RESIDENTIAL GRID-CONNECTED PV SYSTEM

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A report submitted in partial fulfillment of the requirement for the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)

Faculty of Electrical Engineering

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2014

I hereby declare that I have read through this report entitle "Residential Grid Connected PV System" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation).

Signature : .....

Name : Dr Gan Chin Kim

Date : 17 Jun 2014

I declare that this report "Residential Grid-Connected PV System" 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 candidature of any other degree.

Signature : .....

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Date : 17 Jun 2014

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ABSTRACT

Generating electric by using renewable energy such as solar energy, wind energy and geothermal energy is a good move because it can reduce the emission of carbon dioxide. Nowadays, the price of electric is increase due to the increasing of oil price. The price of electric will continue to increase because the oil is decreasing due to always being used in daily activities .To cope with the increase in electricity prices, this study has made to help the public to generate their own electricity. The purpose of this study is to design a 4 kW residential grid- connected PV system on the rooftop and to analyses the performance of the system. In order to achieve that the type of solar module, tilt angle and the function of related component such as inverter, AC distribution board and metering need to be identify. The main result for this project is the drawing of the 4 kW grid connected PV system which is suitable for the selected house. At the end of this project, a comprehensive report about analysis and discussion made based on the results obtained is produced.

ABSTRAK

Menjana elektrik dengan menggunakan tenaga boleh diperbaharui seperti tenaga solar, tenaga angin dan tenaga geoterma adalah satu langkah yang baik kerana ia boleh mengurangkan pelepasan karbon dioksida. Pada masa kini , harga elektrik semakin meningkatan disebabkan oleh peningkatan harga minyak. Harga elektrik akan terus meningkat kerana minyak semakin berkurangan kerana sentiasa digunakan dalam aktiviti harian. Untuk mengatasi peningkatan harga elektrik, kajian ini telah dibuat bagi membantu orang awam supaya dapat menjana elektrik mereka sendiri . Tujuan kajian ini ialah mereka bentuk 4 kW kediaman grid yang berkaitan sistem PV di atas bumbung serta menganalisis prestasi sistem .Dalam usaha untuk mencapai sasaran ,jenis modul solar, sudut kecondongan dan fungsi komponen yang berkaitan seperti penyongsang , AC papan agihan dan pemeteran perlu dikenal pasti. Keputusan utama bagi projek ini adalah lukisan daripada 4 KWP grid berkaitan sistem PV yang sesuai untuk rumah yang dipilih. Pada akhir projek ini, satu laporan komprehensif tentang analisis dan perbincangan dibuat berdasarkan keputusan yang diperolehi .

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INTRODUCTION

1.1.1 Project Background

By using the sun as the source of energy, there are several types of solar power systems but there are two systems that commonly used. There are solar thermal systems and solar PV systems. Solar thermal systems absorb heat to warm up water while solar PV systems using sunlight to generate electricity. The main advantages for using renewable system are they can save energy (generate profit) and reduce environmental pollution. [1]Solar PV systems have two main types: grid-connected and off-grid solar PV system. This research will explain about the design of grid-connected PV system.

1.1.2 Grid –Connected Solar PV System

Figure 1 below show an example of grid connected PV system and the component that need to be considered before making a design .There are two parallel power supplies for building which is from power grid and from solar PV system. These two power supply were combined to feeds all the loads that connected to the main AC distribution board.

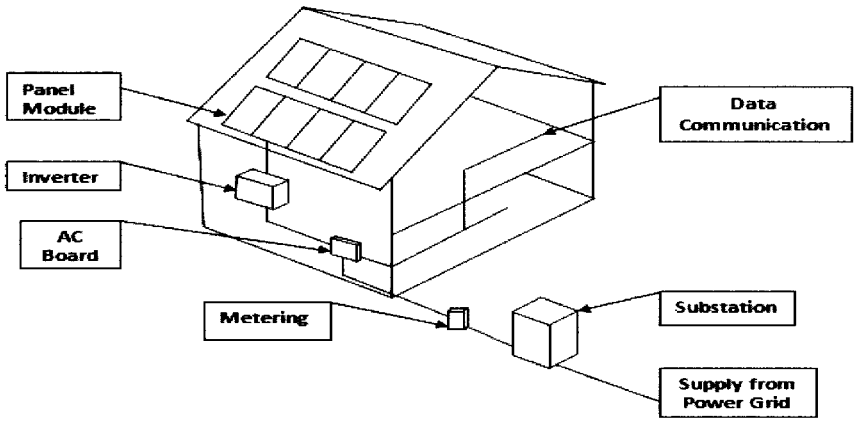

Figure 1: Grid-connected PV system configuration

The size of solar PV system will determine the ratio of solar PV supply to the power grid supply. If there is excess electricity, it will be exported into the grid. When there is a storm, rain or at night which means the solar module cannot generate electricity, building demand will be supplied by the power grid. [2]As we know, the grid connected PV system generates direct current by using sunlight. This direct current was converted to alternating current by using the inverter and supplied into the grid. Grid-connected PV system is divided by two which are central system and distributed system (residential). [3]

1.1.3 Central System

A central grid-connected PV system operates similarly. For the central system, it usually uses a lot of space because its produce large energy. Figure 2 shows the project of solar PV systems at Rembia World Solar Valley recently completed in September 2013. This project is the largest solar PV central system in Malaysia so far.

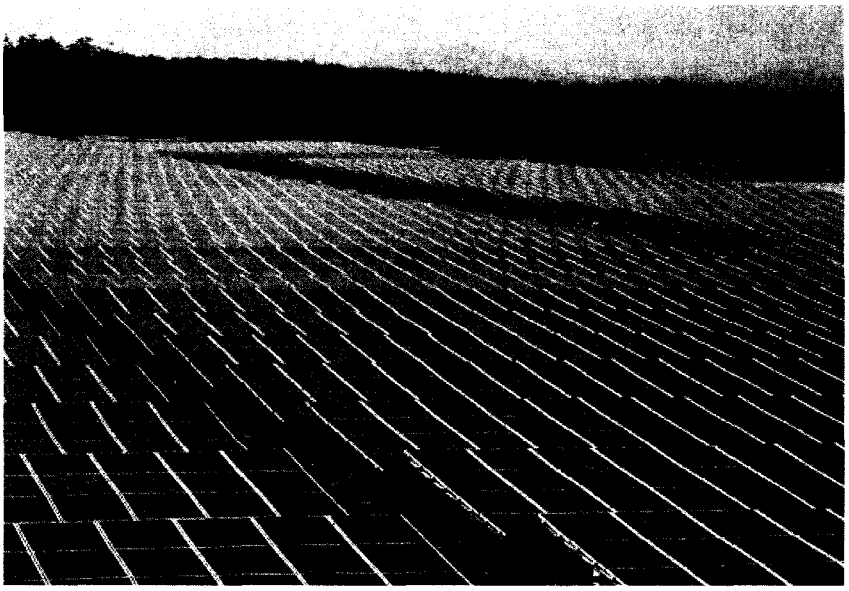

Figure 2: Rembia World Solar Valley 5MWp central PV system

1.1.4 Distributed System

There are two types of distributed system: commercial and domestic. Commercial system is usually greater than 10kWp and commonly used for building. The power generated by distributed systems is consumed by the loads within the building and no power exported to the electricity grid. The domestic system range is lower than 10 kW (usually between 1 to 5 kW) and is suitable to be installed on the roof of the house. Domestic system will generate electric power and will be used by the operating load at home. The excess power generators by these systems will be fed into the grid. Then it will provide the power to nearby houses and the owner will get profit from it. [4] Figure 3 and 4 shows the example of the domestic system which located in Melaka and Germany.

Figure 3: Kumpulan Melaka Berhad 10kWp commercial PV system

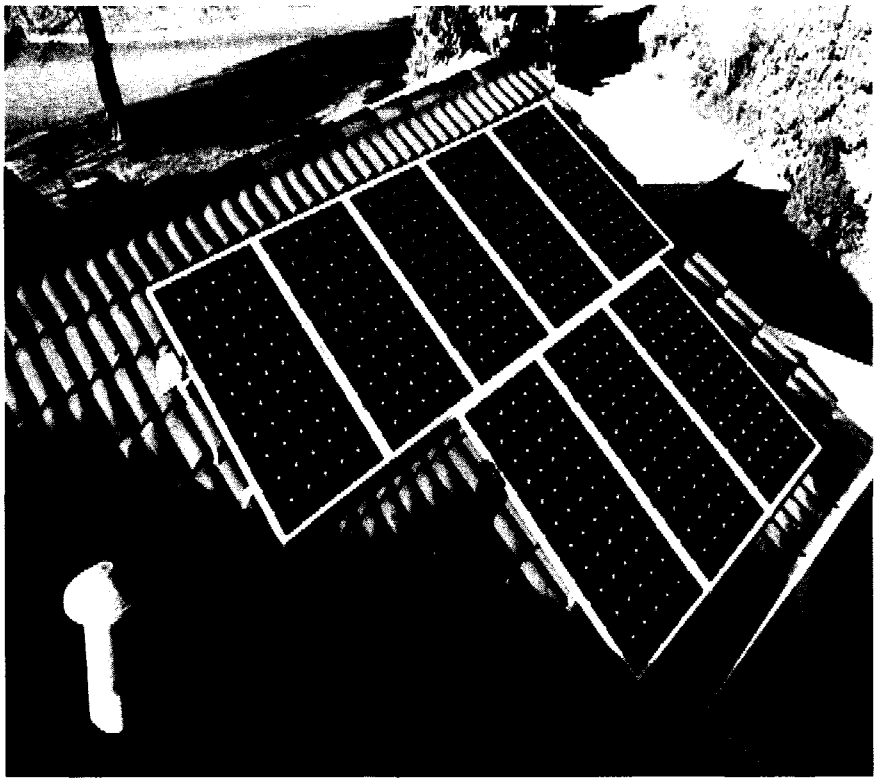

Figure 4: Rooftop 2kWp domestic PV system.

1.2 Project Motivation

Renewable energy has several advantages such as energy security, income for owner, energy for future generation and increase environments and human health. By using renewable energy, our country's energy security problem can be solved because we no longer depend on fossil fuel. According to Bonnie Raitt, "Promoting renewable energy is the most patriotic act we can commit. It makes our country less dependent on foreign oil and less likely to go to war." In addition, it also gives monthly income to the owner for long period of time. Renewable energy sources also replenished. This means if we using renewable energy system, so it will not only benefits us now, but will also benefits to the generation after us. Besides that, it also friendlier to the environment compare to the fossil fuel system. As we know, fossil fuels contribute to many environmental issue that we face today such as greenhouse gases, air pollution and soil contamination. The problem above will lead to global warming. Fortunately, renewable energy system will reduce the emission of carbon dioxide and make our environment clean.

1.3 Project Statement

Nowadays, electricity is the most important to our life because it does so many jobs for us. Without electricity, we can't use televisions, computers, refrigerators and other things. We also wouldn't be able to see at night if we do not have electricity. Try to imagine if we had to live without electricity for one month? What will happen to us?. Every year the price for electricity is rising due to the demands, why not we generate our electricity. According to Tenaga National (http://www.tnb.com.my/residential/pricing-and-tariff.html), they have

raised the tariff for electricity (7.12 %) since 1st June 2011 because of the price of oil rises. All the information regarding new tariff is displayed in the Tenaga National website.

For that reason, the government has already introduced the renewable energy such as solar energy, wind energy and geothermal energy. For housing, we can generate electricity by using solar PV systems. Actually, Malaysia is very suitable for solar PV system because the weather is hot and dry throughout the year. However most people do not know about the solar PV systems and makes them lost interest in this system. To overcome the problem of rising electricity prices, the solar PV system is the best solution because its give long term profit and reduce pollution.

1.4 Objectives

a) To identify the function of related component such as inverter, AC distribution board and metering.

b) To design a 4 kWp residential grid-connected PV system on the rooftop.

c) To determine the return of investment of 4kWp residential grid connected PV system.

Scope of Research

a) Determine the total solar module that can be installed on the roof.

b) Design a 4 kWp residential grid connected PV system on the rooftop.

c) Determine the type of solar module and tilt angle.

d) To identify the function of related component such as inverter, AC distribution board and metering.

e) Another aspect such as the construction of solar panels and the factors that affect the performance of the PV system will not be covered in this report.

1.5 Report Outlines

This progress report consists of five chapters. In the first chapter, it will focus on the background, scope of the project, objective and the problem statement. In Chapter 2, literature review of the project is will be briefly explained. In this chapter, it will focus on the explanation of the related component for design a grid-connected PV system such as PV cells, solar module, inverter and distribution board.

Chapter 3 will be focusing on how to calculate the total solar module that used, the tilt angle of solar module and the design of grid connected PV system. This chapter also explains the simulation of the project. The result and discussion are presented and discussed in the Chapter 4. All the output obtained from the simulation process are analyzed and discussed. Finally Chapter 5 will discuss the recommendation for future work and conclusion of this project was given and provided.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Solar PV System

2.1.1 Solar Radiation

2.1.1.1 Irradiance

Solar constant can be defined as the energy from the sun that arrive in the earth's atmosphere at peak value of 1367 kWm^{-2} while the ordinance is total of solar power available per unit area. [5] A summary of the solar parameters is listed in table 1.

Table 1: Summary of solar parameters

Parameter	Symbol	Quantity and unit
Irradiance	G	kWm^{-2}, Wm^{-2}, $mWcm^{-2}$
Measuring devises	Pyranometer (thermopile or reference solar PV cells)	_
Solar constant	Gas	1.367 kWm^{-2}
Peak value at sea level	G_o	1kWm^{-2}, 1000 Wm^{-2}, 100 $mWcm^{-2}$
Nominal value	_	0.8kWm^{-2}, 800 Wm^{-2}, 80 $mWcm^{-2}$

2.1.1.2 Geometric Effect

The sun altitude angle α is very important to make sure the module collects all incoming 12 rays from the sun. If the module is placed without the sun altitude angle α, it only can collect 9 rays and the output cannot reach the maximum. This theory can be seen in Figure 5. The module will face either north or south depending the location of the khatulistiwa. At noon, the position of the module will be 90 degrees to the sun as shown in Figure 6 to make sure the module can generate maximum output. [5]

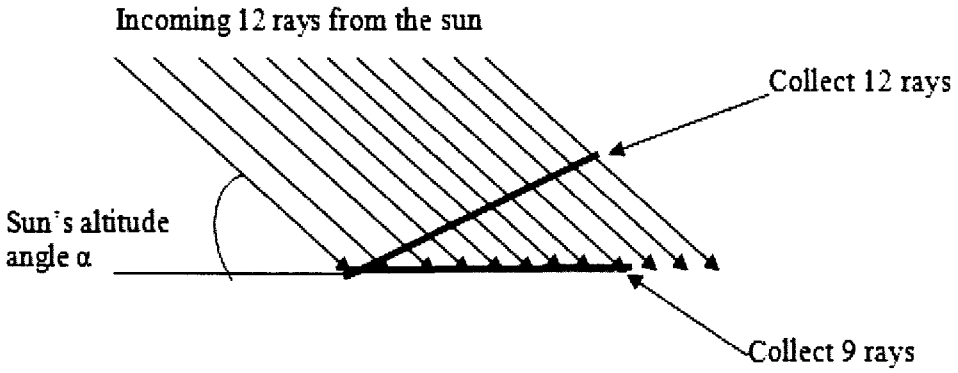

Figure 5: Effect of varying tilt angles on solar capture

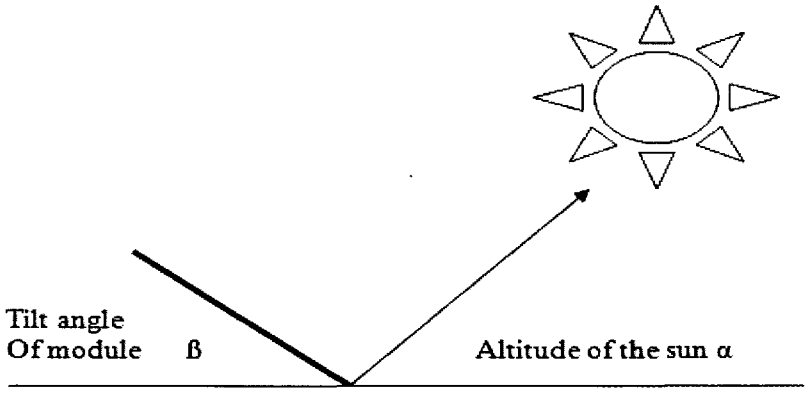

Figure 6: Placement of solar module in relation to Sun's altitude.

2.1.2 PV cells

2.1.2.1 Atomic Structure of Silicon

Silicon made up from:

- Photons (positive charge)
- Neutrons (neutral charge)
- Electrons (negative charge)

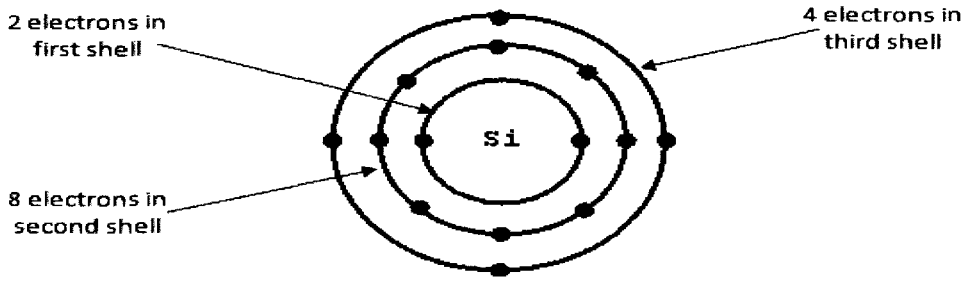

Figure 7: Atomic structure of silicon

The first shell of the Sillicon as shown in Figure 7 only can store 2 electrons and second shell can store 8 electrons. Since it's already filled up, it cannot take any electrons. Besides, they are tightly bound to nucleus so they cannot become free electrons. However the third shell is not completely filled with the electrons. There are 4 electrons that needed in order to form complete bonding. The electrons in the third shell will become free electrons if they receive the energy that equal or larger than the energy binding provide by the silicon. [6] Figure 8 will shows us the process for photoelectric effect in order to become free electron.

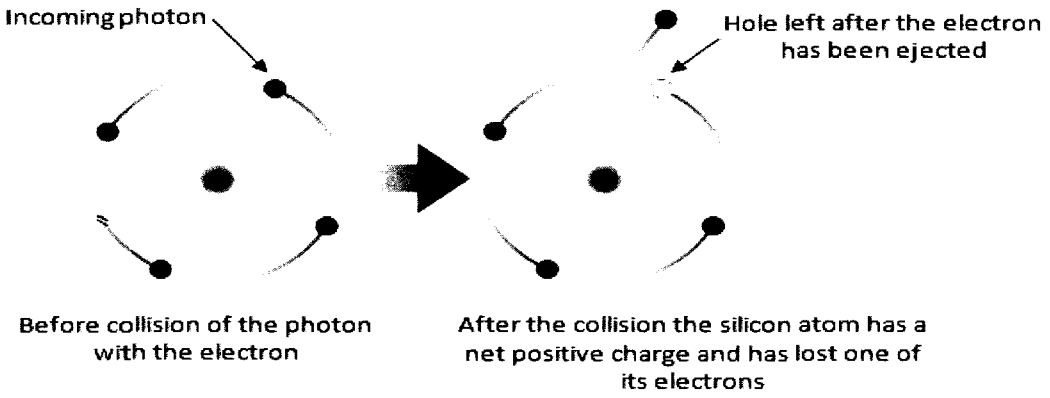

Figure 8: The photoelectric effect

2.1.3 Solar PV module

Solar PV module made up from the combination of identical cells and produce an open circuit voltage greater or equal to 20V. It's also suitable for charging a 12V battery.

2.1.3.1 Cell Connection

If the cell is combined together with two or more identical in series, the voltage will increase while the current remains the same.This idea can be visualised in Figure 9 and 9.1.

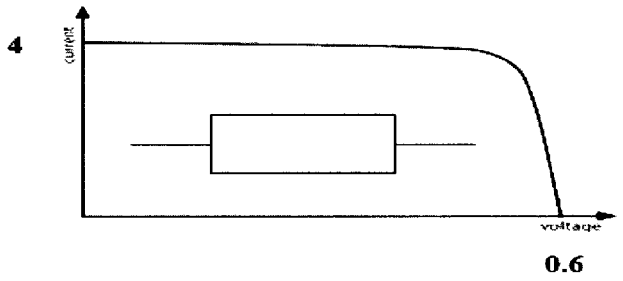

Figure 9: The IV characteristic of single module

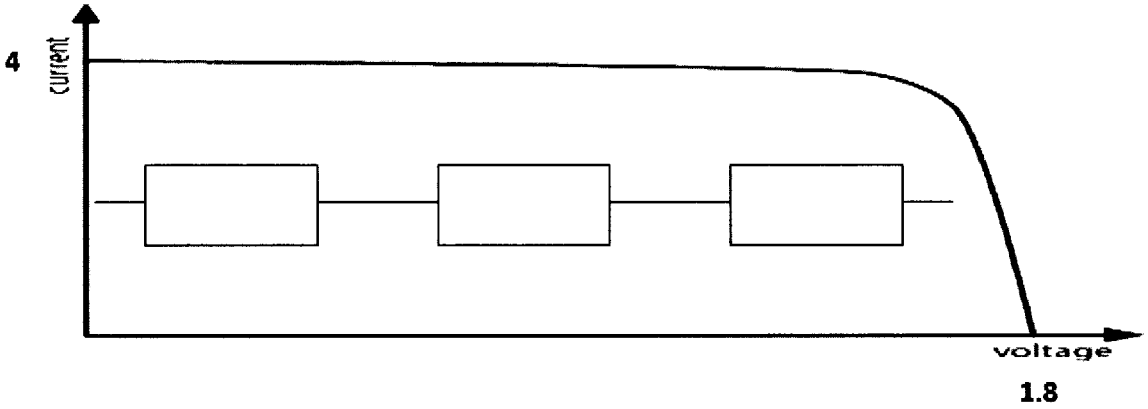

Figure 9.1: The IV characteristic of combined cells (identical cells)

The voltage will remain the same if the dissimilar cells are combined together but the current will follow the smaller value of the cells. [7] This idea can be visualised in Figure 10 and 10.1

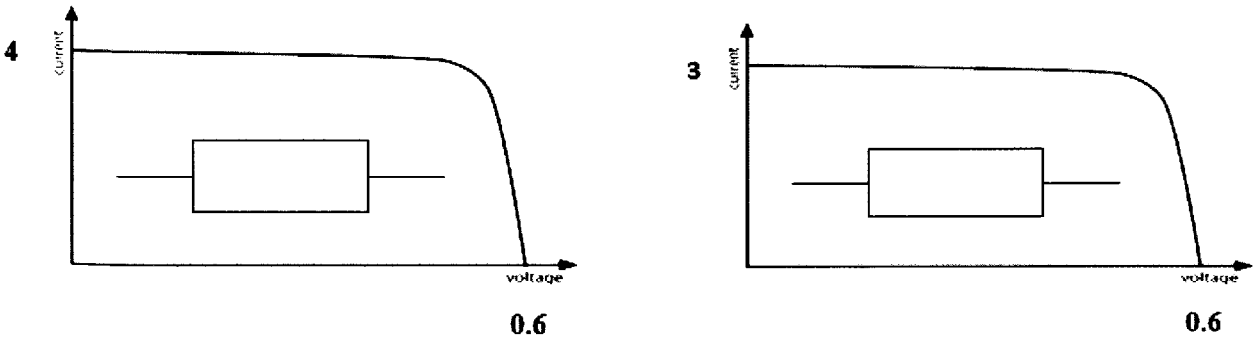

Figure 10: The IV characteristic of dissimilar cells