OAK RIDGE National Laboratory

Challenges to Updating Timing In The Power Grid

Terry Jones, Oak Ridge National Laboratory
David Schoenwald, Sandia National Laboratories
Frank Tuffner, Pacific Northwest National Laboratory

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

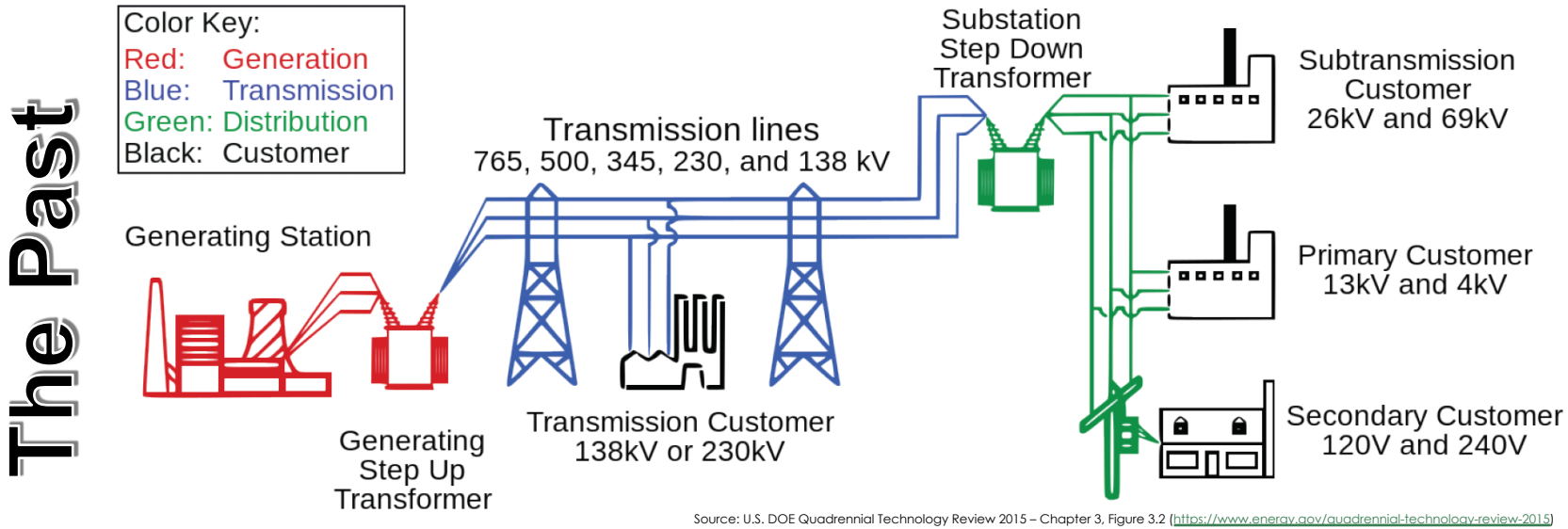
U.S. DEPARTMENT OF ENERGY

Outline

- Our Changing Power Grid
- How The Power Grid Got Synchronized: PMUs & Damping Control
- A Look Toward The Future

The Need For Time Agreement

The Grid Used To Be Simpler in Design & Operation



Source: U.S. DOE Quadrennial Technology Review 2015 – Chapter 3, Figure 3.2 (https://www.energy.gov/quadrennial-technology-review-2015)

The Need For Time Agreement

The Grid Used To Be Simpler in Design & Operation

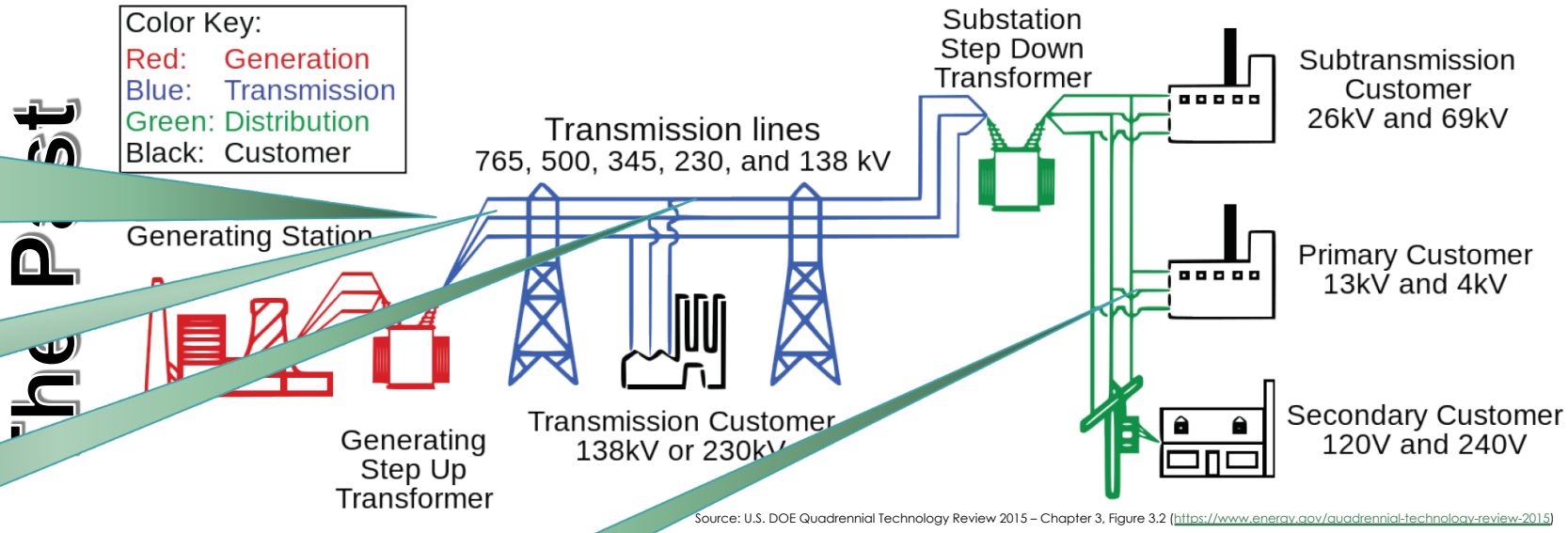
Scope of power network was more limited in geographical size

Flow is uni-directional from station

Load is over-provisioned predicted based on past usage

Distribution is one-to-many (hierarchical):

one station, many customers

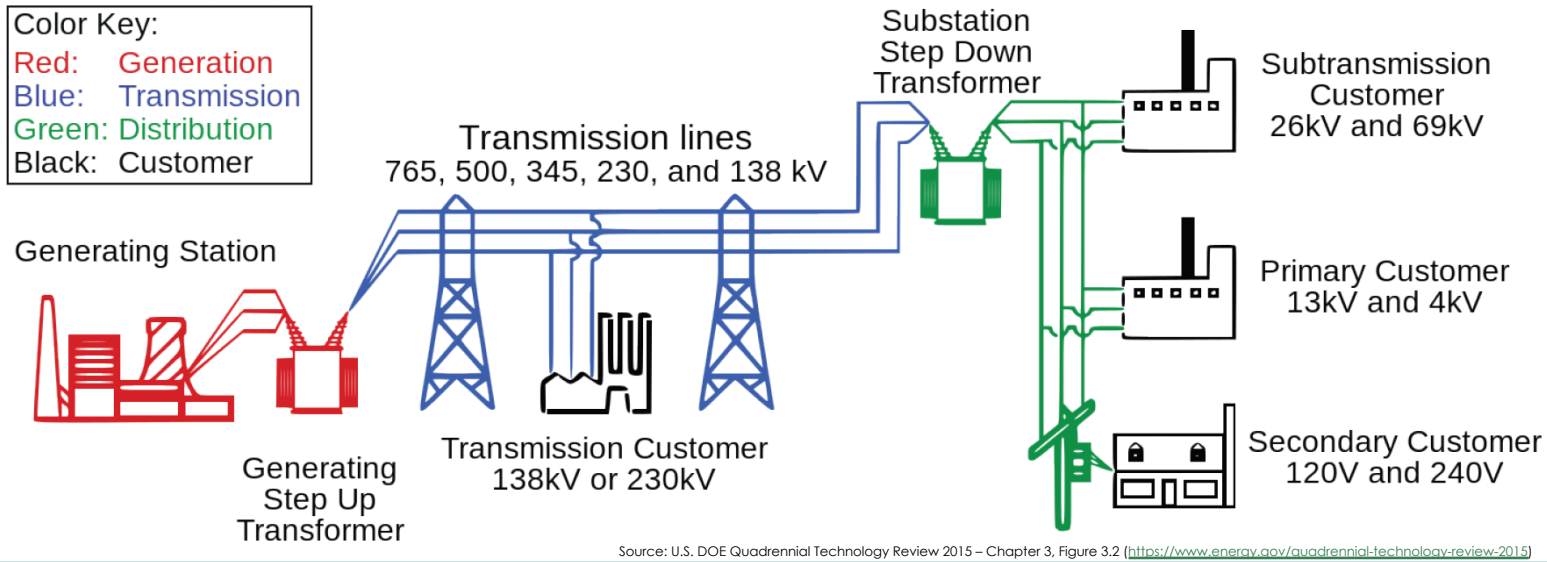


Source: U.S. DOE Quadrennial Technology Review 2015 – Chapter 3, Figure 3.2 (https://www.energy.gov/quadrennial-technology-review-2015)

The Need For Time Agreement

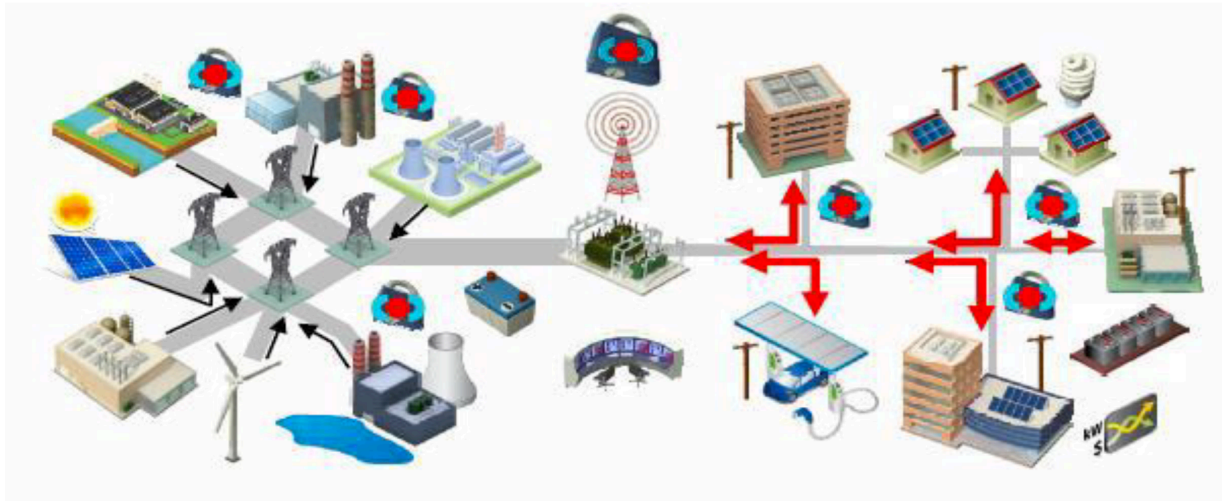
The Grid Is Becoming More Like A Wide Area Network

The Past



Source: U.S. DOE Quadrennial Technology Review 2015 – Chapter 3, Figure 3.2 (https://www.energy.gov/quadrennial-technology-review-2015)

The Future



OAK RIDGE National Laboratory

The Need For Time Agreement

The Grid Is Becoming More Like A Wide Area Network

Flow is no longer one way

Generation is not controlled or dispatched

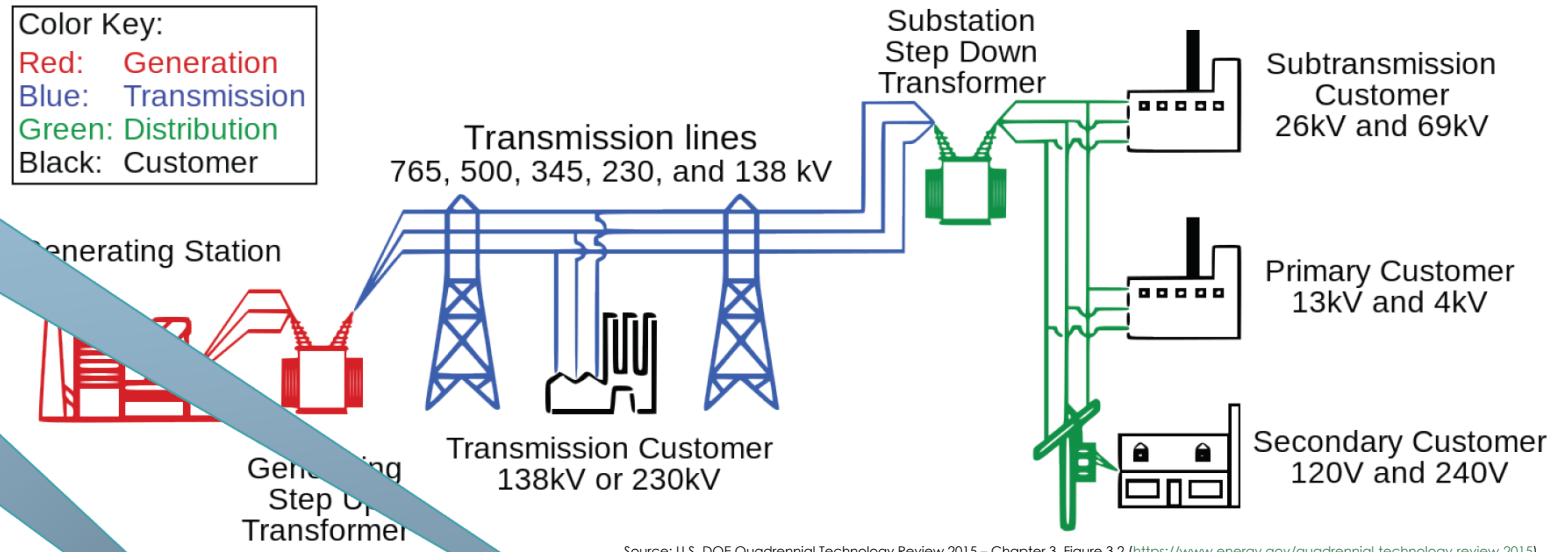
No longer deterministic architecture with pre-known flows

No longer over-provisioned for arbitrary regulations & lack of holistic knowledge

Rely less on experience and intuition and more on computational analytics

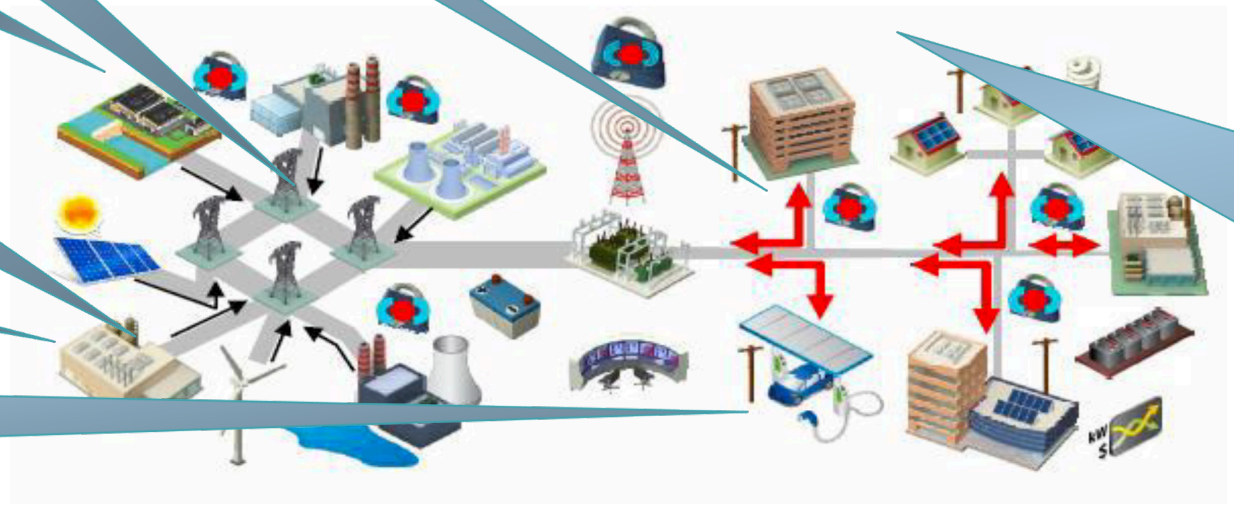
Connections move from hierarchical to peer-to-peer

The Past

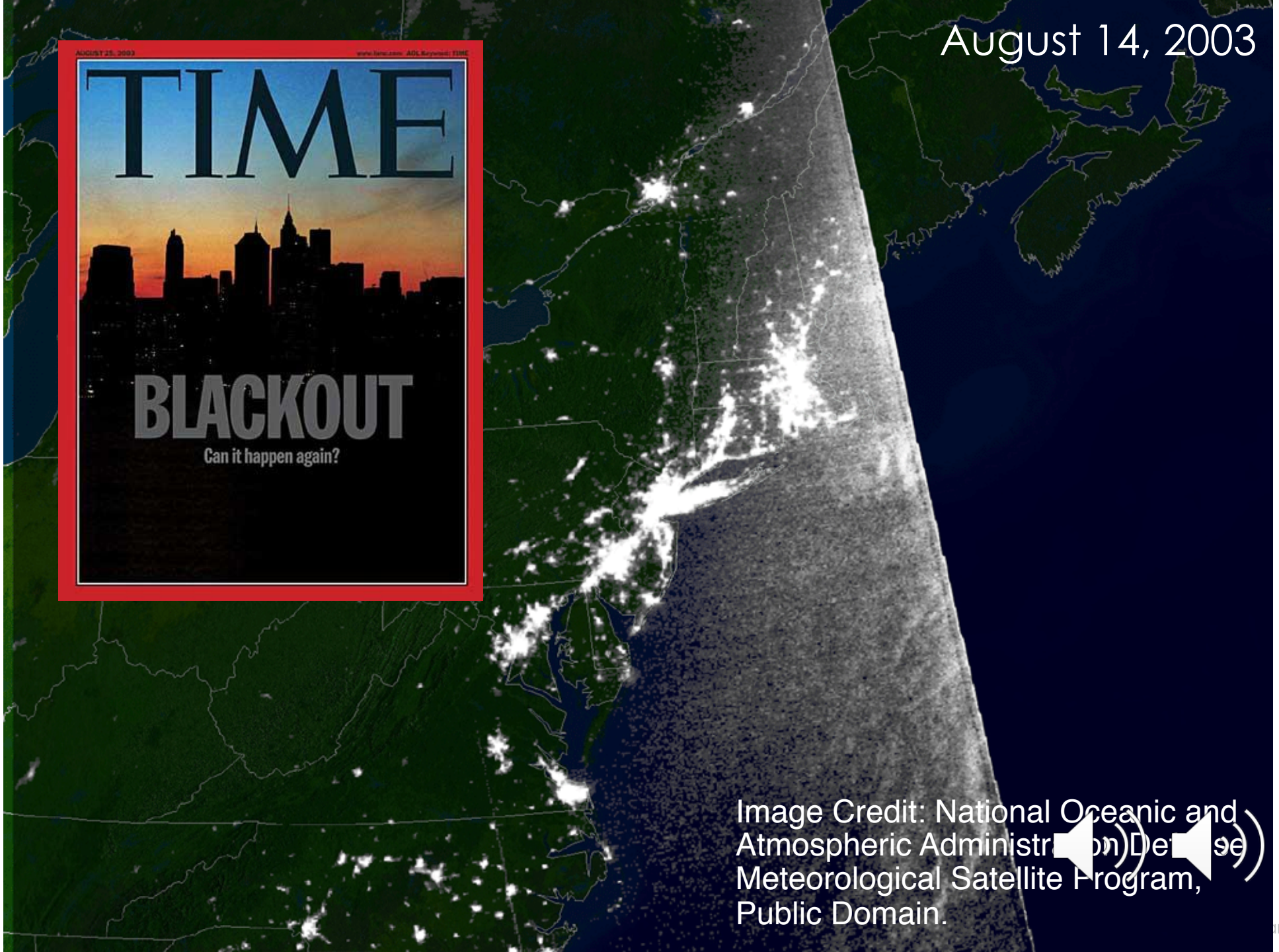


Source: U.S. DOE Quadrennial Technology Review 2015 – Chapter 3, Figure 3.2 (https://www.energy.gov/quadrennial-technology-review-2015)

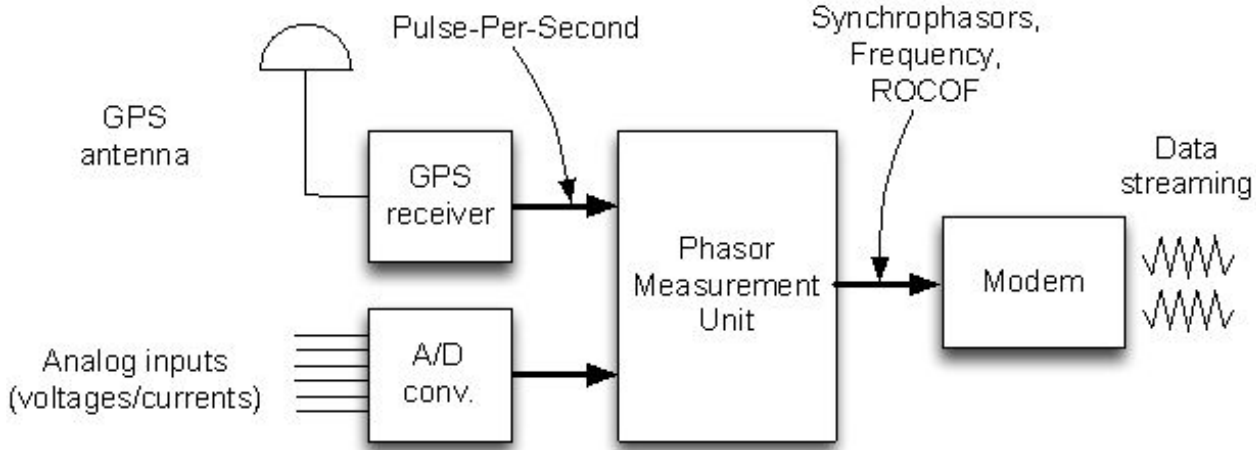
The Future



Scope expanded with inter-connected regions


August 14, 2003
TIME
BLACKOUT
Can it happen again?
Image Credit: National Oceanic and Atmospheric Administration Defense Meteorological Satellite Program, Public Domain.

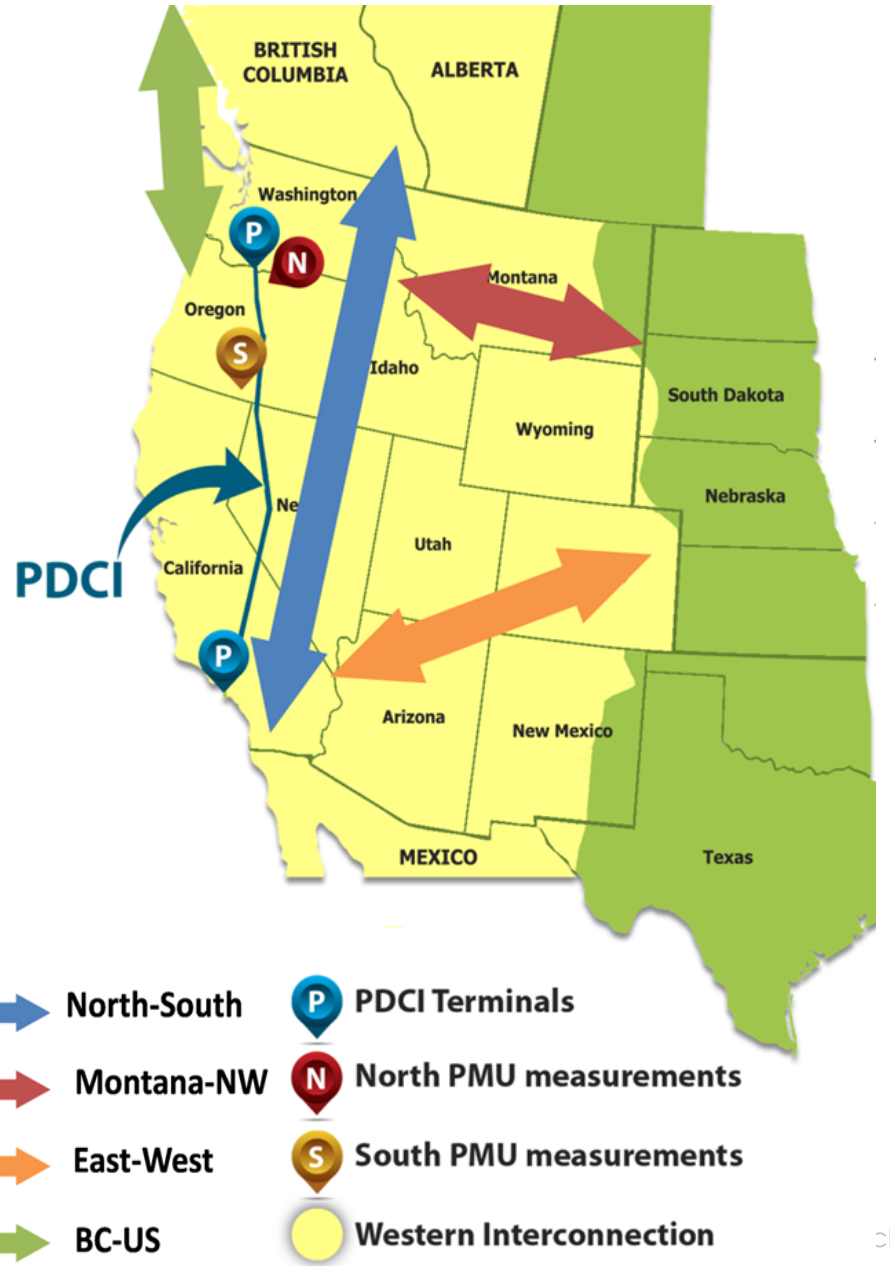
Phasor Measurement Units (PMUs)



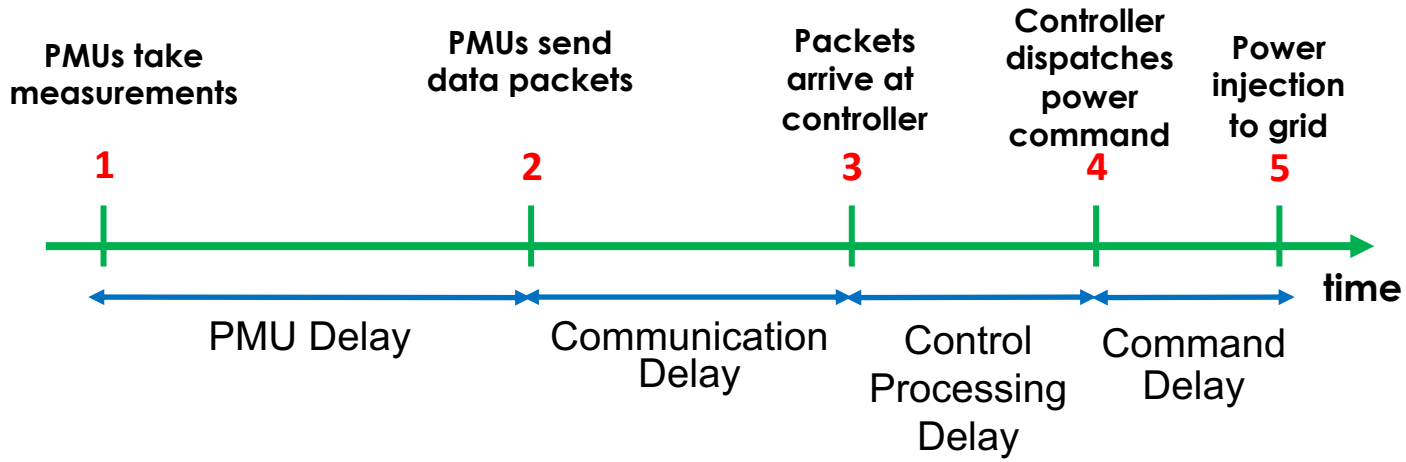
- Prototypes developed at Virginia Tech (Profs. Phadke, Thorp)
- Time-synchronized using GPS
- Stream measurements throughout system providing significant improvements in monitoring and situational awareness on grid
- Measures 50/60 Hz waveform (voltages and currents)
- 60 samples per second (120 samples/sec is now available)

PMU Application: Inter-Area Oscillation Damping Control

- Project launched in 2013 as a collaboration of Sandia, Montana Tech, BPA, and DOE to develop and demonstrate damping control on the North-South oscillatory mode using PMUs for real-time feedback.
- Project successfully demonstrated significantly improved damping on the Western Interconnection.
- Real-time PMU feedback from north and south is the key to stable control.
- GPS vulnerabilities (jamming, spoofing, etc.) can lead to disarming of controller, unstable control (from mis-aligned timestamps), etc.



Communication and Delays

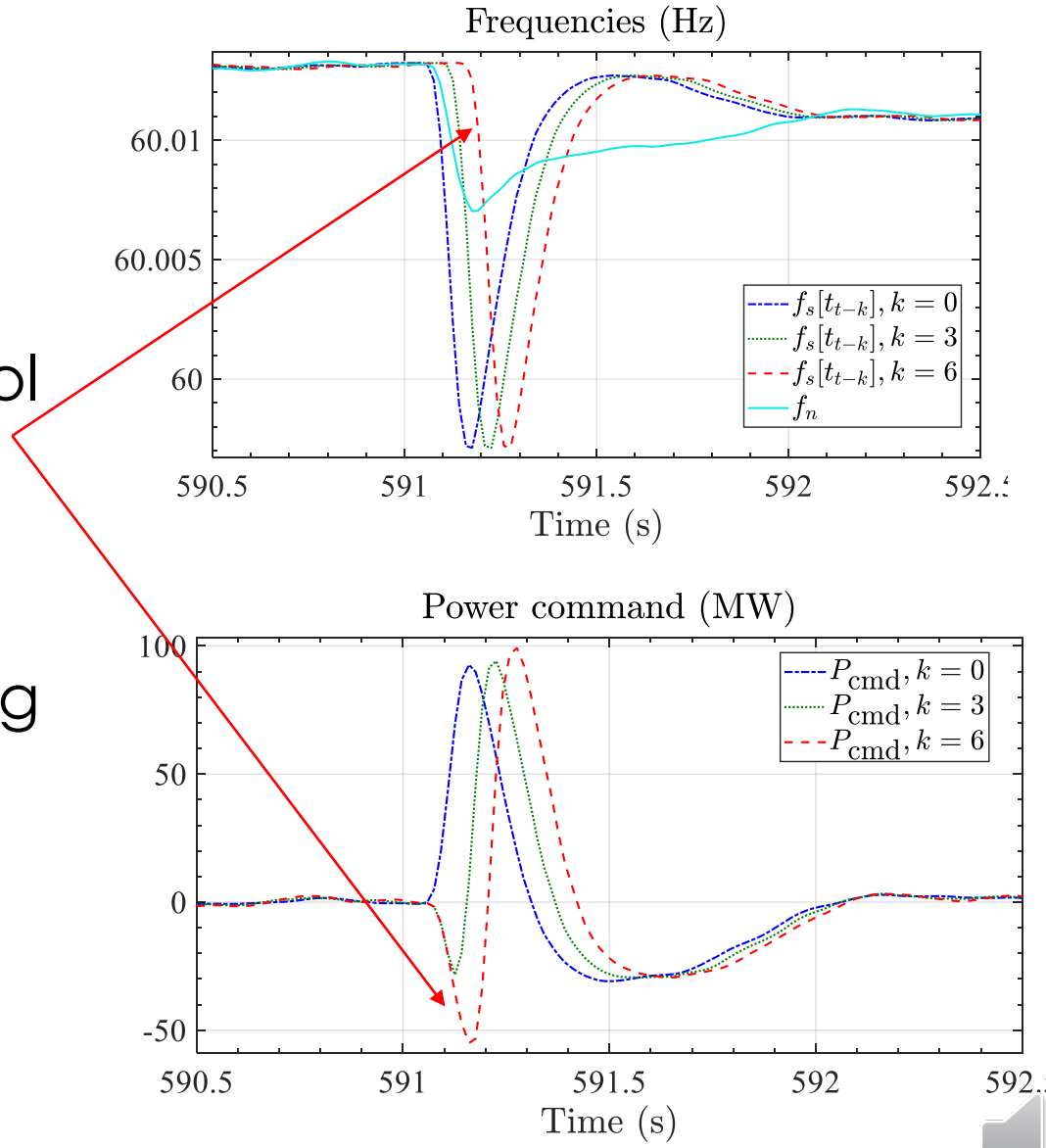


Name	Mean	Range	Note
PMU Delay	44 ms	40 – 48 ms	Dependent on PMU settings. Normal distribution
Communication Delay	16 ms	15 – 40 ms	Heavy tail
Control Processing Delay	11 ms	2 – 17 ms	Normal around 9 ms, but a peak at 16 ms due to control windows when no data arrives (inconsistent data arrival)
Command Delay	11 ms	11 ms	Tests were consistent, fixed at 11 ms
Effective Delay	**82 ms**	**69 – 113 ms**	**Total delay**

Total time delays are well within tolerances (<< 150 ms) for stable control

PMU Data Considerations

- North and South PMU measurements need to have the same timestamp
- Control system time aligns the data
- If data is too far apart in time, the control instance is disabled
- GPS vulnerabilities can lead to delayed data, no data, false data ➔ control instance being disabled, controller being disarmed for extended periods, potentially unstable control, resp.
- Alternative time sources and/or redundant time sources to GPS are needed for robust control



Toward the Future – Alternative Sources to GPS for Timing for Power System Applications

- Alternative GNSS
  - GLONASS, Galileo, BeiDou
  - Alternative frequencies (if possible)
- Terrestrial-based Wireless Approaches
  - eLORAN concept
  - UK's National Timing Centre proposal
- Local/Network Solutions
  - Stable local oscillators/clock sources (Rb/Cs clocks)
  - PTP via mechanisms outlined in IEEE 1588-2019

Toward the Future – Deployment Challenges

- Avoiding new vulnerabilities
  - Accidental/Malicious RF Interference
  - Network Cybersecurity Concerns
- Physical location considerations
- Compatibility with existing equipment
  - Proper Interface
  - Desired precision and accuracy
- Cost

Conclusion

- Wide-area coordination of power system measurements and controls needs precise and accurate timing, but GPS has some inherent flaws
- Multiple robust/reliable sources are needed, especially for applications with controls
- Physical constraints, security, and cybersecurity should be present in the whole evaluation process