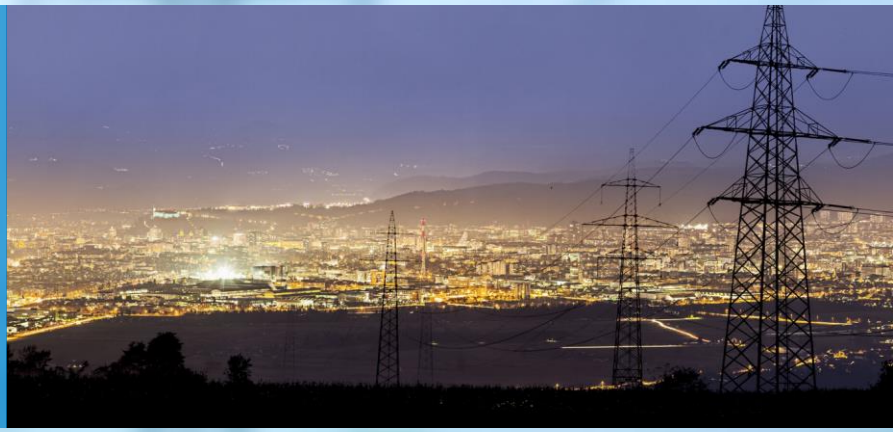
IRED 2018
17-19 OCTOBER 2018
VIENNA, AUSTRIA

TRANSMISSION DISTRIBUTION CO-SIMULATION MODELING



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Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

OUTLINE

ARGONNE-NERC JOINT RESEARCH PORTFOLIO

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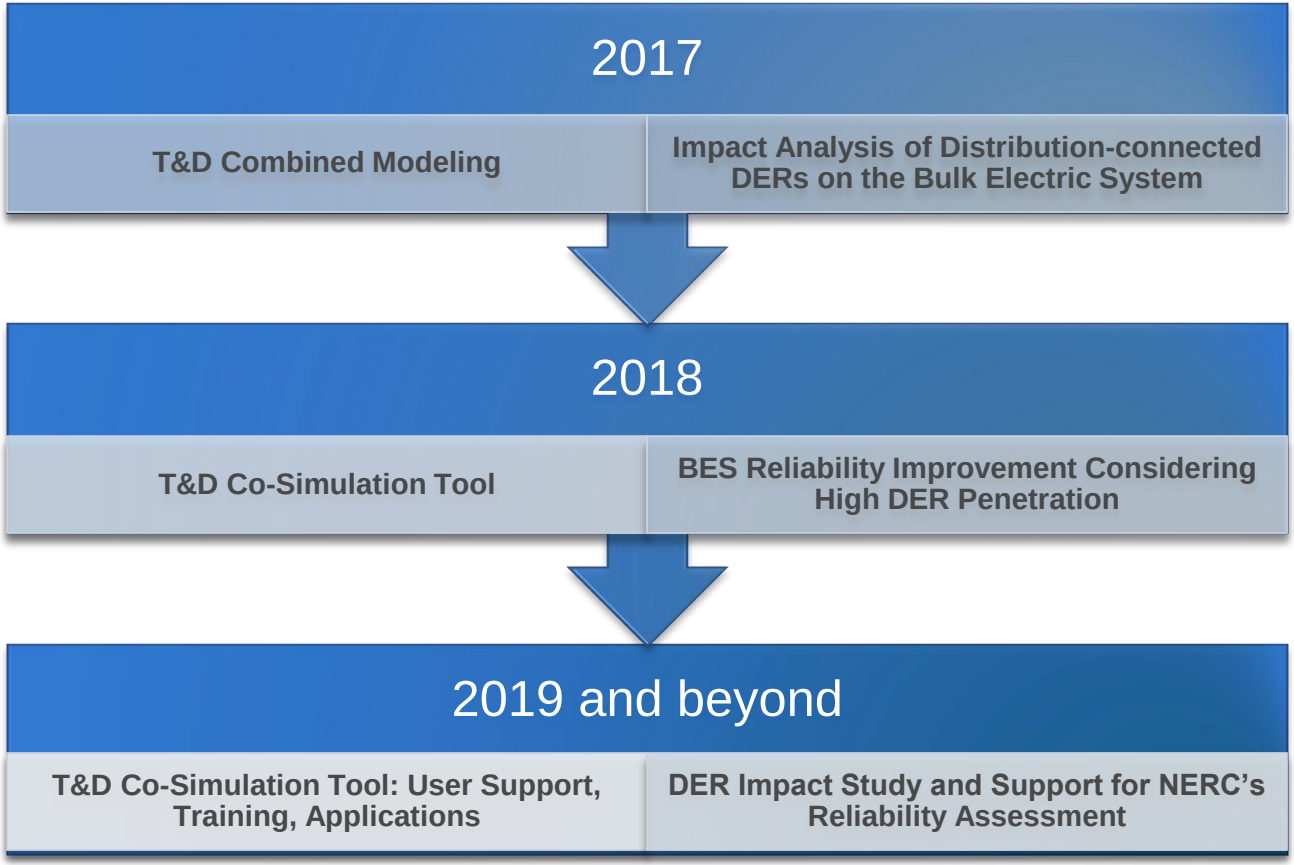
BES RELIABILITY IMPROVEMENT CONSIDERING DER

T&D CO-SIMULATION TOOL DEVELOPMENT

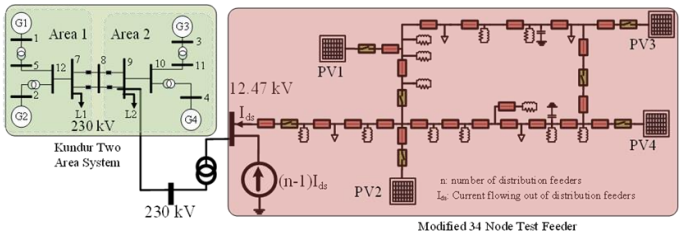
FUTURE WORK

ARGONNE-NERC JOINT RESEARCH PORTFOLIO

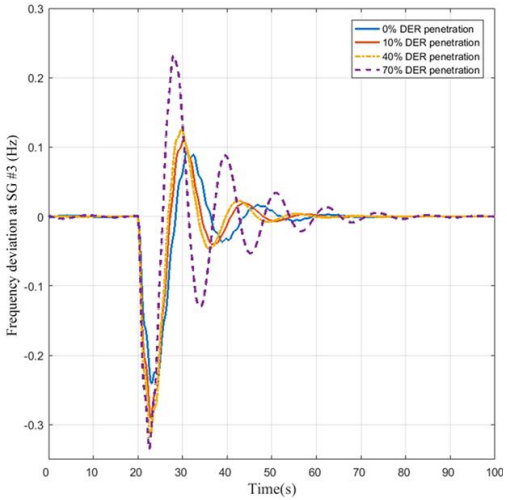


IMPACT OF DER ON THE BES

- Developed combined modeling of transmission and distribution systems
- Conducted benchmark case studies: DER impact on BES voltage stability, frequency regulation, and dynamic stability of BES
- Supported NERC's Essential Reliability Working Group (ERSWG) and Distributed Energy Resources Task Force (DERTF)



(a)



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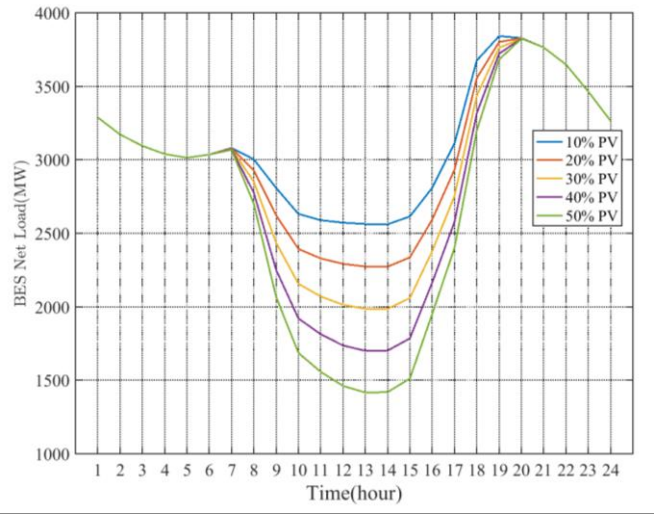

(c)

Figs: (a) Combined modeling of T&D system; (b) DER impact on BES inertial frequency response; (c) DER impact on BES net load and ramping requirements

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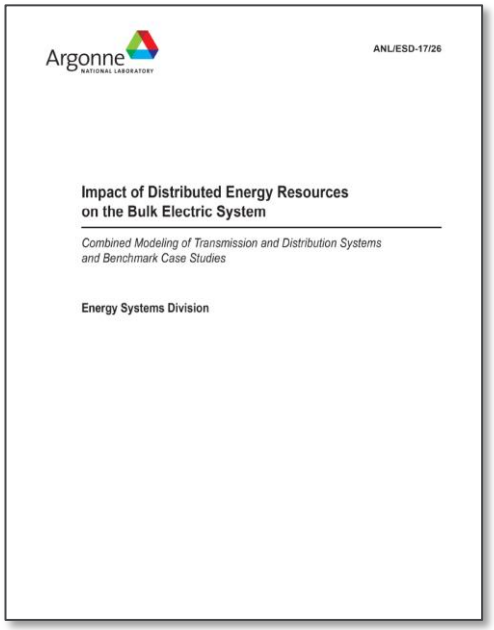
DISSEMINATION INITIATIVES

- Argonne-NERC jointly authored report "**Impact of Distributed Energy Resources on the Bulk Electric System – Combined Modeling of Transmission and Distribution Systems and Benchmark Case Studies**," November 2017
- Argonne and NERC's ERSWG/DERTF jointly organized panel "**Reliability Considerations of High-Penetration DER on the Bulk Power System**," IEEE PES T&D Conf & Expo, April 2018
- Panel discussion at the FERC Technical Conference "**Distributed Energy Resources – Technical Considerations for the Bulk Power System**", April 2018



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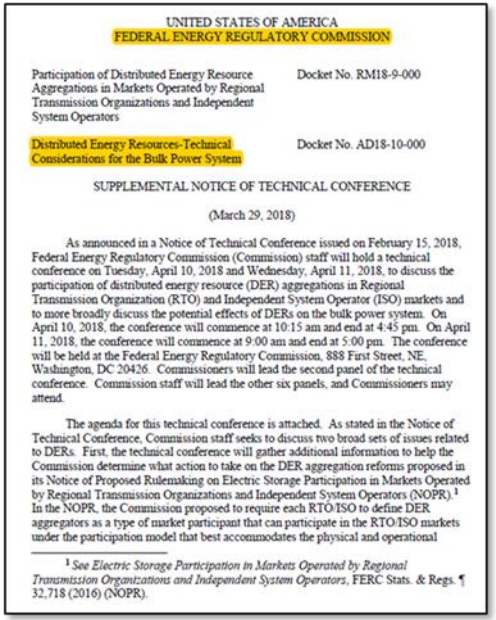
ANL/ESD-17/26

Impact of Distributed Energy Resources on the Bulk Electric System

Combined Modeling of Transmission and Distribution Systems and Benchmark Case Studies

Energy Systems Division



UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

Participation of Distributed Energy Resource Aggregations in Markets Operated by Regional Transmission Organizations and Independent System Operators — Docket No. RM18-9-000

Distributed Energy Resources-Technical Considerations for the Bulk Power System — Docket No. AD18-10-000

SUPPLEMENTAL NOTICE OF TECHNICAL CONFERENCE

(March 29, 2018)

As announced in a Notice of Technical Conference issued on February 15, 2018, Federal Energy Regulatory Commission (Commission) staff will hold a technical conference on Tuesday, April 10, 2018 and Wednesday, April 11, 2018, to discuss the participation of distributed energy resource (DER) aggregations in Regional Transmission Organization (RTO) and Independent System Operator (ISO) markets and to more broadly discuss the potential effects of DERs on the bulk power system. On April 10, 2018, the conference will commence at 10:15 am and end at 4:45 pm. On April 11, 2018, the conference will commence at 9:00 am and end at 5:00 pm. The conference will be held at the Federal Energy Regulatory Commission, 888 First Street, NE, Washington, DC 20426. Commissioners will lead the second panel of the technical conference. Commission staff will lead the other six panels, and Commissioners may attend.

The agenda for this technical conference is attached. As stated in the Notice of Technical Conference, Commission staff seeks to discuss two broad sets of issues related to DERs. First, the technical conference will gather additional information to help the Commission determine what action to take on the DER aggregation reforms proposed in its Notice of Proposed Rulemaking on Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators (NOPR).[1] In the NOPR, the Commission proposed to require each RTO/ISO to define DER aggregators as a type of market participant that can participate in the RTO/ISO markets under the participation model that best accommodates the physical and operational

[1] *See Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators*, FERC Stats. & Regs. ¶ 32,718 (2016) (NOPR).

BES RELIABILITY IMPROVEMENT CONSIDERING HIGH DER PENETRATION

- Investigated DER contribution to BES frequency regulation from inertial response to load following
- Investigated DER contribution to enhance voltage control of BES
- Following IEEE Std. 1547-2018 and studying DER impact on distribution system protection and BES reliability

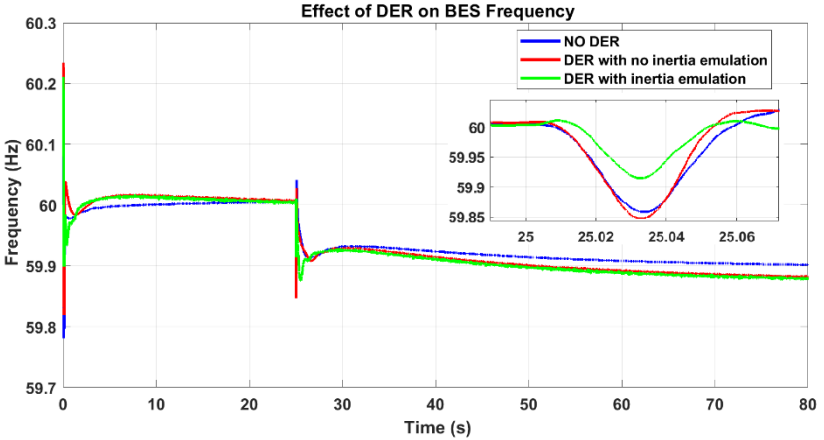
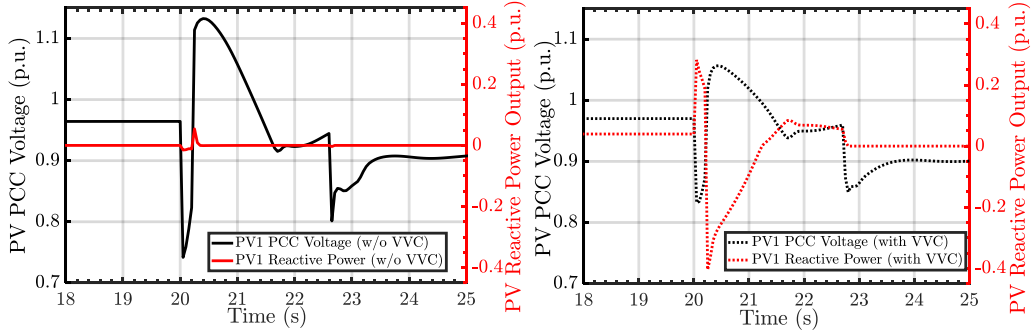
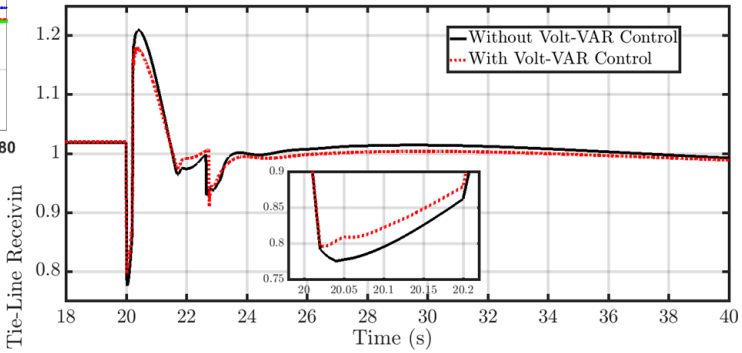


Fig: Virtual inertia emulated by DERs can help improve inertial response of BES (disturbance: load increase at 25s)





Figs: VVC helps maintain DER PCC voltage and improve tie-line voltage (disturbance: a self-clearing fault on the tie line at 20 s)

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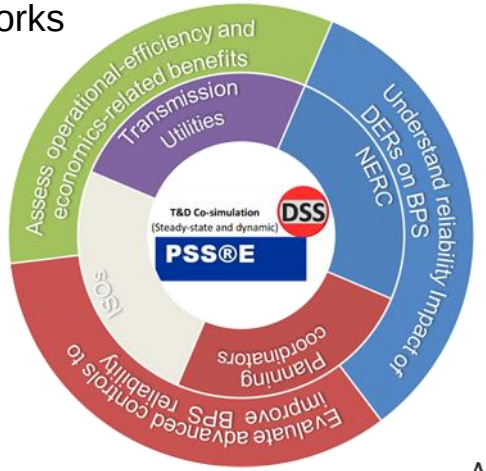
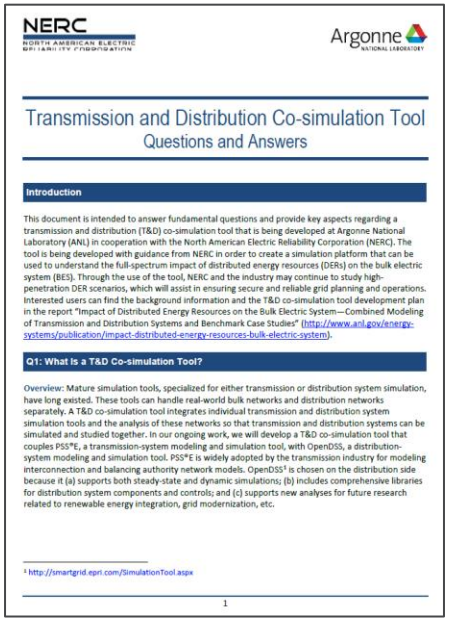
T&D CO-SIMULATION TOOL DEVELOPMENT

- T&D combined modeling approach suffers scalability and computational complexity
- A T&D co-simulation tool is needed : transmission system entities can perform day-to-day planning, operational, and control studies for high-DER-penetration scenarios to ensure secure and reliable grid planning and operations
- T&D co-simulation tool functional requirements
  - Steady-state and dynamic (for transient stability and disturbance ride-thru studies) simulations
  - Scalability to model real-world interconnections and distribution networks
  - Flexibility to implement DER interconnection standards
  - Flexibility to implement advanced DER control functions
- T&D co-simulation
  - PSSE for T-Simulator
  - OpenDSS for D-Simulator



ADDRESSING INDUSTRY NEEDS

- Argonne-NERC jointly authored brochure “Transmission and Distribution Co-simulation Tool – Questions and Answers,” January 2018
- NERC industry webinar “NERC and Argonne project: Overview of Transmission and Distribution Co-Simulation Tool and Benchmark Case Studies,” February 2018
- Argonne-NERC joint presentation “NERC’s Efforts to Include DER in Planning Models and Argonne’s Combined T&D Co-Simulation Tool Enabling Bulk Power System Reliability Studies,” IEEE PES General Meeting, August 2018



NERC

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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

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- Q1: What is a T&D co-simulation tool?
- Q2: Why is a T&D co-simulation tool needed?
- Q3: Who will use it? Planners? Operators?
- Q4: What are the benefits? Operational Efficiencies? Risk reduction?
- Q5: Is it used for real-time operations?

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T&D CO-SIMULATION TOOL ARCHITECTURE AND OPERATION SEQUENCE

- Python-based T&D interface tool
- Load T&D cases into respective simulators (PSS/E and OpenDSS)
- Prompt user to select simulation type and scenarios
- Establish internal mapping between T&D networks
- Carry out simulation and visualize results

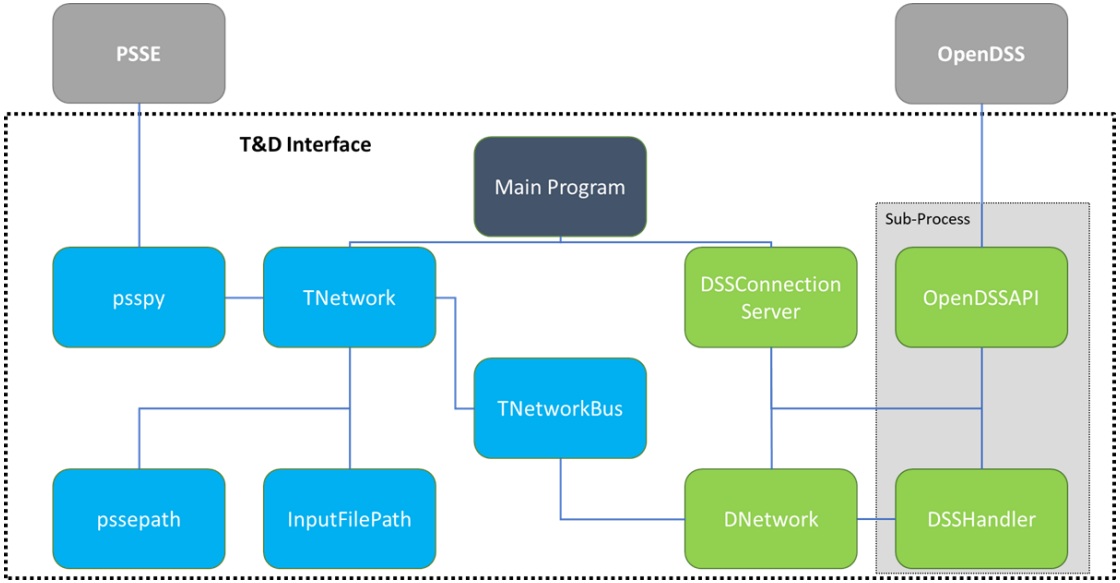


Fig: Architecture of the T&D co-simulation tool

STEADY-STATE T&D CO-SIMULATION

- Transmission system: IEEE 14-bus system
- Distribution system: 1 IEEE 123-node system connected to transmission load bus #5
- PV: 1 PV system connected to the distribution system
  - Modeled as static generator operating at unity power factor
  - Rated at 24 KW
  - Representing 7% penetration in the feeder

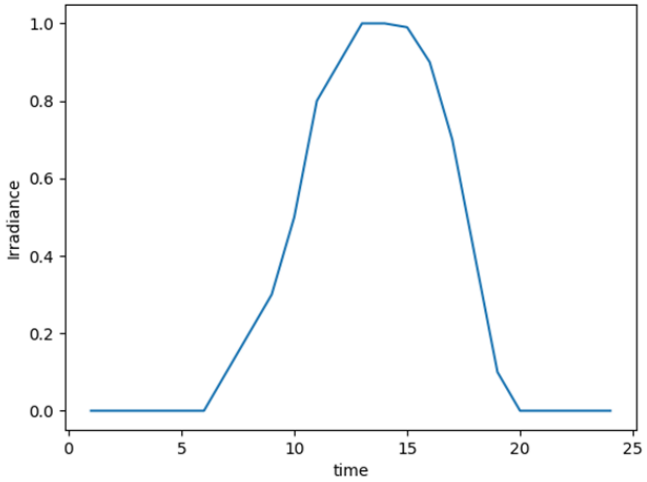


Fig: 24-hour solar irradiance profile

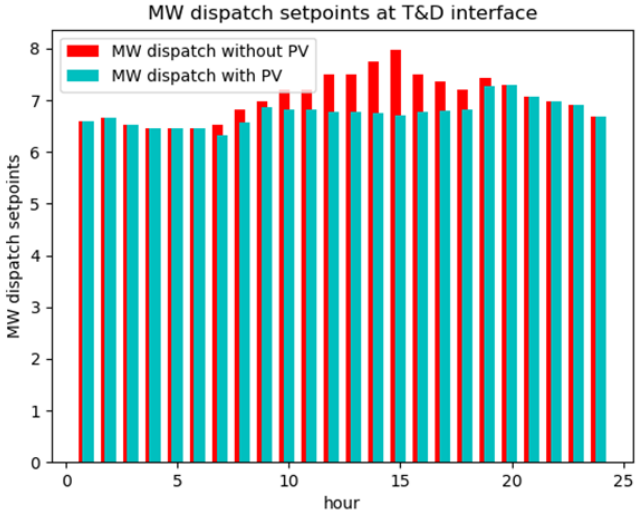
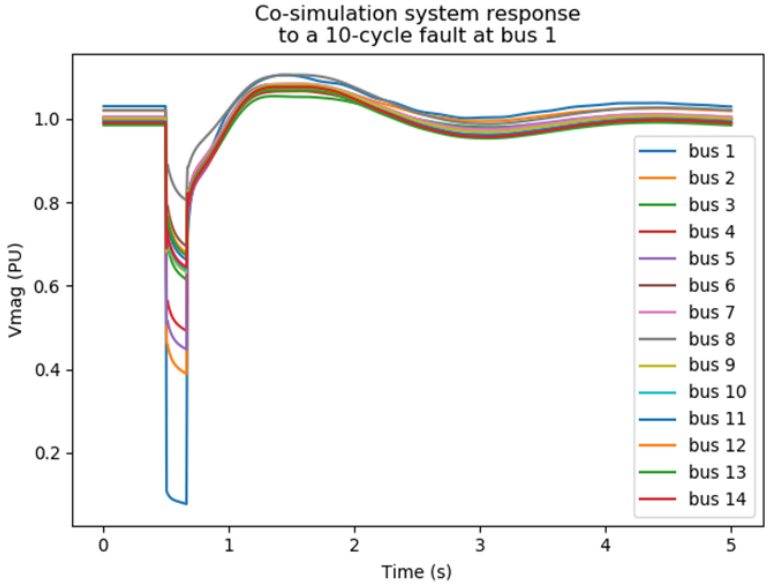


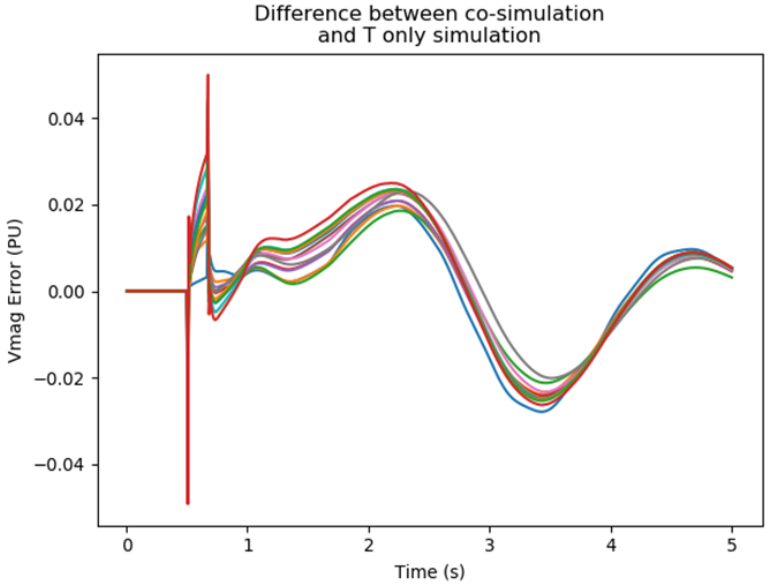
Fig: 24-hour active power dispatch profile at T&D boundary bus

DYNAMIC T&D CO-SIMULATION

- Transmission system: IEEE 14-bus system
- Distribution system: every transmission system load bus is replaced with IEEE 13-node feeder



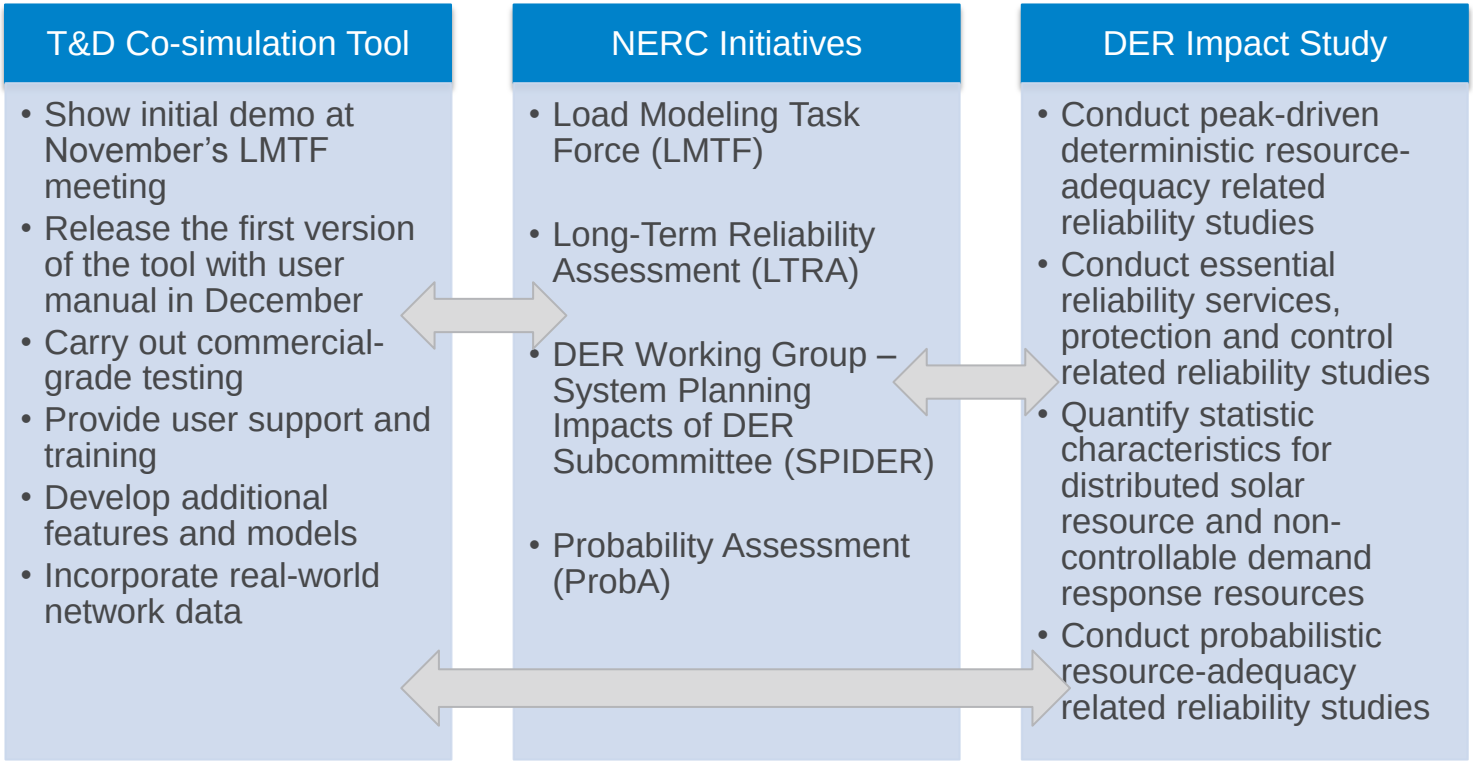
(a)



(b)

(a) Change in voltage magnitude in response to a 10-cycle fault at bus 1 on transmission system.
(b) Difference in voltage magnitude between transmission only and co-simulation approach.

FUTURE WORK


T&D Co-simulation Tool
• Show initial demo at November's LMTF meeting
• Release the first version of the tool with user manual in December
• Carry out commercial-grade testing
• Provide user support and training
• Develop additional features and models
• Incorporate real-world network data
NERC Initiatives
• Load Modeling Task Force (LMTF)
• Long-Term Reliability Assessment (LTRA)
• DER Working Group – System Planning Impacts of DER Subcommittee (SPIDER)
• Probability Assessment (ProbA)
DER Impact Study
• Conduct peak-driven deterministic resource-adequacy related reliability studies
• Conduct essential reliability services, protection and control related reliability studies
• Quantify statistic characteristics for distributed solar resource and non-controllable demand response resources
• Conduct probabilistic resource-adequacy related reliability studies

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Work supported by U.S. DOE Office of Electricity, Advanced Grid Research and Development , Program managers: Ali Ghassemian and Dan Ton