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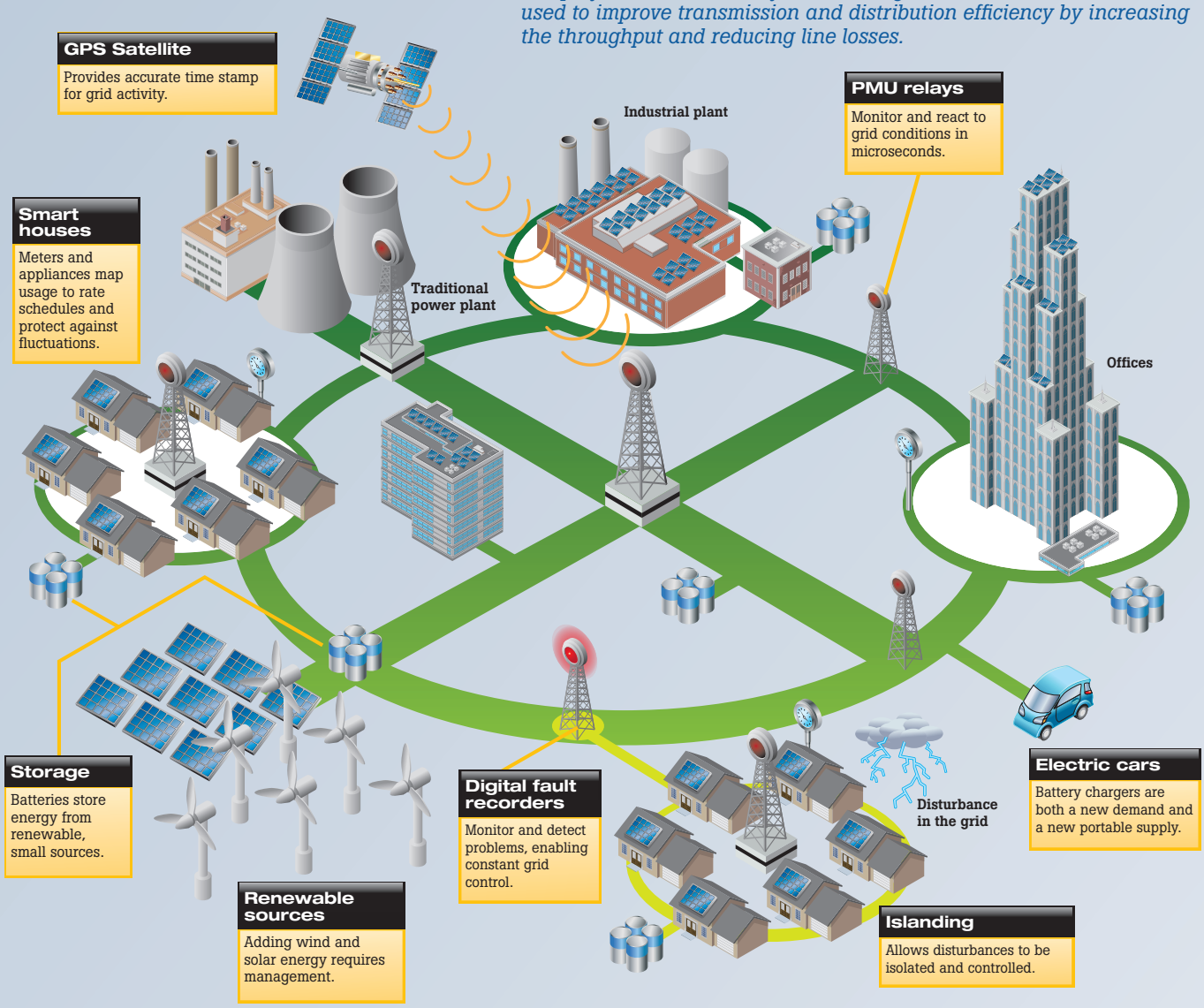
FLUKE®
Calibration

# 6135A/PMUCAL Phasor Measurement Unit Calibration System

## Fast, automated, traceable calibrations that comply with IEEE C37.118.1™-2011

# The only commercially available, automated and traceable solution for PMU testing and calibration

*As the primary measurement and sensing tool in the Smart Grid, PMUs will play a broader role beyond avoiding blackouts. PMU data will be used to improve transmission and distribution efficiency by increasing the throughput and reducing line losses.*




Today's smart grid relies on phasor measurement units (PMUs) to deliver real-time, mission critical data on the voltage, current, frequency and phase within the distribution grid. To ensure consistent, accurate and credible PMU data, it is essential that PMUs be properly calibrated.

The 6135A/PMUCAL Phasor Measurement Unit Calibration System is the only fully automated and traceable PMU calibration system available today. It is an ideal solution for PMU designers and manufacturers, as well as for national metrology institutes (NMIs). It's also a perfect solution for third party calibration houses, electrical power utilities and organizations associated with electrical power transmission.

Applications include calibrating PMUs before they are installed, and as required throughout their operational life; performing type tests of PMUs and other power grid tools; and performing first article approvals. Because the 6135A includes a three-phase 6135A Electrical Power Calibration Standard, you can also use it to calibrate wide workload of electrical power and power quality test instruments.

The integrated 6135A/PMUCAL system fully complies to the IEEE C37.118.1-2011 and PC37.242 standards for PMU operation and verification. Because it is fully automated, even non-expert users can start using it quickly, performing a complete complement of required tests in just a few hours, as opposed to many days with manual techniques.

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| Revised steady-state tests IEEE C37.118.1-2011 | Test Parameter | Range | Error Requirements |
|---|---|---|---|
| Steady-state compliance tests Section 5.5.5 | Signal frequency | ±2 Hz for Protection (P class)<br>±5 Hz for Measurement (M class) | 1% TVE<br>0.005 Hz Frequency Error (FE)<br>0.01 Hz/s Rate of Change of Frequency Error (RFE) |
| | Signal magnitude: voltage | 10 to 120 % of nominal (M Class)<br>80 to 120 % (P Class) | |
| | Signal magnitude: current | 10 to 200 % of nominal | |
| | Phase angle | ± π radians (+/- 180°) | |
| | Harmonic distortion | 1%, to 50th harmonic (P class)<br>10%, to 50th harmonic (M class) | |
| | Out-of-band interference (M class only) | 10%,<br>10 Hz to 120 Hz | |
| **Dynamic Tests IEEE C37.118.1-2011** | **Test Parameter** | **Range** | **Metrics (units)** |
| Dynamic compliance tests Sections 5.5.6 through 5.5.8 | Modulation of amplitude and phase, individually or in combination | 0.1 Hz to 2 Hz (P)<br>0.1 Hz to 5 Hz (M) | 3% TVE<br>0.01 to 0.3 Hz FE<br>0.2 to 30 Hz/s RFE |
| | Linear ramp of system frequency | 1.0 Hz/s over<br>±2 Hz (P),<br>±5 Hz (M) | 1% TVE, 0.005 to 0.01 Hz FE,<br>0.1 Hz/s RFE |
| | Step changes in amplitude and phase | Amplitude = ± 10% of nominal<br>Phase angle ± 10° from nominal | Response time (s)<br>Response delay (s)<br>Overshoot (%) |
| **Latency Tests IEEE C37.118.1-2011** | **Test Parameter** | **Range** | **Requirements** |
| Measurement reporting latency compliance Sections 5.59 | Maximum measurement reporting latency | 2 / Frequency of data reporting (Fs) (P class)<br>5 / Frequency of data reporting (Fs) (M class) | 0.0001 second |

*Tests required by IEEE C37.118.1-2011. The PMU calibration system is designed to test and calibrate PMUs to meet these specifications.*

IEEE STANDARDS ASSOCIATION
IEEE

IEEE Standard for Synchrophasor Measurements for Power Systems

IEEE Power & Energy Society

Sponsored by the Power System Relaying Committee

IEEE Std C37.118.1™-2011

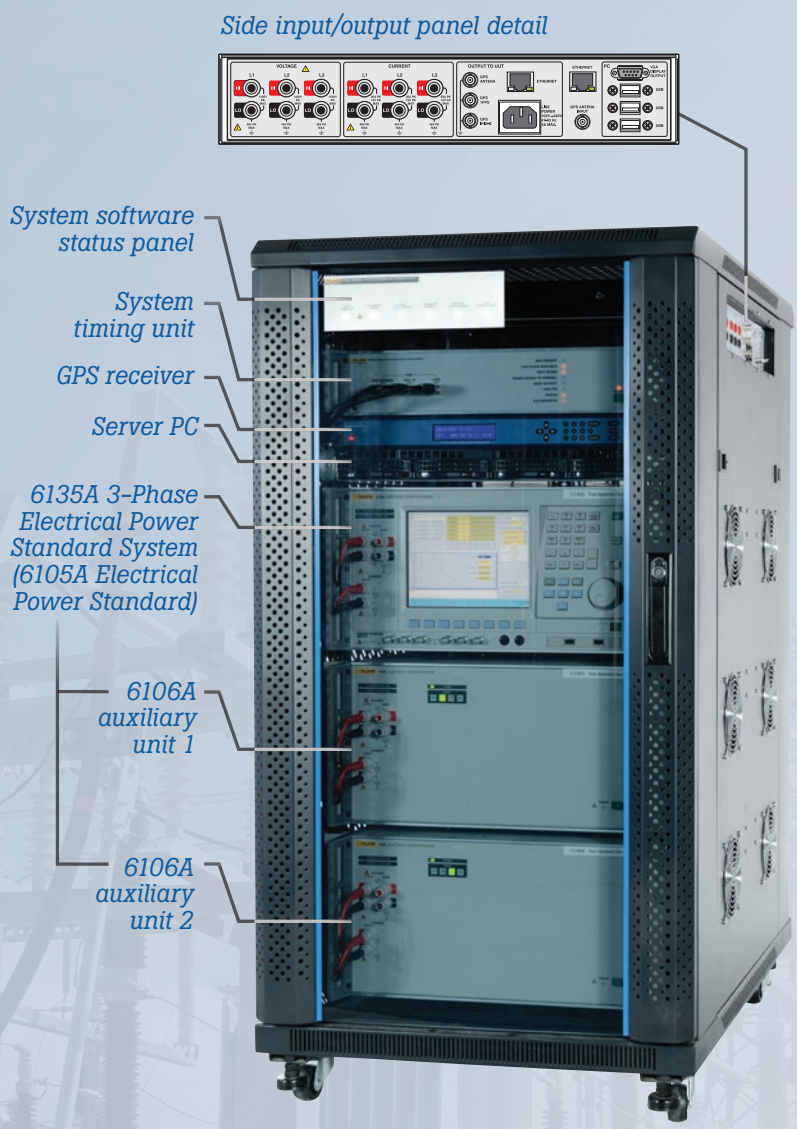
*The integrated 6135A/PMUCAL system fully tests PMUs to the IEEE C37.118.1-2011 and PC37.242 standards with full and complete test documentation.*

## 6135A/PMUCAL at a glance

### The 6135A/PMUCAL system enables you to:

- Calibrate and test a PMU from a client PC, either at the site of the test system or remotely over the Internet
- Quickly set up a PMU test
- Speed through automated calibration procedures
- Provide the required static and dynamic voltage and current conditions that occur in a power distribution grid specified by the standard
- Apply those signals to a phasor measurement unit
- Capture the PMU's reported results
- Compare those results with the original stimulus
- Evaluate against the thresholds defined in IEEE Std C37.118.1™-2011
- Create test reports, graphs and calibration certificates that can be readily printed or shared electronically

# The only commercially available, automated and traceable solution for PMU testing and calibration




## The 6135A/PMUCAL is made up of these hardware components, shipped in a 19-inch system rack with an integrated test connection panel:

- **Three-phase 6135A Electrical Power Standard:** Includes one 6105A Electrical Power Standard Master Unit and two 6106A Electrical Power Standard Auxiliary Units. Provides voltage and current stimuli to the PMU under test
- **6135A System Timing Unit:** controls timing and synchronizes the tests done throughout the calibration system
- **GPS receiver:** supplies the 6135A/PMUCAL system and the PMU under test with a source of Universal Coordinated Time (UTC)
- **Server PC:** functions as a dedicated application controller, receiving commands from the client PC to control the calibration system
- **Status panel:** The system can be operated remotely from anywhere in the world via the Internet but the System Software Status Panel gives an at-a-glance indication of status

**A user-supplied client PC** is also required, separate from the server PC but connected via a common network.

Calibration software is the control interface to the 6135A/PMUCAL system, enabling you to configure the testing process and control the testing and calibration of the PMU under test. The software is also an advanced capability analysis tool for the test results. Two modes of operation are available. In Simulate Mode, the software operates without being connected to an actual PMU, but rather simulates the PMU responses in order to do test development, system training, or use the calibration software without actually being connected to a calibration system. The PMU Test Mode enables you to test a PMU and collect actual testing data.

## With the software on a client PC, you can use it to:

- Fully test a PMU to the IEEE C37.118.1-2011 standard with the pre-loaded suite of required tests
- Perform custom testing on a PMU to verify operation in ways not specifically required by the standard
- Refer to test data for results and analysis
- Modify and create new testing procedures as needed

The test system architecture allows the client PC to access the test system over the Internet, from anywhere in the world. You can complete an automated PMU test in approximately six to twelve hours per PMU configuration (frequency, sample rate, class), compared with many days using manual techniques. And the initial setup is also fast—just a few minutes of user interaction is required at the beginning of the automated test.

System accuracy yields a test accuracy ratio of 10:1 against the the IEEE 37.118.1-2011 measurement requirements.

Creating reports with the 6135A/PMUCAL system is flexible and convenient. Pre-configured reports are included with the system to help you minimize creation time. Use these reports "as is" or as templates that you customize to meet your specific needs.

## 6135A Electrical Power Standard Three-Phase System

The 6135A Electrical Power Standard Three Phase System at the heart of the PMU calibration system can be operated in standalone mode, independent of the 6105A System Timing Unit and the server PC. The 6135A sets a new benchmark for accuracy in electrical power calibration standards. Voltage and current are generated with up to six digits precision and accuracies better than 0.005% (50 ppm). Phase adjustment provides for 1 milli-degree or 10 micro-radian resolutions. Phase performance is exceptional, with voltage to current phase accuracy to 2.3 milli-degrees for the 6105A. Voltage-to-voltage phase accuracy is 5 milli-degrees.

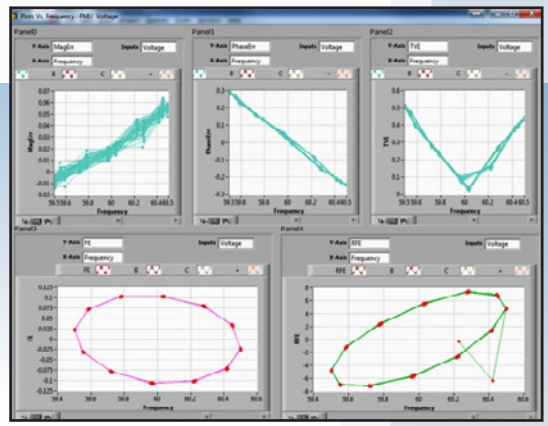
Use the 6135A to generate a wide variety of complex signals, including flicker; harmonics; dips and swells; interharmonics; fluctuating harmonics; simultaneous application.

This feature gives you enormous flexibility to calibrate a wide workload of electrical power test instruments, including:

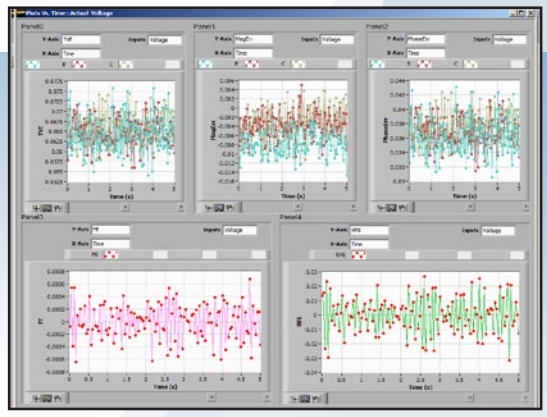
- AC voltmeters
- AC ammeters
- Current transformers
- Flicker meters
- Phase angle meters
- Power factor meters
- Power analyzers
- Power recorders
- Power transducers-relay testers
- VA meters
- VAR meters
- Voltage transformers
- Wattmeters (3- or 4-wire)
- Watthour meters
- and more

*Top level test menu*

*Interactive testing for PMU analysis*



*Plots of tested PMU measurement errors versus frequency*



*Plots of PMU errors versus time*

# Specifications

## Client PC requirements

- Microsoft Windows 7 operating System
- Microsoft Excel 2003 or later
- 2 GHz processor
- 2 GB RAM
- 20 GB free hard disk storage space for program and data
- Network connection at > 300 KB/s
- 32X DVD drive to install calibration software

## Electrical Source Accuracy Specifications

***See specifications in the 6100B/6105A Users Manual.***

| | |
|---|---|
| **Output voltage, per phase** | 1008 V |
| **Output current, per phase** | 21 A |
| **Output current compliance** | 9 V |
| **Output frequency range** | 16 Hz – 6 kHz |

## Performance Specifications for C37.118.1-2011 Tests

| Parameter | TVE (%) | FE (Hz) | RFE (Hz/s) |
|---|---|---|---|
| Steady state | 0.1 | 0.0005 | 0.001 |
| Dynamic, modulation | 0.3 | 0.001 | 0.02 |
| Dynamic, ramp | 0.1 | 0.0005 | 0.01 |

| Parameter | Delay time (s) |
|---|---|
| Step time accuracy | 0.0002 |
| Measurement reporting latency test accuracy(s) | 0.00005 |
| THD of fundamental (% of setting) | 0.02 |

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# PMU Test: Limits to Range of Influence Quantities

## General Test Limits

| Influence Quantity | Range (voltage) | Range (current) |
|---|---|---|
| PMU nominal frequency | 50 Hz or 60 Hz | 50 Hz or 60 Hz |
| PMU nominal magnitude | 10 V to 240 V | 0 A to 10 A |
| Signal magnitude (percent of PMU nominal) | 10 % to 120 % | 10 % to 200 % |
| Signal frequency range | 44.0 Hz to 65.9 Hz | 44.0 Hz to 65.9 Hz |
| Test duration (single test) | 1 to 65,535 seconds | 1 to 65,535 seconds |

## Steady State Tests

| Influence Quantity | Range |
|---|---|
| Phase angle | ±180 ° |
| Harmonic distortion – harmonic order[1] | 2 to 100 |
| Harmonic distortion – harmonic index[2] | 0 % to 40 % |
| Out of band interference frequency | 5 Hz to 180 Hz |
| Out of band interference magnitude (percent of PMU nominal voltage)[3] | 0 % to 40 % |

***Notes:***

[1] Maximum harmonic frequency is 6 kHz.

[2] Within the 6135a amplitude/frequency profile limits. See the the 6100B/6105A user's manual for details.

[3] Limited to 30% of 6135A range setting. See the 6100B/6105A user's manual for details.

## Modulation Tests

| Influence Quantity | Range |
|---|---|
| Signal magnitude | 100 % of PMU nominal voltage/current |
| Signal phase angle | ±180 ° |
| Modulation frequency | 0.1 Hz to 12 Hz |
| Amplitude modulation index | 0 to 0.1 |
| Phase modulation index (radians) | 0 to 0.1 radians |
| Settling time | 0 to 10 seconds |

## Frequency Ramp Tests

| Influence Quantity | Range |
|---|---|
| Signal magnitude | 100 % of PMU nominal voltage/current |
| Frequency ramp | 44.0 Hz to 65.9 Hz |
| Ramp rate | 0.1 Hz/s to 6 Hz/s |
| Phase shift | ±180 ° |
| Transition time | 0 to 255 reports |

## Input Step Change Tests

| Influence Quantity | Range |
|---|---|
| Signal magnitude | 100 % of PMU nominal voltage/current |
| Frequency | 44.0 Hz to 65.9 Hz |
| Phase shift | ±180 ° |
| Amplitude step magnitude[1] | 0 to ±50 % |
| Delay before step | 255 seconds |
| Number of steps[2] | 1 to 40 |

***Notes:***

[1] Positive amplitude step cannot exceed the 6135A range limit. See the the 6100B/6105A user's manual for details.

[2] PMU response and delay times are small relative to PMU reporting intervals so multiple steps are staggered to increase the resolution of the measurement.

# Specifications (continued)

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## General Specifications

| | |
|---|---|
| **Input Power** | |
| Voltage | 100 V to 240 V with up to ±10 % fluctuations |
| Frequency | 47 Hz to 63 Hz |
| Maximum consumption | 3,500 VA Max |
| **Dimensions** | |
| **Size:** | |
| Height | 1,170 mm (46 in) |
| Width | 600 mm (24 in) |
| Depth | 800 mm (32 in) |
| Weight | 170 kg (374 lb) |
| Weight in shipment crate | 210 kg (462 lb) |
| **Environment** | |
| Warm-up time | 1 Hour |
| **Temperature and performance:** | |
| Operating | 5 °C to 35 °C |
| Storage | 0 °C to 50 °C |
| Transit temperature range and limited time transit conditions | 0 °C to 50 °C. Transit outside this temperature range (-20 °C to 0 °C, or 50 °C to 60 °C) must be limited to <100 hours |
| **Relative humidity:** | |
| Operating | <80 % 5 °C to 30 °C ramping down linearly to 50 % at 35 °C |
| Storage | <95 %, non-condensing 0 °C to 50 °C |
| Operating altitude | 0 m to 2,000 m |
| Storage altitude | 0 m to 12,000 m |
| **Standard and Agency Approvals** | |
| Safety | Complies with IEC 61010-1, overvoltage category II, Pollution degree 2 |
| EMI/RFI/EMC | IEC 61326-1: Controlled EM environments, FCC part 15 sub-part B class A |

## Ordering information for 6135A/PMUCAL Phasor Measurement Unit Calibration System

| **Each system includes:** |
|---|
| 6135A Electrical Power Standard |
| 19-inch system rack with 6105A/PMU controller, GPS receiver, server PC |
| ISO 17025 accredited certificate of calibration at date of manufacture |
| Getting Started Guide, hardcopy and electronic, in multiple languages |
| Operator's Manual on DVD |
| Voltage leads (3) |
| Current leads (3) |
| Cables: CAT 5 (2), Coax (7), USB (1), GPIB (1) |
| GPS antenna and cable |
| Electrical mains cords (3) |
| Reusable shipping crate to facilitate any necessary system transportation |

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Printed in U.S.A. 10/2013 4230214B_EN
Pub-ID: 12088-eng

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