Real-time Model Validation and Calibration for Wide-area Electric Power Systems†

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Abstract

The fact that power systems managed by different utility companies are interconnected requires knowledge of the entire interconnection, or wide-area electric power system (the power grid), for more reliable operations. Current industry practice relies on offline models and studies to provide guidance for real-time control. This approach has become less effective due to the following trends in the power grid: more dynamic market activities, intermittent renewable resources, and emerging demand response schemes, all of which are driving the system further away from its status assumed in offline models. Power grid models representing their true state in real time are needed in the new smart grid era.

Difficulties with modeling a complex system, such as the power grid, are normally realized from two aspects: 1) high uncertainty caused by continually-changing operating environment, system configurations, and human involvements, and 2) large scale complexity caused by the number of elements and the way they interact. Model validation and calibration (MV&C) is the way to reduce these uncertainties in the models. However, the following aspects with current MV&C methods have limited the achievable fidelity: 1) focus on component-based approaches, which are difficult for a large complex system and add to computational challenges; 2) depend on the test of grid equipments, which interrupts equipment service and/or introduces disturbances into the system and 3) use static and deterministic models mostly, which is not adequate for the description of a system variable and stochastic by nature. Due to these limitations, it is becoming more difficult to achieve the high reliability and efficiency in power system operations in light of the new trends mentioned at the beginning.

This work will focus on the following modeling techniques to improve the power grid models for real-time applications: 1) use a hierarchical structure and reduced-order models to represent the power grid, as illustrated in Fig. 1, which reduces the external system to several lower order systems; 2) use online measurement data for validation and calibration in real time, as shown in Fig. 2. Continual MV&C will be performed to keep the reduced system models accurate, capable of predicting the emergent behavior, as well as faithfully revealing consequences of desired or undesired stimulus to the system.

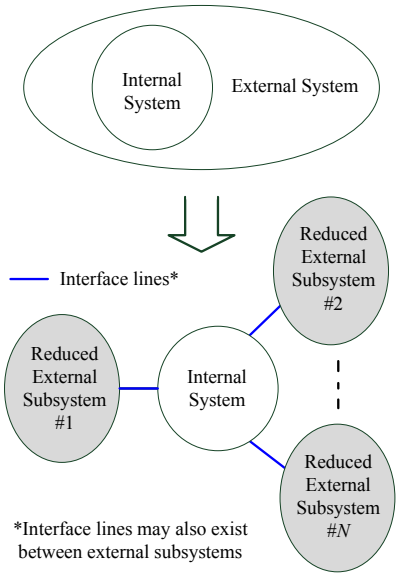

Fig. 1. Modeling approach for real-time stability analysis in a power system

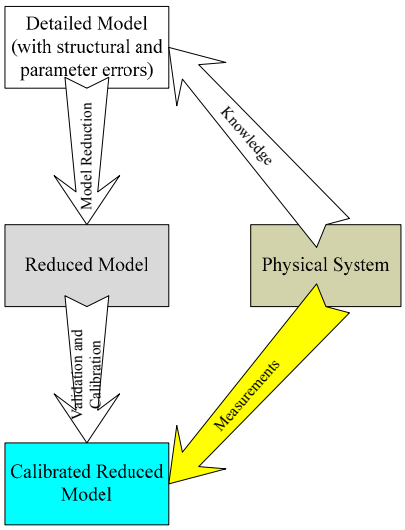

Fig. 2. Process to generate calibrated reduced models for external power systems

In collaboration with Washington State University, we are also working on applying these techniques to validate and calibrate the aggregated models of wind farms, solar power plants and loads. The final outcome of this work is expected to be a methodology and framework for the development of reduced power grid models that can be calibrated online using measurement data.

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