



Real-time Synchrophasor Data Quality Analysis and Improvement

Final Project Report

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Power Systems Engineering Research Center
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Executive Summary

This project is motivated by the need to monitor and mitigate data quality issues in phasor measurement unit (PMU) data streams. As utilities and vendors develop more and more PMU-based decision making tools, there is an urgent need to develop scalable, real-time methods to monitor and improve PMU data quality. Unlike traditional supervisory control and data acquisition (SCADA) measurements, PMU data has much higher sampling rate as well as accuracy requirement. Conventional bad data detection algorithms are therefore rendered ineffective.

Built upon the recent success of dimensionality reduction of PMU data together with the vast experience gained in handling real-time data quality problems for real-time application development, the project team proposes a two-thrust approach to monitoring and correcting PMU data quality. First, we develop an online data-driven algorithm that is well suited bad data detection during both normal and eventful conditions. Second, we investigate the root causes of the data quality issues by different mechanisms such as GPS clock issues and communication network delays, and develop mitigation strategies for “fixing” or “filling” the problems utilizing advanced signal processing tools and dynamic state estimation methods.

Part I: Online Detection of Low-Quality PMU Measurements: A Data-Driven Approach

Part I of the report presents a data-driven approach for online detection of low-quality PMU measurements. It leverages the spatio-temporal similarities among multi-time-instant PMU data, and applies density-based local outlier detection technique to detect low-quality PMU measurements. The major advantages of the proposed approach are summarized as follows. (1) This is a purely data-driven approach, without requiring any prior knowledge on system topology or model parameters, which eliminates the potential misdetections caused by inaccurate system information; (2) the proposed approach can operate without any converged state estimation results and is suitable for filtering out gross measurement errors for advanced power system analytics; (3) the proposed approach has fast computational speed, which could be beneficial for real-time applications; and (4) the algorithm is able to perform detections under both normal and fault-on operating conditions. The proposed detection algorithm differentiates high-quality PMU data recorded during system physical disturbances (faults) from the low-quality data, which avoids potential false alarms caused by physical disturbances. The proposed detection algorithm has been implemented as a desktop application to analyze offline data.

Part II: Multi-signal Analytical Guesstimation using Intelligent Collaboration (MAGIC) for synchrophasor data

Part II of the report presents algorithms for reconstruction of missing PMU data by using available measurements from neighboring locations. As noted in Part I of the report, PMU data may be unavailable or unusable for a variety of reasons such as from measurement errors or loss of data during communication. Traditional methods such as those based on linear interpolation are inaccurate and they do not preserve the dynamic features of the system response if any of the data is lost during system events. This report introduces a data-driven approach that uses available measurements from nearby signals and from data available from recent past as cross-references to obtain accurate reconstructions of the missing data. a) The proposed technique provides highly accurate reconstructions in preserving system modal information and the results match well with those from actual values in test studies. b) The proposed method is computationally fast and can

be implemented in real-time for correcting data that could be used in subsequent PMU applications. c) The proposed method can reconstruct data over long time-intervals as long as 20 seconds provided suitable measurements are available from its neighbors. d) The reconstructed signals can be used for improving the accuracy of PMU based applications such as dynamic state estimation, oscillation monitoring and model validation.

Project Publications:

- [1] Meng Wu, and Le Xie, "Online Detection of Low-Quality Synchrophasor Measurements: A Data-Driven Approach," *IEEE Transactions on Power Systems*, vol. 32, no. 4, pp. 2817-2827, Jul. 2017.
- [2] Meng Wu, and Le Xie, "Online Detection of False Data Injection Attacks to Synchrophasor Measurements: A Data-Driven Approach", *2017 50th Hawaii International Conference on System Sciences (HICSS)*, Hawaii, US, Jan. 2017.
- [3] Meng Wu, and Le Xie, "Online Identification of Bad Synchrophasor Measurements via Spatio-Temporal Correlations", *2016 Power Systems Computation Conference (PSCC)*, Genoa, Italy, Jun. 2016.
- [4] V. Venkatasubramanian, Y. Zheng and M. M. Farrokhifard, "Systems and Devices for Automatic Data Recovery in Synchrophasor Data Streams and Associated Methods", US patent application, May 2018.

Student Theses:

- [1] Meng Wu. *Physics-Based and Data-Driven Analytics for Enhanced Planning and Operations in Power Systems with Deep Renewable Penetration*. PhD Dissertation, Texas A&M University, December 2017.
- [2] Yang Zheng. *Cross-referencing Reconstruction of Missing PMU Data using Collaborative Filtering*, M.S. Thesis, July 2017.

Software Application:

- [1] D. Wu, "Desktop Bad-Data Detection Application", <https://github.com/dqw/LOF-Bad-Data-Detection>, January 2018