UNIVERSITI TEKNOLOGI MARA

OPTIMIZED NON-LINEAR –PI CONTROLLER DESIGN FOR PHOTOVOLTAIC (PV) BASED DISTRIBUTED GENERATION (DG) INTEGRATION AND ISLANDING DETECTION AGAINST MICROGRID APPLICATION

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Thesis submitted in fulfilment
Of the requirements for the degree of
Doctor of Philosophy
(Electrical Engineering)

Faculty of Electrical Engineering

July 2025

ABSTRACT

This thesis presents a comprehensive study on the integration and control of a 400-kW photovoltaic (PV) farm connected to a 25 kV main grid, focusing on developing advanced control strategies to enhance stability, efficiency, and reliability. Distributed Generation (DG), particularly through solar energy, has become increasingly vital for its potential to improve energy security, reduce environmental impact, and support decentralized power generation. The research begins with an extensive review of existing literature on PV systems, control strategies, Maximum Power Point Tracking (MPPT) techniques, islanding detection methods, and stability analysis, identifying gaps in current approaches that underscore the need for innovative solutions to improve the performance and reliability of PV systems. To address these challenges, a novel adaptive fuzzy Proportional-Integral (PI) control strategy is proposed. This controller integrates fuzzy logic with traditional PI control to dynamically adjust control parameters, thereby enhancing stability and fault tolerance. The methodology involves dynamic modeling of MPPT and Voltage Source Converter (VSC) systems, the development of a nonlinear control strategy, and thorough simulation-based validation using MATLAB/SIMULINK. The results demonstrate that the proposed adaptive fuzzy PI control significantly outperforms conventional PI and fuzzy PI controls in terms of stability, efficiency, and fault tolerance. Various case studies, including different solar irradiance levels, three-phase ground faults, and islanding scenarios, validate the robustness of the control strategy. Furthermore, this research delves into the integration of PV arrays with VSC devices for Distributed Generation in Microgrid applications, highlighting the stability concerns associated with conventional VSC dynamics and the necessity for a more sophisticated control approach. The developed adaptive-based Optimized Fuzzy Logic - Proportional-Integral (FL-PI) controller addresses these issues, excelling in small-signal stability and dynamic oscillations. The study employs comprehensive transient and steady-state simulations to evaluate system performance under various fault conditions and PV irradiance fluctuations, with the "400-kW Grid-Connected PV Farm" model serving as a significant platform for detailed research and performance evaluation, providing critical insights into renewable energy integration. In conclusion, this research makes significant contributions to the field of PV system control methodologies by offering a robust solution for enhancing the stability and performance of grid-connected PV farms. The findings support the integration of renewable energy sources into the grid, promoting sustainable and reliable energy systems. This new proposed innovative controller validated through extensive data analysis and modeling, demonstrates its effectiveness in addressing stability issues and optimizing performance under dynamic conditions, paving the way for future advancements in control methods and renewable energy integration in Microgrid environments.

ACKNOWLEDGEMENT

First and foremost, I would like to thank to everyone involved in helping me until I have completed this study with success. All praise to God for the entire incredible gift endowed upon me and for giving me the opportunity, good health, and strength to conclude my study.

I would also like to gratitude and thank my supervisor, Assoc. Prof. Dr Naeem M. S. Hannoon. For his valuable ideas, suggestions, and his hard work that guided me throughout my studies.

Moreover, I would like to extend my gratitude to my co-supervisor, Assoc. Prof. Dr Muhammad Nabil Bin Hidayat, for his help and interest. Thanks be to him for always giving necessary advice and guidance and arranging all the facilities to make it convenient for me to complete the project.

Also, thanks to my family and friends who are incredibly supportive throughout the time given and for the good days during this completion of study. The selfless kindness, teamwork, and positive influence that I witnessed in each of them will be with me forever.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

Distributed Generation (DG) establishes electricity from small-scale renewable energy sources such as solar PV, wind energy, fuel cells, and micro turbines, unlike centralized power plants. The most important advantage of embracing DG is that it can be installed near the load. Energy supports the use of renewable energy by increasing the contribution of solar energy in the total energy mix, extending electricity to farms and remote/off-grid areas, using solar home systems, and advancing solar PV applications to ensure that solar energy can be used to make electricity, preserve the environment, and reduce pollution from the use of fossil fuels (Kabeyi, 2020).

The growth of new technologies, such as fuel cells, wind turbines, and solar cells, as well as advancements in power electronics to meet consumer demands for higher power quality and dependability, is forcing the power industry to migrate to DG. DG has gained popularity in the electricity business due to market deregulation and environmental concerns. Islanding occurs when a segment of the distribution system becomes electrically isolated from the rest of the power system while continuing to be powered by DGs. The fundamental issue with interconnecting a DG to a power distribution system is islanding. Failure to trip islanded generators can cause various problems for both the generators and the loads they power. All DGs must be disconnected immediately following the occurrence of islanding, typically within 100 to 300 ms of the main supply interruption. To achieve this purpose, each DG must be equipped with an islanding detection technique (Y. Elshrief, 2020).

Utilities have options for deploying microgrids, renewable energy, and other energy services to their customers, leading to a global shift toward decentralized energy systems. A microgrid, regarded as one of the cornerstones of the future smart grid, uses distributed generations and information technology to create a widely distributed automated energy delivery network. A review of the microgrid concept, classification, and control strategies has been presented. Besides, various prospective issues and challenges of microgrid implementation are highlighted and explained. Finally,