Faculty of Engineering

ISLANDING DETECTION ON GRID-CONNECTED PV SYSTEM

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Bachelor of Engineering

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Final Year Project Report ☑

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ISLANDING DETECTION ON GRID-CONNECTED PV SYSTEM

Clairedora Jezreel John

A dissertation submitted in partial fulfilment
of the requirement for the degree of
Bachelor of Engineering
Electrical and Electronics Engineering with Honours

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ABSTRACT

In the integration of a photovoltaic (PV) system with the power grid, reliable islanding detection mechanisms are crucial for safety. Islanding occurs when a PV system continues to generate power in an isolated state after unintentional disconnection from the grid. Detecting and disconnecting the PV system during islanding events protects employees and equipment. This study evaluates two islanding detection approaches: active and passive. Both methods aim to quickly and accurately identify islanding events, ensuring system and grid stability. In the active approach, faults is created into the system, and the PV system's response is analysed to determine if it is operating in an islanded state. The passive approach focuses on controlling the irradiance parameters to see the deviations of the parameters during islanding, as distinct deviations occur compared to grid-connected operation. The study employs the droop control approach, which adjusts the PV system's power output to maintain voltage and frequency within the IEEE 1547 standard during islanding. When disconnected from the grid, the droop control approach modifies parameters, such as adjusting the PV array's irradiance, to ensure stability. The study utilizes MATLAB/Simulink to simulate and compare the performance and reliability of active and passive islanding detection methods. The aim is to demonstrate the effectiveness of both approaches in promptly identifying islanding events, thereby safeguarding the PV system and the grid.

ABSTRAK

Dalam integrasi sistem fotovoltaik (PV) dengan grid kuasa, mekanisme pengesanan pulau yang boleh dipercayai adalah penting untuk keselamatan. Pulau berlaku apabila sistem PV terus menghasilkan kuasa dalam keadaan terasing selepas terputus secara tidak sengaja daripada grid. Pengesanan dan memutuskan sambungan sistem PV semasa peristiwa pulau melindungi pekerja dan peralatan. Kajian ini menilai dua pendekatan pengesanan pulau: aktif dan pasif. Kedua-dua kaedah bertujuan untuk mengenal pasti peristiwa pulau dengan cepat dan tepat, memastikan kestabilan sistem dan grid. Dalam pendekatan aktif, kerosakan disengaja dicipta dalam sistem, dan respons sistem PV dianalisis untuk menentukan sama ada ia beroperasi dalam keadaan terasing. Pendekatan pasif memberi tumpuan kepada mengawal parameter irradiance untuk melihat penyimpangan parameter semasa pulau, kerana penyimpangan yang berbeza berlaku berbanding operasi berhubung grid. Kajian ini menggunakan pendekatan kawalan droop, yang melaraskan output kuasa sistem PV untuk mengekalkan voltan dan frekuensi dalam piawaian IEEE 1547 semasa pulau. Apabila terputus dari grid, pendekatan kawalan droop mengubahsuai parameter, seperti menyesuaikan irradiance jajaran PV, untuk memastikan kestabilan. Kajian ini menggunakan MATLAB/Simulink untuk mensimulasikan dan membandingkan prestasi dan kebolehpercayaan kaedah pengesanan pulau aktif dan pasif. Tujuannya adalah untuk mendemonstrasikan keberkesanan kedua-dua pendekatan dalam mengenal pasti peristiwa pulau dengan segera, dengan itu melindungi sistem PV dan grid.

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LIST OF ABBREVIATIONS

AC	Alternating Current
AFD	Active Frequency Drift
ANN	Artificial Neural Network-based
CFC	Closed-Loop Frequency
DC	Direct Current
DER	Distributed Energy Resources
DG	Distributed Generation
IDM	Islanding Detection Method
IEEE	Institute of Electrical and Electronics Engineer
LPS	Load Parameter Space
MG	Microgrid
NDZ	Non-Detection Zone
PCC	Point of Common Coupling
PLC	Programmable Logic Controller
PMS	Power Mismatch Space
PV	Photovoltaic
RES	Renewable Energy Resources
ROCOF	Rate of Change of Frequency
SCADA	Supervisory Control and Data Acquisition
THD	Total Harmonic Distortion
UFP/OFP	Under/Over Frequency
UVP/OVP	Under/Over Voltage
WPT	Wavelet Packet Transform

CHAPTER 1

INTRODUCTION

1.1 Introduction

This section provides the background research of this paper, the objectives and their significance, the limitations, and the scope.

1.2 Background

The transmission and distribution of electrical energy over a considerable region employing networks are referred to variously as power grids, power distribution grids, electrical grids, and national grids. These are all terminology that is used to describe the same operation. The power grid is equipped with facilities for both the generation of energy and its distribution to consumers. After being generated at a power plant, the electricity must first travel along a transmission line to reach distribution facilities, which are then responsible for delivering it to customers [1]. In general, the objective of the power grid is to ensure the responsible use of energy resources, enhance the efficiency and reliability of power system operations, extend the capacity of the power supply, and increase the capacity of the power supply [2]. Users can have access to the energy that is provided by power plants for their homes and companies thanks to the power grid, which is a common resource.

Research funding has been allotted to the development of renewable energy sources (RES), such as solar, biomass, wind and hydropower sources that run in parallel with the grid [3]. This development has occurred in conjunction with the progression of technology. These advancements in Distributed Generation (DG) aim to enhance power quality, lower costs, and boost local control over energy resources [4]. The architecture of the grid has been modified as a result of the addition of a greater quantity of renewable energy sources to the system. As a consequence of this, unexpected islanding may take place, which poses a risk to the reliability of the power grid's voltage and frequency standards and may result in damage to the equipment.

In the past years, there has been a notable rise in the number of DG installations. As a direct consequence of this trend, the concept of a microgrid (MG) has emerged due to the existence of a large number of DG units inside the power system. The majority of MG, which consists of several DG units, is capable of operating either in parallel with or independently from the primary grid, and it is often linked through power electronics [7]. MGs commonly provide support during emergencies such as power outages and disruptions from the main grid; nonetheless, these small-scale grids would meet issues, particularly when islanding develops [8]. Both the utility grid and the microgrid are susceptible to faults. When the microgrid is operating in islanded mode, either an intentional or unintended action may have extremely negative consequences. This has negatives including a risk to the staff. So, it is critical to spot islanding as soon as possible.

The Grid-Connected Photovoltaic (PV) system, the renewable energy source for DG, is one of the well-known microgrids. An islanding operation occurs when the local load is supplied by the grid-connected PV system even after the system has been disconnected from the main power source. For the safety of the personnel as well as to prevent any equipment damage, islanding operations are extremely important. The attached standard protection relays at the Point of Common Coupling (PCC) may sustain damage during islanding. Asynchronous issues will occur between the microgrid and the main grid when the primary power or main grid is completely recovered.

Islanding detection is a process used to identify when a microgrid is operating independently from the traditional electrical grid, or "islanded." Islanding is a condition in which a part of a distribution system gets isolated from the grid but the system as a whole continues to be powered by the distribution generation [5]. To protect the safety of employees, this problem must be discovered as soon as feasible. Intentional and inadvertent islanding modes may be distinguished from one another. Islanding detection is typically accomplished using specialized sensors and control systems that monitor the electrical characteristics of the microgrid and compare them to those of the traditional grid. When the microgrid is operating in an islanded mode, the sensors and control systems will detect differences in the electrical characteristics and trigger an islanding detection alarm. Due to the absence of voltage and frequency regulation, islanding may occur with unpredictability. This renders its occurrence uncertain. According to the IEEE

1547 standard [6], islanding must be identified by disconnecting the DG source within two seconds after the utility grid's disconnection.

There are many types of islanding detections methods which usually can be divided into passive and active. One example of active method is when small signal perturbations is injected to the distribution system which leads the DG to be in an abnormal situation that cause some deteriorations in the quality of the power. The benefit of this active method can mostly be seen in terms of Non-Detection Zone (NDZ) since active islanding method has the lower NDZ compared to passive method. The common active islanding method is the signal injection-based technique that is commonly used to the inverter controllers with the low or high frequency signals. The islanding phenomenon is detected at the PCC, the electrical quantities and parameters are measured then the microgrid is decided to be islanded or not islanded.

There are several different methods used for islanding detection, including voltage and frequency monitoring, phase angle monitoring, and power flow monitoring. Each method has its own advantages and disadvantages, and the appropriate method for a particular application will depend on the specific characteristics of the microgrid and the electrical grid to which it is connected. Islanding detection is an important consideration in the design and operation of microgrids, as it helps to ensure the safety of electrical workers and the reliability of the electrical system.

When a grid-connected PV system becomes disconnected from the main power source, it may continue to supply power to the local load, leading to an islanding operation. This can be dangerous for personnel and may cause damage to equipment. To prevent these issues, it is important to detect islanding operations and take appropriate action. There are several methods for detecting islanding, which can be divided into passive and active methods. An example of an active method is the signal injection-based technique, which involves injecting small signal perturbations into the distribution system. This can cause the DG system to experience abnormal conditions that affect the quality of power.

Hence, in this paper, a grid connected PV system is modelled by using MATLAB/Simulink. Then, the active and passive islanding method will be implemented on the model system to detect islanding that is happening. The anti-islanding method will be focused on monitoring the frequency, voltage, current and islanding detection period for each method.

1.3 Problem Statement

Islanding in a PV system can pose safety hazards and equipment damage. For instance, if the PV array continues generating electricity while disconnected from the grid, it creates a hazardous environment for maintenance personnel due to high voltage presence in the operating equipment. Delayed detection of islanding can lead to system faults, potentially damaging the inverter and other components not designed for island mode operation. During grid voltage and frequency deviations, PV inverters must maintain a temporary grid connection to withstand and "ride-through" these irregularities. This ensures system balance, prevents cascading effects, and facilitates the resynchronization of the PV system with the grid following intentional or unintentional islanding events. The integration of Battery Energy Storage Systems (BESS) in the system can further enhance the islanding detection and response, providing additional grid stability and power supply continuity.

1.4 Objectives

The objectives of this experimental study are:

1. To detect islanding situation at the PCC of the grid-connected PV System by using active and passive islanding method.
2. To utilize and compare the results of the active and passive islanding method for the modelled PV System by using MATLAB/Simulink.
3. To determine the best islanding detection methods that had been utilised for modelled PV system.

1.5 Scope of study

The integration of renewable energy sources, including PV systems, into power distribution networks raises concerns about grid safety and reliability. Preventing islanding, where a section of the distribution network operates independently, disconnected from the main grid, is crucial. Islanding poses safety risks, affects power quality, and can damage equipment. Effective islanding detection mechanisms are necessary, requiring precise control of power quality parameters like voltage and frequency at the PV system. Additionally, intentional fault creation within the PV system is important for testing islanding detection algorithms. This study focuses on implementing active and passive islanding methods in a microgrid with a PV system using MATLAB/Simulink. Islanding detection occurs in two scenarios. First, by controlling the irradiance parameters in the PV Solar Array to ensure accurate control of power quality parameters within the PV system and enable precise detection of deviations from the main grid. Second, by developing a method to intentionally create faults within the PV system to simulate realistic fault conditions. This allows thorough testing and validation of the islanding detection algorithms, monitoring critical parameters such as phase, frequency, current, and voltage.

1.6 Research Limitation

The following are the research limitations:

i. Complexity and costly: Anti-islanding can be very complex and require more specialized knowledge or equipment to analyze and implement
ii. Limited data: Not all the research papers related to islanding methods have shown the details of the process during the simulation process and some designs are not shown in the figures.
iii. Different parameters: There are so many different parameters of the research studies that are being used. For example, there are quite a number of standards that can be followed such as IEEE 1547, IEEE 929, UL 1741, and UK G83. Due to this problem, confusion can occur during the simulation process.

1.7 Study Outline

This study will be focused on five (5) main chapters.

Chapter 1: Background of the study

This section provides the background research of this paper, the objectives, the problem statement, the study limitations, and the scope.

Chapter 2: Literature review

This topic discusses the specific details of the whole study. Overview of microgrid and PV system will be explained. Mostly of the chapter will focus on the islanding detection methods and non-detection zone, the advantages, and disadvantages of each method as well as the standard use in islanding.

Chapter 3: Methodology

This topic is about the planning of methodology in this study, including the parameters used, the modelling in study software (MATLAB), stability simulations, the performance of voltage and frequency variations.

Chapter 4: Results and Analysis

It discussed the simulation result of the microgrid's islanded and non-islanded modes, as well as the system performance during the disturbance.

Chapter 5: Conclusions

This topic summarizes the study based on the simulation result according to the objectives of the experimental research. Besides, provide any recommendations for improvement is written.

Chapter 2

LITERATURE REVIEW

2.1 Overview

This topic covers the overview details of a microgrid and PV system. The main focus of the chapter will be on explaining the different methods used for islanding detection as well as the advantages and disadvantages of each method. The chapter will also discuss the standard requirements for islanding which are technical standards that provide guidelines for the design and operation of microgrids and PV systems. The purpose of this study is to understand the various methods used for islanding detection, how they work, and their benefits and limitations in order to improve the design and operation of microgrids and PV systems.

2.2 Microgrid

Microgrids have become necessary as the power supply system has recently experienced considerable changes and the demand is getting to increase each day. These microgrids are small grids that can function individually or combine with the utility grid in the region that make the microgrid to be very reliable because microgrid can help in reducing the demand in the main utility [30]. Like conventional grids, microgrids are powered by energy production. Batteries and diesel generators are the two most popular solutions, but there are also solar panels, wind turbines, and fuel cells. These microgrids frequently consist of renewable energy sources such as solar photovoltaic plants, wind turbine plants, and micro-hydroelectric plants. The system's overall orientation has changed due to the increased use of these renewable sources. **Figure 2.1** shows a common microgrid that consists of a large, medium, and small scale microgrid.

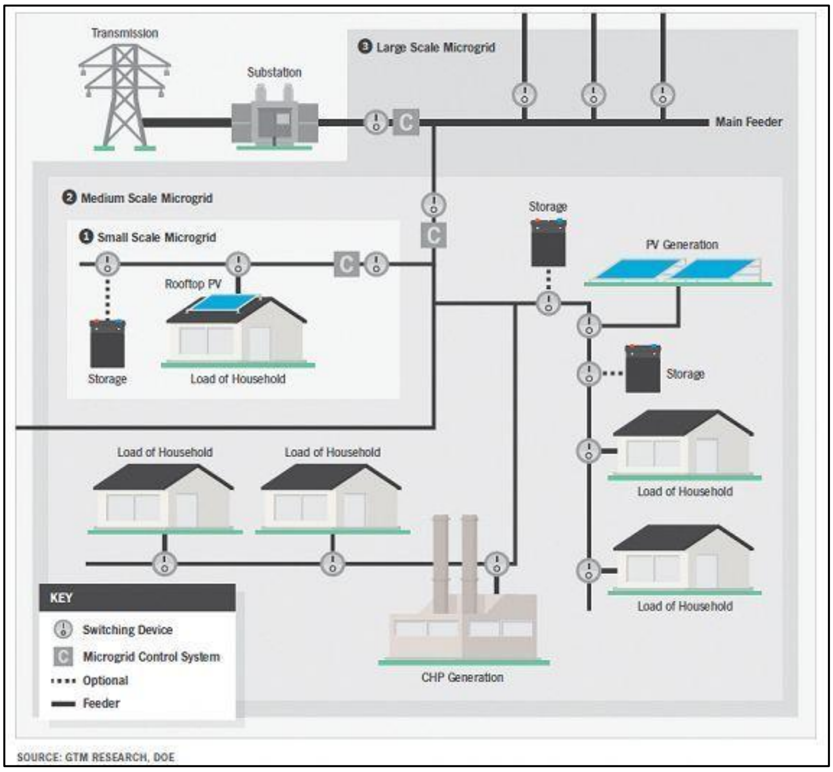

Figure 2.1: Microgrid System

The advantages of microgrids include better energy efficiency, less reliance on fossil fuels, and higher energy security and resilience. Promoting the use of renewable energy sources can also aid in the reduction of greenhouse gas emissions. Microgrids can be applied in various contexts, including residences, workplaces, medical facilities, and other crucial infrastructures. Microgrids may need careful planning and coordination to maintain a steady and dependable power supply, but they can also be technically challenging to construct and run. To preserve electrical workers' safety and the dependability of the electrical system, islanding detection, and protection procedures may also be required.

2.2.1 Grid Islanding Scheme

Grid Islanding scheme is the protective relay that will detect a grid disturbance and send a trip instruction to the grid incomer breaker whenever the grid disturbance exceeds a certain threshold. The Grid Islanding scheme is also referred to as a grid isolation scheme. **Figure 2.2** illustrates the common islanding scheme. By allowing the plant to be disconnected from the grid, the scheme can safeguard the generator against disturbance. However, various factors, such as load and generation imbalance, load volatility and main power failure, may lead to issues in the grid network [10].

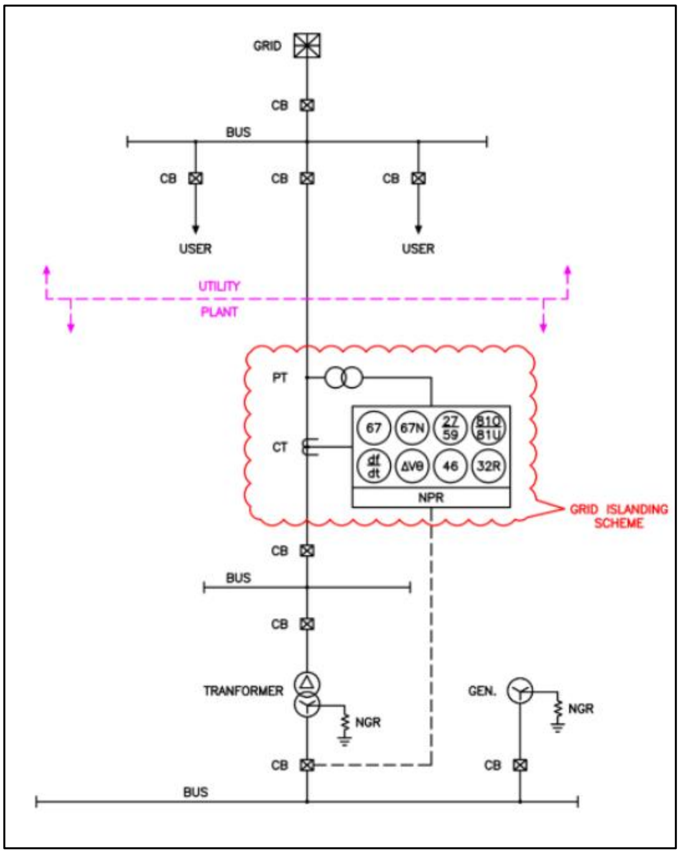

Figure 2.2: Grid Islanding Scheme

It is crucial to carefully select the grid islanding relay for a microgrid because it plays an essential role in determining the reliability and safety of the system. The grid islanding relay should have protection functions, such as directional overcurrent and earth fault protection, reverse power protection, voltage vector shift protection, frequency change rate protection, under/over voltage protection, under/over frequency protection, negative phase sequence protection, and residual overvoltage protection, to ensure the proper operation of the grid islanding scheme. These functions should be present in the protective device that is chosen for the system.

2.2.2 Grid-connected PV system

A grid-connected photovoltaic (PV) system is a type of PV system that is connected to the traditional electrical grid and can both consume and generate electricity as shown in **Figure 2.3**. In a grid-connected PV system, the PV panels generate electricity when the sun is shining, and this electricity is used to power the building or equipment that the PV system is connected to. If the building or equipment does not need all of the electricity that is being generated, the excess electricity can be fed back into the grid, providing a

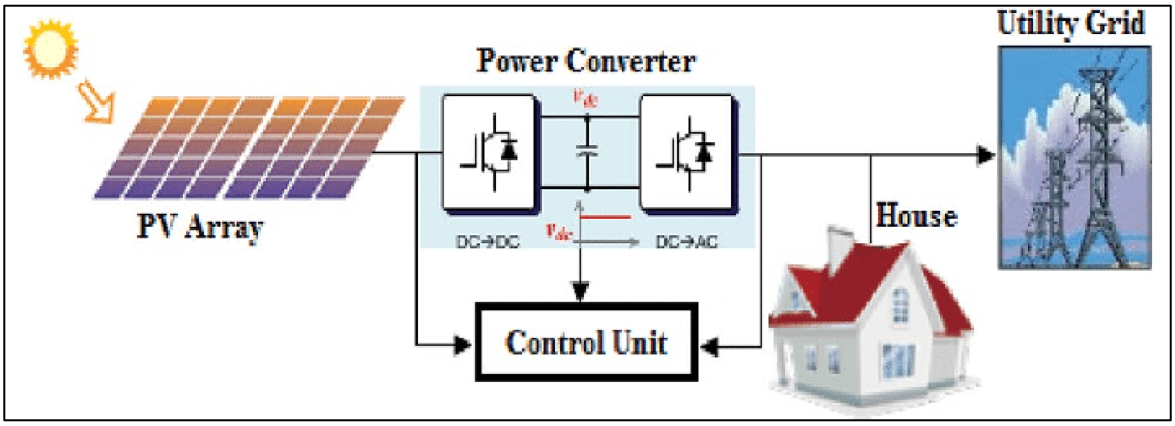

Figure 2.3: Configuration of Grid-Connected PV System

source of renewable energy for other users. Grid-connected PV systems offer a number of benefits, including the ability to reduce reliance on fossil fuels, reduce greenhouse gas emissions, and provide a stable, reliable source of electricity. They can also be used to offset energy costs and potentially earn revenue through net metering or other compensation programs.

Grid-connected PV systems, however, might not be appropriate for every location, and they could need careful planning and construction to provide a steady and dependable power supply. To ensure the security and dependability of the system, additional islanding detection and protection procedures can be required. The PV system's grid connection presents the greatest challenge since an island will form if the main grid is cut off from the local load. Therefore, in order to keep the PV system and the grid in balance, it is necessary to adopt protection of the anti-islanding measures [19].

2.2.3 Point of common coupling (PCC)

The point of common coupling (PCC) is a point in an electrical system at which a distributed generations (DG) such as a microgrid or solar PV panel system, is connected to the main electrical grid. The PCC is the point at which the DG and the grid are electrically connected, and exchange power as shown in **Figure 2.4**. The PCC is important because it determines how the DG will interact with the grid, including how it will be compensated for the electricity it generates and how it will be regulated.