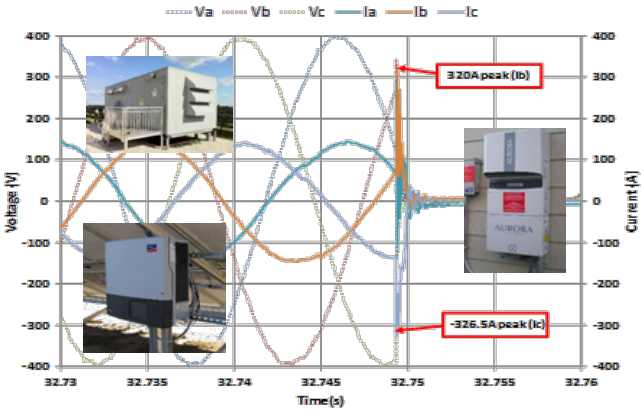
EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Inverter-Based DER Dynamic Response Characterization for Protection, Planning, and Power Quality



Example inverter fault response characteristics

Background, Objectives, and New Learnings

Distributed Energy Resource (DER) installations are increasing, and in response, efforts are proposed to better understand their dynamic impact on distribution protection, bulk system stability, and power quality immunity and emissions. As an emerging technology, data that characterizes inverter behavior with a diverse range of grid conditions is limited.

Ongoing EPRI research has provided improved planning and protection models available in commercial power system simulation tools including the DER_A model in transmission dynamic stability tools (such as Siemens PSS/E and GE PSLF) and the wind and PV models in short-circuit packages (such as Electron CAPE and Aspen OneLiner). Research to develop related models for commercial distribution analysis tools is also underway, and there is interest in accelerating this process.

An inverter's dynamic response to grid disturbances depends on the control design of the specific make and model. Hence it is critical to evaluate a variety of inverter products to develop more realistic models, related parameter values, and behaviors. Results are expected to enhance understanding of emerging power system reliability issues as more grid-supportive DER are being deployed. Characterization of inverter behavior across various inverter makes, sizes, and types will improve both generic and plant-specific evaluations.

This project aims to provide comprehensive characterization of DER behavior during grid events, balanced and unbalanced faults, open circuits, phase shifts, and frequency changes. Results will be tailored to inform and improve DER models in commercial distribution and transmission protection, planning, and power quality analysis packages.

Project Highlights:

- Understand dynamic behavior of a variety of inverter based DER types and scales
- Develop, improve, and verify models based on measured data
- Develop a standard set of tests for model validation for inverter manufacturers
- Standardize uniform templates for DER models to streamline protection and planning studies with higher degree of DER

Benefits

This project intends to help utility engineers make informed decisions to safely and effectively integrate more DER. The results will expand industry knowledge of inverter response to grid disturbance conditions, accelerate the development of dynamic models, provide evaluation and advancement of existing models, and identify critical parameters and ranges for sensitivity analysis. Utilities may further benefit through enhanced knowledge of inverters' dynamic behavior, including, but not limited to:

- Response to grid faults (L-L, L-L-G, L-G, and 3-phase)
- Short-circuit current magnitude, duration, and phase angle
- Active/reactive current during fault ride through
- Transient over-voltage (TOV)
- Response to phase shift, frequency change, transient voltage change, single phase opening, and other abnormal grid conditions
- Grid impacts of active islanding detection
- Reconnection time and behavior after fault

The development of industry accepted standard testing procedures and resulting reporting templates will simplify inclusion of future product behaviors in grid reliability studies.

The public benefits of this work could include specification and verification of performance of inverter-based DER that is reasonably predictable and beneficial—while at the same time not detrimental—to the distribution and bulk system stability, protection, and power quality.

Project Approach and Summary

EPRI plans to facilitate an advisory group of participating utilities, transmission operators, and NERC/FERC/WECC to determine the requirements for DER dynamic modeling to support protection and planning studies. Working with participants, EPRI will select and acquire representative PV and energy storage inverters with IEEE 1547-2018 functional capability. Standard test plans and reporting templates will be created for each of the dynamic characteristics identified by the advisory group. EPRI plans to evaluate a wide range of inverter types and sizes to capture diversity in their dynamic responses to a variety of grid faults and disturbance conditions.

Findings from these evaluations will help develop, improve, or verify existing DER models for more accurate grid reliability studies. Improvements of existing and development of new models or specifications will be initiated through appropriate industry working groups.

This project plans to include an optional simulation-based dynamic characterization of selected DER plants task to demonstrate how plant design may affect, and differ from, the individual inverter dynamic response. Dynamic characterization at the DER plant level is expected to provide guidance for "DER plant design evaluations" as required by IEEE Std 1547-2018. This project will coordinate closely with related EPRI research in its transmission and distribution areas.

Deliverables

- Documented utility use cases that require understanding of DER dynamic behavior
- Requirements of inverter dynamic response characteristics, accuracy, and ranges of values for key parameters
- Test plans and procedures to determine needed dynamic attributes
- Standard templates to support reporting and automated exchange of inverter model parameters
- Inverter evaluation results including time-domain characteristics and key parameters
- Assessment of existing inverter models, identification of needed improvements, and (as necessary) more detailed, EMT-type models developed in EMTP and/or PSCAD
- Industry engagement for consensus building and contribution at appropriate industry working groups (e.g., IEEE, WECC, NERC, FERC)
- Tech transfer and training events

The non-proprietary results of this work will be incorporated into EPRI Integration of Distributed Energy Resources, Distribution Operations and Planning, Transmission Planning, and Bulk Power System Integration of Variable Generation R&D programs and made available to the public for purchase or otherwise.

Price of Project

There are two price tiers. The total cost of participation for large utilities (>20,000 GWh/year distribution throughput) is $120,000. For all others, including those that do not have distribution throughput, total cost is $60,000. This project qualifies for Self-Directed Funding (SDF) or Tailored Collaboration (TC) funds. The project can be funded over three calendar years (2019–2021).

The price for the optional Dynamic Characterization of DER Plant is $15,000 for each DER plant design type. Decision regarding the optional task can be made when joining the project or later.

Project Status and Schedule

This project will begin when sufficient funding is achieved and run for approximately 24 months.

Who Should Join

Distribution and bulk system planners, protection, and power quality engineers, as well as stakeholders involved in DER interconnection strategy, research, and regulatory interface.

Contact Information

For more information, contact the EPRI Customer Assistance Center at 800.313.3774 (askepri@epri.com).

Technical Contacts

Aminul Huque at 865.218.8051 (mhuque@epri.com)
Sean McGuinness at 704.595.2981 (smcguiness@epri.com)
Anish Gaikwad at 865.218.8040 (agaikwad@epri.com)

Member Support Contacts

Brian Dupin at 650.906.2936 (bdupin@epri.com)
Barry Batson at 704.905.2787 (bbatson@epri.com)
Todd Myers at 972.207.4034(tmyers@epri.com)
Abby Crison at 704.595.2694 (acrison@epri.com)

Product ID: 3002014731 Project ID: 1-111290 March 2019

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com