Faculty of Electrical Engineering

SHADING ANALYSIS FOR DESIGN OF PV POWER PLANT

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Bachelor in Electrical Engineering (Industrial Power)

2014

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A report submitted

in partial fulfillment of the requirements for the Bachelor in Electrical Engineering

(Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

DECLARATION

I declare that this report entitle "***Shading Analysis for Design of PV Power Plant***" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : ....

Name : VINODH A/L ANNATHURAI

Date : ....

APPROVAL

I hereby declare that I have read through this report entitle "**Shading Analysis for Design of PV Power Plant**" and found that it has complied the partial fulfillment for awarding the Bachelor in Electrical Engineering (Industrial Power)

Signature : ....

Supervisor's Name : DR. GAN CHIN KIM

Date : ....

DEDICATION

Dedicate to my beloved parents and family

ACKNOWLEDGEMENT

First of all, I would like to thank all the good people who have helped me in various ways to complete my Final Year Project.

My utmost gratitude goes to my main project supervisor Dr. Gan Chin Kim for continued patience and guidance, and for incredible expertise that he brings to all phases of the project. I highly appreciate his valuable time in giving me useful ideas to complete this project.

Very special thanks to all my course mates, who have provided insights into both the topic and technical guidance in this compilation. Cooperation between my class members helps me so much. The information that we have exchanged with each other ease the way of my project completion.

I would also like to thank my senior postgraduate students and everyone who have helped me to complete my Final Year Project successfully. Lastly, I am truly grateful for all the hands and hearts that made this project possible. Thank you from the bottom of my heart.

ABSTRACT

PV system is environment friendly which is designed to reduce consumption of electricity from non-renewable energy sources. However, the PV system is exposed to weather conditions causing declination in power generation efficiency. Shading of photovoltaic modules is a widespread phenomenon which affects the performances of the PV system. In accordance to it, this research aims to improve the shading factors which will affect the performances of photovoltaic (PV) system in the solar power plant. Shading of solar cells not only reduces the cell power P_{MPP}, but also changes the open circuit voltage V_{OC}, short circuit current I_{SC}, fill factor and its efficiency. The objective of this research is to design a PV power plant with a low or zero shading factor. This report has classified the shading into two aspects; the distance between buildings to PV power plant and height of the building. The Solar Pro software is used to analyze the shading and identification of the suitable ways to minimize the shading factor. The data obtained from the simulation were compared with the Meteonorm software, journals and experiment for the validity of the data. The findings from this research will give a clear view of the height of the buildings and the exact distance from the PV power plant to achieve zero shading factor. The exact specific distance can be calculated using the multiplier of the height of the building. The multiplier of the height is varied with different size of the PV power plant.

ABSTRAK

Sistem PV adalah mesra alam sekitar yang direka untuk mengurangkan penggunaan tenaga elektrik daripada sumber tenaga yang tidak boleh diperbaharui. Walau bagaimanapun, sistem PV yang terdedah kepada keadaan cuaca yang menyebabkan kemerosotan dalam kecekapan penjanaan kuasa. Teduhan modul fotovoltaic adalah satu fenomena yang meluas yang menjejaskan prestasi sistem PV. Selaras dengan itu, kajian ini bertujuan untuk memperbaiki faktor teduhan yang akan memberi kesan kepada prestasi photovoltaic (PV) sistem di loji janakuasa solar. Teduhan sel solar bukan sahaja mengurangkan kuasa PMPP, tetapi juga menukar voltan litar terbuka Voc, arus litar pintas ISC, Fill faktor dan kecekapannya. Objektif kajian ini adalah untuk mereka bentuk loji janakuasa PV dengan faktor yang rendah atau sifar teduhan. Laporan ini telah mengklasifikasikan teduhan kepada dua aspek; jarak antara bangunan untuk loji janakuasa PV dan ketinggian bangunan. Perisian Pro Solar digunakan untuk menganalisis teduhan dan mengenal pasti cara-cara yang sesuai untuk mengurangkan faktor teduhan itu. Data yang diperolehi daripada simulasi dibandingkan dengan perisian Meteonorm, jurnal dan ujikaji untuk kesahihan data. Penemuan daripada kajian ini akan memberikan gambaran yang jelas tentang ketinggian bangunan dan jarak yang tepat dari loji janakuasa PV untuk mencapai sifar faktor teduhan. Jarak tertentu yang tepat boleh dikira menggunakan penggandaan daripada ketinggian bangunan. Penggandaan ketinggian diubah dengan saiz yang berbeza loji janakuasa PV.

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LIST OF ABBREVIATIONS

AC	Alternating Current
DC	Direct Current
FF	Fill Factor
FKE	Fakulti Kejuruteraan Elektrik
I	Current
kW	KiloWatt
kWh	KiloWatt hour
MPPT	Maximum Power Point Tracking
PR	Performance Ratio
PSH	Peak Sun Hour
PV	Photovoltaic
RE	Renewable Energy
SEDA	Sustainable Energy Development Authority
SPF	Solar Path Finder
UTeM	Universiti Teknikal Malaysia Melaka
V	Voltage

CHAPTER 1

INTRODUCTION

1.1 Research Background

At present, electrical energy plays an important role in our daily life. Most of the electrical energy is produced by fossil fuels and nuclear energy. Since these kinds of energy sources are exhaustible, many countries have started to promote and practice the renewable energy. Among all the renewable energy, solar energy has higher demand than others. The photovoltaic (PV) system is installed to convert the solar energy to electrical energy. However; few main factors influences the performances of the PV system. The shading phenomenon is one of the main problems that decrease the PV performances. This research is carried out to study the analysis of shading effect of the nearby buildings in PV module by using Solar Pro simulation method. These findings will give a clear view for the PV system installer in setting up any solar power plant in Melaka area with the coordinate of 2.2^{o}N, 102.25^{o}E.

1.2 Problem Statement

The main aim of this research is to improve the shading factors which will affect the performances of photovoltaic (PV) system in the solar power plant. The major factor affecting the performance of this PV system is the shading phenomenon. There are several types of shading phenomenon in PV system; the front row PV array shading phenomenon, the height and distance of the surrounding buildings shading phenomenon and the nearby power distribution room and wire pole shading phenomenon. This research is carried out to ensure that the exact height and distance of surrounding buildings of the solar power plant which is free from shading that improves the performance of the PV system. The shading analysis and the system improvement are conducted by the simulation assisted by the Solar Pro software.

1.3 Objectives

The main objectives of this project are;

- To identify the suitable distance between the surrounding building and solar power plant which minimizes the shading factor.
- To verify the suitable height of the surrounding building which results in the zero shading factor.

1.4 Scope of Work

This research focuses on the shading analysis of the surrounding building towards the PV power plant which is situated in the flat ground base. The distance of the surrounding building from the power plant and the height of surrounding building are considered as the shading phenomenon. The main aim of the research is to improve the performance of PV system by minimizing the shading factor. The solar panel is facing towards south and designed in Melaka with the coordinate of 2.2^{o}N, 102.25^{o}E. The house-shape building size is 20m by 20m which is kept constant with the varied height and placed in east and west direction of the power plant. The PV power plant is only designed for the size of 400m^2, 1600m^2, 3600m^2, 6400m^2 and 10000m^2 with the maximum capacity of 16.2kW, 58.32kW, 126.36kW, 233.28kW and 356.40kW respectively. The Solar Pro software is used to simulate the shading analysis process.

1.5. Expected Project Outcome

At the end of the research, findings such as suitable distance of the surrounding building from the solar power plant which results in free shading is to be expected. Moreover, the suitable height of the surrounding building which causes the zero shading factor also is to be determined. Furthermore, the Solar Pro software simulates and produces shading analysis, which helps to improve the performances of the PV power plant is foreseeable.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss the theoretical background of the project. The theoretical background will explore the basic history, analysis of solar shading, and simulation software review, especially Solar Pro and Solar Pathfinder that were used in this project. In the basic principles part the types of shading, the effect of the photovoltaic shading array, influence of shading on the electrical parameters and methods to mitigate the shading problem were explained.

2.2 Theory and the Basic Principles

This part will be discuss the theory and the basic principles of the photovoltaic principles, types of shading, the effect of the photovoltaic shading array, influence of shading on the electrical parameters and methods to mitigate the shading problem.

2.2.1 Photovoltaic System

Photovoltaic is a technology of the solar energy which uses the unique properties of certain semi-conductors to directly convert solar radiation into electricity. A photovoltaic system is an electrical system, consisting of a PV module array and other electrical components needed to convert solar energy into electricity usable loads. The PV system is a distributed system, which generates the small amount of power to the consumers. A utility-connected PV system is the most common system design. Figure 2.1 and Figure 2.2 show the common system of PV configuration and its Grid-Connected system respectively.

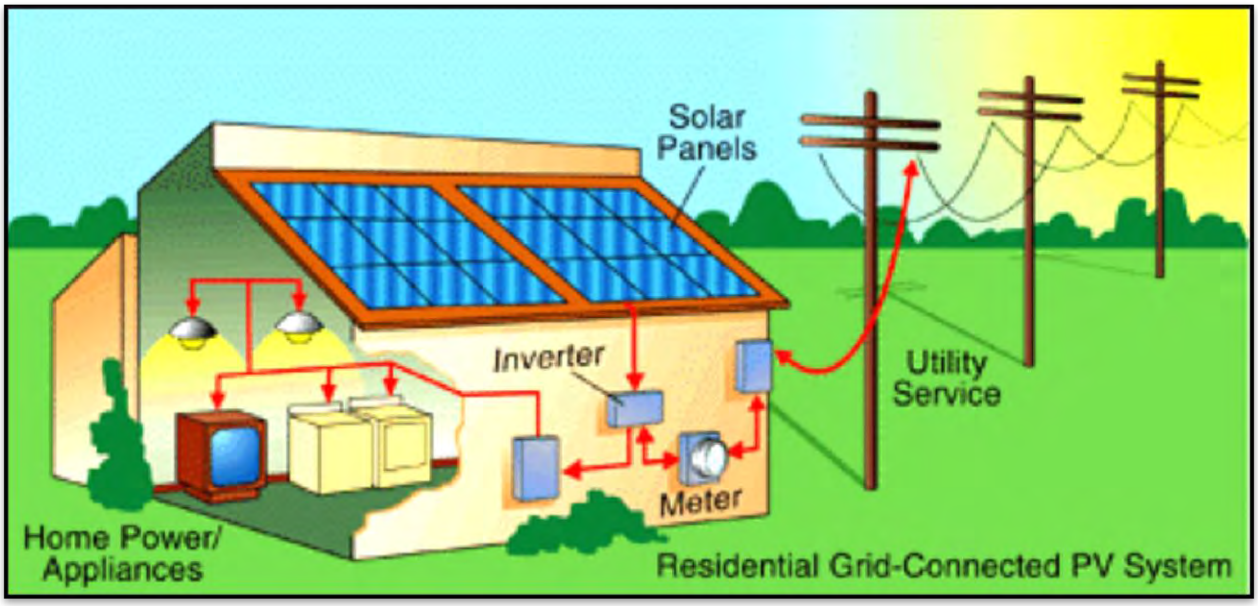

Figure 2.1: A Utility-Connected PV System

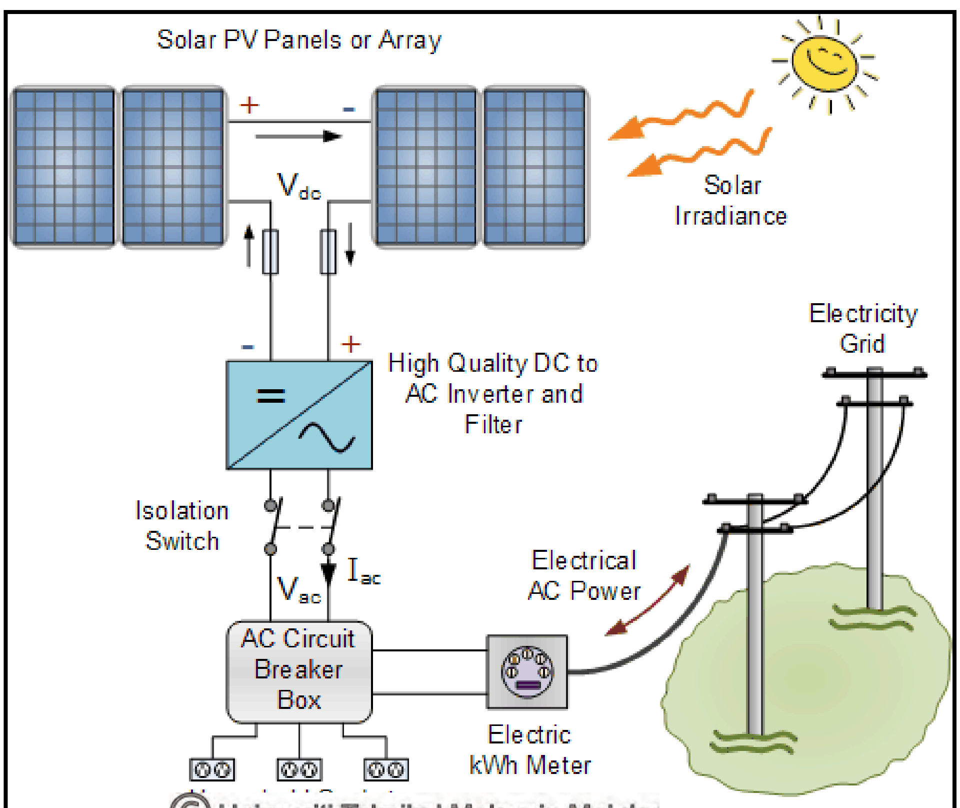

Figure 2.2: The Grid Connected PV System

2.2.2 Types of Shading

There are many factors influencing the performance of this system during the real installations of Photovoltaic (PV) system. Shading is one of the main factors which influence the performance of PV system. There are many types of shading phenomena in a PV system, and it can be divided into the following categories after long time surveys and observation on one large ground-based grid connected PV system [1].

1. The surrounding plant and guano (bird drop) shading phenomenon (Figure 2.3).
2. The front row shading phenomenon (Figure 2.4).
3. The nearby power distribution room and wire pole shading phenomenon (Figure 2.5).

Figure 2.3: The Surrounding Plant and Guano Shading Phenomenon

Figure 2.4: Front Row Shading Phenomenon

Figure 2.5: The Nearby Power Distribution Room and Wire Pole Shading Phenomenon

2.2.3 The Effect of Photovoltaic Shading Array

A PV system comprises of many PV modules that are connected in series and parallel way. If the array layout is irrational or there are shades around the arrays, shading will occur in some modules [1]. In practical condition, a module with shading in a long series will not generate photovoltage, while other modules in the same series still produce voltage normally. So there is current going through this shaded module [2,3].

2.2.4 Influence of Shading on the Electrical Parameters

The shading in the photovoltaic can effect in disproportional high losses in performance. Shaded solar cells are frequently driven in the negative voltage range. The annual loss in a performance in some systems is more than 10% [4]. The influence of cell shading on electrical parameters are the short circuit current I_{sc}, open circuit voltage V_{oc}, fill factor, maximum power point P_{MPP} and efficiency [4,5]. Figure 2.6 is a simple example of the solar system which obtains all the electrical parameters.

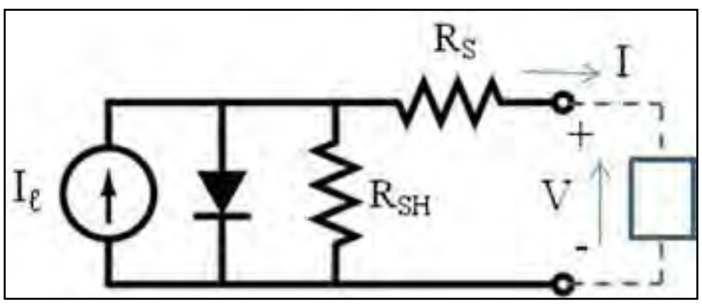

Figure 2.6: Solar system Circuit

i.) 2.2.4.1 Current-Voltage (I-V) Curves

The current-voltage (I-V) characteristic is the basic electrical output profile of PV device. The I-V characteristic represents all possible current-voltage operating point (and power output) for a given PV device (cell, module, or array) at a specified condition of incident solar radiation and cell temperature [4,5]. Figure 2.7 shows an I-V curve, which illustrates the electrical output profile of a PV cell, module or array at a specific operating condition [4,5, 6].

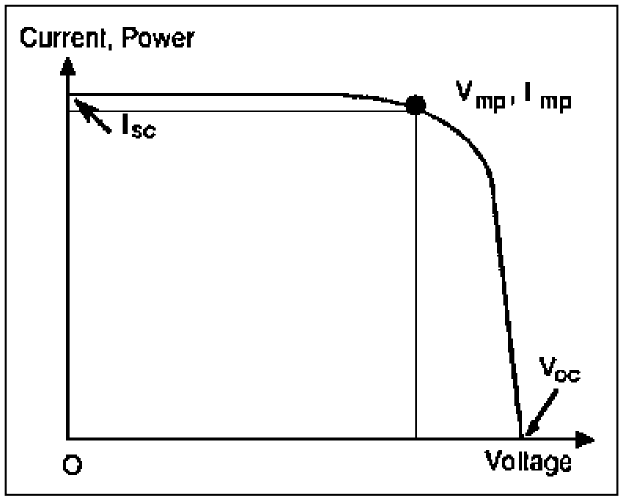

Figure 2.7: An I-V Curve Graph

A PV device can function at any place along its I-V curve, depending on the electrical load. At any specific voltage on an I-V curve there is an associated current, and this operating point is known as an I-V pair.

2.2.4.2 The Basic I-V Curve Parameters.

i.) Open circuit voltage

The open circuit voltage V_{oc} is the maximum voltage on an I-V curve and is the operating point of a PV device under infinite load or open circuit condition, and no current output [4].

$$V(\text{at } I=0) = Voc \qquad (2.1)$$

V_{oc} is also the maximum voltage difference across the cell for a forward-bias sweep in the power quadrant [4-7].

$$V_{OC} = V_{MAX} \text{ for forward-bias power quadrant} \qquad (2.2)$$

ii.) Short circuit current

The short circuit current I_{sc} is the maximum current on an I-V curve and is the operating point of a PV device under no load or short circuit condition, and no voltage output. Since the voltage is zero at the short-circuit current, the power output is also zero. I (at V=0) = I_{sc}. For an ideal solar cell, this maximum current value is the total current generated in the solar cell by photon excitation. $I_{sc} = I_{MAX} = I_{\ell}$ for forward-bias power quadrant [4-7].

iii.) Maximum power point

The operating point at which a PV device produces its maximum power output lies between the open-circuit and short circuit condition, when the device is electrically loaded at some finite resistance [2]. Figure 2.8 shows the voltage and current at this maximum power point which denoted as V_{MP} and I_{MP} respectively [4,6,7].