PJM Regulation Study

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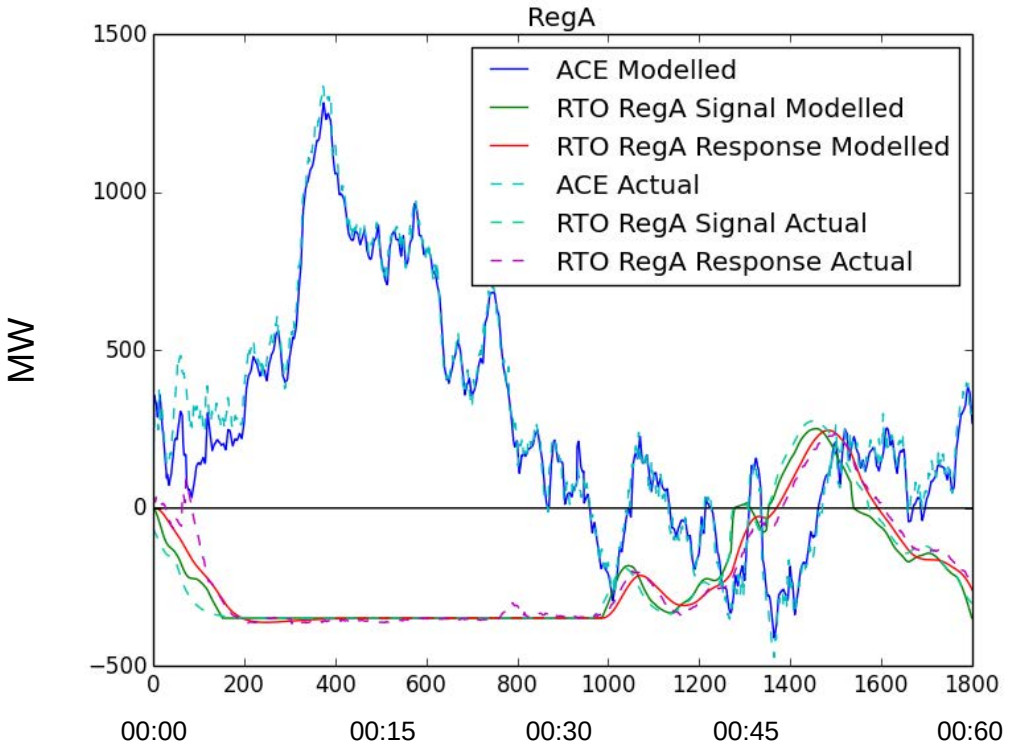
Agenda

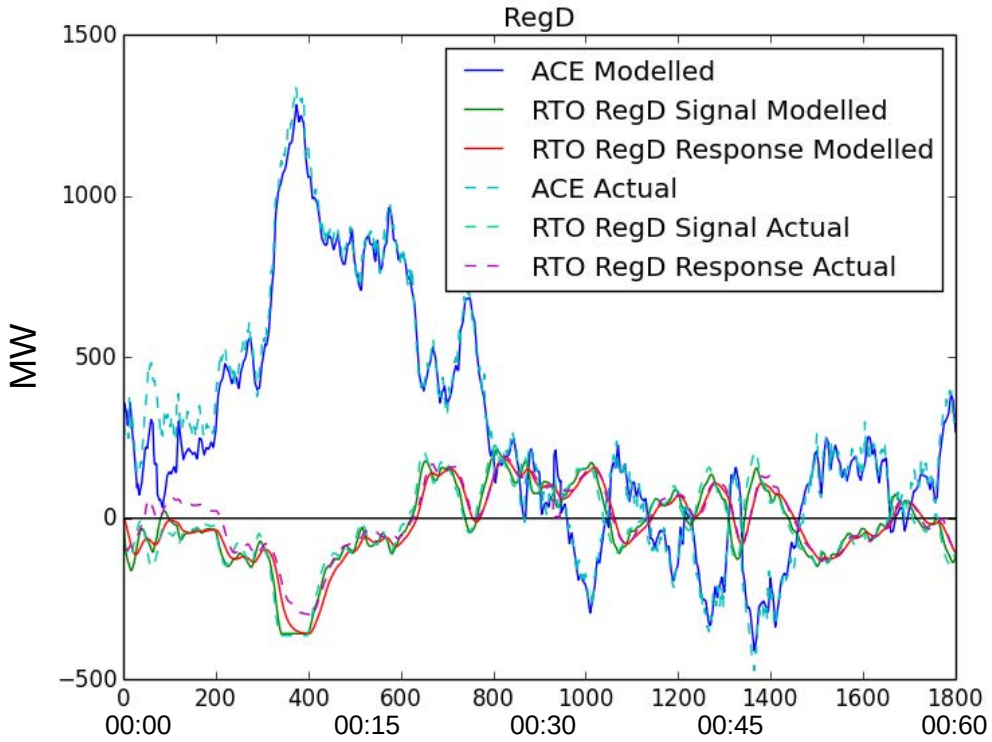
1. Study Creation
2. Benchmarking Simulations
3. Control Metric
4. Analysis
5. Future Studies

Study Creation

- Code from PJM's Automatic Generation Control (AGC)
  - Re-coded functionality in Python
  - Created additional variables to adjust control parameters
- Regulation D Signal
  - Uses a dynamic controller
    - This causes the signal to turn around if the regulation signal is held in one direction for an extended period of time (signal neutrality)
- Regulation Resource Responses
  - Based modelled response of regulation units off of an IEEE research paper
    - http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=1268066
  - Modelled response graded against actual response until low error achieved
  - Responses averaged for RegD and RegA resources to simplify model and maintain accurate results

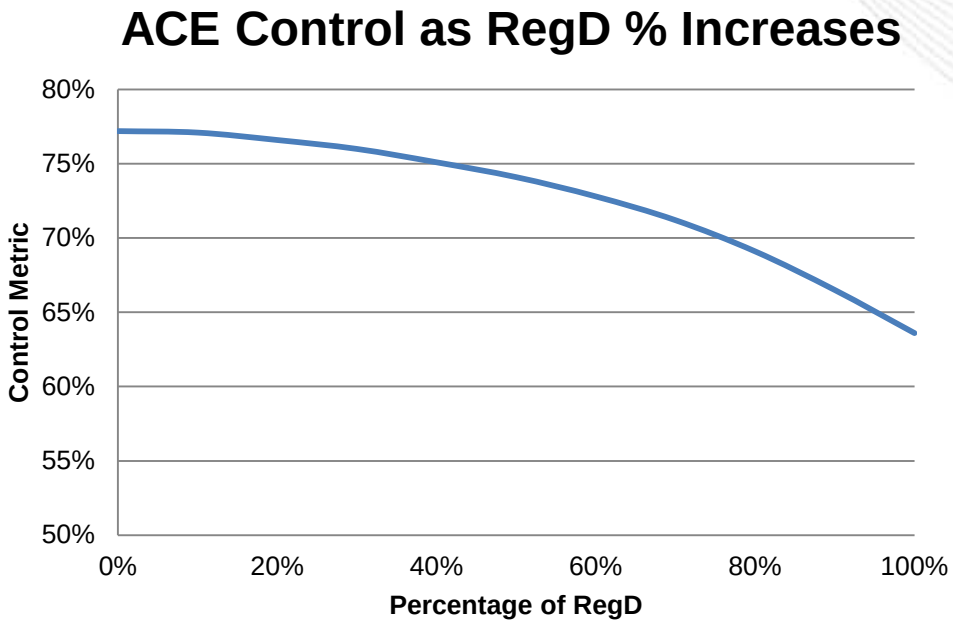
Operation Simulation of Market Analysis – Base Case

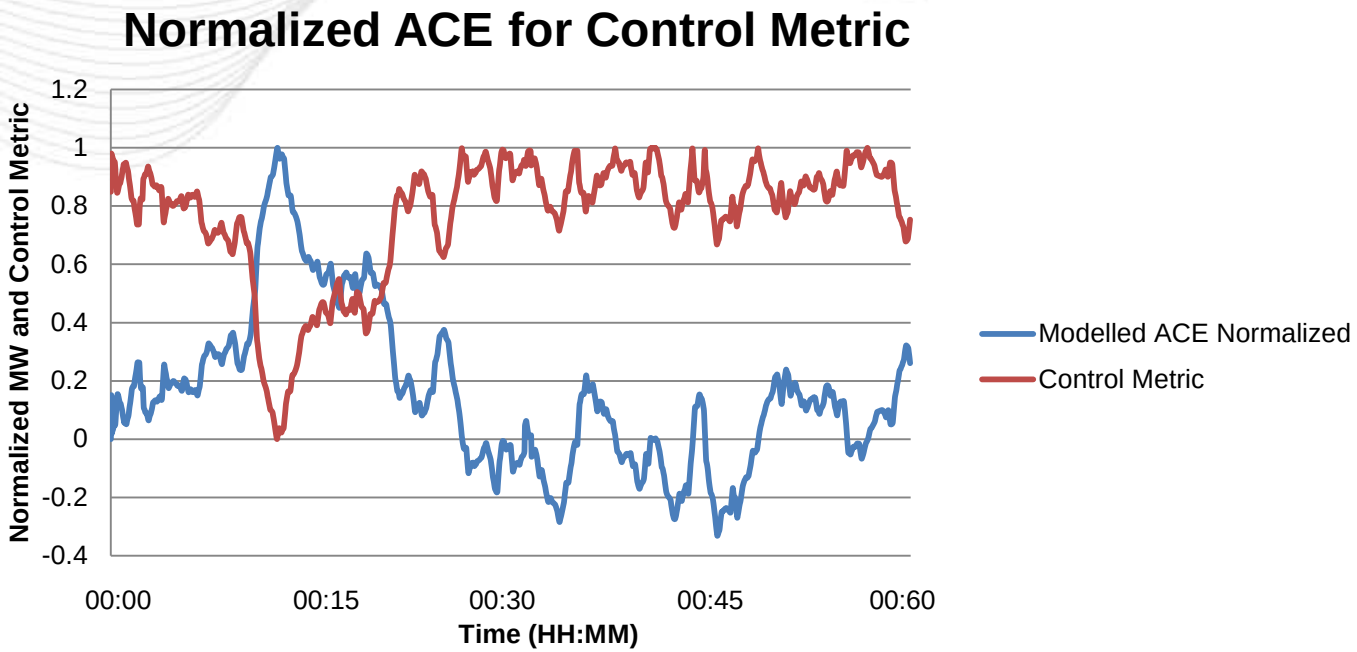




- June 02, 2015 HB13 EPT
- Less than 1% error with respect to calculated CPS1 score
- Modelled ACE very closely matches actual recorded ACE during hour
- Regulation resources simulated based on historical performance

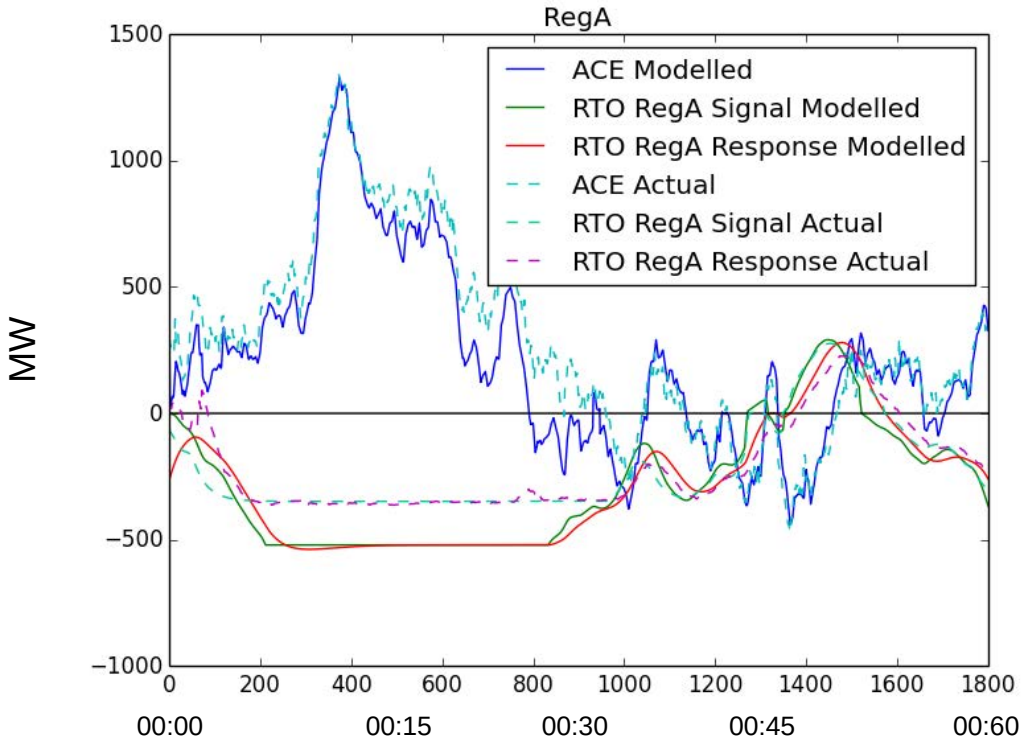
Operation Simulation – Control Metric

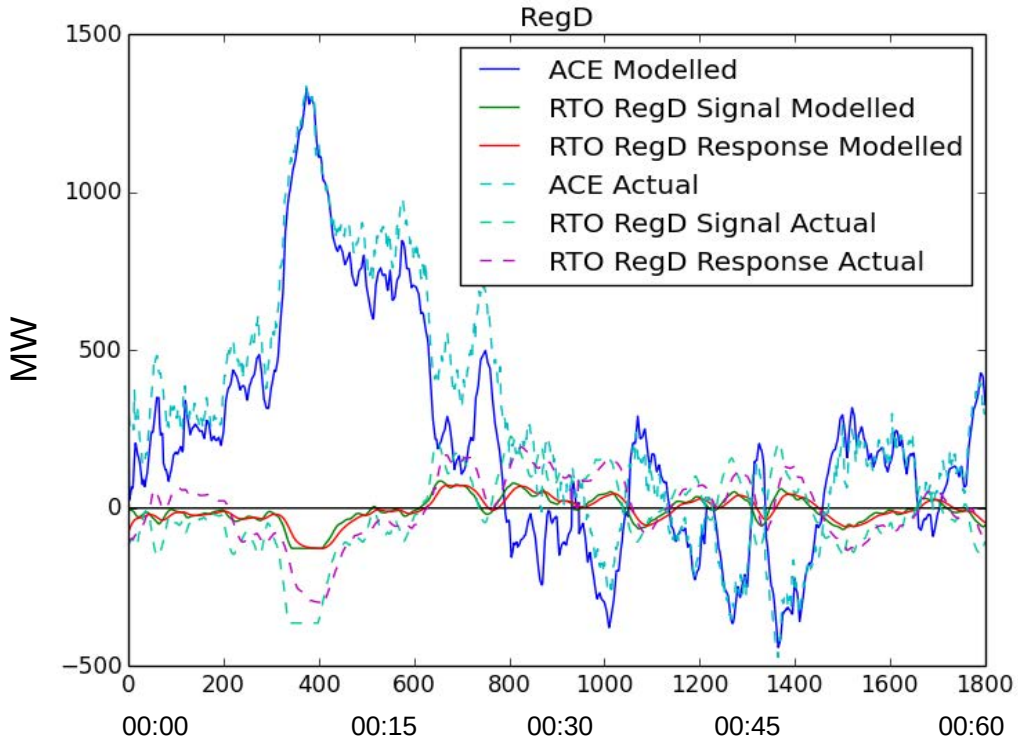




- Control Metric calculated based on June 02, 2015 HB13 EPT data
- Total regulation MW held constant at 700 raw MW while % of RegD changed from 0 to 100
- Higher Control Metric = Better Control (100% = ACE at 0)
- Control Metric purely based on amount of deviation of ACE from 0
  - CPS1 is partly based on frequency error which does not change in current simulation software

Operation Simulation of Market Analysis





- Control Metric Improvement from 74% to 76.7%
- Large increase in control during large ACE excursion
- Decrease in control when ACE is more neutral (second half of hour)

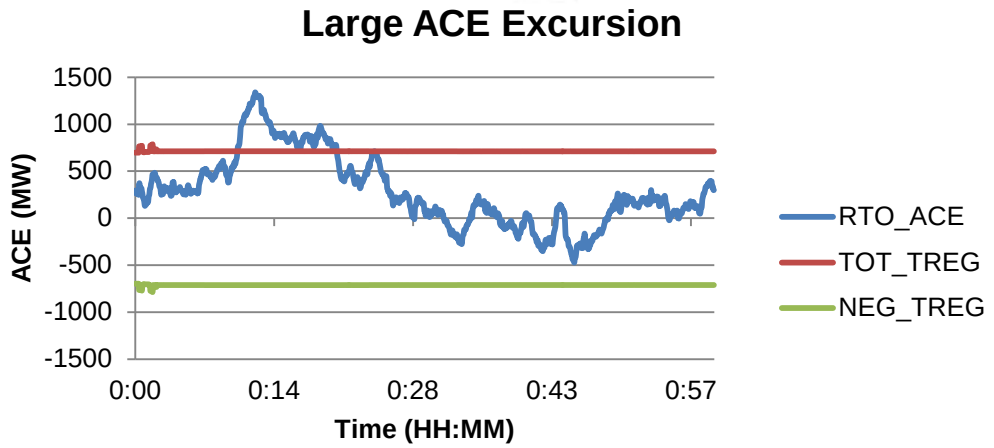
RegA = 521.0 Raw MW

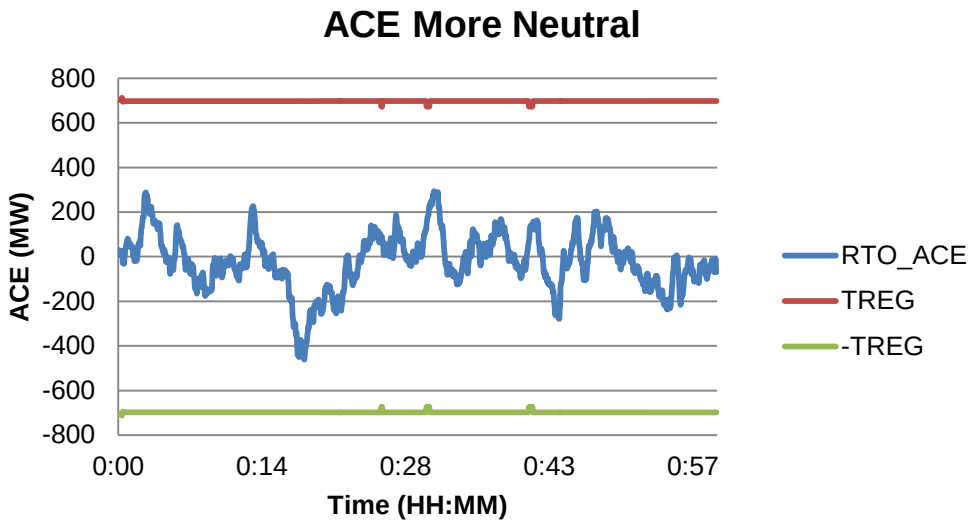
RegD = 127.3 Raw MW

RegD % = 19.6%

Analysis of Regulation D Impact

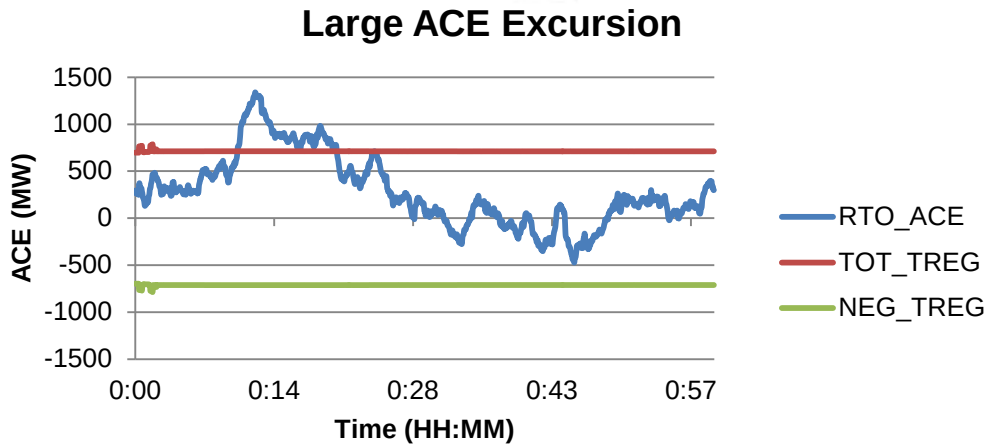
- Investigated various regulation hours
  - Hours with large ACE excursion
  - Hours where ACE is neutral
- Run hours through Python simulation tool
  - Vary Regulation D from 0% to 100% and observe Control Metric
- Determine optimal mix for reliable system control
  - Needed for interim solution

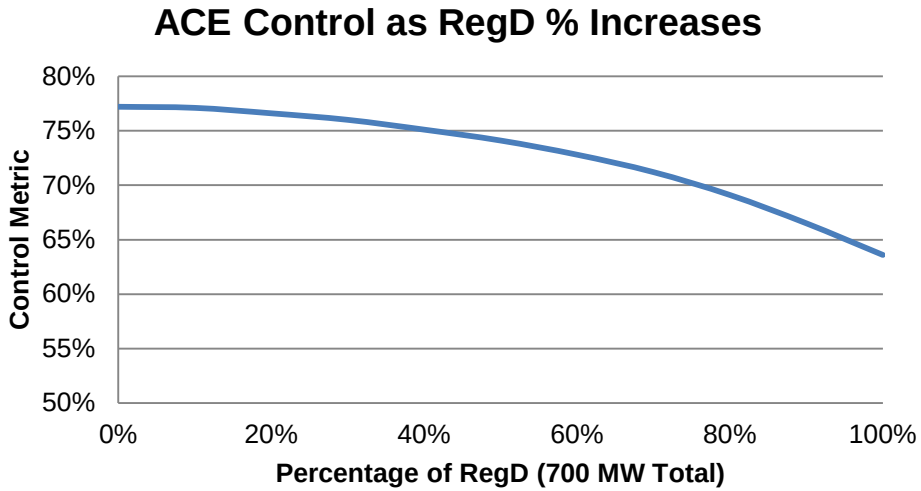




Large ACE Excursion

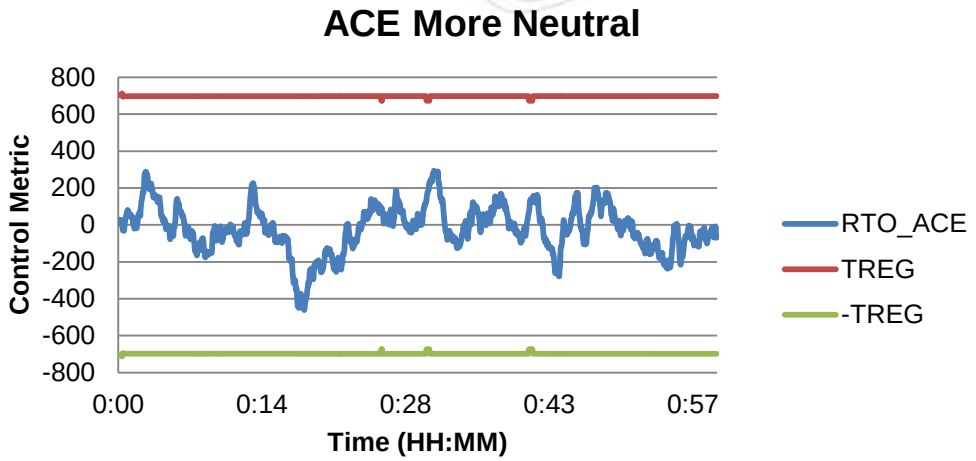
- During large ACE excursion, less RegD needed for optimal control
  - After approximately 20% of RegD we see diminishing returns as more RegA is swapped for RegD resources
- Why is this true?
  - During ACE excursions greater than 15 minutes, RegD signal will turn against ACE control
  - With adjustment to RegD signal neutrality this curve would change (see later slide)

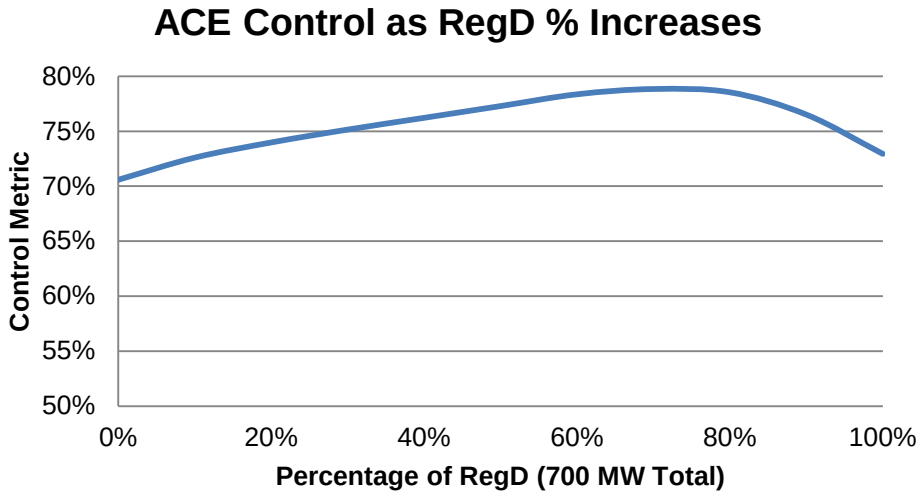




More Neutral ACE

- During more neutral ACE movement, more RegD needed for optimal control
  - With 78% of the MW consisting of RegD there is optimal control
- After 78%?
  - Because the neutrality component still exists, there is a saturation point where too much RegD is controlling ACE (> 78% RegD)





Continued Analysis

- Continue to Analyze Alternate Solutions
  - No Neutrality
  - Adjustments to Time Constants of Filters
  - Regulation Signal Tuning
- Results are Recorded
  - Will turn into documented procedure for studies