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BORANG PENGESAHAN STATUS TESIS[♦]

JUDUL: **ANALYSIS ENERGY DEMAND AND DESIGN OF SOLAR ENERGY IN UMP MOSQUE**
SESI PENGAJIAN: 2009/2010

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MOSQUE

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This thesis is submitted as partial fulfillment of the requirements for the award of the
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Dedicated, in thankful appreciation for support, encouragement and understanding to my beloved mother, father, brothers, sisters, friends and beloved lecturers.

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ABSTRACT

Photovoltaic system is very popular in the renewable energy system. The improvement in the technology itself is very high. The improvement in this technology is to ensure that the system may result in low cost, high performance PV cells, long life time period, and maintenance-free lifetime. Every year engineers make an improvement on the products that have been in existence for many years. The application of this system also was acknowledgement around the world nowadays and this system was applicable in many industries. The application of this system in our country also is very efficient because of our climatic condition is suitable for this system. The most popular application of this system is the application as a supply system for the building. This project is conducted to choose the type of solar module and inverter that can be implemented to UMP mosque. At the end of this project, we will know the suitable solar module and inverter that can be implemented to UMP mosque.

ABSTRAK

Sistem photovoltaic adalah salah satu sistem yang sangat popular di antara system yang ada dalam tenaga baru. Peningkatan dalam segi teknologi dalam sistem ini juga adalah sangat cepat. Peningkatan atau baik pulih dalam sistem ini adalah untuk memastikan bahawa kos bagi sistem ini akan berkurangan dari semasa ke semasa serta untuk mempertingkatkan keupayaan sell PV tersebut, dan juga untuk memastikan bahawa sistem ini tahan lama dan memerlukan kos penjagaan yang rendah. Setiap tahun, jurutera akan membuat pembaharuan terhadap teknologi yang ada untuk memastikan bahawa teknologi ini dapat digunapakai oleh setiap orang suatu hari nanti. Penggunaan teknologi ini juga sudah dikenali diserata dunia dan penggunaannya juga sudah meluas. Teknologi ini juga sangat sesuai digunakan dinegara kita disebabkan oleh keadaan cuaca yang sangat baik. Projek ini dijalankan adalah untuk memilih jenis solar module dan inverter yang boleh digunakan untuk diguna pakai di masjid UMP.. Di akhir projek ini, kita akan dapat mengetahui jenis solar module dan inverter yang sesuai untuk diguna pakai di masjid UMP.

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LIST OF SYMBOL

RE - Renewable Energy

PV - Photovoltaic

UV - Ultra Viole

kWp - Kilo Watt Peak

DC - Direct Current

AC - Alternative Current

H_{tilt} - Global Irradation

η_{inv} - Inverter Efficiency

$\eta_{\text{PV_SS}}$ - Sub-system efficiency

E_{sys} - The average yearly energy yield (real energy) of PV system

P_{α_STC} - Rating PV array at STC

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CHAPTER 1

INTRODUCTION

1.1 Background Of Study

Ever since the industrial revolution, human activities have constantly changed the natural composition of Earth's atmosphere. Concentrations of trace atmospheric gases, nowadays termed "greenhouse gases" are increasing at an alarming rate. The consumption of fossil fuels, conversion of forests to agricultural land and the emission of industrial chemicals are principal contribution factor to air pollution. Under normal atmospheric conditions, energy from the sun controls Earth's weather and climate pattern. Heating of Earth's surface from the sun radiates energy back to the space. This will result the greenhouse effect or global warming.

Global and national scenarios of primary and in particular electrical energy consumption for the coming decades basically all predict a strong increase in technical utilization of renewable energy (RE). A significant increase in the use of RE satisfies the requirements of climate protection and allows suitable growth in energy consumption for newly developed and developing countries. At the same time, the aims to decrease the share of fossil primary energies in the medium and long time, and has the potential to reduce the share of nuclear energy to zero. However, to achieve this goal all RE technologies (hydro power, wind power, biomass, geothermal heat and solar irradiation) have to be mobilized in a balanced way and in coordinated time sequence, which is according to their economic market relevance and their technical potential.

Among RE, solar irradiation will in the long term have to become the main contributor to a global renewable energy supply because of its unlimited potential. Photovoltaic (PV) is favored by its flexibility with respect to size and fields of application, its long life-time and low required maintenance. PV system is a device that mainly used to convert solar energy (which is the utilization of the radiant energy from the sun) to the electricity. Solar power is often used interchangeably with solar energy but refer more specifically to the conversion of sunlight into electricity. Presented of PV technology that used to convert solar energy to the electric energy was acknowledge and used in many countries around the world nowadays.

Photovoltaic (PV) is the technology used to convert the energy directly from the sunlight into electricity by using the solar cell. The photon from the sunlight knock electron into higher energy which will produce electricity. A typical photovoltaic cell produces less than 3 watts at approximately 0.5 volt dc, cells must be connected in series-parallel configurations to produce enough power for high-power applications. The electricity produce are in direct current which can be used to power equipment or to recharge battery. The first application of photovoltaic was used to power up the orbiting satellites and space shuttle. Nowadays, photovoltaic is important in grid-connection generation which required an inverter to convert DC current to AC current.

There are several advantages of PV system and also the factor that can attract people interested using PV system;

- a) System is very durable and not easily damage.
- b) Have a warranty until 20 years and more.(Experts say the panel can last up to 30 years)
- c) Solar energy production is quite.
- d) Payoff point (which mean no need pay monthly bill)

Even there are a lot of advantages of PV system, this system also have several disadvantages;

- a) The production of electricity is uneven throughout the day.
- b) System does not produce electricity at the night or when it is overcast.
- c) Initial cost of installation PV system is very high.

1.2 Problem Statement

There is increasing of interest and activity toward the development and application of alternative/renewable energy such as solar energy, wind turbine and hydropower. In addition, the World Solar Photovoltaic installation/demand has grown consistently over this two decade. There is a difficulty on decision making on designing of the power system. Before designing a power generation plant, there must consider on the type of energy use. For example; to build photovoltaic power to supply electricity to the UMP mosque , the importance thing that the designer must make sure is to choose the suitable solar panel that can be enough to supply electricity based on the power consumption that the used per annual.

Beside that the designer must to choose the suitable inverter that can be match with the solar panel that be used. To determine the suitable solar panel and inverter, the designer must have to get the data for the power consumption that the place used per annual. From this data, the designer must have to make the manual calculation to choose the suitable solar panel module and inverter. This project will consider a new software that can make the calculation more easier.

1.3 Objective

The objectives of this Final Year Report are:

- i. To implement solar energy to UMP mosque.
- ii. To calculate energy demand and analyze the energy demands.
- iii. To design how many solar panel that can be implemented to UMP mosque.
- iv. To develop software for designing solar system.

1.4 Scope Of Work

This project is involved to design the software to make the calculation to choose the solar panel and inverter become easier. The software must be based on the case study to implement the solar panel to the UMP mosque.

To choose the suitable solar panel and inverter that can be implemented to UMP mosque, the data of the power consumption must be get first before can design the suitable software to make the calculation to find and choose the suitable inverter and solar panel that can be implemented to UMP mosque. The data also must be analyzing first before design the software. Lastly, after do all the task, the task to design the software will be start.

1.5 Thesis Outline

This thesis is divided into the following 6 chapters namely:

Chapter 1: Introduction

This chapter discusses on the background of the Solar System of the alternative Energy, Example is the history and advantage of solar system of the renewable energy. Besides that, this chapter also includes the Problem Statement. However, objective and scope of the works is also including in this chapter.

Chapter 2: Literature Review

In this chapter, the issues of renewable energy for the basic of the solar system energy will be discussed. These include the basic operation of the solar system.

Chapter 3: Methodology

Methodology is to discuss the ways or methods use to conduct this Final Year Project. Some of the Tables are shown in this chapter for easier understanding on the Software.

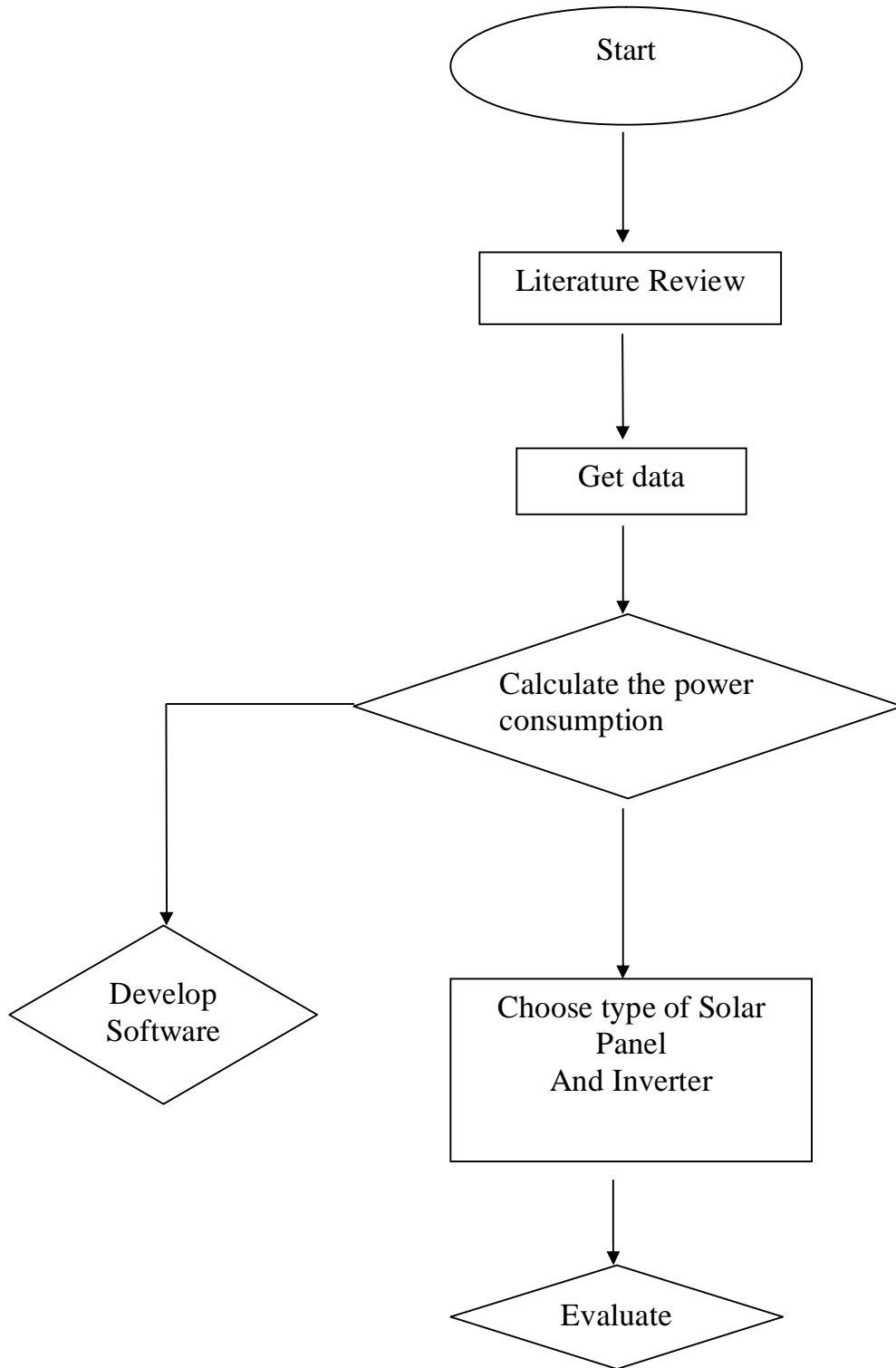
Chapter 4: Result and Discussion

In this chapter, it presents the results and discussion of this project.

Chapter 5: Conclusion and Recommendation

Finally, chapter 5 presents the conclusions of the project and recommendations For future works.

1.6 Summary of Work



CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The energy supply from the sun is truly enormous on the average. The Earth surface receives about 1.2×10^7 W of solar power. This means that in less than one hour enough energy to supply to the Earth to satisfy the entire energy demands of the human pollution over the whole year. The history of PV was start over than 170 years ago when in 1839, Alexandre-Edmund Becquerel observed that electrical currents arose from certain light-induced chemical reactions. A similar effect was observed in a solid (selenium) several decades later. A comprehensive understanding of these phenomena however had to wait the progress of science towards the quantum theory in the early parts of the nineteenth century. The development of the first solid-state devices in the late 1940s then paved the way to the announcement of silicon solar cell with 6% efficiency, this is the first usable solar. In the year 1958, this solar application was used on the Vanguard 1, the first satellite to use electricity from the sun. The year 1960, this application was used widely in space technology as an energy source to the satellite. Solar technology has been developing ever since and the effect from this, the technology has become more sophisticated, more efficiency and the cost also are much lower. Much interest in solar electricity appeared particularly in the wake of the oil crisis in the early 1970s.

Today, the direct conversion of light into electricity or PV is becoming accepted as an important form of power generation.

2.2 Potential of Solar Energy

Malaysia lies in the tropical region between 1°N and 7°N, and 100°E and 119°E. Malaysia is made up of Peninsular Malaysia and the states of Sabah and Sarawak on the island of Borneo. The climate is hot and humid throughout the year with heavy rainfall. Rainfall range is 2032-2540mm, temperature 21-32°C, relative humidity 80-90%, solar radiation 12-20 MJ/m² and wind speed 2-22 m/s. There are approximately 6 hours of sunshine per day.

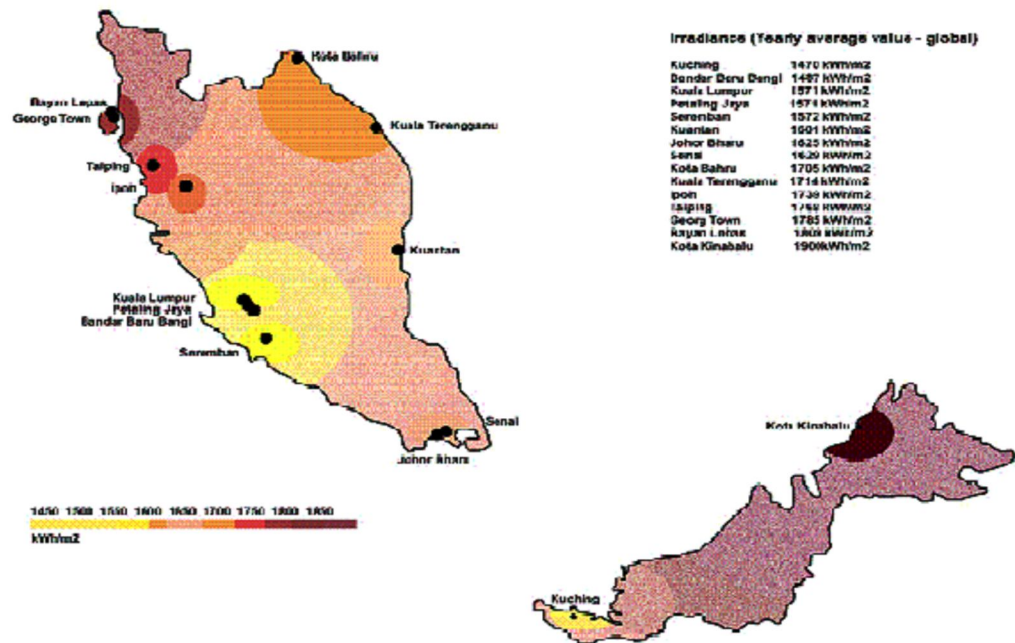


Figure 2.1: Solar Irradiation map of Malaysia

The UV radiation pattern in Malaysia has been divided to five types according to the group of solar radiation research, Universiti Kebangsaan Malaysia:

- i. Sunshine everyday
- ii. Cloud or Rain everyday
- iii. Cloud pattern is not stable everyday
- iv. Rain in the evening
- v. UV radiation is more than UV constant

2.3 General Principle of Photovoltaic System

Solar or photovoltaic (PV), cells are electronic devices that essentially convert the solar energy of sunlight into electric energy or electricity. The physics of solar cells is based on the same semiconductor principles as diodes and transistors. Solar cells convert energy as long as there is sunlight. In the evenings and during cloudy conditions, the conversion process diminishes. It stops completely at dusk and resume at dawn. Solar cells do not store electricity, but batteries can be used to store the energy.

One of the most fascinating aspects of solar cells is the ability to convert the most abundant and free form of energy into the electricity, without moving parts or component and without producing any adverse forms of pollution that effect the ecology, as is associated with most known forms of nonrenewable energy production methods, such as fossil fuel, hydroelectric or nuclear energy plants.

2.4 Type of Photovoltaic Cell

A solar cell is composed of a semiconducting material such as silicon which has electrical conduction properties somewhere between those of metals like silver or copper and insulators like glass and quartz. An electric current in such materials is carried by negatively charged elementary particles, the electron. In semiconductors the energies of these electrons are restricted to energetically separated “energy band”. Important for the understanding of the photovoltaic effect are two bands, the lower lying so-called valence band and the energetically higher lying conduction band. The two bands are energetically separated by a band gap. Under the condition of thermal equilibrium the valence band of a pure semiconductor is practically fully occupied by immobile electrons virtually “sitting” between neighboring semiconductor atoms. To the same extent the conduction band is empty. Under these conditions no electrons can move about freely in the solid and the semiconductor behaves more or less like an electrical insulator.

Understanding of solar cell composition is important to consider before election of type of solar cell. The main objective of research and development (R&D) of solar cell is to increase the energy conversion efficiency and the material of the cell to reduce the cost of the cell. From this continuous R&D, it was produce a lot of type of PV cell with high efficiency and lower cost. Currently, solar cells essentially are manufactured from mono crystalline, polycrystalline, amorphous and thin film based materials.

2.4.1 Monocrystalline Silicon

The heart of this cell is a crystalline silicon semiconductor. This semiconductor is manufactured by a silicon purification process, ingot fabrication, and wafer slicing, etching and doping which finally forms a PNP junction that traps photons, resulting in the release of electrons within the junction barrier, thereby creating a current flow.

This cell has efficiency in the range of 11-18%. This cell also is very stable in chemical structure and is very durable. The advantage of this cell is its efficiency is more than other product but the price is quite high because it was creating from pure silicon material. Figure 2.2 shows the example of monocrystalline silicon module.



Figure 2.2: Monocrystalline Silicon.

2.4.2 Polycrystalline Silicon

In the polycrystalline process, the silicon melt is cooled very slowly, under controlled conditions. The silicon ingot produced in this process has crystalline regions, which are separated by grain boundaries. After solar cell production, the gaps in the grain boundaries cause this type of cell to have a lower efficiency, 9%-13% compared to that of the monocrystalline. Despite the efficiency disadvantage, a number of manufacturers favor polycrystalline PV cell production because of the lower manufacturing cost and fast production electricity. Figure 2.3 shows the example of polycrystalline silicon module.



Figure 2.3: Polycrystalline Silicon.

2.4.2 Polycrystalline Silicon

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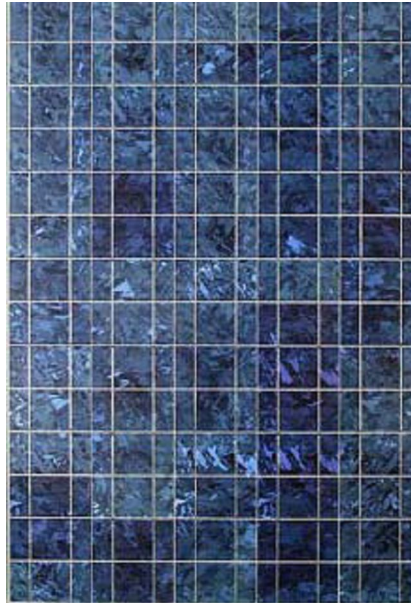


Figure 2.4: Polycrystalline Silicon.

2.4.3 Amorphous Silicon

In the amorphous process, a thin wafer of silicon is deposited on a carrier material and doped in several process steps. An amorphous silicon film is produced by a method similar to the monocrystalline manufacturing process and is sandwiched between glass plates, which form the basic PV solar panel module as shown in Figure 2.5.

Even though the process yields relatively inexpensive solar panel technology, it has the following disadvantages:

- a) Larger installation surface
- b) Lower conversion efficiency
- c) Inherent degradation during the initial months of operation, which continues over the life span of the PV panels

The advantages of this technology are:

- a) Relatively simple manufacturing process
- b) Lower manufacturing cost



Figure 2.5: Amorphous Silicon

2.4.4 Thin-Film Cadmium Telluride

In this process, thin crystalline layers of cadmium telluride (CdTe), this cell has efficiency about 15% and has the ideal bandgap about 1.44eV for a solar absorber material. Otherwise the copper indium diselenide (CIS or CuInSe) has efficiency about 19%. This both cell layer are deposited on the surface of a carrier base. This process uses very little energy and is very economical. It has simple manufacturing processes and relatively high conversion efficiencies. Figure 2.6 and Figure 2.7 shows the example of CdTe and CIS module.



Figure 2.6: Cadmium Telluride.

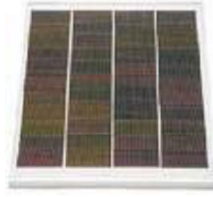


Figure 2.7: Copper Indium Diselenide.

2.4.5 Gallium-Arsenide

This manufacturing process yields a highly efficient PV cell. But as a result of the rarity of gallium deposit and the poisonous qualities of arsenic, the process is very expensive. The main feature of gallium-arsenide (GaAs) cells, in addition to their high efficiency, is that their output is relatively independent of the operating temperature and is primarily used in space programs. Figure 2.8 shows the example of GaAs module.



Figure 2.8: Gallium Arsenide.

2.4.6 Multijunction

This process employs two layers of solar cells, such as silicon (Si) and GaAs component, one on the top of another, to convert solar power with higher efficiency. Staggering of two layers provides trapping of wider bandwidth of solar rays thus

enhancing the solar cell solar energy conversion efficiency. The example of multijunction cell shows in Figure 2.9.

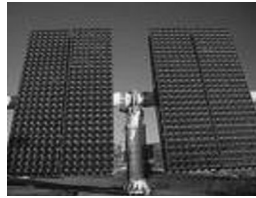


Figure 2.9: Multijunction Cell.

2.5 The Photovoltaic Collector

The PV collector is an assembly of interconnected solar cells which produce DC energy when exposed to sunlight. The Figure 2.10 shows the construction of PV cell. In Figure 2.10, electrical current is generated when sunlight (photons) strikes the N-type semiconductor layer of the cell, dislodging an electron from its energy level. These “free” electrons and the resultant positive charges or “holes” drift in opposite directions through the semiconductor material and are collected at the metallic contacts applied to the front and back surface of the cells.

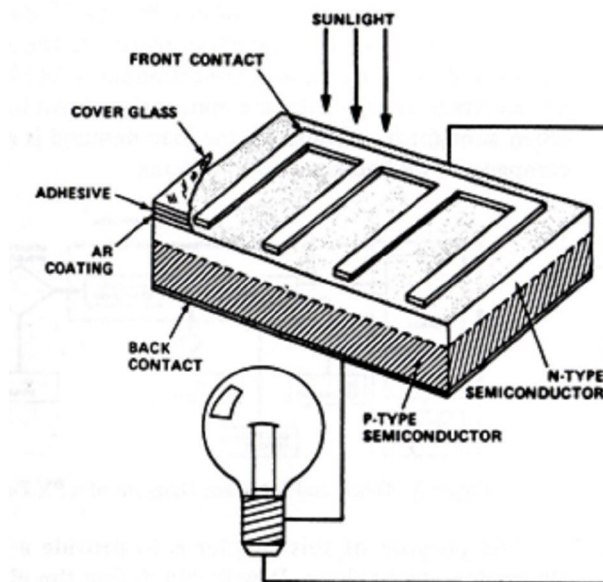


Figure 2.10: PV Cell Construction.

The electrical characteristics of a module or array can be represented using its current-voltage (I-V) relationship; Figure 2.11 shows the characteristic of the module.

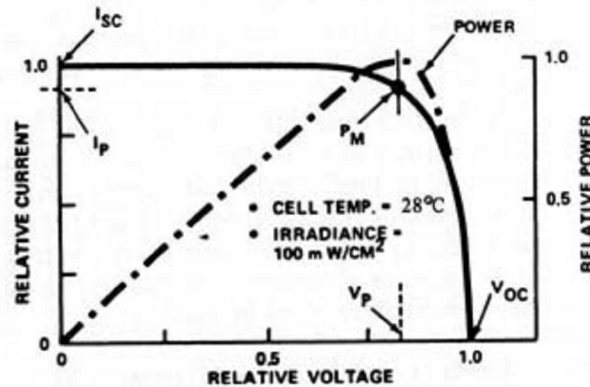


Figure 2.11: Typical I-V Curve for a PV Cell, Module, Panel, or Array.

The standard I-V curve relates the solar cell's output current and voltage from a short circuit (zero resistance) to an open circuit (infinite resistance) condition when the cell is at a standard specified condition or peak rating. This condition is defined as a cell temperature of a 25°C and an irradiance of 100mW/cm² (1000 W/m²).

PV cells are interconnected in series and parallel to form strings at useful voltage and current levels. When cells are put in series, their voltage is additive and when the cells connect in parallel their current is additive. These interconnected solar cells are fabricated into modules to protect the user from possible safety hazards. Typical module construction uses glass for the top cover, an encapsulant over around the cells and a high resistivity polymer back cover for electrical isolation.

2.6 Photovoltaic Cell, Module and Array

PV cells are connected in series and or parallel circuit to produce better output. Meanwhile, PV modules consist of PV cell circuit sealed in an environmental protective laminate and are the fundamental building block of the PV system. Otherwise, the PV panel consists of one or more PV modules assembled as pre-wired, field installable unit. The PV array is the complete power generation unit that consists of any number of PV modules. Figure 2.12 shows the construction of PV array.

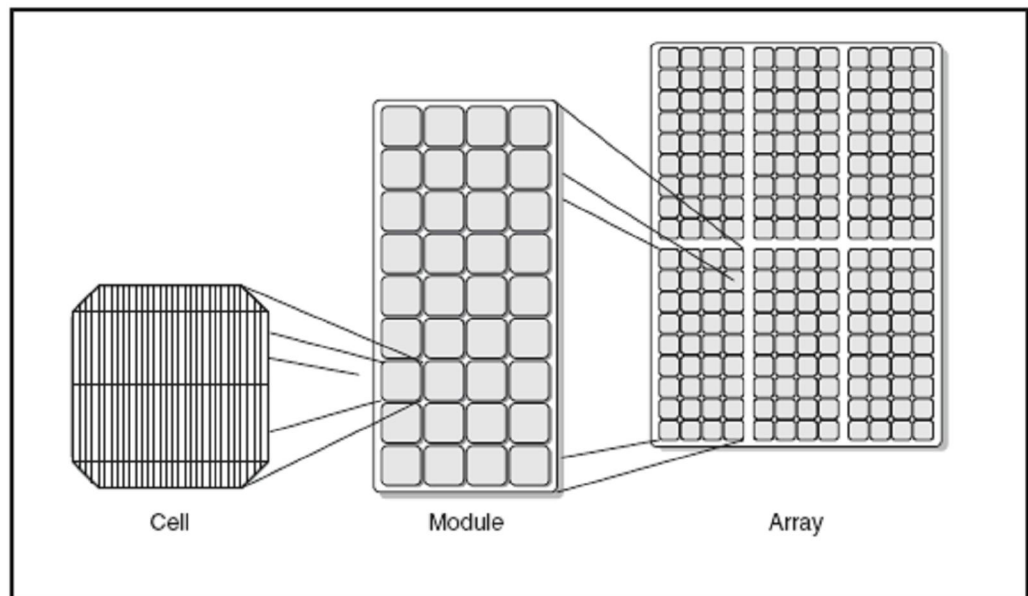


Figure 2.12: PV Cell, Module and Array.

2.7 Types of Photovoltaic System

A photovoltaic system is an integrated assembly of modules and other components that are designed to convert the solar energy into electricity to provide a particular service. There are two main categories of PV system which are standalone and grid-connected systems. This type of system is also divided into several types of systems, which are:

2.7.1 Standalone DC System without Battery

- A standalone PV system consists of the array supplying the load directly. Figure 2.13 shows the connection of the standalone DC system without battery.

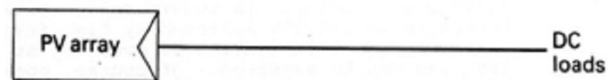


Figure 2.13: Standalone dc system without battery.

2.7.2 Standalone AC System without Battery

- This system uses an inverter to convert the DC source that is produced from the array to an AC supply to make it suitable for AC loads. Figure 2.14 shows the connection of the standalone AC system without battery.

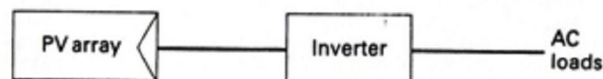


Figure 2.14: Standalone ac system without battery.

2.7.3 Standalone DC System with Battery.

- The storage battery with the charge regulator must be added to supply overnight and during period of low irradiance. Figure 2.15 shows the connection of the standalone DC system with battery.

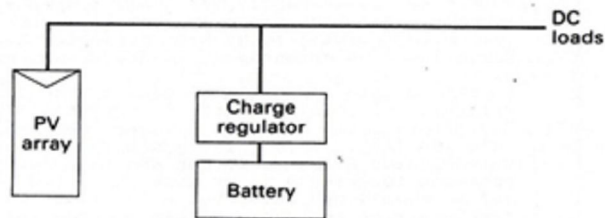


Figure 2.15: Standalone dc system with battery.

2.7.4 Standalone AC/DC System with Battery.

- These systems give a mixed ac/dc system with battery and this type is appropriate for domestic supplies in remote houses and villages. The connection of this system shows in Figure 2.16.

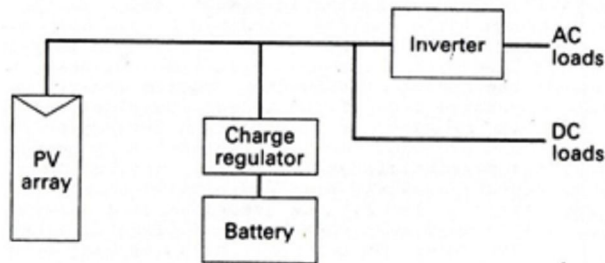


Figure 2.16: Standalone ac/dc System with Battery.

2.7.5 Standalone AC System with Battery and Back-up.

- A backup generator is commonly used to improve the security of the supply. The connection of this system shows in Figure 2.17.

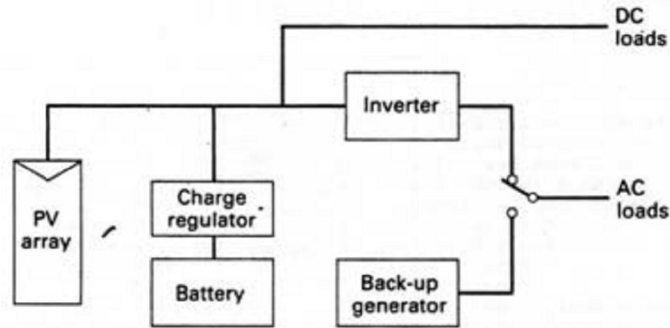


Figure 2.17: Standalone ac system with battery and back-up.

2.7.6 Grid Back-up System.

- This is the basic ac system with self-commutated inverter and grid back-up system. The connection of this system shows in Figure 2.18.

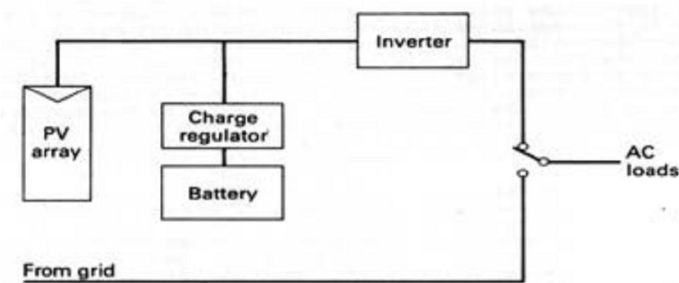


Figure 2.18: Grid back-up system.

2.7.7 Grid Interactive System

- The surplus PV power is fed to the grid through a second inverter which is usually line-commutated. This inverter can also serve as a rectifier for

charging the battery from the grid. The connection of this system shows in Figure 2.19.

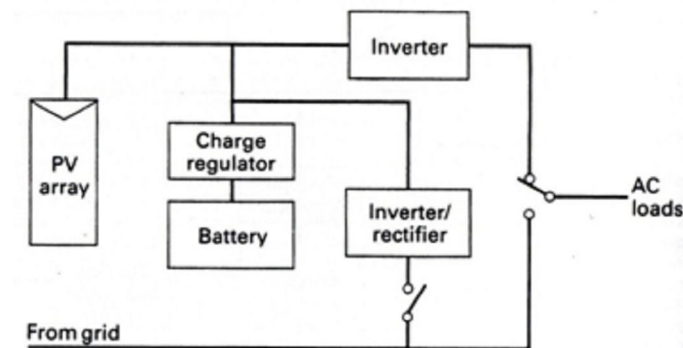


Figure 2.19: Grid interactive system.

2.8 Grid Connected

National Grid, Malaysia is the primary electricity transmission network linking the electricity generation, transmission, distribution and consumption in Malaysia. It was founded on 1959. The first line on the national grid was the transmission line from Tanjung Kling in Melaka to the city of Melaka. It is operated and owned by Tenaga Nasional Berhad (TNB). With this grid connection, renewable energy may connect to grid connection to produce sufficient power.

The voltages for distribution system in Malaysia are 33 kV, 22 kV, 11kV, 6.6 kV and 415/240 volt in distribution network. In Malaysia, the transmission line is mostly using High Voltage Alternating Current (HVAC). However there is a small portion of High Voltage Direct Current (HVDC) connected to Thailand. In the future, there will be a link from Bakun Dam, Sarawak to West Malaysia using submarine HVDC which will be possible completely construct after 2012.

CHAPTER 3

METHODOLOGY

3.1 Introduction.

The methodology of this project consists of several approaches and procedure. In order to complete this project, many aspects has been taken into consideration. The procedure that had been taken is referred from literature review on PV system that discussed in chapter 2. The analysis of UMP mosque was conducted to gather all information about the supply system and energy consumption of this building.

After we calculate the energy consumption using calculation to determine the suitable solar panel and inverter, we must design the programmed that can be use to find the suitable solar panel and inverter automatically.

3.2 Energy consumption at UMP Mosque.

Energy consumption is very important to this project to determine the PV system that suitable to install at UMP Mosque. Figure 3.2 shows the energy consumption at UMP Mosque from January until December. This data was collected from the department of electrical engineering at Office of Asset and Construction UMP based on TNB bill. From the table the total energy consumption is 35339 Watt and the average total power for every month is 2945 Watt. From the graph at figure 3.3, the energy consumption at May and June is lower because during that time the building is not being used due to university vacation.

Month	DATA RECORD		TOTAL
	25/12/2008	25/11/2008	
	STARTING	FINAL	
January	72,157	68,905	3252
February	74,693	72,157	2536
March	77,863	74,693	3170
April	81,261	77,863	3398
May	83,147	81,261	2488
June	85,749	83,147	2602
July	88,662	85,749	3183
August	91,541	88,662	2879
September	96,584	91,541	5043
October	99,275	96,584	2691
November	101,826	99,275	2551
December	104,344	101,826	2581

Figure 3.2: Data for Energy Consumption at UMP Mosque

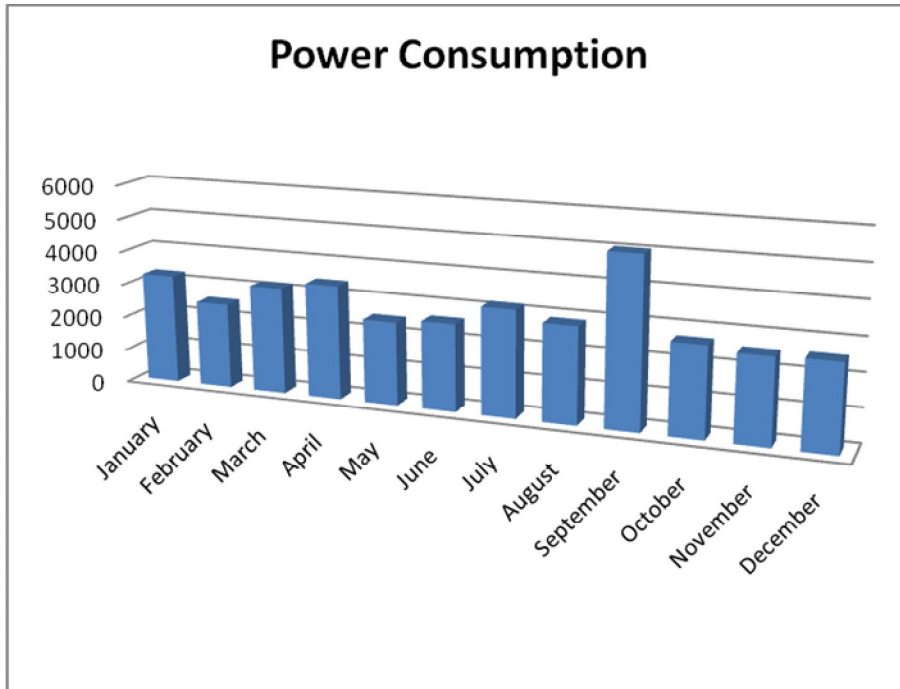


Figure 3.3: Energy Consumption at UMP Mosque

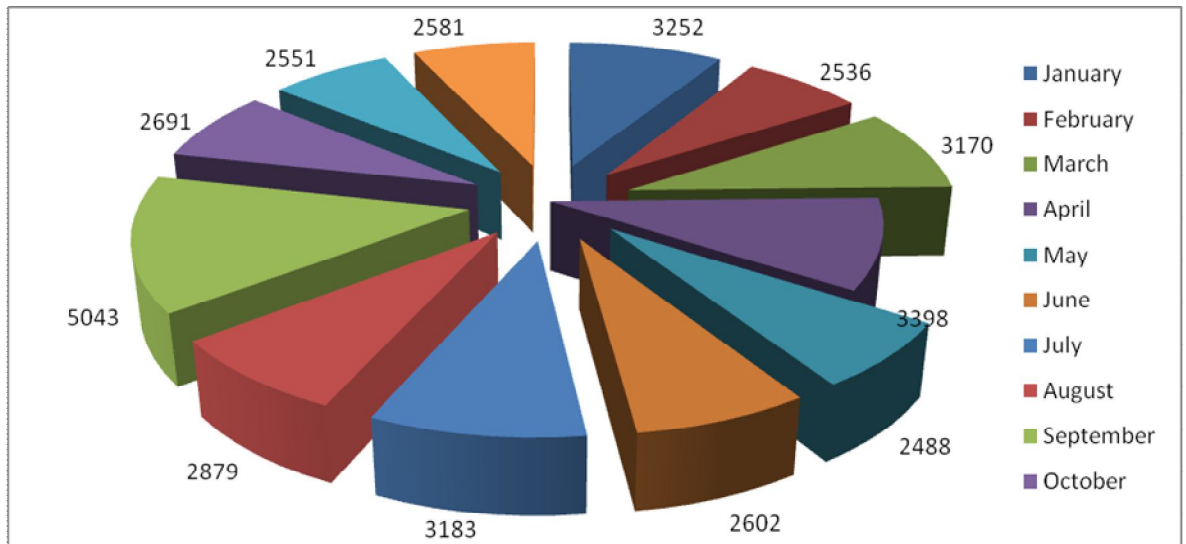


Figure 3.4 Pie Chart Energy Consumption at UMP Mosque

3.3 Photovoltaic System (PV)

Every component in the PV system have their own function and its is very important to ensure that the optimization of energy yield by the system. The function of component are discuss in the Table 3.5 below.

COMPONENT	FUNCTION
PV Module	<ul style="list-style-type: none">• Covert solar radiation to Electricity
Over current Protection	<ul style="list-style-type: none">• For protection the system, this device will function when current produce by the module exceed the setting.
Inverter	<ul style="list-style-type: none">• Convert DC current produce by the module to the AC current.
PV AC Main Switch	<ul style="list-style-type: none">• As a main switch for this PV System
PV Meter	<ul style="list-style-type: none">• This meter are function to shows the energy output from this PV system
TNB Meter	<ul style="list-style-type: none">• This meter will integrate with the PV meter and this meter will shows how much power that used from utility (TNB)

Figure 3.5 Function Of the Component Of PV System.

3.4 Determine the suitable Solar Module and Inverter

3.4.1 Using Manual Calculation

To determine the suitable Solar Module and Inverter that can be implemented to UMP Mosque there are some equation that we must follow. For this project there are some assumption that we must consider:

Inverter efficiency of 96%

Average daily maximum ambient temperature of 30 degrees

Dirt derating of 95 %

Total voltage drop of 3%

Yearly average global irradiation of 1400Kwh

Minimum number of modules required to ensure the customer annual energy usage is completely supplied by the grid connected PV system.

The sub-system efficiency is:

$$\eta_{pv_ss} = \eta_{pv_inv} \times \eta_{inv}$$

The average yearly energy yield (real energy) of the PV system is:

$$E_{sys} = E_{pv} \times \eta_{pv_ss}$$

To get the actual PV array capacity, use:

$$E_{pv} = P_{array} \times H_{tilt}$$

The derated PV array is:

$$P_{array} = P_{a_STC} \times f_{imm} \times f_{dirt} \times f_{temp}$$

$$f_{temp} = 1 - [\gamma_{Pmp} \times (T_{cell_eff} - T_{STC})]$$

$$= 1 - [\gamma_{Pmp} \times ((T_{a_day} + 25) - T_{STC})]$$

The inverter should ideally be between 75% to 85%. We also used the assumption that the temperature used is 75 deg C and 20 deg C. This give the $V_{min_mp} = 25.4V$ and the effective minimum voltage at inverter from the module, $V_{min_eff} = 24.13V$.

Based on the 10% and 5% safety margin, the window for inverter:

$$V_{min_window_allow} = \text{lower threshold} \times 1.1$$

$$V_{max_allow} = \text{upper threshold} \times 0.95$$

$$\text{Minimum number in string} = \frac{V_{min_window_allow}}{24.13V}$$

$$\text{Maximum number in string} = \frac{V_{max_allow}}{43.34V}$$

3.4.2 Using Program based on Visual Basic 6.0

Programmers have undergone a major change in many years of programming various machines. For example what could be created in minutes with Visual Basic could take days in other languages such: as "C" or "Pascal". Visual Basic provides many interesting sets of tools to aid ours in building exciting applications. Visual Basic provides these tools to make our life far more easier because all the real hard code is already written for ours.

With controls like these we can create many applications which use certain parts of windows. For example, one of the controls could be a button, which we have demonstrated in the "Hello World" program below. First create the control on the screen, then write the code which would be executed once the control button is pressed. With this sort of operation in mind, simple programs would take very little code. Why do it like the poor old "C" programmer who would have to write code to even display a window on the screen, when Visual Basic already has this part written for ours.

Even though people tend to say Visual Basic's compiler is far behind the compilers of Pascal and C, it has earned itself the status of a professional programming language, and has almost freed BASIC of the reputation of a children's language. Overall you would class Visual Basic as a Graphics User Interface(GUI). Because as ours draw, our write for the program. This must always be remembered in any kind of creation of a Visual Basic program. All in all, VB is the preferred language of many future programmers. If you want to start programming Windows, and don't know *how* to start, give Visual Basic a shot.

In this project, I choose to used the Visual Basic software to make my programming about the solar calculator. I make this program to make the calculation to chose the suitable inverter and solar module become more easier. In this program there are 3 form where the first form is the home of Solar Calculator, the second form is for the solar module calculation and third form is inverter and last form is form is for power consumption.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter presents the result from the manual calculation and the simulation by using Visual Basic 6.0 Programming. The comparison result from this two way will judge it to make the best choice of the type of solar module and inverter that can be implemented to UMP mosque will be discussed in this chapter.

4.2 Mathematical/manual Calculation.

4.2.1 Solar Module.

Total Power Consumption = 36373 kWh

We make the assumption:

- Global Irradiation, $H_{\text{ciltt}} = 1400 \text{ kWh m}^{-2}$
- Inverter Efficiency, $\eta_{\text{inv}} = 96\%$
- Average daily maximum ambient temperature = 30 degrees
- Total average drop 3%, $\eta_{\text{pv_inv}} = 0.97$
- Sub-system efficiency is:

$$\eta_{\text{pv_ss}} = \eta_{\text{pv_inv}} \times \eta_{\text{inv}}$$

$$= 0.96 \times 0.97$$

$$= 0.9312$$

The average yearly energy yield (real energy) of PV system is:

$$E_{sys} = E_{pv} \times \eta_{pv_{ss}}$$

$$E_{pv} = \frac{36373}{0.9312}$$

$$= 39060.4 \text{ kWh p.a}$$

Actual PV array capacity:

$$E_{pv} = P_{array} \times H_{tilt}$$

$$P_{array} = \frac{39060.4}{1400}$$

$$= 27.9 \text{ kW}$$

Derated PV array is:

$$P_{array} = P_{a_STC} \times f_{mm} \times f_{dirt} \times f_{temp}$$

$$f_{temp} = 1 - [\gamma_{mp} \times ((T_{a_day} + 25) - T_{STC})]$$

$$= 1 - \left[\frac{0.5}{100} \times ((30 + 25) - 25) \right]$$

$$= 0.85$$

Rating PV array at STC is:

$$P_{a_STC} = P_{array} \div (f_{mm} \times f_{dirt} \times f_{temp})$$

$$= \frac{27900}{0.95 \times 0.95 \times 0.85}$$

$$= 36\,369.6 \text{ W}_p$$

$$\approx 36\,370 \text{ W}_p$$

We make the comparison between the model on the database based on the value of P_{a_STC} that we make. But in the database, we must look the maximum power output. On this project I have choose 4 model to look the different if we used the different model and to look what will happen if we choose different model.

- Hirler VAEPLAN GMBH (VAEPLAN F SOLAR 408 Dachbauteil)
Maximum power output = 408 Watt

$$\frac{36\,370}{408} = 89.14 \text{ round up to 90 modules}$$

- Bharat Heavy electric (L1270) Maximum power output = 270 Watt

$$\frac{36\,370}{270} = 134.70 \text{ up rounds to 135 modules}$$

- First Solar GMBH (F275) Maximum power output = 275 Watt

$$\frac{36\,370}{275} = 134.70 \text{ up rounds to 135 modules}$$

- Zytech Solar (ZT 200S) Maximum power output = 200 Watt

$$\frac{36\,370}{200} = 181.85 \text{ up rounds to 182 modules}$$

Based on the comparison that I make, I can said that if we choose the VAEPLAN model it can make we used only 90 modules. It can make we not have large space to installed the PV solar module compare to other model. From the calculation also I can make the conclusion that if we want to choose the solar module, we must look at the maximum power output and must choose the large value of power output if our power consumption is large to make we save the space for installation. So the best choose of solar module for UMP Mosque is Hirler VAEPLAN GMBH (VAEPLAN F SOLAR 408 Dachbauteil).

4.2.2 Inverter

Inverter should ideally between 75% to 80 % from the value of the Rating PV array at STC. From the result that we get from the solar module calculation the value of Rating PV array at STC is 36 370 W_p , so the ideally inverter for this solar module is between 25.7 kW to 27.4 kW. From the inverter database I have choose 4 type of model for the inverter to compare where the best inverter that can be used.

- Solar Konzept Hauk (SKN 406) Power output = 30 kW
 - Lower Threshold = 300V
 - Upper Threshold = 450V
- Sputnik Engineering AG (SolarMax 30C) Power output = 30 kW
 - Lower Threshold = 430V
 - Upper Threshold = 800V
- ACE Ingenieur-Team GbR (ACE 3001) Power output = 30 kW

- Lower Threshold = 300V
- Upper Threshold = 420V
- Power Solutions Australia (SGI-30-260-3) Power output = 30 kW
 - Lower Threshold = 240V
 - Upper Threshold = 360V

From the database the best inverter model that can be implemented to UMP mosque is from the model SGI-30-260-3. This model has been choose because the lower threshold than the others. From this calculation we can said that we must choose the lower threshold to choose the suitable model.

$$V_{amp_cell_eff} = V_{m_STC} - [\gamma_{mp} \times (T_{cell_eff} - T_{STC})]$$

$$= 33 - [0.152 \times (75-25)]$$

$$= 25.4 \text{ V}$$

$$V_{min_eff} = 0.95 \times 25.4$$

$$= 24.13 \text{ V}$$

$$V_{oc_cell_eff} = V_{oc_STC} - [\gamma_{oc} \times (T_{cell_eff} - T_{STC})]$$

$$= 42.6 - [0.148 \times (20-25)]$$

$$= 43.34 \text{ V}$$

For the safety we must consider on the 10% and 5% safety margin, the window inverter:

$$V_{window_lower} = 240 \times 1.1$$

$$= 264 \text{ V}$$

$$V_{\max} = 360 \times 0.95$$

$$= 342 \text{ V}$$

This will allow min number of string:

$$\frac{264 \text{ V}}{43.34} = 6.09 \text{ up to 7 modules}$$

And a maximum number in the string is:

$$\frac{342}{24.13} = 14.17 \text{ up to 14 modules}$$

So I have choose to put 10 parallel string of 9 module to make sure the solar module can supply the enough voltage based on the value Rating PV array at STC is 36 370 W_p . Total power from the 10 parallel string of 9 module is :

$$90 \times 408 = 36\,720 \text{ } W_p$$

4.3 Visual Basic Programming

4.3.1 Home of the Program

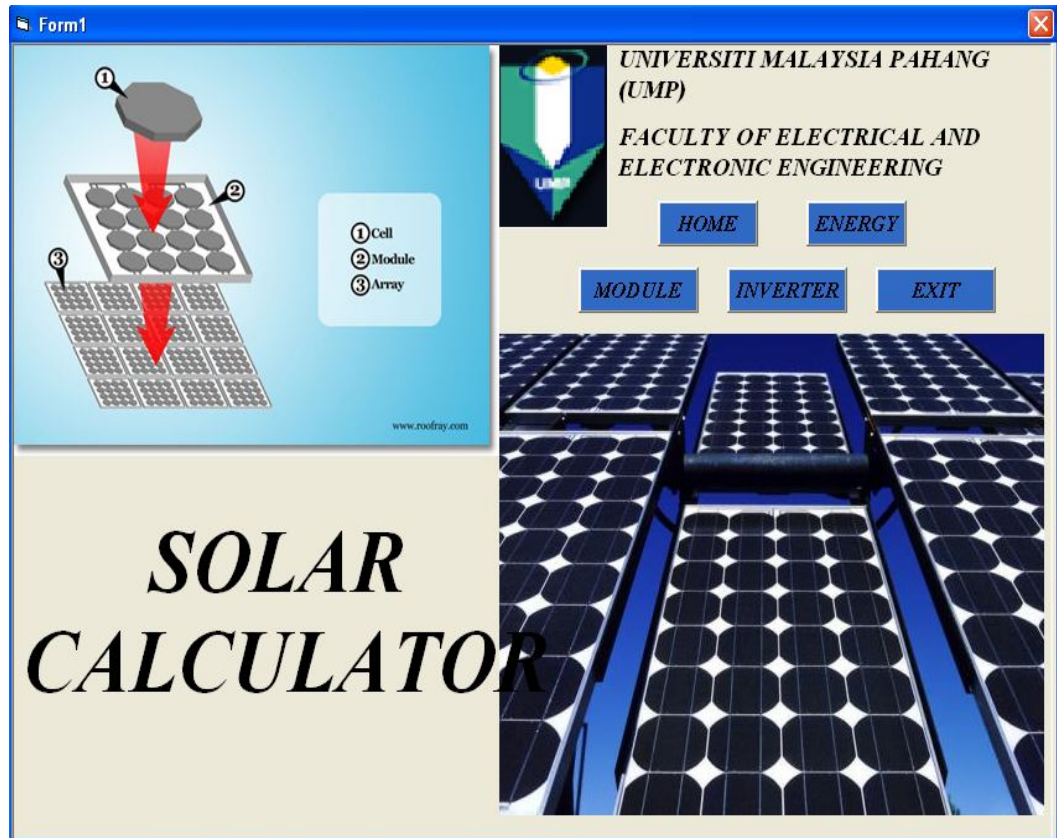


Figure 4.1 Home of the Programming

From this home the user can choose what the calculation that they want the program to calculate. If the user want to calculate the energy or module, the user just have to click the button and the program will go to the form and make the calculation.

4.3.2 Power Consumption

The screenshot shows a web form titled "POWER CONSUMPTION" with a blue header bar. The form is set against a light beige background. It features input fields for each month of the year, with values already entered. Below the monthly inputs, there are two summary fields: "Energy used for half of the year" and "Total Energy Consumption". At the bottom, there are three buttons: "HOME", "CALCULATE", and "SOLAR MODULE".

Month	Value
January	3252
February	2536
March	3170
April	3398
May	2488
June	2602
July	3183
August	2879
September	5042
October	2691
November	2551
December	2581
Energy used for half of the year	17446
Total Energy Consumption	36373

Figure 4.2 The page for the Power Consumption.

For this page the user can calculate easily the value of the power consumption that they used based on the TNB bill. From this page also, the user will also know the value of energy usage for the half of the year. From this result of the total power consumption, the user will go further to the main point to find the suitable solar module and the inverter.

4.3.3 Solar Module

SOLAR CALCULATOR

Power Consumption Per Annual (Kwh):

Total PV array at STC :

CALCULATE TOTAL PV ARRAY

Type of Model:

Maximum Power Output:

Total Module :

CALCULATE SOLAR MODULE

HOME **INVERTER**

Figure 4.3 The page of the solar module.

From this program the user must fill in the value of the power consumption and if the user does not enter the value the combo box will be shown to make sure the user fill in the power consumption box. After the value is fill in the program will calculate the total PV array first and after that the user must choose the type of the model that they want to use and the program will show the maximum power output for every model that have in the database. The user can make a comparison based on the different type of model to make a best choice. After that the result for the total module that the user must have will be shown in the box of the total module.

4.3.4 Inverter

The screenshot shows a software window titled "Form3" with a blue title bar. The main content area has a light beige background and is titled "INVERTER" in blue, italicized font. The form contains several input fields and buttons:

- Total PV array at STC :** Input field with value "36370".
- Value Of Inverter :** Input field with value "27277.5" and "to 29096".
- CALCULATE INVERTER** button.
- Type Of Inverter :** Input field with value "SGI-30-260-3" and navigation arrows.
- Upper Threshold:** Input field with value "360".
- Lower Threshold:** Input field with value "240".
- CALCULATE STRING** button.
- Vmin:** Input field with value "342".
- Vmax :** Input field with value "264".
- Minimum String:** Input field with value "6.09137055837563".
- Maximum String:** Input field with value "14.1732283464567".
- Navigation buttons: **HOME**, **BACK**, and **EXIT**.

Figure 4.4 The page for the inverter.

From this form the user must fill in the value of the total PV array at STC before the program can run. If the user does not fill it the combo box will be shown to make sure the user has fill in the input box. After that the program will be run and the value will be shown and the user will be choose the type or model of inverter that they want to use. The user can make a comparison same as the solar module to make sure the user make a best choice. The program will be shown the value of the lower and upper threshold based on the choice of the model. Lastly the program will make the calculation to user to make sure the user can know the minimum and maximum voltage and also the minimum and maximum string that can be used in per module to make sure the total of the power is more that the value of the total PV array.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion.

The result from the analysis has shown that the total solar module and the type of inverter that we must choose to implement the solar module in the UMP mosque is Hirler VAEPLAN GMBH (VAEPLAN F SOLAR 408 Dachbauteil) for solar module and Power Solutions Australia (SGI-30-260-3) for inverter. From the result also we can make the conclusion that if we want to choose the type of solar module we must know the Rating PV array at STC first before we can make the choice of solar module. If the Rating PV array at STC is high, we must choose the suitable power output to save a space to install the solar module. The more higher of power output the more small quantity of solar module that we can install. This will also cut the cost to install it.

From the result also, we can make a summary that the best type of inverter is between 75% to 80 % from the value of the Rating PV array at STC. We must also look the value of lower threshold of the inverter because more lower the lower threshold the more efficient the inverter. For safety we must consider on the 10% and 5% safety margin on our calculation to choose the model of the inverter.

From the power consumption that we get, we can make a conclusion that the UMP have to paid so much money to TNB for only mosque not include the other building in the UMP campus. So the best way to decrease the power consumption is to use solar module system that can make we save money for the cost of electrical.

If this analysis are discussed in short term, the PV system of course is not suitable to install in UMP mosque building because the price is very high compared to utility. But in a long term period this system are very applicable because of the price of this system is become lower. Meanwhile for the utility cost, the price become higher because of the increasing of the electricity generation cost.

Every years, engineer make improvements on the product that have been in existence for many years in order to give the high performance PV cell, and also the lower cost. Figure 5.1 below shows that the prediction of generation cost of PV electricity. While Figure 5.2 shows the demand for the solar system.

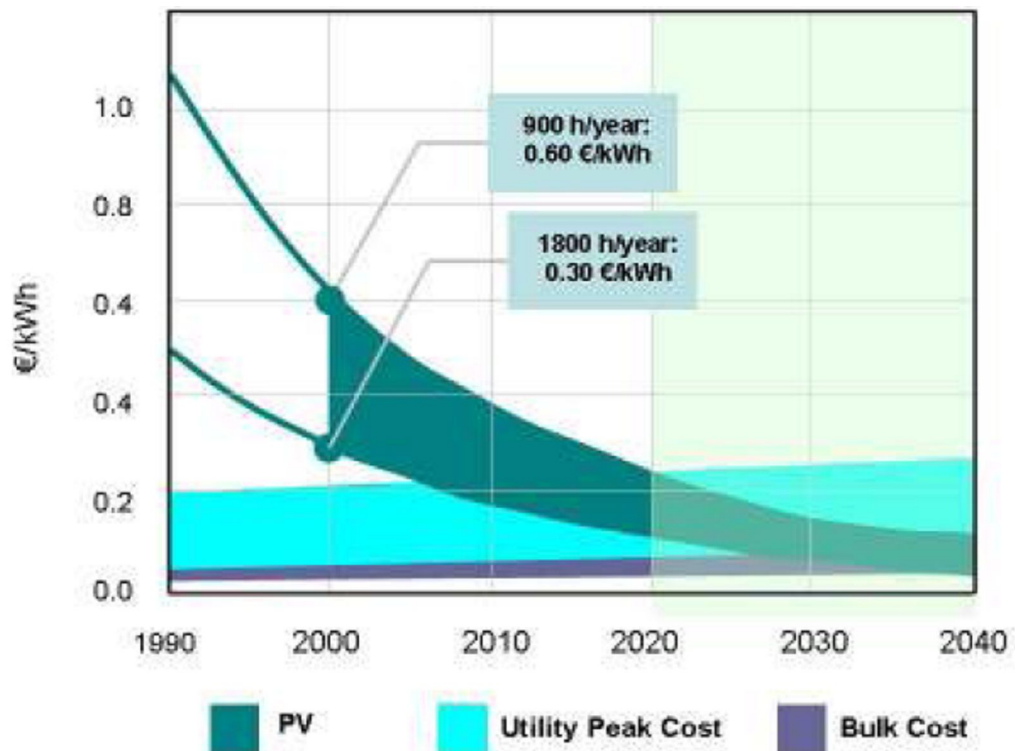


Figure 5.1: Prediction of Generation Cost of PV Electricity

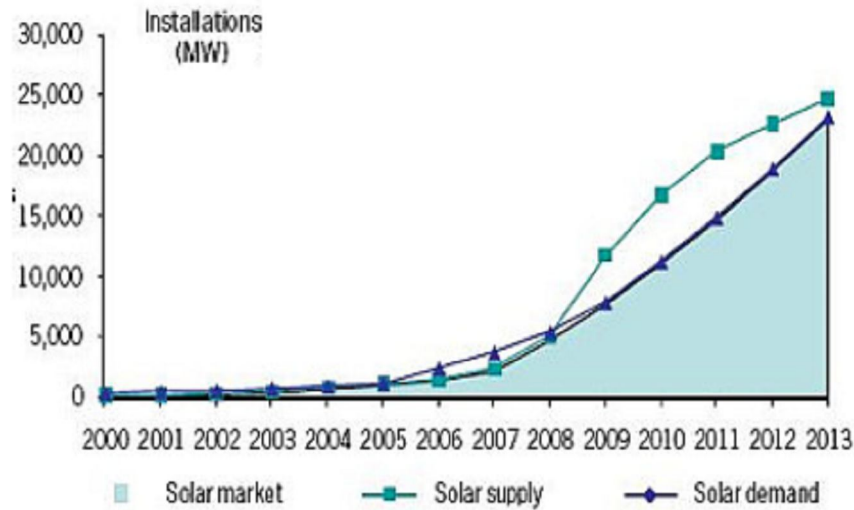


Figure 5.2: Demand for the Solar System.

5.2 Recommendations

There are some recommendation for the future research in order to improve and upgrade the existing project which includes:

- a) Develop the PV system calculator using the other software like a Matlab and also by using the Microsoft excel.
- b) Identify the exact climatic data for the location that need to do the PV system installation to ensure that the result gathered are more accurate.
- c) Conduct the analysis using the different type of the PV system software and compare the result.

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APPENDIX A

Solar Module Database

solarModule		
Model	Brand	MaxPowerOutput(watt)
210PIIIH	CNPV Power	210
220PIIIH	CNPV Power	220
230PIIIH	CNPV Power	230
A-10	ATERSA	10
A-120	ATERSA	120
A-130	ATERSA	130
A-20	ATERSA	20
A-38	ATERSA	38
A-60	ATERSA	60
AC-125P	Axitec/Krannich Solartechn	125
AC-157 P	Axitec/Krannich Solartechn	157
AC-160 P	Axitec/Krannich Solartechn	160
AC-185 P	Axitec/Krannich Solartechn	185
AC-190 P	Axitec/Krannich Solartechn	190
AC-195 P	Axitec/Krannich Solartechn	195
AC-200 P	Axitec/Krannich Solartechn	200
AC-260 P	Axitec/Krannich Solartechn	260
Advent 160	Advent Solar	160
Advent 165	Advent Solar	165
Advent 170	Advent Solar	170
Advent 175	Advent Solar	175
Advent 180	Advent Solar	180
aleo S03 135 Wp	aleo solar GmbH	135
aleo S03 140 Wp	aleo solar Gmb	140
aleo S03 145 Wp	aleo solar Gmb	145
aleo S03 160 Wp	aleo solar GmbH	160
aleo S17 170 W	aleo solar Gmb	170
aleo S17 180 Wp	aleo solar Gmb	180
aleo S17 185W	aleo solar Gmb	185
aleo S17 190W	aleo solar Gmb	190
aleo S17 195 W	aleo solar Gmb	195
aleo S17 200 W	aleo solar Gmb	200
APi-055-G (Gecko Tile)	Astro Power	55
APi-100	Astro Power	100
APi-110	Astro Power	110
APi-165	Astro Power	165
APx-045	Astro Power	45
AS Anteres P (225Wp)	AS Solar	225
AS Anteres P (230Wp)	AS Solar	230
AS Celeano M (200Wp)	AS Solar	200
AS Seginus P (235Wp)	AS Solar	235

solarModule		
Model	Brand	MaxPowerOutput(watt)
ATF 36	ANTEC Solar GmbH	36
ATF 43	ANTEC Solar GmbH	43
ATF 50	ANTEC Solar GmbH	50
AZUR P 170-3	Azur Solar GmbH	170
AZUR P 200-3	Azur Solar GmbH	200
AZUR P 205-3	Azur Solar GmbH	205
AZUR P 210-3	Azur Solar GmbH	210
AZUR P 215-3	Azur Solar GmbH	215
BP 3125S	BP Solar	125
BP 3150S	BP Solar	150
BP 3160N	BP Solar	160
BP 3165N	BP Solar	165
BP 3185N	BP Solar	185
BP 3210N	BP Solar	210
BP 3220N	BP Solar	220
CS6P-200W	Canadian Solar Inc.	200
CS6P-210W	Canadian Solar Inc.	210
CS6P-220W	Canadian Solar Inc.	220
CS6P-230W	Canadian Solar Inc.	230
Day4 48MC 165	DAY4 SYSTEMS GmbH	165
Day4 48MC 170	DAY4 SYSTEMS GmbH	170
Day4 48MC 175	DAY4 SYSTEMS GmbH	175
Day4 48MC 180	DAY4 SYSTEMS GmbH	180
Day4 48MC 185	DAY4 SYSTEMS GmbH	185
Day4 48MC 190	DAY4 SYSTEMS GmbH	190
eco line 72 LX-155M	Luxor Solar GmbH	155
eco line 72 LX-165M	Luxor Solar GmbH	165
eco line 72 LX-170M	Luxor Solar GmbH	170
eco line 72 LX-175M	Luxor Solar GmbH	175
eco line 72 LX-180M	Luxor Solar GmbH	180
ecoPv EPV-1250-M-R-150W	ecoTec Energy	150
ecoPv EPV-1250-M-R-155W	ecoTec Energy	155
ecoPv EPV-1250-M-R-160W	ecoTec Energy	160
ecoPv EPV-1250-M-R-165W	ecoTec Energy	165
ecoPv EPV-1250-M-R-170W	ecoTec Energy	170
ecoPv EPV-1250-M-R-175W	ecoTec Energy	175
ecoPv EPV-1250-M-R-180W	ecoTec Energy	180
ecoPv EPV-1250-M-R-185W	ecoTec Energy	185
EGM 170	Eing	170
EGM 175	Eging	175
EGM 180	Eging	180
Elara P165	aimex-solar GmbH	165
Elara P170	aimex-solar GmbH	170
Elara P175	aimex-solar GmbH	175
Elara P180	aimex-solar GmbH	180
Elara P185	aimex-solar GmbH	185

solarModule		
Model	Brand	MaxPowerOutput(watt)
ET-M572150	ET Solar	150
ET-M572160	ET Solar	160
ET-M572165	ET Solar	165
ET-M572170	ET Solar	170
ET-M572175	ET Solar	175
ET-M572180	ET Solar	180
FC130GX-2P	Kyocera Fineceramics	130
FS-265	First Solar GmbH	265
FS-267	First Solar GmbH	267
FS-270	First Solar GmbH	270
FS-272	First Solar GmbH	272
FS-275	First Solar GmbH	275
GP 120	BIC	120
GP 40	BIC	40
GP 65	BIC	65
GP 75	BIC	75
GSD 100	GermanSolar AG	100
GSM6 185	GermanSolar AG	185
GSM6 195	GermanSolar AG	195
GSP6 170	GermanSolar AG	170
GSP6 175	GermanSolar AG	175
GSP6 180	GermanSolar AG	180
GSP6 185	GermanSolar AG	185
HIP-205NKHE1	Sanyo Energy Corporate	205
HIP-210NKHE1	Sanyo Energy Corporate	210
HIP-215NKHE1	Sanyo Energy Corporate	215
HIP-220HDE1	Sanyo Energy Corporate	220
HIP-225HDE1	Sanyo Energy Corporate	225
HIP-230HDE1	Sanyo Energy Corporate	230
HS-PL 125	Heckert-Solar	125
HS-PL 135	Heckert-Solar	135
Kalysto P170	aimex-solar GmbH	170
KC175GH-2P	Kyocera Fineceramics	175
KPV PE 195 NSP	KIOTO Photovoltaics GmbH	195
KPV ME 210 E6M+	KIOTO Photovoltaics GmbH	210
L1210	Bharat Heavy Electricals	210
L1235	Bharat Heavy Electricals	235
LI270	Bharat Heavy Electricals	270
LPB 130 M (120 Wp)	FiveStarEnergy	120
LPB 130 M (125 Wp)	FiveStarEnergy	125
LPB 130 M (130 Wp)	FiveStarEnergy	130
LPB 130 M (135 Wp)	FiveStarEnergy	135
LPP 125-120	MSK Corporation	120
LPP 155-170	MSK Corporation	170
LPS 125-135	MSK Corporation	135
MegaSlate Laminat 1316*975	3S Swiss Solar System	148

solarModule		
Model	Brand	MaxPowerOutput(watt)
mono		
MegaSlate Laminat 1316*975 poly	3S Swiss Solar System	136
NE-80E2E	SHARP Corporation	80
NE-L5E2E	SHARP Corporation	125
NE-Q5E3E	SHARP Corporation	165
Peak On P220-60(210Wp)	a2peak	210
Peak On P220-60(215Wp)	a2peak	215
Peak On P220-60(220Wp)	a2peak	220
Peak On P220-60(225Wp)	a2peak	225
Peak On P220-60(230Wp)	a2peak	230
Powermax Plus 150-C	Shell Solar GmbH	150
Powermax Plus 160-C	Shell Solar GmbH	160
Powermax Ultra 155-C	Shell Solar GmbH	155
Powermax Ultra 175-C	Shell Solar GmbH	175
PS 170-5M	PerfectSolar GmbH	170
PS 215-6P	PerfectSolar GmbH	215
PS 220-6P	PerfectSolar GmbH	220
PS 225-6P	PerfectSolar GmbH	225
PVT-100AE-A	PVT Austria Photovoltaik Technik GmbH	100
PVT-200AE-A	PVT Austria Photovoltaik Technik GmbH	200
SPR-210-WHT	SunPower	210
SPR-230-WHT	SunPower	230
Uni-Solar SSR-128	Bekaert ECD Solar	128
Uni-Solar SSR-192	Bekaert ECD Solar	192
Uni-Solar SSR-256	Bekaert ECD Solar	256
VAEPLAN F Solar 408 Dachbauteil	Hirler VAEPLAN GmbH	408
VAEPLAN V Solar 272	Hirler VAEPLAN GmbH	272
ZT 200S	Zytech Solar	200
ZT 205S	Zytech Solar	205

APPENDIX B

Inverter Database

inverter				
Model	Brand	LlowerThreshold (V)	UpperThreshold (V)	PowerOutput (Kw)
"SI 5000"	Delta Energy Systems	150	450	5
ACE 1001	ACE Ingenieur-Team GbR	300	420	12
ACE 2001	ACE Ingenieur-Team GbR	300	420	20
ACE 2501	ACE Ingenieur-Team GbR	300	420	25
ACE 3001	ACE Ingenieur-Team GbR	300	420	30
ACE 4001	ACE Ingenieur-Team GbR	300	420	40
ACE 4501	ACE Ingenieur-Team GbR	300	420	45
ACE 5001	ACE Ingenieur-Team GbR	300	420	50
ACE 8001	ACE Ingenieur-Team GbR	300	420	80
AT 5000	Sunways AG	150	600	5
BWR 2500	Bahrmann GmbH	330	550	2
Conergy IPG 110k	Conergy AG	493	780	100
Conergy IPG 280k	Conergy AG	493	780	250
Conergy IPG 60k	Conergy AG	493	780	54
convert 6T	Solar-Fabrik AG	180	850	5
DEW 20	Grosse Elektrotechnik	360	750	2
EVO 2000 - Slave	Philips Lighting B.V.	80	420	2
FRONIUS IG Plus 100-1	Fronius International	230	500	8
FRONIUS IG Plus 120	Fronius International	230	500	10
FRONIUS IG Plus 150	Fronius International	230	500	12
FRONIUS IG Plus 50	Fronius International	230	500	4
FRONIUS IG300	Fronius International	210	420	24
FRONIUS IG400	Fronius International	210	420	32
FRONIUS IG500	Fronius International	210	420	40
Gridfit 30	EXENDIS	125	800	27
Ingecon Sun 10 LV	Ingeteam S.A.	330	750	10

inverter				
Model	Brand	LlowerThreshold (V)	UpperThreshold (V)	PowerOutput (Kw)
Ingecon Sun 100	Ingeteam S.A.	405	750	100
Ingecon Sun 20	Ingeteam S.A.	405	750	20
Ingecon Sun 25	Ingeteam S.A.	405	750	25
Ingecon Sun 5	Ingeteam S.A.	125	450	5
Ingecon Sun 60	Ingeteam S.A.	405	750	60
Ingecon Sun 70	Ingeteam S.A.	405	750	70
Ingecon Sun 80	Ingeteam S.A.	405	750	80
Ingecon Sun 90	Ingeteam S.A.	405	750	90
NEG 4	UfE GmbH	54	90	4
NT 10000	Sunways AG	420	800	10
PAC 1 - 3	Oelmaier Technology GmbH	330	600	3
PAC 1 - 5	Oelmaier Technology GmbH	330	600	5
PAC 2 S	Oelmaier Technology GmbH	200	600	2
PAC 4 S	Oelmaier Technology GmbH	220	600	4
PESOS PVI 2300T	PAIRAN elektronik	125	400	2
PESOS PVI 3500	PAIRAN elektronik	125	400	3
PIKO 5.5	Kostal	180	850	5
Powador 25000xi-park	KACO Gerätetechnik	350	600	25
Powador 8000xi	KACO Gerätetechnik	350	600	8
PT 30k	Sunways AG	420	800	30
PVI 2600-2,0	KACO Gerätetechnik	350	600	2
PV-PN06B3	Mitsubishi Electric Corporation	115	350	5
PVUP 10 000-120	Sun Power Solartechnik	145	300	10
PVUP 15 000-120	Sun Power Solartechnik	218	400	15
PVUP 20 000-240	Sun Power Solartechnik	290	550	20
PVUP 5000-120	Sun Power Solartechnik	145	300	4
PW 4201	HelioTec	350	600	4
REFUSOL 11K	REFU Elektronik GmbH	250	850	11
REFUSOL 15K	REFU Elektronik GmbH	250	850	15
SGL-10-110	Power Solutions Australia	105	155	10
SGL-30-260-3	Power Solutions Australia	240	360	30
SGL-5-110	Power Solutions	105	155	5

inverter				
Model	Brand	LlowerThreshold (V)	UpperThreshold (V)	PowerOutput (Kw)
	Australia			
SINVERT solar 150	Siemens	450	750	122
SINVERT solar 20	Siemens	450	750	15
SINVERT solar 200	Siemens	450	750	173
SINVERT solar 2x 150	Siemens	450	750	300
SINVERT solar 2x 20	Siemens	450	750	40
SINVERT solar 2x 200	Siemens	450	750	400
SINVERT solar 2x 340	Siemens	450	750	680
SINVERT solar 2x 40	Siemens	450	750	80
SINVERT solar 2x 400	Siemens	450	750	800
SINVERT solar 2x 60	Siemens	450	750	120
SINVERT solar 2x 80	Siemens	450	750	160
SINVERT solar 30 Ratio	Siemens	450	750	26
SINVERT solar 300	Siemens	450	750	276
SINVERT solar 340	Siemens	450	750	323
SINVERT solar 3x 150	Siemens	450	750	450
SINVERT solar 3x 30	Siemens	450	750	90
SINVERT solar 3x 340	Siemens	450	750	1020
SINVERT solar 3x 400	Siemens	450	750	1200
SINVERT solar 3x 60	Siemens	450	750	180
SINVERT solar 3x 80	Siemens	450	750	210
SINVERT solar 40 Ratio	Siemens	450	750	34
SINVERT solar 400	Siemens	450	750	402
SINVERT solar 4x 150	Siemens	450	750	600
SINVERT solar 4x 300	Siemens	450	750	1200
SINVERT solar 4x 340	Siemens	450	750	1360
SINVERT solar 4x 400	Siemens	450	750	1600
SINVERT solar 4x 60	Siemens	450	750	240
SINVERT solar 4x 80	Siemens	450	750	320
SINVERT solar 80	Siemens	450	750	70
Sitop solar 2000 Slave	Siemens	200	630	2
Sitop solar 3000 IP 65	Siemens	200	630	3
Sitop solar 4000 IP 65	Siemens	200	630	4
SKN 1000 Outdoor	Solar Konzept Hauk	120	200	1
SKN 1010	Solar Konzept Hauk	120	200	1

inverter				
Model	Brand	LlowerThreshold (V)	UpperThreshold (V)	PowerOutput (Kw)
SKN 1050 Multistring M4	Solar Konzept Hauk	120	200	4
SKN 401	Solar Konzept Hauk	300	450	10
SKN 402	Solar Konzept Hauk	300	450	14
SKN 403	Solar Konzept Hauk	300	450	18
SKN 404	Solar Konzept Hauk	300	450	22
SKN 405	Solar Konzept Hauk	300	450	26
SKN 406	Solar Konzept Hauk	300	450	30
SKN 407	Solar Konzept Hauk	300	450	40
SKN 408	Solar Konzept Hauk	300	450	50
SKN 409	Solar Konzept Hauk	300	450	60
SKN 410	Solar Konzept Hauk	300	450	80
SKN 411	Solar Konzept Hauk	300	450	100
SolarMax 100C	Sputnik Engineering AG	430	800	100
SolarMax 20C	Sputnik Engineering AG	430	800	20
SolarMax 25C	Sputnik Engineering AG	430	800	25
SolarMax 300C	Sputnik Engineering AG	430	800	300
SolarMax 30C	Sputnik Engineering AG	430	800	30
SolarMax 35C	Sputnik Engineering AG	430	800	35
SolarMax 35S	Sputnik Engineering AG	430	800	35
SolarMax 50C	Sputnik Engineering AG	430	800	50
SolarMax 80C	Sputnik Engineering AG	430	800	80
Solarstar 1200	Würth Solergy	26	44	1
SP 100 000	Sun Power Solartechnik	493	965	100
SP 12000-750	Sun Power Solartechnik	300	750	12
SP 25 000	Sun Power Solartechnik	493	965	22
SP 250 000	Sun Power Solartechnik	493	965	250
SP 40 000	Sun Power Solartechnik	493	965	40
SP 5000 E-120	Sun Power Solartechnik	145	300	5
Steca Grid 9000 3ph	Steca	300	750	9
STZ 110	SunTechnics	493	780	100
STZ 280	SunTechnics	493	780	250
STZ 60	SunTechnics	493	780	54

inverter				
Model	Brand	LlowerThreshold (V)	UpperThreshold (V)	PowerOutput (Kw)
SUNRISE MINI-S	Fronius International	230	500	1
SUNVILLE 1000	PHOENIXTEC Power Co.,Ltd	150	450	1
SUNVILLE 2000	PHOENIXTEC Power Co.,Ltd	150	450	2
SUNVILLE 4000	PHOENIXTEC Power Co.,Ltd	150	450	4
SUNVILLE10000	PHOENIXTEC Power Co.,Ltd	300	800	10
SUNWAY TG 290 - 600V	Elettronica Santerno	315	630	220
SUNWAY TG 290 - 600V - MT	Elettronica Santerno	430	760	224
SUNWAY TG 310 - 800V	Elettronica Santerno	430	760	239
SUNWAY TG 310 - 800V - MT	Elettronica Santerno	430	760	242
SUNWAY TG 365 - 600V	Elettronica Santerno	430	760	280
SUNWAY TG 365 - 600V - MT	Elettronica Santerno	315	630	285
SUNWAY TG 385 - 800V	Elettronica Santerno	430	760	295
SUNWAY TG 385 - 800V - MT	Elettronica Santerno	430	760	299
SUNWAY TG 455 - 600V	Elettronica Santerno	315	630	350
SUNWAY TG 455 - 600V - MT	Elettronica Santerno	315	630	356
SUNWAY TG 485 - 800V	Elettronica Santerno	430	760	374
SUNWAY TG 485 - 800V - MT	Elettronica Santerno	430	760	380
SUNWAY TG 550 - 600V	Elettronica Santerno	430	760	420
SUNWAY TG 550 - 600V - MT	Elettronica Santerno	430	760	427
SUNWAY TG 610 - 800V	Elettronica Santerno	430	760	468
SUNWAY TG 610 - 800V - MT	Elettronica Santerno	430	760	475
SUNWAY TG 730 - 800V	Elettronica Santerno	430	760	561
SUNWAY TG 730 - 800V - MT	Elettronica Santerno	430	760	570
TLX 10k	Danfoss Solar Inverters	250	800	10
TLX 15k	Danfoss Solar Inverters	250	800	15

inverter				
Model	Brand	LlowerThreshold (V)	UpperThreshold (V)	PowerOutput (Kw)
XL10k 3Ph	Mastervolt	100	600	10
XL15k 3Ph	Mastervolt	100	600	15
XS6500 IP44	Mastervolt	100	600	5

APPENDIX C

Coding for Visual Basic 6.0 Programming

Home:

```
Private Sub Command1_Click()
```

```
Unload Me
```

```
Form1.Show
```

```
End Sub
```

```
Private Sub Command2_Click()
```

```
Me.Hide
```

```
form2.Show
```

```
End Sub
```

```
Private Sub Command3_Click()
```

```
Me.Hide
```

```
Form3.Show
```

```
End Sub
```

```
Private Sub Command4_Click()
```

```
Me.Hide
```

```
Form4.Show
```

```
End Sub
```

```
Private Sub Command5_Click()
```

```
End
```

```
End Sub
```

Power Consumption:

```
Private Sub Command1_Click()
```

```
Me.Hide
```

```
Form1.Show

End Sub

Private Sub Command2_Click()

Dim a As Integer

Dim b As Integer

Dim c As Integer

Dim d As Integer

Dim e As Integer

Dim f As Integer

Dim g As Integer

Dim h As Integer

Dim i As Integer

Dim j As Integer

Dim k As Integer

Dim l As Integer

If Text1.Text = "" Then

    MsgBox "Please insert the value", vbCritical

Else

a = Text1.Text

b = Text2.Text

c = Text3.Text

d = Text4.Text

e = Text5.Text

f = Text6.Text

g = Text7.Text
```

```

h = Text8.Text

i = Text9.Text

j = Text10.Text

k = Text11.Text

l = Text12.Text

Text14.Text = a + b + c + d + e + f

Text13.Text = Text14.Text + g + h + i + j + k + l

End If

End Sub

Private Sub Command3_Click()

Me.Hide

form2.Show

End Sub

Solar Module:

Private Sub Combo1_Change()

'Data5.Recordset.FindFirst "Student_id =" & Text1.Text & ""

End Sub

Private Sub Command1_Click()

If Text1.Text = "" Then

    MsgBox "Please insert the power consumption par annual value.Solar Calculator",
vbCritical

'Assumptions:

'inverter efficiency,a= 96%

'Average daily maximum ambient temperature,b=30

'Dirt derating,c=95 %

'Total voltage drop, d = 3%

```


'Yearly average global irradiation,e = 1400Kwh

'Subsystem efficiency, f = 0.9312

Else

a = 0.96

b = 30

c = 0.95

d = 0.03

e = 1400

f = 0.9312

'Average yearly energy (real energy) of PV sys,g

avgPV = Text1.Text / f

'Actual PV array,h

'actPV

actPV = avgPV / 1400

actPV1 = actPV * 1000

ftemp = 0.85

' Total PV array at STC

Text2.Text = actPV1 / (c * c * 0.85)

Label4.Visible = True

Label5.Visible = True

Label6.Visible = True

Text4.Visible = True

Text3.Visible = True

Command5.Visible = True

Data1.Visible = True

```
        Combo1.Visible = True

    End If

End Sub

Private Sub Command2_Click()

    Me.Hide

    Form1.Show

End Sub

Private Sub Command3_Click()

    If Text2.Text = "" Or Text2.Text = 0 Then

        MsgBox "Please make sure the total array at ATC have values.Solar Calculator",
        vbCritical

    Else

        Me.Hide

        Form3.Show

        Form3.Show

    End If

End Sub

Private Sub Command4_Click()

    Data1.RecordSource = "select MaxPowerOutput from SolarCalculator where Model
    LIKE '*' & Combo1.Text & '*'"

    Data1.Refresh

End Sub

Private Sub Command5_Click()

    If Text1.Text = "" Then

        MsgBox "Please insert the power consumption par annual value.Solar Calculator",
        vbCritical

    Else
```

```
Text4.Text = Text1.Text / Text3.Text

Command3.Visible = True

End If

End Sub

Private Sub Form_Load()

'Data1.DatabaseName = App.Path & "\SolarCalculator.mdb"

'Data1.RecordSource = "SELECT * FROM solarModule"

End Sub

Inverter:

Private Sub Command1_Click()

'Assumptions:

'Based on the lower temperature 20 deg C and the upper temperature of 75 deg C

' The type of inverter should ideally between 75% to 80%

End Sub

Private Sub Command2_Click()

Me.Hide

Form1.Show

End Sub

Private Sub Command3_Click()

End

End Sub

Private Sub Command4_Click()

Me.Hide

form2.Show
```

End Sub

Private Sub Command5_Click()

If Text3.Text = "" Then

 MsgBox "Please insert your value first", vbCritical

Else

Label6.Caption = Text3.Text * 75 / 100

Label8.Caption = "to"

Label9.Caption = Text3.Text * 80 / 100

Label4.Visible = True

Label10.Visible = True

Label13.Visible = True

Text1.Visible = True

Text2.Visible = True

Command7.Visible = True

Data1.Visible = True

Combo1.Visible = True

End If

End Sub

Private Sub Command6_Click()

Data1.RecordSource = "select LowerThreshold from SolarCalculator where Model
LIKE '*' & Combo1.Text & '*'"

Data1.RecordSource = "select UpperThreshold from SolarCalculator where Model
LIKE '*' & Combo1.Text & '*'"

Data1.Refresh

End Sub

Private Sub Command7_Click()

Text5.Text = Text1.Text * 0.95

Text4.Text = Text2.Text * 1.1

a = Text5.Text

b = Text4.Text

Text6.Text = a / 24.13

Text7.Text = b / 43.34

Label11.Visible = True

Label14.Visible = True

Label12.Visible = True

Label15.Visible = True

Text4.Visible = True

Text5.Visible = True

Text6.Visible = True

Text7.Visible = True

End Sub

Private Sub Form_Load()

Dim form2 As New form2

End Sub

