed to study a power systems frequency behavior over a 24 hour period
  - Able to simulate AGC signals as well as grid-scale storage
  - Defines hourly and sub-hourly generation schedules for 100s of generators



- Emission feature of KERMIT Tools
  - Incorporates a dynamic emissions model to estimate CO2 and NOx emissions for combustion turbines, coal plants, and combined cycle plants
    - Estimates emissions based on a generators current output level and for utilizes ramp rates for combustion turbines



Courtesy Dr. Jay Apt & Dr. Warren Katzenstein

Results for PJM Territory

- Emissions reductions seen for PJM
  - Key Points about PJM
    - Largest of the ISO/RTO Territories
    - Regulation provided by a combination of coal, combined cycle, and hydro plants
    - Largest of ISO territories – regulation typically represents approximately 1% of total load

Selected Day	CO2 Tons Base Case	CO2 Tons 50% Storage	Difference	Estimated Month Total
21-Jan	887359	887314	45	1395
18-Feb	639117	639081	36	1008
20-Mar	544915	544881	34	1054
11-Apr	665802	665765	37	1110
10-May	658456	658406	50	1550
15-Jun	999290	999230	60	1800
10-Jul	944278	944250	28	868
15-Aug	848813	848763	50	1550
7-Sep	842677	842613	64	1920
28-Oct	675138	675097	41	1271
11-Nov	667589	667553	36	1080
13-Dec	961636	961605	31	961
		Total Year		15567

- Drivers for the market
  - Only a portion of the generators supplying services considered less efficient – hence optimal savings occurred when portion of regulation total supplied by storage
  - Really don't have devices dedicated to regulation, typically will provide 5-20% of their output to regulation market
  - Can't really "bump" device out of market – devices typically go back to performing in real time energy market

Results for CAISO Study

- Results less conclusive
  - Simulations were run over 6 days throughout the year – model was not able to pick up trends or patterns of reduction or increases
    - Why? Regulation market made up of pumped hydro, combustion turbines, combined cycle plants
  - Follows similar trends to PJM where generators contribute partial amounts of nameplate capacity to regulation

- Using storage to replace Spinning Reserve
  - Examined as a potential area of benefit
  - Four cases examined
    - Hypothetical 100 MW of spinning reserve where it is replaced by 20 MW of storage and 80 MW of traditional generation

Case	CO2 (ton)		NOx (lb)	
	Before	After	Before	After
1	64.59	63.20	70.81	56.65
2	3.32	0	5.67	0
3	79.00	63.20	70.81	56.65
4	15.80	0	14.16	0

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Questions?