Introduction to Grid Sensing & Communications

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What is Sensing and Measurement?

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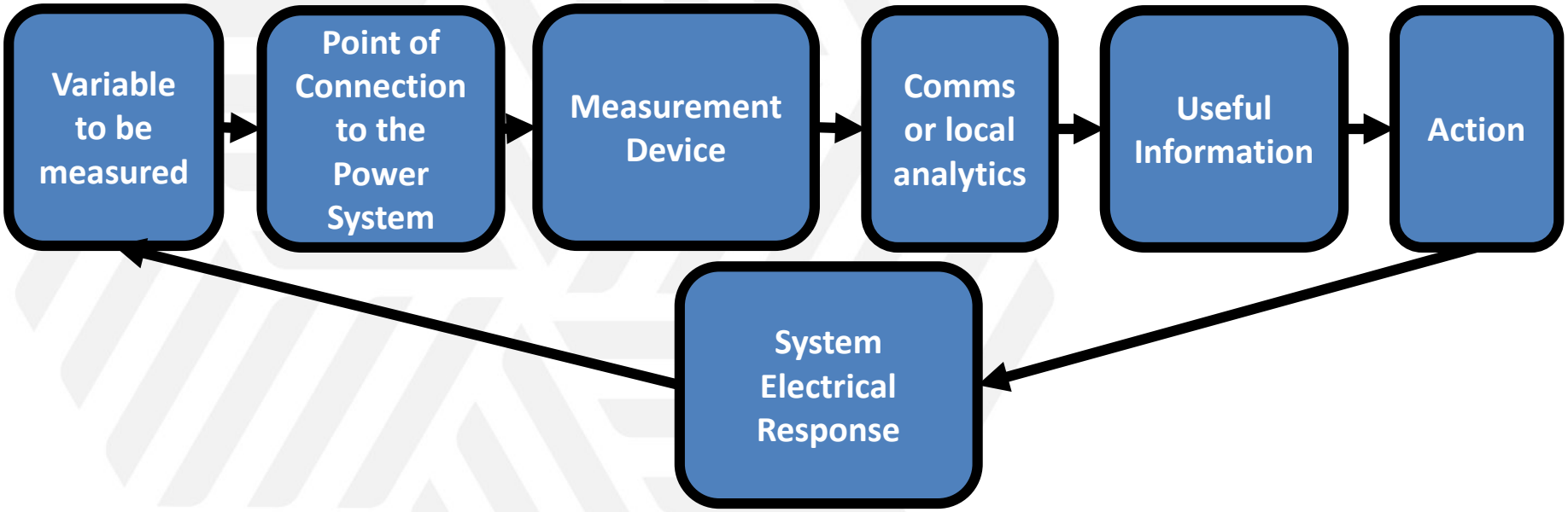
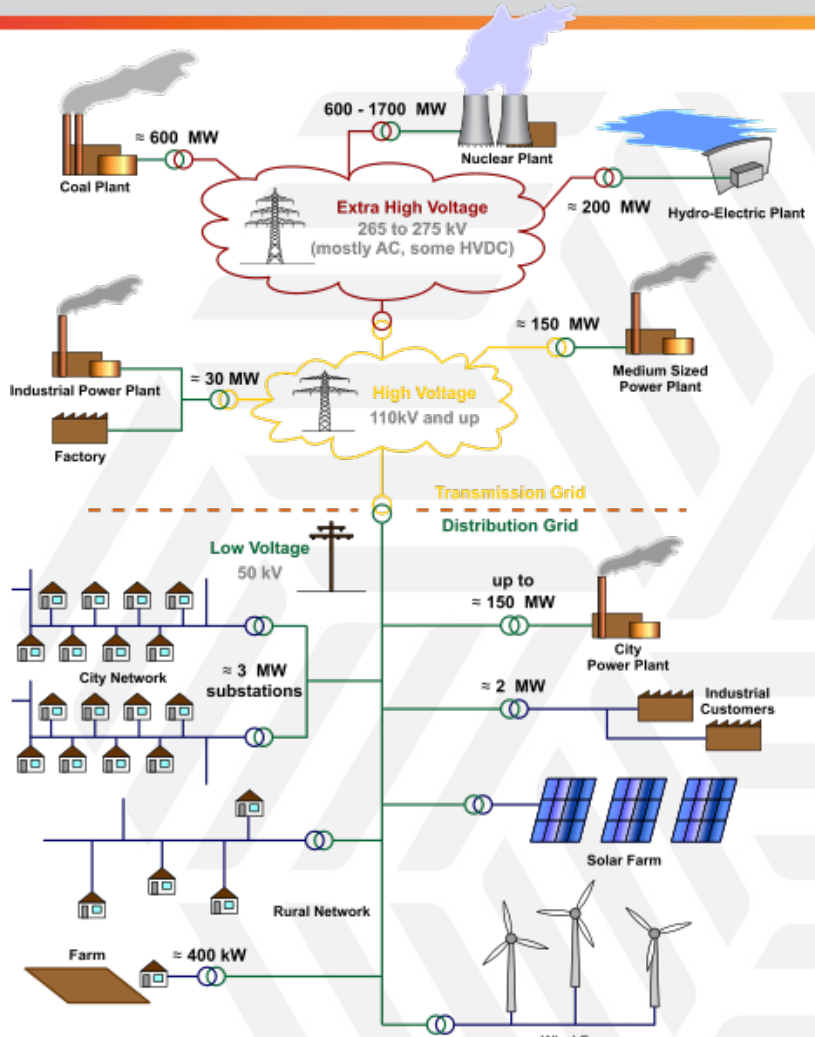


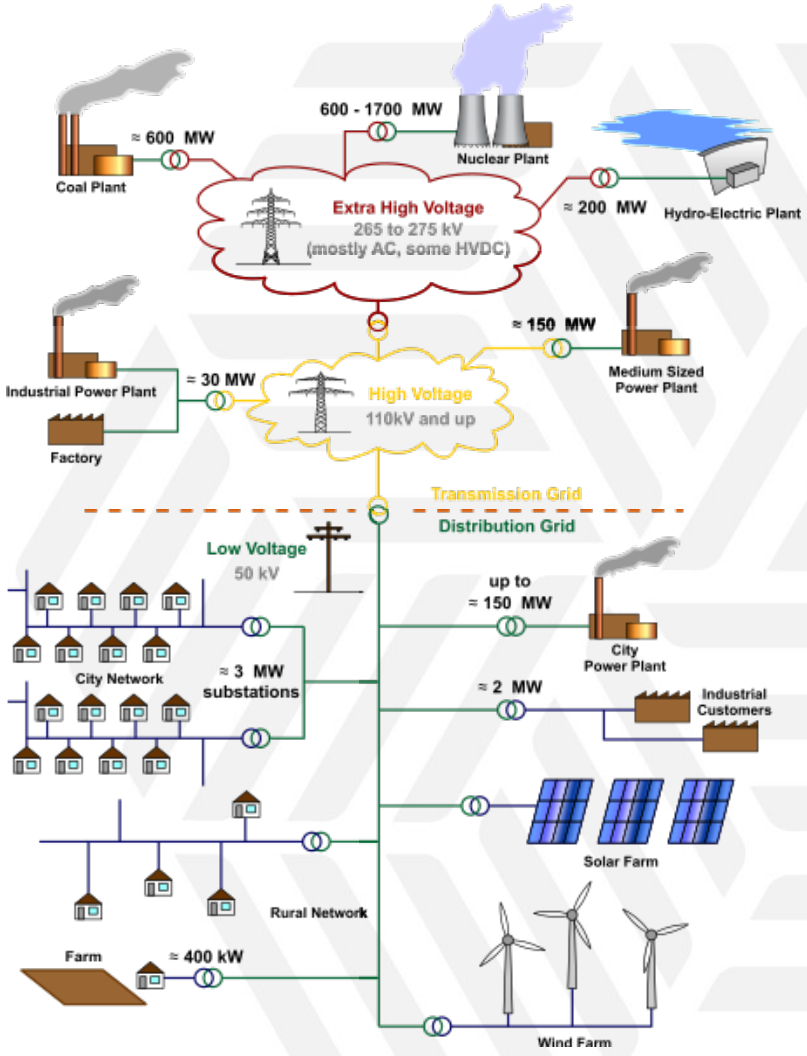
Communications are critical to many functions of the grid



https://commons.wikimedia.org/wiki/File:Electricity_Grid_Schematic_English.svg

- Telecom networks support:
  - Real-time monitoring and control
  - Protective relays
  - Energy management
  - Outage management
  - Smart meter communications
  - Substation automation
- Utilities rely on both public and private communications networks
  - Telco fiber lines could be widely used as “dedicated to utilities”
  - Utilities also can purchase private communications networks

Different communications media are used throughout the grid



Generation

- Wireless and radio networks are used to transmit control and monitoring messages within plants
- Cell, POTS (plain old telephone service), and fiber are used to transmit messages between plants

Transmission

- Power lines can be used to transmit information – power line carrier
- Substations use radio and wireless within substations and microwave between substations
- Land mobile radios and satellite phones are used during restoration and repair

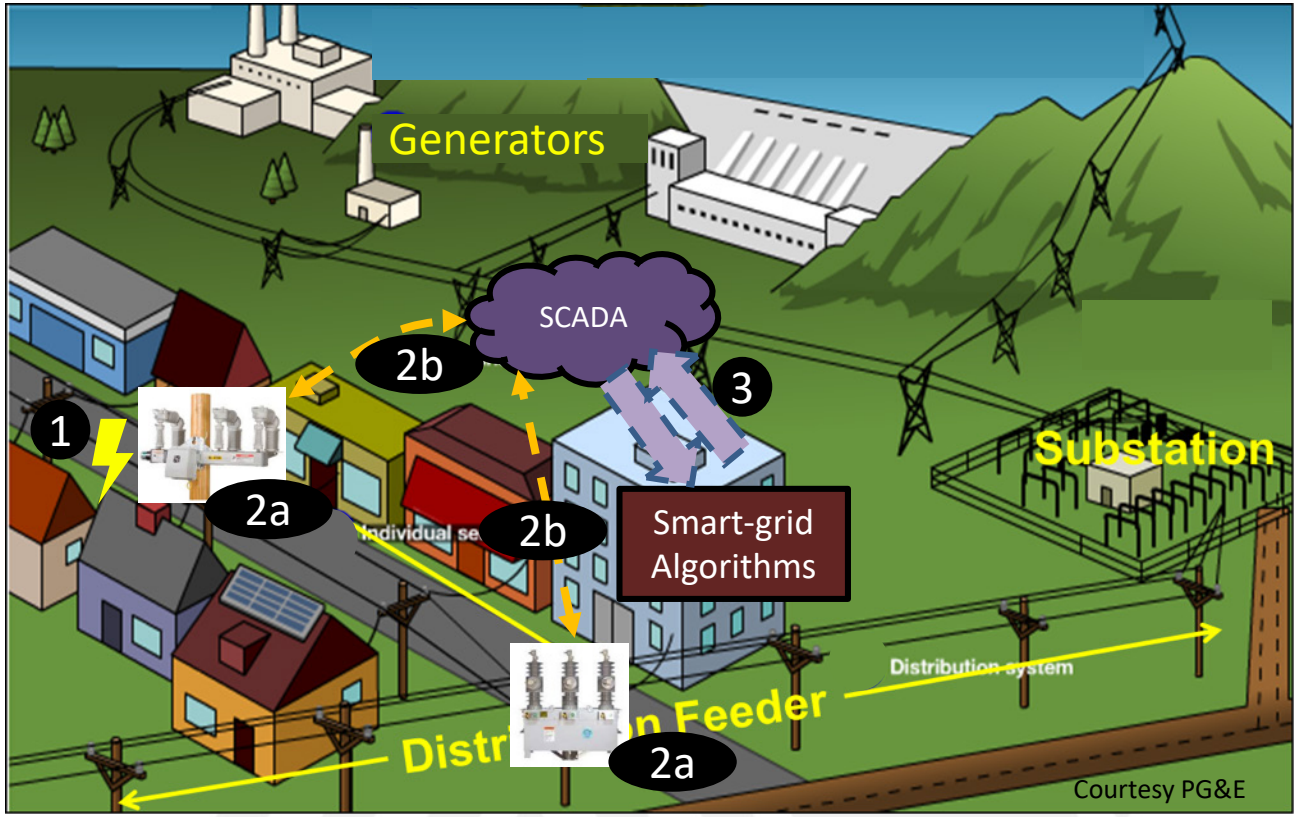
Distribution

- Some fiber used for controlling loads, but is generally expensive to run
- Microwave links, land mobile radio, and satellite phones are used

Smart Grid Communications

- For smart meter networks and control of distributed generation, wireless mesh networks can be formed

Interdependencies in smart grid communications



- Interdependencies complicate mitigation of electrical faults through Distribution Automation devices
- Utility primarily relies on DA devices to detect/isolate faults
  - Local operation
  - Remote operation
- If we have communications issues, we can't send operational commands to devices

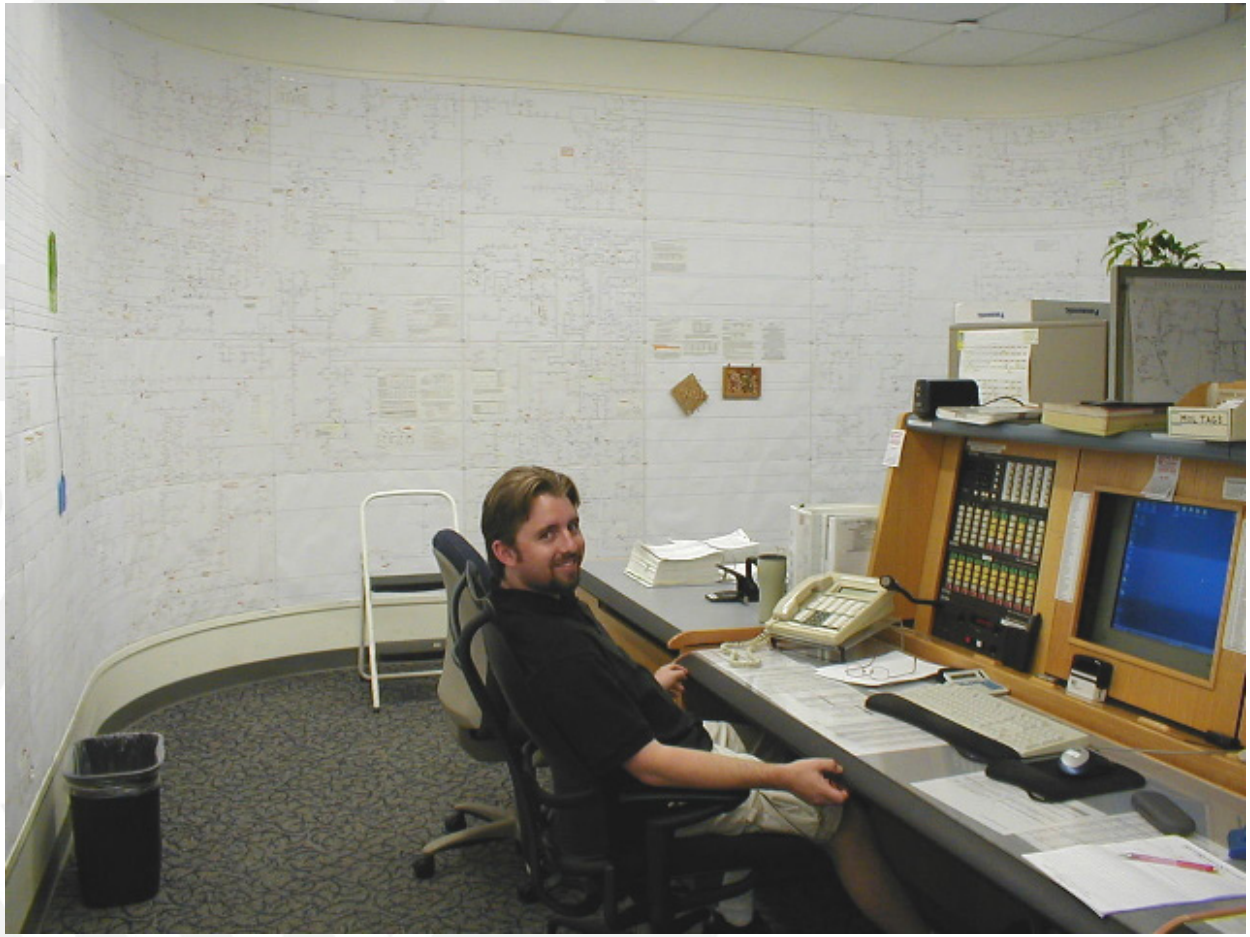
1 Fault occurs

2a Lack of power inhibits DA devices operation, or

2b Communication networks fail

3 Remote switch operations prevented

Expectation versus Reality



Time scales of measurement and operations are diverse

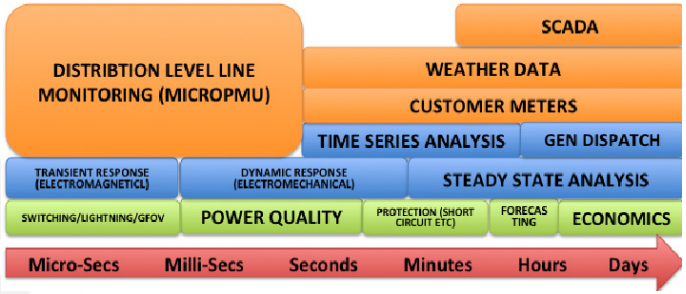
Key Questions for both research and industry

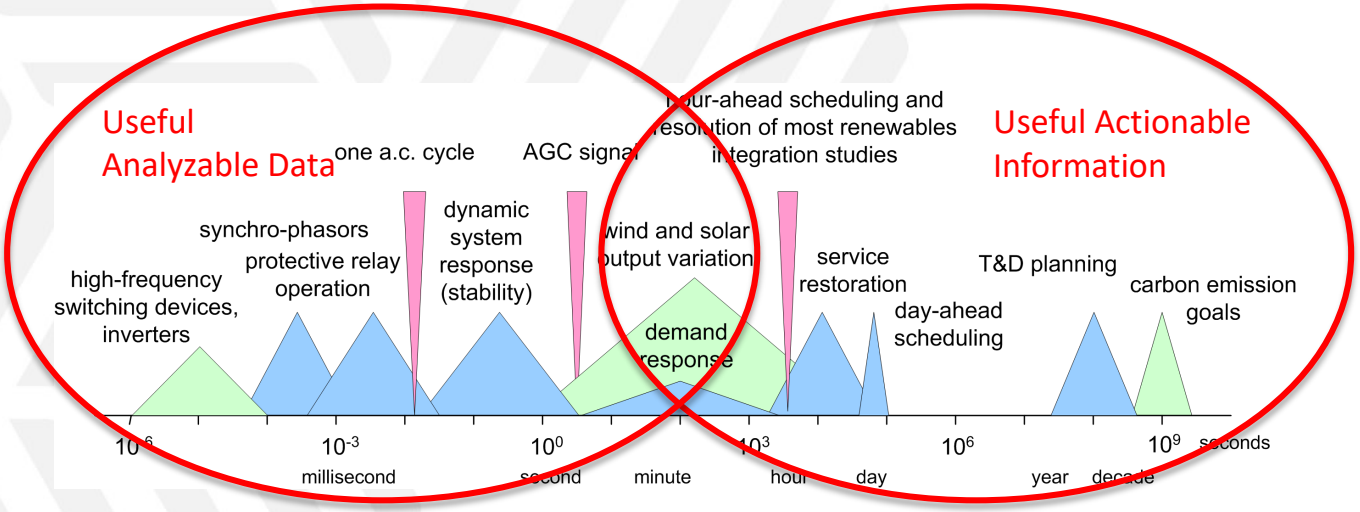
What measurements do we need?

Where do we need the measurement and analytics?

Who needs the information?

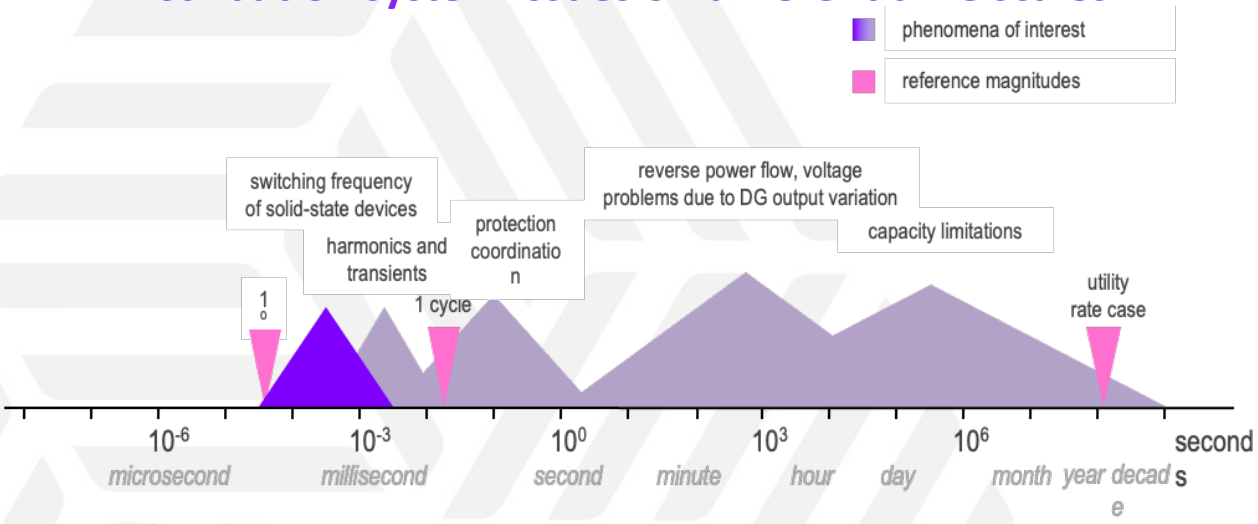
When and how do they need it?



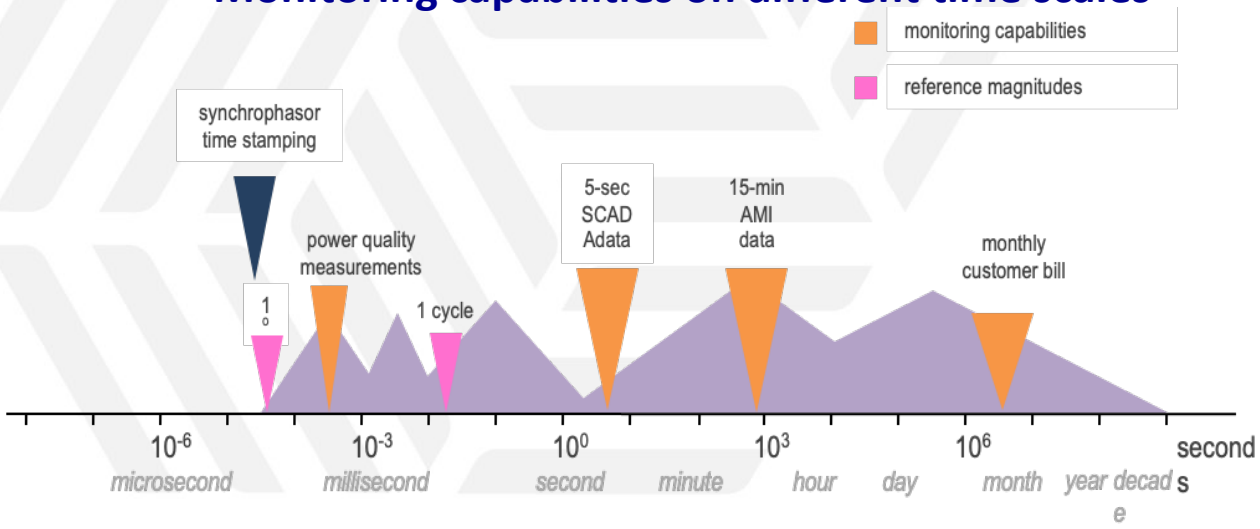


Events versus Measurement

Distribution system issues on different time scales



Monitoring capabilities on different time scales



Supervisory Control and Data Acquisition (SCADA) Components

Sensors: instruments measuring physical quantities (current, voltage)

Remote terminal units (**RTUs**): perform analog-to-digital "A to D" conversion of sensor signals; may include basic control capability

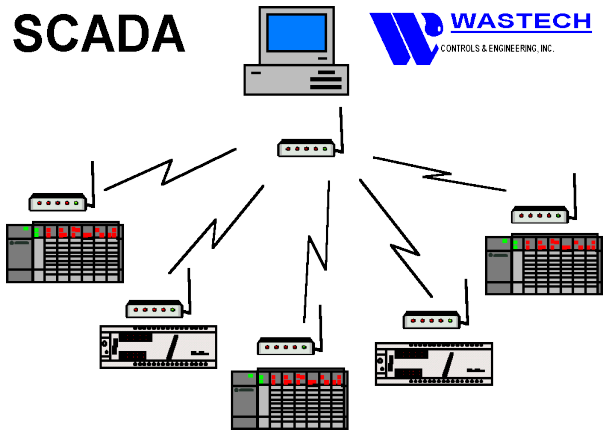
Programmable Logic Controllers (**PLCs**): similar to RTUs, more sophisticated controls

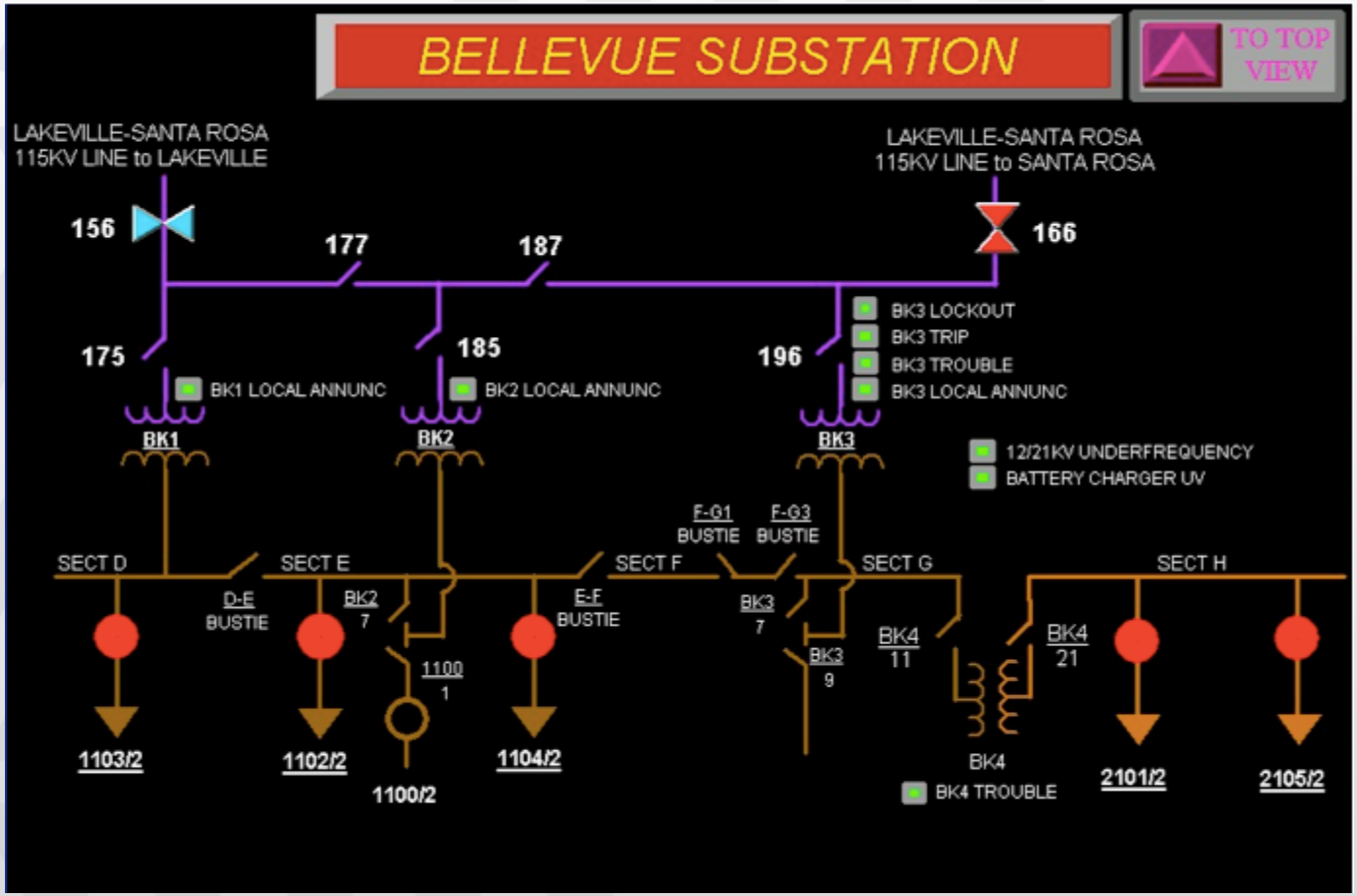
Telemetry: provides connection for signals between field devices and control center, using some **physical communication layers** (telephone wires, radio, satellite, microwave, 3G wireless)

Data Acquisition Server: manages data from field devices

Data Historian: stores data

Human-machine interface (HMI): client for data from server; presents to operator; may receive control inputs from human operator




BELLEVUE SUBSTATION
TO TOP VIEW
LAKEVILLE-SANTA ROSA
115KV LINE to LAKEVILLE
LAKEVILLE-SANTA ROSA
115KV LINE to SANTA ROSA
156
177
187
166
175
185
196
BK1 LOCAL ANNUNC
BK2 LOCAL ANNUNC
BK3 LOCKOUT
BK3 TRIP
BK3 TROUBLE
BK3 LOCAL ANNUNC
BK1
BK2
BK3
12/21KV UNDERFREQUENCY
BATTERY CHARGER UV
F-G1 BUSTIE
F-G3 BUSTIE
SECT D
SECT E
SECT F
SECT G
SECT H
D-E BUSTIE
BK2 7
E-F BUSTIE
BK3 7
BK3 9
BK4 11
BK4 21
1100 1
1103/2
1102/2
1100/2
1104/2
BK4
BK4 TROUBLE
2101/2
2105/2

Smart Meters

Primary purpose: Settlement
(time-differentiated meter reading)

Secondary purpose:
identify outages
other operations support

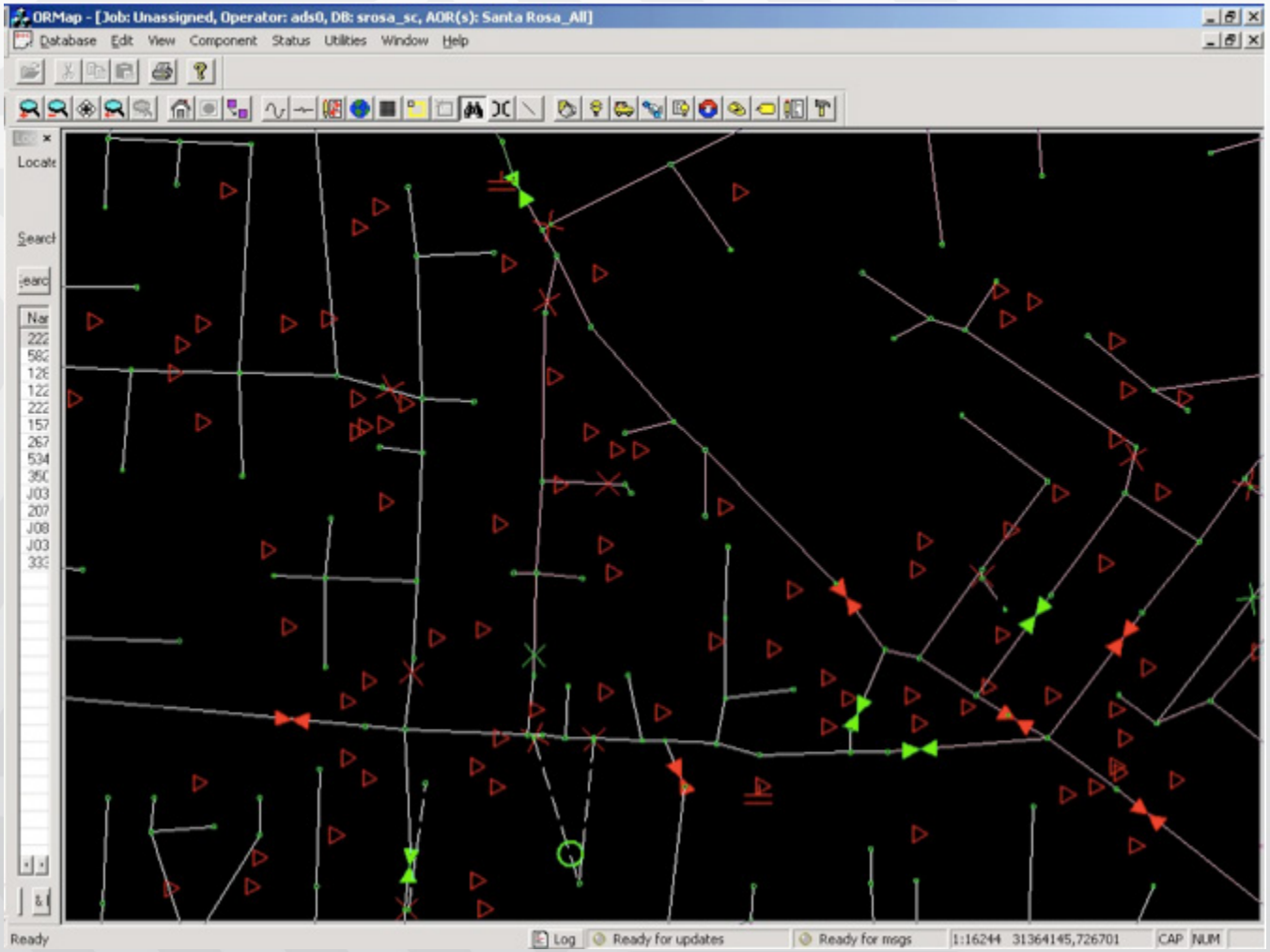
Typical activity:

record kWh usage, voltage at 15-min intervals
report 8 hrs worth of 15-min kWh data to access point 3x per day
send “death chirp” in case of outage

Headroom on communications network allows querying subset of meters for some additional data, reported within minutes

Automated Meter Reading (AMR): one-way communication
Advanced Metering Infrastructure (AMI): two-way communication

- not enough resolution to observe short-term power variations
- typically do not report voltage (although it is sensed)
- data may not be provided in real-time
- data may be provided only to billing department, not operations
- most likely early operational application: fault location, isolation and service restoration (FLISR)



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Restoration Spatial View Overview

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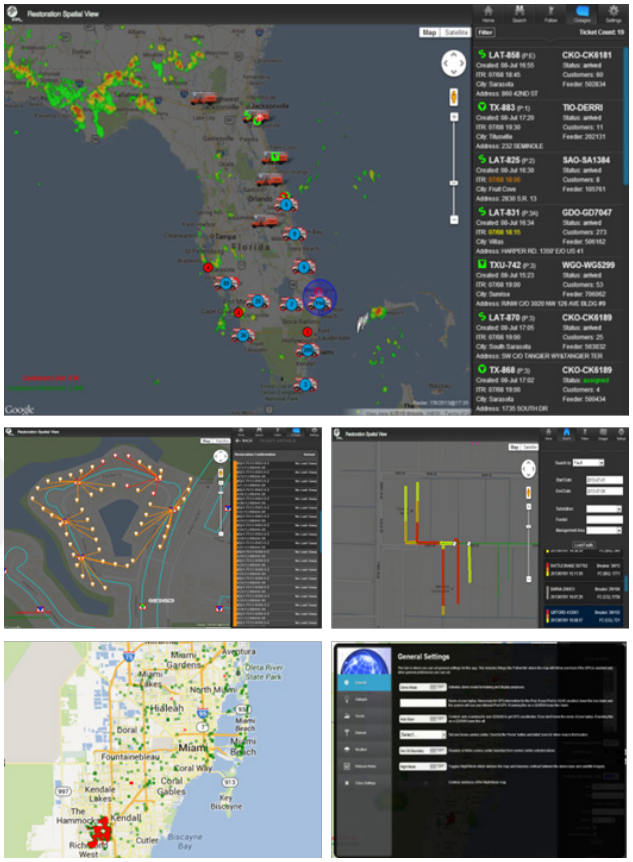
RSV 2.0 – State of the art mobile application placing the smart grid in the hands of our crews

- Customer Information
- Trouble Tickets
- Truck Locations
  - FPL, Vegetation and External Crews during Storm (pilot)
- Weather
  - Radar
  - Real-time lightning within 100-mile radius
  - Weather Station
  - Storm information (Tracks/Development Areas)
  - Customized weather alerts based on location
- Street View & Driving Directions
- Restoration Confirmation
- Fault Location (DMS/SynerGEE)
- Device detail, including drawings
- Real-time AMI outage activity
- Fully customizable by user



FPL

The goal is to have a single application giving our crews everything they need to restore power safely and efficiently

Further Reading

- http://gridarchitecture.pnnl.gov
- https://gmlc.doe.gov/projects/1.4.09
- https://www.osti.gov/scitech/biblio/1353149
- https://www.osti.gov/biblio/1136774-software-based-barriers-integration-renewables-future-distribution-grid

Backup Material

Common Sensor Types

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Sensor Type	Description
faulted circuit indicator	Provides a binary indication of the passage of a fault current (based on magnitude) past the sensing point.
line sensor	Typically sample voltage and/or current and provide various derived quantities, such as RMS volts and/or amps, real and reactive power, power factor, a small number of harmonics of voltage or current, and THD. Transducers may be electrical, magnetic, or optical.
PMU	Phasor measurement unit – provides voltage and current synchrophasors; may also provide line frequency and power flows.
partial discharge	Detects and counts arcing partial discharges in power transformers
cable tan delta	Measures phase shift on cable insulation
line temperature	Measures temperature distributions on power lines - typically done with fiber optics.
residential meter	In addition to usage (energy), may measure secondary voltage; may record data on voltage sags as measured on the secondary at the premise; a few also record real and reactive power and power quality measures such as voltage Total Harmonic Distortion (THD)
Commercial and Industrial (C&I) meter	In addition to usage (energy), measures secondary voltage and current, computes real and reactive power, THD and a variety of other configurable quantities; may capture power waveforms on a trigger basis for later retrieval
feeder meter	Provides meter quality measurement of feeder primary quantities, including voltage, current; real and reactive power

Courtesy of Jeff Taft - PNNL

Common Grid Devices with Sensing Capability

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Device	Sensing capability
switch controller	Measure voltage, may record peak fault currents
capacitor controller	Measure voltage, may record peak fault currents, may compute real and reactive power
recloser controller	Measure voltage, may record peak fault currents
voltage regulator	Measures line voltage
substation IED's (microprocessor relays)	Can take transducer inputs for voltage and current directly; can compute many derived values, including real and reactive power, phasors, THD, power factor, etc; also act as a gateway for other kinds of measurements, such as oil temperature, partial discharge data, etc

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Relevant Building Sensors

Device	Sensing capability
Smart Metering	RMS voltage and current and power flow at whole building level
Solar	Irradiance and kWh generated
Thermal Comfort	Dry bulb air temperature
Occupancy	Measures presence and number of people based on IR or sound or both

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