Synchrophasors for Distribution, Microgrids: PQube® 3 **MicroPMU**

0,001° & 2 PPM resolution for research projects on distribution grid, microgrid stability

Synchrophasors measure the angle between voltages, and currents, at different physical locations on a grid. Traditionally, synchrophasors have been used to investigate the stability of transmission grids. Distribution grids have much tinier angle differences – too small, and changing too rapidly, to resolve with traditional transmission-type Phasor Measurement Units (PMU's).

Dispersed ge neration (photovoltaics, fuel cells, battery storage, small wind turbines) on the distribution grid has raised questions about stability of the distribution grid – questions that can be answered with synchrophasor measurements.

The U.S. Department of Energy's Advanced Research Project Agency funded a US$4 million project to adapt the new PQube 3 in to the most precise synchrophasor instrument ever made, with 100 times the resolution of traditional transmission-type PMU's.

The PQube 3 MicroPMU is ideal for research projects that need ultra-precise synchrophasor measurements for investigating stability and impedance questions on distribution grids and microgrids.

PQube 3 MicroPMU Highlights

- **0,001° resolution** on voltage and current phase angles, **2 PPM resolution** on voltage and current magnitudes (short term).
- Connects directly to any world-wide power grid voltage: 16.67/50/60/400 Hz, 100V ~ 690V, single-phase or three-phase.
- Fully supports PT's (up to 100kV) and CT's (up to 6 000 amps)
- Ethernet connection – HTTP web page, FTP file downloads and uploads, IEEE C37.118 streaming
- Fully compatible with OpenPDC, the standard phasor data concentrator software.
- **Reference instrument for University of California at Berkeley's Quasar synchrophasor research software, optimized for synchrophasor research on distribution and microgrids**.
- Built-in instrument power for 24-48VDC, 24VAC, and Power-over-Ethernet, with 10-second supercapacitor backup. Optional plug-in modules for 100V-240V power, 30-minute UPS.
- 3 voltage and 3 current angle-magnitude pairs reported 2 times per cycle (100/sec at 50 Hz, 120/sec at 60 Hz)
- Measurement data is recorded in on-board 30 day buffer – tolerates complete loss of communication channel with no loss of research data
- Patent-pending calibrated GPS antenna/receiver is fully electrically isolated for safety – absolutely no electrical connection between GPS antenna/receiver and PQube 3 MicroPMU. Cable is entirely dig ital, so length is not important.
- Tiny PQube 3 footprint. Can be snapped into electrical panels, distribution poles, pad-mount transformers
- UL Listed, CE-marked, fully certified for emissions and immunity, temperature stability, and more.
- Platform is 100% compatible with Class A Power Quality recorder, Class 0.2 % Energy recorder – just upload firmware.

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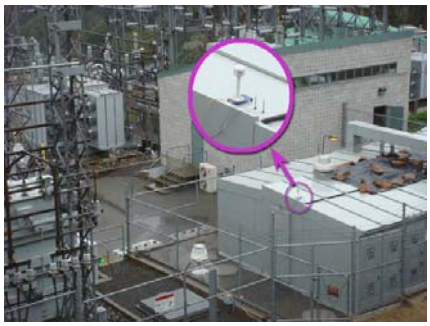
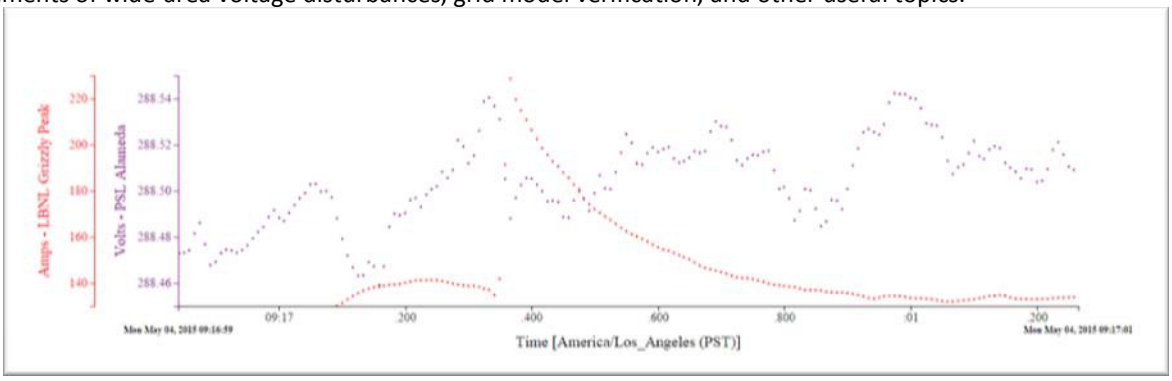
U.S. Government ARPA-E Research Project on Micro-Synchrophasors
(Award No.DE-AR0000340)



The U.S. Department of Energy's ARPA-E project is a 3-year, US$4 million effort by Power Sensors Ltd, CIEE, Lawrence Berkeley National Lab, and the University of California at Berkeley.

The project is installing about 100 PQube 3 MicroPMU's at LBNL's substations and U.S. utility distribution grids. Every day, several gigabytes of research data flows from the MicroPMU's to a server at UC Berkeley, where an astonishing new open-source software package called Quasar makes the data available to researchers through a web interface.

Researchers use measurements from the PQube 3 MicroPMU to investigate grid impedances, grid stability, synchronized measurements of wide-area voltage disturbances, grid model verification, and other useful topics.



A small current surge at Lawrence Berkeley National Lab lowers the voltage at PSL, 40 km away. The microPMU's precise time synchronization and ultra-high resolution is necessary to see these kinds of relationships in a distribution grid. Data see here through the web interface of U.C. Berkeley's open-source Quasar software.

PT's, CT's and Micro-Synchrophasors

Those familiar with distribution grid Potential Transformers and Current Transformers will quickly recognized that the accuracy specifications of the PQube 3 microPMU greatly exceed the accuracy specifications of PT's and CT's on distribution grids.

The ARPA-E project found two solutions to PT and CT accuracy.

First, the errors in distribution PT's and CT's tend to be large but stable. So measurement differences (over a short time interval) at an individual location contain useful information, even at resolutions that are far beyond the accuracy specifications of the PT's and CT's. Research based on measurement differences may be the best approach.

Second, due to their stability over time, it is possible to calibrate PT's and CT's for magnitude and angle – often to more than an order of magnitude better than original OEM specifications. The ARPA-E project selected Power Standards Lab (www.PowerStandards.com) to perform these distribution-level PT and CT calibrations.

Micro PMU Specifications

The PQube 3 MicroPMU is a research-grade instrument. The specifications below are given for guidance in developing your research project, and are subject to change. Please contact Power Sensors Ltd to discuss your planned research project with an experienced distribution grid MicroPMU engineer.

PHASOR MEASUREMENTS

Phasor Measurement Method	512 samples per nominal 50/60 Hz cycle, phase-locked to calibrated GPS PPS signal Patent-pending phase-angle calibration methods Digital process similar to IEEE C37.118, but with filters optimized for distribution and microgrid measurements
TVE (Total Vector Error)	Typical TVE ±0,01% Typical short-term TVE stability for differential measurements: ±0.002%
Streaming output	100/120 frames per sec – 3 voltage channels , 3 current channels
On-board Storage	8 gigabytes – typically sufficient for more than 1 month of measurements

MAINS MEASURING CHANNELS

Amplitude resolution	0,0002%FS (2 PPM)	(noise floor – useful for short-term difference measurements)
Amplitude Accuracy (±% rdg + ±% FS)	Typical : Factory pass/fail: Guaranteed:	±0,010% (120V - 600VAC L-N) ±0,025% ±0,050% (10VAC - 750VAC L-N).
Angle resolution	0,001°	(noise floor - useful for short-term difference measurements)
Angle Accuracy	Typical : Factory pass/fail: Guaranteed:	±0,003° ±0,005° ±0,010° 1 Standard Deviation
Measurement Channels	3× Line-to-Earth voltage, 3x Line currents. (Hardware fully supports 4 voltage channels, 4MHz sampling, 8 current channels for Class A Power Quality Recording and Class 0.2% Energy Recording firmware)	

Order Information

Part No: PQ3P-mPMU-0000-00 (includes MicroPMU, PM2 and GPS1-MS1 modules)
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Web site: www.pqube3.com