PERFORMANCE ANALYSIS OF SOLAR-WIND-DIESEL HYBRID STANDALONE RENEWABLE ENERGY SYSTEMS SUITABLE FOR MALAYSIAN CLIMATE

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<u>ORIGINAL LITERARY WORK DECLARATION</u>

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ABSTRACT

A large number of populations of the world live in rural or remote areas those are geographically isolated. Power supply and uninterrupted fuel transportation to produce electrical power for these areas poses a great challenge. Using renewable energy in off grid hybrid energy system might be a pathway to solve this problem. Malaysia is a hilly land with the gift of renewable energy resources such as solar energy, wind energy, wave energy, tidal energy, biomass etc. There is a possibility to utilize these renewable resources to produce electrical power and to limit the dependency on the fossil fuel. In this perspective, a research is carried out to analyze the performance of three different hybrid renewable energy systems suitable for different territories of Malaysia. Three different hybrid renewable energy systems are off-grid PV-diesel hybrid energy system, off-grid wind-diesel hybrid energy system and off-grid PV-wind-diesel-battery hybrid energy system. The performance analysis of the three different energy systems have been conducted for southern region of Malaysia, Cameron highlands of Malaysia and a remote area named Kuala Lumpur International Airport Sepang station in the state of Selangor, Malaysia. Real time field data of solar radiation and wind speed are used for the simulation and optimization of operations using "HOMER" renewable energy software. The analyzed system can assure the reduction of CO_2 emission in about 16 tons per year in comparison with other energy system. The analyzed hybrid energy system might be applicable for other region of the world where the climate conditions are similar. The electrification process of the remote areas and decentralized areas are being a vital fact for the improvement of its agricultural, eco-tourism and industrial issues of various territories of Malaysia. Renewable energy resources can be used extensively to fulfil the demand of expected loads of these areas. This dissertation presents an analysis of an off-grid PV-diesel, wind-diesel and a PV-wind-diesel energy system. The main objective of the present analysis is to visualize the optimum volume

of systems capable of fulfilling the requirements of expected loads for a decentralized area of the region. From the analysis it is observed that according to the cost of energy (COE) or per unit cost and the load demand for the three different conditions three representative energy systems has been developed as follows southern region (PV enriched area), Cameron highland (wind enriched) and the KILA Sepang station (solar and wind both enriched) and the COE sequentially USD 0.895/kWh, USD 0.199/kWh and USD 1.877/kWh. The load demand had been considered sequentially 38, 85 and 33kWh/d for the three different territories of Malaysia as follows southern region (PV enriched area), Cameron highland (wind enriched) and the KILA Sepang station (solar and wind both enriched). The main theme of this analysis is to minimize the electricity unit cost and ensure the most reliable and feasible system to fulfil the requirements of the desired or expected energy system using HOMER software. The decrement of the CO_2 emissions also can be identified from the simulation results (with experimental data collected from Malaysian Meteorological department) by using that most feasible renewable energy system.

ABSTRAK

Sebilangan besar penduduk dunia tinggal di kawasan luar bandar di mana kawasan geografi adalah terpencil. Bekalan kuasa dan pengangkutan bahan api yang berterusan untuk menghasilkan kuasa elektrik untuk kawasan-kawasan ini menjadi cabaran yang besar. Penggunaan tenaga boleh diperbaharui di sistem grid hibrid tenaga luar mungkin menjadi jalan untuk menyelesaikan masalah ini. Malaysia adalah tanah berbukit yang dikurniakan dengan sumber tenaga boleh diperbaharui. Disebabkan faktor ini ada kemungkinan untuk menggunakan sumber-sumber yang boleh diperbaharui untuk menghasilkan kuasa elektrik dan sekaligus menghadkan pergantungan kepada bahan api fosil. Dalam perspektif ini, penyelidikan telah dijalankan untuk menganalisis prestasi sistem tenaga hibrid grid PV-angin-diesel-bateri untuk kawasan terpencil iaitu Stesen Lapangan Terbang Antarabangsa Kuala Lumpur Sepang di negeri Selangor, Malaysia. Dalam kajian ini, 56 kW sistem tenaga hibrid telah dianalisis. Sistem ini berupaya untuk menyokong 35 isi rumah dan 4 kedai dalam permintaan beban purata kawasan itu. Data sebenar untuk sinaran solar dan kelajuan angin digunakan untuk simulasi dan pengoptimuman operasi menggunakan perisian tenaga "HOMER". Analisis sistem ini yang boleh memberi jaminan pengurangan pelepasan CO_2 dalam kira-kira 16 tan setahun berbanding dengan sel-sel bahan api lain. Sistem tenaga hibrid yang telah dianalisis boleh digunakan untuk daerah yang lain di dunia yang menpunyai keadaan iklim yang sama. Proses bekalan elektrik di kawasan pedalaman dan kawasan-kawasan yang tidak berpusat menjadi faktor penting untuk memperbaiki isu-isu pertanian dan industrinya seperti di selatan Malaysia. Sumber tenaga boleh diperbaharui boleh digunakan secara meluas untuk memenuhi beban permintaan bagi kawasan-kawasan ini. Disertasi ini membentangkan analisis luar grid PV-diesel, angin-diesel dan sistem tenaga PV-angin-diesel. Objektif utama analisis ini adalah untuk mempero barkan jumlah optimum sistem yang mampu memenuhi keperluan beban bagi kawasan yang

berpusat di rantau tersebut. Daripada analisis ini, didapati bahawa menurut kos tenaga (COE) atau setiap kos unit dan permintaan beban untuk tiga keadaan yang berbeza tiga sistem tenaga wakil telah dibangunkan seperti berikut Wilayah Selatan (PV kawasan diperkaya), Cameron highland (angin diperkaya) dan stesen KLIA Sepang (solar dan angin kedua-dua diperkaya) dan COE berurutan USD 0.895/kWh, USD 0.199/kWh dan USD 1.877/kWh. Permintaan beban telah dianggap secara berurutan 38 kWh/d, 85 kWh/d dan 33 kWh/d untuk tiga wilayah yang berlainan di Malaysia seperti berikut Wilayah Selatan (PV kawasan diperkaya), Cameron highland (angin diperkaya) dan stesen Kila Sepang (solar dan angin kedua-dua diperkaya). Tujuan utama analisis ini adalah untuk mengurangkan kos unit elektrik dan memastikan sistem yang boleh dipercayai dilaksanakan untuk memenuhi keperluan sistem tenaga yang dikehendaki atau dijangka menggunakan perisian HOMER. Penyusutan daripada keseluruhan pelepasan CO_2 juga boleh dikenal pasti dari hasil simulasi (dengan data uji kaji yang dikumpul daripada Jabatan Meteorologi Malaysia) dengan menggunakan sistem tenaga boleh diperbaharui yang boleh dilaksanakan termasuk nilai pecahan yang boleh diperbaharui adalah.

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LIST OF SYMBOLS AND ABBREVIATIONS

AC	Alternating Current
Ah	Ampere hour
COP	Coefficient of performance
DC	Direct Current
EC	European Commission
GPI	Green Power Inverter
IEA	International Energy Agency
NASA	National Aeronautics and Space Administration
PV/T	Photovoltaic Thermal
HOMER	Hybrid Optimization Model for Electrical Renewable
NREL	National Renewable Energy Laboratory
COE	Cost of Energy
NPC	Net Present Cost
MTOE	Million Tonnes of Oil Equivalent
KLIA	Kuala Lumpur International Airport

CHAPTER 1: INTRODUCTION

1.1 Introduction

Energy is one kind of substance which can not be destroyed but only can be converted into different form (Koch, 2002). Renewable energy is one kind of energy resource which can be used for again with the same kinds of equipments and setup. Renewable energy resources such as solar energy, wind energy, biomass, and wave energy are being used extensively.

1.2 Energy

The word energy derives from the ancient Greek: “energeia” “activity operation”, which possibly appears for the first time in the work of Aristotle in the 4th century BC. In contrast to the modern definition, energeia was a qualitative philosophical concept, broad enough to include ideas such as happiness and pleasure (Machamer & Wolters, 2006). Energy is the soul of the Modern World. The economic growth and technological advancement of a country depend on it (Hassan, Mohamad, & Al-Ansary, 2012).

The three very important factors named residents, wealth and the per capital energy consumption. From the last 40 years have been causing to increase the energy demand which is one of the gigantic disputes for this century (Hassan & Mohamad, 2012a). Presently in that advanced globe, correspondence, for hauling, mechanical, instructive plus residential rationales fossil powers are utilized for warming, cooling, cooking, lighting and running modern and additionally household apparatuses. But, the headache has been increasing day by day about fossil fuel for having some negative impacts on the environment of it. For example, it has not only a limited source but also responsibility for global warming by depleting the ozone layer. Actually, the CO_2 is produced when the fossil fuel is burnt which causes the increasing of the earth temperature as well as the green-house gas effect on ozone layer at atmosphere (Afshar, Saidur, Hasanuzzaman, & Jameel, 2012).

Corresponding to the latest investigation of NASA, there is a hole in ozonosphere over the two poles of earth about 28,300,000 km^2 since it was about 24,000,000 km^2 in 1994. As a consequence, the European Commission (EC) implemented a workshop to control and schedule of all the ozone depleting materials on 1st October 2000. It is revealed that all HCFCs will be prohibited within 2015 (Hassan & Mohamad, 2012b). So, the issue arises to find out the alternative of fossil fuel before ending the resources of it as well as to protect the beautiful earth (Afshar et al., 2012) and renewable energy is the best alternative for this issue.

The aggregate energy of a system can be subdivided and ordered in different ways. For instance, traditional mechanics recognizes motor energy, which is controlled with a substance's development through probable energy and gap. It is a component of space of the item inside of a field (Xin-sheng, Shui-liang, & Xin-jian, 2006). It might be effective to recognize gravitational energy, heat energy, few sorts of atomic energy and attractive energy (striking sector), surrounded by other sectors (Seielstad, 1983).

A few sorts of energies are a differing blend of both potential and active energy. An illustration is mechanical energy which is the whole of (typically naturally visible) motor and potential energy in a system. Versatile energy within resources is additionally subordinate leading electrical potential energy. Because of the substance vitality, that is put away as well as discharged as of a repository of electrical prospective vitality in the middle of electrons, and the particles or nuclear cores that pull in them. The rundown is additionally not so much finish. At whatever point physical researchers find with the aim of a positive wonder seems to damage the decree of vitality protection, new structures are commonly included that record for the inconsistency.

1.3 Renewable Energy

The expression "Renewable vitality" alludes to that vitality which is delivered from a characteristic asset having the attributes of endlessness inside of the time and the restore capacity and in addition actually recharged. The renewable vitality incorporates hydropower, wind, biomass, geothermal, tidal, wave and sunlight based vitality source (Jacobson & Delucchi, 2009). This kind of energy is cost-effective over fossil fuel and pollution free (Afshar et al., 2012).

There are such a variety of endeavours taken by the created nations to accomplish the distinctive renewable vitality advances. The utilization of wind vitality has been being expanded significantly amid the most recent couple of years. Case in point, the majority of the European nations like Netherlands and Germany are utilizing the wind turbine as a part of the north and west for creating power (Lucas & Raoult-Wack, 1998). Likewise some Asian nations like Malaysia and India have some wind (turbine force) plant to create power.

In the Mangil City situated of Iran, some wind energy system with geothermal force has been introduced (Balaras et al., 2007). In the Iceland, there are seventy percents of industrial units where for industrial purposes the geothermal energy has been used (Abu Hamdeh & Al-Muhtaseb, 2010). This kind of power is lucrative over fossil fuel and environment friendly (Afshar et al., 2012).

Usage of renewable energy for electricity generation is a priority research topic nowadays. Remarkable efforts to expand the sources of various forms of energy to intensify a deployment of renewable and sustainable energy slots have been increasing all over the humanity.

The first priority in intensifying renewable energy deployment in the 21st century is the combined effects of the depletion of fossil fuels and the awareness of environmental degradation (H. H. Chen, Kang, & Lee, 2010). Therefore, policy makers and researchers are paying more attention to research in this field.

For an instance, before 2020 the European Union countries aim to use renewable sources and get at least 30% of its potential energy (Ringel, 2006). There are several renewable energy resources such as biomass, wind, geothermal energy, solar, hydro-electric and tidal power. Hybrid renewable energy resources can reduce the emission of harmful gases and reduce the use of imported power.

Malaysia is blessed with abundant resources specially the potential renewable energy resources as like as the wind energy and the larger global horizontal solar radiation contains for its geographical position (Solangi, Islam, Saidur, Rahim, & Fayaz, 2011). The sort of hydroelectric essentialness utilizes gravitational aptitude of raised water. It is not by any means chitchat about renewable energy while every supplies above the extended pull top off and require to a great degree immoderate unearthing ending up significant yet again.

At this moment, the dominant part of the available ranges for hydroelectric dams that have started for the civilized world (Jacobson & Delucchi, 2011). Biomass is the source of energy that is really effective for the modern day energy crisis (Campbell, Lobell, & Field, 2009; Demirbas, 2005). Biomass and fuel cell can make a hybrid energy system effective for the decentralized and remote areas. For the advancement in the technologies of agriculture it is very important to improve the power generation and power distribution management (Demirbas, 2005; Panwar, Kaushik, & Kothari, 2011). There are various areas in the world detached from the main stream of the development due to the lack of power generation. Biomass and other renewable energy resources can be a very effective and fruitful source of energy to produce electricity to make that places much more advanced (Schmer, Vogel, Mitchell, & Perrin, 2008). There are several places of Saudi Arabia really are out of the grid connected power supply. So, to provide proper power supplies and other facilities on that area are very hard task for them. These problems can be solved really very easily by using the solar energy, wind energy and geothermal energy sources (Alnatheer, 2005).

Power units and hydrogen are the successful wellspring of renewable vitality. These are also not so much renewable imperativeness resources but instead are to a great degree limitless in honesty are low in pollution in the time of utilizes. Hydrogen is the alternate as fossil fuel and water base can be another effective mix with it (Cadwallader & Herring, 1999). Dirt-free blazing fuel can make environment free electricity in urban areas. As part of energy units the hydrogen bas can be used, like batteries, to control an electric engine. On the other event huge creation of hydrogen obliges plentiful force (Lyons & Harmon, 2012).

Because of the requirement for vitality to create the beginning hydrogen gas, the outcome is the movement of contamination from the urban areas to the force plants. There are a few promising strategies to create hydrogen, for example, sunlight based force, that may adjust this photo definitely (Edwards, Kuznetsov, David, & Brandon, 2008).

Geothermal power is one of the very applicable sources of renewable energy. Importance left over from the first moderate extension of the planet and stretched out by warmth from radioactive rot gaps out a tiny bit at a time all around, general.

Specifically districts the geothermal inclination (expansion in temperature with essentialness) is sufficiently high to endeavour to make power (Jacobson & Delucchi, 2011). This probability is obliged to a few areas on Earth and different specific issues exist that point of confinement its utility. Another kind of geothermal vitality is Earth significance, a result of the shine stockpiling in the Earth's surface (Education, 2012). Soil everywhere on tends to stay at a respectably enduring temperature, the yearly ordinary, and can be used with warmth pumps to warmth a building in winter and cool a building in summer (Kachadorian, 2006).

This type of vitality can diminish the requirement for other energy to keep up agreeable temperatures in structures, yet can not be utilized to create power. Energy from tides, the oceans and hot hydrogen fusion are other forms that can be used to generate electricity (Moriarty & Honnery, 2007). Each of these is discussed in some detail with the final result being that each suffers from one or another significant drawback and cannot be relied upon at this time to solve the upcoming energy crunch (Kalogirou, 2013).

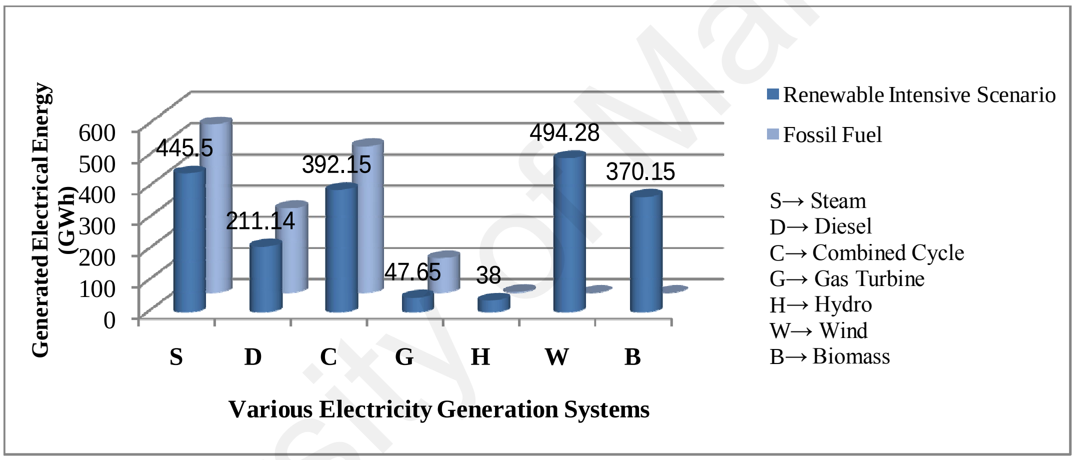


Figure 1.1: Electricity generation in Crete, Greece for the year 2005 (Mirasgedis, Diakoulaki, Papagiannakis, & Zervos, 2000)

Hence, there are huge energies produced from renewable sources in all over the world. Figure 1.1 shows a comparative energy generation in Crete, Greece for the year of 2005. Among all these sources, for the most environmentally friendly and naturally availability than others, wind energy stands on top position of the list of renewable energy (Hassan & Mohamad, 2012a).

1.4 Solar Energy

There are several types of solar energies; solar energy can be used both in the solar panel and as a solar thermal. The average temperature and average irradiation are relay vital factor for the solar panel. The photovoltaic cells can be used properly where the sunshine is really high and the temperature is controlled and in the range of earth (Wolf, 1960).

For the expeditious increasing of energy shortage all over the world, the scientists have paid the more attention to the solar energy in the recent years. Plenty of technologies have been invented to receive and hold the sun's power. These comprise solar water heating; cooking, space heating, power generation, food drying, refrigeration and others (Mekhilef, Saidur, & Safari, 2011).

Eventually, all of the energy resources on the earth are originated from the sun except nuclear and geothermal energy. However, in the recent years many of the countries of the world have been facing troubles to handle the issue of refrigeration system.

This is occurred especially during the hot season the demand of air conditioning for both the commercial as well as the residential purposes is increasing day by day (Hassan et al., 2012). Moreover, heating is essential through the year round. Hence a huge amount of energy should be needed to handle this issue adeptly. Especially, in developing countries, there is more lack of electrical energy and a few energy rests to handle such a huge energy consumptive system like heating and cooling. Hence, the PV based cogeneration energy systems have become the worldwide focal point for concern again (Hedström et al., 2004).

1.5 Wind Energy:

The development of the environment is driven by contrasts of temperature at the Earth's surface because of shifting temperatures of the Earth's surface when lit by daylight. Wind vitality can be utilized to pump water or create power, however requires broad areal scope to deliver critical measures of vitality (H. Chen et al., 2009). Results from field operation of more than 17,800 wind turbines in Denmark and California amid the previous 10 years exhibit that the present era of wind turbine innovation has been completely tried and demonstrated.

Unwavering quality is presently agreeable, moreover, wind ranch operation and upkeep methods have been aced. Unit size has expanded by a function of 10 amid the previous decade. The wind turbines evaluated at 0.5 megawatts are presently accessible economically from a few producers.

In addition, propels in wind turbine innovation in the following 20 years, for example, propelled materials for airfoils and transmissions, better controls and working procedures, and enhanced high power-taking care of hardware, will considerably diminish capital expenses and additionally operation and upkeep costs. In areas with good wind resources [450 watts per square meter (Ahmed, Miyatake, & Al-Othman) wind power density at hub height], wind turbines now generate electricity at a cost of USD 0.053 per kilowatt-hour (kWh) (6 percent interest, all taxes neglected).

By properly utilizing the wind energy the energy production cost can be reduced to USD 0.029 per unit. Wind energy is really effective for the costal areas, because in that area the average wind speeds are very high and really very effective for the wind typical turbines (Puller, 2007).

The specialists considers wind speed and burden estimates slips and incline rates of ordinary warm units to focus framework hold edges in the wind-hydro-warm interconnected Swedish power generation (Soder, 1993). Thought is given to the connection of wind ranch conjectures inside of an area and between diverse areas and connections the store levels to a likelihood of too low a recurrence because of burden and wind changes.

Persuad et al. experimented the wind power for user friendly ways of generator to produce the electricity at a rapid rate. The wind power generation did not rapidly increase the ramping cycle in the system. The unpredicted wind power has been decreased and predicted wind power has been increased. The non-wind peak generation has been decreased effectively (Persaud, Fox, & Flynn, 2003).

Dany et al. took a new dimension of high average wind speed according to wind turbines, generators and specific area. A technical calculation of the optimal amount of spinning reserve has been introduced to generate power from wind panel and also for finding the errors related with it (Ortega-Vazquez & Kirschen, 2009). Various researchers evaluate the impact of different forecasting techniques on fossil fuel savings and spinning reserve requirements on a large scale electricity system. A new approach has been represented to quantify the amount of reserves needed for the system to solve the uncertainty problem of wind energy. A model has been developed to fulfil the electricity demand for the islands and remote areas with reliable wind energy resources (Doherty & O'Malley, 2005).

1.6 Solar and Wind Cogeneration Energy System

The cogeneration energy system refers to the system which is capable to produce the electricity by two different kinds of generators. Hence the cogeneration system also increases the system efficiency significantly. Moreover, sometimes the standalone energy system is not able to handle the heating or cooling devices after fulfilling the demand of electricity. Hence, the PV based cogeneration energy system with wind is making more attraction to the researchers and getting more and more popular day by day for its efficient and cost effective and the environmentally friendly behaviour (Hedström et al., 2004).

1.7 Optimization Problems and Advancement in Renewable Energy Researches

Optimization is the selection of a best element from some set of available alternatives. In the most straightforward case, an optimization problem comprises of boosting or minimizing a genuine capacity by deliberately picking information values from inside of a permitted set and registering the capacity's estimation. The speculation of streamlining hypothesis and strategies to different definitions includes a vast territory of connected science. All the more by and large, advancement incorporates discovering "best accessible" estimations of some target capacity given a characterized space (or an arrangement of requirements), including an assortment of distinctive sorts of target capacities and diverse sorts of areas (Ekren & Ekren, 2008).

From the last few decades the researchers have been using several types of optimization techniques and algorithms to represent and predict the energy systems with non-conventional ways. According to the general mechanism there are two types of power plants usually known to everyone such as the conventional and non-conventional power plants.

The most popular and effective non-conventional power plant is the renewable energy system. Without conducting any prediction and optimization operation, proper establishment of a renewable energy system is impossible. Only for this reason the researchers tried to find out the most feasible and efficient energy system according to the renewable energy resources such as solar energy, wind energy, wave energy, biomass and etc (de la Nuez Pestana, Latorre, Espinoza, & Gotor, 2004).

1.8 Problem Statement

The demand of electrical energy has been increased dramatically from the last decade. Moreover, the conventional fossil fuels used in heat and power generation are not only limited in sources but also threatening to be finished very soon (Murray et. Al, 2012). From the analysis and demonstration of various researchers it can be said that the average wind speed is not sufficient to make feasible energy systems according to the large windmills in many places of Malaysia. It is also proved that the solar irradiation is not also suitable for the hilly area like Cameron highlands due to the clouds. But in some places like Pulau, Langkawi and other sea shore areas might be effective for the wind mills. In some remote areas like KLIA Sepang station might be effective for the solar energy. Moreover, the micro-turbines are might be suitable for those areas where average wind speed is lower (Sims, Rogner, & Gregory, 2003). According to the geographical isolation three different representative energy systems should be introduced. Because some places are being enriched with solar energy such as the southern region of Malaysia, some places are being enriched with the wind energy such as Cameron highland and some places are being enriched with both solar and wind energy such as the KILA Sepang station. Many places of Malaysia are not feasible for wind energy but some pocket areas can be effectively feasible for wind energy with the micro-turbines. Due to the increasing rate load demand some more source of energy should be found out to save the fossil fuels. Besides, some European countries and some others parts of the world where the temperature is very low and snowing all the year round require huge fossil fuels to produce more electrical power, which is needed for water heating and the room heating as well. Similarly, for some of the industrial applications huge amount of heat energy supply is required (Hadjipaschalis, Poullikkas, & Efthimiou, 2009). To handle adeptly the aforementioned cooling and heating loads, a huge electrical energy with fossil fuel is required which is the burning headache of recent world (Hosey, 2012). Hence, such a PV-wind based hybrid energy system with diesel generator is not only an alternative solution of electricity generation for remote and decentralized areas but also a best solution to produce the pollution free environmentally friendly energy throughout the years (Kaundinya, Balachandra, & Ravindranath, 2009). Moreover, the green house gas has been increased in an alarming rate day by day due to the emission of huge amount of CO_2 (Saber & Venayagamoorthy, 2011). (Rasul, Dahe, & Chaudhry, 2008).

1.9 Objectives

The objectives reflect some vital factors as like as cost analysis, performance analysis, load-demand, solar-wind, PV-diesel, wind-diesel and hybrid energy system. Some places of Malaysia are geographically isolated, some places are based on hill tracks and some places are based on the in land. In the problem statement section the drawbacks of solar-wind and other energy system have been described according to the lacking of average wind speed and solar irradiation. Though it is proved that many in places of Malaysia average wind speed is not feasible, but it can be solved by using many micro-turbines integrated together and coupled with the solar panels. Moreover, Wind mills might be more suitable for the sea shore areas where the average wind speed is higher. The best use of solar panel can also be varied by areas to areas in Malaysia. In some places the solar energy might be feasible and in some places might not be feasible. So, in this perspective there are may be three representative hybrid energy systems have to be introduced for the whole Malaysian territory. Each and every objective has its own goal or aim. Based on the problem statements following objectives are being rectified:

a) Performance investigation of a PV-diesel hybrid energy system:

This analysis presents a performance investigation of a complete off-grid PV-Diesel Generator-Battery Hybrid renewable energy model with a backup of a 5 kW diesel generator for the solar energy enriched area such as the southern region of Malaysia. The simulation ensures that the system is suitably feasible with respect to net present cost (NPC) and cost of energy (COE).

b) Optimization of a wind-diesel hybrid energy system:

An analysis of a complete off-grid wind-diesel-battery hybrid renewable energy model has been carried out. The main objective of the present analysis is to visualize the optimum volume of systems capable of fulfilling the requirements of load demand for wind energy enriched area such as the Cameron Highlands. The hybrid power system can be outstanding for the tourists of that area as it is a decentralized region of Malaysia. This analysis is to minimize the electricity unit cost and ensure the most reliable and feasible system to fulfil the requirements of the desired or expected energy system.

c) Performance analysis of a solar-wind hybrid energy system:

A research work is carried out to analyze the performance of an off-grid PV-wind-diesel-battery hybrid energy system for a remote region which is both solar and wind energy enriched area named "KLIA Sepang station" located in the state of Selangor, Malaysia.

The simulation ensures that the system is suitably feasible with respect to net present cost (NPC) and CO_2 emission reduction purpose.

1.10 Outline of the Dissertation

There are five chapters encompassed in this dissertation. The contents of each chapter have been described below:

CHAPTER 1: This chapter is the primary introductory chapter which presents the concise summary on most energy connected problems of the world, greenhouse gases and demand of energy history. Renewable energy resources all over the world have been briefly discussed. Backgrounds of the study, problems and the objectives of this study have been discussed in this chapter.

CHAPTER 2: This is the literature review chapter and in this chapter the present work, which have been done in this field have been highlighted. The literature review of this study has been divided into two main parts namely conventional cogeneration energy system and the renewable energy resources with the solar (PV) module and wind turbines technology. Then the recent achievements on various solar energy system and wind energy system have been discussed finally.

CHAPTER 3: Methodology chapter contains three main parts. Firstly, the system is designed and described. Then the investigation of the system is done and the data is taken from the experiment. Finally, the mathematical model of the system is used to compare the data/result with experimental works that includes some power as well as efficiency measurements of different parts of the system.

CHAPTER 4: This is the result and discussion chapter. In this chapter, the performance of the solar-wind hybrid system as well as the PV-diesel energy system are analyzed and discussed. Also, a comparison is made on the performances of solar-wind hybrid energy system with others work.

CHAPTER 5: In this chapter the main outcome of the dissertation with the conclusion and recommendation has been given very precisely. The main outcomes of the cogeneration energy system with solar-wind hybrid energy systems are highlighted. The suggestions have been given for the future work.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The researches related with renewable energy had been started many years ago due to the increasing rate of load demand. Due to the advancement of technologies and increasing demand of energy, some new ways of energy generation has been find out. There are several ways of generating energy from conventional system or non-conventional system. But the fossil fuels are being decreased at a rapid rate. So, now scientist and researchers are trying to find out some more ways of energy generation. The most popular, feasible and reliable way of energy generation is the renewable energy system. Among the renewable energy resources solar energy, wind energy, biomass, wave energy, tidal energy are the most significant renewable energy resources. Moreover, some recent studies related to the hybrid energy system with Solar and wind energy resources and generator back-up have been emphasized (Twidell & Weir, 2006). Hybrid renewable energy system has been becoming more and important sector for the world. Hybrid renewable energy system consisting of solar energy, wind energy, biomass, wave energy, generator, fuel cell etc (Deshmukh & Deshmukh, 2008).

2.2 Renewable Energy Resources

As stated by the estimation of universal vitality agency, 53% of worldwide vitality utilization has a chance to be expanded by 2030. For 70% of the development sought after hailing starting with the developing nations (Oh, Pang, & Chua, 2010). Malaysia will be a standout amongst the practically developing nations around Asian nations next might be Singapore. With GDP of USD15,400 for every capital (PPP basis), more enduring GDP development from claiming 4.6% in the year 2009 for Singapore (Shiu & Lam, 2004). Due to the doctors and hospitals activity (i.e. operations, diagnosis, treatments) the energy demand has been increased and the energy generation need to be increased rather than the normal energy growth rate (Saidur et al., 2009).

The utilization growth rate of energy in Malaysia had been increased to 5.6% from 2000 to 2005. After that it reached 38.9 million tonnes from 37 million tonnes. That last vitality utilization is relied on the range of 98 %. 7 Mtoe On 2030, about three times the 2002 level. Those mechanical segments will have the most noteworthy growth rate of 4.3 %. Modern segment accounted for a portion 48% about downright vitality utilize clinched alongside 2007 which speaks to the most elevated rate (Chakraborty, 2011).

It may be evaluated that the gas reservation may be anticipated to be finished in around 70 years. At the same time oil will be expected to be drained over 16 tonnes. In the past the rate from claiming use was little bit reasonable than the present rate (Shigeoka, 2004). As an example it can be considered that the load of 100% power distribution where is the lack of renewable energy system to fulfil the demand, so two or more renewable energy system can be coupled.

Moreover, it can be considered that 60% from a biomass plant, 20% from a wind energy system, 10% from a solar energy system can be utilized for the power generation. By combining all these renewable energy resources 100% of the power and energy demand for the load such as industries, home and small business can be fulfilled (Xuan, Leung, Leung, & Ni, 2009).

The vital test confronting the energy segment on Malaysia will be the issue of practicality that is to guarantee that security furthermore unwavering quality about energy supply and the broadening of the different energy sources (Ahmad, Yasin, Derek, & Lim, 2011). Those inquiries about security and unwavering quality for supply may be critical. To ensure the smooth birch usage of improvement activities will drive good development clinched alongside Malaysia. At the same time broadening from claiming vitality assets will be incredulous to guarantee of those nations which are not really under the improved development (Bailey, Bailey, & Burch, 2010).

In Malaysia, green innovation requisition will be seen concerning illustration a standout amongst those sensible results which would being received by numerous nations. (Lai & Macer).

To Malaysia, there appears a chance to be replenished stimulus clinched alongside pushing the development for an indigenous "green economy." Those nations face the danger for environmental change and contamination. The administration still need to find new sources of development and climb the quality chain (Rahman Mohamed & Lee, 2006). Therefore, the various vitality approaches have been embraced in this way and the renewable vitality advancement for Malaysia need to be tested.

There are numerous structures of renewable energy. Wind energy can reduce the dependency on hydroelectric energies that are the immediate outcome of differential warming of the earth's surface. The fact of warming the earth's surface prompts air moving around (wind) and precipitation framing concerning illustration those air may be lifted. Sun powered vitality will be the immediate transformation about daylight utilizing panels or collectors. Biomass vitality may be put away the power plants which are being active in the daylight.

Other renewable energies that do not rely on daylight would be the geothermal energy that will be an after effect for radioactive rot in the outside joined for the unique heat from claiming accreting those Earth. On the other hand tidal energy, which may be a transformation from claiming gravitational vitality (Dincer, 2000).

There are several developing countries are being affected by serious damage on the agriculture side due to lack of power generation. The rural electrification process can be conducted fruitfully by using some renewable energy resources like wave energy, wind energy, solar energy and biomass etc (Mondal & Denich, 2010).

Integration of various renewable energy technologies can be differentiated by high concentration solar thermal technologies from the photovoltaic cell. The dish-Stirling system can be very promising for electricity generation especially for distributed energy. Because, the specific modularity and high efficiency of a dish-Stirling system is very much depended on the solar energy technologies (Bravo et al., 2014).

A simple evaluation mechanism for the installation capacity has been designed to obtain the ratio of installation capacity in accordance with different installation locations of the hybrid energy system (Wai, Lin, & Chen, 2014).

2.3 Conventional cogeneration Energy Systems

The conventional cogeneration energy system can be designed and installed in various ways but renewable energy systems are most preferable. Nowadays, the biomass cogeneration energy system is becoming popular widely all over the world for its renewability and usage of natural fuel (no fossil fuel). On the other hand, the solar collector is the recent burning topic to harvest the heat energy from the Sun which can be used for heating and cooling purpose simultaneously (Østergaard, 2009). Moreover, photovoltaic (PV) convert, relying upon mobile type, 5–15% of the approaching sunlight based radiation under electricity, with those more excellent rate changed over under heat.

The sunlight based radiation increase the temperature of PV modules, bringing about a drop about their electrical effectiveness. The purposes of presentation from claiming both PV module surfaces of the encompassing permit their regular cooling. Anyhow over slanted top establishment the warm misfortunes are decreased more PV modules work toward higher temperatures (Baig, Sellami, Chemisana, Rosell, & Mallick, 2014). This undesirable impact of these PV modules can be incompletely avoided toward applying a suitableness heat extraction mode with a liquid circulation, keeping the electrical effectiveness toward an acceptable level.

The PV modules that need aid consolidated for warm units, the place circle air or water from claiming easier temperature over that for PV module will be heated. Constitute the mixture photovoltaic/thermal (PV/T alternately PVT) frameworks that can give more acceptable warm energy and expanding in this manner the aggregate vitality results starting with PV modules (Tripanagnostopoulos, 2007).

The PV/T sun based frameworks could make successful utilization within the provincial modern sector, basically for preheating water or air. Those water-cooled PV modules (PVT/water systems) comprise of a water heat exchanger in warm contact for those PV back side also are suitableness for water heating, space warming furthermore different requisitions. Air-cooled PV modules (PVT/air systems) could make incorporated on fabricating roofs also slanted and separated of the electrical load they could spread building warming and air ventilation necessities (Tiwari, Mishra, & Solanki, 2011).

PV/T sun based collectors coordinated once building roofs furthermore facades camwood trade differentiate installation of thermal collectors and photovoltaic, resulting to cost effective and aesthetic application of solar energy systems (Mohammad Rozali, Wan Alwi, Manan, & Klemeš).

2.4 Solar Energy Resource:

Solar energy based hybrid system is being very effective and popular for scaling-up renewable energy program (SREP) for the low income nations, similarly as a standout amongst the renewable energy system (RES). After 2003 the greater part of the sun powered force utilized within Malaysia which is provincial level with main module and huge scale business. The utilization of solar energy resources may not be very critical yet. Sun powered force for Malaysia alternately otherwise called PV framework will be evaluated should a chance to be four times those planet fossil fuel assets (Chalk &

Miller, 2006). In 2005, the 5-year Malaysian Building Integrated photovoltaic technology application project (MBIPV) was launched.

This project may be mutually financed by the administration of Malaysia, those worldwide surroundings office (GEF) and the private segment (Appanah, Shono, Mansur, & Krezdorn, 2009). Those project need a few show PV tasks done different parts including private houses and business fabricating. The majority huge late venture will be the green energy office (GEO) building, an administration-cum-research office for phase change material (PCM) (Luque & Hegedus, 2011).

The SURIA-1000, another national MBIPV program that has started in 2007, focusing on the private and business division to build up the new BIPV market and give direct chances to people in general and industry in renewable energy activities. The global horizontal solar radiation data has been collected from Malaysian Meteorological department for several regions of Malaysia for better performance analysis (Seng, Lalchand, & Lin, 2008).

In this setting the point of the present study is to control the attainability, break down and renovate a wind-diesel generator-battery half breed energy system. Numerous exploration works including achievability, advancement, and reproduction studies have been done on half energy systems (Khelif, Talha, Belhamel, & Hadj Arab, 2012; Nfah & Ngundam, 2009; Shafiullah, Amanullah, Shawkat Ali, Jarvis, & Wolfs, 2012).

Khelif et al. have investigated an attainability of a cross breed PV-battery-diesel generator force plant utilizing genuine meteorological information hardware expenses to demonstrate the likelihood of altering a stand-alone diesel generator establishment situated in Afra, south of Algeria, into a half breed framework (Khelif et al., 2012).
Shafiullah et al. have investigated an attainability study to explore the sun oriented and wind potential in a few areas in Australia for renewable vitality era. Those areas have been investigated with an attainability study to explore the sun oriented and wind

potential in a few areas in Australia for renewable vitality era (Shafiullah et al., 2012). Pico-hydro (PH) and photovoltaic (PV) half and half frameworks joining a biogas generator for remote towns in Cameroon have been mimicked and displayed by Nfah and Ngundam (Nfah & Ngundam, 2009).

Bagul et al. had represented a stand-alone wind-PV hybrid energy system based on statistical approach with PV arrays sizes. The actual distribution of energy generated by hybrid systems can be matched with the conventional two-event approach is less efficient than a three-event probalistic approach described on this proposed system (Bagul, Salameh, & Borowy, 1996). An optimization and techno-economic analysis of a wind-PV hybrid energy system has been made by Celik in recent time (Celik, 2002).

With the consideration of conditions such as load demand, wind speeds and insulations a comparative analysis of a solar and wind system has been also done. With the consideration of the state of voltage (SOV) instead of state of charge (SOC) Morgan et al. have analyzed the performance investigation of a battery module by varying the temperature (Morgan, Marshall, & Brinkworth, 1997).

Malaysia is blessed with abundant resources especially the potential renewable energy such as sufficient amount of wind sources and the larger global solar radiation for its geographical position (Solangi et al., 2011). During the last two decades, electrical energy consumption in Malaysia increased significantly for the dramatically economic expansion and the lack of measurement of energy preservation.

It is expected that peak loads will reach 60 GW in 2023 which causes over $90 billion as the total investment. For sustainable development, an imperative step has been taken to build up policies of energy conservation (Al-Ajlan, Al-Ibrahim, Abdulkhaleq, & Alghamdi, 2006). The fossil fuels have been used to generate most of the electrical power neglecting the use of its renewable energy resources such as wind and solar to generate electricity (Alyousef & Stevens, 2011).

2.5 Wind Energy Resources:

In Malaysia, wind vitality transformation is a genuine thought. In present innovation, wind vitality in Malaysia is not suitable to produce power monetarily or wind is not especially great in Malaysia when contrasted with the United Kingdom or Denmark. However islands like Perhentian without a doubt can pick up a ton of influence particularly when wind turbine is together furnished with sunlight based panels which Malaysia is rich in.

When there will be less wind, the sun based boards will cover the additional burden and during the evening, the wind turbines will be the ones creating more power. In 2005 a research work had been carried out and had shown a 150 kW wind turbine in Perhentian Terumbu Layang Island with some accomplishment by a group from University Kebangsan Malaysia (UKM). The accessibility of wind asset differs with area, average wind speed and population. The station situated at Mersing (ocean side) town has the best potential with a mean force thickness of 85.61 W/m2 at 10 m above ocean level (Sopian, Othman, & Wirsat, 1995).

The average wind speed of several years for different regions of Malaysia has been collected from Malaysian meteorological department for better performance analysis. The adverse effect of expanding the range of acceptable wind speed will cause the whole system to become unstable.

Different distinctive components add to the general wind force gauge slip, for example, the exactness of the conjectures for individual wind cultivates, the connection of wind force estimate lapses between diverse winds cultivates, the figure skyline, the extent of the individual wind ranches and their geological scattering around the nation. Much work has been done in surveying the execution of wind gauging methods in Ireland (Doherty, Denny, & O'Malley, 2004) and in general the wind power await mistake can be expressed as a function of the estimate possibility. This is based on results from a physical wind power forecasting tool (Giebel, Landberg, Kariniotakis, & Brownsword, 2003) and results from numerical/fuzzy forecasting system (Pinson & Kariniotakis, 2003).

Relationship between individual wind ranches' conjecture lapses is a vital issue and can possibly altogether build the general vulnerability that the framework is presented to from wind limit. It ought to be noticed that this relationship is unmistakable from the connection between individual wind ranches estimated yields, which do not open the framework to more noteworthy levels of instability (Righter, 1996). It has been demonstrated in different research article that the connection between wind force conjecture blunders of individual wind homesteads is emphatically reliant on the separation between the wind ranches (Upfield, 2014).

A 8.9MW RDF Power plant at Semenyih Selangor (Malaysia) at the similar situation, just a single power plant of this type utilizes community waste as fuel situated in South East Asia which owned by Recycle Energy Sdn. Bhd. (Abd Kadir, Yin, Rosli Sulaiman, Chen, & El-Harbawi, 2013). The combination of two 100 KW wind turbines, one 100 kW solar module, two diesel generators accomplished of 150 and 200 KW successively and the aptitude of 650 kilowatts is the solitary hybrid power plant in Perhentian Kecil Island (Tina, Gagliano, & Raiti, 2006).

The advancement with renewable energy especially win wind energy resources in Saudi Arabia cannot be considered as an aristocratic model, just as an environmental friendly model and discretion in petroleum manufacturing strategy and the power station depended on fossil fuel can be replaced by the windmills and solar panels (Al-Saleh, 2009; Alawaji, 2000).

The researches with ecological analysis has been concluded that the use of energy effectiveness resources and renewable energy gives significant environmental benefits (Alnatheer, 2005, 2006). There are some previous works on hybrid energy systems consisting of wind energy, fuel cell (diesel generator) and photovoltaic array for different region of the world (P. Nema, R. Nema, & S. Rangnekar, 2009).

A maximum power point tracking (MPPT) system is also discussed on wind and photovoltaic energies by various scientists (Ahmed et al., 2008; Hill, Such, Chen, Gonzalez, & Grady, 2012; Jaleel & Omega, 2013; Kim, Jeon, Cho, Ahn, & Kwon, 2008; Mohod & Aware, 2012; Valenzuela, 2013).

2.6 Recent Development of Optimization in Renewable Energy Researches

Optimization is the determination of the best component from some arrangement of accessible options. There are two types of optimization as follows the mathematical optimization and the programming optimization (Löfberg, 2004). Programming optimization is the procedure of changing a product framework to make some part of it work all the more productively or utilization less assets. In the easiest case, an improvement issue comprises of augmenting or minimizing a genuine capacity by deliberately picking info values from inside of a permitted set and figuring the estimation of the capacity (Gerwin, 1993).

The model, created in Matlab, utilizes straight programming and gives the arranging method to make in every time stride, which will impact the next hours. The reproduction period considered is one day, sub-partitioned in hourly time steps. The guidelines got as yield of the streamlining techniques are along these lines presented in a pressure driven test system (e.g. EPANET), with a specific end goal to check the framework conduct along the re-enactment period (Vieira & Ramos, 2009).

Researchers have been using several types of optimization techniques, optimization softwares and algorithms. There are a lots of researchers have used Matlab to conduct the optimization operations. Proper control system of a hybrid energy system has been signed by the previous researcher using Matlab. Fuzzy logic platform in

Matlab has been used extensively to predict the best result and power generation, power factor, feasibility, reliability and user friendly (Kaundinya et al., 2009). Various researchers also utilize Simulink of Matlab for the optimization operation. To get the proper results some other people have been using HOMER also (Seeling-Hochmuth, 1997). The popular algorithms which are being used for conducting optimization operation are the genetic algorithm, fuzzy logic and etc (Fonseca & Fleming, 1995) (Simoes, Bose, & Spiegel, 1997).

Feasibility analysis for a standalone wind-solar hybrid energy system for Ethiopia has been conducted. For the optimization process of this feasibility analysis has been carried out by Matlab simulation technique (P. Nema, R. K. Nema, & S. Rangnekar, 2009).

Dynamic behaviour of a standalone hybrid micro turbine-solar array and battery storage energy system has been represented with supervisory controller. The optimization process of this energy system has been carried out by fuzzy logic (Kalantar & Mousavi G, 2010).

An optimized stand alone PV-wind hybrid energy system with loss of power supply probability has been designed and analyzed by genetic algorithm (Kalantar & Mousavi G, 2010; Yang, Zhou, Lu, & Fang, 2008). An optimized solar-wind hybrid energy system has been designed and analyzed by artificial bee colony algorithm (Nasiraghdam & Jadid, 2012).

Feasibility and economic analysis of a stand-alone grid connected solar-wind hybrid energy system has been designed and analyzed for the remote and coastal areas. The optimization process of this grid connected energy system has been carried out by HOMER (Türkay & Telli, 2011).

2.7 Optimization with HOMER

The HOMER Micro-power Optimization Model is a computer model developed by the U.S. National Renewable Energy Laboratory (NREL) to assist in the design of Micro-power systems and to facilitate the comparison of power generation technologies across a wide range of applications.

HOMER is the global standard for micro-grid optimization. HOMER models a power framework's physical conduct and its life-cycle cost, which is the aggregate expense of introducing and working the framework over its life compass. HOMER permits the modeller to look at various outline alternatives in light of their specialized and financial benefits. It additionally helps with understanding and measuring the impacts of instability or changes in the inputs.

A small scale power framework that produces power, and potentially warmth, to serve an adjacent burden. Such a framework may utilize any blend of electrical era and capacity innovations and may be matrix associated or self-sufficient, importance separate from any transmission lattice.

The only limitations are that it is not random, and the schedule must be consistent during each month. For the ambiguity in key parameters and the huge quantity of design options, such as load size and future fuel price, the analysis and design of Micro-power systems can be challenging (Chandrakasan, Daly, Kwong, & Ramadass, 2008). There are several complexities can be observed from renewable power sources. The output power from the renewable power resources might be inconsistent, dispatchable and non-feasible. HOMER had been designed to overcome these challenges (Akella, Sharma, & Saini, 2007).

There are three principal tasks that can be performed by HOMER such as simulation, optimization, and sensitivity analysis. To determine and calculate the technical feasibility and life-cycle cost of a Micro-power system, each hour of the year has to be configured in simulation process (Lambert, Gilman, & Lilienthal, 2006).

HOMER performs multiple optimizations under a range of input assumptions to gauge the effects of uncertainty in the sensitivity analysis process (Akyuz, Oktay, & Dincer, 2011). The sensitivity analysis helps to assess the whole simulation and optimization process. The other optimization technology can not be performed in HOMER.

Those reproduction transform determines how a specific arrangement configuration, a consolidation for framework segments for particular sizes also a operating methodology that characterizes how the individuals segments worth of effort together, might carry on for a provided for setting over a in length time of time (Zhang, Dube, McLean, & Kates, 2003).

Matlab could mirror an expansive differing qualities for micro control framework configurations, including any consolidation of a PV array, you quit offering on that one alternately that's only the tip of the iceberg wind turbines, a run-of-river hydro-turbine, and up to three generators, a battery bank, a hydrogen capacity tank, an electrolyzer and a ac to dc converter (Farzan, 2013).

The framework could make grid joined alternately self-sufficient system. Moreover DC and AC electric loads also can work as a warm load. In the model an arrangement holding a PV array with wind turbines (Sumathi, Kumar, & Surekha, 2015). Sun oriented asset information show the measure about worldwide sunlight based radiation (beam radiation advancing specifically from those sun, also diffuse radiation hailing starting with every last bit parts of the sky) that strikes Earth’s surface clinched alongside an ordinary quite a while (Borfecchia et al., 2013).

Those information could make to a standout amongst three forms: hourly normal worldwide sunlight based radiation on the flat surface (kW/m^2), month to month

Normal worldwide sun based radiation on the flat surface (kWh/m^2/day), alternately month to month normal clearness list (Hamman, Fackler, & Malte, 2008). The clearness list may be that proportion of the sunlight based radiation striking Earth's surface of the sunlight based radiation striking those highest priority on the air. A number the middle of zero also 1, the clearness list is a measure of the clearness of the air (Piliougine, Elizondo, Mora-López, & Sidrach-de-Cardona, 2015).

CHAPTER 3: METHODOLOGY

3.1 Introduction

The methodology section consists of the system description, system modelling, energy resources and other components required to fulfil the analysis. It also contains the experimental effort and the simulation operations with HOMER energy software by a brief description as well as the working procedure of the experimental part. Figure 3.1 shows the sequential procedure of total methodology. The sequential procedure starts with the description of equipments. The equipments consist of the solar panel, solar charge controller, wind turbines, main controller, inverter circuit, battery bank, ac motor and etc. The whole mechanism conducted by the main controller. Usually from wind turbine ac power can be generated and then AC power can be converted into DC by a converter. From the solar panel DC power can be generated and must be stored in a battery bank.

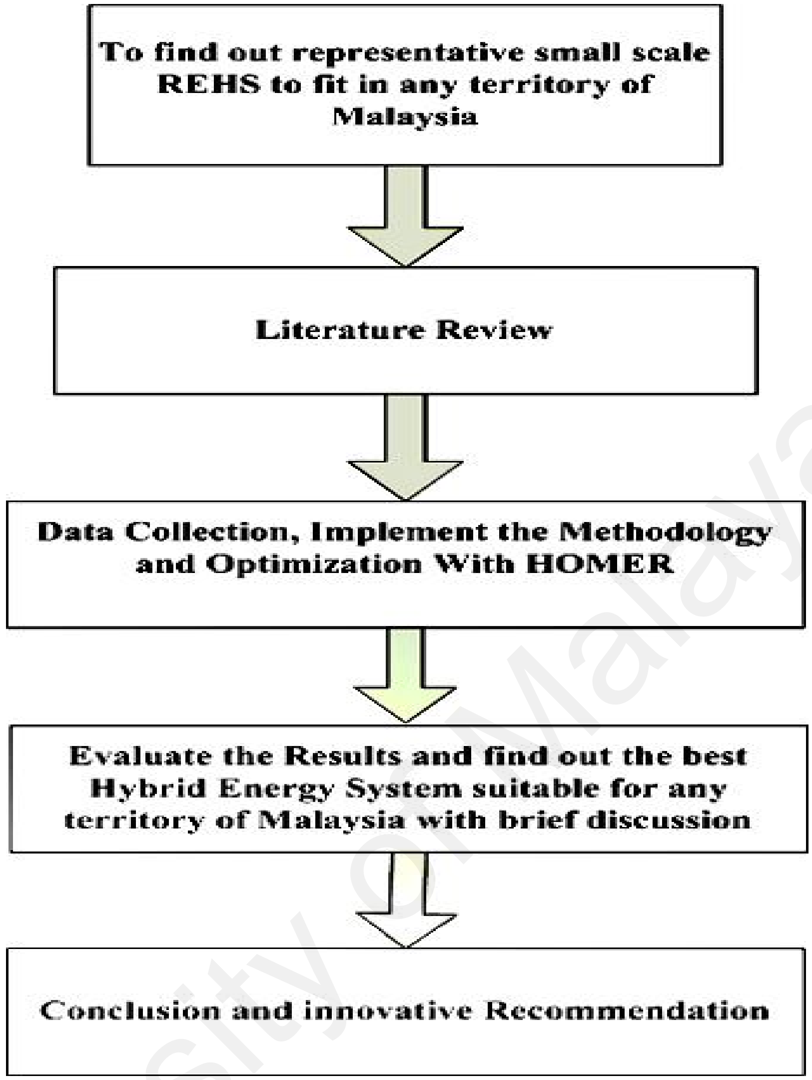


Figure 3.1: The general flow chart of methodology of the study.

3.2 Description of Equipment

In this analysis, a solar module is used with wind turbine and diesel generator with battery back-up has been coupled. The Figure 3.2 shows the schematic diagram of proposed renewable energy system. The first step of a PV-wind energy system is measurement of solar irradiation and average wind speed for a specific area. The second step is the calculation of an estimated power demand for a specific community. Then a proper control system can be introduced to handle the whole procedure. After installing all the parts and equipments properly the operation and maintenance can be conducted.

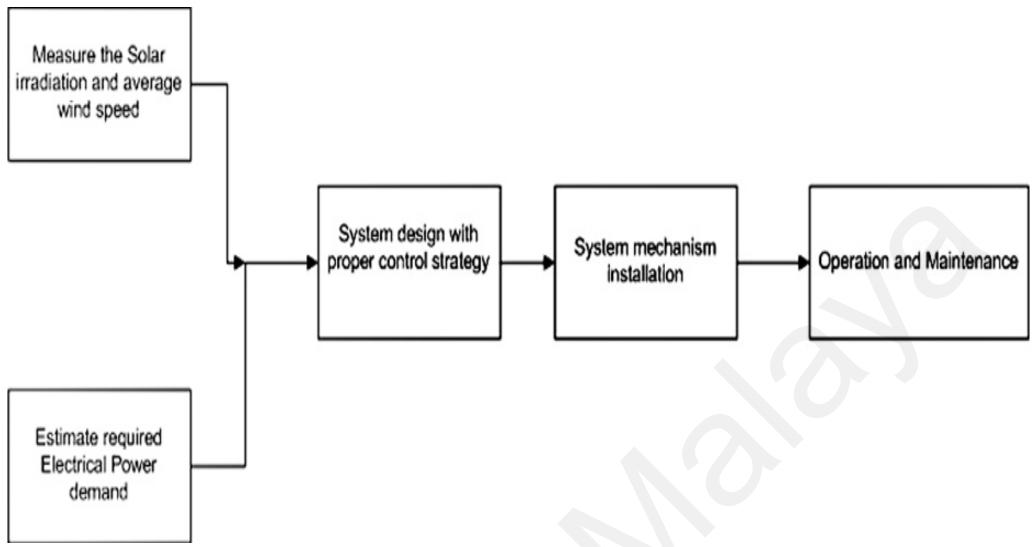


Figure 3.2: The block diagram of the PV-wind energy system with general flow of operation.

3.2.1. Solar module (PV array)

PV is a technique for converting so as to create electrical force sunlight based radiation into direct current power utilizing semiconductors that display the photovoltaic impact. Photovoltaic force era utilizes sun powered boards made out of various sun based cells containing a photovoltaic material (Rustemli & Dincer, 2011).

Materials in the blink of an eye utilized for photovoltaic incorporate mono-crystalline silicon, polycrystalline silicon, formless silicon, cadmium telluride, and copper indium gallium selenide/sulphide (Chu, 2011). Because of the expanded interest for renewable vitality sources, the assembling of sunlight based cells and photovoltaic exhibits has progressed significantly as of late (Kouchaki, Iman-Eini, & Asaei, 2013). In the experiment, the PV made with mono-crystalline silicon is used. Figure 3.3 shows an equivalent circuit of a PV cell.

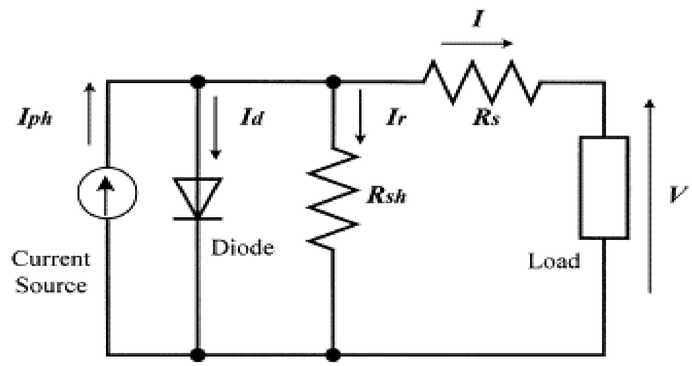


Figure 3.3: Equivalent circuit of a PV cell (Kouchaki et al., 2013)

3.2.2. Solar charge controller

A charge controller, similarly called charge controller alternately battery controller, limits the rate toward which electric current may be included with alternately drawn starting with electric batteries (Bourbeau, 1997). It forestalls deceiving and might neutralize against through voltage, which cam wood renter battery execution or lifespan. The charge controller for solar array of a hybrid satellite system had been established with several coupon and cells (Kawasaki, Hosoda, Kim, Toyoda, & Cho, 2006). It could similarly suspect completely depleting ("profound releasing") a battery, or perform controlled releases, unforeseen upon the battery innovation, to guarantee battery existence (Vosen & Keller, 1999).

Those expressions "charge controller" might escape to possibly a remain solitary gadget, alternately should control fittings facilitated inside of a battery pack, battery-fuelled gadget, or battery recharger (Gibson & Kelly, 2010). An arrangement accuse controller alternately arrangement controller disables further present stream under batteries at they would full. A shunt charge controller alternately shunt controller diverts overabundance power will a assistant or "shunt" load, for example, such that a electric water heater, at batteries would full (De Leon, Frías-Ferrer, González-García, Szánto, & Walsh, 2006).

3.2.3. Battery bank

The battery bank consists of several batteries to store the electrical power as DC form received from the PV array as well as fuel cell. It also carries the responsibility to provide the DC power to the electrolyzer for hydrogen production and handles all the DC electrical loads connected with the battery (system) (Parida, Iniyan, & Goic, 2011).

In this analysis, the valve regulated lead-acid battery is chosen because it has relatively low cost and high energy efficiency. The disadvantages of lead acid batteries are low specific energy and low lifetime if discharge more than allowable level of discharge. The lead acid battery is separated into two parallel groups and two series groups. The capacity of battery is100Ah, since the 200Ah is needed to ensure the backup power can operate the DC appliances in the absence of sunlight (Hadjipaschalis et al., 2009).

The batteries are connected in parallel to increase the capacity of the power supply. The battery voltage output also becomes double when connected in series. The connection configuration of batteries is shown in Figure 3.4. The optimum storage battery in general should have minimum size which meets the demand requirements during the application period (Saidur et al., 2008).

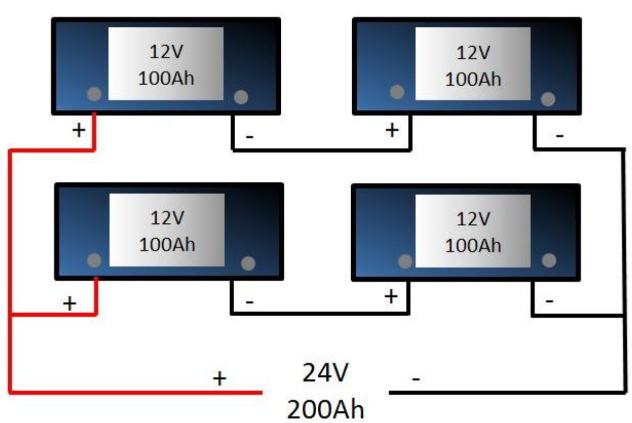


Figure 3.4: Connection configurations of batteries.

However, battery is the weakest components of stand-alone photovoltaic system because the batteries can be over discharged or operated under partial state of charge. It lifespan in photovoltaic system is shorter than expected. So the solar charge controller is used to prevent over discharge and over charge of the battery. The lifetime of the valve regulated lead-acid battery is 6 to 10 years and the photovoltaic module is 24 years (Hua, Zhou, Kong, & Ma, 2006).

Therefore, it is very important to reduce the battery cost by extending battery lifetime. Furthermore, mainly corrosion and self-discharge are accelerated by the increase of the temperatures. The ideal operating temperature for valve regulated lead-acid battery is 25ºC ±5%. The reliability of the system largely depends on the performance of the battery as well as on its expected lifetime. Since the design and sizing of a photovoltaic array strongly depends on the size and performance of the storage unit, a rather accurate prediction of the behaviour of valve regulated lead-acid battery is essential (Saidur et al., 2008).

3.2.4. Inverter circuit

The outputs of the PV array as well as fuel cell are direct current (DC) power, which can be used to run the DC appliances directly. In order to run the alternating current (AC) appliances, the DC power needs to be converted into AC. This responsibility is carried by the inverter circuit. Actually, the inverter is an electrical circuit which converts the DC electrical energy into AC.

The DC to AC converter is uncommonly intended for operation at a wide DC information voltage range. The end goal to permit ideal photovoltaic force transformation with a self-assertive number of 2 to 10 arrangement associated sunlight based clusters each appraised 20V/2.5A crest force. Thus, photovoltaic force transformation may be connected in private applications at moderately minimal effort toward the starting, permitting further power boosting by association of extra sun oriented boards in arrangement (Herrmann, Langer, & van der Broeck, 1993).

Numerous converter topologies are explored for photovoltaic cells and for energy units. The diverse converter topologies are contrasted with respects with the converter proficiency and expense. The special application must be considered in order to select a proper converter topology and the overall performance requirements to the Green Power Inverter are (GPI) (Andersen, Klumpner, Kjær, & Blaabjerg, 2002):

- To control the solar panel voltage according to a given reference,
- To deliver a grid current with a high power factor and a low current Total Harmonic Distortion (THD),
- To have a high efficiency in the whole operating range,
- The high frequency ripple of the fuel cell current should be small,
- The cost should be minimized.

Figure 3.5 shows a push-pull inverter circuit which output voltage is 220V (AC).

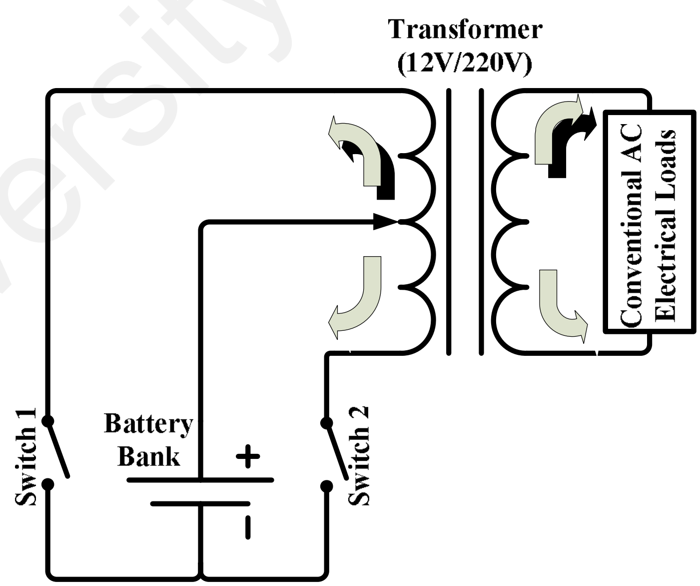


Figure 3.5: Push-pull inverter circuit.

Since a transformer has been used to build the inverter and the input power of the inverter is DC, hence the switching speed of the switches should be higher (preferably kHz~ MHz) (within transient period that is needed to complete the switching). For this inverter, the Metal Oxide Field Effect Transistor (MOSFET) is used as switch.

The operation is very simple of a push-pull inverter. When the current flows clockwise around the loop of primary side of the transformer, in secondary side it follows the anticlockwise and vice versa. That means, if switch is turned ON, then a positive polarity has been got in the upper portion of the secondary side, and by turning ON the switch 2, positive polarity has been got in the bottom portion of the secondary side of transformer. Hence an alternating current (AC) at secondary side can be generated. The wave shape of this AC power is rectangular. To get the pure sinusoidal AC wave shape, it is required to set a low pass (or band pass) filter at the end of the terminal in secondary side of the transformer.

3.3 Mathematical Model of Solar and Wind Energy Systems:

The mathematical analysis for Solar Module (PV array) and Wind (Wind turbines) Energy Systems are presented below:

3.3.1 Solar photovoltaic:

PV efficiency is highly affected by the solar irradiance, tilt angle and the ambient temperature of the module. The mostly used equation to calculate the PV efficiency is given by (Notton, Lazarov, & Stoyanov, 2010):

$$\eta_{PV} = \eta_{ref}\left[1 - \beta'\left(\theta_{cell} - \theta_{cell,ref}\right) + \gamma \log\left(\frac{G_{\beta}}{G_{\beta,ref}}\right)\right] \tag{3.1}$$

where, η_{ref} denotes the reference efficiency of module at reference temperature ($\theta_{cell,ref}$=25°C), β' and γ represent the temperature coefficient and the solar irradiance coefficient respectively. Moreover, θ_{cell} is for PV cell temperature, G_β for solar irradiance and $G_{\beta,ref}$ for the reference solar irradiance respectively. γ and β are mainly dependent on the materials of PV modules. Usually the values of $\theta_{cell,ref}$,η_{ref}, β', γ are provided by the manufacturer. Besides, considering the power correction factor (α) in ambient temperature, the efficiency of silicon based PV cell can be calculated using the following equation (Notton et al., 2010):

$$\eta_{PV} = \eta_{ref}\left\{1-\alpha\left[\left(\frac{G_\beta}{18}\right)+\theta_a - 20\right]\right\} \tag{3.2}$$

where, the value of α is considered about 0.0042. The cell temperature, θ_{cell} can be calculated by the following equation (Notton et al., 2010):

$$\theta_{cell} = \theta_a + \left(\theta_{NOCT} - 20°C\right)\left(\frac{G_\beta}{800}\right) \tag{3.3}$$

where, θ_{NOCT} denotes the Normal Operating Cell Temperature of PV module provided by the manufacturer which is calculated at θ_a = 20 °C and G_β = 800 W m^{-2} where the wind speed = 1 ms^{-1}. The module maximum power can be calculated using following equation (Notton et al., 2010):

$$P_{mp} = \eta_{PV} G_\beta A \tag{3.4}$$

where, A is the surface area of PV module. The total power generated by photovoltaic array is given as

$$W_{PV} = V_{PV}\ I_{total} \tag{3.5}$$

where I_{total} can be defined as

$$I_{total} = I_{Load} + I_{SOEC} \tag{3.6}$$

Here I_{SOEC} is the delivered current by the photovoltaic array for water electrolysis.

The total current delivered by the PV can be calculated by solving the following equations:

$$I = I_{SC}\left\{1 - C_1\left[\exp\left(\frac{V-\Delta V}{C_2 V_{OC}}\right) - 1\right]\right\} + \Delta I \tag{3.7}$$

The constants in equation (3.1) can be expressed by:

$$C_1 = \left(1 - \frac{I_{mp}}{I_{SC}}\right)\exp\left(-\frac{V_{mp}}{C_2 V_{OC}}\right) \tag{3.8}$$

$$C_2 = \frac{V_{mp}/V_{OC} - 1}{\ln\left(1 - I_{mp}/I_{SC}\right)} \tag{3.9}$$

$$\Delta I = \alpha\left(\frac{S}{S_{ref}}\right)\Delta T + \left(\frac{S}{S_{ref}} - 1\right)I_{sc} \tag{3.10}$$

$$\Delta V = -\beta \Delta T - R_s \Delta I \tag{3.11}$$

$$T = T_{amb} + 0.02S \tag{3.12}$$

where,

α Current change temperature coefficient at reference insulation (Amps/°C)

β Voltage change temperature coefficient at reference insulation (Volts/°C)

I Module current (Amperes)

I_{amp} Module maximum power current (Amperes)

I_{sc} Module short circuit current (Amperes)

S Total tilt insulation

S_{ref} Reference solar radiation (1000 W/m^2)

R_s Module series resistance (Ohms)

T Cell temperature (°C)

T_A Ambient temperature (°C)

T_{ref} Reference temperature of the solar cell (25 °C)

ΔT Temperature change in cells (°C)

V Module voltage (Volts)

V_{mp} Module maximum power voltage (Volts)

V_{oc} Module opens circuit voltage (Volts)

3.3.1.1 Electrical power from PV module:

The electrical energy generation as an output of a photovoltaic system can be estimated by a worldwide formulated equation as follows:

$$E = A \times r \times H \times PR \tag{3.13}$$

where,

E = Energy (kWh)

A = Total Solar panel area (m^2)

r = Solar panel yield (%)

H= Annual average solar radiation on tilted panels (shadings not included).

PR= Performance ratio, coefficient for losses.

The annual average solar radiation data can be collected from the meteorological department.

The Performance ratio (PR) range will be 0.5 to 0.9, build in rate= 0.75) r is the ratio of electrical power (in kWp) of a particular PV module divided by the area of a particular module. PR can be considered as a very important value to estimate the eminence of a photovoltaic installation.

3.3.2 Wind energy (wind turbines) system

Wind turbines work by converting the kinetic energy in the wind first into rotational kinetic energy in the turbine and then electrical energy that can be supplied. From the national grids around the United Kingdom (UK) we have come to know that the remote and eco-tourism areas are still deprived of grid connection but some organizations have been trying to implement the wind turbines to generate electrical power through the average wind resources (Camacho, Samad, Garcia-Sanz, & Hiskens, 2011; Draper, Vincent, Kroll, & Swanson, 2005; Walker, Devine-Wright, Hunter, High, & Evans, 2010).

A rotor combining of two or more blades mechanically joined to an electrical generator which can generate wind's kinetic energy that can be captured by the wind turbines (Beltran, Ahmed-Ali, & Benbouzid, 2008). With the constant acceleration, mass m the work will W in the conditional force F

$$E = W = Fs \tag{3.14}$$

According to Newton's Law, the force is

$$F = ma \tag{3.15}$$

Hence,

$$E = mas \tag{3.16}$$

Using the third equation of motion:

$$V^2 = u^2 + 2as \tag{3.17}$$

Now it can be written as:

$$a = \frac{(V^2 - u^2)}{2s} \tag{3.18}$$

Substituting it in equation (3.16), the kinetic energy of a mass in motions is:

$$E = \frac{1}{2} m V^2 \tag{3.19}$$

The power in the wind is given by the rate of change of energy:

$$P = \frac{dE}{dt} = \frac{1}{2} V^2 \frac{dm}{dt} \tag{3.20}$$

As mass flow rate is given by:

$$\frac{dm}{dt} = \rho A \frac{dX}{dt} \qquad (3.21)$$

And the rate of change of distance is given by:

$$\frac{dX}{dt} = V$$

Now it can be written as:

$$\frac{dm}{dt} = \rho AV \qquad (3.22)$$

Where, $A = \pi r^2$

Hence, from equation (3.20), the power can be defined as:

$$P = \frac{1}{2}\rho AV^3 \qquad (3.23)$$

A German physicist Albert Betz find out at 1919 that no wind turbine can be changed over more than 16/27 (59. 3%) of the dynamic vitality of the wind under mechanical vitality turning a rotor. At present time this is known as the Betz cut-off or Betz' theory.

The hypothetical greatest energy effectiveness whatever plan from claiming wind turbine is 0. 59 (i. e. close to 59% of the vitality conveyed toward the wind could a chance to be concentrated by a wind turbine). This is called the “power coefficient” and is defined as:

$$C_{Pmax} = 0.59$$

From the equation the mechanical power captured from wind speed by a wind turbine (Chinchilla, Arnaltes, & Burgos, 2006) (when power P= Maximum Power P_m) can be formulated as:

$$P_m = 0.5\rho AC_p v^3 \qquad (3.24)$$

The highest value of the power coefficient has been preferred as 0.59 theoretically. It is dependent on two variables, the tip speed ratio (TSR) and the pitch angle. The pitch angle refers to the angle in which the turbine blades are aligned with respect to its longitudinal axis. The linear speed of the rotor to the wind speed has been addressed by TSR (Beltran et al., 2008; Johnson, Pao, Balas, & Fingersh, 2006).

Tip speed ratio is defined as:

$$\lambda = \frac{blade\ tip\ speed}{wind\ speed}$$

So, as follows,

$$TSR = \lambda = \frac{\omega R}{v} \tag{3.25}$$

where,

E kinetic Energy (J)

m mass(kg)

v wind speed(m/s)

P power (W)

$\frac{dm}{dt}$ Mass flow rate (kg/s)

$\frac{dE}{dt}$ energy flow rate

ρ density (Kg/m^3)

A swept Area (m^2)

C_p Power Coefficient

r Radius (m)

x distance (m)

t time (s)

Figure 3.6 shows a typical "C_P Vs. λ" curve for a wind turbine. For the realistic designing of wind turbines two different conditions have been implemented such as the range of 0.4 to 0.5 for the speedy wind turbines and the range of 0.2 to 0.4 for relatively slower wind turbines.

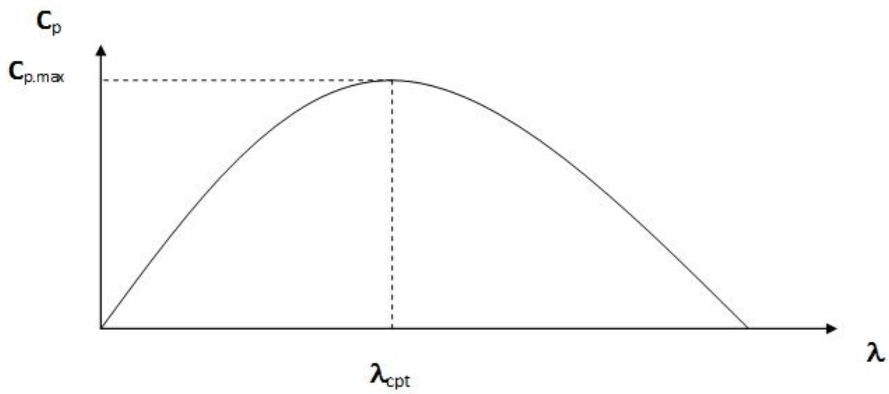


Figure 3.6: Power coefficient vs. tip speed ratio (Zalba, Mari ́ ŋ Cabeza, & Mehling, 2003).

As shown in figure 3.6 at λ_{opt} it has the highest value. According to the wind turbine the maximum power and optimum efficiency can be captured with the expected outcomes. The output power of a wind turbine versus rotor speed is illustrated in Figure 3.7 while wind speed has been changed from v_1 to v_4. In this figure the highest power can be captured while speed is v_1, at rotor speed ω_1 and while speed increases from v_1 to v_4 as the maximum power point tracking system. Tracking rotor speed is also increases from ω_1 to ω_4.

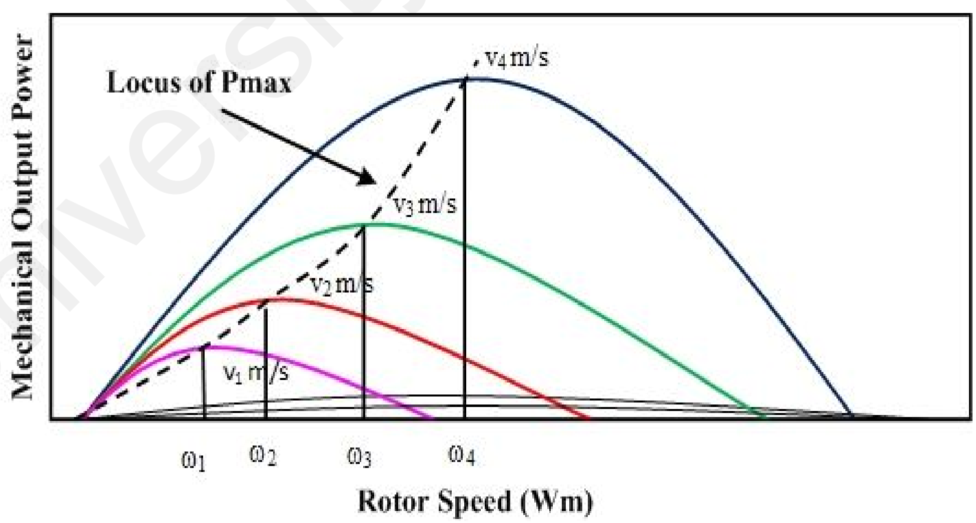


Figure 3.7: Output power vs. rotor speed of different speeds (Marín, Zalba, Cabeza, & Mehling, 2005).

3.3.3 Meteorological data of Kuala Lumpur International Airport

Table 3.1 shows the meteorological data of Kuala Lumpur International Airport (KLIA) Sepang station in the year 2008 and 2009 and also defined the Weibull values with power density and energy density. From the monthly averages data the hourly data can be engendered unnaturally if hourly data cannot be collected. There is a minor difference between the global radiation data and average artificial wind speed data generator of HOMER (Kaygusuz & Sarı, 2003).

Table 3.1: Yearly wind power density and wind energy density (Nandi & Ghosh, 2010):

Station	**Year**	**Meteorological**		**Weibull**		V_{mp} (m/s)	$V_{max,E}$ (m/s)
		P/A (W/m^2)	E/A (J/m^2)	P/A (Wm^2)	E/A (J/m^2)		
KLIA Sepang	2008	20.36	175.91	20.63	178.24	1.43	4.40
	2009	17.73	153.19	18.16	156.90	0.72	4.55

The measurement of the distribution of wind speed over the year is called the Weibull value which is addressed by k. The value of k has been taken 2 for this analysis. The measurement of the arbitrariness of the wind has been conducted by the auto-correlation parameter. From the observation of the higher values of the wind speed in 1 hour leans it is indicated that the wind speed leans of 1 hour is firmly depended on the wind speed of the past hour. The vacillation of the wind speed leans in a more arbitrary way from time to time has been indicated by the lower values.

The rate of autocorrelation parameter has been taken as 0.85. How firmly the wind speed confides on the time of the day can be identified by the diurnal pattern strength. The value of diurnal pattern strength has been taken as 0.25 for this analysis. The time of day leans to be the windiest on a standard all through the year can be addressed by the term hour of peak wind speed. The value of the hour of peak wind speed has been taken as 15 for this analysis (Nandi & Ghosh, 2010).

AXLS BWC EXCEL-S 10 kW wind turbine has been considered for this off-grid hybrid renewable energy system (K Hossain & Badr, 2007). Table 3.2 shows the monthly average wind speed of KLIA Sepang station for a specific area. Table 3.3 represents the financial and methodological factors for preferred wind turbine. Figure 3.8, 3.9 and 3.10 show average wind speed of every month in 2009 of KLIA Sepang station of Malaysia, average hourly wind speed profile data and average monthly wind speed data respectively.

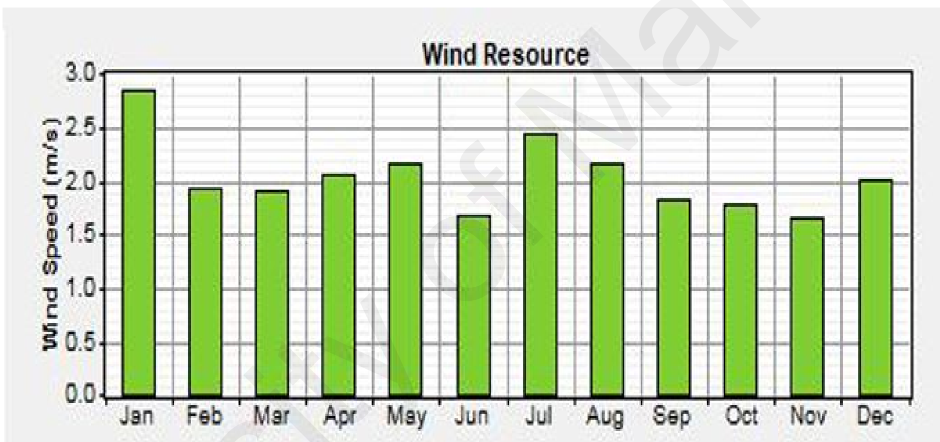


Figure 3.8: Average wind speed of every month in 2009 of KLIA Sepang station of Malaysia.

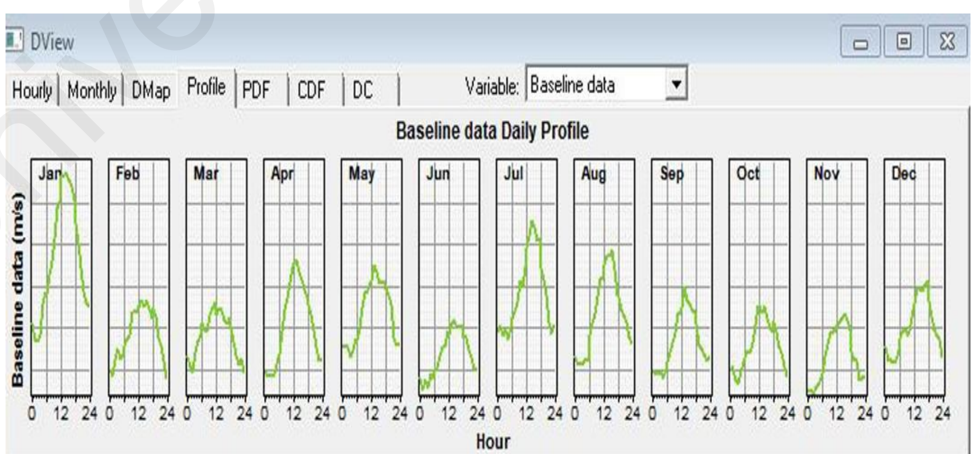


Figure 3.9: Average hourly wind speed profile data.

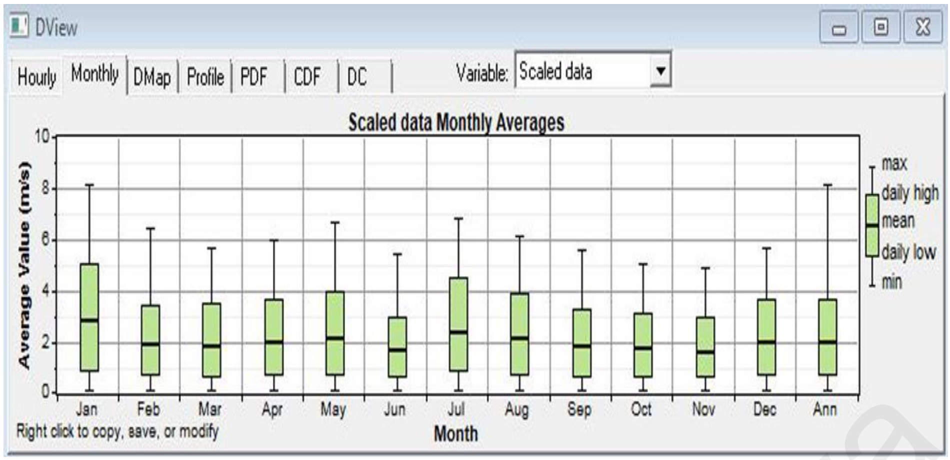


Figure 3.10: Average monthly wind speed data.

Table 3.2: Monthly average wind speed data for a specific area of KLIA Sepang Station.

Month	Average Wind Speed (m/s)
January	2.860
February	1.920
March	1.900
April	2.050
May	2.170
June	1.680
July	2.430
August	2.170
September	1.840
October	1.790
November	1.660
December	2.010
Average	2.04

Table 3.3: Financial and procedural factors of wind turbine.

Factors	Value
Rated Wind Speed	8 m/s
Starting Wind Speed	3 m/s
Cut-off Wind Speed	5.5 m/s
Rated Power	10 kW
Net Cost	60 $/kW
Substitution Cost	50 $/kW
Lifetime	15 Years
Maintenance and Operation expense	1 $/kW

Table 3.4: Monthly average solar irradiation of KLIA Sepang Station.

Month	Solar Irradiation (kWh/m^2)
January	4.825
February	4.74
March	4.68
April	5.05
May	5.22
June	4.96
July	4.71
August	4.85
September	4.81
October	4.93
November	3.90
December	4.23
Average	4.74

3.4 Experimental Investigation

This subsection illustrates the experimental part of the study with its system description and procedure.

3.4.1 System description

The daily solar radiation data have been collected for every month of the year 2009 from the Malaysian meteorological department. All the data used for the analysis collected from KLIA Sepang Station, Malaysian Meteorological Department, the nearest meteorological station from Selangor, Malaysia (Lee & Pradhan, 2007).

Moreover, the department of Labour and Regulation (DLR, Germany) has manifested a technique for Global Horizontal Insulation (GHI) to get the output for 16.3 km spatial resolution. Malaysian Meteorological Department has considered that method to collect that data for Malaysian energy systems (Shen, 2009).

Figure 3.11 shows the geographical position of KLIA Sepang Meteorological Station (Lat.: 2° 44' N, Long.: 101° 42' E) (Yahya et al., 2012). DLR method used the data collected from the satellite for various factors such as rainfall, water vapour and vaporizer optical depth, cloud cover, water vapour to Calculate GHI. To calculate wind resources data, Malaysian Meteorological Department has measured wind speed for the year 2009 by maintaining the height of 30 m upwards from the ground surface level.

Figure 3.11: KLIA Sepang meteorological station (Lat.: 2° 44' N, Long.: 101° 42' E) (Yahya et al., 2012).

Renewable energy analysis with biomass had not been fruitful yet due to the lack of biogas resources. Tidal research stations were set up by Malaysian Meteorological department and Malaysian Renewable Energy Committee for the practicability justification of tidal energy (Lee & Pradhan, 2007). The result was not up to the expectation level that is why just the wind, solar resources and average temperature data have been considered to design the most efficient hybrid renewable energy system. Figure 3.12 shows the schematic diagram of hybrid energy system.

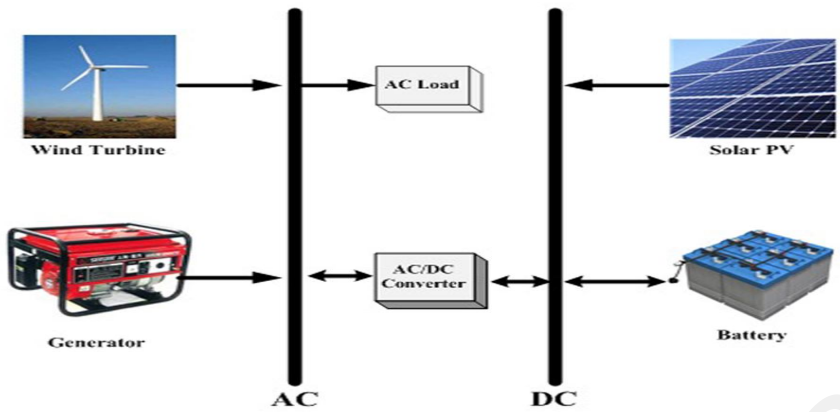


Figure 3.12: Schematic diagram of hybrid energy systems.

3.4.2 Simulation and optimization technique:

The meteorological data of global solar radiation and yearly average wind speed have been used to the analytic results. The data has been collected from Malaysian Meteorological department. The HOMER energy software has been used to conduct the optimization, Simulation operations. The simulation process consists of two different modules such as the solar module and the wind module.

Figure 3.13 shows the sequential process of simulation and optimization operation in HOMER. The process starts with the data collection. In the data collection module the data needs to be collected are the meteorological data such as the average solar irradiation and average wind speed for the specific areas. After collecting the average solar irradiation data and the average wind speed data for a specific area, the power from solar panel and wind turbine can be calculated. After calculating power from solar panel and wind turbine, cost of energy (COE) and net present cost (NOC) can be calculated by HOMER. Finally from the feasibility analysis the best results can be found out.

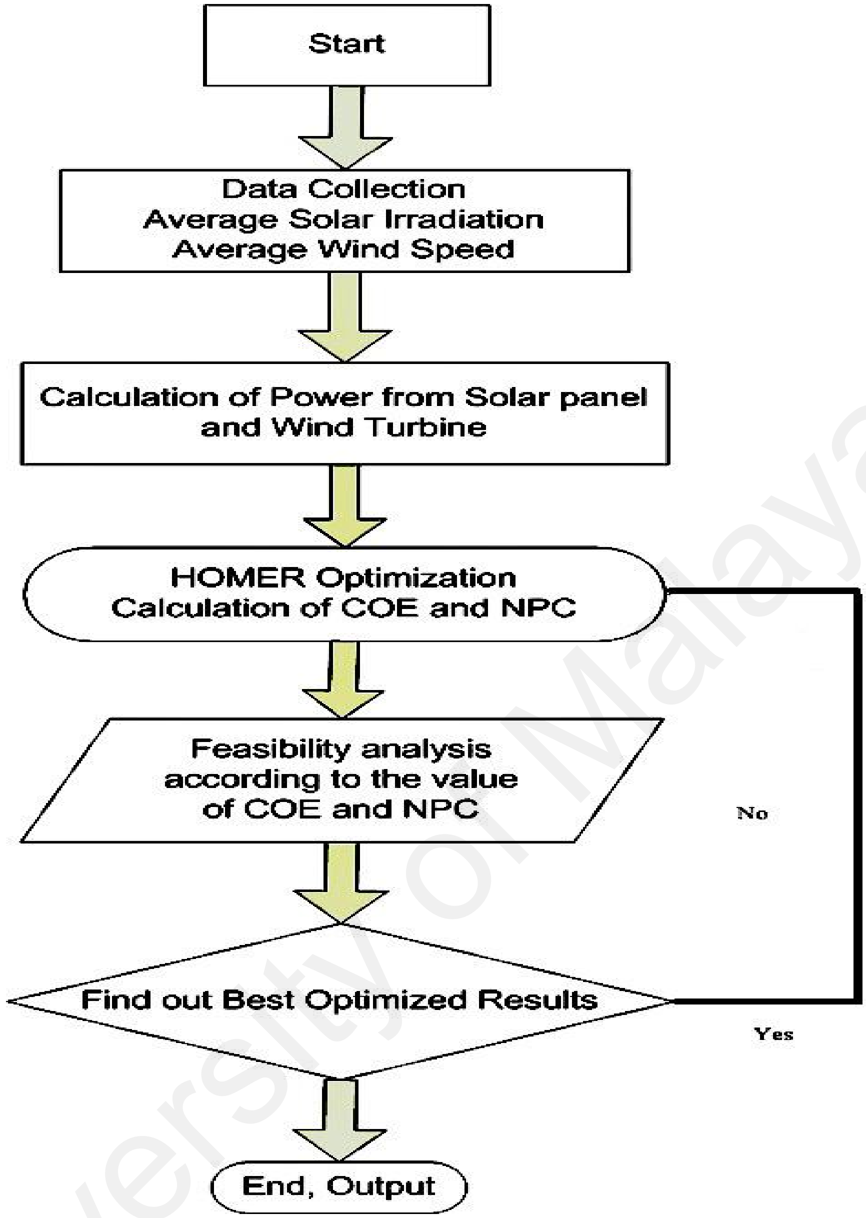


Figure 3.13: Flow chart of Optimization operation in HOMER.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This chapter performs various calculation and analysis of different parameters of the system, basically the system input and output power measurement and the efficiency measurement of diesel generator, PV array, wind turbine, battery module, and converter module. Finally, a comparison is made between the other energy systems and Solar-Wind hybrid renewable energy system.

4.2. System Performance Analysis

There are so many elements considered in the proposed system. But, the main concentration goes only on PV array (solar module), diesel generator, wind turbine, battery module and converter muddle parts of the system. Hence, only the performance of these five parts is analyzed through following three sub-sections.

4.3 Simulation Results and Analysis

4.3.1. Performance analysis of PV-diesel energy system

The performance analysis of solar-diesel generator hybrid energy system for southern region of Malaysia especially for eco-tourism management has been completed by meteorological data of global solar radiation in HOMER Platform. For the assessment of the performances of different hybrid renewable energy systems in this research, HOMER simulation mechanisms have been used to perpetrate optimal systems performance analysis.

The optimized outcomes for a specific group of sensitivity parameters akin to global horizontal solar radiation, highest yearly capacity shortage, diesel cost, and renewable fraction are represented emphatically in that optimization software. An optimal hybrid renewable energy system can be designed by HOMER renewable energy software through large number of hourly simulations again and again.

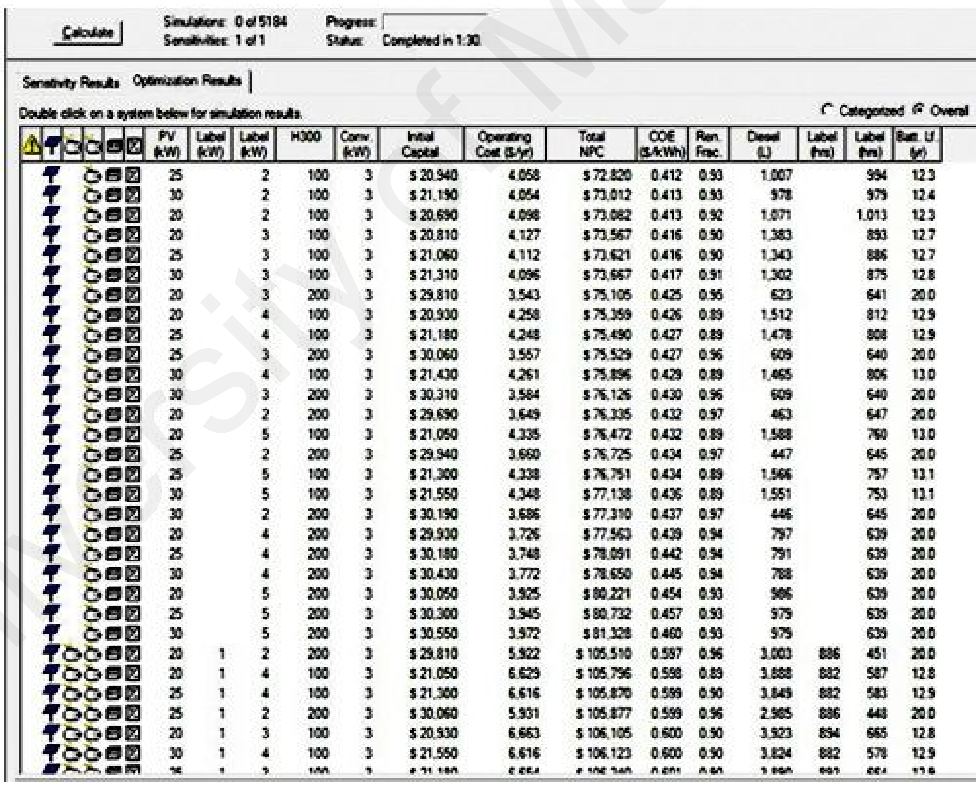
Various values for solar radiation, diesel cost and least renewable fraction have been contemplated to conduct simulations and these values assuring much more suppleness in the analysis. The load demand for the analyzed energy system has been considered 38 kWh/d for a community of southern region of Malaysia where solar energy is feasible relatively.

Figure 4.1 shows simulation outcomes in considering an off-grid hybrid PV-diesel- battery hybrid energy model with an average solar radiation of 2.23 $kWh/m^2/d$, diesel cost of 0.8$/L and the highest capacity shortage of 0.03%. USD has been considered as the currency for all costs related with that hybrid system. Actually the diesel price has been considered in the range of 0.4-1 USD for the analysis of all other energy systems.

Figure 4.2 shows the details calculation, simulation results and cost analysis with system architecture, NPC, COE, operating cost, electrical energy produced by wind turbine, PV, and diesel generator system, unmet load, excess electricity, capacity shortage and renewable fraction of the most monetarily practicable hybrid energy system relevant for the preferred area in both simple case and best case.

Figure 4.2 (a) refers to the worst case with a 5 kW PV and 2 generators. Figure 4.2 (b) refers to the average case with a 4 kW PV and a 4 kW generator. Figure 4.2 (c) refers to the best case with a 5 kW PV and a 5 kW generator. In this figure the consideration of different parameters such as specific diesel cost 1 USD and global horizontal scaled solar radiation 1.7 $kWh/m^2/d$ has been presented for the optimization results. With a base NPC of USD 158,206 and base COE of USD 0.895/kWh, an off-grid hybrid PV-diesel generator-battery hybrid system is efficiently more feasible and this is observed by the sensitivity analysis in the most economically feasible case.

Figure 4.3 shows the electrical energy generated with practicability from the off-grid hybrid PV-diesel- battery system in different case with generator 1 and 2 with the expected power generation and the back-up power resource respectively. Figure 4.3 (a) refers to the worst case. During manipulating various cases of simulation results the first step is (a). Figure 4.3 (b) refers to the average case. In this case the average simulations result according to the analysis can be found. Figure 4.3 (c) refers to the best case. In this case the best result according to the analysis can be found. A hybrid energy system can be considered as the most feasible renewable energy system constituted of 5 kW PV module, a diesel generation with a divisional power of 5 kW (utilizing 5 kW) and 100 storage batteries in cementation to 3 kW converters and rectifiers.



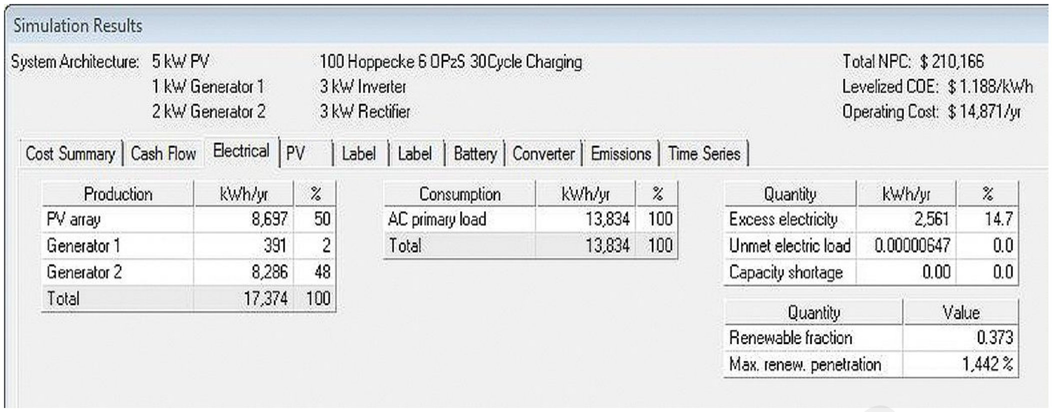
Calculate | Simulations: 0 of 5184 | Progress:
Sensitivities: 1 of 1 | Status: Completed in 1:30

Sensitivity Results | Optimization Results

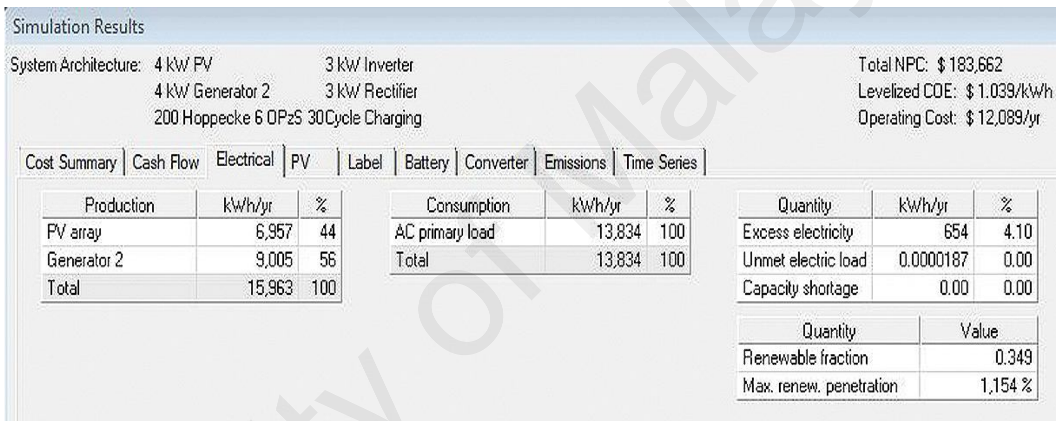
Double click on a system below for simulation results. | Categorized | Overall

PV (kW)	Label (kW)	Label (kW)	H300	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)	Label (hrs)	Batt. Lf. (yr)
25		2	100	3	$ 20,940	4,058	$ 72,820	0.412	0.93	1,007		994	12.3
30		2	100	3	$ 21,190	4,054	$ 73,012	0.413	0.93	978		979	12.4
20		2	100	3	$ 20,690	4,098	$ 73,082	0.413	0.92	1,071		1,013	12.3
20		3	100	3	$ 20,810	4,127	$ 73,567	0.416	0.90	1,383		893	12.7
25		3	100	3	$ 21,060	4,112	$ 73,621	0.416	0.90	1,343		886	12.7
30		3	100	3	$ 21,310	4,096	$ 73,667	0.417	0.91	1,302		875	12.8
20		3	200	3	$ 29,810	3,543	$ 75,105	0.425	0.96	623		641	20.0
20		4	100	3	$ 20,930	4,258	$ 75,359	0.426	0.89	1,512		812	12.9
25		4	100	3	$ 21,180	4,248	$ 75,490	0.427	0.89	1,478		808	12.9
25		3	200	3	$ 30,060	3,557	$ 75,529	0.427	0.96	609		640	20.0
30		4	100	3	$ 21,430	4,261	$ 75,896	0.429	0.89	1,465		806	13.0
30		3	200	3	$ 30,310	3,584	$ 76,126	0.430	0.96	609		640	20.0
20		2	200	3	$ 29,690	3,649	$ 76,335	0.432	0.97	463		647	20.0
20		5	100	3	$ 21,050	4,335	$ 76,472	0.432	0.89	1,588		760	13.0
25		2	200	3	$ 29,940	3,660	$ 76,725	0.434	0.97	447		645	20.0
25		5	100	3	$ 21,300	4,338	$ 76,751	0.434	0.89	1,566		757	13.1
30		5	100	3	$ 21,550	4,348	$ 77,138	0.436	0.89	1,551		753	13.1
30		2	200	3	$ 30,190	3,686	$ 77,310	0.437	0.97	446		645	20.0
20		4	200	3	$ 29,930	3,726	$ 77,563	0.439	0.94	797		639	20.0
25		4	200	3	$ 30,180	3,748	$ 78,091	0.442	0.94	791		639	20.0
30		4	200	3	$ 30,430	3,772	$ 78,650	0.445	0.94	788		639	20.0
20		5	200	3	$ 30,050	3,925	$ 80,221	0.454	0.93	586		639	20.0
25		5	200	3	$ 30,300	3,945	$ 80,732	0.457	0.93	579		639	20.0
30		5	200	3	$ 30,550	3,972	$ 81,328	0.460	0.93	579		639	20.0
20	1	2	200	3	$ 29,810	5,922	$ 105,510	0.597	0.96	3,003	886	451	20.0
20	1	4	100	3	$ 21,050	6,629	$ 105,796	0.598	0.89	3,888	882	587	12.8
25	1	4	100	3	$ 21,300	6,616	$ 105,870	0.599	0.90	3,849	882	583	12.9
25	1	2	200	3	$ 30,060	5,931	$ 105,877	0.599	0.96	2,985	886	448	20.0
20	1	3	100	3	$ 20,930	6,663	$ 106,105	0.600	0.90	3,523	894	665	12.8
30	1	4	100	3	$ 21,550	6,616	$ 106,123	0.600	0.90	3,824	882	578	12.9

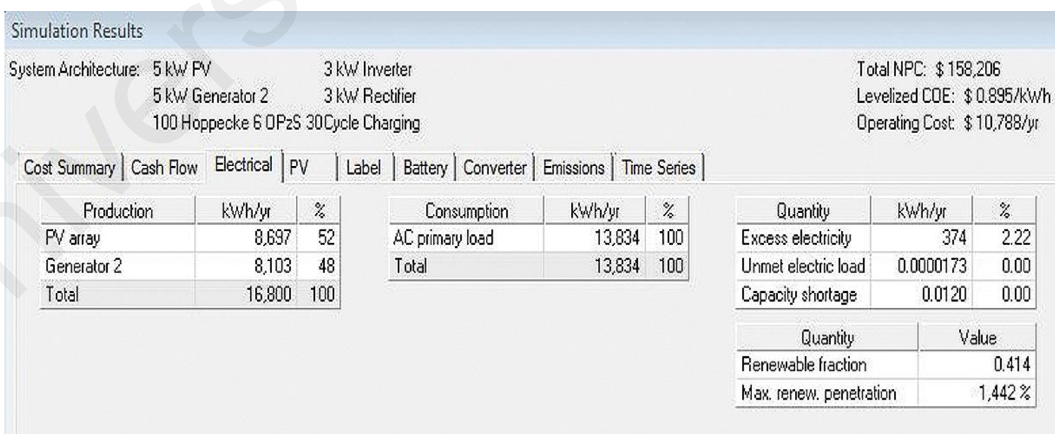
Figure 4.1: Simulation results of a complete PV-diesel-battery hybrid renewable energy system.



(a) Worst case with NPC- USD 210,166 and COE- USD 1.188/kWh.

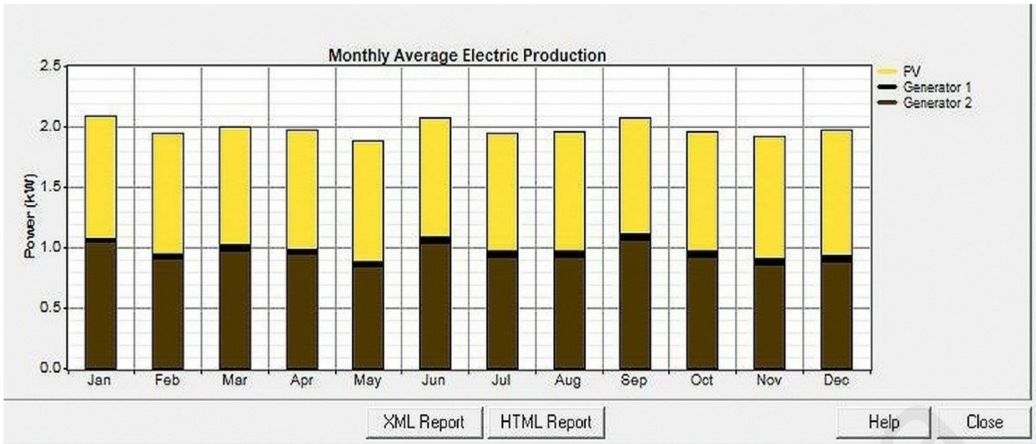


(b) Average case with NPC-USD 183,662 and COE-USD 1.039/kWh.

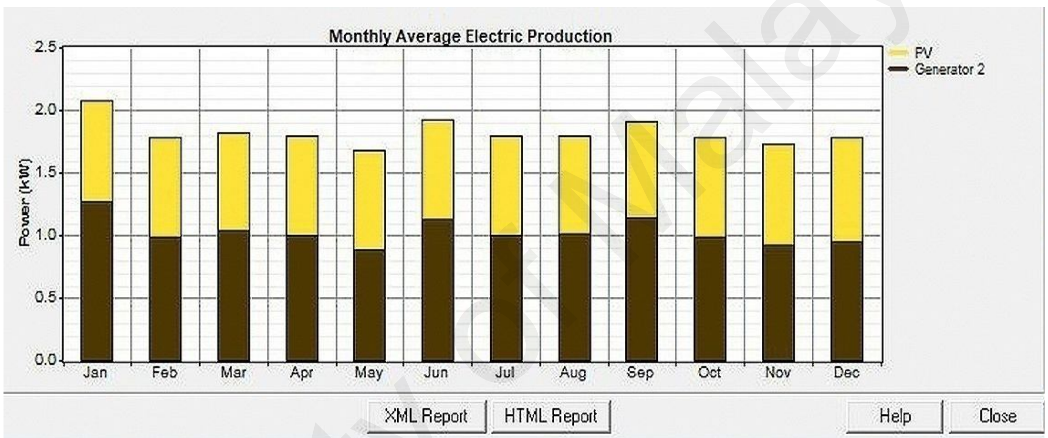


(c) Best case with NPC-USD 158,206 and COE-USD 0.895/kWh.

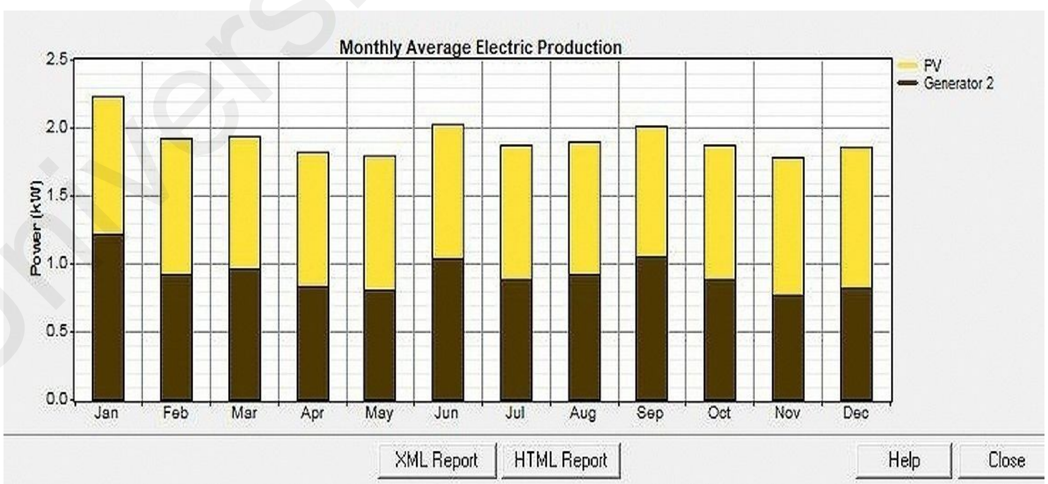
Figure 4.2: Simulation Results for (a) Gen-1,2 and PV, (b)Gen-2 and PV, (c)PV and Gen-2, (d) PV and Gen-2 (Best case).



(a) Worst case with NPC- USD 210,166 and COE- USD 1.188/kWh.



(b) Average case with NPC-USD 183,662 and COE-USD 1.039/kWh.



(c) Best case with NPC-USD 158,206 and COE-USD 0.895/kWh.

Figure 4.3: Power generation in different conditions with generator 1 and generator 2 coupled with PV module.

4.3.2. Performance analysis of wind-diesel hybrid energy system

For the assessment of the performances of different hybrid renewable energy systems in this research, HOMER simulation mechanisms have been used to perpetrate optimal systems performance analysis (Kaundinya et al., 2009). The optimized outcomes for a specific group of sensitivity parameters akin to average wind speed, global horizontal solar radiation, highest yearly capacity shortage, diesel cost, and renewable fraction are represented emphatically in that optimization software (Merckx et al., 2009).

An optimal hybrid renewable energy system can be designed by HOMER renewable energy software through large number of hourly simulations again and again. Various values for wind speed, diesel cost and least renewable fraction have been contemplated to conduct simulations and these values assuring much more suppleness in the analysis (Hotza & da Costa, 2008). The load demand for the analyzed energy system has been considered 85 kWh/d for a community of Cameron Highland of Malaysia where wind energy is feasible relatively.

Figure 4.4 shows simulation and optimization outcomes in considering an off-grid hybrid wind-diesel-battery hybrid energy model with an average wind speed of 2.690 m/s, diesel cost of 0.5$/L, highest capacity shortage of 0.03%. USD has been considered as the currency for all costs related with that hybrid system. Figure 4.5 shows the details calculation, simulation results and cost analysis with system architecture, NPC, COE, operating cost, electrical energy produced by diesel generator, wind turbine, control system, unmet load, capacity shortage, excess electricity and renewable fraction of the most monetarily practicable hybrid energy system relevant for the preferred area in both simple case and best case (Shaahid & Elhadidy, 2007).

In Figure 4.6 the consideration of different parameters such as specific wind speed 2.690 m/s and diesel cost 0.5 USD has been represented for the optimization results. With a base NPC of USD 77,019 and base COE of USD 0.199/kWh, an off-grid hybrid wind turbine, diesel generator and battery hybrid system is efficiently more feasible and this is observed by the sensitivity analysis.

In HOMER some specific equations has been used to calculate the COE and NPC respectively. A hybrid energy system can be considered as the most feasible renewable energy system constituted of 15 generic wind turbines (10 kW DC each), a diesel generation with a divisional power of 4 kW and 2 storage batteries in cementation to 1 kW inverters and 1 kW rectifiers. The annual power from the wind turbine has been calculated by HOMER about 43,407 kW/yr and 44,057 kW/yr for best case and average respectively which follows the dedicated equations.

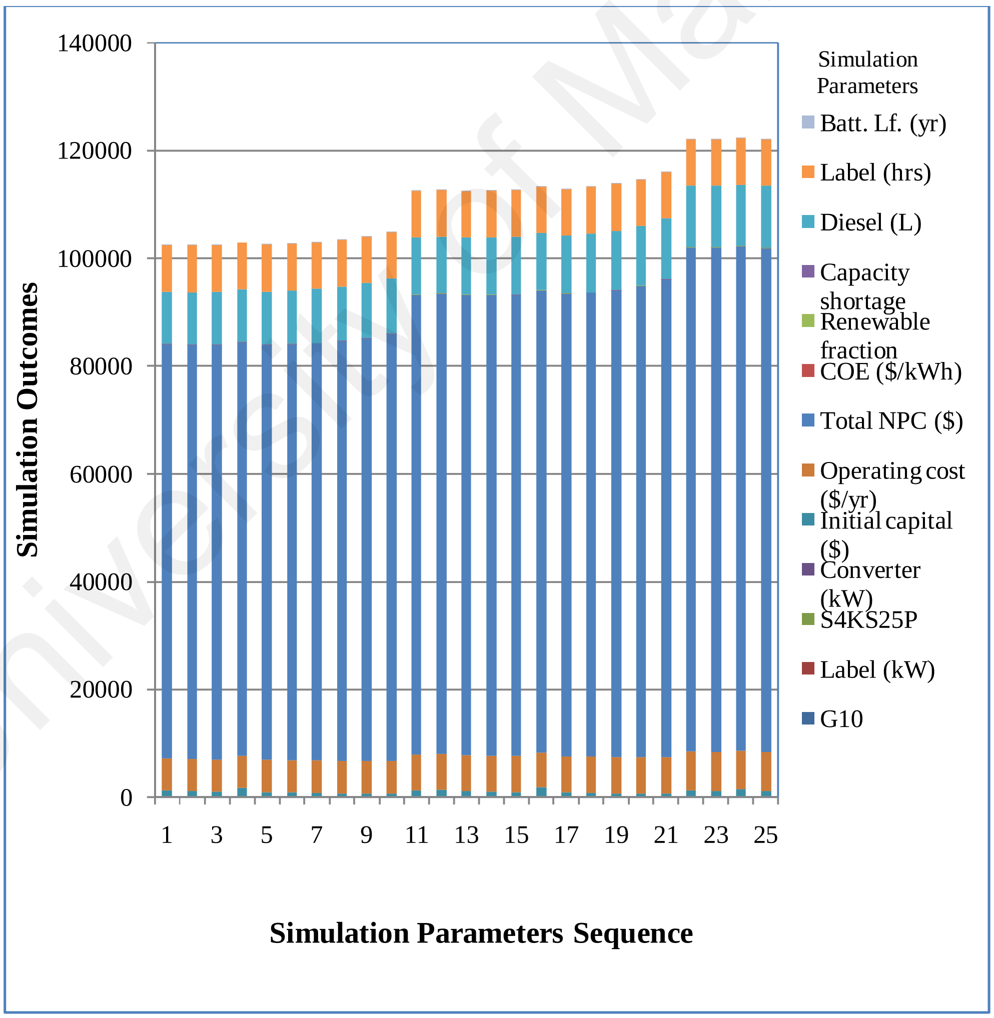
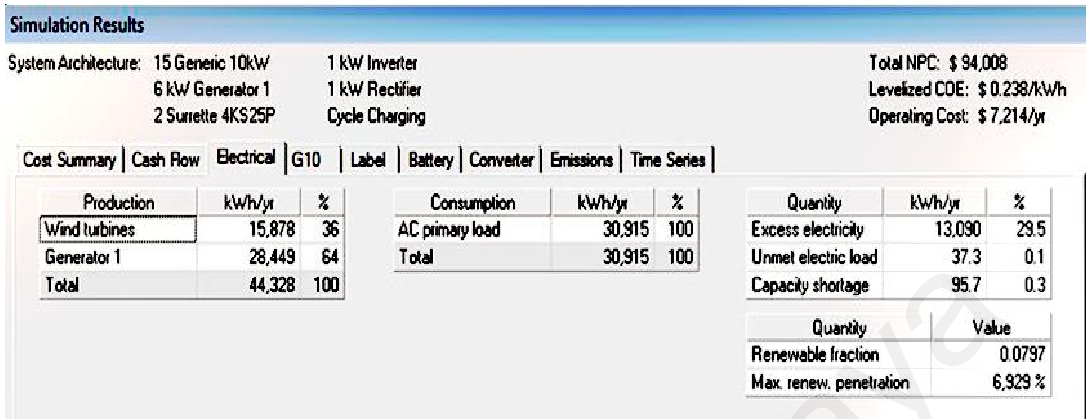
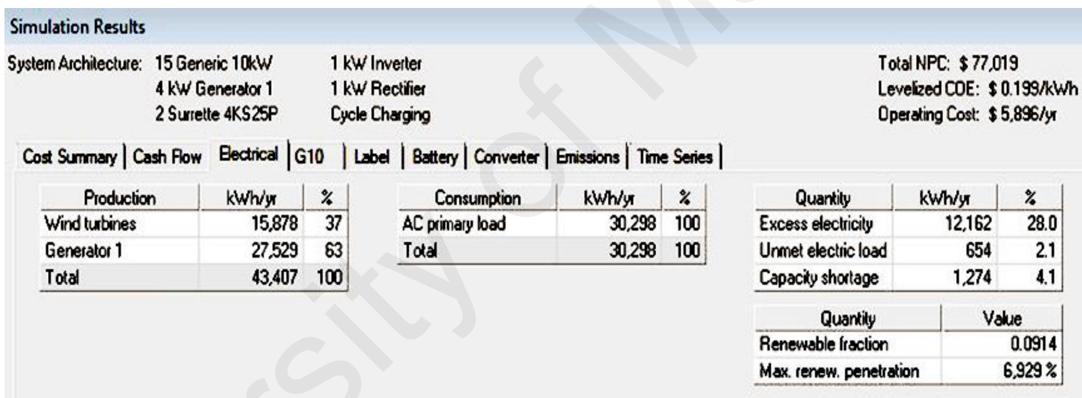


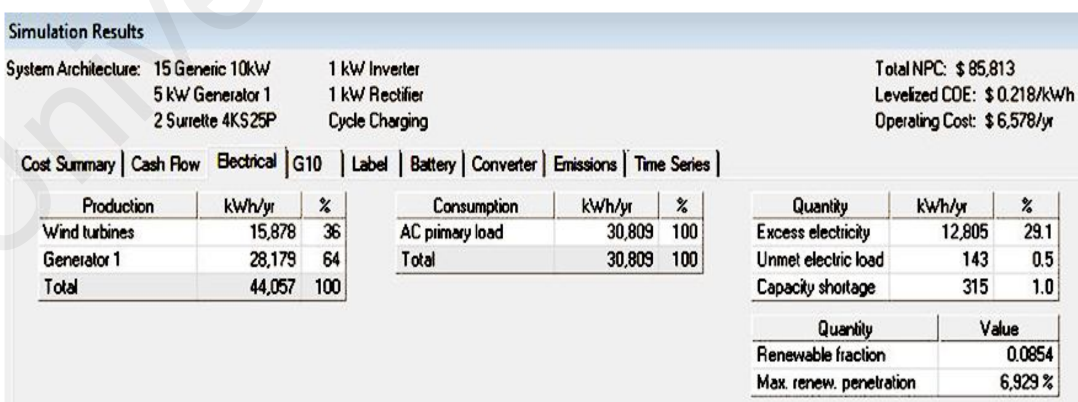
Figure 4.4: Simulation and optimization results of a wind-diesel hybrid energy system.



(a) Worst case with NPC-USD 94,008 and COE-USD 0.238/kWh

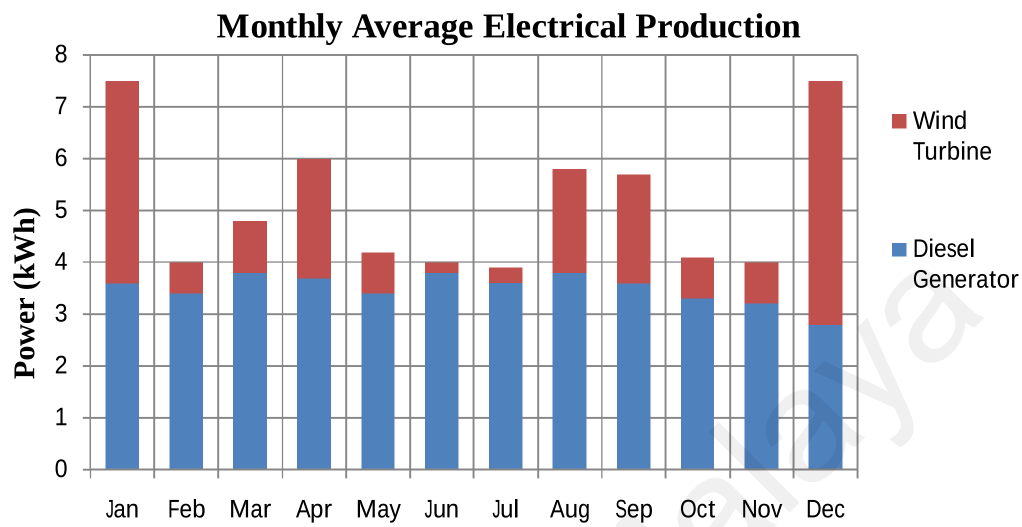


(b) Best case with NPC-USD 77,019 and COE-USD 0.199/kWh.

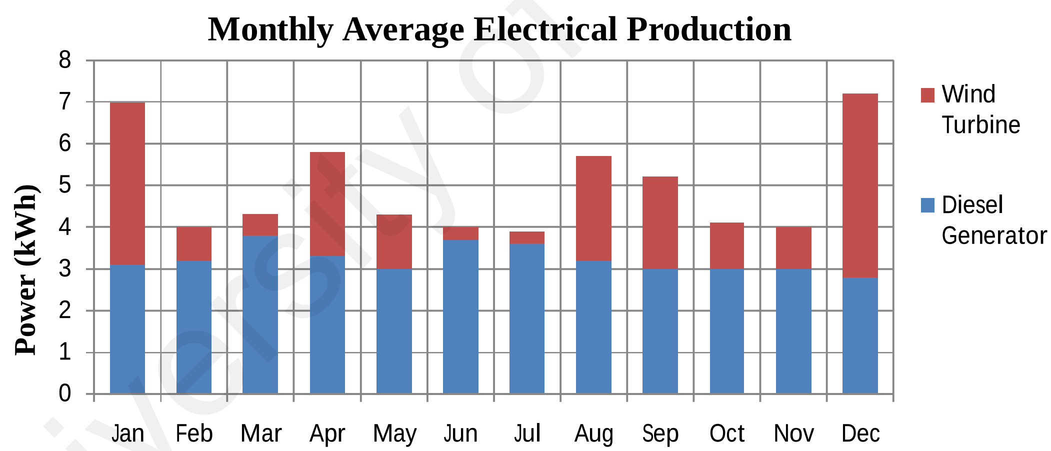


(c) Average case with NPC-USD 85,813 and COE-USD 0.218/kWh.

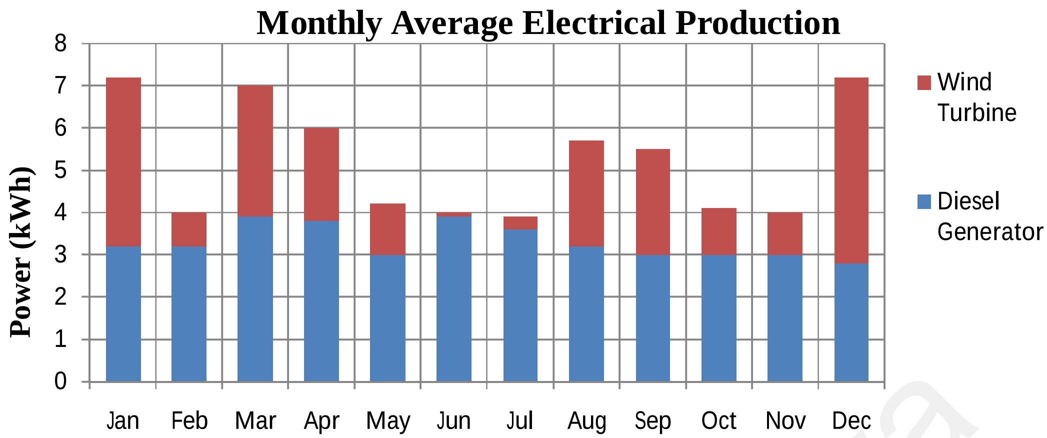
Figure 4.5: Power calculation in different simulation strategies with the variation of NPC, COE and operating cost.



(a) Worst case with NPC-USD 94,008 and COE-USD 0.238/kWh.



(b) Best case with NPC-USD 77,019 and COE-USD 0.199/kWh.



(c) Average case with NPC-USD 85,813 and COE-USD 0.218/kWh.

Figure 4.6: Power generation curve according to wind and diesel generator with different conditions.

4.3.2.1 Economic analysis and GHG emissions analysis:

Table 4.1 shows the comparison between RES and conventional power plant with consideration of CO_2 emission and NPC.

Table 4.1: Comparison of CO_2 emission and NPC between the RES and conventional power plant.

Parameters	**Hybrid Renewable energy system**	**Conventional power station**
CO_2 Emission/Year (kt)	198347.984	198,348.00
NPC/Year (USD)	77,019.00	297,000.00
COE/Unit (USD)	0.199/kWh	0.25/kWh

According to the test the CO_2 emissions rate per year has been found 198347.984 kilotons which is 16 tons less than the conventional power plants per year considering the year of 2009 for Malaysian perspective (Shafiullah, Oo et al. 2013).

The NPC can be varied by fuel cost, equipment cost, life time, operation and maintenance cost. From the comparison between the RES and conventional power plant it can be clearly identified that the NPC for the proposed hybrid energy system has been reduced in comparison with the NPC for the conventional power station in Malaysian perspective. The NPC for the designed hybrid energy system is 25.93 % less than the NPC for the conventional power plant per year considering the year of 2009 for Malaysian climate and also the per unit COE is USD 0.051/kWh less than the COE of the conventional power plant in a particular year (Ali, Daut et al. 2012).

Table 4.2 shows the emission rate of other GHG from the analyzed hybrid renewable energy system.

Table 4.2: The emission rate of other GHG from the analyzed hybrid energy system.

Name of Gasses	Emission Rate (%)
Carbon Monoxide(g/L of fuel)	6.5
Unburned Hydrocarbons(g/L of fuel)	0.72
Particulate matter(g/L of fuel)	0.49
Proportion of fuel Sulphur converted to PM (%)	2.2
Nitrogen oxides(g/L of fuel)	58

4.3.3. Performance analysis of solar-wind hybrid model

For the assessment of the performances of different hybrid renewable energy systems, HOMER simulation mechanisms have been used to perpetrate optimal systems performance analysis. The optimized outcomes for a specific group of sensitivity parameters akin to average wind speed, global horizontal solar radiation, highest yearly capacity shortage, diesel cost, and renewable fraction are represented emphatically in that optimization software. The load demand for the analyzed energy system has been considered 33 kWh/d for a community of KLIA Sepang station of Malaysia where solar energy and wind energy both are feasible relatively.

Figure 4.7 shows simulation outcomes in considering an off-grid hybrid PV-diesel-wind-battery hybrid energy model with an average solar horizontal radiation of

2.23 kWh/m^2/d, diesel cost of 0.4$/L and the maximum capability shortage of 0.03%.USD have been considered as the currency for all costs related with that hybrid system. Figure 4.8 shows the electrical energy generated with practicability from the off-grid hybrid PV-diesel-wind-battery system. The power calculation in different simulation strategies has been shown. The four different conditions have been applied and counted for finding out the best results. Each phase considered with particular power generation from generator and turbines.

The phase 4.8 (b) is considered as the best case because of majority the power generation from wind turbines with feasibility and stability according to the most economically feasible and reliable NPC and COE. Figure 4.9 shows the power generation curve according to wind and diesel generator in different conditions. The power generation curves with magenta and blue color. The magenta curves indicated the wind turbines and the blue curves indicated the diesel generators. In the 4.9 (b) phase shows the best case according to the most economically feasible NPC and COE.

In Figure 4.7 the simulation and optimization results of an off-grid hybrid PV-Diesel-Wind-Battery energy model has been shown. The simulation and optimization results reflect various analytic diagrams under different conditions. Each and every simulation result represents individual analysis with wind turbines and generators.

In Figure 4.8 the consideration of different parameters such as specific wind speed 2.04 m/s, diesel cost 1 USD and global horizontal scaled solar radiation 1.7 kWh/m^2/d (Mekhilef, 2010) has been represented for the optimization results. With a base NPC of USD 288,194 and base COE of USD 1.877/kWh, an off-grid hybrid PV, wind turbine, diesel generator and battery hybrid system is efficiently more feasible and this is observed by the sensitivity analysis (Khan & Iqbal, 2005).

Figure 4.9 shows the details calculation, simulation results and cost analysis with System architecture, NPC, COE, operating cost, electrical energy produced by wind turbine, PV, and diesel generator system, unmet load, excess electricity, capacity shortage and renewable fraction of the most monetarily practicable hybrid energy system relevant for the preferred area in several cases. A hybrid energy system can be considered as a most feasible renewable energy system constituted of 18 kW PV module, two wind turbines (10 kW each), a diesel generation with a divisional power of 15 kW (utilizing 3kW) and 25 storage batteries in cementation to 3 kW converters (Fadaee & Radzi, 2012).

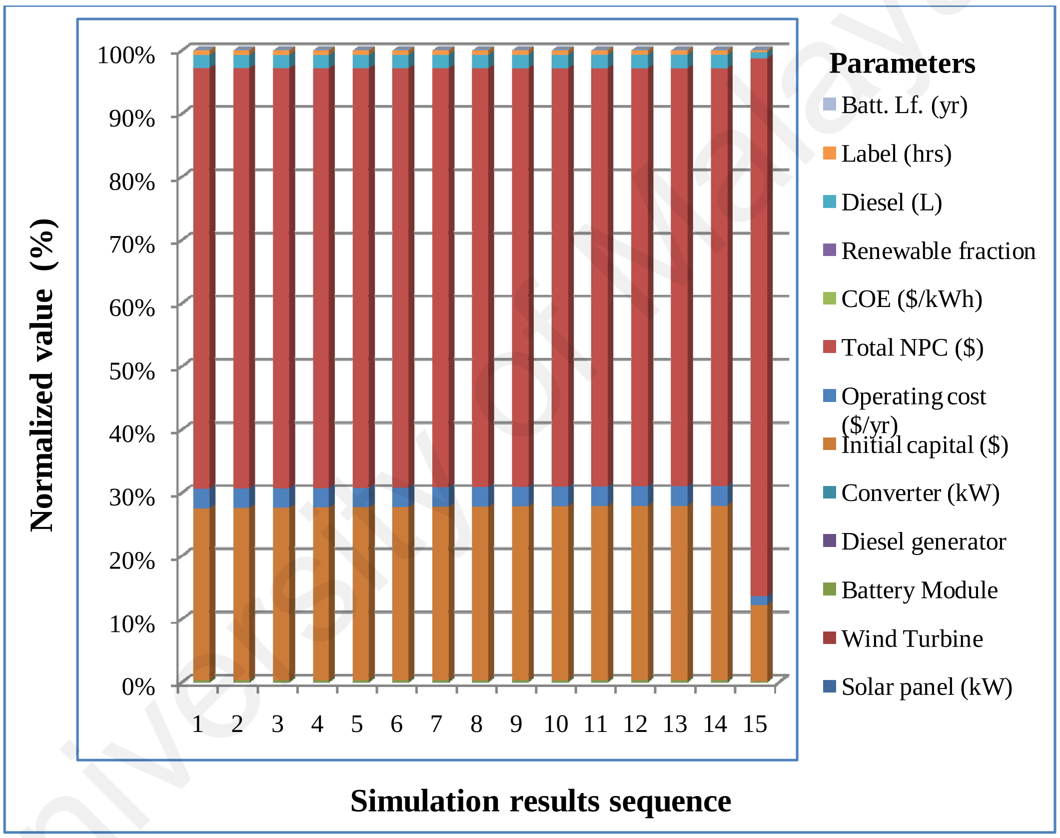


Figure 4.7: Simulation outcomes in considering an off-grid hybrid PV-diesel-wind-battery energy model with.

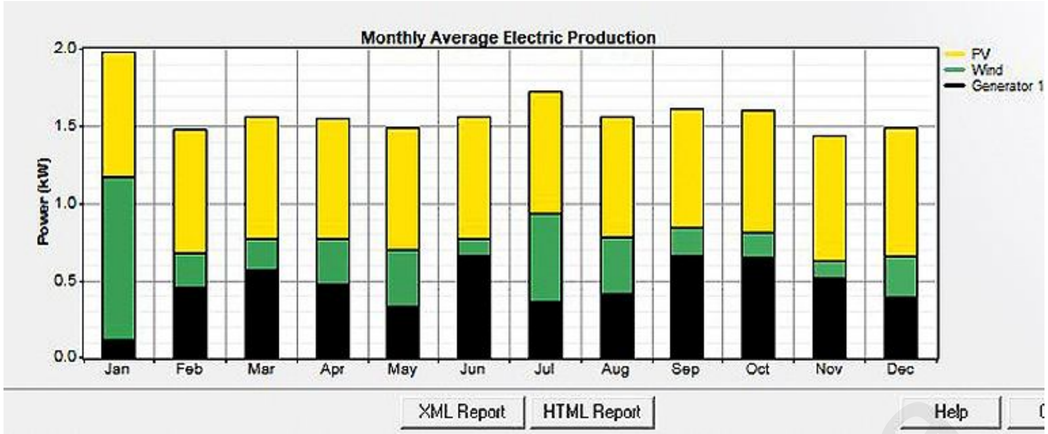


Figure 4.8: Energy generated with practicability from the off-grid hybrid PV-diesel-wind-battery system.

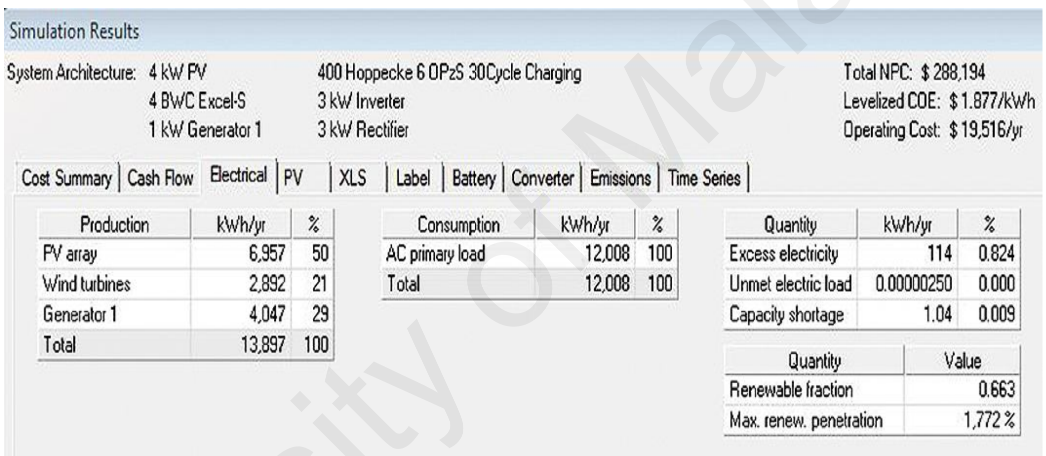


Figure 4.9: Simulation results with system architecture, NPC, COE, operating cost, electrical energy produced by wind turbine, PV, and diesel generator system, unmet load, excess electricity, renewable fraction and capacity shortage.

4.4. Analytic Results and Analysis

The energy generation from a solar panel depends on various parameters such as performance ratio, annual solar irradiation, solar panel yield and solar panel area. The energy generation from a wind turbine depends on various parameters such as average wind speed, power co-efficient, swept area and air density (Skoplaki & Palyvos, 2009).

Figure 4.10 shows the energy generation for KLIA Sepang station. The performance analysis of a solar-wind coupled hybrid energy system depends on various parameters such as the horizontal solar irradiation, average wind speed, fuel price, price of battery module, price of converter, price of photovoltaic cell, price of wind turbines, price of various controller and etc (Delucchi & Jacobson, 2011). The x axis of the figure 4.10 shows the parameters such as power(P), energy(E), performance ratio(PR), annual solar irradiation(H), solar panel yield(r) and solar panel area(A). The y axis of the figure 4.10 shows the normalized for each parameters.

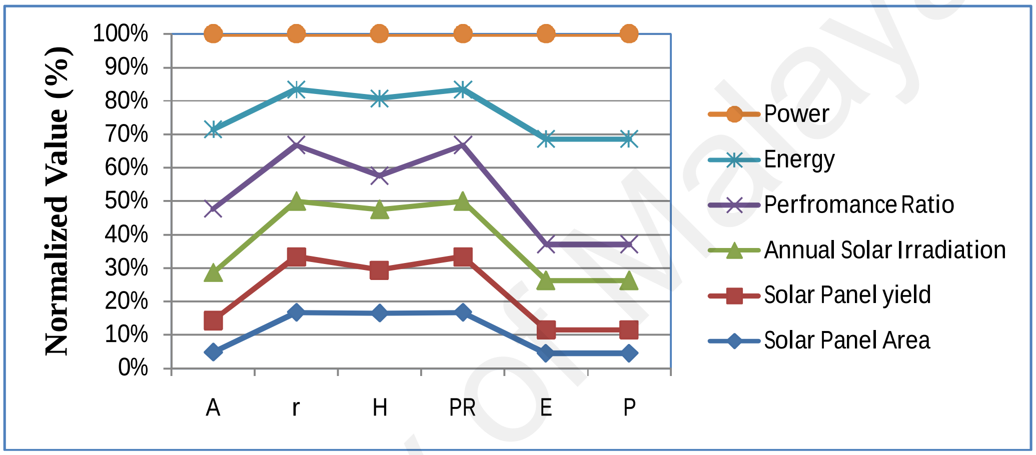


Figure 4.10: Energy and power generation for a specific area according to the meteorological data.

4.5 Power Generation from Wind Turbines for Different Areas of Malaysia:

The power calculation of the Cameron Highland for a specific community depends on the meteorological condition of that area. The meteorological data and the other parameters are inter-related with each other. There is a huge amount of wind resource available in Cameron Highland area (Simard et al., 2009). Figure 4.11 shows the power generation from the wind turbine according to the average wind speed for a specific community of Cameron Highland. Cameron Highland is a very suitable spot for the tourist. The eco-tourism management should be very strong on that area. To make a proper eco-tourism management the power supply of that area should be consistent and uninterrupted (Dalton, Lockington, & Baldock, 2008). The x axis of the figure 4.11

shows the number of months for the power generation with the other parameters. The y axis of the figure 4.11 shows the normalized value of the wind speed, power co-efficient, swept area, air density and power.

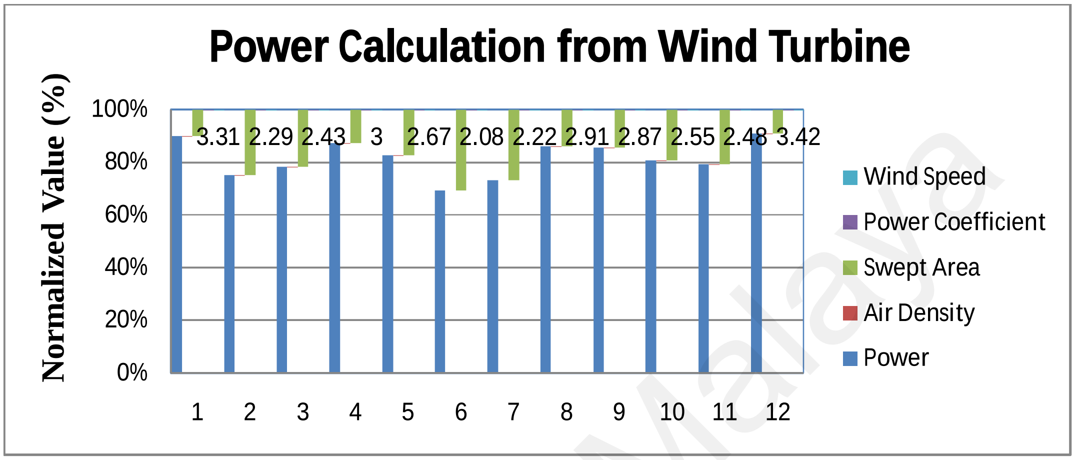


Figure 4.11: Power calculation from wind turbine for Cameron Highland.

To ensure a proper and uninterrupted power only dependency over the national grid is an unwise thing. So, to ensure the power supply uninterrupted and properly nurtured the more options like renewable energy resources should be utilized properly and effectively. As Cameron highland consists of huge amount of wind energy, the power generation technology should be different and alternate (Kadir, Yin, Sulaiman, Chen, & El-Harbawi, 2013).

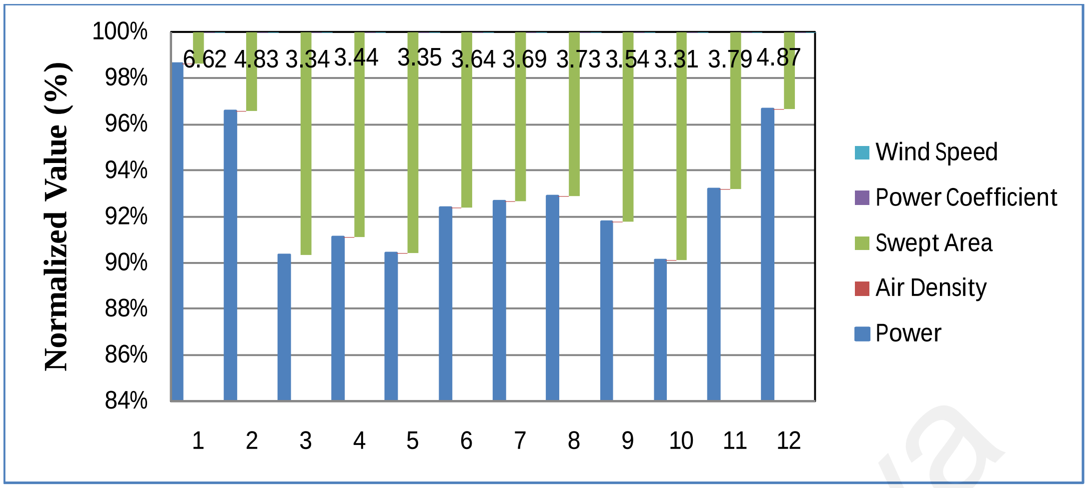


Figure 4.12: Power calculation from wind turbine for KLIA Sepang station.

In the KLIA Sepang area the average wind speed is very efficient to produce sufficient electricity for the decentralized people. Figure 4.12 shows the power generation from the wind turbine for the KLIA Sepang station (Roberts, 2012). The annual average wind speed for KLIA Sepang station is 2.044 m/s. The x axis of the figure 4.12 shows the number of months for the power generation with the other parameters. The y axis of the figure 4.12 shows the normalized value of the wind speed, power co-efficient, swept area, air density and power. The lowest average wind speed is 1.66 m/s in the month of November. For KLIA Sepang station there is no significant change in the wind speed variations. Therefore, the power generation might be very similar throughout the year and the load demand can be full filled without any interruption (Wadi Abbas Al-Fatlawi, Rahim, Saidur, & Ward, 2015).

The diurnal factor is very important for the power generation from the wind turbines. At the current technology, some horizontal axis wind turbine can generate electricity for KLIA Sepang area. The rated wind speed and Weibull value are very much suitable for the power generation in KLIA Sepang area (Zaharim et al., 2008).

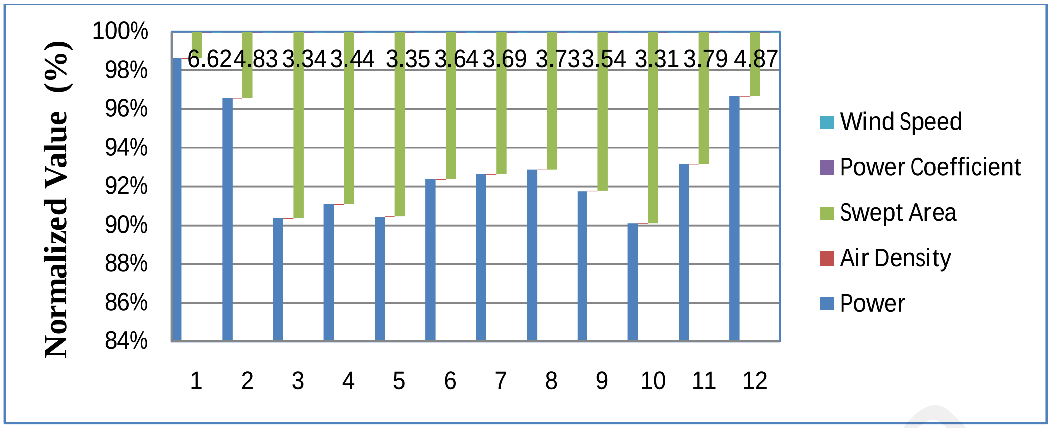


Figure 4.13: Power calculation from wind turbine for Mersing Town.

In Mersing there is a very strong blow of wind is available and very suitable for wind turbines. Figure 4.13 shows the power generation from wind turbine according to the meteorological data of that area. According to the monthly average wind speed it can be identified that the variation of the wind speed in Mersing town is not very high. Due to less variation of the wind speed, the power generation by a wind turbine is very predictable. The x axis of the figure 4.13 shows the number of months for the power generation with the other parameters. The y axis of the figure 4.13 shows the normalized value of the wind speed, power co-efficient, swept area, air density and power.

For a specific area the load demand is very much apposite and might be feasible in accordance with the power generation (Islam, Rahim, Solangi, & Saidur, 2012). Figure 4.13 shows the average monthly wind speed and power generation for Mersing town. The power generation can be varies time to time according to the change of the climate. The average wind speed can be varies time to time and hour to hour. According to the change of wind speed the mechanism of wind turbine must be changed and it will affect on power generation (Sfetsos, 2002).

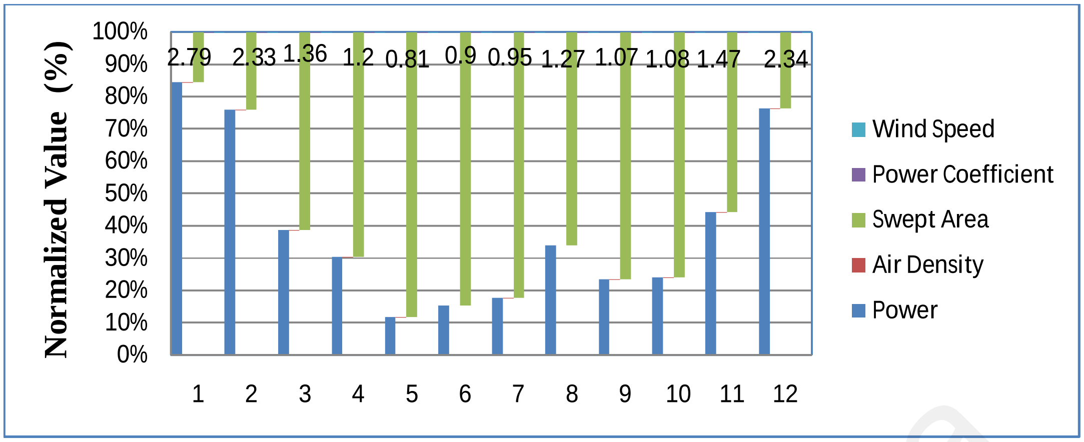


Figure 4.14: Power calculation from wind turbine for Malacca.

Figure 4.14 shows the power generation from wind turbine according the wind resource of Mersing town. By considering the power density values of different months, it is clearly indicated that January 2009 at Malacca devotes the greatest values with 227.1 W/m^2. The results of calculated mean wind speeds, standard deviation and wind power density revealed some problems about the wind power densities (A Greening, Greene, & Difiglio, 2000; Augeri, 2005). The x axis of the figure 4.14 shows the number of months for the power generation with the other parameters. The y axis of the figure 4.14 shows the normalized value of the wind speed, power co-efficient, swept area, air density and power.

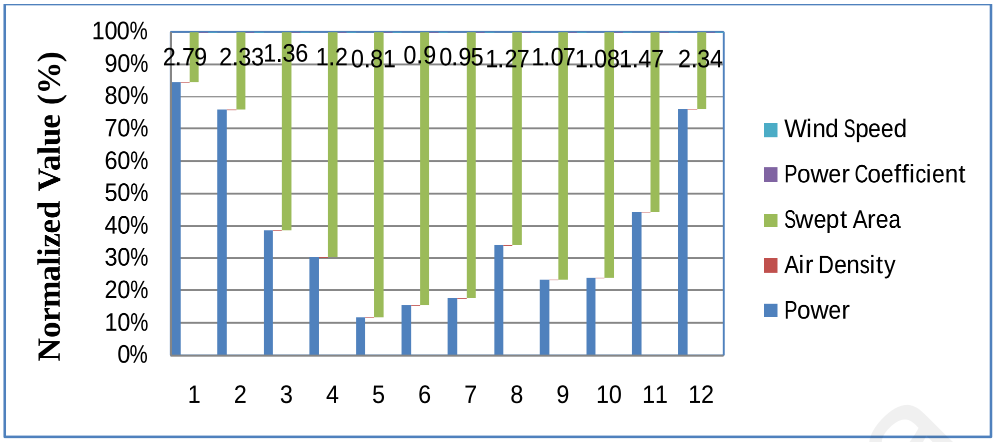


Figure 4.15: Power calculation from wind turbine for Chuping.

Figure 4.15 shows the power generation from the wind turbine according to the average wind speeds of Chuping. Chuping is a small town in Perlis is situated on the northeast of Kangar. The average wind speed of chuping area during the monsoon is very high. The air density is almost same for each and every area (Teng, 2006). To estimate the wind energy potentials, the difference may always be ignored for the wind turbines where little or even or energy output under which low wind speeds are provided. The x axis of the figure 4.15 shows the number of months for the power generation with the other parameters. The y axis of the figure 4.15 shows the normalized value of the wind speed, power co-efficient, swept area, air density and power.

4.6 Representation of Various Energy Systems according to the COE and NPC:

Table 4.3 shows the complete representation of the three representative energy systems with the energy generation and distribution in different locality and applicable for the different territories of Malaysia. The representation of energy systems based on the feasibility calculation with CO_2 emission rate analysis and also by the COE and NPC.

Table 4.3: Energy generation and distribution from different types of energy system according to the load demand, COE and NPC.

Type of Energy System	Energy Combination	Net Present Cost (USD)	Cost of Energy	Load Demand
PV-Diesel Hybrid Energy System	5 kW PV module, a diesel generation with a divisional power of 5 kW (utilizing 5 kW) and 100 storage batteries in cementation to 3 kW converters and rectifiers	158,206	0.895/kWh	38 kWh/d with 5 kW peak.
Wind-Diesel Hybrid Energy System	15 generic wind turbines each of 10 kW dc together with a 4 kW diesel generator and 2 numbers of batteries of which each has a nominal voltage of 4, capacity of 1900 Ah and 7.6 kWh	77,019	0.199/kWh	85 kWh/d with 8.7 kW peak.
Solar-Wind Hybrid Energy System	5 kW PV module, a diesel generator with a divisional power of 5 kW (utilizing 5 kW) and 100 storage batteries in cementation to 3 kW converters and rectifiers.	288,194	1.877/kWh	33 kWh/d with 3.9 kW peak.

From the distribution of power generation of various types of energy system calculated by optimization, three different types of representative energy systems have been developed for the different territories of Malaysia. In some places of Malaysia solar energy is feasible, in some places of Malaysia wind energy is feasible and in some places of Malaysia solar and wind both are feasible. So, the developed energy systems will be applicable for the different areas according to the climate, geographical position and meteorological condition.

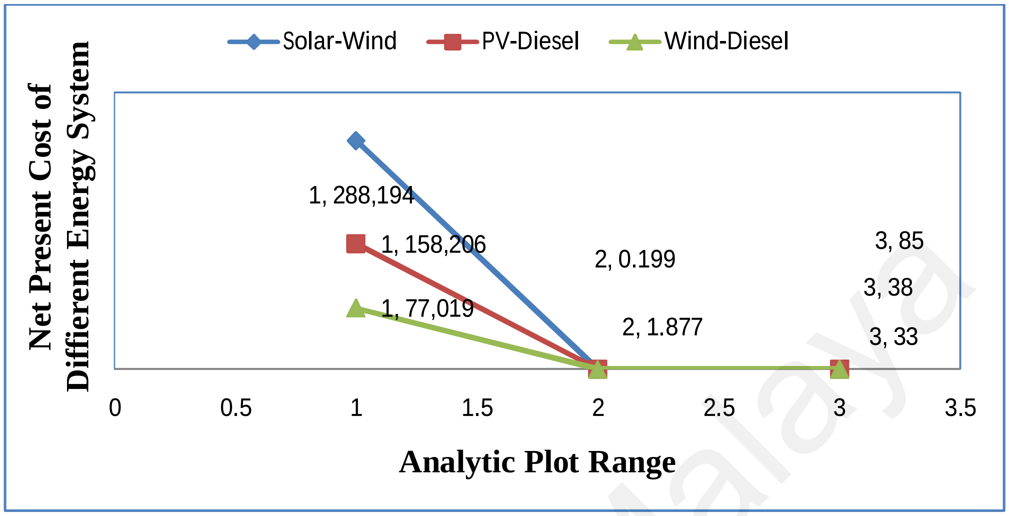


Figure 4.16: Energy generation and distribution from different energy system.

From the Figure 4.16 it can be seen that the observation and justification of three different power systems is very clear and easily noticeable. The x axis of the figure 4.16 shows the energy analytic plot range of COE, NPC and the unmet load. The y axis of the figure 4.16 shows the NPC, COE and the unmet load values in the graph. From the observation it is can be said that the three different energy systems are economically feasible and suitable for different territories of Malaysia. The justification parameters are the NPC, COE and unmet load.

4.7 Summary:

In this section the results have been represented in two ways such as the simulation and optimization results and another one is the analytic results with discussion. In the last part of this section relates to the observation and justification of three different energy systems with the simulation results and CO_2 emissions. The wind-diesel energy system has been proved as the best energy system due to less NPC, COE and less CO_2 emission.

There are three different energy systems have represented technically and briefly in this chapter. The simulation areas are also different and it has been discussed effectively and elaborately. The problems arises due to the increasing demand of electricity for the advancement of the world's economy can be solved by using renewable energy resources and proper utilization of electrical power.

Not only the decentralized areas but also the remote and costal also can be a very effective event or subject for these kinds of experiments and demonstration. Only demonstration cannot be the solution of some several problems but also it needs to be practically implemented on those particular areas.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

In this section the final remarks are drawn. The chapter concludes the findings of the work with a brief summarization and provides some recommendation concerning the hybrid renewable energy system.

5.1 Conclusion

This study simulates a PV-wind-diesel-battery hybrid energy system in KLIA Sepang Station of Malaysia, a PV-diesel-battery hybrid energy system in the southern region of Malaysia and a wind-diesel hybrid energy system in Cameron highland of Malaysia. Then, by considering manufacturing cost and efficiency three different optimized hybrid energy systems have been analyzed.

From the first objective it can be observed that, with the consideration of the demand of huge amount of load demand a complete hybrid PV-Diesel-Battery renewable energy model has been developed. The load demand has been considered 38 kwh/d for the southern region of Malaysia which is solar energy enriched area. This hybrid energy system will be applicable especially for decentralized and remote areas. Since, diesel based power generation system completely depends on fossil fuel which is too expensive, therefore, only diesel generator cannot be feasible to supply the electrical power to the remote areas. Therefore, the hybrid renewable energy system with some sustainable resource based technology like PV can be a good option to supply the required energy with economically feasible conditions. The result represents that the COE of the simulated system is USD 0.895/kWh and the NPC of the optimized system is USD 158,206

From the second objective it is observed that by considering the demand of huge amount of load demand a complete hybrid wind-diesel-battery energy model has been developed. The load demand has been considered 85 kwh/d for the Cameron Highlands of Malaysia as it is wind energy enriched area. This hybrid energy system will be applicable for decentralized and remote areas where grid connection is not available. The result represents that the COE of the simulated system is USD 0.199/kWh and the NPC of the optimized system is USD 77,019. The total sensitivity analysis, optimization and simulation process has been conducted through HOMER renewable energy software. As the generator can diminish the problem would bear sienna wind turbines. This system can give improved performance in comparison with the other systems and also represented the way of reducing the cost of power and energy generation from the in general hybrid energy systems.

From the third objective it is observed that the simulation reveals that the selected location has a huge potentiality of solar radiation about 2.23–4.825 kWh/ m^2/day which exhibits a promising feasibility to develop a solar-wind-diesel generator-battery hybrid energy system. The load demand has been considered 33 kwh/d for the KLIA Sepang station of Malaysia as it is solar energy and wind energy both enriched area. This analysis also represents the renewable energy setup for the KLIA Sepang station of Malaysia. The investigation of the best results represents the COE might be USD 1.877/kWh and the NPC of the optimized system is USD 288,194. The total sensitivity analysis, optimization and simulation process has been conducted through HOMER renewable energy software.

Utilizing these energy systems for electricity generation in comparison with the other conventional power sources would decrease the operating hours and consequently the diesel consumption of the generators and would lead to reduction in emissions of GHG. As the generator can diminish the problem would bear in PV panel and wind turbines. These systems can give improved performance in comparison with the other systems and also has been tried to reduce the cost of power generation from the in general hybrid energy systems. From this overall study and analysis it can be said that all the three energy systems will be applicable for the different territory of Malaysia according to the meteorological and other conditions. In the near future, it can be tried to introduce some more convenient renewable energy model and proper control system of the hybrid energy system for the different area of the world.

5.2 Future Prospects:

Some recommendations can be made for the acceleration of the advancement and implementation of the solar-wind hybrid renewable energy system with generator support and battery back-up for residential as well as industrial application.

I. The gasoline generator can be attached or coupled with the solar-wind hybrid energy system for the acceleration of the performance of the energy system and at the same time the fuel cost can be reduced by using gasoline.

II. The operation and maintenance cost can be reduced by using long lasting equipments.

III. The fuzzy logic controller can be introduced to control the entire system with a feasible and optimized way.

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1. **S.K.A. Shezan**, S. Julai, , M.A.Kibria, A. Hossain, R. Saidur, WT Chong, R.K. Akikur. Performance Analysis of an off-grid PV-Wind-Diesel-Battery Hybrid Energy System: Possibilities in Malaysia, *Cleaner Production*, 2016 (Published).
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International Conference Attended and SCOPUS indexing Publications:

1. **S.K.A. Shezan,** R. Saidur, A. Hossain, WT. Chong, M.A. Kibria, Performance Analysis of Solar-Wind-Diesel-Battery Hybrid Energy System for KLIA Sepang Station of Malaysia, *7th International Conference on Cooling & Heating Technologies (ICCHT 2014),* 4th – 6th November 2014, Subang Jaya, Selangor, Malaysia.

2. **S.K. A. Shezan,** A. Hossain, R. Saidur, WT. Chong, Performance Investigation of PV-Wind-Diesel-Battery Hybrid Energy System for Malaysian climate, *Advanced Materials Conference*(AMC2014) November 24-26, 2014, Langkawi, Malaysia.