

SHORT-CIRCUIT MODELING AND PROTECTION SYSTEM PERFORMANCE ANALYSIS FOR SYSTEMS WITH HIGH LEVELS OF INVERTER-BASED RESOURCES

IBR Impacted Protection Functions

Power swing protection

ROCOF protection

Negative sequence elements

Directional elements

Overcurrent protection

Fault identification

Pilot protection

Differential protection

Distance protection

PROJECT HIGHLIGHTS

- Increased and reliable integration of renewable energy resources
- Advanced short circuit models of renewable energy resources for accurate system protection studies
- Improved protection schemes design for grids with renewable energy resources

Background, Objectives, and New Learnings

Decarbonization of the electricity sector is changing the generation mix. Synchronous generators (SGs) that have traditionally been the main generation sources are being displaced by renewable inverter-based resources (IBRs). This has caused several challenges to ensuring reliable and resilient operation of the power system, one of them being protection of transmission systems. IBRs exhibit a different fault current behavior compared to SGs, leading to an anticipated impact on the performance of the legacy protective relays and corresponding schemes, such as distance, overcurrent, and differential protection. Traditionally, the relays were set based on the fault current signature of SGs. However, increasing levels of IBRs are changing the short-circuit behavior of the power system, jeopardizing the dependability and security of legacy protection schemes. As the power system transitions towards an IBR-dominated grid, it is critical to identify the impact of these sources on various protection schemes and design remedial solutions for the reliable protection of transmission systems.

The objective of this supplemental research project is to investigate the performance of the protection system in grids with high penetration of IBRs, including 100% IBR-dominated systems. Advanced short-circuit (SC) models of IBRs with various control systems, including grid following and grid forming inverters, will be used to investigate the fault response of IBRs in real-world systems. The performance of the protection system will then be assessed in various scenarios, and potential challenges identified. Then mitigation measures will be proposed through improving the existing protection schemes or designing new ones.

Benefits

This work will contribute to a better understanding of the performance of transmission system protection schemes in power systems dominated by IBRs. It will provide protection engineers with models, tools, and guidelines required to perform accurate protection studies on systems with elevated levels of IBRs. The project results will benefit the participants through improved grid reliability and secure system integration of renewable energy resources.

Project Approach and Summary

EPRI plans to conduct the project through the following tasks.

Task 1: Short Circuit Modeling and Fault Analysis

IBR SC Modeling and Parameterization: Apply recently developed IBR SC models in commercial fault analysis programs (e.g., PSS®CAPE and ASPEN Oneliner), including both the Voltage-Controlled Current Source (VCCS) tabular model and the generic equation-based models. EPRI will offer tutorials, trainings, and demos on the IBR models algorithms, parameters, controls, and fault response. Parameterization of the models will be conducted using the EPRI VCCS Parameterization Tool.

IBR SC Model Validation and Conformity Assessment: Validate IBR SC model(s) corresponding to selected IBR plant(s) in the participant's transmission grid against available fault records and/or manufacturer-specific models. Assess conformity of the IBR fault response with the relevant IBR interconnection requirements of the project participant.

Fault Analysis Studies: Perform fault analysis on a selected portion of the participant's transmission grid with IBR SC models. Scope may include scenarios with high level of IBRs. Investigate modeling aspects such as numerical solver convergence and load impact.

Task 2: Time Domain Modeling and Protection Studies

EMT Modeling and Fault Analysis: Conduct time domain fault studies using Electromagnetic Transient (EMT) models and tools on a selected portion of the participant's transmission grid with IBR SC models. The impact of various IBR control schemes, such as grid following/forming and different penetration levels of IBRs may be included. The scope also includes EMT modeling of protective relays.

EMT Protection Performance Analysis: Conduct time domain protection studies to investigate performance of selected protection schemes within the modeled participant's power grid. Various protection functions will be considered to identify potential shortcomings of the existing relay settings and protection system coordination in the presence of IBRs. The analysis may include several scenarios with varying IBR levels and control schemes.

Protection Misoperation Mitigation: Develop mitigating strategies to address protection system deficiencies. Recommendations will be provided either in form of new relay settings or additional protection schemes.

Deliverables

1. Training Material (from Task 1).
2. Technical Report (from Task 1 and Task 2).
3. Simulation models (from Task 1 and Task 2).

The non-proprietary results of this work will be incorporated into EPRI's R&D programs.

Price of Project

The cost of participation is shown below. Participants may select either or both Tasks. Contact EPRI for tailored scope options. This project qualifies for self-directed funding (SDF).

Task	Price
Task 1	\$80,000
Task 2	\$100,000
Tasks 1 & 2	\$160,000

Project Status and Schedule

Each task is expected to take approximately 9 months. Tasks can be performed in parallel if both are selected.

Who Should Join

Utilities facing existing or anticipated protection related concerns related to utility-scale renewable energy resources integration into their system.

Contact Information

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

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