Feasibility Study for Implementation of Renewable Energy Based Electricity Generating System

By

NUR SYAZANA BINTI AHMAD TAJUDDIN

FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Feasibility Study for Implementation of Renewable Energy Based Electricity Generating System

by

Nur Syazana Binti Ahmad Tajuddin

A project dissertation submitted to the
Department of Electrical & Electronic Engineering
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

Approved:

____

Assoc. Prof. Dr. Balbir Singh Mahinder Singh

Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2013

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.

____

Nur Syazana Binti Ahmad Tajuddin

ABSTRACT

Nowadays, renewable energy sources are becoming important in contributing to the electricity generation to reduce dependency on fossil fuels that are predicted to deplete soon. Besides, the world's energy demand is growing rapidly from year to year. Implementation of renewable energy system could solve this problem. In addition, a lot of benefits can be obtained by the country especially in the effort to reduce carbon dioxide emission from non-renewable energy resources such as coal and fossil fuels. Malaysia is one of the potential countries that can make use of renewable energy sources for electricity generation. This is because this country receives abundance of renewable energy such as solar, wind, water and others. This project intends to look into the possibility of implementation of renewable energy based electricity generating system in Malaysia and also the implementation strategies. This paper highlights the analysis of resource data, electricity production, techno-economic, land area and software development. Three types of system were compared in this study which is hybrid solar-wind with generator system, solar with generator system, and hybrid solar-wind system. Eventually, the project was successfully done.

ACKNOWLEDGEMENTS

First and foremost, my deepest gratitude to God, for given me strength and guidance to overcome the challenges and problems in completing the whole 28 weeks of my final year project. I also would like to greet my family especially my parents for giving me great support from the beginning of my journey until the end.

My sincerest appreciation goes to my Supervisor, Assoc. Prof. Dr. Balbir Singh Mahinder Singh for his patience in guiding me and his determination to make me learn as much as I can throughout my final year project period. He has motivated me to become a better person and ready to face challenges in future and also technical competency in the area of renewable energy utilization for electricity generation.

Also not to forgot to the Final Year Project Committee that arranging and managing my final year project in order to successfully complete the course. It has been such a superb and knowledgeable experience being exposed to this project.

To all my colleagues, thank you for all your support, and motivation to me. I truly appreciate the knowledge and experience shared that made me strives to be a better somebody. Hope we continue the friendship and cooperation in the future.

May God bless all of you and thank you.

Nur Syazana Binti Ahmad Tajuddin
Electrical & Electronic Engineering
Universiti Teknologi PETRONAS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

LPP	Lumut Power Plant
SEV	Segari Energy Venture
FiT	Feed in Tariff
UTP	Universiti Teknologi PETRONAS
FYP	Final Year Project
SREP	Small Renewable Energy Power Programme
CCGT	Combine Cycle Gas Turbine

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Nowadays, renewable energy has become popular all over the world. According to the 10th Malaysia Plan, in order to meet the growing energy demand, Malaysia has to make use of renewable energy for electricity generation **[1]**.

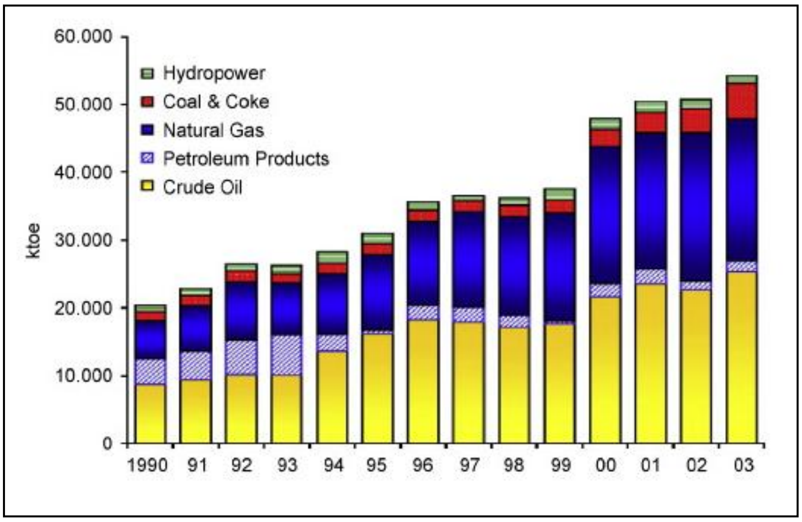


Figure 1 : Electricity generation fuel mix in Malaysia, 1990–2003 [2]

Thermal generation and hydro generation are the main sectors that supply electricity in Malaysia. Figure 1 shows the electricity generation fuel mix in Malaysia from 1990 to 2003 **[2]**. As can be seen from the year 1990 to 2003, the electricity generation is highly depending on crude oil and natural gas which are non-renewable resources. The demand toward these energy resources keep on increasing throughout the years. Thus, as an effort to the contribution of the electricity generation based on renewable energy, Ministry of Energy, Green Technology and Water introduced SREP. The purpose of this program is to encourage the development of new source of renewable energy such as hydro, solar, wind, biomass and biogas **[3]**. There are three principles identified to develop energy sector; having high efficient, cost-effective energy supplies and minimizing negative impacts on energy production. Government changed the Four-Fuel Policy to Five-Fuel Policy by adding the renewable energy as the fifth fuel in May 2001. Approximately 5% of electricity will be provided by the renewable energy as targeted in this new policy **[4]**.

In this project, author will be focusing on a feasibility study of implementing hybrid renewable solar-wind electricity generator since there are various important aspects regarding the engineering of this project that need to be considered. This is very important since the decision whether to implement a renewable energy plant or not should be based on this feasibility study **[5]**.

1.2 Problem Statement

Malaysia is one of the potential countries that can make use of renewable energy sources to generate electricity. In order to implement a renewable energy system, feasibility study need to be carried out. This study will attempt to cover the aspects that might affect the amount of electricity generated by the renewable plant in the future. One of the main factors that affect the electricity generation is weather pattern of the specific plant location. A study on the average of wind speed and solar radiation of the location needs to be done since it will affect the sustainability of the plant. Furthermore, to obtain optimum electricity generation, a proper plant sizing is required. So, basically this feasibility study is done to ensure the plant to be implemented having high efficient, cost-effective and minimizing the negative impacts to meet the load demand.

1.3 Objectives

The objectives of this project are:

- To carry out a feasibility study on the potential of implementing renewable energy based hybrid solar-wind power plant in Malaysia
- To establish the implementation strategies for the hybrid wind-solar electricity generating system.

1.4 Scope of Study

The scope of this project can be divided into three major categories which are wind speed and solar radiation data, projection of load demand and comparison with the existing power plant. For the first element which is wind speed and solar radiation data, the author collected wind speed and solar radiation data in UTP. A research on the average of solar radiation and wind speed rate at the selected plant area will be conducted. Once the data is available, author did an analysis how these elements will affect the electricity sustainability of the plant.

Moving to the next element, author did load demand analysis. There is a relationship between load demand and system sizing. Appropriate system sizing is needed to make sure adequate power supply to the loads. For the last part, author will do a comparison between one of the existing power plants which is Segari Lumut Power Plant, located in Perak and a proposed hybrid renewable solar-wind electricity generator.

1.5 The Relevancy of Study

This project basically stresses more on Energy & Power discipline. Previously, author had been exposed to the subjects that related to Energy & Power such as Electrical Energy System and Electrical Machine. Thus, this early exposure can help the author to complete the project.

1.6 Feasibility of the Project within the Scope and Time Frame

The scope of the project is feasible to be done within the time frame given. In Final Year Project 2, students should be able to complete the whole project activities. Thus, the time frame given should be sufficient to complete the whole project.

CHAPTER 2

LITERATURE REVIEW

2.1 Solar Distribution Analysis

Basically there are several researches related to solar radiation distribution in Malaysia. Solar radiation data need to be collected in order to calculate the land area required for the implementation of solar panel.

Figure 2 below shows the distribution of solar radiation of few towns in Malaysia that been done by **[6]**. According to the research, Malaysia receives average approximately 16.86MJm^{-2} of solar radiation per day. From 1989 to 2009 there is no trend that the solar radiations will changes in Malaysia except for Kuala Terengganu and Senai **[6]**.

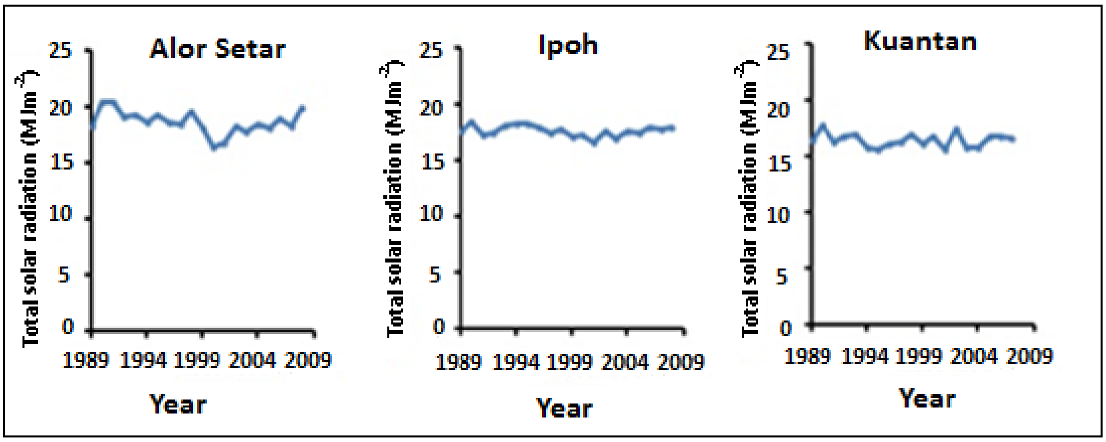


Figure 2 : Solar radiation of few towns in Malaysia [6]

Table 1 : Average of solar radiation in Malaysia

Location	Solar Radiation (MJm^{-2})
Alor Setar	18.40
Bayan Lepas	17.70
Chuping	17.90
Ipoh	17.60
Kota Bharu	18.00
Kota Kinabalu	17.80
Kuala Terengganu	16.90
Kuantan	16.00
Kuching	15.10
Labuan	17.30
Melaka	16.80
Mersing	16.00
Senai	14.60
Subang	15.90
Average	16.86

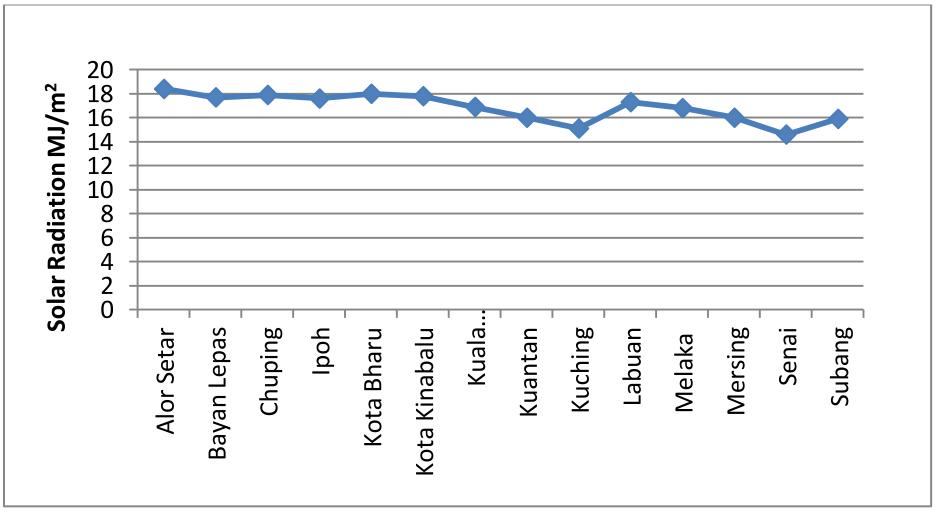


Figure 3 : Average of solar radiation of few towns in Malaysia

In average Malaysia receives 4682.5 Whm^{-2} per day. Based on his research approximately 73,000 m^2 of land area is required to generate every 1 MW of electricity in Malaysia **[6]**. The photovoltaic sizing is highly depending on power required from the system. The size of solar panel is depending on solar energy and load demand of the location. Hence, to solve this problem, there is a need to minimize energy consumption by using the most efficient equipment and design this solar power system around the energy-efficient system **[7]**.

2.2 Wind Distribution Analysis

The average annual wind speeds in Malaysia is approximately 1.8 ms^{-1}. The strongest wind speed locations are at Mersing, Kuala Terengganu and Kota Baharu. All the locations show similar trend which have strongest wind speed during early and late of the year except for Kota Kinabalu, Kuching, Subang and Serdang. This is depending on the land condition of the specific locations **[6].**

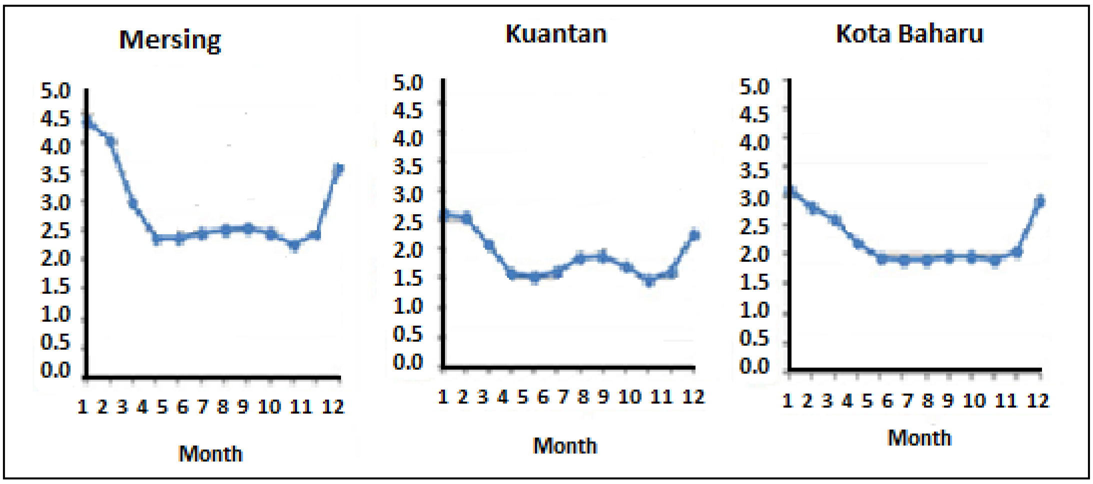


Figure 4 : Wind speed distribution of few towns in Malaysia [6]

Table 2 : Average of wind speed in Malaysia

Location	Wind Speed (ms^{-1})
Alor Setar	1.48
Bayan Lepas	1.79
Chuping	1.42
Ipoh	1.33
Kota Bharu	2.28
Kota Kinabalu	2.02
Kuala Terengganu	2.87
Kuantan	1.90
Kuching	1.20
Labuan	2.25
Melaka	1.62
Mersing	2.87
Senai	1.37
Subang	1.53
Average	1.85

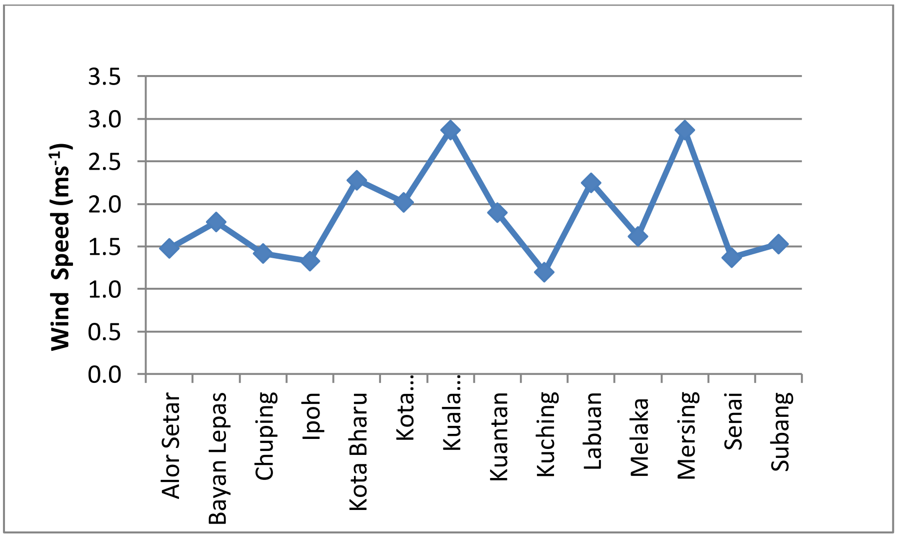


Figure 5 : Average of wind speed of few towns in Malaysia

According to this research the land area required to implement windmill generator is 18,977 km^2 to meet 10 % of the demand of electricity in Malaysia by 2020 which is expected to reach 124,677 GWh. This is based on few assumptions, the wind turbine has diameter of 25m, air density is $1.3kgm^{-3}$, the windmill efficiency is 50% and average wind speed is equal to $3ms^{-1}$. Thus, a single windmill is expected to generate 4309 W **[6]**.

From this result, we can say that the implementation area that required for windmill in Malaysia is quiet large. In order to reduce this amount, we need to improve the wind output. There are three ways of improving the wind output. Firstly is by increasing the wind speed. This can be done by finding the better site or use taller tower. Seconds is by increasing the swept area of the rotor. As for this case, a wind turbine with larger rotor diameter can be used. For the last one, improve the wind turbine conversion efficiency which is by using different wind turbine with better efficiency **[8]**.

2.3 Existing Power Plants

2.3.1 Lumut Power Plant

LPP uses the CCGT and is owned by SEV Sdn Bhd. This power plant is located at district of Manjung in Lumut, Perak. The base area of the plant is approximately 80 acre site which was previously an old tin mining land. Lumut combine cycle power plant is designed to produce the net output capacity approximately 1,300 MW power generations. It is the biggest gas fired power plant in Malaysia **[9].** LPP is designed with the latest technology to reduce emissions and effluents below the good level requirement. Generally, this plant is consisting of two identical 650MW blocks. Each block comes with three 143MW gas turbines, three heat recovery steam generators, and one condensing steam turbine generator unit **[9]**.

2.3.2 Arnedo Solar Power Plant

Figure 6 : Arnedo Solar Power Plant [10].

Arnado Solar Plant is located in Spain. This plant basically produces about 34 GWh every year which harvested about 70 hectares of land to locate 172,000 of solar panels. This plant produced approximately 94.44 MWh each day. This project was using solar panel which rated 200 W each. The cost to implement this project is extremely high which is around RM 720 million in Malaysia Ringgit. However this plant can power 12,000 households and can prevent 375,000 tonnes of carbon dioxide emission **[10]**.

2.3.3 Alta Wind Farm

Figure 7 shows Alta Wind Farm that is located in California. It is the largest wind farm in the world. The rated capacity of this plant is 1,020 MW. Roughly this plant produced 2,680.6 GWh each year. More than 52 million metric tonnes of carbon dioxide emission are reduces which is equivalent to 446,000 numbers of cars on the road. The total land area required by this farm is 3,642 hectares **[11].**

Figure 7 : Alta Wind Farm [11]

2.3.4 Comparison between renewable energy system with existing power plants.

Table 3 shows the comparison of Lumut Power Plant with Arnedo Solar Power Plant and Alta Wind Farm. As can be seen from the table, Lumut Power Plant has highest plant capacity which is 1,300 MW. Alta Wind Farm recorded 1020 MW plant capacity, then followed by Arnedo Solar Power Plant which is 17 MW. Thus, the highest annual production also will be Lumut Power Plant followed by Alta Wind Farm and Arnedo Solar Power Plant. In term of total land area, Alta Wind Farm harvested the largest area which is 3,642 hectares. Then, it is followed by Arnedo Power Plant and Lumut Power Plant. Moving to the last element of the comparison, we will look into reduction of carbon dioxide of each plant. Alta Wind Farm can reduce approximately 52 million tonnes of carbon dioxide and then followed by Arnedo Power Plant which is 375,000 tonnes of carbon dioxide.

Table 3 : Plant Comparison [9] [10] [11].

Plant	Arnedo Solar Power Plant	Alta Wind Farm	Lumut Power Plant
Capacity (MW)	17	1020	1,300
Annual Production (GWh)	34	2680.6	11,388
Total Land Area (hectares)	70	3,642	32
CO_2 Reduction Emission	375,000 tonnes	52,000,000 tonnes	Not Available

2.4 Future of Hybrid Power Plant in Malaysia

The sustainability of renewable energy power plant can be achieved if the system depends on more than one renewable energy sources. Hybridization of solar energy and wind energy is one of the examples of hybrid renewable energy system that suitable to be implemented in Malaysia. This is because wind speed in Malaysia is higher during early and late in the year and coastal area especially in East Peninsular Malaysia and East Malaysia will give high wind speed rate. The amount of solar radiation that available in Malaysia is abundance. However, this solar radiation is only available at daytime. Hence, hybrid renewable based electricity generating system is the best solution to provide sustainability of electricity generation in Malaysia **[6].**

Figure 8 : Hybrid Solar Wind System

2.5 Current electricity tariff in Malaysia

Figure 9 shows the electricity tariff for domestic used in Malaysia. This table is provided by **[12]**.

	TARIFF CATEGORY	UNIT	RATES
1.	**Tariff A - Domestic Tariff**		
	For the first 200 kWh (1 - 200 kWh) per month	sen/kWh	21.8
	For the next 100 kWh (201 - 300 kWh) per month	sen/kWh	33.4
	For the next 100 kWh (301 - 400 kWh) per month	sen/kWh	40.0
	For the first 100kWh (401 - 500 kWh) per month	sen/kWh	40.2
	For the next 100 kWh (501 - 600 kWh) per month	sen/kWh	41.6
	For the next 100 kWh (601 - 700 kWh) per month	sen/kWh	42.6
	For the next 100 kWh (701 - 800 kWh) per month	sen/kWh	43.7
	For the next 100 kWh (801 - 900 kWh) per month	sen/kWh	45.3
	For the next kWh (901 kWh onwards) per month	sen/kWh	45.4
	The minimum monthly charge is RM3.00		

Figure 9: Electricity Tariff for Domestic use in Malaysia

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Resources Data Collection

Earlier, the data for solar radiation and wind speed were taken around UTP. They are several readings were taken to get more accurate representation of the resources at that location. Anemometer and solarimeter were used to take the reading of wind speed and solar radiation respectively. Based on these data, it proved that the solar radiation and wind speed at UTP is not constant throughout the day. Solar radiation is only available during daytime and not available at night-time. While wind speed is available at any time but not stable throughout the day. However, these two resources can be combined in order to produce sustainable electricity generation.

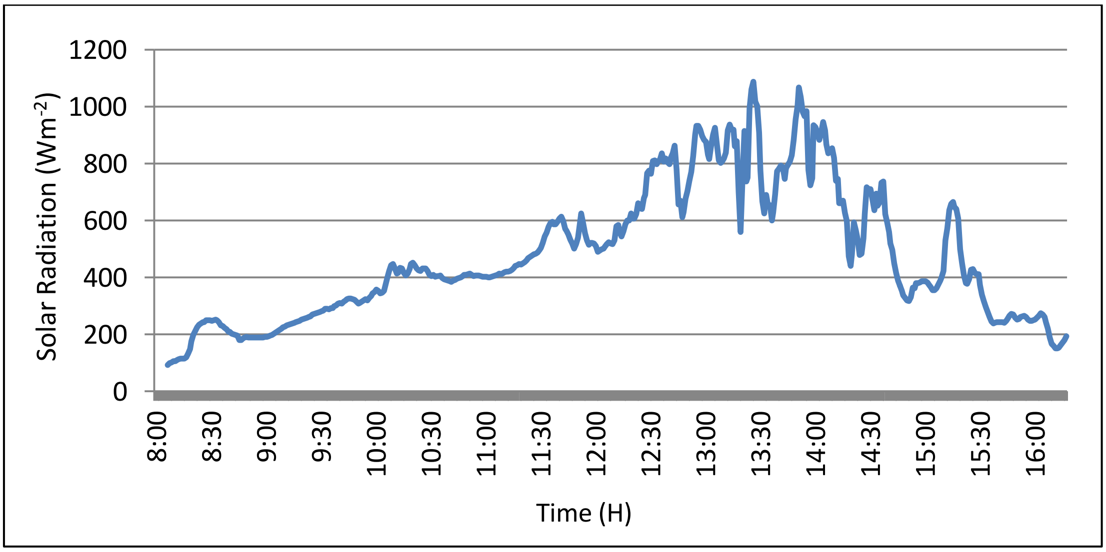


Figure 10 : Solar Radiation taken in UTP

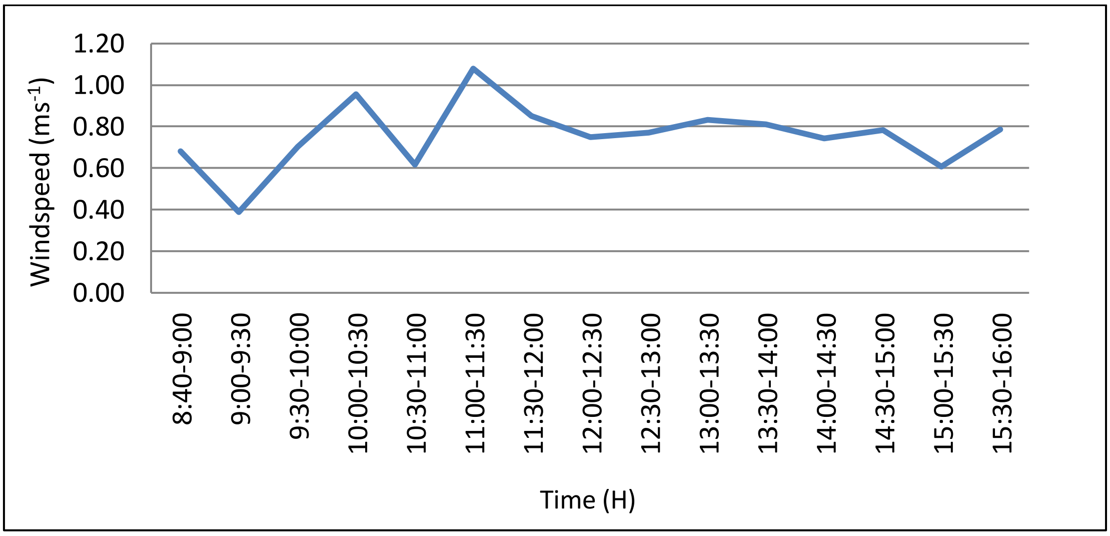


Figure 11 : Wind Speed Data taken in UTP

3.2 System Optimization Using HOMER Software

HOMER is energy modeling software that being used in this project to identify the most optimizes system for renewable energy based electricity generating system in this project through a process called techno-economic analysis. Firstly, author will identify the system architectures to be considered in the system. Then, the software will run several simulations to identify the most optimize system to be implemented by considering all factors that were specified by the user such as the solar radiation, wind speed distribution and load demand of specific location.

In this system a warning will be indicated if the system architecture specify by the user is not feasible at all and the user will need to modify the design by increasing or decreasing the size of photovoltaic to be considered, size of generator and number of wind turbines.

3.2.1 Load Demand

According to **[13]**, the average for a household electricity use in Malaysia is 251 kWh per month. For this study, from Figure 10 the plant to be built can supply average load demand of 28,950 kWh per day which is equivalent to 868,500 kWh per month. Therefore, this plant can power up approximately 3460 unit of houses at one time. Currently, in Bandar Universiti, Seri Iskandar they are 2000 unit of houses as stated in **[14]**. Thus, the plant model to be built in this study satisfy the load demand that required by the houses in Bandar Universiti and even more than that.

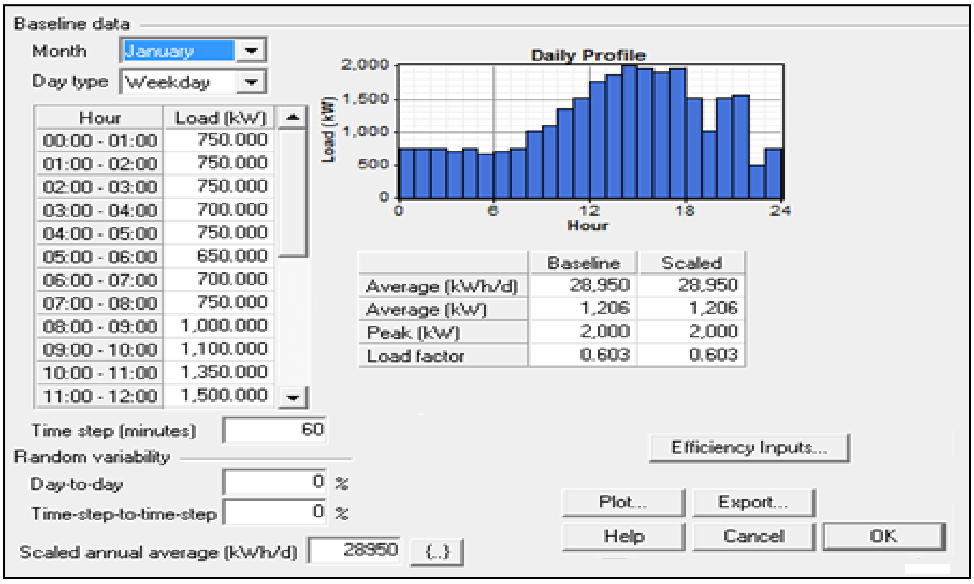


Figure 12 : Load Demand Estimation

3.2.2 Solar Resource

The solar radiation data were taken from **[12]** to estimate the data in Tronoh, Perak. The data are more reliable since they were predicted for one complete year from January to December. The average of solar radiation received by Tronoh is 5.506 $kWhm^{-2}day^{-1}$. The highest amount of solar radiation recorded is 6.042 $kWhm^{-2}day^{-1}$ on February. The lowest amount of solar radiation is recorded on December which is around 4.825 $kWhm^{-2}day^{-1}$.

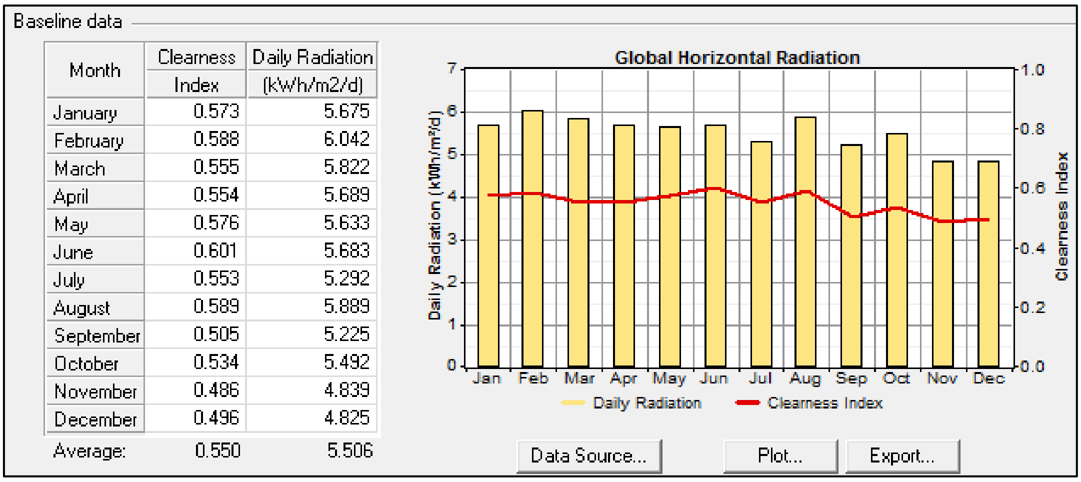


Figure 13 : Daily solar radiation data

3.2.3 Wind Resource

Similar with solar radiation, the wind speed distribution also were taken for one year from January to December in Tronoh. The highest wind speed is recorded in December which is 4.050 ms^{-1}. The average of wind speed in Tronoh is 2.891 ms^{-1} **[12]**.

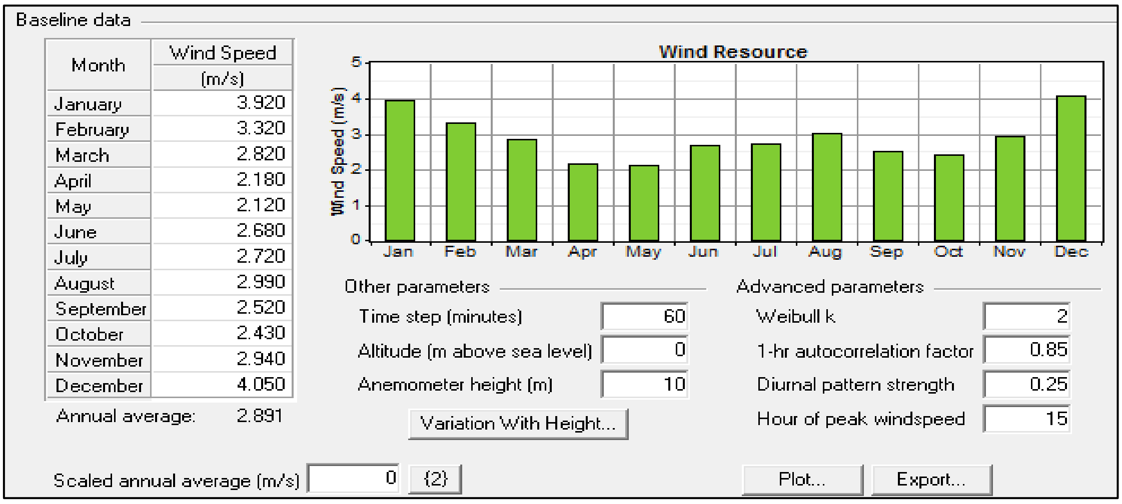


Figure 14 : Daily wind speed data

3.2.4 System Specifications

In this project there are three different system configurations to be considered which are hybrid wind-solar with generator system, solar with generator and hybrid wind-solar system. For this section, the author will only be focusing on main components of the system which are generator, PV array, wind turbine and battery used for this project.

- *Generator*

  The generator in this project is treated as the existing system for the plant. The generator utilized diesel fuel to generate electricity. All the system used generator as a backup supply except for the last design configuration that only used wind turbine and PV array to generate electricity. The generator is set to operate during night and force off during daytime where the system was expected to depend on other sources during that time.

- *PV array*

  300 W solar panel power rating is selected in this feasibility study. Thus, to calculate the quantity of solar panel required is:

$$Number\ of\ solar\ panel\ required = \frac{Size\ of\ Solar\ Panel\ Array(W)}{Solar\ Panel\ Power\ Rating(W)} \dots (1)$$

- *Wind Turbine*

  The type of wind turbine system selected in this project is Vestas V82. This is because it has highest wind turbine capacity that is available in market nowadays. The power rating of the wind turbine is 1.65 MW. The justification of choosing high capacity of wind turbine is because it can capture more energy from wind without need of implementing high number of wind turbine. One more reason of choosing this wind turbine is because it is optimize for low to medium winds which is suitable for wind speed condition in Malaysia which is in low to medium range. The rotor diameter for this wind turbine is 82 m and the hub heights that can be considered are 50 m, 70 m, and 80 m according to the manufacturer recommendation. The height that is chosen is 50 m because, at this height, the wind turbine can generate optimize system according to HOMER software.

- *Battery*

  The type of battery used in this project is Trojan L16P. This battery has maximum capacity of 391 Ah with 10 years float life.

3.2.5 System Architecture

In this project, author has come out with three system models that are feasible to be implemented in Tronoh. They are hybrid wind-solar with generator system, hybrid solar with generator system and hybrid wind-solar system. These systems will be further discussed clearly as follow:

- *Hybrid wind-solar with generator system*

  As can be seen from the Figure 15, the equipment to be considered for this system are 2 wind turbine Vestas V82 that directly supply AC power to the primary load, 3 MW PV array that produce DC power, a generator with 1.5 MW capacity, 4,000 units of Trojan L16P Battery, and a converter with 3 MW capacity. The power produced by the wind turbine and generator can be directly supplied to primary load since they will produce AC power. However the power produced from PV array has to be converted to AC power in order to be supplied to primary load.

Table 4 : System architecture 1

Equipment	Size	Quantity
PV Array	3 MW	10,000
Wind turbine (Vestas V82)	1.65 MW	2
Generator 1	1.50 MW	1
Battery (Trojan L16P)	0.00216 MWh	4,000
Inverter	3 MW	1
Rectifier	3 MW	1
Dispatch strategy	Cycle Charging	

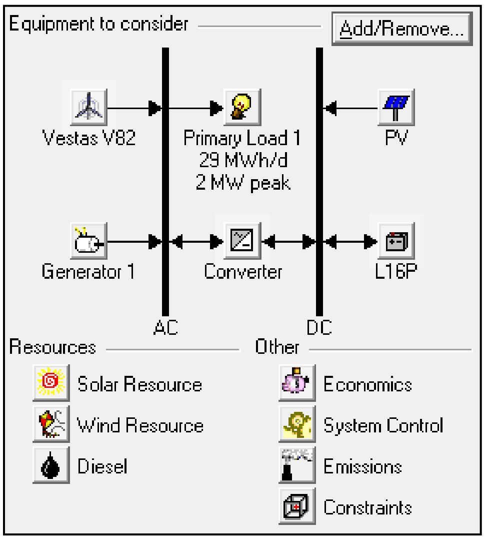


Figure 15 : Hybrid wind-solar with generator system

- *Hybrid solar with generator*

For system in Figure 16, wind turbine is not considered in this system. Thus, the primary load only consumes the power produced from generator and PV arrays. The generator power rating is 1.5 MW while the PV array size is 3 MW. The battery used for this system is same as previous one which is Trojan L16P battery which is about 4,000 units. The converter used is 4 MW capacities.

Table 5 : System architecture 2

Equipment	Size	Quantity
PV Array	3 MW	10,000
Generator 1	1.5 MW	1
Battery (Trojan L16P)	0.00216 MWh	4000
Inverter	4 MW	1
Rectifier	4 MW	1
Dispatch strategy	Cycle charging	

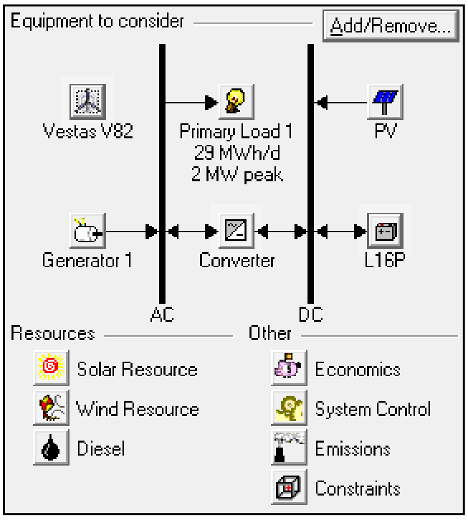


Figure 16 : Hybrid solar with generator system

- *Hybrid wind-solar renewable energy system*

The system in Figure 17 is designed to be completely depended on renewable energy sources only which are wind and solar energy. Thus, the size of PV array is bigger from the previous case which is 4.2 MW to capture more energy from solar radiation. The number of wind turbine used also higher which are 4 units. Without generator, the system will need to increase the capacity of each components of the system in order to sustain the electricity supply. The number of battery used about 21,000 units. The capacity of converter is 5 MW.

Table 6 : System architecture 3

Equipment	Size	Quantity
PV Array	4.2 MW	14,000
Wind Turbine (Vestas V82)	1.65 MW	4
Battery (Trojan L16P)	0.00216 MWh	21,000
Inverter	5 MW	1
Rectifier	5 MW	1

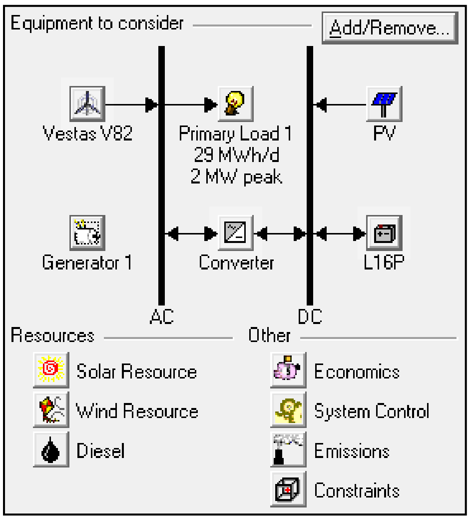


Figure 17 : Hybrid wind-solar renewable energy system

3.2.6 Software Development

The output parameters from HOMER software are treated as the input for this software that was developed to further identify the final parameters for the system which is the land area required to be harvested for the hybrid renewable energy plant. Author used Visual Basic Express 2010 to develop the new software. The structure for the software will be developed by taking into account the resources data for wind speed and solar radiation and also the load demand data. The other main component that will take into consideration in this early phase of software development can be seen in Figure 19.

To identify the land area required for the system, author would take consideration of the space for wind turbines, solar panel, generator and some space for battery, converter and also the access route for maintenance purpose.

- *Solar Panel*

  The land area would be depended on how many solar panels will be used and the size of each solar panel. Proper engineering studies should be done in term of how the solar panels should be arranged in order to optimally make use of the land area that available.

$$Land\ Area\ Required = Area\ of\ each\ solar\ panel\ (m^2) \times Number\ of\ Solar\ Panel \ldots (2)$$

- *Wind Turbine*

  Essentially, windmills should not be placed closely to one another. This is because; placing them too near to each other will reduce the performances of the windmills. However, if they are to be placed far from one another will cause wastes of land area. The energy losses can be minimized by ensuring strategic placement and arrangement of the wind turbines in a farm. It is known as farm layout planning. Figure 18 shows one of the wind farm layouts that had been developed. The wind turbines are arranged in rows and columns. Wind turbine should be placed at least 5 times of its diameter to ensure optimize power generation **[13].**

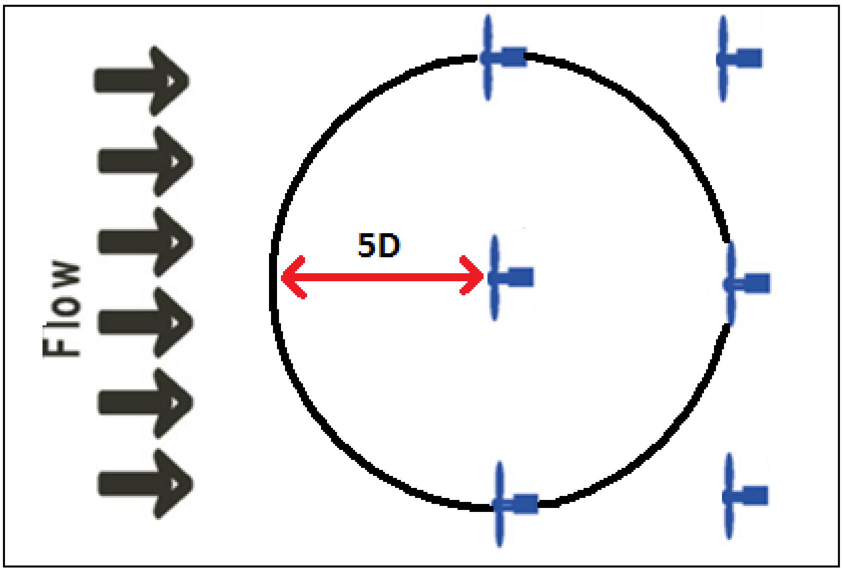


Figure 18 : Optimize Layout Design for Windmills [13]

Figure 19 below shows the flow to implement renewable energy solar-wind power plant.

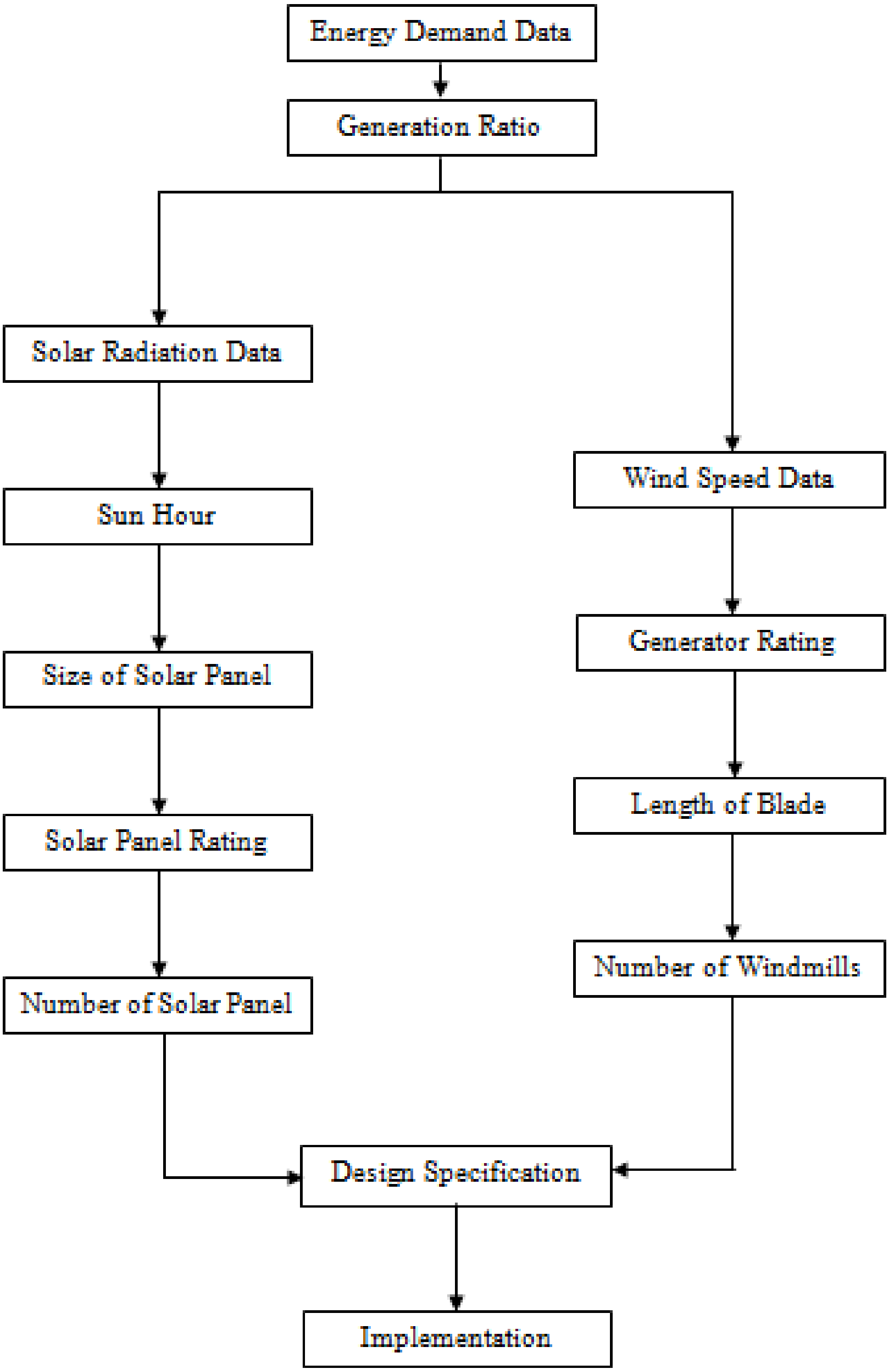
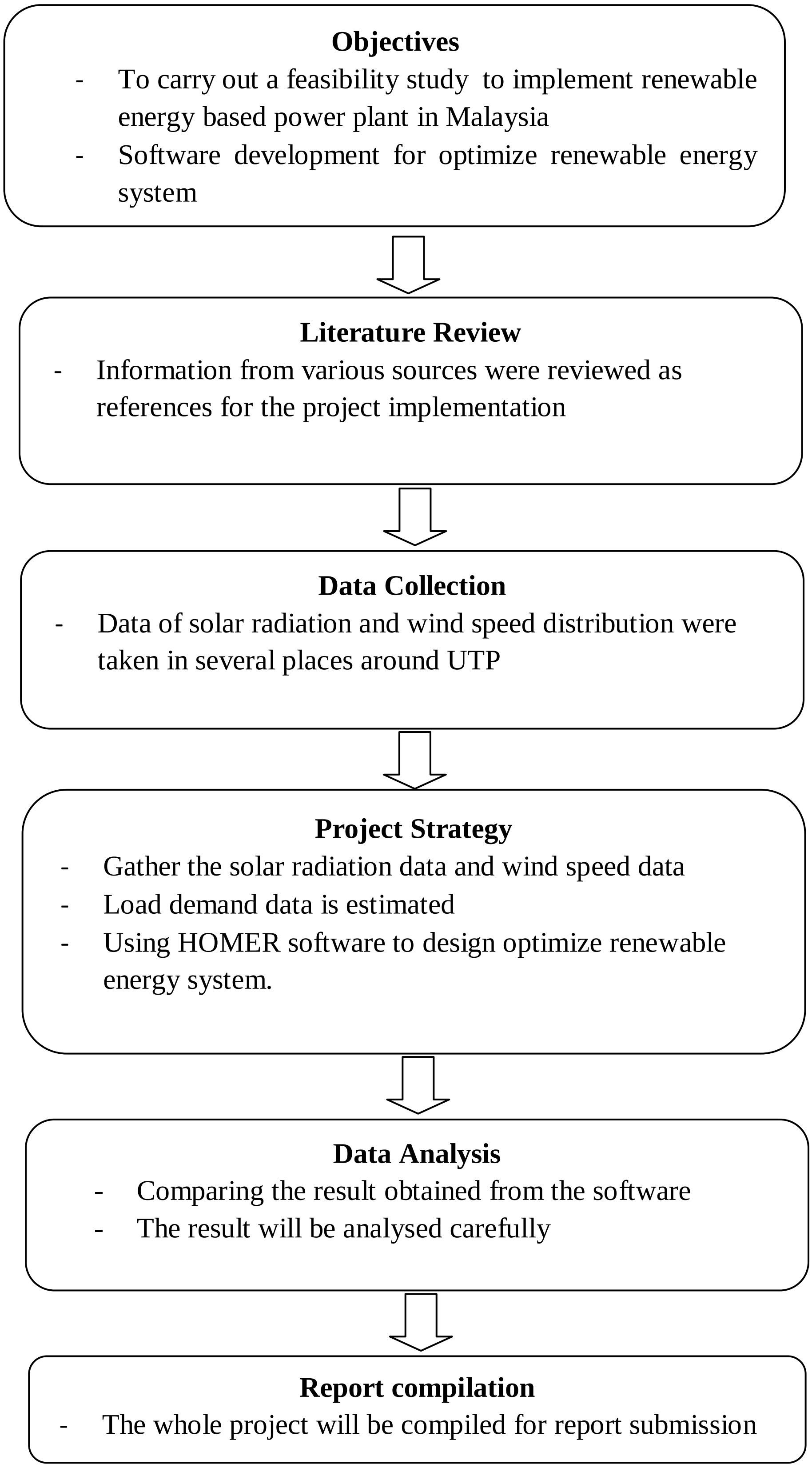


Figure 19: The flow to implement renewable energy system

3.3 Project work flow

The diagram below shows the project work flow throughout 28 weeks.



3.4 Project Gantt Chart & Key Milestones

Table 7 : Gantt Chart for FYP1

No	Detail/week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Topic Selection																
2	Preliminary Research Work & Literature Review																
3	Submission of Extended Proposal Defense						√										
4	Preparation for Oral Proposal Defense																
5	Oral Proposal Defense Presentation										√						
6	Detailed Literature Review																
7	Interim Report Progress																
8	Submission of Interim Draft Report																√
9	Submission of Interim Final Report																√

Table 8 : Gantt Chart for FYP 2

No	Detail/week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Project Work Continue																
2	Submission Progress Report							√									
3	Project Work Continue																
4	Pre-SEDEX											√					
5	Submission of Draft Report												√				
6	Submission of Dissertation (soft bound)													√			
7	Submission of Technical Paper													√			
8	Oral Presentation														√		
9	Submission of Project Dissertation (hard bound)																√

√ Suggested milestone   Mid-semester break   Work progress

CHAPTER 4

RESULTS AND DISCUSSION

4.1 System Simulation

In this chapter, author will discuss regarding the result from HOMER software simulation in term of electrical production and economic analysis for the systems. This is important because a feasible optimize hybrid system will highly depend on electrical production of the power plant and the economic aspect.

4.1.1 Electrical Production

- **Hybrid wind-solar with generator**

  As can be seen from Table 9, the largest electricity is contributed by PV arrays which contribute about 46% of power. It is followed by generator which recorded 39% and the smallest contribution is from wind turbine which is about 14%. As can be seen in Figure 20, the electricity generation ratio is different according to the weather from January to December. The power produced from wind turbine is lowest during April and May where during these months, the wind speed is low. Thus, the system will have to depend to generator and PV array to generate electricity.

Table 9 : Components ratio 1

Component	Production (kWh/yr)	Fraction
PV array	6,310,685	46%
Wind turbines	1,933,316	14%
Generator 1	5,361,562	39%
Total	13,605,562	100%

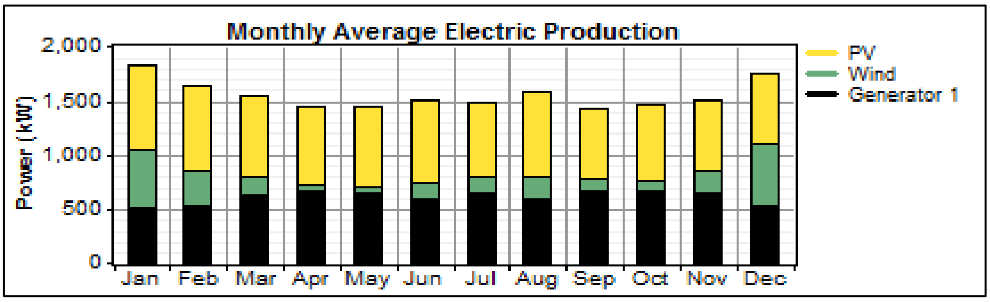


Figure 20: Monthly average electric production 1

- **Hybrid solar with generator**

For this system, the power supply from PV array and generator which contributes about 51% and 49% of electricity respectively. Throughout the year, the electricity generation from both sources show slightly same ratio of electricity production.

Table 10 : Components ratio 2

Component	Production (kWh/yr)	Fraction
PV array	6,310,685	51%
Generator 1	6,101,941	49%
Total	12,412,625	100%

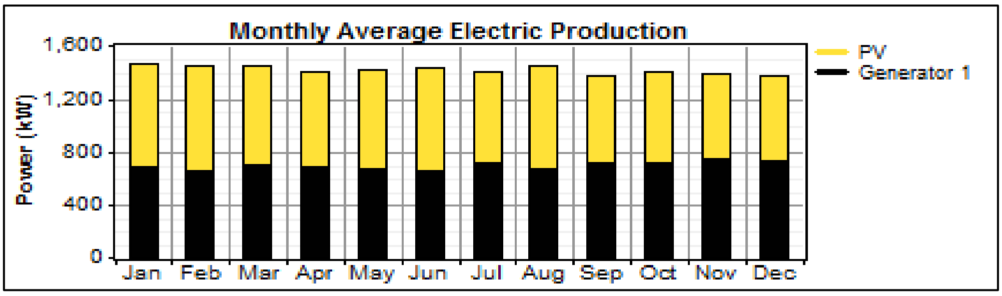


Figure 21: Monthly average electric production 2

- **Hybrid wind-solar renewable energy system**

As can be seen from Table 11, the system is only depended on renewable energy sources to generate electricity. 70% of power is generated from PV array and another 30% from wind turbine. The system is highly depends on PV array because the total amount of solar radiation received is quiet high compared to wind speed. Thus, the wind turbine will act as backup to in order to sustain the electricity generation of the system.

Table 11 : Components ratio 3

Component	Production (kWh/yr)	Fraction
PV array	8,834,961	70%
Wind turbines	3,866,632	30%
Total	12,701,593	100%

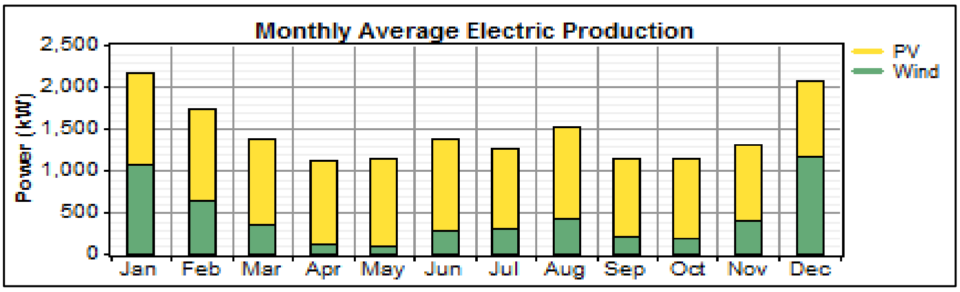


Figure 22: Monthly average electric production 3

4.1.2 Economic Analysis

- **Hybrid wind-solar with generator**

  Table 12 and Table 13 show the net present cost and annual cost to implement and operate the system respectively. The total net present cost of the system is USD 56,257,548 and the annual cost for the system is USD 4,400,843. Since generator being used in this system, diesel fuel is needed to generate electricity. Thus, the annualized cost becomes higher in order to maintain the system.

Table 12 : Net present cost 1

Component	Capital (USD)	Replacement (USD)	O&M (USD	Fuel (USD)	Salvage (USD)	Total (USD)
PV	13,500,000	4,209,369	0	0	-2,359,115	15,350,254
Vestas V82	3,000,000	1,251,796	0	0	-232,999	4,018,797
Generator 1	0	3,725,754	2,765,042	15,589,760	-73,786	22,006,768
Trojan L16P	4,400,000	7,217,083	511,335	0	-761,723	11,366,698
Converter	2,700,000	1,001,437	0	0	-186,399	3,515,038
System	23,600,000	17,405,438	3,276,376	15,589,760	-3,614,022	56,257,548

Table 13 : Annualized cost 1

Component	Capital (USD /yr)	Replacement (USD /yr)	O&M (USD /yr)	Fuel (USD /yr)	Salvage (USD /yr)	Total (USD /yr)
PV	1,056,061	329,285	0	0	-184,546	1,200,800
Vestas V82	234,680	97,924	0	0	-18,227	314,377
Generator 1	0	291,453	216,300	1,219,536	-5,772	1,721,517
Trojan L16P	344,198	564,569	40,000	0	-59,587	889,179
Converter	211,212	78,339	0	0	-14,581	274,970
System	1,846,151	1,361,570	256,300	1,219,536	-282,713	4,400,843

- **Hybrid solar with generator**

According to Table 14 and Table 15, the total net present cost is USD 57,270,564 while the annualized cost is USD 4,480,088. As can be seen, the generator still consumes largest cost in term of net present cost and also the annualized cost. The higher dependency of the system to generator is, the higher the overall cost for the system.

Table 14 : Net present cost 2

Component	Capital (USD)	Replacement (USD)	O&M (USD)	Fuel (USD)	Salvage (USD)	Total (USD)
PV	13,500,000	4,209,369	0	0	-2,359,115	15,350,254
Generator 1	0	3,682,790	2,713,269	16,910,026	-108,135	23,197,952
Trojan L16P	4,400,000	9,631,074	511,335	0	-506,772	14,035,640
Converter	3,600,000	1,335,249	0	0	-248,532	4,686,717
System	21,500,000	18,858,480	3,224,603	16,910,026	-3,222,553	57,270,564

Table 15 : Annualized cost 2

Component	Capital (USD /yr)	Replacement (USD /yr)	O&M (USD /yr)	Fuel (USD /yr)	Salvage (USD /yr)	Total (USD /yr)
PV	1,056,061	329,285	0	0	-184,546	1,200,800
Generator 1	0	288,093	212,250	1,322,816	-8,459	1,814,700
Trojan L16P	344,198	753,407	40,000	0	-39,643	1,097,962
Converter	281,616	104,452	0	0	-19,442	366,626
System	1,681,874	1,475,237	252,250	1,322,816	-252,090	4,480,088

- **Hybrid wind-solar renewable energy system**

For this system, the net present cost is USD 48,744,584 while the annualized cost is USD 3,813,129. As can be seen, the cost is slightly lower compared to the previous cases. This is because this system does not depend to generator to produce electricity. It only depends on renewable energy sources; wind speed and solar distribution to produce power. Thus, it reduces the overall cost of the system.

Table 16 : Net present cost 3

Component	Capital (USD)	Replacement (USD)	O&M (USD)	Fuel (USD)	Salvage (USD)	Total (USD)
PV	18,900,000	5,893,116	0	0	-3,302,760	21,490,356
Vestas V82	6,000,000	2,503,592	0	0	-465,998	8,037,594
Trojan L16P	4,200,000	7,402,321	2,684,506	0	-928,587	13,358,240
Converter	4,500,000	1,669,062	0	0	-310,665	5,858,396
System	33,600,000	17,468,090	2,684,506	0	-5,008,010	48,744,584

Table 17: Annualized cost 3

Component	Capital (USD /yr)	Replacement (USD /yr)	O&M (USD /yr)	Fuel (USD /yr)	Salvage (USD /yr)	Total (USD /yr)
PV	1,478,485	460,999	0	0	-258,364	1,681,120
Vestas V82	469,360	195,848	0	0	-36,453	628,755
Trojan L16P	328,552	579,059	210,000	0	-72,640	1,044,971
Converter	352,020	130,565	0	0	-24,302	458,283
System	2,628,418	1,366,471	210,000	0	-391,760	3,813,129

4.1.3 System Comparison

Table 18 shows the summary of design architecture and cost of each system. From this data, the payback period can be calculated easily. Every system have different payback period depends on the net annual revenue and the capital investment cost. The higher electricity production by the system and the smaller capital investment of the project will greatly reduce the payback period as shown in Table 21.

Table 18 : Summary of design architecture and cost

System	Component	Size	Power Rating	Qty (unit)	Production (kWh/year)	Net Present Cost (USD)	Annual Cost (USD)
Hybrid with Generator	Wind (14%)	3.3 MW	1.65 MW	2	13,605,562	56,257,548	4,400,843
	Solar (46%)	3 MW	300 W	10,000			
	Generator (39%)	1.5 MW	1.5 MW	1			
	Battery	2.16 kWh	-	4,000			
	Converter	3,000 kW	-	1			
Solar with Generator	Solar (51%)	3 MW	300 W	10,000	12,412,625	57,270,564	4,480,088
	Generator (49%)	1.5 MW	1.5 MW	1			
	Battery	2.16 kWh	-	4,000			
	Converter	4,000 kW	-	1			
Hybrid Solar Wind System	Solar (70%)	4.2 MW	300 W	14,000	12,701,593	48,744,584	3,813,129
	Wind (30%)	6.6 MW	1.65 MW	4			
	Battery	2.16 kWh	-	21,000			
	Converter	5000 kW	-	1			

In term of environmental issue, hybrid solar with generator system contributes the highest pollution gaseous to the atmosphere followed by hybrid wind-solar with generator. However, hybrid wind-solar system does not release any pollution gas to atmosphere since the system is 100% depends on renewable energy sources. Less dependency of the system to diesel fuel to generate electricity will result in less emission of pollution gaseous to the atmosphere.

Table 19 : Summary of components ratio for each system with the pollutants emission

System	Hybrid with Generator		Solar with Generator		Hybrid Solar Wind	
Component	**Production (kWh/yr)**	**Fraction (%)**	**Production (kWh/yr)**	**Fraction (%)**	**Production (kWh/yr)**	**Fraction (%)**
PV array	6,310,685	46%	6,310,685	51%	8,834,961	70%
Wind turbines	1,933,316	14%	0	0%	3,866,632	30%
Generator 1	5,361,562	39%	6,101,941	49%	0	0%
Total	13,605,562	100%	12,412,625	100%	12,701,593	100%
Pollutants	**Emission (kg/yr)**					
Carbon dioxide	5,352,396		5,805,679		0	
Carbon monoxide	13,212		14,330		0	
Unburned hydrocarbons	1,463		1,587		0	
Particulate matter	996		1,080		0	
Sulfur dioxide	10,749		11,659		0	
Nitrogen oxides	117,888		127,872		0	

4.1.4 Payback Period Calculation

Based on **[17]**, in Malaysia the FiT rate including the bonus FiT rate for every kWh from renewable energy production is RM 1.31 which equivalent to USD 0.40. From this rate, the payback period can be calculated as follows.

Table 20 : Payback Period

System	Capital Cost (USD) [a]	Production (kWh/year) [b]	Annual Cost (USD) [c]	Annual Revenue (USD /year) [d = b x USD 0.4]	Net Annual Profit (USD/year) [e = d - c]	Payback Period [f = a / e]
Hybrid with Generator	56,257,548	13,605,562	4,400,843	5,442,225	1,041,382	54 years
Solar with Generator	57,270,564	12,412,625	4,480,088	4,965,050	484,962	118 years
Hybrid Solar Wind System	48,744,584	12,701,593	3,813,129	5,080,637	1,267,508	**38 years**

As can be seen in Table 20, it shows the payback period of each system. The shortest payback period is recorded by hybrid solar wind system followed by hybrid with generator system. The payback period of solar with generator system is 118 years which is the longest period compared to other system. The payback period can be reduced if the FiT price for every kWh is increasing. This will result in the annual profit significantly increase. The payback period also can be reduced if the equipments price is decreasing which result in capital cost to reduce. Market trend shows the main equipments price which are solar panel and wind turbine are getting lower from year to year. Thus, the implementation of renewable energy based electricity generating system becomes one of highly recommended option to replace diesel fuel based electricity generating system. In addition, the income from generating electricity from clean energy is much higher compared to the existing electricity generation by Tenaga Nasional Berhad (TNB) which is RM 1.31 every kWh generated. The price sell by TNB for every kWh is RM 0.22.

4.1.5 Land Area Calculation

The size for 300 W of solar panel rating is 1.63 m^2. To calculate the land area required by the solar system, the numbers of solar panel have to be multiplied with the area of each solar panel. While for wind turbine system, the distance between wind turbines have to be placed at least 5 times of its diameter in order to maximize the power output. The diameter of wind turbine used in this study having 82 m rotor diameter. By using this strategy, the area for the whole system can be calculated as follow:

Table 21 : Total land area required by each system

System	Number of solar panel (unit)	Number of wind turbine (unit)	Total Land Area (m^2)	Total Land Area (km^2)
Hybrid with Generator	10,000	2	336,200	0.58
Solar with Generator	10,000	-	16,300	0.13
Hybrid Solar Wind Generator	14,000	4	695,220	0.83

In Tronoh, there is a lot of land that available for the implementation of this system thus there is no land area issue for implementation of this renewable energy plant in this place.

4.2 Software development

For this part, author manages to develop a hybrid generating system sizing software using Microsoft Visual Basic Express 2010 in order to assist the implementation strategy for the development of a new renewable energy power plant based on the resources data and load demand of the implementation site. The desire output of this software will be the number of main equipments which are wind turbine and solar panel and also the total land area required for the renewable energy implementation purpose. The estimation of land area and number of equipments use for the implementation will help the user to properly manage and arrange the strategy of the power plant.

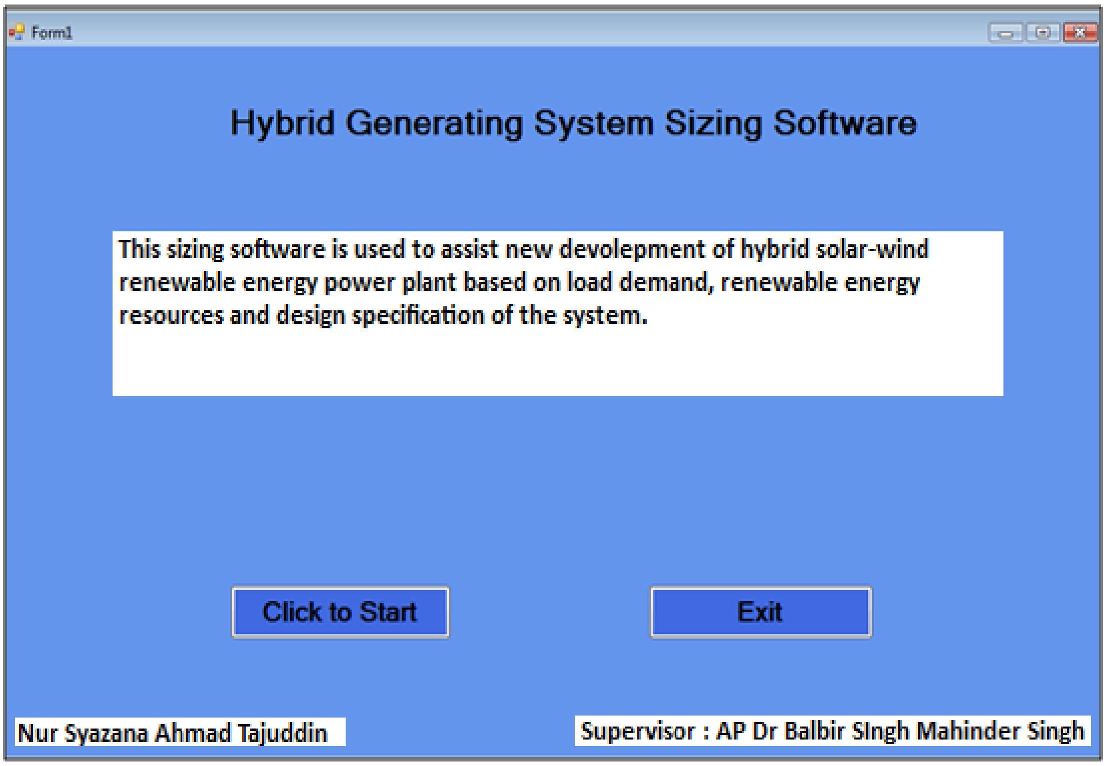


Figure 23 : Start-Up form

Figure 24 indicates the load demand form to be filled by the user for 24 hours load demand basis. The load demand data can be manually inserted or imported from Microsoft Excel to this software. There are losses of power in the system that needs to be considered by the user. This is because power from wind turbine and solar panel are not fully converted to electricity in real situation.

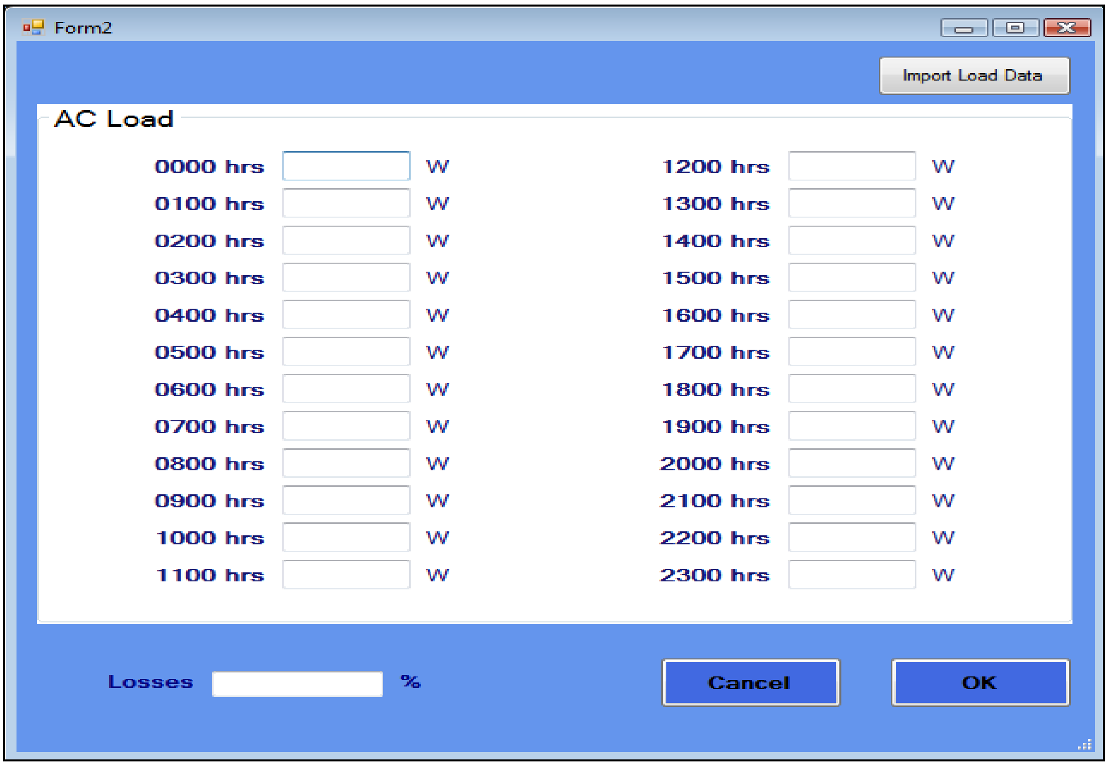


Figure 24 : AC Load Demand

Based on Figure 25, the user can key in the data for solar radiation up to 7 days reading into solar resources form. This is to ensure the data can provide better estimation of solar radiation for the specific location. In this system, user can choose whether to design solar system, wind system or solar wind system. Similar method is applied to key in the data for wind resources.

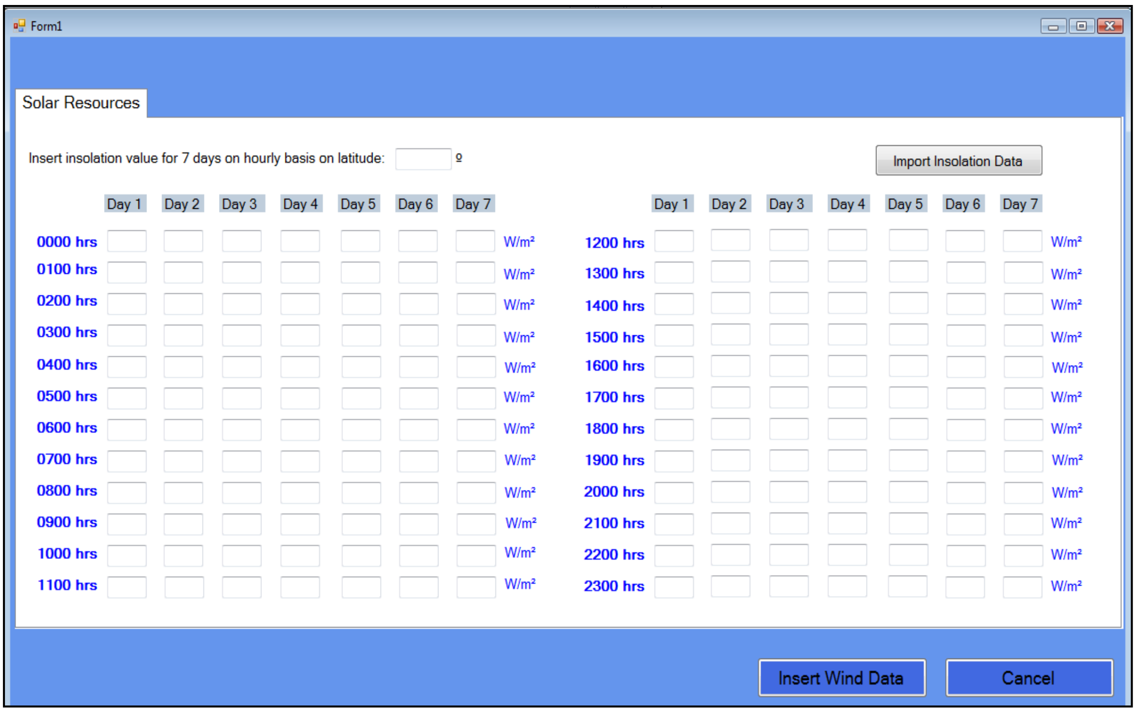


Figure 25 : Solar Resources Data

Figure 26 indicates the design strategy of the system. In this section, user has to fill the resources ratio that they are desired for the system. Next, the design specification such as the PV panel rating, area of solar panel, turbine diameter and turbine efficiency need to be key in into the software.

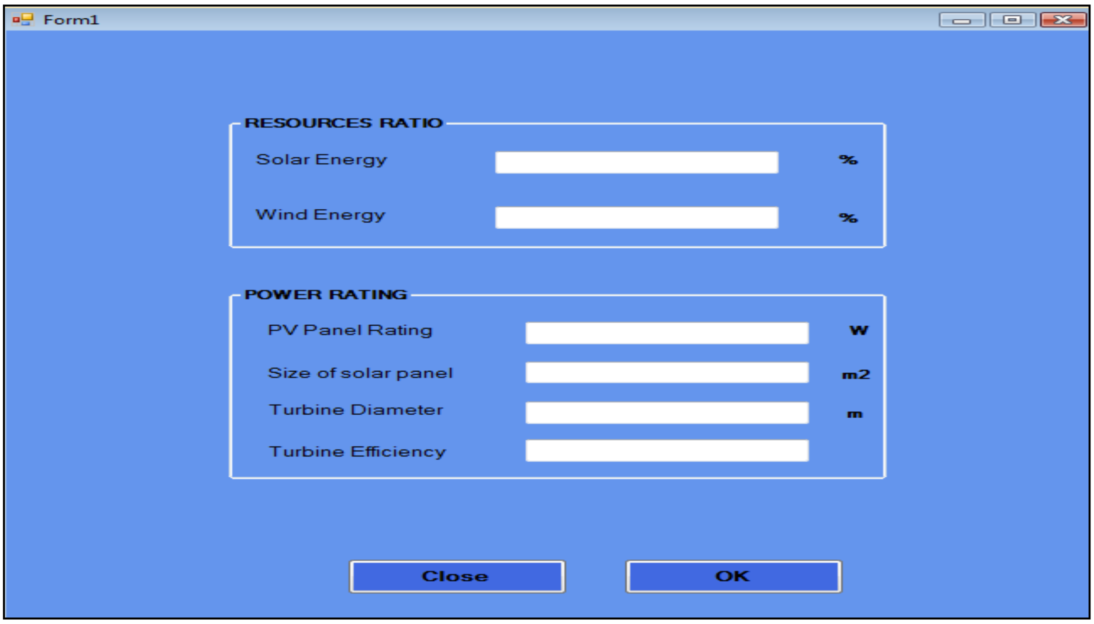


Figure 26 : Design Strategy

Finally, after completed inserting all the data into the software, user can directly obtain the final output of the system such as solar energy, sun hour, wind energy and wind power produced by their system as shown in Figure 27.

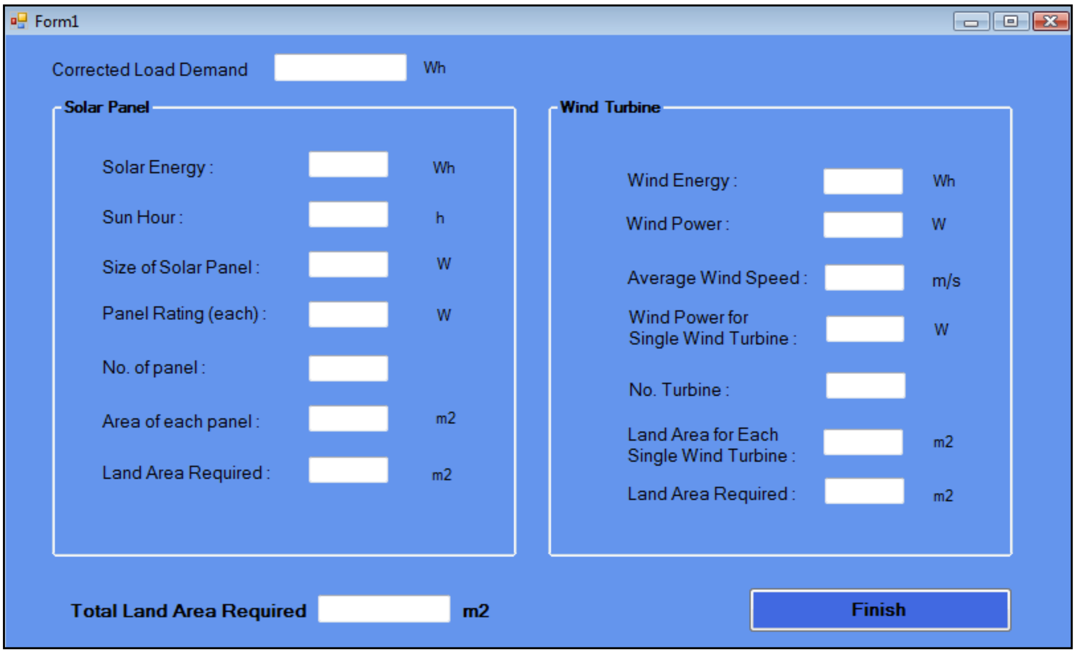


Figure 27 : Final Output

CHAPTER 5

CONCLUSION & RECOMMENDATION

As a conclusion, the implementation of renewable energy plant in Malaysia specifically in Tronoh is feasible after done the resources data collection, load demand analysis, techno-economic analysis using HOMER software and also the land area analysis. Based on the results obtained, the payback period for the implementation of this system will take about 38 to 118 years to recover the capital investment considering the annual cost of the system. With the cost of range between USD 50,000,000 to USD 60,000,000 this system can provide power supply up to 3460 unit of houses where the average for a household electricity use in Malaysia is 251 kWh per month. However, the capital cost can be reduced if the trend of solar panel and wind turbine price is decreasing on future. The payback period also will be significantly reduced if the FiT per kWh produced is increasing.

In term of land area required for the implementation of the system, another alternative that can be considered is by mounted the system on roof top of building. By doing this, the usage of land area can be minimized. It is highly recommended for the government to further extent this feasibility study for the implementation of renewable energy based electricity generating system in Malaysia for future development of power generation.

REFERENCES

[1] E. Ang, "Renewable energy a growth sector for Malaysia," 28 August 2010. [Online]. Available: http://biz.thestar.com.my.

[2] A. H. Jafar, A. Q. Al-Amin and C. Siwar, "Environmental impact of alternative fuel mix in electricity generation in Malaysia," *Renewable Energy An International Journal,* p. 2229–2235, 2008.

[3] "Small Renewable Energy Power Programme (SREP)," 8 December 2009. [Online]. Available: http://www.kettha.gov.my.

[4] S. Yusoff and R. Kardooni, "Barriers and challenges for developing RE policy in Malaysia," IACSIT Press, Singapore, 2012.

[5] J. F. Walker and N. Jenkins, Wind Energy Techology, West Sussex: John Wiley & Sons, 1997.

[6] C. T. B. Sung, "Electricity from solar energy in Malaysia: Clean, renewable, and abundant energy source, so what's the problem?," 4 May 2012. [Online]. Available: http://christopherteh.com.

[7] R. Foster, M. Ghassemi and A. Cota, Solar Energy, Boca Raton: CRC Press, 2010.

[8] P. Gipe, Wind Power, London: James & James (Science Publishers) Ltd, 2004.

[9] "Lumut or Segari Power Plant," 29 January 2008. [Online]. Available: http://instrumentations.blogspot.com.

[10] "Top 5 Largest Solar Power Plants of the World," Solarinsure Website, [Online]. Available: http://www.solarinsure.com. [Accessed 2013 April 9].

[11] "Alta Wind Energy Center," Clean Energy Action Project , [Online]. Available: http://www.cleanenergyactionproject.com/. [Accessed 16 April 2013].

[12] "Pricing and Tariff," Tenaga Nasional Berhad (TNB), 2013. [Online]. Available: http://www.tnb.com.my/. [Accessed 12 August 2013].

[13] "What is your Household Electricity Use?," The Green Mechanics, 21 July 2012. [Online]. Available: http://www.thegreenmechanics.com. [Accessed 12 August 2013].

[14] F. P. Yee, "Properties in gated and guarded communities increasingly popular," The Star Online, 2 June 2012. [Online]. Available: http://www.thestar.com.my/. [Accessed 12 August 2013].

[15] "Surface meteorology and Solar Energy," POWER: Prediction of Worldwide Energy Resource Project, [Online]. Available: https://eosweb.larc.nasa.gov. [Accessed 10 July 2013].

[16] J. Zhang, A. Messac and L. Castillo, "Optimizing the arrangement and the selection of turbines for wind farms subject to varying wind conditions," *Multidisciplinary Design and Optimization Laboratory,* vol. 52, pp. 273-282, 2013.

[17] "Feed-In Tariff (FiT) in Malaysia," Sustainable Energy Development Authority Malaysia (SEDA), 2013. [Online]. Available: http://seda.gov.my/. [Accessed 12 August 2013].

[18] M. F. I. Khamis, Z. Baharudin and N. H. Hamid, "Electricity Forecasting for Small Scale Power System," IEEE, Tronoh, 2010.

[19] J. Layton, "How Wind Power Works," HowStuffWorks, Inc, [Online]. Available: http://science.howstuffworks.com/. [Accessed 10 April 2013].

[20] "Wind Turbine Power Calculation," RWE npower renwables, [Online]. Available: http://www.raeng.org.uk/. [Accessed 18 April 2013].