

# Transient Stability Analysis of a Power System with Distributed Generation Penetration

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**Abstract**—In recent years, while fossil fuel prices have increased, these fuels have reduced to access. More importantly, it has reached an irreversible point in climate change. This situation has led to increasing importance of renewable energy resources, notably wind and solar energy. In particular, developments in technology and efforts to implement smart grids increase the share of renewable energy sources in energy generation. Due to this increased share, it has caused some changes in the power system. The most important of these changes is the power system stability, which plays a vital role in system planning and operation. These sources have tended to leave the grid in the event of a failure. Also, variable generation features always pose a risk for system stability. In this paper, IEEE 9 bus power system is used to investigate the behavior and risks of these resources with variable generation structures under various fault scenarios.

**Keywords**—power system stability, renewable energy source, distributed generation.

## I. INTRODUCTION

Most of the energy needs in the world are provided by large scale central generation systems. These systems benefit from the potential energy of water as well as fossil and nuclear fuels. Initially, these systems provided huge gains in meeting energy demand. As time passed by, we have faced some limitations arising from the selection of installation places, economic, geographic, political, medical and security-related concerns [1]. In addition to these limitations, the frequent interruption of the existing electrical grids and the increased environmental concerns caused by energy generation have made it necessary to improve the electrical grids. In recent years, developments in both technology and energy have increased the importance of smart grid technologies.

Due to technical and technological reasons, the change from existing grids to the smart grid should not be sudden. The power system must make progress in certain stages. System engineers aim to form a more reliable, flexible and economical network with smart grids. For this purpose, the least certain percentage of the energy consumed need supply by renewable energy sources. The use of distributed generation systems based on renewable energy sources should increase in the grid. This is the first step to be taken.

The increase in distributed generation systems based on renewable energy sources in power systems provides several advantages. The advantages that offer an opportunity for reliable and quality energy supply are as follows;

- It reduces greenhouse gas emissions and has a less negative impact on global warming.

- It has a short-term installation and can be expanded with additions if necessary.
- It reduces losses in transmission and distribution lines, and ensures more efficient use of energy by preventing overloads in transmission and distribution lines at peak power demand.
- It provides fuel diversity along with traditional energy fuels as well as resources such as wind, solar and geothermal energy.
- It reduces power generation, transmission, distribution, maintenance, and repair costs [2],[3],[4],[5].

In spite of all these advantages, the distributed generation systems based on renewable energy sources have cause changes in the grid. The effects of low power distributed generation can ignore in the distribution system. Nevertheless, the effects of high power distributed generation can't ignore in the transmission and distribution system. The reason for this situation is high generation rates and it affects the whole grid [4], [5]. The most noteworthy influence is that it causes some problems in power system stability. These problems can be instantaneous and transient or can turn into serious events such as power blackout. The most prominent example of this serious event is in the case of a power blackout that occurred in South Australia as a result of severe storms in 2016. The storm has caused the electrical faults which can't restore. After a short time, the system began to lose distributed generations, because almost 50 percent of energy demand was meeting by wind and solar energy. Following the loss of generation, angular instability has occurred in the whole system [6]. Southern Australia's power blackout has shown that when high penetration renewable energy sources are used, grid reliability can be dangerous. In order to overcome these difficulties and ensure the reliable operation of smart grids, the stability of distributed generation systems needs to be improved.

This paper consists of the following sections; The second section explains the impact of increasing distributed generations on power system transient stability, thanks to the smart grid. The third section gives information about the test system and distributed generation integration. The fourth section presents the making of various fault scenarios for the test system via Matlab. Finally, it has evaluated the effects over rotor angle stability of distributed generations based on renewable energy sources in the fifth section.

## II. RESEARCH APPROACH

Conventional systems consist of synchronous generators. These generators produce the inertia constant and damping torque that plays a vital role in making system stability. When

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**Lauren Gardner**

A decorative graphic element consisting of a light blue horizontal bar with a rounded right end, and a red-to-white gradient semi-circle on the right side of the bar.

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**Handbook of Energy and Environment in the 21st Century** Muhammad Asif, Guller Sahin, Muhammad Khalid, 2024-06-27 The Handbook of Energy and Environment in the 21st Century discusses the key dimensions of the present energy scenario as well as the emerging trends. Global responses to environmental challenges are examined taking into account technical, economic, social, and policy perspectives. Responding to the latest developments, the book also discusses the impacts of natural disasters and pandemics on energy in the context of energy and environmental implications. Further, it presents various related topics such as the dynamics of sustainable energy transition, renewable energy implementation, decarbonization of fossil fuels, electric mobility, distributed generation systems, and energy security. The book will benefit a wide range of stakeholders from the fields of energy, environment, socioeconomics, geopolitics, and sustainable development. It serves as a valuable reference for academics, researchers, and analysts in these fields. Provides a comprehensive and balanced account of the interwoven subjects of energy and environment in terms of technology and policy dynamics. Incorporates up-to-date data, case studies, and comparative assessments. *Advances in Electrical and Computer Technologies* Thangaprakash Sengodan, Sanjay Misra, Murugappan M, 2025-07-04 This book comprises a selection of papers presented at the Sixth International Conference on Advances in Electrical and Computer Technologies (ICAECT 2024). It compiles groundbreaking research and advancements in the field of electrical engineering, electronics engineering, computer engineering, and communication technologies. The book touches upon a wide array of topics including smart grids, soft computing techniques in power systems, smart energy management systems, and power electronics under the Electrical Engineering track, and biomedical engineering, antennas, and waveguides, image and signal processing, and broad band and mobile communication under the Electronics Engineering track. With special emphasis on Computer Engineering, this book highlights emerging trends in computer vision, pattern recognition, cloud computing, pervasive computing, intelligent systems, artificial intelligence, neural networks, and fuzzy logic, machine learning, deep learning, data science, video processing, and wireless communication. This is a valuable resource for students, researchers, and engineers within the field of innovative research and practical applications of electrical and computer technologies. *Advanced Analytics for Reliability and Resilience of Energy System* Fausto Pedro Garcia Marquez, René Vinicio Sánchez Loja, Mayorkinos Papaefias, 2026-02-10 *Advanced Analytics for Reliability and Resilience of Energy Systems* prepares students, researchers, and industry engineers to design and maintain reliable, sustainable energy systems using state-of-the-art AI techniques. This book provides a clear foundation in the fundamentals of power systems, statistics, and reliability, including resilience principles and strategies, practical applications, and real-world solutions. The AI tools presented range across forecasting the Internet of Things, machine learning, digital twin technology, and big data analysis, with a variety of applications to avoid power outages, minimize disruption, and accurately assess system resilience. Including case studies and details, methodology for practical techniques. *Advanced Analytics for Reliability and*

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*Renewable Energy Devices and Systems with Simulations in MATLAB® and ANSYS®* Frede Blaabjerg, Dan M. Ionel, 2017-05-18 Due to the increasing world population energy consumption is steadily climbing and there is a demand to provide solutions for sustainable and renewable energy production such as wind turbines and photovoltaics Power electronics are being used to interface renewable sources in order to maximize the energy yield as well as smoothly integrate them within the grid In many cases power electronics are able to ensure a large amount of energy saving in pumps compressors and ventilation systems This book explains the operations behind different renewable generation technologies in order to better prepare the reader for practical applications Multiple chapters are included on the state of the art and possible technology developments within the next 15 years The book provides a comprehensive overview of the current renewable energy technology in terms of system configuration power circuit usage and control It contains two design examples for small wind turbine system and PV power system respectively which are useful for real life installation as well as many computer simulation models

*Innovative Testing and Measurement Solutions for Smart Grid* Qi Huang, Shi Jing, Jianbo Yi, Wei Zhen, 2016-04-25 Focuses on sensor applications and smart meters in the newly developing interconnected smart grid Focuses on sensor applications and smart meters in the newly developing interconnected smart grid Presents the most updated technological developments in the measurement and testing of power systems within the smart grid environment Reflects the modernization of electric utility power systems with the extensive use of computer sensor and data communications technologies providing benefits to energy consumers and utility companies alike The leading author heads a group of researchers focusing on the construction of smart grid and smart substation for Sichuan Power Grid one of the largest in China's power system

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