ESTIMATION, ANALYSIS AND CONTROL METHODS FOR LARGE-SCALE ELECTRIC POWER SYSTEMS USING SYNCHRONIZED PHASOR MEASUREMENTS

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An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Electrical Engineering

The original of the complete thesis is on file
in the Rensselaer Polytechnic Institute Library

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July 2008
(For Graduation August 2008)

ABSTRACT

Recent advances in wide-area measurement system (WAMS) technology using phasor measurement units (PMU) have given a new impetus to control-oriented research in large-scale electric power systems. One of the main challenges in the dynamic analysis and control of power systems is the development of analytical tools from limited measurement data. In this thesis we address this problem and develop novel methods for model identification, model reduction, dynamic stability assessment and controller designs for nonlinear power systems using synchronized phasor measurements. The thesis is divided into two parts in accordance to the topics. In Part-1, we present coherency based identification algorithms for constructing two-machine equivalents of two-area radial power systems, with and without intermediate voltage control, using dominant interarea voltage oscillations following a disturbance in the system. The primary tools used for this identification are the characteristics of spatial variations of phasors along the power transfer paths after disturbances. The results are illustrated with real power systems disturbance events, thereafter. In Part-2, we address the problem of formulating well-defined performance metrics for efficient monitoring of phasor responses in two-area power systems following a disturbance, and how such metrics can be shaped by appropriate control tuning. We first consider passivity-based methods for constructing Lyapunov energy functions using PMU measurements, serving as an effective tool for transient stability analysis. We further illustrate how this energy-metric can be used to interpret the relative connection strengths between the equivalent generators of different areas. Finally, we present several robust control designs for stabilization and transient performance recovery of nonlinear differential-algebraic (DAE) models of multimachine power systems with various classes of representative uncertainties. These include matched additive uncertainties (eg. unknown load reactive power demand, line outages etc.) and input multiplicative uncertainties (eg. changes in load or generation). The designs employ phasor variables for state feedback, which are assumed to be available from direct measurements in specified locations in the system.