The background of the slide features a landscape with a large, white, lattice-structured high-voltage power line tower in the center. The tower is situated in a field of dry, brownish grass. In the distance, there are several other smaller towers and a city skyline under a blue sky with scattered white clouds. A faint rainbow is visible in the sky behind the main tower.

# **HVDC Users Conference 2011**

**Shanghai, China**

**October 24, 2011**



# Frequency



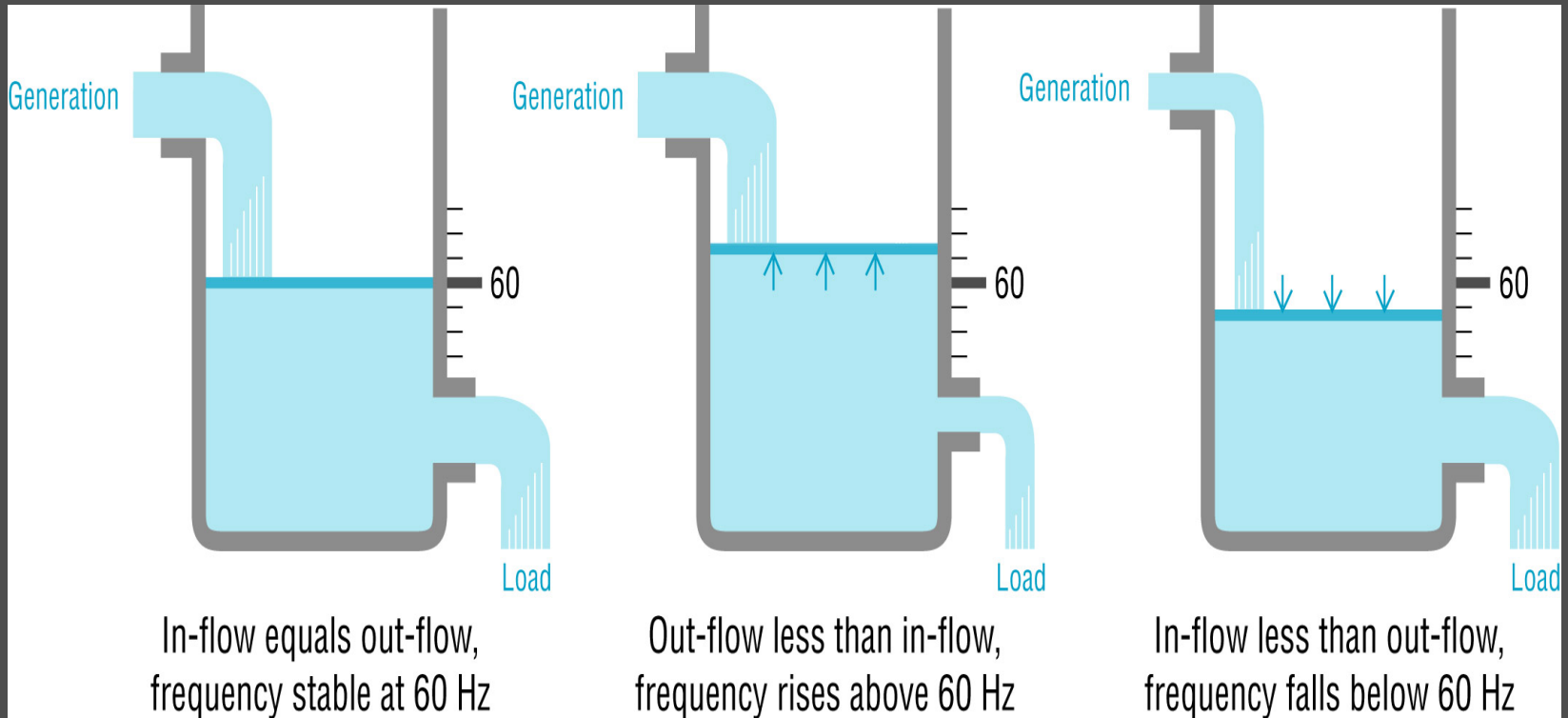
**How fast does something vibrate – measured in cycles per second or Hertz. (One note from an instrument)**

# Frequency Response



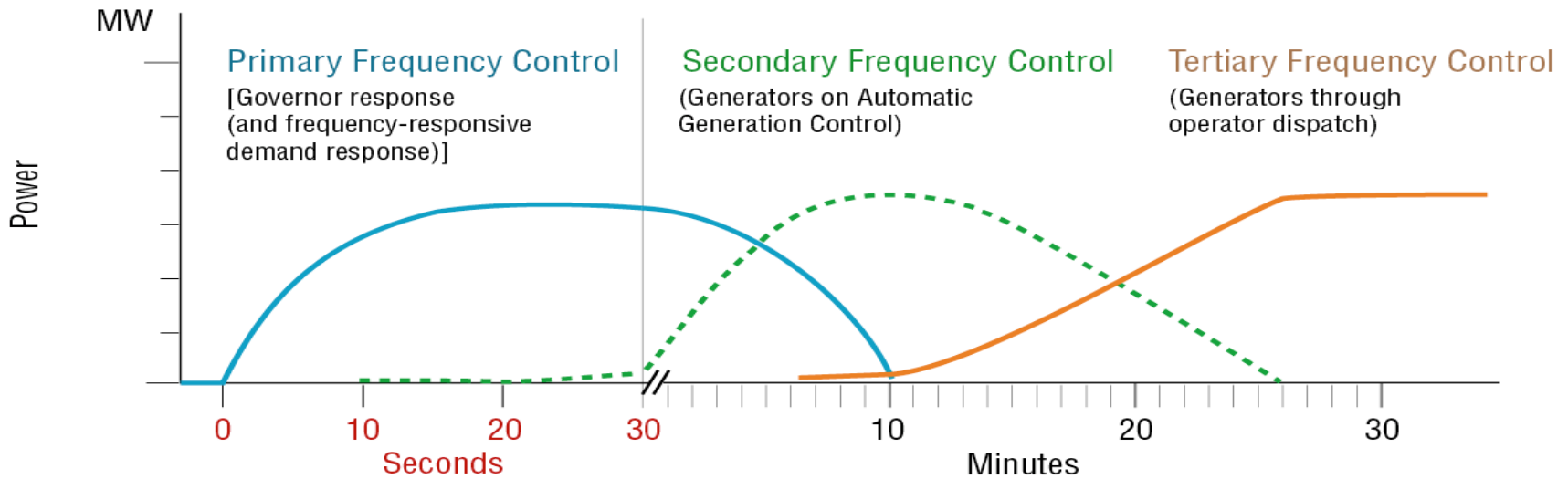
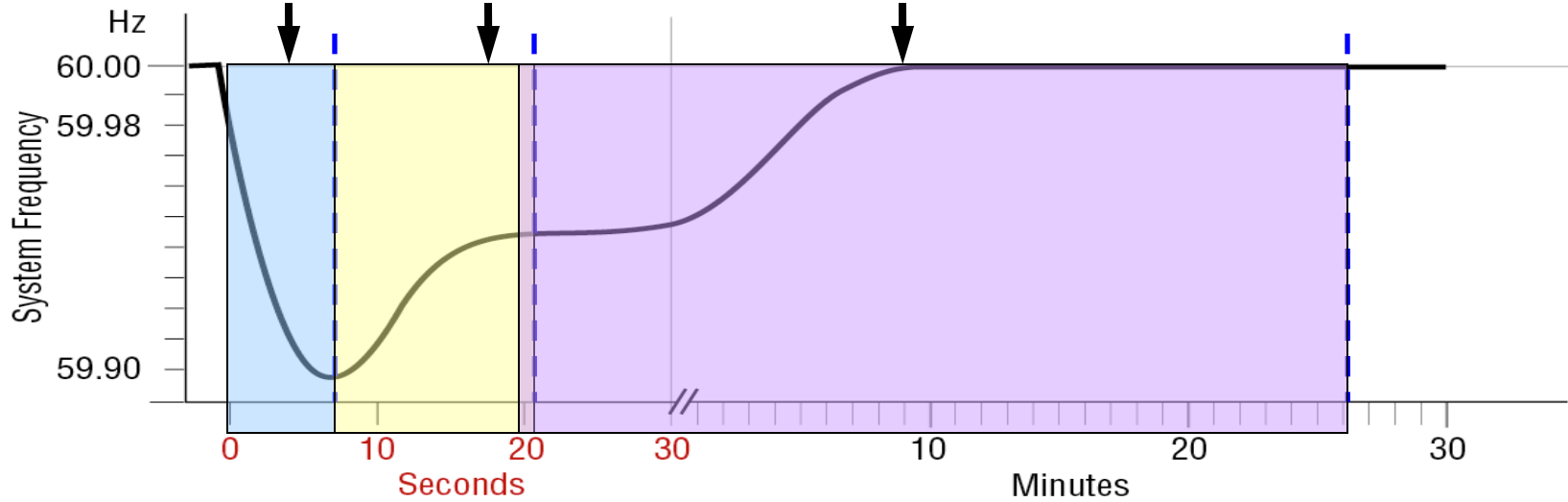
**How large a power imbalance does it take to observe a 0.1 Hz change in Frequency –measured in MW/0.1 Hz. (force needed to tilt an object by one degree)**

# Power Balance



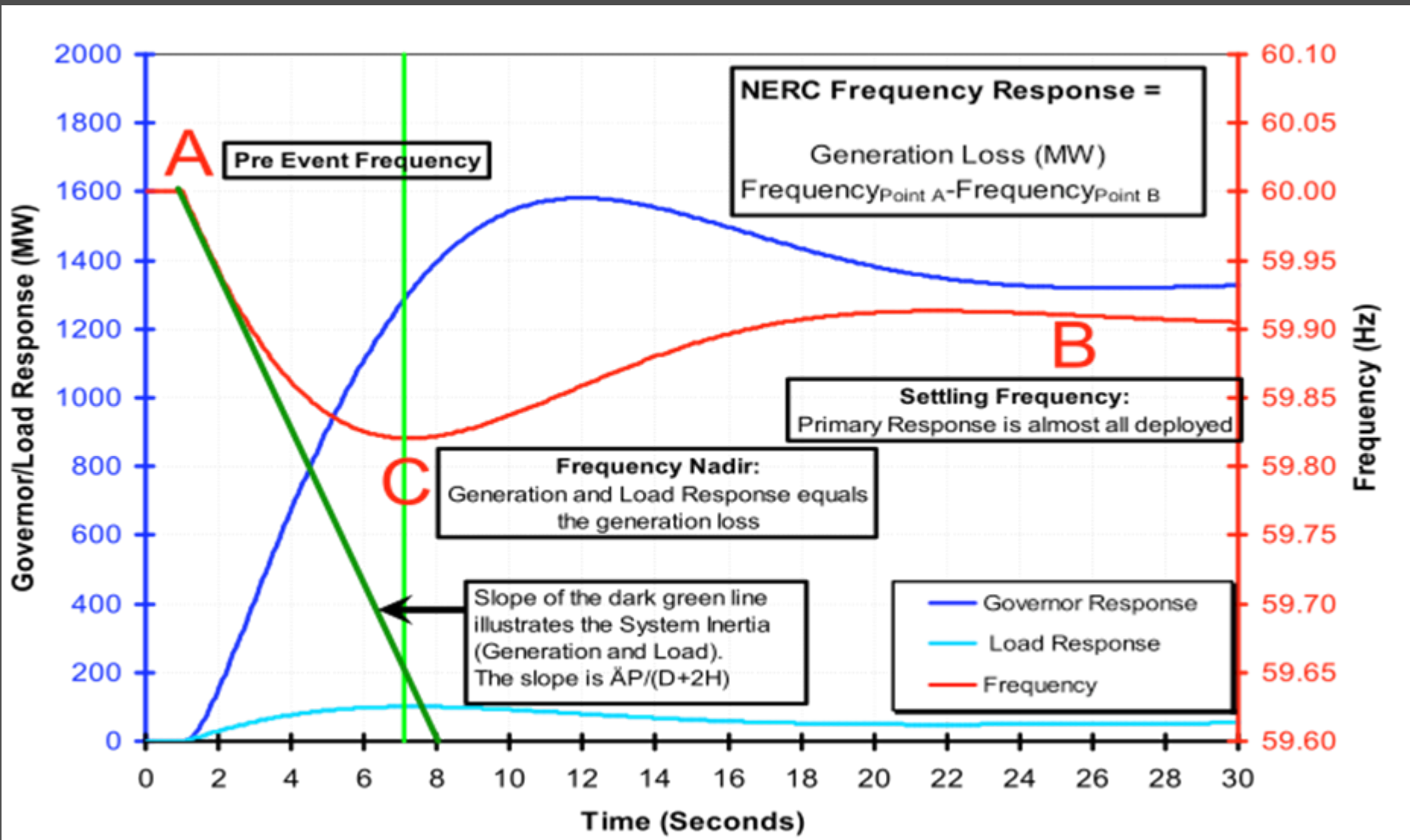
# Frequency Performance

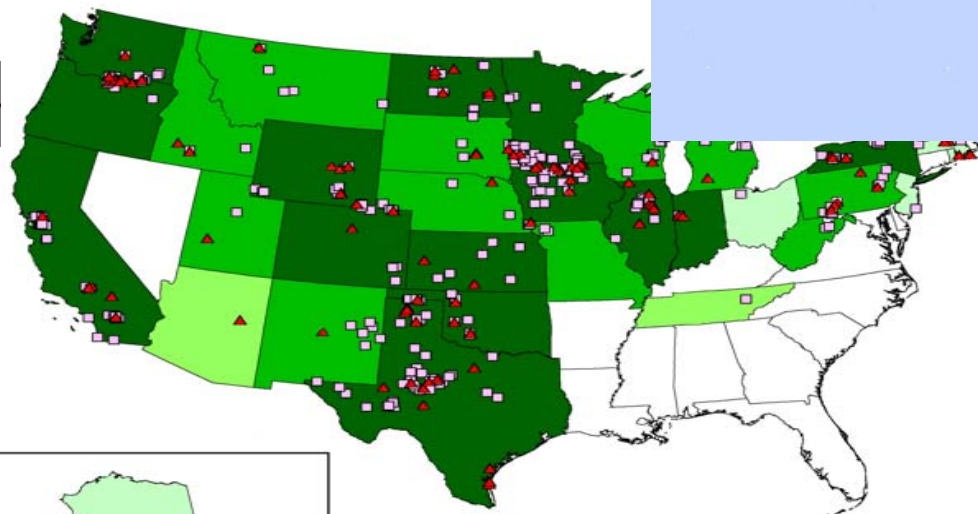
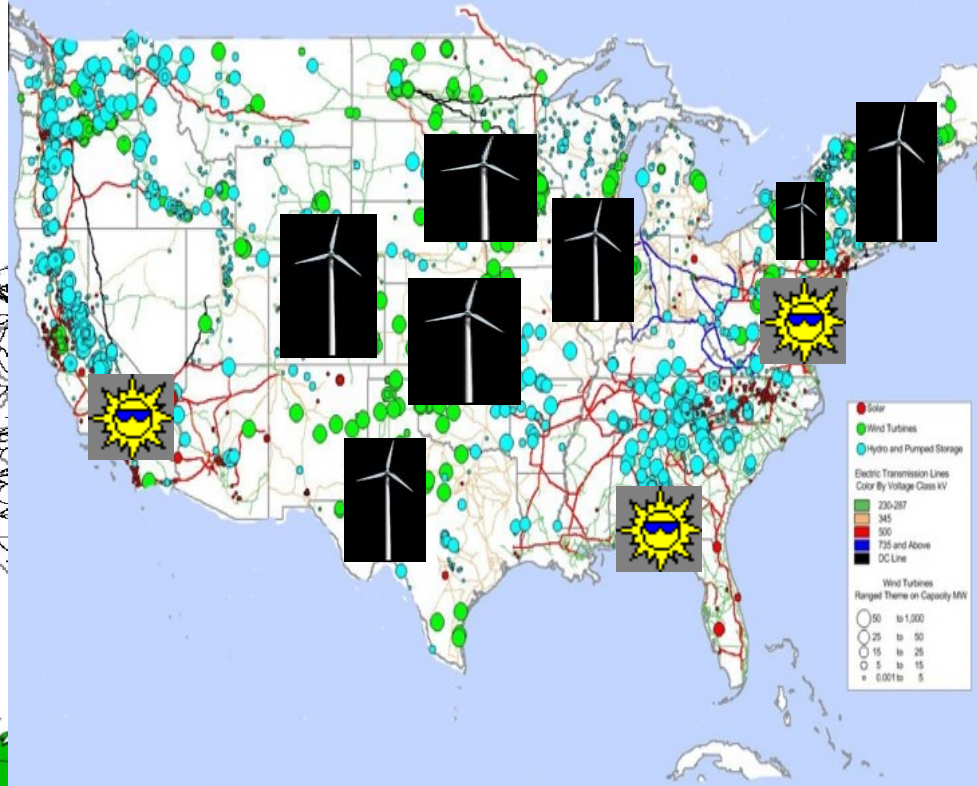
Arresting Period      Rebound Period      Recovery Period



# Frequency Response Basics

(Using a 1400 MW generation loss event as an example)

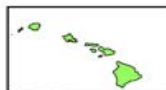




— >= 230 kV TL

**Wind power capacity**  
 in megawatts  
 ■ 1,000-9,500  
 ■ 100-999  
 ■ 20-99  
 ■ 1-19

**Wind projects ≥ 1 megawatt**  
 ■ Online before 2009  
 ▲ Added in 2009





# GreenBiz - VERGE

**Energy**



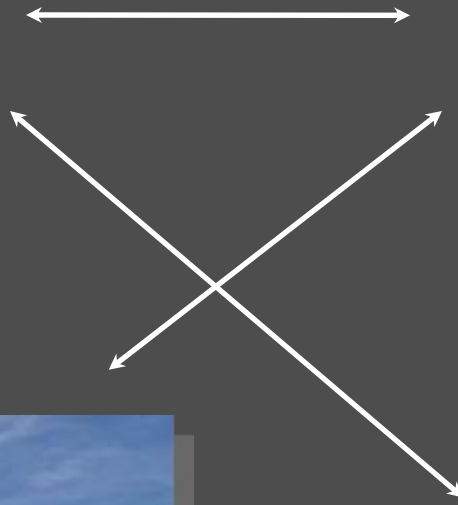
**Information**

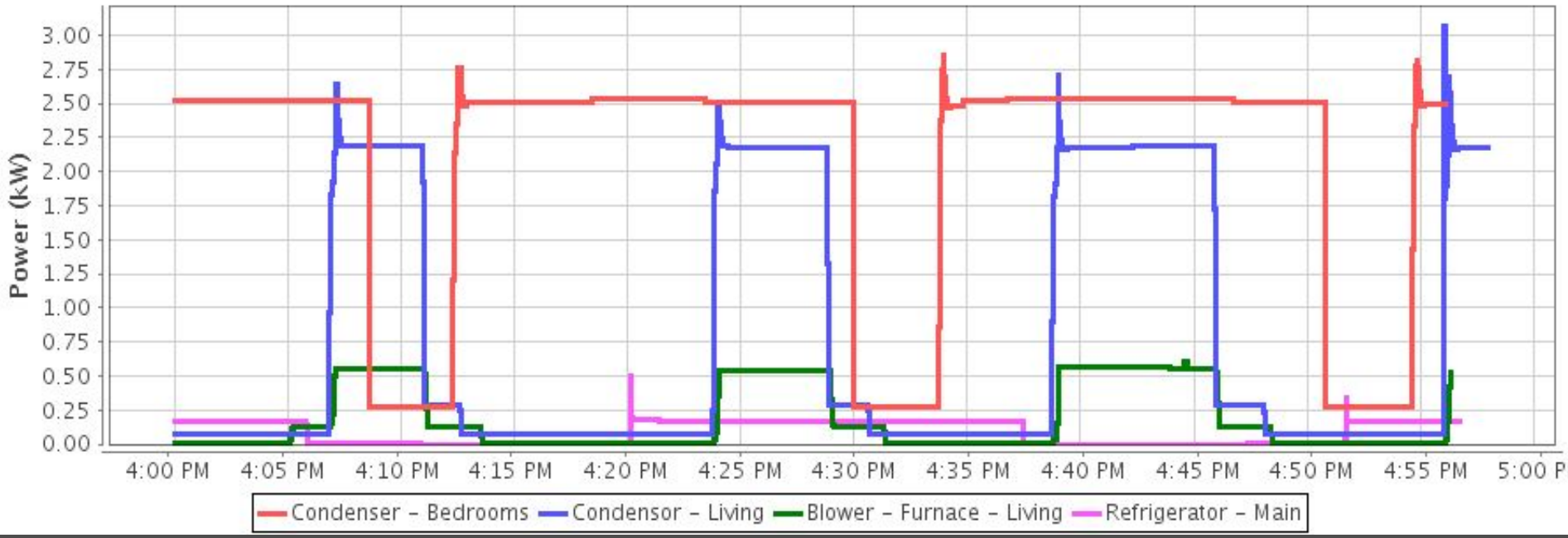


**Buildings**



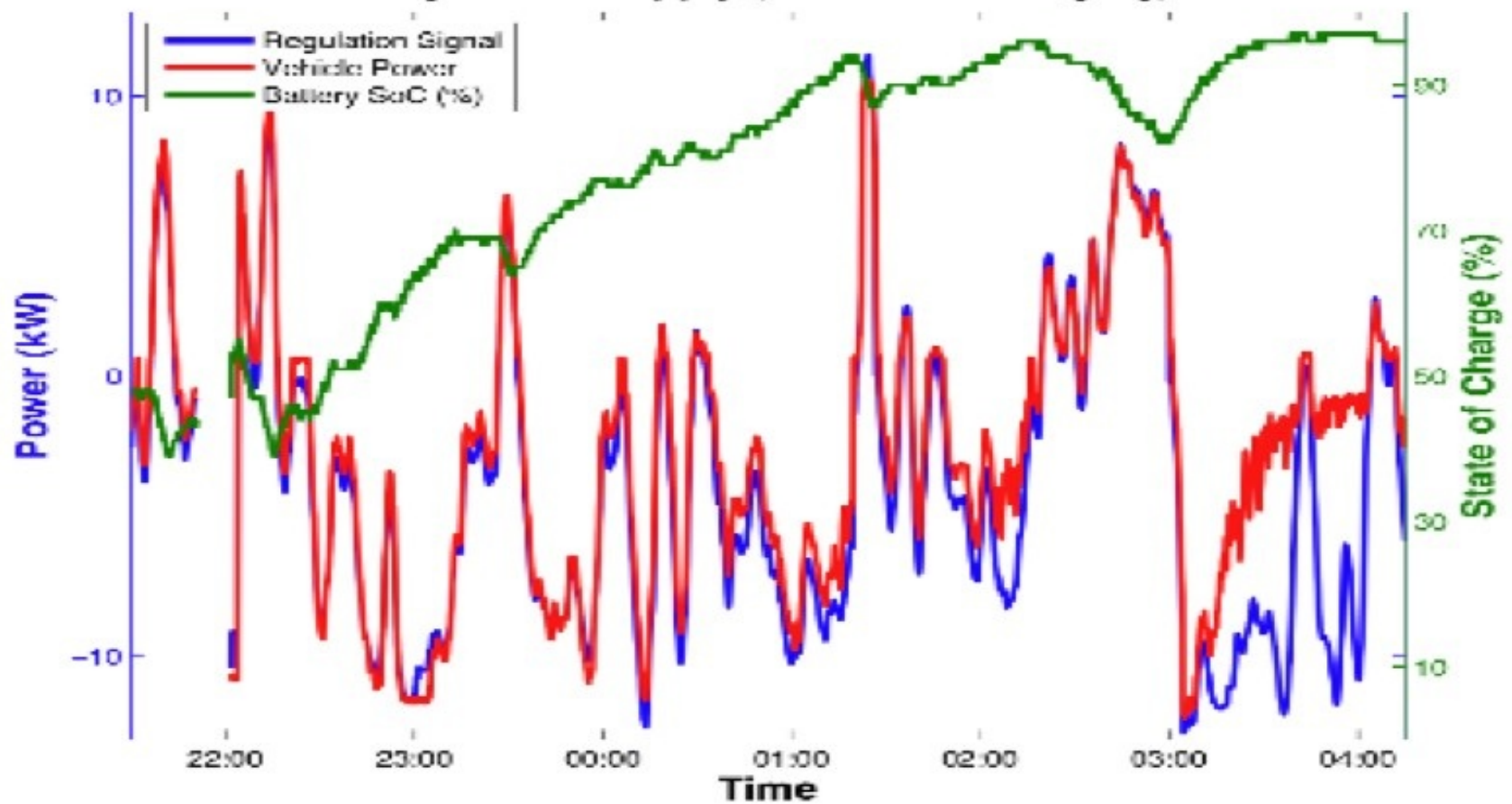
**Vehicles**







### Regulation Supply (incidental charging)



# Key Frequency Study Factors

The background of the slide features a landscape with several high-voltage electrical transmission towers and power lines stretching across the horizon. The sky is a mix of blue and orange, suggesting a sunset or sunrise. The text is overlaid on this background.

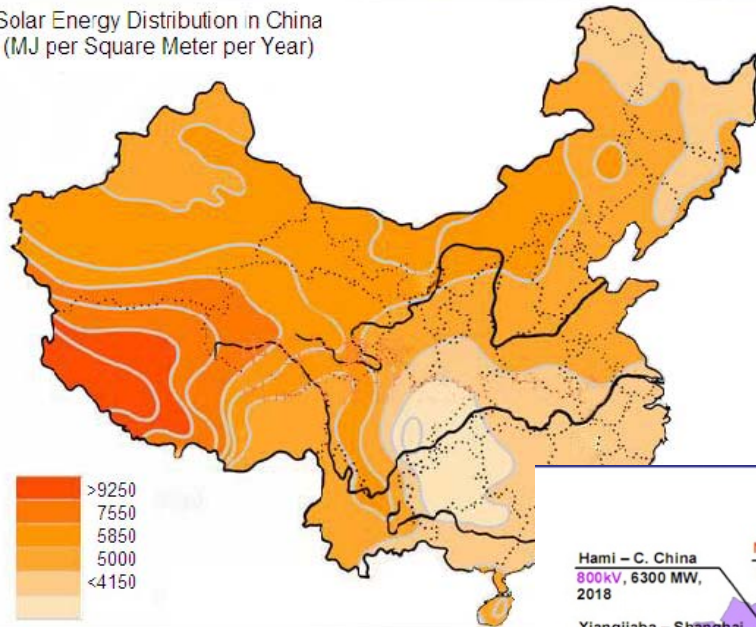
- Displacement of Primary
- Location of Resources
- Interaction of Primary and Secondary
- Variations of Wind Power Output

# Summary Frequency Response Study

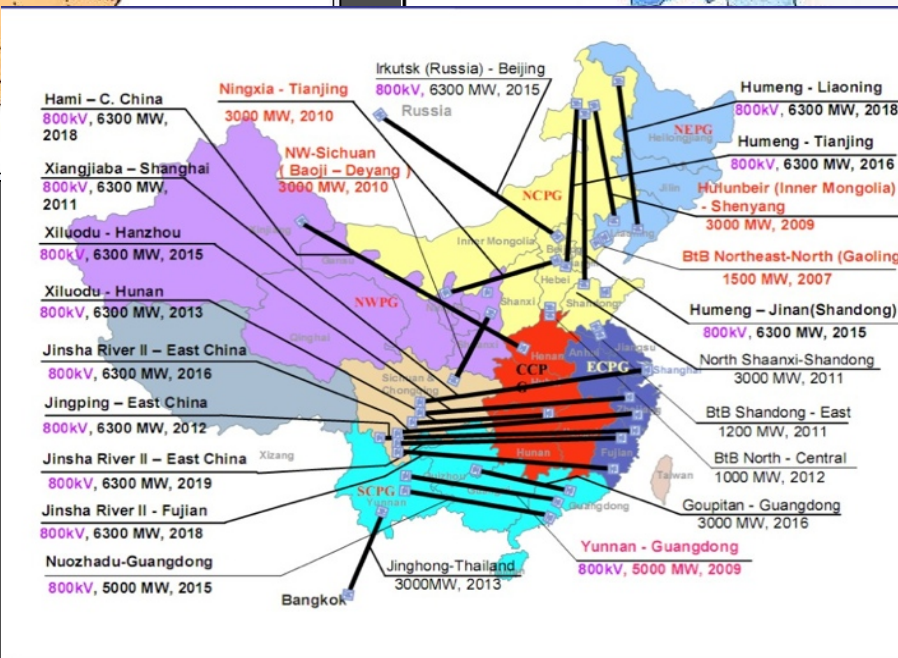
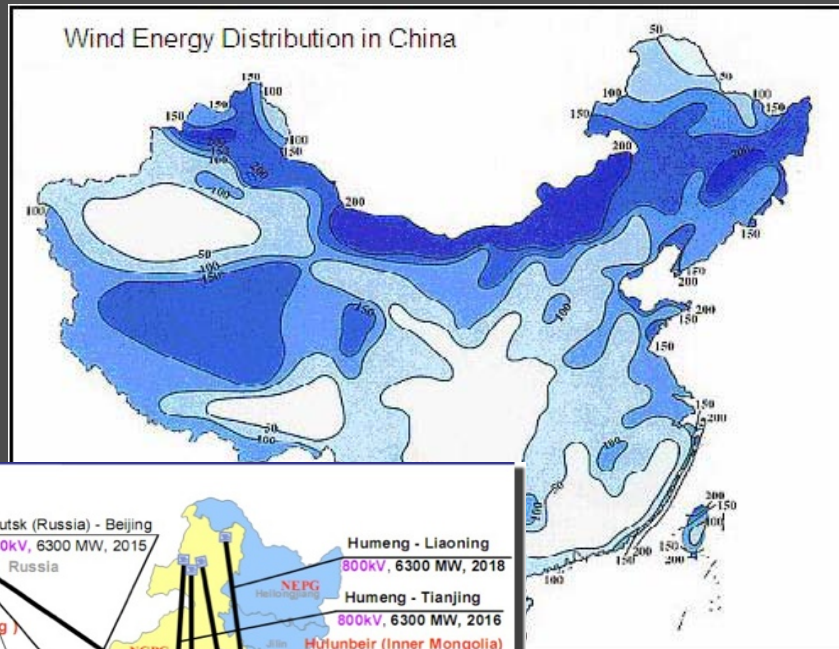
- Important to reliability as evidenced by actual events and near misses
- Change in inertia not a significant issue
- Amount and deployment of secondary changes with more wind resources
- Must have necessary primary frequency control (magnitude and speed) at all times

# China Transmission for Renewable Energy

Solar Energy Distribution in China  
(MJ per Square Meter per Year)



Wind Energy Distribution in China



A landscape photograph featuring several high-voltage power line towers in the foreground and middle ground. A vibrant rainbow arches across the sky, partially obscured by the towers. The sky is filled with soft, white clouds, and the ground is covered in dry, brownish grass. In the far distance, a city skyline with various buildings and structures is visible under a blue sky.

**Thank you!**