Data-Based Optimal Estimation of Frequency Bias: The case of Southwest Power Pool

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Introduction

Regulation reserves bounds

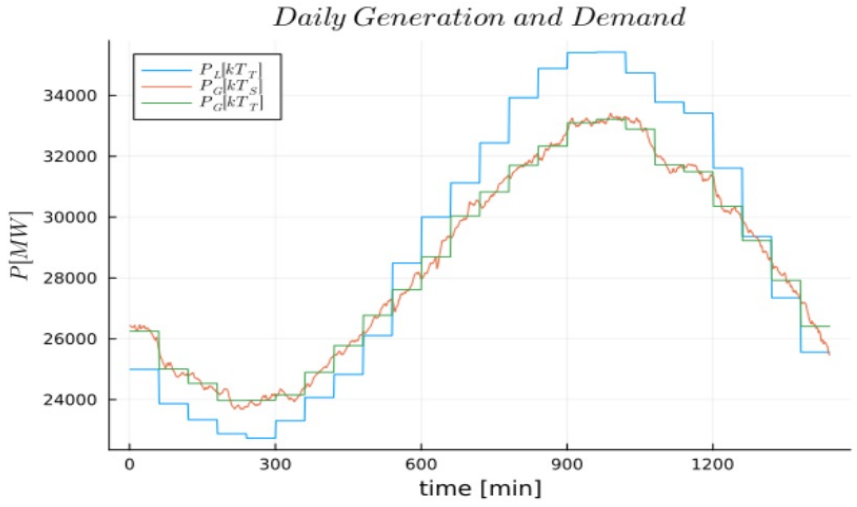
Introduction

- SPP net load volatility has increased since 2016 and is expected to further increase. Penetration of renewables, primarily wind generation, increased these changes in the net load but has also created transmission congestion issues.

Introduction contd

- Another imminent issue, due to increase in intermittent power, are effects on the regulation reserves.

- Question: “**How can one understand the tightness imposed on the needed reserves?**“



Annual expenditure on reserves?

Problem

Changing nature of frequency bias

Problem

- Regulation reserves bounds(regulation up and down) are different during the low-load seasons (spring and autumn) and high-load seasons(summer and winter). What happens on a daily basis?

- Our concern is estimating bounds for these reserves, on a secondary timescale (10-15 minutes) , as their role is to correct for hourly dispatch due to load changes. As such it is important to be able to predict bounds on regulation up and down reserves as tightly as possible.

Problem contd

- To correctly predict for the load changes on this timescale with the provided data we use relationship:

$$\Delta P_L[kT_s] = -10\beta[kT_s]\Delta f[kT_s]$$

- But what is the value of frequency bias **β** ? How can one estimate it without online knowledge of one system equipment (no knowledge of online generators in the system)?

$$\beta^I[kT_s] = \Sigma_{j\in I}\frac{1}{\sigma_j}$$

Method

Optimal estimation of frequency bias

Method

- We introduce a method to optimally estimate time-varying frequency bias **β** as current industry practice is to assume that **β** should be updated only annually
- Time-varying frequency bias parameter estimation is posed as L2 optimization problem

Method contd

Summary of available data	
Data	Short description
$\Delta T[min]$	interchange part of ACE in MW
$ACE_f[min]$	frequency part of ACE in MW
$f^{ref}[min]$	scheduled frequency in Hz
$f[min]$	measured frequency in Hz
$P_G[min]$	actual generation of the system
$NAI[min]$	net actual interchange

- Aggregate area droop characteristic for an area **S** is of the form:

$$\omega_S[kT_s] = \alpha[kT_s]\omega_S^{ref}[kT_s] - \sigma[kT_s]P_S[kT_s]$$

- But this can be also seen as an aggregate model and casted as regression problem solved through ordinary least squares by minimizing L2 norm:

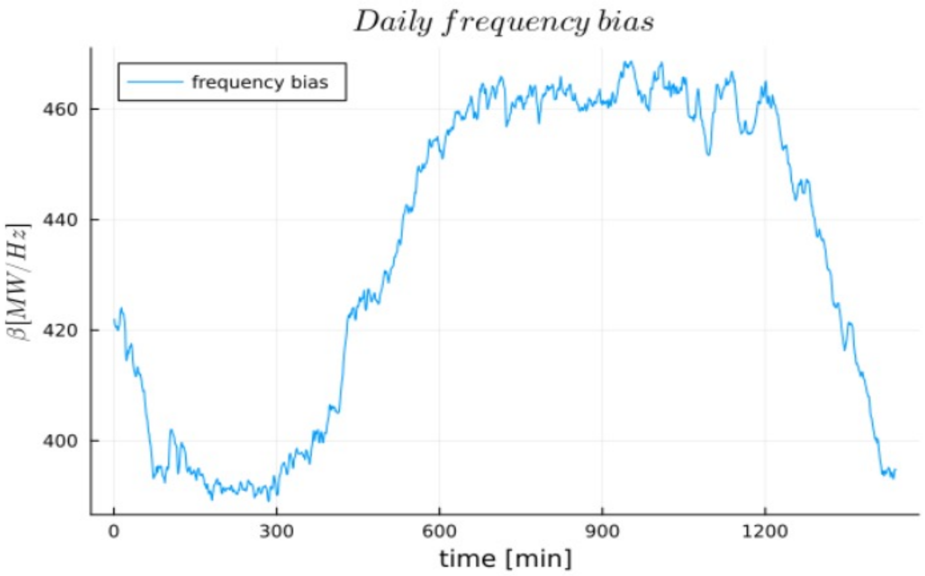
$$\begin{bmatrix}\alpha\\ \sigma\end{bmatrix} = \left(\begin{bmatrix}f_s^{ref}[k]\\ -P_S[k]\end{bmatrix}\begin{bmatrix}f_s^{ref}[k]\\ -P_S[k]\end{bmatrix}^T\right)^{-1}\begin{bmatrix}f_s^{ref}[k]\\ -P_S[k]\end{bmatrix} f_s[k]$$

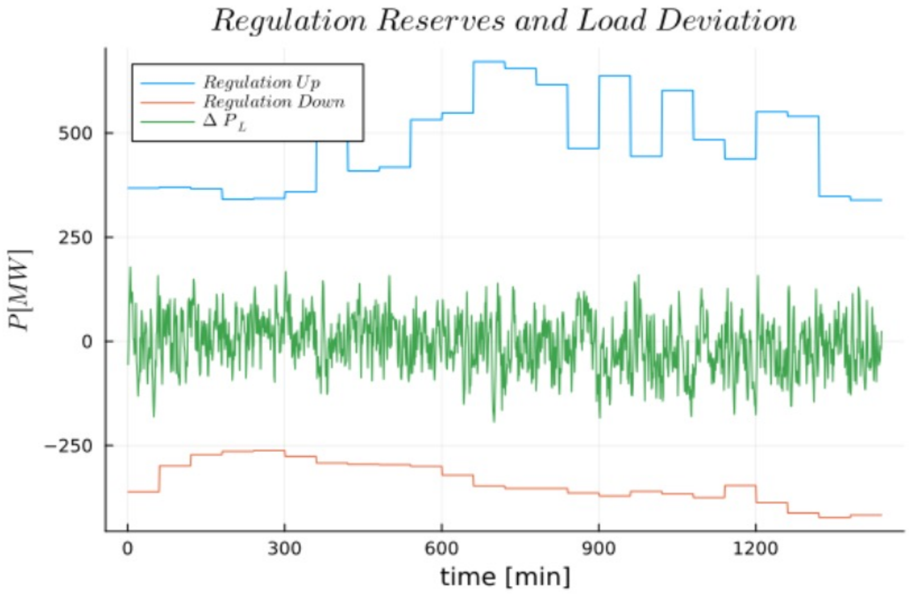
Results

Discrepancy between situation on a daily basis and NERC imposed condition

Results

- Frequency bias is not constant, and changes daily
- By observing only load, it seems that reserve bounds are too conservative, but…



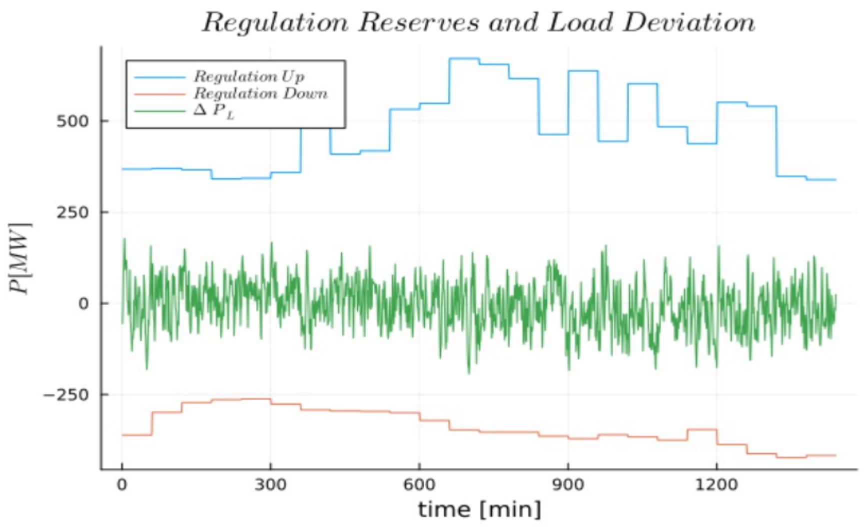


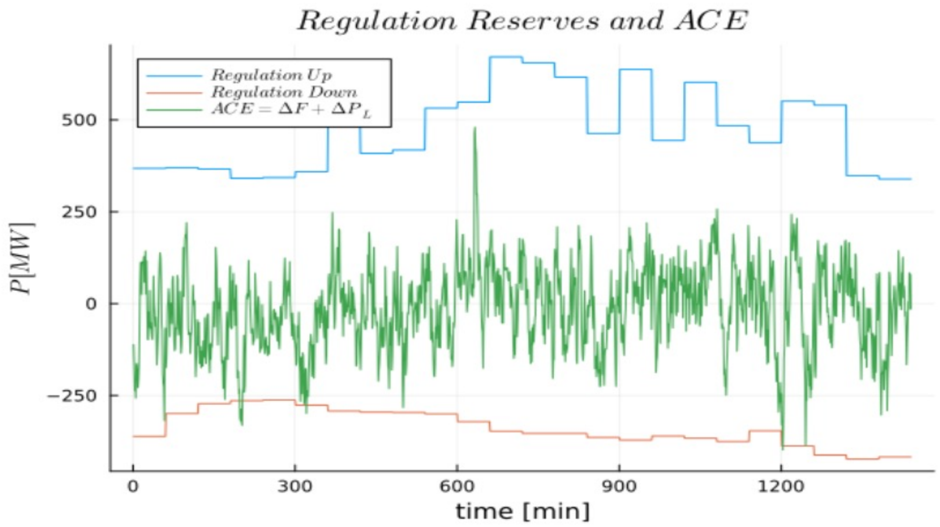
Conclusions

Can estimation provide us with a better bounds?

Conclusions

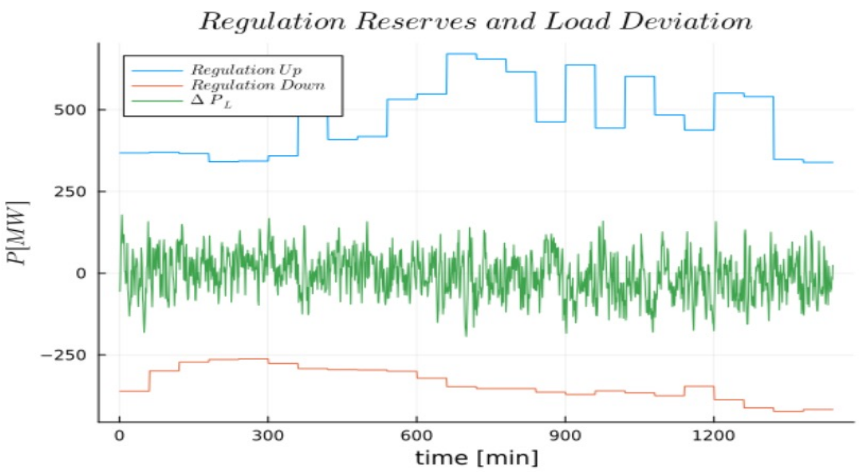
- NERC recommends that change in frequency bias happens annually
- If on top of the load mismatch we add interchange, we obtain Area Control Error, generation-load mismatch, from which follows that bounds are conservative at certain parts of the day, and in other parts can be relaxed

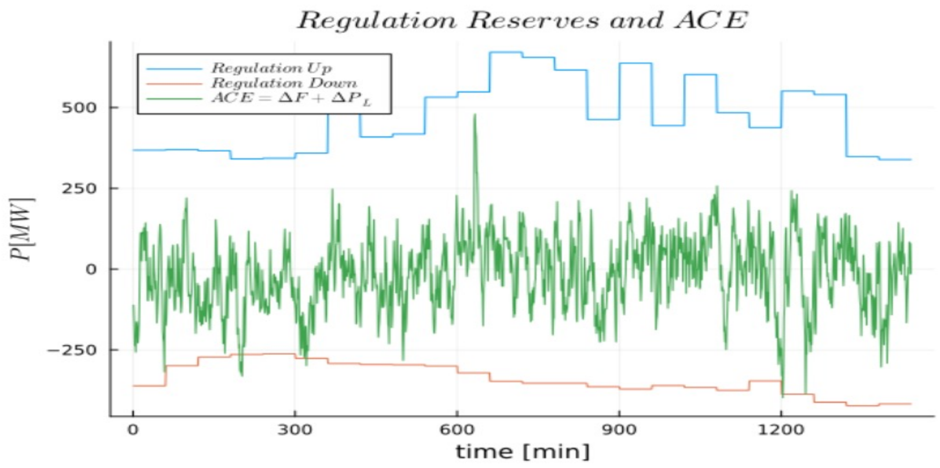




Conclusions

- This relaxation can only happen through frequency bias estimation and consequently its day-ahead prediction
- Predicted annual savings using this method for the SPP system are close to 250-300 million per year (total expenditure on regulation reserves is around 800-900 million annually)





Thanks!

Questions?