A Particle Filter Based Approach for Calibrating Electric Power System Models in Real Time

ASCR Project: Real-time Model Validation and Calibration for Large Interconnected Time-variant Systems Using Online Measurement Data

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Abstract

Dynamic models of a power system play a vital role in power system planning and operations. An accurate dynamic model can faithfully reveal system responses to different disturbances and help establish an accurate stability boundary. Yet, because of the complexity and ever changing operational conditions of a typical power system, there have been significant challenges of obtaining and maintaining an accurate dynamic model in real time. Currently, power system operations are still guided by simulation studies using off-line models. These off-line models are built based on prior knowledge gained through staged tests, manufacture manuals, and simulated with typical scenarios. With high penetration of smart grid devices and renewable generations, it is expected that the power grid will experience more variability and uncertainty, which, in turn, brings in more errors when using an offline model to study the system in real time. Lower confidence on model accuracy usually leads to conservative operation and lowers asset usage.

In this study, we propose a particle filter based calibration method to improve modeling accuracy, which determines the best set of model parameters using real-time measurement data. Phasor Measurement Unit (PMU) data are sampled at a rate of 30 samples/s or higher, synchronized with GPS clock, and can capture the system dynamic responses in real time. The particle filter based model calibration is a Bayesian approach of tuning model parameters so that the new information carried by the measurement data can be merged with prior knowledge to form posterior estimates. With added information from measurement data, the posterior estimates usually are improved estimates (with less variance and bias) based on the prior knowledge.

The particle filter is chosen because of the non-linearity,non-Gaussian, and high complexity of power system models. Many well established methods need some strong assumptions (e.g linear model, Gaussian distribution) to achieve a close form solution. The power system is very complex, with many non-linear components and non-Gausian parameters. The particle filter, also known as the sequential Monte Carlo method, is a simulation based method. It uses the particles (or a set of random samples) to represent the probability distribution of a random variable. It propagates the uncertainty through simulation and determines the posterior estimates through importance sampling. Therefore, it is well suited for the calibration of power system models.

To apply the particle filter to calibrate power system parameters, we have performed the following:

1) A standard particle filter is implemented and tested with a typical non-linear non-Gaussian problem.
2) A couple of modified particle filter approaches are implemented and tested with the typical problem to understand their potentials.
3) The standard particle filter is tested with an IEEE 3-machine 9-bus simulation model to reveal its performance in on-line parameter calibration for power system models.

It is shown that the accuracy of a dynamic power system model can be improved through real-time model calibration, and the particle filter based approach is very promising for calibrating power system models with PMU measurements.