Synchrometrology and PMU Testing at NIST

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NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Topics for Today

- NIST Mission
- SGIP
- NIST Synchrometrology Testbed
- PMU Testing

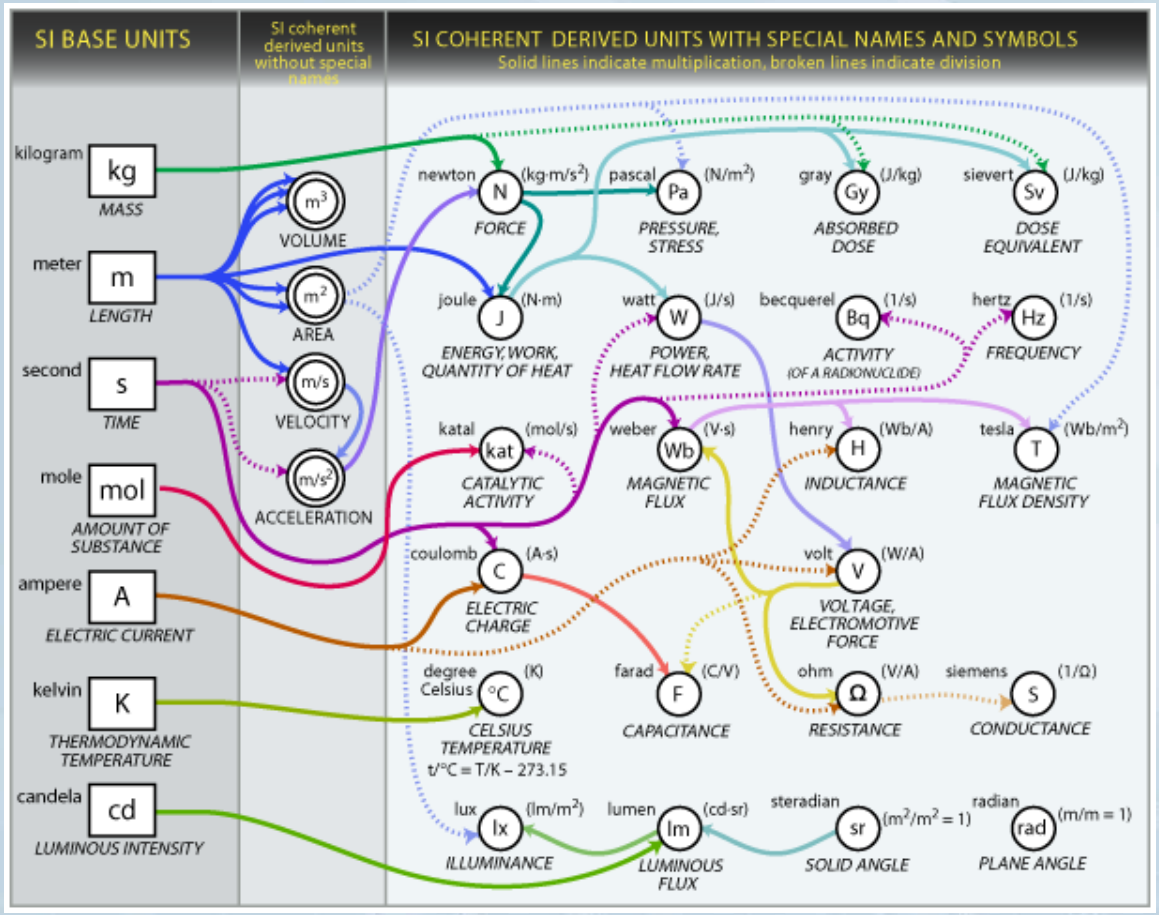
Physical Measurement Laboratory Mission

Promote U.S. innovation and industrial competitiveness by advancing the frontiers of measurement science and by realizing, disseminating, and internationally coordinating the physical standards of measurement

We carry out this mission by:

- Providing measurement, calibration, and data services
- Developing new standards and measurement methods
- Conducting an aggressive dissemination program
- Pursuing long-term fundamental research that anticipates future needs
- Partnering with universities, industry, and government agencies

PML is Responsible for the International System of Units (SI)



How it is…

- Scientifically based
- Defined by consensus
- Realized in practice
- Disseminated for routine uses
- Disseminated for new and novel uses
- Maintained and Improved

SI underpins *all* measurements, whether expressed in metric units, traditional British units, or other units

The NIST Role

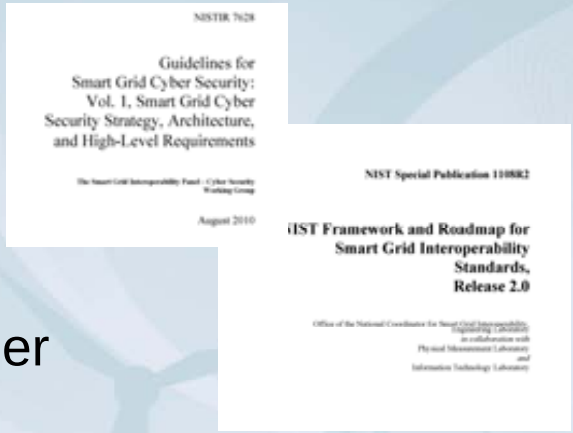
Energy Independence and Security Act (EISA) of 2007
Title XIII, Section 1305.
Smart Grid Interoperability Framework

"In cooperation with the DoE, NEMA, IEEE, GWAC, and other stakeholders, **NIST** has "primary responsibility to **coordinate development of a framework** that includes protocols and model standards for information management **to achieve interoperability of smart grid devices and systems**…"

Smart Grid Interoperability Standards Coordination

NIST Smart Grid Framework document

- Release 2 (Feb 2012) and Release 1 (Jan 2010)
- Smart Grid vision & architectural reference model
- Identifies 100+ key standards; cybersecurity
- guidelines, testing and certification framework
- Provided a foundation for IEC, IEEE, ITU, and other
- national and regional standardization efforts



NIST Smart Grid Interoperability Panel (SGIP)

- Over 800 organizations, 1900 participants, many international members
- Governing Board and committees, **priority action plans**
- Coordination of standards development by SDOs
- New SGIP 2.0, Inc. legal entity established

NIST SynchroMetrology Laboratory

Tom Nelson

Jerry Stenbakken

Allen Goldstein

Yi-hua Tang

NIST National Institute of Standards and Technology U.S. Department of Commerce

Overall Purpose and Objective

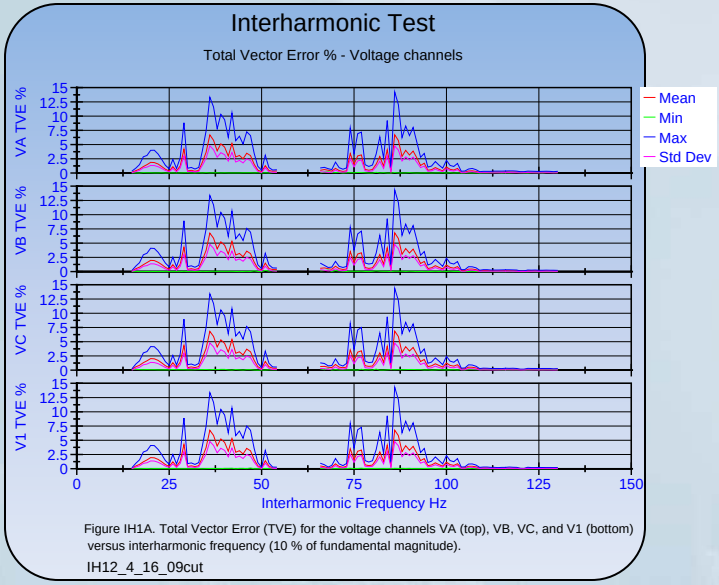
- NIST SynchroMetrology Laboratory established to provide state-of-the-art standards and performance testing facility for time synchronized power grid instrumentation – focus on PMUs
- Created in 2006 – DoC/DoE funding
- Static Calibration System 2008
- Dynamic Calibration System 2009

NIST SynchroMetrology Laboratory

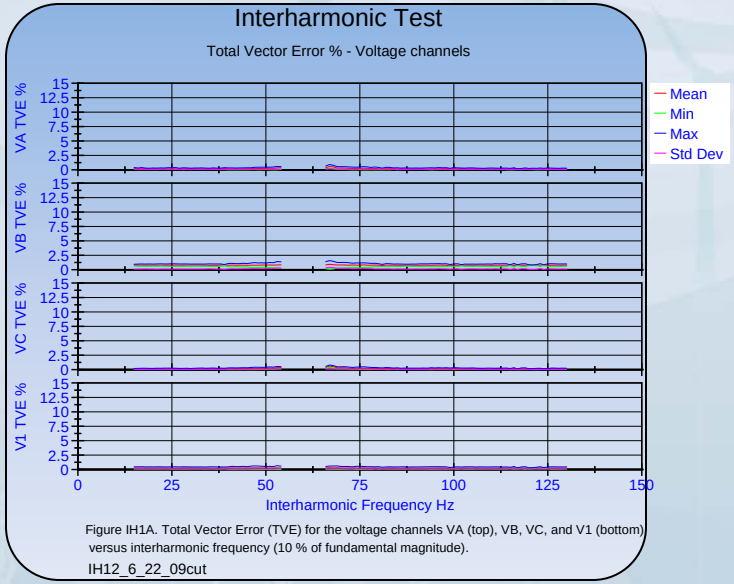
- We are the only NMI to offer calibrations for PMUs
- Combine NIST Capabilities in Time Metrology and in Waveform Metrology
- Developed Laboratory to Perform Calibrations of Phasor Measurement Units (PMUs)
- Provide Assistance to Manufacturers and Utilities on Design and Use of PMUs
- Developing capability to calibrate PMU calibrators

Improved PMU Performance

Before



After



Standards used by PMUs

- IEEE Std. C37.118.1-2011 “Synchrophasor measurement”
- IEEE Std. C37.118.2-2011 “Synchrophasor communications”
- IEEE Std. 754-1985 “Standard for Binary Floating Point Arithmetic”
- IEC 61850-90-5 “Use of IEC 61850 to transmit synchrophasor information according to IEEE C37.118 “
- Various communications standards (Ethernet, TCP, UDP, etc.)
- Various timing standards (GPS, IRIG Std. 200-04, Universal Time Coordinated (UTC), IEEE Std. 1588, etc.)
- (future) IEEE PC37.240 “Standard for cyber Security Requirements for Substation Automation, Protection and Control Systems.

Conformance is necessary:

PMUs must be interoperable in a very large system!

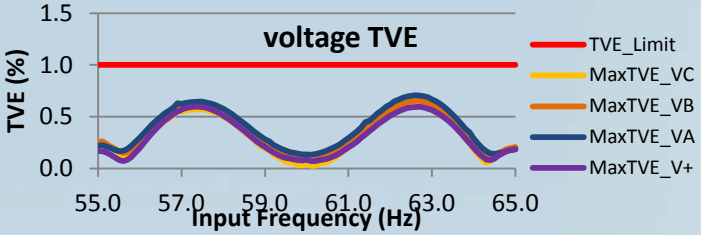
- 21 or more PMU manufacturers
- More than 50 different models of PMU
- PMU functions included in “multifunction devices”:
  - protective relays
  - digital fault recorders
  - power quality meters
- PMUs will be used in almost every power transmission system worldwide.
- Each PMU has ***18 or more*** configurations of nominal frequency (F0), reporting rate (Fs), and class (M or P)

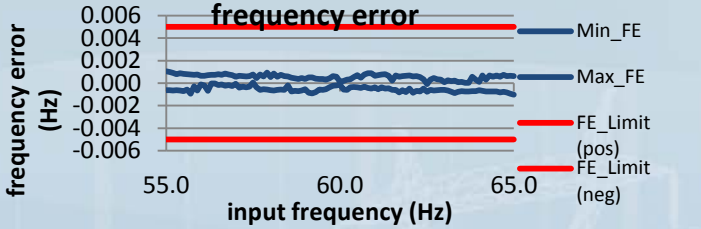
Measuring PMU electrical conformance

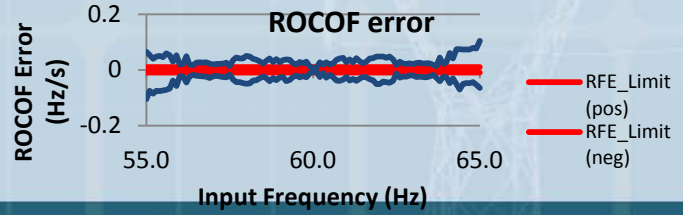
- *IEEE Std. C37.118.1-2011 Section 5: Synchrophasor measurement requirements and compliance verification*
  - 5.5.5 Steady state compliance:
    - Signal frequency range tests (up to 100 tests per configuration)
    - Signal magnitude tests (up to 20 tests/configuration)
    - Harmonic distortion tests (50 tests /configuration)
    - Out of band interfering signals (50 to 100 tests/configuration)
  - 5.5.6 Dynamic measurement bandwidth (modulation tests) (up to 100 tests/configuration)
  - 5.5.7 Dynamic ramp tests (2 tests/configuration)
  - 5.5.8 Dynamic step tests (40 tests/configuration*)
  - 5.5.9 Measurement reporting latency (1 test)

* 4 tests of 10 iterations each

Jerry Stenbakken and the first NIST PMU steady state calibration system







Far left: Jerry Stenbakken, middle: NIST's first PMU dynamic test system, far right: commercially available, fully automated PMU calibration system.

Requirements for a PMU calibration system

- Signal source magnitude and absolute phase shall be traceable to first principles as represented by national standards
  - “absolute” phase is phase relative to time.
- “True” (reference) value uncertainty shall be verified.
  - “True” values are the values of the signal source which are compared to the PMU Under Test’s output to determine TVE, Fe, and RFe.
- Result calculations shall be verified to be compliant with IEEE C37.118.1:2011.
  - Result calculations include TVE, Fe, RFe, Step Response Time, Step Delay Time, and Step Overshoot.

Future Changes Expected for NIST Test Systems

- PMUs with IEEE 1588 Synchronization Capability

- New NIST Developed Amplifiers to the Dynamic test system for Increased Stability and Reduced Noise

2013 Plans and Expectations

- Implement New C37.118.1-2011 Tests
- 61850-90-5 Message Transmission
- Develop Tests for PMU Calibrators
- Calibrate PMU Calibrators
- Conduct a PMU test lab round robin
- Make recommendations to PSRC WG H11 on frequency error and ROCOF limits

Thank you!