DEVELOPMENT OF SINGLE PHASE TRANSFORMERLESS INVERTER

NUR SYAMIMI BINTI AHMAD FAUZI

BACHELOR OF ELECTRICAL ENGINEERING
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

"I hereby declare that I have read through this report entitle "*Development of Single-Phase Tranformerless Inverter*" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering"

Signature : ……………………………

Supervisor's Name : DR. Maaspaliza Binti Azri

Date : ……………………………

DEVELOPMENT OF SINGLE-PHASE TRANSFORMERLESS INVERTER

NUR SYAMIMI BINTI AHMAD FAUZI

A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JUNE 2018

I declare that this report entitles "*Single-Phase Transformerless Inverter*" is the result of my own research except as cited in the reference. The report has not been accepted for any degree and is not concurrently submitted in candidate of any other degree.

Signature : ……………………………………

Name : Nur Syamimi Binti Ahmad Fauzi

Date : …………………………………….

DEDICATION

This word is dedicated to my beloved parents and family for their supporting and for their helper no matter in what sense. Not forget to my beloved supervisor DR. Maaspaliza Binti Azri, which is the important person in helping and guide me to do this project with successful. Even though there are some problems that I faced in doing this project. Besides, thanks to all friends and lecturer that willing to give their hands to help me, without them I can’t complete this project successful. Thank you everyone.

ACKNOWLEDGEMENT

First of all, I would like to thanks God with all His kindness to letting me finish this final year project. I can't achieve anything without His permission. Every project whether it big or small is successful largely due to the effort of a number of wonderful people who have always given their valuable advice or lend a helping hand.

I would like to express my deepest appreciation to my parents and all my family that always supports me till the end of this final year project. This project requires me to gain so many strength, patience and support to finish my final year project. My family is my strength and they were my everything.

At this junction I feel deeply honored in expressing my sincere thanks to my final year project's supervisor, Dr. Maaspaliza Binti Azri, whose have invested his full effort in guiding me in achieving the goal. She teaches me, guide me and give much information to complete this project. With all her advice and tips I had been used for this project came with expected output result. Without her, I will not solve the project's entire problem hence completing this final year project due to the date.

Last but not least, I want to give a special gratitude to Universiti Teknikal Malaysia Melaka (UTeM), Faculty of Electrical Engineering (FKE) and to all my friends for their critical advice and guidance without them, this project would not have been possible.

ABSTRACT

The efficiency of the inverter can be improved when there is no transformer used in photovoltaic (PV) single-phase inverter system. One of the main problems in single-phase photovoltaic (PV) inverter is to control leakage current appearing between parasitic capacitor and ground. The main problem of ground leakage current is, its poses an electrical hazard to anyone touching the photovoltaic (PV) array's surface. As required in VDE-0126-1-1 German standard, the ground leakage current must be below 300mA$_{rms}$ for safety issues. To reduce the ground leakage current, the single-phase transformerless inverter is analyzed, verified and compared in this report. There are four factor that effect the ground leakage current which is the switching technique, parasitic capacitance, filter design and topology used. The effective way to control the ground leakage current is by keeping the common-mode voltage constant. H-bridge inverter topology was used to investigate the suitable switching technique, which is bipolar SPWM and unipolar SPWM is used. In order to analyze the effect of filter design to the bipolar H-bride transformerless inverter, the LC filter using one inductor and LC filter split inductor with same value is investigate. Filter design using LC filter split inductor with same value having a low leakage current. Therefore, the effect filter impedance matching was analyzed. In addition, the effect of the parasitic capacitance on the bipolar H-bridge transformerless inverter is studied. After the three factors have been analyzed, a switching frequency of single-phase transformerless inverter using bipolar SPWM is analyzed in terms of ground leakage current. Appearing leakage current is causes the safety problem and increased system losses.

ABSTRAK

Kecekapan boleh ditingkatkan apabila tiada pengubah yang digunakan dalam sistem penyongsang fasa tunggal fotovoltaik (PV). Salah satu masalah utama dalam penyongsang photovoltaic (PV) fasa tunggal adalah untuk mengawal arus kebocoran ke bumi yang muncul di antara kapasitor parasit dan bumi. Masalah utama kebocoran arus bumi adalah, ia menimbulkan bahaya elektrik kepada sesiapa yang menyentuh permukaan array photovoltaic (PV). Seperti yang dikehendaki dalam standard Jerman VDE-0126-1-1, arus kebocoran tanah mestilah di bawah $300m_{rms}$ untuk isu keselamatan. Untuk mengurangkan arus kebocoran tanah, pengubah penyongsang fasa tunggal dianalisis, disahkan dan dibandingkan dalam laporan ini. Terdapat empat faktor yang mempengaruhi arus kebocoran ke bumi iaitu teknik pensuisan, kapasitans parasit, reka bentuk penapis dan topologi yang digunakan. Cara yang berkesan untuk mengawal arus kebocoran ke bumi adalah dengan mengekalkan pemalar voltan biasa mod. Topologi penyongsang H-bridge digunakan untuk menyiasat teknik penukaran yang sesuai, iaitu *bipolar SPWM* dan *unipolar SPWM* digunakan. Untuk menganalisis kesan reka bentuk penapis kepada penyongsang penukar *H-bridge bipolar*, penapis LC menggunakan satu penunjuk induktor dan LC penukar berpecah induktor dengan nilai yang sama disiasat. Reka bentuk penapis menggunakan LC penapis pemisah pecah dengan nilai yang sama mempunyai arus kebocoran yang rendah. Oleh itu, pemadanan impak penapis kesan telah dianalisis. Di samping itu, kesan kapasitans parasit pada penyongsang penukar *H-bipolar* dipelajari. Selepas tiga faktor telah dianalisis, satu penukar penyongsang fasa yang dicadangkan dan dianalisis dari segi kebocoran ke bumi. Kebocoran arus ke bumi menyebabkan masalah keselamatan dan peningkatan kehilangan sistem.

TABLE OF CONTENT

LIST OF FIGURE

LIST OF TABLE

LIST OF APPENDICES

APPENDIX	TITLE	PAGE

CHAPTER 1

INTRODUCTION

1.1 Background

Inverter is the power electronic circuit that converts direct current (DC) to alternating current (AC). In specifically, inverters convert power from a DC source to an AC source. The inverters are commonly used to supply AC fed from DC source such as grid-connected PV systems, grid connected fuel cell system and batteries. The grid-connected inverters play a crucial role in providing the electric power supply in an eco-friendly manner. Grid connected system required a galvanic isolation to prevent from ground leakage current. Nowadays, the technology of transformerless for grid-connected PV systems are introduced due to offer the high efficiency power conversion, less weight and low cost.

In the transformerless grid-connected PV systems, the path for the ground leakage current to flow, which is the parasitic capacitor is appear between positive and negative terminal of PV grid with the ground. Ground leakage current can produce serious electromagnetic interference either through directed or radiated emission that cause safety issues. In view of the VDE-0126-1-1 standard, the level of ground leakage current must be lower than 300 mA_{rms}, the level that can cause ventricular fibrillation and involuntary muscle contractions. Therefore, the topologies, switching algorithm, AC filter design have been proposed by previous researchers.

In the AC signal, the quality of signal is important parameter to consider. In electrical power distribution system, there are many non-linear loads drawing non-sinusoidal current is exists. It cause serious problem to power quality of the power distribution system. The harmonic of the voltage and current will affect the power system components. Moreover, the harmonic can cause extra losses, overheating and over-loading to the system.

1.2 Problem Statement

Mostly, the commercial grid connected photovoltaic inverter will use line-frequency transformer, which is provide galvanic isolation and safety. However, the line-frequency transformers are big and weighty that causes the system bulky and makes the system become complex. Besides using line-frequency transformer, high-frequency isolation transformers also can be used which is cheaper, small size and weight. But, the inverters with high-frequency transformers have a several power stages that make the system complexity and decrease the system efficiency. Therefore, to make the system become more efficiency, the transformerless grid is used due to small loss. The advantages of the system are smaller size, lower cost, weight and high power density.

Due to the capacitance between the Photovoltaic grid- connected system and earth, potential differences enforced by switching actions of the inverter introduce a ground leakage current. The leakage current is appearing because there is no galvanic isolation when using transformerless. Factor effected ground leakage current is based on the topology used, switching strategy, parasitic capacitor and filter design. Appearing leakage current is causes the safety problem and increased system losses.

Low-power PV applications have limited input voltage range. Therefore, an expansive number of PV modules are joined in series to get high dc input voltage. Even though this setup is meets the target input voltage anyhow, it influence the power output level of the PV modules [12]. Thus, the single-phase transformerless inverter is used to extract power from the PV modules.

1.3 Objective

The objectives of this project are:

1. To model and analyze the single-phase transformerless inverter using Matlab/Simulink.
2. To design and develop hardware of single-phase transformerless inverter.
3. To verify the performance of single phase transformerless inverter between the simulation and hardware result.

1.4 Scope

The aim of this project is to focus the performance of single-phase transformerless inverter on reducing ground leakage current less than 300mA_{rms} based on VDE0126-1-1 German Standard but at the same time maintain the THD below 5% based on IEEE Standard 519. The Matlab Simulink is used to model and analyze the performance of ground leakage current by using simulation approach that are switching technique, parasitic capacitor, filter design and topology used. The single-phase transformerless inverter is tested using R loads. The single-phase transformerless inverter is simulated to determine the factor that effected ground leakage current.

The performance of the single-phase transformerless are analyze by using bipolar switching schemes. The purpose of this simulation is to compare the performance of the single-phase transformerless inverter in terms of ground leakage current and total harmonic distortion (THD).

The experiment single-phase transformerless inverter will be developed after the simulation result is obtained. The equipment contain of gate drive to turn ON and OFF IGBT. The H-Bridge involves of Insulated Gate Bipolar Transistor (IGBT) type G4PC50UD-E and connected with LC filter. For the control plan of the power switches, the PWM algorithm will be transferred to the microcontroller XMC 4500 as the fundamental controller. At long last, the information and result from the equipment will be studied and compare with the simulation result from the MATLAB Simulink.

1.5 Report Outline

This report consist five chapters that is start with the introduction of the project and the following five chapters of this report are arranged as follows:

Chapter 1 covers a little explanation of the background project, problem statement, objectives and scope of the project.

Chapter 2 covers the theoretical background of this project including the detail about the general renewable energy, basic type of single-phase inverter, the general topologies of single-phase transformerless inverter, PWM consideration, common mode leakage current definition and total harmonic distortion definition.

Chapter 3 covers about the project methodology. This chapter consists of the flowchart of the project, milestone, Gantt chart, factor that affects the ground leakage current, simulation model, hardware design and the switching method used in this project.

Chapter 4 discusses the simulation result by using PWM switching technique, filter design, parasitic capacitor analysis, ground leakage current analysis and the harmonic analysis to evaluate the performance of the inverter.

Chapter 5 is the summary of this project and the recommendation for the further research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Inverter is a circuit that converts a direct current (DC) power to an alternating current (AC) power at a desired output voltage and frequency. The output powers are fully come from DC source. DC source that used is coming from local energy source such as fuel cell, photovoltaic cell (PV), small turbines and small hydroelectric plants. Single-phase inverters are mostly used in numerous applications involving variable voltage and variable frequency AC supply. The examples of several main applications are adjustable-speed AC motor drives, DC motor drive, induction heating, standby power supply, uninterruptible power supplies (UPS) and high voltage DC transmission systems. The inverter can be designed using transformer or transformerless.

2.2 Renewable Power Source

Renewable energy is energy that is produced from natural processes that are nonstop replenished. Such as sunlight, geothermal heat, wind, tides, and water. Renewable energy sources have been taken the place of the traditional sources and especially rapidly developments of photovoltaic (PV) technology and Fuel cell (FC) technology have been put forward these renewable energy sources in all others renewable energy source. The common renewable power source used is solar energy system, wind energy system and fuel cell system.