Micro-synchrophasors (µPMUs) for Distribution Systems:
New, ultra-precise sensing technology for unprecedented visibility of the grid

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

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This project has built a micro-synchrophasor network with live 4G wireless communication across the UC Berkeley and Lawrence Berkeley Lab campus and selected distribution circuits in the field at seven U.S. utilities, including Riverside Public Utilities, Southern California Edison, and Southern Company-Alabama Power.

Data is streamed from µPMUs to the Berkeley Tree Database (BTrDB) server at 120 samples per second, where it is available for visualization, online and off-line analytics. To date, our rapidly searchable archives include 80+ terabytes.

Team members have explored and developed diverse applications for µPMU data, informed by opportunities and challenges discovered in the empirical data.

What’s a micro-PMU?
The µMU is a new tool to provide real-time visibility and deep analytics for power distribution circuits:

- PQube power quality recording instrument with GPS receiver to enable highly accurate time stamping and synchronization for phasor measurements
- six input channels for 3-phase voltage and current
- µMU can connect to secondary distribution, potential transformer at substation or line device, or single phase outlet at 100 ~ 690 V_L-L
- µMU mode yields 120 samples per second of magnitude and angle; PQube mode uses all 512 samples per cycle to characterize harmonics
- multiple options for data retrieval: ethernet, wireless, and locally stored on SD card as low-cost backup
- conventional PMUs in use for the transmission system typically have ± 1° accuracy; µPMU has attained 0.01°

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What’s hard about distribution synchrophasors?

Distribution system measurements are more challenging than in the transmission network in many respects:

- Small fractions of a degree must be measured to obtain the phasor difference between two locations.
- Small signal to noise ratio and many possible sources of error can compromise measurements, including transformers (PTs and CTs).
- Cost / value proposition at the distribution level must consider equipment, installation cost and logistics.
- Variation and idiosyncrasies among distribution circuits means that installation strategies need to be carefully adapted to the local situation.
- Data analysis poses interesting challenges: mathematical approximations from transmission systems do not apply when relating phasor measurements to real and reactive power flows on distribution networks, where resistance is not negligible and phases are often unbalanced.

Distribution System Applications for μPMU Data Under Study and Development

- Event Detection and Identification: recognize disturbances such as voltage sags or reverse power flow, provide notification and diagnose origin.
- Model validation and planning support: reconcile circuit models with empirical measurement data.
- Phase Identification: confirm ABC labels using phase angles and time-series correlations.
- Characterize dynamic behaviors of loads, distributed generation and system interactions.
- State Estimation: integrate μPMU measurements with available SCADA and load data in a fast, linearized method for estimating state variables at non-instrumented nodes.
- Topology Detection: use characteristic signatures of time-series phasor measurements to recognize changes in topology, e.g. to confirm switch opening or closing.
- Fault Location: use high-precision phasor measurements to estimate distance between instrumented locations and fault.
- Control of distributed resources: use phasor measurements for a robust indication of real and reactive power flows throughout the network.