TIP 299: Synchrophasor Linear State Estimator and PMU Data Validation & Calibration

Context

One of the major challenges for real-time operations is having a comprehensive, trustworthy snapshot of the power system. Many utilities deploy SCADA state estimators to capture an unsynchronized, validated view of the system state (complex voltage magnitude and phase angle) and rely heavily on these tools.

In 2003, failures of the Midwest ISO (MISO) state estimator and their lack of situational awareness was one of the major drivers contributing to the blackout of the Northeast US and Canada. US DOE published an estimated cost of this blackout to be about $6 billion.

Any improvement to conventional measurement and monitoring of the system state reduces the probability and risk of low-probability, high-consequence events.

Recent deployments of wide-area synchrophasor systems have improved real-time situational awareness, providing higher-accuracy synchronized snapshots from across the grid. These implementations have brought additional challenges, including the validation of millions of data points per day, and the processing of large quantities of PMU measurements both in real time and from historical archives.

As system operators incorporate synchrophasor-based applications in the control room, validating measurements becomes paramount to ensure system reliability.

Description

This project developed approaches for data mining and data validation using synchrophasors through two methods: PMU-based Linear State Estimator (LSE) and formal data mining tools. The LSE is an advanced PMU application that builds off traditional state estimation techniques to estimate system state but also validate incoming measurements, calibrate the measurements, and predict the next measurement through filtering. Using the LSE as a front-end application will enhance the robustness of the synchrophasor network as BPA moves towards utilizing high-resolution, synchronized measurements in control and operation of the power grid.

The PMU LSE was developed in the BPA Synchrophasor Lab for this project, with progression plans developed for real-time implementation for operator applications.

In addition, this project developed applications to detect system events contained within real-time PMU data and perform automated analysis when events are found. Also, data mining tools were created to scan synchrophasor archives for past events and perform long-term baselining of power system measurements. These tools are undergoing further development for implementation in the BPA Synchophasor Lab.

Benefits

The existing synchrophasor network currently does not use the wide-area, time-synchronized perspective of PMUs to detect bad data. Therefore, “bad” data may enter the real-time synchrophasor applications as “good”.

The methods explored, implemented, and deployed through this project mitigate the risk of this data entering both online and offline tools. The need for this project is driven by the lack of data quality monitoring tools applied to both real-time and historical data. Advancements of synchrophasor technology at BPA make it possible to address this problem at this time.

State estimators are effective and proven tools used for accumulating large quantities of data and providing an indication of system conditions. This project moves BPA towards a more accurate, more robust, and more trustworthy state estimate using the PMU architecture.

Accomplishments

The goal of this project was to explore, develop, and implement PMU data quality applications via two integrated yet independent focuses to provide a breadth of advancement as well as parallel tracks for development and analysis.

The project successfully:

- developed and implemented a PMU-based linear state estimator (LSE)
- further developed and deployed BPA event detection tools using PMU data
- developed and implemented data mining tools applicable to oscillation monitoring and detection; adaptive security/dependability algorithms and protection; PMU data baselining; bad data detection and validation; fault-induced delayed voltage recovery (FIDVR); and post-contingency oscillation damping.

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Project Start Date: October 1, 2013

Project End Date: September 30, 2017

Deliverables

Progress report on preliminary development and implementation of the PMU Linear State Estimator.

Scoping document for BPA requirements for data mining applications for either conventional SCADA or PMU measurements.

Detailed report on development and implementation of data mining applications in both pseudo-real time and online versions.

Detailed report for BPA Event Detection Algorithm updates, improvements, modifications, validation, and tuning. Implemented data mining applications, including all source code and logic.

Final Project Report.

Project Cost

Total Project Cost: $440,000

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Related Projects

- TIP 51 – Response-based Voltage Stability Controls
- TIP 376 - Time Series Learning on PMU Data for Event Detection

Participating Organizations

Virginia Tech
Dominion Virginia Power
Grid Protection Alliance: openPDC

Conclusions

TIP 299 was successfully executed with all milestones completed. Each of the three tracks produced positive results, tangible deliverables, and a clear path for future advancement in their respective fields:

1. *Linear State Estimator*. The software produced by EPG was tested and verified, and the next phase of applications is currently in development.
2. *Event detection*. The team applied frequency event detection techniques in a platform for real-time event detection with PMU data. This platform will continue to provide the framework for future detection algorithms.
3. *Data mining*. Long-term mining and baselining was performed using a new distributed storage and computing platform, which will be employed for many future big-data analysis tasks.

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