“I hereby declare that I have read through this report entitle “ Design And Develop Single Phase Grid Connected Solar Inverter” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation & Automation)”

Signature: ....

Supervisor’s Name: PROF ISMADI BIN BUGIS

Date: 25 June 2012

DESIGN AND DEVELOP SINGLE PHASE GRID CONNECTED SOLAR INVERTER

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This report is submitted in partial fulfillment of requirements for the Degree of Bachelor in Electrical Engineering (Power Electronic and Drive)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JUNE 2012

I declare that this report entitle "Design And Develop Single Phase Grid Connected Solar Inverter" is the result of my own research except as sited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature: ………………………………………….

Name: RAVIN NAIR A/L P.NAGARAJAN

Date: 25 June 2012

Specially dedicated to:

My beloved father, mother, brothers, sister, lecturers and all my friends

for their eternal support, encouragement, and inspiration

throughout my journey of education.

May God bless us.

ACKNOWLEDGEMENT

I would like to take this opportunity to express my gratitude to those who support me to finish this final year project 1. First and foremost my gratitude goes to the god for bestowing the strength and patience for me in completing this final year project 1. My warmest gratitude goes to my supervisor which is Prof Ismadi bin Bugis for giving the most beneficial guidance and assists me in completing this final year project 1.

I also want to express my gratitude to my entire friend in helping me to finish this final year project 1. Last but not least, I would like to express my deepest gratitude to my beloved father and mother, as well as my family member and everyone who has involved directly or indirectly for their moral support and understanding.

Thank you.

ABSTRACT

This project is to design and develops a single phase grid connected solar inverter. A list of objective and scope of study are identified in this project. This system mainly consists of 4 main parts. The first part is the photovoltaic cell which solar panel. The solar panel used in this project is to collect the sun power and supplied to the DC-DC converter as the voltage source. The DC-DC converter that used this design is the flyback converter. The function of the flyback converter is to boost the voltage up to 340VDC.In this report also contain the literature review and methodology that was used to finish this project. Besides that analysis was done based on the intensity and temperature of the sun on how much the voltage can be produce by the system. Finally discussion was done based on the analysis.

ABSTRAK

Projek ini mengandungi reka bentuk untuk membangunkan grid satu fasa yang disambunkan kepada ‘inverter’ solar. Senarai objektif dan skop kajian telah dikenalpasti untuk menjayakan projek ini. Sistem ini terdiri daripada 4 bahagian utama. Bahagian pertama adalah penggunaan sell solar atau pun dikenali sebagai ‘panel solar’. ‘Panel solar’ telah digunakan dalam projek ini adalah untuk menggumpul tenaga daripada cahaya matahari dan membekalkan tenaga tersebut kepada penukar DC-DC sebagai sumber voltan. Penukar DC-DC yang digunakan dalam projek ini adalah penukar ‘flyback’ dimana penukar ini akan meninggikan voltan daripada maximum power point kepada 240VDC. Laporan ini juga mengandungi analisis dimana intensiti dan suhu cahaya matahari dipilih sebagai faktor yang mempengaruhi keluaran penukar. Selain itu, laporan ini juga mengandungi perbincangan mengenai keluaran pada penukar dengan intensity and suhu daripada chaya matahari.

TABLE OF CONTENTS

LIST OF FIGURE

LIST OF TABLE

CHAPTER 1

INTRODUCTION

This chapter will explain briefly about the project. Besides that, this chapter also discuss about the problem statement, objective of the project and finally the scope of the project.

1.1 Introduction

Nowadays solar energy has become more and more popular as a renewable energy to fulfil demand of power usage. The energy from the sun is radiated out in all directions as light. In order to fully use this renewable power, many engineers from all over the world have come out with various type of technologies to harvest the solar energy and use it to generate single phase or three phase voltage of electrical energy[1].

The aim of this project is to design and develops of single phase grid connected solar inverter. The systems mainly consist of 4 main parts. The first part is the solar panel which is photovoltaic cell. The second part is the flyback converter with DC link capacitor and transformer. The third part is the three phase inverter with H bridge connection.

The solar panels used to receive the solar energy from the sun and mount into DC power of electrical energy. The solar panel act as current source and give supply to the flyback converter with the DC link capacitor. The transformer amplifies 12VDC to 340VDC using the transformer in the flyback converter.

Then the capacitor is used to store the voltage from the flyback converter. The block diagram describing the system in this project is shown in Figure 1.0 below. All systems are designed based on the research work. This particular research aims to develop a product oriented solution for creating new green energy which can be implemented in everyday use. The futures that influence the performance of the system will be identified.

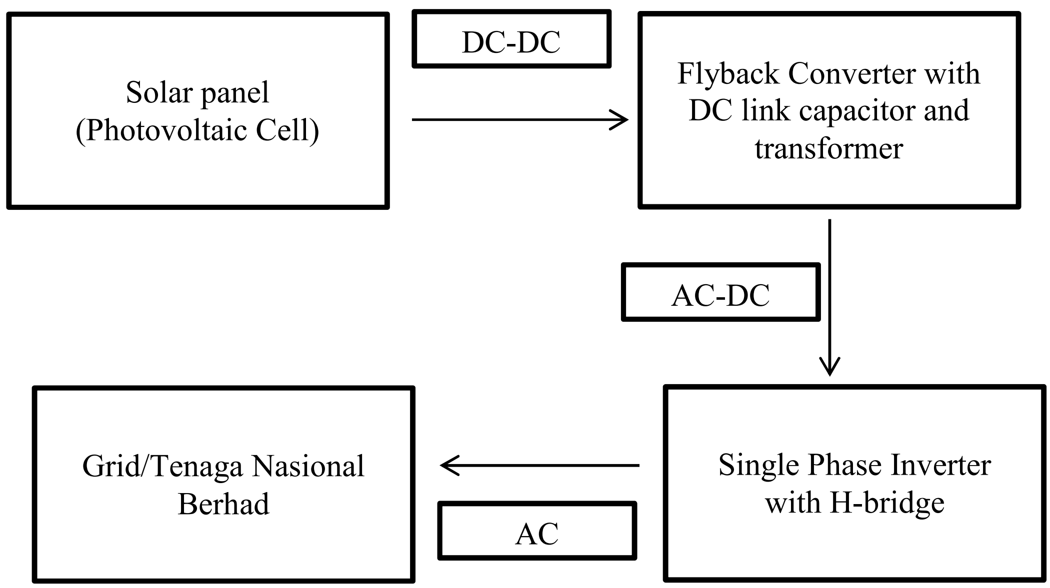

Figure 1.0: Show the overall process of the project

1.2 Problem Statement

In this modern society, conventional fossil energy increasingly will be dried up. To overcome this problem solar energy was used to substitute of the conventional fossil energy source. Nowadays solar energy system primarily contains two types. The first one is connecting with utility grid and the second is an isolate power system .The second system at daytime save the output electrical power of photovoltaic array (PV array) into storage battery and convert the chemical energy of storage battery into electric power at night or at cloudy days. This kind of solar energy system requests the photovoltaic PV array to work at maximum power point (MPPT). However by using the battery the system will not last forever and require maintenances and the cost is also expensive. On the other hands, grid connecter solar power supply is not necessarily required of battery because it work on line directly deliver power to power system grid. To stabilize the output DC power it implemented capacitor.

1.3 Project Objective

There are three objectives of this project to make it successful. There are:

1.3.1 To be able to designs the transformer which can produce 12VDC to 340VDC

1.3.2 To be able to design flyback converter and three phase inverter with H-bridge connection.

1.4 Scope of Project

The scope of this project mainly focused on photovoltaic array, maximum power point tracker, flyback converter (DC-DC converter), capacitances and inverter which consist of MOSFET and H-bridge. The photovoltaic will receive power from the solar and start charging the large capacitances. The variation of the voltage from the solar can be controlled by adjusting the duty ratio. Voltage from the solar panel is then amplified by using the flyback converter. The voltage from the capacitances is supplied to the inverter which consists of MOSFET and H-bridge and the voltage from the inverter.

CHAPTER 2

LITERATURE REVIEW

This chapter will discuss about the journal and the other reading materials that are used as references in order to understand, design and develop the project.

2.1: Introduction

In this chapter, the article review, journal and other research material were reviewed in order to get general idea about the project design, conception and any information that related to improve project. Besides that, this chapter also reviews the projects that have been done by other researches with difference concept and design. By doing the review will provides a better understanding of the system and its design. Furthermore this chapter will discuss the overall theories and concept of the project. Finally this chapter also will explain the theories used in order to implement the project.

2.1.1: Optimal Control of Solar Energy Combined With MPPT and Battery Charging

This project was developed by Wang Jian, Liu Jianzheng, Wui Libo and Zhao Zhengming. This paper discussed about an optimum controlled method by combining the photovoltaic array maximum power point tracker (MPPT) technique and lead-acid storage optimal charging method [1]. This project mainly consists of 2 parts. The first part discussed about photovoltaic (PV) array characteristic and one order maximum power point tracker (MPPT) algorithm [1]. The second part discussed about lead-acid storage battery input characteristics, charge requirement.

The output characteristic of photovoltaic (PV) array is nonlinear and sensitive to the solar to radiation and environment temperature. To fully use photovoltaic (PV) array, it should be controlled to work at maximum power point [1]. If the characteristic of the load can be changed to match photovoltaic (PV) array, the maximum output power and high efficiency could be achieved [1]. To fully use the maximum power point tracker, three conditions must be obeyed. The first condition is the power range of the load should be wide enough. The second condition is the characteristic of load can control to vary continually and finally the last condition is a stable maximum power point tracker (MPPT) algorithm and brief criterion should be develops [1]. From the research one order differential maximum power point tracker was used to track the maximum power point stably and quickly under varied condition of solar radiation and temperature. The equation for one order differential maximum power point algorithm is:

$$\frac{dP}{dV} = \frac{d(VI)}{dV} = V\frac{dI}{dV} + I\frac{dV}{dV} = 0 \qquad (1)$$

If

$$V\frac{dI}{dV} + I\frac{dV}{dV} = 0 \qquad (2)$$

If

$$V\frac{dI}{dV} + I\frac{dV}{dV} > 0 \qquad (3)$$

To increase the output power, the voltage from the photovoltaic panel should be increased.

If

$$V\frac{dI}{dV} + I\frac{dV}{dV} < 0 \qquad (4)$$

To increase the output power, the voltage from the photovoltaic panel should be decreased.

In this research the circuit containing photovoltaic PV array, buck converter and the storage battery was used. The control block was used to sample the voltage and current of both photovoltaic panel and battery. When the control block detect the PV contains enough exportation, the system will enter charging process. The system will first enter the MPPT buck process if the battery isn't full [1]. The duty ratio of the IGBT is changed by the control block by comparing the PV array output power of present time and past time [1].

The second part is the about lead-acid storage battery input characteristics, charge requirement. The capacity and life of the battery depends on the charging method. In this research the capacity are measured in ampere hour. When using the solar energy system the conventional charging strategic cannot be apply because the characteristic of the photovoltaic array is nonlinear and the output depend on the temperature and radiation of the sun [1].

This researched also discussed about the strategic to optimize the battery charging. The strategic is divided into three parts. The first part is to adopt one order differential MPPT technology when the battery is lack of the electric power [1]. The second parts is applies the constant voltage control of PI regulation when the terminal voltage of the battery is over the threshold value of the over-charging state. The last part is the battery comes into the float charging state [1].

In conclusion, in order to control the circuit accurately, the system needs to sample the value of voltage and current of PV array and the storage battery. Besides that, many variables affect the charging process of storage battery.

Table 2.1.1: Experiment during the charging process of the solar panel [1]

Time	8.20	9.00	9.30	10.30	11.20	12.00	1.00	2.00	3.00	4.00
Radiation (W/m^2)	413	502	589	636	691	723	799	715	567	13.1
Temperature ($^\circ C$)	7.4	13.2	15.0	16.7	18.4	22.5	25.3	24.1	16.6	13.1

PV voltage (V)	62.3	65.1 1	68.7	68.9	69.0	68.6	68.5	66.3	65.1	64.3
PV current (A)	1.11	1.71	2.31	2.84	3.02	3.11	2.92	1.84	1.51	0.83
Battery Capacity (%)	70.4	72.2	74.4	78.7	82.1	86.1	92.4	96.9	97.6	98
Battery voltage (V)	37.6	38.6	38.2	38.6	39.8	41.3	42.8	45.0	45.0	42.5
Battery current (A)	1.69	2.66	3.82	4.66	4.61	4.55	4.24	2.49	1.97	1.18
Charging Process	Bulk	Bulk	Bulk	Bulk	Bulk	Bulk	Bulk	Over	Over	Float

2.1.2: Modeling and control a photovoltaic (PV) charger system with SEPIC converter

This project was developed by S.I Chiching, Hsin Jang Shieh and Ming Chieh Chen. This paper discussed about the modeling and controller design of the PV charger system implemented with the single- primary inductances converter (SEPIC) and thsis system is a standalone system. To utilize PV power effectively and the battery is charged with three charging stages the control have to balance to the power flow from the PV module to the battery and load. Besides that, this paper also discussed about the modeling of the SEPIC converter with PV module input and peak-current mode control first [2].

The standalone system requires battery because of the shortage of the solar power. Since the characteristic of PV module is varied with temperature and the radiation of the sun, if the peak power voltage of the PV module does not match with the battery voltage, the energy conversion of the PV module will be reduces. In order to overcome the problem, a battery charger is requires to track the peak power of the PV module. Besides that, the battery charging needs control for achieving high state of charge (SOC) [2].

In this research the SEPIC converter is used, although the boost converter has higher efficiency compare to SEPIC converter. In the view of the efficiency factor the SEPIC converter is not a best option, however the output of the SEPIC converter is non-inverting polarity. Furthermore it's easy to drive switch converter and low input pulse sating for high precise maximum power point (MPPT) that make its integral characteristic suitable for low power PV charger [2].

Figure 2.1.2 show the connection of the SEPIC converter where the SEPIC converter employs the peak current-mode control with outer PV voltage regulating loop, where the voltage command (Vp) reference is generated by combining the MPPT control loop and the battery charging loop. This combination is for instantaneously balancing the system power to charger the battery in three stages which is constant-current, constant voltage, and floating charges stages [2].

This system can operate in three different operation modes. The first one is discharging mode where the battery discharging the power. The second mode is partial charging mode where the charge current is less that the charge current command. This third mode is charging mode where the charge current is equal to the charge current command [2].

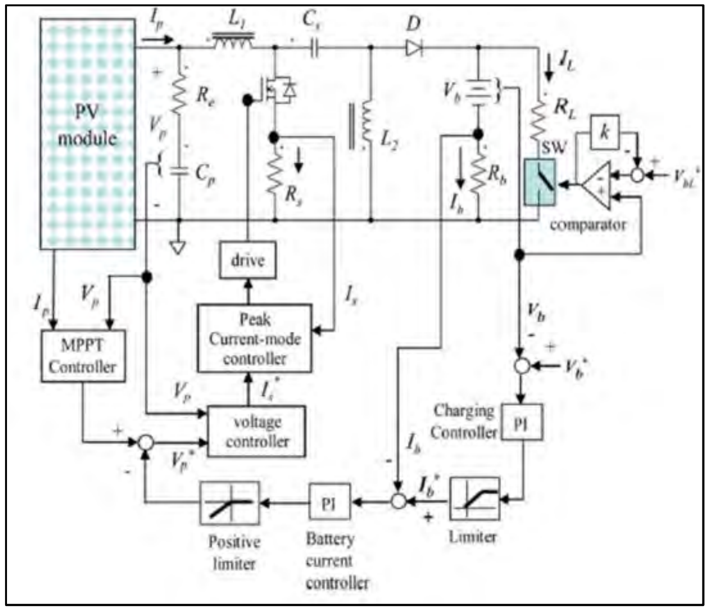

Figure 2.1.2 (a): Circuit configuration of the proposed PV charger [2]

The SEPIC converter was design in continuous current mode (CCM). The CCM operation is used in this converter because it can reduce the input-current ripple and reduced the switch current stress. In this researcher also the switching frequency of converter is set high enough to reduced significantly; the tantalum and the ceramic capacitor with lower equivalent series resistance (ESR) can be adopted cost effectively. The designation of the capacitor can be changed to be with charge and discharge of the capacitor but not with the ESR [2].

From the characteristic of the power-voltage $(P - V_p)$, in the positive-slope region $\left(\frac{dP}{dV_p} > 0\right)$, the operation of the voltage is increased as the power increased. On the other hand in the negative slope region$\left(\frac{dP}{dV_p} < 0\right)$, the operation of the voltage is decreased as the power decreased. Through a few step of voltage adjustment the peak power point starting from any operation point will be finally reached. The adjustment speed will be slower in the positive region and will be fast in the negative region. At the peak power point the adjustment speed will be slow down. This is effective to prevent the tracking oscillation near the peak power point to increase the MPPT precision [2].

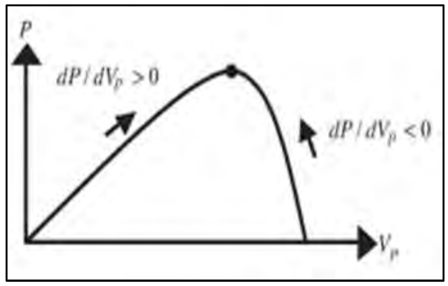

Figure 2.1.2 (b): Adopted incremental conductance MPPT control algorithm [2]

In conclusion, this system is proved to be effective in MPPT and power balance control. This modeling method also can be used in other type of converter to control the power balances control method. This system can ne improves by implemented with the microprocessor or DSP and integrated with the voltage controller and PWM to make the system more practical in the future [2].

2.1.3: A Single-phase current source solar inverter with Reduced size DC link

This project was developed by Craig R.Bush and Bingsen Wang. This paper mainly discuss about the new current source converter for single phase photovoltaic application low frequency. The first improvement is the ripple at low frequency in single phase inverter has been eliminated. The second improvement is the absent of low frequency ripples enables significantly reduced size passive component to achieve necessary stiffness and finally improved maximum power point tracker performances is readily achieved due to the tightened current ripple even with reduced size of passive component [3].

Since the life time of photovoltaic inverter has very short life which is approximately 5-10 years as opposed to the life time of PV panel. This short time not only increases the effective operating cost, but also has a significant stress on the environment in light of life cycle analysis. Besides that, PV inverter also negatively affects the reliability performances include the electrolytic capacitor which commonly exist in PV inverter [3]. The overcome this problem, current source inverter was purposed. By using the current source inverter the (CSIs) could potentially eliminate the electrolytic capacitor while providing additional benefits [3].

For single phase dc/ac inverter system the pulsating power will flow manifest itself in the form of either dc-link current ripple or voltage ripple. In a single phase grid voltage the equation for the grid voltage and the injected current will be [3]:

$$v(t) = V\cos(wt) \;\; ; \;\; i(t) = I\cos(wt + \theta)$$

Where V and I are the magnitude of the grid voltage and the current supplied by the inverter, respectively: w is the angular frequency of the ac system and θ is the phase difference between the voltage and current. It is also known as the power factor [3].

The equation for the instantaneous power flow $p(t)$:

$$\begin{aligned} p(t) &= v(t)i(t) \\ &= \frac{1}{2}vi\cos(\theta) + \frac{1}{2}vi\cos(2wt + \theta) \end{aligned}$$

Since the low frequency will cause the dc current ripple and voltage current ripple in both VSI and CSI. This ripple current and voltage will degrade the performances of the MPPT and the photovoltaic power generation system. The new purpose of current source inverter (CSI) consists of the six voltage bidirectional switches. Besides that, this switches also can be replace with the reverse blocking IGBT [3].

An inductor L_{dc} was connected to the PV panel on the dc side of the converter. In the common single phase inverter the dc link inductor are significantly large to maintain the double frequency ripple current which is resulted from the pulsating instantaneous power flow [3].