Comparative Analysis of DC-DC Converters for Photovoltaic Maximum Power Point Tracking Applications

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DECLARATION OF THESIS

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ANALISIS PERBANDINGAN PENUKAR DC-DC UNTUK APLIKASI PENJEJAK TITIK KUASA MAKSIMUM PHOTOVOLTA

ABSTRAK

Fotovolta adalah satu kaedah yang mengubah tenaga cahaya kepada tenaga elektrik di dalam bentuk atom, dimana kesan fotoelektrik yang dihasilkan fotovolta telah menyerap foton cahaya dan mengeluarkan elektrona. Di atas sebab permintaan yang tinggi terhadap tenaga yang bersih, alat penjana kuasa melalui tenaga solar telah mula berkembang dan ia dikenali sebagai panel solar. Panel solar mengandungi beberapa sel-sel solar yang menukar cahaya kepada voltan DC, voltan yang keluar atau kuasa daripada panel solar adalah tidak stabil kerana beberapa faktor seperti penggelapan separa, rintangan dalaman, kerosakan daripada pembuat, dan pelbagai lagi. Oleh itu, faktor-faktor mengganggu pengeluaran panel solar boleh dikawal dengan mengatur keluaran kuasa menggunakan algoritma penjejak titik kuasa maksimum (MPPT). Terdapat beberapa cara untuk algoritma MPPT beroperasi. Penukar DC-DC adalah satu alat yang penting. Penukar Buck boleh digunakan untuk menurunkan tahap pengeluaran voltan, sementara penukar Boost boleh menaikkan dan menurunkan tahap pengeluaran voltan. Fokus utama projek ini adalah untuk membandingkan di antara penukar-penukar dalam menjejak titik kuasa maksimum (MPP) mengikut keadaan semasa. Modul solar, penukar SEPIC, penukar Buck, dan Penukar Buck-Boost telah dibina menggunakan perisian MATLAB Simulink dan SimPowerSystem Library. Keputusan daripada projek ini telah mengenal pasti penukar SEPIC adalah penukar yang sesuai untuk digunakan dengan algoritma MPPT sebagai pengawal litar kuasa DC-DC. Hal ini kerana penukar SEPIC telah mengatasi dua masalah, yang pertama kawasan tidak beroperasi separti terdapat didalam penukar Buck dan Boost. Kedua, pengeluaran negatif yang terjadi di dalam penukar Buck-Boost telah juga diatasi di dalam SEPIC. Projek ini juga menunjukkan bahawa SEPIC mampu beroperasi dengan kadar kecekapan yang tinggi.

Kata kunci: Panel Solar, Sepic, Buck, Boost, MPPT, Converters, voltan, “current”, Kuasa, Alat Kawalan.

COMPARATIVE ANALYSIS OF DC - DC CONVERTERS FOR PHOTOVOLTAIC MAXIMUM POWER POINT TRACKING APPLICATIONS

ABSTRACT

Photovoltaic can be termed as a method to convert light into electricity at the atomic level, a photovoltaic material exhibits a state known as the photoelectric effect which causes them to absorb photons of light and release electrons. Due to larger demand of clean energy, this has led to the improvement of solar energy power generator device which is known as the solar panel. Solar panel comprises of multiple solar cells that convert sunlight into DC voltage, this output voltage or power is unstable due to several factors such as partial shadow, internal resistance, manufacturer defect and lots more. Therefore, undesirable factor that affects the output of solar module can be controlled by regulating the power output using maximum power point tracking algorithm. There are several methods for MPPT algorithm. The DC-DC converter is one of the most important electronic devices. Buck converter can be used to step down the output voltage, while the boost converter can be used to step up the output voltage. SEPIC and buck-boost converter can be used to step up or step down the output voltage. The main focus in this project is to compare between the converters in terms of tracking maximum power point MPP independently on the environment conditions. Solar module, SEPIC, buck, boost and buck- boost converter are all developed with MATLAB Simulink using SimPowerSystem Library. The result of this study indicated that, SEPIC converter is the most suitable converter for MPPT algorithm as a DC-DC power controller circuit because the SEPIC converter overcomes two limitations, first is non-operational region that appears in buck and boost converter. Second limitation is negative output voltage that appears for buck-boost converter. Also this work proved that the best converter which can work with high efficiency is SEPIC converter.

Keywords: Solar Panel, SEPIC, Buck, Boost, MPPT, Converters, Voltage, Current, Power, Controller.

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LIST OF ABBREVIATIONS

AC	Alternating Current
CV	Constant Voltage
DC	Direct Current
DMPPT	Distributed Maximum Power Point Tracking
IDBS	Integrated Double Boost SEPIC
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MPPT	Maximum Power Point Tracking
P&O	Perturb and Observe
SEPIC	Single Ended Primary Inductor Converter

LIST OF SYMBOLS

D	Duty Cycle
F	Frequency
I	Current
L	Inductor
P	Power
R	Resistance
V	Voltage
C	Capacitor

CHAPTER 1

INTRODUCTION OF STUDY

1.1 Introduction

A direct conversion of light into electricity at the atomic level is called photovoltaic. A photovoltaic material exhibits a state known as the photoelectric effect which causes them to absorb photons of light and release electronics (Yablonovitch, Miller, & Kurtz, 2012). When the released free electrons are captured, electric current will be generated. A most common photovoltaic material is the so called photovoltaic cell or commonly known as a solar cell. Solar cell is made up of semiconductor material like silicon. The cell composition is a thin semiconductor wafer that is particularly used to form an electric field, positive on one side and negative in the other side (Kempa, Day, Kim, Park, & Lieber, 2013). The electrons will become loose from the atom of a semiconductor material when a light energy strikes the solar cell. If there is a load attached between the positive and negative terminals, an electric current will flow.

Solar energy need for future power generation is growing vigorously. However, there is huge unbalance availability and price concern of it component, yet required optimization and improvement. Among all renewable energy, solar energy as prove to be never ending renewable energy because it is energy from sun.

Solar cell is typically used to collect solar energy and convert it into DC voltage system with multiple of solar cell can be term as Photovoltaic system or photovoltaic module. The system maintenance is less costly. However, some believe it is maintenance free and have a longer life span in comparison with other renewable energy power supply. Basic photovoltaic system comprises of photovoltaic panel and power electronics and electrical converters circuit. However, controlling a DC output voltage in order to achieve a desire, controllable or maximum voltage output is challenging (Subudhi & Pradhan, 2013).

Photovoltaic array power outputs usually rely upon the irradiance and environment temperature while this are vary. Therefore, power control scheme utilize to maintain or regulate power conditioning of PV panel and load required to be higher power quality control and high efficiency.

Circuits run best with more specific and steady input, this Input control to particular sub-circuits is challenging for fulfilling most circuit design and requirement. However, AC-AC electrical power conversion is more easier and can implement via transformer but the conversion of dc-dc as become a major task in power circuit application and it is not simple (Alonso, Viña, Vaquero, Martínez, & Osorio, 2012). Diode bridge circuit is one of the common method for decreasing voltage by a set amount but they do not produce optimum power efficient. Voltage controllers such as regulator can be utilized to give a reference voltage. Also, battery voltage diminishes as batteries discharge which can bring about numerous issues if there is no voltage control. There are different types of converters; these include Single Ended Primary- Inductor converter (SEPIC) converter, buck converter, bust converter, buck-boost converter, and cuk converter. All types of these converters have been utilized in different power application. In this project, SEPIC converter will be the main focus because of their ability to reduce or increase voltages which make them suitable for major voltage control application such as solar panel voltage control.

The SEPIC converter is selected in these study because is a type of converter that is very useful to maintain that output voltage level of PV module with respective to solar isolation. Also the maximum power point of the solar power module can also achieve by adjusting the switch frequency of SEPIC converter. .

The present study will develop SEPIC converter and MPPT application using MATLAB software and enhance the efficiency for a system and improve the Maximum Power Point tracking by optimizing the operational region of SEPIC converter.

One major difference in the proposed MPPT method other than methods being proposed by lot of researchers for PV array output is the additional control features, that is dc/dc converter and also help to reduce the complexity of the system.

1.2 Problem Statement

The most productive technique for regulating DC supply voltage of solar panel is with a dc-dc converter. There are five major types of dc-dc converters that are commonly used. These are Buck converters which can just reduce voltage. Another one is boost converter which help to increase voltage level while the third, fourth and fifth type of converters are Cuk, buck-boost, and SEPIC which they all can decrease or increase voltage.

Some applications only requires to either buck or boost voltage concept, sort of application can remain in usage of either buck converter or boost converter devices.

There are number of cases whereby, required output voltage within the range of input voltage, this cannot be handle with just buck converter or boost converter alone. This has to be type of converter that can technically have the capability to decrease or increase voltage, SEPIC or buck-boost converter is suitable for this type of application.

Buck-boost converters can be less expensive because their circuit construction usually requires single capacitor and inductor. In any case, these converters experience high amount of input current ripple. This make the converter not suitable for much application those are sensitive to high harmonic input causing by high amount of input current ripple.

For MPP tracking application, normally non isolated DC-DC converter such as buck and boost converter is mutilated. However, buck and boost converter have some limitation, one of the drawbacks of buck and boost converter is non- operational region. The non-operational region is the condition of buck and boost converter where the non-duty cycle value able to impose the operating point on the Maximum Power Point. To overcome this problem, a SEPIC converter has many advantages compared to conventional buck, boost and buck-boost converters. However, the challenge is on how to design efficient DC-DC converter to get maximum power point tracking in Photovoltaic applications.

1.3 Objectives

The primary project object is described as follow:

1. To design DC-DC converters for MPPT applications.
2. To develop and verify the DC-DC converters for MPP tracking application using MATLAB/Simulink.
3. To analyze and comparatively studies the performance of the converter in dealing with PV system environments in terms of efficiency and its tracking capability.

1.4 Scope of Study

In this project DC-DC converters for MPPT application to extract maximum available solar power energy is studied in detail. For the power circuit section, the expectation would be to select components that are best match to the system. One of the expected outcomes is to provide working equations needed to design DC-DC converters for MPPT application. Final result shows a working simulation of DC-DC converters by using MATLAB/Simulink.

Other scope of this study includes:

- Equation derivations needed in designing buck, boost, buck-boost & SEPIC converters and their components selection.
- Calculation of power dissipations, switching stress and efficiency.

1.5 Thesis Outline

Chapter one introduces the main goal and motivation of the current study along with the problem that led to the formation of research objectives. It also describes five different types of dc-dc converters that are commonly used. These are Buck, boost, Cuk, buck-boost, and SEPIC converters.

Chapter two introduces the literatures and provides a detail explanation for PV module, maximum power point tracking and DC-DC converter. Most described information in this section are related, work done by other researchers it also describes (Photovoltaic as conventional way of converting light into electricity).

Chapter three describes the design aspects for the proposed DC-DC converters (design SEPIC, buck, boost, and buck-boost) along with introducing the analysis mechanism and simulation setting to gather the result.

Chapter four discuses and analysis the results obtained from the MATLAB simulation, this include data collection and result simulation been performed on solar module and DC-DC converters.

Chapter five presents the conclusion and research summary and possible future work.

1.6 Summary

This chapter introduces the main goal and motivation of the current study along with the problem that led to the formation of research objectives. It also describes five different types of dc-dc converters that are commonly used. These are Buck, boost, buck-boost, Cuk and SEPIC converter. Also this chapter had discussed about MPP Tracking. In addition, this chapter pointed out the advantages for SEPIC converter and disadvantages for buck, boost, and buck-boost converter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Photovoltaic can be term as a conventional way of converting light into electricity at the atomic level. A photovoltaic material are type exhibit a common state known as the photoelectric effect, this effect causes the material to absorb photons of light in order to release free electrons (Yablonovitch et al., 2012). When the released free electrons are captured, electric current will be generated. A most common photovoltaic material is the so called photovoltaic cell or commonly known as a solar cell. Solar cell is made up of semiconductor material like silicon. The cell composition comprise of thin semiconductor wafer that is particularly used to create an electric field resulting to one side negative charge and other side positive charge (Kempa et al., 2013). The electrons will become loose from the atom of a semiconductor material when a light energy strikes the solar cell. If there is a load attached between the positive and negative terminals, an electric current will flow. The PV system consists of solar cell, DC-DC converter, DC-AC inverter and load. The Figure 2.1 shows the diagram of PV systems.

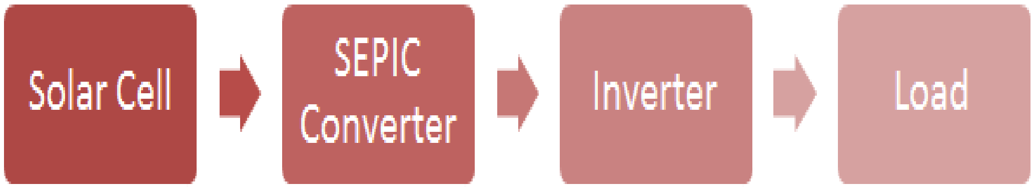

Figure 2.1: Shows the diagram of PV systems.

Each solar cell is capable of producing 0.5V typically. In order to get a higher voltage level, solar cells are connected in series. In order to support higher current applications, solar cells are connected in parallel. A module consisting of several solar cells is often called a solar panel and this is what most people know (Singh, 2013). There is lot of commercial solar panels nowadays that comes in different voltage levels. Solar panel energy is dependent to weather conditions and it can vary continuously (Sommer-Larsen, at el 2013). At its best, a solar panel can produced output higher voltage than its typical rating while a lower voltage during unfavorable weather.

A solar panel output voltage will vary depending on weather conditions; that is why specialized circuits are often used to regulate its output voltage to a certain level. For instance the system that uses the solar panel requires 12V input; a solar panel with a 12V rating is not advisable to be used directly. The solar panel output may go as high as 18V while may go lower than 12V depending on the weather condition. The role of the added specialized circuit is to regulate the 12V level (Rauschenbach, 2012) . Such circuits are buck, boost or buck-boost converter. A buck circuit will output a lower voltage than its input. So, in order to maintain a 12V voltage level, the solar panel voltage must be always higher than 12V and a buck circuit has two regions, first region is known as operational region and the second region is called non-operational region as shown in Figure 2.2.