SYSTEM DESIGN AND ANALYSIS FOR RURAL SOLAR PV APPLICATION

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DECLARATION

I hereby declare that the material in this dissertation is my own except for quotations, equations, summaries, and references, which have been acknowledge accordingly to the main resource.

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VERIFICATION

Signature

SUPERVISOR

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ABSTRACT

Energy poverty and a lack of power in rural areas increase poverty in emerging countries. In Sabah, most of the rural area are not connected to the national electrical grid due to not practicable nor cost-effective to expand the grid to serve a tiny town across difficult terrain and dense jungle. Due to high distribution costs and transmission losses, grid energy delivery in rural areas is not economically viable. In these cases, engine generators are frequently employed as the primary option for lighting this area. In fact, this strategy has limitations such as high fuel and maintenance costs. The most effective and efficient option is to generate power from renewable energy resources sustainably. The high potential of solar energy signifies the preference for generating off-grid electricity in Sabah rural areas. A standalone SPV system is believed to be cost-effective than diesel/petrol generator to increase socio-economic advancement for remote communities.

ABSTRAK

Kemiskinan tenaga dan kekurangan kuasa di kawasan luar bandar meningkatkan kemiskinan di negara sedang membangun. Di Sabah, kebanyakan kawasan luar bandar tidak disambungkan ke grid elektrik negara kerana tidak praktikal dan tidak menjimatkan kos untuk mengembangkan grid untuk memberi perkhidmatan kepada sebuah bandar kecil merentasi rupa bumi yang sukar dan hutan tebal. Disebabkan oleh kos pengedaran yang tinggi dan kerugian penghantaran, penghantaran tenaga grid di kawasan luar bandar tidak berdaya maju dari segi ekonomi. Dalam kes ini, penjana enjin sering digunakan sebagai pilihan utama untuk menyalakan kawasan ini. Malah, strategi ini mempunyai batasan seperti kos bahan api dan penyelenggaraan yang tinggi. Pilihan yang paling berkesan dan cekap ialah menjana kuasa daripada sumber tenaga boleh diperbaharui secara mampan. Potensi tenaga suria yang tinggi menandakan keutamaan untuk menjana elektrik luar grid di kawasan luar bandar Sabah. Sistem SPV kendiri dipercayai kos efektif daripada penjana diesel/petrol untuk meningkatkan kemajuan sosio-ekonomi bagi komuniti terpencil.

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LIST OF ABBREVIATIONS

AC- Alternate Current

DC- Direct Current

BOS- Balanced of System

ROI- Return of Investment

CHAPTER 1

INTRODUCTION

Energy use has become a big concern as a result of the significant increase in energy demand in recent decades. Solar energy is largely regarded as the most promising answer for addressing future electricity needs. The cost of power produced by a PV system has dropped significantly. PV energy, on the other hand, is still more expensive than electricity from your power utility. Furthermore, the initial cost of PV is still higher than an engine generator (Khatib, 2010).

Energy poverty and a lack of power in rural areas increase poverty in emerging countries. Electrification of remote rural areas that are not connected to the national electrical grid is a key issue for developing countries like Malaysia. According to World Bank data, access to electricity in Malaysia has increased greatly over the last two decades, with over 100% of the population (urban and rural) having access by 2012(The World Bank Group, 2014). Rural electrification has lately followed a similar pattern. According to the data, the target is to power up rural areas, which represent for 22.84 % of total population (The World Bank, 2016).

In general, two characteristics distinguish Peninsular Malaysia from East Malaysia: the number of people living in rural areas and the amount of electrification. According to current data, 99.7% of population in Peninsular Malaysia have access to electricity, but electrification in Borneo (Sabah and Sarawak) is lower than in Peninsular Malaysia (Borhanazad et al., 2013). In fact, remote rural areas are the places where energy is limited. It is not practicable nor cost-effective to expand the grid to serve a tiny town across difficult terrain and dense jungle. Due to high distribution costs and transmission losses, grid energy delivery in rural areas is not economically viable. In these cases, engine generators are frequently employed as the primary option for lighting these regions, despite the fact that this strategy has limitations such as high fuel and maintenance costs. In addition, fuel costs fluctuate based on oil prices, therefore the cost of operating an engine generator is unpredictably expensive. In terms of environmental effect, a large amount of harmful gases emitted by engine generators, it is necessary to investigate alternate energy and ecologically acceptable sources in terms of cost and other constraints.

Figure 1.1: Diesel Generator in Peladang Sandakan

As a result, the most effective and efficient option is to generate power from renewable energy resources sustainably. On this note therefore, the goal of this study is to look at the possibility of utilising solar energy through off-grid solar photovoltaic (SPV) systems for electricity generation in rural area of Sabah along with the technical and economic analyses. The high potential of solar energy signifies the best preference for generating off-grid electricity in Sabah rural areas, Malaysia. A standalone SPV system is believed to be more cost-effective than grid connectivity for increased socio-economic advancement in such isolated regions (Valer et al., 2017). The SPV system is advantageous for rural electrification because of its flexibility, enhanced efficiency, portability, simplicity, improved standardisation, cost reduction, decreased hazardous emissions, and increased fuel security.

1.1 Problem Statement

Sabah has unique geographical location and landscape, such as steep hills and rivers. Connecting the rural areas in Sabah with power grid would be deemed economically and technically challenging. It is very challenging to getting access to rural locations, most villages were reached after a half-day ride in a four-wheel-drive pickup truck from the nearest town. Moreover, engine generators are commonly used as the primary source to generate electricity. It is not a good strategy due to high fuel consumption and maintenance cost. Also, it gives bad impact to environment because a lot of harmful gases emitted from the engine generators. In this case, the introduction of sustainable energy presents an opportunity to offer a large number of people with a better source of energy leading to better quality of life while minimizing the impact of global warming that is caused by non-renewable energy resources. An off-grid Solar PV energy could be one of the feasible means of providing electricity to the isolated communities.

1.2 Research Objectives

The objectives of the project are:

a) To identify the load power consumed by rural villagers through site assessment in various location in Sabah
b) To analyse and design ideal capacity requirement of solar system through load requirement and solar system design.

c) To install and evaluate solar power system in rural areas and optimize the system design through data assessment of production capacity.

1.3 Scope of Works

In this project, the following scope of work is planned in order to achieve the objectives and complete the project which is to design system and analysis of PV solar system for rural application.

i. Carry out the literature review on the existing and past research related to a PV solar system for rural application from multiple sources including journals, article, and books.
ii. Study the essential requirement and consideration on designing PV solar system including sizing, material, and functionality.
iii. Provide some common solar PV questions and travels to remote locations to conduct a solar PV system survey.
iv. Design a PV solar system that produces enough supply to fulfil demand while maintaining a cheap price.
v. Construct the solar PV system according to sizing of the system.
vi. Optimize the solar PV system to optimum performance.
vii. Carry out analysis on the power generated from solar panel and load consumption.
viii. Carry out documentation of the project progress and data.

1.4 Research Gantt chart

SEMESTER 1 (2021/2022)

No.	Item		Week												
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	First Project Briefing														

2	Project Proposal														
3	Proposal moderation														
4	Literature review														
5	Proposed site of location														
6	Characterize electrical appliances														
7	Progress report preparation														
8	Submission of project report														
9	Presentation Report														

SEMESTER 2 (2021/2022)

No.	Item		Week												
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Design system														
2	installation														
3	System optimization														
4	System analysis and														

	data collection														
5	Thesis														
6	Thesis submission														
7	Presentation														

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Malaysia is situated in Southeast Asia and mainly consists of Peninsular Malaysia, Sabah and Sarawak. The largest ocean around Malaysia is the South China Sea. Malaysia is a hot and humid country with a latitude of 3.164 north and a longitude of 101.7 east, can be considered totally equatorial. The average daily solar radiation is about 4500Wh/m^2 and the ambient temperature ranges from 27 °C to 33 °C (Borhanazad et al., 2013). Due to the availability of solar radiation averaging 4.8–6.1 kW h/m2 /day, Malaysia has a good solar energy potential (Halabi et al., 2017).

Authors in (Izadyar et al., 2016), remarked that solar energy system resources have huge potential in the generation of electricity. As a result, they concluded that installing a solar energy system in Malaysia is highly feasible. Furthermore, PV solar energy applications are the most efficient technique to collect the sun's energy, and their use will reduce fossil fuel consumption (Jayaraman et al., 2017). According to recent study (Prestasi et al., 2018), Peninsular Malaysia's power plants in 2018 were made up of 47% gas power plants, 38% coal power plants, 9% hydroelectric power plants, and 1% diesel power plants.. RE and industrial waste heat account for the remaining 5%. Small hydro and large scale solar (LSS) are two further types of renewable energy. Natural gas was utilized in 64 % of the power plants in Sabah, followed by diesel 15%, RE and others 17%, and hydro 4%. In Sarawak, hydro accounted for 67.9% of total installed capacity, natural gas for 19.4%, coal for 9.4%, diesel/MFO for 2.4%, renewable energy for 0.8%, and other fuels made up the remainder. Details of power plant generation are shown in the following charts:

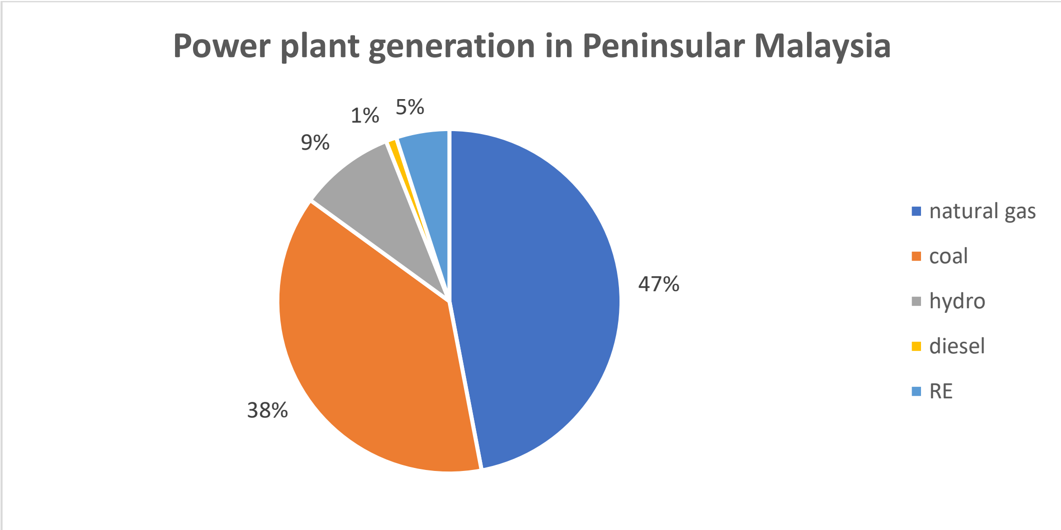

Figure 2.1 : Power plant generation in Peninsular Malaysia

Source : Performance and Statistical information on the Malaysian Electricity Supply Industry 2018 (Prestasi et al., 2018)

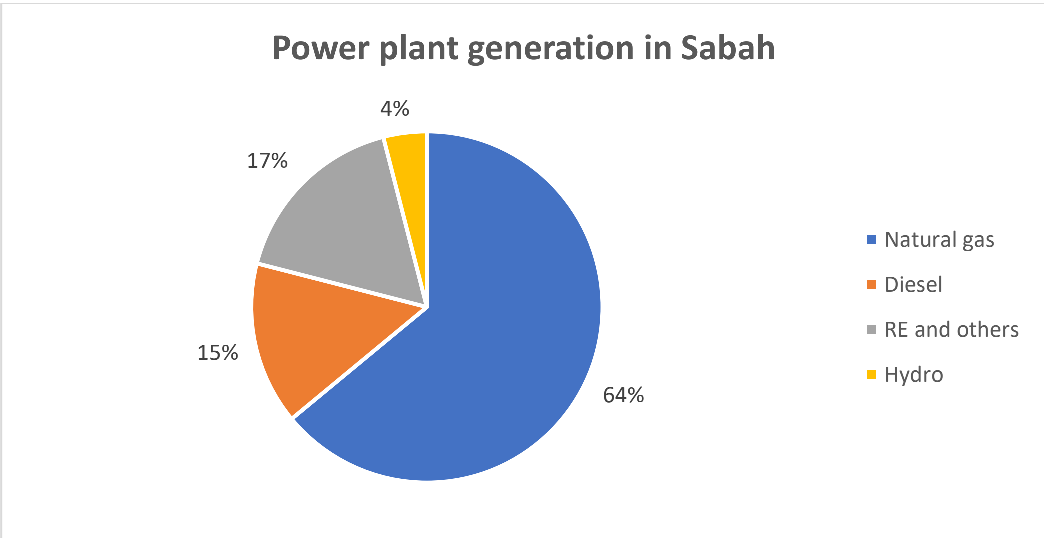

Figure 2.2 : Power plant generation in Sabah

Source : Performance and Statistical information on the Malaysian Electricity Supply Industry 2018 (Prestasi et al., 2018)

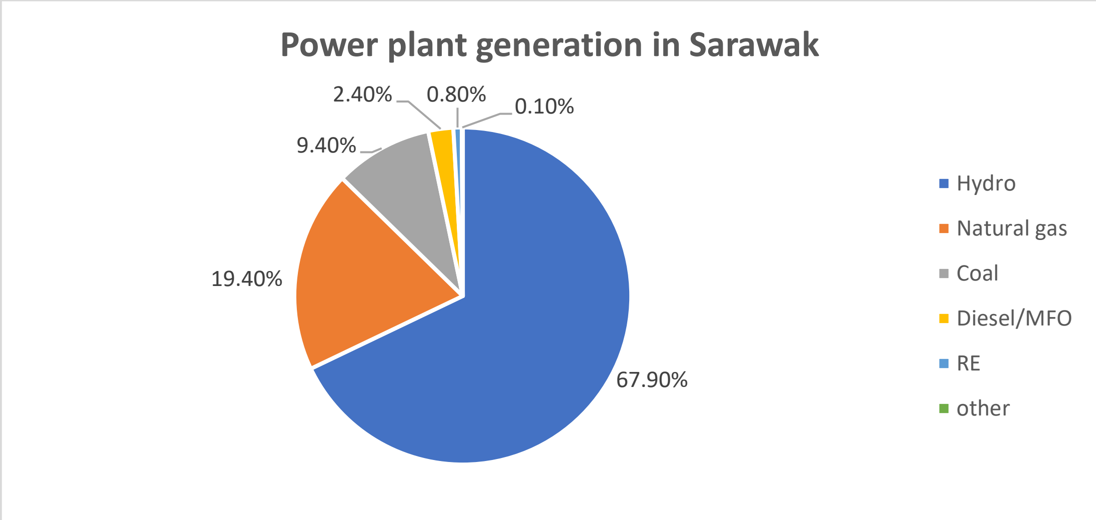

Figure 2.3 : Power plant generation in Sarawak

Source : Performance and Statistical information on the Malaysian Electricity Supply Industry 2018 (Prestasi et al., 2018)

2.2 Photovoltaic Cell

Swiss scientists invented a warm trap, which was a small-scale greenhouse, in the 18th century. He created a hot box by sandwiching a glass box between two bigger glass boxes, resulting in a total of five hot boxes. The temperature in the deepest box may be elevated to 108 °C when they are advised to synchronies the solar light; warm enough to soak water and prepare meals. The first solar collection in the world is housed in these boxes. Certain firms and research institutions started constructing a silicon-based solar cell in the late 1950s with the purpose of controlling Earth-orbiting satellites. The United States Army Alert Corps, RCA, and Hoffman Electronics are among them (Desideri et al., 2013).

A photovoltaic cell, also known as a solar cell, is a natural and man-made wonder that converts the energy of photons striking it into electrical energy. A single cell unit can be linked to a frame module, often known as a solar panel. A solar photovoltaic board, also known as a 7 module, is made up of numerous solar cells arranged in a logical pattern on a plane. To enable light to pass through while shielding the semiconductor plate within the box, a glass is typically put in front of the PV panel.

Depending on the demands of the client, solar cells are typically joined together and put in a series or parallel module. Since of their enlightened complicity and the reversal of dark cell tendencies, the parallel interface unit receives a higher current; however, the problem that shadow effects can turn off weaker (less bright) parallel strings (different permutations of cells) can cause great unpleasant effects and may cause damage. Stackable modules are normally autonomous and not linked in parallel, however starting in 2014, each module will produce a single power box on a regular basis and will link in parallel.

2.3 Working Principle of Solar Panel

When light falls on a solid or liquid system, it appears as an electric voltage between two electrodes linked to the system. The photovoltaic effect is created by solar cells. In these solar cells, a p-n junction is generated by linking two distinct types of semiconductors - a p-type and an n-type - together. When these two types of semiconductors are connected, an electric field is formed as electrons flow to the positive p-side and holes flow to the negative n-side. Photons are little bundles of electromagnetic radiation or energy that make up light. These photons may be absorbed by a photovoltaic cell, which is the type of cell used in solar panels. When light of an appropriate wavelength is shined on these cells, photon energy is passed to one atom of the semiconducting material in the p-n junction. The energy is sent directly to the electrons of the substance. The electrons subsequently enter the conduction band, a higher-energy state. The electron jumped up and pierced the valence band, leaving a hole. The electron travels as a result of the extra energy, generating two charge carriers.

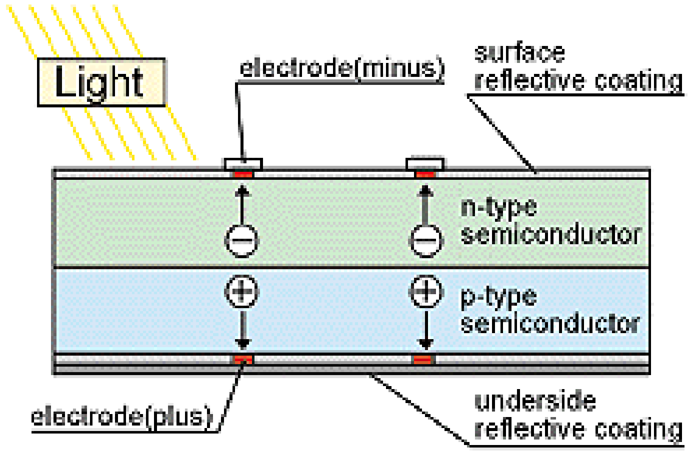

Figure 2.4 : Working of solar cell

Source : Principle of Solar Cell (KYOCERA, 2020)

2.4 Geography And Climate of Sabah

East Malaysia (which comprises the Malaysian states of Sabah, Sarawak, and the Federal Territory of Labuan) is part of Malaysia and is situated on the island of Borneo. The South China Sea separates Borneo from West Malaysia, making it the world's third biggest island (Zhang, 2016). Borneo is covered by lush jungle, boasts some of the world's oldest and most biodiverse rainforests, as well as long shorelines and a wealth of natural beauties.

Sabah geographical structure consists of a combination of coastal regions, mountains, and tropical rainforests. Sabah is a state in Malaysia that comprises 73,904 square kilometers and has a coastline of around 1,440 kilometers (900 miles) that is bordered on the west by the South China Sea and on the east by the Sulu Sea and Celebes Sea (Of & In, 2016). The Crocker Range, located in the center of central Sabah, is one of the most significant locations in Sabah, with several mountains range in height from 1,000 metres to 4,000 metres. Mount Kinabalu, at 4095 metres (13435 feet) above sea level, is the highest peak in this group and one of Southeast Asia's highest peaks(In et al., 1998). It is protected as Kinabalu park, a world heritage site(Hamid et al., 2018). The Kinabatangan River is the longest river in Sabah, flowing

560 kilometres from the Crocker Mountain Range to the Sulu Sea east of Sandakan(Harun et al., 2015). The Kinabatangan River, like the state's lush tropical woods, supports numerous diverse creatures and is home to a unique environment found exclusively in the region.

Figure 2.5 : Map of Sabah

Source : Sabah Map (*Sabah Maps, Wonders of Borneo Island _ Bike and Tours*, n.d.)

Sabah has an equatorial climate (tropical rainforest climate) with year-round constant temperatures, high humidity, minimal wind, and plenty of rain (Liang, 2016). Rainfall patterns vary due to topographical features, seasonal monsoon winds, and on occasion, irregular and complicated climate fluctuation.

2.5 Development of Electricity Industry in Sabah.

Use of electricity in Sabah reported to take place as early as 1910. supply by the Sandakan Light & Power Co. Ltd. Consolidation of electricity supply functions in Sabah began in 1957 when North Borneo Electricity Board was formed under the Sabah State Government after formation of Malaysia(Energy Commision, 2014). North Borneo Electricity Board was created in 1957 by joining three companies that had been supplying electricity to North Borneo since 1910. When East Malaysia joined Malaysia in 1963, it was renamed to Sabah Electricity Board (SEB)(Generation, 2003). After the formation of Malaysia, the state governments of Sarawak and Sabah accepted responsibility of power supply regulation and management, mostly through statutory boards or ownership of corporate shares. Sabah Electricity Sdn. Bhd established in 1998, Tenaga Nasional Berhad (TNB) owns 80% of Sabah Electricity Sdn Bhd, while the States Government of Sabah owns the other 20%.

By bringing in Independent Power Producers in the early 1990s, the federal government encouraged competition to boost reserve capacity, supply dependability, and cost effectiveness (IPPs). IPPs were only involved in the generating phase, and the power they generated was subsequently sold to electric utility companies under the provisions of Power Purchase Agreements. In Sabah, there were eight IPPs at the end of 2014.

After the passing of the Energy Commission Act in 2001, the Energy Commission was founded. It was given the job of regulating energy supply operations (including electricity) as well as enforcing supply rules. Peninsula Malaysia and Sabah are under its control. Power producers in Sabah who use renewable energy sources have been authorized to sell electricity to SESB under the Feed-in-Tariff (FiT) program in recent years, after the implementation of the Renewable Energy Act 2011 and the Sustainable Energy Development Act 2011.