Micro-synchrophasors (µPMUs) for Distribution Systems

Dr. Alexandra “Sascha” von Meier
Co-Director, Electric Grid Research

http://uc-ciee.org

Adjunct Associate Professor
Dept. of Electrical Engineering and Computer Science
U.C. Berkeley
Micro-synchrophasors (µPMUs) for Distribution Systems

Three-year, $4M ARPA-E project starting March 1, 2013

Research partners CIEE, UC Berkeley, LBNL, Power Standards Lab
Distribution vs. transmission
Important differences:
• architecture
• diversity
• time variation
• vulnerability
• opacity
Why PMUs mostly on transmission, not distribution?

- cost / value proposition
- more challenging measurements – fractions of a degree
- historically, no need:
  - unidirectional power flow, from substation to load
  - unquestioned stability of distribution system
  - but this is changing...
µPMU concept – Power Standards Lab

- very low cost: piggy-back on existing distribution instrument, PQube
- allows sync with disturbance recordings
- local data storage on SD card as low-cost backup
- µPMU can connect to single- or 3-phase, secondary distribution or substation PT
µPMU concept – Power Standards Lab

- higher resolution than conventional PMUs: aiming for < 0.05°
- 512 samples per cycle
- phase-locked sampling for power quality measurements, and time-based sampling for synchronized measurements
Traditional PMU, optimized for transmission system
Partial schematic, showing analog path for typical \( \pm 1^\circ \) angle resolution

Proposed \( \mu \)PMU, optimized for distribution system
Partial schematic, showing analog path for precision \( \pm 0.01^\circ \) angle resolution
μPMU concept

- 512 samples per cycle
- 10^{-3} to 10^{0} seconds
- Accuracy of GPS time stamp: differential/absolute
- 0.1° to 1° angular resolution
- 1 cycle to 12 cycles
- W, VAR, VA, +/−/0 sequence imbalance
- Frequency, dF/dt, angle meas. interval
- Min/avg/max recording
- Temperature, humidity
- Waveform changes

- Proposed μPMU measurements
- Proposed device capabilities
- Reference magnitudes

- μPMU data buffer and notifications
- Nanosecond, microsecond, millisecond, second, minute, hour, day, month
Some interesting problems at the micro-scale

- Need to separate signal from noise
  
  *Combine phase angle and frequency with info about disturbances, harmonics, lightning strikes...*

- Need sampling rate consistent with frequency of phenomena to be observed
  
  *Find angular sampling rate required to observe relevant behavior on the scale of inverter control loops (> 10 kHz)*

- How to define “frequency” and “phase angle” when signal < single cycle?

- Need to account for signal latencies everywhere

- What do you mean by “real time”? 
ARPA-E Research Project Plan

- Validate µPMU performance
- Develop µPnet: implement communications, data analysis based on sMAP (simple Measurement and Actuation Profile, developed by UC Berkeley)
- Install on selected distribution feeders to make first empirical observations of voltage angle at very high resolution
- Study the promise of voltage angle as a state variable
- Examine diagnostic and control applications for µPMU data
μPMU concept

TRADITIONAL PMU NETWORK
- Transmission (Bulk) System

PROPOSED μPMU NETWORK
- Distribution System
Possible diagnostic applications for μPMU data:
- island detection
- oscillation detection
- characterization of inertia
- FIDVR diagnosis
- fault location, protective relaying

Possible control applications:
- Volt-VAR optimization
- microgrid coordination
- seamless intentional islanding and re-synchronization of microgrids
- creative recruitment of distributed resources for ancillary services
Possible diagnostic applications for μPMU data:
- island detection
- oscillation detection
- characterization of inertia
- FIDVR diagnosis
- fault location, protective relaying

Possible control applications:
- Volt-VAR optimization
- microgrid coordination
- seamless intentional islanding and re-synchronization of microgrids
- creative recruitment of distributed resources for ancillary services

Applications will have different requirements for
- measurement accuracy
- communication speed
- data transfer rate
- data continuity

We plan to identify these requirements
(and hope to meet them)
...but for starters, we don’t even know:

What are we going to see?
What are we going to see?
Things that matter in a world with lots of distributed resources? *(We think, probably yes.)*

- Power flow direction
- Rapid changes in voltage or power flow - transients
- Oscillations, stability issues?
- How inverters interact with the legacy grid?
- Nothing interesting?

“If we knew what we’re doing, it wouldn’t be called research.”
Okay, now listen up. Nobody gets in here without answering the following question:

A PMU is installed at a train station. Another PMU is on a train traveling at 0.8 the speed of light... Say, you need some paper?