

Beacon Power, LLC

Overview of FERC Order 755 and Pay-for-Performance Regulation

March 21, 2014



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About Beacon Power, LLC



About Beacon Power, LLC

- ▶ Wholly owned subsidiary of Rockland Capital, based in Houston, TX
- ▶ Market-leading flywheel energy storage company, with three commercial-scale plants, over 5 million operating hours, and 15 years of leadership
 - ▶ Leader in development of market rules for storage and Frequency Regulation compensation

>5 Million Operating Hours



Tyngsboro, MA
1 MW Facility
Operating since 2008



Stephentown, NY
20 MW Facility
Operating since 2011

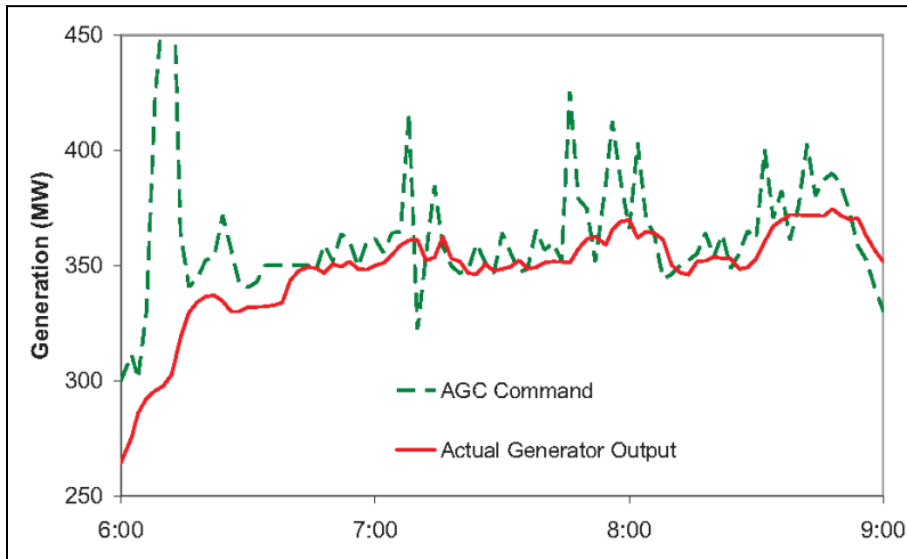


Hazle, PA
20 MW Facility
Initial COD Sep 2013
Full COD June 2014

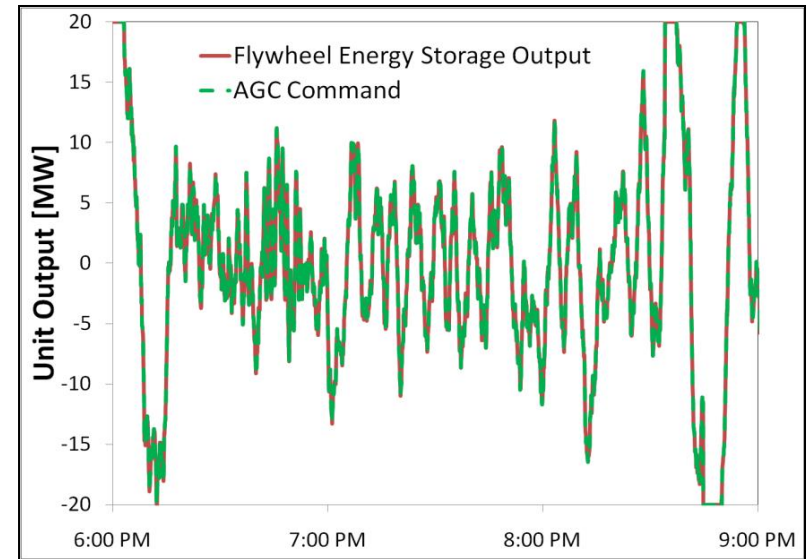


Frequency Regulation Compensation before Order 755

Frequency Regulation – Speed Matters



Slow ramping
Generator



Fast response
Flywheel Energy Storage

**Resources with superior speed and accuracy
are significantly more effective at responding to system imbalances,
but were paid the same for Frequency Regulation before
“Pay-for-Performance”**

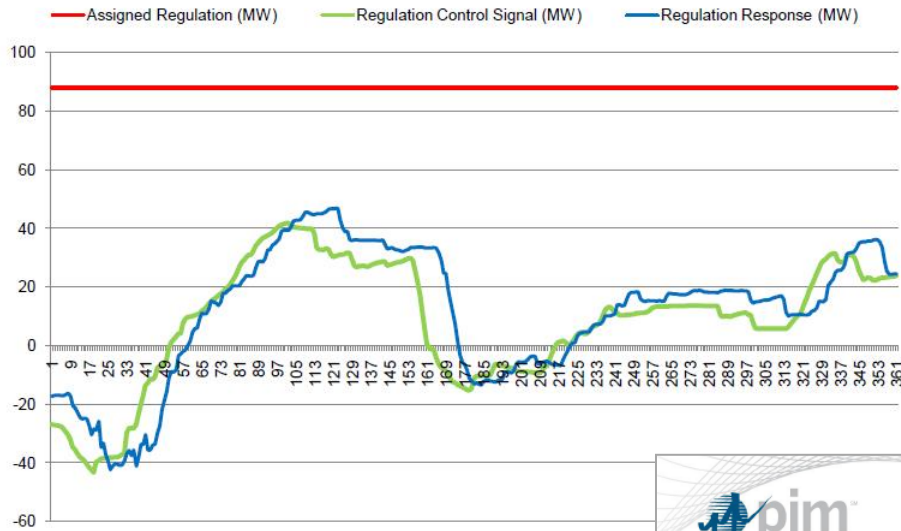
Frequency Regulation Compensation in ISOs (Before FERC Order 755)

- ▶ Prior to FERC Order 755, most ISO markets paid regulation providers a “capacity payment” to make some capacity available in 5-15 minutes
 - ▶ Regulation capacity price included Capacity offer cost + estimated Lost Opportunity Cost (“LOC”)
 - ▶ PJM, ISO-NE – much LOC paid out of market as “make-whole” payments
 - ▶ Regulation price vs. regulation cost
 - ▶ Only ISO-NE had Mileage Payment – and benefited from incenting speed of response
- ▶ Payments not tied to resource performance
 - ▶ Resources paid the same regardless of whether they were used (or remained on standby), and how accurately they responded
 - ▶ Fast and slow resources paid the same

Regulation Performance Examples



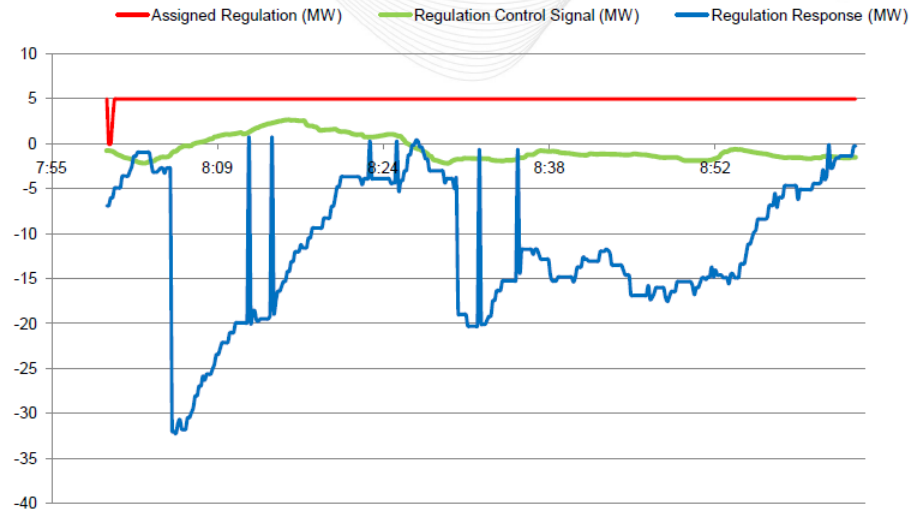
Performance Score Example – Combined Cycle



Received 100% payment before PFP

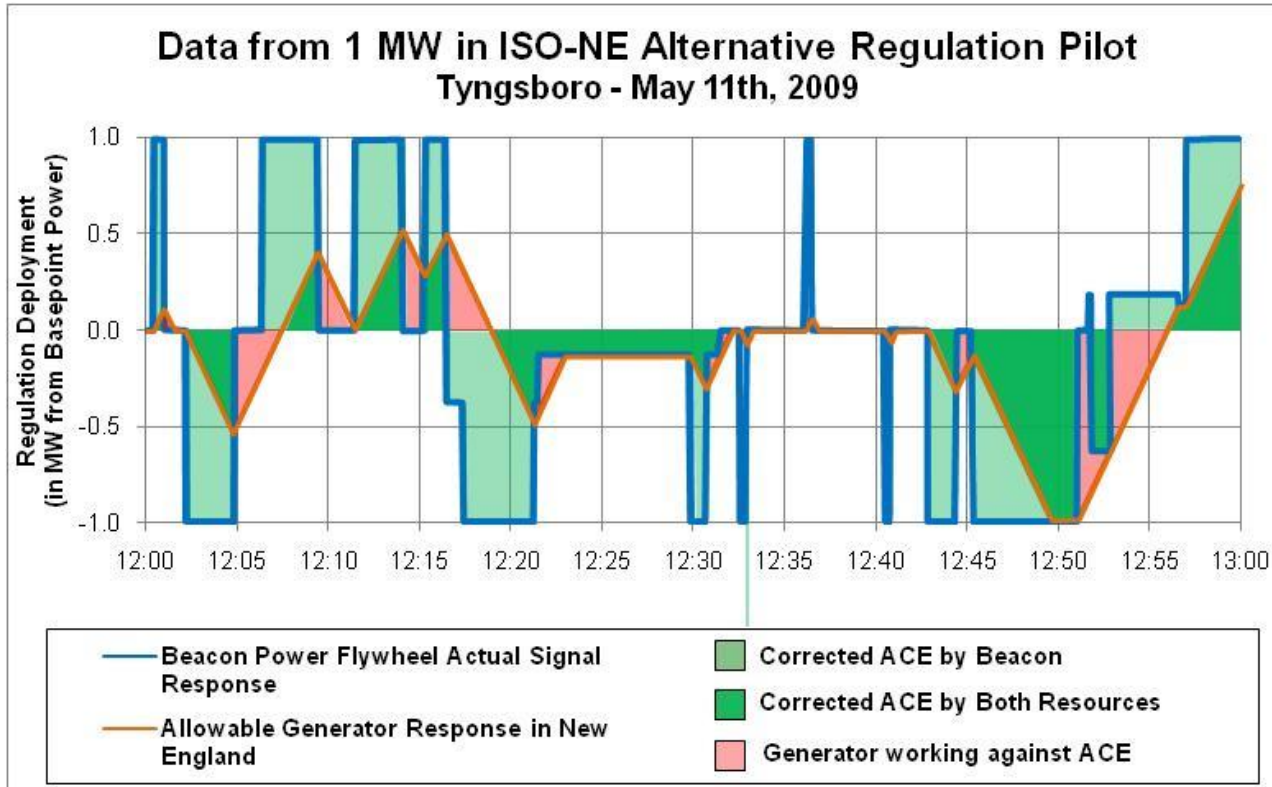


Performance Score Example – Steam Unit



The Need for Reform in Frequency Regulation Compensation

- ▶ Chart shows actual operating data from Beacon's Tyngsboro facility (blue-green line) versus a traditional generator with a 5 minute response rate (red line)



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

- The area under each curve is the amount of energy provided by resource to correct frequency imbalance, i.e. ACE Correction.

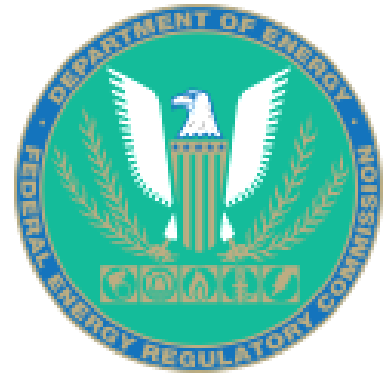
On average, Beacon's Flywheels provide 2 - 4x more Regulation Service per MW capacity



FERC Order 755 –
Frequency Regulation Compensation –
“Pay-for-Performance”

FERC Order 755: “Pay-for-Performance” - Overview

- ▶ On October 20, 2011 FERC issued new rules for compensating frequency regulation resources, i.e. “pay-for-performance”
 - ▶ Noted current compensation for frequency regulation is unjust, unreasonable and unduly discriminatory
 - ▶ Acknowledged inherently greater amount of frequency regulation service being provided by faster-ramping resources
 - ▶ Required ISO/RTOs to pay regulation resources based on actual amount of regulation service provided (i.e. speed and accuracy)



Should result in appropriate incentives for resources to offer faster ramp rates and respond more quickly and accurately to the regulation control signal and therefore provide more regulation service and better operational control to the grid.

FERC Order 755: “Pay-for-Performance” – Details (1/2)

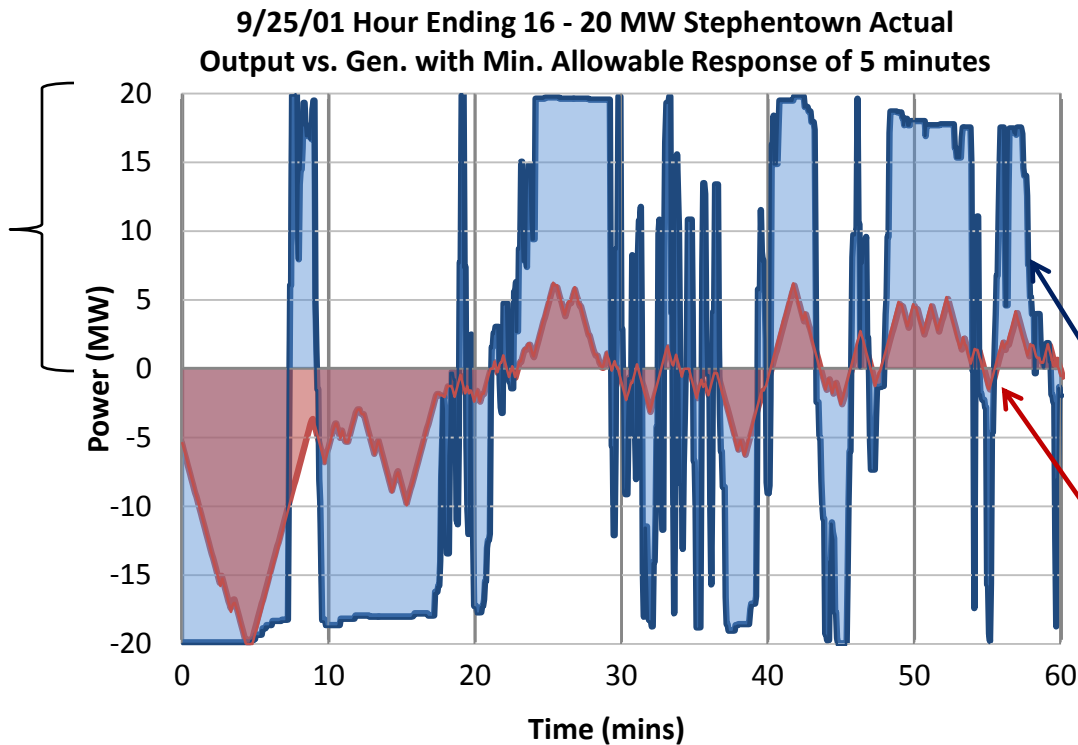
- ▶ Two-part regulation payment to compensate resources based on the actual service provided
 - ▶ **Capacity payment** - for making capacity available
 - ▶ including the marginal resource’s LOC
 - ▶ **Performance payment** - based on resource’s actual quantity of regulation “service” provided
 - ▶ adjusted for accuracy in following the ISO’s signal
- ▶ Regulation service measured as “mileage”; i.e. absolute value of sum of up and down movement

FERC Order 755: “Pay-for-Performance” – Two-Part Payment

- Resources must be paid based on **(1)** the amount of MW set-aside (capacity) to provide regulation and **(2)** the actual amount of service provided during the hour (performance)

Capacity Payment

- Amount set-aside
- Both the flywheel and generator provided 20 MW Capacity



Performance Payment

- Sum of resource’s up and down movement, i.e. “mileage”

Flywheel miles

Generator miles

FERC Order 755: “Pay-for-Performance” – Details (2/2)

- ▶ Two-part regulation payment to compensate resources based on the actual service provided
 - ▶ **Capacity payment** - for making capacity available
 - ▶ including the marginal resource’s LOC
 - ▶ **Performance payment** - based on resource’s actual quantity of regulation “service” provided
 - ▶ adjusted for accuracy in following the ISO’s signal
 - ▶ Regulation service measured as “mileage”; i.e. absolute value of sum of up and down movement
-
- ▶ Two part bidding: Capacity offer (\$/MW) and Performance offer (\$/mile)
 - ▶ Implement by October 2012
 - ▶ ISOs given flexibility in market design
 - ▶ Each ISO implementing with slight variations
 - ▶ One year review to FERC

ISO Order 755 / “PFP” Market Designs

	PJM	MISO	CAISO	NYISO	ISO-NE
Market Clearing	Single Part – Rank Summed Bids plus OC <ul style="list-style-type: none"> Offer costs adjusted by historical accuracy and benefits factor 	Single Part – Rank Summed Bids plus OC <ul style="list-style-type: none"> System mileage multiplier 	Two Part – Satisfy both Capacity and Mileage Constraints <ul style="list-style-type: none"> Resource-specific mileage multipliers 	Single Part – Rank Summed Bids plus OC <ul style="list-style-type: none"> System mileage multiplier 	Two Part – Satisfy both Capacity and Mileage Constraints <ul style="list-style-type: none"> Resource-specific mileage multipliers
Mileage Price (MP)	Highest accepted offer (\$/MW)	Highest accepted offer (\$/mile)	Marginal unit offer (\$/mile)	Marginal unit offer (\$/mile)	Highest accepted offer (\$/mile)
Capacity Price (CP)	Total Cost less Mileage Price (\$/MW)	Marginal unit offer + OC (\$/MW)	Marginal unit offer + OC (\$/MW)	Marginal unit offer + OC (\$/MW)	Highest price for “efficient” payments (\$/MW)
Dispatch	Two-signals <ul style="list-style-type: none"> Fast & slow 	Fast-first <ul style="list-style-type: none"> 5 dispatch groups 	Fast-first	Based on 6-second response rate	Fast-first
Payment	$[(CP * MW) + (MP * MW * Mileage Ratio)] * Performance Score$	$CP * MW + MP * Incremental actual mileage$; subject to accuracy thresholds	$CP * MW + MP * Actual instructed miles$	$CP * MW + Inaccuracy charge + MP * Instructed miles * Accuracy Score$	$CP * MW + MP * Instructed miles$; subject to accuracy thresholds
Start Date	October 1, 2012	December 17, 2012	June 1, 2013	June 26, 2013	<i>October 1, 2014</i>



Note: SPP filed its 755 proposal June 21, 2013, which is similar to the MISO design (requested March 1, 2015 start date)

Pay-for-Performance – Key Elements

- ▶ Take into account resources' Accuracy – pay less for lower performance
- ▶ Two part pricing: Capacity and Performance – pay more for more service
- ▶ Lost Opportunity Cost included in market price – incent lower cost resources
- ▶ Set mileage price as highest of accepted offers – encourage highest level of performance
- ▶ Multiple AGC signals – allow resources to offer maximum ramp rate and provide maximum service

FERC Order 755 Implementation in PJM – Performance-Based Regulation

PJM Order 755 and Regulation Offers

- ▶ PJM was first ISO to implement Order 755 (October 1, 2012)
- ▶ Two-part bidding and two-part payment for regulation – Capability & Performance
- ▶ PJM calculates resource Lost Opportunity Cost (LOC), and adds to resource offer
- ▶ Offer costs adjusted for Benefits Factor and historical Performance Score
- ▶ Benefits Factor = Relative system benefit from Fast regulation resource
- ▶ Two regulation signals
 - ▶ Slow “RegA” and Fast “RegD”
- ▶ Performance Score = Accuracy
- ▶ Regulation is Real Time market only
- ▶ Manual 11, Section 3.2.7

$$\text{Adjusted Regulating Capability Cost (\$)} = \frac{\left(\text{Offer} \left(\frac{\$}{\text{MW}} \right) \right)}{\left(\begin{array}{c} \text{Benefits Factor} \\ \text{of} \\ \text{Offered Resource} \end{array} \right)} * \frac{\left(\begin{array}{c} \text{Capability} \\ \text{(MW)} \end{array} \right)}{\left(\begin{array}{c} \text{Historic} \\ \text{Performance} \\ \text{Score} \end{array} \right)}$$

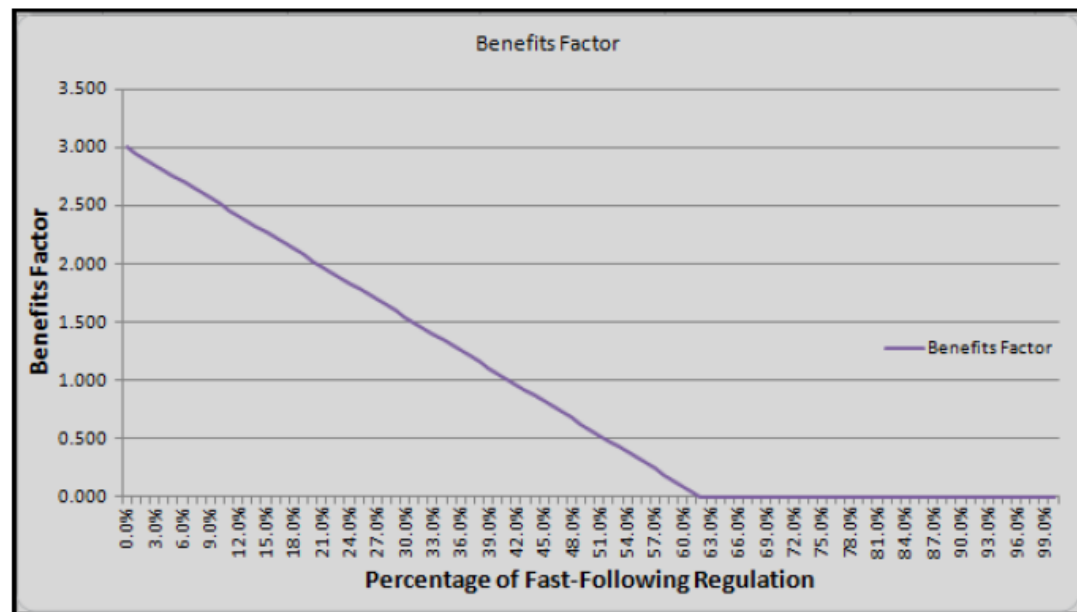
$$\text{Adjusted Lost Opportunity Cost (\$)} = \frac{\left(\begin{array}{c} \text{Estimated Lost Opportunity} \\ \left(\frac{\$}{\text{MW}} \right) \end{array} \right)}{\left(\begin{array}{c} \text{Benefits Factor} \\ \text{of} \\ \text{Offered Resource} \end{array} \right)} * \frac{\left(\begin{array}{c} \text{Capability} \\ \text{(MW)} \end{array} \right)}{\left(\begin{array}{c} \text{Historic} \\ \text{Performance} \\ \text{Score} \end{array} \right)}$$

$$\begin{aligned} & \text{Adjusted Performance Cost (\$)} \\ &= \frac{\left(\begin{array}{c} \text{Performance} \\ \text{Offer} \\ \left(\frac{\$}{\Delta \text{MW}} \right) \end{array} \right) * \left(\begin{array}{c} \text{Mileage ratio} \\ \text{of} \\ \text{Offered Resource Signal Type } (\Delta \text{MW} / \text{MW}) \end{array} \right)}{\left(\begin{array}{c} \text{Benefits Factor} \\ \text{of} \\ \text{Offered Resource} \end{array} \right) * \left(\begin{array}{c} \text{Historic} \\ \text{Performance} \\ \text{Score} \end{array} \right)} * \left(\begin{array}{c} \text{Capability} \\ \text{(MW)} \end{array} \right) \end{aligned}$$



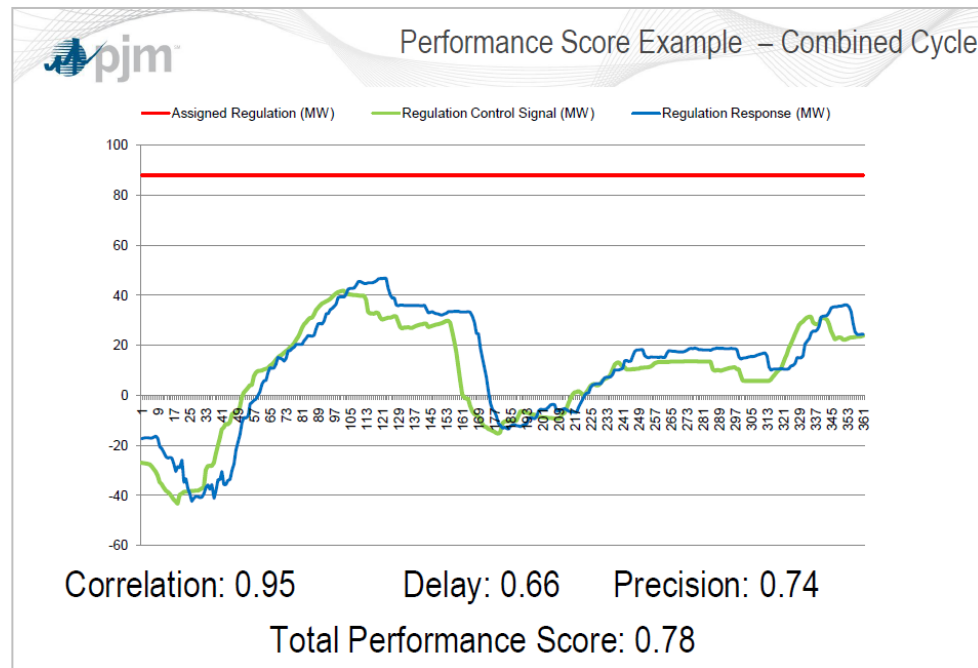
PJM 755 Regulation “Benefits Factor”

- ▶ Relative system benefit of Fast regulation resources
- ▶ Rate of substitution between resources following the different regulation signals
- ▶ Based on current two regulation signal system and KEMA analysis in 2011
 - ▶ Slow “RegA” and Fast “RegD”
- ▶ Used to normalize regulation offers from Fast and Slow resources
 - ▶ Regulation offer costs divided by resource-specific Benefits Factor
 - ▶ Manual 11, Section 3.2.7



PJM 755 Regulation “Performance Score”

- ▶ Performance Score Calculation
 - A. Delay Score - Delay in responding
 - B. Correlation Score - Ability to control
 - C. Precision Score - Systemic error
- ▶ Composite score is equal weighted ave.
- ▶ Data sampled every 10 seconds
- ▶ Averaged over 5 minutes, then over the hour
- ▶ Regulation qualification = 75%
- ▶ Disqualification = 40%
- ▶ Manual 12, Section 4.5.6



$$\text{Delay Score} = \text{Abs} \left| \frac{\delta - 5 \text{ Minutes}}{5 \text{ Minutes}} \right|$$

$$\text{Correlation Score}_{\delta=0 \text{ to } 5 \text{ Min}} = r_{\text{Signal, Response}(\delta, \delta+5 \text{ Min})}$$

$$\text{Error} = \text{Avg of Abs} \left| \frac{\text{Response} - \text{Regulation Signal}}{\text{Hourly Average Regulation Signal}} \right|$$

$$\text{Precision Score} = 1 - \frac{1}{n} \sum \text{Abs}(\text{Error})$$

$$\text{Performance Score} = \max \left[A * \left(\frac{\text{Delay Score}}{100} \right) + B * \left(\frac{\text{Correlation Score}}{100} \right) \right] (A * + B *) + C * \left(\frac{\text{Precision Score}}{100} \right)$$



PJM 755 Regulation Market Clearing & Settlement

- ▶ Regulation Requirement - “Effective MWs”
 - ▶ Capacity adjusted for Benefits Factor and Performance Score
- ▶ Single part clearing
 - ▶ Unit that meets Regulation (capacity) requirement sets Total Market Clearing Price

$$\text{Adjusted Total Offer Cost (\$)} = \left(\begin{array}{c} \text{Adjusted} \\ \text{Regulation} \\ \text{Capability} \\ \text{Cost} \\ (\$) \end{array} \right) + \left(\begin{array}{c} \text{Adjusted} \\ \text{Lost} \\ \text{Opportunity} \\ \text{Cost} \\ (\$) \end{array} \right) + \left(\begin{array}{c} \text{Adjusted} \\ \text{Performance} \\ \text{Cost} \\ (\$) \end{array} \right)$$

$$\text{Rank Price} = \frac{\text{Adjusted Total Offer Cost (\$)}}{\text{Capability (MW)}}$$

- ▶ Performance Price set as highest of adjusted Performance offers
 - ▶ Capacity Price set as residual from Total Market Clearing Price
- } emphasis on Performance

$$\text{Regulation Market Capability Clearing Price } \$/\text{MW} = \left(\begin{array}{c} \text{Regulation Market} \\ \text{Clearing Price} \\ \$/\text{MW} \end{array} \right) - \left(\begin{array}{c} \text{RM Performance} \\ \text{Clearing Price} \\ \$/\text{MW} \end{array} \right)$$

- ▶ Prices set every five minutes, averaged over hour for settlement

$$\text{Regulation Capacity Credit} = \text{Capacity Price (\$/MW)} \times \text{Regulation Capacity (MW)} \times \text{Performance Score (\%)}$$

$$\text{Regulation Performance Credit} = \text{Performance Price (\$/MW)} \times \text{Regulation Capacity (MW)} \times \text{Performance Score (\%)} \times \text{Mileage Ratio}$$

- ▶ Mileage Ratio – ratio of mileage of resource’s Regulation signal to Slow / RegA signal
 - ▶ Ratio of Fast to Slow signals ~3x

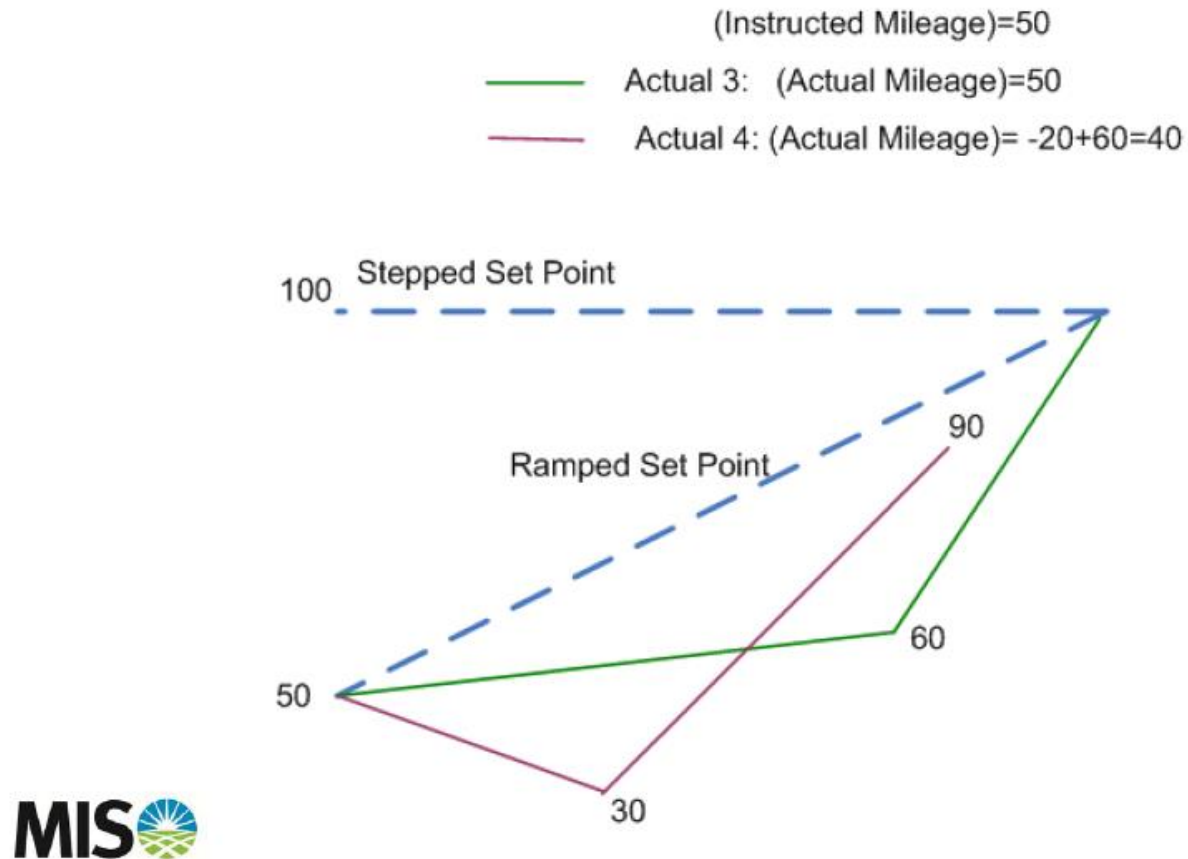
FERC Order 755 Implementation in MISO

MISO 755 Regulation Market Clearing and Dispatch

- ▶ Single part clearing - Regulation capacity requirement
- ▶ Capacity offer price (\$/MW) plus Mileage offer prices (\$/mile) * mileage multiplier (mile/MW)
 - ▶ Mileage multiplier = average system mileage, is currently ~7 miles/MW/hr (0.6 miles/MW/5 minute interval)
- ▶ Setting Market Clearing Prices (MCP)
 - ▶ Regulating Reserve (Capacity) Price - includes (1) Regulating Capacity Offer, (2) LOC, (3) One full deployment of regulation mileage cost in every dispatch interval
 - ▶ Regulating Mileage Price - the highest Regulating Mileage Offer from all cleared resources
 - ▶ Used to pay for actual regulation mileage beyond one full deployment on each dispatch interval
 - ▶ Any un-deployed regulation mileage is charged back at Regulating Mileage MCP
 - ▶ Example: Capacity price of \$10/MW covers capacity and “pre-pays” for one deployment of mileage. Mileage volume of 10 miles/hr, yields payment of $10 - 7 = 3$ miles at Mileage MCP.
- ▶ AGC Signal Design and Dispatch – multiple signals
 - ▶ Scheduled Regulation resources sorted based on ramp rate
 - ▶ Divided into 5 equal groups, based on number of resources
 - ▶ First group (fastest ramp rates) moved first
- ▶ Business Practice Manual for Market Operations

MISO 755 Regulation Dispatch Accuracy

Example 2



- ▶ Accuracy = every five minutes take ratio of actual mileage over instructed mileage
- ▶ System performance to date has averaged 65%

MISO 755 Regulation Settlement

- ▶ Regulation priced hourly in Day Ahead and every 5 minutes in Real Time; and settled on hourly basis
- ▶ LOC included in Capacity price

$$\text{Regulation Capacity Credit} = \text{Capacity Price (\$/MW)} \times \text{Regulation Capacity (MW)}$$

$$\text{Regulation Mileage Credit} = \text{Mileage Price (\$/Mile)} \times \text{Incremental Actual Mileage (Miles)} \text{ [x Accuracy (\%) if <70\%]}$$

- ▶ If Accuracy < 70% for four consecutive intervals, lose any Regulation credit in that hour

FERC Order 755 Implementation in CAISO

CAISO 755 Regulation Market Clearing, Dispatch, and Settlement

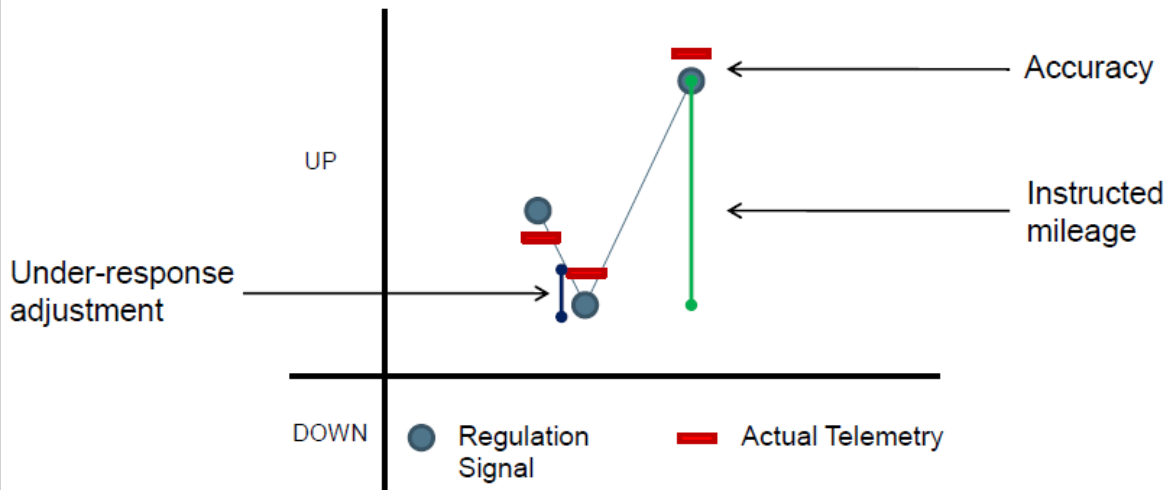
- ▶ CAISO procures most of its Regulation need in the Day Ahead
 - ▶ Regulation Requirement – two part clearing
 - ▶ Capacity – % of forecasted load
 - ▶ Mileage – lower of: (1) capacity requirement times system mileage multiplier, (2) prior seven days average actual mileage for each hour, (3) sum of each resource-specific mileage multiplier times resource bid-in regulation capacity
 - ▶ Regulation Awards – Capacity and Mileage, but Mileage award not financially binding
 - ▶ Each requirement yields a marginal unit that sets the market prices
- ▶ AGC Signal Design and Dispatch
 - ▶ Resources dispatched based on ramp rate – multiple signals
- ▶ Prices and Settlement
 - ▶ Regulation priced and settled on 15 minute basis
 - ▶ LOC included in Capacity price

$$\text{Regulation Capacity Credit} = \text{Capacity Price (\$/MW)} \times \text{Regulation Capacity (MW)}$$

$$\text{Regulation Mileage Credit} = \text{Mileage Price (\$/Mile)} \times \text{Actual Mileage (Miles)} \times \text{Accuracy (\%)}$$

CAISO 755 Regulation Dispatch Accuracy

Accuracy adjustments reduce mileage payment based upon performance



1. Under-response adjustment reduces mileage paid when a resource doesn't provide actual movement
2. Accuracy measured by actual telemetry versus regulation signal

- ▶ Accuracy = every four seconds compare signal and response
- ▶ 50% accuracy threshold for disqualification

FERC Order 755 Implementation in NYISO

NYISO 755 Regulation Market Clearing and Dispatch

- ▶ NYISO procures its Regulation need both in the Day Ahead and Real Time markets
- ▶ Single part clearing - Regulation capacity requirement
- ▶ Capacity offer price (\$/MW) (plus LOC) plus Movement offer prices (\$/mile) * mileage multiplier (mile/MW)
 - ▶ Mileage multiplier = average system mileage = 10 miles/MW/hr
- ▶ Setting market clearing prices
 - ▶ Unit that meets Regulation (capacity) requirement sets both Regulation Capacity Market Price and Regulation Movement Market Price
 - ▶ In DA, only Capacity Market Price published
- ▶ DA (Capacity) prices set every hour; RT prices (Capacity and Movement) set every five minutes
- ▶ AGC Signal Design and Dispatch – unit-specific signals
 - ▶ Resources submit Regulation Movement Response Rate (RMRR), in MW/6 seconds
 - ▶ AGC is allocated to resources proportionally based on the amount of Regulation Movement MWs they are able to provide in the next six seconds
- ▶ Ancillary Services Manual, Section 4

NYISO 755 Regulation Dispatch Accuracy and Settlement

- ▶ Accuracy = “Performance Index”
 - ▶ $[\text{Scheduled Reg MW} - (\text{Signal MW} - \text{Response MW})] / \text{Scheduled Reg MW} + 0.10$
 - ▶ Sampled every 30 seconds; averaged over 5 minute RT interval
 - ▶ 0.10 adder to account for latency effects
 - ▶ Accounting and Billing Manual, Appendix G
- ▶ If Performance Index < 85% for a month, get audited
- ▶ Settlement
 - ▶ Regulation settled hourly in DA and every 5 minutes in RT
 - ▶ Accounting and Billing Manual, Section 5.2

Regulation Capacity Credit (\$) = Capacity Price (\$/MW) x Regulation Capacity (MW) – Capacity Charge

*Capacity Charge (\$) =
(DA or RT) Capacity Price (\$/MW) x (DA or RT) Regulation Capacity (MW) x (1 - Performance Index (%)) x -1.1*

Regulation Movement Credit (\$) = Movement Price (\$/Mile) x Movement (Miles) x Performance Index (%)

FERC Order 755 Implementation in ISO-NE

ISO-NE 755 Regulation Market Clearing

- ▶ ISO-NE was only ISO to have mileage payment, since 2005, until 755 markets started
 - ▶ However, did not meet other Order 755 requirements of including lost opportunity cost in market price, two-part bidding, and market-based pricing
 - ▶ LOC included in Regulation Capacity price, as of July 1, 2013
- ▶ ISO-NE filed most recent 755 market proposal on February 6, 2013 and subsequently requested and received approval for an October 1, 2014 start date.
- ▶ ISO-NE does, and will in its 755 market , procure its Regulation need only in Real Time
 - ▶ Current – single part clearing based on capacity
 - ▶ 755 market – two part clearing
 - ▶ Capacity – based on historical control performance, by month, day-type and hour.
 - ▶ Mileage – as required to maintain system control and reliability
- ▶ Prices set hourly
 - ▶ Current – mileage price administratively set as 1/10 of capacity price
 - ▶ ISO-NE found average resource moves 10 miles/MW/hr
 - ▶ 755 market – market-based
 - ▶ Mileage Price set as highest of Mileage offers
 - ▶ Capacity Price set as highest price for “efficient” payments – which include mileage and capacity offers, calculated lost opportunity cost, and calculated incremental cost savings

ISO-NE 755 Regulation Dispatch, Accuracy, and Settlement

- ▶ AGC Signal Design and Dispatch
 - ▶ Resources dispatched based on ramp rate – multiple signals
- ▶ Accuracy = “Performance Monitoring”
 - ▶ Given a grace period (of 2-4 minutes), a ramp rate tolerance on Automatic Response Rate (of 80-95%), and a tolerance band around the AGC SetPoint equal to a percentage of the Regulation Capacity (5-15%)
 - ▶ More details forthcoming
 - ▶ Measured every AGC cycle (four seconds), averaged over hour
 - ▶ Tariff section III.14.7
- ▶ Regulation priced and settled on hourly basis

Regulation Capacity Credit = Capacity Price (\$/MW) x Regulation Capacity (MW)

Regulation Mileage Credit = Mileage Price (\$/Mile) x Mileage (Miles)

subject to accuracy thresholds

FERC Order 755 Implementation in SPP

FERC Order 755 Implementation in SPP

- ▶ SPP was given additional time to comply with Order 755 as it did not have a fully functioning, ISO-administered Regulation market at the time of the Order
- ▶ SPP filed its Order 755 proposal on June 21, 2013
- ▶ The SPP 755 market design is similar to the MISO design
- ▶ SPP requested an effective date of March 1, 2015, one year after Integrated Marketplace start
- ▶ On March 7, 2014, FERC issued a letter requesting more information on the 755 filing

Thank you!

Mike Berlinski

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