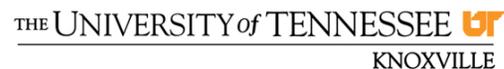




Wide Area Control

Kevin Tomsovic
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Stanford University Smart Grid Workshop
April 25, 2012



Northeastern



Rensselaer



TUSKEGEE
UNIVERSITY

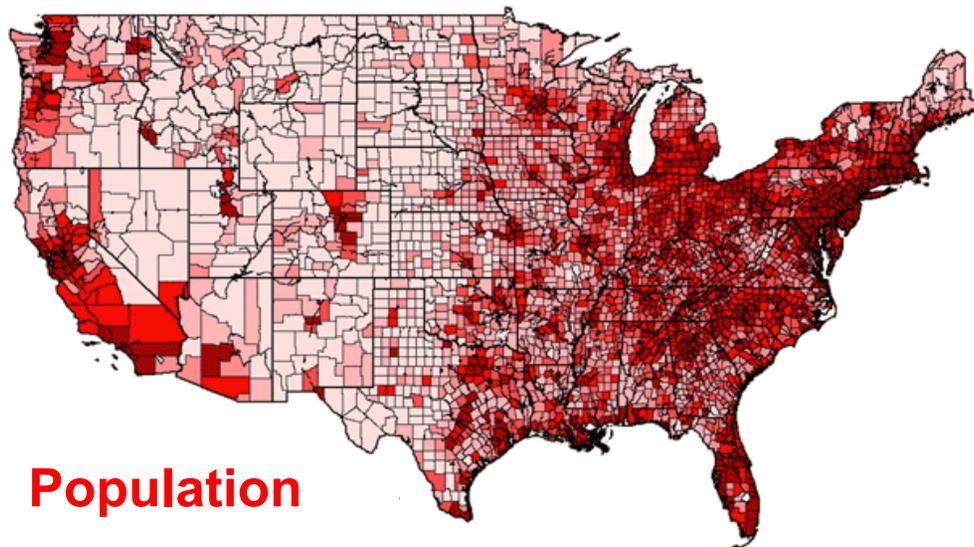


ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ
NATIONAL TECHNICAL UNIVERSITY OF ATHENS



清华大学
Tsinghua University

US Wind and Solar Resources

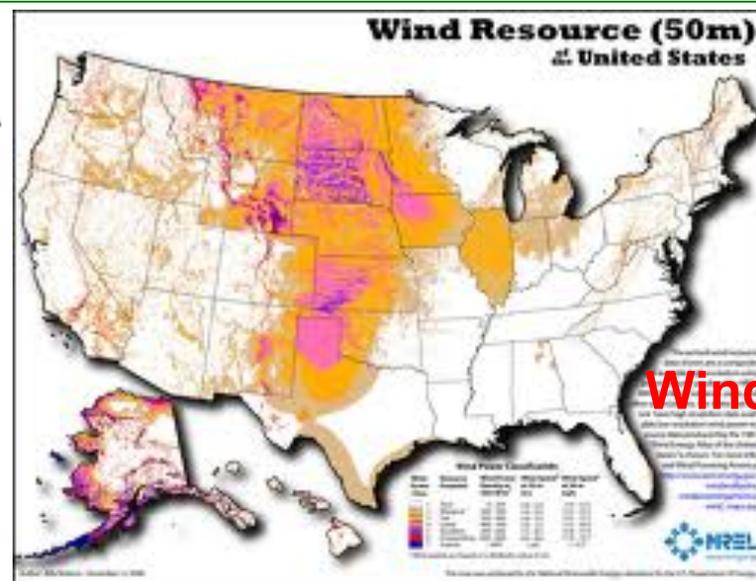


Population

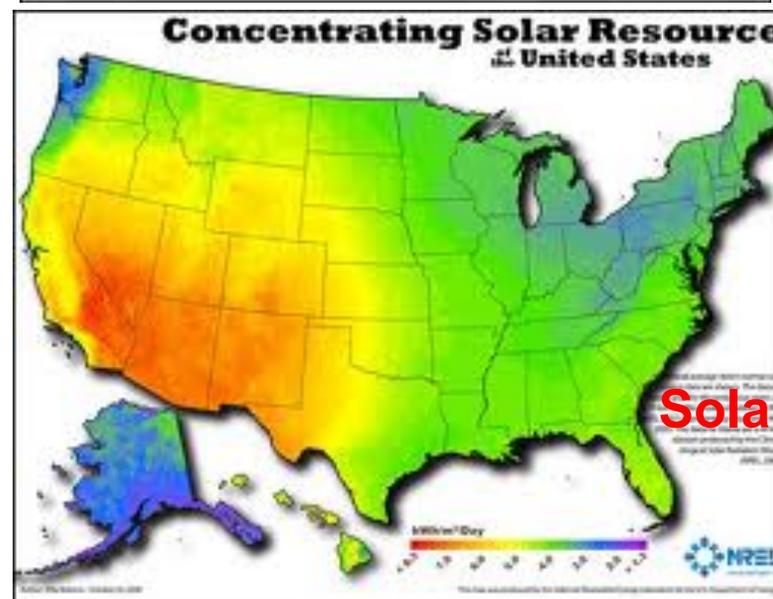
Best wind and solar sources are far from load centers.

Distance provides diversity of sources.

Transmission networks must play a central role in integration.

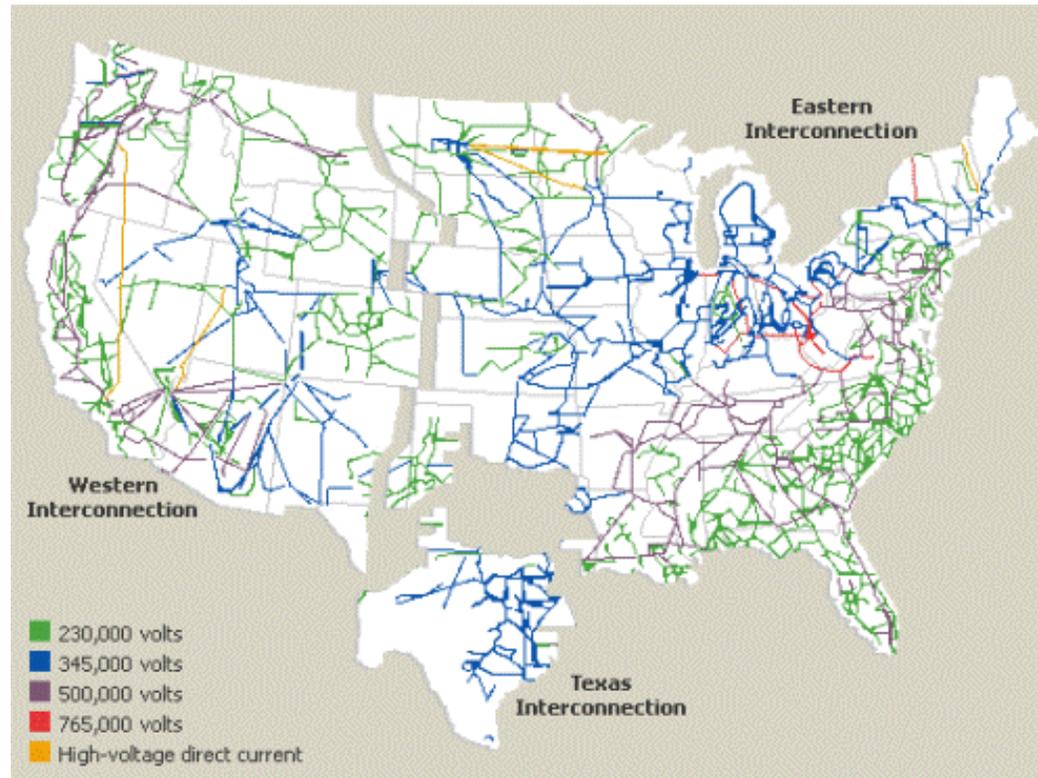


Wind



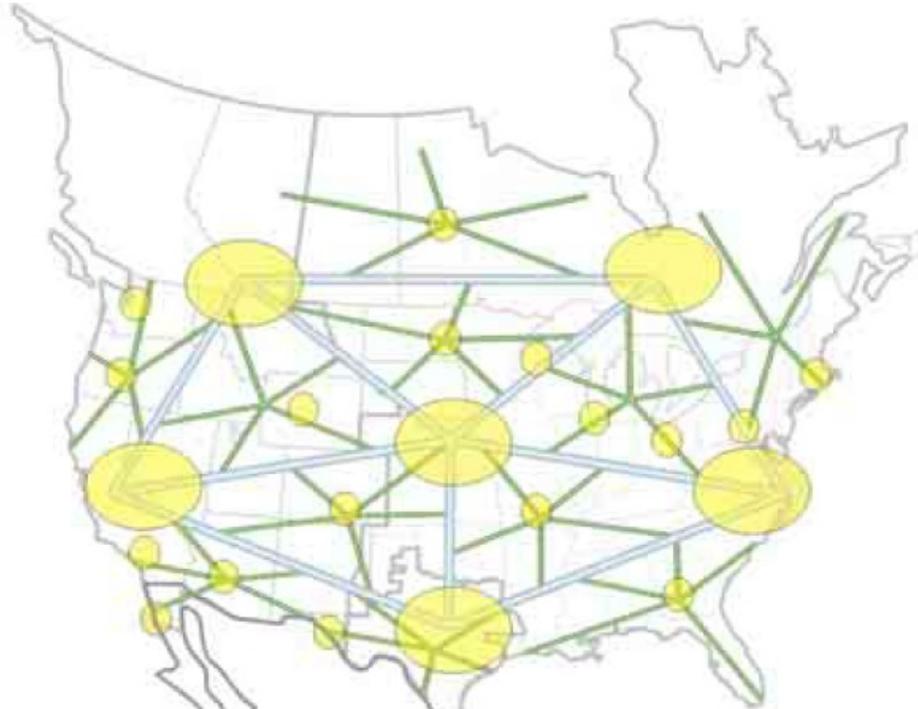
Solar

Today's System



- **Low penetration of renewable energy sources**
- **Dominated by inflexible AC transmissions; large capacity margin**
- **Load variability only; generation following load**
- **Limited situational awareness; mostly local control**

Future System



DOE: "GRID 2030" VISION

Electricity Backbone, Regional Interconnection, Plus Local Distribution, Mini- and Micro-Grids

- **High penetration of renewable energy sources (>50%)**
- **Flexible DC and AC transmissions with small (~0) margin**
- **Load and source variability; responsive load**
- **High situational awareness; ultra-wide-area control**

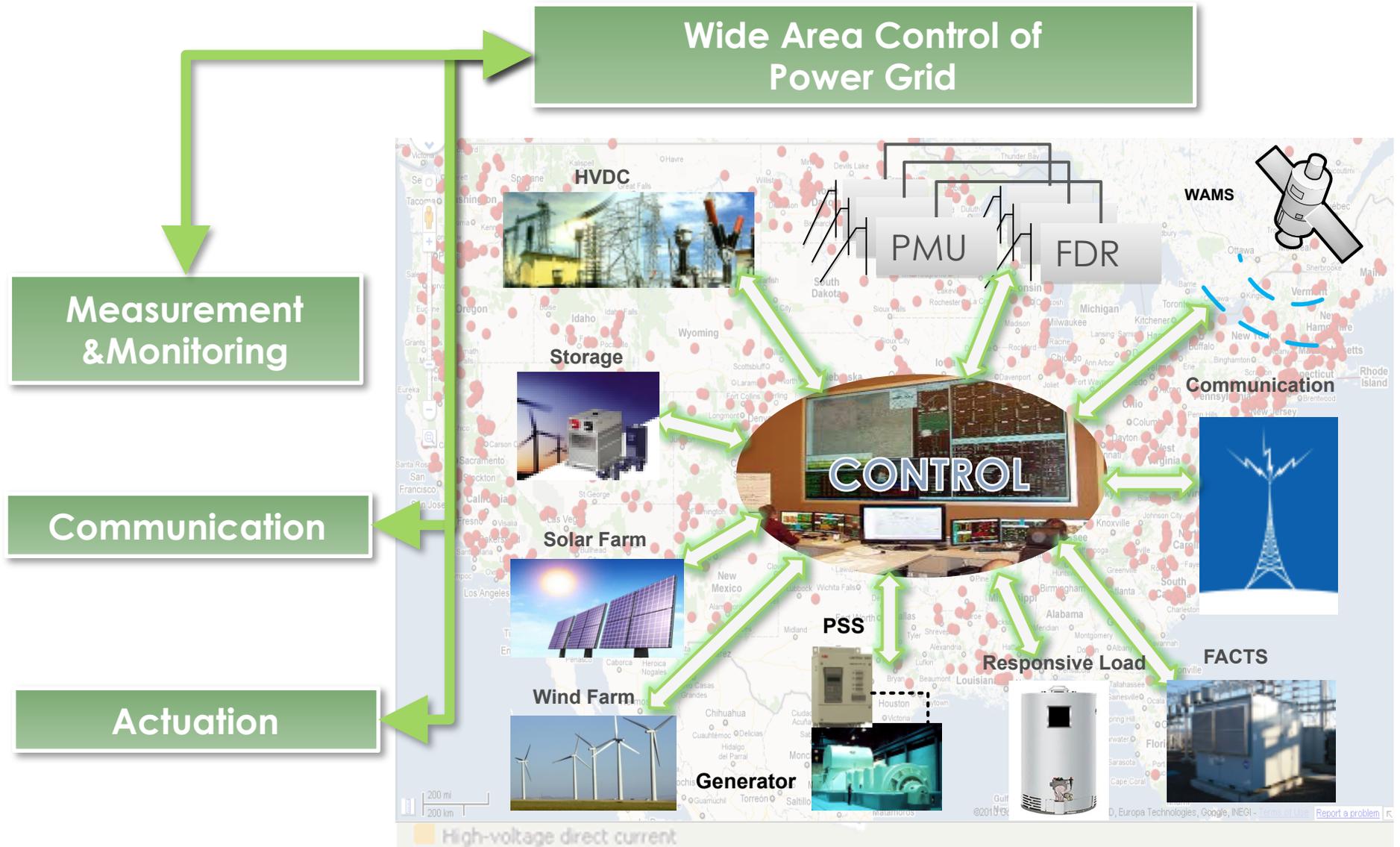
Existing Power System Control

- **Connected system built upon rotating machines with high inertia and relies on dependable patterns of consumption**
 - **Very little load is controllable, instead generation tracks daily load curve**
 - **System engineered to meet peak demands**
 - **Numerous centralized controls acting largely independent**
 - **Localized control schemes primarily for protection**
- ➔ **Driven by reliability and fuel costs. Current system does have many advantages including high efficiency (from electrical viewpoint) and high reliability.**

Other Views of These Controls

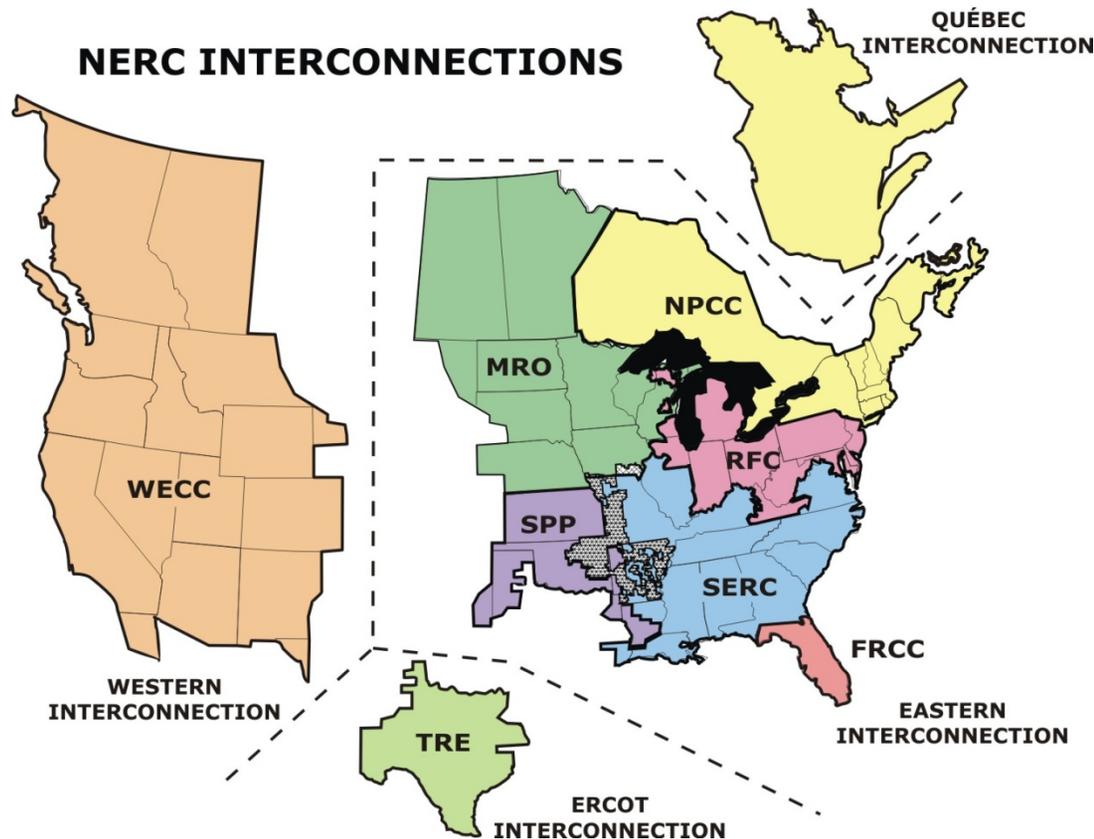
- **Variables of interest**
 - Frequency and phase (corresponds to real power)
 - Voltage (we'll skip voltage)
- **Time (milliseconds to seasonal)**
 - Protection → Stability → Balancing/Reserves
 - Dispatch → Unit Commitment → Resource Planning
- **Primary concern**
 - Reliability
 - Economics

Wide Area Control of the Power Grid



Synchronism

Since most generation is from synchronous machines, the interconnected power system swings together.



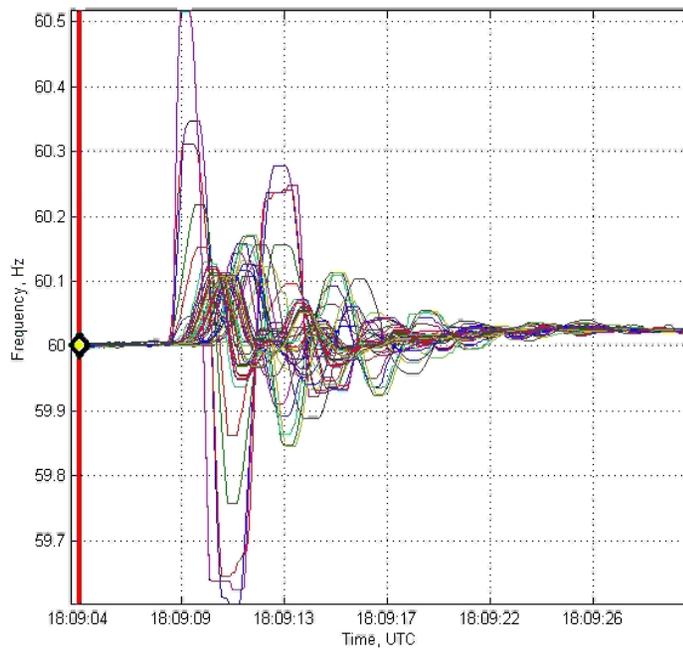
Wide Area Measurement

UWA real-time grid monitoring system at UTK – Dr. Yilu Liu

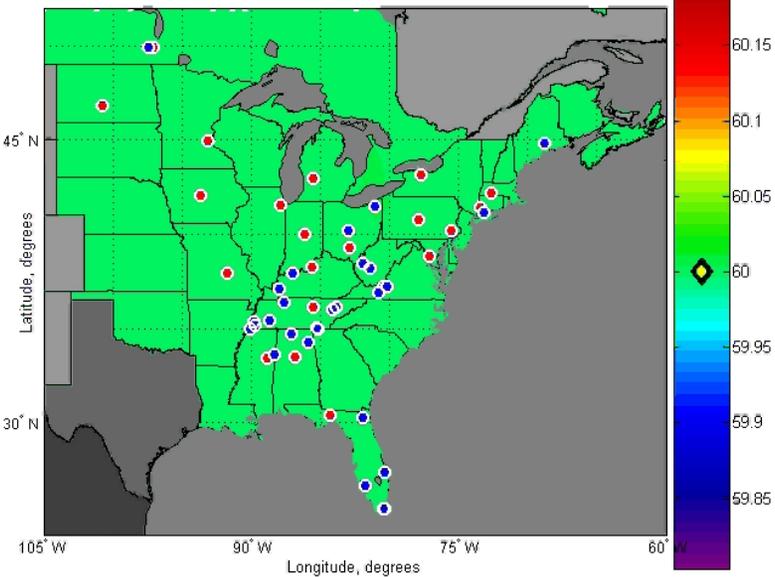
FDR Sensor



FNET Monitors
in the Field



Florida Event Replay based on FNET(Red) and PMU(Blue) Measurements
2/26/2008 Time: 18:09:4.4 UTC 60.0003 Hz



Frequency Control

- To maintain frequency, load and generation (minus losses) must balance
- An increase in load decreases frequency so generators respond to frequency dip by increasing output
- Coordination from control centers results in a simple but very effective means of load following
- Load frequency control
 - Inputs – scheduled and actual tie line flows (difference is area control errors), frequency deviation (also frequency response characteristic)
 - Output – generator set point adjustments around once every 4 seconds

North American Control Areas

