NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Argonne NATIONAL LABORATORY

Transmission and Distribution Co-simulation Tool
Questions and Answers

Introduction

This document is intended to answer fundamental questions and provide key aspects regarding a transmission and distribution (T&D) co-simulation tool that is being developed at Argonne National Laboratory (ANL) in cooperation with the North American Electric Reliability Corporation (NERC). The tool is being developed with guidance from NERC in order to create a simulation platform that can be used to understand the full-spectrum impact of distributed energy resources (DERs) on the bulk electric system (BES). Through the use of the tool, NERC and the industry may continue to study high-penetration DER scenarios, which will assist in ensuring secure and reliable grid planning and operations. Interested users can find the background information and the T&D co-simulation tool development plan in the report "Impact of Distributed Energy Resources on the Bulk Electric System—Combined Modeling of Transmission and Distribution Systems and Benchmark Case Studies" (http://www.anl.gov/energy-systems/publication/impact-distributed-energy-resources-bulk-electric-system).

Q1: What Is a T&D Co-simulation Tool?

Overview: Mature simulation tools, specialized for either transmission or distribution system simulation, have long existed. These tools can handle real-world bulk networks and distribution networks separately. A T&D co-simulation tool integrates individual transmission and distribution system simulation tools and the analysis of these networks so that transmission and distribution systems can be simulated and studied together. In our ongoing work, we will develop a T&D co-simulation tool that couples PSS®E, a transmission-system modeling and simulation tool, with OpenDSS, a distribution-system modeling and simulation tool. PSS®E is widely adopted by the transmission industry for modeling interconnection and balancing authority network models. OpenDSS[1] is chosen on the distribution side because it (a) supports both steady-state and dynamic simulations; (b) includes comprehensive libraries for distribution system components and controls; and (c) supports new analyses for future research related to renewable energy integration, grid modernization, etc.

[1] http://smartgrid.epri.com/SimulationTool.aspx

Technical answer: Two approaches can be taken with regard to T&D simulation. The first approach is called T&D combined modeling. In this approach, both transmission and distribution systems are modeled on the same platform and there is no need for information exchange, mainly because the combined system is solved simultaneously as one system. We have created a T&D combined model on the MATLAB/Simulink platform, where the Kundur Two-Area system is modeled on the transmission side and the IEEE 34-node feeder is modeled on the distribution side. However, to date, no single simulation tool, including MATLAB/ Simulink, is capable of single-handedly modeling and simulating a real-world combined T&D system at the scale of actual interconnections and distribution networks. Moreover, traditional transmission simulation tools usually model the transmission system as a three-phase balanced network represented using sequence components, which cannot be simply extended to model multi-phase unbalanced distribution networks. In the short term, it can be highly complex and time-consuming to develop a new simulation platform that can address the network size and computational complexity issues. Therefore, we are taking the second approach, i.e., creating a T&D co-simulation tool, which integrates existing tools that are specialized for simulating transmission and distribution systems separately. The transmission and distribution systems are simulated using two independent platforms (for example, transmission on PSS®E and distribution on OpenDSS), and these two platforms exchange data with each other on the boundary buses. Based on the exchanged data, each system (transmission or distribution) is solved independently. As the simulation time continues, the two platforms exchange data in a cyclical manner.

Q2: Why Is a T&D Co-simulation Tool Needed?

Overview: A T&D co-simulation tool is needed to:

- Analyze the operational and reliability impacts of DERs interconnected to the distribution system on the BES; and
- Develop appropriate control strategies to mitigate these impacts.

Transmission system entities and NERC can use the tool for day-to-day planning, operational, and control studies for high-DER-penetration scenarios. These studies can be done with physically realistic scenarios (such as contingency analysis) on actual T&D network models. These studies will offer benefits in terms of risk reduction and mitigation by increasing the awareness of the reliability impacts from high DER penetration, identifying remedial control strategies that address future reliability concerns, and ensuring reliable and secure operation of the national grid. The tool can support analysis and strategies that offer operational efficiency and economic benefits to various stakeholders across T&D. The benefits are described in more detail in the reply to Q4.

Technical answer: Transmission system entities and NERC need a real-world tool for routine planning and operations studies of high-DER-penetration scenarios and a mechanism for handling practical scenarios on T&D networks. However, such studies cannot be performed with existing tools used for modeling and simulations of combined T&D systems, mainly because those tools are restrictive in terms of network size and computational complexity. For instance, the T&D combined model we developed on the MATLAB/Simulink platform cannot be scaled to a level that models the physical network size and meets the computational requirements of the BES, because of MATLAB's inherent limitations. Thus, a more practical approach is to utilize existing, separate tools for transmission and distribution simulation and integrate them together as a full-fledged T&D co-simulation tool.

Q3: Who Will Use It? Planners? Operators?

Both transmission system planners and operators will be able to use the tool to (a) evaluate the aggregate effects of unbalanced multi-phase DERs on the T&D interface; (b) understand the reliability impact of DERs on the BES; (c) evaluate advanced control strategies to improve BES reliability; and (d) assess operational-efficiency and economics-related benefits to various stakeholders across T&D. The co-simulation tool will be useful to NERC, planning coordinators, ISOs, transmission utilities, distribution operators, and PPAs.

Q4: What Are the Benefits? Operational Efficiencies? Risk Reduction?

Overview: While the majority of benefits will be on the risk reduction and mitigation side, the T&D co-simulation tool will also help improve operational efficiencies.

Technical answer: The T&D co-simulation tool will enable NERC and transmission system entities to understand the reliability impact of DERs on the planning and operation of the BES and evaluate potential advanced controls using DERs to improve the reliability of the BES.

The benefits related to risk reduction and mitigation are as follows:

- Enable secure network configuration through BES planning studies, including power flow analysis and contingency analysis.
- Ensure stability of the BES through active power and reactive power resource adequacy appropriation and proper control system design using dynamic stability analysis, voltage stability analysis, and frequency stability analysis.
- Ensure BES safety through accurate protection device ratings and parameter settings using short-circuit studies and protection studies.
- Ensure BES reliability through accurate and region-specific DER voltage/frequency ride-through parameter settings using disturbance ride-through studies.
- Evaluate the potential to improve BES reliability through advanced controls (smart inverter functions) of DERs.

The benefits related to operational efficiency are as follows:

- Maximize economic network expansion and upgrade through BES planning power flow studies.
- Optimize economic dispatch strategies of the BES in terms of load following on a daily and seasonal basis across T&D to various stakeholders through DER participation in energy markets.
- Evaluate the potential operational and economic benefits across T&D to various stakeholders through DER providing ancillary services in terms of frequency and voltage support.

Q5: Is It Used for Real-time Operations?

Overview: The tool will only be used in offline planning, operational and control studies. It will not be used for real-time operations. PSS®E itself is a planning tool for BES planners and operators and is not used in the control room for real-time operations.

Technical answer: The users can use the tool to run the following planning, operational, and control studies considering high DER penetration:

- Short-term and long-term BES planning studies including power flow analysis, short-circuit analysis, and contingency analysis.
- BES voltage stability studies following small disturbances.
- BES voltage stability studies following large disturbances such as faults, loss of load, or loss of generator.
- Dynamic stability analysis, including small-signal stability and transient stability.
- Frequency stability analysis, including inertial frequency response, primary frequency response, and spinning reserve.
- System protection studies and relay coordination.
- BES disturbance ride-through studies (e.g., voltage and frequency).
- Impact on the transmission system's secondary frequency response, typically controlled through the system operator's automatic generation control.
- Impact on the BES's load-following or ramping requirements throughout the day and over the course of the seasons through economic dispatch.
- Control system design for both transmission and distribution systems.

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