CERTIFICATION OF APPROVAL

SIMULATION STUDIES OF A PV SYSTEM
FOR RESIDENTIAL SECTOR.

by

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MERETGELDY BABAYEV

Abstract

The aim of this project is to carry out simulation studies on a photovoltaic based system, to be used in residential sector. Photovoltaic is a semiconductor device that generates electrical power, from solar radiation. Sunlight received by the solar cell, and will be used to generate direct current. Sunlight is necessary for PV to generate electricity, and in order to ensure continuous supply of power storage is required. A proper analysis of a PV based system is necessary, as the sunlight that is received at the surface of earth is transient in nature. On the average, Malaysia receives between 6 – 9 sunshine hours. Due to this, the system identification process is rather critical and the main specification is related to the PV array sizing. Since sunlight is mandatory; then the next important aspect is the battery array sizing. A typical house model was used to do load calculation, and this is an important process to assist in the planning of the number of PV panels and batteries required. To safely ensure sustainable power supply, storage is vital. Experiments were carried out by using a standard 80W PV array, subjected to local weather condition at UTP. Results obtained clearly indicated that a system simulation, based on precise mathematical model is very important. Visual Basic Software was used as a programming tool for simulation of the project. A simulation of a project is simple and user-friendly to design PV system for the house such as sizing PV array, sizing battery and load calculation. The objective of the project has been accomplished. The result has been successfully achieved and project working effectively.

ACKNOWLEDGEMENTS

First of all, I would like to express my deepest gratitude to my Final Year Project supervisors, Dr. A'fza Shafie and Dr. Balbir Singh for their continuous support and guidance throughout the duration of the Final Year Project.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The sun is the most important source of energy for this planet since the ancient time. The sunlight has been identified as one of the energy source and in the industrial ages the understanding about the sunlight becoming very large. The energy supply from the sun is important and truly huge. On average, the earth's surface receives about 1.2 x 10^{17} W of solar power. Actually the usage of sunlight as the energy source has been used in the biological organisms over millions of years.(Nansen, 1995). Furthermore most of the renewable power generation also depends on the sun as main source such as hydraulic, wind and wave power. As a country of Malaysia that situated in the region that receives sunshine all along the year, it should be taken advantage of this type of energy (refer to appendix B for an example of solar panel application).

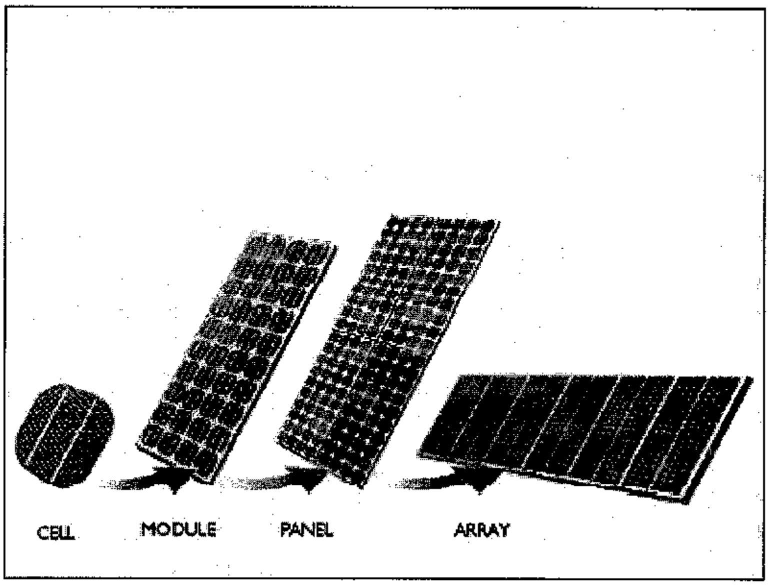


Figure 1.1: Photovoltaic Cell – Module – Panel - Array

Over last two decades, there have been major events that led the world's industrialized nations to look at renewable energy sources as a supplement to providing the projected increase in energy demand in their respective nations. Among a wide range of renewable energy projects in progress throughout the world, photovoltaic (PV) systems are the most promising as future energy technology. The overall objective of photovoltaic technology is to obtain electricity from the sun that is cost competitive and even advantageous with respect to other energy sources. Early applications of the photovoltaic energy are only restricted to space programs in the United States.(Berger, 1997). The application of solar energy includes water pumping, electric fences, gate openers, commercial lightings, telecommunications, roadside signs and also consumer electronics (calculators, cameras, watches, etc.)

One of the most popular solar PV power applications is residential power. Over 500,000 homes worldwide use PV power as the only sources of electricity. An average house has more than enough roof area to produce enough solar electricity to supply all of its power needs. With an inverter, which converts direct current (DC) power from the solar cells to alternating cells (AC) which is what most home appliances run on, a solar home can look and operate very much like a home that is connected to a power line.(Berger, 1997).

1.2 Problem Statement

A person average inhales about 20,000 liters of air every day. Breathing the air, it is risky inhaling dangerous chemicals that found their way into the air. Every year the world causes different types of cases, threats happens where getting change in temperature and pollution. Burning dirty fossil fuel (oil, coal and gas) to power cars, homes and industry releases the heat gas which alters climate change in the world. By increase the temperature in the world will cause melting the iceberg on the north part of the world and will lead to the extreme weather events such as stronger winds, heavier rains and larger storm surges. All these events cost us a death of people and ruining the cities, towns and villages which located near the ocean, sea.

One of the aspects is air pollution. Air pollution can be simply said as the contamination of the atmosphere due to the burning dirty fossil fuel and/or waste products. Air pollution and air quality has become a huge topic in the world today. In almost every country, people are trying to create ways to improve our air quality. Air pollution also causes our health such as asthma, heart and lung diseases.

Another aspect is high cost in energy power. These days' technology developing non-stop and demands in electric power also increases. As increase demands in energy, the price also increases which most people looking alternate way to generate energy. Instability of fuel price also affects the price in electric power. The price to fuel increased by 30 cent in Malaysia, on March 2006. As the increasing the price, everything is increased. Definitely the price of electric power is increased. On March 2006, there was recorded that the price in oil reached the highest price of history in New York. Most engineering estimated that producing electricity by burning fuel or chemical reaction, price may increase, air pollution increase and has less safety.

Most of the rural places do not have the electricity in the world. Because people don't consider much who is living in the rural, old places where less people coming there. To supply there electricity from city is expensive. So, people using candle to light the house at night hours. But in rural places, there is a lot space.

1.3 Objectives

The main objectives of this project work are to:

- do load analysis in a typical house.
- predict the size of battery and PV module.
- to design a PV – based power system.
- carry out a simulation on the designed PV system.

1.4 Scope of Study

The scope of this study is only for the residential houses and its applications. The main concentration is to gain knowledge of photovoltaic system in theoretically/experimentally and estimate the load of the typical houses to develop it and apply it to simulation via Visual Basic or MATLAB software. Be aware of changing the price of oil and redo the load analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 History of Photovoltaic

The origin of the solar cells can be traced back to 1839 and Becquerel's discovery of a photovoltaic when light was shown on an electrode in an electrolyte solution. Adams and Day reported a similar effect in solid selenium material in 1877. Subsequent work in selenium and copper oxide led to development of selenium solar cell and its wide use in photographic exposure meters. By 1914 selenium solar cells had reached about 1% efficiency in directly converting sunlight into DC electricity. The modern semiconductor era of solar cells began in 1954. Since the mid – 1980s there have been dramatic increases in the efficiencies of laboratory demonstration cells.(Goetzberger *et.all.*,1998).

As the price for the solar cell dropped by the years, it is cheaper electric power for the small – scale electric demand. By increasing the efficiency for the solar panel can be increased for the large - scale electric demands. Different materials used in past and nowadays experiment to improve the efficiency of the solar panel. There are different types of solar cells consequence work of the scientists. The most common solar cell materials are;

2.1.1 Single – crystal silicon

Single-crystal silicon cells are the most common in the PV industry. The main technique for producing single-crystal silicon is the Czochralski (CZ) method. Single-crystal silicon has a uniform molecular structure. Compared to non crystalline materials, its high uniformity results in higher energy conversion efficiency -- the ratio of electric power produced by the cell to the amount of available sunlight power i.e. power-out divided by power-in. The conversion efficiency for single-silicon commercial modules ranges between 15-20%. Not only are they energy efficient, single-silicon modules are highly reliable for outdoor power applications.

2.1.2 Polycrystalline silicon

Consisting of small grains of single-crystal silicon, polycrystalline PV cells are less energy efficient than single-crystalline silicon PV cells. The grain boundaries in polycrystalline silicon hinder the flow of electrons and reduce the power output of the cell. The energy conversion efficiency for a commercial module made of polycrystalline silicon ranges between 10 to 14%. Compared to single-crystalline silicon, polycrystalline silicon material is stronger and can be cut into one-third the thickness of single-crystal material. It also has slightly lower wafer cost and less strict growth requirements. However, their lower manufacturing cost is offset by the lower cell efficiency.

2.1.3 Thin film

Another approach in solar cell design is to significantly reduce the amount of raw material used in the manufacture of solar cells. The various thin-film technologies currently being developed make use of this approach to reducing the cost of electricity from solar cells. Hence, the next step in reducing the cost of solar cells and panels seems certain to come from thin-film technology. Thin-film solar cells use less than 1% of the raw material (silicon or other light absorbers) compared to wafer based solar cells, leading to a significant price drop per kWh. There are many research groups around the world actively researching different thin-film approaches and/or materials.

One particularly promising technology is crystalline silicon thin films on glass substrates. This technology makes use of the advantages of crystalline silicon as a solar cell material, with the cost savings of using a thin-film approach.

2.2 The Photovoltaic Generator

The photovoltaic generator consists of photovoltaic modules, which are connected to form a DC power – producing unit. The combination of modules with supports is called an array.

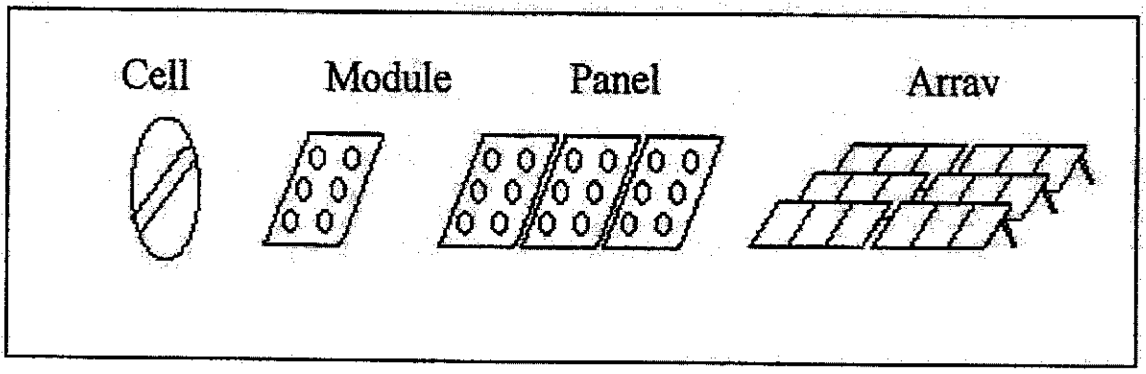


Figure 2.1: The photovoltaic hierarchy

The cells in the module are interconnected in series. A typical 10 cm diameter crystalline silicon solar cell will provide between 1 and 1.5W under standard conditions, depending on the cell efficiency. This power will supplied at a voltage 0.5 to 0.6 V. The number of cells in a module is governed by the voltage of the module. The nominal operating voltage of the system usually has to be matched to the nominal voltage of the storage subsystem. Most developers have standard configurations that can work with 12V batteries.

2.3 Controller

There are various devices are used to accommodate the variable nature of power output from PV generator. The main objective of this conditioning and control is to avoid the malfunction of the system. The criteria that need to be examined are the usage of blocking diode, self – regulating systems, charge regulator and the power converter.

2.3.1 The Blocking diode

The PV generator is differ from other generator because of the source of the energy that is the sunlight .It will only charging in a daylight, but in the night or in the dark, the solar cell behave as a diode. The characteristic of a photovoltaic generator at night can be obtained by displacing its usual characteristic under illumination along the current axis, until it passes through the origin. This operation will provide a discharge path for the battery. In order to overcome this problem, the usage of blocking diode can be applied in between the generator and battery. It is shown in Figure 2.2. When the voltage at the battery exceeds the voltage at the generator, the diode becomes reverse biased and prevent the battery discharge. However the blocking diode application sometimes discharged from the circuit because the battery discharge current can be very small.

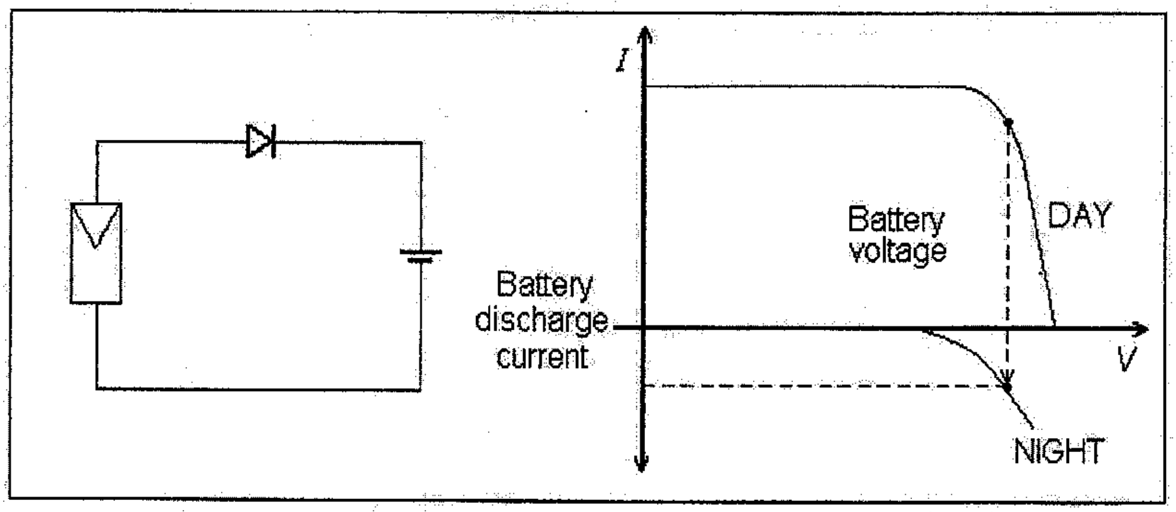


Figure 2.2: The operation of blocking diode

2.3.2 Charge Regulator

The function of charge regulator is to prevent excessive discharge or overcharge of batteries. Excessive discharge is avoided by monitoring the battery voltage and disconnecting the load from the battery if the voltage falls and disconnecting the load from the battery if the voltage falls below a pre – set minimum value. This would typically be about 10.8 V per cell for a lead – acid battery. The regulator will not reconnect the load until the battery voltage has risen to a value significantly higher than this minimum value. This is necessary to ensure that the load is not reconnected until some charge been returned to the battery.

While power is being supplied by the PV array the main role of the regulator is to limit the maximum battery voltage to prevent excessive gassing and to prevent overcharging the battery. A very large array is used with a very bulk charge phase unless when the battery voltage is below the liming value. The voltage regulation may achieve by the use of either a shunt regulator or a series regulator. Figure 2.3 is a simple solar regulator includes a blocking diode and therefore a blocking diode only be incorporated in a system when the solar regulator is not being used.

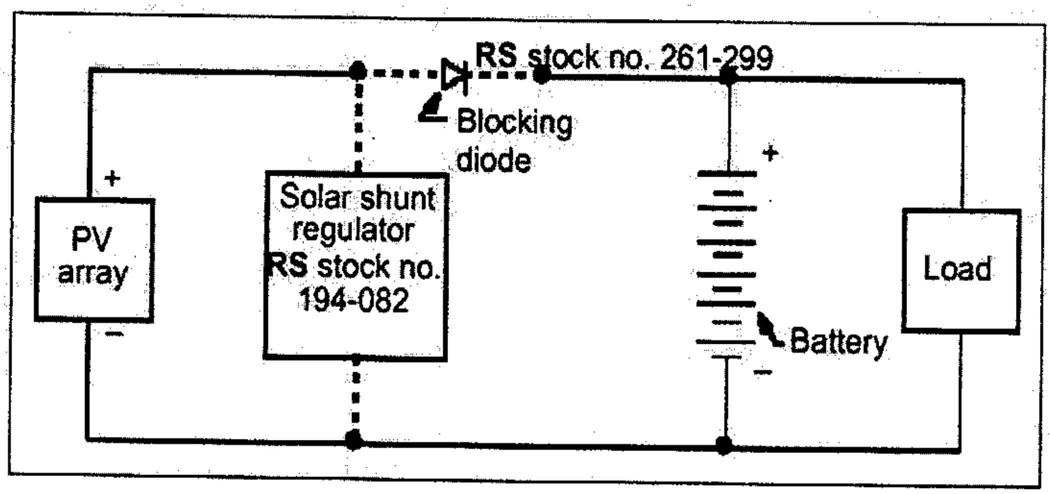


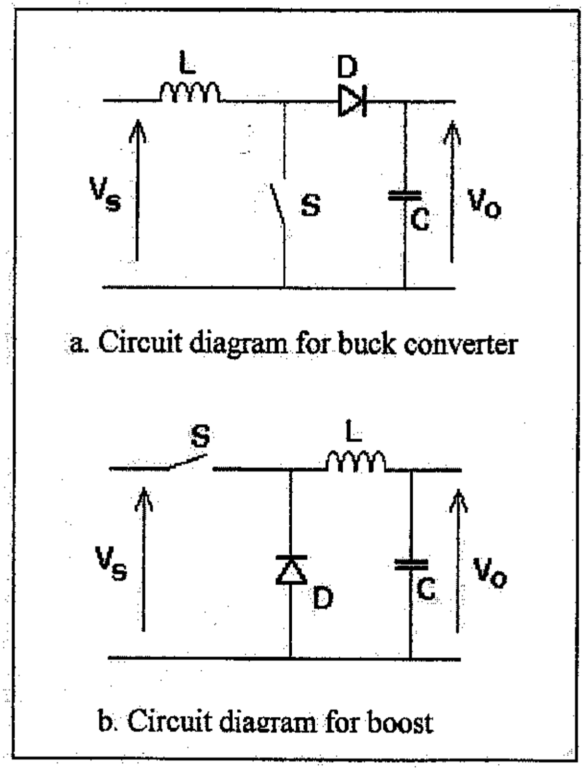
Figure 2.3: Simple solar regulator

2.3.3 Self Regulating Systems

The connection of the blocking diode provides the simplest solution for a small system. The configuration relies on a correct choice of the operating point of the PV generator to match the battery charging requirement. The usual operation of the system takes place between the battery voltage under the minimum allowed state of charge, and the voltage at the full charge, allowing for a voltage drop across the blocking diode. If the array operating voltage is set at the upper end of this voltage range, a slight increase in the battery voltage then sharply reduces the charging current from the PV Generator and prevents battery overcharging. Actually there is no battery discharge protection can have a very detrimental effect on the battery life.

2.3.4 DC/DC Converter

Figure 2.4 illustrate the basic circuit topology of two of the simplest types of converter. The buck converter reduces the voltage while the boost converter increases it. In both cases the voltage transformation is performed with only a small loss of power. The switch is an electronic device, usually a field effect transistor (MOSFET) or at higher power level an insulated gate bipolar transistor (IGBT).



a. Circuit diagram for buck converter

b. Circuit diagram for boost

Figure 2.4: DC to DC converter

2.4 Energy Storage

Stand alone photovoltaic systems usually make a provision for energy storage and battery storage is the suitable device for that matter. The batteries in most common use are the lead-acid batteries because of their good availability and cost effectiveness. Nickel cadmium batteries are used in some smaller applications where their ruggedness, both mechanical and electrical, is considered essential. However, their high cost per amount of energy stored has been prevented their wide use in photovoltaic.

Batteries in PV systems operate under specific conditions that must be allowed for in the system design, as they affect battery life and the efficiency of the battery operation. The most prominent feature is cycling with various cycles of different degree of regularity. During the daily cycle, the battery is charged during the day and discharged by the night time load. The depth of discharge in the daily cycle for systems without back up is always fairly shallow.

Batteries are used in solar electric systems to store electricity generated during daylight hour for later use. Rechargeable batteries are required for this purpose: the main used in solar electric systems are lead-acid batteries and nickel-cadmium batteries. Rechargeable batteries are made up of secondary cells. Batteries that can be used only once are made up of primary cells. When primary cells become fully discharged, their useful life ends. A cell is a combination of two electrodes and liquid called the electrolyte. When a cell is discharging or being charged, the chemical reactions produce electricity between the active material of each electrode and the electrolyte. The electrodes provide structural support for the active material and carry current to the two terminals on top. The polarity of the electrodes refers to which sign of charge they have. It is essential that the positive and negative electrodes do not touch each other otherwise a short circuit is caused and the cell discharges rapidly. The electrodes are kept apart by the separator, which is made of a porous insulating material. During discharge, the active materials are converted from a charged form to a discharged form. When all the active material on either one of the electrodes is converted, the cell is completely discharged on flat. Charging is the process of converting the active material from the discharged form back to the charged form.

2.4.1 Capacity

The measure of how much electricity or charge can be stored in a cell is called its capacity. The capacity is determined by the amount of active material that may come into contact with the electrolyte.

2.4.2 Ah units of capacity

The Ah or ampere–hour is the unit of charge measurement of battery capacity although the coulomb (C) is the basic unit of charge in electricity. To measure the capacity of a cell, a fixed current is drawn and the number of hours that the cell can be supplies this current before complete discharge is counted. Multiplying the current by the number of hours gives capacity in Ah.

2.4.3 State of charge

The state of charge at any moment is the amount of charge left that can be used compared to the fully charged capacity. It is measured as a percentage, so 100% is for a fully charged cell, 50% for a cell half discharged and 0% for a completely flat cell.

2.4.4 Cycle Depth

The sequence of discharging and then charging back up to the state of charge at the start is called cycle. The depth of discharge in one cycle depends on what the cell is being used for and is not always down to 0% state charged. A shallow cycle is when a cell is discharged by only a few percent before being charged back up. In deep cycle, the depth of discharge is 50% or more.

2.4.5 Cell life

On each cycle of a cell, small amounts of active materials come off the electrodes and sink to the bottom of container. Once this material has separated from its electrodes, it cannot be used anymore so the capacity of the cell is reduced. The number of cycles that can be obtained from a cell before the capacity is reduced. The number of cycles that can be obtained from a cell before the capacity is reduced to 80% is called the cycle life. It depends on cycle depth, discharge current and temperature.

2.5 Stand – Alone Photovoltaic System

Stand Alone PV systems are designed to operate independent of the electric utility grid and sized to supply certain DC and AC electrical load (Refer to Figure 2.5). These types of systems may be powered by a PV array only or may use wind, hydro or other engine – generator or utility power as an auxiliary power source, which is called a PV hybrid system.

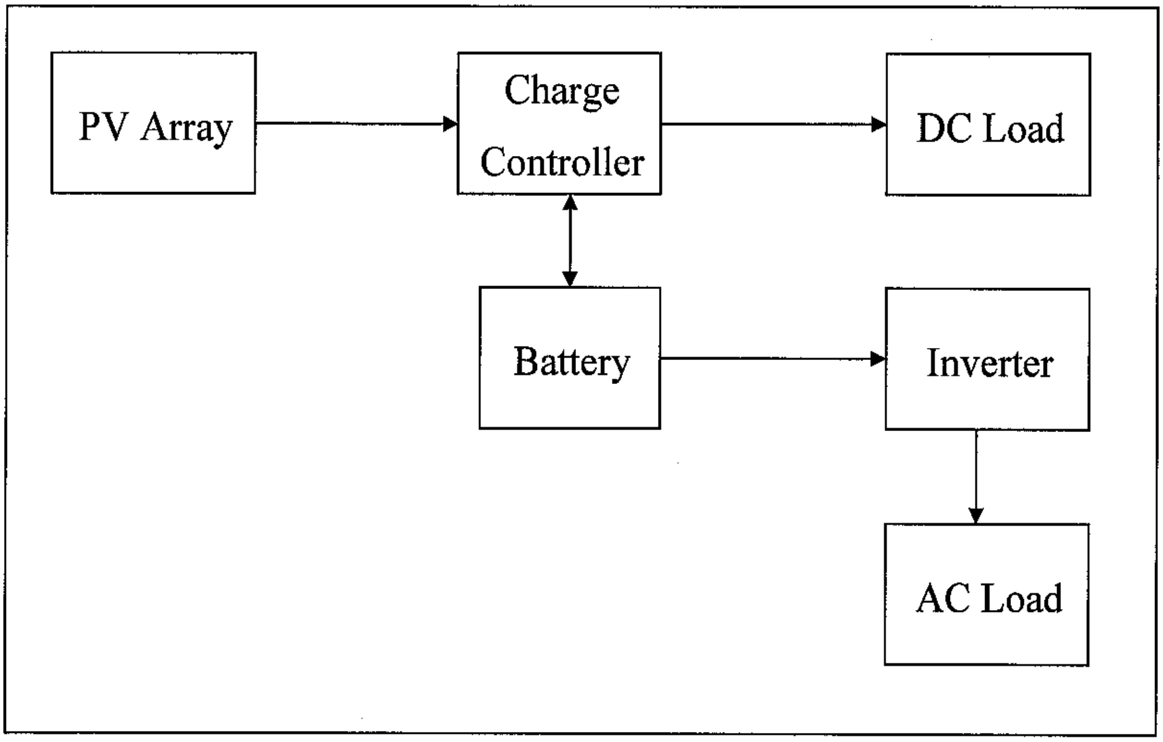


Figure 2.5: Diagram of stand – alone PV system battery storage powering DC and AC loads.

CHAPTER 3

METHODOLOGY & PROJECT WORK

3.1 Process Flow

In order to ensure that the project is a success, several procedures need to be followed. A complete flowchart of the project's procedure is shown below;

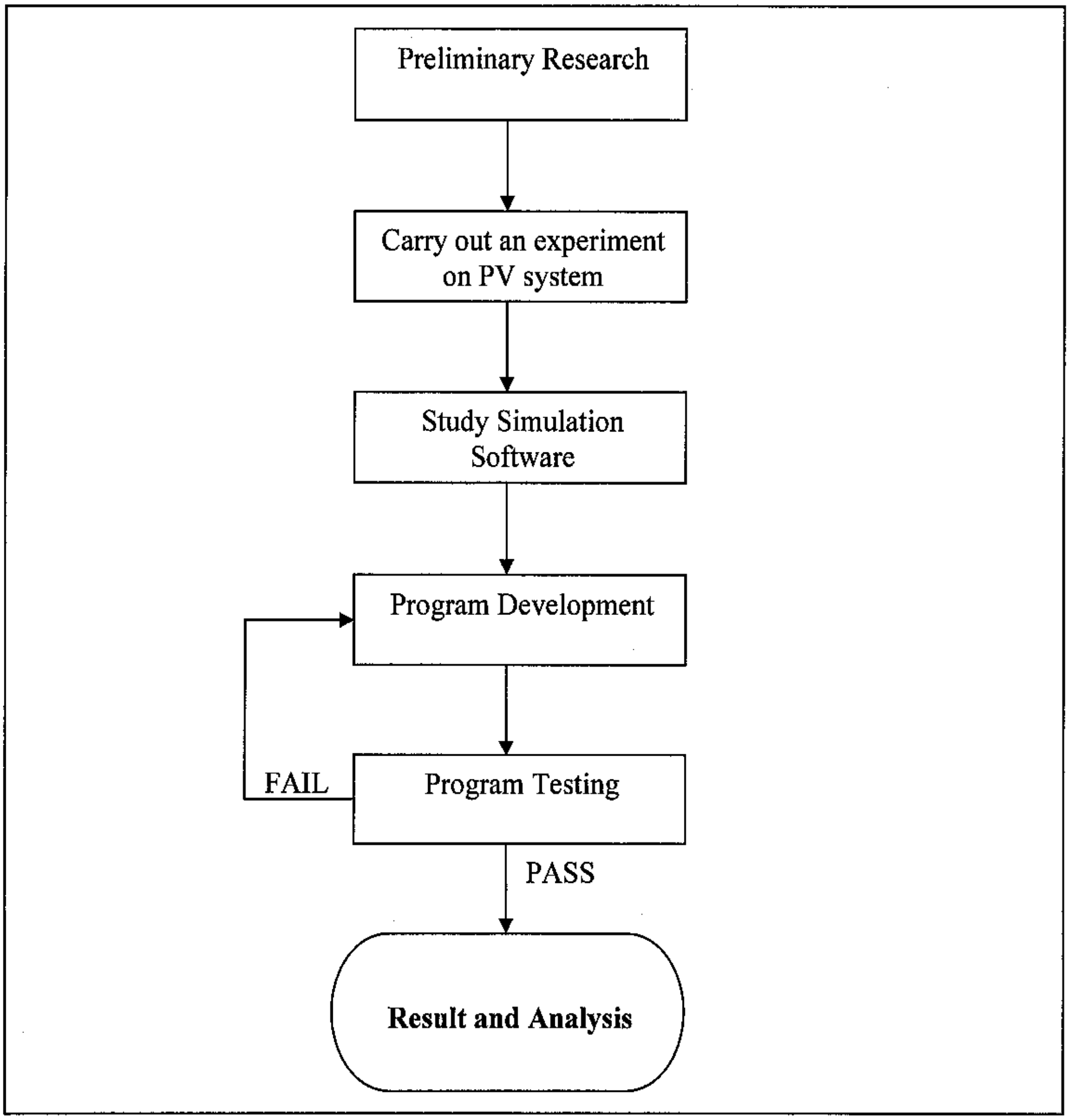


Figure3.1: Process Flow of the Project

Preliminary research is first done in order to better obtain an overall view of the project and the scope involved by doing research based on books, journals and other reference sources. The research will be concentrate on the photovoltaic generator, battery as energy storage and power conditioning. Based on the research, the overall design of the system will be produced. The designing period will be base on stand – alone house, how many modules required for the system, the energy storage capacity.

The experiment was carried out to measure the number of Ampere Hours and Energy produced by the photovoltaic system in one day. The experiment will be explained in detail in the following section.

After the design has been completed, the study simulation will carry out. All the design will be transformed to the simulation and lastly the system will be analyzed to ensure smooth simulation work has been done.

3.2 Experiment

The below experiment was held on 15th March, 2006, in University Technology Petronas. That day was hot but still the sky is covered with some cloud which affected our result. Then the experiment was done near the building which also affects the result. In this experiment, the measurement was done based on the current and voltage to find out the power according to the time. The irradiance is also measured to check how much energy receives one meter squares area. The ambient temperature, panel temperature and wind also measured through. Data is taken every 20 min. The data is given in Table 3.1. The angle of photovoltaic system is changed according to the time. The panel area of PV module is 51x57 cm^2 and the PV cells are 36 cells. The PV system is shown in figure 3.2. Our load is used the water pumping. The water is pumped from one bottle to another bottle. We used PV module connection directly to the load without connecting it to the battery.

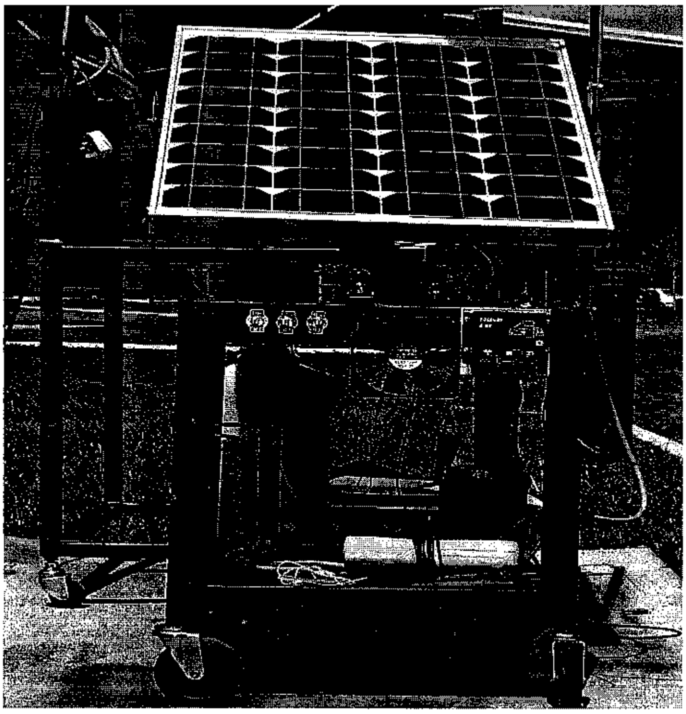


Figure 3.2: PV System.

It follows that when the Sun shines, the water pumped speed increase but as soon as it gets cloudy the speed decreases and all measured values are low due to the system difficulty to absorb the Sun photons. From figure 3.3, the irradiance dropped sharply at 16:30 when the sky was cloudy.

The irradiance drops of;

$$\eta = \frac{463 - 84.5}{463} * 100\% \quad \textbf{(3.1)}$$

$$\eta = 81.75\% \quad \textbf{(3.2)}$$

It is resulting poor irradiance when there is distraction from meteorology.

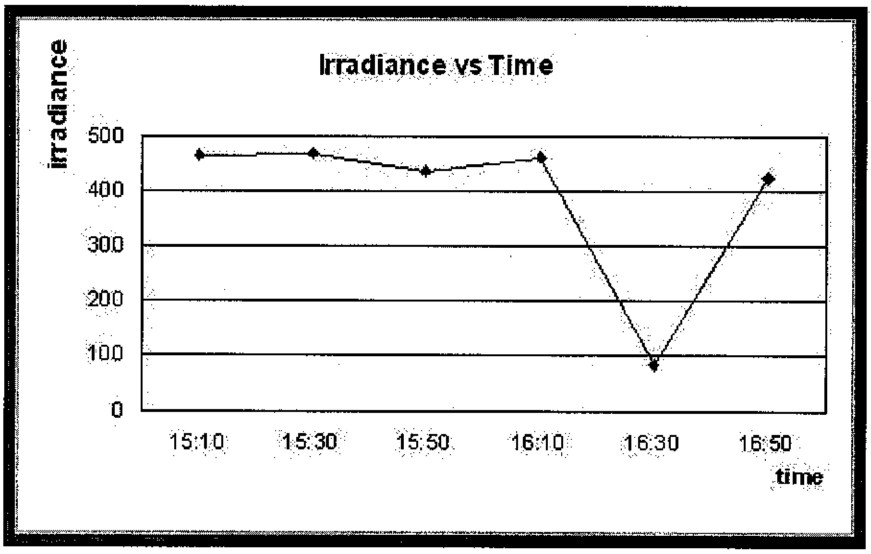


Figure 3.3: Cloud disturbance.

The main objective of this experiment is to find peak time hour in Malaysian condition. That day was hot and our result shows peak time is from 12 noon till 4 o'clock. After 4 o'clock afternoon, the sun go down which will decrease the irradiance and current voltage. But the peak time was seen at 1 o'clock. The figure 3.4 shows the graph of irradiance versus time. Mostly the irradiance changes between 400 and 500 W/m^2.

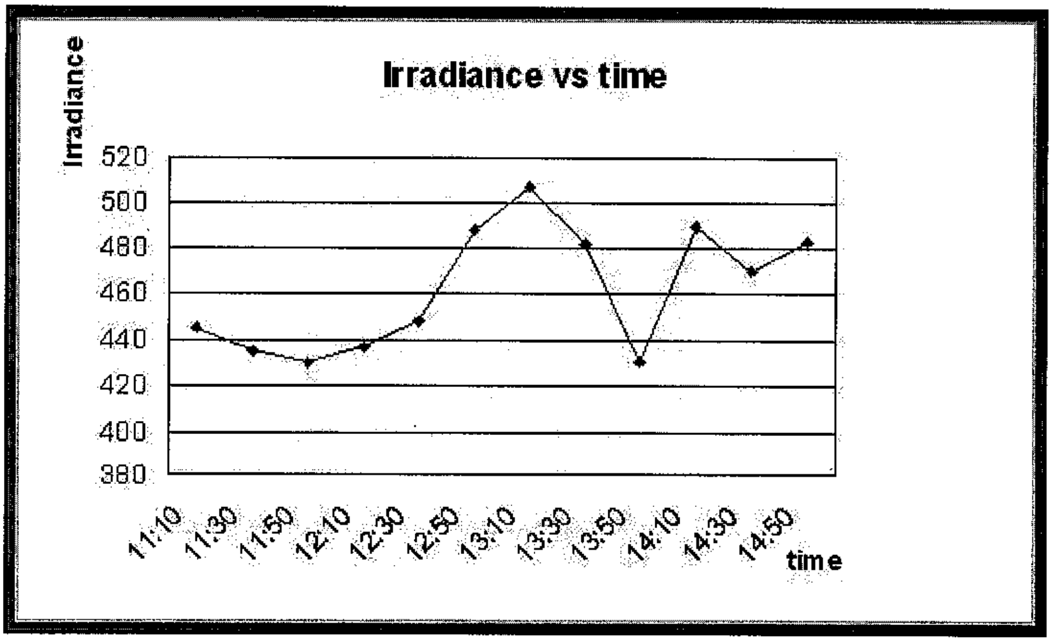


Figure 3.4: Peak time of irradiance.

Table 3.1: Result of experiment on peak time calculation.

ime	Voltage	Current	Irradiance	Ambient Temperature	Panel Temperature	Wind	Angle
	V	A	W/m^2	^{0}C	^{0}C	m/s	degree
1:10	9.58	2.17	445	32.2	44.2	0.04	30
1:30	9.61	2.17	435	33.8	46	0.28	35
1:50	9.38	2.17	430	33.1	47	0.18	35
2:10	9.54	2.64	437	34.5	48	0.21	35
2:30	9.89	2.28	448	34.5	48	0.21	15
2:50	9.83	2.29	488	34.2	48	0.3	15
3:10	10.46	2.49	507	34.3	44	1.4	7
3:30	9.96	2.37	482	34.8	42	0.36	5
3:50	9.47	2.22	431	35.5	43	0.63	4
4:10	9.53	2.31	490	36.5	47	0.15	0
4:30	9.57	2.34	470	37.6	43	0.07	2
4:50	9.61	2.35	483	38.6	45	0.20	4
5:10	9.62	2.32	466	37.3	44	0.21	8
5:30	9.50	2.29	470	37.4	43	0.04	158
5:50	8.97	2.14	438	36.4	41	0.03	25
5:10	9.42	2.27	463	36.1	49	0.31	34
5:30	2.59	0.45	84.5	35.5	40	0.06	35
5:50	9.07	2.14	426	35.2	44	0.06	35

3.3 Sizing and Design of Stand Alone PV system

- Establish the quantity of load needed.
- Determine the magnitude and duration of the electrical load on average daily, weekly and monthly.
- Estimate PV array size
- Estimate battery storage size.

3.3.1 Determine the Power Consumption

First of all, a list of appliances and loads that are going to be used from the solar system is made. The wattage of each device is determined and electrical tag attached to the cable or in the instruction book. The number of unit's appliances is determined by the design type of house and each appliance will be used specific time period per day or per week depend on the appliance and user. Kilowatt-Hour (KWh) per day is calculated;

$$\text{Power of Appliance (W)} \times \text{No of Units} \times \text{Average Hour (Hr)} = \text{KWh (per day)}$$

Kilowatt-Hour (KWh) per week or KWh per month can be calculated by multiplying KWh per day to number of day in week or month.

3.3.2 Determine the Size of Array

These are the steps in determining the size of PV array:

- Obtain solar radiation data and determine the optimal array tilt angle required to maximize the minimum monthly rating solar insolation to electrical load.
- Increase the system load requirement due to system losses and inefficient in charging and discharging batteries.
- Select a PV module and derate the module output for temperature and degradation.
- Determine the number of parallel-connection modules required to satisfy the average daily system amp-hour demand under design month solar insolation.

- Determine the number of series-connected PV modules based on the nominal system voltage and module peak power voltage.

$$\text{Rated PV Module Output (W)} \times \text{Daily Insolation (peak-hours per day)} = \text{Daily Output of One Module (W h per day)}$$

$$\text{Daily Requirement of Appliance (W h per day)} \times 100\ (\%) \div \text{Daily Output of One Module (W h per day)} \div \text{Charging Efficiency of Battery (\%)} = \text{Minimum Number of Modules Needed}$$

$$\text{Average Daily Ah Requirement (Ah)} \div \left[\text{Module Peak Current (A)} \times \text{Derating Factor} \times \text{Daily Insolation (hours per day)}\right] = \text{Number of Parallel PV Module}$$

$$\text{Nominal System Voltage (V)} \div \left[\text{Module Peak Voltage (V)} \times \text{Derating Factor}\right] = \text{Number of PV Module in Series}$$

The product of the series and parallel modules gives the total number of modules required for the application.

3.3.3 Determine the Size of Battery

Batteries charge up during the day ready for use at night. Batteries also smooth out the daily variations of insolation. They do this by storing excess charge received during the sunny days ready for use during cloudy days that follow. The period of storage required should be based on the maximum number of consecutive days with rain or heavy cloud.

The number of batteries required is calculated from the daily electrical requirement and period of storage as follows:

Daily requirement of appliances (W h per day) X Period of storage required (Days) ÷ 12 V = Total usable capacity needed (Ah at 12V)

Total usable capacity needed (Ah at 12V) X 100 % ÷ Full capacity specified for one battery (Ah) ÷ Maximum depth of cycles (%) = Minimum number of 12V batteries required

3.4 PV Design on Computer Program

The PV design program developed on Visual Basic programming language. Visual Basic is most interactive and user-friendly software which can be learnt owns self. The program generate automatically exe file which user can test the output of the work done. It is simple and easy to analyze, check error and compile while working. The software has graphical user interface (GUI) and programming code. The work will be done on graphical user interface and the purpose of coding is to function properly all the GUI element. There are different application can be produced by using Visual Basic Software.

Simulation of PV system for residential houses is produced by Visual Basic Software. The program will be opened by double clicking on the icon. It consists of four parts. Each section of the application performs a particular task and user is asked for the input variable needed to execute specific output. There are menu bar where file can be saved or opened and program can also be ended.

3.5 Program Content

This block of the program simply contains the content of the program. Each block can be opened by double clicking on it.

3.5.1 Load Analysis

This section of the block will execute kilowatt-Hour per day, per week and per month. It also will calculate the total price in Malaysian Ringgit (RM) of KWh monthly used electricity. This block will ask user to key in these variables:

- Number of units each appliances
- Expected daily use of each appliances

3.5.2 Battery Sizing

This section of the block will execute the number of batteries needed for the designed system. User will have to key in the following variables:

- Period of storage (Days of cloudiness)
- Choose the types of battery

3.5.3 PV Module Sizing

This part of the block will execute the number of PV modules needed for the designed system. User need to have key in the following variables:

- Choose the panel type
- Daily Sun Hour
- Loss of the PV Panel

3.5.4 Layout of the House

This part of the block is shown the house layout of my design. The house is designed for Malaysian standard houses. It consists of three bedrooms, kitchen, dining room, hall, back porch and front porch.

CHAPTER 4

RESULTS & DISCUSSION

4.1 Implementation Issues

Design Specification

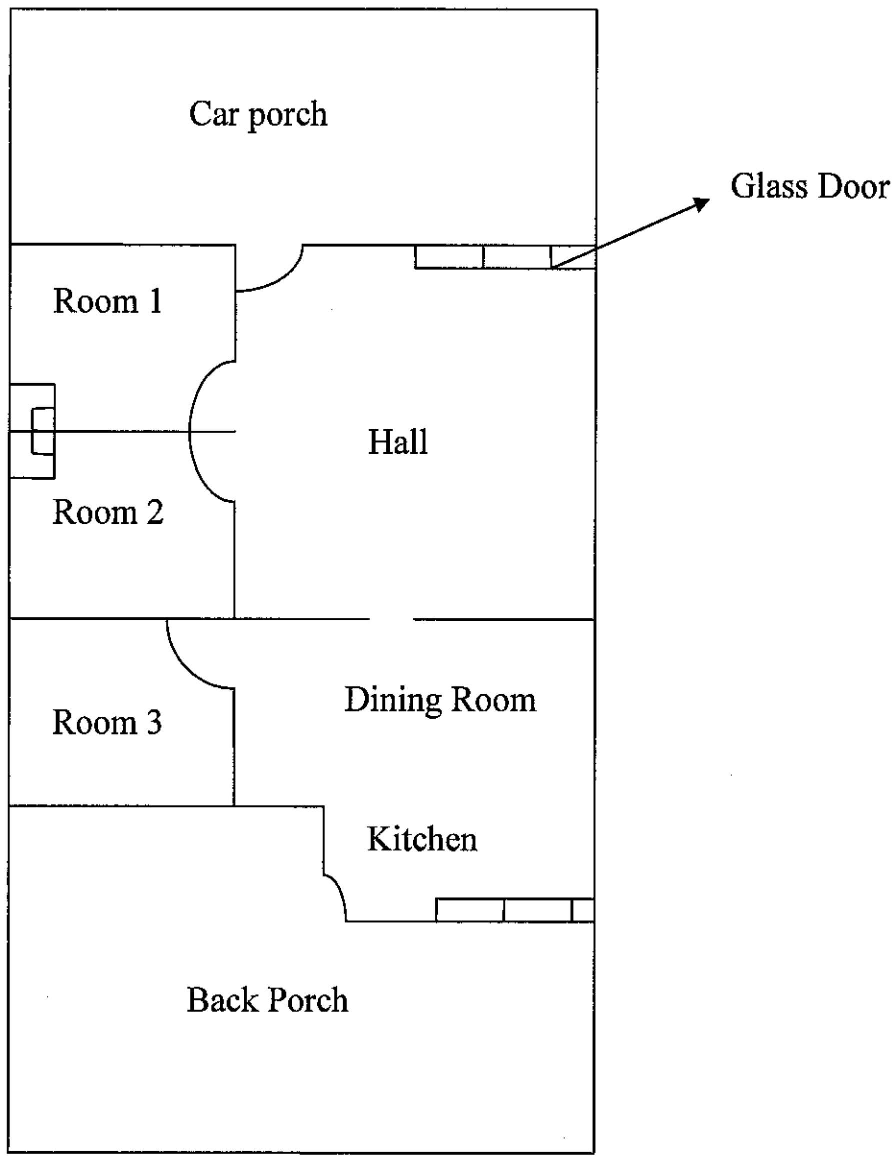


Figure 4.1: Stand – alone house layout

The figure above shows us stand – alone house layout. The house will have a kitchen light, a dining room light, light in each room, a bathroom light, hall light, light in car porch and back porch, a ceiling fan in each room, kitchen, dining room and two ceiling fan in the hall. In addition, the house also will have fridge, TV, washing machine, water heater, etc.

In the recent past, stand – alone house systems have been designed around a 12-Volt system voltage. The PV array will be rack mounted at ground level, so the feasibility of seasonal adjustment of array tilt will be explored as a means of optimizing system performance. The storage will be used as a part of keeping system maintenance. (Fanney, 2000).

4.2 Load Analysis

Load analysis is divided into two groups;

- **Load with PV System**
- **Load without PV System**

Table 4.1: Monthly consumption of energy for PV system

Appliances	Power	No of units	Avg hrs	KWh (per day)	KWh (per week)	KWh per month
Lights	20	11	9	1.98	13.86	59.4
Fan	50	7	10	3.5	24.5	105
TV	110	1	6	0.66	4.62	19.8
Washing	400	1	2	0	0.8	3.2
W_heater	450	1	1	0.45	3.15	13.5
Toaster	90	1	1.5	0	0.135	0.54
Total			29.5	6.59	47.065	201.44

Table 4.2: Tariff Calculation

First 200	43.60
Next 800	0.37152
Add	
Total	43.97

The load for PV system is shown in Table 4.1. Calculating energy use based on a description of our own house and appliances can help identify the best opportunities for energy savings. If we want an estimate of how much electricity our appliances consume, refer to the Monthly consumption of energy for PV system (Table 4.1). If we want a more exact estimate, we can generally find the wattage stamped on the bottom or back of the appliance, or on its "nameplate." The wattage listed is the maximum power drawn by the appliance. Since many appliances have a range of settings (for example, the volume on a radio), the actual amount of power consumed depends on the setting used at any one time. These calculations based on small house or flat which consist of three rooms and latest tariff for Malaysian cost of energy (Table 4.2). I assume my load which is commonly used in the houses.

At this point, it should be abundantly clear that the only reasonable choice for the fridge will be high efficiency dc unit. The only fridge is going to get energy from the electricity generation. The array sizing and battery selection will be done based on above loads. (Table 4.1)

4.3 Battery Sizing

The sizing battery is one of the important issues on designing the PV system. Every PV designing system should consider the storage where energy must be kept and available to use when it's needed such as at night times or cloudy days. Its also should consider the time for emergency repair of the generator as a replacement for the sun. Since the batteries need to hold sufficient charge to power up the loads, the charge and discharge derating factors will both be unity. The factors that affect battery selection are monthly variation in average daily energy use.

As an example of calculation of battery sizing for PV system is shown below;

The Total Load Requirement is taken from above Load Analysis. (Table 4.1) The period of storage are days of consecutive cloudiness. It is assumed two days.

Battery Capacity Required

= Period of Storage x Total Load Requirement

= 2 x 4565

= 9130 Whr/day

There are several types of battery and user can choose which is suitable for it. For instance;
Lead-Acid Battery = 180Ah/ 12V battery of 80% efficiency and lifetime is 8 years.

Capacity of Selected Battery

= Efficiency x (Battery Current x Battery Voltage)

= 0.8 x (180 x 12)

= 1728 W/ block

Number of batteries required

= Battery Capacity / Capacity of Selected Battery

= 9130 / 1728

= 5.28 ≈ 6 blocks

It can also be calculated the series and parallel of batteries. It is shown as following:

System voltage is 24V DC to 240 AC

Number of batteries in series

= System Voltage / Battery Voltage

= 24 / 12

= 2 blocks

Number of batteries in parallel

= 6 blocks / 2 blocks

= 3 blocks

As an example it is shown that system required six (6) blocks of lead-acid batteries where three (3) of them stands as parallel and two (2) of them in series.

4.4 PV Module Sizing

One of the main aspects of the designing PV system is Sizing PV Module. After proper calculation of the load, PV array can be calculated. Choosing adequate number of modules to meet system requirements depends upon knowledge of average insolation condition. Procedure involves choosing appropriate module. There are several types of panel can be chosen by user. For instance calculation of PV array sizing are shown below:

Choosing Panel type is of SET 115W. The Sun hour per day estimated 5 – 6 hours in Malaysia.

Daily PV module output

=Peak Watt x Average Sun Hour

=115 W x 6 hours

= 690 W

Assuming 20% losses from panels

Total average daily array output

= Daily PV Module Output - %Losses

= 690 W – (690 x 0.2)

= 552 W

The Total Load is taken from Load Analysis calculation. (Table 4.1)

Number of panels required

= Total Load / Total Average Daily Array Output

= 4565 / 552

= 8.27 panels

≈ 9 panels

The above calculation gives us the sample of calculation for the PV array sizing. It can be used to any types of PV sizing calculation.

4.5 Cost Analysis

The system is designed for typical house and it can be applied to any system for basic knowledge. Cost analysis is done after calculation the load requirement and sizing of batteries and arrays. The cost of the PV system for typical house is around RM 3000.00. It depends on the types of batteries and arrays. The payback period starts after 4-5 years and will prolong the system 8-10 years. The price is not so high.

4.6 Solar PV Computer Program

The program was used in sizing the system for a residential house with basic DC loads in the solar system design.

4.6.1 Main Page

The program starts with main page refer to Figure 4.2. There are four buttons where each button has specific function to work. The main menu contains File and View. The file menu contains Open, Save and Exit. Open means can open the file where it is located. Save means can save file where user desired. Exit means will exit the program. The View menu contains house Layout, Appliances, Battery Sizing and PV Sizing. It is located to make easy and user friendly for the user to open anytime the user desired.

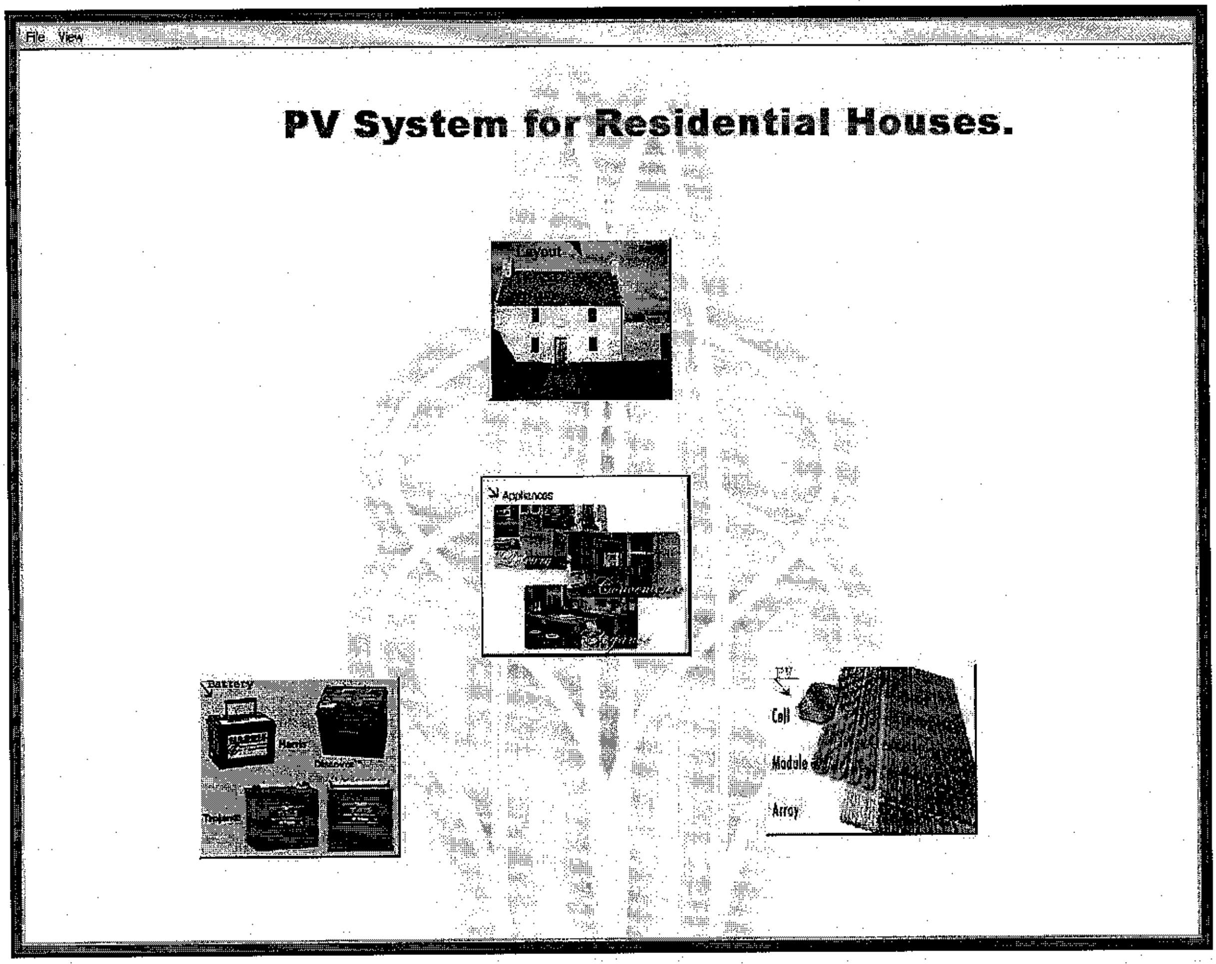


Figure 4.2: PV System Main Page

4.6.2 House Layout

The first button from above is House Layout. By clicking on the button, lay out of the house will appear in a new window. It is shown Figure 4.3. From View Menu can also open House Layout. The basic design of the designed house is shown. It is designed to similar Malaysian single storey house. The user can return to main page by clicking Main button or go desired window from View Menu.

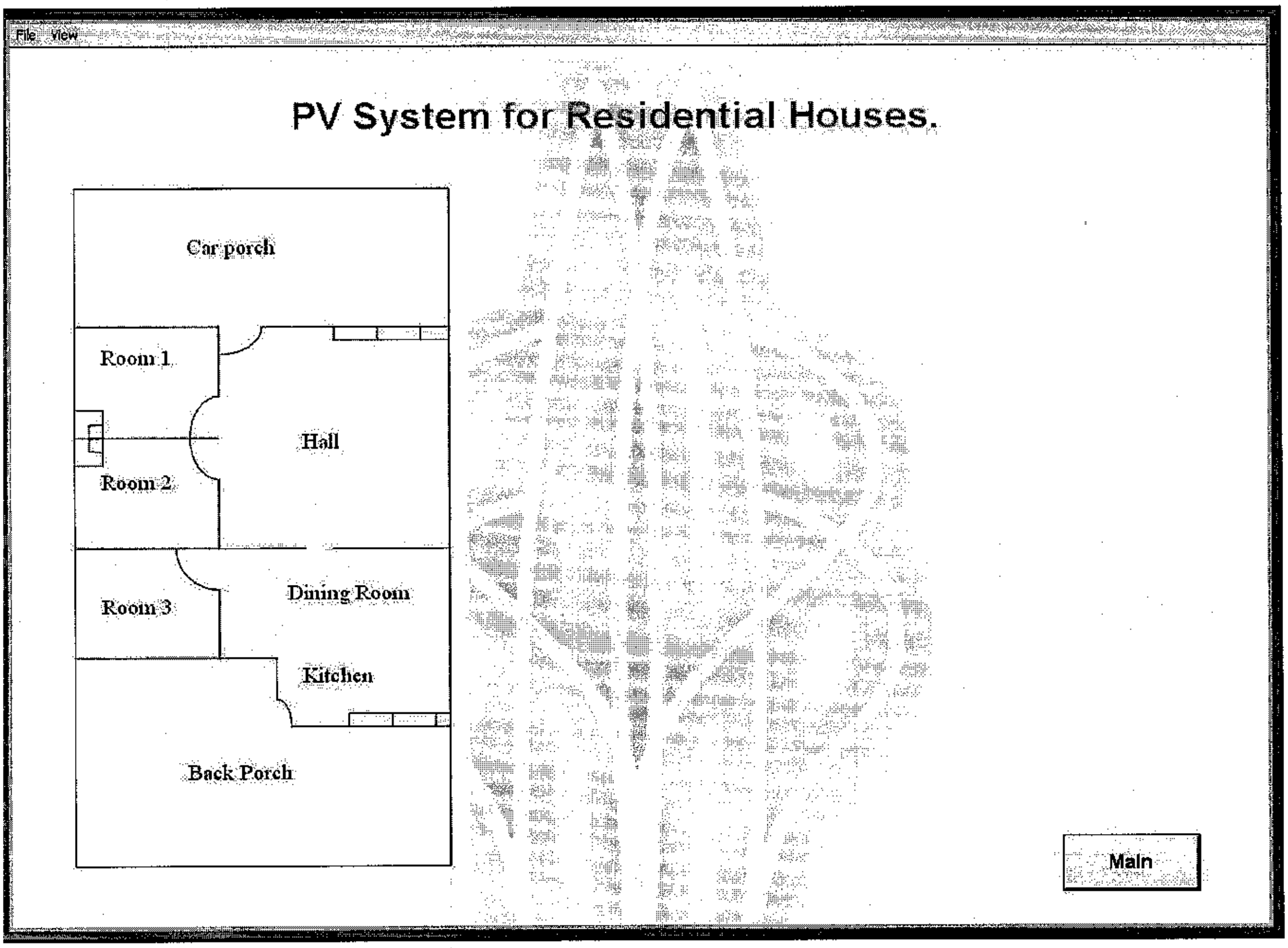
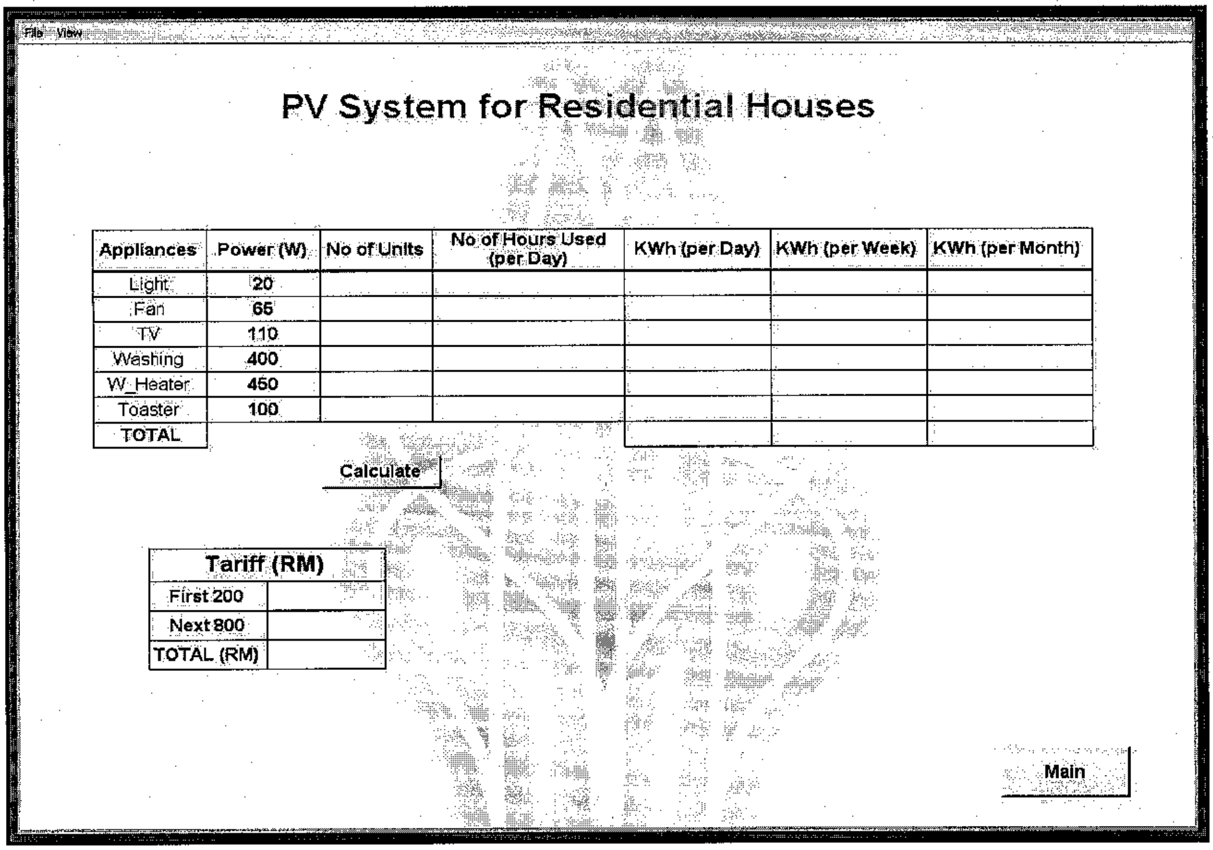


Figure 4.3: Layout of the House

4.6.3 Appliances

The Appliances button symbolizes second button from above refer to Figure 4.2. By clicking to the button, new window will appear. It is shown in Figure 4.4. The basic loads were located by designer and each loads power. The user need to key in number of units and number of hours used per day of each appliance. By clicking on calculate button will result the kilowatt-hour (KWh) per day, per week and per month. Monthly cost will also be resulted. The tariff calculation based on new cost of Malaysian energy. User can be referred to Figure 4.5 where specific output resulted by giving the input.



File View

PV System for Residential Houses

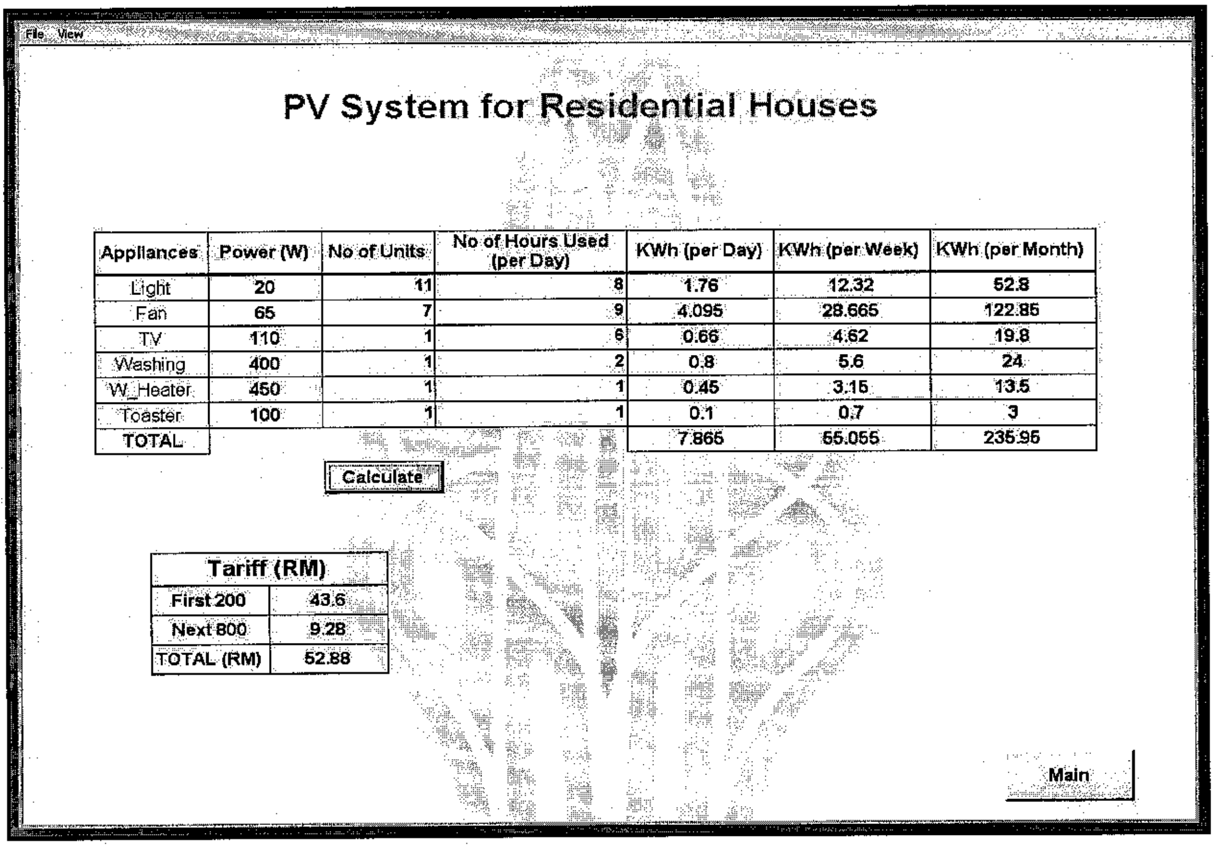
Appliances	Power (W)	No of Units	No of Hours Used (per Day)	KWh (per Day)	KWh (per Week)	KWh (per Month)
Light	20					
Fan	65					
TV	110					
Washing	400					
W_Heater	450					
Toaster	100					
TOTAL						

Calculate

Tariff (RM)	
First 200	
Next 800	
TOTAL (RM)	

Main

Figure 4.4: Load Analyses from Program



File View

PV System for Residential Houses

Appliances	Power (W)	No of Units	No of Hours Used (per Day)	KWh (per Day)	KWh (per Week)	KWh (per Month)
Light	20	11	8	1.76	12.32	52.8
Fan	65	7	9	4.095	28.665	122.85
TV	110	1	6	0.66	4.62	19.8
Washing	400	1	2	0.8	5.6	24
W_Heater	450	1	1	0.45	3.15	13.5
Toaster	100	1	1	0.1	0.7	3
TOTAL				7.865	55.055	235.95

Calculate

Tariff (RM)	
First 200	43.6
Next 800	9.28
TOTAL (RM)	52.88

Main

Figure 4.5: Load Analyses with output.

4.6.4 Battery Sizing.

The battery button is placed below on the left side in main page. It is shown in Figure 4.2. By clicking on the button, the new window will appear. It is shown in Figure 4.6. Before start to size the battery, load analysis should be done before. Because the value for Daily Load will appear in the box automatically after daily load calculated in load analysis. Period storage is the days of cloudiness in the area where the system will be located. The battery can be chosen by user. After values placed and chosen properly, calculate button will be pressed. The result will come out near the Number of Battery. It is shown in Figure 4.7.

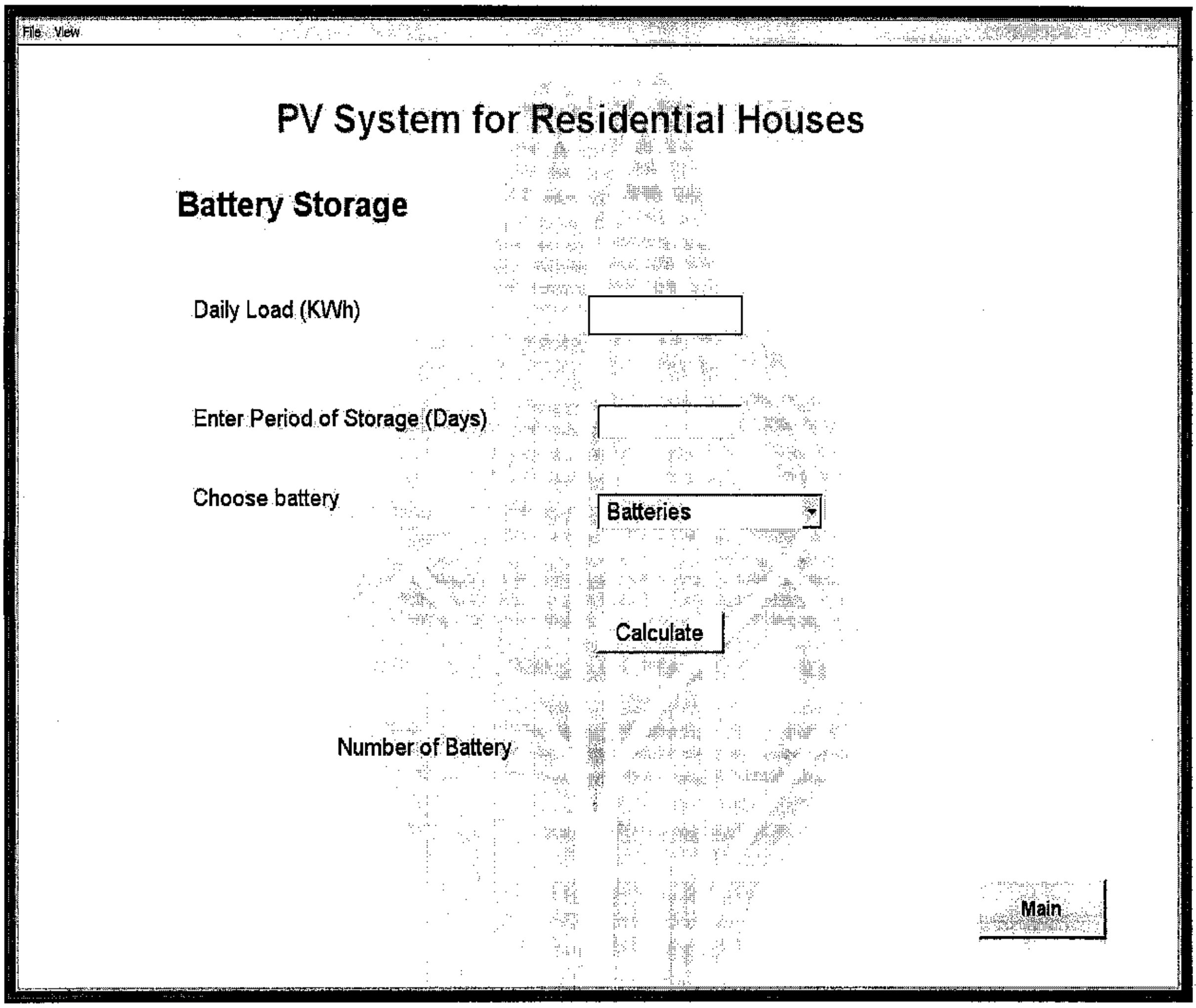


Figure 4.6: Battery Sizing from Program

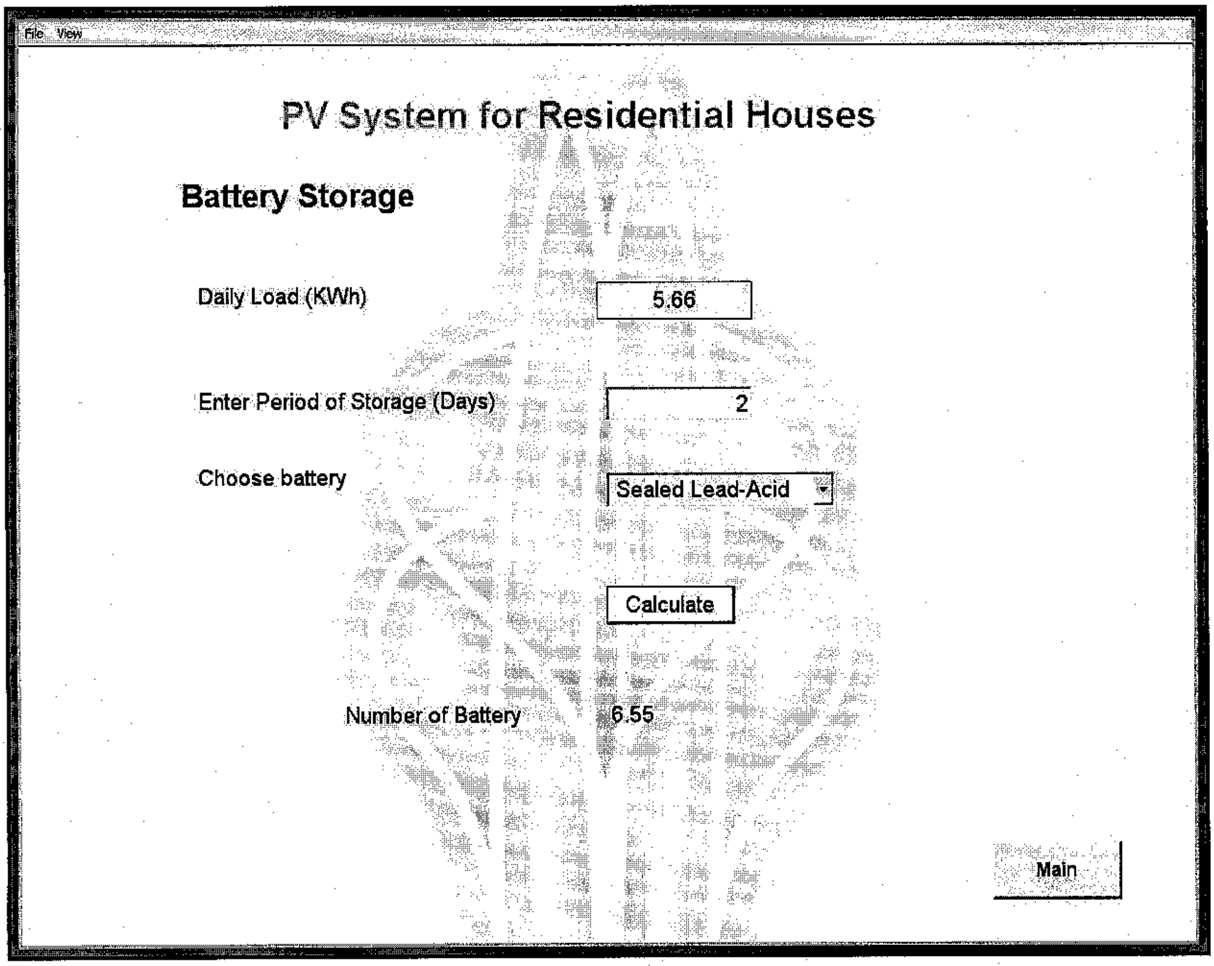


Figure 4.7: Calculated Battery Size

4.6.5 PV Array Sizing

The last button below is placed on the right in the main page Figure 4.2. By clicking on the button, the new window will appear refer to Figure 4.8. As stated in previously section, the load analysis should be done the array sizing too. The daily load will appear in the box automatically. The panel type should be chosen. The average sun hour should be entered in the area, the system located. The panel loss also should be considered in this calculation will ask to user key in the value. The calculate button used to calculate key in values and place the result below near the Number of PV module. It is shown in Figure 4.9.

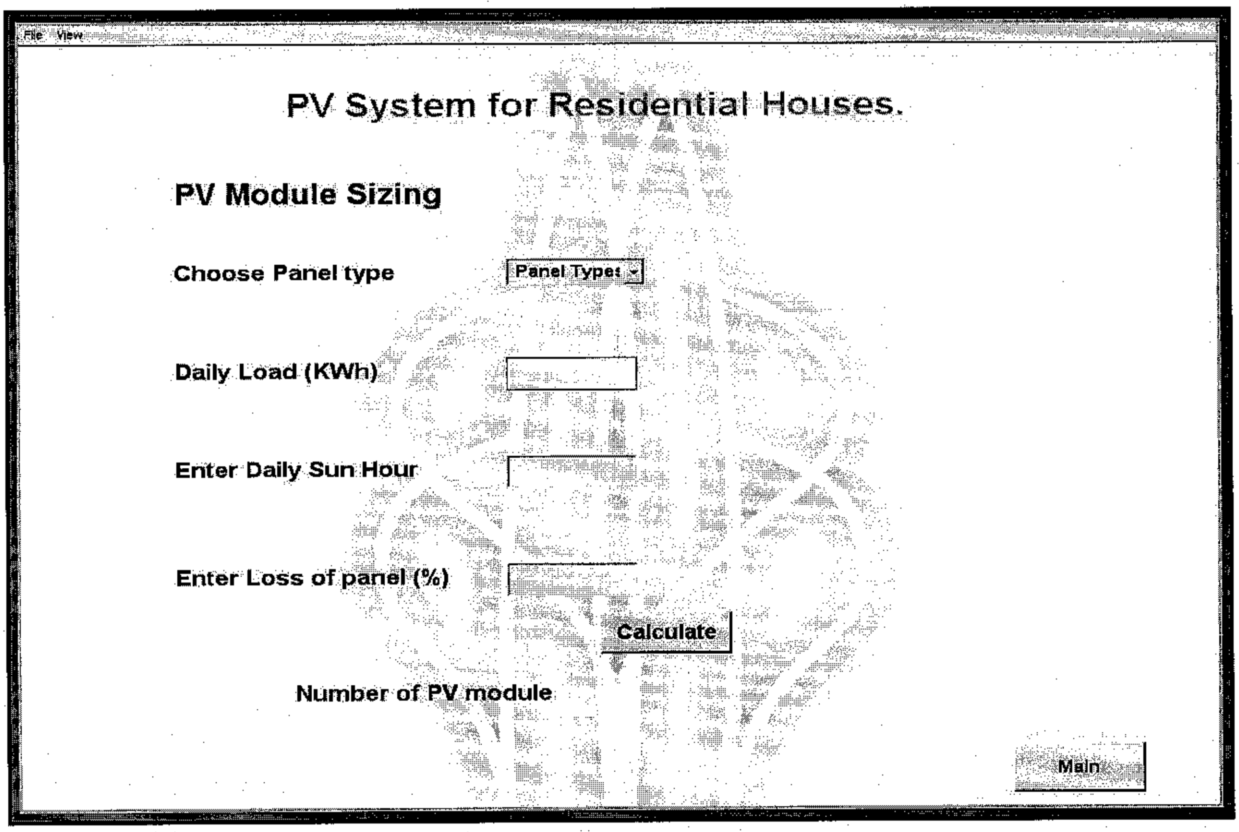


Figure 4.8: PV Module Sizing from Program

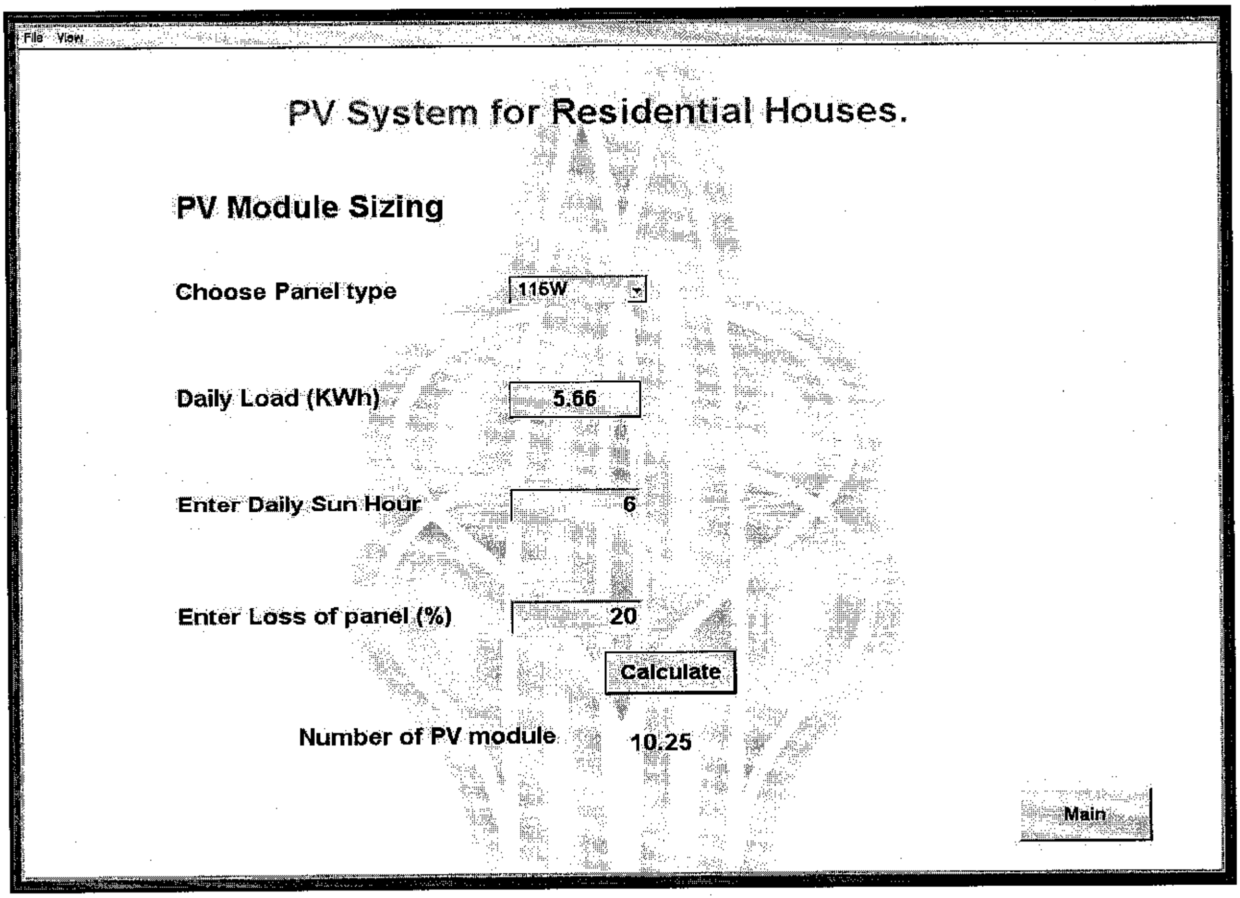


Figure 4.9: Calculated PV Module Size

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Conclusion

The stand-alone solar photovoltaic system designed in reliable and practical as it is designed with basic loads used in homes. The loads assumed to be DC and it is easy to understand the concept of the Photovoltaic System. This design can be used in designing solar powered house in rural areas where the installing normal distribution line can be much hassle and not economical. The design is also reliable as it is designed to be able to supply the loads with solar energy which is abundant in supply and does not require much maintenance and can supply energy for up to two days without sun.

Stand-alone photovoltaic systems usually make a provision for energy storage and battery storage is the suitable device for that matter. The sizing of PV array and batteries play a great role in terms of lifetime and efficiency on designing the PV system. The batteries in most common use are the lead-acid batteries because of their good availability and cost effectiveness. The battery comprises two electrodes of lead and lead dioxide, and the electrolyte of sulphuric acid diluted with water. There are different kind of PV cells are working to make efficiency greater and mostly materials are made from silicon.

This program contains basic calculation for the basic loads of PV system. By using the solar design program, the sizing of any stand-alone solar photovoltaic system is much easier as the program is user-friendly, reliable and saves time. The program can be used as a guide in designing any stand-alone solar photovoltaic system. It can be improved in many ways such as include AC loads, inverter, etc.

5.2 Recommendation

Based on works performed, there are some recommendations for the future studies and improvement of the system.

The AC design can be constructed with real hardware and further analysis on the reliability of the design can be analyzed. The program can be improved by adding estimates of insolation in an area and the economic analysis of the design system. Cost comparison which includes the starting cost, annual running cost and investment cost can be done between solar electricity and normal distribution line. This will help designers in determining the feasibility of installing any stand-lone solar photovoltaic system.

More research can be done on other types of solar system. Any building (in the university) can be chosen to be used as the solar powered building. The loads in the building are to be powered up by the PV modules. This building is also connected to the utility grid. The building will use the energy from solar but when the energy is insufficient, the building will be using the normal power supplied from the distribution line. On the other hand, when the energy obtained is more than the required energy, the energy will be pumped to the utility grid. This will save energy consumption and save cost too.

The project was mainly concentrated to the typical house but for recommendation it can enlarged the capacity of room or house. This project can be used as a reference for future and enlarged projects. The software also can be improved in much way such as put all screens in one main screen so the user no need to go to separate screen. It will be much user friendly and simple.

Load factor also need to be considered to get more accurate result. Because some light are used four hour and some light used 7 hours. The loads are changing variously and taking load factor will result more accurate values.

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APPENDIX A: Project Milestone chart

Milestone for the First semester of 2 Semester Final Year Project

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic	■													
	-Propose Topic														
	-Topic assigned to students														
2	Preliminary Research Work		■	■											
	-Introduction														
	-Objective														
	-List of references/literature														
	-Project planning														
3	Submission of Preliminary Report			●											
4	Project Work				■	■	■	■							
	-Reference/Literature														
	-Practical/Laboratory Work														
5	Submission of Progress Report								●						
6	Project work continue								■	■	■	■			
	-Practical/Laboratory Work														
7	Submission of Interim Report Final Draft												●		
8	Oral Presentation													●	
9	Submission of Interim Report														●

● Suggested milestone

■ Process

Suggested Milestone for the Second Semester of 2 Semester Final Year Project

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work Continue														
	-Practical/Laboratory Work														
2	Submission of Progress Report 1			●											
3	Project Work Continue														
	-Practical/Laboratory Work														
4	Submission of Progress Report 2								●						
5	Project work continue														
	-Practical/Laboratory Work														
6	Submission of Dissertation Final Draft												●		
7	Oral Presentation													●	
8	Submission of Project Dissertation														●

● Suggested milestone

.ppendix B: Example of solar system application

Stand-Alone Power Systems for Rural Health Facilities
by Tony Jimenez 11/99

Background

It is estimated that two billion people currently live in areas that lack electricity. Many of these areas will not be connected to the electric grid in the foreseeable future due to high grid-extension costs. However, areas beyond the grid can be serviced by a variety of stand-alone systems. These stand-alone systems can consist of combinations of photovoltaic (PV) panels, wind turbines, and generators running on diesel, gasoline, or propane. Stand-alone systems range in size from small solar lighting systems that provide 100–200 watt-hours for lighting at night, to diesel-powered mini grids with peak capacities of more than a megawatt. In remote communities, the local health clinic is often the first facility to be provided with electricity. Traditionally, the power has been supplied with fossil-fuel generators. More recently, PV panels have been installed in some clinics to provide electricity. Wind turbine generators have received less consideration for providing electricity to clinics.

Typical Clinic Services

- Inoculations
- Treatments for: Respiratory infections
  - Venereal diseases
  - Diarrheal diseases
  - Skin disease
  - Eye disease
  - Malaria
  - Parasitical diseases
- Trauma: Burns
  - Simple fractures
  - Wounds
  - Snake bites
- Prenatal/postnatal care and child birth
- Dental
- Referral to hospitals
- Public health education
- Family planning

Typical Applications

Typically, health clinics require electricity for lighting, communication equipment, and refrigeration. Electric lighting is vastly superior to candles and kerosene lamps. Often, when a clinic is electrified, lights are included in the initial installation package. Because of the need to conserve power, most off-grid clinics use compact fluorescent lights that typically draw from 5 to 20 watts each. Even clinics that use daylighting need electric lights for emergency night care. Emergencies also require reliable communication equipment. Electricity provides radio and satellite communications that enable the clinic staff to consult with specialists as needed and to arrange for the speedy evacuation of seriously ill or injured patients. Health clinics also rely heavily on refrigeration to maintain the viability of medicines and vaccines. In the last 15 years, great progress has been made in the development of vaccine refrigerators. These small, highly efficient, usually DC, refrigerators can be powered by a modest-sized solar array. Typical models draw 80–120 watts and will run for around 10 hours per day. Some super-efficient models use even less energy. Although they are expensive, these refrigerators are becoming increasingly popular and are considered so important that the World Health Organization has set standards for them. Like lighting, a vaccine refrigerator is often included in the installation package when a clinic is initially electrified. Other applications for electric power in clinics include small water pumps, ceiling fans, small sterilizing stoves, vaporizers, computers, centrifuges, and TVs and VCRs. The latter are used not only for entertainment, but also to show instructional and public health videos. Larger facilities such as district hospitals also may have additional laboratory equipment.