Design and Optimization of Hybrid (Wind/Solar) System for Domestic Consumers

By

Irfan Khan Niazi

NUST201260730MCES64112F

Session 2012-14

Supervised by

Dr. Muhammad Bilal Khan

A Thesis Submitted to the Centre for Energy Systems in partial fulfillment of the requirements for the degree of

MASTERS of SCIENCE

In

ENERGY SYSTEMS ENGINEERING

Center for Energy Systems (CES)

National University of Sciences and Technology (NUST)

H-12, Islamabad 44000, Pakistan

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Dedication

To my all respectable teachers who taught me even single word in my life and who support me in my education career, to all my friends who help me in my thesis and my educational life. To my all educational institutes who made me capable to get knowledge.

Acknowledgement

All prays to ALLAH Almighty and HIS beloved Prophet MUHAMMAD (PBUH), HE gave me courage and patience to complete this thesis. No words are sufficient to express my gratitude to my loving parents for their exemplary patience, understanding and co-operation during my Thesis. I express my most sincere gratitude to my advisors, Dr. Muhammad Bilal Khan for their guidance, patience, understanding and encouragement throughout my work. I also like to thank the members of my committee, Dr. Adeel Waqas, Mr. Rashid Wazir, and Mr. Waqas Cheema. Special thanks to Engr. Rashid Wazir, Dr. Adeel Waqas and Dr. Zuhair S khan and all faculty members. Their advice and kindness were much helping during my stay in the Centre of Energy System (CES) NUST. Without the help of staff of Centre for Energy System department, I would never be able to complete this project.

I hope that you will find this effort better than ever before.

Thank you again to all of you**.**

Abstract

This project aims to focus on technical and economical analysis of small scale wind/solar hybrid system for domestic consumers. The analysis is carried out on HOMER II simulation software. HOMER is developed by National Renewable Energy Laboratory (NREL) of United States of America (USA). Pakistan is one of those developing countries which are encountered with severe energy crises. The purpose of this project is to introduce a technically and economically feasible system to meet the domestic consumer's demand, as well as contribute to the central grid. Different systems are analyzed to obtain the most reliable and feasible system for the domestic consumers. Simulation was carried out to find an economically and technically feasible system. Sensitivity analysis was carried out with different hub heights of wind turbine, 80 % PV De-rating factor, PV life of 25 years, Different Wind speed, and Different PV slope angel. Sites selections for analysis are based on resource availability. Comparison was made with higher wind speed and lower solar radiation area with higher solar radiation and lower wind speed area. Change in hub height drastically affected energy production and economic prospect as the main factors of the system. Implementing such type of small hybrid systems on domestic level can be truly helpful to overcome energy shortage. Higher wind speed areas are technically more feasible due to higher operating hours of wind but economically slightly expensive due to wind turbines initial cost and its O&M cost. Furthermore some other variables such as capacity shortage, alternative small fraction, extra electrical power, COE, diesel powered energy usage had been additionally thought to what is specialized capacity in order to pick a system which is suitable within techno-economic elements. Cost of Energy for solar/wind/grid hybrid system is most suitable at all locations due to net metering process. COE at D.G.Khan is $ 0.079 while off-grid has $ 0.133, on-grid hybrid system at Kakul has $ 0.060 COE and off-grid has $ 0.121. Two methods had been utilized because evaluation of comparison to pick reliable energy system through the preferred choices providing merit on the basis of the measuring instrument (renewable fraction as well as levelized cost of energy).

Keywords: Net Present Cost (NPC), Cost of Energy (COE), Renewable Fraction, Capacity Factor, Renewable Penetration.

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- *Irfan Khan Niazi, Dr. Muhammad Bilal Khan, Rashid Wazir "Techno-Economic Analysis of Hybrid System (PV/Wind/Diesel Generator/Grid) for Domestic Consumers in Balochistan (Nokkundi & Ormara)" World Journal of Engineering (Paper Published).

*Attached at Annexure 1

List of Abbreviations

COE ……. Cost of Energy

NPC …… Net Present Cost

DOD ……. Depth of Discharge [%]

$(DOD)_{max}$ …… Maximum Depth of Discharge [%]

CC ……. Cycle Charging

CF ……. Capacity Factor [%]

kW …… Kilowatt

kWh ……. Kilowatt Hour

NREL ……... National Renewable Energy Laboratory

HOMER ……... Hybrid Optimization Model for Electric Renewable

NOCT …… Nominal Operating Cell Temperature

RES ……..... Renewable Energy System

HS ……. Hybrid System

η ……..... Efficiency [%]

β …… Slope [º]

γ …… Azimuth [º]

λ …….. Tip Speed Ratio

V_{OC} …….. Open Circuit Voltage

RF ……. Renewable Fraction

PV ……. Photovoltaic

WT …… Wind Turbine

Chapter 1
Introduction

1.1. Overview

Global warming is a serious threat to our environment. Increase in GHG (Green House Gases) emission is a main factor in rising global warming. This current situation stimulates the scientist's interest about reducing GHG emission from different sources e.g. Industrial, Agriculture, Automotive etc. One these industrial sources of GHG are electricity production. Researchers are taking keen interest to reduce GHG emission from different conventional electricity production methods to control global warming. Moreover depleting fossil fuels resources and increasing extraction cost of these fossil fuels raise the security concern about energy resources. The energy security concern diverts the researchers and scientist's attention towards sustainable energy resources to replace conventional fossil fuels, clean energies like Solar and Wind energies provide sustainable and environmental friendly resources of power generation.

In hybrid renewable systems different technologies are used for energy conversion which may include: Photovoltaic (PV), Micro Hydro, Wind Turbine, Biomass, Fuel cell etc. "Moreover, grid scale energy storage technologies are improving rapidly, and can soon boost the integral part of any HPS to address the intermittency problem and boost the integration of RES powered Distributed Generation (DG) in Power System" [1, 2].

Wind and solar both complement each other particularly the daily and seasonal profile of the wind and solar shows the availability difference of both. In some areas wind blows at night when there is no sunshine or solar radiations available. Different renewable sources integration in a single power system with energy storage or any other backup can be a suitable solution for power production. This complementary nature of solar and wind improve the hybrid renewable system more reliable and cost effective. This type of integrated system is usually referred to as 'Hybrid Power System (HPS)'[3].

1.2. Motivation

Pakistan is currently facing worst energy crises in its history. Growing demand of electricity and frequently electricity outages are causing public unrest and slowing down its economy pace. Conventional methods of power production from fossil fuels are producing green house gases from ejective pollution. Currently Photovoltaic PV stand alone systems are installed on domestic level but there is no major work done on the hybrid (wind/solar) on domestic level. Pakistan has a very good potential of wind. "As per the collected data, the coastal belt of Pakistan is blessed with a God gifted wind corridor that is 60 km wide (Gharo ~ Kati Bandar) and 180 km long (up to Hyderabad). This corridor has the exploitable potential of 50,000 MW of electricity generation through wind energy"[4]. Hybrid renewable system increases the reliability as compared to single source systems. Higher hours of operation for wind turbine make hybrid system more reliable. Size and component of the system have to be selected carefully for optimum cost and energy production of the system. Education and Health are some mandatory services for any community to come out from poverty and development. Uninterrupted supply of energy to these services is necessary for their better service.

1.3. Why Wind and Solar

Solar and Wind energies are most possible clean, low cost and abundant renewable resources in Pakistan. These two resources reduce dependency on fossil fuels which we need to import. At the same time these are an optimal solution to remote locations where utility company cannot reach [5].

In contrast to other approaches associated with electricity production wherever fuel is actually delivered to some running power plant, wind power creates electrical power in the supply of local resource that is totally free. Wind energy is really an indigenous energy that will not have to be extracted or even moved, using too costly expenses from extensive power costs [6].

Pakistan's most areas lie in the sunny belt on the earth. Daily sunshine hours are about 6 to 8.5 hours per day. These radiations contain lot of energy; more than 90 % solar radiations are available all over the Pakistan expect cloudy days. In Pakistan annual average solar radiations received on the ground is about 4.7 to 6.2 kWh/m² while the total average is 5.45 kWh/m² [7]. Now even the lower side of solar radiation is much higher than the radiations in European countries. In spite of this

small radiation amount they utilize maximum of their available radiations for residential and industrial use.

Potential of wind energy which is officially identified for Sindh and Balochistan is about 50,000 MW and for Punjab it is about 10,000 MW [7].

1.4. Objectives

The main aim and objectives of the thesis is to analyze and develop a different design strategy to find optimum, cost effective and technically feasible system for different locations. Hybrid (solar/wind) system analysis that can supply optimum power and fulfill the energy demand either in case of grid connected power system or off grid power system.

Following study and analysis are taken into account for analysis of the hybrid system for optimum results.

- Study the resource availability for different sites and locations.
- Study of domestic load profile.
- Wind Turbine selection
- Inverter design study
- Analysis of Hybrid System (solar/wind) reliability for domestic consumers.
- Comparison of different hybrid system on the location
- Economical and technical analysis of the system

1.5. Thesis Organization

This thesis is organized in such a way that wind and solar potential of Pakistan is analyzed for different areas. Solar power systems at domestic level as well as at industrial level are already adapted in Pakistan. Wind energy at domestic level was not remaining focus in this area. Wind and solar hybrid system for different areas are analyzed and compared with single source systems for their reliability and economic analysis. Detailed analysis and performance of each system are discussed in the thesis.

CHAPTER-2 (Literature Review)

Classification of Wind turbines, Tip Speed Ratio, Solar PV Systems, Tracking non tracking systems, H-Bridge system Design

CHAPTER-3 (METHADOLOGY)

Simulation, Optimization, Sensitivity Analysis of hybrid system, Domestic Load Calculation, Solar PV size and cost, Wind size and cost, Types of Hybrid System.

CHAPTER-4 (RESULT and DISCUSSION)

Selection Scenarios and System Optimization, Net Present Cost for different systems, COE of different systems, Design analysis and performance analysis for selected locations

CHAPTER-5 (Conclusion and Recommendations)

Conclusion of research work, Future recommendations for the hybrid (wind/solar) system

Summary

This chapter is about the introduction and the importance of solar and wind energy. Limited supply of natural resources diverts researcher's attention towards alternative energy resources. Increase in global warming from ejective pollution from conventional power production. Researchers are now focusing on renewable energy technologies; Wind turbine converts the kinetic energy of wind into electrical energy. Solar Photovoltaic PV is a technology which converts the sunlight energy into electrical energy. Hybrid (solar/wind) system increase the system reliability due to different operational hours of solar PV and wind. Operation hours of wind are higher than solar PV. There are different kinds of hybrid energy system PV/wind, PV/Wind/Diesel, Wind/Diesel, PV/Wind/Grid etc.

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Chapter 2

Literature Review

2.1. Review of Related Works

In order to assemble logical information with reference to potential of renewable energy resource of the country, hybrid (wind/solar) energy systems, remote areas electrification techniques applying mutual resources a thorough study of this all was required. There are lots of research efforts which are made for the implementation of renewable energy options. Different options are considered for the renewable resource potential and different hybrid system. Given bellow different researchers conducted analysis of different hybrid systems on different locations and for different countries; methodology used for these analysis were the simulation from HOMER.

In Cameron analysis was conducted for the stand alone electric production system for remote area. The basic requirement of the village is discussed in the paper. Basic requirement of the village was lightening, television, and radio. So the total requirement of energy for the village is from 0.2 to 1 kWh/day. Different hybrid systems were analyzed for the village requirement. Systems which were analyzed were (hydro/LPG generator/battery). (micro hydro/diesel generator/battery), (solar/LPG generator), (solar/diesel/battery). Simulation results show the different levelized cost of energy for different energy options. It was found that the 14 kW micro hydro generator, 36 kWh of battery storage and 15 kW LPG generator produce the energy at the rate of 0.296 €/kWh. In this analysis the second simulation shows that PV hybrid system which consist of 18 kW PV, 72 kWh of battery storage and 15 kW of LPG generator generates the energy at the cost of 0.576 €/kWh. The price of petrol and LPC price were 0.1 €/kWh and 0.7 €/kWh respectively. In this analysis micro hydro was the most optimal and cheapest system. So it was the best option for the southern part of the Cameroon. For the southern part of the country PV hybrid was the best option [1].

An analysis was carried out for the hybrid system which was designed for the power generation. Power generation was for the 100 domestic consumers, an elementary school and health clinic. This hybrid system was hybrid of wind and solar. Research

was carried out with the study of solar and wind potential of the site so either it is suitable for both resources or not. Different simulation results of the system shows that wind/PV/diesel generator/battery and converter configured system. So the levilized cost of energy for the system was 0.302 $/kWh and the total net present cost NPC of the system is about $ 103,914. So the diesel fuel consumed per annum was 1955 litter and its operating hours were 633 hours/year [2].

A study for feasibility report was conducted by [3] for standalone hybrid (wind/solar) energy system. It was designed to supply electricity to the remote areas of Ethiopia. The simulations presented in paper were for wind/PV/diesel and battery to provide electricity requirement for 200 domestic consumer's model population. In this paper the most optimized and cost efficient system was hybrid (diesel generator/battery) and converter. There was no contribution of renewable source fraction. There were also other most optimized cost effectual combinations of PV/diesel generator and converter, following load strategy was applied in case of dispatch strategy.

A research carried out in which off grid system (wind/diesel generator) for Saudi Arabia is analyzed. This system was designed for the supply of energy to the hot coastal areas of Dhahran. In this paper it is considered that wind energy will be harvested for the 100 domestic consumers. As wind is an blinking resource of energy thus from energy fluctuation preservation wind/diesel and battery are considered for the hybrid system [4].

A renewable hybrid energy system of PV/wind/micro-hydro with diesel generator backup was simulated for Sundargarh district of Orissa State, India. In case study two different simulations were carried out. First one was wind/solar PV and diesel generator and the second study case was combination of wind/PV/small hydro and diesel generator. In this analysis author suggest that wind power fluctuation and demand of household difference is the only hamper influencing the structure [5].

In a research design is described and implementation of proficient renewable energy power-driven energy scheme for domestic use in Khartoum, the Sudan's capital. The simulation action was performing for entity domestic consumers and for a collection of 10 to 25 domestic consumers. The power delivered from PV/battery arrangement for the particular users was costly than wind/PV for collection of domestic consumers. To list a number of the expenses, the COE for solo residence is about

49.5 SP/Wh, for 10 household it is about 25.8 SP/Wh and for 25 household is concerning 20.1SP/Wh [6].

A research of different system offered the viability learning of the wind turbines hybridizing to an accessible off grid diesel power plant in the northern countryside region of the Kingdom of Saudi Arabia. The research was principally to play down the operation costs of wind turbines by combining with diesel generator and for that reason to diminish environmental contamination. Sensitivity analysis was also completed by captivating sensitive parameter for example wind speed which can shape the power system all through its lifetime. The results of simulation shows that retrofitting wind turbine to the presented diesel generator was not reasonable for wind speeds not as much of 6m/s and petroleum price of $0.1/litter [7].

Research completed by researchers to judge the variety of off-grid electrification within the countryside communities within the Empire associated with Bhutan. The research had been happened within 4 various locations from the nation. In addition, the actual challenging masse had been regarded as with regard to illumination as well as conversation solutions just. The primary focus on from the papers had been optimization associated with hybrid energy producing models. PV/battery energy producing program is the least expensive technologies with regard to Muselina as well as Lunana, while the actual diesel/PV/battery hybrid program is the least expensive within Getena region. Execution associated with wind/battery program had been far better to use within Yangtse site [8].

Based on the papers analyzed that was dedicated to study regarding techno-economic facets of hybrid (wind as well as diesel powered generator) plans for any countryside local community within Algeria. The research had been carried out to include the wind generator in order to current diesel powered engine power techniques to lessen energy usage. The writer came to the conclusion with regard to wind pace beneath 5m/s the present diesel powered controlled flower along with 0.05-0.179 $/liter is actually inexpensive compared to hybrid program. The actual feasibility from the hybrid program guaranteed in wind pace associated with 5.48m/s, optimum yearly capability lack 0%, minimal alternative small fraction 0% as well as $0.162/liter energy cost [9].

In this paper investigated and looked into the actual use associated with hybrid alternative energy techniques because supply of main power with regard to cellular phone channels within the Democratic Republic associated with Congo. The research had been carried out for 3 place to place that are not really coupled to the main grid specifically; Kamina, Mbuji-Mayi as well as Kabinda. The actual feasible set-up choices carried out through the writers tend to be PV-wind generator, diesel powered power generator, genuine PHOTOVOLTAIC as well as genuine wind speed plans had been set up, furthermore techno-economic as well as environment impact had been analyzed. With regard to Kabinda the perfect hybrid program consists of two wind generators, 11kW photovoltaic, 82 battery 7.5kW converter, and also the NPC as well as COE tend to be $196, 975 and0.372 $/kWh correspondingly [10].

Different systems are analyzed for Urumqi, China. Different off grid systems are analyzed for optimum solution PV/wind/battery, PV/battery, Wind/battery. Atmosphere and climate of Urumqi is explained in the paper that has feasible and optimal solar radiation and wind speed. The actual hybrid wind/PV/battery system along with 5 kW associated with photovoltaic arrays (72% solar power penetration), 1 wind turbine generator of 2.5 kW (28% wind power penetration), 8 unit device battery all of 6.94 kWh as well as 5 kW sized energy conversion includes a good optimum energy program for your home; this decreases the entire net existing price (NPC) regarding 9% as well as 11% in contrast to PV/battery as well as wind/battery energy techniques, with a comparable result for your levelized cost of energy (COE) [11].

Even though authors explained over utilized HOMER being an optimization tool in order to actualize their own research, the actual hybrid systems setups had been analyzed utilizing various load demands and also the applications, area associated with research along with weather data’s these people utilized had been various. A few of the research had been used in places which have absolutely no electrical power whatsoever while others within places which have electrical power accessibility that was supplied utilizing diesel powered power generator. Each and every hybrid energy system needs to be developed in the new way for your site in line with the accessible weather data’s, amount of domestic consumers, support centers as well as customer load profile.

2.2. Classification of Wind Turbines

Technology of wind turbines entail generators which rely on sleek pull as well as raise causes. Wind speed devices involving sleek raise pressure may also be assembled in line with the set up from the axis associated with rotator, in to horizontally axis as well as vertical axis devices (Darrieus turbines). Horizontally axis wind turbines tend to be devices getting axis associated with rotator similar towards the wind circulation flow. The actual horizontally axis wind turbine generators are composed of tower and also the nacelle that contains the power generator, the actual gear-box and a rotor. Within small wind turbines the actual nacelle as well as one given to wind path using end vane; while, upon big wind turbines the actual nacelle as well as one aimed electrically in to or even out-of wind by using transmission through the yaw [12]. These kinds of machines possess lower cut-in pace plus they fairly possess greater energy percentage. Horizontally axis wind turbines tend to be classified in line with the putting on wind generator; solitary bladed, dual bladed, 3 bladed as well as multiple bladed. Figure 2.1 displays the actual distinction associated with wind turbine in various elements.

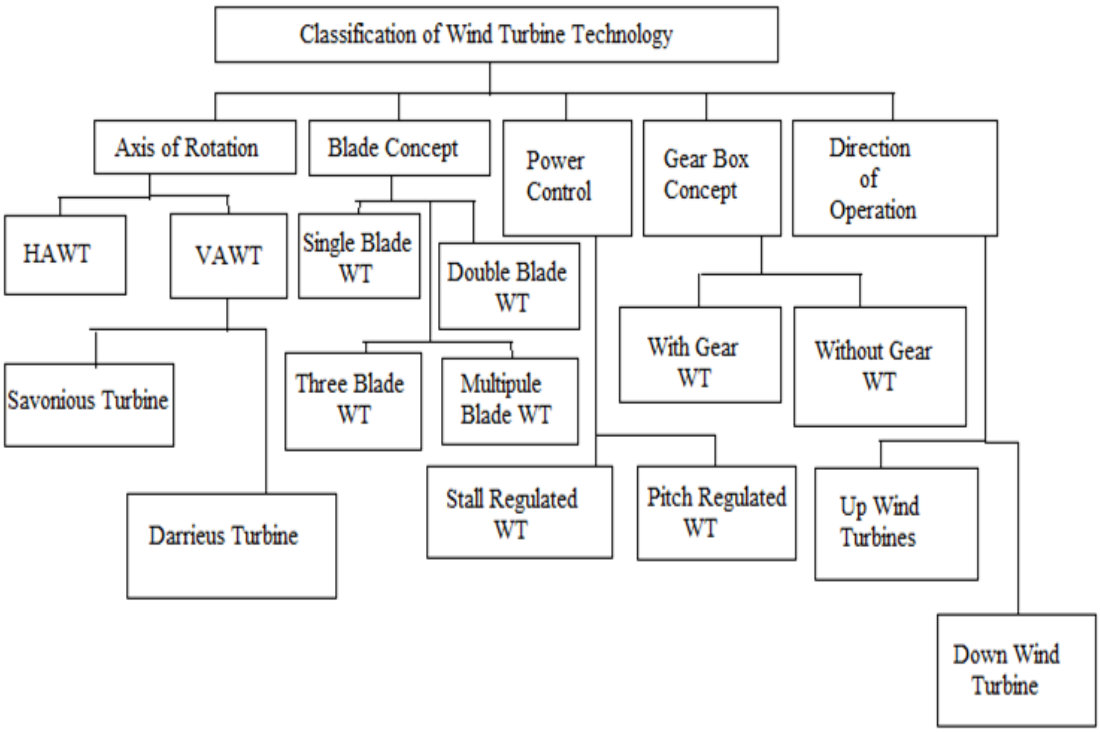

Fig. 2.1 Block Diagram of wind turbine classification [13]

The most famous types with regard to electrical power era would be the horizontally axis wind turbines along with 3 cutting blades [13]. The reason is the lower cut-in wind pace, higher energy percentage, simple styling as well as its balance. Wind turbines along with even amount of cutting blades possess balance issues simply because once the uppermost edge changes back again, the actual lowest one goes by in to the wind speed tone in front associated with system. Wind generators using more than twenty cutting blades tend to be used for pumping water and they are not really relevant with regard to electrical power era because of greater aerodynamics losses.

2.3. Tip Speed Ratio

There is indirect relation between Tip speed ratio (TSR) and wind turbine. It is the ratio of the blade tip speed to the wind speed, mathematical expression for the equation is given bellow [14].

$$\pi = \omega R/V \quad \ldots\ldots\ldots\ldots\ldots\ldots (2.1)$$

λ= Tip Speed Ratio

ω= Frequency of Distribution

R= Rotor Radius (m)

V= Wind Speed (m/s)

The larger the amount of cutting blades the low TSR proportion with good beginning torque. Wind turbines along with 2 or 3 cutting blades must pay back higher suggestion pace proportion. Horizontally axis wind turbines one can be upwind associated with system as well as downwind associated with system path. The actual raise pressure may be the rotating element of the actual horizontally axis wind turbine. Vertical axis wind generators tend to be devices getting axis associated with rotator vertical with respect towards the wind circulation. Darrieus turbine is actually vertical axis kind which features in addition to the wind speed circulation path. This kind of device gets wind energy through any kind of path, which means they cannot require any kind of yaw system to modify each time towards the wind speed circulation path. Additionally they you don't have presentation rules, the actual power generator is placed in walk out that makes the actual structure guaranteed

cheaper however the massive issue with this kind of kind of device, which is not really self-starter it requires a few system in order to rotate. Vertical axis wind turbines could be separated into 2 primary groups: the ones that utilize sleek pull in order to control energy through the speed of wind (cup anemometer) and the ones involving raise pressure. We are able to additional separate vertical axis wind turbines (VAWT) depending on airfoils in to directly cutting blades and the ones along with bent cutting blades [15].

2.4. Wind Energy Physics

The ability through the sunlight which involves the actual globe's environment gets to about 1.7*1014 kW [15]. This is actually the quantity of rays which warms the actual environment air flow and also the regarding heating system will get greater in the equator. The difference between pressure gradient through the unequal heating system from the earth’s environment (between the poles as well as equator) leads to wind power generation. Variance associated with blowing wind speed as well as path over a walk out is essential with regard to power transformation. The Wind generator will get the energy enter through the wind circulation that triggers to build up the switching pressure from the one. Wind power could be extracted through the aerodynamics utilizing raise and pull causes.

2.4.1. Lift Force

This works vertical with respect towards the wind circulation path which is developed because of uneven deference associated with stress over the surface area from the blade profile. Rise powered device need to be created and they are more effective compared to pull powered device. Generator cutting blades generates stress distinction within the best as well as bottom part areas from the edge that lead in to raise pressure appropriately the actual kinetic power from the wind is actually removed.

2.4.2. Drag Force

This idea serves parallel on the route involving wind flow movement. Savonius rotor one is amongst the windmills range in which employed drag force for you to twist typically the turbine one thereby to come up with electrical power. It truly is an easy task to production at any basic classes.

2.4.3. Swept Area of Rotor

It is the region developed once the turbines cutting blades tend to be revolving. It really is based on the actual turbine's edge size; furthermore, this rises using the improvement associated with blade size. As the size or diameter of the blade increases the ability outcome from the turbine also increases. The actual one taken region is actually indicated mathematically.

$$A = \pi D^2/4 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.2)$$

A= Area of Rotor (m^2)

D= Diameter of Rotor (m)

The swept area of vertical axis (VAWT) turbine can be calculated by given formula [16].

$$A = \frac{2}{3} w_r h_r \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.3)$$

Where

w_r = width of rotor (m)

h_r = height of rotor (m)

2.4.4. Cut-in Wind Speed

It is the speed of wind at which wind turbine starts producing electrical power. Normally it is about 3 to 5 m/s for different kind of wind turbines. Below this wind speed turbine will not generate any power.

2.4.5. Cut-out Wind Speed

It is the highest wind speed at which wind turbine stops producing any power. At this wind speed turbine should stop and protect it from any kind of damage. Average cut-out or cut-off wind speed is about 25 m/s [16].

2.4.6. Rated Wind Speed or Nominal Wind Speed

Wind pace where the utmost energy has been derived from. This particular wind pace is considered the most essential one that decides the ability competition. Ahead of this particular wind speed greater power generation is achievable along with unique manage towards the energy outcome to lessen the tension on blades. Power

Curve getting reduced ranked pace generate much more power since it will certainly generate much more power among cut-in as well as rated wind pace. For many turbines the actual rated wind speed is actually among 11.5 to 15 m/sec [16].

2.4.7. Survival Wind Speed

Any kind of wind generator device will never in a position to along with remain wind speed beyond the actual cut-out wind rate. It is far from actual power curve part, however essential is that you identify the design wind speed from the turbine. Survival wind speed range is from 50 m/s to 60 m/s [16].

2.5. Solar Photovoltaic PV

Photovoltaic PV strategy is probably the most a fact approach to transforming solar power straight into energy utilizing semiconductor cells. Modern day PV cells are mostly made of the semiconductor materials known as Silicon, that is accessible generously within the earth's crusting and it is free from degree of toxicity. Segments made from through mixing transparent Silicon cells are extremely long lasting, reliable; sound free as well as energy totally free equipment's to create electrical power. Solar power may be the solo resource in order to energy PHOTOVOLTAIC that is unlimited. PV cells are capable associated with changing 1/6 associated with photo voltaic sources in to electrical power. Photovoltaic techniques have time associated with relocating components and are generally environment pleasant. The actual duration of PHOTOVOLTAIC tissues may finish along with more than 3 decades. Photovoltaic techniques offer electrical power in order to remote locations where there is absolutely no entry to power main grid, therefore improves the life span associated with town. Within a photovoltaic cell you will find 2 heavy semiconductor levels, P-type (hole) as well as N-type coating (electron) that is divided to one another with a verse. The natural electrical area is actually created in the boundary that describes the actual path from the present circulation over the verse. To get electrical power from the photovoltaic, the daylight penetrate the glass include as well as antireflection covering. The actual product created in order to control solar power had been essentially through the traditional western, planed building central electrical power era as well as transferring electrical power through transmitting cables towards the customers. Power effectiveness associated with photo

voltaic PV is actually determined since the energy outcome from the photovoltaic divided by the incident rays towards the photo voltaic region [17].

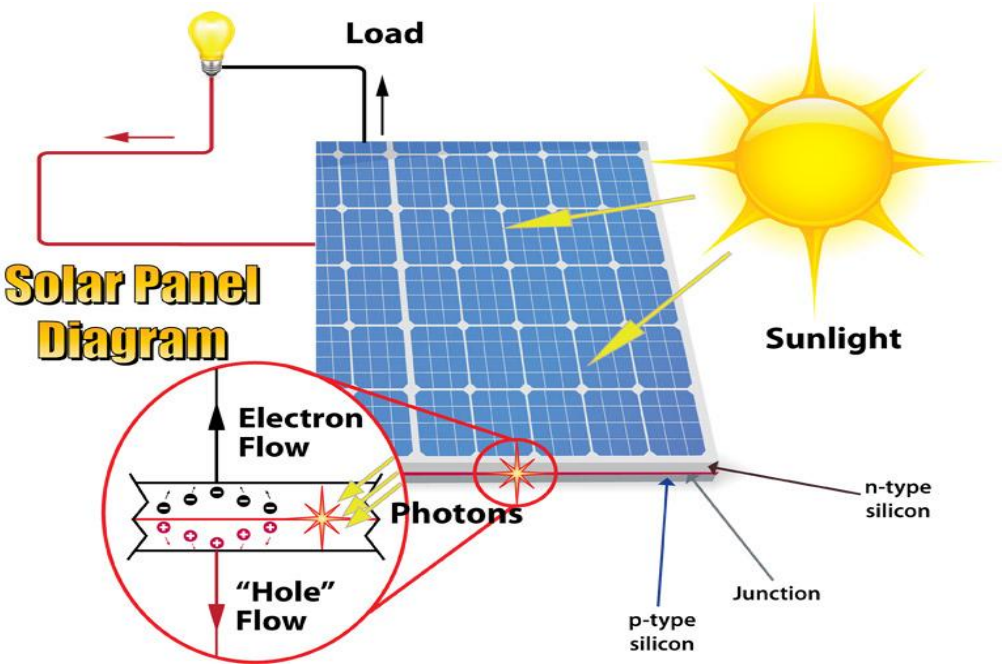

Figure 2.1. Solar PV Diagram and Function

2.6. Solar Cell Types

Various components are more comfortable with create photovoltaic cells, along with silicon extracted from fine sand has been the primary materials with regard to which is obtainable in the actual earth's crust. The actual electrical power output depends upon the dimensions of the actual photovoltaic cell, the actual transformation effectiveness, as well as radiation intensity on local region. Depending on the material that it really is created by different ways and also the ways of production, photovoltaic cells associated with silicon materials tend to be categorized in to the following.

2.6.1. Mono-crystalline Cells

They are produced from uncontaminated silicon solitary deposits, cut-off through ingots. Excellent darkish color as well as together almost all the edges is actually well trimmed; this really is one crystal clear distinction through the poly-crystalline sections. This kind of photovoltaic PV cell may be the effective one because it is made of one amazingly however the priciest as well. This features much better within locations where lower powers are needed. This particular technology may be

the very first era of most photovoltaic cells and it has high temperature proof capability. Drawback with this particular technology is it uses additional time in order to produce. The actual ways of creation associated with mono-crystalline silicon will be heating system higher super saturated state with silicon in to extremely over loaded condition, 2nd is placing seeds amazingly in to the smelted silicon. After that finally gradually tugging the actual seeds amazingly from the dissolved mono-crystalline using Czochralski system to obtain silicon ingot; furthermore, cutting the actual amazingly into items to help make the cells after that in order to segments as well as arrays. This particular technology is able to transform 1000W/m2 photo solar rays to 140W associated with electrical power within photovoltaic cell area associated with 1 m² [17].

2.6.2. PV Poly-crystalline Cell

It is produced from mixture of smaller sized amounts of silicon blocks. They may be regarded as probably the most popular cells these days. This kind of photovoltaic cells tend to be ineffective compared to solitary silicon cells because of the cause they are not really developed through solitary however they are mixture of numerous deposits. These cells gives much better than the actual mono-crystalline within somewhat shaded circumstances. This particular technologies is able to transform 1000 W/m² solar rays to 130 W associated with electrical power within photovoltaic cell area associated with 1m². Scale poly-crystalline -panel is actually bigger than mono-crystalline size to obtain the exact same wattage simply because mono-crystalline much more effective for each region compared to poly-crystalline. When evaluating both photovoltaic sections when it comes to dimension to obtain higher energy outcome, Single crystalline is within effectiveness [17].

2.6.3. Thin Film Solar Cells

These kinds of solar cells aren't produced from actual deposits instead the actual silicon is actually transferred upon stainless-steel, covers or even glass sheet to create the actual photo voltaic component. These kinds of photovoltaic cells tend to be much less effective compared to above two types of cell however the creation procedure expenses much less. The actual ineffectiveness implies that bigger sections of the kind needed generating exact same energy since the mono or even

polycrystalline cells. They have an efficiency of about 5% to 13% and the life-span about 15-20 years.

2.7. Solar Photovoltaic Installation Modes

Harvesting of solar energy depends on solar tracking system on which PV modules are mounted. These kinds of tracking systems are used to maximize the incident radiation on the solar module or panel. Normally most off the PV systems are non tracking or fix PV modules. Some of these tracking systems are given bellow.

2.7.1. Fixed or No Tracking

Photovoltaic modules are mounted at a fixed angle and azimuth in this type; furthermore it's most easy simplest and cost efficient method. Most preferable is to adjust the panel equal to equator (south in the northern hemisphere) generally the angle of slope is equivalent to the latitude of the particular location. A little increase or reduce from latitude may result better for the wintry weather and summer respectively.

2.7.2. Monthly Adjustment on Horizontal Axis

This kind of monitoring program or tracking system, this moves flat through eastern in order to the west path. The actual position associated with desire from the photovoltaic is actually modified within the starting of each 30 days so the ray attacks in 90º towards the photovoltaic screen whenever sunlight is actually over head.

2.7.3. Weekly Adjustment on Horizontal Axis

In this kind of installation program, the axis associated with rotation is actually through eastern in order to the west path. The actual photovoltaic position associated with monitoring (slope) is actually modified within the very first day of the 7 days, therefore photo voltaic rays reaches 90º in order to photovoltaic in midday from the related time. The actual photovoltaic module slanted in the direction of parallel to the ground.

2.7.4. Daly Adjustment on Horizontal Axis

Axis associated with rotation is all about the horizontally east-west path to the actual photo voltaic rays. The actual downward slope is actually modified every day so the

rays of the sun are in 90º levels in order to photovoltaic in midday from the related time.

2.7.5. Continuous Adjustment on Horizontal Axis

This is a kind of photovoltaic installation program by which downward slope associated with PV is actually modified constantly as well as rotation is all about the horizontally east-west axis. The actual downward slope is actually modified continuously to be able to reduce the actual angle of incident.

2.7.6. Continuous Adjustment on Vertical Axis

Photovoltaic axis associated with rotation is all about the straight according to floor surface area. The downward slope is actually set, however the azimuth is actually continuously modified to reduce the actual position associated with incident.

2.7.7. Two Axis Tracking System

The particular solar panels are usually rotating concerning the two to be able to east-west and also coming from north-south possessing a couple of hangs to be able to move. But it's the most high-priced approach.

2.8. H-Bridge Inverter Design

Inverter is usual electric device being used these days. A good inverter is definitely an electric device which changes household power (DC) in order to alternating electric current (AC)- the actual transformed AC could be any kind voltage as well frequency.

Solid-state inverters do not have relocating components and they are utilized in an array of systems, through little changing energy switches within computer systems, in order to large electrical power high-voltage household power systems which transport huge amount of energy. Inverters are generally utilized to provide AC energy through power resources for example solar power panels or even battery. The actual inverter works functionality opposing to that particular rectifier. Inverters possess many different types such as pure sine wave, square wave, and modified square wave inverters.

2.8.1. Specifications

For the inverter designs, following specifications were considered:

- Provided PWM 5V of 50% duty cycle.
- Power supply 24V, 10A

2.8.2. Design

Generally a good H-bridge is really a relatively easy signal, that contains 4 changing component, using the load in the middle, within an H-like settings: The actual changing components (Q1.. Q4) are often bi-polar or even FET diffusion, in certain high-voltage systems IGBTs. The actual diodes (D1-D4) these are known as capture diodes and they are generally of the Schottky kind. Generally all changing components could be switched on as well as off independently, although there are several apparent limitations. Although there is absolutely no assumptive limitation like this, the most predominant load combined with H-bridges are DC brushless motors or even bipolar stepper motors (steppers require 2 H-bridges for each motor).

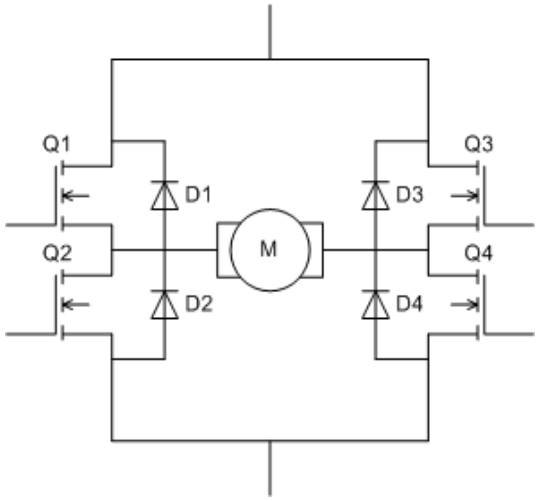

Figure 2.2: H-Bridge basic design [18]

2.8.3. Basic operation

The fundamental working setting of the H-bridge is rather easy: in case Q2 as well as Q3 tend to be switched on, the load linked between is going to be linked to ground, as the right lead is actually coupled to the power. Current begins flowing within the load in a single path. In case Q1 as well as Q4 tend to be switched on, the converse

could happen and also the current begins in order to flow within opposing path. The actual changes tend to be managed within a pulse width modulation style. The typical voltage observed through the load is going to be based on the actual proportion between ‘on’ as well as ‘off’ period from the pulse width modulation transmission.

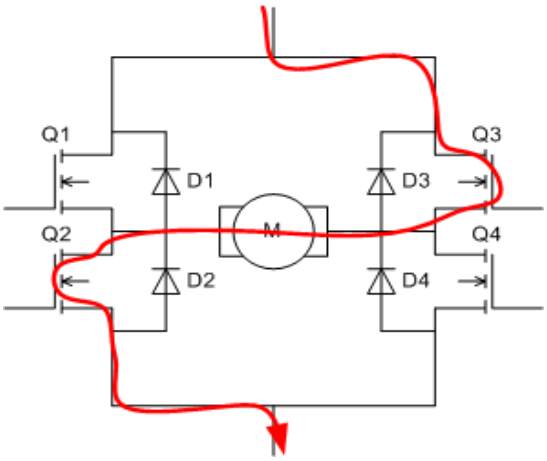

Figure 2.3: Current in forward direction [18]

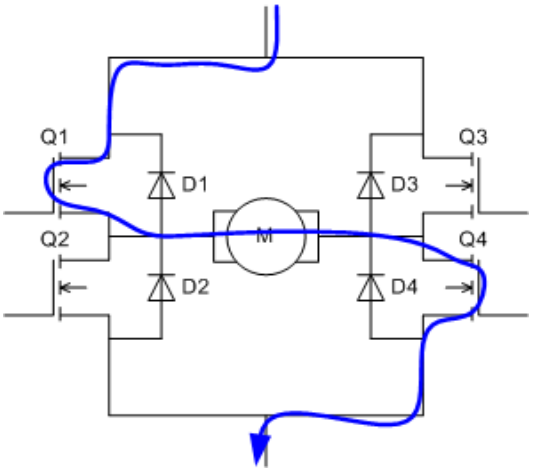

Figure 2.4: Current in Reverse Direction [18]

Typically, the important thing to choice to create to an H-bridge may be the choice of the actual switching components. There are lots of aspects to become regarded as; the most crucial types would be the followings.

- Operating current,
- The operating voltage
- The switching (PWM) frequency

For many instances the MOSFET switching component is an immense choice.

MOSFETs, whenever controlled because switches possess 2 states: off and on. Within the ‘on’ condition they have got pretty much act just like a little resistor. Their opposition is known as channel resistance, and it is denoted through rdson. Certainly the larger this particular worth, the larger the actual deficits are recorded the actual MOSFET. Whilst effectiveness is not really a big issue for many H-bridge inverter designs. Because the reduction within the MOSFET is actually transformed into temperature that should be dissipated, the low rdson may be the much better. An additional element to think about is the fact that rdson is actually temperature-dependent as well as raises along with temperatures The associated choice is to made that either ‘N’-channel or even ‘P’-channel MOSFETs are utilized. ‘N’ channel MOSFETs have a reduced rdson beliefs but are challenging manage within the high-side (Q1 as well as Q3). Generally the actual low-side changes are usually ‘N’-channel diffusion, as the high-side types tend to be at some point ‘N’ as well as at some point ‘P’ kind. When the kind of the actual switch is determined, the actual working present and also the accessible cooling system will certainly figure out the utmost permitted rdson. Like a guide, the larger the actual package is the greater temperature it may dissipate, so the greater current it may be utilized in for just about any provided rdson[18].

One essential function associated with MOSFET diffusion is they consist of a good intrinsic (unavoidable, built-in) diode among their own drain as well as resource. This particular diode may act as the capture diode within an H-bridge configuration, and many MOSFET datasheets identify the actual variables of the diode. It really is therefore feasible to make use of this particular built/in diode for the transistor and never offer exterior ones when the standards of the diode fulfill the design specifications. With regard to bipolar transistor there is absolutely no this kind of intrinsic diode therefore exterior diodes usually have to be provided [19].

2.8.4. Block Diagram

Right after getting the choice of elements, circuit is required to become drawn up like a system or even block diagram. Entire signal could be broken into various stages or even blocks. Information tends to be the following. Basic circuit of the inverter is designed in the LT spice software which is shown in the next section of this thesis. In the block diagram of the inverter design it is shown that short circuit is place right after the power supply to protect the inverter from any damage due to short circuit in

the power supply. When we consider about the current demonstrated within the figure, current becoming moving via s1 in order to electric motor and also to s4. Right now since the signal in the gate from the switching modifications its polarity as well as s1 becoming disabling as well as s3 becoming switching upon exact same time. In such a circumstance after that there might be because short circuit through s1 in order to s3 towards the ground and could result in a wide range of current in order to circulate momentarily. H Bridge as a whole is simple circuit to control and steer current through load and designing motor drives. Usually inverters available in the market are of the type of square wave or modified square wave as they can be implemented at low cost and are readily useful for the devices which do not require pure sine wave.

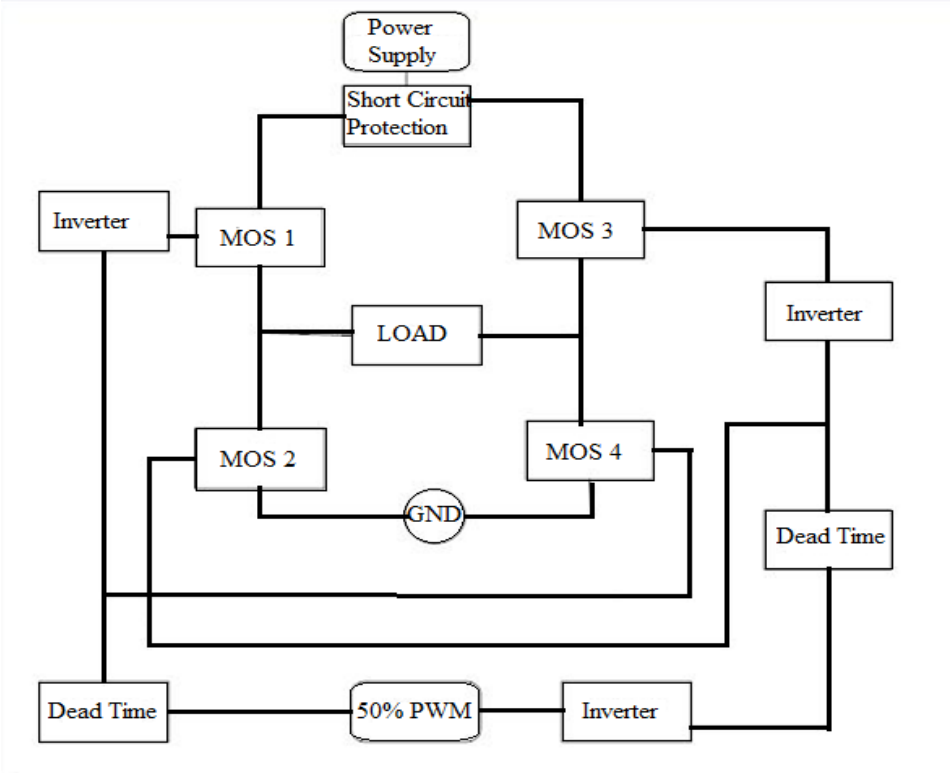

Figure 2.5: Inverter Block Diagram

There have an issue with the actual H-bridge that whenever it really is switching among the current circulation path generally there might be short circuit. When we consider about the current demonstrated within the figure, current becoming moving via s1 in order to electric motor and also to s4. Right now since the signal in the gate from the switching modifications its polarity as well as s1 becoming disabling as well as s3 becoming switching upon exact same time. In such a circumstance after that there might be because short circuit through s1 in order to s3 towards the ground

and could result in a wide range of current in order to circulate momentarily. One essential function associated with MOSFET diffusion is they consist of a good intrinsic (unavoidable, built-in) diode among their own drain as well as resource. This particular diode may act as the capture diode within an H-bridge configuration, and many MOSFET datasheets identify the actual variables of the diode. It really is therefore feasible to make use of this particular built/in diode for the transistor and never offer exterior ones when the standards of the diode fulfill the design specifications.

2.8.5. Dead Time

There have an issue with the actual H-bridge that whenever it really is switching among the current circulation path generally there might be short circuit. When we consider about the current demonstrated within the figure, current becoming moving via s1 in order to electric motor and also to s4. Right now since the signal in the gate from the switching modifications its polarity as well as s1 becoming disabling as well as s3 becoming switching upon exact same time. In such a circumstance after that there might be because short circuit through s1 in order to s3 towards the ground and could result in a wide range of current in order to circulate momentarily. This particular trend is needed to become conquer through placing hold off inside the switch associated with MOSFET's [19].

2.8.6. Circuit Diagram

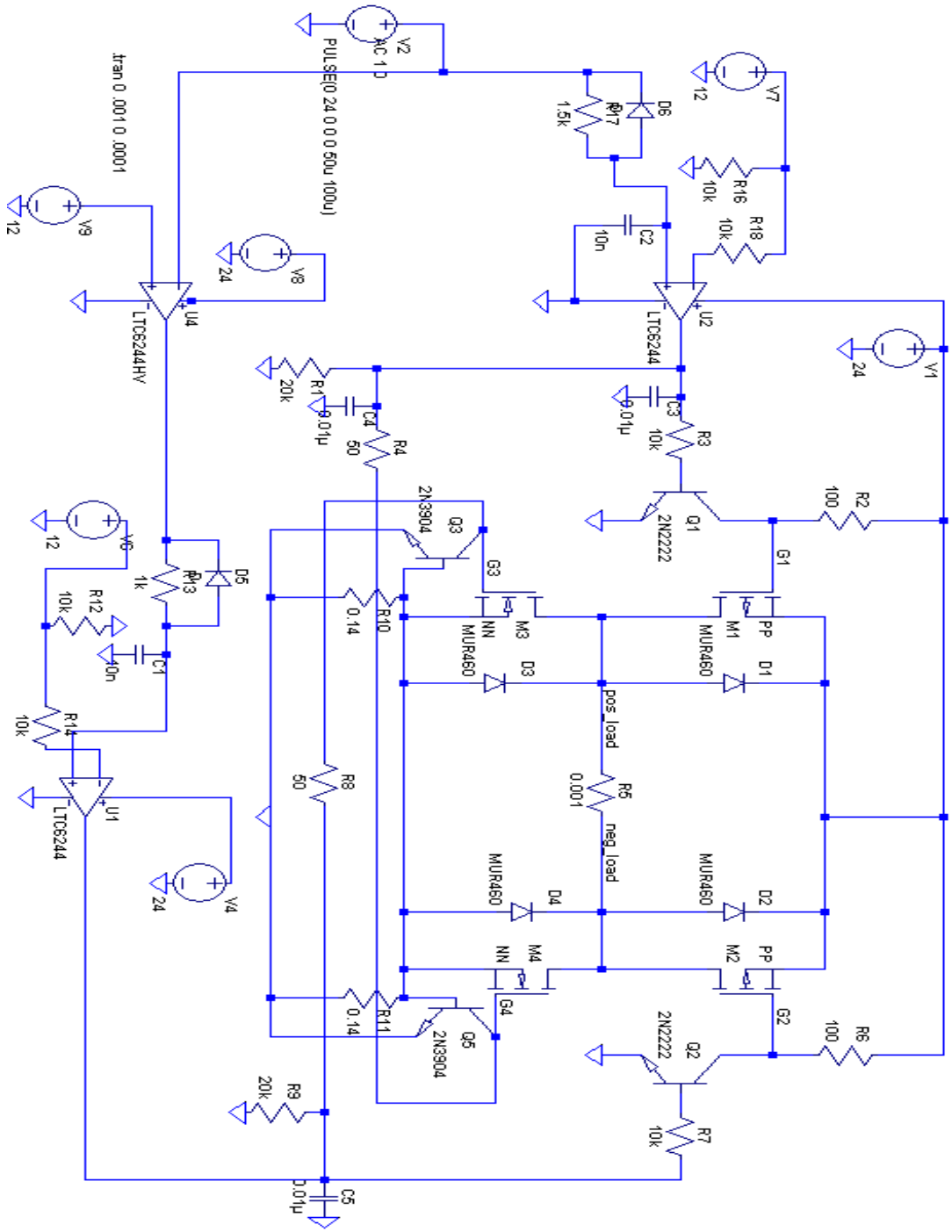

Figure 2.6: Inverter Circuit Diagram

Summary

Authors explicate above utilized HOMER being an optimization tool in order to actualize their personal research, the actual hybrid systems setups had been analyzed utilizing various load demands and also the applications, area associated with research along with climate data's these people utilized had been various. A few of the research had been used in places which have absolutely no electrical power whatsoever while others within places which have electrical power accessibility that was supplied utilizing diesel powered power generator. Each and every hybrid energy system needs to be developed in the new way for your site in line with the accessible climate data's, amount of domestic consumers, support centers as well as customer load profile. Price minimization continues to be usually the main goal wanted whenever a hybrid energy system strategy is designed. Complete expense of the actual hybrid power system consists of each onetime expenses (i.e. capital) as well as repeating expenses (i.e. operational), happening in various parts of time.

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Chapter 3

METHODOLOGY

3.1. Hybrid Energy System and HOMER

Hybrid energy system is the settings associated with several alternative as well as non-renewable powers because primary causes of power era so the capability deficit of energy from resource will certainly replace through some other accessible resources in order to accommodate lasting energy. It really is suitable ways to offer electrical power through in your area accessible powers with regard to locations where main grid expansion is actually funds rigorous, geographically separated locations which is why electrical power transmitting through central power is actually hard. Normally talented alternative resources could be controlled to create electrical power within a lasting method to offer energy and create comfy the actual residing regular of individuals. You will find various value and downsides of just alternative resources with regard to electrical power era within countryside communities, value such as energy price slope, energy transportation price is actually higher, problems of worldwide heating as well as environment enhancements made on big. The actual disadvantages of alternative resources because off-grid/standalone energy techniques, they have intermittence character which makes hard to control the ability outcome to handle using the masse wanted. To ensure for your dependability as well as cost from the provider, mixing traditional diesel powered power generator along with nonconventional power generators may resolve the issue noticeable whilst working separately. A few of the benefits mixing both causes of power creation tend to be mentioned the following [1].

- Diesel powered power generator energy utilization as well as green house fuel decrease
- Ingenious utilization of in your area accessible sources
- Deducts/avoids energy shortfalls, improve durability power
- It offers electrical power accessibility in a nutshell intervals compared to awaiting main grid expansion as well as relieve in order to scale-up anytime

Hybrid standalone energy system has energy manage versatility as well as value associated with environment safety compared to diesel powered power generator alone. Hybrid techniques may increase the capability whenever load demand gets greater later on, through alternative techniques, diesel powered power generator ranked energy or even they are all. A few of the elements generate DC power as well as others AC power directly without any utilization of conversion.

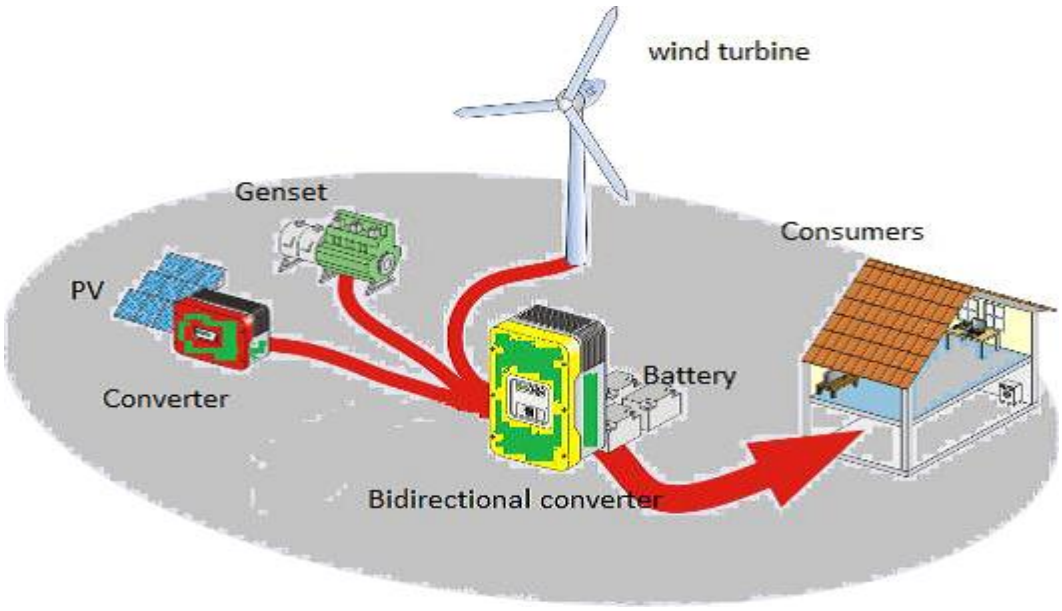

Figure 3.1: Configuration of Hybrid system [3]

3.2. Types of Hybrid System Configuration

Hybrid energy techniques could be created in line with the subsequent specialized topologies in order to control the actual accessible alternative resources and also to fulfill the load demand. This is often set up in various methods using the attention and also the load demand since the determinant aspects. Different configurations can be made for hybrid system some of them are given below [3].

3.2.1. Configuration of AC/DC Coupled System

Hybrid energy techniques could be classified in to 4 typical designs based on the voltage and also the load need they may be attached with.

3.2.2. DC Coupled Hybrid System

Within the household energy mixture all of the power transformation techniques tend to be coupled to the primary DC power bus prior to couple to the AC load part. Almost all AC energy resources tend to be changed into power energy resources after

that coupled to the AC load customer utilizing an appropriate converter is used. These kinds of mixtures are utilized within photovoltaic house techniques up to specific scale of kW. House program power companies could be backed along with inverters to supply AC load because required. Single house program energy providers tend to be coupled with some other producing units/systems whenever wide range of power is actually wanted. Additional power producing units are usually wind power as well as diesel powered power generator. With reference to figure 3.2 almost all energy resources are utilized towards the power bus, after that towards the customer. The actual value associated with DC-coupled topology could be that the need has been reached without any reduce offs. Regardless of the benefit of this particular, they have drawbacks associated with lower transformation effectiveness, absolutely no energy effects of diesel powered power generator. Wind generator as well as diesel powered power generator generates AC potential and requirements AC/DC converter to provide suitable load towards the power bus. Cost control can also be used to safeguard the actual heavy release and also cost from the electric battery. In case needed AC load could be provided utilizing inverter [2].

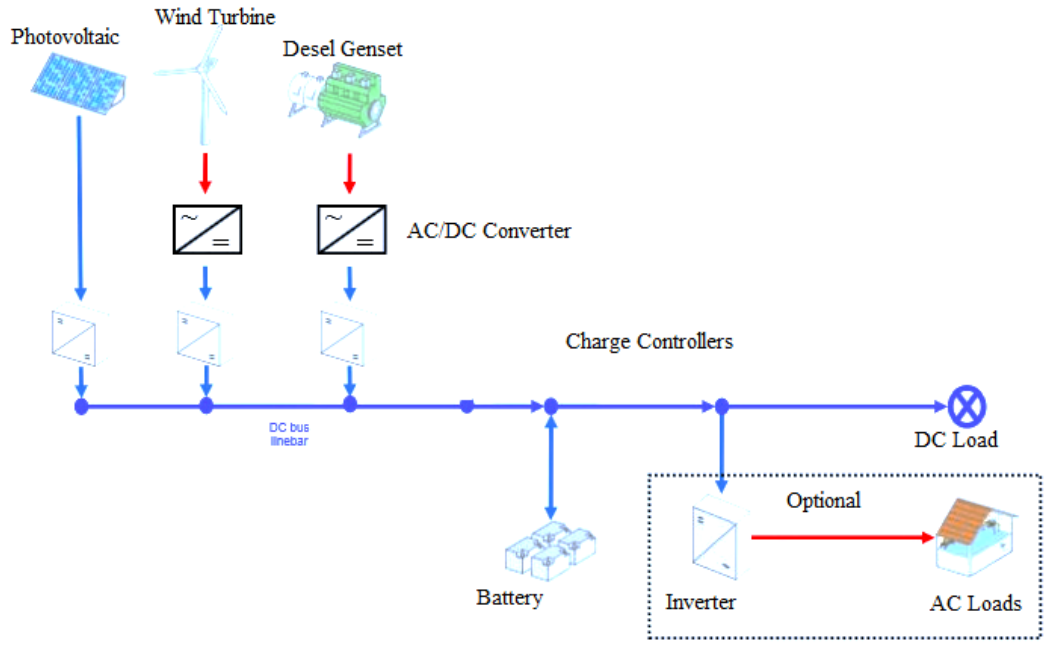

Figure 3.2: DC Coupled hybrid configuration [3]

Single house program energy providers tend to be coupled with some other producing units/systems whenever wide range of power is actually wanted. Additional power producing units are usually wind power as well as diesel powered

power generator. AC energy resources tend to be changed into power energy resources after that coupled to the AC load customer utilizing an appropriate converter is used.

3.2.3. AC Coupled Hybrid Configuration

Such topology all of the power producing elements or even models and also the power storage technology tend to be coupled to the AC bus in line load or even straight to the load (in the situation associated with decentralized configuration). This kind of energy program set up may also subdivide in to central as well as decentralized settings techniques.

3.2.4. AC Coupled Centralized Hybrid System

All of the elements tend to be coupled to the AC line. AC electrical power producing elements might link straight to AC bus or even may need AC/AC converter to obtain steady element joining topology. The actual learn inverter helps you to manage the power circulation towards the electric battery as well as from the electric battery towards the load. In addition the DC electrical power could be supplied through electric battery in case if required. Figure 3.3 describes AC coupled centralized hybrid system setting.

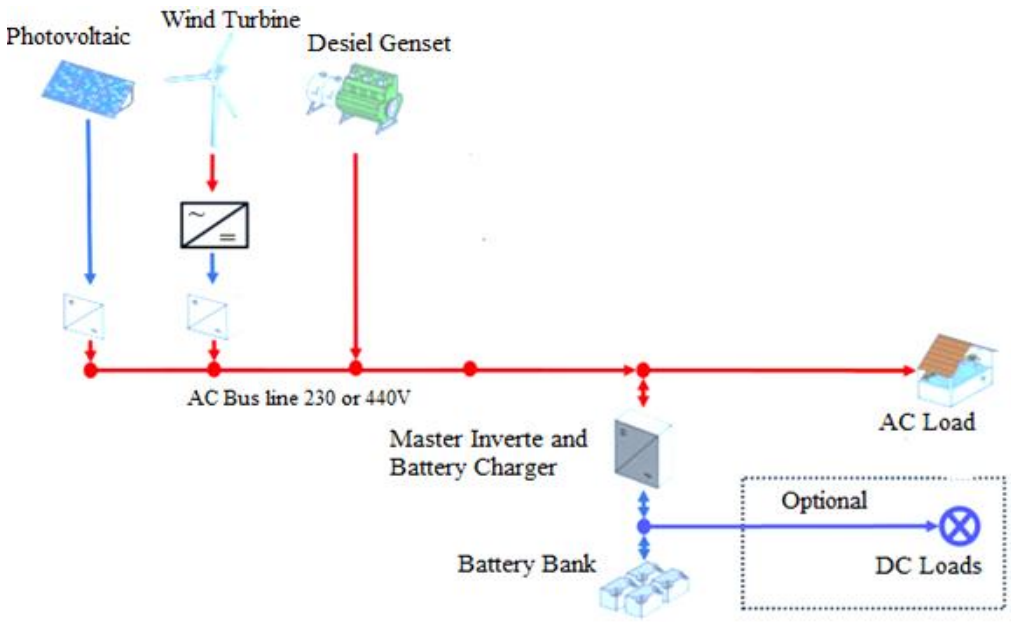

Figure 3.3: Ac coupled centralized Hybrid System [3]

3.2.5. Advantages of Centralized System

The actual central system offers capacity of growing battery-life because of the existence associated with main control system for your charging an overpriced charges and deep cycle discharging. Additionally it is suitable for power plants as well as allows in order exporting extra electrical power throughout minimal load demand occasions; furthermore electric battery can be charged through speed of wind as well as photovoltaic. Similar procedure from the elements enables additional growth from the program along with secure dependability.

3.2.6. AC Coupled Decentralized Hybrid System

Within this kind of structures all of the technology isn't linked to some of the bus, instead these individuals separately connect with the load directly. Figure 3.4 displays the actual combination of the device topology, currently noticeable through the number powers might not be located in one area or even near to each other plus they may connect with the load through anyplace the actual alternative sources can be obtained.

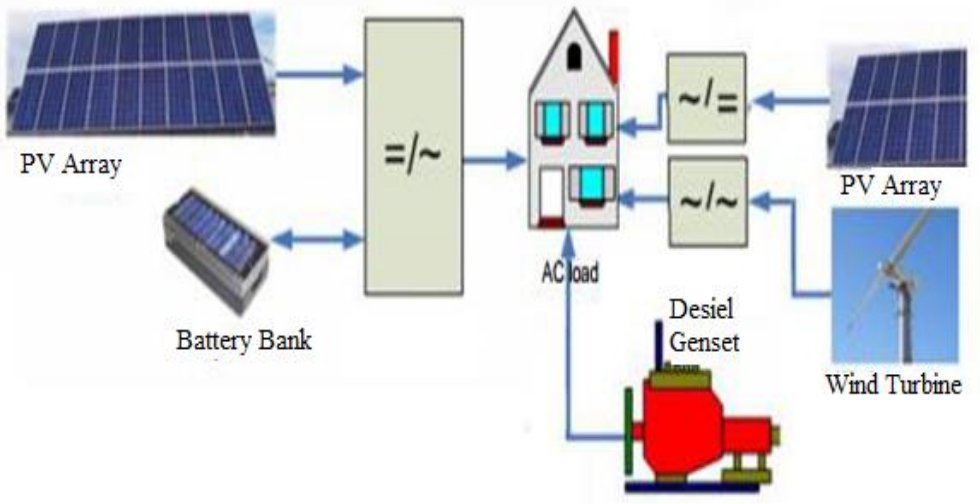

Figure 3.4: AC coupled distributed Hybrid System [4]

The actual value associated with this kind of settings could be that the energy producing elements may set up through the area wherever alternative reference can be obtained. However it features a drawback because of the trouble associated with energy effects of the device. Therefore, evaluating both designs the actual central

strategy is much better because of its controllability compared to dispersed program [4].

3.3. Series and Parallel Hybrid Energy System

Hybrid energy techniques will also be categorized in to 2 fundamental designs depending on exactly how load is actually supplied through renewable power techniques as well as diesel powered power generator. Series hybrid system as well as parallel hybrid energy techniques would be the 2 designs and the fine detail discussion has the following [5].

3.4. HOMER Software Overview

Within creating energy techniques various choices could be produced concerning the settings from the system, for example; exactly what components to integrate in the system, the size and also the quantity of the components and also the expense of every components. Wrong energy system style can result in smaller source of revenue associated with electric battery; improve cost of power Production, inadequate flow of electrical power need. Hybrid Optimization Product with regard to Electrical Renewable (HOMER) is really a computer product created initially through the National Renewable Laboratory (NREL). They have various power producing elements inside the library. The consumer should choose the elements through the collection to symbolize the actual structures regarded as. This particular building device utilizes period stage through one moment to many hours. HOMER makes simple or even assists founder in order to numerous energy techniques choices depending on specialized as well as financial elements. This software can answer lot of questions like given below.

- Either the designed system can meet the required demand or not
- What kind of hybrid system is suitable for the required location (e.g. Wind, Solar, Hydro, all of them combined or single source etc)
- How much batteries are required for the stand alone system
- How can we control the designed power system
- What will be the effect of fuel price change on the system

The software additionally selects between different techniques (cycle charging and load following) by causing comparison. Design as well as analysis associated with techniques could be difficult job since the big mixture of technique choices and also the addition associated with concerns. The method complexness as well as doubt improves whenever alternative resources tend to be within the program, as they are non-dispatch capable as well as irregular character. HOMER created in order to overcome these types of difficulties. HOMER operation method is shown in the figure, given figure shows clearly how homer simulate the systems to evaluate suitable system. Figure shown below indicates that how Homer simulates the systems, it performs sensitive analysis on the basis of sensitive input given by user. Sensitive inputs may be anyone according to project or user choice. Homer selects the most optimized system according to the given resources. Homer takes the energy balance on hourly basis, it need energy requirement for each hour of the whole day. It takes the seasonal variation into account for simulation process. It can simulate different combination of hybrid systems and calculates their fraction in the system and make a detail analysis.

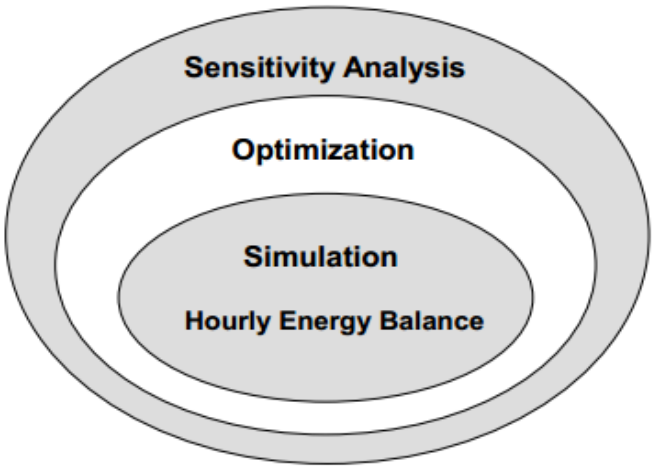

Figure 3.5: Simulation, Optimization, Sensitivity Analysis [6]

3.5. Simulation

This even comes close the power provide through the system and also the load demand within one hour, from the 8760 hrs. During this period this makes a decision possibly to make use of load following or even dispatch technique to run battery as well as power generator. For any system which has electric battery as well as power

generator needs getting dispatch strategy. Dispatch strategies are of two styles, load following as well as cycle charging techniques.

3.6. Optimization

Within this procedure this imitates every various system designs looking for the cheapest NPC as well as listings every energy techniques which fulfill the load demand. The objective of optimization would be to figure out the perfect system in line with the choice factors enforced through the developer. Choice variable is really a variable which has managed through the designer. HOMERs choice factors might include such as; photovoltaic variety dimension, amount of wind generators, power generator dimension, converter size, amount of battery dispatch technique, as well as and so on Looking the perfect program consists of determining the combination of energy elements such as size, quantity simultaneously the actual dispatch technique [6].

3.7. Sensitivity Analysis

This looks at the result associated with external variables and do optimization for every sensitivity factors. But initially defining the variables so as to influence the system over its total life is compulsory to input of the software. The actual optimization procedure is actually repetitive right after indicating the actual sensitive parametric factors being an input in the software program. The actual awareness factors could be weather information variants, elements as well as energy price, rate of interest, capability shortages, operating reserves as well as others. HOMER really does several optimizations utilizing numerous sensitive inputs to find out exactly how sensitive outcome from the energy system. The actual awareness outcomes through HOMER tend to be shown within listed as well as image form.

3.8. Domestic Load

The HOMER consumer identifies some main load in kilo watts for every hour for the whole year, possibly through adding file that contains per hour information or even through permitting HOMER in order to synthesize per hour information through typical everyday load information. Whenever synthesizing load information, HOMER produces per hour load beliefs depending on user-specified everyday load information. The actual modeler may identify just single 24-hour user profile which

is applicable throughout every season, or even may identify range of information of several or few months and a range of information with regard to weekdays as well as week-ends. HOMER provides the user-specified quantity of randomness in order to produced load information to ensure that each and every day's load design is exclusive. HOMER may produce two individual main loads, all of which may be AC or even DC.

Annual average consumption (kWh) = ((appliances power rating × No. of appliances × operating hours × No. of days)/1000)/ 7 days

One of the three kinds of loads patterned within HOMER, main load gets unique therapy in this it takes the user-specified quantity of operating reserves. Operation reserves are actual excess electric producing capability which is operating and may react immediately to some unexpected increase the actual electrical load or perhaps a quick decrease in output of renewable energy. Even though it has got the exact same which means since the more prevalent phrase spinning reserve, all of us call these operating reserves simply because battery, and also the main grid can offer this, however they usually do not spin. Whenever simulating the actual procedure from the system, HOMER efforts to make sure that the actual system's working capability is definitely adequate to provide the main load and also the needed operating reserves. When the alternative power actually exceeds the main load, they may provide to the deferrable load instead of likely to waste the energy [7].

3.9. Solar Source

In order to model a method that contains the photovoltaic array, the actual HOMER user should recommend photovoltaic resource information for your region. Photovoltaic resource information reveals the quantity of global radiation (beam rays arriving directly from sunlight, in addition dispersed rays of all areas of the sky) which attacks Earth's surface area within a typical year. The information could be in one of 3 types: per hour typical global solar rays within the horizontally surface area (kW/m^2), monthly average global solar radiation within the horizontally surface area ($kWh/m^2/day$), or even monthly clearness index. The clearness index catalog may be the proportion from the photo voltaic rays striking Earth's surface area towards the photo voltaic rays striking the atmosphere. Several among absolutely from zero to

one, the actual quality catalog are really a way of measuring the actual quality of atmosphere clearness.

HOMER creates synthetic per hour global solar radiations information utilizing a formula produced by Graham as well as Hollands [8]. The actual input for this formula would be the monthly average solar radiations values and also the latitude. The outcome is definitely 8760-hour information arranged along with record features much like the ones from actual calculated information models. Among those record attributes is actually autocorrelation that is it tends for just one day to become just like the previous time, as it is for 1 hour to become just like the previous hours.

3.10. Wind Source

In order to produce a method composed of a number of wind turbines, the actual HOMER consumer should offer wind resource information showing wind speed the turbine might encounter within a typical year. The consumer can offer calculated per hour wind speed information in case accessible. Or else, HOMER may produce synthetic per hour information through twelve month-to-month typical wind rates of speed and 4 extra parameters: the actual Weibull shape factor, the actual autocorrelation factor, the actual diurnal pattern strength, and also the hours associated with peak wind pace. Distribution measurement of wind speed over a year is called Weibull shape factor. The autocorrelation factor is a measure of how powerfully the wind pace in one hour tends to depend on the wind pace in the previous hour. The diurnal pattern strength and the hour of crest wind speed specify the amount and the phase, correspondingly, of the average daily pattern in the wind speed. HOMER offers default entities for all of these factors.

3.11. Components

Within HOMER, a component is actually any kinds of part of the micro power system which generate, provides, alter, or even store power. HOMER contains 10 kinds of component. 3 produce electrical power through irregular alternative resources: PV module, wind generators, as well as hydro generators. An additional 3 kinds of component, power generators, the actual main grid, as well as central heating boiler, tend to be dispatch able powers, which mean that the device may manage all of them as required.

3.11.1. Solar PV Size and Cost

Homer software use following equations to calculate the output of photovoltaic PV module array [kW] [8].

$$P_{PV} = Y_{PV} f_{PV} \left\{ \frac{\bar{G}_T}{\bar{G}_{T,STC}} \right\} [1 + \alpha_p (T_c - T_{c,STC})] \quad \text{.....(3.1)}$$

Y_{PV} This is the rated power of the Solar PV array, its power production under standard test conditions (STC).

f_{PV} It is Derating factor of PV module

$\bar{G}_T$ Incident solar radiations on solar PV panel in unit time step [kW/m²]

$\bar{G}_{T,STC}$ It is the incident radiations at STC

α_p Is the average temp coefficient of Power [% / ºC]

T_c Is the temperature of cell in unit time step [ºC]

$T_{c,STC}$ Is the cell temperature at STC [25ºC]

In case within the photovoltaic windowpane you select to not produce the result associated with temperatures within the photovoltaic array, HOMER will assumes that this temperatures coefficient of power is actually absolutely zero, so the over formula makes simple in order to

$$P_{PV} = Y_{PV} f_{PV} \left\{ \frac{\bar{G}_T}{\bar{G}_{T,STC}} \right\} \text{..... (3.2)}$$

Right after surveying various items concentrating on the price supplied the PV Silicon technology PST-300 panel had been selected. The reason behind finding the item through the mentioned organization is a result of the affordable shipped so long as effectiveness is really a large issue right here. Considered solar panel was of 300W rating [8]. Efficiency of selected solar panel was 16% to 17% and the price of the selected solar panel was $1/watt. Operation and maintenance cost of the solar panel is very much low it that's why it is considered as $10/yr. Total number of panels which are considered in for search space were 0,1,2,3 and 4. Homer selects the best number of panels in combination with wind turbine or any other source to produce feasible system.

Table 3.1: Solar PV input Parameters

PV Size (KW)	Capital Cost ($)	Life (years)	Considered Size
2	2000	25	0,1,2,3,4

No tracking system is considered in this hybrid system, thus fixed system is modeled without any tracking mount at ground. The term derating factor is used for both solar PV panel efficiency and as well as charge controller efficiency as charge controller are not designed by HOMER. This derating factor term is used for dust, elevated temperature, shading effect, electric wiring losses, and so on. The size of the actual photovoltaic panel enter into HOMER is within kW, not really within m^2, so the efficiency is not really evaluated being enter additionally. The actual azimuth position or even direction as well as position associated with desire from the photovoltaic screen would be the 2 key elements that need to be regarded as throughout solar-system design. With regard to adequate quantity of electrical power production the perfect direction associated with photovoltaic array is due south, however nevertheless it can also be feasible to handle south-east or even south-west, there is little decline in performance because of the change associated with to the west or even eastern associated with south. Some factors had been considered as with regard to design of the power system such as; the derating factor had been used 80%, ground reflectance had been additionally regarded as 20%, slope equal to latitude and 45^o and azimuth 0^o.

3.11.2. Size and Cost of Wind turbine

HOMER computes the ability result from the wind turbine within every time step. This particular involves the three-step procedure in order to very first determine wind speed in the hub height from the wind turbine, after that in order to determine just how much energy wind generator might generate too wind pace in regular air flow density, after that to modify which energy outcome worth for your real air flow density. Within every time step HOMER computes wind speed in the hub height from the wind generator utilizing the input a person identify within the input of wind resource input window and also the wind Shear input window.

If you select to apply the logarithmic law, HOMER computes the hub height wind speed with the subsequent equation.

$$U_{hub} = U_{anem} \cdot \frac{\ln\left(\frac{Z_{hub}}{Z_\circ}\right)}{\ln\left(\frac{Z_{anem}}{Z_\circ}\right)} \quad \text{.....(3.3)}$$

U_{hub} Is speed of wind at wind turbines hub height [m/s]

U_{anem} Is speed of wind at anemometer's height [m/s]

Z_{hub} Is the wind turbines hub height [m]

Z_{anem} Is height of anemometer [m]

$Z_\circ$ Is length of surface roughness [m]

ln Is natural Logarithm

As soon as HOMER suggest certain hub height wind speed, this appertains to the wind turbines energy production in order to determine the capacity power output you might expect as a result wind turbine at wind speed under standard testing conditions.

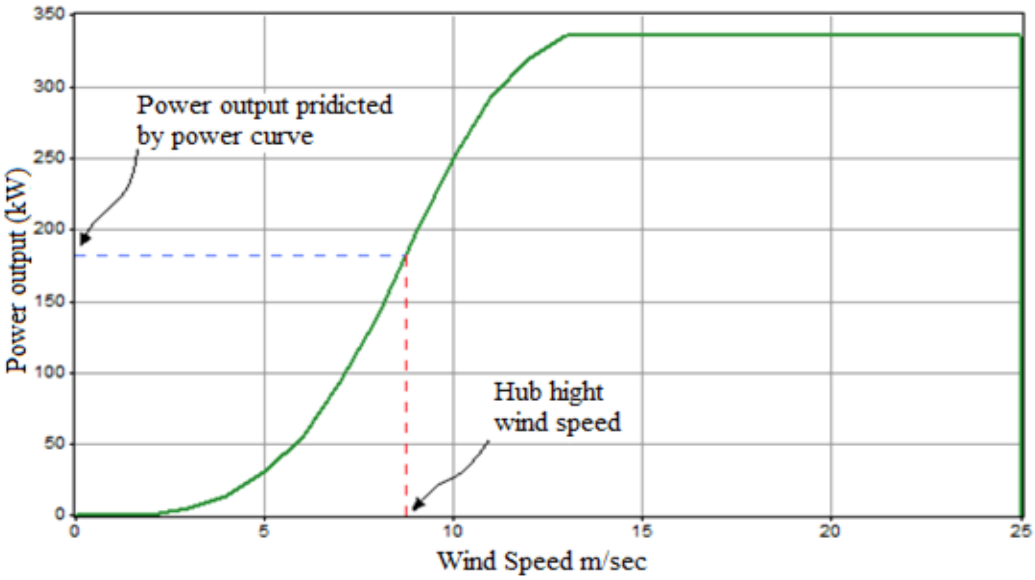

Figure 3.6: Wind Power output at standard air density

Within the diagram above, the actual red-colored signifies the actual hub height wind speed, and also the glowing blue line signifies wind turbine energy production that that the power curve forecast for that wind speed. In Homer power curve for each

wind turbine is given by the manufacturer. Figure given below indicates how homer calculates the power output on standard air density.

Power curves in general indicate wind turbine production under circumstances of standard temperature and pressure (STP). To regulate to actual conditions, HOMER multiply the power rate forecast by the power curve by means of the air density ratio, according to given equation.

$$P_{WTG} = \left(\frac{\rho}{\rho_{\circ}}\right) . P_{WTG,STP} \qquad (3.4)$$

P_{WTG} Is output of wind turbine [kW]

ρ Is air density [kg/m^3]

$P_{WTG,STP}$ Is output of wind turbine at standard temperature and pressure [kW]

$\rho_{\circ}$ Is density of air at standard temperature and pressure [1.225 kg/m^3]

Based on the wind pace resources the actual generator needs to produce wide range of power in order to lead sizeable alternative small fraction which could be carried out utilizing single big wind generator or even amount of smaller sized generators. Amounts associated with generators, service period, hub height, Expense of the actual component, kind of electrical power produced, cut-in wind speed would be the limited values to pick wind turbine. The chosen generators may produce AC/DC electrical power to meet the requirement of AC/DC load customer home appliances. Wind turbine selected for this thesis is Bergey Excel 1 kW wind turbine. O&M cost is estimated about 2% of the capital cost of wind turbine [9]. Replacement cost is considered about 75% of initial cost of wind turbine.

Table 3.2: Wind turbine output parameters

Size (kW)	Initial Capital Cost ($)	O&M Cost ($)	Replacement Cost ($)	Life (year)	Hub Height (m)	Quantity
1	3000	100	2500	25	10,20	0,1,2,3

Specifications of Bergey excel 1 kW wind turbine are given below [10].

- Start-up Wind Speed: 3 m/s (6.7mph)

- Cut-in Wind Speed: 2.5 m/s (5.6 mph)
- Rated Wind Speed: 11 m/s (24.6 mph)
- Rated Power: 1000 watts
- Cut-Out Wind Speed: None
- Furling Wind Speed: 13 m/s (29 mph)
- Max. Design Wind Speed: 54 m/s (120 mph)
- Type: 3 Blade Upwind
- Rotor Diameter: 2.5 m (8.2 ft.)
- Blade Pitch Control: None, Fixed Pitch
- Over speed Protection: AUTOFURL
- Gearbox: None, Direct Drive
- Temperature Range: -40 to +60 Deg. C (-40 to +140 Deg. F)
- Generator: Permanent Magnet Alternator
- Output Form: 12 – 48 VDC Nominal.

3.11.3. Batteries Size and Cost

Size of the battery is main entity or main component of the system which can affect the system cost and performance as well. The autonomy or battery bank is ratio between size of battery bank and electric load. HOMER use following equation to calculate the size of battery bank.

$$A_{batt} = \frac{N_{batt}\ V_{nom}\ Q_{nom}\ \left(1-\frac{q_{min}}{100}\right)\left(\frac{24h}{d}\right)}{L_{prim\ ,ave}\ \left(\frac{1000\,Wh}{kW\,h}\right)} \qquad (3.5)$$

N_{batt} Is total No. of batteries in battery bank

V_{nom} Is single battery's nominal voltage [V]

Q_{nom} Is nominal capacity of battery [Ah]

q_{min} Is the lowest state of charge for battery bank [%]

$L_{prim\ ,ave}$ Is average primary Load [kWh/d]

Within HOMER, 2 self-employed aspects might restrict the actual duration of the actual electric battery: the actual life time throughput and also the electric battery float life. Quite simply, battery may expire possibly through use or even through old

age. Whenever you develop a brand new electric battery, you can choose if the electric battery life time is restricted through time, throughput, or even both. The life of battery bank is calculated by Homer through following equation.

$$R_{bat} = \begin{cases} \frac{N_{batt} \cdot Q_{lifetime}}{Q_{thrpt}} & If\ Limited\ by\ throughput \\ R_{bat,f} & If\ limited\ by\ time \\ MIN\left(N_{batt} \cdot \frac{Q_{lifetime}}{Q_{thrpt}}, R_{bat,f}\right) & If\ limited\ by\ time\ and\ throughput \end{cases} \quad \text{.....(3.6)}$$

R_{bat} Is life time of the battery bank [yr]

N_{batt} Is the total number of batteries in battery bank

$Q_{lifetime}$ Is single battery's throughput [kWh]

Q_{thrpt} Is annual throughput of the battery [kWh/yr]

$R_{bat,f}$ Is floating life of the battery [yr]

Such as the some other aspects of the energy system, enter variables placing in to the software program tend to be price as well as amount of battery may be the condition associated with cost beneath that the electric battery will certainly not be released to avoid through damage. Through 30-50 % may be the suggested minimal condition associated with cost. Round-trip electric battery effectiveness may be the flow of energy in to the electric battery which can be removed or extracted for further use. The battery for battery which is chosen is H1000 from the manufacturer Hoppecke. This battery is present in the Homer battery library. Characteristics of the chosen battery are given below. The selected battery contain the nominal capacity of 1000 Ah and having the nominal voltage of 2V. The total amount of energy which can be stored in the selected battery is 2.0 kWh and the maximum current for charging is about 202 A. batteries round-trip efficiency is about 86%. Minimum state of charge for the selected batteries is 30 %. Battery's life time throughput is taken as 3438 kWh. Replacement cost of the batteries is considered same as capital cost of the batteries. The cycle charging technique is really a lay technique where every time a power generator must run in order to provide the main load, this works in complete outcome energy. Excess electric creation will go towards the actual lower-priority goals for example battery bank or load. to be able associated with reducing concern: helping the actual deferrable load getting the actual electric battery bank, as well as

helping the actual electrolyzer. One of the main drawbacks of the Homer is that it cannot consider temperature factor for batteries life. As temperature is the main factor which degrades the life of battery bank. A country like Pakistan has an issue with temperature which increases the cost of the system as temperature decreases the life of batteries. Charging and discharging are also the main factors which contribute in the batteries life. This factor is calculated by homer as shown below in the figure.

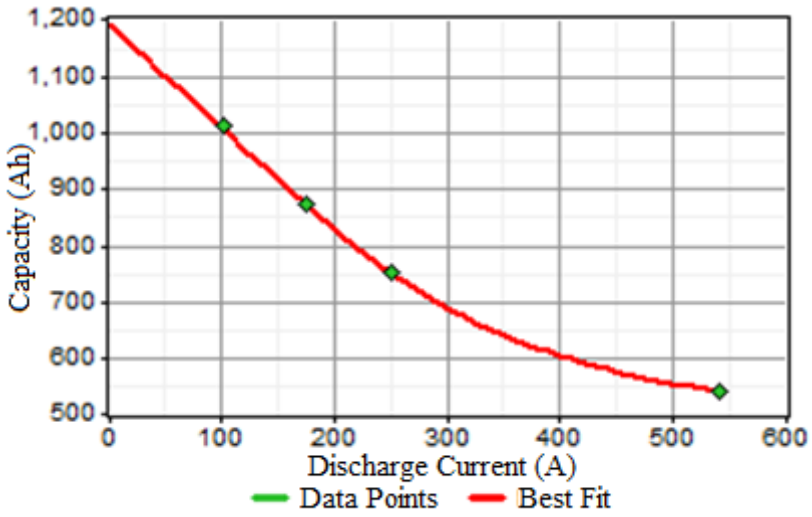

Fig. 3.7 Capacity Curve of battery

3.11.4. Size and Cost of Power Converter

The converter must sustain circulation of current flow between AC as well as DC power energy products. The actual rated power of the actual inverter have to be equivalent to or even larger than the high peak or peak load will give each through the alternative as well as non-renewable, in fact lower than the peak will be set up. There is absolutely no approximated working repairs and maintenance price with this situation.

Converter capital cost is taken as $ 450 and its replacement cost is also the same of the initial cost [11]. Efficiency of the power converter is taken as 90 %. Power converter life time is considered as 20 years.

3.11.5. Cost and Size of Diesel Generator

Diesel powered power generators can be found in a variety; nevertheless various providers accommodate various price evidences which can make difficult in order to. Diesel powered power generators do not let operating in under the actual minimal

load proportion associated with 30%. Power generators procedures life time is actually calculated within hrs. Because power generators life time rely on energy high quality as well as working circumstances can make hard to obtain life time information. The actual a fact engine utilized to generate electrical power tend to be internal combustion engine which diesel powered engine last for very long compared to gasoline engines [6]. Regular load variance leads to the indigent overall performance associated with power generator and higher energy usage as well as greater O&M price appropriately more expensive of one's will be acquired. Power generator size are one of the enter size to think about dealing with wind as well as photovoltaic to satisfy the load necessity when it comes to absolutely no wind speed or with no sunlight occasions. Therefore selection of size the actual power generator might be under the height load demand since it might functionality within cooperation using the alternative resources as well as electric battery bank. Picking out diesel powered power generator trading accounts the actual limitations associated with energy providing capability, the type of load, price effectiveness as well as fuel usage. Selecting a specific power generator size deliberates the actual restriction associated with price effectiveness as well as capability associated with providing the necessary energy. Generator capital cost is taken as $ 456 and replacement cost is the same as initial cost. Generator size considered for the system is 3 kW. The minimum ratio for the load is 30 %. Life time of the generator is taken as 15000 operating hours.

3.11.6. Size and Cost of Grid

When the strategy is coupled to the main grid and possesses a few other energy generating device (such like a micro turbine, the fuel cell, the photovoltaic variety, or perhaps a wind turbine), the actual main grid initial price is actually corresponding to the actual interconnection cost. Or else, the actual main grid initial price is actually absolutely zero. Often the replacement cost with the main grid is usually absolutely zero. The actual main grid O&M price is actually corresponding to the actual yearly expense of purchasing electrical power through the main grid (energy price in addition with demand cost) minus any kind of income through the sale associated with electrical power towards the main grid. With regard to grid-connected techniques which contain a few other energy generating device (such like a micro turbine, the fuel cell, the photovoltaic variety, or perhaps a wind turbine), the actual

main grid O&M price also contains the actual standby cost. Here grid purchase price is taken as $15/kWh and grid feed or sales are taken as $17/kWh. Grid purchase capacity for the system is considered as 0 kW, 100kW, 200kW, 300kW and 400kW.

Summary

The actual HOMER optimization product is really a computer product produced by the U.S National Renewable Energy Laboratory (NREL) to aid within the type of micro power techniques and also to help the actual a comparison of energy technology throughout a range of different application. HOMER models an electrical system's actual physical behavior as well as its life price, which is the entire cost of installation as well as working the system over its life time. HOMER enables the modeler in order to a variety of design choices depending on their own specialized as well as financial value. Additionally, it helps understand as well as quantifying the consequence of doubt or even modifications in the inputs of power system. The actual evaluation as well as type of micro power system techniques could be difficult, because of the large numbers of design choices and also the doubt within crucial variables, for example load size as well as upcoming energy cost. Alternative energy resources include additional complexness simply because their own energy outcome might be irregular, periodic, as well as non-dispatchable, and also the accessibility to alternative sources might be unstable. HOMER was created to conquer these types of difficulties.

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Chapter 4

RESULTS AND DISCUSSIONS

This particular section gives the facts from the optimization outcomes for selected hybrid energy system to a normal home load demand. The system had been made with the aid of HOMER without any provided a lot issue towards the effectiveness from the elements. Right after presenting all the input factors in the modeling tool; the software is actually operated frequently to obtain the achievable outcomes. Optimization answers are shown by means of general as well as classified displaying probably the most achievable energy techniques structures that satisfies the load and also the input constrains created by the modeler. The actual achievable options tend to be introduced within a growing order of net present cost (NPC) through top to bottom. The actual classified small table introduced least economical combination through of most elements set up, while, the entire optimization outcomes shown all the inexpensive system combination depending on their own NPC. Energy techniques tend to be chosen right after depending on mainly minimal net present cost (NPC). Along with these types of variables much less expense of power, higher alternative fraction, lower capacity shortage, lower extra electrical power generation, and fewer diesel powered energy usage might be utilized for a comparison of energy producing strategy to be able to examine their own specialized technical feasibility.

4.1. Selection Scenarios and System Optimization

Even though HOMER created various designs of energy system components, nevertheless it just shows the actual feasible energy strategy situations for extra comprehensive evaluation. The actual complexness as well as calculation period is influenced by the number of variables as well as number associated with possible values in the design. Energy plans (scenarios) along with much less NPC, much less COE, greater alternative fraction, much less capability shortage, smaller sized extra electrical power as well as minimal fuel usage will be recommended as an optimum system.

Following different scenarios are considered for each location.

- Solar/Wind/Grid/Genset
- Solar/Grid/Genset
- Wind/Grid/Genset
- Solar/Wind/Battery
- Solar/Battery
- Wind/Battery

Systems are analyzed for grid connected system as well as for off grid system. Different design choices are considered for each specific location to obtain a suitable system according to net present cost and levelized cost of energy. . Sensitivity analysis was also completed by captivating sensitive parameter for example wind speed which can shape the power system all through its lifetime [1]. Solar radiation of different areas are obtained from Homer database. Schematic diagram of grid connected system and off grid system are given below.

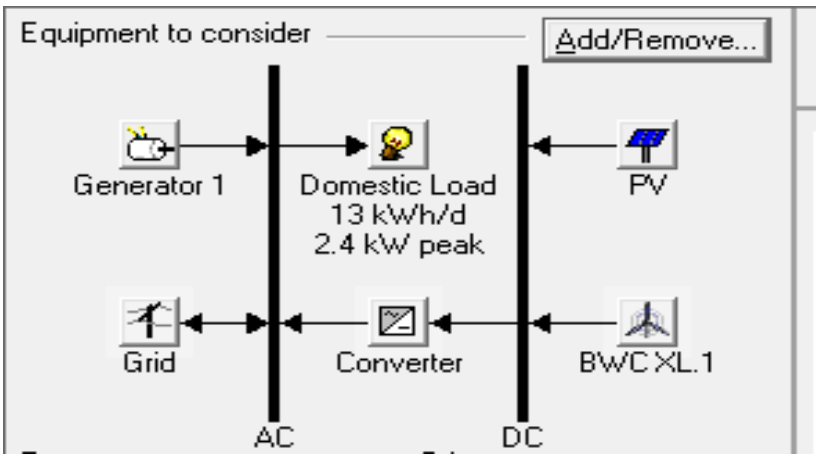

Figure 4.1: Grid connected system

Above given schematic diagram of grid connected system is designed in HOMER software. Each component of the hybrid power system is visible in the schematic diagram.

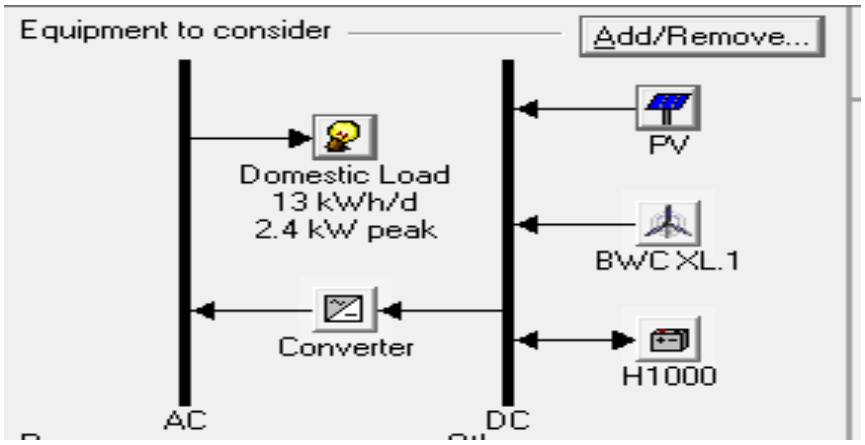

Figure 4.2: Off Grid schematic diagram

4.2. System Analysis for D.G.Khan

Different systems are analyzed at the specific site to indicate the optimum system for the location as mentioned above. Analysis of Solar/Wind/Grid/Genset is shown here. In overall production of electricity or energy from the different components of hybrid renewable energy are given below. In wind/solar hybrid system solar produce 43% of the total production and wind produce 16% of the total production grid purchases are 41%. HOMER creates synthetic per hour global solar radiations information utilizing a formula produced by Graham as well as Hollands [2]. Wind penetration is lower due to lower wind speed at the specific site or location.

Table 4.1: Electricity production from each component

Production	kWh/yr	%
PV Array	3391	43
Wind Turbine	1284	16
Generator	0	0
Grid Purchases	3225	41
Total	7901	100

According to the resource availability capacity factor of each component is different for the specific site. Capacity factor and penetration of each source is given below in the table. As solar radiation at the given site are higher than the wind speed that's why capacity factor of solar PV array is higher than the wind turbine. As in the table it is shown that capacity factor for solar PV is 19.4% and for wind it is 14.7%. The operating hours of wind turbine are higher than solar PV module as shown in the

given table. So as a result the total production of energy from each component is different. Energy produced by solar PV is much higher than energy produced my wind turbine. Wind power fluctuation and demand of household difference is the only hamper influencing the structure [3].

Table 4.2: Resources parameters at D.G.Khan

Source	Rated Capacity (kW)	Capacity Factor (%)	Penetration Level (%)	Operating hours (hrs)	Total Production (kWh/yr)
Solar	2	19.4	70.9	4,376	3,391
Wind	1	14.7	26.8	5,948	1,284

According to above given methodology different systems are analyzed with different combination for achieving optimum output on the specific location. In the same way systems are analyzed for D.G.Khan and following results are obtained for the location.

Table 4.3: Optimum system for D.G.Khan

Options	Operating Cost ($/yr)	Total NPC	COE ($/kWh)
PV/Grid/ Gen	333	$ 11,063	0.072
PV/Wind/Grid/Gen	303	$ 13,320	0.079
Wind/Grid/Gen	-	-	-

Most suitable grid connected system for the D.G.Khan location is PV/Grid/Genset as compared to PV/Wind/Grid/Genset and Wind/Grid/Genset due to its low Net Present Cost and lower Cost of Energy. Off grid system designs are also analyzed for the location to analyze the optimum system. Normally, cost of off grid or stand alone systems are higher due to batteries shorter life and higher cost of batteries. Replacement cost of batteries is another main factor which increases the cost of energy and total net present cost of the system. Now if we talk about the off grid system design choice for the location then after different simulation and results analysis suitable systems are selected their preference looks like given below in the

table. Energy systems are selected on the basis of net present cost NPC and levelized cost of energy (COE).

Table 4.4: Optimum off-grid system

Options	Operating Cost ($/yr)	Total NPC	COE ($/kWh)
PV/Wind/battery	258	$ 12,489	0.132
PV/Battery	296	$ 14,269	0.133
Wind/Battery	-	-	-

According to the above given table most optimum off-grid system for D.G.Khan is PV/Wind/Battery hybrid system on the basis of total net present cost and levelized cost of energy. Second optimum system for the location is PV/Battery system but Wind/Battery is not feasible system for the location as average wind speed is not much high. Average wind speed for D.G.Khan is 3.9 m/sec. Solar radiation for D.G.Khan is much better than wind speed. Grid connected system are more suitable on the basis of cost effectiveness as compared to off grid system.

4.3. Design Analysis for Kakul

Climate of Kakul is much different from the above given location D.G.Khan. Solar radiations at Kakul are less than the previous location and the average wind speed for the Kakul is much batter then D.G.Khan. Average wind speed at Kakul is about 5 m/sec and operating hours of wind turbine are also higher. Electrical production at this site is different than previous one. Due to difference in resources availability and density capacity factor may also change. Higher wind speed availability increases the capacity factor of wind turbine while lower solar radiation may decrease the capacity factor of solar PV modules. All these factors affect the individual production of each component of the system which may contribute in the overall production of the system. This difference make system either reliable or not. Individual contributions to the overall system and total production from the system are different. Production from each component of the system is given bellow in the table.

Table 4.5: Electrical production at Kakul

Component	Production (kWh/yr)	Fraction
PV array	3,239	37%
Wind turbine	2,412	28%
Generator 1	0	0%
Grid purchases	3,069	35%
Total	8,720	100%

Analysis of Solar/Wind/Grid/Genset is shown here. In overall production of electricity or energy from the different components of hybrid renewable energy are given in the table. In wind/solar/Grid hybrid system solar produce 37% of the total production and wind produce 28% of the total production grid purchases are 35%. Wind penetration is higher as compared to previous location due to higher wind speed at the specific site or location. In PV/Wind/Grid system solar fraction is 37% and wind fraction is 28%, while grid purchases are 35%. Total NPC of the system is $ 10,927 and COE of the system is $ 0.06/kWh. The Wind/Grid is not feasible system due to higher O&M cost of wind turbine.

Table 4.6: Resource Parameters at Kakul

Source	Rated Capacity (kW)	Capacity Factor (%)	Penetration Level (%)	Operating hours (hrs)	Total Production (kWh/yr)
Solar	2	18.5	67.7	4,385	3,239
Wind	1	27.5	50.5	6,916	2,412

According to the resource availability capacity factor of each component is different for the specific site. Capacity factor and penetration of each source is given above in the table. As solar radiation at the given site are lower than the previous site that's why capacity factor of solar PV array is lower than PV array at previous site. Capacity factor for wind turbine is higher as compared to previous site. This is all due to higher wind speed at present location. As in the table it is shown that capacity factor for solar PV modules is 18.5% and for wind turbine it is 50.5%. The operating hours of wind turbine are higher than solar PV module as shown in the given table. So as a result the total production of energy from each component is different.

Energy produced by solar PV is higher than energy produced my wind turbine due to the size of solar PV modules.

Table 4.7: Optimization Grid connected system at Kakul

Options	Operating Cost ($/yr)	Total NPC	COE ($/kWh)
PV/Wind/Grid/Gen	201	$ 10,927	0.060
PV/Grid/Gen	362	$ 11,954	0.079
Wind/Grid/Gen	-	-	-

Most suitable grid connected system for the Kakul location is PV/Wind/Grid/Genset as compared to PV/Grid/Genset and Wind/Grid/Genset due to its low Net Present Cost and lower Cost of Energy. Off grid system designs are also analyzed for the location to analyze the optimum system. Normally, cost of off grid or stand alone systems are higher due to batteries shorter life and higher cost of batteries. Replacement cost of batteries is another main factor which increases the cost of energy and total net present cost of the system. Now if we talk about the off grid system design choice for the location then after different simulation and results analysis suitable systems are selected their preference looks like given below in the table. Energy systems are selected on the basis of net present cost NPC and levelized cost of energy (COE). Hybrid systems which are evaluated on the site with the available renewable source are evaluated on the net present cost NPC of the systems.

Table 4.8: Optimized Off-Grid system at Kakul

Options	Operating Cost ($/yr)	Total NPC	COE ($/kWh)
Wind/battery	275	$ 12,078	0.142
PV/Wind/Battery	256	$ 12,432	0.121
PV/Battery	-	-	-

According to the above given table most optimum off-grid system for Kakul is Wind/Battery hybrid system on the basis of total net present cost and levelized cost of energy. Second optimum system for the location is PV/Wind/Battery system but PV/Battery is not feasible system for the location as average solar radiations are not much high. Average wind speed for Kakul is 5 m/sec that is much better for

production of energy from small size wind turbine. Solar radiations for Kakul are much less than wind speed. Grid connected system are more suitable on the basis of cost effectiveness as compared to off grid system.

4.4. Grid Connected Hybrid System for Different Locations

Grid connected hybrid systems are analyzed at different locations of Pakistan. Solar radiations are almost very good in all areas of Pakistan. Wind speed is the main factor for solar/wind hybrid system. Taking wind speed as sensitive input total net present cost of the system is analyzed for different locations of Pakistan. Diversity in wind nature produces different results for hybrid system feasibility. As the wind speed varies from one location to other location system response changes to economic feasibility. Technically hybrid system (wind/solar) are strong enough to produce reliable power even in low wind speed areas, but economically these systems are not feasible due to higher coat of Wind turbine and its operation and maintenance O&M cost.

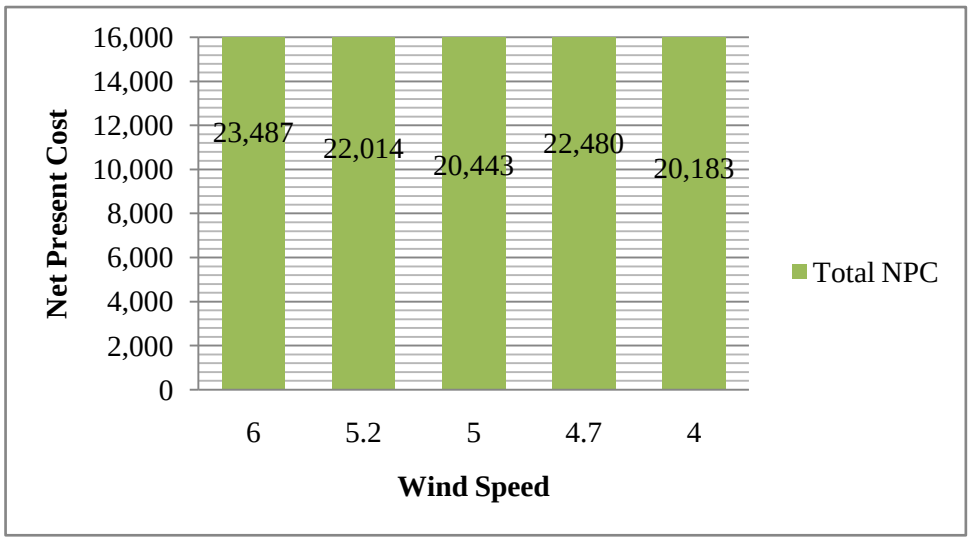

Figure 4.3: Graph of Hybrid systems NPC with different wind speed

Graph given above shows the total net present cost of the wind/solar/grid hybrid system at different locations. Change in wind speed drastically affects the total net present cost of the system. Graph shows as the wind speed decreases the net present of the system increases gradually. Wind speed at 4 m/sec or below drastically effect the net present cost of the system as it is shown above in the graph. As the cut in

speed for most of the small turbines is 3.0 m/sec at which it starts producing electricity but for optimum output it needs rated wind speed [4].

4.5. Grid Connected System COE on Different Wind Speed

The actual levelized cost of power is actually which means typical price for each kilowatt hour associated with useful energy created by the system. HOMER energy system use following given equation for levelized cost calculation [5]. Even though levelized cost of power is usually a handy metric which in order to the expenses various techniques, HOMER utilizes the entire NPC rather because it is main financial number associated with value. Hybrid (Wind/Solar) systems are analyzed at different wind speed areas to obtain the feasible system for the location, behavior of wind speed in the economical analysis of the hybrid systems are also analyzed on these locations.

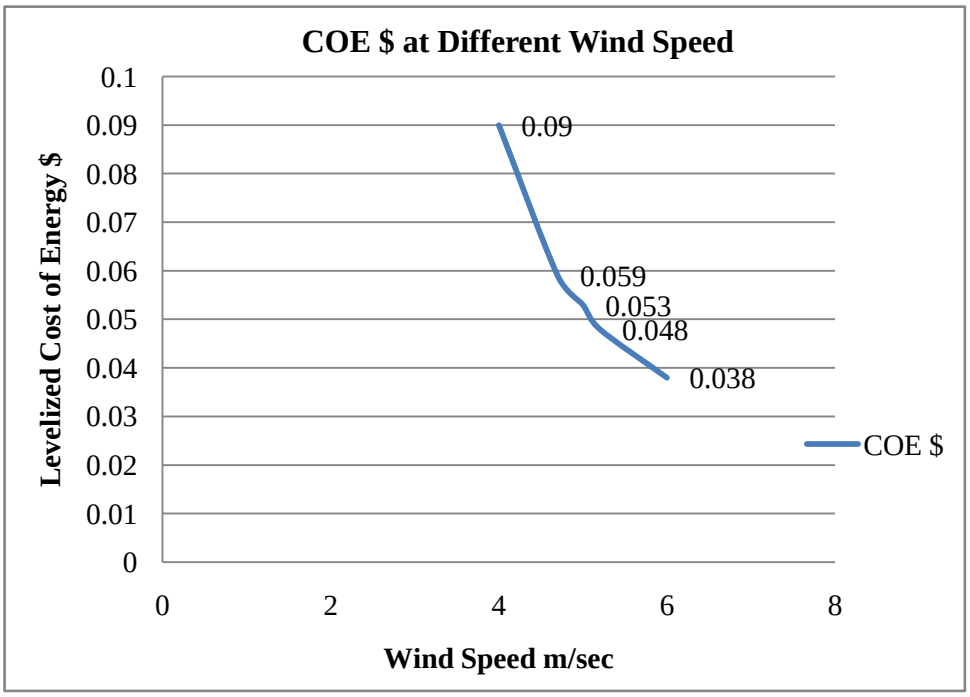

Figure 4.4: Graph of Levelized COE at different wind speed

Areas with different wind speed shows different levelized cost of energy. Graph given above shows the variation in levelized cost of energy with variable wind speed. As the wind speed increases the COE decreases due to higher penetration of wind energy and solar radiation. HOMER rates the device designs based on NPC instead of levelized cost of power. The reason being the definition from the levelized

expense of power is actually disputable in a manner that the definition from the complete NPC is not really.

4.6. Net Present Cost of Hybrid System for Different Locations

HOMER rates the system designs based on NPC instead of levelized cost of power. The reason being the definition from the levelized expense of power is actually disputable in a manner that the definition from the complete NPC is not really. HOMER utilizes the entire net present cost (NPC) to symbolize the actual cycle expense of a system. The entire NPC condenses all of the expenses as well as profits which happen inside the task life time as one time within modern day currency, along with upcoming money moves reduced returning to the current utilizing the low cost price. The actual designer identifies the actual low cost price and also the task life time. The actual NPC consists of the expenses associated with preliminary building, element replacement, servicing, energy, as well as the expense of purchasing energy through the main grid as well as assorted expenses for example fines caused by pollutant emissions etc. Solar PV has low operation and maintenance cost and long life which make it suitable in Hybrid system. This particular technologies is able to transform 1000 W/m² solar rays to 130 W associated with electrical power within photovoltaic cell area associated with 1m² [6].

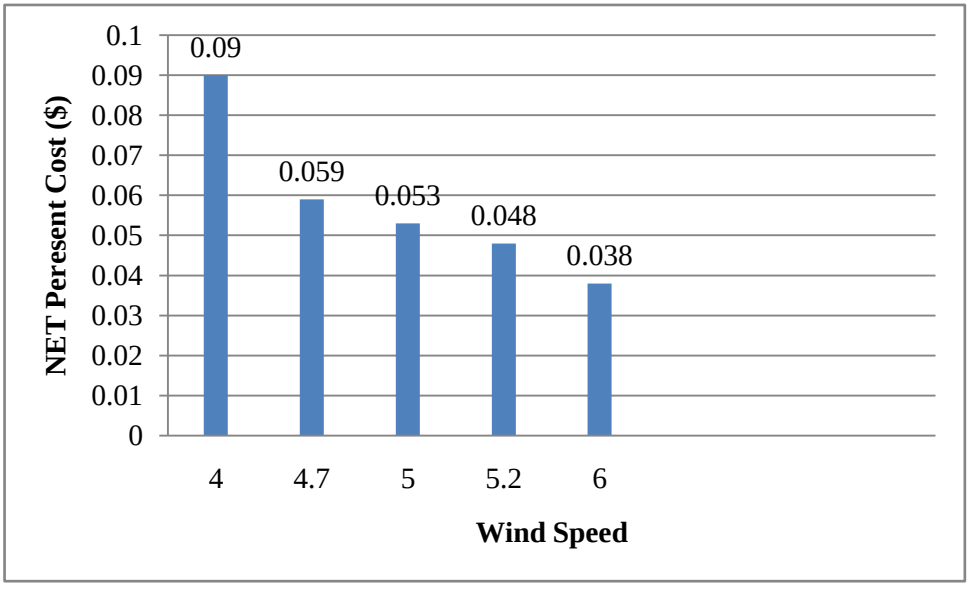

Figure 4.5: Graph of NPC for different areas

Above given graph shows the total net present cost of wind/solar hybrid system at the given locations. Taftan has the lowest NPC as compared to the other places as this site has the lot of potential of wind energy. Technically wind energy is more suitable as compared to solar because operating hours of wind energy are much higher than solar operating hours. Malam Jabba and Kakul have also much better efficiency of hybrid energy system. Areas with good wind speed decrease the overall NPC as compared to single source wind or solar system [7].

Summary

Right after presenting all the input factors in the modeling tool; the software is actually operated frequently to obtain the achievable outcomes. Optimization answers are shown by means of general as well as classified displaying probably the most achievable energy techniques structures that satisfies the load and also the input constrains created by the modeler. The actual achievable options tend to be introduced within a growing order of net present cost (NPC) through top to bottom. Different systems are analyzed with different wind speed inputs and different solar radiations at different sites. Hybrid systems (solar/wind) are suitable in areas where wind speed is higher than 4 m/sec due to higher price of wind turbine. Hybrid systems are more feasible than single source power system due to higher operating hours of wind turbine. In low wind speed areas where wind is lower than 3.5 m/sec these systems are not suitable due to lower capacity factor of wind turbine. Higher price of wind turbine and higher operating and maintenance cost of the wind turbine make it non feasible for low wind speed areas. While on the other hand solar has low operating hours and very low operation and maintenance cost which made it more cost effective.

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CHAPTER 5

Conclusion and Recommendations

Conclusion

This particular thesis function is actually dedicated to design a good off-grid and main grid linked alternative hybrid system with regard to household customers within countryside along with city. Rural places electrification is currently and can stay difficult project with regard to developing nations such as Pakistan. To satisfy the power dependence on area hybridizing power technology may accommodate as long-term options. In case due-merit has towards the electrical power deficiency of the nation, it might have a determining role within the enhancement associated with living high quality from the local community residing in the agricultural places simultaneously it will likewise enhance the high quality associated with education, decrease fire wood farming and also in house pollution, using all of this in to factors this particular more expensive must not be considered an issue. Therefore, the actual execution associated with some other power resources such as photo voltaic and wind power energy techniques may raise the actual country's electrical power shortage.

Throughout the design of the actual off-grid system set-up it had been carried out an optimization procedure in line with the electrical power load, weather data resources, and the economics from the energy elements where the NPC needs to be decreased to pick a fiscal achievable energy system. HOMER simulation outcome shown probably the most affordable and achievable systems categorized through NPC through best in order to straight decreasing way. The top hybrid system rated very first at D.G.Khan has solar fraction of 48% while the grid purchases in this system are 52%. System contains 2 kW of solar Modules and a utility grid. The second system is wind and solar hybrid system which has 43% solar fraction, 16% wind fraction and 41% grid purchases. This system contains 2 kW Solar PV and 1 kW wind turbine and utility grid. The total NPC for the P/Grid/Gen is $ 11,063 and total NPC for second one is $ 13,320. Wind/Grid/Gen is not feasible power system for this location due to lower wind speed, higher O$M cost of wind turbine and lower wind speed make it unfeasible for the location.

Analysis of Off-Grid system design for D.G.Khan shows that PV/Wind/Battery system is most feasible system as compared to any single source system. It decrease the charging discharging cycle of battery bank and also prolong batteries life. Size of battery bank decreases due to hybrid system, system contains 2 kW of solar PV and 1 kW wind turbine. Solar fraction in the system is 70% and wind contributes 30 % in the system. Total NPC for the system is $ 12489 and COE is $ 0.132/kWh. Second system for the location was PV/Battery stand alone system. Total NPC increases to $ 14269 due to increase in the solar modules as it increases to 4 kW. Cost of energy for this system is $ 0.133/kWh. After comparing all these systems at the site PV/Grid is most suitable and feasible system for the location.

Climate of Kakul is much different from the above given location D.G.Khan. Solar radiations at Kakul are less than the previous location and the average wind speed for the Kakul is much batter then D.G.Khan. Average wind speed at Kakul is about 5 m/sec and operating hours of wind turbine are also higher. Electrical production at this site is different than previous one. Due to difference in resources availability and density capacity factor may also change. Higher wind speed availability increases the capacity factor of wind turbine while lower solar radiation may decrease the capacity factor of solar PV modules.

Analysis of Grid connected system show that PV/Wind/Grid system is most feasible system as compared to PV/Grid or Wind/Grid system. In PV/Wind/Grid system solar fraction is 37% and wind fraction is 28%, while grid purchases are 35%. Total NPC of the system is $ 10,927 and COE of the system is $ 0.06/kWh. Analysis of the second feasible system shows that PV/Grid is second most feasible system in which solar fraction is 48% and grid purchases are 52%. Total NPC of the system is $ 11,954 and COE of the system is $ 0.079/kWh. Again the Wind/Grid is not feasible system due to higher O&M cost of wind turbine.

Analysis of off-grid system shows that Wind/Battery system is most feasible system as compared to PV/Battery or PV/Wind/Battery system. In Wind/Battery system wind fraction is 100%. Total NPC of the system is $ 12,078 and COE of the system is $0.142/kWh. Analysis of the second feasible system shows that PV/Wind/Battery is second most feasible system in which solar fraction is 57% and wind fraction are 43%. Total NPC of the system is $ 12,432 and COE of the system is $ 0.121/kWh. In this off-grid category PV/Battery is not feasible system due to lower solar radiation and shorter sun shine hours.

Therefore various designs had been acquired; nevertheless the choice might be carried out by providing because of focus on each evaluation variables individually. The outcomes revealed which numerous achievable hybrid system setups with various efforts created by renewable fractions.

Sensitivity evaluation had been additionally carried out for the systems, 4 sensitivity instances had been utilized for example; 6 values associated with PV size, four instances associated with wind turbine size , 2 instances associated with tower height and 2 instances associated with PV tilt angle. The actual sensitivity evaluation revealed which nearly exactly the same settings had been acquired other than in certain situation there was slight change in size and dimension modify from the elements.

Individually, wind and the solar power work can be used to energize a house or perhaps an industry however could be restricted because of insufficient sunlight or perhaps an unexpected change within the velocity of wind. Utilizing a hybrid of these types will certainly offer a steady power outcome in order to energize your house or even an industry. Analysis shows that on-grid hybrid systems are more reliable than off grid systems. Off grid systems main drawback is their initial cost and maintenance cost. In off-grid systems the panel's size increases or wind turbine with higher power is required. So that system will produce enough excess power to charge battery bank. Particularly in Pakistan temperature is the main factor which reduces the battery life, this factor cause inflation or periodic change and maintenance of battery bank. Second drawback for standalone hybrid system is payback period, due to higher operation and maintenance cost of the wind turbine and periodic change of batteries extends the payback period for the system. On the other hand grid connected hybrid systems are less expensive, more reliable, and have shorter payback period. Net metering can make this system more reliable and attract investors to invest in these systems on small scale to produce money through selling energy to national grid.

Recommendations

Different sites of Pakistan have lot of renewable resources which can be harvested. Resources availability changes from one location to other according to its latitude and climatic conditions of the site. To enhance the power insufficiency in nationwide and on the provincial level, main grid or grid connected systems and off-grid power

technologies techniques needs to be advertised, utilizing various systems such as subsidized system by government. By strengthening the agricultural communities' earnings to develop renewable systems which produced electrical power buying energy can also is basic. In case attention should be given to land degradation, environment air pollution and bad residing standard from the rural local community, alternative resources hybrid energy system should be promoted to raise their standard, nevertheless the present electrification tendency of Pakistan's federal government is through building big hydropower dam and in some way available wind energy facilities. In addition within an uncommon situation photovoltaic stand alone systems for separate houses are also installed but main drawback of these systems are their reliability and durability. Therefore hybridizing associated with wind energy and solar photo voltaic should be promoted because of price, durability and clean energy as compared to fossil fuels and hybrid system can give a 24 hour high quality electrical power.

Future Work Suggestions

- Evaluating the present research along with main grid expansion and solar heating system rather than PHOTOVOLTAIC.
- The desired location or site can be analyzed for different hybrid systems according to availability of resources (e.g. Biomass, Micro Hydro, Fuel Cell etc.).
- Research can be extended to storage technology it might be Hydrogen Storage, Fly Wheel Storage and Batteries.
- Analysis of medium scale or large scale on-grid hybrid (wind/Solar) system with net metering can attract investors.
- Sites in Pakistan can be analyzed with any combination of hybrid system to recommend complete renewable power package zone for industries.

Annexture I

Techno-Economic Analysis of Hybrid System (PV/Wind/Diesel Generator/Grid) for Domestic Consumers in Balochistan (Nokkundi & Ormara)

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Abstract: This paper aims to focus on technical and economical analysis of small scale wind/solar hybrid system for domestic consumers. The analysis is carried out on HOMER II simulation software. Pakistan is one of those developing countries which are encountered with severe energy crises. The purpose of this paper is to introduce a technically and economically feasible system to meet the domestic consumer's demand, as well as contribute to the central grid. HOMER Energy software is used to analyze different systems and to obtain the most reliable and feasible system for the customer. Simulation was carried out to find an economically and technically feasible system. Sensitivity analysis was carried out with hub height, PV De-rating factor, PV life, Wind turbine life. Change in hub height drastically affected energy production and economic prospect as the main factors of the system. Implementing such type of small hybrid systems on domestic level can be truly helpful to overcome energy shortage.

1. Introduction

Alternative energies are receiving growing attention these days. Rapid depletion of conventional fuels and change in climate divert scientists' attention towards renewable energies. In the region of single-family villas with facility to consume electricity, solar/wind hybrid generating system is the preferred way in generating electricity with the additional benefits of environmental protection combined with energy savings (W. Jinggang *et al.*, 2009). The study of the hybrid systems is based on the logistic type numerical models implemented in the HOMER (Hybrid Optimization Model for Electric Renewable) software developed by National Renewable Energy Laboratory (NREL), Colorado, USA (Moniruzzaman, 2012). This paper addresses the hybrid renewable energy system at a small scale. The

advancement in small scale wind turbine makes it more attractive and viable. The renewable power along with traditional energy producing technologies could be modeled via HOMER. Visual outcomes helps to determine the marketplace possibilities and also the obstacles simultaneously for every micro power technologies (Lal *et al.*, 2011). Solar PV and battery backup are commonly used by domestic consumers in case of grid supply outages. Many private companies are working in Pakistan for solar PV installation, but major problem in this sector is lack of skilled man power and cost. Hybrid system (solar PV/Wind) is not in practice in Pakistan. Proper calculations and simulation on the site are likely to reveal that hybrid system is far better than single source system. Moreover wind energy availability along with solar energy can make the system more reliable with comparatively more efficient performance. As a matter of fact solar irradiance duration is short that may last 5 to 7 hours. So combining both the solar and the wind energy ensures its reliability and durability. Capital cost for renewable energy system is a main hurdle in developing countries especially like Pakistan (Islam *et al.*, 2013). A hybrid (PV/wind/fuel cell) system was analyzed on HOMER software. Fuzzy logic power controller was proposed to provide uninterrupted power supply in remote areas applications. Conclusion was made that these renewable hybrid systems are viable solution for remote distributed generations (Alam *et al.* , 2007) [5]. Techno-economic feasibility study of autonomous hybrid wind/PV/battery power system for a household in Urumqi china shows that the 5 kW of PV array, 2.5 kW of wind turbine and 8 units of batteries each having 6.94 kWh hybrid (wind/PV/Battery) system shows 9% and 11% decline in total NPC as compared to PV/battery and wind/battery respectively (Chong Li *et al.* , 2013) [7]. Assessment of economic viability for PV/wind/diesel hybrid energy system in southern peninsular Malaysia shows seven different configurations analysis but PV-wind-diesel hybrid system with and without battery system were studied and analyzed in detail. Conclusion shows that diesel stand alone system at the site is viable due to low cost of fuel and low wind speed but emits higher CO_2 amount (Mei *et al.* , 2012) [8]. Techno-economic analysis of photovoltaic wind hybrid system for onshore/remote areas in Indonesia shows the production of wind turbine and PV array of same size on the site. Wind turbine shows the capacity to produce 496 kWh/yr and PV array has 2079 kWh/yr. Conclusion indicates that wind and battery are important for load demand at night (Ayong Hiendro *et al. , 2013*) [9]. Techno-economical analysis of stand-alone hybrid

renewable power system for Ras Musherib in United Arab Emirates shows the hybrid (PV/Wind/Battery/Diesel) evaluation results. Hybrid system was evaluate to meet the load demand of 250, 500, 2500 households. Different combination of hybrid systems were analyzed to obtained an optimum system on the basis of total NPC. Analysis shows that system with 30% wind penetration and 15% PV penetration is the most optimal one for 500 kW household load (Gulbarg *et al.* , 2013)[10]. This paper presents the comparison of the outcomes of two different places with different wind speed and solar irradiance for the same system. Nokkundi is a plain while Ormara is a coastal area of Balochistan. Solar irradiance and wind speed data is taken from NASA SSE (Surface meteorology and Solar Energy. The area with higher wind speed comparatively has low operating and levelized cost for the same system installed at both sites. Levilized cost of the system for Ormara is $ 0.078/kWh and for Nokkundi it is $0.087/kWh. The operating cost for Ormara and Nokkundi are $ 191/year and $ 246/year respectively. Total NPC (Net Present Cost) for Ormara is $ 14,508 and for Nok Kundi is $15,872.

If we install single source (Solar PV) system instead of hybrid system then the capital cost will be much higher because solar PV needs much bigger size for the same duty and due to limited sunshine hours. The latitude and longitude for Ormara and Nok kundi are 25.2147° N, 64.6339° E and 28.8167° N, 62.7667° E respectively. Average daily solar radiation for Ormara is 5.03 kWh/m²/day and for Nok Kundi it is 5.457 kWh/m²/day. The present system is designed for the domestic load of 3.117 kW. Domestic load increases during summer season in Pakistan. Monthly average wind speed for Ormara is 3.69 m/s at 2 meter height from the surface and for Nok Kundi it is 5.91 m/s at 10 meter height from earth's surface.

2.0- System Description

2.1- Primary Load:

Load is the basic requirement to design the system. Load can be categorized as Industrial or Residential. The major concern of this research article is about the domestic or residential load. Residential load may contain different domestic appliances. The appliances for a domestic load that are considered are Ceiling fan, Fluorescent bulb, Washing machine, Microwave oven, Television, Laptop, Mobile chargers and Iron press. Total load of 3.117 kW is considered for a house. Peak load of the system changes with the season. In summer there is maximum peak load from

May to June. Annual average peak load is 2.94 kW and annual average energy is 13.1 kWh/d and the load factor for the system is 0.186. Daily load profile of the system is given below.

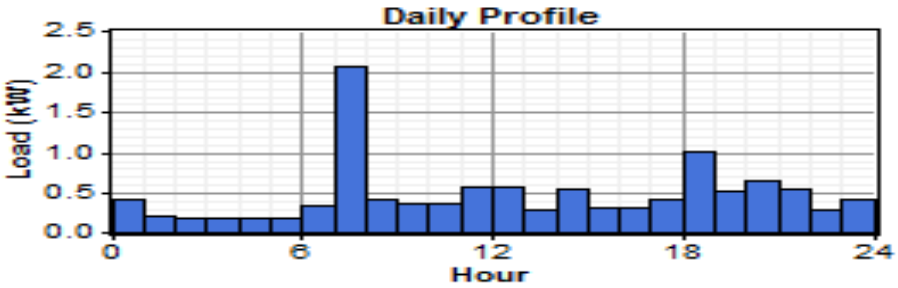

Figure 1: Daily Load profile

Figure 1 shows the typical daily profile of the load in kilowatt. The load profile describes the load distribution over 24 hours. If we look at the daily profile, the peak load is a round 7:00 AM, which increases after 6:00 PM.

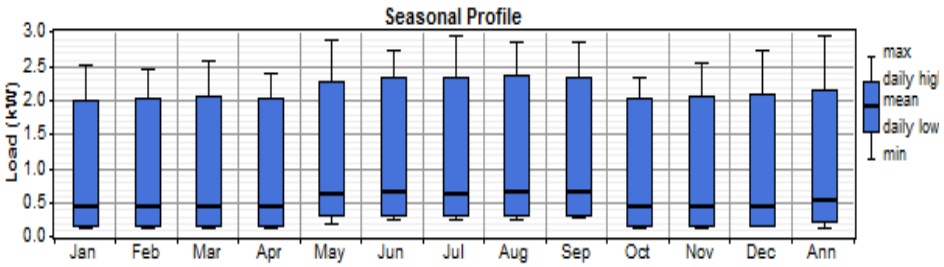

Figure 2: Seasonal variation in load

Figure 2 indicates the seasonal variation of load. Lot of energy is used in Pakistan in summer to overcome heat from the residential buildings. Figure 2 clearly indicates the increase in load during summer from May – August. On the other hand, both wind availability and solar radiation increases during summer.

2.2- PV Source:

Average daily solar radiation in Pakistan is much better and quite suitable for solar energy utilization but temperature is the main factor which reduces the efficiency of solar PV module. In summer maximum temperature goes up to 50º C. PV modules are temperature sensitive as with temperature increase beyond its nominal cell temperature, efficiency of solar photo voltaic decreases.

Month	Clearness Index	Daily Radiation (kWh/m²/d)	Month	Clearness Index	Daily Radiation (kWh/m²/d)
January	0.459	3.084	July	0.595	6.604
February	0.499	3.915	August	0.540	5.719
March	0.520	4.803	September	0.576	5.527
April	0.571	5.946	October	0.559	4.596
May	0.627	6.928	November	0.494	3.432
June	0.636	7.142	December	0.405	2.570

Table 9: Monthly average solar radiation for Ormara

Table 1 shows the monthly average daily solar radiation and clearness index of Ormara for the 12 months. Solar radiations vary with the season and depend upon climatic condition of the area. Table 1 indicates that solar radiations are higher in May and June.

Month	Clearness Index	Daily Radiation (kWh/m²/d)	Month	Clearness Index	Daily Radiation (kWh/m²/d)
January	0.614	3.830	July	0.607	6.790
February	0.620	4.610	August	0.613	6.470
March	0.584	5.230	September	0.640	6.010
April	0.607	6.250	October	0.641	5.040
May	0.610	6.760	November	0.622	4.040
June	0.617	7.000	December	0.584	3.420

Table 10: Monthly average solar radiation for Nok Kundi.

Table 2 shows the monthly average daily solar radiation and clearness index of Nok Kundi for the 12 months. Average radiations are higher during June and July.

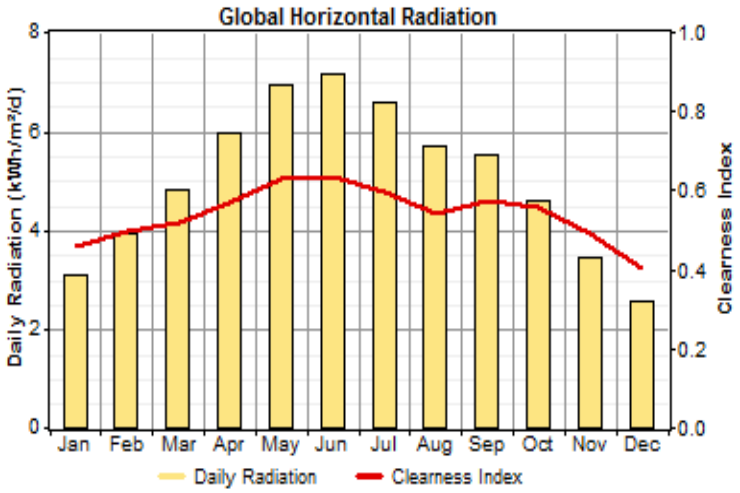

Figure 3: Ormara Global Horizontal Radiation

Figure 3 shows the global horizontal solar radiation at Ormara. Graphical representation of horizontal radiation is shown in the figure. Red line indicates the clearness index of solar radiation.

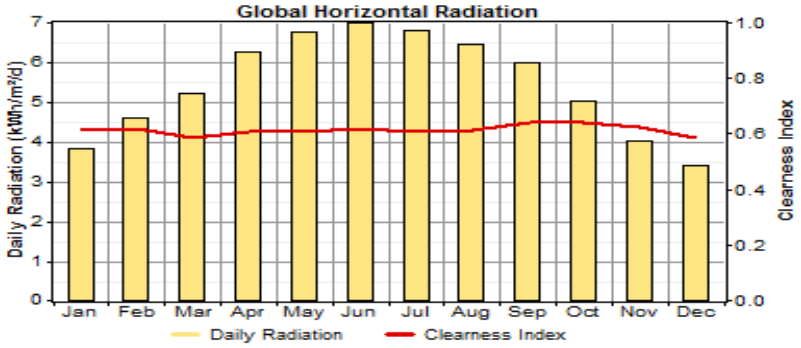

Figure 4: Nok Kundi Global Horizontal Radiation

Figure 4 shows the global horizontal solar radiation at Nok Kundi.

NASA SSE (Surface meteorology and Solar Energy) data are used for analysis of the system. According to the above tables and figures it is obvious that radiation in Nok Kundi is higher than Ormara. Scaled annual average radiations for Nok Kundi are 5.45704kWh/m²/d and for Ormara it is 5.03 kWh/m²/d. Solar PV of 1 kW with the efficiency of 17 % is considered for the system having cost of $ 914 and replacement cost of $ 800. Annual operation and maintenance cost of $ 10/yr is considered. Life time and derating factors (%) have sensitive inputs.

2.3- Wind Resource:

Much study has been carried out on wind turbines that have been reported in the literature [4]. Sites Ormara and Nok Kundi, reside in the wind corridor, thus are the ideal places for wind energy harvesting. Being a coastal site Ormara has good wind

potential as compared to Nok Kundi. According to PMD (Pakistan Metrological Department) Ormara wind speed taken from installed equipment at 2 meter height from sea level is given in the graph [6].

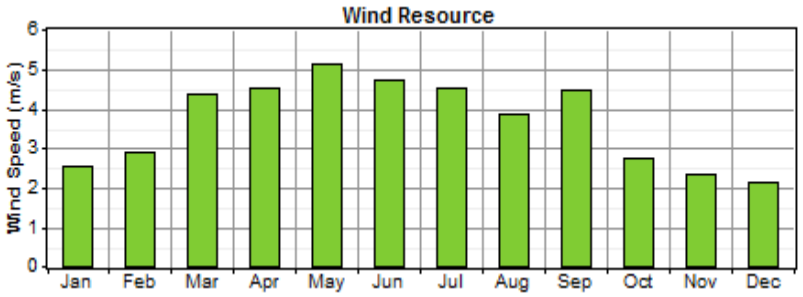

Figure 5: Graphical representation of wind speed at Ormara.

Figure 5 shows monthly average wind speed for Ormara. Above figures indicate that highest wind speed occurs in the month of May.

Month	Wind Speed (m/s)	Month	Wind Speed (m/s)
January	2.520	July	4.500
February	2.880	August	3.880
March	4.380	September	4.480
April	4.510	October	2.740
May	5.120	November	2.350
June	4.750	December	2.160

Table. 3: Wind speed of Ormara 1

Table 3 shows the numerical values of wind speed at Ormara. Wind speed vary from January to December. It is higher during summer season. Scaled annual average wind speed for Ormara is 3.69 m/s.

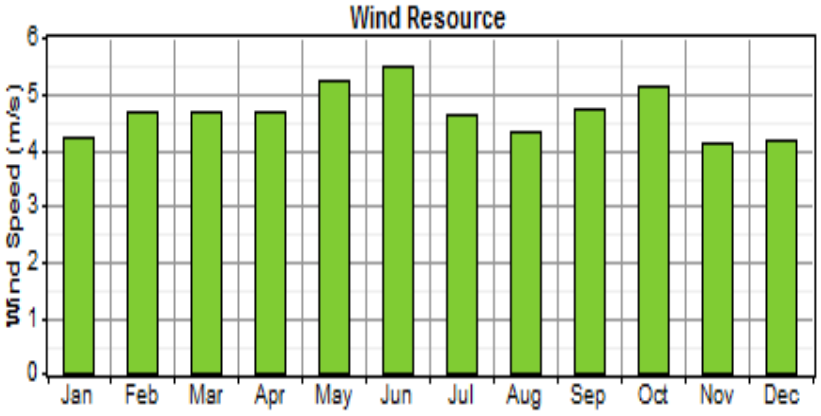

Figure 6: Graphical representation of wind speed at Nokkundi

Figure 6 shows the wind speed variation over twelve months. Monthly average wind speed varies from January to December. The highest wind speed is in the month of June.

Month	Wind Speed (m/s)	Month	Wind Speed (m/s)
January	4.200	July	4.610
February	4.680	August	4.300
March	4.660	September	4.720
April	4.680	October	5.130
May	5.260	November	4.120
June	5.500	December	4.190

Table 4: Wind Speed at Nok Kundi

Table 4 shows the numerical data of the wind speed at Nok Kundi. Average wind speed is higher in May, June, and October.

The wind speed is taken at 10 meter height above the ground. Scaled annual average wind speed for Nok Kundi is 4.67 m/s. Bergey Excel BWXL 1 kW DC wind turbines are used for simulation of hybrid system. Capital cost of $4000 is considered and replacement cost of $3500. Two wind turbines are taken for the simulation. Hub height and life time of wind turbine are 25 meter and 25 years respectively.

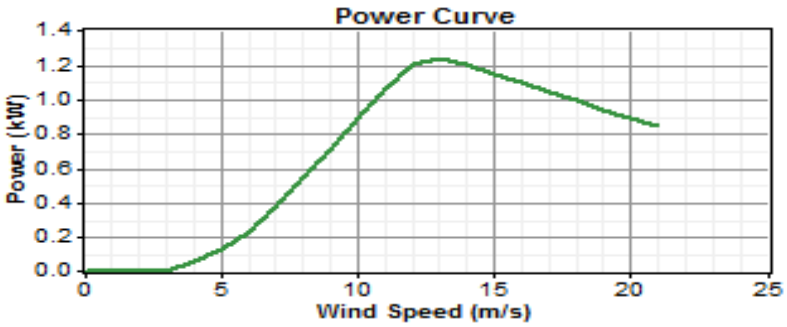

Figure 7: Power Curve of BWXL 1 kW

Figure 7 shows the power curve of the bergey excel 1 kW wind turbine. Its cut in speed is 2.5 m/s (5.6 mph) [7].

2.4- Diesel Generator:

Diesel generator rated of 2 kW is considered as a backup for the system. Commercially available 2 kW Diesel Generator cost is $ 456 and Operation and maintenance cost for the generator is $ 0.30/hr. Diesel fuel price is taken as sensitive input; price is taken from GOP official figures $1.1 to $ 1.25.

2.5- Converter (AC to DC):

Inverter is considered according to the load. Inverter with the rating of 3 kW is considered for the simulation. Cost of the inverter is $ 810 and operation and maintenance cost is $ 10/yr.

3.0- Simulated Hybrid System:

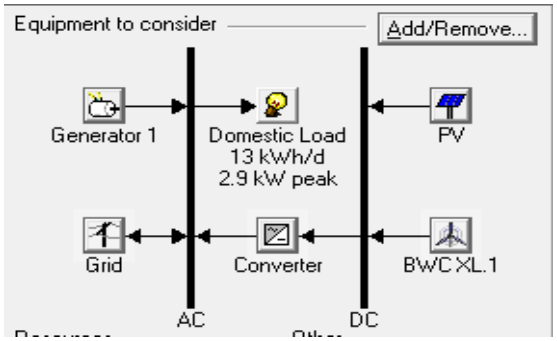

Figure 8: Components of proposed Hybrid System

Figure 8 shows schematic diagram of the model. The model contains 1 kW PV array having cost of $ 914 with the replacement of $ 800 Bergey Excel 1 kW wind turbine having cost of $ 4000 and replacement of $ 3500. Converter of 3 kW with the price of $ 810 and domestic load with the peak of 2.9 kW is considered for the simulation.

3.1- Cash Flow Diagrams:

Nok Kundi and Ormara differ with solar radiations and wind speed. If we look at the outcomes on both sites there is a difference in the output.

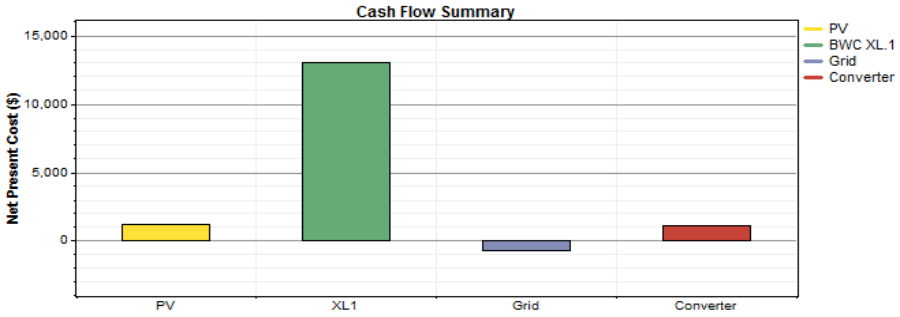

Figure 9: Cash flow summary of Ormara

Figure 9 shows the cash flow summary of Ormara. Levelized cost of energy for Omara is $0.078/kWh as deducted from the output and operating cost is $ 191/yr. Total NPC (Net Present Cost) for the system in Ormara is $ 14,508.

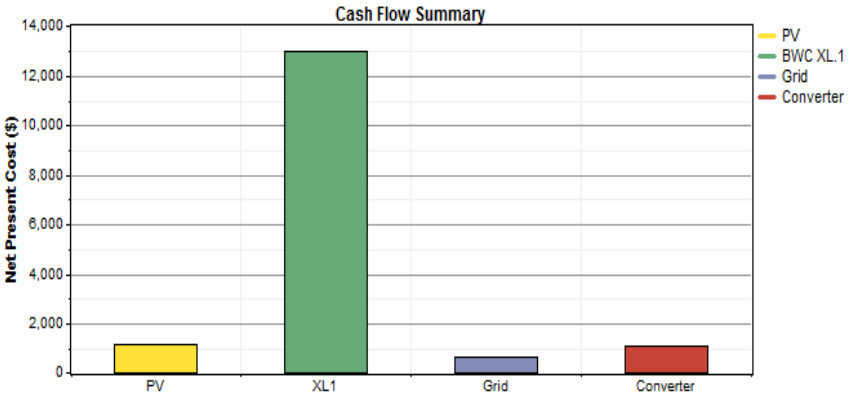

Figure 10: Cash flow summary of Nuk Kundi

Figure 10 shows the cash flow summary of Nok Kundi. Total NPC of the system in Nok Kundi is $ 15,872; levelized COE is $ 0.087/kWh as deducted from the output. Operating cost of the system in Nok Kundi is $ 246/yr.

3.2- Electrical Production:

Production	kWh/yr	%
PV Array	1410	16
Wind Turbine	4705	52
Grid Purchases	2868	32
Total	8984	100

Table 11: Electrical production at Ormara

Table 5 shows the electricity production of individual resource at Ormara. Higher electricity is produced from wind turbine. PV array contribution is 16%. Grid purchases are 32% at Ormara.

Production	kWh/yr	%
PV Array	1625	19
Wind Turbine	4145	47
Grid Purchases	2995	34
Total	8765	100

Table 12: Electrical production at Nok Kundi

Table 6 shows production of electricity by each source. Energy produced by wind turbine is higher than other available resources. PV array contribution is 19% and grid purchases are 34%.

Above given tables of electrical production shows the difference between both sites. Wind energy production is higher at both sites between all individual resources. As Ormara is a coastal area that's why electrical production through wind energy is

higher than that Nok Kundi. On the other hand solar radiation at Nok Kundi is higher than that of Ormara, Hence production through PV is higher at Nok Kundi. Capacity factor for both the sites is different. Capacity factor for PV at Nok Kundi and Ormara is 18.6 % and 16.1 % respectively. On the other hand wind turbines capacity factor at Ormara is higher than Nok Kundi. Capacity factor of wind turbine at Ormara is 26.9 % and for Nok Kundi it is 23.7 %.

3.3- Monthly Average Electricity Production:

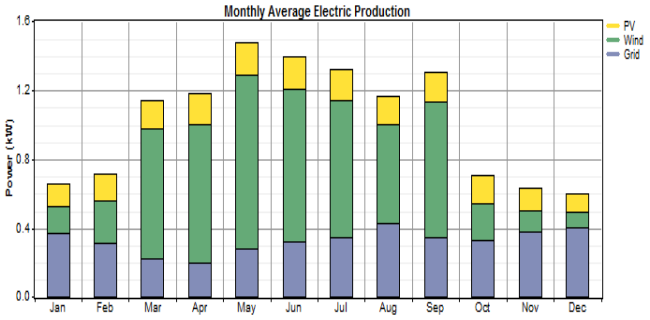

Figure 11: Monthly Average Electric Production of Ormara

Figure 11 shows monthly average production of electricity by individual resources at Ormara.

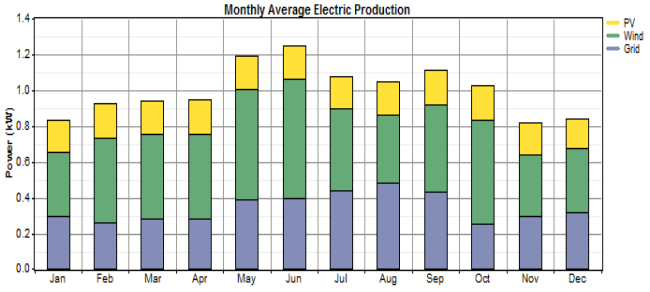

Figure 12: Monthly Average Electric Production of Nuk Kundi

Figure 12 shows monthly average production of electricity by individual resources at Nok Kundi.

4- Conclusion:

After analyzing both systems keenly it is easy to come up with the conclusion that wind energy is more reliable and feasible for the hybrid system. Ormara is coastal area and has higher wind potential which makes it more feasible hybrid system. Nok Kundi has higher solar radiation than Ormara but solar PV is less effective as compared to wind. According to the electric production grid purchase at Ormara is less as compared to Nok Kundi. Also the levelized COE, total NPC, and operating cost of the system at Ormara are much less than Nok Kundi. Modeling of this hybrid system clearly shows that this system is much better than single source system. It is a

significant fact that cost and concern of energy produced by fossil fuels is regularly growing due to increasing cost of fuel and depleting resources. Integration of renewable energy resources with the conventional power grid system attracted noteworthy attention from the researchers worldwide to alleviate the immense demand of energy in the world. The simulation was performed to utilize the wind energy and solar radiation to trim down the reliance on fossil fuel for power generation to fulfill the energy demand for a small house [8].

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