UTILIZATION OF SOLAR ENERGY IN VERTICAL FARMING

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

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A report submitted
in partial fulfillment 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 “UTILIZATION OF SOLAR ENERGY IN VERTICAL FARMING 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.

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APPROVAL

I hereby declare that I have checked this report entitled “Utilization of Solar Energy in Vertical Farming” 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 : Aimie Nazmin bin Azmi

Date : 05/07/2021

DEDICATIONS

To my beloved Umi and Abah along with my siblings.

ACKNOWLEDGEMENTS

While reviewing this project, I contacted many people to assist me in this study. They have helped me a lot in choosing a title, so I understand my title in various aspects. Also taught me to prepare this Final Year Project report as this is the first time I did my final year project. Many thanks to my supervisor, Dr Aimie Nazmin Bin Azmi who guided me even in a pandemic situation. Also not to be forgotten and the most important ones are my parents, who provided a lot of encouragement and support for both mentally and physically. Apart from them, my comrades-in-arms also helped a lot while they were also busy with their own affairs. Not to be outdone, the supervisor during my internship, Mr Nasrul Fahmi Bin Nasaruddin, a robotic engineer in giving ideas in this project.

ABSTRACT

Towards the future, as the population grows, so does the demand for energy. While the world still relies on conventional energy use, efforts to replace it with solar energy are also appropriate. As conventional energy from non-reusable sources, it will be reduced and depleted in the future. This is also to achieve a healthier and more economical environment by implementing the use of solar energy in generating electricity. Thus, the idea of solar energy and vertical agriculture is a good collaboration to meet the needs of life in the future. Vertical farming is the practice of planting crops vertically suitable to overcome the problem of land shortage due to the increase in population, housing land is also increasing so that land for agriculture is also limited. Therefore, in this project is to expand the use of solar energy instead of conventional energy in producing LED growth light as lighting around 18 hours required for plants to undergo the process of photosynthesis followed by water pump for water irrigation in vertical agricultural systems. Then, from data collection, analyzing how efficient solar energy can be made to see how well solar energy is compared to conventional energy. In conclusion, an examination of this paper will provide the best exposure for the benefits of using renewable energy such as solar energy in agricultural technology.

ABSTRAK

Pada masa akan datang, dalam pertambahan populasi, begitu juga permintaan tenaga. Walaupun, dunia masih bergantung pada penggunaan tenaga konvensional, usaha untuk menggantinya dengan tenaga suria juga seiring. Sebagai tenaga konvensional dari sumber yang tidak dapat diperbaharui, maka sumber itu akan berkurangan dan habis pada masa akan datang. Ini juga untuk mencapai persekitaran yang lebih sihat dan ekonomik dengan melaksanakan penggunaan tenaga suria dalam menjana elektrik. Oleh itu, idea tenaga suria dan pertanian menegak adalah kerjasama yang baik untuk memenuhi keperluan hidup pada masa akan datang. Pertanian menegak adalah amalan menanam tanaman secara menegak sesuai untuk mengatasi masalah kekurangan tanah kerana pertambahan penduduk, tanah perumahan juga meningkat sehingga tanah untuk pertanian juga terbatas. Oleh itu, dalam projek ini adalah untuk memperluaskan penggunaan tenaga suria dan bukannya tenaga konvensional dalam menghasilkan cahaya pertumbuhan LED sebagai pencahayaan sekitar 18 jam yang diperlukan agar tanaman menjalani proses fotosintesis diikuti dengan pam air untuk pengairan air dalam sistem pertanian menegak. Kemudian, dari pengumpulan data, menganalisis seberapa efisien tenaga suria dapat dibuat untuk melihat sejauh mana tenaga suria dibandingkan dengan tenaga konvensional. Kesimpulannya, maka ini kajian akan memberikan pendedahan terbaik untuk faedah menggunakan tenaga boleh diperbaharui seperti tenaga suria dalam teknologi pertanian.

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LIST OF SYMBOLS AND ABBREVIATIONS

kW	-	kilowatt
h	-	hour
NEM	-	Net Energy Metering
GHG	-	Greenhouse gases
PV	-	photovoltaic
CO_2	-	carbon dioxide
kg	-	kilogram
HPS	-	high-pressure sodium
LED	-	light emitting diode
MW	-	Megawatts
Ah	-	Ampere per hour
kWp	-	Kilowatts peak
IoT	-	Internet of Things

LIST OF APPENDICES

Appendix A: Arduino coding.

Appendix B: Arduino Coding connected to PLX-DAQ Excel.

CHAPTER 1

INTRODUCTION

1.1 Overview

In this chapter, will discuss specifically on beginning research for this project. Starting with the motivation on preparing to do this project along with problem statement, objective and scope so the project is guided well along the journey.

1.2 Motivation

As the Sun delivers interminable electromagnetic power (solar energy) so with solar panel it can be captured and converts it into electricity energy. Thereupon, as solar energy is free of cost non-stop universal availability and contributes in reduction of carbon emission after replacing the conventional energy[1]. Solar power has become one of the most feasible solutions to the current global warming crisis as the range of CO_2 emission per kilowatt-h generated are estimated with 0.64~1.63 kg of coal, 0.27~0.91 kg of natural gas, and solar with 0.03~0.09 kg which emission ratio of 18:9.5:1 respectively [2]. As stated that Malaysia potentially to establish solar power plant as it is located at equatorial zone[1] with average annual radiation of 1643 kWh/m^2 [2][3]. Following with Figure 1.1 below shows the solar energy capacity in Malaysia from 2008 until 2017[1]. The capacity increases from 9 MW to 362 MW in 9 years.

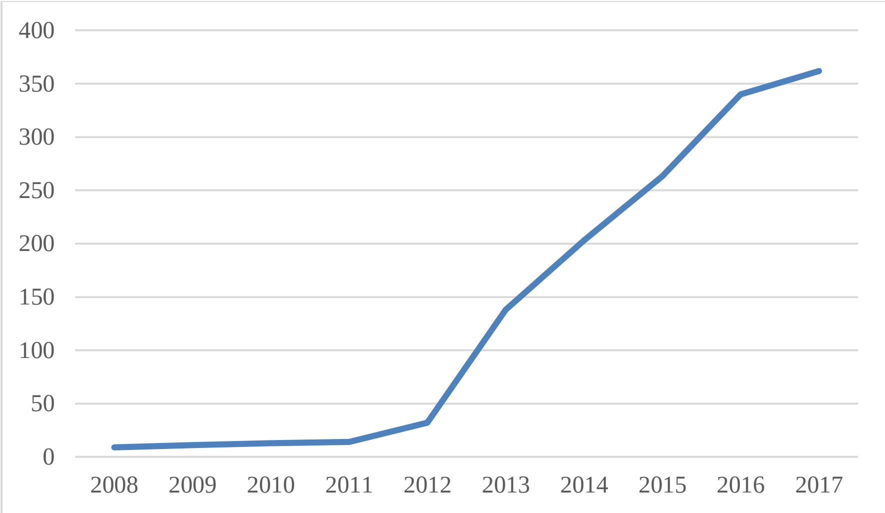

Figure 1-1 Solar energy capacity (MW) in Malaysia from 2008 to 2017[1]

Therefore, the idea of combination between the use of solar energy and vertical farming is a great choice as both are saving the environment. As according to the Department of Statistics (Anon, 2019), Malaysia population increased from 32.4 million in 2018 to 32.6 million in 2019 [4]. Following in Figure 1-2 below shows the population size in Malaysia.

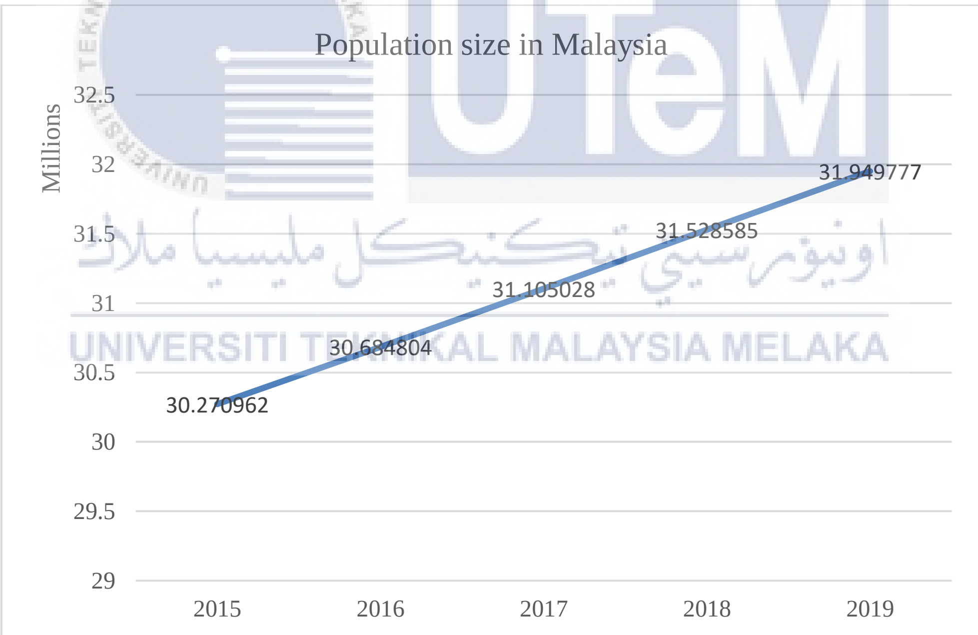

Figure 1-2 Population size in Malaysia

Data source: worldbank.org

As increases in population, the world food production also increases in the next 40 years by 70% [5]. So, the vertical farming is proposed indoor with urban farming technology which estimated that one acre of it is equivalent to 10-20 soil based farmlands[6].

1.3 Problem Statement

Solar energy is defined as energy that is clean, non-polluting, and long-lasting. Malaysia, on the other hand, has hot and humid weather all year, according to the Malaysian Information Department. Malaysia's average daily temperature ranges from 21 to 32 degrees Celsius, however the country's climate is influenced by winds from the Indian Ocean (Southwest Monsoon Winds from May to September) and the South China Sea (Northeast Monsoon Winds from November to March). The annual rainfall ranges from 2000mm to 2500mm, accounting for 80% of the total. This illustrates that it rains most of the time in Malaysia, causing the intensity of illumination to drop at some point. Furthermore, the relevance of vertical farming has not yet been effectively communicated to the general public. As Malaysia's population expands, so does the need for homes, necessitating the use of a huge quantity of land for construction. At the same time, demand for foods such as vegetables and fruits is on the rise. Food production is restricted, however, because much of the land has been used to build dwellings to maintain the current population. As a result, the idea of a new style of planting, known as vertical planting, evolved to meet the needs.

1.4 Objective

These are objectives of this project need to be achieved:

I. To develop a model of vertical farming by utilizing solar energy.
II. To analyze the power consumed by the vertical farming.
III. To compare the usage of solar and conventional energy in vertical farming system.

1.5 Scope

The scope of this project is to construct vertical farming while also utilizing solar energy to power loads such as LED lamps and water pumps. Vertical farming is designed to accommodate the average height of a human being, which is 1.74 meters tall and 0.7 meters wide, so that the crop can be easily examined and damaged equipment can be repaired quickly. Crops are grown in a hydroponic method, which replaces soil cultivation with water. Crops are also limited to kinds that reach about 7 inches in height. Following that, one vertical farming consumes 26.3 W of power, whilst a water pump and three LED lighting consume 2.3 W and 24 W of power, respectively. The project is evaluated in the domestic tariff category and all calculations do not evaluate consider any losses means calculated ideally.

1.6 Report Outline

In this report, there are divided into five chapters specifically. In Chapter 1, the overview of this project is explained in sub-chapter such as for motivation, problem statement, objective, scope and report outline. Followed by Chapter 2 with especially on literature review that has been done after studies and reading of articles and journals regarding to the title of project.

While in Chapter 3, it is exactly for project methodology. Including on how prototype is designed, the calculation of materials and simulation through Arduino and Proteus software. For Chapter 4, is for after experiment of this project are done which the results are collected and discussion are made. Lastly, in Chapter 5 is clearly for the conclusion of this experimental project had been carried along the journey.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter, will be focused on the literature review about Solar Energy in Malaysia from the previous research for the availability the use of solar energy in accordance with the geometric position of Malaysia. Along with types of organic agriculture to be used in vertical farming is reviewed and concluded.

2.2 Solar Energy in Malaysia

Today, the use of solar energy is not a new thing to Malaysia as a developing country. As Malaysia is located at equatorial zone which potential to establish solar power plant[1]. Solar energy exhibits and possesses the best potential among all renewable resources (e.g. hydro, wind, biomass, geothermal and marine) and also known as "Mother of Renewable Energy Source" on account of free cost of non-stop universal availability with free pollution delivery and contrasting to be affected by any natural disaster[1][7]. Even though, other renewable alternatives availability are much more cost-effective such as geothermal sources, unfortunately, they are limited to a few locations with the supply of biomass is not available everywhere[7].

As mentioned in [1], Malaysia received daily average solar radiation about 4500 kWh/m^2 with abundant sunshine for about 10 to 12 hours a day [1][2]. In terms of solar irradiation where the radiation is falling on the surface of the panel, which is Malaysia received daily average solar irradiation for about 4.21 kWh/m^2 to 5.56 kWh/m^2 resulting in average of 1643 kWh/m^2 every year from the annual solar insolation ranges starting with 400 kWh/m^2 to 1900 kWh/m^2 [2][3]. The utilization of solar energy is promoted to help Malaysia to achieve in lowering the carbon intensity to 35% for its long-term goals by 2030 [8]. This initiative is empowered by the government which the 11th Malaysian Plan implemented to develop successful renewable energy. For examples of the government agencies such as PETRONAS, Tenaga Nasional Berhad (TNB), Sustainable Energy

Development Authority Malaysia (SEDA) and Malaysia Energy Centre (PTM) which are playing a very crucial role in setting the importance in the nation's energy development. In planning for future, Tenaga Nasional Berhad (TNB) will build the biggest solar plant on 98 ha site in Malaysia [1]. Along with the effort of the government to decrease by 25% of buildings electricity consumption with the help of Sustainable Energy Development Authority Malaysia (SEDA) in implementing net energy metering (NEM) to generate 450 MW of electricity by 2020 using solar PV in Peninsular Malaysia [8].

Solar energy is clean energy because it does not produce carbon and nitrogen as it does in conventional energy production. The conventional energy is from power plants which especially fossil-fuels are a source of greenhouse gases (GHG) significantly which are responsible for round about 25% of all anthropogenic emissions which may lead to causing health problem like heart attacks and breathing problem [7]. However, there are limitations in most domestic solar panel which is the efficiency still below 20% as the shortcoming of solar technology or else in order to get more than 20% efficiency of solar panels at higher prices which costing more after the high cost of installation. Nevertheless, solar energy promising low costs of operation which relatively stable for over long periods unlike the conventional energy which prone to substantial price swings.

2.3 Solar Energy Parameters

In ideal solar cells where a current source is connected parallely with a diode with resistors that represent the losses and sometimes with additional diode that takes into account other phenomena[9]. In Figure 2-1 below shows the equivalent circuit of the solar panel, instructed as mentioned earlier with two resistors connected in parallel and series, each of it.

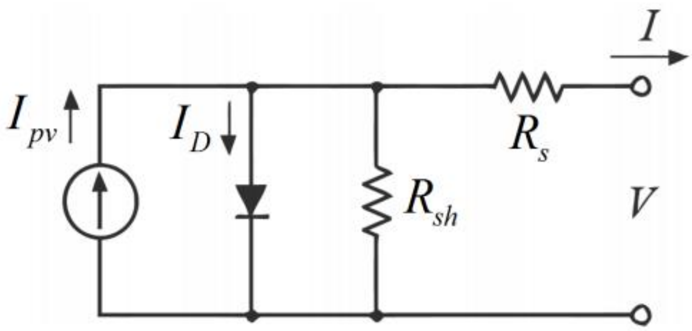

Figure 2-1: Equivalent circuit of solar panel.

The I_{pv} represents the photocurrent of the cell delivered from the constant current source. I_D represents the reverse PV saturation current corresponding to the diode followed by R_{sh} that connected in parallel with the I_{pv} and I_D, while R_s that connected in series in the circuit. Both resistors can be neglected to simplify the analysis as the value of R_{sh} is very large and for R_s is too small.

Then, the mathematical model of PV panel as shows below.

For photocurrent, I_{PV}

$$I_{PV} = [I_{SCr} + K_i\,(T - T_r)] * \frac{S}{1000} \qquad 2.1$$

For reverse saturation current, I_D

$$I_D = {I_{SCr}}/{\left[\exp\left(\frac{qV_{OC}}{NskAT}\right) - 1\right]} \qquad 2.2$$

For saturation current, I_S

$$I_S = I_D[{T}/{T_r}]^3 \exp\left[\frac{qEg}{Ak\left(\frac{1}{T_r} - \frac{1}{T}\right)}\right] \qquad 2.3$$

For output current, I_O

$$I_O = N_p * I_{PV} - N_p * I_{PV}\left[\exp\left\{\frac{q * V_{PV} + I_{PV}R_S}{NskAT}\right\} - 1\right] \qquad 2.4$$

Where value of $V_{PV} = V_{OC}$, N_P and N_S are provided from manufacturer's datasheet.

In order to achieve I-V curve, parameters of solar energy such as maximum power (P_{max}), voltage at maximum power (V_{mp}), current at maximum power (I_{mp}), open circuit voltage (V_{OC}), short circuit current (I_{SC}) are important to have so that panel efficiency can be reached. Thus, as Figure 2-2 shown below,

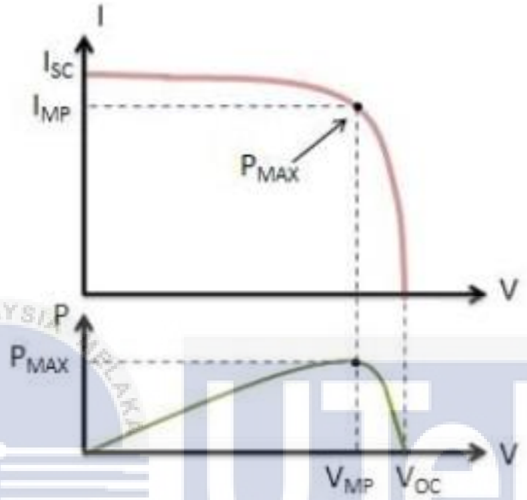

Figure 2-2: I-V and P-V curve of solar energy.

Besides, it is important that these parameters are derived under Standard Test Conditions (STC) which are the temperature is at 25˚C with solar radiation at 1000 W/m^2 along with atmospheric density, AM1.5. The maximum power, P_{max} represents the highest output power of solar panel under STC and measured in Watts. It is derived from multiplication of the current and the voltage at certain point, then as the higher the value of P_{max} can be achieved, the powerful a solar panel can be performed. Therefore, the voltage that generated by the solar is the voltage at maximum power, V_{mp} when it is connected to a charge controller or an inverter under STC. Followed by, the current, I_{mp} that generated along with the voltage by the solar is the actual amperage that connected to solar equipment.

2.4 Vertical Farming

The migration of the population and concentrated in urban are led from the process of urbanization as estimated about 1.7 billion people chose to live in urban areas, generally the population of the cities in the world have increased by 500,000 with an average annual increase at 2.4% (2000-2018), which is equal to one million people in every city around the world and expected to grow until 2030[4]. As for that, the agenda of food security has prevailed to be a global concern, with world food production would need to increase by 70% speculated in the next 40 years to meet the population of exceeding 9.1 billion by 2050 demands [5].

Vertical farming is an indoor plants system that the crops stack vertically [10] and promises to eliminate external natural processes and the need for fossil fuels to run machinery during the different stages of farming such as plowing, seeding, weeding and harvesting [6]. As the crops will be grown under careful in ensuring an optimal growth rate of the plants year-round. In this vertical farming system, hydroponic, a system of cultivation technology that applies nutrient solutions without the soil substrates from hydroponic system, it offers the ability to reuse water and nutrients which ease of environmental variability control, higher production yield and soil-borne diseases and pests [5]. Furthermore, vertical farming can run without pesticides to prevent pests and diseases resulting good quality organic plants production. Also, in vertical farming, a small root system is optimal as it allows the plant to invest more in shoot biomass which optimal O_2 levels and root zone temperatures help to optimize water and nutrient uptake [10]. On account of limited access to land for farming, in order to pave the way for adding to food needs, the vertical farming can help to control it. In order to manage the production line, either the vertical farm is planned to be totally using artificial light or both artificial and natural lights should be taken seriously. To enhance the growth of vegetation which is contingent where the range of light intensity is needed. There are two options available which are LED (light emitting diode) and HPS (high-pressure sodium). The indoor plant light required 18 hours a day[11].