Micro-synchrophasors (µPMUs) in Electric Power Distribution Systems
5/29/15 SF PES Chapter Workshop

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Micro-synchrophasors (µPMUs) for Distribution Systems

Three-year, $4.4 M ARPA-e project started April, 2013

Research partners CIEE, UC Berkeley, Lawrence Berkeley National Lab, Power Standards Lab

Objective: Explore the value and applications for high-resolution measurements of voltage phasors across distribution systems

Key: cross-referencing simultaneous, high-precision measurements at separate locations, using GPS time stamps

- GPS time stamp: differential absolute
- Instrument sampling rate 512/cycle
- Phasor measurements reported 120/sec
- SCADA measurements

Clock accuracy:
- Nanosecond: $10^{-9}$
- Microsecond: $10^{-6}$
- Millisecond: $10^{-3}$
- Time scale in sec: 1

Voltage phase angle (timing) in degrees

Voltage magnitude
Monitoring of the power system exists at high-voltage and at customer level, with a significant gap at the medium-voltage distribution level.

Typical instrumentation: SCADA (Supervisory Control and Data Acquisition) at the transmission level, down to substation.

Smart meters and devices at building level.
Distribution Synchrophasor network concept: Create observability and transparency for medium-voltage circuits to support integration of distributed resources.

Synchrophasors (PMUs) already increasingly being deployed on transmission systems.

Micro-synchrophasor (μPMU) network for distribution.
General Project Objectives

- develop a network of high-precision phasor measurement units (µPMUs) to measure voltage phase angle to within 0.01°
- understand the value of voltage phase angle as a state variable on power distribution systems
- explore applications of µPMU data for distribution systems to improve operations, increase reliability, and enable integration of renewables and other distributed resources
- evaluate the requirements for µPMU data to support specific diagnostic and control applications:
  - topology detection
  - state estimation
  - fault location
  - dynamic characterization (load, DG, oscillations)
  - volt-VAR optimization
  - real power / load balancing with DER
  - microgrid islanding control
  - transient mitigation with DER
- advance the adoption of this technology and its successful applications through technology transfer and outreach
Micro-synchrophasor (µPMU) based on PQube power quality recorder installed at Grizzly Substation reporting to UCB server via 4G wireless
Sample µPMU Data from UCB Quasar Server:
Local Arc Flash (Fault) Incident
Current during arc flash momentarily increases six-fold on phase 3, voltage sags by 0.02 p.u.
The arc flash caused a voltage sag of about 0.02 p.u. at Grizzly, propagating through the transmission network and visible at PSL in Alameda.
Voltage disturbance propagation due to arc flash:
about 0.0015 p.u. at neighboring transformer Bank 514 and 0.0003 p.u. at PSL

*Relevant applications: Fault location; equipment health diagnostics*
Sample µPMU data from UCB Quasar Server:
Transmission-level voltage sag observed at different locations

Relevant applications: Distinguishing transmission from distribution level events; Phase identification
Loss of load due to voltage sag

Relevant applications: Identifying causes of downtime
The power factor drops in response to the voltage sag...
...and recovers.

Relevant applications: Load diagnostics, Volt-VAR optimization
WECC frequency response characteristic $\approx 800$ to $1000$ MW/0.1 Hz so we are looking at the loss of 1600+ MW
Pacific DC Intertie Trip April 28, 2015

oscillations preceding the loss of generation
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local voltage phase angle oscillations during event
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