COMPARATIVE STUDY ON PHOTOVOLTAIC TRACER BETWEEN CAPACITIVE LOAD AND CONVERTER APPROACHES UNDER PARTIAL SHADING

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DEDICATION

This project report is dedicated to my parents, who taught me that the best kind of knowledge to have is that which is learned for its own sake and even the largest task can be accomplished if it is done one step at a time. To my loving wife, for her endless support during my postgraduate study. And last to my supervisor for his many guidance. Without all these people in my postgraduate life, this project report will never be accomplished.

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ABSTRACT

Generation of electrical energy through the photovoltaic (PV) conversion of incoming sunlight represents a significant alternative. Shading and PV material degradation are examples of aspects that affects the quality of PV system. The output power of PV decreases is a lot worse than it initially seems. To quickly identify the losses affecting the PV system, PV tracers are introduced. PV tracers are commonly used to determine the health of the PV module during commissioning and annual maintenance of a plant. The plant is taken offline during this operation and the I-V curve is then shows by an impedance sweep. There are many PV tracers on the market. They are primarily focused on fault detection and performance assessment of PV plants. The acquisition of this equipment is limited to specific tasks because of its high cost. Because of lower price, higher sampling rate and portability, the I-V curve tracers with a capacitive load are more desirable. However, the device design and operation entail higher complexity and requires the scale of the capacitor. This project report presents the comparative study between capacitor load method and Cuk converter approaches under partial shading condition. The capacitor sizing solve the issue of acquiring appropriate capacitor for the system. It was properly sized by taking into account the various configurations of PV modules and the charge time required for service at different irradiance levels. These optimal sampling rate for the recording of I-V data is decided. A high sample rate requires a lot of memory, especially for long tracking periods of the I-V curve. In comparison, during the short I-V tracking period, the low sampling rate can yield to missing data. The problem lies in designing an on-line PV tracer that enables the I-V curve to be registered on request from an online PV device without interrupting the power flow. In strategic plant maintenance, this approach of I-V curve-based plant surveillance can be efficient in reducing downtime and optimizing production. The Cuk converter known as having optimum performance under DC-DC converter was analyzed. Obtaining the appropriate duty ratio to achieve fine result was studied to prove the performance of Cuk converter. Simulations under partial shading condition was generated to verify this study. With preliminary results, details on the analysis and design process for the developed PV tracer are presented.

ABSTRAK

Penjanaan tenaga elektrik melalui penukaran fotovoltaik (PV) cahaya matahari masuk merupakan alternatif yang ketara. Bayangan dan degradasi bahan PV adalah contoh aspek yang mempengaruhi kualiti sistem PV. Kuasa output PV menurun jauh lebih buruk daripada yang kelihatannya pada mulanya. Untuk mengenal pasti kerugian yang mempengaruhi sistem PV, pelacak PV diperkenalkan. Pelacak PV biasanya digunakan untuk menentukan tahap kesihatan modul PV semasa operasi dan penyelenggaraan tahunan loji. Loji dibawa ke luar talian semasa operasi ini dan lengkung I-V kemudian ditunjukkan oleh sapu impedans. Terdapat banyak pelacak PV di pasaran. Mereka terutamanya tertumpu pada pengesanan kesalahan dan penilaian prestasi loji PV. Perolehan peralatan ini terhad kepada tugas-tugas tertentu kerana harganya yang tinggi. Kerana harga yang lebih rendah, kadar pengambilan sampel yang lebih tinggi dan mudah dibawa, pelacak lengkung I-V dengan beban kapasitif lebih diinginkan. Walau bagaimanapun, reka bentuk dan operasi peranti memerlukan kerumitan yang lebih tinggi dan memerlukan skala kapasitor. Laporan projek ini menyajikan kajian perbandingan antara kaedah beban kapasitor dan pendekatan penukar Cuk dalam keadaan bayangan separa. Ukuran kapasitor menyelesaikan masalah memperoleh kapasitor yang sesuai untuk sistem. Ukurannya sesuai dengan mempertimbangkan pelbagai konfigurasi modul PV dan masa pengecasan yang diperlukan untuk servis pada tahap cahaya yang berbeza. Kadar persampelan optimum ini untuk rakaman data I-V ditentukan. Kadar sampel yang tinggi memerlukan banyak memori, terutamanya untuk jangka masa panjang lengkung I-V. Sebagai perbandingan, dalam tempoh penjejakan I-V yang pendek, kadar persampelan rendah dapat menghasilkan data yang hilang. Masalahnya terletak pada reka bentuk pelacak PV dalam talian yang membolehkan kurva I-V didaftarkan atas permintaan dari peranti PV dalam talian tanpa mengganggu aliran kuasa. Dalam penyelenggaraan kilang yang strategik, pendekatan pengawasan tanaman berdasarkan kurva I-V ini dapat menjadi efisien dalam mengurangi waktu henti dan mengoptimumkan pengeluaran. Penukar Cuk yang dikenali mempunyai prestasi optimum di bawah penukar DC-DC dianalisis. Mendapatkan nisbah tugas yang sesuai untuk mencapai hasil yang baik dikaji untuk membuktikan prestasi penukar Cuk. Simulasi dalam keadaan bayangan separa dihasilkan untuk mengesahkan kajian ini. Dengan hasil awal, perincian mengenai analisis dan proses reka bentuk untuk PV pengesan yang dikembangkan akan dikemukakan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

PV	-	Photovoltaic
I-V	-	Current vs Voltage
P-V	-	Power vs Voltage
DC-DC	-	Direct Current to Direct Current
STC	-	Standard Test Condition
UTM	-	Universiti Teknologi Malaysia
p-n	-	Positive side to negative side
IR	-	Infrared
EMI	-	Electromagnetic Interference
PWM	-	Pulse Width Modulation
MPP	-	Maximum Power Point
RMSD	-	Root-Mean-Square Deviation

LIST OF SYMBOLS

I_L	-	Photo-current
I_0	-	Diode saturation current
I_{sc}	-	Short Circuit Current
I_{mpp}	-	Current at maximum power point
P_{mpp}	-	Power at maximum power point
V_{mpp}	-	Voltage at maximum power point
V_{oc}	-	Open Circuit Voltage
R_i	-	Resistor at input
R_o	-	Resistor at output
R_s	-	Series resistance
R_{eq}	-	Equivalent Resistance
G	-	Irradiance
m-Si	-	Monocrystalline silicon
a-Si	-	Amorphous silicon
N_c	-	No. of series cell in a module
N_p	-	No. of parallel connection
N_s	-	No. of series connection
C	-	Capacitor
L	-	Inductor
t	-	Time
t_0	-	Initial time
t_f	-	Final time
T	-	Temperature
D	-	Duty ratio
D_{sc}	-	Deviation on short circuit point
D_{oc}	-	Deviation on open circuit point
k	-	Measure point slope

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Problem Background

As the world's ever-growing energy demand needs to be met while international agreements have been set up to reduce CO_2 emissions, alternative energy are needed to replace the existing fossil fuel-based energy sources [2,6]. Positively, throughout the past decade, renewable energies have experienced substantial growth the production of more effective and sustainable systems has been accomplished from a technical perspective. In this context, because of its inherent characteristics, the generation of electrical energy through the photovoltaic (PV) conversion of incoming sunlight represents a significant alternative [1]. Solar energy is abundant, clean, and sustainable among several other renewable energy sources and offers low operating and maintenance costs. Another interesting issue is that the solar energy incident on the surface of the Earth is thought to be approximately ten thousand times greater than the consumption of world energy [4].

The great number of applications and high efficiency can be highlighted as some of the most outstanding features of PV compared to other energy generation systems. Furthermore, PV applications that can be applied at both commercial and residential levels, allowing the public to contribute further towards reducing CO_2 emissions [2]. Systematic studies are therefore necessary to evaluate and clarify the operational principles of various related technologies, whether current or under development. This is important for optimizing operational efficiency and for exploring the techniques used to harness the electricity generated [1].

PV systems generate electricity based on amount of sunlight they receive. Shading and PV material degradation are examples of aspects that affects the quality of PV system. The output power of PV decreases is a lot worse than it initially seems.

To quickly identify the losses affecting the PV system, PV tracers are introduced. PV tracers are commonly used to determine the health of the PV module, string or array during commissioning and annual maintenance of a plant. The plant is taken offline during this operation. The I-V curve is then shows by an impedance sweep [3]. There are many PV tracers on the market. They are primarily focused on fault detection and performance assessment of PV plants. The acquisition of this equipment is limited to specific tasks because of its high cost [1]. There are many factors causing losses in photovoltaic systems. In the design process to maximize output power, each of these factors must be minimized and the return on investment must be the quickest, the most significant loss due to a malfunctioning which can be divided into the following subsections [2]:

1. Fabrication
2. Temperature
3. Irregular soiling
4. Cloud refraction and shading
5. Failed bypass diodes
6. Variable degradation
7. Potential induced degradation
8. Bond degradation
9. Interconnect degradation
10. Packaging material degradation

11. Semiconductor degradation

12. Damp interference

A significant proportion of these losses have been characterized while others are supposed to be caused by variables. The solar energy plant can be either optimized to mitigate the loss or left untreated if it is not financially viable, depending on the energy part that is lost.

Commercial PV tracers are very costly and require the load to be disconnected from the panels during PV trace. Examples of PV tracers to produce I-V curves and perform other tests are the DayStar DS-100C and Seaward PV 2010. They are both limited in that it is possible to test only one module or array at a time. The Daystar multitracer and load module may be used for long-term testing of multiple PV arrays. However, this equipment is also heavy and bulky, in addition to the high cost [5].

1.2 Problem Statement

Because of lower price, higher sampling rate and portability, the I-V curve tracers with a capacitive load are more desirable. However, the device design and operation entail higher complexity and requires the scale of the capacitor. The capacitor needs to be properly sized by taking into account the various configurations of PV modules and the charge time required for service at different irradiance levels. These help to decide the optimal sampling rate for the recording of I-V data. A high sample rate requires a lot of memory, especially for long tracking periods of the I-V curve. In comparison, during the short I-V tracking period, the low sampling rate can yield to missing data [6].

The problem lies in designing an on-line PV tracer that enables the I-V curve to be registered on request from an online PV device without interrupting the power flow. In strategic plant maintenance, this approach of I-V curve-based plant surveillance can be efficient in reducing downtime and optimizing production [3].

1.3 Project Goal

This research goal is to develop a low-cost PV tracer using few different methods. The methods that are proposed are capacitor load method and DC-DC converter method with Cuk topology. From the design, all of the proposed method will be simulate using MATLAB Simulink. The performance of PV tracer during partial shading condition will be studied. Comparison of performance for sampling rate and other important aspect.

1.4 Project Objectives

The objectives of the research are:

a. To design a low-cost PV tracer using capacitor load method and Cuk converter method

b. To simulate the PV tracer design using MATLAB Simulink

c. To study the performance of PV tracer during partial shading condition

d. To compare the performance of the capacitor load method and Cuk converter method

1.5 Scopes of Project

1. The DC-DC converter topology that will be used in this method is Cuk topology. Cuk converter uses L-C type filter, so peak-peak ripple current of inductors is less as compared to the Buck-Boost converter.

2. Two partial shading factors (25% and 50% shaded scenario) will be analyzed to identify the speed of sampling rate for each method.

3. Cost of each PV tracer are constructed referring to current price of each component available in the online market.

4. Comparison of performance for the proposed methods are based on simulation results. Obtain the details of components from manufacture data sheets. Standard Test Condition (STC) is the condition of PV panel that will be simulated.

1.6 Research Methodology

Refer to the Figure 1.1, the flowchart of this project are described. Begin with literature review where PV tracer concept, and method used for PV tracer are studied. Next step of this project is to do research methodology. In research methodology, work done for this project are shows. It includes, the PV model parameters for simulation purposes, partial shading condition simulation and the methods used for PV tracer. The next phase is to provide the results of the simulations (PV module, Partial shading condition, capacitor load method and Cuk converter method). The results are then discussed. Finally, the conclusion for the project will be determine and proposal for future works on the project will be stated.

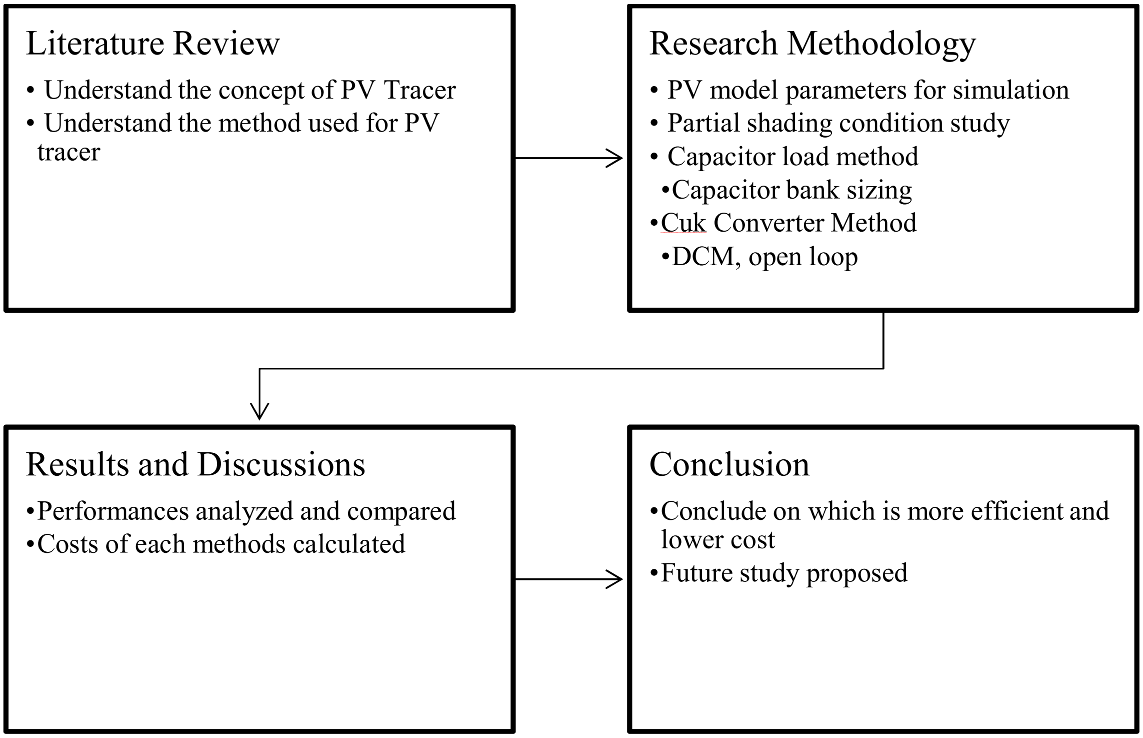

Figure 1.1 Flowchart of the project report

Table 1.1 Gantt chart for this project

Activities	**2020**					
	5-Oct	2-Nov	1-Dec	4-Jan	8-Mac	2-May
To develop the PV tracers based on the capacitance load and DC-DC converter methods using MATLAB/Simulink simulation software.				1		
To analyze the performance of the PV tracers in term of accuracy, tracing speed, tracing distribution, and implementation cost.						
To compare the performance of the PV tracers with capacitive load and DC-DC converter methods						2

Milestones:

- Completion of mathematical analysis: interim report

- Completion simulation and discussion: final report

Table 1.1 shows the proposed activities throughout the semesters and the targeted completion of report of this project. From the table, to develop the PV tracers takes 5 months due to process of understanding the PV tracer and to search the methods that are used in PV tracer. Performance analysis of the PV tracers based on the attributes will take another 4 months. Finally, the comparison of proposed methods of PV tracer will be discussed. And together with it, completion of final report

CHAPTER 2

REVIEW OF PHOTOVOLTAIC EMULATOR

2.1 Introduction

This literature review will discuss photovoltaic cells, how these cells generate electricity, and the current-voltage properties of PV cells. The new commercially available I-V tracers will continue to be debated, and why the deficiency of autonomy for current I-V tracers is a concern. Justification will be seen after the selection of capacitor-load method and Cuk topology to trace the I-V curve, and an average approach useful in designing the Cuk will be checked.

2.2 Photovoltaic Cell Review

The p-n junction that experiences the photovoltaic effect is a photovoltaic cell. An atom consists of a nucleus of protons and neutrons and orbiting electrons, according to atomic theory. Such electrons are located around the nucleus in 'chains'. From inside to outside, electrons fill the bands, hence only the outmost band has the chance of being vacant. The Valence Band is termed the outermost band of electrons. Insulators have fairly complete bands of valence, conductors have fairly vacant bands of valence, and someplace in between are semiconductors. Often, electrons in the band of valence may become actively sufficient to move into another band, further away from the nucleus of the atom. The band is known as conduction band. The energy needed for an electron to transition from the valence band to the conduction band is identified as the energy of the band gap. Inside PV cell, if the cell is struck by a photon with enough energy, an electron is removed from the valence band and moves into the conduction band where electricity can be used [7]. This is clarified in Figure 2.1.

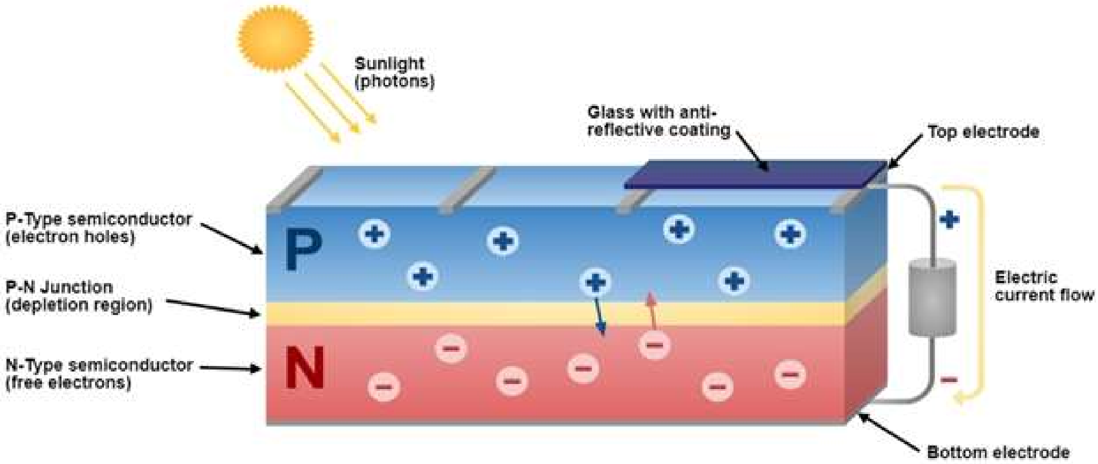

Figure 2.1 Illustration of Photovoltaic Cell (Kiran, 2016)

2.2.1 PV Cell Properties

If any photon does not reach the PV cell, the cell is actually a p-n junction that functions like a diode. A diode is a system which operates when a positive voltage is supplied to the cathode from the anode, if a negative voltage is applied that is not too high, it blocks the current. There are 3 operating areas of a diode [7]:

- Forward Bias: The conducting area of the diode
- Reverse Bias: The blocking area of the diode
- Breakdown: The diode will not block and become conductive if the reverse voltage is too high.

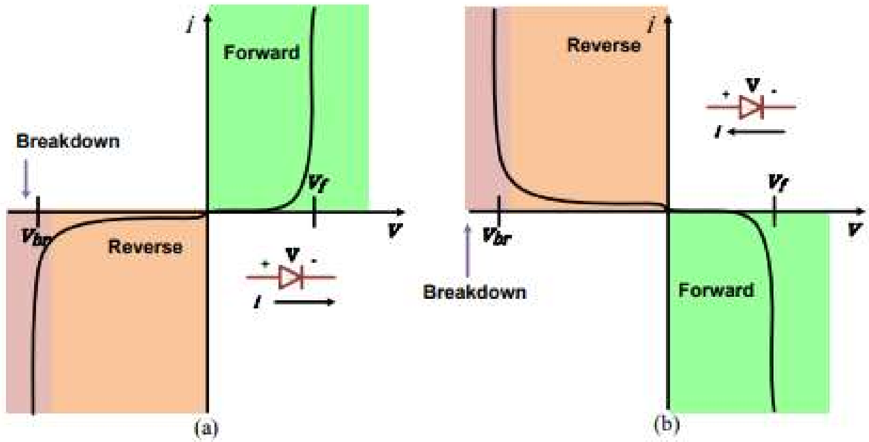

Figure 2.2 (a) I-V Curve of Diode (b) I-V Curve with Current Notation of Diode [27]

The current pact is opposed to that of a diode in a PV cell. This is shows in Figure 2.2 (b) by flipping the curve around the x-axis and noticing the current shift in direction. The I-V curve shifts by moving upward when light strikes the PV cell. The I-V curve of a lightened cell can be considered to be the un-lightened I-V curve moved by the current of the short circuit for simple analysis. A PV cell's I-V curve in lighting is shows in Figure 2.3 with the same current representation as Figure 2.2 (b).

A PV cell's power generation capabilities are restricted by the strength of the incident of solar energy towards the cell. Solar energy originates from the sun. A cosmic entity that emits energy is the sun. The flux of solar energy occurring on the normal and directed surface to the sun's emissions has a mean value of approximately 1350W/m2 at the exterior edge of the atmosphere [7]. Because of the filtering properties of the atmosphere of the earth, this value is attenuated. It can be estimated to be around 1000 W/m2 when the energy hits the earth's ground, but this is reliant on a huge number of variables. At all times, the real irradiance depends on latitude, cloud cover, atmospheric features, and sun position. Nonetheless, the normal irradiance to be used when evaluating PV cells under standard test conditions is specified as 1000W/m2 (STC).

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