TIP 303: Dimensionality Reduction and Early Oscillation Detection Using Online Synchrophasor Data

Context

Power system oscillations have been studied since the early 1960s, and inter-area oscillations have gained increasing attention, and are still under intense investigation. With the deployment of synchrophasor technology, Phasor Measurement Unit (PMU) data can be used to facilitate faster detection and more detailed analysis of inter-area oscillations. Currently, real-time measurements from the frequency monitoring network (FNET) are employed to detect the oscillations triggered by line and generator tripping. Currently, most existing work focuses on using synchrophasor data for the post-event analysis to analyze and localize oscillation. Online PMU data promises the development of tools to better detect oscillations, and can enable mitigation tools in real-time.

Description

The project envisions enabling real-time PMU-based analytics for large scale power systems. This involves development of a comprehensive suite of online PMU data-driven algorithms for early oscillation detection which leverages the huge potential of efficient dimensionality reduction of massive synchrophasor measurements.

Dimensionality reduction methods have only recently been recognized in power systems for their adaptive machine learning features. Principal Component Analysis (PCA), as one of the premier linear dimensionality reduction methods, reduces dimensionality while preserving most of the variance in the original data. It makes feasible very fast computation, which is important in the areas of coherency identification, extraction of fault features, and fault location.

PCA has been previously performed on synchrophasor data for dimensionality reduction. Using the participation weights and principal components (PCs), the reconstruction errors are utilized to extract correlations of different variables and therefore reduce the dimensionality. The reconstruction accuracy was found to be very high for the global variables like bus frequency, due to the globally similar profiles. However, for some local variables, such as voltage magnitude or reactive power, the reconstructions may not exhibit high accuracy, a condition for which a new algorithm for dimensionality reduction is needed.

The project tasks and deliverables are summarized as follows:

Task 1.1 Investigate the inherent correlation among large number of online PMU data

Task 1.2 Establish linear PCA-based dimensionality reduction algorithms for PMU data

Task 1.3 Establish nonlinear an isomap-based dimensionality reduction algorithm for PMU data

Task 2.1 Develop an indicator for oscillation detection based on PMU data

Task 2.2 Analyze the performance of the oscillation detection by comparing with state-of-the-art model-based approaches

Task 2.3 Develop the online implementation algorithm for oscillation detection using PMU data

Task 3.1 Build an online test algorithm which integrates data dimensionality reduction and oscillation detection methods

Task 3.2 Test the performance of the proposed algorithm with extensive online data

Task 3.3 Complete the final report with all the findings and recommendations for synchrophasor data intelligence

Why It Matters

Overall, the potential benefit for this project is substantial, as it opens a new paradigm of system monitoring and event detection through large-scale synchrophasor data analysis. The improved system monitoring and reduced response time to oscillation events will benefit BPA operational reliability and potentially result in increased line limits.

Goals and Objectives

The primary goal is the development of a comprehensive suite of online algorithms for real-time synchrophasor data management, and to demonstrate the potential value of dimensionality reduction for early detection of inter-area oscillations in an operational environment (such as in BPA or PJM control rooms).

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Project Start Date: October 1, 2013

Project End Date: September 30, 2016

Funding

Total Project Cost:	$941,537
BPA Share:	$461,606
External Share:	$479,931
BPA FY2014 Budget:	$149,793

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PJM

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