

# Fuzzy based Dynamic Stability Enhancing Control Strategy for power systems with High-Level PV Penetration

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**Abstract:** The deregulated power system has paved the way for a significant number of distributed energy resources (DER). This results in a large installation of renewable sources in the grid. Thus large installations of PV systems are becoming more common. These Centralized PV systems can cause major issues in the existing grid if these are not adequately addressed. The significant contribution of these systems can cause problems with the dynamic stability of the power system. The intermittent and inertia-less nature of PV systems can produce significant power oscillations. At the present condition, the penetration level of PV into the grid is limited by the utilities, to prevent problems of power oscillation. Thus the PV plant capacity cannot be increased beyond the penetration limit. The penetration limit depends on several factors such as the types of loads and stability enhancement devices on the grid. The penetration limit is regulated cyclically. This paper proposes a Fuzzy control strategy for power oscillation damping in power systems implemented in Grid connected converters (GCC) so that the power system stability is enhanced without any additional cost of equipment. This, in turn, helps to provide a penetration margin and thereby to increase the PV capacity of the grid.

**Keywords -** Distributed Generation (DG), Grid connected Converter (GCC), PV penetration, Point of Common Coupling (PCC), Power Oscillation Damping (POD), Structure Preserving Energy Functions (SPEF)

## I. Introduction

The global energy demand is increasing every year, to meet the future demand more energy resources are required. The International Energy Agency (IEA) says the world's energy needs could be 50% higher in 2030 than they are today [1]. The security of global energy supplies continues to be problematic. Today, oil and gas reserves are in the hands of a small group of nations, several of which are considered political unstable or have testy relationships with large consuming countries [2]. In 2010, the total renewable energy capacity was only 5% of the total capacity, but as of now, we have about 18% of renewable capacity [1]. Among the renewable source of energy, the most prominent are the PV systems; the declining prices of solar panels coupled with government incentives have made solar PV systems much favorable among other sources of renewable energy. In 2010, among world's total installed power capacity, the contribution of PV systems was less than 5%. In the new policy scenario, power generated from PV systems is expected to be 600 GW as of 2035. Moreover, now we have centralized PV plants of large capacities such as the 648 MWp plant in Tamil Nadu & 12 MWp in Kerala, resulting in a significant amount of PV penetration into the grid. The existing grids were designed for systems with powerhouses at one end & the load at the other. The integration of several renewables has caused several detrimental effects on the grid. Besides the power quality & protection issues, one of biggest concern is the system stability. The PV-DG systems are inertia-less systems, integration of such systems into the grid can result in reduced system inertia and thereby affecting the transient system stability. Several studies [3]-[6] has concluded that the system stability is compromised during high PV penetration. During high PV

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## **Dynamic Stability Enhancing Control Strategy For Power:**

*The proceedings of the 10th Frontier Academic Forum of Electrical Engineering (FAFEE2022)* Xuzhu Dong, Qingxin Yang, Weiming Ma, 2023-08-23 This book includes the original peer reviewed research papers from the 10th Frontier Academic Forum of Electrical Engineering FAFEE 2022 held in Xi an China in August 2022 It gathers the latest research innovations and applications in the fields of Electrical Engineering The topics it covers include electrical materials and equipment electrical energy storage and device power electronics and drives new energy electric power system equipment IntelliSense and intelligent equipment biological electromagnetism and its applications and insulation and discharge computation for power equipment Given its scope the book benefits all researchers engineers and graduate students who want to learn about cutting edge advances in Electrical Engineering

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*Recent Advances in Renewable Energy Automation and Energy Forecasting* Sarat Kumar Sahoo, Franco Fernando Yanine, Vikram Kulkarni, Akhtar Kalam, 2023-12-08 The advancement of sustainable energy is becoming an important concern for many countries The traditional electrical grid supports only one way interaction of power being delivered to the consumers The emergence of improved sensors actuators and automation technologies has consequently improved the control monitoring and communication techniques within the energy sector including the Smart Grid system With the support of the aforementioned modern technologies the information flows in two ways between the consumer and supplier This data communication helps the supplier in overcoming challenges like integration of renewable technologies management of energy demand load automation and control Renewable energy RE is intermittent in nature and therefore difficult to predict The accurate RE forecasting is very essential to improve the power system operations The forecasting models are based on complex function combinations that include seasonality fluctuation and dynamic nonlinearity The advanced intelligent computing algorithms for forecasting should consider the proper parameter determinations for achieving optimization For this we need new generation research areas like Machine learning ML and Artificial Intelligence AI to enable the efficient integration of distributed and renewable generation at large scale and at all voltage levels The modern research in the above areas will improve the efficiency reliability and sustainability in the Smart grid

*Advances in Neural Networks - ISSN 2005* Jun Wang, Xiaofeng Liao, Zhang Yi, 2005-05-04 The three volume set LNCS 3496 3497 3498 constitutes the refereed proceedings of the Second International Symposium on Neural Networks

ISNN 2005 held in Chongqing China in May June 2005 The 483 revised papers presented were carefully reviewed and selected from 1 425 submissions The papers are organized in topical sections on theoretical analysis model design learning methods optimization methods kernel methods component analysis pattern analysis systems modeling signal processing image processing financial analysis control systems robotic systems telecommunication networks incidence detection fault diagnosis power systems biomedical applications industrial applications and other applications **Advanced technologies for planning and operation of prosumer energy systems** Bin Zhou,Siqi Bu,Liansong Xiong,Hugo Morais, Junjie Hu,Jingyang Fang,Jian Zhao,Peng Hou,2023-04-28 **Enhancing Resilience in Smart Grids: Cyber-Physical Systems Security, Simulations, and Adaptive Defense Strategies** Pengfei Zhao,Liwei Ju,Shiyu Yang,Duo Li ,Shuangqi Li,2026-03-12 The integration of advanced technologies into the energy sector has led to the emergence of smart grids which promise enhanced efficiency reliability and sustainability in electricity distribution However this evolution also introduces increased vulnerability to cyber physical attacks threatening the stability and security of energy systems worldwide As these grids become more interconnected and dependent on digital technologies the potential impact of cyber physical threats escalates necessitating robust defense strategies Enhancing resilience in smart grids involves not only fortifying them against attacks but also ensuring they can recover swiftly and continue operations under adverse conditions The primary objective of this Research Topic is to address the escalating challenge of ensuring the resilience of smart grids against both cyber and physical threats in an era where energy systems are increasingly interconnected and reliant on digital technologies This challenge is not only technical but also strategic encompassing the need for comprehensive security solutions that can adapt to evolving threats The latest advancements in artificial intelligence AI machine learning ML and simulation technologies present promising avenues for augmenting the security and resilience of cyber physical systems CPS in smart grids These technologies offer the potential to predict and mitigate attacks before they can cause significant damage ensuring the grid s stability and reliability To achieve the goal contributions are sought that explore innovative approaches to security from the development of advanced simulation models that can accurately predict attack vectors and their impacts on grid operations to the implementation of adaptive defense strategies that can autonomously evolve in response to new threats Furthermore research that bridges the gap between theoretical models and practical applications demonstrating real world effectiveness and feasibility of proposed solutions is particularly valuable By harnessing recent technological advances and fostering collaboration across disciplines this research aims to explore innovative approaches to enhancing smart grid resilience against cyber physical attacks Some specific themes that potential contributors can address may include but are not limited to 1 Integration of cybersecurity and physical security measures for comprehensive protection 2 Advanced simulation techniques for identifying vulnerabilities and predicting attack scenarios 3 Adaptive defense strategies that evolve with emerging threats to smart grids 4 Application of machine learning and AI in the detection analysis and neutralization of

threats 5 Case studies on successful defense implementations and recovery strategies in smart grids 6 Policy and regulatory frameworks that support the development and adoption of resilient smart grid technologies *Proceedings of the Tenth Power Systems Computation Conference, Graz, Austria, 19-24 August 1990* Denis Sjelvgren,1990 *AI-based Energy Storage Systems* Muhammad Khalid,Elżbieta Jasińska,2025-08-07 As the world transitions toward a more sustainable energy future the role of storage facilities has become crucial to realizing this vision This call for papers invites researchers professionals and experts in the field of power storage and smart power infrastructure to share their findings and insights The purpose of this Research Topic is to investigate cutting edge technologies and strategies that facilitate the efficient integration of advanced storage systems and their seamless integration with traditional energy infrastructures Advanced energy storage systems and its impacts on grid management and control demand response optimization algorithms and innovative grid architectures with improved energy storage geothermal chemical and hydro are of particular interest

*Rising Stars in Energy Research: 2022* Prodip K. Das,2023-07-06 **Fifth International Conference on Advances in Power System Control, Operation & Management** ,2000 **Control of Power Plants and Power Systems 1992** International Federation of Automatic Control,1992 The aim of this symposium is to bring together control engineers and scientists in power plant and power system design Problems concerning the modelling and the control of single power plant units as well as problems concerning the long mid and short term dynamics and the control of power systems in detail were treated **Proceedings of the IEEE International Symposium on Industrial Electronics** ,1992 IEEE/PES Transmission and Distribution Conference and Exhibition 2002: Asia Pacific ,2002 *IEE Proceedings* Institution of Electrical Engineers,1999 Indexes IEE proceedings parts A through I UKACC International Conference on Control '98 ,1998 Energy Engineering and Environmental Engineering Tony Sun,2013-04-10 Selected peer reviewed papers from the 2013 International Conference on Energy Engineering and Environmental Engineering ICEEEE 2013 January 18 19 2013 Hangzhou China **APSCOM-97** ,1997 **Energy Research Abstracts** ,1977 Semiannual with semiannual and annual indexes References to all scientific and technical literature coming from DOE its laboratories energy centers and contractors Includes all works deriving from DOE other related government sponsored information and foreign nonnuclear information Arranged under 39 categories e g Biomedical sciences basic studies Biomedical sciences applied studies Health and safety and Fusion energy Entry gives bibliographical information and abstract Corporate author subject report number indexes **Voltage Stability Enhancement Via Model Predictive Control** Bo Gong,2008 *Archives of Electrical Engineering* ,2004

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