DEVELOPMENT OF HYBRID RENEWABLE ENERGY BASED ELECTRICAL POWER GENERATION SYSTEM

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By

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FINAL PROJECT REPORT

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Universiti Teknologi PETRONAS
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CERTIFICATION OF APPROVAL

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Raveen Kumar A/L Ramalingam

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
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TRONOH, PERAK

June 2010

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.

Raveen Kumar Ramalingam

ABSTRACT

Due to the global warming and other effects on Earth, the world is moving towards utilizing renewable energy. Malaysia is situated near to the equator where the ambient temperature remains uniformly high throughout the year, between 27 and 33°C, with an average daily solar radiation of 4500 kWh per square meter and an average daily sunshine duration of about 6-7 hours. Most locations have a relative humidity of 80–88%, rising to nearly 90% in the highland areas. Renewable Energy Based Island Generation (REBIG) consists of the combination of solar and wind electrical power generating system for island electrification. A strategic location for the utilization of REBIG is definitely along the coastal areas and also islands. In this study, Pulau Pangkor which is located in Perak is selected based on the geographic of its land and the availability of solar and wind energy. This project is to study the feasibility of implementing REBIG by conducting experiments and data collection. In addition, REBIG is developed to reduce the dependence on natural gases and fossil fuels as the source of generators. Initially, at the theoretical development stage, the modeling equations were formulated for sizing simulations. The results from data collection at Pulau Pangkor such as the solar radiation data and wind speed data are then used to develop sizing calculation software.

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Finally, I would like to thank Universiti Teknologi PETRONAS (UTP) for providing us with the excellent environment and access to facilities to complete this project on our own initiative. The progress of this project would have been slow should the Pyranometer and Anemometer were not made available for the experimentation.

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CHAPTER 1
INTRODUCTION

Malaysia is a country with significant wind and solar power potential. Furthermore, Malaysia has almost 6-7 hours of sun hour's daily and hence favorable conditions for PV (photovoltaic) installations. The location of Malaysia at the equator enhances the chances of utilizing renewable energies such as solar and wind energy for power system generation.

1.1 Background of study

For this project, literature review on the environment and the solar radiation of Malaysia is to be done because the radiation received for a particular location differs from others. Solar radiation is then measured using relevant instrument and this can be used to estimate the generated power. Pulau Pangkor is chosen as the case study for this project and the solar radiation data can be measured and to be used for PV sizing. Measured solar radiation can be processed to be used in developing solar power electricity generating system. Besides solar radiation, the wind energy in Pulau Pangkor is also strong feasible to provide power especially during monsoon season. Since solar energy is only available during sunshine hours, a mixture of energy with wind energy will enhance the reliability of REBIG. This is because wind occurs practically all the time and although not much power can be received, it is still significant once it is accumulated.

1.2 Problem Statement

Due to the availability of solar and wind energy in Malaysia, the energy received should be harnessed. The usage of renewable energy in Malaysia focused mainly for street lighting, water heaters, and telecommunications. The energy received daily is not utilized and that is a total waste. Therefore, the main outcome of this project would be to utilize these energies to be able to withstand the power consumption of Pulau Pangkor. As for the wind energy, it is almost not applied in Malaysia although we are already in the year 2010 comparing other countries such as Denmark and Sweden, which had already started wind energy from the year 1970s.

The reasons why the renewable energy is not developed vigorously in Malaysia are due to financial aspects and technical knowledge. Cost for development of solar and wind energy is undoubtedly high but for long term, it is proven to cover the initial cost of development and construction.

The problems that have motivated this project are the usage of natural gases and fossil fuels as source of generation. These two sources of energy are non-renewable and depletion will soon be a problem if Malaysia does not find an alternative solution. One possible solution is integrated hybrid renewable energy system. Another common problem is the volatility of fossil-fuel prices.

Figure 1 Hybrid Renewable Energy

1.3 Objectives

The objectives of this project are:

- To carry out feasibility study on the possibility of using island hybrid renewable energy system for electrical power generation.
- To carry out simulation studies to develop mathematical models for designing REBIG
- To develop software for hybrid renewable electricity generation system.

1.4 Scope of study

The scope of study of this project covers the following:

- Research on the current generation, distribution and transmission power system for Pulau Pangkor.
- Utilization of the Solar Lab in Universiti Teknologi PETRONAS for the measurement of solar radiation data
- Develop a user-friendly programme for the design of REBIG

CHAPTER 2
LITERATURE REVIEW AND THEORY

Places where solar energy and wind energy are naturally complementary, the application of Renewable Energy Based Island Generation (REBIG) can reduce the total cost of stand-alone Photovoltaic (PV) or wind generation system.

2.1 Solar Power

The energy from the sun can be converted directly into electrical energy using semiconductor cells. The semiconductor cells releases electrons when hit with rays of photons from the sunlight which produces an electrical current. PV captures the sun's energy and converts it to electricity. PV industry is vastly improving in terms of efficiency and reliability. [16]

A photovoltaic cell is usually made from silicon alloys. The silicon has dopant atoms introduced to create a p-type and an n-type region and thereby producing a p-n junction. This doping can be done by high temperature diffusion or ion implantation. Light of certain wavelengths is able to ionize the atoms in the silicon and the internal field produced by the junction separates some of the positive charges (holes) from the negative charges (electron) within the photovoltaic device. Although these opposite charges are attracted to each other, most of them can only recombine by passing through and external circuit outside the material because of the internal potential energy barrier. Therefore, power can be produced from the cells under illumination, since the free electrons have to pass through the load to recombine with the positive holes. [16]

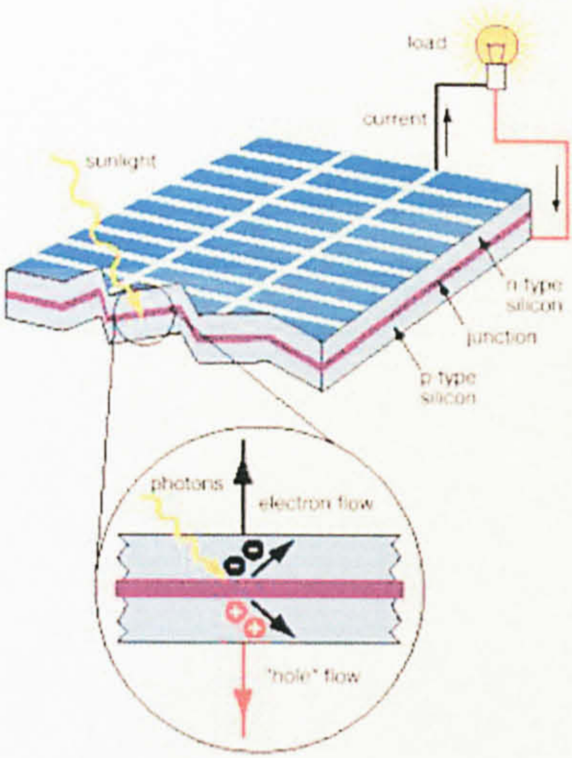

Figure 2 The PV effect in solar cell to produce electricity

2.2 Types of PV

There are many types of PV currently available in the industry. The efficiency of these PV is different depending on the material used to construct. The three main solar cell technologies current on the market are of mono-crystalline silicon, poly-crystalline silicon and dye-synthesized solar cell (DSSC).

2.2.1 Mono-crystalline silicon cell

Mono-crystalline silicon cells are thin wafers about 300μm in thickness, sliced from a large single crystal ingot which has been grown at around 1400°C , which is a very expensive process. The silicon must be of very high purity and have a near perfect crystal structure [16]

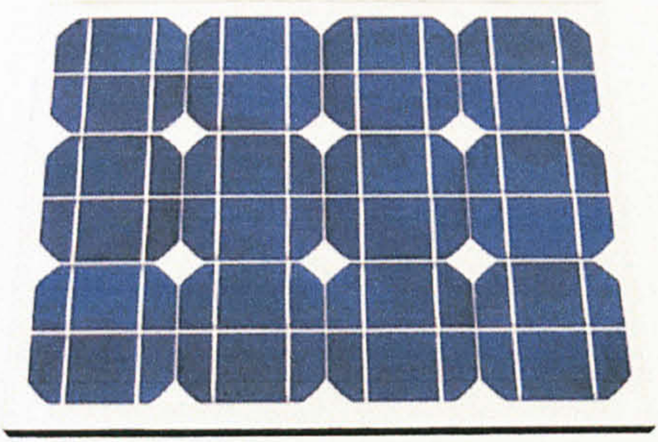

Figure 3 Mono-crystalline silicon cell solar panel

2.2.2 Poly-crystalline silicon cell

Poly-crystalline wafers are made by a casting process in which molten silicon is poured into a mould and allowed to set. Then it is sliced into wafers. As poly-crystalline wafers are made by casting, they are significantly cheaper than to produce, but not as efficient as mono-crystalline cells. The lower efficiency is due to imperfections in the crystal structure resulting from the casting process. [16]

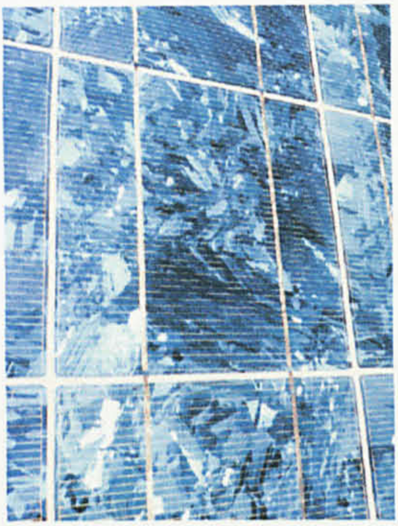

Figure 4 Poly-crystalline solar panel

2.2.3 Dye-synthesized solar cell (DSSC)

DSSC is the latest PV technology introduced. DSSC is a relatively new class of low cost solar cell. Although in terms of efficiency it still almost equal to mono-crystalline cells, the cost of production are lower. The working mechanism is based on photo electrochemical mechanism.

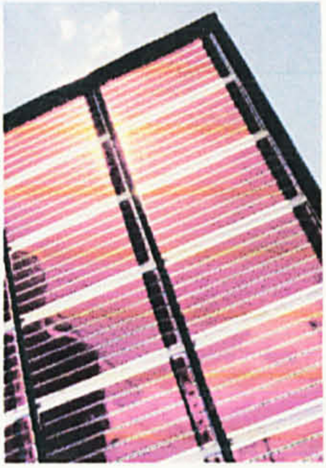

Figure 5 Dye-synthesized solar cell (DSSC)

2.3 Wind Power

Wind energy is converted into electrical energy by an electromechanical device called the wind turbine. Wind energy is another renewable energy that has been used for more than a thousand year. At the beginning, windmills have been used to harness the energy in the wind. Although the wind is not reliable as a power source due to the inconsistence, it can be operated in parallel with solar energy to obtain a fairly constant output.

Wind energy is an indirect form of solar energy as the winds result from the Earth's equatorial regions receives more solar radiation and this causes large-scale convection currents in the atmosphere. As for the wind energy, the basic kinetic energy formula can be used since wind energy is a kind of kinetic energy. The vital part of wind energy is the design of the wind turbine. Wind turbines are used to generate electricity from the kinetic power of the wind. Historical they were more frequently used as a mechanical device to turn machinery. There are two main kinds of wind generators, those with a vertical axis, and those with a horizontal axis. Wind turbines can be used to generate large amounts of electricity in wind farms both onshore and offshore. [8] There are several other essential parts of a wind turbine. Some of the main elements of a wind turbine generator are aerodynamics, stall, generator, gear box and controller.

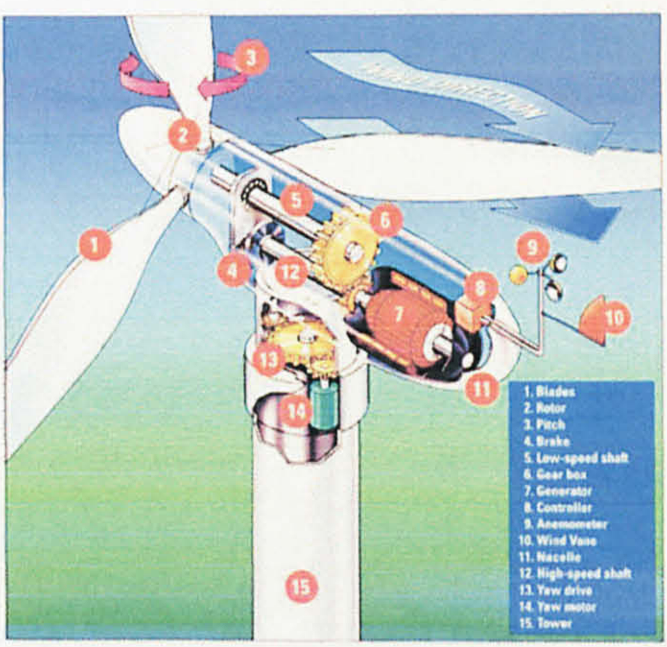

Figure 6 Main parts of a wind turbine

The power of the wind is calculated as shown in Equation (1) [8]

$$P\text{ (kinetic energy)} = 1/2\ (mv^2) \text{ or } P\text{ (kinetic energy)} = ½(\rho A v^3) \quad (1)$$

Whereby;

P (Kinetic energy) = kinetic power (energy/sec) W (J/s)

m= mass flow or also known as $\rho A v$

ρ= air density (kg/m^3)

A= area (m^2) $A = \pi r^2$

v= speed (m/s)

The density of air varies depending on the country and the height of sea level. The density is estimated at 1.25 kg/m^3 for calculation purposes. The power of the wind per m^2 by using Equation (2.1) is then;

P (kinetic energy) = ½(1.25) $v^3 = 0.625v^3$

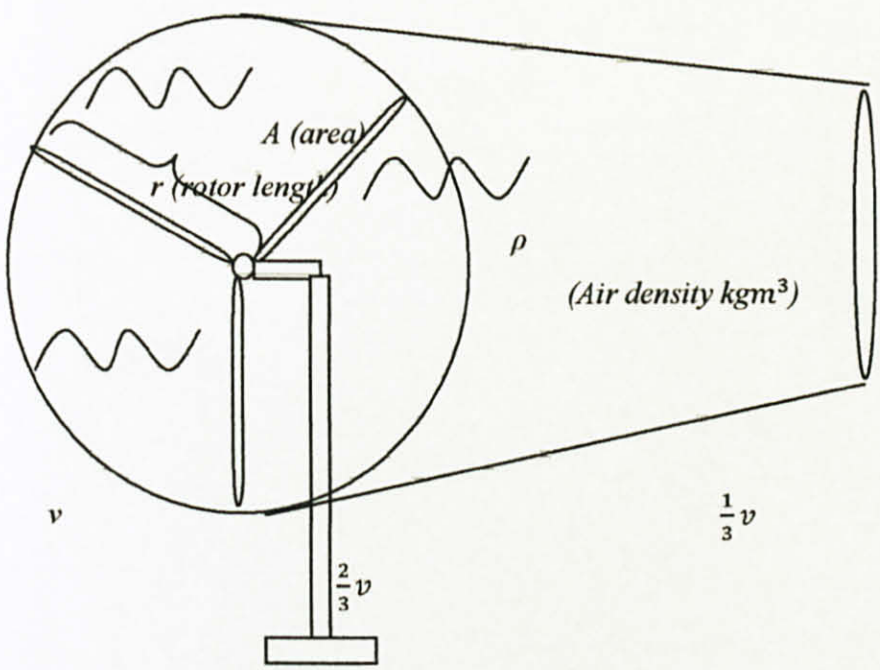

Figure 7 Typical Wind Turbine

2.3.1 Betz Law

According to Betz Law, wind turbine is most efficient when the wind speed is retarded by one third just in front of the rotor, and by another third behind the rotor. The undisturbed wind v is retarded by the rotor to $\frac{2}{3}v$ and will decrease to $\frac{1}{3}v$ behind the rotor before it regains its original wind speed due to the influence of the surrounding winds. The power in the wind is used most efficiently in this case -16/27 (59per cent) of the power in the wind can be extracted, ignoring aerodynamics and mechanical losses.

The share of the power in the wind that can be utilized by the rotor is called the power coefficient, C_p. Its maximum value is $C_{pmax} = 16/27\,(\approx 0.593)$. Therefore, the power that a wind turbine can attain can be expressed as Equation (2). [8].

$$P = \frac{1}{2}\rho A v^3 C_p \tag{2}$$

The power of the wind is proportional to the cube of the wind speed

For v= 5m/s, P = 0.625. 5^3 = 78W

For v= 10m/s, P = 0.625. 10^3 = 625W

625W= **8 times** 78

Therefore, when the wind doubles, the power increases by a factor of 8. The cubic of the velocity actually gives a big effect in the power generated and therefore it is advisable to install wind turbines at sites with the possible wind resources. Over limited ranges of height, this variation of wind speed can be represented using a simple power law to estimate the velocity of the wind at desired height. This can be done using the basic power law as Equation (3). [6].

$$\frac{V_h}{V_{10}} = \left(\frac{h}{10}\right)^n \tag{3}$$

Whereby V_h is the velocity at height h and V_{10} is the velocity at h = 10m. The magnitude of exponent n depends on the terrain roughness, but for flat open country n is approximately one seventh. It is proven that the wind speed at height about 60m is consequently 30% higher than the speed at h=10m. Besides that, the wind speed might also differ significantly within short distances depending on the geographic condition. As an example, location of a wind turbine on a hilltop will definitely have a higher speed compared to other locations. Hence, the wind turbine site selection should be undertaken with care and provisional site selection confirmed by wind speed measurements made over an extended period.

Although wind turbines cannot provide firm power they do have important energy saving roles such as operating in parallel with solar energy as proposed for this project to reduce the redundancy especially for off grid locations for example Pulau Pangkor.

2.3.2 Wind blade design types

The wind turbine has several designs according to the usage. Each design has its own advantage and methods of using it. Different types of wind turbine yields different amount of energy output when exposed to the same amount of wind.

An even number of blades are often avoided due to stability issues as described by [15]. An even number of blades are said to give a stiff structure and hence not preferable in designing a wind turbine. A rotor with an odd number of rotor blades can be considered to be similar to a disc when calculating the dynamic properties of the machine [15]. Table 1 shows the types of wind turbine available and its advantage

Table 1 Wind types and description

Single Bladed	Double Bladed	Triple Bladed
• Cheap • A counter weight needed to balance the blade • Not popular due to balancing problem	• Flexible in the vertical plane • Balancing problem • Require higher rotational speed to yield the same energy output.	• Rigid and weight • Most stable as the aerodynamic loading will be relatively uniform • Lesser aerodynamic losses

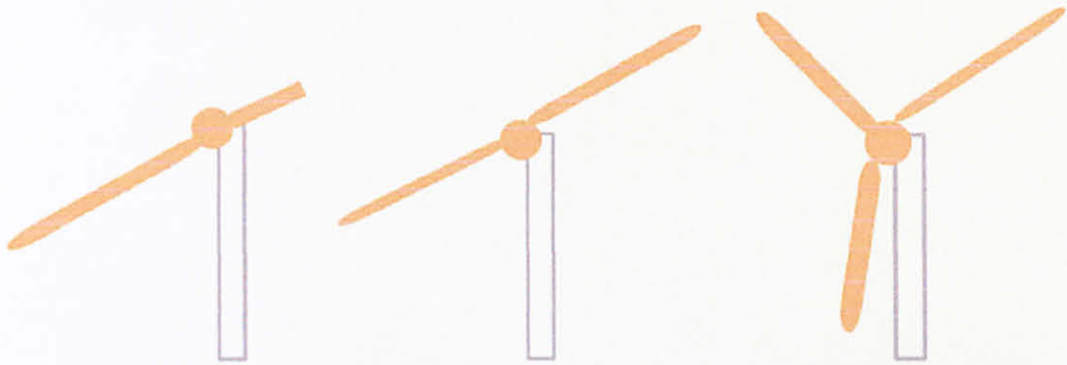

Figure 12 Single, double and triple bladed wind turbine respectively

CHAPTER 3
METHODOLOGY AND PROJECT WORK

3.1 Flow of project for Final Year Project

Preliminary steps and planning were carried before the construction of a working prototype. The steps are illustrated in the flow chart in the following figure.

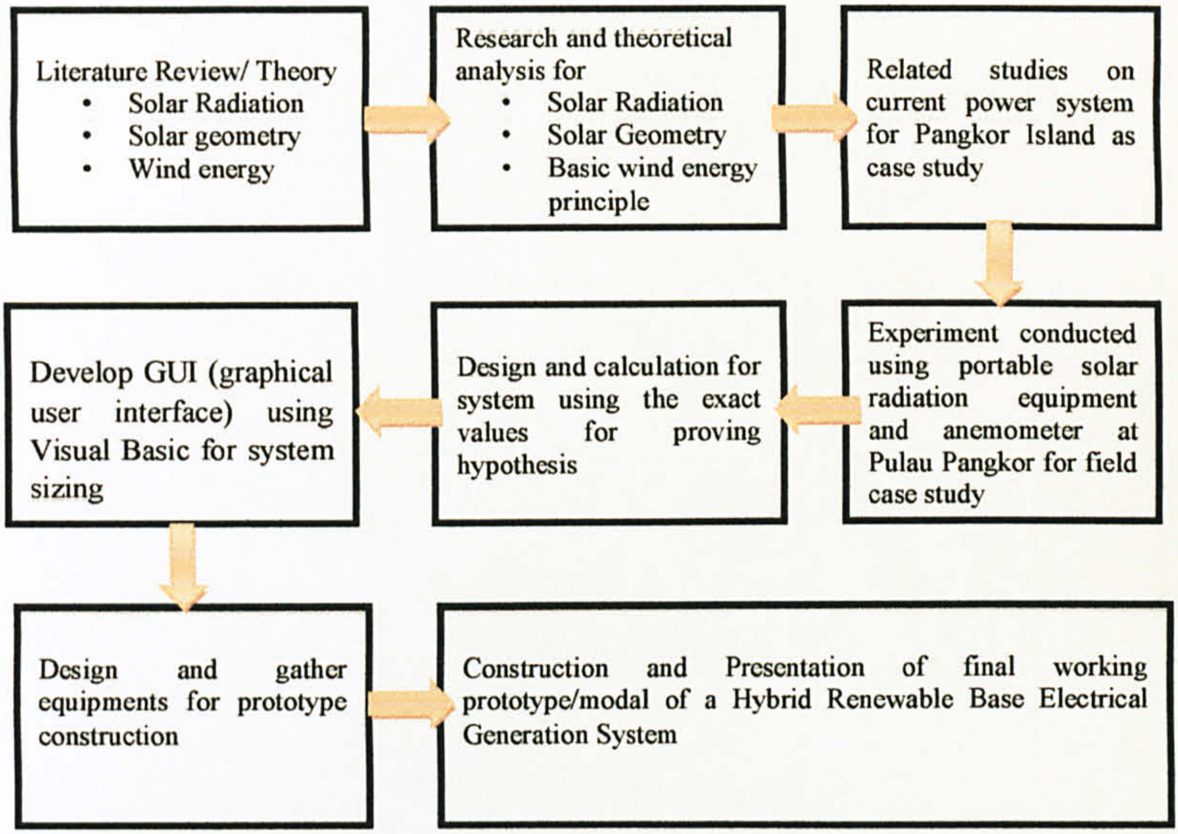

Figure 13 Flow chart of project methodology

Figure 13 illustrates the general progression of the project throughout the final year. During the time of writing, the current progress has reached the final stage. Current works includes the construction and presentation of final prototype of the hybrid renewable energy based electrical generation system.

3.2 Solar geometry calculation

The calculation for solar radiation of Pulau Pangkor is for the date 24th October 2009 at 0700 hours.

$n = 296$

From Equation (9)

$$\delta = 23.5 \sin\left(360 \frac{284 + n}{365}\right)$$

$$\delta = 17.68° = 0.309 rads^{-1}$$

From Equation (13)

$$\omega_s = cos^{-1}(-\tan\theta \tan\delta)$$

$$\omega_s = cos^{-1}(-\tan 4.17° \tan 17.68°)$$

$$\omega_s = 91.33° = 1.594 rads^{-1}$$

By using Equation (11)

$$I_{sc} = 1353\ W/m^2$$

$$I_{ext} = I_{sc}\left[1 + 0.033 \cos\frac{360n}{365}\right]$$

$$I_{ext} = 1369.7\, W/m^2$$

From Equation (12)

$$H_0 = 27490.91 I_{ext}\left[\cos\emptyset \cos\delta \sin\omega_s + \left(\frac{11}{630}\omega_s \sin\emptyset \sin\delta\right)\right]$$

$$H_o = 35.79M\ J/m^2$$

From Equation (14)

$$\overline{K_T} = \frac{\overline{H}}{\overline{H_o}}$$

$$\overline{K_T} = \frac{1.38M}{35.79M}$$

$$\overline{K}_T = 0.039$$

From Equation (15)

$$\overline{H}_d = (1.000 - 1.130\overline{K}_T)\overline{H}$$
$$\overline{H}_d = \left(1.000 - 1.130(0.039)\right)1.38M$$
$$\overline{H}_d = 1.32\ MJ/m^2 - day$$

For time 0700 hours, using Equation (16)

$$\overline{I}_d = \frac{11\overline{H}_d}{84}\left[\frac{\cos\omega - \cos\omega_s}{\sin\omega_s - \frac{11}{630}\omega_s\cos\omega_s}\right]$$
$$\overline{I}_d = 27.3kJ/m^2 - h$$

Therefore, the beam radiation can be obtained by using Equation (17)

$$I_b = \overline{I}_G - \overline{I}_d$$
$$\overline{I}_b = 0.19M - 27.3K$$
$$\overline{I}_b = 162.7K\ J/m^2 - h$$
$$\overline{I}_b = 45.2\ W/m^2$$

3.3 Tools and software requirements

Table 2 lists the revised hardware and software requirements for this project

Table 2 List of tools and equipment required

NO	ITEM	Quantity	Unit Price (MYR)
1.	Photovoltaic(PV) Array Panel (20W)	1	450.00
2.	12V Lead Acid Battery (1.3AH)	1	50.00
3.	6 Blade Rotor Set	1	5.90
4.	Induction motor (12V)	1	15.00
5.	Solar Charge Controller (Max 5Amp)	1	200.00
6.	Support structure for PV Panel and Wind Turbine	1 Unit	n/a
7.	Power Electronics component	1 Lot	n/a
8.	Visual Basic .NET 2005 Edition	1 Lot	n/a
9.	HOMER Software	1 Lot	n/a
Grand Total			720.90

The cost planning for this project is RM 720.90, which exceeds the given allocation cost allowance allocated by the university. However, the solar PV array panel and solar charge controller are share among other 2 students which therefore within the stipulated allowance.

3.4 Development of user-friendly programme using Visual Basic .NET

In order to achieve the objective of the project, a user-friendly based programme is developed so that user can size up hybrid renewable energy based electrical power generation system. The programme is developed into 3 different forms. The first one is to size up the battery or storage element. Sizing a battery is very essential because it is connected directly to load and if shortage will lead to insufficient supply. Figure 14 shows the battery sizing programme.

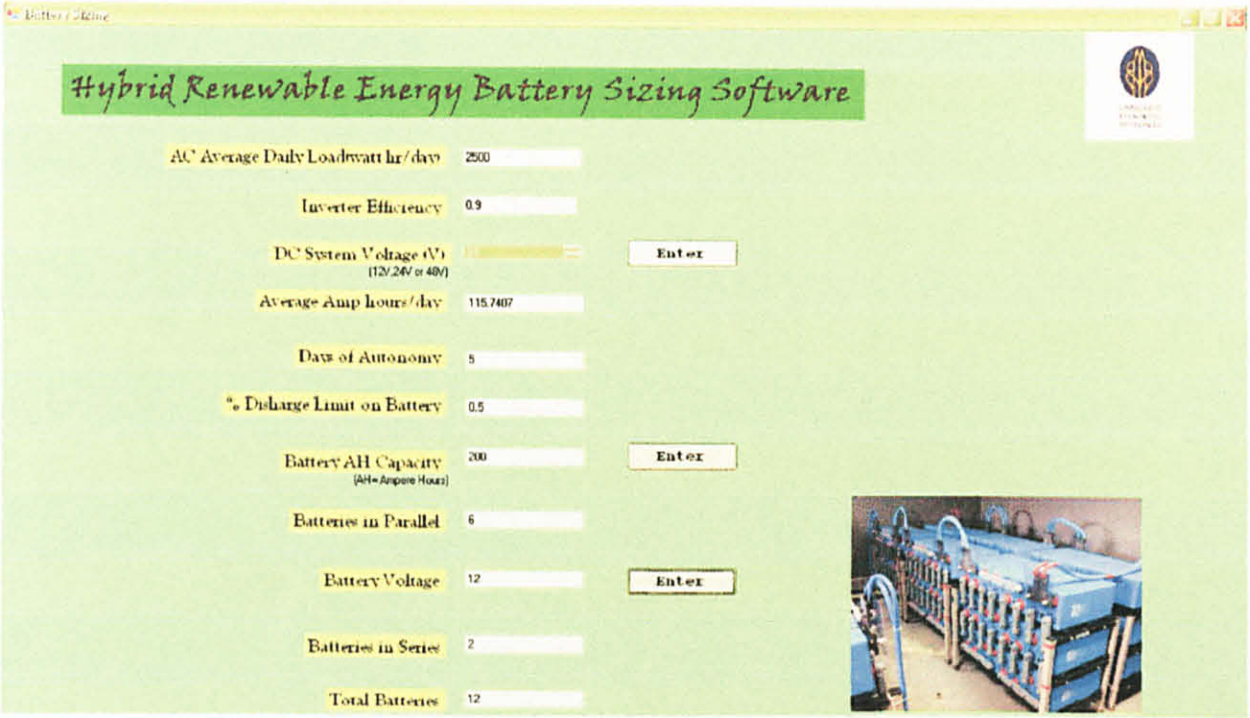

Figure 14 Battery Sizing Programme

The software is designed to calculate the batteries needed to be connected in parallel and in series and finally to calculate the total batteries needed based on the rating of the selected battery. The second software is used to size PV array panel and wind turbines needed based on user's input specifications. The calculations are based on theoretical formulas. This programme is designed to help user to build their hybrid renewable energy system according to their daily load. Figure 15 represents the software for hybrid renewable energy sizing.

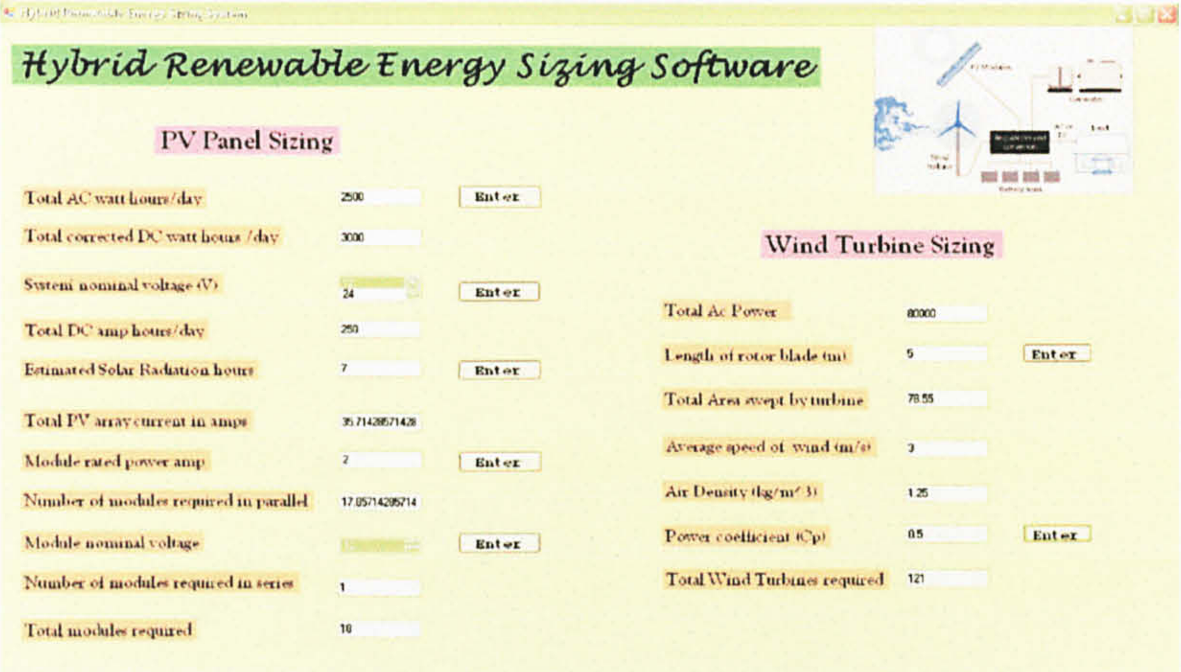

Figure 15 Hybrid Renewable Energy Sizing Programme

By using this software, user can now easily design their home hybrid renewable energy system to reduce the electricity bill. In case of less wind power around the location, one can design solely using solar PV array panel to power up their home instead of using hybrid system based on the software shown in figure 16.

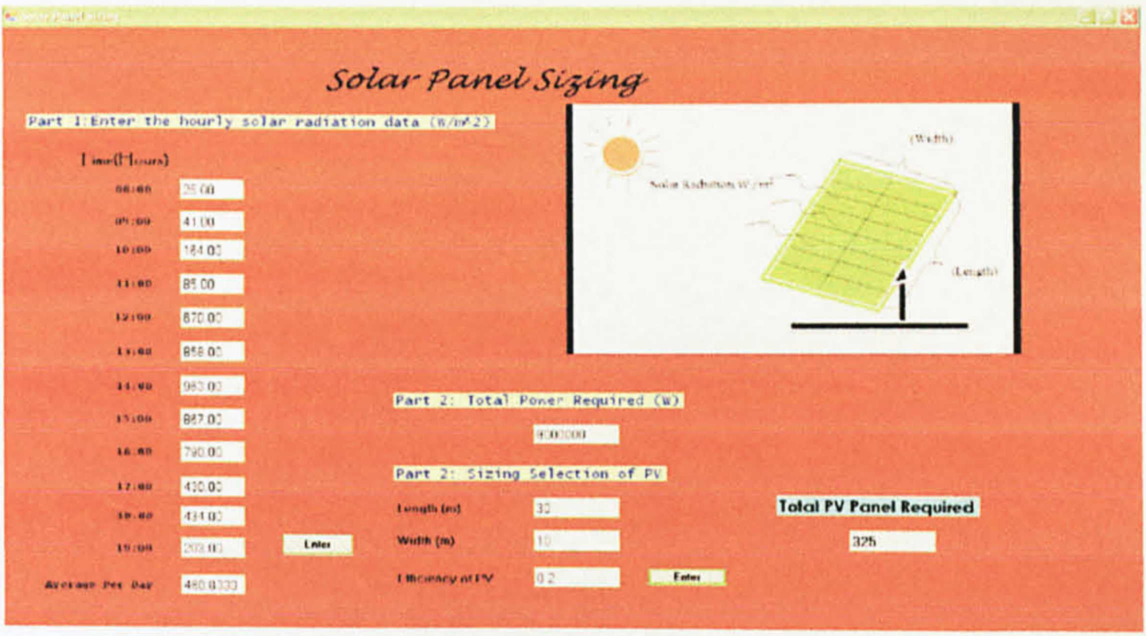

Figure 16 Solar Panel Sizing Programme

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Analysis on current power system analysis of Pulau Pangkor

The PPU TLDM via a submarine cable is supplying the current power system of Pulau Pangkor. It is supplied using the 2 parallel submarine cable of length 100km each. The power generation method being used is the conventional method by using the diesel and gas operated generators. With the current global warming and the concern on the availability of natural gasses in a few years time, it is high time for Malaysia to implement hybrid renewable energy to certain areas to reduce the dependency on natural gasses for power generation. Besides that, several disadvantages using submarine cables are as follow; [3]

- The cable must have the mechanical strength and flexibility to withstand the tensional and torsional stresses encountered during installation and if necessary during retrieval.
- Must be resistant to the penetration and corrosion or salt water means it is prone to corrosion.
- The environment not only affects the cable mechanically but also affects the transmission of energy through the cable.
- The mechanical protection sheath and the sea water may become part of the transmission line and therefore, may affect the transmission of energy.
- The use of metallic sheathing on a cable in a water environment changes the primary cable characteristics of resistance and inductance. These factors determine the system losses, voltage regulation, and ampacity and thus the suitability_of the cable for its intended.
- Moreover, the weight and torsional rigidity, and the difficulty in splicing and handling.
- The ampacity of a submarine power cable is most often limited by the higher ambient temperatures of the portion of the cable necessarily brought ashore and leading to the tie-in points.
- The line losses for long lengths can be substantial especially in AC system.

- High risk of catastrophic failure as the equipment and procedures are unique and only a few people are fully knowledgeable and qualified. [4]

In addition, there a total of 32 substations currently operating at Pulau Pangkor and this shows the amount of wiring cables needed to connect each other as it uses the ring connection system in which if one of the cable's trip, the other cable will supply as they are connected in circular ring. Some of the substation and its locations are shown in figure 17.

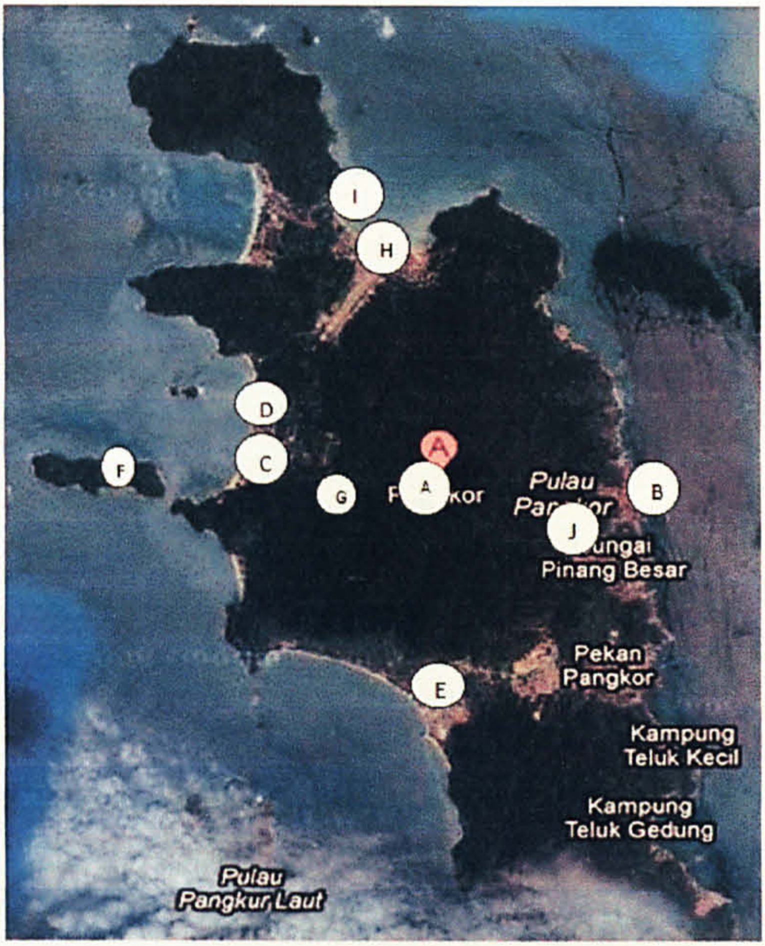

Figure 17 Pulau Pangkor

List of Substations

A. TMN Desa Pangkor
B. Pangkor Village
C. Bayview Hotel & Apartment
D. Coral Bay Resort
E. Sea View
F. Pulau Mentagor
G. Pat Tlk Nipah 2
H. Tlk Dalam Resort
I. Tlk Dalam
J. Sg Pinang 1

Table 3 Approximation of daily rated current for PPU Pulau Pangkor for August 2009

Supply PPU Pulau Pangkor 33/11	Rated current (Ampere) Daylight	Rated Current (Ampere) Night
Taman Seri Pangkor	112	140
Bay view	5	5
Desa Pangkor	32	40
Sinar Segari	10	10
Majlis Daerah Manjung	55	62
Total	214	257

Based on the data provided by Tenaga Nasional Berhad(TNB) Seri Manjung, the maximum demand which is needed for Pulau Pangkor is during night time which is 8.8306MW. Therefore, the REBIG should be sufficient to supply this amount to support the whole island.

4.2 Implementation of renewable energy for Pulau Pangkor

4.2.1 Availability of solar energy in Pulau Pangkor (Field Study)

Location : Pulau Pangkor (Teluk Nipah) (4°13'48"N, 100°32'45"E)

Date of experiment : 20th January 2010 (800Hrs – 1600Hrs)

Equipment used : i) Pyranometer

ii) Solar METEON

Table 4 Result of experiment for 20th January 2010

Time (Hours)	Solar Radiation (W/m^2)
8:00	25.00
8:30	37.00
9:00	41.00
9:30	144.00
10:00	164.00
10:30	69.00
11:00	85.00
11.30	88.00
12:00	670.00
12.30	710.00
13:00	858.00
13:30	902.00
14:00	963.00
14:30	938.00
15:00	867.00
15:30	573.00
16:00	790.00
16:30	777.00
17:00	430.00
17:30	434.00
18:00	203.00

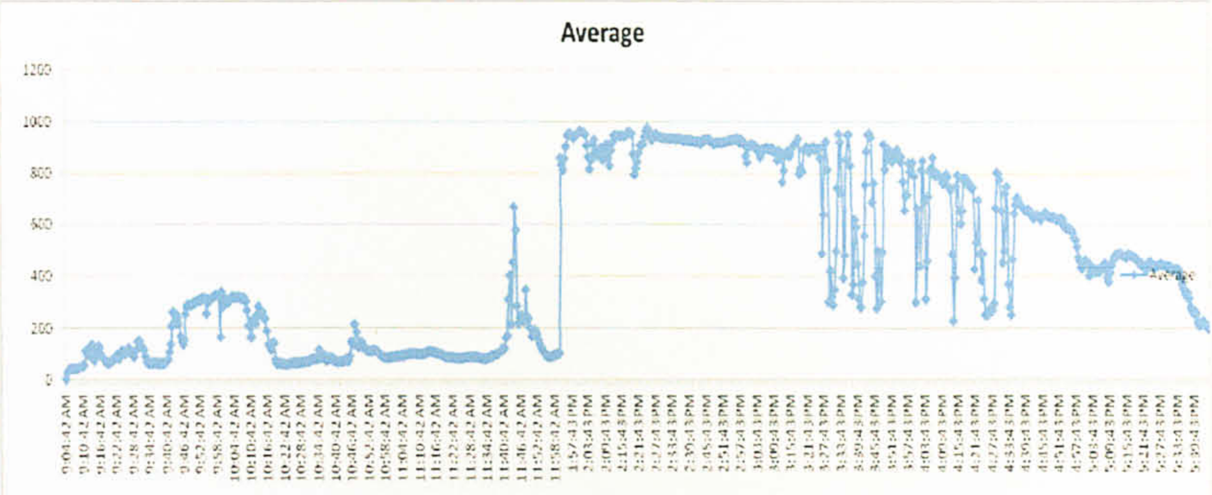

Figure 18 Overall solar radiation data for Pulau Pangkor (20th January 2010)

Figure 19 Pyranometer

4.2.1.1 Analysis of data collection

The overall solar radiation in Pulau Pangkor is as expected and predicted. The amount of solar radiation received is sufficient to electrify the island with proper photovoltaic (PV) design. However, there are a few drawbacks which are observed throughout the experiment period which may affect the global radiation received. The main concern is due to cloud. Cloudy days will affect the radiation from sun and it causes fluctuations. Besides that, another drawback is that the total sunshine hours are lesser compared to mainland but that too depending on the month. The instrument being used for the measurement is Pyranometer. This instrument is handy and the memory storage is also big as in it can save up data up to 14 days.

4.2.1.2 Comparison of Pulau Pangkor reading and the solar tracker in Universiti Teknologi PETRONAS

Date : 24th January 2010

Equipment : Solar Tracker, UTP

Table 5 Solar Radiation Data at Universiti Teknologi PETRONAS

Time (Hours)	Solar Radiation (W/m^2)
8:00	65.5
8.30	146.54
9:00	195.84
9:30	214.07
10:00	515.93
10.30	602.03
11:00	710.75
11.30	805.30
12:00	1017.00
12.30	1012.61
13:00	1111.1
13:30	1028.82
14:00	752.62
14:30	913.01
15:00	946.43
15:30	1042.33
16:00	203.94
16:30	11.82
17:00	16.88
17:30	16.21
18:00	15.53
Average (W/m^2)	540.24

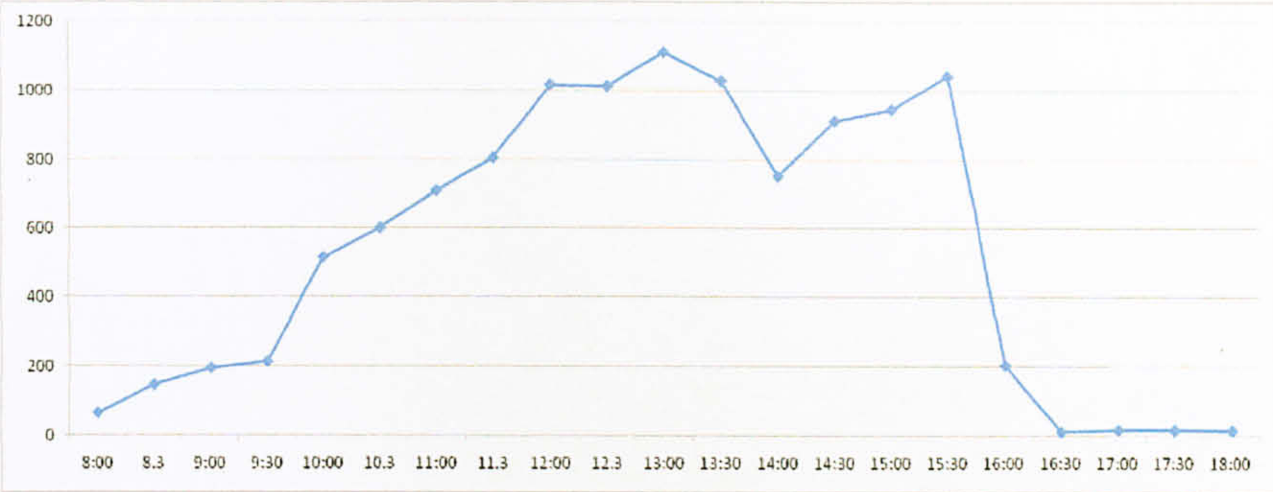

Figure 20 : Graph of solar radiation using the solar tracker of UTP

Figure 21 Solar tracking system situated on a tower at UTP

The radiation is considered lower than as expected due to several reasons. Cloudy days are the main concern because it can affect the reading massively resulting in lesser energy can be harnessed. This is the reason why the load cannot be connected directly due to its fluctuations. However, this can be overcome by using batteries and the energy from solar and wind can be used to charge the batteries. Hence the load can be connected directly to the batteries instead of direct supply from the sun or wind. Uninterruptible power supply (UPS) can also be used to supply a certain area depending on the demand.

4.2.1.3 Design calculation of solar collector

$$\eta(efficiency) = \frac{P_{output}}{P_{input}}$$

For the purpose of calculation, the efficiency is assumed to be 20%.

The output power that can be harnessed from the solar radiation can be calculated using the Equation (4)

$$P = \eta \times (Amount\ of\ solar\ radiation) \times Width(W) \times Length(L) \quad (4)$$

$$P = 0.2 \times (700\,W/m^2) \times 25m \times 30m$$

$$P = 0.105MW$$

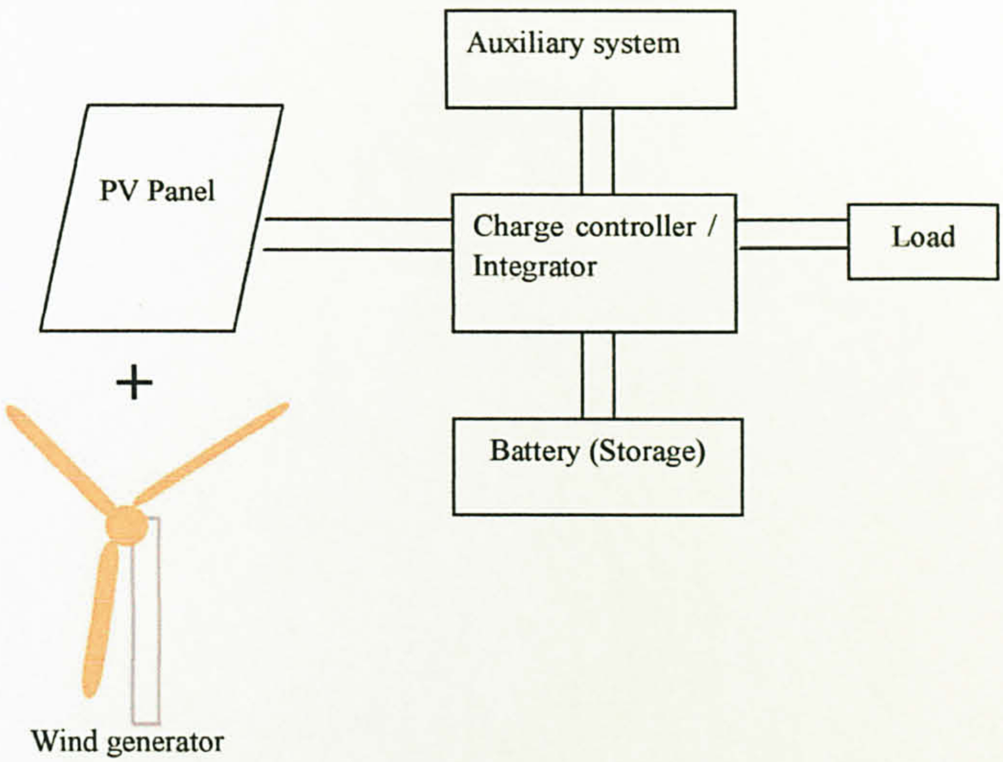

Figure 22 Proposed system for Pulau Pangkor REBIG

4.2.2 Wind energy at Pulau Pangkor

Date : 19th January 2010

Location : Teluk Nipah, Pulau Pangkor (4°13'48"N, 100°32'45"E)

Equipment : Anemometer

Table 6 Wind speed

Time (Hours)	Wind Speed (m/s)
14:00	1.9
15:00	2.0
16:00	3.1
17:00	3.7
18:00	3.2
19:00	4.0
20:00	2.2
Average (m/s)	3.35

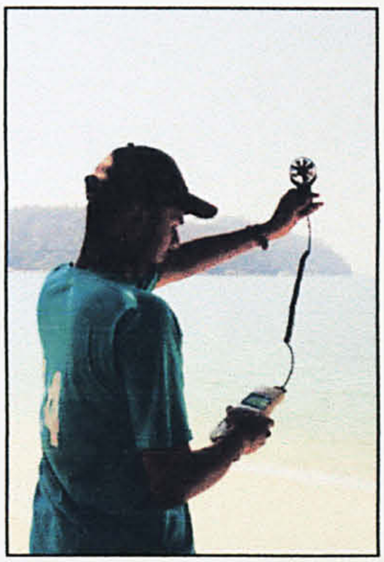

Figure 23 :Anemometer

4.2.2.1 Analysis of data collection (wind energy)

The average wind speed of Pulau Pangkor based from the Firstlook, website base software is 3 m/s. The experiment done in Pulau Pangkor proves that the average wind speed is 3.35m/s. However this number fluctuates according to the time and environment. Windy days provides stronger wind and therefore and advantage because of the cubic effect explained earlier. The instrument used is Anemometer which is sensitive and accurate to measure wind speed. One of the advantages of anemometer is that it can store data and it records highest speed recorded.

Using this speed value, the power, $P = \frac{1}{2}\rho A v^3 C_p$.The density of air varies depending on the country and the height of sea level. The density is estimated at 1.25 $kg/m^3$for calculation purposes. The power coefficient is normally selected as 0.5.

For design and calculation purpose

- the height of the wind turbine =20m
- length of blade = 1m
- Area covered = $\pi (r^2)$
- Wind speed(V) = $3.35\ m/s$

Total power for a wind turbine $= \frac{1}{2}(1.25 \times (\pi \times 1^2) \times 0.5 \times 3.15^3$

$\approx 30.685W \times 8760$

$\approx 268.804KWh/\,m^2/year$

4.2.3 Design conceptual

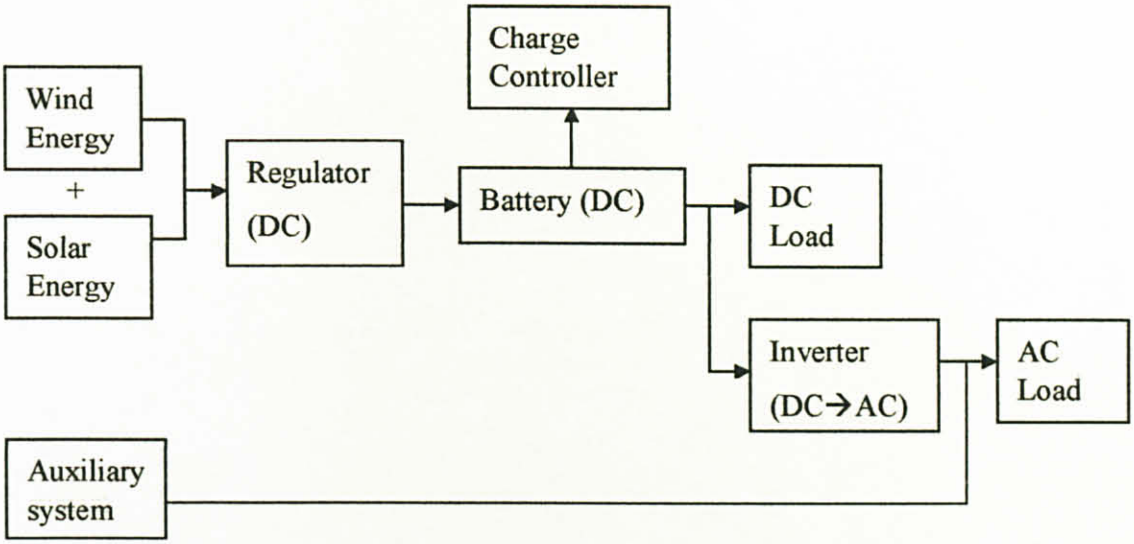

Figure 24 Basic flow design of prototype

Proposed Power System;

Size for solar collector is $25m \times 35m$ (4set for each power station)

Height for wind turbine is 20m. (5 turbines for each station)

Rotor length of wind turbine is 1m.

Using these values, to match or provide sufficient load of Pulau Pangkor, 4 power substations needed. The basic idea of location is shown at figure 2.The location is chosen based on the number of users and the area covered.

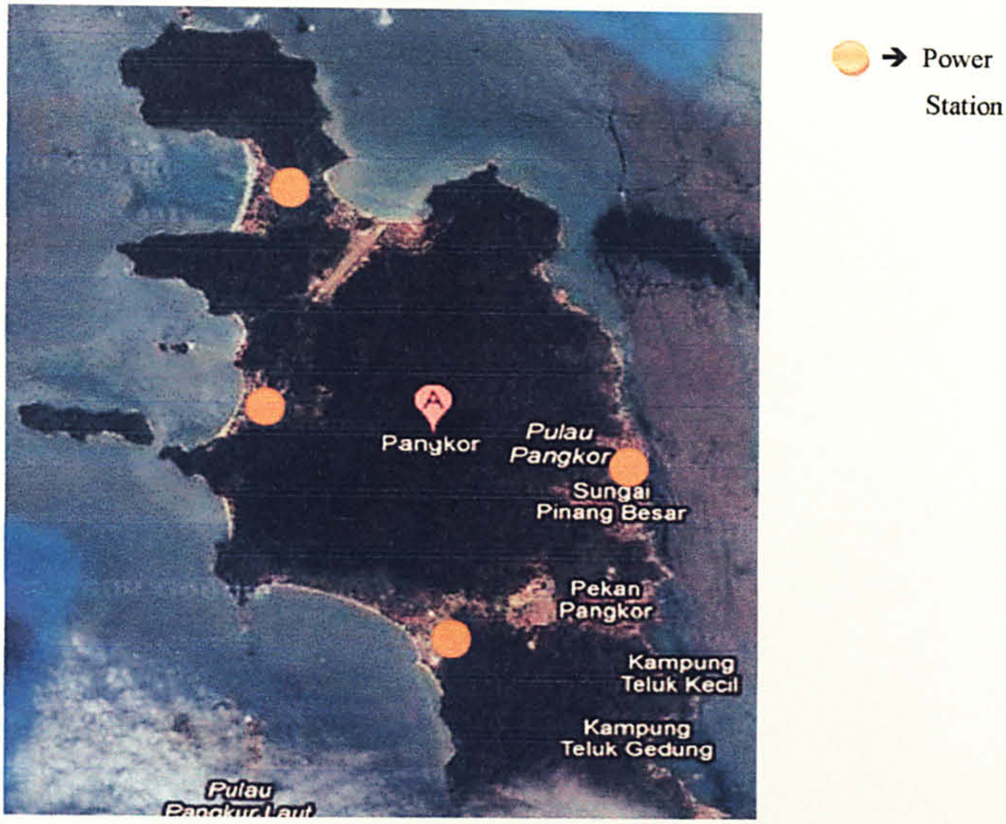

Figure 25   Proposed location for power substation.

By using distributed power generation system, the overall generation cost to supply Pulau Pangkor can be reduced. The usage of conventional power system comprises of transformer to step up and step down voltage is undoubtedly high and the power loss too. Besides that, the dependency on natural gasses and diesel generators can also be reduced. In future, if shortage of natural gasses and diesel, renewable energy can be an alternative supply and hence reduce the global warming indirectly. Moreover, there might be a possibility whereby the whole Pulau Pangkor can be supplied without any auxiliary system in near future.

4.3 Storage (Battery)

One of the vital parts of this project is the storage. Storage is essential since both solar and wind energy fluctuates and therefore cannot be connected directly to the load. A suitable battery bank is needed to meet the load requirement and hence the renewable energy can be used to charge the battery.

The charge controller is a part of the storage element and this controller monitors the condition of the battery and only charges when needed. Overcharging the battery will reduce the life span of a battery and damages the battery.

Using the developed programme, the battery sizing for Pulau Pangkor can be calculated by inserting needed information and details. The days of autonomy of the battery are also important in case the supply from the solar and wind is continuously not available for a certain days.

4.4 Prototype development

Based on the table 2, the equipments needed for this project are listed. Using these equipments, the hybrid renewable energy based electrical power generation system can be proved. Nevertheless, the prototype is small scale since it is just to prove and show briefly the idea of this project.

4.4.1 Experiment conducted for Solar Panel (20W)

The main issue of sizing a panel is the battery capacity used for it to charge. The sizing of battery is essential since it is required to supply continuous power to the load. Therefore, the choice of solar panel should have the capacity to charge the battery. For this project the solar panel is rated 20W and the battery used is lead acid type rated at 12V, 1.3AH. An experiment was conducted in order to determine the rate of charging the battery and the result is shown in table 7.

Table 7 Rate of battery charging

Time	Duration (hour)	Sun's Radiation (W/m^2)	Battery Voltage (V)
11.00 am	0	769.89	8.52
12.00 am	1	810.72	9.47
1.00 pm	2	828.23	10.56
2.00 pm	3	865.14	10.92
3.00 pm	4	833.27	12.55

Based on table 7, the solar panel is proven to be able to charge the 12V, 1.3AH seal lead acid battery within 4 hours of exposing to the direct sunlight. The rate of charging a battery actually depends on the power of solar panel. If the power of the solar panel is found to be lower than the battery, it will take longer time to fully charge the battery. This is the reason why sizing the panel and battery is vital in REBIG.

CHAPTER 5
CONCLUSION

This project basically enhances the knowledge on the renewable energy consists of wind and solar energy. Renewable energy is currently a hot prospect since most of the advanced countries such as United States, Japan and France has already developed this energy and utilized it in various kinds of industries. Other than that, the usage of oil and gas for power generation will also be reduced. Besides that, the field study conducted in Pulau Pangkor further increase the reliability of the hybrid system using the original data. A user friendly design software has been developed Visual Basic for user to implement hybrid system based on several equipment specifications.

5.1 Recommendations

Further studies can be conducted to further improve the hybrid renewable based electrical power generation system. The section below describes each individual approach:

5.1.1 Solar tracker

The common problem in using solar panel is that utilization of the panel itself. Based on previous operation, the solar panel is tilt to an angle to provide us optimum electricity. However, due to the location of the sun moving hourly, the area exposed to solar radiation defers according to time. Hence, using solar tracker, the total solar radiation emitted can be harnessed and will increase the efficiency of the overall system. This will generate more energy and the number of solar panel can be reduced. Solar tracker consists of active and passive. Active solar tracker are mounted to the solar panel array and controlled by motor to adjust according to the location of sun to optimize the solar radiation. Passive solar tracker is when manual adjustment of solar panel tilt angle based on seasonal period depending on previous data and weather forecasting authorities. Nevertheless, since Malaysia is situated at the equator, the tilt angle to optimize the solar panel is almost horizontal. Therefore, the solar tracker is actually not needed but it is useful for other European countries.

5.1.2 Tracking Wind Turbine

Malaysia has an average of 3 m/s speed of wind and it is not strong as other countries in different region. This is the main reason behind choosing an island as the case study because the wind speed at islands and coastal areas are higher than other locations. Hence, to utilize the wind turbine, future research and modification of using tracking wind turbine whereby the turbine changes its angle according to stronger wind power. Further studies can be developed to compare between a non tracking and tracking wind turbine to prove the hypothesis.

5.1.3 Addition of another renewable energy

Another recommendation useful to this project is adding the tidal wave energy to the current hybrid renewable energy system. Since, the implementation of this project is at island, it would be more reliable if it is added with the tidal wave energy. Especially during monsoon season whereby the solar energy is not consistent, the wind energy added with the tidal wave energy can provide uninterruptible supply. Tidal wave is a renewable energy because it is due to the gravitational effect of Earth with the Moon and Sun. A tidal generator uses this phenomenon to generate electricity. The stronger the tide, either in water level height or tidal current velocities, the greater the potential for tidal electricity generation.

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APPENDICES

APPENDIX A
OVERALL PROJECT SCHEDULE

	Semester 1														Semester 2														
Details Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Selection of project title/ supervisor	■		HIN1 HOLIDAY						MIDSEM BREAK													MIDSEM BREAK							
Preliminary research → Solar radiation → Solar geometry		■		■																									
Research on wind sources and turbines				■	■																								
Submission of Prelim Report				■																									
Research on case study – Pulau Pangkor						■	■																						
Submission of progress report								■																					
Project work →Calculation → Project Proposal								■		■	■	■	■																
Seminar											■																		
Submission of final interim report														■															
Oral Presentation														■															
Experiment at Pulau Pangkor for • Solar radiation data • Wind speed data															■														
Feasibility study using actual data																■													
Development of GUI using Visual Basic for • Hybrid Sizing software • PV Sizing Software • Battery Sizing software																	■	■	■	■	■								
Submission of progress report																					■								
Prototype construction and development																							■	■	■				
Poster exhibition																										■			
Draft report submission																											■		
Submission of dissertation (Soft bound)																												■	
Final presentation																													■
Submission of dissertation (Hard bound)																													■

APPENDIX B
FINAL WORKING PROTOTYPE

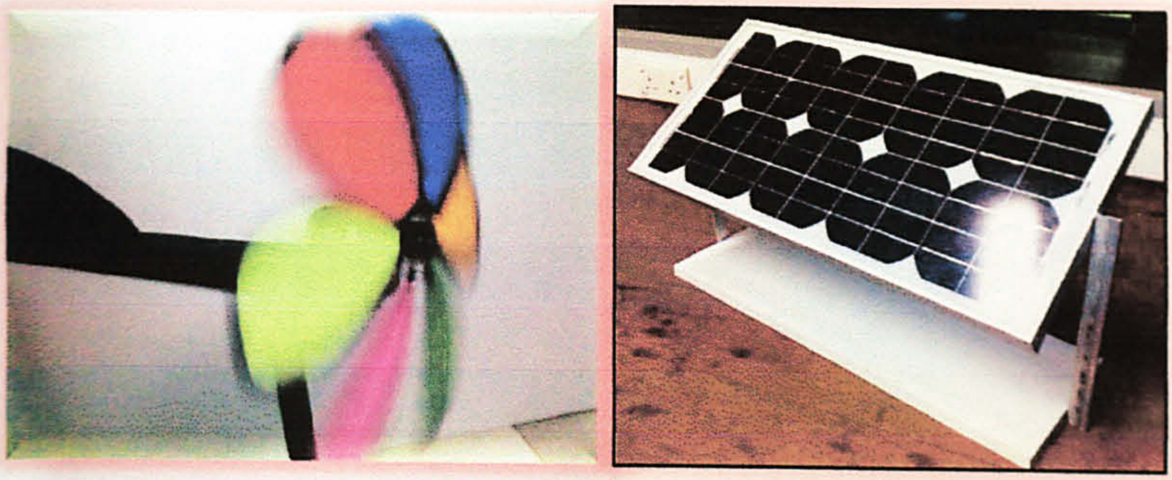

Figure 26 Wind turbine and Solar Panel (20W)

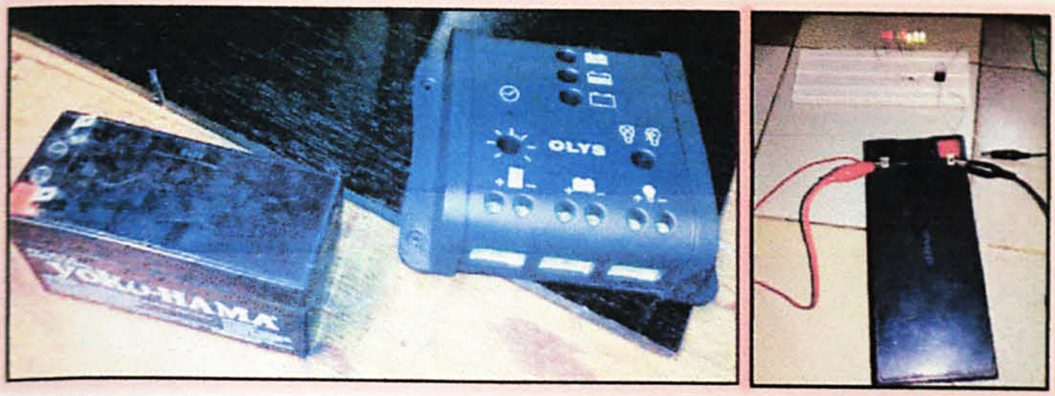

Figure 27 Charge controller(5AH) and battery 12V,1.3AH

APPENDIX C
LIST OF EQUATIONS FOR MATHEMATIC MODELLING

$$E = 229.2(0.000075+0.001868\cos B-0.032077\sin B-0.014615\cos 2B-\sin 2B \tag{5}$$

$$B = (n-1)\frac{360}{365} \quad and\ 1 \leq n \leq 365 \tag{6}$$

$$t_s - t_1 = 4(L_{st} - L_{loc}) + E \tag{7}$$

$$\omega = 15(t_s - 12) \tag{8}$$

$$\delta = 23.5 sin\left(360\frac{284+n}{365}\right) \tag{9}$$

$$cos\theta = sin^2\delta + cos^2\delta cos\omega \tag{10}$$

$$I_{ext} = I_{sc}\left[1 + 0.033\cos\frac{360n}{365}\right] \tag{11}$$

$$H_0 = 27490.91 I_{ext}\left[\cos\emptyset\cos\delta\sin\omega_s + \left(\frac{11}{630}\omega_s\sin\emptyset\sin\delta\right)\right] \tag{12}$$

$$\omega_s = cos^{-1}(-\tan\theta\tan\delta) \tag{13}$$

$$\overline{K_T} = \frac{\bar{H}}{\bar{H_o}} \tag{14}$$

$$\bar{H} = (1.000 - 1.130\bar{K}_T)\bar{H} \tag{15}$$

$$\bar{I}_d = \frac{11\bar{H}_d}{84}\left[\frac{\cos\omega - \cos\omega_s}{\sin\omega_s - \frac{11}{630}\omega_s\cos\omega_s}\right] \tag{16}$$

$$I_b = \bar{I}_G - \bar{I}_d \tag{17}$$

$$R_b = \frac{cos\theta}{cos\theta_z} \tag{18}$$

$$R_b = \frac{1+cos\beta}{2} \tag{19}$$