National Institute of Standards and Technology

Smart Grid Synchrophasor Standards and SynchroMetrology Laboratory Support

Summary Webinar
Quarterly Report No. 2
(January 2011 –April 2011 period)

Transmission and Distribution DEWG Meeting

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Agenda

- Project Background
- Project Scope
- Progress During the Reporting Period
- Project Status
- Contacts

Project Background

- The 2007 Energy Independence and Security Act (EISA) tasked NIST to coordinate the development of interoperability standards.
- NIST released a public tender for consulting services in July 2010 to expedite harmonization of standards and support the activities of PAP12 and PAP13 and, enhance its SynchroMetrology facilities.
  - NIST outlined a detailed scope of work to accelerate the harmonization between standards for measuring equipment and communication relevant to measurement of grid conditions by Phasor Measurement Units (PMUs) and standards that cover substation automation, transmitting data from field equipment within the substation and beyond.
  - The scope also included support for the further development of the NIST SynchroMetrology Laboratory to extend its capabilities to support future communication standards and interoperability testing.
- Through competitive procurement, NIST selected ESTA International, LLC (ESTA), an energy strategy and technology advisory firm and its subcontractor Quanta Technology LLC (QT), an energy technology consulting firm, to support this program.
- The ESTA/QT team and the NIST project team launched the project with a kick-off meeting in October 2010 and will conclude the project in September 2011.

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Project Scope

Task 1 - Identify gaps/ issues and requirements between current NIST Synchrophasor testbed and industry needs; develop justified written recommendations for extension of the NIST SynchroMetrology testbed to address these issues, meet the requirements, and add capability to support PAP 12 and 13 and other WASA needs.

Task 2 - Provide justified written recommendations, including text and models needed for harmonization of DNP3 (now adopted as IEEE 1815) and IEC 61850, and IEEE C37.118 with IEC 61850, in coordination with the PAP12 and PAP13 working groups, with coordination and approval of the Standards Developing Organizations (SDOs).

Task 3 - Develop recommendation for requirements, testing and certification approaches for PMUs and PDCs, and design for extension of the NIST SynchroMetrology testbed for interoperability testing/standards development. The development of requirements, testing and certification approaches shall be performed in coordination with input from the NIST and North American Synchrophasor Initiative Performance Standards Task Team (NASPI-PSTT).

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Quarterly Report No. 2 Deliverables

Task	Description	Quarterly Report No. 2
Task 1 a	Preliminary recommendations for design for enhancement of capabilities and design for extension of the NIST SynchroMetrology testbed, (Task 1).	X
Task 2c	Recommended changes as input to IEC WG 10 and the DNP3 Working Group for harmonization of IEC 61850 and DNP3 including text, diagrams, and models, (Task 2). PAP 12	X
Task 2e	Recommendations for harmonization of IEC 61850 and IEEE C37.118, including text, diagrams, and models as input to IEC WG 10 for the draft mapping document IEC 61850-90-5, sufficient to complete PAP13 tasks (Task 2)	X
Task 3b	Recommendations for methods for PMU-PDC/PDC-PDC communications as input to the NASPI PSTT (Task 3)	X
Task 3c	Recommendations for PDC testing and certification approaches as input to the NASPI PSTT (Task 3)	X

Progress During the Reporting Period
Task 1: SynchroMetrology Testbed Requirement Analysis
Summary of Recommendations

- There is a clear need for NIST to take action to further enhance and develop its testbed to support SGIG projects and other synchrophasor deployment projects
- There are two identified areas that need NIST's urgent action to develop test procedures and test & calibration capabilities from NIST existing testbed and other test facilities
  - Full IEEE C37.118.1 compliance test and calibration (Current Testbed is based on C37.118-2005)
  - GPS clock testing and certification
- There are three other areas that NIST should closely follow with the various standard / guideline development activities on a regular basis and take appropriate actions when the time is ready:
  - IEEE 1588 compliance test
  - IEEE C37.118.2 and IEC 61850-90-5 compliance test
  - PDC testing and calibration

Progress During the Reporting Period
Task 1: SynchroMetrology Testbed Requirement Analysis
New Capabilities – select sample

New Requirement C37.118.1 or C37. 118.2?	Requirement	Currently tested by NIST	Changes needed for NIST?	Type of change	Difficulty of testing changes	Difficulty of analysis changes
C37.118.1-2011 Table 4. Steady-state Frequency and ROCOF Requirements						
Yes	Signal Frequency	No	Yes	New test	Moderate	Moderate
Yes	Harmonic Distortion	No	Yes	New test	Moderate	Moderate
Yes	Out-of-Band Interference	No	Yes	New test	Moderate	Moderate
C37.118.1-2011 Table 5. Phasor Bandwidth Requirements with modulated signals						
Yes	Amplitude and Phase modulation	Yes	Yes	Limit based on Maximum TVE versus average	Slight	Moderate
Yes	Phase modulation	Yes	Yes	Limit based on Maximum TVE versus average	Slight	Moderate

Progress During the Reporting Period
Task 1: SynchroMetrology Testbed Requirement Analysis
New Capabilities – select sample

New Requirement C37.118.1 or C37. 118.2?	Requirement	Currently tested by NIST	Changes needed for NIST?	Type of change	Difficulty of testing changes	Difficulty of analysis changes
C37.118.1-2011 Table 6. Frequency and ROCOF Requirements with modulated signals						
Yes	Amplitude and Phase modulation	No	Yes	New test	Significant	Significant
Yes	Phase modulation	No	Yes	New test	Significant	Significant
C37.118.1-2011 Table 7. Phasor Requirements with Frequency Ramp						
Yes	Linear Ramp	No	Yes	New test	Significant	Significant
Yes	Ramp plus 3rd Harmonic	No	Yes	New test	Significant	Significant
C37.118.1-2011 Table 8. Frequency and ROCOF Requirements with Frequency Ramp						
Yes	Linear Ramp	No	Yes	New test	Significant	Significant
Yes	Ramp plus 3rd Harmonic	No	Yes	New test	Significant	Significant

Progress During the Reporting Period
Task 1: SynchroMetrology Testbed Requirement Analysis
GPS Clock

- GPS clock is currently used as a primary timing source to provide accurate UTC traceable clock to PMUs.
- GPS clocks by different vendors have diverse performance characteristics in terms of sensitivity, stability and so on.
- The interfaces of GPS clocks to PMUs are also not uniform from product to product, and some do not provide necessary signaling to PMUs to support the proper implementation of the C37.118 standard for time quality marking.
- Not all GPS clocks can drive all PMUs. Some measure of GPS output drive and PMU input impedance would be useful.
- It is extremely important to:
  - Have various GPS clocks calibrated and tested for sensitivity and stability,
  - Identify whether the interface of a GPS clock will be able to support a PMU to implement the standard required time quality marking.
- This problem may lessen as more utilities progress to adopt the use of IEEE 1588 standard for network based accurate timing source distribution.

Progress During the Reporting Period
Task 1: SynchroMetrology Testbed Requirement Analysis
GPS Clock

- Although NIST already has facility to perform calibration on a GPS clock when it is locked to the satellite signals, new procedures need to be developed to calibrate and certify a GPS clock for sensitivity and stability.
- Proper identification of the GPS clock interface, whether it is compatible to PMU and support standard required time quality marking, should also be verified and certified.
- As a large number of GPS clocks will be purchased and installed along with PMUs and PDCs for SGIG and other synchrophasor projects, this testing and certification capability should be developed by NIST within a short time period

Progress During the Reporting Period
Task 1: SynchroMetrology Testbed Requirement Analysis
IEEE 1588

- The NIST test system has obtained a 1588 compatible card for the Dynamic PMU test system.
- NIST is starting to explore the application of this to test future PMUs that may use 1588 as its primary timing source.
- However, since no PMU product, based on our knowledge, is currently supporting 1588, the need to establish the test capability for PMUs using 1588 is considered as not as urgent as other areas at this moment.
- However, NIST testbed should start to make plans to establish this capability, and be ready when PMU products supporting 1588 become available.

Progress During the Reporting Period
Task 1: SynchroMetrology Testbed Requirement Analysis
IEEE C37.118.2 and IEC 61850-90-5

- Both IEEE C37.118.2 and IEC 61850-90-5 are expected to be published in 2011 (or 2012 the latest). Once they become available, it is expected that PMU products supporting both will become available soon. Thus, there will be a need to test and calibrate PMUs that implement these two new standards.

- Tracking the development of both standards, and having a preliminary plan to implement both standards once they are published, are needed for NIST at this stage.

Progress During the Reporting Period
Task 1: SynchroMetrology Testbed Requirement Analysis
PDC Test and Calibration

- PDC requirements document and PMU-PDC/PDC-PDC communication methods, and the PDC test guideline are still under review by NASPI PSTT.
- Since NIST is directly supporting PSTT in the above three activities, NIST should be ready to start the PDC test and calibration planning and preparation immediately once PSTT completes its tasks.

Progress During the Reporting Period
Task 2: Support PAP12 and PAP13 Activities

- The ESTA/QT team has actively participated in all PAP 12 and PAP 13 meetings since the start of the project and has become an integral part of these Priority Action Plan working groups.

- **Priority Action Plan 12 (PAP 12)**
  - Working closely with PAP 12 members, the ESTA/QT team embarked on a fast track approach of developing the draft IEEE 1815.1 Standard. The ESTA/QT team, using the outline previously prepared by the PAP 12 mapping committee, developed the draft of the standard in IEEE format. The standard is designated as IEEE 1815.1. ESTA/QT team provided weekly revisions of the document to the newly established IEEE WG C14 for review and comment.
  - IEEE WG C14 is working hard in finalizing IEEE 1815.1

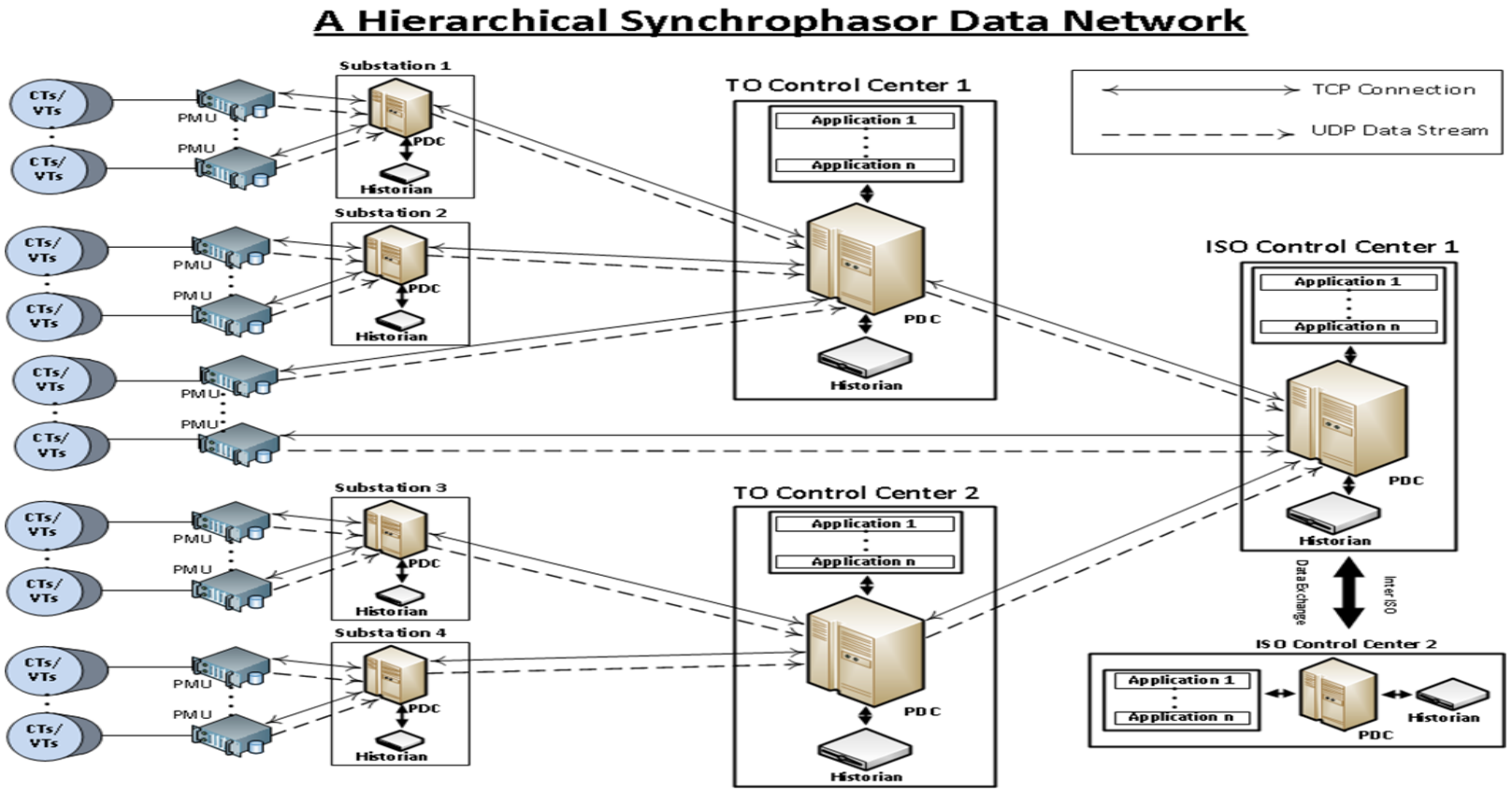
Progress During the Reporting Period
Task 2: Support PAP12 and PAP13 Activities (Cont.)
PAP 13 Summary

- **Priority Action Plan 13 (PAP 13)**
  - The ESTA/QT team provided recommendations and contributions to Synchrophasor message types and Object Modeling of Synchrophasor Based Devices System Hierarchy in support of PAP 13 in the following areas:
    - Synchrophasor Message Types
    - Object Modeling of Synchrophasor based devices system hierarchy
      - PMU Model
      - Substation PDC Model
      - Regional or System level PDC

Progress During the Reporting Period
Task 3: Recommended Requirements, Testing and Certification Approaches for PMUs and PDCs

- The scope of work associate with this task during this period was
  - Recommendations for methods for PMU-PDC/PDC-PDC communications as input to the NASPI PSTT (Task 3b)
  - Recommendations for PDC testing and certification approaches as input to the NASPI PSTT (Task 3c)
- This work was completed on schedule and the recommended documents are currently under review by the North American Synchrophasor Initiative (NASPI) Performance and Standard Task Force (PSTT).

Hierarchical Synchrophasor Data Network

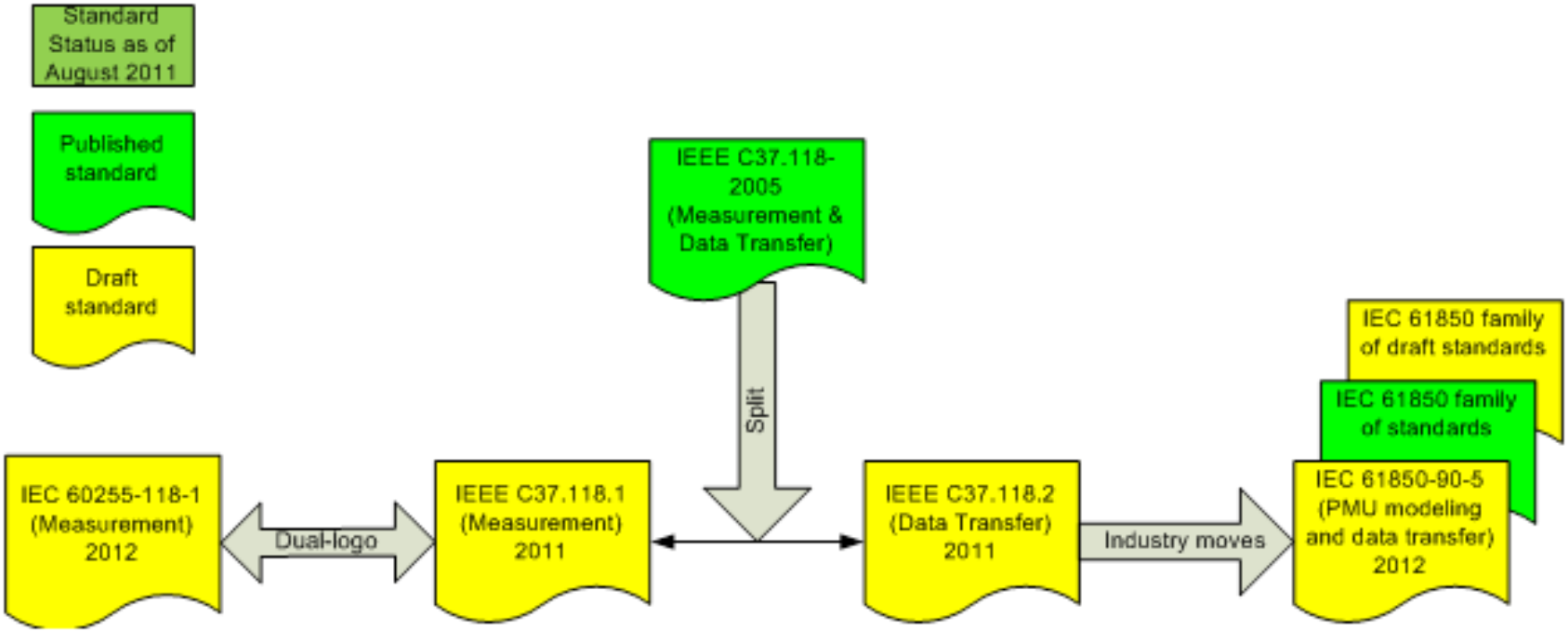


Progress During the Reporting Period
Task 3: Recommended Requirements, Testing and Certification Approaches for PMUs and PDCs

- In the real-time mode, information obtained at the PMUs are coordinated and transferred to advanced application programs at the control center via a series of Phasor Data Concentrators (PDCs), hence, the focus on PMU-PDC and PDC-PDC communications.

- IEEE C37.118-2005 is the current standard most commonly used for PMU to PDC and PDC to PDC communications. At present, extensive effort is underway to identify and address potential gaps in current standards.
  - Developing IEEE C37.118.1 for Measurement and C37.118.2 for communications aspects of synchrophasors. A driving factor in development of the two standards C37.118.1 and C37.118.2 is the desire for harmonization with IEC standards, namely the report IEC61850-90-5 which focuses on communications aspects.

Progress During the Reporting Period
Task 3: Recommended Requirements, Testing and Certification Approaches for PMUs and PDCs



Progress During the Reporting Period
Task 3: Recommended Requirements, Testing and Certification Approaches for PMUs and PDCs

- In addressing the communications aspects of PMU to PDC and PDC to PDC communications, several issues must be addressed. These issues can be broadly categorized into :
  - **Data Flow Management**
    - Data Latency
    - Data Loss
    - Data Quality Indication
  - **Configuration Management**
    - Changes in configuration
    - Hierarchical configuration

Progress During the Reporting Period
Task 3: Recommended Requirements, Testing and Certification Approaches for PMUs and PDCs - **Data Latency Issues**

- ***Data Latency Recommended Settings***
  - Wait Time
  - Late Time
  - Retrieval Time
  - Retrieval Count
- ***Data Latency Recommended Quality Features***
  - Use Absent Data Tag for absent data
  - Accept Absent Data Tag in data field
  - Data Quality Tag
- ***Retrieve Data Messages***
  - Send Retrieved Data packet
  - Accept / decode Retrieved Data packet

Progress During the Reporting Period
Task 3: Recommended Requirements, Testing and Certification Approaches for PMUs and PDCs - **Data Loss Issues**

- ***Lost Data Issues***
  - It is possible that data may be lost during transmission.
  - It may be possible that this data is retained and stored by the Source temporarily.
  - Currently there is no mechanism for the Destination to retrieve such stored data for possible playback and analytical functions.

- ***Lost Data Recommendations***
  - Send Data Retrieval Request
  - Receive / decode Data Retrieval Request
  - Identify available / not available data
  - Send Lost Data message
  - Split Data Retrieval Request for Sources
  - Accept / decode Lost Data packet
  - Mark archive with Lost Data

Progress During the Reporting Period
Task 3: Recommended Requirements, Testing and Certification Approaches for PMUs and PDCs –**Change of Configuration Issues**

- ***Change of Configuration Issues –***
  - Currently, addition of a PMU or any modification to an existing PMU requires a termination of the existing data stream.
  - Its configuration must be changed and data stream restarted.
  - In this process some data, such as the unchanged signals or devices may be lost while the data stream is stopped.

- ***Change of Configuration Recommendations***
  - new commands/timing be devised for the protocol to communicate the configuration information up and down the data network;
  - allow devices to be ready for change of configuration;
  - allow Sources to change data stream seamlessly, and
  - allow Destinations to latch to the new data stream knowing in advance what the changes would be.

Progress During the Reporting Period
Task 3: Recommended Requirements, Testing and Certification Approaches for PMUs and PDCs **Change of Configuration Issues**

- ***Recommended Change of Configuration Command Messages***
  - Send Device On / Off line
  - Split Device On / Off line command
  - New Configuration Command
  - Split New Configuration Command
- ***Recommended Change of Configuration Information Messages***
  - New Configuration Information
  - Aggregate New Configuration Info
  - Current Configuration Information
  - Request Current Configuration Information
  - Aggregate Current Configuration Information

Progress During the Reporting Period
Task 3: Recommended Requirements, Testing and Certification Approaches for PMUs and PDCs -**Hierarchical Configuration**

- ***Hierarchical Configurations Issues***
  - Each device (PMUs and PDCs) in the Synchrophasor network needs to be configured separately for Synchrophasor settings - data formats, data rates, signal content list etc.,
  - For the proper operation of the Synchrophasor network such settings must be consistent with each other.
  - However, at present there is no method to configure all devices from the control center through a single setup that would ensure consistency and ensure operation.

- ***Hierarchical Configuration Recommendation***
  - New commands/timings be devised in the protocol to configure the entire network in one setting block.
  - Permit intermediate devices to interpret such configuration blocks, split them as appropriate, and send them to further source devices.
  - These commands will permit appropriate acknowledge / compliance / non-compliance etc. messages between devices.
  - These commands would be consistent with the configuration change information / commands recommended in the previous section.

Progress During the Reporting Period
Task 3: Recommended Requirements, Testing and Certification Approaches for PMUs and PDCs – **Testing**

- ESTA/QT recommends that PDC Testing be focused on the "core" PDC functional requirements as outlined in the NASPI PSTT draft PDC functional Specification. These include basic communication tests and the following:
  - Format conversion
  - Coordinate conversion
  - Wait Time and Latency calculation
  - Data Alignment
  - Data re-sampling
  - Data Validation
  - Internal buffering
  - Configuration validation
  - Phase and amplitude adjustment

- Additional common functions that many PDCs have, but are not necessarily part of every PDC are:
  - Data Storage and Retrieval Function
  - PMU/PDC Performance Monitoring Function
  - Event Detection Function
  - Phasor Data Gateway Function
  - Synchrophasor System Latency Measurements

Progress During the Reporting Period
Task 3: Recommended Requirements, Testing and Certification Approaches for PMUs and PDCs - **Testing**

- The tests to be performed on PDCs can be divided into several categories. These include:
  - Design tests
  - Type tests
  - Application tests
  - Interoperability tests
  - Commissioning tests
  - Cyber security tests

- There are several different types of PDCs, serving different applications and functions.

- Even though the PDC Testing Guide should focus on core PDC requirements, it should also encourage the users to develop a specific test plan based on the applications/functions of interest (now and in the foreseeable future) being served by the PDC.

Progress During the Reporting Period
Task 3: Recommended Requirements, Testing and Certification Approaches for PMUs and PDCs -**Testing**

- ESTA/QT recommends that PSTT coordinate with projects that have synchrophasor system testing (especially SGIG synchrophasor projects) to validate the content of the PDC Testing Guide (and PDC Functional Requirements Document) and revise the guide.

- Also, consider performing more plug-fests at NASPI-PSTT, showing PDC testing and interoperability. Perhaps the October 2011 NASPI meeting would be an excellent venue to show and validate some of the PDC and interoperability tests.

- ESTA/QT recommends that various synchrophasor communication requirements and details captured in IEC 61850-90-5 in the coming months be reviewed and PSRC C4 working group consider developing or modifying PDC tests to allow testing for features introduced in IEC 61850-90-5.

Project Status

- Project is progressing well
- Active Participation in the new IEEE 1815.1 Standard development have helped expedite the development significantly and helped PAP12 goals. WG C14 1815.1 activities are near pre-ballot Working Group review and IEEE editing.
- Inputs to NASPI/PSTT have helped NASPI/PSTT meet its initial goals. PSRC WG C4 activities are progressing well.

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Smart Grid Synchrophasor Standards
and SynchroMetrology Laboratory Support Project

National Institute of Standards and Technology (NIST)

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