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# PV DC MICROGRID DESIGN FOR APPLICATIONS ON REMOTE AREAS


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# PV DC MICROGRID DESIGN FOR APPLICATIONS ON REMOTE AREAS

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**This Progress Report is submitted to Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka in partial fulfillment for Bachelors of Electrical Engineering**

**Faculty of Electrical Engineering**
**Universiti Teknikal Malaysia Melaka**
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# DECLARATION

"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references"

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# APPROVAL

"I hereby declared that I have read through this progress report entitled 'PV DC Microgrid Design For Applications On Remote Areas"

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| Supervisor's Signature | : …………………………………….. |
| Supervisor's Name | : …………………………………….. |
| Date | : …………………………………….. |

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# ABSTRACT

In this report, a microgrid distribution system was studied. This microgrid provides power in the form of direct current (DC) and uses a renewable energy source as its generation. The renewable energy source implemented is the solar power harvested by photovoltaic panels. This project proposes a DC microgrid that is suitable to be used in rural areas, since most rural areas do not have their own source of electricity. The problem with using a standard microgrid is that it has an inverter embedded into the system, which could cause unnecessary power loss. As scope of this project, the designed DC microgrid can only supply power for common household loads and it provides power directly into DC form without the use of an inverter. The calculation method used in this project is to determine the parameters of the needed components for the microgrid to provide stable and reliable power within the boundaries of the design.

# ABSTRAK

Dalam laporan ini, sistem pengedaran kuasa mikrogrid dikaji dengan lebih mendalam. Mikrogrid ini memberikan kuasa dalam bentuk "direct current" (DC) dan menggunakan sumber tenaga boleh diperbaharui sebagai penjanaannya. Sumber tenaga boleh diperbaharui yang dilaksanakan adalah tenaga solar yang dituai oleh panel fotovoltaik. Projek ini mencadangkan mikrogrid DC yang sesuai untuk digunakan di kawasan luar bandar, kerana kebanyakan kawasan luar bandar tidak mempunyai sumber elektrik sendiri. Masalah dengan menggunakan mikrogrid standard ialah ia mempunyai "inverter" yang dimasukkan ke dalam sistem, yang boleh menyebabkan kehilangan kuasa yang boleh dielakkan. Sebagai skop projek ini, mikrogrid DC yang direka hanya boleh membekalkan kuasa untuk beban isi rumah yang biasa dan ia memberikan kuasa terus ke bentuk DC tanpa menggunakan penyongsang. Kaedah pengiraan yang digunakan dalam projek ini adalah untuk menentukan parameter komponen yang diperlukan untuk microgrid untuk menyediakan kuasa yang stabil dan boleh dipercayai dalam sempadan reka bentuk.

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| | | |
|---|---|---|
| DC | - | Direct Current |
| AC | - | Alternating Current |
| PV | - | Photovoltaic |
| IEA | - | International Energy Agency |
| DER | - | Distributed Energy Resource |
| LV | - | Low Voltage |
| HOMER | - | Hybrid Optimization Model for Electric Renewable |
| PMU | - | Power Management Unit |

# CHAPTER 1

# INTRODUCTION

## 1.1 Overview

Electricity is a very important commodity to have in a world where technological advancements are rapidly growing. But not everyone currently has access to electricity. Without access to electricity, these people will also not have access to current news of the outside world which includes the advancements in technology that are being discovered on a daily basis.

According to the International Energy Agency (IEA), the number of people that does not have access to electricity in 2016 is 1.1 billion people ~ which is about 14.47% of the total world population. Although there is decrease since 2014, which is about 1.3 billion people ~ 17.1% of the world population without electricity, that is still a large number of people that does not have access to the development of the rest of the world. This can cause some adverse effects on the education and economical aspects of a country [11].

While there are no official reports saying how many people in Malaysia currently do not have access to electricity, the news site "FMT News" reports that 36% of the rural populace in Malaysia still does not have access to electricity. That is 36% of 31 million people without access to electricity. Imagine the possibility if that amount of people had electrical access, that would no doubt cause a staggering level of knowledge increase in Malaysia's population alone [12].

Providing electricity to rural areas are also not cost effective since the nearest power plant could probably be located at quite a distance away. This makes the grid installation cost to be high. Grid operators would also face disadvantageous factors if they were to connect these rural areas with electricity such as very high transmission losses and unreliable electricity supply to the users. To generate electricity, they would need a power plant close enough to their location in the rural regions. Most power plants run on fossil fuels, which could cause negative effects on the people and the environment.

With the cost of solar panels being quite cheap since the past few years, it presents a new viable option rather than the grid connected electricity. Recent field studies showed that an exclusively dc photovoltaic-powered system that has its own distributed storage increases the efficiency of the system while reducing the cost [1], [2].

It is best to design the solar photovoltaic system to deliver electrical power in dc form since most of the loads in a common household nowadays uses dc power. Since remote areas are usually  small, there would be no need to convert the dc power generated by the photovoltaic panels to ac, then converting it back to dc for the end user because this can create more unnecessary losses [3].

## 1.2 Problem Statement

A microgrid does not depend on electricity from the main/national grid. It contains certain characteristics of a main grid such as generation and distribution. But it does all of these within a small area. Most microgrids are installed with an inverter to support loads that will eventually revert back to DC. But this could lead the system to have unneeded power loss that can be prevented.

The design of this microgrid will be influenced by a few factors. These factors are the reliability of the microgrid system to generate electricity, the physical design of the system and the cost for producing said system. In this project, a solar photovoltaic microgrid is designed to generate, transmit and distribute power in DC form. Taking into factor that this design will be used in remote areas where there is likely to be no electricity, it needs to be a reliable system to produce and maintain power for usage. The physical design needs to be simple but also durable to operate in rural conditions. Lastly, it should also be as inexpensive as possible so that it can be afforded.

## 1.2 Objective

Based on the problem statement, this project aims to build a solar photovoltaic microgrid that is able to generate electricity that can power DC loads directly without the use of inverters. This dc microgrid can be used in rural or remote areas without depending on the main grid network. The microgrid network should also be as simple as it can in terms of construction so that the maintenance cost could be lowered. The main objectives can be summarized as : -

1. Determine the parameters of a dc microgrid through calculation.
2. Build a dc microgrid fit to operate in remote areas.
3. Run the system to determine its power output and performance.

In order for the microgrid to properly operate during emergency conditions, it should be able to provide power without any disturbances. The key factor for the microgrid to be able to maintain power is in the design of the system itself. Thus, the design calculation is a very prominent factor for the microgrid system.

Although this project aims to provide electrical power for remote areas, it can also prove to be useful in emergency conditions such as during natural disasters. Therefore, secondary objectives are set. The microgrid system should be able to provide electricity for important appliances during emergency conditions. Such appliances are electrical fans, lighting, charging ports and radios.

Taking into consideration that this system would be used in emergency conditions, the design factors that should be taken as secondary objectives are that the system should be robust in its construction and the total weight of the whole system should be an amount that is possible for people to carry around.

## 1.3 Project Scope

The scope of this project is to make a solar photovoltaic microgrid specifically designed to generate power to run DC loads. The loads will be small and likely to be for everyday use such as televisions and fans. This project will have limitations in that it will not supply power for bigger loads and that it will not use an inverter to transmit the power. This is because the system will provide power only for critical/important loads and that it will only transmit power over very short distances, thus the transmission losses are negligible.

# CHAPTER 2

# LITERATURE REVIEW

In this section of the report, the project title will briefly be discussed, which is "Photovoltaic DC microgrid". There will be three parts in this chapter. The first part will discuss about the solar photovoltaic panel, which includes it's working principle, the construction of the panel and the different types of panels. The second part will discuss about the microgrid itself, each type of microgrids and advantages and disadvantages of each. The third part delves into the previous work done on the DC microgrid and how each of them achieve the objectives that they set.

## 2.1 The Solar Photovoltaic Panel

The word 'photovoltaic' is actually a term that describes the conversion of light into electricity by using semiconducting materials that shows the characteristics of the 'photovoltaic effect'. A solar panel essentially uses this property to generate electrical power by converting the light energy from the sun. This method of generating electrical power is very advantageous since it does not create any type of pollution nor does it create any greenhouse emission effects. It is also advantageous that the material needed to make these panels are quite abundant in the Earth's crust, which is silicon.

Though the solar panel is not in any sense a perfect power generator. It has quite a number of disadvantages. Solar panels depend solely on the presence of the sun, even it's direction. A solar panel that is installed in a static position will not have the same output as a solar panel that has a sun tracking system in it. This is because solar panels require direct sunlight to produce the optimum rated power set by the manufacturers. Other things in the atmosphere such as the clouds, dust and impurities will also reduce the power output[4].

Solar panels produce electrical power in DC form. This makes it easy for applications such as charging a battery. Solar panels had first been used to generate power for satellites orbiting the earth. Then as market demand for renewable energy increases, they start to incorporate this technology for commercial use.

### 2.1.1 The Construction

A solar panel is actually made up of a few solar cells being connected in series. Each of these cells consists of two layers of doped silicon, one being the n-type and the other is the p-type. These two layers are set to be in contact to create a junction, where each layer having an electrical connection [9]. Each of these cells are capable to produce voltages of up to 0.7 volt, while providing maximum power at 0.4 volt.

The solar panel or module is made up of a few of these cells to increase the output. If a manufacturer would want to make a panel to have a nominal voltage of 36 volts, the panel will have to have 90 cells within the panel.

$$Number\ of\ cells\ in\ a\ panel = 0.4 \times 90 = 36\ \text{V} \tag{2.1}$$

The construction of the solar panel will usually make sure that it is protected from the weather. The solar cells are placed on a hard backing plate, while the electrical connections are above and below the cells. The positive connection of one cell will be connected to the negative connection of another cell to create series connection. On top of these cells will be a non-reflective coat so as to increase the absorption of light. The final top layer will be a piece of durable glass, then the whole construction will be encased in an aluminum frame to make it protected from weather conditions.

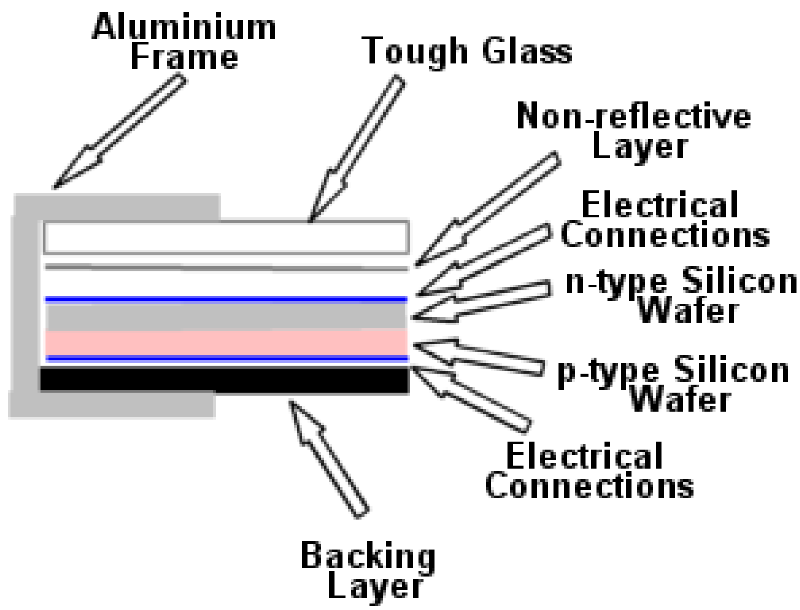


Figure 2.1 : Illustration of solar panel construction

### 2.1.2 Types Of Solar Panels

With the increase of commercial use of solar panels, there is also the varying types of solar panels in the market. With almost 90% of the worlds solar panels are made with some form of silicon, manufacturers try to take this as an advantage to make more types of solar panels based on the purity of the silicon[10].

The purity of silicon is the main factor of the efficiency of a solar panel. The alignment of the silicon molecules will show how good it is in converting sunlight into electrical energy. If the solar molecules are more perfectly aligned, then the better the solar panel will be in converting sunlight into electrical energy. The same applies for the inverse of the alignment of the solar molecules.

It might sound easy to just make a solar panel to have perfect alignment of silicon molecules, but the key factor is cost. Since the process of enhancing the purity of silicon are quite expensive. Most customers would focus on the total cost of installing a PV system and the space that is required for such installation.

There are basically three main types of solar panels available in the market today and probably a few new types that are currently being researched upon. The three main types are the Monocrystalline silicon solar cells, Polycrystalline silicon solar cells and the Thin-Film solar panels.

### 2.1.2.1 Monocrystalline Silicon Solar Cell

Monocrystalline silicon (mono-Si) cells, also known as single-crystalline silicon (single-crystal-Si) can be easily distinguished by the uniform look of the panel, which indicates a high concentration of pure silicon. Cylindrical shaped silicon ingots are used to make monocrystalline solar cells. To increase the performance and decrease the cost for each monocrystalline cell, four sides of the silicon ingot are cut out to make thin wafers. This gives the monocrystalline solar cells its distinctive look. It is an easy way to differentiate between monocrystalline and polycrystalline cells, since polycrystalline cells does not have the rounded edges like the monocrystalline.

In terms of advantage, the monocrystalline solar cells are rated to have the highest efficiency because they are made out of the purest silicon. Since they are the most efficient, they are also very space-efficient. It would take only one monocrystalline solar panel to produce the same amount of electricity as four thin-film solar panels. On top of all these, it also has the longest life time out of the other types of solar panels.

But with all it's advantages, it comes to the user whether to choose the monocrystalline solar panel or not, since it is the most expensive out of all the other types of solar panels. Another significant disadvantage of the monocrystalline panel is that if a part of the panel is covered in shade, there is a possibility that the entire circuit will break down. The monocrystalline solar panels efficiency depends on the weather temperature. If the temperature goes too high, the performance of the panel will noticeably be lower. This is because this type of panel is more efficient in warm weather.