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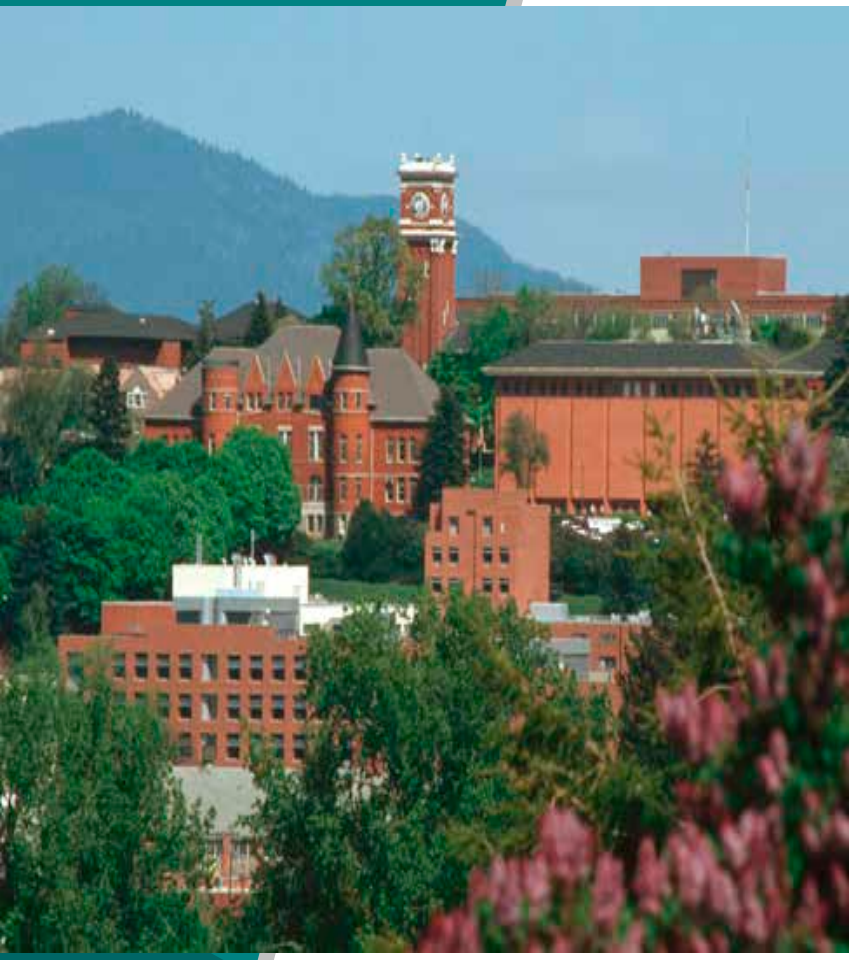

Evolution of Control Centers for the Future Grid

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Washington State University
Pullman, Washington, USA

Grid of the Future Workshop

Albuquerque, NM

August 22, 2018

THE INTERCONNECTED GRID

- **Economics**
  - **Transfer electric energy from areas where it is cheap to where it is expensive. Electricity trading dates back to the beginning**
- **Reliability**
  - **Neighbors can back up each other. The cost of redundancy is shared.**

The Control Center (since 1960s)

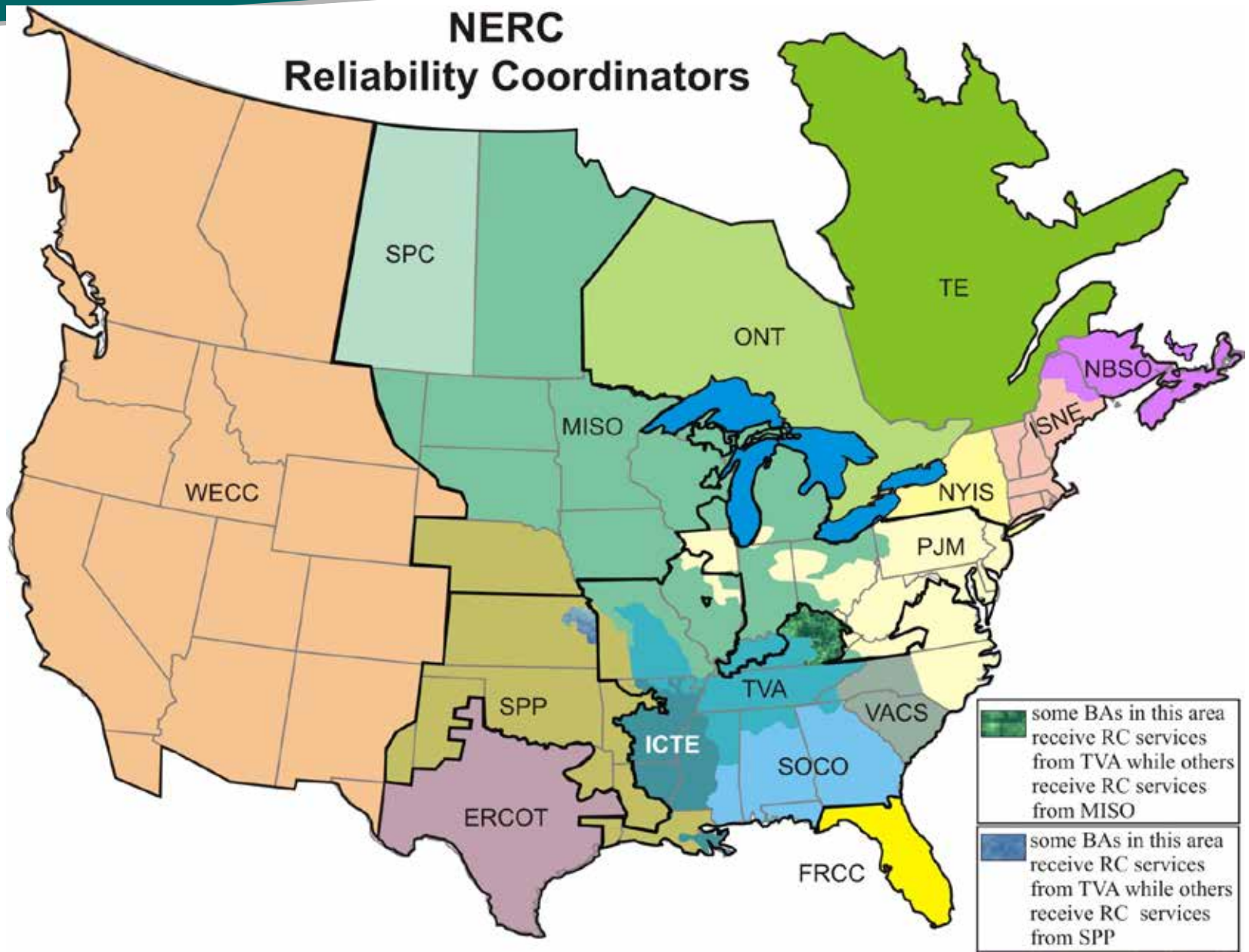
- The digital control center (SCADA-AGC)
- The RTU to gather digital data at substation
- Comm. channel from sub to control center (CC)
- The SCADA
  - § The Data Acquisition from RTU to CC
  - § The Supervisory Control signal from CC to RTU
- The screen based operator display
- Automatic Generation Control (AGC)
  - § The digital algorithm for ED
  - § The digital version of LFC

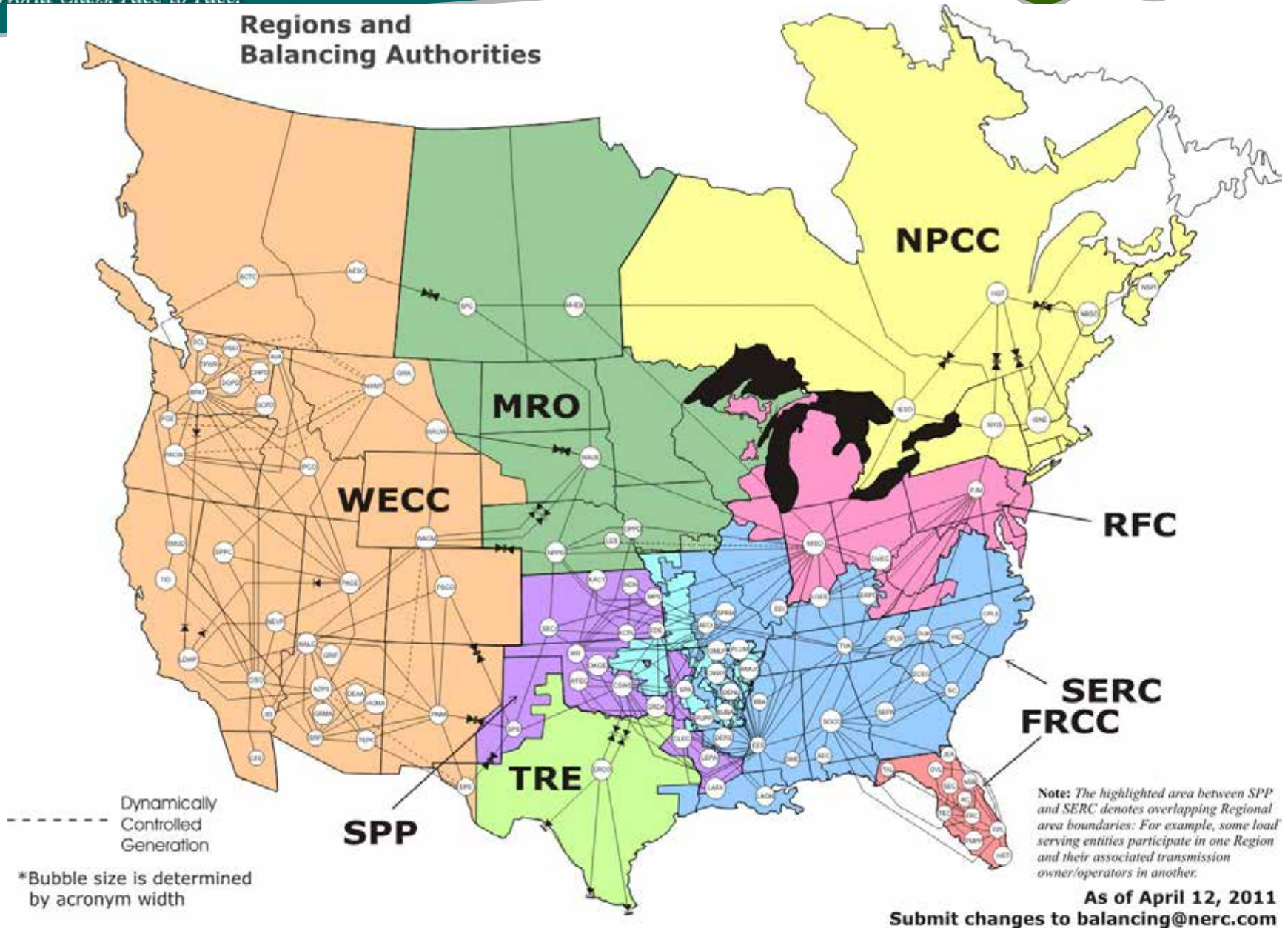
The Control Center (since 1970s) - EMS

- The Energy Management System (EMS)
- State Estimation (SE)
- Static Security Analysis (n-1)
- Dynamic Security Analysis (stability)
  - § Transient, Oscillatory, Voltage
- Optimal Power Flow based analysis
  - § Preventive Action calculation
  - § Corrective Action calculation

Evolution of Control Center Architecture

- Special real time computers for SCADA-AGC
- Mainframe computer back ends for EMS
- Redundant hardware configuration with checkpoint and failover
- Multiple workstation configuration
  - § Back-up is more flexible
- Open architecture initiated
- CIM (Common Information Model) standard


NERC
Reliability Coordinators
SPC
TE
ONT
NBSO
ISNE
MISO
WECC
NYIS
PJM
TVA
SPP
VACS
ICTE
SOCO
ERCOT
FRCC
some BAs in this area receive RC services from TVA while others receive RC services from MISO
some BAs in this area receive RC services from TVA while others receive RC services from SPP


Regions and
Balancing Authorities
NPCC
MRO
WECC
RFC
SERC
FRCC
TRE
SPP
Dynamically
Controlled
Generation
*Bubble size is determined
by acronym width
Note: The highlighted area between SPP and SERC denotes overlapping Regional area boundaries: For example, some load serving entities participate in one Region and their associated transmission owner/operators in another.
As of April 12, 2011
Submit changes to balancing@nerc.com

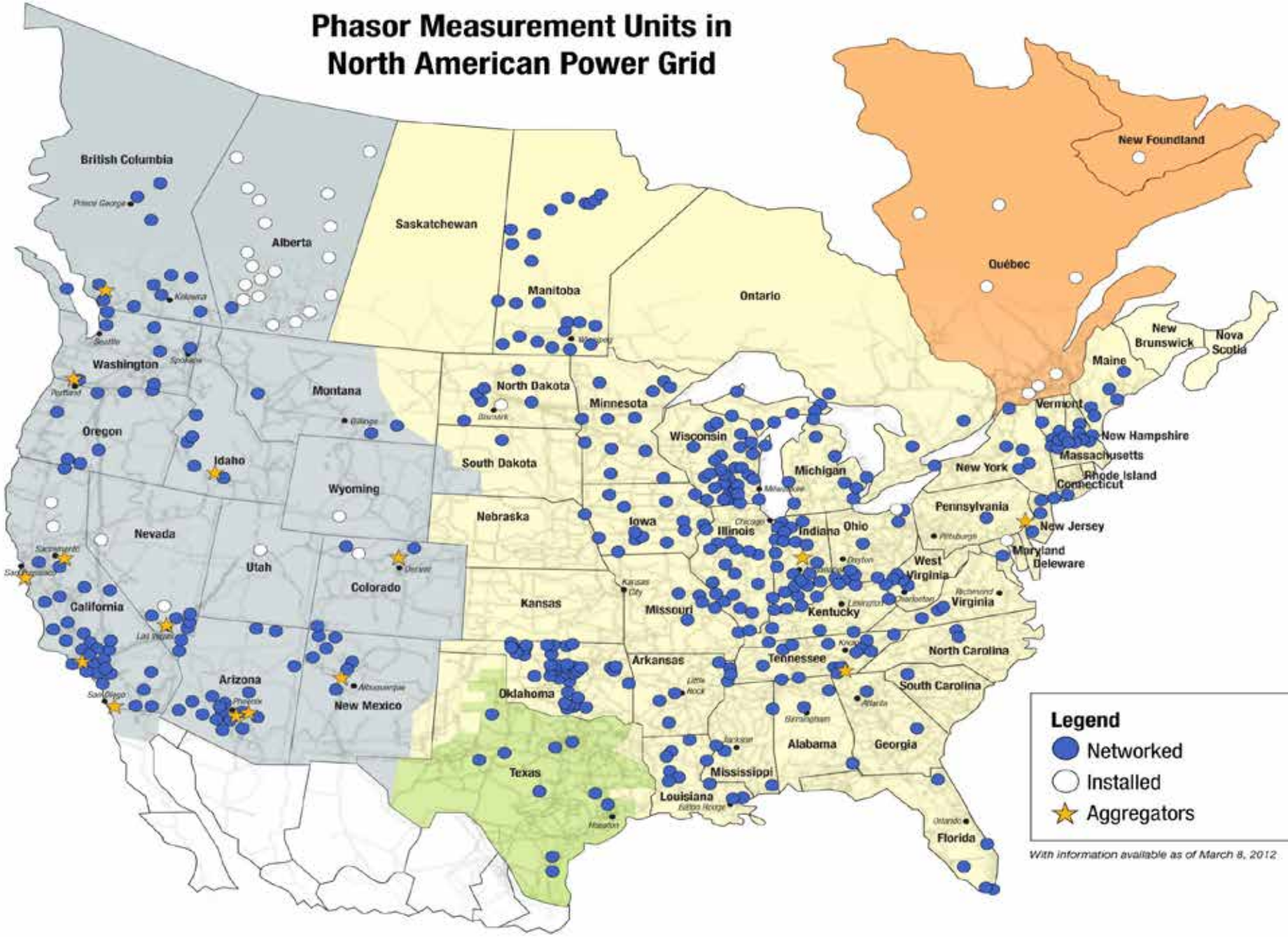
Phasor Measurement Units

- Measurements at substations are now handled by microprocessors
- Measurements can be sampled at very high rates
- Measurements can be time-stamped by satellite

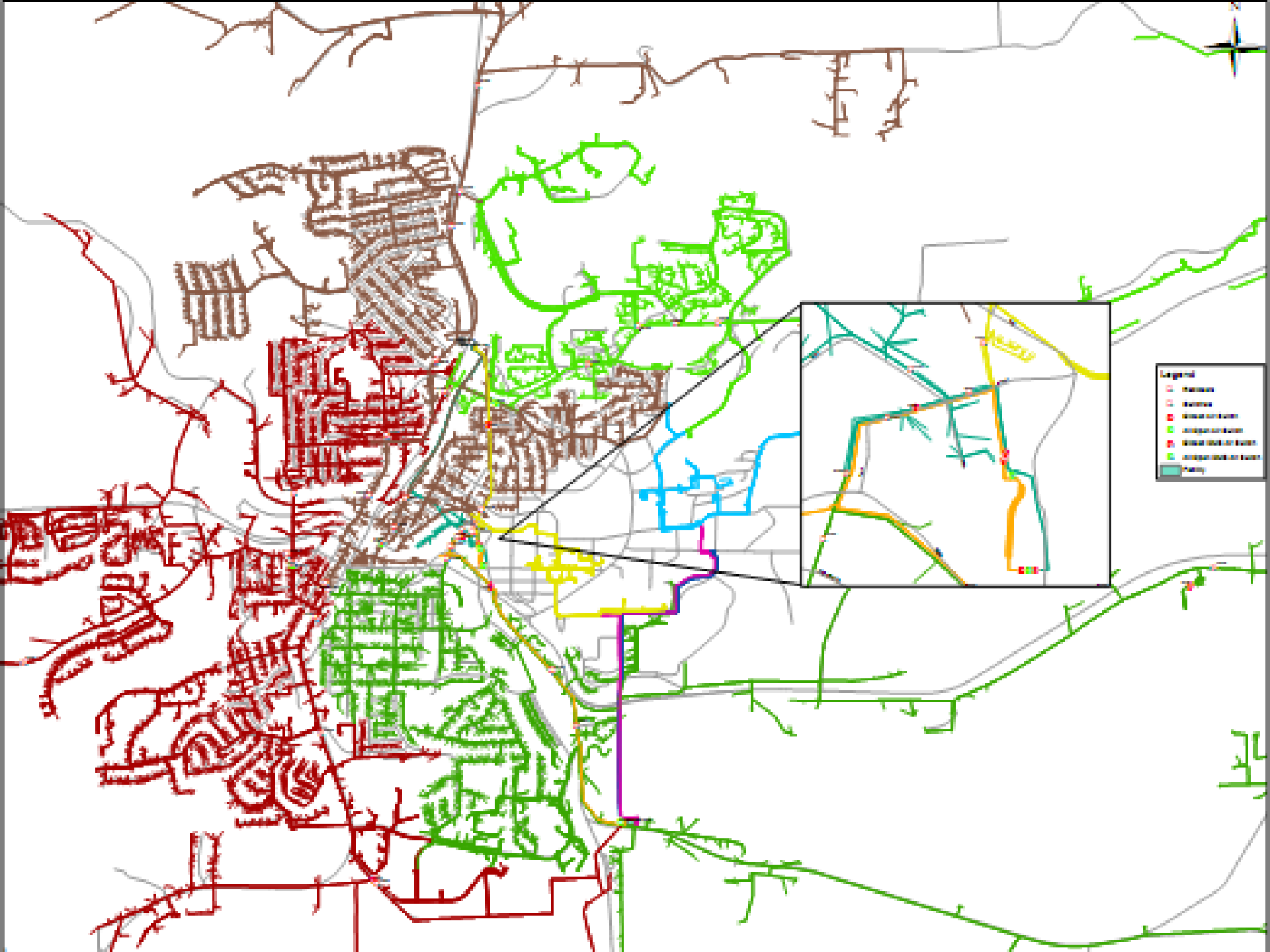
Measure magnitude and phase angle (PMU)

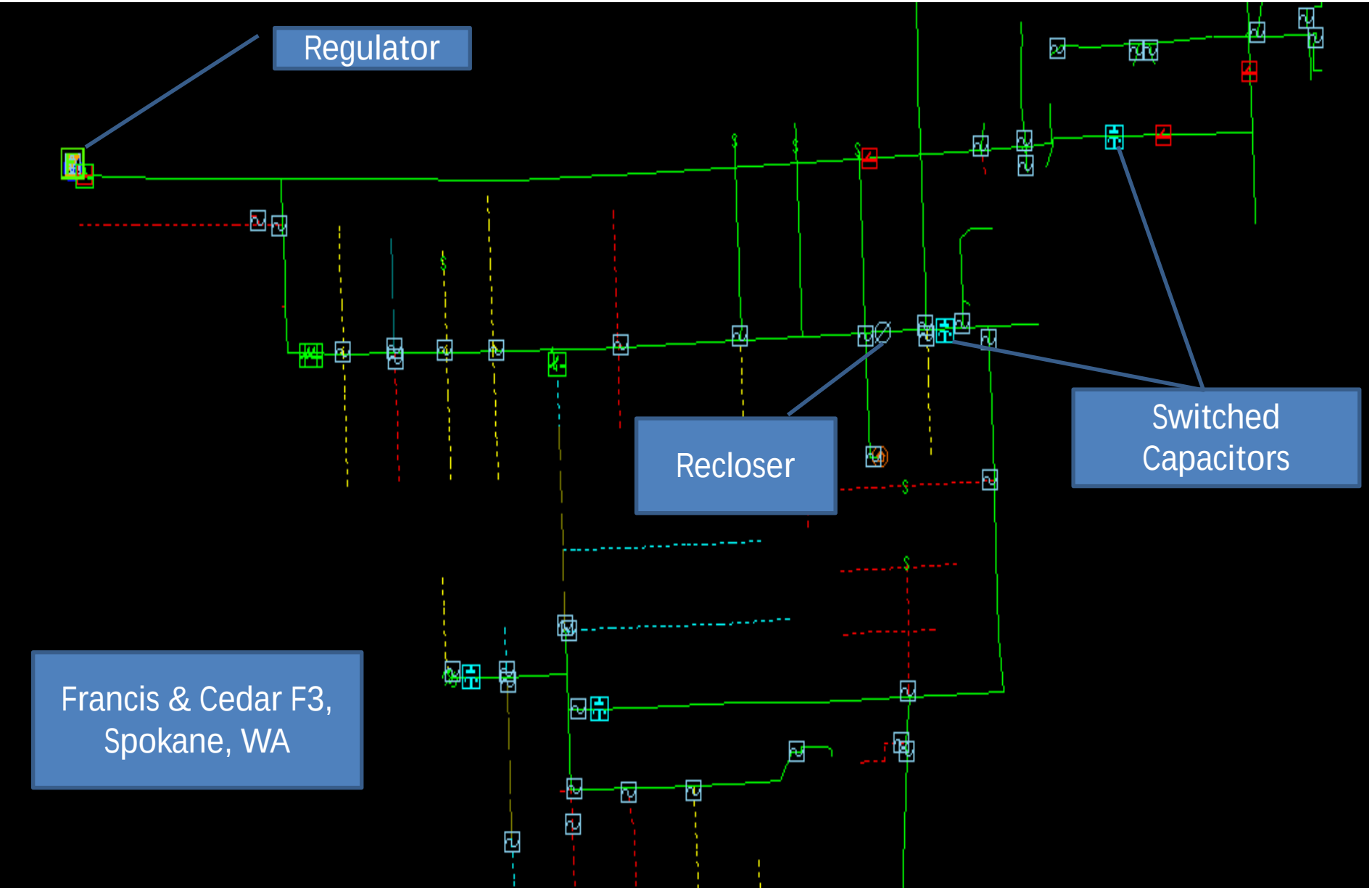
- PMU output rates: 30-120 per second
- Data rates for control centers will increase by 2-3 magnitudes

Phasor Measurement Units in North American Power Grid



With information available as of March 8, 2012




Regulator
Recloser
Switched Capacitors
Francis & Cedar F3, Spokane, WA

DISTRIBUTION MANAGEMENT SYSTEM

- Measurements along the feeder
- Switches, transformer taps, shunt capacitor and inductor controls
- Communications: Radio, Power Line Carrier, Fiber backhaul
- Closer voltage control increases efficiency
- Greater switching ability increases reliability
- Better coordination with outage management
- Sets up for distributed generation, demand response, electric vehicles or local storage

Distribution Applications

- **Integrated Volt-Var Control (IVVC)**
  - § **Use remote control of transformer taps and capacitor banks**
  - § **Minimize losses**
- **Conservation Voltage Reduction (CVR)**
  - § **Minimize voltage to reduce load**
- **Remote control of sectionalizers for reconfiguration around faults**
  - § **Minimize outage of customers**

Distributed Energy Resource Management Systems

- Relatively new function not very well defined
- Refers mainly to generation on the other side of the utility meter
- Mostly used today for demand response - Enables industrial customers to participate in that market
- Could enable aggregation of residential resources like solar (or other loads like water heaters)

Advanced Metering Infrastructure

- **Smart Meters**
  - § **Gateway between utility and customer**
  - § **Communication to utility and home appliances**
  - § **Time-of-day and real-time rates**
- **Applications**
  - § **Optimize energy efficiency and energy cost**
  - § **Demand response**
  - § **Can integrate generation (roof PV), storage (EV)**
- **Microgrids**

Substation Automation

- Many substations have
  - § Microprocessor based devices (IED)
  - § Data acquisition at faster rates (30-60 Hz)
  - § Digital protection and control systems
  - § Remote setting capabilities
- Data can be time-stamped by satellite
  - § Measure magnitude and phase angle (PMU)
- Local Area Network to control room (LAN)
- New substation applications

Geographic Information System

- GIS is getting more integrated into all aspects of system operations, especially
  - § Distribution management
  - § Outage management
- This has been helpful in other applications like Crew Management, Distribution Planning, etc

Customer Applications

- **Large customers can play the market**
  - § **Demand response**
  - § **Optimize consumption by rescheduling heating-cooling-large equipment**
  - § **Optimize solar, electric vehicles, other storage**
- **Smaller customers have less opportunities**
  - § **Time-of-day or real-time pricing**
  - § **Neighborhood microgrid**

Outage Management System

- The computerization of Outage Management has made huge strides
- Requires less people to handle customer calls
- Requires less people to do crew dispatching
- Time savings are significant

Building Automation

- **Smart Meters**
  - § **Gateway between utility and customer**
  - § **Utility can send price signals or control signals**
  - § **Change rates (in real time?)**
  - § **Control appliances (especially heating/cooling)**
- **Customer Applications**
  - § **Optimize energy efficiency and energy cost**
  - § **Demand response**
  - § **Can integrate generation (roof PV), storage (EV)**
- **Microgrids**

Some Observations

- Smart grid is developing piecemeal – A holistic systems approach is needed for operating the grid
- The systems approach will have to be driven by utilities – and regulators of reliability/resiliency
- The technologies – sensors, computers, communications, controllers - are all available, the system vision is not there
- R&D is needed with a clear path towards implementation
- Institutional policies updated to encourage technological solutions to meet goals