Beacon Power Corporation

Frequency Regulation Compensation in the ISO/RTO Markets

Prepared for:

FERC

May 26, 2010

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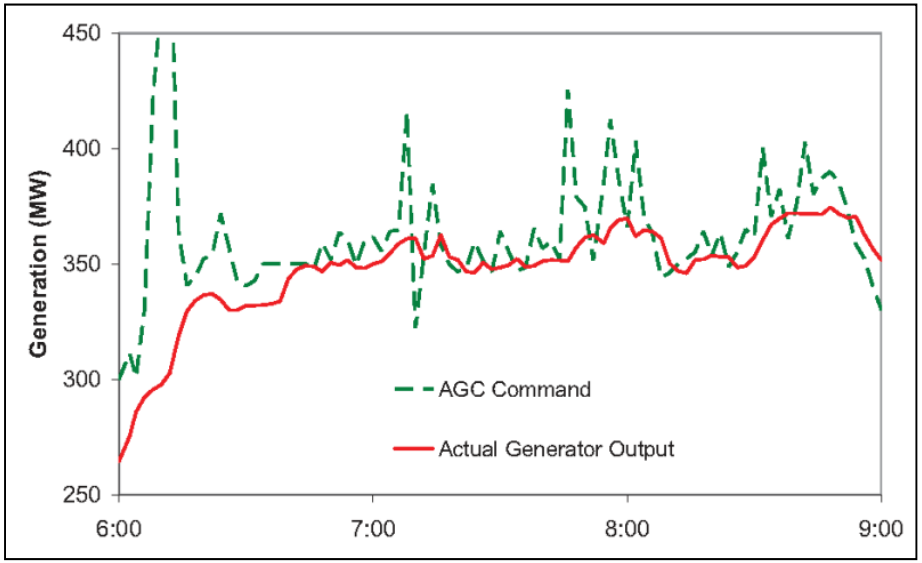
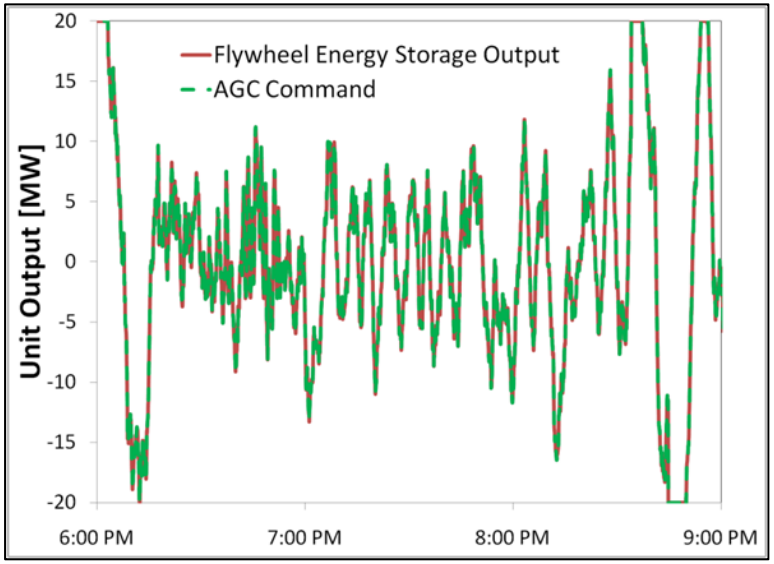
1. Q1: Flywheels are more capable of following a faster, frequently changing Regulation signal



Slow ramping Generator



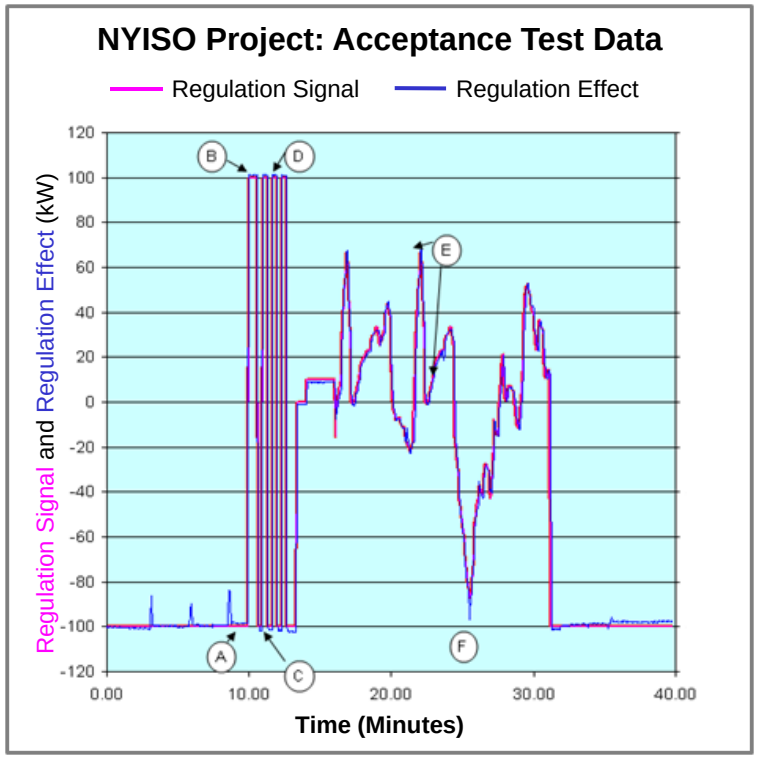
Flywheel Energy Storage

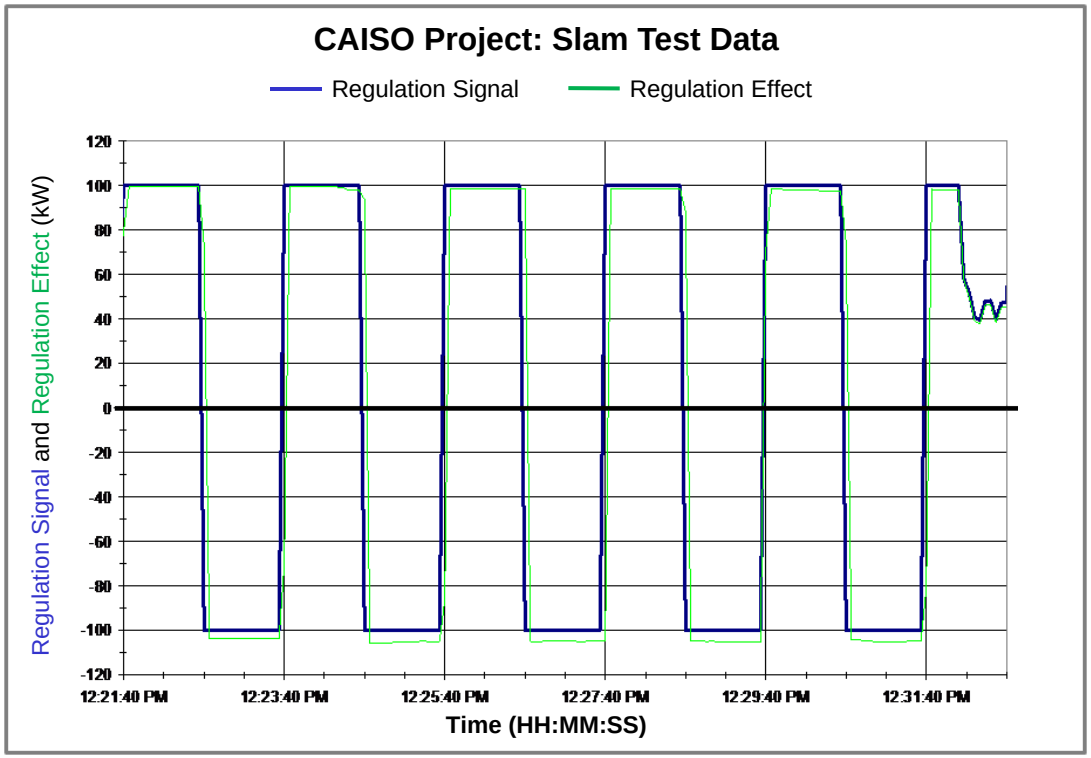
Advanced Energy Storage provides near instantaneous response to a control signal

Sources:
- Kirby, B. "Ancillary Services: Technical and Commercial Insights." Wartsilla, July, 2007. pg. 13

1. Q1: Beacon Power's operating data supports this assertion

- In 2006/2007 Beacon Power conducted two 12-month 100 kW grid-scale demonstrations in CAISO and NYISO
- Data from both projects confirms the flywheels ability to respond within seconds

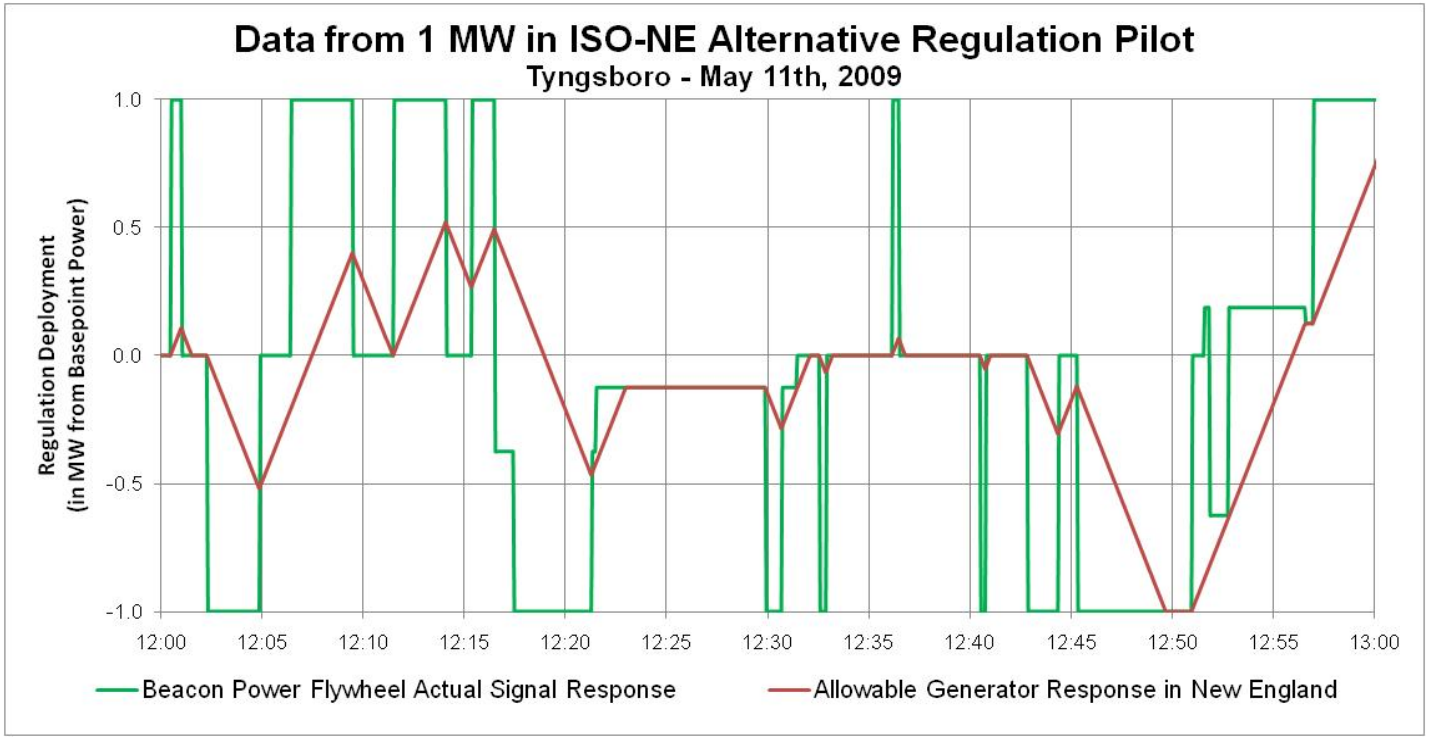




"The unit's high speed response rate and outstanding performance was clearly demonstrated to the California ISO, the CEC and documented in the report provided to the Department of Energy." *– Letter from CAISO dated December 26, 2006*

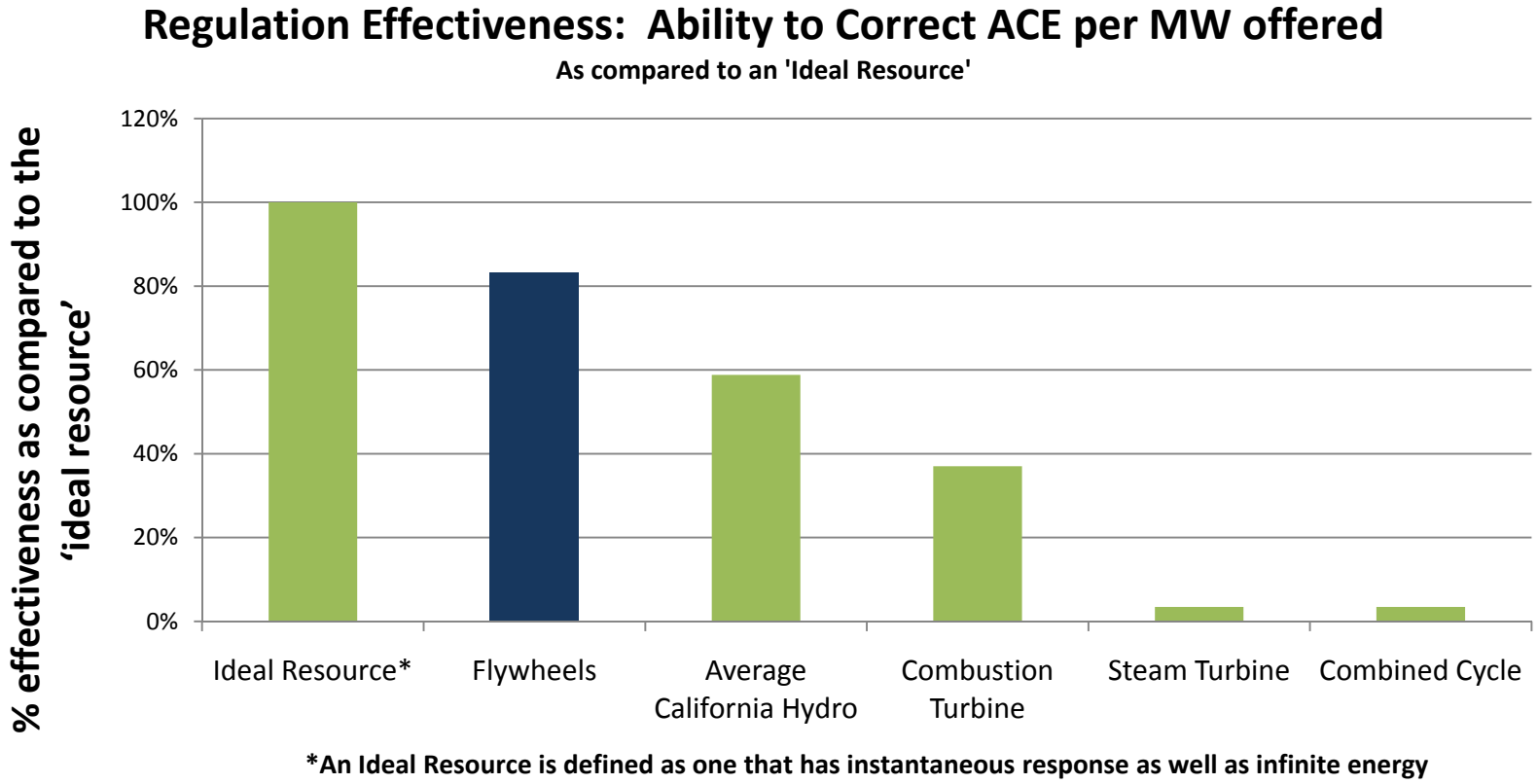
1. Q1: Data from Beacon Power's 3 MW Project in ISO-NE supports this assertion

- Beacon has been operating flywheels in ISO-NE Pilot since November 18, 2008
- Figure below compares actual data from 1 MW of flywheels responding within four seconds to a fast, frequently changing regulation signal (green line)
- Versus the response of a Generator providing 1 MW of Regulation that takes 5 minutes (the allowable response time) to ramp to its full output



Data from Beacon Power's flywheel plant in ISO-NE demonstrates its superior capability to respond to a faster, more frequently changing signal

1. Q2: Studies have shown that fast response resources can control the grid with less MWs

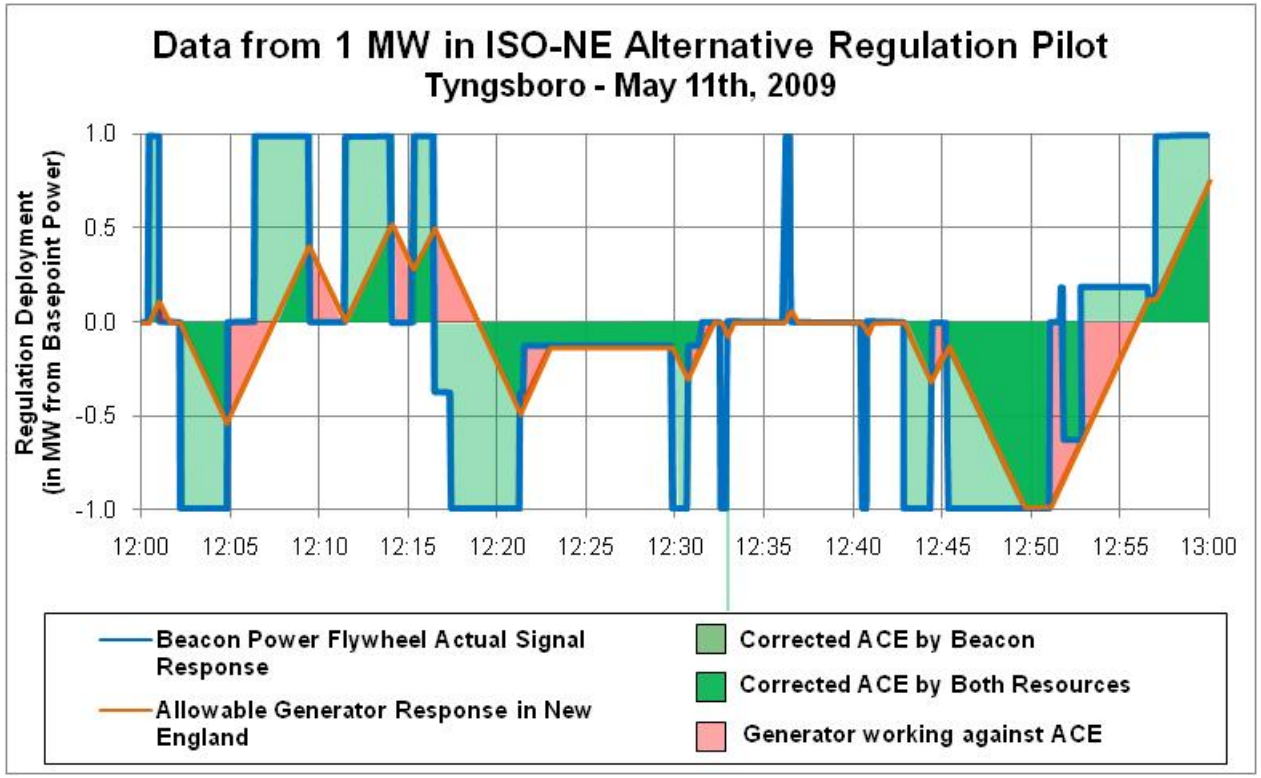


Fast Resources have more ability to correct ACE per MW offered; Enabling less total procurement and cost

*Source: Makarov, Y.V., et al. "Assessing the value of Regulation Resources Based on Their Time Response Characteristics." Pacific Northwest National Laboratory, PNNL – 17632, June 2008.

1. Q2: Beacon Power's ISO-NE operating data illustrates its potential to lower total costs

- Per MW offered, Beacon Power with its under 4 second response time is correcting more of the ACE as compared to a generator with a 5 minute ramp
- In addition, slow ramping resources can add imbalance to the system because of their inability to quickly change direction (from 'Up' to 'Down')



	1 MW of Regulation	
	Flywheel	Generator
ACE Corrected	0.48 MWh	0.18 MWh
Against ACE	0 MWh	-0.07 MWh
Net ACE Correction	0.48 MWh	0.11 MWh

Fast response flywheels provide more Regulation Service per MW offered

1. Q2: ISO/RTO Market data supports the benefits of utilizing faster resources

- Deploying regulation resources based on the amount of MWs offered and the resources ramping capability has been demonstrated to lower total regulation procurement & cost to ratepayers

2009 Status	ISO-NE	MISO	PJM	NYISO	CAISO
Deployed based on MWs & Ramp	✓	✓	N	N	N
Deployed based on MWs only	N	N	✓	✓	✓
Pay-for-Performance	✓	N	N	N	N
Maximum Allowable Response time	5 minutes	5 minutes	5 minutes	5 minutes	10 minutes
Regulation Procurement (as % of Avg. Load)	0.66%	0.68%	1.03%	1.17%	1.43%
Regulation Procurement vs. NE	100% (baseline)	103%	156%	177%	216%

Note: NYISO implemented Fast First Dispatch for energy storage resources, though no such resources were operating in 2009.
PJM implemented a Fast signal for energy storage resources, though only 1 MW was operating in 2009.

ISO-NE, which dispatches and incents resources to respond to faster and more frequently changing signals, procures least amount of Regulation as a % of load

1. Q3: New fast storage technologies can reliably respond to the rapid changes in VER output

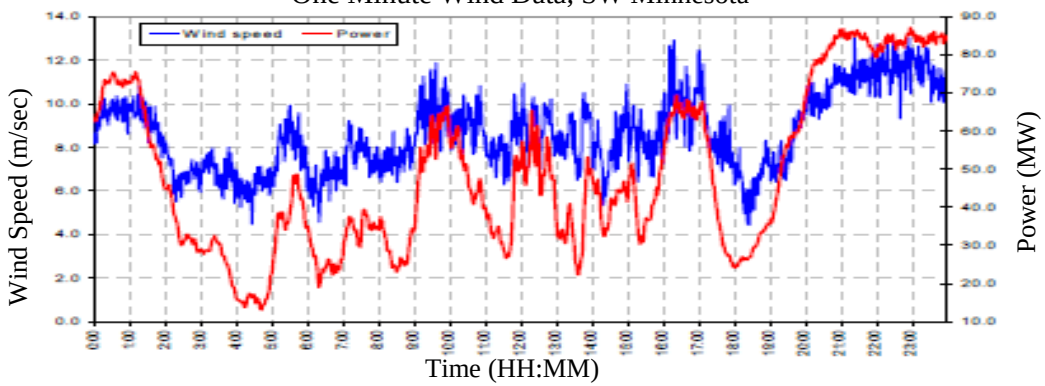
"[Limited Energy Storage Resources ("LESRs")] assist in addressing the control issues presented by the introduction of wind generating and other intermittent resources. These devices can react almost instantaneously to the unpredictable minute by minute changes in wind output."

"LESR devices should help manage control performance, assisting the NYISO in continuing to meet or exceed North American Electricity Reliability Council (NERC) control performance criteria."

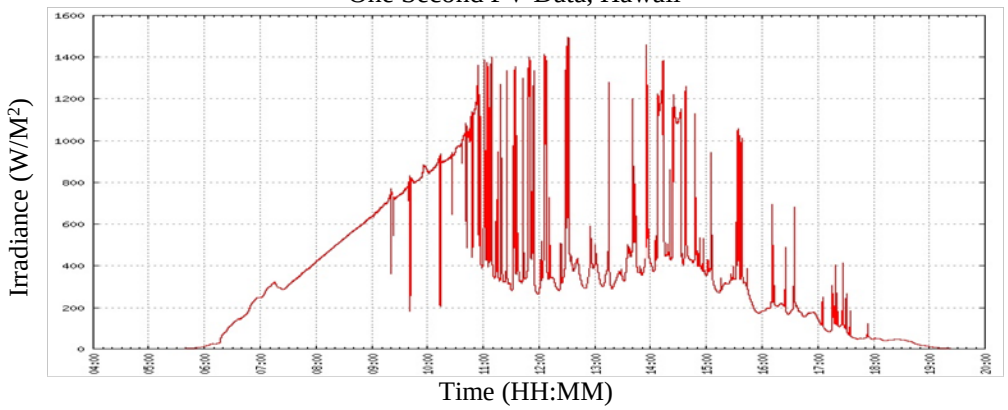
- Mukerji, R.; et al, "Integration of Advanced Storage Technologies into the New York Wholesale Electric Market." CIGRE, C5-2010; May, 2010.

Wind and Solar Data Show High Variability

One Minute Wind Data, SW Minnesota



One Second PV Data, Hawaii



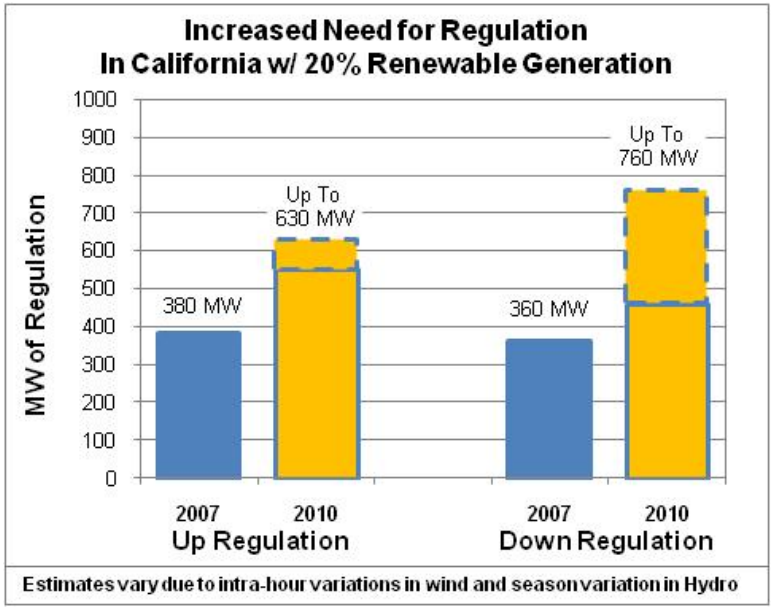
Flywheels have the capability to provide near "instantaneous" control to frequent and unpredictable changes in wind/solar

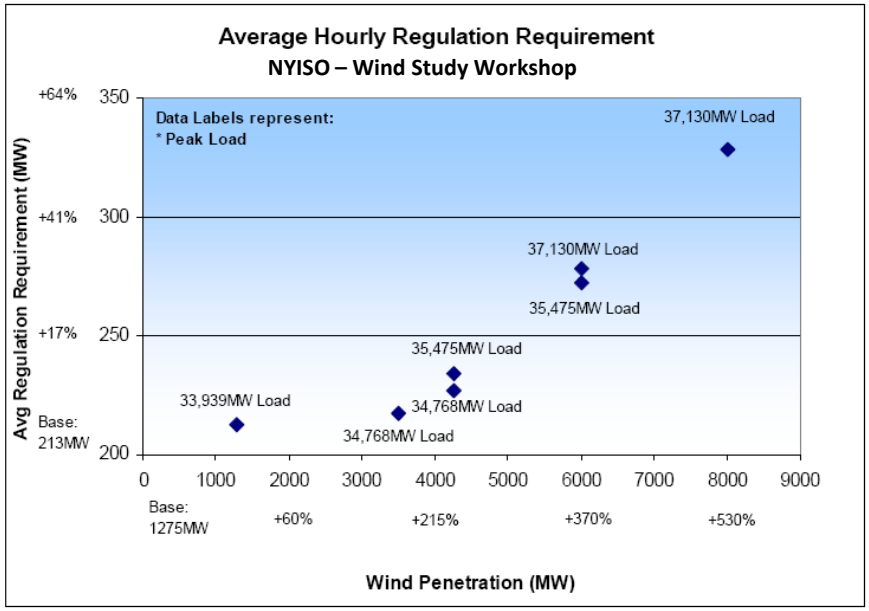
Graph Sources:
- Wan, Y. "Wind Power Plant Behaviors: Analyses of Long-Term Wind Power Data." National Renewable Energy Laboratory, September 2004.
- George, R. "Developing Data Sets for PV Integration Studies." National Renewable Energy Laboratory, Utility-scale PV Variability Workshop – 11/7/2009.

1. Q3: Studies have shown that increased penetration of VERs will require more Regulation

- Frequent and unpredictable changes in wind/solar creates need for more Regulation in order to maintain reliability
- Multiple studies are confirming this result

ISO Studies Show the Growing Need for Regulation





Fast response storage has the potential to reliably and cost effectively integrate greater amounts of VERs

Sources:
- Loutan, C.; Hawkins, D. Integration of Renewables. Renewable Workgroup, The California Independent System Operator. Folom, CA : The California Independent System Operator, 2007. p. 7. http://www.caiso.com/1ca5/1ca5a7a026270.pdf
- "Wind Integration Study: Regulation Requirements." NYISO, NYISO Wind Study Workshop; October 19th, 2009.

1. Q3: NYISO FERC Order confirms the reliability benefits of fast response regulation resources

- Excerpts from May 15, 2009 FERC Order approving NYISO's tariff changes to integrate Limited Energy Storage Resources ("LESRs") into its Regulation market:
  - We find that the proposed tariff revisions to incorporate LESRs will benefit NYISO's markets by providing them with a **new source of regulation service with unique operational characteristics that enable very fast responses** to needs for regulation.
  - We recognize that these **LESRs can assist in the effective integration of wind resources** into the New York control area.
  - Further, the integration of LESRs in the regulation service market should **improve the NYISO's control performance** and assist it in meeting or exceeding NERC control performance criteria.

1. Q4: Example of how deploying and paying for speed can lower overall costs to ratepayers

Traditional Regulation method *Same signal all resources*						"Fast first" method *Dispatch and Pay based on Response Speed*							
Ramp Rate	RCP	Awarded Reg	Reg Service	Total Payment	$/MW	Ramp Rate	RCP	Awarded Reg	Reg Service	Reg Payment	Service Payment	Total Payment	$/MW
Average	$36	20 MW	200 MW	$720	$36	Average	$18	20 MW	**200 MW**	$360	$360	$720	$36
Average	$36	20 MW	200 MW	$720	$36	Average	$18	20 MW	**200 MW**	$360	$360	$720	$36
Fast	$36	20 MW	200 MW	$720	$36	Fast	$18	20 MW	**600 MW**	$360	$1,080	$1,440	$72
Slow	$36	20 MW	200 MW	$720	$36	~~Slow~~	~~$18~~	~~20 MW~~	~~**0 MW**~~	~~$360~~	~~$0~~	~~$360~~	~~$18~~
Slow	$36	20 MW	200 MW	$720	$36	~~Slow~~	~~$18~~	~~20 MW~~	~~**0 MW**~~	~~$360~~	~~$0~~	~~$360~~	~~$18~~
Total Market	**$36**	**100 MW**	**1,000 MW**	**$3,600**	**$36**	**Total Market**	**$18**	**60 MW**	**1,000 MW**	**$1,080**	**$1,800**	**$2,880**	**$48**
												20% savings	

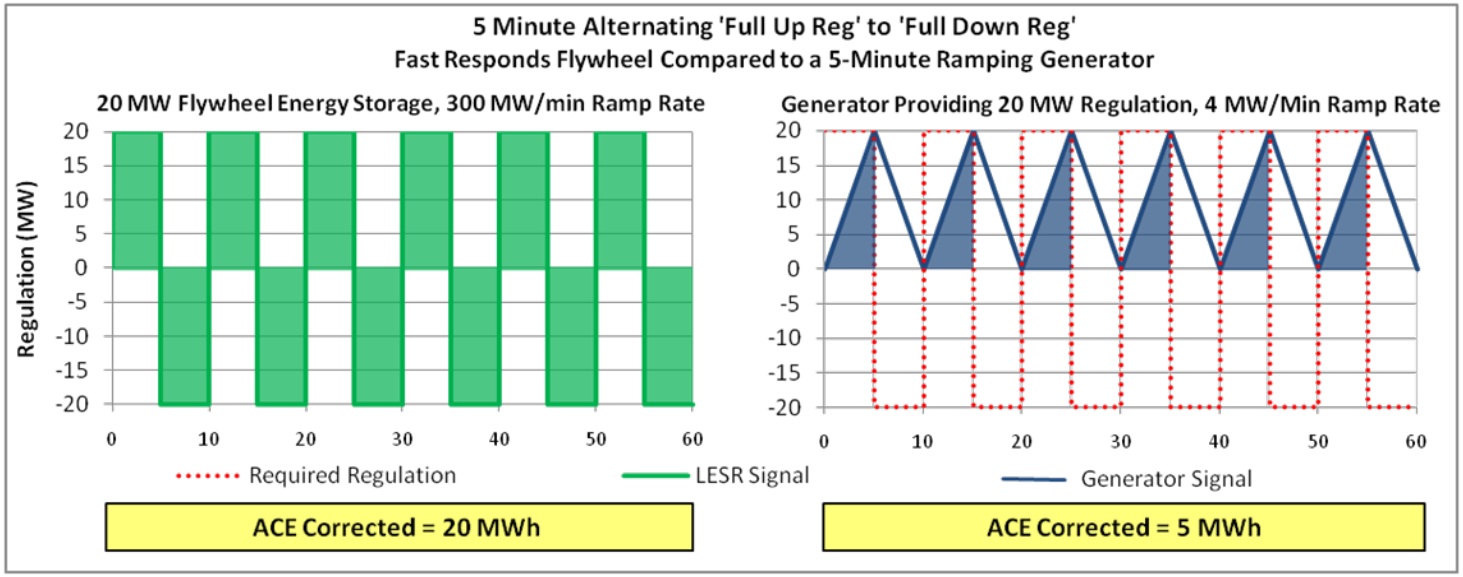
"Fast First" method results in same Regulation effectiveness with less overall cost for ratepayers

Example: 20% savings in cost, 40% savings in MWs procured

Frees Up 40 MW of capacity to provide energy or other reserves

2. Q1: Only ISO-NE's market design sends an efficient price signal to new fast technologies

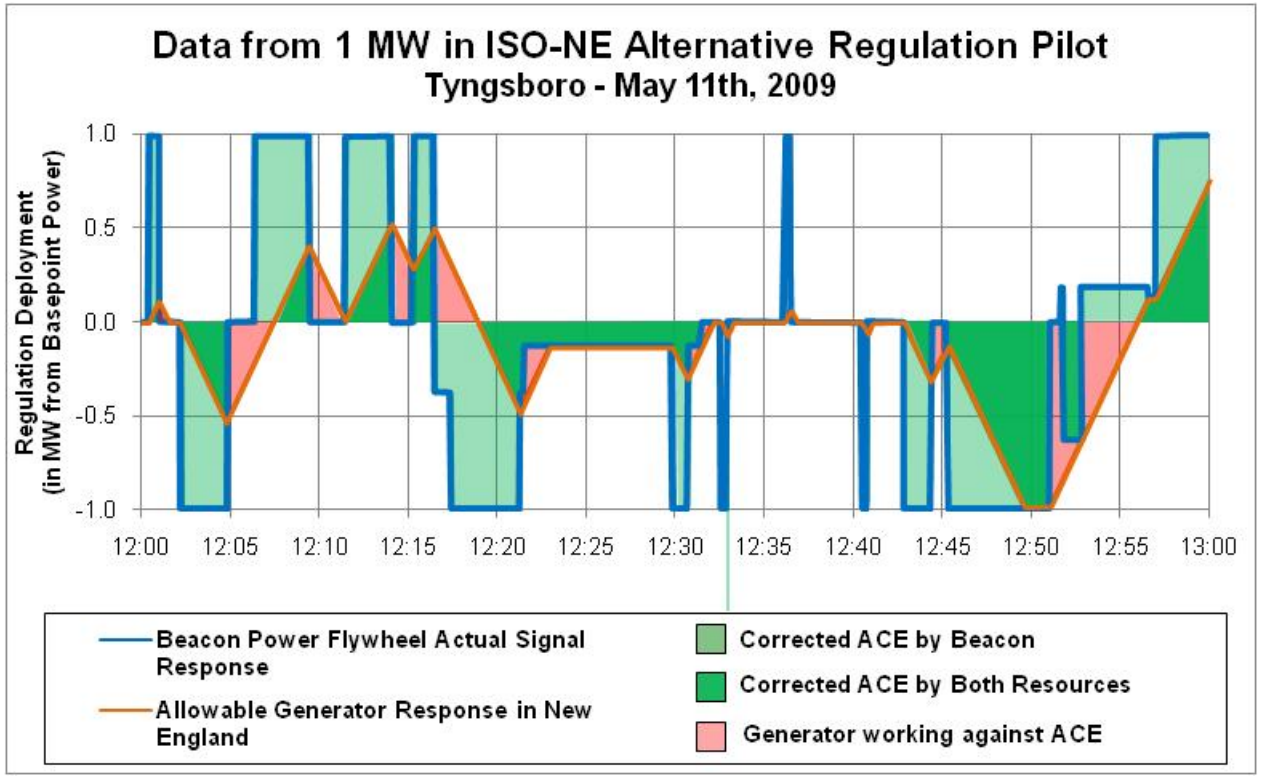
- Only ISO-NE's compensation method sends a price signal for resources to respond faster than the allowable response time (5 minutes most markets)
  - Compensation based on capacity offered and sum of Up and Down movement
- All other markets compensate resources based solely on range of MWs power available in 5 minutes. Therefore, no incentive for fast response. Example:
  - 20 MW flywheel ramp rate = 300 MW/minute
  - Potential capacity = 300 MW/minute * 5 minutes = 1500 MW, yet only has 20 MW storage
  - Therefore, 300 MW/min flywheel paid the same as 20 MW Generator with 4 MW/min ramp rate



In all markets, except ISO-NE, the resources are compensated the same
No price signal to new technologies that can respond with their full capacity faster than 5 mins

2. Q2: ISO-NE "Mileage" measurement is a good proxy for the Regulation service provided

- Per MW offered, Beacon Power with its under 4 second response time is correcting more of the ACE as compared to a generator with a 5 minute ramp



	1 MW of Regulation	
	Flywheel	Generator
ACE Corrected	0.48 MWh	0.18 MWh
Against ACE	0 MWh	-0.07 MWh
Net ACE Correction	0.48 MWh	0.11 MWh
Mileage	25 MW miles	8 MW miles
Accurately followed signal?	Yes	Yes

ISO-NE's mileage payment (sum of up and down movement) recognizes and pays resources for providing more Regulation Service to the grid

2. Q3: It is appropriate to pay based on both 1) MWs "on call" and 2) changes in power output

- Frequency error is function of the amount (MW) of imbalance <u>and</u> the time it takes to correct the imbalance
  - The sooner ACE is corrected the less amount of regulation that needs to be deployed
- Basing regulation payments on both the amount of MWs offered <u>and resource speed of response</u> correctly values the service provided
  - Resources that are more flexible and that can ramp more quickly will reach their dispatch target more quickly, and therefore be ready to be re-dispatched (change output) more often.
- Two component regulation payment formula recognizes that faster responding resources actually provide more regulation service to the grid than slower responding units for the same amount of MWs offered and pay appropriately

2. Q3: ISO-NE's two component formula appropriately compensates Regulation

- ISO-NE formula:

1. **Time on Regulation Credit:** Based on the amount of capacity available to the ISO to provide Regulation

$$\text{Time on Regulation Credit} = (\text{Regulation Clearing Price}) \ \text{x} \ (\text{Regulation Capacity MW})$$

2. **Regulation Service ("Mileage") Credit**: Based on the resource's total amount of actual up and down movement.

$$\text{Regulation Service Miles} = \sum |\text{Changes in output MW}|$$

$$\text{Regulation Service Credit} = (\text{Regulation Clearing Price}) \ \text{x} \ 0.1 \ \text{x} \ (\text{Regulation Service "Miles"})$$

(0.1 = 1 MW of Average Regulation provides 10 MW of Mileage)

ISO-NE's formula encourages resources to respond faster and more accurately; ensures resources are paid comparably

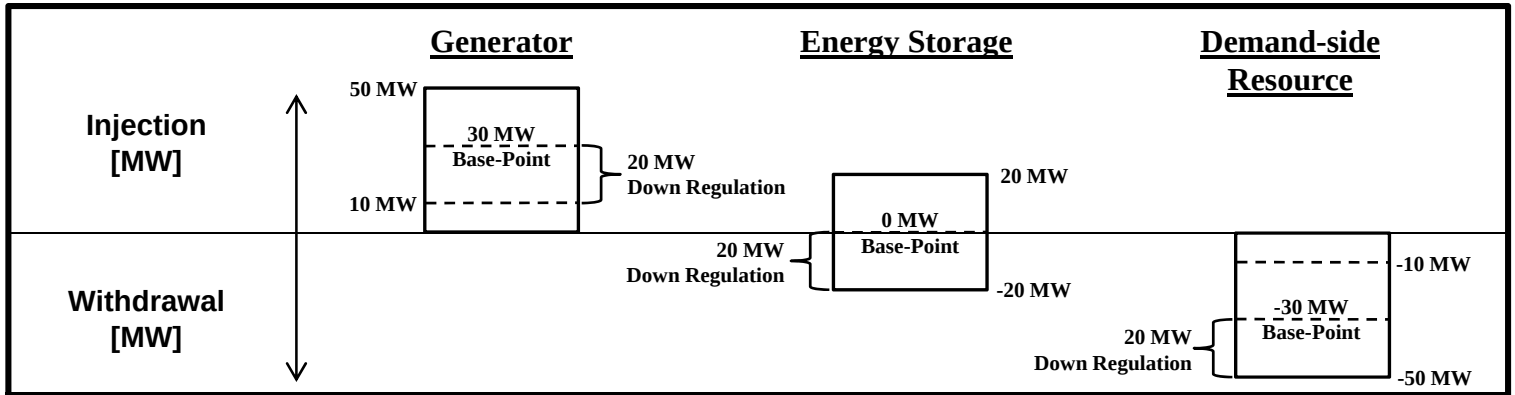
2. Q4 & Q5: The best compensation model incents resources to respond both quickly and accurately

	"Mileage"	Accuracy Only
Advantages	• Compensates resources based on value they provide – it is a proxy for the resources contribution to correcting ACE • Provides comparable payment to all technologies • Sends a market signal to maximize amount of ramp capability • Can be implemented in conjunction with accuracy performance metrics • Dispatching and paying based on resource response can reduce overall procurement	• Encourages resources to accurately respond to the control signal sent by the ISO
Disadvantages	• None	• Does not value fast response & does not provide comparable payment. Slow resources that respond accurately to slow signals do not provide as much value as fast resources that respond accurately to fast signals. Yet both resources are paid the same amount.
How should compensation be set?	• Use ISO-NE method: A single Clearing Price that is used in both formulas (mileage and capacity).	• Accuracy only works if compensation results in an accurate fast resource being paid more than an accurate slow resource
Send efficient signal for new investment	**Yes**	**No**

Compensation model should value <u>both</u> speed and accuracy of response

2. Q7: Storage should be paid for both "Regulation Down" *and* pay for the Energy withdrawn

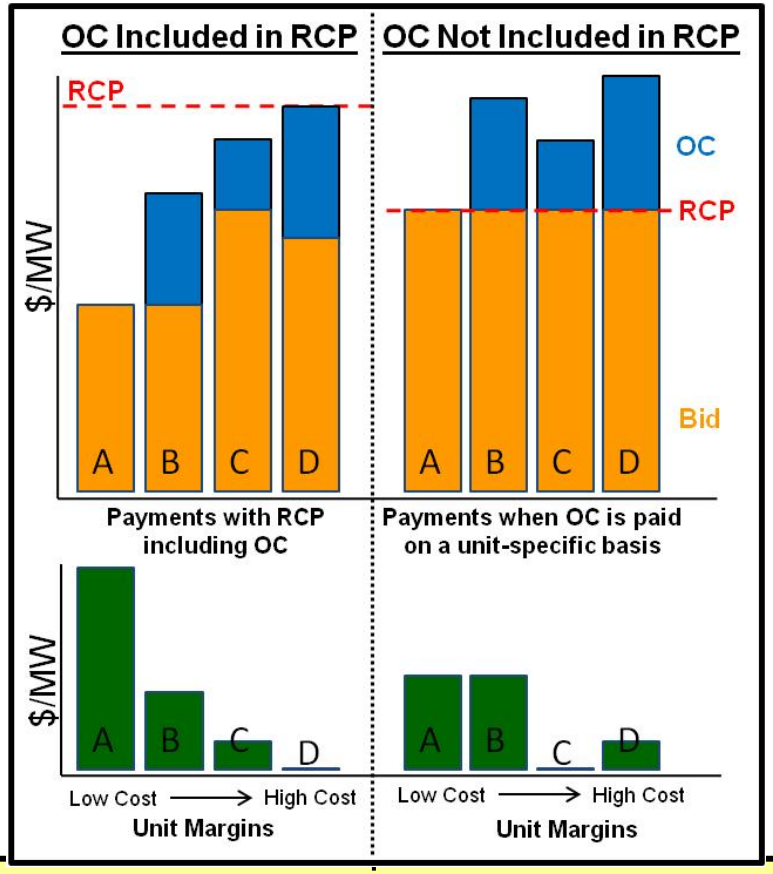
- Regulation is a separate market to pay resources for modifying their output per ISO control signal
  - In the diagram below, the Generator, Energy Storage and Demand-side resource each provide an equivalent 20 MW of Regulation
  - Therefore, each resource should get paid for 20 MW Regulation
- In addition, each resource should either be paid or pay for the energy it injects/withdraws
- FERC has approved an energy settlement formula for storage providing regulation:
  - Hourly Energy Settlement = (Injections – Withdrawals) * LMP



	Generator	Energy Storage	Demand-side Resource
Base-Point **ISO Signal Target** **Effect on the Grid**	30 MW 10 MW **20 MW Less on the Grid**	0 MW -20 MW **20 MW Less on the Grid**	-30 MW -50 MW **20 MW Less on the Grid**
Regulation Provided	**20 MW**	**20 MW**	**20 MW**
Energy Settlement	(30 - 20) MW = 10 MW **Sells 10 MW**	(0 – 20) MW = -20 MW **Buys 20 MW**	(-30 – 20) MW = -50 MW **Buys 50 MW**

2. Q8: Marginal unit's opportunity cost should be included in the Regulation Clearing Price

- Regulation clearing price should include the total cost of the marginal unit to provide Regulation including its Opportunity Cost (OC)
- All markets, except ISO-NE, include OC in the Regulation Clearing Price
  - Sends the strongest price signal to low cost resources
  - Results in lower cost resources receiving highest margin
- Unit-specific OC payments do not send correct market signals
  - Can result in higher cost resources receiving higher margins than lower cost resources
  - Punishes resources with low OC
- RCP w/OC should be used in both the calculation of the payment for capacity "on call" and the payment for "mileage"



Sends correct market signals:

– **Unit A** is cheapest and receives the highest margin

– **Unit D** is the most expensive and receives the lowest margin

Doesn't send correct signals:

– **Unit A** receives the same margin as **Unit B** even though **Unit A** is less expensive

– **Unit D** receives a greater margin than **Unit C** even though **Unit D** is more expensive

Regulation Market Pricing Down 40+%

- Difficult to finance advanced storage projects with drop in regulation pricing
- Mileage payments would send the right market signals to fast technologies (storage, V2G, DR) and provide the economic incentive to build

ISO Regulation Market "All-in" Clearing Price

Market	2008	2009	Change (%)
New England	$47.03	$27.84	-41%
New York	$59.51	$38.17	-36%
PJM	$58.96	$31.01	-45%
California	$33.41	$13.78	-59%
Midwest ISO	N.A.	$12.43	N.A.

Appropriately valuing fast response resources more critical than ever
Sends the right market signals to fast technologies – storage, V2G, DR

Beacon Power's Recommendation for Next Steps

- Beacon Power respectfully requests that FERC:
  - Issue an Order wherein ISOs are directed to compensate Regulation providers comparably, based upon the speed and accuracy in which they regulate the grid; and
  - Direct ISOs to submit a tariff for FERC's approval that implements a 'pay-for-performance' mechanism that compensates resources for the additional value that superior speed and accuracy of regulation response provides the grid.

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