TIP 357: Techniques and Tools for System Level Validation of Transient Stability Models using PMU Data

Context

A transient stability simulation assesses the short term (several to 30 seconds) angular and voltage stability of the power system, following a major disturbance. Power system models and software packages are used to run these simulations, as well as make decisions regarding design, planning and operating the grid. In the past two decades, it has been noted that in some cases models are still not able to accurately represent actual system response. This is a cause of concern as operational limits are set based on simulation studies, and hence inaccurate models can cause over or under-utilization of the grid, or even lead to cascading disturbances and black-outs.

Description

This project is a follow-up ***TIP 268: Verification and Validation of Transient Stability Model and Results*** involving BPA, University of Illinois and Washington State University. TIP 268 has been successful in comparing and resolving discrepancies seen across commercial transient stability packages used by BPA for their system studies such as PowerWorld Simulator, GE-PSLF, and TSAT, and has brought about improvements in certain packages to make simulation results significantly more consistent.

This project strove to automate, as much as possible, the process of validation and providing tools that can be useful to BPA engineers to quickly perform dynamic simulations using real-time cases, and find or at least narrow down to the root causes when simulations do not match measurements. The project explored the feasibility of automatic dynamic performance monitoring of synchronous generators, wind farms, and other control devices by combining PMU responses from major events with model based simulations.

In order to meet its objectives, five main tasks were performed. These tasks pertained to the development of tools/methodologies and the associated features of what will eventually be a "holistic" validation tool. The major tasks are listed below:

1. Development of tools to create validation base cases using real-time cases and dynamic data from planning cases,
2. Development of tools to automatically quantify differences between PMU data and simulations, and visualize/ summarize results,
3. Development of sensitivity analysis-based tools to determine causes of discrepancies between simulations and PMU data,
4. Development of parameter estimation /optimization techniques to determine better model parameter values,
5. Development of tools for performance monitoring of dynamic models.

Benefits

Validation of dynamic models is an ongoing effort in WECC as well as in BPA. This work supplements those efforts, by developing tools for system-level validation that use transmission system-level PMU measurements across the large system, perform sensitivity analysis to determine which models and subsystems are causing validation errors issues in validation, and determine suitable parameters for them. Thus, the existing model validation work in BPA will benefit from this project.

Our investigation of the different dynamic performance criteria such as generator ringdown, frequency droop and voltage regulator operation etc. can help BPA in its efforts to monitor their components and system performance automatically.

The qualitative benefits of this project are validated dynamic models, leading to improved system studies (planning and operations) and hence better decisions regarding grid operations.

The economic benefits of optimal grid performance are monumental, potentially saving both BPA and its customers a substantial amount of money. Better operational strategies arising from validated models will enable more reliable power service which will thus benefit the electricity consumers at large.

Accomplishments

The overall goal was to provide BPA with better models and simulation tools to perform more trustworthy dynamic studies on their systems, leading to better planning and operations.

Deliverables

All the methodologies and tools developed in this project, documentation on how to use them are provided at the end of this project. We also performed validation studies using these tools and the results of those were delivered through reports, including the discrepancies found between simulations and measurements, and the model or parameter adjustments made to make them match. Similarly, the results of dynamic performance monitoring studies were also reported.

The final report describes the execution and achievements of the entire project in detail, as well as charting out the future steps for this work.

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Project Start Date: October 2015

Project End Date: September 2017

Related Projects

TIP 268-Verification and Validation of Transient Stability Model and Results

Participating Organizations

University of Illinois at Urbana-Champaign (UIUC)
Washington State University (WSU)

Related Projects

TIP 268: Verification and Validation of Transient Stability Model and Results

Funding

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Conclusions

One of the main takeaways of this project is that transmission level voltage and frequency simulation results can be improved by automatic parameter estimation of load models on a wide area basis, and that load model validation does not always need lower voltage level measurements. This was demonstrated using the simple static load model and a motor model, suggesting that it may not always be necessary to use the 130+ parameter load models, especially for such large system validation and estimation problems. The level of detail of models used should depend on the application; for example, CMPLDW is important for recreating FIDVR events.

This project provided several methodologies and tools; A State Estimator validation tool was created in Visual Studio as a Windows Application named ValidationCaseSetup.exe. This tool includes a geographic coordinates mapping of substations and a composite load model between the State Estimator and Planning case. A Simulation, plotting and parameter estimation Tool was also built using Matlab R2017a.

Although there were some improvements in the results, they are certainly not perfect. These tools can be used by BPA for validation or estimation, with better results expected when, for instance, the state estimator snapshot is available in its entirety. The results can also see significant improvement if any inherent generator validation issues, which may affect system response such as causing forced oscillations, are resolved as well. For even better results, the tools described here could be used in conjunction with the widely available generator validation tools, for a holistic system level validation.

A measurement-based framework for generator model validation framework successfully reduces the initial errors to a significantly small level. Model parameter set which results in lower error is believe to be more accurate as a whole. However, a side note for the case studies is: certain set of parameters can result in optimal model response with smaller errors than actual model response in certain events. The actual model parameters in these three generator units are available as benchmark to be compared with optimal model parameters. Multiple "optimal" sets of parameters with small errors are possible in real-time operation. Further effort in model parameter identification is required to determine the most realistic set.

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