ESIG SPRING TECHNICAL WORKSHOP

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T&D CO-SIMULATION TOOL (TDCOSIM) AND CASE STUDIES

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

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MOTIVATION

PRIOR WORK

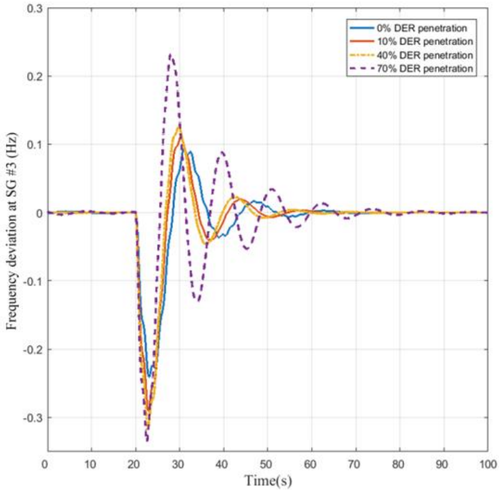
OVERVIEW OF TDCOSIM

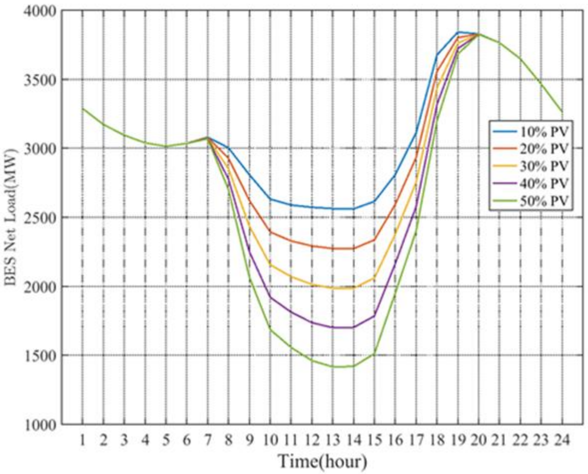
CASE STUDIES

FUTURE WORK

INDUSTRY CHALLENGES

- According to NERC 2018 December Long-Term Reliability Assessment
  - *California is projected to have over 18 GW of distributed solar photovoltaic (PV) by 2023, which is nearly 40 percent of its projected peak demand for the same period. New Jersey, Massachusetts, and New York are projected to each have between 3.5 and four GW of distributed solar PV by 2023.*
  - *Over 30 GW of New Distributed Solar Photovoltaic Expected by the End of 2023 to Impact System Planning, Forecasting, and Modeling Needs.*
- New approaches to incorporate DER impact in BPS planning studies and to model interactions between transmission and distribution systems needed

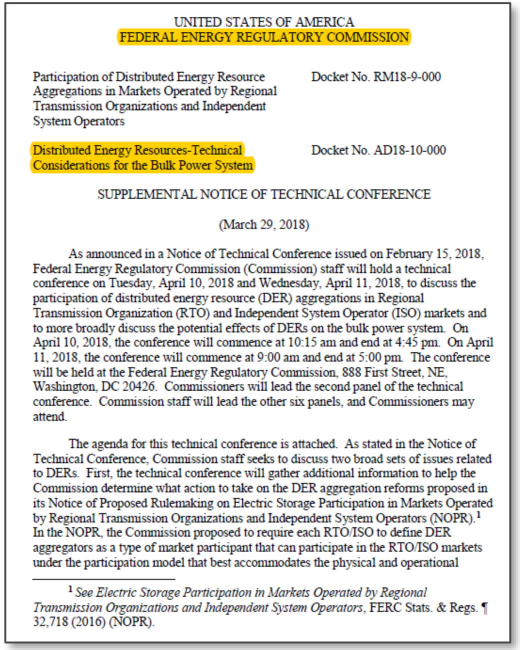




Figs: (left) DER impact on BPS inertial frequency response; (right) DER impact on BPS net load and ramping requirements

INDUSTRY RECOGNITION OF CHALLENGES

- NERC Essential Reliability Service Working Group in 2014 and DER Task Force in 2015
- FERC Distributed Energy Resource Technical Conference, Washington DC, April 10-11, 2018
- NERC System Planning Impacts of DER Working Group (SPIDERWG) in 2018



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

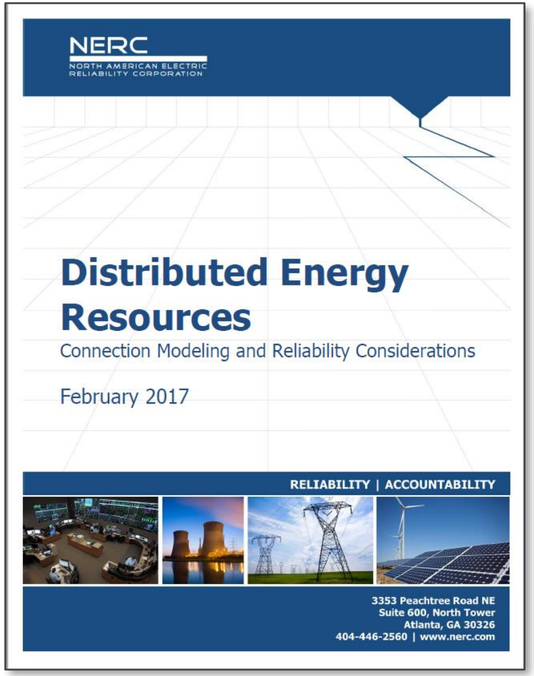
SUPPLEMENTAL NOTICE OF TECHNICAL CONFERENCE

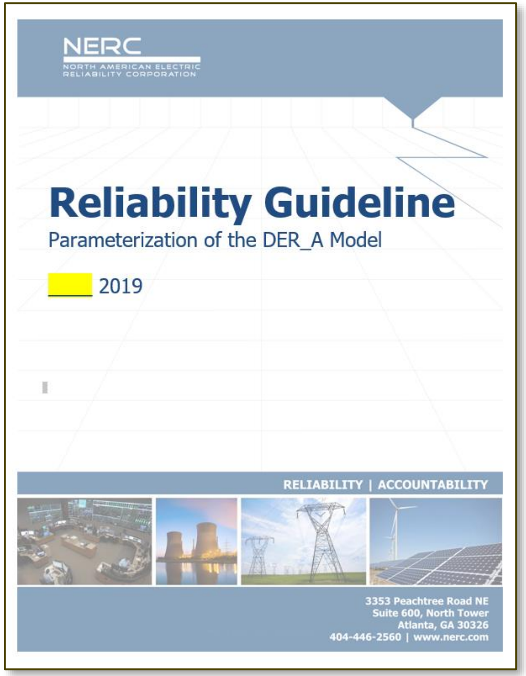
(March 29, 2018)

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).





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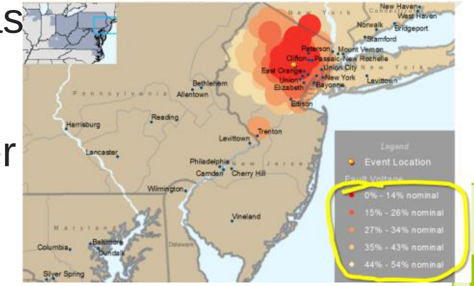
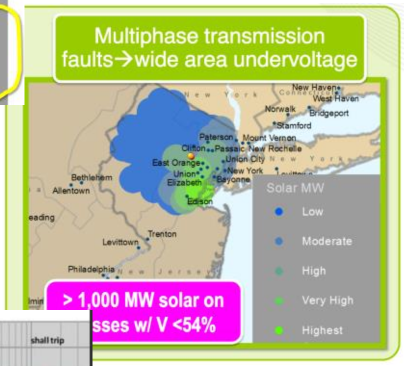
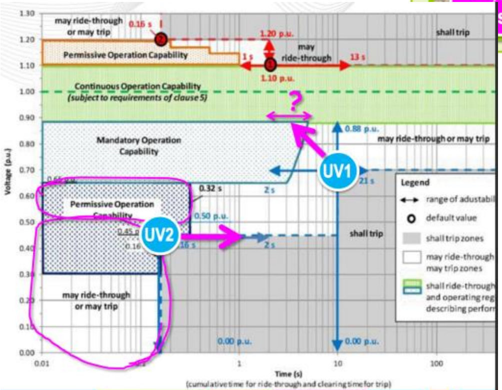
SUPPORTING PJM'S DER RIDE THROUGH TASK FORCE UNDER NEW CRADA

- The DER Ride Through Task Force (DERRTTF) was endorsed by PJM's Planning Committee in November 2018
  - PJM concern that lack of ride through and faster trip times could lead to a transmission fault triggering widespread DER tripping and subsequent reliability issues
- Tasked with arriving at PJM-wide consensus across Transmission and Distribution on preferred IEEE 1547-2018 Ride-Through/Trip Settings for DER
- Deliverables will be Ride-Through/Trip settings, proposed PJM manual language changes or other applicable PJM governing documents, and a guide of best practices for state/local regulators
- Argonne researcher embedded for 3 months into PJM team to run PSSE and OpenDSS simulations in support of Task Force



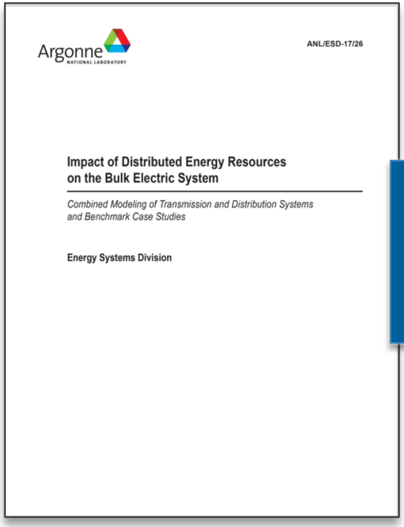




Source for charts: https://www.pjm.com/-/media/committees-groups/task-forces/derrttf/20190115/20190115-item-03-intro-to-ride-through-and-ieee-1547.ashx

PRIOR WORK

- Impact of Distributed Energy Resources on the Bulk Electric System
  - Combined modeling of transmission and distribution systems
  - Benchmark case studies
- Technical report "Impact of Distributed Energy Resources on the Bulk Electric System – Combined Modelling of Transmission and Distribution Systems and Benchmark Case Studies (ANL/ESD-17/26)," November 2017



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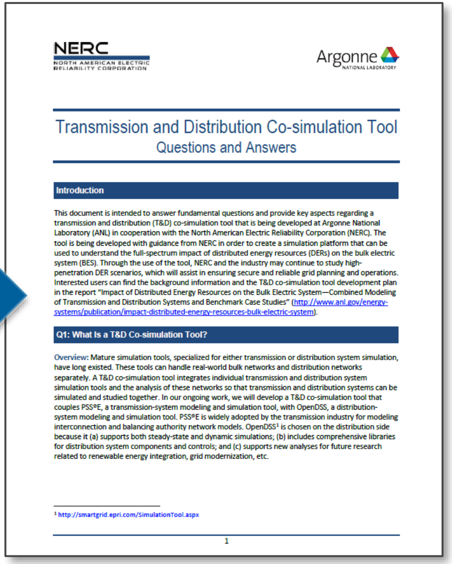
ANL/ESD-17/26

Impact of Distributed Energy Resources on the Bulk Electric System

Combined Modeling of Transmission and Distribution Systems and Benchmark Case Studies

Energy Systems Division

T&D combined modeling with DERs on the distribution side is not realistic and scalable



NERC NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

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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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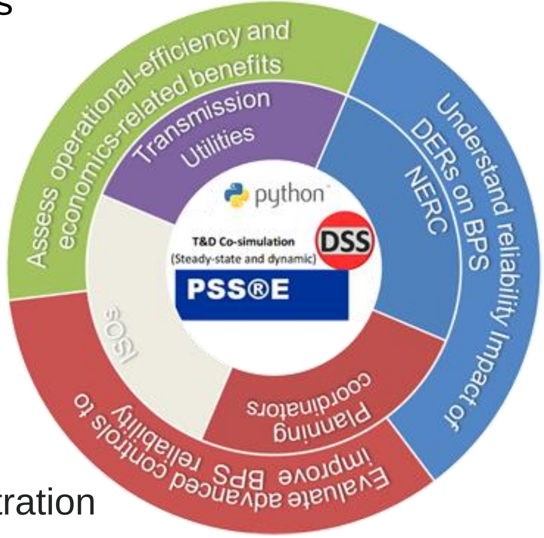
OVERVIEW OF ARGONNE'S T&D CO-SIMULATION TOOL (TDCOSIM)

- Functional requirements
  - Steady-state and dynamic (for transient stability and disturbance ride-thru studies) simulations
  - Scalability to model realistic interconnections and distribution networks
  - Flexibility to implement DER interconnection standards
  - Flexibility to implement advanced DER control functions
- Software components
  - PSS®E for T-Simulator
  - OpenDSS for D-Simulator
  - Python-based T&D interface
- Benefits for transmission system entities
  - Increase the awareness of the reliability impacts from high DER penetration
  - Identify remedial control strategies that address future reliability concerns
  - Ensure reliable and secure operation of the national grid
  - Offer operational efficiency and economic benefits to various stakeholders across T&D



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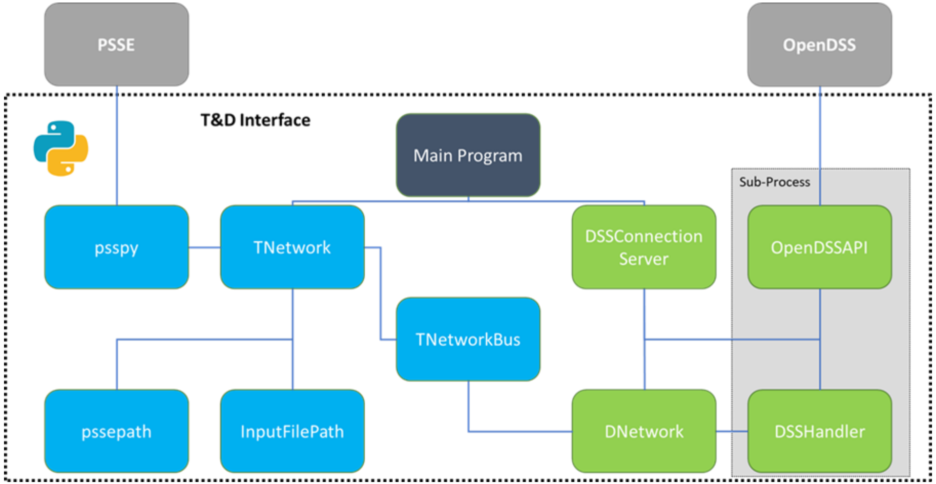
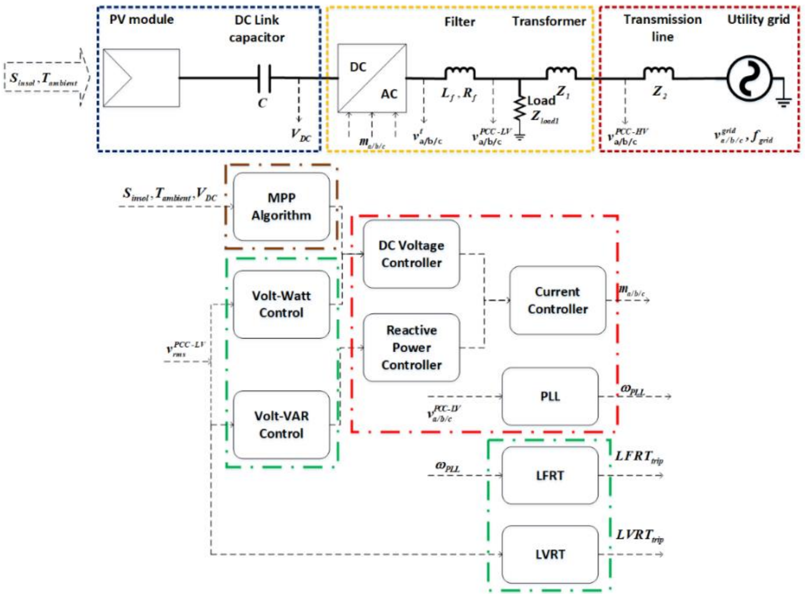
TDCOSIM ARCHITECTURE AND OPERATION SEQUENCE

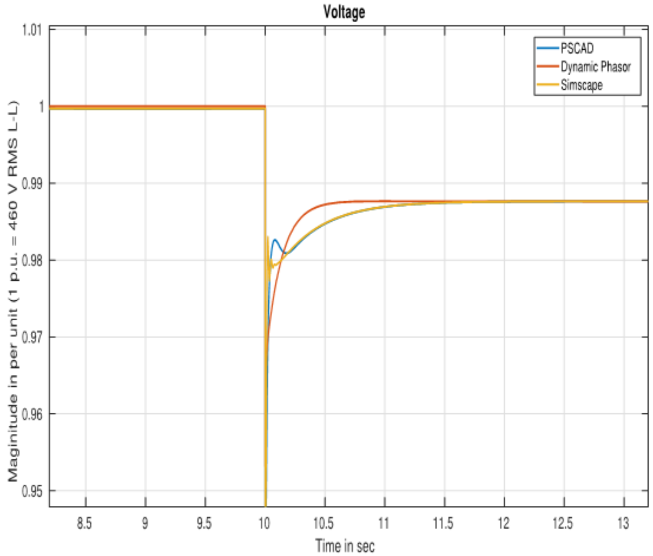
- Load T&D cases into respective simulators (PSS®E and OpenDSS)
- Prompt user to select simulation type and scenarios
- Establish internal mapping between T&D networks
- Carry out simulation and visualize results



DYNAMIC DER MODEL

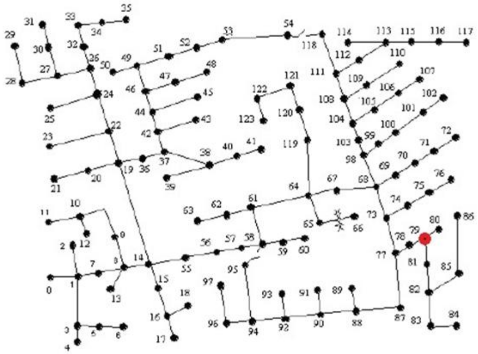
- PV dynamic modeling (stand-alone Python-based code)
  - Phasor models of three-phase and single-phase distributed solar PV system with inverter, controls, and protection
  - Volt-VAR and Volt-WATT implemented
  - Voltage/frequency-deviation based protection compliant IEEE Std 1547 implemented
- Integrated dynamic DER models into TDcosim





USE CASE 1: A QSTS STUDY

- 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



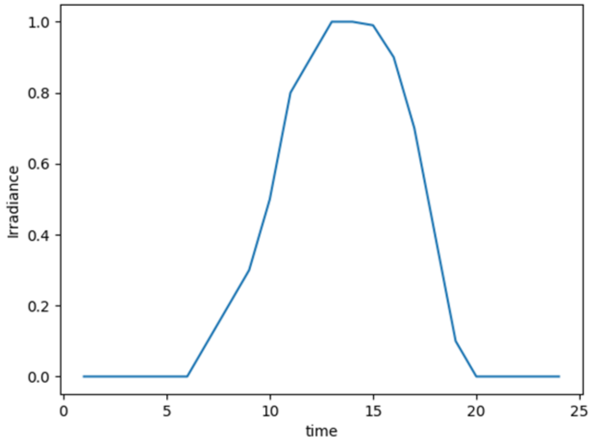


Fig: 24-hour solar irradiance profile

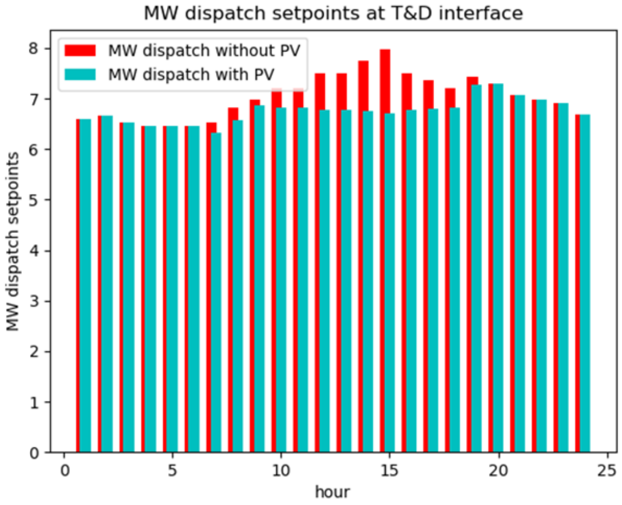


Fig: 24-hour active power dispatch profile at T&D boundary bus

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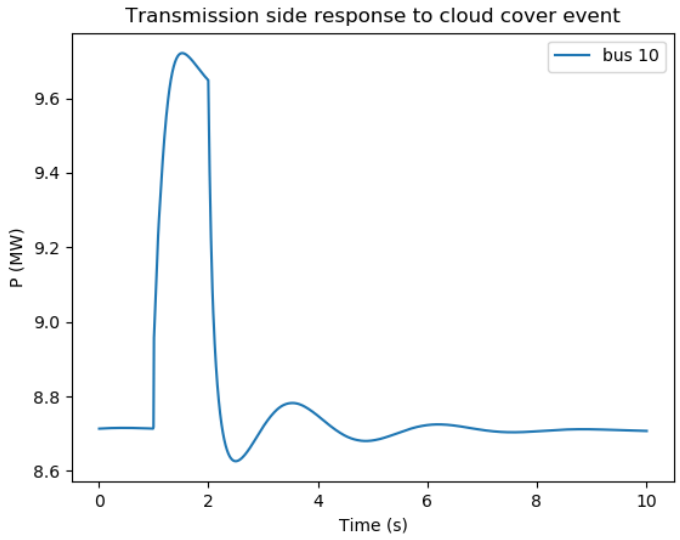
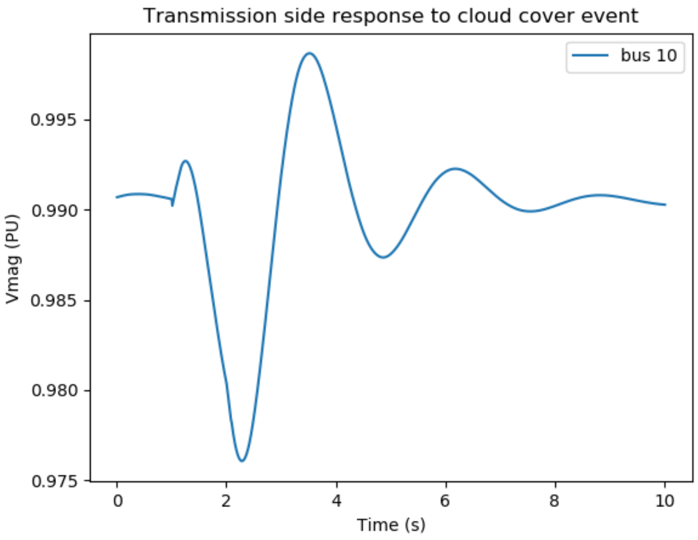
USE CASE 2: A CLOUD-COVER EVENT

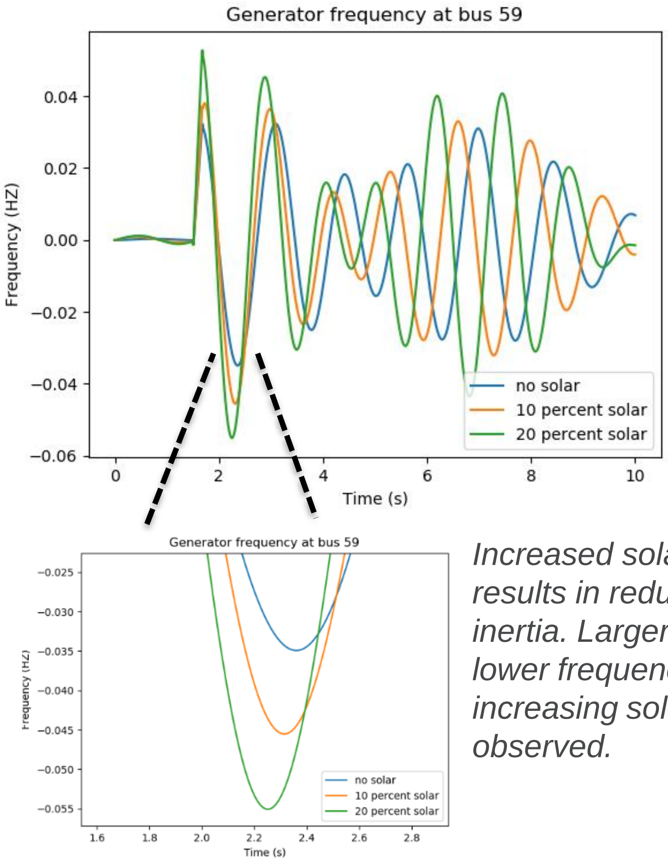




- IEEE 14-bus test system (T)
- IEEE 13-node feeder (D) interfaced at buses 9, 10 and 11
- 10% solar penetration
- Each PV system is rated at 50kVA and operating at unity power factor
- Cloud cover event at t=1 sec results in solar output to drop to zero
- Reduction in solar generation results in increased load
- The cloud cover event is assumed to end at t=2 sec

USE CASE 3: DER IMPACT ON TRANSIENT STABILITY OF BPS

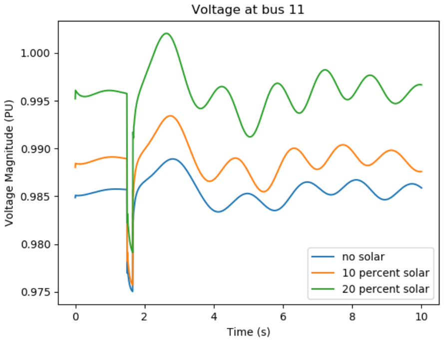
- Transmission: IEEE 118-bus test system
- Distribution: 30 instances of 8500-node feeder (no PV penetration) + 22 instances of 123-node feeder with variable PV penetration levels
- Overall PV penetration level with respect to the entire bulk system load
  - 10%
  - 20%
- In all about 150K buses (half a million variables)
- A 10-cycle temporary fault is applied at bus #60 on transmission system

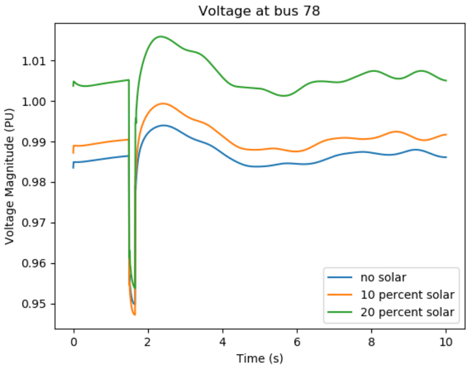


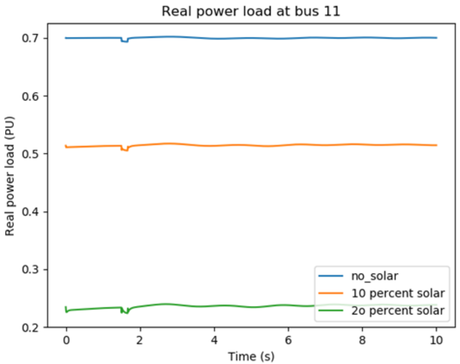
Increased solar penetration results in reduced system inertia. Larger first swing and lower frequency nadir with increasing solar penetration observed.

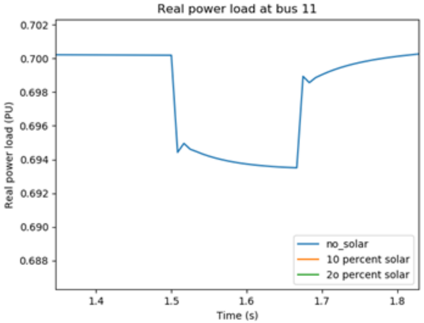
USE CASE 3: DER IMPACT ON TRANSIENT STABILITY OF BPS

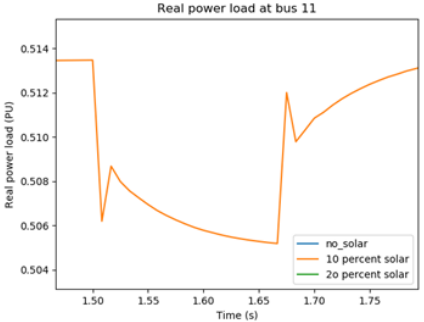
- Increasing solar penetration results in reduction of load as seen from the transmission side which in turn increases the voltage at load buses
- Different solar penetration level results in different system dynamics

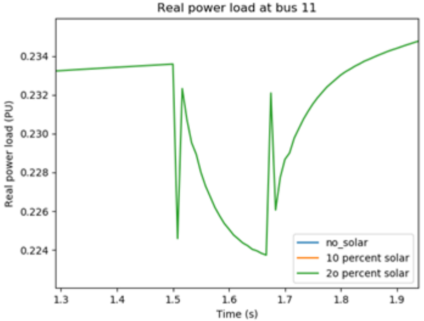












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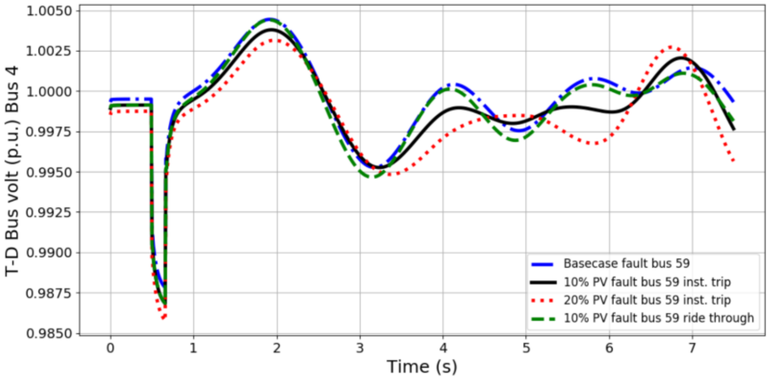
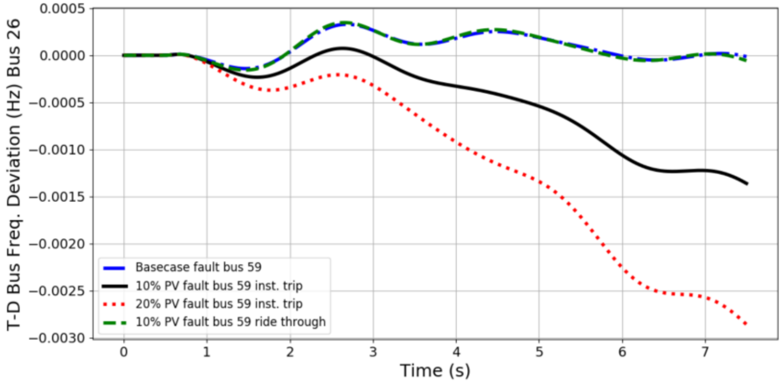
USE CASE 4: IMPACT OF DER TRIP AND RIDE-THROUGH SETTINGS ON BPS STABILITY

- Transmission: IEEE 118-bus test system
- Distribution: IEEE 123-node feeder connected to buses 54, 59, 80, 90, and 116
- 10% and 20% PV penetration level implemented for the feeders above
- Four study scenarios
  - Base case without PV penetration
  - 10% PV penetration with instant tripping
  - 10% PV penetration with ride-through setting
  - 20% PV penetration with instant tripping
- A 10-cycle temporary three-phase fault is applied at bus #59 on transmission system at 0.5 sec
- Total simulation time: 7 sec



Increased PV penetration results in more severe voltage sag during the fault and higher swing after the fault



- *Increased PV penetration results in more frequency deviation when they trip offline*
- *PV ride-through helps maintain system frequency*

WORK PLAN – 2019 AND BEYOND

T&D Co-simulation Tool

- Release the first version of the tool with user manual by June 2019
- Carry out commercial-grade testing
- Provide user support and training
- Develop additional features and models
- Incorporate real-world network data
- Develop related tools for transmission and distribution grid modeling and planning

Initiatives and Applications

- Support SPIDERWG, LMTF
- Applications in T&D planning coordination (DER tripping/ride-thru settings, DER_A model parameterization and performance verification)
- Support NERC Long-Term Reliability Assessment and Probability Assessment
- Applications in T&D operation coordination (in conjuction with DERMS to manage DERs to provide T&D coordinated congestion management, system balancing, frequency and voltage control, and flexibility)
- Defining the operating challenges, dynamics over time
- Applications in T&D resilience enhancement

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

Advanced Grid Research

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