Verifying Interoperability and Application Performance of PMUs and PMU-Enabled IEDs at the Device and System Level

Final Project Report

Power Systems Engineering Research Center

Empowering Minds to Engineer the Future Electric Energy System
Verifying Interoperability and Application Performance of PMUs and PMU-Enabled IEDs at the Device and System Level

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Executive Summary

The project report presents a new test methodology for verifying the conformance, interoperability and application performance of Phasor Measurement Units (PMUs), PMU-enabled IEDs and Phasor Data Concentrator (PDCs) at the device and system level. Two types of tests are defined to evaluate the performance of synchrophasor devices verifying two different aspects: design and application. Discussion of the results from performing the Design Test and Application Test is also provided. The test platform, such as the test equipment and tools, and the configuration of the device under test, are also included for the purpose of making the procedure repetitive should a third party wish to verify the results.

The tests were performed using a synchrophasor testing and calibration system. The system has an uncertainty of less than 0.08% TVE (Total Vector Error). It consists of a GPS receiver used to synchronize the system to UTC (Coordinated Universal Time), a signal acquisition system used to generate and sample test signals up to 500 kHz, three voltage and current amplifiers connected to PMUs and PMU enabled IEDs providing test signals at typical level, three voltage attenuators and three current shunts. Both GPS signal, time codes (IRIG-B) and IEEE 1588 are available for various synchrophasor devices. A series of software models is developed in LabVIEW for implementing two types of tests. The software is capable of automating test procedures and analyzing test results. A communication network toolbox called “Impairator” is developed and implemented in a newly implemented synchrophasor testbed.

The Design Test aims at verifying the conformance and interoperability compliance of PMUs and PMU-enabled IEDs, time synchronization methods and PDCs against standards. The standards’ conformance under specific test conditions was evaluated by comparing the amplitude, phase angle, frequency, and rate of change of frequency (ROCOF) estimates to corresponding reference values. The test conditions, including steady state and dynamic state, are defined in IEEE C37.118-2005, C37.118.1, C37.118.2 and draft “Guide for Phasor Data Concentrator Requirements for Power System Protection, Control, and Monitoring”. The interoperability compliance between synchrophasor devices, time clock and PMU, and PMU and PDC, was verified by interchanging equivalent parts. The compliance was evaluated using the function outcome and numerical indices defined in the standards.

- Nine commercial PMUs and PMU-enabled IEDs from eight different vendors were selected to perform the conformance test. From the conformance test results we concluded that most PMUs meet the steady state performance requirement, but all of them failed to provide conformance under some dynamic conditions.
- The interoperability test results indicated that issues between PMUs and time synchronizations options, PMUs and PDCs exist and can be identified using the test method.
The Application Test aims at verifying performances of specific applications (fault location and state estimation are selected to perform the application test) under variations of PMUs, time synchronization options, PDCs and communication protocols. The application test results indicate the following:

- Fault location errors using different pairs of PMUs vary from 0.4% to 2.9%, and it has larger errors and uncertainties as the packet loss grows in the communication network. However, this impact may be alleviated by increasing the PMUs’ reporting rate.

- The variances of PMU errors and tuning weights can be estimated by the state estimation system using a recursive tuning algorithm. The impact on bad data detection of PMU measurements was investigated. In addition, an improved method was proposed to integrate existing WLS state estimators and enhances the robustness of error detection and identification for PMU measurements.

Future work related to this project should include:

- Development of a virtual PMU testbed to store and play back PMU source data. This method will be able to emulate network with a large number of PMUs while leveraging a small number of physical devices. Such set-up will allow evaluation of the performance of the entire synchrophasor system solution.

- Assessment of cyber security issues in the synchrophasor data transfer. This will entail definition of vulnerabilities, assessment of conformance with cyber security standards and penetration testing to verify cyber security interoperability and impacts of cyber security breaches on application performance.
Project Publications


Student Dissertations


[3] Zhang, L., Not decided yet. This doctoral dissertation is in the process of being completed. Anticipated completed and graduation from Northeastern University: N/A.
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