TIP 376: Time Series Learning on PMU Data for Event Detection

Context

Phasor Measurement Units (PMUs, or 'synchrophasors') are widely used for monitoring the operational status of power systems. PMUs record time-stamped voltage and current phasors (magnitude and phase angle), from which other values may be calculated, including voltage, current, complex power, frequency and their rate of change. The high data reporting rate of PMUs, up to 60 measurements per second, enhances situational awareness for power system operators.

Currently, BPA is acquiring more than 2 TB of data annually from its synchrophasor network. That data archive continues to grow as the installation base is extended. However, this data is only useful if it can be examined in a meaningful way. Unfortunately, the sheer scale of the data means that traditional techniques for data analysis are either non-viable, or must necessarily be limited in scope. New tools are needed to be able to find/extract salient information from within the BPA dataset within a reasonable time frame.

Description

From 2014 to 2016, we successfully completed TI Project #319 to mine the BPA synchrophasor data with machine learning techniques for the purposes of performing event detection, classification, clustering, and outcome prediction.

We were able to obtain 95% accuracy from the developed classifier with input from the PMU data: each PMU's measurements are examined at each point in time and each moment in time is treated independently.

In this one-year successor project, we built on the success of TIP#319, and extended that research in the following two directions:

(1) Base new classifiers on the time series nature of the data (i.e., using a window of measurements for classification as opposed to measurements at a single moment in time);

(2) Build the classifiers using features that are validated by power systems theory to improve classification performance. This step up in model fidelity will allow our system to identify more phenomena of interest and may also improve classification performance on the currently detected phenomena.

There were four major tasks for this project.

1) *Feature Identification:* A set of candidate features that may be useful for identifying power system events in time series data.
2) *Feature Extraction Implementation:* Develop a set of software tools to extract candidate features identified in Task 1.
3) *Feature Analysis/Feature Engineering:* A ranking for each feature that describes whether it should be a required candidate, possible candidate, or not a candidate for identifying each target power system event.
4) *Training and Testing of Event Detectors:* A large scale evaluation of the best performing classifier(s) on contiguous data from multiple PMUs.

Benefits

This project maximizes the benefit of the investment BPA has already put into its synchrophasor installation by helping to identify phenomena of interest from within the PMU streams using automated classifiers. This will not only allow BPA to act on these observations in the near-term, but could also be used to help BPA prioritize what historical data is preserved for future analysis.

Accomplishments

The goal of this project was to develop new event detection and classification methods for the BPA PMU data stream using machine learning techniques.

The three main objectives for this project were met.

- First, our Electrical Engineering team identified signal patterns predicted by power systems theory that occur prior to, or as a result of, specific phenomena we are interested in automatically identifying.
- Second, our Computer Science team used machine learning tools to determine which patterns, in practice, are most useful for automated identification.
- And third, we compared the effects of different representations or features on the identification/ classification process.

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Project Start Date: October 2016

Project End Date: May 2018

Deliverables

Final Report: J. Berrios, X. Zhao, S. Wallace, E. Cotilla-Sanchez, and R. Bass, *Generator Event Detection from Synchrophasor Data Using a Two-Step Time-Series Machine Learning Algorithm*

Project results include software tools for extracting useful features from PMU time series data, as well as machine learning techniques and associated algorithms for event detection based on these features.

Electronic copies of publications/technical reports which cover the system design, development process, performance evaluation and next steps for potential follow on projects.

Related Projects

TIP 319: Multidimensional Learning on PMU Data for Event Detection, Characterization, and Prediction

Funding

Total Project Cost: $163,000

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Participating Organizations

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Portland State University (PSU)

Oregon State University (OSU)

Conclusions

Results from the project show that the two-step classifier is able to accurately and efficiently identify the appearance of generator events within an electrical grid. We were also able to provide a fault network map that should be a powerful tool for troubleshooting.

The event detection and classification processes can be applied in future projects. The PMU Lab has begun using the frequency-based data filtering in our data mining tasks, and have encouraged others to do so when presenting at meetings/conferences. The Lab is building upon the concepts developed by WSU for fault detection/classification and applying them more widely to other types of events.