PHOTOVOLTAIC POWERED SYSTEM WITH BUCK-BOOST CONVERTER FOR PEST MONITORING AND MANAGEMENT SYSTEM

AMEERAH RASYEED BINTI ADNAN

BACHELOR OF ELECTRICAL ENGINEERING WITH HONOURS
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

PHOTOVOLTAIC POWERED SYSTEM WITH BUCK-BOOST CONVERTER FOR PEST MONITORING AND MANAGEMENT SYSTEM

AMEERAH RASYEED BINTI ADNAN

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this thesis entitled “Photovoltaic Powered System with Buck-Boost Converter for Pest Monitoring and Management System is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	
Name	:	AMEERAH RASYEED BINTI ADNAN
Date	:	05/07/2021

APPROVAL

I hereby declare that I have checked this report entitled “Photovoltaic Powered System with Buck-Boost Converter for Pest Monitoring and Management System” and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature :

Supervisor Name : Dr. Azrita binti Alias

Date : 05/07/2021

DEDICATIONS

To my beloved mother and father,

Pn. Hazlinda Binti Hussain and En. Adnan Bin Bakar

ACKNOWLEDGEMENTS

In preparing this report, many people have contributed towards my understanding and thought. I wish to express my sincere appreciation to my main project supervisor, Dr. Azrita Binti Alias, for encouragement, guidance critics and friendship. Without her continued support and interest, this project would not have been same as presented here.

My fellow undergraduate students should also be recognised for their support particularly those who stood by my side. I am especially thankful to my comrades, Jeyaahthaarsine A/P Ravindar, Jackson Lee Jian Soon and Khalisah Binti Zulkifle for the sleepless nights spent helping me to complete this final year project.

I am grateful to all my family members. My parents, Encik Adnan Bin Bakar and Puan Hazlinda Binti Hussain has been my great motivators throughout this project. Not to forget my siblings. They have supported me in an any way they can.

ABSTRACT

A pest monitoring and management system is operated to monitor the presence and activity of rodents. It includes an image processing system operated using Raspberry Pi with Linux operating system. The input needed for this system to work is at least 5V. This project focuses more on the DC-to-DC converter particularly buck-boost converter providing that amount of input voltage so that the system can work. The reason being that the system is powered by implementing photovoltaic powered system that would generate unstable voltage input due to the sun. As per knowledge, buck-boost can step up or step down the voltage source according to requirements. A closed loop circuit based on the suitable topology which is the SEPIC converter with to ensure constant ouput of 5V no matter what input voltage it receives from the PV system. Three types of feedback controllers which are PI controller, P controller and I controller are implemented and compared using the data collected from the simulation in MATLAB software. From all analysis, the PI controller is proven to be the best in controlling the output that the system requires.

ABSTRAK

Sistem pengurusan dan pemantauan perosak dikendalikan untuk memantau kehadiran dan aktiviti perosak. Ia mengandungi sistem pemprosesan imej yang dikendalikan menggunakan Raspberry Pi dengan sistem operasi Linux. Voltan masuk yang diperlukan agar sistem ini berfungsi adalah sekurang-kurangnya 5V. Projek ini lebih menumpukan pada penukar arus terus kepada arus terus terutamanya penukar *buck-boost* menyediakan jumlah voltan masuk supaya sistem dapat berfungsi. Hal ini disebabkan sistem ini digerakkan dengan mengimplementasikan sistem bertenaga yang akan menghasilkan voltan masuk yang tidak stabil akibat cahaya matahari. Seperti pengetahuan sedia ada, buck-boost dapat meningkatkan atau menurunkan input voltan mengikut keperluan. Litar gelung tertutup berdasarkan topologi yang sesuai iaitu penukar SEPIC untuk memastikan keluaran berterusan 5V tidak kira voltan masuk yang diterimanya dari sistem fotovoltaik. Tiga jenis pengawal maklum balas iaitu pengawal PI, pengawal P dan pengawal I dilaksanakan dan dibandingkan dengan menggunakan data yang dikumpulkan dari simulasi dalam perisian MATLAB. Dari semua analisis, pengawal PI terbukti terbaik dalam mengawal keluaran yang diperlukan oleh sistem.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

DC	-	Direct Current
DSP	-	Digital Signal Processing
ZOH	-	Zero-Order Hold
CCM	-	Continuous Current Mode
V	-	Voltage
D	-	Duty Ratio
L	-	Inductor
C	-	Capacitance
R	-	Resistance
H	-	Henry
F	-	Farad
μ	-	X 10^{-6}
MOSFET	-	Metal-Oxide-Semiconductor Field-Effect Transistor
PV	-	Photovoltaic
Ω	-	Ohm
f_{sw}	-	Switching frequency

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

DC-DC converters which are also known as electronic components that provide a specific voltage and isolation between input and output. The function of a DC-DC converter is to fix the load to the input. Next, it is also used to set apart the primary and secondary circuit. It also helps to simplify the system in general. The common applications of DC-DC converter are to step-down or step-up the voltage from voltage source/input to obtain a specific output. DC-DC converters can be divided consists of into five three main types which are buck converter, boost converter, and buck-boost. For a wider usage, buck-boost converter is introduced to function either as buck or boost converter. The DC-DC converters are widely used in solar photovoltaic (PV) systems, battery charging, fuel cell, and electric vehicle systems. The project includes the design of DC-DC converters to provide a stable DC voltage supply from photovoltaic powered system for the pest monitoring and management system [1]. The converter will have to supply enough amount of voltage input for the system to work perfectly. The pest monitoring and management system will then go through Image Processing into Raspberry Pi. However, the yellow box in Figure 1.1 shows the focus of this project which is the source and the buck-boost converter.

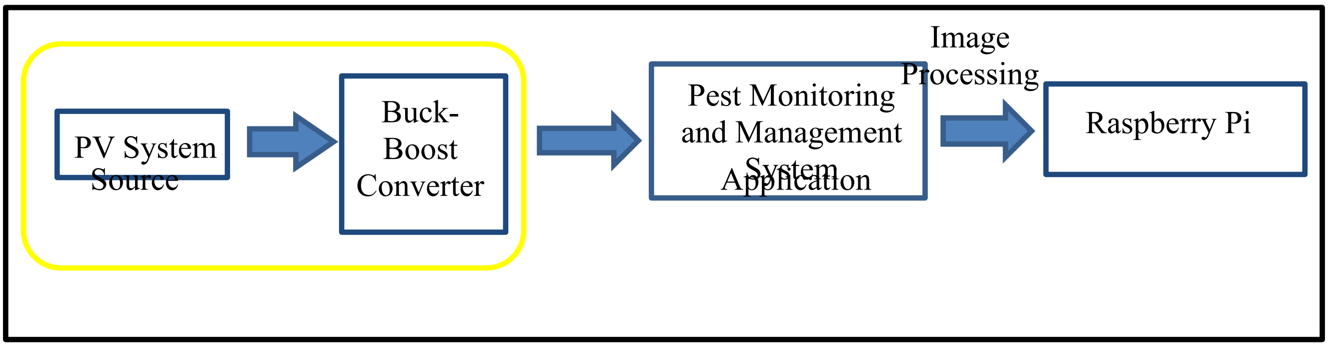

Figure 1.1 Overall System

1.2 Motivation

Fossil fuels meet to some degree of all world energy demand. In view of their depletion rates and pollution regulations, these fossil fuels should gradually be substituted with renewable energy. Renewable energy sources will reduce discharges of contaminants. Solar energy can play a crucial role in a developing country [2]. Solar energy is known as the radiation of the sun to the earth also the most common energy source. The sun makes up the power station of Earth and the source of all power on our planet. Nowadays, methods on how solar energy is harvested for many applications has become an important field of study. In developing countries like India, where energy issues are very severe, despite the discovery of oil and gas off the west coast, there is a continuous rise in the amount of crude oil and the price charged for all other expenditure [3]. As for the feedback controller, it is smarter and pales in comparison the feedback signal and the reference input and creates an error signal and causes the controlled variable to obey the reference input. Therefore, we can obtain the required result. In theory, it is identified as a closed loop system [4].

1.3 Problem Statement

The controller is designed for disturbance signal and if any, the disturbance varies due to internal or external conditions, the controller designed for specific disturbance might not be as efficient as for that disturbance. Desired result will not be obtained. In theory, this system is named an open-loop system because the loop has not been closed to provide information on the status of controlled output [4]. Since the source of the pest system is photovoltaic system, the input voltage would be unstable as it depends on five factors stated by Wasfi, Mahmud [5]. Five contributing factors in the performance output of photovoltaic panels are load resistance, sunlight intensity, cell temperature, shading, and crystalline structure. In short, the input voltage changes. Therefore, a converter is designed to overcome this issue. Some controllers have damaging effect on the output voltage and not suitable for overall system. The system can be very unstable and cause damages to the system or device.

1.4 Objective

The project includes the design of DC-DC converters to provide a stable DC voltage supply from photovoltaic powered system for the pest monitoring and management system. The project aims to:

i. To design buck-boost converter circuit using MATLAB to provide a stable DC voltage supply from photovoltaic powered system.
ii. To design feedback controller implemented to buck-boost converter for a robust system towards the output voltage.
iii. To compare the performance of different types of controllers.

1.5 Scope Project

This project will be focusing on the design of the buck-boost converter that can provide a stable output voltage using MATLAB Simulink. By choosing the suitable topology of buck-boost converter, an open loop circuit is designed, and the output voltage is obtained by adjusting the duty ratio. A closed-loop circuit is then designed by implementing P, I, and PI controller and determine the one with the best transient properties.

CHAPTER 2

LITERATURE REVIEW

2.1 DC to DC Converter

In most industrial applications, constant DC voltage is usually converted into a variable DC voltage. DC converter is like ac transformer where it can be implemented into a system whether to lower or increase the input voltage [6]. These converters are popular to generate regulated voltage from a source efficiently. The source can be controlled or not connected to a load that can be constant or not. These converters usually use capacitors, transformers, inductors and switches. When using controllers, the input voltage and output current will change and not remain constant. This can be fixed using closed feedback loops.

2.2 Classification of DC-to-DC Converter

In principle, DC to DC converter is classified into isolated and non-isolated converters. Isolation means that in between the inputs and the output of the converter there is an electrical barrier the converter will cease to provide the required output. A transformer which can serve that purpose. It is used for high voltage applications. In addition, these converters are in positive or negative configuration. Flyback, forward, resonant, push-pull, bridge converters are categorized as isolated converters [7]. Buck, boost, buck-boost converters are often used non-isolated converters. This paper will be focused more on non-isolated converters.

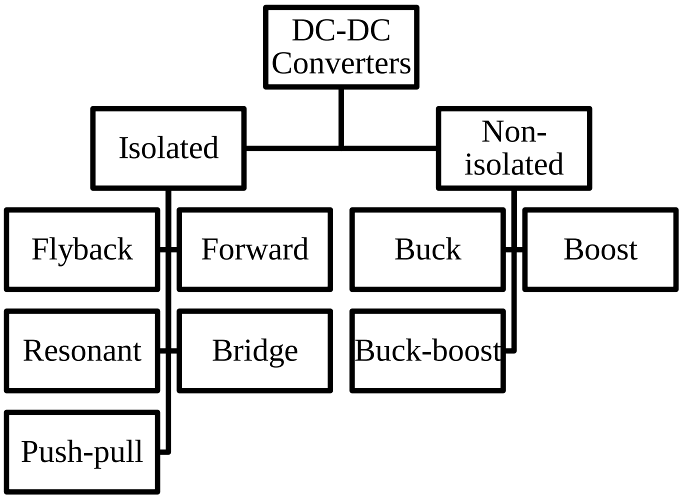

Figure 2.1 Classification of DC-to-DC Converters

2.3 Buck Converter

A Buck converter is basically a step-down converter which means it will lower the output voltage from input but doing the complete opposite on current. In [8], states that it has DC input voltage source, regulated switch S, diode D, filter inductor L, filter capacitor C, and load resistance R. Another method to use this topology is to combine larger module voltages with smaller loads or battery voltages. Many solar PV applications combined with buck converters in stand-alone solar PV pumping systems that allows the application of water source in the countryside [9].

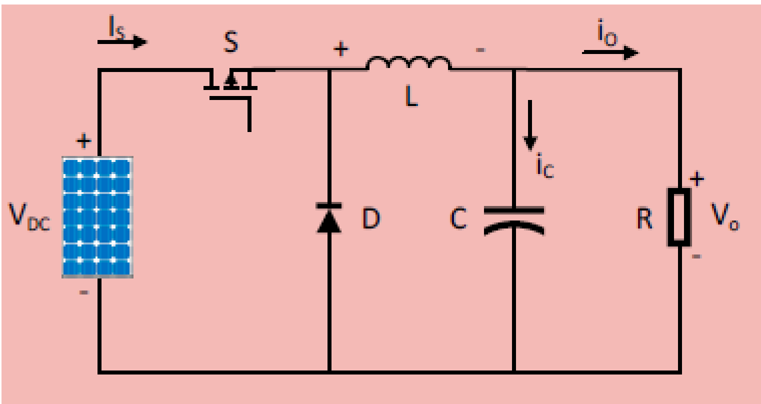

Figure 2.2 Circuit of Buck converter

2.4 Boost Converter

A boost converter is a step-up converter, which increases the voltage whilst lowering the current. It has DC input voltage source VS, boost inductor L, controlled switch S, diode D, filter capacitor C, and load resistance R [8]. In some PV applications, the load voltage must be superior compared to the output voltage. So, in this circumstance, the boost converter is included in the MPPT converter [10].

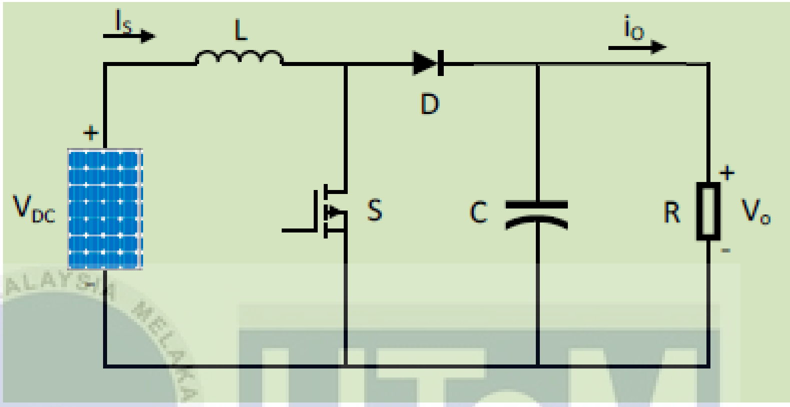

Figure 2.3 Circuit of Boost converter

2.5 Buck-Boost Converter

The buck-boost converter can generate a higher output voltage also lower depending on the application, hence the name [11]. The buck-boost converter is developed by the integration of basic buck and boost converter topology that are very useful as stand-alone/grid-connected PV systems and motor drives. This circuit operates in two modes. The first mode is switch ON mode whereas the switch S in turned on. The current will flow only to the inductor and the transistor switch because of the reverse biased diode. Next in switch OFF mode, current will flow from the charged inductor towards the capacitor, load resistant and diode (now in forward bias). So, the inductor current will decrease until the switch is turned on again to recharge it [12].

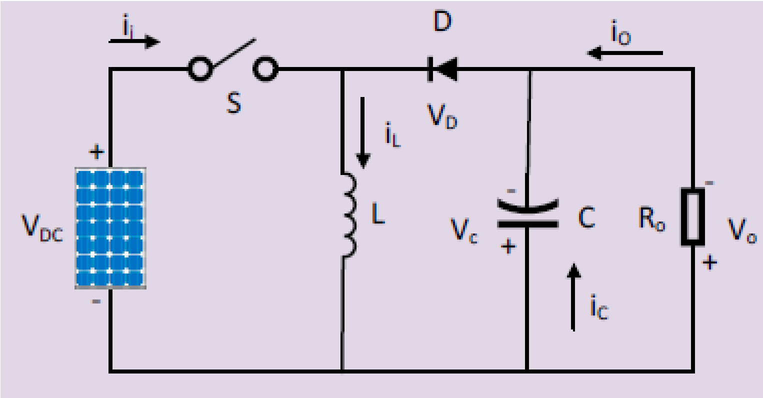

Figure 2.4 Circuit of Buck-boost converter

2.6 Buck-Boost Developed Topologies

Present studies on buck-boost are still ongoing for solar PV applications [13-19]. In terms of increasing the voltage gain, researchers are currently inventing different non-isolated DC-DC converter topologies, notably Cuk, SEPIC, and Luo converters, which are developed from the conventional buck-boost.

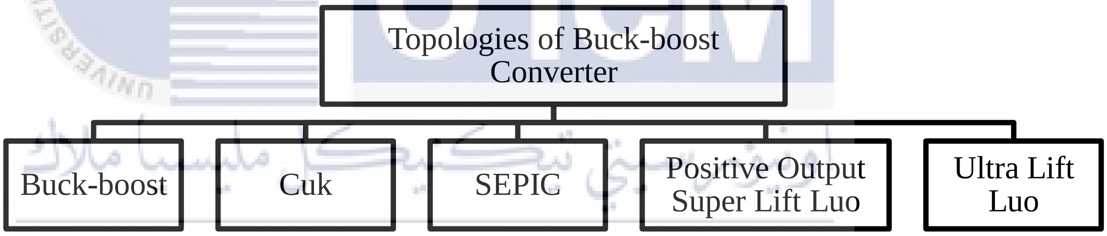

Figure 2.5 Topologies of Buck-boost converter

2.6.1 Cuk Converter

Cuk converters are developed from conventional buck-boost converter, which was changed to a capacitor instead of the inductor which is used for energy storage and power transfer [20]. Cuk converters have voltage source, inductor, switch, capacitor, diode, inductor, and resistance. Like the name, the magnitude of the output voltage will either be larger or smaller than the input, and the output polarity is reversed. The input inductor functions as a dc supply filter to prevent high harmonic information. The converter produces inverted output suitable connections generating ripple-free output [21-24]. For optimum bidirectional operation to control the voltage and current, the overall efficiency is suitable [25]. As Rashid points out [3, pp. 218], this topology runs in Continuous Current Mode (CCM). Presence of switch, diode and capacitor can only mean more reactive components and more current strains. Thus, these components can be said to add to its cons.

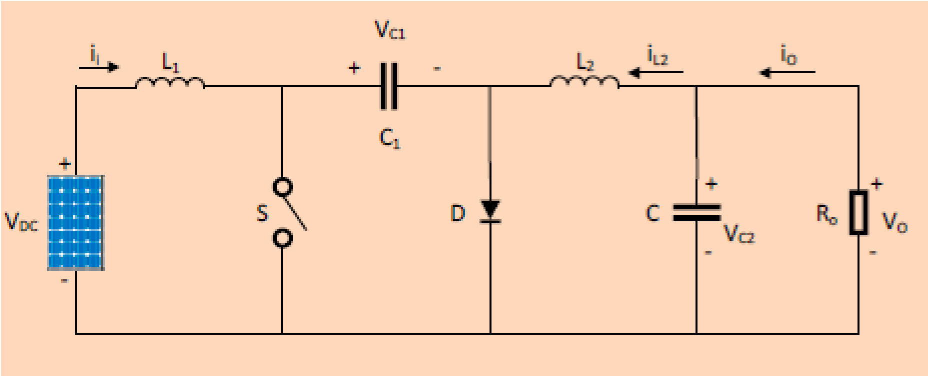

Figure 2.6 Circuit of Cuk converter

2.6.2 Single-Ended Primary Inductance Converter (SEPIC)

It is a Cuk-like converter called single-ended primary inductance converter (SEPIC). SEPIC can produce a larger or smaller output but without reversed polarity [7]. Essentially, during switching, the ON time is longer than the OFF time so that the output voltage is better because the inductor needs a longer charging time. Unless the capacitor is not fully charged, the converter will not provide the required output. There are quite few drawbacks that requires consideration during the design of the converter. When a transformer of a high frequency is powered with a traditional SEPIC converter, it should lessen the output voltage ripple. This configuration benefits from main features such as continuous output current, reducing switching tension, and output ripple [26-29]. The SEPIC converter is designed for the sensor less control of a solar-powered DC motor that can broaden its application to solar-powered transport [30]. Although the buck-boost converter performs the same operation as the SEPIC converter, its performance is weaker as opposed to the SEPIC converter. This is the result of a high-efficiency application such as a spacecraft using a SEPIC converter. It gives a consistent output when the input differs. The SEPIC have a high efficiency range of between 90% and 95% [26].

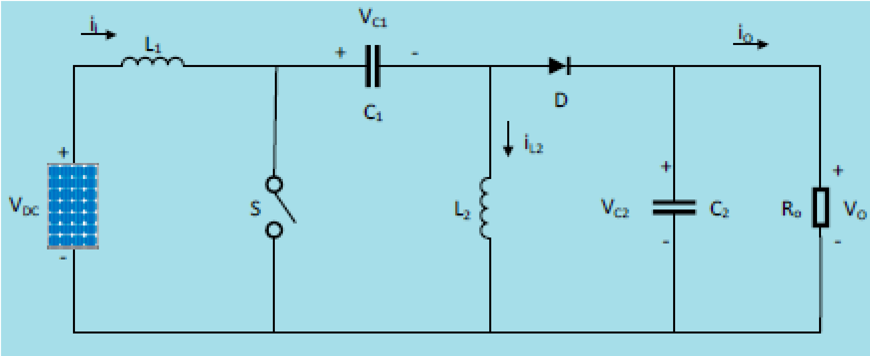

Figure 2.7 Circuit of SEPIC Converter

2.6.3 Positive-Output Super Lift Luo

Positive-Output Super Lift Luo converter is also developed from buck-boost converter. It can step-up or step-down input source. It has an additional inductor and capacitor [9, pp. 338]. The LUO converter consists of C1 capacitor, which is connected parallel to the source, C2 connected to the load, inductor L1, freewheeling diodes D1, D2, power switch S. There are two phases in this system which are switch on and switch off. The voltage boost is performed by the L1 inductor and the C1 capacitor. During turn ON cycle, which is when the switch is closed, the inductor current rises when voltage rises. This will charge the capacitors to the source voltage. The load energy is fed only by capacitor C2 [31].

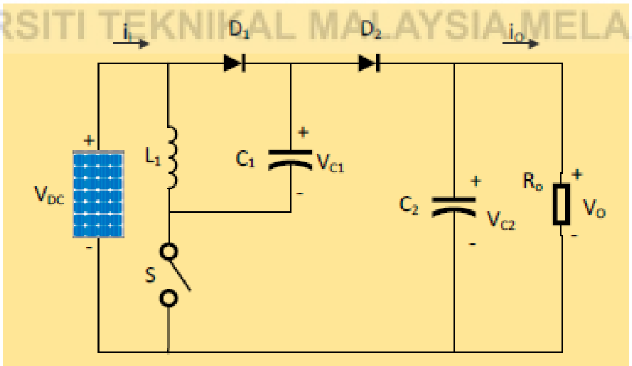

Figure 2.8 Circuit of Positive-output super lift luo converter

This converter is the most efficient out of Cuk and SEPIC converters. The distinctive capabilities of this converter are the enhanced performance, the output voltage produced in terms of arithmetic progression. During evaluations, these converters have a larger transfer voltage gain if they are powered at the first Quadrant.