



Modeling, Characterization, and Suppression of Temporary Overvoltages in Power Grids with High Share of Inverter-Based Resources

Final Project Report

T-66

Power Systems Engineering Research Center
*Empowering Minds to Engineer
the Future Electric Energy System*



Modeling, Characterization, and Suppression of Temporary Overvoltages in Power Grids with High Share of Inverter-Based Resources

Final Project Report

Project Team

Saeed Lotfifard, Project Leader
Washington State University

Sakis A. P. Meliopoulos
George J. Cokkinides
Georgia Institute of Technology

Graduate Students

Hassan Yazdani
Washington State University

Abdulaziz M. Qwbaiban
Georgia Institute of Technology

PSERC Publication 24-09

December 2024

For information about this project, contact:

Saeed Lotfifard
Washington State University
School of Electrical Engineering and Computer Science
Pullman, Washington 99164-2752
Phone: 509-335-0903
Email: s.lotfifard@wsu.edu

Power Systems Engineering Research Center

The Power Systems Engineering Research Center (PSERC) is a multi-university Center conducting research on challenges facing the electric power industry and educating the next generation of power engineers. More information about PSERC can be found at the Center's website: <http://www.pserc.org>.

For additional information, contact:

Power Systems Engineering Research Center
Arizona State University
527 Engineering Research Center
Tempe, Arizona 85287-5706
Phone: 480-965-1643
Fax: 480-727-2052

Notice Concerning Copyright Material

PSERC members are given permission to copy without fee all or part of this publication for internal use if appropriate attribution is given to this document as the source material. This report is available for downloading from the PSERC website.

© 2024 Washington State University. All rights reserved.

Acknowledgements

This is the final report for the Power Systems Engineering Research Center (PSERC) research project T-66 titled “Modeling, Characterization, and Suppression of Temporary Overvoltages in Power Grids with High Share of Inverter-Based Resources”. We also express our appreciation for the support provided by PSERC’s industrial members and the National Science Foundation’s Industry / University Cooperative Research Center program. We would like to recognize the following project advisors for their support to the project.

Aftab Alam (CAISO), Ran Xu (CAISO), Alan Engelmann (ComEd), Shikhar Pandey (ComEd), Mohit Singh (ComEd), Kurt Lafrance (CMS), Dennis R. Woycehoski (CMS), Ibukunoluwa Korede (dominionenergy), Zhongxia Zhang (dominionenergy), Gad Ilunga (dominionenergy), Evangelos Farantatos (EPRI), Aboutaleb Haddadi (EPRI), Alberto Del Rosso (EPRI), Deepak Ramasubramanian (EPRI), Kwok Cheung (GE), Deepak Konka (GE), Miaolei Shao (GE), Bishnu Sapkota (GE), Rijesh Akkanusery (GE), Panitarn Chongfuangprinya (Hitachi), Bo Yang (Hitachi), David Rieken (Hubbell), Mingguo Hong (ISO-NE), Xiaochuan Luo (ISO-NE), Yonghong Chen (MISO), Akshay Korad (MISO), Kun Zhu (MISO), David Till (NERC), Hongtao Ma (NERC), Fathalla Eldali (NRECA), Benjamin Kroposki (NREL), Kumaraguru Prabakar (NREL), Gab-Su Seo (NREL), Jianzhong Tong (PJM), Casey Cathey (SPP), Harvey Scribner (SPP), Bo Gong (SRP), Wisam Al Sudani (WAPA)

Executive Summary

This project focused on temporary overvoltage in IBR dominated power grids. The summary of the studies are as follows:

Part 1: Temporary overvoltage In IBRs Connected Power Systems

Part I of this project was focused on temporary overvoltages in IBRs connected power grids and the factors affecting the values of TOVs. The main results of the projects are as follows:

- The strength of the system is one of indicators that can be used to identify the possible vulnerable areas to TOVs. Accordingly, a variety of grid strength indicators were studied, and their advantages and limitations are discussed in this report.
- The impact of delays in the control loops and protection logics of IBRs on TOV were studied and time domain simulations were performed to demonstrate the impacts numerically.
- Impacts of different factors such as bandwidth of PLLs and changes in the grid strength were studied and the results are reported and discussed.
- Different factors affecting the TOV in IBR connected were studied using analytical methods such as state space analysis, Bode plots, and Generalized Nyquist Criterion.
- Time domain simulations were performed to demonstrate the impacts of the identified factors on the TOVs.
- The outcome of the studies can be used for tuning of the controllers and site location of IBRs to reduce the TOV impacts.

Part 2: Temporary overvoltage Analysis

- The Georgia Tech effort for this project has been focused on the following three parts of the study. (1) Proper representation of inverter-based resources in dynamic studies, (2) Conducting temporary overvoltage parametric studies, and (3) Studying the effects of temporary transients on the performance of the system.
- This report aims to understand the causes of overvoltage when Inverter-Based Resources (IBR) are suddenly connected or disconnected from the grid. It explores the extent to which overvoltage are expected to occur and examines the implications for existing legacy protection schemes using real-life test cases. The report begins by introducing the problem statement and providing examples of real-life incidents that occurred in Germany and Greece due to IBR triggered overvoltages and other transients. The report provides explanations why this work is crucial for determining the optimal design and positioning of new IBR projects to minimize overvoltages in the grid.
- In the second section, the report investigates the proper way to represent an IBR for the purpose of properly predicting overvoltages and other dynamic transients. It justifies the need for proper reorientation in modeling these systems and discusses previous work on modeling IBRs. It highlights the importance of establishing a model that is efficient in terms of hardware resources and time, providing real-time data for field operations. This is especially important when dealing with protection schemes that need to operate within a few cycles. A mathematical model for developing a high-fidelity representation of IBRs is presented.

- The third section introduces a real-life test system subject to the requirements outlined earlier. A detailed test case system is provided, covering all components from the generators and collector substation to the distribution network hosting the IBRs. The example test system includes several PV farms.
- In the fourth section, the report presents simulation results for selected events. It summarizes the percentage deviations of overvoltages for each of the three PV farms in the example test system and provides potential remedial actions to reduce overvoltage levels. The remedial actions help prevent physical damage to components and reduce the likelihood of false tripping in legacy protection schemes.
- Finally, the fifth section discusses the effects of temporary transients on system performance. A case study of an actual event on the Greek island of Rhodes is included. The sequence of events is modeled and simulated using a high-fidelity approach, incorporating mitigation and detection schemes, such as estimation-based protection, to avoid unnecessary generator tripping when IBR resources are suddenly generating transients that affect operation of IBRs and legacy power system components.

Project Publications:

- [1] Hassan Yazdani, Saeed Lotfifard, “Temporary Overvoltages in IBR Connected Power grids” to be submitted, 2024.

Student Theses:

- [1] Hassan Yazdani, Expected Ph.D thesis title “Grid Synchronization Stability Assessment and Enhancement of Inverter Based Resources”, Washington State University.