# A Brief History of Regulation Signals at PJM

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# History

- Zonal Regulation Signals A & B
- **Spinning & Regulation Market** (SPREGO)
- Market Area Regulation Signal A
- Ancillary Service Area Regulation Signal A
- Dynamic Regulation Signal D
- RTO Regulation Signal A
- **Performance Based Regulation** Market (ASO)

# Vertical Utility Regulation

- In the 1990s, Regulation was a Cost of Service managed Zonally by LSEs (by Transmission Zone)
  - Load zones had an obligation to purchase regulation at a requirement equal to 1.1% of on/off peak load forecast MW
  - Generation provides the service at cost, based on lost opportunity (hydro) or heat rate degradation (steam) and variable costs
  - Utilities managed fleet-based regulation from their own resource pools, or created bilateral contracts to exchange MW between zones

# Regulation Signals A & B

- In 1998, the Siemens EMS (C1) generated two signal shapes
  - Regulation A as a function of **total ACE**
    - Lower gain with longer time constant (slow convergence)
    - Tuned for slower ramping Steam generation
  - Regulation B as a function of **total ACE**
    - Higher gain with shorter time constant (fast convergence)
    - Tuned for faster ramping Hydro generation
    - CTs were too uneconomical to provide regulation service
  - “Islanding” model supported regulation signals on control zones

# Ancillary Service Market

- In 2001, PJM implemented the Ancillary Service Market
  - Co-optimized Spinning & Regulation
  - Single regulation product meant all regulation must be offered and cleared as substitutable MW
    - Regulation B was depreciated, and merged into Regulation A
- Regulating resources bid into the market to meet requirement
  - Self-scheduled resources meet LSE obligations at zero cost
  - Pool-scheduled resources are cleared by PJM in least-cost merit order to meet remaining requirement

# PJM and the concept of RTO

- In 2002, AP joined PJM, and became PJM RTO
  - MidAtlantic followed MAAC rules, AP followed ECAR rules
  - PJM managed separate Control Zone Requirements, with non-transferrable resources
  - Regulation A as a function of **control zone pseudo-ACE**
    - Market area ties (actual) vs generation transfer (schedule), plus share of frequency bias, mathematically equivalent to RTO ACE
- In 2004 & 2005, the concept extended to ComEd, AEP, Dayton, Duquesne and Dominion market integration areas
  - RTO was split into two Regulation Zones: West & MidAtl

# Merging the Markets

- In Aug 2005, the Regulation Markets merged into a single RTO Regulation Zone, with requirement of 1% of on/off peak load forecast
  - All resources in the RTO were interchangeable
  - Regulation A as a function of **control zone pseudo-ACE**

- By end of 2006, Demand Response became eligible to provide ancillary services, but no activity in the market at this time

# Dawn of Energy Storage

- In 2009, PJM was approached by AES to collaborate on a new bulk electric energy storage system, a. k. a. the battery
  - Began feeding “Regulation B”–like signal to the device, with dubious results . . .
  - PJM uses regulation to absorb large changes in ACE, and does not see a problem with “utilizing” the service by sending full raises and lowers
  - Extended periods of full raise and lower lead to over-charge or depletion of batteries following the normal signal, so . . .

# Regulation D, for Dynamic

- Regulation D was developed specifically for energy storage devices with limited storage capabilities
  - High gain and short time constants meant that the signal converged very fast on ACE correcting signal, but . . .
  - Energy Neutrality integration term meant that the signal will converge back to zero after a period of time, targeting 5 minutes
    - 95% of the time, the controller converges in < 15 minutes
- Designed so that batteries can provide more signal correcting "work" (MW) in short-term with less storage needs (MWh)
  - Lithium Ion batteries typically operate to a 4:1 MW : MWh ratio

# FERC Order 755

- By 2011, PJM had resources following different signal shapes, with varying performance, all clearing equivalently in the market
  - PJM forms RPSTF to investigate market rule changes
  - Commissions KEMA study to analyze trade-offs for A/D signals

- FERC Order 755, Performance Based Regulation, changes this
  - Measure performance with a standard metric
  - Rank the clearing based on performance and benefit (eff. MW)
  - Shortage Pricing implementations co-optimizes price with LOC

# Back to RTO Regulation Signal

- In Apr 2012, during Performance Based Regulation (PBR) development, zonal signals were no longer needed
  - Affected ability to aggregate resources across zones
  - Mileage concept based on movement of regulation signal
  - Regulation Signal A as a function of **total ACE**

- On Oct 1, 2012, PJM implemented PBR and began reducing the regulation requirement
  - 0.78% of on/off peak load forecast, then 0.73%, then 0.7% by Dec
  - In Nov 2013, implemented fixed on/off peak requirements

# Benefit Factor Equates Regulation Signals

- Performance Based Regulation had some caveats . . .
  - Unit-specific Benefit Factor used for Clearing
  - Unit-specific Benefit Factor used for Pricing
  - Mileage Ratio used for Settlements

- Benefit Factor Curve was derived from KEMA analysis in 2011, using seasonal-representative operating weeks
  - Implemented as a fixed curve & not revisited since 2012

# Regulation D in Operations

- In 2014, Hydroelectric began to qualify for Regulation D
  - Always had been able to provide more than Regulation A
  - Regulation D payment structure incentivizes participation

- By Summer 2014, PJM Dispatch began noticing deviations
  - Regulation D signal moving to zero when ACE deviation persists

- By Fall 2014, PJM Real-time Market Operations observed that in some hours, more than 70% of the requirement was composed of Regulation D, well beyond the original benefit factor design

# Regulation in Operations

- How saturated is Regulation D (from Jun2014 - Jun2015 )?
  - 26.4% of hours have greater than 42% ratio Reg D / Requirement
  - 0.05% of hours have greater than 70% ratio Reg D / Requirement
- In those hours, if ACE is at extremes, Regulation D logic brings the signal back to zero, which goes against ACE correction

- Manual intervention by Dispatch to force signal to specific utilization % (typically back to full raise)
  - Forcing Regulation D to extreme depletes batteries, lowering scores