
# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## DESIGN OF SINGLE PHASE H-BRIDGE MULTILEVEL INVERTER BY USING MICROCONTROLLER

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology Bachelor's Degree of Electrical Engineering Technology (Industrial Power) with Honours

by

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## BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **DESIGN OF SINGLE PHASE H-BRIDGE MULTILEVEL INVERTER BY USING MICROCONTROLLER**

SESI PENGAJIAN: **2015/16 Semester 2**

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# APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology Bachelor's Degree of Electrical Engineering Technology (Industrial Power) with Honours. The member of the supervisory is as follow:

…….

(EN. SYAHRUL HISHAM BIN MOHAMAD @ ABD. RAHMAN)

# ABSTRACT

The demand of producing electrical power by using renewable energy is increasing from day to day. Regarding to this matter, modern power electronic technology becomes important as it involves in generation of power electric in renewable energy and also the integration of renewable energy to the electricity grid. An inverter is needed for the distributed power generation in order to convert a DC power to AC power. As the need of producing higher power for the industrial section, the new breed of power converter, a multilevel inverter is emerged. The multilevel inverter began with the three-level cascaded H-bridge multilevel inverter. Then, it comes up with the other topologies. The most popular topologies are diode-clamped, flying capacitor and also cascaded multilevel inverters. This project report involves the single phase H-bridge multilevel inverter. This type of multilevel inverter has many applications nowadays. In renewable energy power generating system, this type of multilevel is suitable to be applied to the photovoltaic system as it satisfies the requirements of solar system. The idea of performing a multilevel inverter over the conventional inverter is to synthesize the stair-case voltage waveform by reducing the harmonics. It is developed by using MOSFET and have a separate DC sources for every each of the full bridge.

# ABSTRAK

Permintaan bagi penghasilan kuasa elektrik dengan menggunakan tenaga boleh diperbaharu semakin meningkat dari hari ke hari. Berturutan dengan perkara ini, teknologi elektronik kuasa moden menjadi penting kerana ianya terlibat dalam penjanaan kuasa elektrik tenaga boleh diperbaharu dan juga integrasi tenaga boleh diperbaharu ke grid elektrik. Penyongsang diperlukan untuk penjanaan kuasa teragih untuk menukar kuasa DC (arus terus) kepada kuasa AC (arus ulang-alik). Sebagai keperluan menghasilkan kuasa yang lebih tinggi dalam sektor industri, bentuk baru bagi sistem kuasa penukar, iaitu penyongsang bertingkat muncul. Penyongsang pelbagai peringkat bermula dengan tiga peringkat penyongsang penerus titi bertingkat. Kemudian, tercetus pula topologi yang lain. Antara topologi yang paling popular adalah diod-terkapit, kapasitor-terkapit dan juga penerus titi penyongsang pelbagai peringkat. Laporan projek ini melibatkan satu fasa penerus titi penyongsang bertingkat. Jenis inverter bertingkat ini mempunyai banyak aplikasi pada masa kini. Dalam sistem penjanaan kuasa tenaga boleh baharu, penyongsang bertingkat amat sesuai untuk digunakan untuk sistem photovoltaic kerana ia memenuhi keperluan sistem solar. Idea melaksanakan penyongsang bertingkat lebih baik berbanding penyonsang konvensional kerana ia mampu untuk mengurangkan harmonik. Ia dibina dengan menggunakan MOSFET dan mempunyai sumber DC (arus terus) berasingan bagi setiap setiap penerus titi.

# DEDICATIONS

To my beloved parents

# ACKNOWLEDGEMENTS

Firstly, I would like to thank god for giving me the opportunities to learn and gain new knowledges and also experiences throughout my final year project. I tend to finish this report followed as I planned.

I would also like to express my appreciation to my supervisor, Mr. Syahrul Hisham Bin Mohamad @ Abd. Rahman for his guidance during the completion of this project report. Moreover, a special gratitude to Cik Suziana Binti Ahmad or guiding me on the simulation part of this project.

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| | | |
|---|---|---|
| AC | - | Alternating Current |
| DC | - | Direct Current |
| FPGA | - | Field-programmable gate array |
| IGBT | - | Insulated Gate Bipolar Transistor |
| MOSFET | - | Metal Oxide Semiconductor Field Effect Transistor |
| PCB | - | Printed Circuit Board |
| PWM | - | Pulse-Width Modulation |
| TRIAC | - | Three terminal semiconductor device for controlling current |
| SMPS | - | Switch Mode Power Supply |

# CHAPTER 1
# INTRODUCTION

## 1.0 Introduction

Nowadays, fossil fuels are the foremost energetic contributor to the global economy. However, it can cause environmental issues such as global warming, air pollution and many more. Therefore, the demand of generating more electrical power from renewable energy is increasing as it is a green technology, which can help in solving the environmental issues. Figure 1.0 below shows the renewable energy goals, according to the Sustainable Energy Development Authority Malaysia (SEDA).

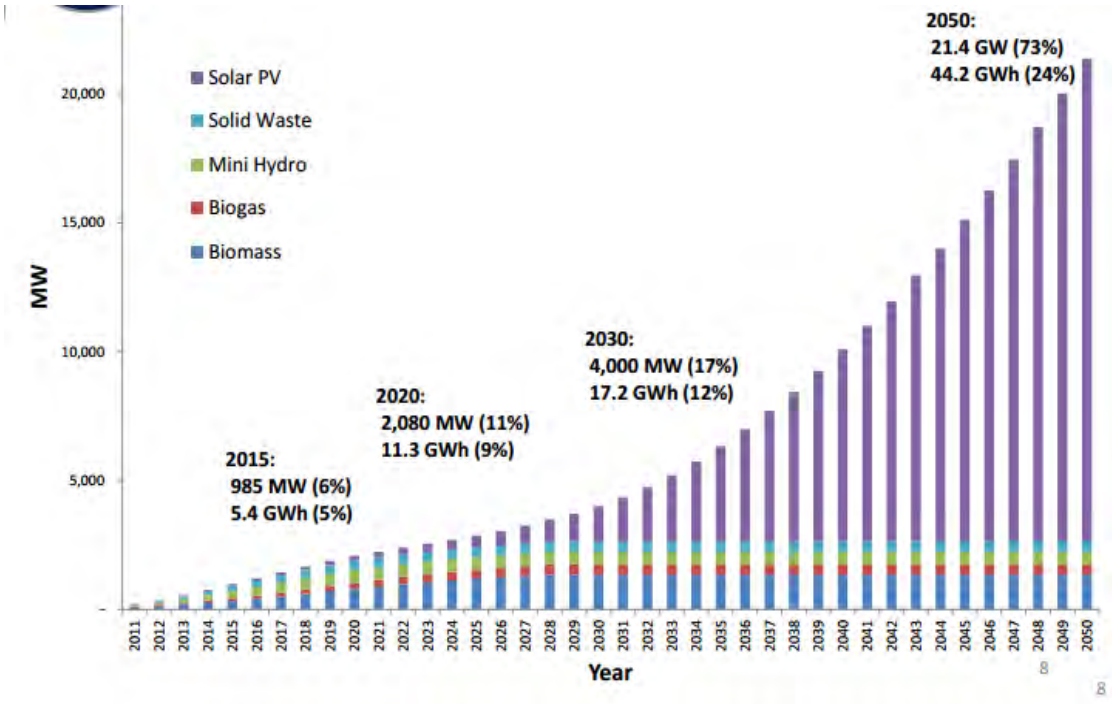


**FIGURE 1.0 : The Renewable Energy Goals in Malaysia**

Figure 1.1 below shows the increment of global installed renewable power capacity.

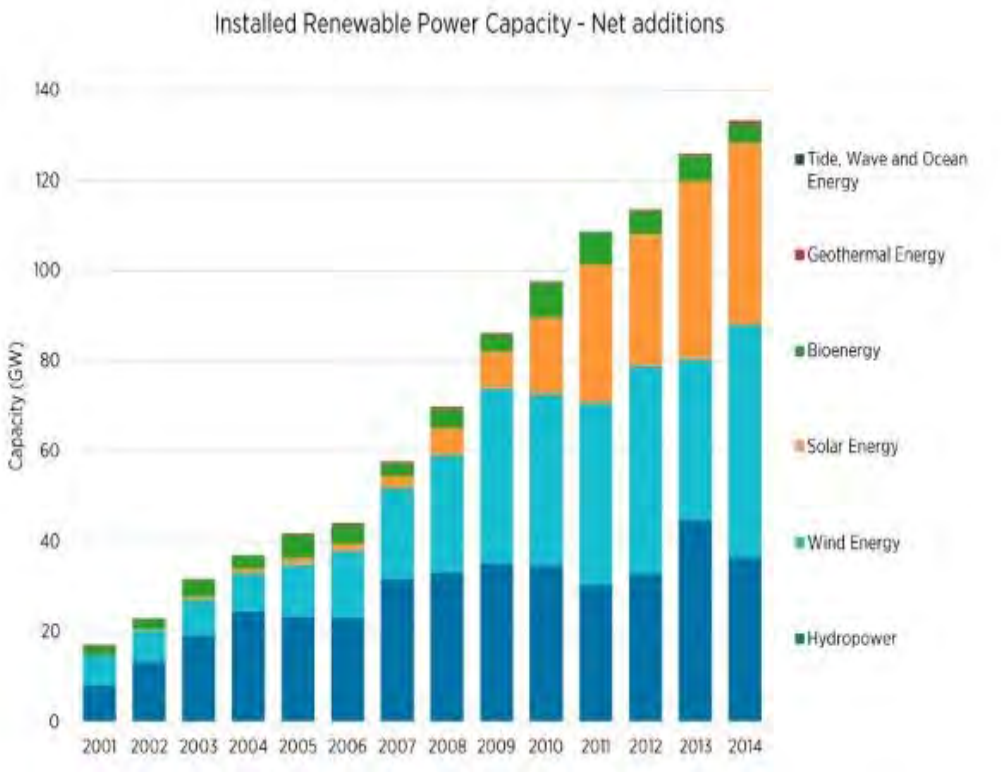


**FIGURE 1.1 : Installed Renewable Power Capacity**

Renewable energy is a form of energy that can be gained from natural resources. There are several types of renewable energy technologies which are Bioenergy, geothermal energy, hydropower, ocean energy, wind energy and solar energy (Kaliamoorthy et al. 2015). Solar energy is one of the most attractive research fields. This is because it can contribute to clean power generation (Villanueva et al. 2009). Photovoltaic (PV) system requires no fuel, no pollution, no noise and also less maintenance. Most of the growth of this system is in grid-connected system. More than 78% of the global market in 2010 comes from the grid-connected applications (Xiao et al. 2011). This system is introduced for the increment of the energy injected into the grid by the methods of decreasing the switching frequency and supplying high reliability (Villanueva et al. 2009). The usage of H-bridge multilevel inverter in this system helps in reducing the device voltage stress, increasing the efficiency and

decreasing the output filters. An inverter is an electronic device that converts direct current (DC) to alternating current (AC). It is assumed that the term of "inverter" was coined by David Prince (L.Owen 1996). This is due to the article that has been published by Prince in 1925 entitled "The Inverter" in GE Review. The article contains the important elements which are required for the modern inverters. Nowadays, there are several types of inverters available such as multilevel inverter. A multilevel inverter is a powerful electronic device which is capable of providing a desired alternating voltage level at the output using multiple lower level DC voltages as an input. It includes the array of power semiconductors and capacitor voltage sources, the output which generates stepped waveform voltages (Subramanian & Rasheed 2013). The concept of this converter has been introduced since 1975 (Ahuja et al. 2013). There are three topologies of multilevel inverter have evolved which are diode clamped multilevel inverter, flying capacitor clamped multilevel inverter and cascaded H-bridge multilevel inverter (Bhargava & Shrivastava 2012). A cascaded H-bridge multilevel inverter satisfy the requirements of PV systems since solar cells can be assembled in a number of separate generators with the additional advantage of the ability to eliminate the DC/DC booster, significant reduction of the power drops caused by sun darkening and the increment of efficiency and reliability. Therefore, the usage of cascaded H-bridge multilevel inverter is important for photovoltaic system.

## 1.1 Problem Statement

Inverters are less efficient, high cost and high switching losses. Mostly a two-level inverter is used in order to convert DC voltage to AC voltage. Although it is effective to be used to create AC, but it has a few disadvantages too. This type of inverter creates harmonic distortions in the output voltage. Besides, it also has high dv/dt stresses. It can create problem regarding those applications require low distortion in the output voltage.

A medium voltage grid also facing a difficulty in connecting one power semiconductor switches directly. Therefore, the multilevel power converter is introduced for high power and medium voltage situations.

The flying capacitor multilevel inverter is difficult to be realized since each of the capacitor need to be charged with different voltages as the voltage level increases. Besides, diode clamped multilevel inverter having the issue of expanding the multilevel because of the voltage unbalancing, the increase in the number of clamping diodes and the difficulty of disposition between the DC link capacitors and the devices when the voltage increases.

## 1.2 Objectives of Research

The objective of this research is mainly focus on:

a) To design the single phase h-bridge multilevel inverter
b) To simulate the design of single phase h-bridge multilevel inverter
c) To replicate and test the single phase h-bridge multilevel inverter

## 1.3 Scope of Research

The scope of this research is limited to the following aspects so that the research could be focused to achieve the stated objectives. This project scopes are as below:

a) To design the single phase h-bridge multilevel inverter for small power usage by using microcontroller
b) To simulate the design of single phase h-bridge multilevel inverter by using MATLAB
c) To replicate and test the single phase h-bridge multilevel inverter for designated input and output

# CHAPTER 2
# LITERATURE REVIEW

## 2.0 Introduction

This chapter will discuss the theory related to this project. It contains some research principles and the topologies introduced. Moreover, this part also consists of circuit designs for different topologies of multilevel inverter. The power electronic converter can be classified into six types which are diode, rectifier, AC to DC converter, DC to DC converter, AC to AC converter, DC to AC converter, and static switches. The inverter is a type of DC to AC converter.

## 2.1 Power electronic conversion device

The technology of the power electronic conversion devices is developing nowadays. Due to the development, the power electronics becomes more applicable. There are many categories of power electronic conversion devices. The most famous type of convertors are AC to DC converters, DC to DC converters, AC to AC converters, and DC to AC converters.

### 2.1.1 AC to DC converter

This type of converter circuit converts AC voltage into DC voltage. A rectifier converts AC to DC by adjusting the voltage and current. As the firing angle of the thyristors is varied, the DC output voltage is able to be controlled. The AC input voltage can be either in single or three phase formed.

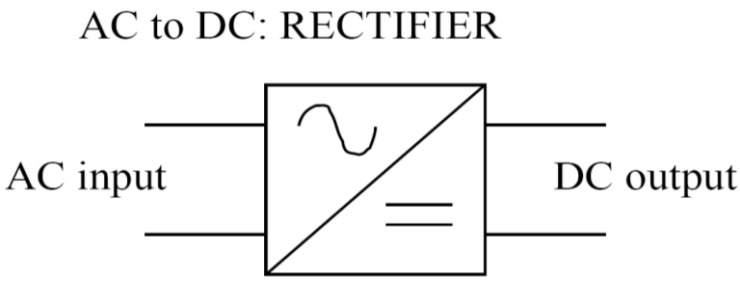


**Figure 2.1 : AC to DC converter**

### 2.1.2 DC to DC converter

This type of converter circuit converts a fixed DC input voltage into variable DC voltage or oppositely. As the duty cycle is varied, the DC output voltage is able to be controlled. The linear regulators and switching choppers is applying this concept of conversion.

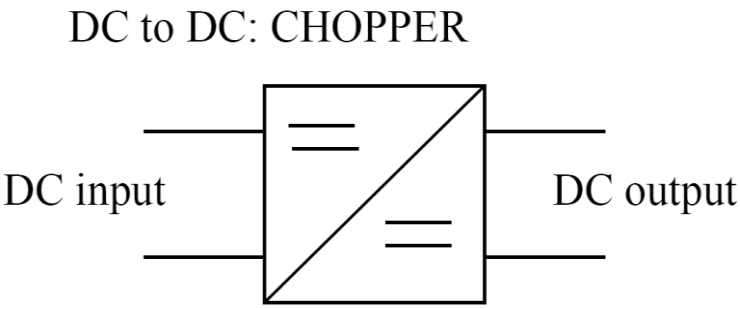


**Figure 2.2 : DC to DC converter**

### 2.1.3 AC to AC converter

This type of converter circuit converts a fixed AC input voltage into variable AC output voltage. As the firing angle of TRIAC (three terminal semiconductor device for controlling current) is varied, the AC output voltage is

able to be controlled. It is known as AC voltage regulator. Its AC frequency, phase, magnitude, and power converters are particularly with an intermediary DC link.

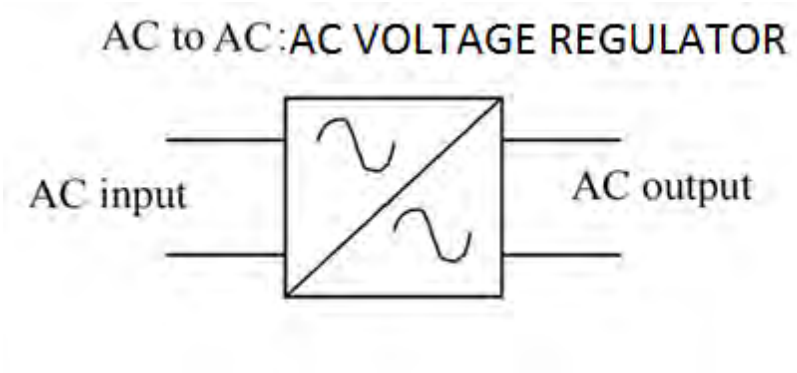


**Figure 2.3 : AC to AC converter**

### 2.1.4 DC to AC converter

Inverters are able to produce AC output voltage from DC input voltage. It can produce the AC of controllable magnitude and frequency.

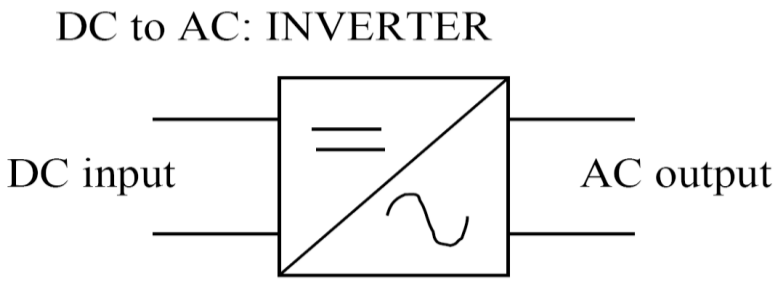


**Figure 2.4 : DC to AC converter**

## 2.2 Inverter

The inverter is an electronic device that converts DC power to AC power at desired output voltage and frequency (Hosseini et al. 2013). Inverter can be categorized into two types which are Voltage Source Inverter (VSI) and Current