Non-intrusive Methods for Mode Estimation in Power Systems using Synchrophasors

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Abstract

Real-time monitoring of electromechanical oscillations is of great significance for power system operators; to this aim, software solutions (algorithms) that use synchrophasor measurements have been developed for this purpose. This thesis investigates different approaches for improving mode estimation process by offering new methods and deepening the understanding of different stages in the mode estimation process.

One of the problems tackled in this thesis is the selection of synchrophasor signals used as the input for mode estimation. The proposed selection is performed using a quantitative criterion that is based on the variance of the critical mode estimate. The proposed criterion and associated selection method, offer a systematic and quantitative approach for PMU signal selection. The thesis also analyzes methods for model order selection used in mode estimation. Further, negative effects of forced oscillations and non-white noise load random changes on mode estimation results have been addressed by exploiting the intrinsic power system property that the characteristics of electromechanical modes are predominately determined by the power generation and transmission network.

An improved accuracy of the mode estimation process can be obtained by intentionally injecting a probing disturbance. The thesis presents an optimization method that finds the optimal spectrum of the probing signals. In addition, the probing signal with the optimal spectrum is generated considering arbitrary time domain signal constraints that can be imposed by various probing signal generating devices.

Finally, the thesis provides a comprehensive description of a practical implementation of a real-time mode estimation tool. This includes description of the hardware, software architecture, graphical user interface, as well as details of the most important components such as the Statnett’s SDK that allows easy access to synchrophasor data streams.

Keywords
Synchrophasors, Phasor measurement units, system identification, mode estimation, electromechanical oscillations, prediction error, signal selection, experiment design, probing