

Performance-based Regulation Compensation Improve PJM Market Efficiency

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FERC Order 755

■ Frequency Regulation Compensation in the Organized Wholesale Power Markets

- On October 20, 2011, FERC issues Order 755.
 - The Order required RTOs and ISOs to compensate frequency regulation resources based on the actual service provided, including:
 - a capacity payment that includes the marginal unit's opportunity costs and
 - a payment for performance that reflects the quantity of frequency regulation service provided by a resource when the resource is accurately following the dispatch signal.
 - The order requires that the performance compensation must be based on:
 - delay time,
 - dispatch accuracy, and
 - Mileage
- in response to system operator's dispatch signal.

Background and Benefits of FERC Order 755

- Prior to Order 755, regulation compensation practices of RTOs /ISOs only considered capacity payment, performance for frequency control was not considered in regulation market clearing and settlement ;
- Drawbacks of market structure:
 - no sufficient incentive for regulation resources to quickly and accurately respond to frequency control signal;
 - operational inefficiency caused by increased regulation requirement to make sure system can meet reliability criteria set by NERC.
- A PNNL study concluded that fast-ramping energy storage resources could be as much as 17 times more effective than conventional ramp-limited regulation resources. The Order intends to provide efficient incentive for investment in well-performing regulation resources.
- Due to increasing penetration of intermittent resources and demand resources, more regulation capabilities are needed to effectively manage the rapid variation of supply and demand in power systems. PBR development also aligns with increased need for regulation.

PERFORMANCE BASED REGULATION (PBR) INTEGRATION INTO PJM

- Prior to and following this Order, PJM had engaged stakeholders through the Regulation Performance Senior Task Force (RPSTF) to redesign the Regulation Market.
- PBR model has been operating in PJM production environment since October 1, 2012.
- PJM Real-Time Markets and Business Processes
 - ❑ **AS market (ASO): PBR Integrated**
 - Kicks off one hour ahead of target time;
 - clearing Reg, synchronized reserve (SR) and primary reserve (PR);
 - ❑ Intermediate-Time Security-Constrained Economic Dispatch (IT SCED);
 - kicks off 15 minutes ahead of target time;
 - performs an incremental commitment recommendation of fast-start resources for energy, SR and PR.
 - ❑ Real-Time Security-Constrained Economic Dispatch (RT SCED);
 - kicks off 15 minutes ahead of target time;
 - dispatch energy and assign resources for the remaining SR and PR requirements;
 - sends out dispatch signals to market participants.
 - ❑ **Locational Price Calculator (LPC) PBR Integrated**
 - provides energy LMP and AS Market Clearing Prices (MCP) for Reg, SR and PR.

- **Reg Signal Types**

- RegA:

- ✓ is a low pass filter of PJM Area Control Error (ACE) sent to traditional regulating resources, such as steam and combined cycle units.
 - ✓ RegA resources have unlimited duration.

- RegD:

- ✓ is a high pass filter of PJM ACE sent to dynamic or fast response regulating resources, such as batteries and flywheels.
 - ✓ lack the ability to remain at that level for an extended time

- **Two-part Regulation Offer**

- a capability offer (RegA and/or RegD) and;
 - a performance offer (RegA and/or RegD).

For a resource qualified for both RegA and RegD offers, i.e., dual-following resources, two offers may have different MW values and different offer prices.

For a dual-following resource, offer shall be cleared exclusively with the least system operation cost.

- **Performance Score (PScore)**

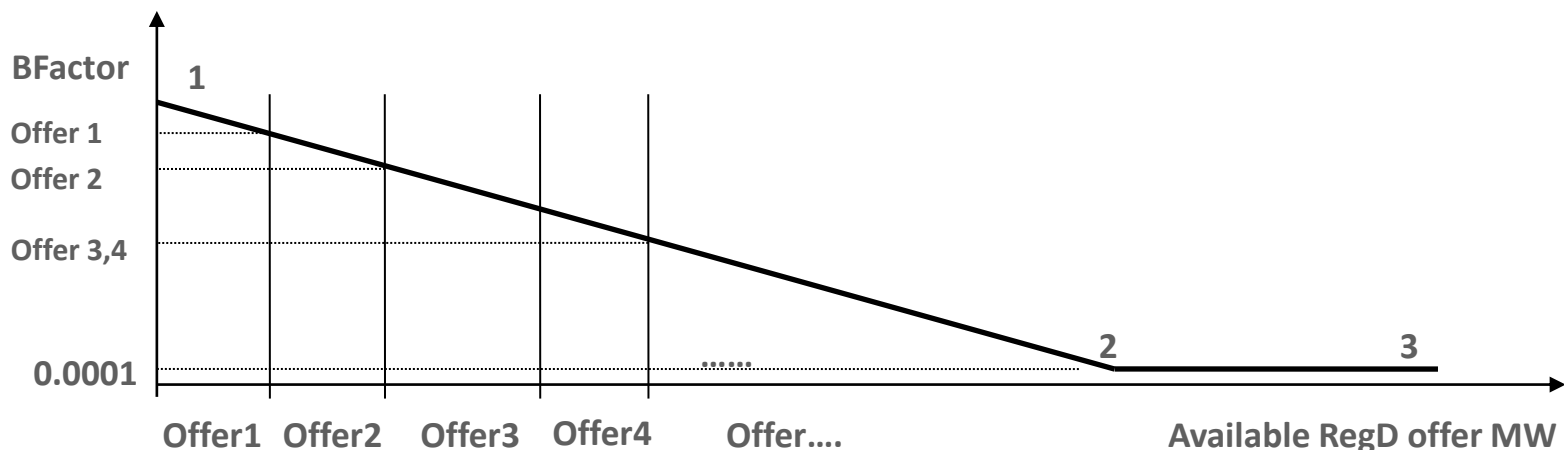
- Calculated by Performance Score Calculation Engine(PSCE) for Reg qualified resources;
- Based on timeliness, accuracy and precision of response to regulation signal historically;
- Value between 0 and 1;

- **Mileage Ratio**

- Calculated by PSCE, represents mileage per MW regulation offer deployment for frequency control;
- Typical ratios for RegA are 3-6 Δ MW/MW of capability; RegD, 10-16 Δ MW/MW;
- is used to normalize the performance between RegA and RegD signal types.

- **Benefit Factor (Bfactor)**

- Enables the market to translate fast moving resource's regulation MWs into traditional MWs or effective MWs. Only apply to RegD offers.
- The impact of BFactor is an increase in the likelihood of fast-following resources getting cleared, up to the point of diminishing returns, i.e., point 2. The low value after point 2 is to prevent the market from clearing more RegD offers than RegD resources can provide in practical systems.
- Bfactor reflects an operational relationship between the regulating resource mix and how the regulation requirement is satisfied;



- **Adjustment to Regulation Offer Prices**

- $$\text{Adjusted Reg Cap Offer Price} (\$/MWh) = \frac{\text{Cap offer Price} (\$/MWh)}{BFactor \times PScore}$$

- $$\text{Adjusted Reg Perf Offer price} (\$/MWh) = \frac{\text{Perf offer Price} (\$/\Delta MWh) \times \text{Mileage Ratio} (\Delta MW / MW)}{BFactor \times PScore}$$

- $$\text{Total Reg Offer Price} =$$

- $$\text{Adjusted Reg Cap Offer price} + \text{Adjusted Reg Perf Offer price}$$

- Adjustment by PScore will make poor-performing resources appear more costly;
- Mileage ratio makes the adjusted performance offer price can reflect resource movement in response to frequency control signal;
- BFactor is used to make faster units appear more economically attractive to the market up to the point they are beneficial.

- **Adjustment to Regulation Offer MW**

- $$\text{Effective Reg Offer MW} = BFactor \times PScore \times \text{Bid_in Reg Offer MW}$$

- **Objective Costs Term for Regulation Clearing**

$$\begin{aligned} \text{Total costs of Reg clearing} = \\ \text{RegA Adjusted Offer Price} \times \text{RegA product clearing MW} + \\ \text{RegD Adjusted Offer Price} \times \text{RegD product clearing MW} \end{aligned}$$

- **System Level Regulation Requirement Constraint**

$$\begin{aligned} \text{Total Reg service clearing} \geq \text{system Reg requirement} \\ \text{Where} \end{aligned}$$

$$\begin{aligned} \text{Total Reg service clearing} \\ = \sum (\text{Reg product clearing MW} \times \text{BFactor} \times \text{PScore}) \end{aligned}$$

- **Resource Level Regulation Product Clearing**

$$\begin{aligned} \text{Reg Product clearing MW} \leq \text{Bid in Reg Offer MW} \\ \text{Dispatch MW} + \text{RegProduct clearing MW} \leq \text{RegMax} \\ \text{Dispatch MW} - \text{RegProduct clearing MW} \geq \text{RegMin} \end{aligned}$$

- **RMCP For Reg Market Settlement**

$$RMCP = \text{Max}(\text{cleared reg resources}, \text{Total Reg Offer Price} + \text{Reg LOC})$$

Where

$$\text{Reg LOC} = \frac{\text{LMP} - \text{Energy Marginal Price}}{\text{BFactor} \times \text{PScore}}$$

- **RMCP includes:**

- Capability Clearing Price (CCP) and,
- Performance Clearing Price (PCP).

$$PCP = \text{Max}(\text{cleared reg resources}, \text{Adjusted Reg Perf Offer Price})$$

$$CCP = RMCP - PCP$$

CCP and PCP are for information only.

PBR IMPACTS ON PJM MARKET

- PERFORMANCE SCORE

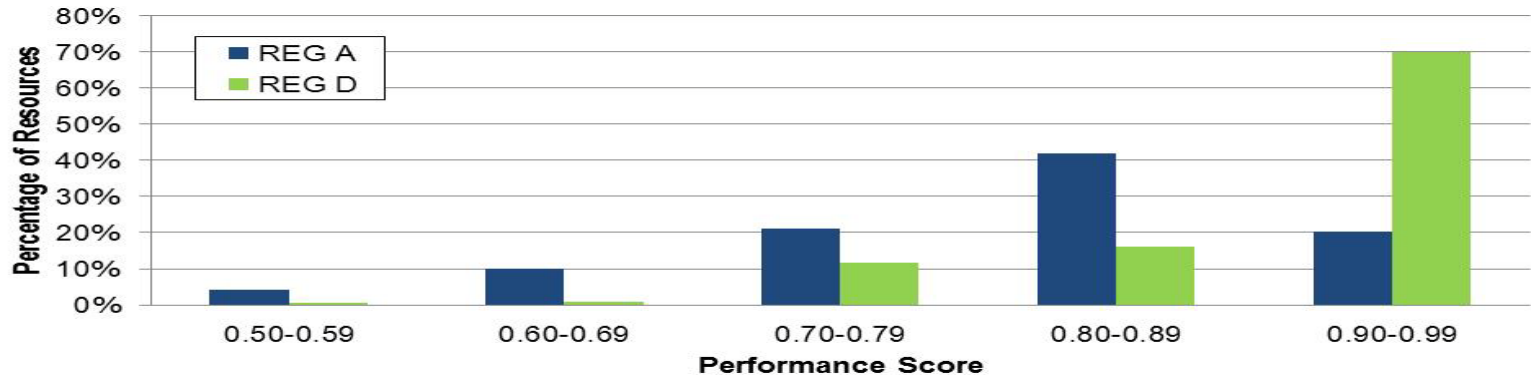


Figure 1. Regulation Performance Scores First Year Analysis

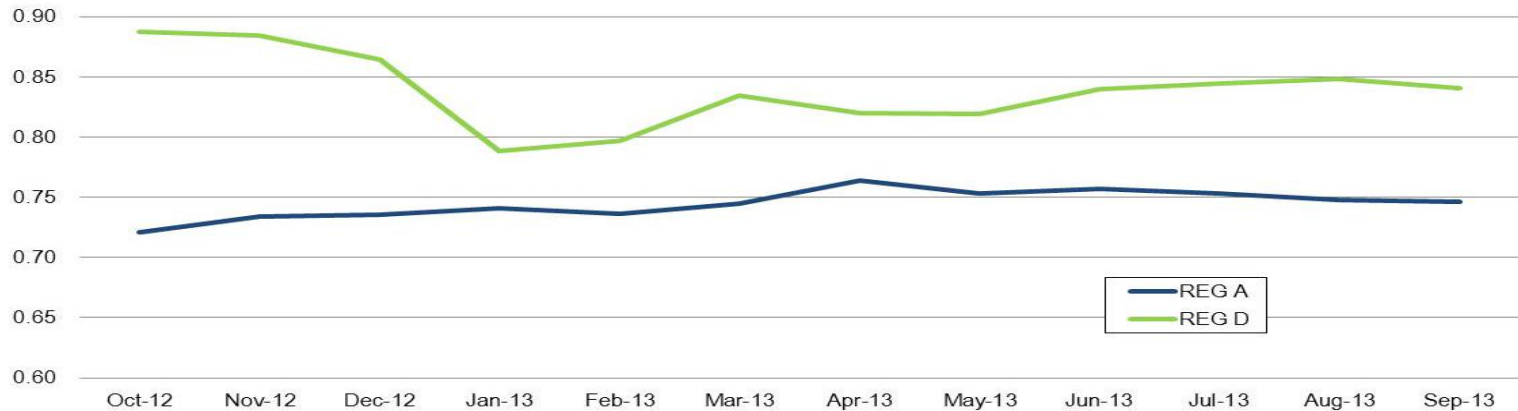


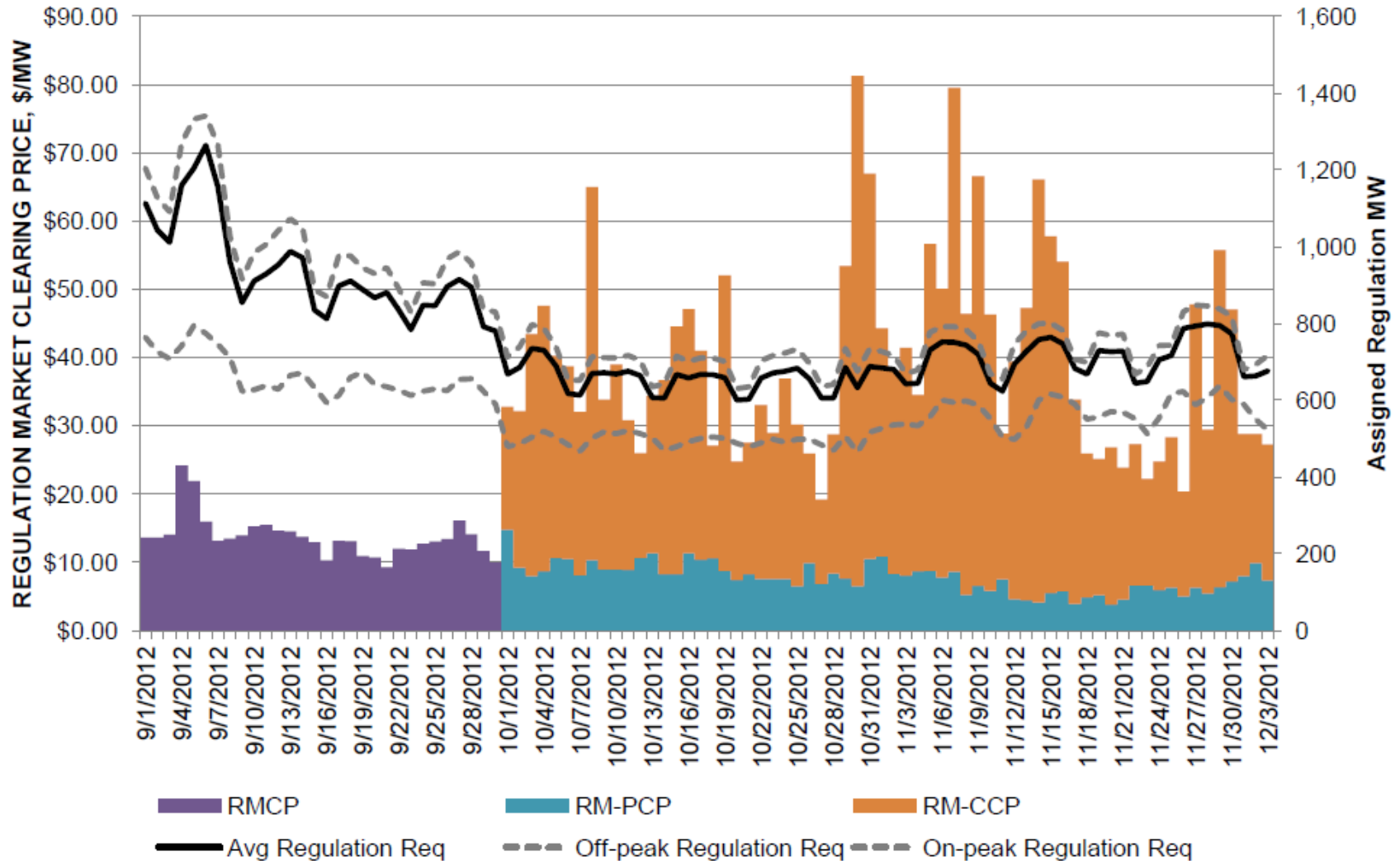
Figure 2 – Average Performance Scores

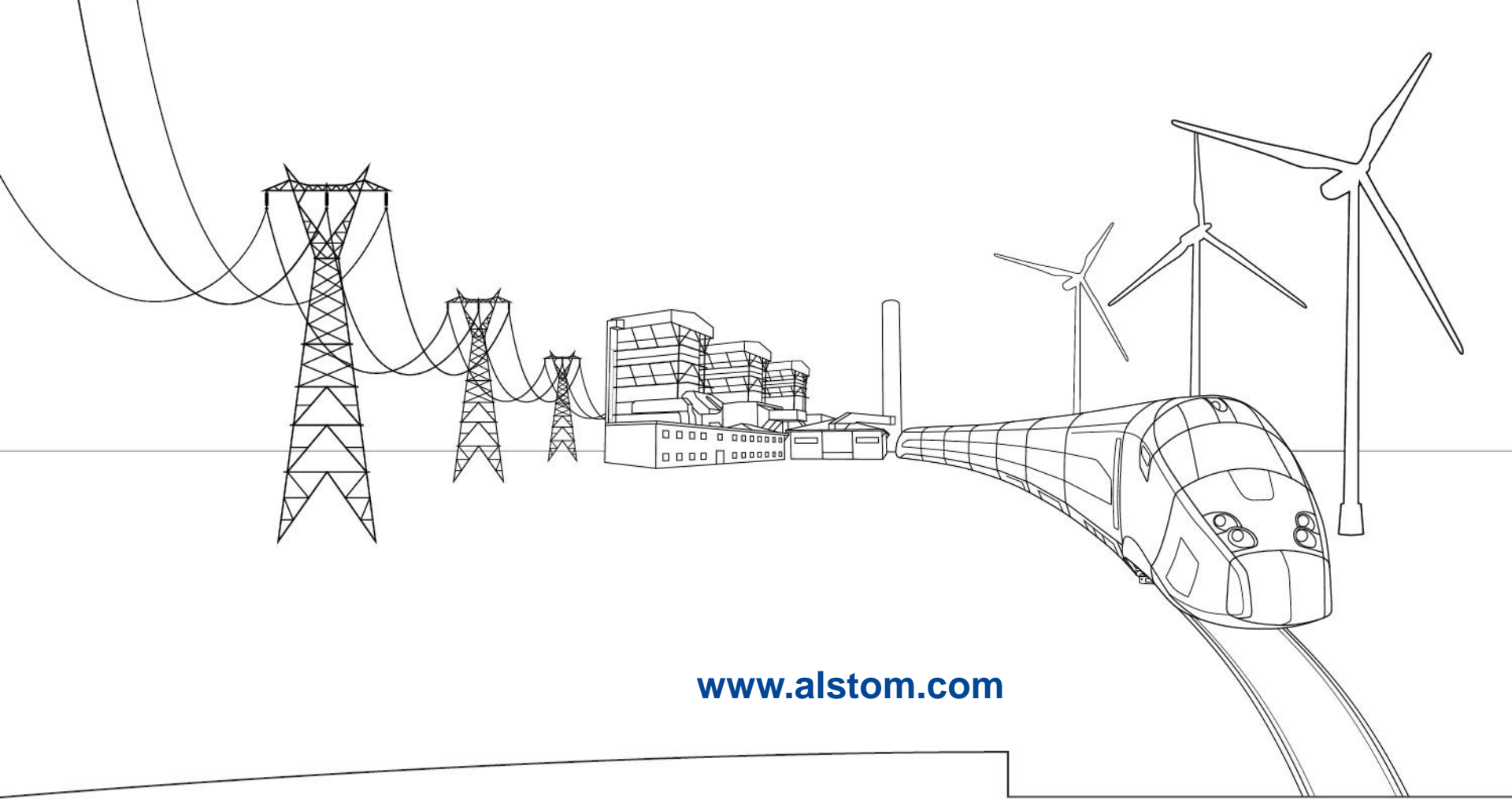
- Since October 1, 2012, the number of fast moving resources following the RegD signal and participating in the Regulation market has grown from six to nineteen.
- In total, they represent a combined regulating capability of approximately 490 MWs though their impact fluctuates based on effective MW evaluation.

- Since October 1, 2012, PJM has lowered the Regulation Requirement on several occasions.
 - In October 2012, the requirement was reduced from 1.0 to 0.78 percent of the peak/valley load forecast.
 - In November 2012, it was further reduced from 0.78 to 0.74 percent.
 - In December 2012, the Regulation Requirement was lowered to its current value of 0.70 percent of the peak/valley load.

PBR IMPACTS ON PJM MARKET

- REGULATION MCP





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