QUANTIFICATION OF THE IMPACT OF RENEWABLE PENETRATION LEVELS ON POWER GRID STABILITY

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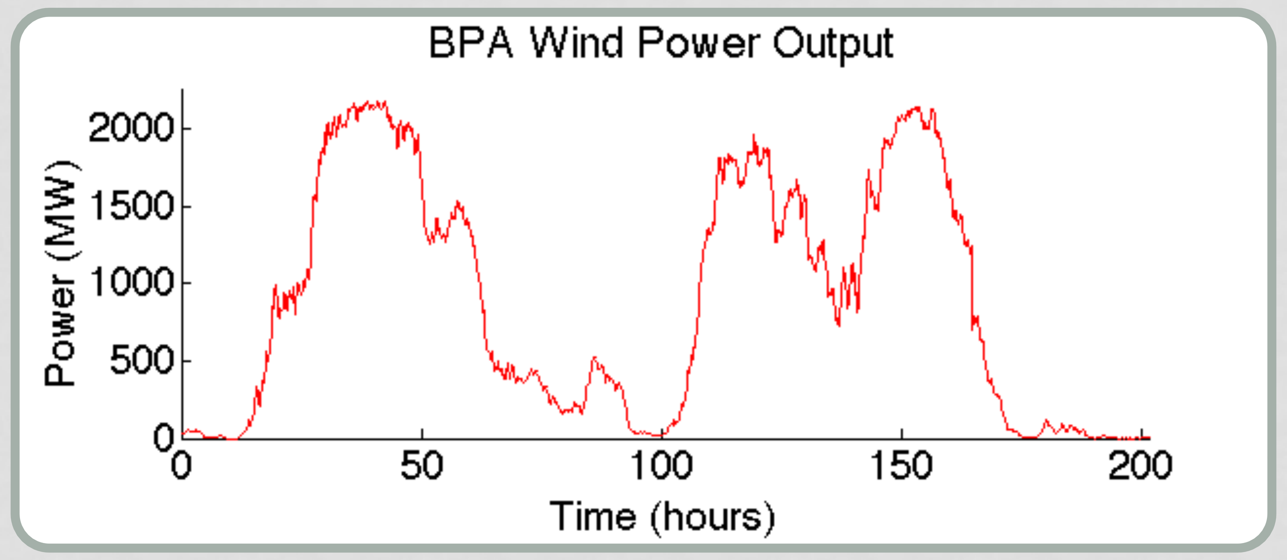
Problem Statement

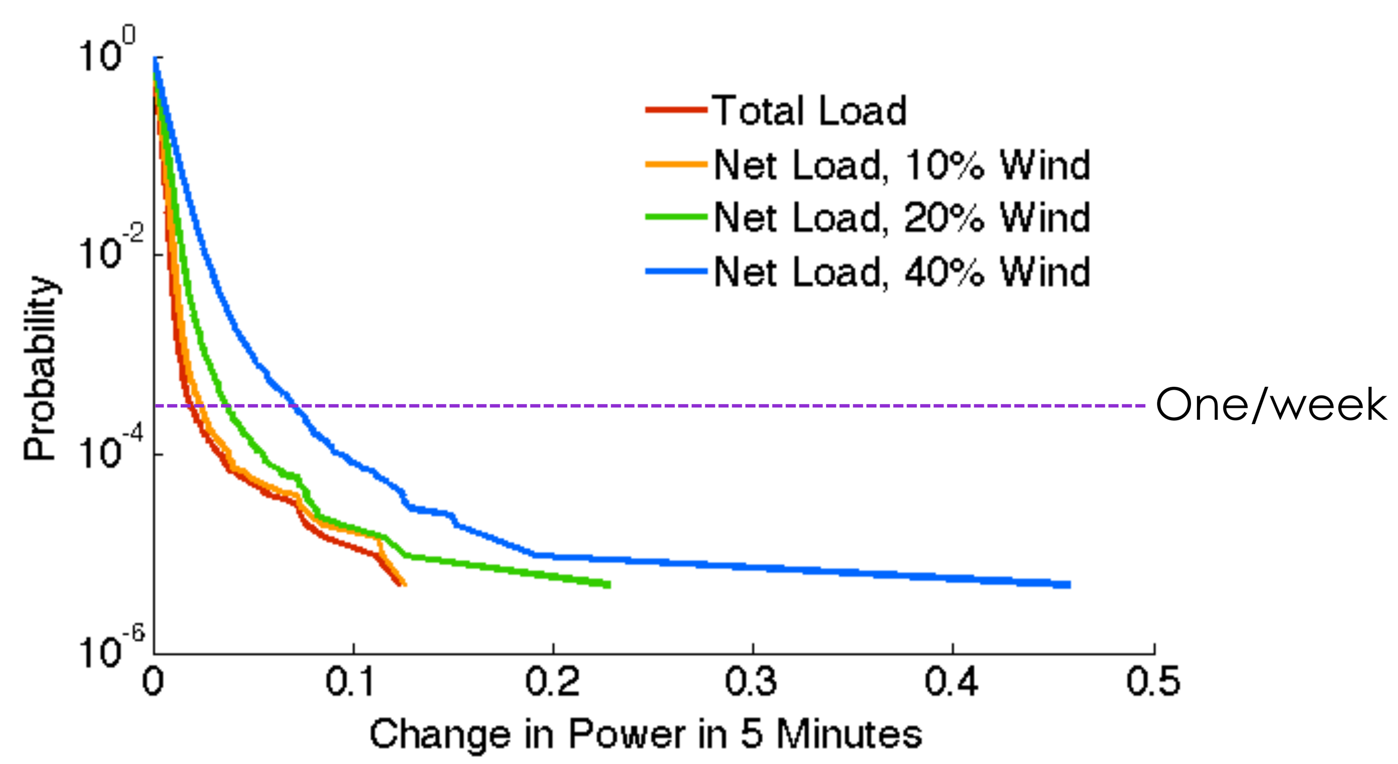
The impact of intermittent renewable generation on the power grid is of significant concern to utilities. Utilities must know the amount of backup generation ("regulation") needed to maintain adequate system performance amid this intermittency. Our research goals are to

- Quantify the amount of regulation needed to maintain stability for varying wind penetration levels
- Identify how this quantity is influenced by
  - Dispatch time
  - Consolidation of balancing area
  - Amount of inertia

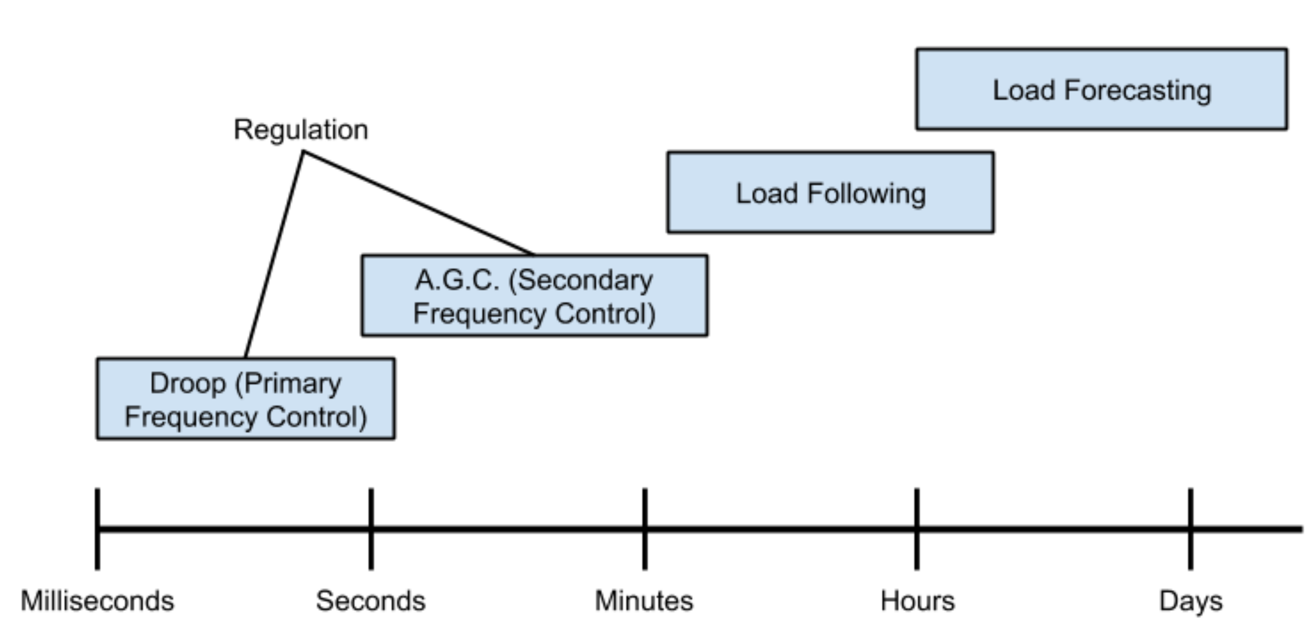


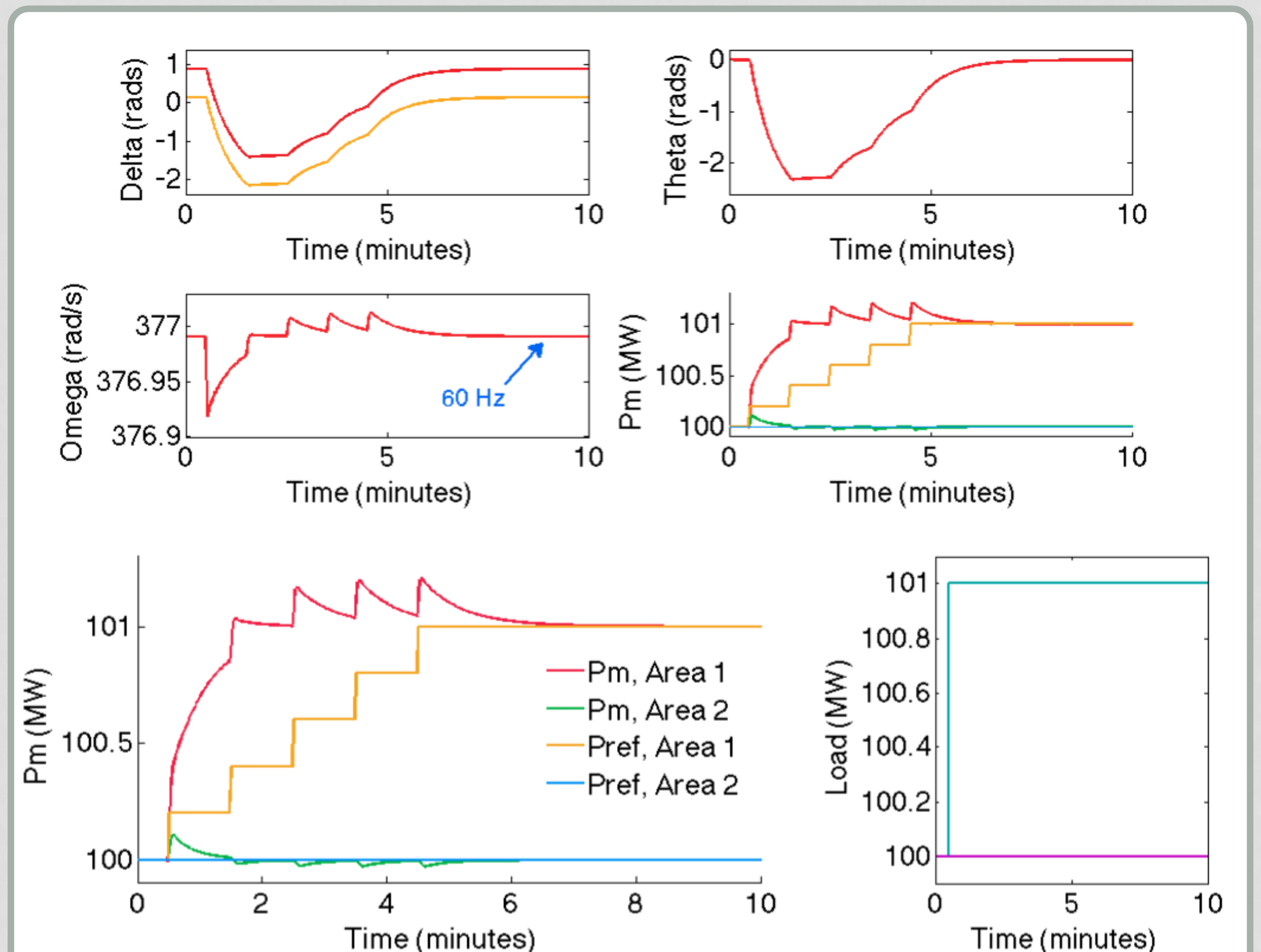
Variability:

While load already presents some intermittency (the current use for regulation), increasing wind penetration level increases the overall variability of the net load (load-wind).



Utility Control of Variability:





Quantification of Frequency Performance:

$$CPS1 = (2 - CF) \cdot 100\%$$

$$CF_{minute} = \left(\frac{ACE}{-10B}\right)_{minute} \cdot \Delta F_{minute}$$

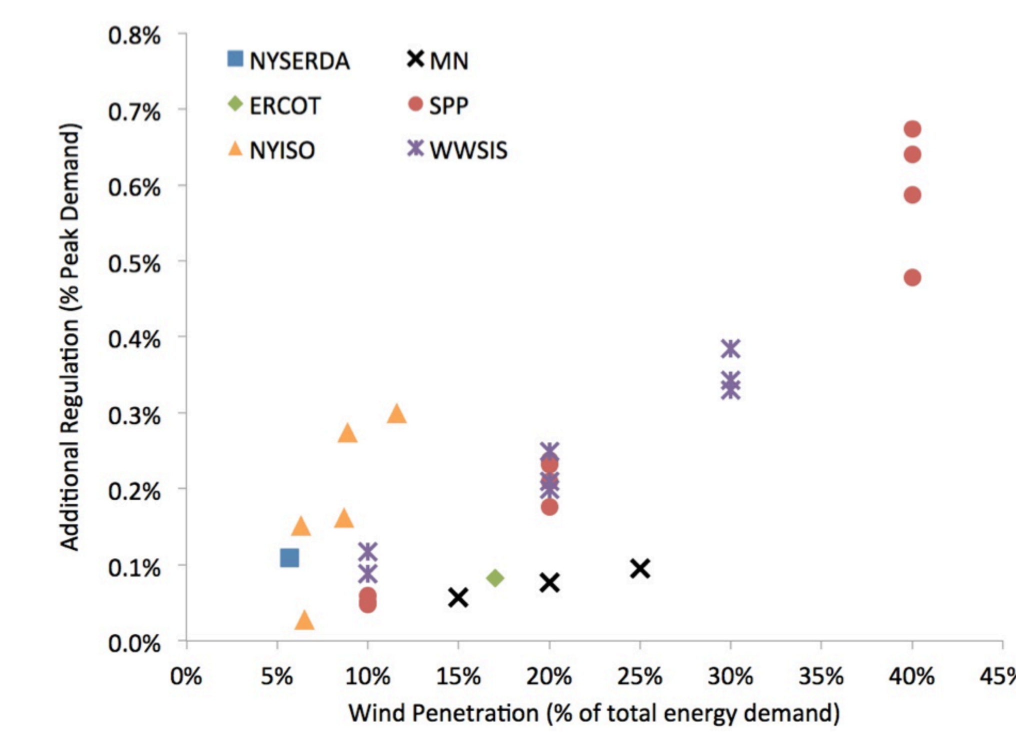
$$CPS2 = \left(1 - \frac{Violations_{month}}{Total\ Periods_{month}}\right) \cdot 100\%$$

$$\left|\frac{\sum ACE}{n_{samples\ in\ 10\ minutes}}\right| > L_{10}$$

Dynamic Simulation:

Recently published wind studies aiming to quantify the necessary regulation tend have two main issues:

1. Limited Data Points: Most studies consider only 3-4 wind penetration levels, making it difficult to predict the general trend



2. Lack of Dynamic Simulation: Most studies rely on statistical inference of wind data to predict the necessary regulation, usually using 5 minute wind data at the highest resolution. However, this misses any performance issues on a sub-5 minute scale. Considering the intermittency of wind at sub-5 minute time scales, we expect to see performances effects on this scale, and thus instead employ a dynamic simulation model, which captures the second-to-second effects on performance.

Swing Equation: Physical Model of Generator

$$P_g = P_m - D\Delta\omega - M\Delta\dot{\omega}$$

$$\dot{\delta} = \omega_0 \Delta\omega$$

Droop Control

$$T_g \dot{P}_m = P_{ref} + \Delta P_c - P_m - \frac{\Delta\omega}{R}$$

Automatic Generation Control (A.G.C.)

$$\dot{P}_c = -k \cdot ACE$$

$$[B]\,\Theta = P_g - P_d$$

Algebraic Equations: Power Injection