

Performance-based Regulation Market in PJM

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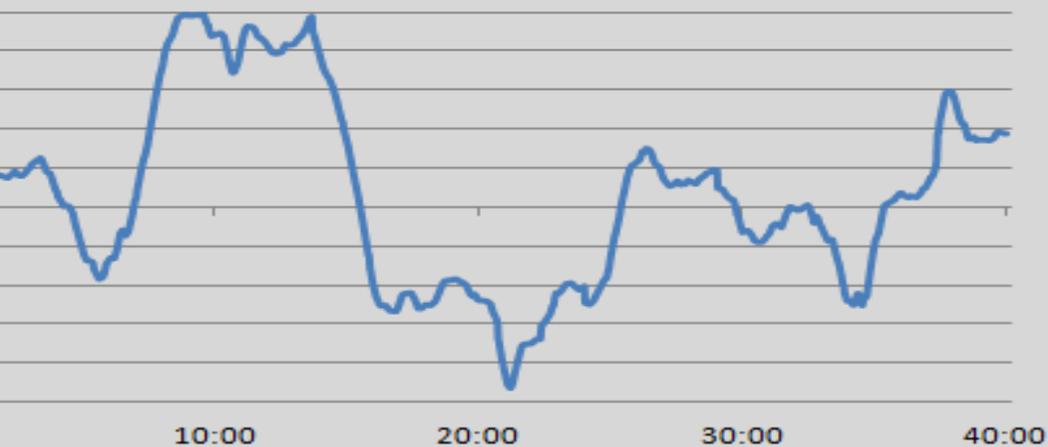
- October 2011 – FERC Order 755 issued
- March 2012 – PJM Original filing w/ Benefits Factor
- May 2012 – Acceptance Order, subject to additional compliance filing
- October 2012 – PJM “go live” of PBR, but without incentive payment structure
- November 2012 – Acceptance Order, subject to additional compliance filing
- January 2013 – PJM Compliance Filing w/ Mileage Ratio
- July 2013 – Acceptance Order, subject to additional compliance filing
- October 2013 – Final Acceptance Order

A decorative graphic of thin, grey, wavy lines spans across the top of the slide, creating a sense of movement and depth. The lines are closely spaced and overlap, forming a series of soft, undulating shapes.

5 MAJOR COMPONENTS OF PERFORMANCE-BASED REGULATION

1. TWO REGULATION SIGNALS

Sample Reg D Test Signal (MW)

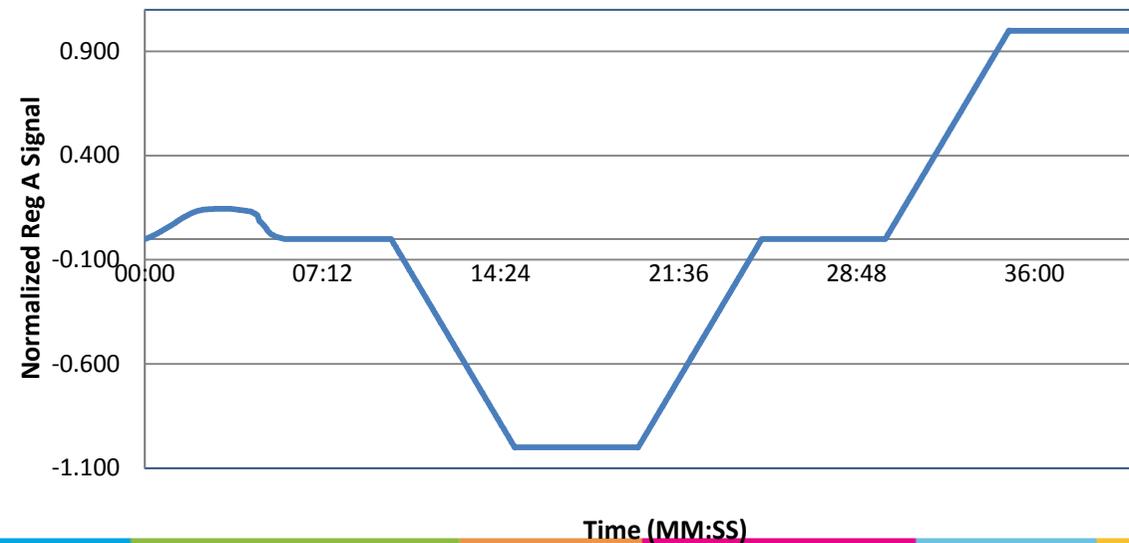


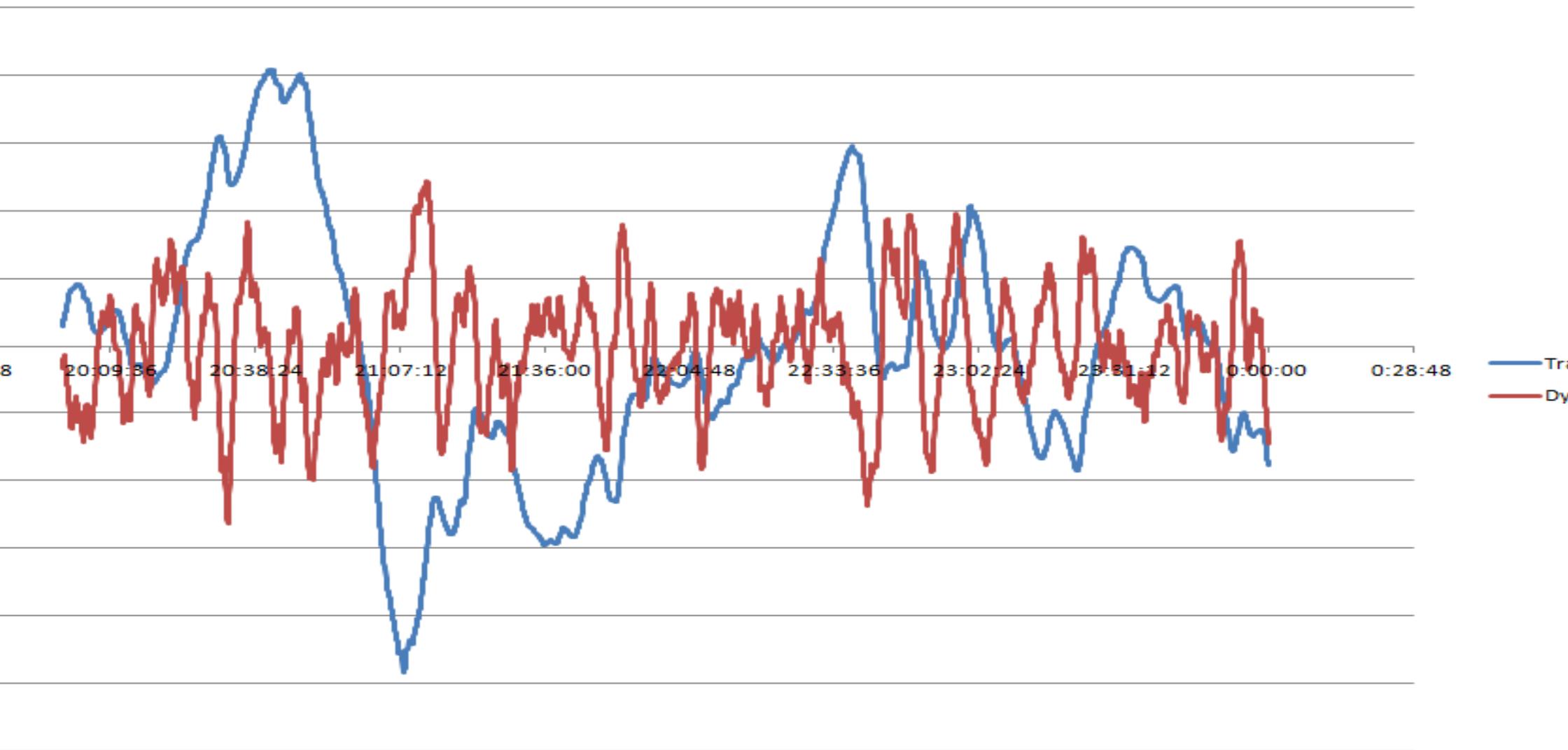
Dynamic Signal (RegD):

- More 'zero' crossings
- "Energy neutral" over operating hour
- Strong correlation with system frequency

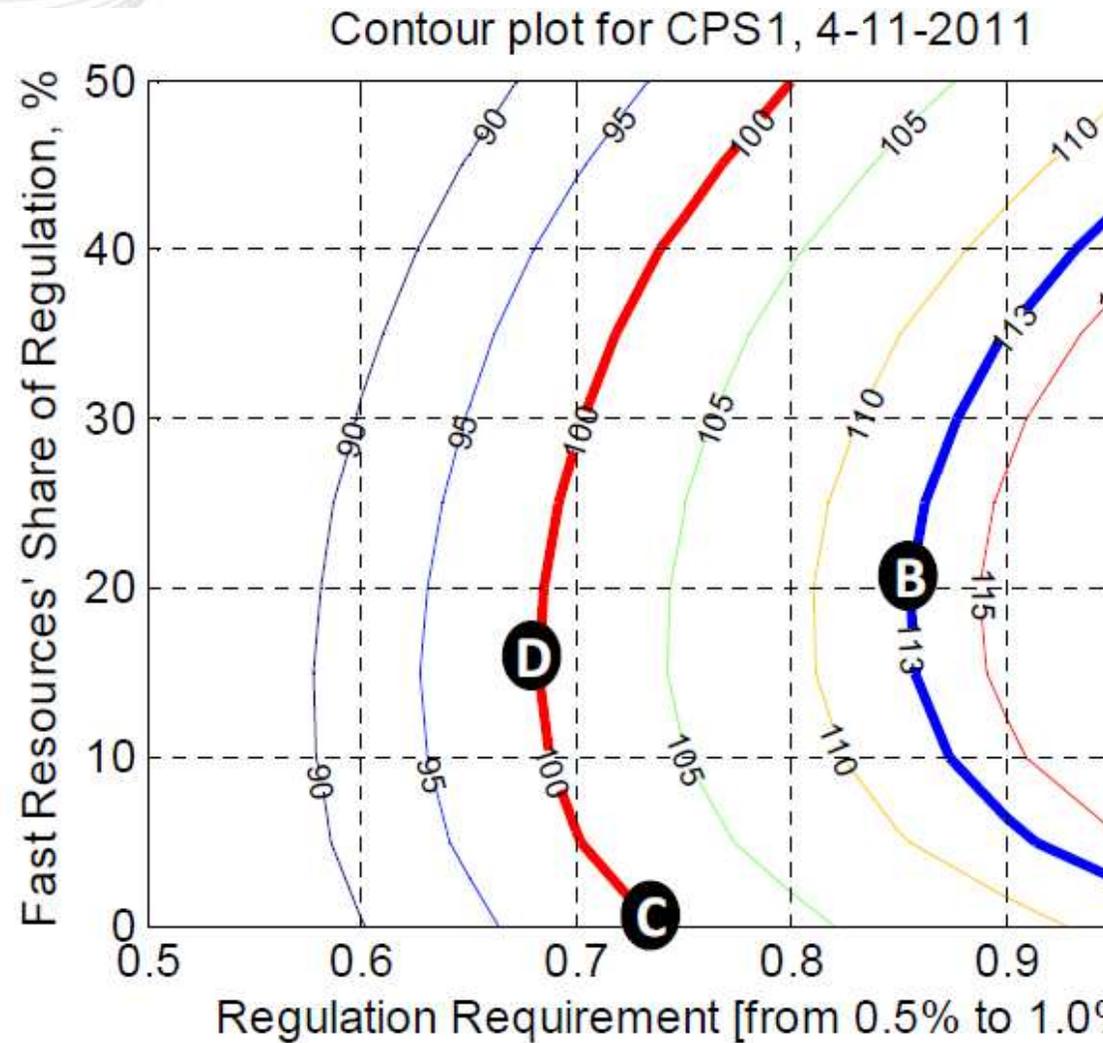
Traditional Signal (RegA):
 Greater time constant, more staying power
 Slower ramping
 Strong correlation with system ACE

Sample RegA Test Signal (MW)



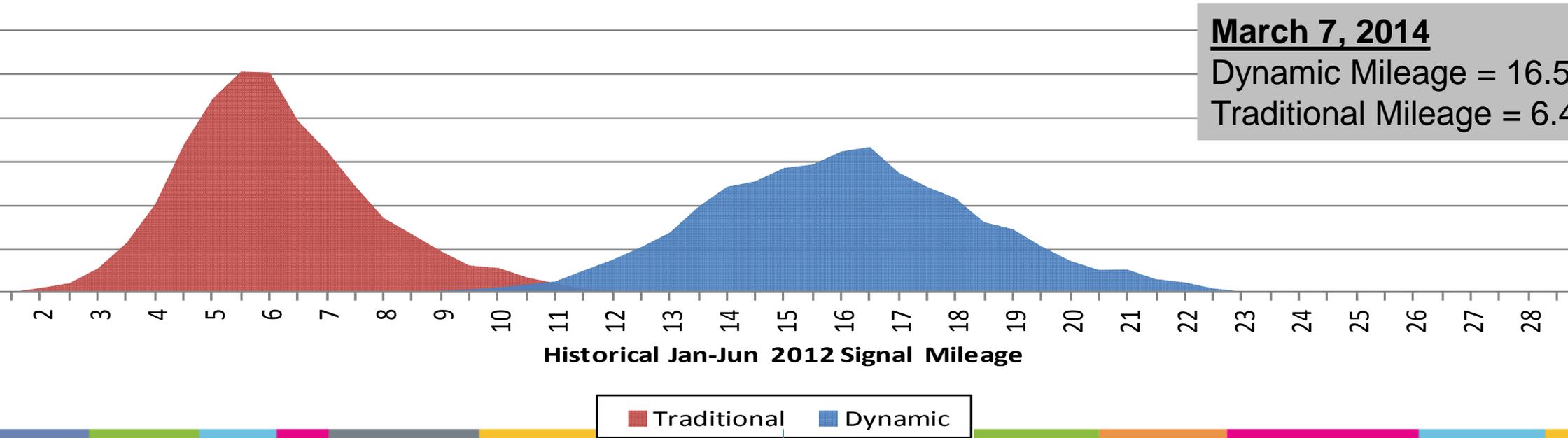


- What is the relative impact on system control with fast vs. traditional resources?
- What is an optimal mix of fast vs. traditional resources, and how does that impact the Regulation Requirement?



2. CALCULATING MILEAGE

- Mileage is the absolute sum of movement of the regulation signal in a given time period ($\Delta MW/MW$)
- Resources following the dynamic signal will move much more than those on traditional signal



3. CALCULATING PERFORMANCE

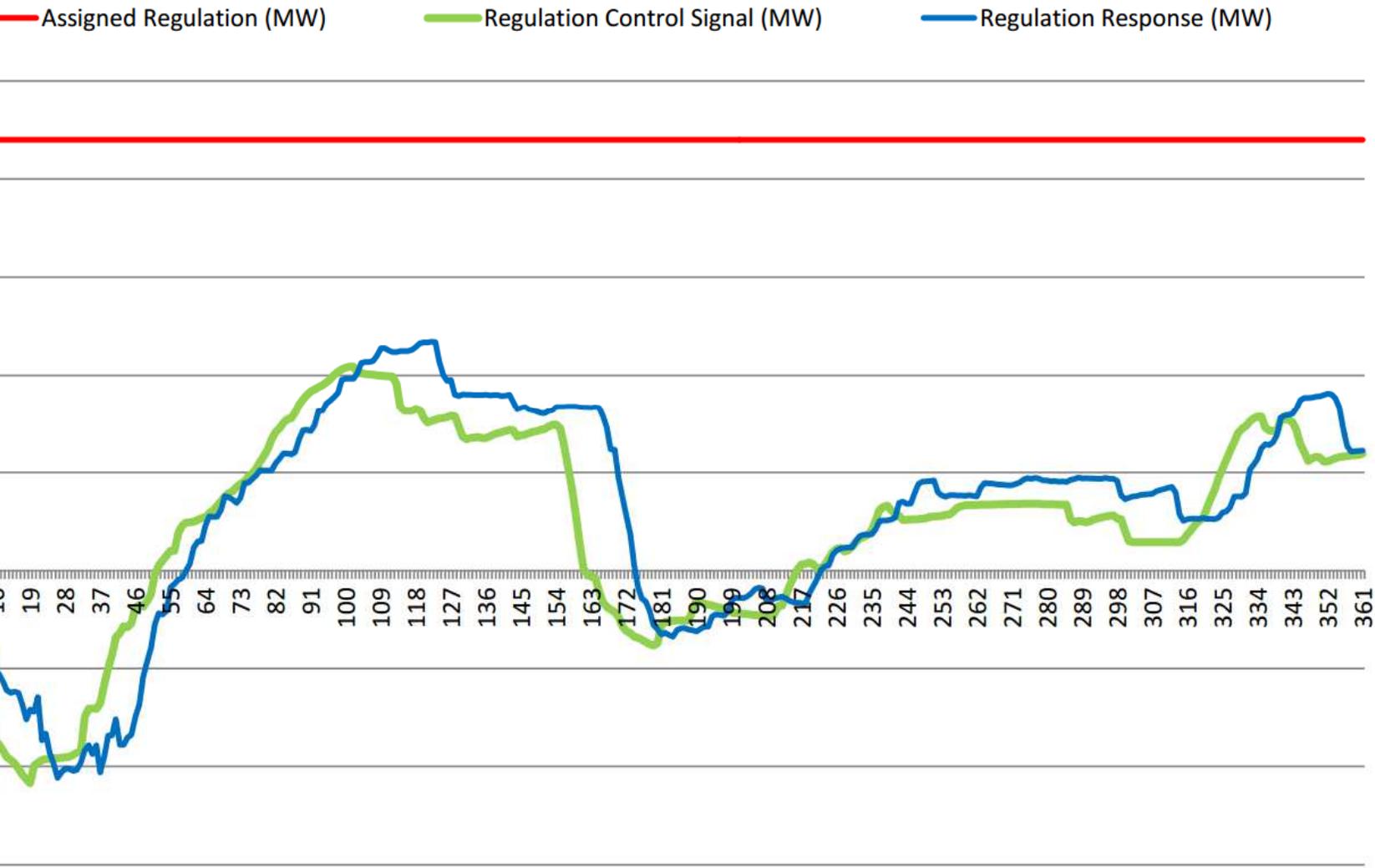
Accuracy – the correlation or degree of relationship between control signal and regulating unit's response

Delay – the time delay between control signal and point of highest correlation (from A).

Precision – Difference between the areas under the curve for the control signal and the regulating unit's response

Composite Performance Score = $A [\text{Score}_C] + B [\text{Score}_D] + C [\text{Score}_P]$

- A, B, C are scalars from [0..1], total to 1
- Produces a weighted average of component scores



Accuracy = 0.95

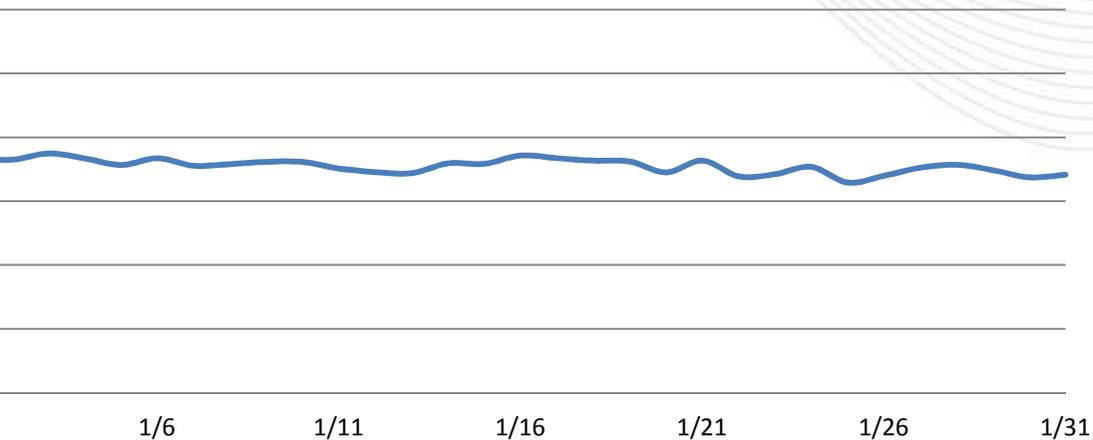
Delay = 0.66

Precision = 0.74

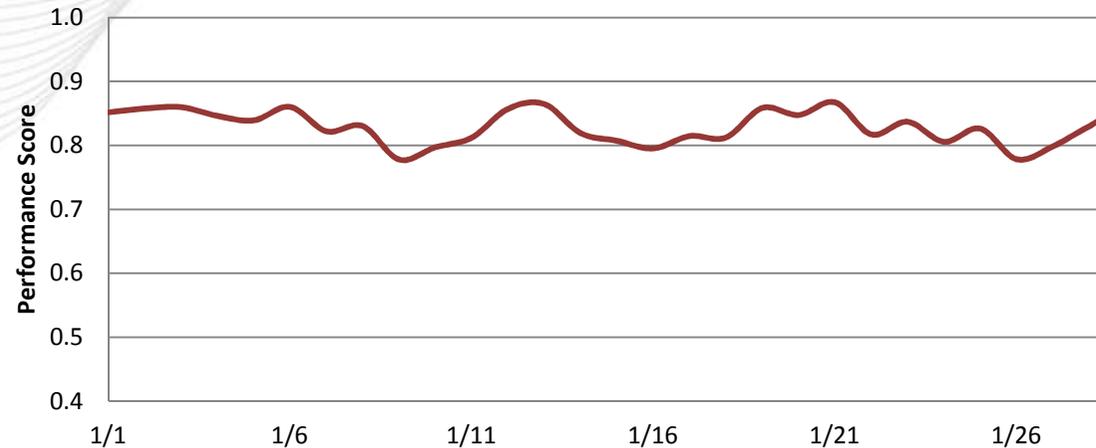
Total Score = 0.78

Average Performance Scores by Resource Type (Jan '15)

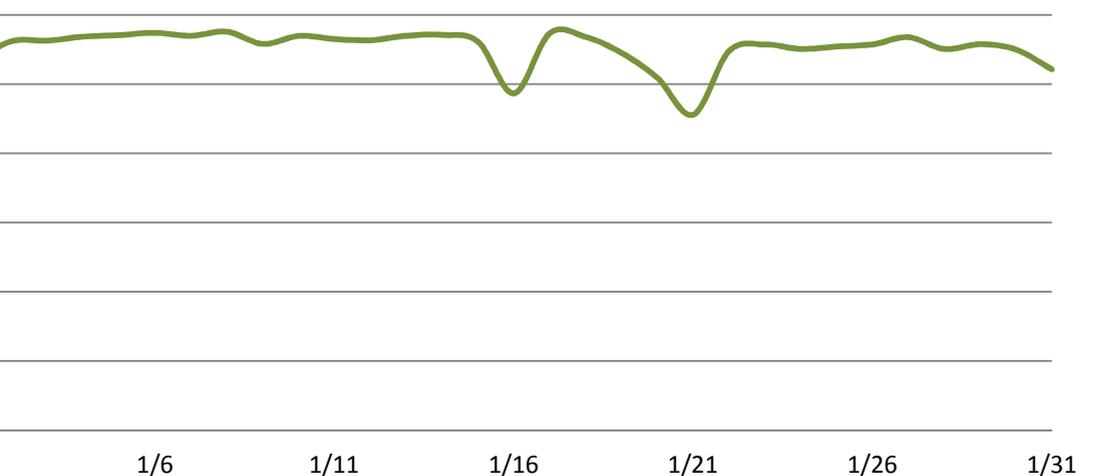
Steam



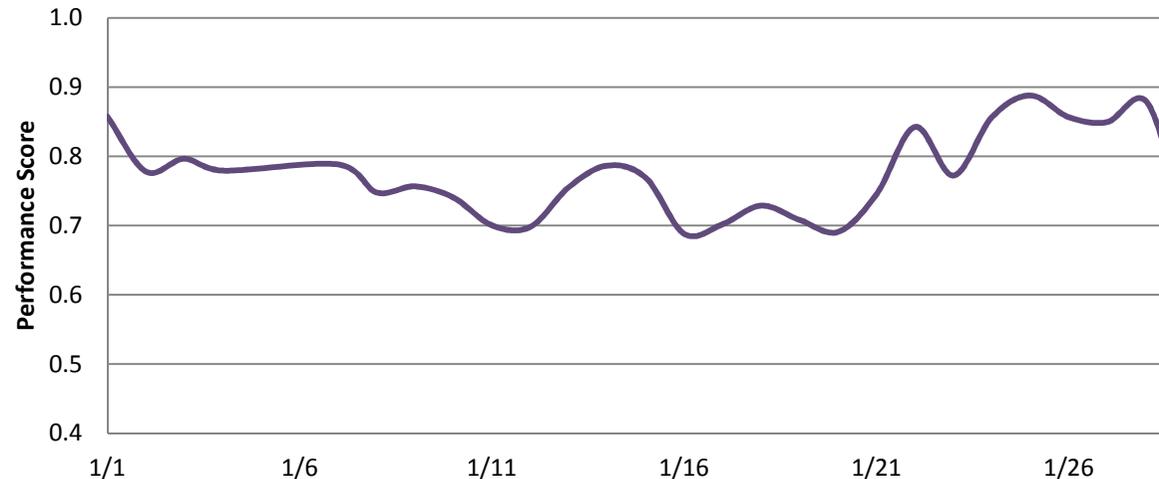
Hydro



Battery



Demand-side Resources

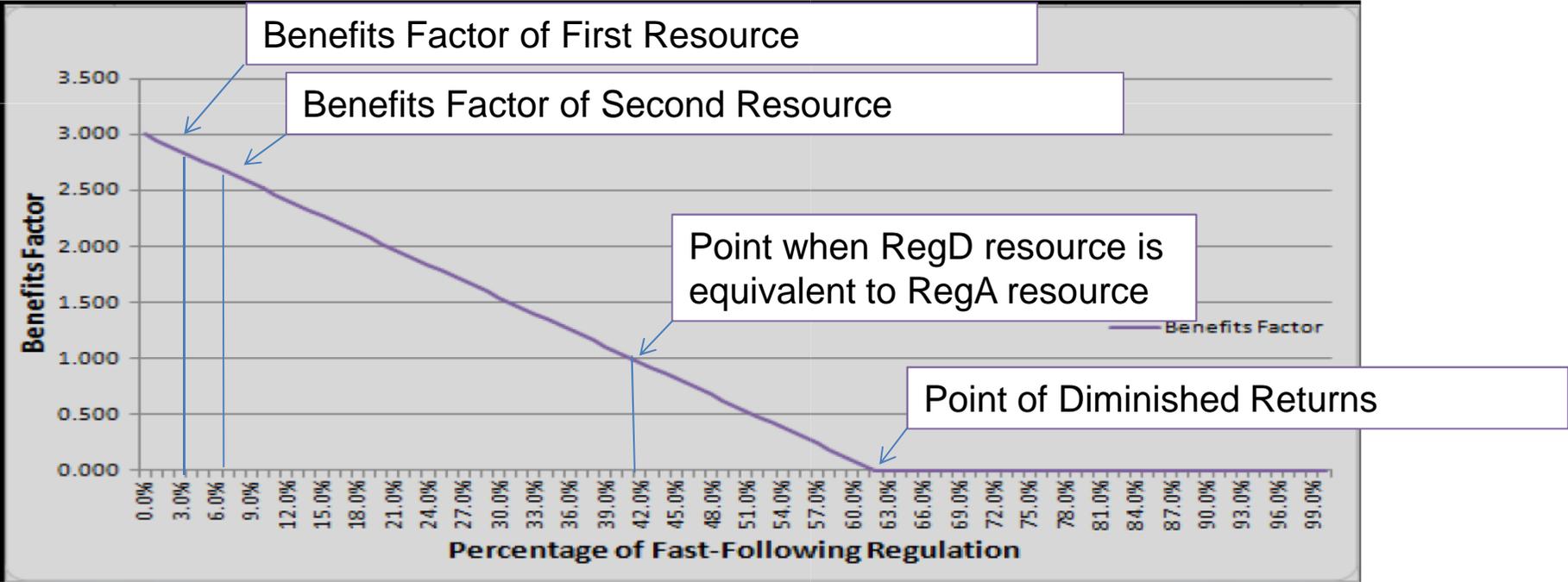


1/6 1/11 1/16 1/21 1/26 1/31

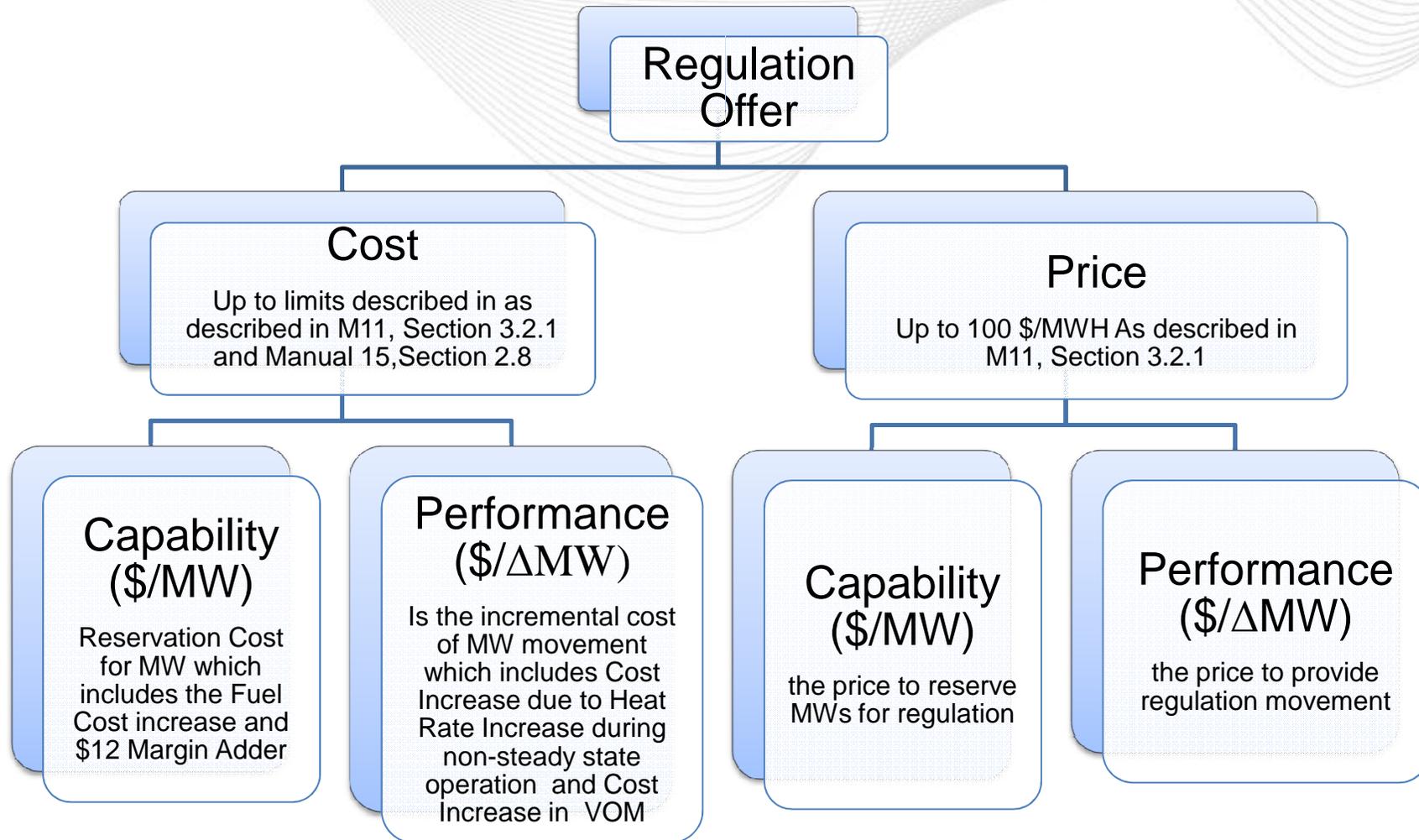
1/1 1/6 1/11 1/16 1/21 1/26

4. EFFECTIVE MEGAWATTS (THE BENEFITS FACTOR)

Benefits factor provides a sliding scale that makes dynamic resources more desirable until the optimal resource mix of dynamic and traditional resources is reached.



5. TWO PART OFFER, TWO PART SETTLEMENT - EFFECTED BY 1-4



- The \$/ΔMW will be multiplied by the ratio of ΔMW/MW for the signal that resource follows to convert to (\$/MW)

The Capability Offer is adjusted as follows:

Resource owner's Offer for reserving MW's

Qualified Regulation MW's

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

Benefits factor translates a Dynamic resource's MWs into traditional MWs to estimate Effective MWs. For Traditional resources, this value is "1".

Average of last 100 hours of performance scores

The Performance Offer is adjusted as follows:

Resource owner's Offer for MW's movement

30 day average of historical mileage

Qualified Regulatory MW's

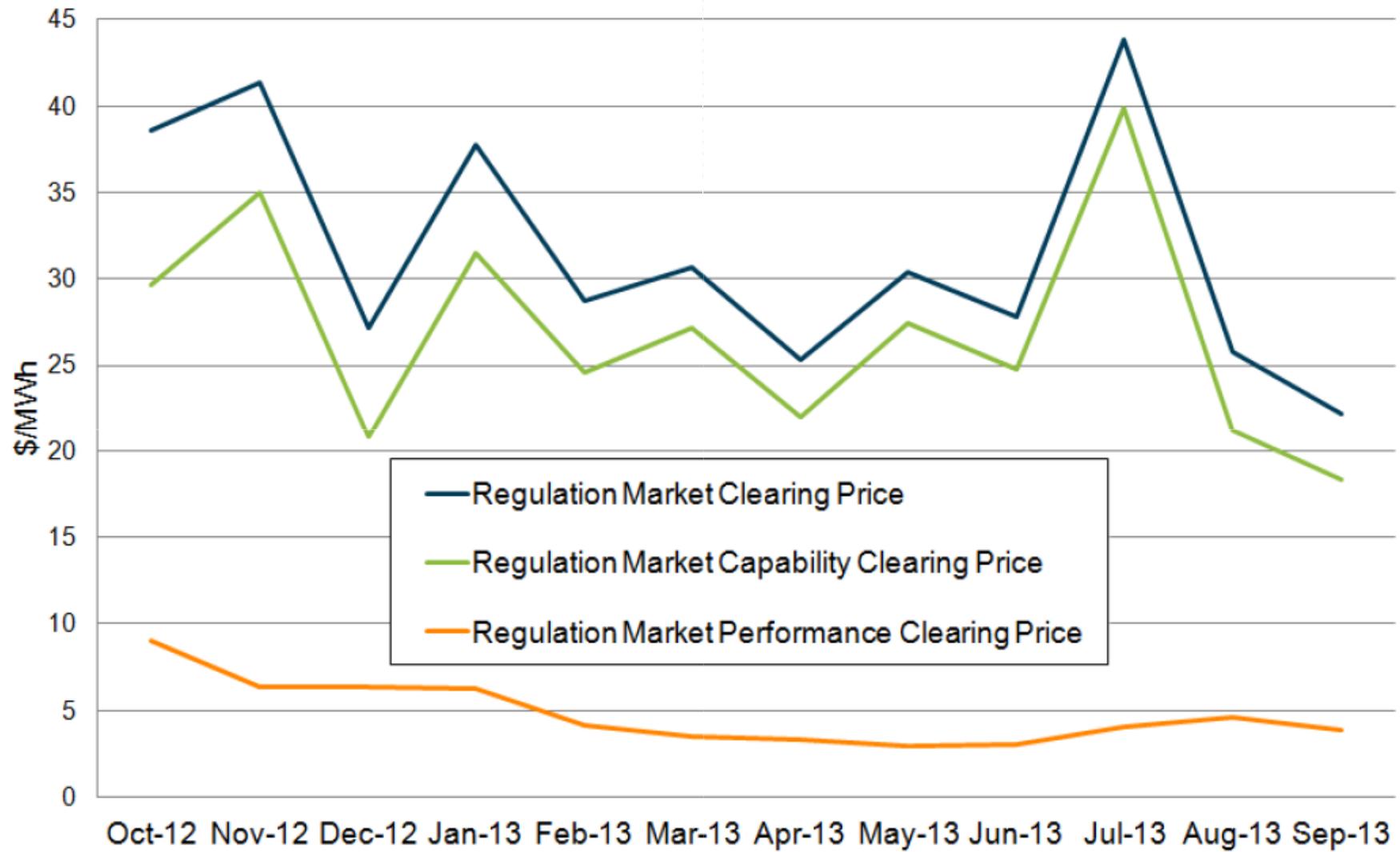
Adjusted Performance Cost (\$)

$$= \frac{\left(\text{Performance Offer } (\$/\Delta MW) \right) * \left(\text{Mileage ratio of Offered Resource Signal Type } (\Delta MW / MW) \right)}{\left(\text{Benefits Factor of Offered Resource} \right) * \left(\text{Historic Performance Score} \right)} * \left(\text{Capability } (MW) \right)$$

Benefits factor translates a Dynamic resource's MWs into traditional MWs to estimate Effective MWs. For Traditional resources, this value is "1".

Average of last 100 hours of performance scores

1 YEAR+ -- RESULTS



Milford Control Center: Solar + Storage





Laurel Mountain, West Virginia (AES Energy Storage)

Largest Li-ion battery in the world

32 MW, 8 MWh

Provides fast-response Frequency Regulation in PJM's Wholesale Markets



Ecoul and Deka Ultrabattery ®

3 MW (<3 MWh)

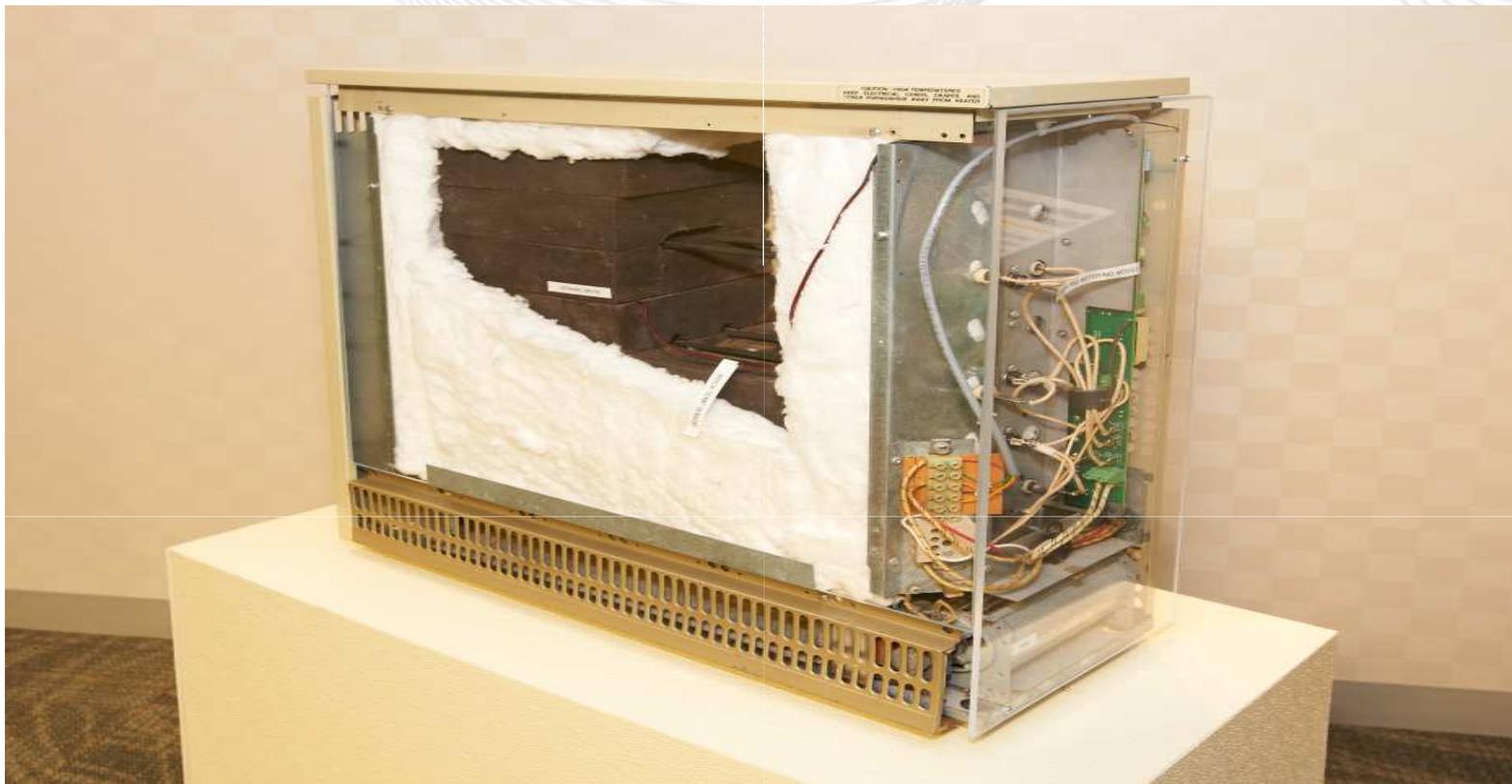
Regulation Service, *from behind the meter*



Viridity Energy and Axion PowerCube™

500 kW

Regulation Service, *from behind the meter*



VCharge, Inc

4-5 kW (aggregated to >100 kW)

Regulation Service, *from behind the meter at multiple locations*



credit: Tim Shaffer for The New York Times