A REABILITY STUDY ON STAND-ALONE ELECTRIC SOLAR SYSTEM FOR DOMESTIC USAGE

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ABSTRACT

Depletion of fossil fuel resources in the world has need urgent search for alternative energy sources to meet current demand. Solar energy is clean, resources are not inexhaustible and environmentally friendly potential among renewable energy options. The objectives of this study are to investigate the reliability of Stand-Alone Electric Solar System (ESS) and estimate ESS equipments specification that able to power up selected household electrical appliances. ESS generated electricity from solar energy as a source. The electricity will supply to a house with capacity 1600 Wh per day using ten solar panel photovoltaic and four battery bank. ESS equipped by solar panel photovoltaic (95 Watt), solar charge controller, inverter, battery bank (12 V, 38 AH) and meter Power Quality Analyzer. The minimum loads required for a domestic house is 400 Wh. Data Logger is used to obtain the pattern of solar irradiation. The best performance of solar irradiation data is when on warm day. ESS equipped can produce energy 160 Wh using one solar panel (95 W) to store into one the battery bank (12 V, 38 AH). ESS specification to meet, it can be concluded that the Batu Pahat is reliable for ESS. This can be proved by the solar irradiation data and energy generated by ESS for home appliances purpose usage.

ABSTRAK

Susutan sumber bahan api fosil di dunia perlu segera untuk mencari sumber tenaga alternatif bagi memenuhi kehendak semasa.Tenaga solar adalah bersih, sumber tidak habis dan potensi mesra alam sekitar di kalangan pilihan tenaga yang boleh diperbaharui. Objektif projek ini untuk menyiasat kebolehpercayaan Stand-Alone Sistem Elektrik Suria (ESS) dan anggaran spesifikasi peralatan ESS yang dapat menghoperasikan perkakas elektrik rumah yang dipilih. ESS elektrik yang dijana daripada tenaga solar sebagai sumber. Elektrik akan dibekalkan kepada sebuah rumah dengan kapasiti 1600 Wh setiap hari dengan menggunakan sepuluh panel solar dan empat biji bateri. ESS yang dilengkapi dengan panel solar photovoltaik (95 Watt), pengawal caj solar, penyongsang, bank bateri (12 V, 38 AH) dan meter Analyzer Kualiti Kuasa. Logger data adalah digunakan untuk mendapatkan corak sinaran suria. Corak terbaik data penyinaran suria adalah ketika cuaca panas. ESS yang lengkapi boleh menghasilkan tenaga 160 Wh dengan menggunakan satu solar panel (95 W) untuk disimpan ke dalam sebiji bank bateri (12 V, 38 AH). Dapat disimpulkan bahawa Batu Pahat boleh dipercayai untuk ESS. Ini boleh dibuktikan dengan data penyinaran suria dan kuasa boleh dihasilkan oleh panel solar untuk diedarkan kepada sebuah rumah dan untuk kegunaan peralatan di rumah.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Project Overview

Renewable energy is a phrase that is loosely used to describe any form of electric energy generated from resources other than fossil and nuclear fuels. Renewable energy resources include hydropower, wind, solar, wave and tide, geothermal and hydrogen. The Sun is the source of all those renewable energies with exception of geothermal and tidal energy, [1]. These resources produce much less pollution than burning fossil fuels and are constantly replenished and thus called renewable. The Sun is the primary source of energy in solar systems; the earth receives 90 % of its total energy from the Sun.

Photovoltaics offer consumers the ability to generate electricity in a clean, quiet and reliable way. Photovoltaic systems are comprised of photovoltaic cells, devices that convert light energy directly into electricity. Because the source of light is usually the Sun, people are often called solar cells, [2]. The word photovoltaic comes from "photo," meaning light, and "voltaic," which refers to producing electricity. Therefore, the photovoltaic process is "producing electricity directly from sunlight." Photovoltaics are often referred to as PV. For some applications where small amounts of electricity are required like emergency call boxes, PV systems are often cost justified even when grid electricity is not very far away. When applications require larger amounts of electricity and are located away from existing power lines, photovoltaic systems can in many cases offer the least expensive, most viable option. In use today on street lights, gate openers and other low power tasks, photovoltaics are gaining popularity in Malaysia and around the world as their price declines and efficiency increases.

A Stand-Alone Electric Solar System (ESS) does not have a connection to the electricity "mains" ("grid"). ESS varies widely in size and application from wristwatches or calculators to remote buildings or spacecraft. If the load is to be supplied independently of solar insulation, the generated power is stored and buffered with a battery, [3]. In non-portable applications where weight is not an issue, such as in buildings, lead acid batteries are most commonly used for their low cost. A charge controller may be incorporated in the system to avoid battery damage by excessive charging or discharging and optimizing the production of the cells or modules by maximum power point tracking (MPPT), [4]. However, in simple PV systems where the PV module voltage is matched to the battery voltage, the use of MPPT electronics is generally considered unnecessary, since the battery voltage is stable enough to provide near-maximum power collection from the PV module.

In domestic applications, the most relevant technology for stand-alone operation is a conventional battery system (as commonly used with PV systems), although flywheel storage may have a role as products become cheaper. However, in general, it may be assumed that, for grid-parallel operation, the grid itself is the "battery" as regards mass electrical storage. Some home owners in Malaysia are turning to PV as a clean and reliable energy source even though it is often more expensive than power available from their electric utility. These home owners can supplement their energy needs with electricity from their local utility when their PV system is not supplying enough energy (at nighttime and on cloudy days) and can export excessive electricity back to their local utility when their PV system is generating more energy than is needed. For locations that are "off the grid" meaning they are far from, or do not use, existing power lines PV systems can be used to power water pumps, electric fences or even an entire household. While PV systems may require a substantial investment, it can be cheaper than paying the costs associated with extending the electric utility grid.

Power systems are most often used to power DC appliances in boats and cabins, as well as farm/ranch appliances like cattle gates and rural telecommunications systems when utility power is not accessible. DC solar power is less expensive than AC solar power because an inverter is not required to convert the electricity produced by solar panels and stored in batteries from DC to AC. While AC off-grid solar power systems are more expensive because of the cost of the inverter. The addition of an inverter allows this system to convert DC electrical current coming from the batteries into AC or alternating current. AC is the standard form of electricity for anything that "plugs in" to utility power and is the appropriate current for common household appliances.

There are many advantages of ESS. Among the advantages are suitable for location where connection to the grid is too expensive or not possible, uninterrupted power protection from power cuts and the ability to power independently in all conditions, reduction in energy bills and maximize the use of alternative energy, uses green alternatives along side traditional options (eco friendly) and the last advantage is adaptable and expandable to changing living and business uses.

Therefore, the purpose of this project is to study the reliability a factor of the Stand-Alone Electric Solar System (ESS) applies for a domestic house without utility supply. For strengthened the research of this project study on reliability stand alone solar electric system will tested at the domestic sector at Batu pahat.

1.2 Problem Statement

Energy is very important to life. Without energy work cannot be done. It also need by people to run their daily lives. The increasing in world population causes more energy to be used. The world demand for energy has increased. It means the world is facing the new crisis that would be serious which is called decrease of energy source.

The usage of renewable sources like wind energy, hydropower, solar, become the vital sources and trend to worldwide to generate electricity. Only some areas of Malaysia suitable applied wind system such as Pulau Perhentian. For the hydropower system, there are many systems in Malaysia such as Empangan Tasek Kenyir is major contributor electricity.

However, Stand-alone Electric Solar System (ESS) is better compared to the other sources like biomass. This is because the cost is low compared to biomass. Malaysia has equatorial climate with wet and dry weather. On the average, Malaysia receives about 6 hours of sunshine per day with the sunniest regions, Alor Setar and Kota Bharu, receiving about 7 hours of sunshine per day while Kuching receives only five hours per day. Average hours of sunshine differ to that of the amount of precipitation that falls. Sunshine hours range from four to five hours throughout the wettest months to eight to nine hours in the dry season. So, solar energy is not a big problem if this system applied in Malaysia.

1.3 Objective of project

The main objectives of the project are:

i. To investigate the reliability factor of the Stand-Alone Electric Solar System (ESS) applies for a domestic house without utility supply.
ii. To estimate ESS equipments specification that able to power up a selected household electrical appliances.

1.4 Scopes

i. Stand-Alone Electric Solar System (ESS) produced electricity from solar energy as a source. The electricity will supply to a house with capacity 1381 Wh. This project used main component such as photovoltaic solar panel (95 Watt), solar charge controller and inverter.

ii. Using Data Logger to get irradiation data and transfer from collecting solar data to graft.

iii. The specification of battery is 12 V and 38 AH.

iv. It is using the Stand-Alone Solar system and Meter Power Quality Analyzer.

v. It can apply at domestic sector depends type of electrical device.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will describe the literature review which related with Electric Stand-Alone Solar System for Domestic Sector. It consists of five literature reviews namely the Feed-in Tariff Engineering and Economic Benefits of Photovoltaic System for Residential Sector in Malaysia, Applications of Solar Energy to Power Stand-Alone Area and Street Lighting, and Research About How to Construct Alternative Energy Systems.

2.2 Previous Study

Bong Yann Kai (Universiti Teknologi Malaysia, 2011). The study shows that the feed-in tariff engineering and economic benefits of photovoltaic system for residential sector in Malaysia. It will be implemented in the year 2011 in accordance with the Tenth Malaysian Plan under the New Renewable Energy Policy, [5]. With the Feed in Tariff, firstly, need to apply for an account. Second, a renewable energy generator installed such as wind turbine or solar photovoltaic (PV) system. The renewable energy generator is installed together with a special two net metering system in our home.

Joshua David Bollinger (University Missouri-rolla, 2007). This study about applications of solar energy to power stand-alone area and street lighting. One of the earliest studies was conducted by the Parks and Recreation Department of Albuquerque, New Mexico, [6]. The design of the system used two 50W photovoltaic panels with a 35W low pressure sodium lamp, [6]. The stand-alone systems were designed to last for six hours a night and used a boost converter due to the design of a working maximum power point tracker was still in the development stage. The results of the study showed the potential of using solar energy to power street lights, and built the groundwork for future designs, [6]. Isolated parts of the world are ideal places to study the abilities of stand-alone lighting systems due to the lack of electricity to those regions.

Haifeng Ge, Liqin Ni, Sohrab Asgarpoor (University of Nebraska – Lincoln, 2008). Previous researches are available on how to construct alternative energy systems, combine them into the traditional power grid, [7] and how to size the storage volume or the energy source capacity to meet the loads' needs, [8]. The impact of the alternative energy on the traditional power grid is also examined in order to improve systems' stability, [9], [10]. But most of the design rules are based on the "meeting the need" strategy, not based on the reliability. There are also some results available, for reliability evaluation of alternative energy systems, [11]. In these papers, wind, photovoltaic, or their hybrid system were evaluated, to calculate the reliability indices at the generation and transmission level, [12]. These indices are very useful for the planning and operation. However, these studies are based on high level performance studies, and do not give a clear guide on how to improve the system's reliability during design phase.

Jasvir Singh (University Thapar Patiala,2010). This study abaout Study And Design of Grid Connected Solar Photovoltaic System, [13]. These systems are connected to a broader electricity network. The PV system is connected to the utility grid using a high quality inverter, which converts DC power from the solar array into AC power that conforms to the grids electrical requirements. During the day, the solar electricity generated by the system is either used immediately or sold off to electricity supply companies. In the evening, when the system is unable to supply immediate power, electricity can be bought back from the network.

From the previous study that have been done by the several researches, it can be concluded that the solar system is the main alternative source of concern from various parties. This can be seen from this that a lot of research before making the study of photovoltaic systems. In addition, demand for electricity from TNB is increasing. Lack of resources and higher prices require further research on the reliability of the ESS as a backup power supply or the mains supply, replace the existing systems for the domestic sector in Malaysia.

2.3 Solar Charge Controller Circuit

For any particular solar cell panel, the open circuit voltage increases exponentially with the intensity of solar radiation, reaching a limiting value. The cell voltage will assume the value of the battery terminal voltage which is an approximately fixed quantity except for the case of a highly drained battery. It is common practice to design photovoltaic solar systems for battery charging with solar panel open circuit saturation voltage being 1.5 times the nominal emf of the battery to be charged. Even with such design, a good deal sun energy under morning, after noon hours and cloudy weather may not be exploited properly due to the fact that the operating point will slip back into the exponential regions.

In order to gain more insight on the problem, the equivalent circuit of the battery charging process shown in Figure 2.1. The solar panel is represented by a voltage source E, an internal resistance r, and a diode D. When the electromotive force E exceeds solar panel voltage, as an example the 12 V solar panel exceeds 12 V, the battery to be charge E_o, charging current i will flow

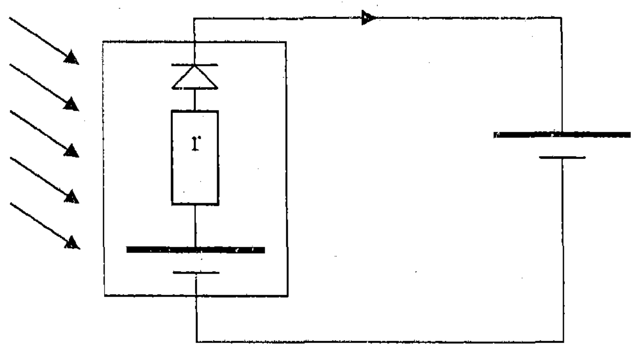


Figure 2.1 – Solar charging equivalent circuit.

$$ir = E - E_o \text{ ....(2.1)}$$

The power stored in the battery will be $P = iE_0$. The solar panel internal resistance r is equal to the open circuit voltage E divided by the short circuit current I_o . For a typical solar panel, this current will be proportional to the radiation fallout φ. Thus, 0 $I = K\varphi$, where K is a panel constant related to the harge conversion efficiency.

$$P = Ei - i^2 r \text{ ....(2.2)}$$

For maximum power condition,

$$i = \frac{E}{2r} = \frac{I_o}{2} = \frac{K_1\phi}{2} \text{ ....(2.3)}$$

For a particular fallout condition, it would be beneficial to try to adjust the charging current value in accordance with equation (2.3). The only way do this, is through the adjustment of the electromotive force of the battery being charged.

Let assume that we have a solar panel that has been designed to charge a battery consisting of N cells each has an electromotive x under full radiation fallout condition. It is not unusual to make the electromotive for such panel equal to (3/

2)Nx . We further assume that this panel is being used to charge a smaller number of series cells $n < N$.

The electromotive force solar fallout relation of a typical solar panel is usually of an exponential type. For such a case, equation (2.1) may be rewritten as

$$(\frac{3}{2})Nx(1-e^{-K_2\phi}) - nx = ir \quad ....(2.4)$$

where K_2 is the conversion efficiency factor.

If one chooses to perform the charging process under maximum power condition, the current i will be that given by equation (2.3). If we further assume that the panel open circuit voltage is approximately equal to $(\frac{3}{2})Nx(1-e^{-K_2\phi})$, equation

(2.4)

becomes

$$(\frac{3}{2})Nx(1-e^{-K_2\phi}) - nx = \frac{K_2\phi}{2}\frac{(\frac{3}{2})NIx(1-e^{K_2\phi})}{K_2\phi} \quad ....(2.5)$$

This gives

$$n = \frac{3N}{4}(1-e^{-K_2\phi}) \quad ....(2.6)$$

Equation (2.6) gives the number of unit cells that can be charged under maximum power condition as a function of the solar radiation fallout. Figure 2.2 shows the optimum values of n plotted against φ for a typical solar panel of 10% conversion efficiency

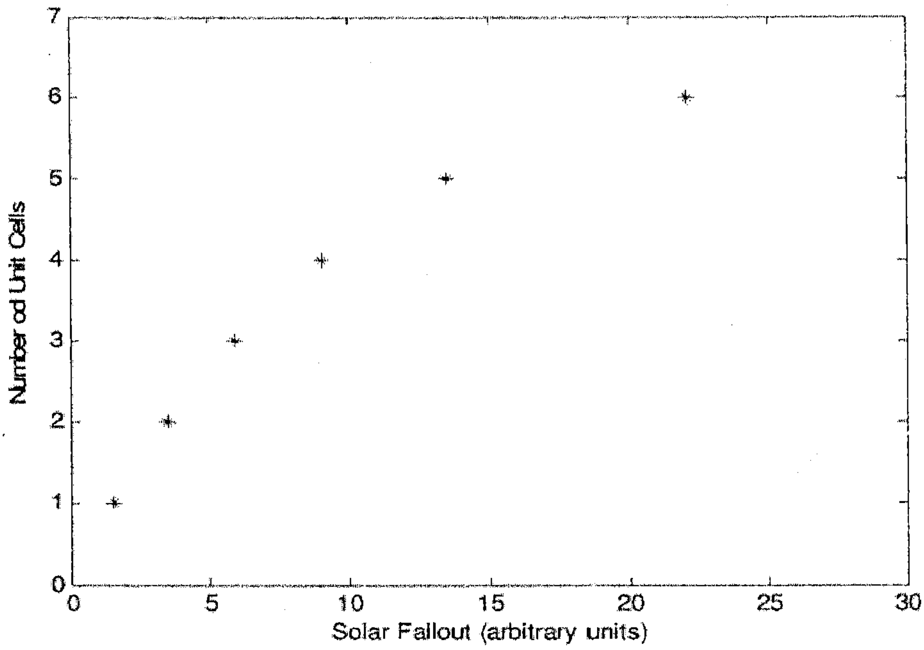


Figure 2.2 – Number of Optimum Number of Unit Cells versus Solar Fallout.

One way to put the above argument into action is through the isolation of a certain number of unit cells from the battery, while charging only a proper number of series cells, in practice, such a process needs two things. The first continues monitoring of the solar panel electromotive force. The second is a reliable switching mechanism that can transfer the charging current to the appropriate number of series unit cells within the battery while excluding the remaining ones for the time being. For example and for 12 V lead-acid battery consisting of 6 cells and each cell has 2 V, the circuit and after monitoring the panel voltage, must direct the current to charge only the first cell when the solar panel voltage is between 2–4 V. The charging current must be redirected to the series combination of the first and second cells for solar panel voltages fall in the range 4-6V, etc. If the monitored voltage is above 12 V, the whole battery will be in a charging state. Finally and in order to avoid any over charging situation, the charging process must seize if the panel voltage exceed a certain limit 14.3 V for example. A block diagram of such arrangement is shown in Figure 2.3.

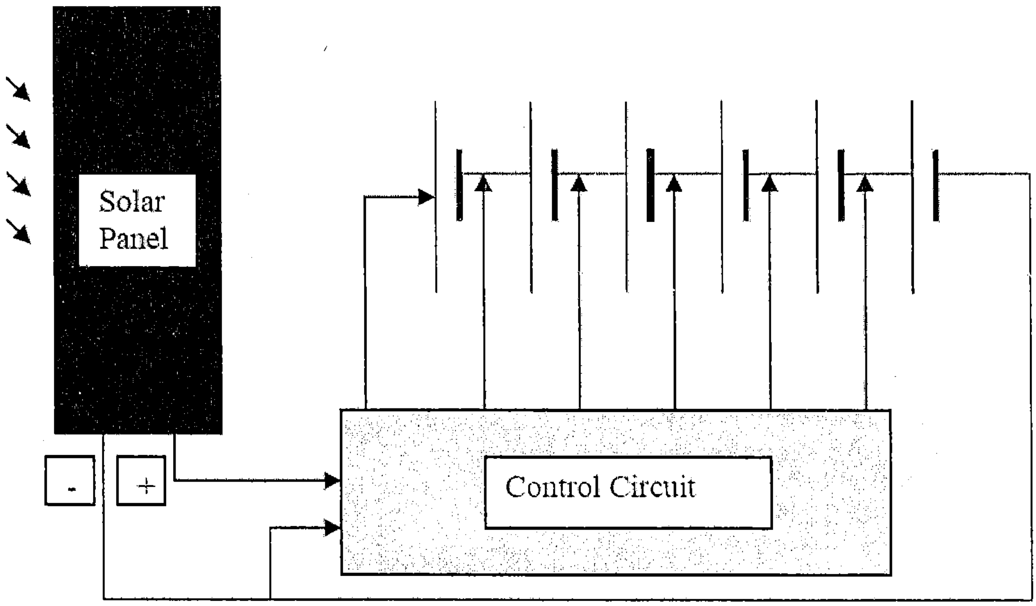


Figure 2.3 – Block diagram of the controlled charging process.

For solar charge controller circuit, it can simulate by using several software. Among the software is Proteus, Multisim, P-Spices, High-Tech and so on. The software a choosing is Proteus because it easy to find component.

2.4 History of Photovoltaic System

In 1963, Sharp Corporation had developed the first usable photovoltaic module from silicon solar cells. The biggest photovoltaic system 242 W module field was set up in Japan. In 1964, Americans applied a 470 W photovoltaic field in the Nimbus space project, [14].

In 1973 Solar Power Corporation started commercial business when a sales office in Braintree, Massachusetts was opened. A silicon solar cell of US$ 30 per W was produced. In 1974, the Japanese Sunshine project commenced. A year later, in 1975, Solec International and Solar Technology International were established, [15]. The American government promoted JPL Laboratories research in the field of photovoltaic systems for application on Earth in the same year. In 1984, a 1 MW photovoltaic power plant began to operate in Sacramento, California. The first amorphous module was introduced by ARCO Solar. BP Solar Systems with EGS donations built a 30 kW photovoltaic system connected to public electric grid nearby Southampton, Great Britain. Solarex Corporation closed the equipment supply for photovoltaic system for Georgetown University Intercultural Center demands with total peak power of 337 kW and 4,464 modules. BP Solar bought Monosolar thin film division, Nortek.

In 1990, a joint company named as United Solar Systems Corporation established for solar cells production. Siemens bought ARCO Solar and established Siemens Solar Industries. Solar Energy Research Institute (SERI) renamed to National Renewable Energy Laboratory (NREL). A year later, in 1991, BP Solar Systems renamed to BP Solar International (BPSI), and became an independent unit within British Petroleum concern. In 1992, a photovoltaic system of 0.5 kW was placed in Antarctica for the laboratory, lighting, personal computers and microwave ovens needs. A silicon solar cell with 20 % efficiency was patented. In 1994, the National Renewable Energy Laboratory's (NREL), and important institution in the field of renewable energy sources in USA, launched its web site on the Internet, [16]. ASE GmbH from Germany purchased Mobil Solar Energy Corporation technology and established ASE Americas, Inc. In 1995, the first international fond for promotion of photovoltaic system commercialization was established, which supported projects in India. The World Bank and the Indian Renewable Energy Sources Agency sponsored projects in co-operation with Siemens Solar. In 1996, BP Solar purchased APS production premises in California, and announced a commercial CIS solar cells production.

In 1997, Greece agreed to sponsor the first 5 MW of total planned 50 MW photovoltaic systems on Crete. Due to misunderstanding among investors the proposed system was not realised. In 1999, Solar Cells Inc (SCI), True North Partners, and LLC of Phoenix, Arizona merged to First Solar, LLC , [14].

Several large power plants were built in Germany in year 2002 - 2003. On April 29th 2003, the world's largest photovoltaic plant was connected to the public grid in Hemau near Regensburg (Bavaria), Germany, [14]. The peak power of the

Solarpark Hemau plant is 4 MW. Many other large systems up to 5 MWp were built in Germany in year 2004 due to renewable energy law EEG.

2.5 Basic Design of Photovoltaic System

2.5.1 Array Sizing

The average daily energy requirement, the battery efficiency, and the month of the worst radiation are used to determine the PV array output required. Since such systems are designed with the least radiation month of the year, the size of the PV array in each subsystem can be estimated as following:

$$P = \sum_{i=1}^{n} L_d / \eta_{pv}\eta_w\eta_{out}Q \qquad (2.7)$$

In this system, the solar cells in the PV system are assumed to be operated at the maximum power point, [17]. The modules can be connected to give the desired voltage according to the design of the PV system and the load specifications.

2.5.2 Solar Radiation Data

The solar radiation data have a great effect on performance of the PV system. The information about the average daily solar energy is used in the city of Osaka from Worldwide Hourly Climate Generator, [17]. As for solar radiation, a model validated in Sandia National Laboratory is employed based on the Perez model.

2.5.3 Photovoltaic Module

Photovoltaic module consists of transparent front side, encapsulated solar cells and backside. As front side material (supersaturate) usually low-iron, tempered glass is used. Backside is usually non transparent, most common used material is PVF. Transparent back side is also possible - transparent back side materials are often used in modules that are integrated into buildings envelope (facade or roof).

The most important module parameters is a short circuit current, an open circuit voltage and a nominal voltage at 1000 W/m2 solar radiation, current and rated power at 1000 W/m2 solar radiation value, [18]. Module parameters are measured at standard test conditions (STC) - solar radiation 1000 W/m2, air mass (AM) 1, 5 and temperature 25oC.

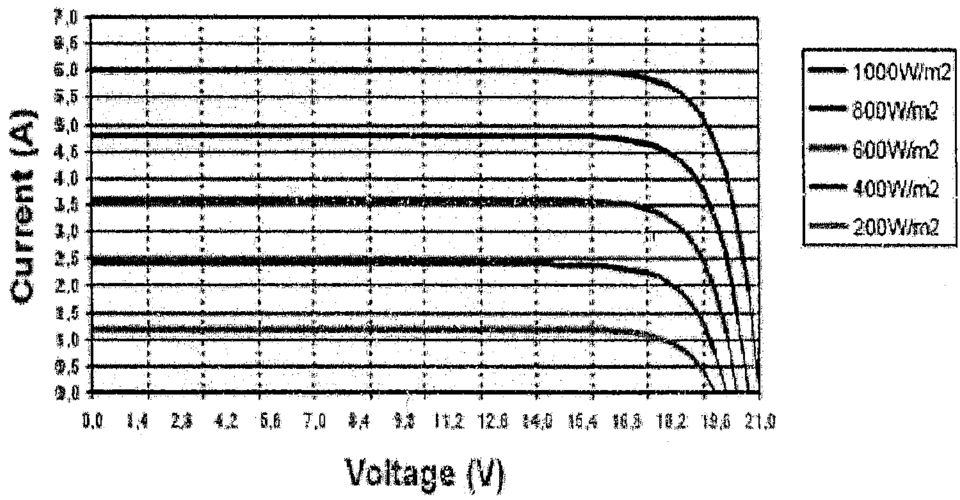


Figure 2.4 : Module I-U characteristic, [18].

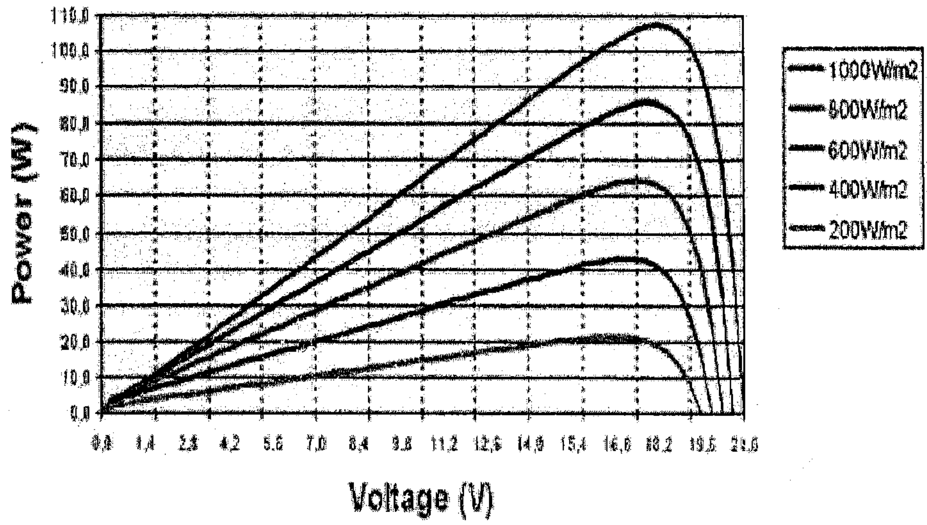


Figure 2.5: Module power characteristic, [18].

2.6 Potential for Photovoltaic System in Malaysia – Solar Radiation Level

Malaysia's tropical climate has good potential for PV systems. The average daily insolation for most parts of the country is between 4.5 and 5.5 kWh/m^2 as shown in Table 2.3 below. The annual variation between maximum and minimum is about 25 %. Therefore the country has a steady solar radiation which is not seasonal in nature. The only problem is that the rainy and humid climate which means almost half of the sunlight received is diffused, and not direct. Therefore collector systemare not suitable but flat plate systems tilted at an angle equal to the latitude would be effective, [19]. As depicted in Table 2.1 that PV systems would be most effective in the northern part of Peninsular Malaysia and Sarawak, where the insolation levels are higher. PTM's BIPV project has also yielded some interesting data about the annual energy output, kWh/kWp, of different project sites. Figure 2.6 below shows the annual energy output for a number of cities. It can be seen that there is a definite correlation between insolation levels and annual energy output.

Table 2.1: Monthly averaged insolation incident on horizontal surface $kWh/m^2/day$, [19].

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
AlorSetar	5.3	5.9	5.8	5.7	5.1	4.8	4.8	4.7	4.7	4.4	4.2	4.4	4.96
George town	5.6	6.1	5.9	5.7	5.1	4.9	4.9	4.7	4.7	4.5	4.8	5.0	5.15
Kota Baru	5.1	5.9	6.2	6.3	5.5	5.3	5.4	5.3	5.4	4.8	3.9	4.2	5.28
Kuala Lumpur	4.8	5.4	5.4	5.3	5.1	4.9	4.9	4.9	4.9	4.8	4.4	4.2	4.90
Johor Baru	4.5	5.2	5.1	4.9	4.6	4.4	4.3	4.3	4.5	4.6	4.3	4.1	4.55
Kota Kinabalu	5.1	5.8	6.4	6.5	5.8	5.3	5.2	5.2	5.3	5.0	4.8	4.7	5.41
Kuching	3.9	4.4	4.7	5.0	4.9	4.9	4.8	4.9	4.7	4.6	4.5	4.2	4.62

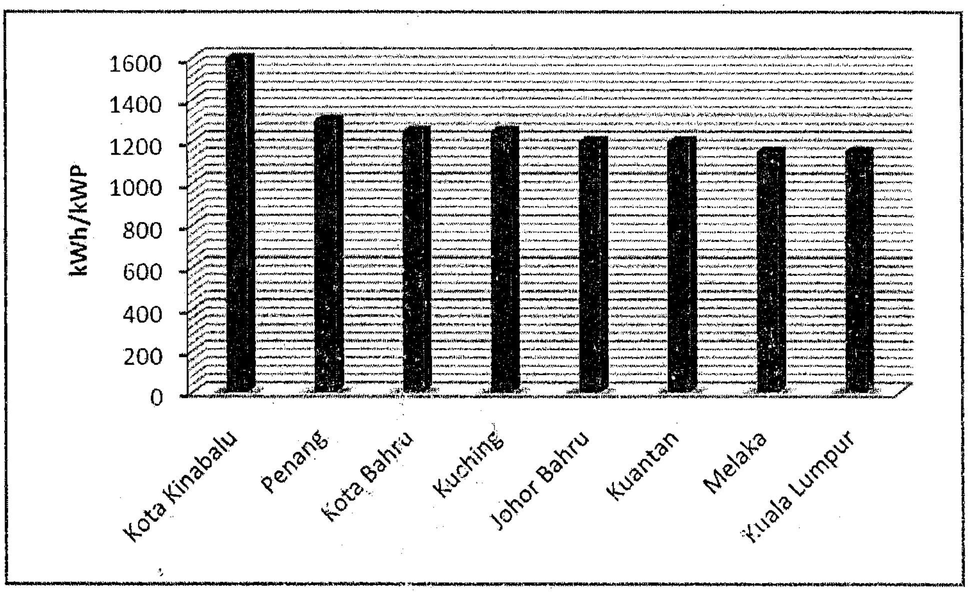


Figure 2.6: Annual energy outputs of rooftop PV installations – Malaysia, [19].

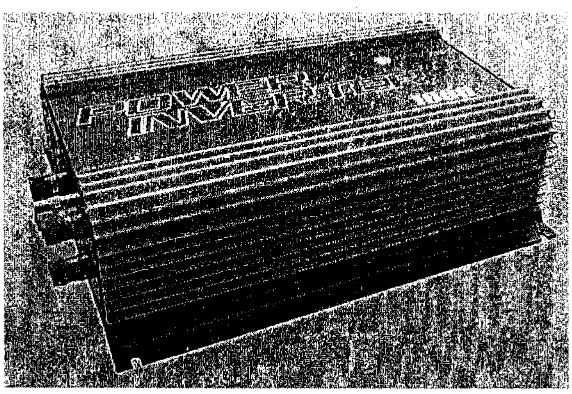
2.7 Solar Inverter

It is a type of electrical equipment that changes the direct current (DC) electricity from a photovoltaic array into alternating current (AC) for use with home appliances and a utility grid.There are several types of solar inverter such as stand-alone inverters, gridtie inverters, and battery backup inverters.

Stand-alone inverter is used in isolated systems where the inverter draws the DC energy from batteries charged by photovoltaic arrays and/or other sources, such as wind turbines, hydro turbines, or engine generators, [17]. Many of the stand-alone inverters also incorporated with integral battery chargers to replenish the battery from an AC source, when available. Normally these schemes do not have interface with the utility grid and anti-islanding protection is not required.

Grid-Tied inverters specially designed to match phase with a utility-supplied sine-wave. Grid-Tied inverters are also designed to shut down automatically upon loss of utility supply, for safety reasons. They do not provide backup power during the utility outages.

Thirdly, battery backup inverters are special converters which are purposely to draw energy from a battery, charging the battery via an onboard charger, and export excess energy to the utility grid. These inverters are capable of supplying AC energy to selected loads during a utility outage, and are required to have anti-islanding protection.



2.8 Types of Solar Cell

2.8.1 Monocrystalline Silicon Solar Cell

Monocrystalline silicon solar cells are actually a one large single crystal of silicon. Currently it is the fastest developing solar cell, the composition and production technology has been finalized in which the products have been widely used for aerospace and ground facilities. Some semiconductor devices can also be used for processing materials and discard ends of silicon materials, solar cells made by redrawing a dedicated silicon rods, [15]. The slice of silicon rods, generally have 0.3 mm thick slices. Wafer after forming, polishing, cleaning and other processes, made of silicon raw material to be processed. Solar cell processing chip, the first doping and diffusion in silicon, usually for the small amount of boron dopant, phosphorus, and antimony. Current silicon photoelectric conversion efficiency of solar cells is about 15% compared to laboratory results which have more than 20 %.

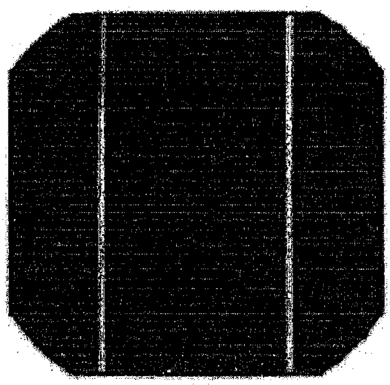


Figure 2.7: Monocrystalline silicon solar cell, [15]

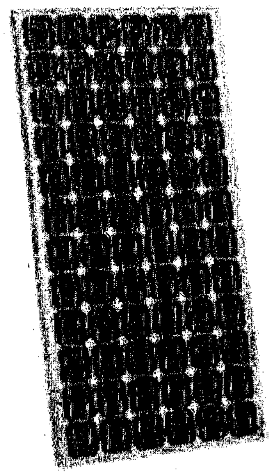


Figure 2.8: Monocrystalline silicon photovoltaic modules, [17]

2.8.2 Polycrystalline Silicon Solar Cell

Polycrystalline is made up from millions or billions of small silicon crystalorsilicon materials from waste materials and metallurgical grade silicon melt molded, [15]. Quartz crucible is installed with poly-silicon materials, the addition of appropriate amount of boron in silicon, release the casting furnace, heating and melting in a vacuum state. Polycrystalline silicon solar cells and solar cell production process is similar to the photoelectric conversion efficiency which is about 12 %, slightly lower than the silicon solar cells. The material is simple and can save power consumption. The total production costs are low. As the technology was improved, the current conversion efficiency of polycrystalline silicon can also be reached around 14 %.

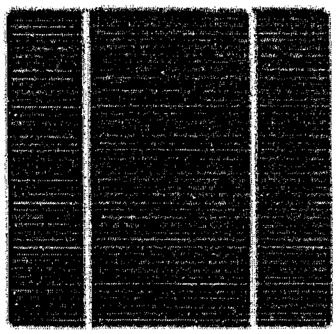


Figure 2.9: Polycrstalline silicon solar cells, [15]

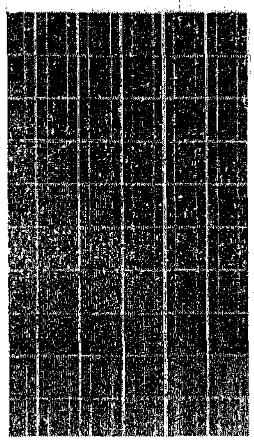


Figure 2.10: Polycrystalline silicon photovoltaic modules, [17]

2.8.3 Amorphous Silicon Solar Cell

The production method of amorphous silicon solar cell is completely different, with very little silicon material consumption and lower power consumption, and very attractive. The glow discharge method is the most common like manufacturing a variety of amorphous silicon solar cells, [18]. The thin amorphous silicon solar cells can be made into laminated type, or use to manufacture integrated circuits in a plane with an appropriate mask technology. A production of multiple batteries in series is applied to obtain higher voltage. The average crystalline silicon solar cells output around is 0.5 V. For example, most of the amorphous silicon production in Japan that brings on to market as solar cells comes with 2.4 V voltage output.

The current challenge is that the amorphous silicon solar cell conversion efficiency is quite low with the international advanced level of about 10 %. The power output is not stable and often decline. Therefore, it is not used in a large-scale solar power. Mostly amorphous PV is used in low light power, such as pocket electronic calculators, electronic watches and clocks and copier. Amorphous silicon solar cells will promote the great development of solar energy, because its low cost, light weight, easier application and it can be combined with the housing of the roof form independent power of households.

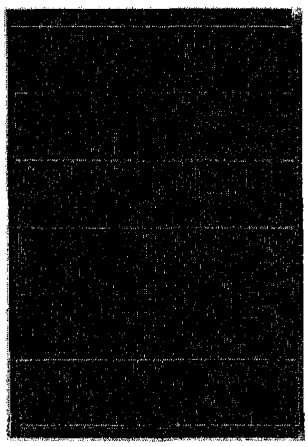


Figure 2.11: Amorphous silicon solar cells, [17]

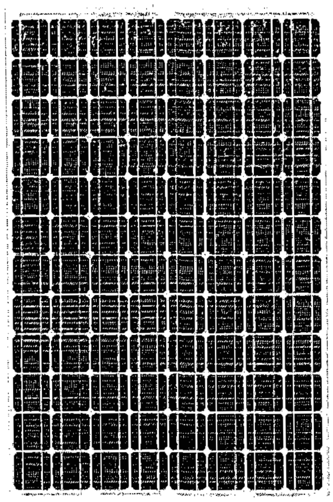


Figure 2.12: Amorphous silicon photovoltaic modules

2.9 DC and AC Current Inverter

In the world today there are currently two forms of electrical transmission, Direct Current (DC) and Alternating Current (AC), each with its own advantages and disadvantages, [19]. DC power is simply the application of a steady constant voltage across a circuit resulting in a constant current. A battery is the most common source of DC transmission as current flows from one end of a circuit to the other. Most digital circuitry today is run off of DC power as it carries the ability to provide either a constant high or constant low voltage, enabling digital logic to process code executions. Historically, electricity was first commercially transmitted by Thomas Edison, and was a DC power line. However, this electricity was low voltage, due to the inability to step up DC voltage at the time, and thus it was not capable of transmitting power over long distances.

$$V = IR \qquad (2.8)$$

$$P = IV = I^2 R \qquad (2.9)$$