Optimization of Cost Analysis of Mini-Grid Hybrid Power System Using HOMER Software

A report presented in partial fulfillment of the requirements for the degree of Bachelor of science in Electrical and Electronics Engineering(EEE)

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December 2018

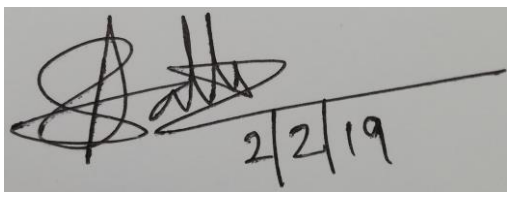
PREFACE

The Thesis Title

Optimization of cost analysis of Mini-Grid hybrid Power System Using HOMER Software

Done Under my supervision,meets acceptable Presentation Standard and can be Submitted by **Md.Abdul Kahar** (ID:151-33-2380) and **Jannatul jenan** (ID:151-33-2317) has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronics Engineering(EEE) on December,2018.

APPROVAL OF THE SUPERVISOR



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Dedication

Our Parents

ACKNOWLEDGEMENT

First we express our heartiest thanks and gratefulness to almighty Allah for his divine blessing makes us possible to complete this thesis successfully. We feel grateful to and wish our profound our indebtedness to Supervisor **Mr. Md. Dara Abdus Satter**,Assistant Professor & Associate Head,Department of EEE Daffodil International University, Dhaka. Deep knowledge & keen interest of our supervisor in the field of Electric power influenced us to carry out this thesis. His endless patience, scholarly guidance, continual encouragement, constant and energetic supervision, constructive criticism, valuable advice at all stage made it possible to complete this thesis.We would like to thank our entire course mate in Daffodil International University, who took part in this discuss while completing the course work.We would like to express our heartiest gratitude to the Assistant Head, Department of EEE, for his kind help to finish our Thesis and also to other faculty member and the staff of EEE department of Daffodil International University.

ABSTRACT

As a developing country, Now focused on renewable energy. Especially Wind energy because this energy source great potential opportunity in power sector. For decentralized or remote areas, where grid connection is almost not possible, renewable energy generation system coupled with diesel engines can be a reliable and optimized source of energy. Bangladesh has to deal with the increasing demand of electricity.The reduced costs of renewable energy technology and improved efficiency and reliability.The techno-economic analysis of the optimal off-grid system modelling is using HOMER software.There are energy resources are considered,Mainly Wind energy beside solar energy and Diesel fuel.In this study,a cost effective mini-grid power station modelling of Wind-Solar-Diesel hybrid power system in a coastal area of Patenga.The main focused of this proposed optimized design is to supply the maximum load demand using renewable energy sources with the minimum cost of energy (COE).Global warming is an alerming issue in todays world. So,We see reduce the burning of fuel and also reduced the emission of Carbon-dioxide. Here, HOMER is used to examine the most cost effective configurations among a set of systems for electricity requirement of 80KWh/day primary load with 18KW peak load.The COE is $0.196/KWh.

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LIST OF ABBREVIATION

DG	Diesel Generator
PV	Photovoltaic
WT	Wind Turbine
COE	Cost of Electricity
NPC	Net Present Cost
UNFCC	United Nations Framework Convention on Climate Change
CDM	Clean Development Mechanism
SREDA	Sustainable & Renewable Energy Development Authority
JICA	Japan International Cooperation Agency
SHSs	Scale of solar home systems
TNPC	Total net present cost

CHAPTER 1

INTRODUCTION

1.1 Background of study

Bangladesh is a vast populated country. About 180 million people are living in this country. To Fulfill the huge amount of people need huge amount of energy. Energy is one of the most important basic ingredients required to alleviate poverty and to bring about socio-economic development of a country. Fossil fuel, sunlight, air, water source and nuclear power plant are the sources of energy throughout the world. Major energy source is still fossil fuel but the reserve is declining. Fossil fuel is being used though it emits greenhouse gases for global warming which is a threat to climate change and sustainable development. In this situation sustainable and secure energy are the major concern worldwide. Under these circumstances there is a transition underway in the energy sector. In our Bangladesh -

• Only 59.6% of its 180 million people have access to electricity. In rural areas, where more than 70% of the population lives, only 42% have access to electricity

- A mere 6% of the entire population has access to natural gas, primarily in urban areas
- Electricity supply is not reliable and peak demand cannot be met
- Substantial amount of energy is used inefficiently
- Most people in the rural areas depend on kerosene lamps for light
- 90% of all Bangladeshis cook with biomass, such as rice straw, dried leaves, jute sticks,cow dung, or wood.

It can be happening due to fall in fossil fuel access, reduction of global emissions pertaining to mitigating climate change along with energy security. Under the changed standpoint renewable energy specially solar panel technology is becoming popular correctly significance in contribution for you to global climate change along with carbon trading prospect. United nations Framework Convention on Climate Change (UNFCC) has taken initiative for Clean Development Mechanism (CDM). In this specific context, solar energy is turning out to be widespread source of energy all over the world. To meet the expanding demand for power inside industries, transportation and household employ many developed countries are actually using solar energy while renewable sources. This it isn't just meeting the bigger area of energy demand but in addition providing significant socio-economic benefit and making an effort to

maintain clean environment. Except for individual renewable sources sometimes it is going to never be reliable for continuous power. Grid connected hybrid system will be more feasible to deliver ongoing power. Wind and solar include the two renewable sources pertaining to hybrid system. When an example may be not in operation, various other can contribute. Renewable energy resources are unlimited and yes it will never be concluded. So we need maximum using those enormous amounts of one's.

Mini-grid hybrid system is more popular way to use exactly what of renewable energy. There are several mini-grid system in Bangladesh by now exists. But this grid only is determined by the solar energy. Sometimes it's almost no cost effective. Our study is essentially for mini-grid hybrid sun wind system [1].

1.2 Introduction of Mini-grid Hybrid System

1.2.1 What is mini grid?

A mini-grid, also sometimes termed as a micro-grid or singled out grid, is an off-grid system that needs small-scale electricity generation. A micro grid is often a small-scale power grid which could operate independently or collaboratively using other small power grids. The practice of using micro grids is termed distributed, dispersed, decentralized, section or embedded energy generation.

Micro grids are normally supported by generators as well as renewable wind and solar panel technology resources and can be used to provide backup power or supplement the principle power grid during times of heavy demand. A micro grid tactic that integrates local breeze or solar resources offers redundancy for essential services and make the principle grid less susceptible for you to localized disaster.

Buildings pre-loaded with electric generation capabilities through solar power systems and contingency generators could also generate energy and profits during downtime. By joining in addition to smart grid deployments, excess energy can be sold time for local micro grids to create revenue besides providing resilience and potential to local electrical grids.

1.2.2 What is a mini hybrid grid?

Mini grids basically contain one source. Solar system is basically used as mini grid mostly. But when two or more renewable sources are together, called hybrid mini grid system. This is the most efficient way for any renewable sources for rural electrification. Hybrid mini grid system

can be solar PV and hydro, Solar PV and wind, Solar PV and biomass and hydro, Solar PV and biomass and wind, solar PV and wind and biomass and also Generator as backup source etc.

1.3 Types of Hybrid mini-grid system

There are many types mini hybrid system for different purposes.

- Campus Environment/Institutional Micro-grid hybrid system
- Remote "Off-grid" Micro-grid hybrid system
- Military Base Micro-grid hybrid system
- Commercial and Industrial (C&I) Micro-grid hybrid system
- Community/Utility Micro-grid hybrid system
- Micro-grid projects hybrid system
- Necessity and Drivers of Micro-grid hybrid system
- Micro-grid-enabling Technologies hybrid system

Our study is basically for Remote area 'Off-grid' hybrid system. Our work basically based on the location of remote village situated in the Chittagong district at Potenga.

1.4 Remote "Off-grid" Micro-grid hybrid system

These Micro-grids never get connected to the Macro grid and instead operate within the island mode continually. Examples of this style of Micro-grid includes the out of the way area power systems with Alaska or on islands that usually include diesels - or wind generation just as Nome, Alaska - which might be interconnected and provide power to the local geography. BC Hydro is working away at a project in Bella Coola, British Columbia where an off-grid Micro-grid is it being developed with with regards to reducing diesel fuel by means of integrating solar photovoltaic (PV), spread wind, and/or run-of-the riv hydropower.

According to Pike Exploration this category represents the best number of current deployments off Micro-grid; however, area power systems represent budget friendly average capacity.

1.5 Statement of Problem

For Mini grid hybrid system to minimize the cost is the most important point. For only mini grids system sometimes it's tough to support or fulfill all the demand for any rural electricity needs. For solar mini grid-Sometimes weather condition not much suitable for only one source dependent off-grid system. Sometimes battery cannot be charge well when the irradiation is too low or when rainy day or in night. So we need more efficient way to solve the problem. To

solve the problem Hybrid mini off-grid system is the best way. For hybrid system contains solar , wind and also generator as backup system.

There is also some problem that should be minimized. The most important problem is high cost. So our study also shows the cost analysis of the hybrid system mini off grid. For any renewable sources cost is the most important thing.

1.6 Objectives

- To know about present renewable condition for Bangladesh.
- To know about the HOMER
- To design an effective hybrid mini off-grid system
- To calculate or optimize the cost form the system

1.6.1 About HOMER

HOMER Energy LLC is a Boulder, Colorado based company incorporated in 2009 to commercialize the HOMER® Hybrid Optimization of Multiple Energy Resources (HOMER) model, which was developed by the National Renewable Energy Lab, a division of the U.S. Department of Energy. HOMER Energy's primary focus is the continuing development, distribution, and support of HOMER.

This HOMER Energy principles are working with economic in addition to engineering optimization of Micro-grid intended for over 2 decades. HOMER Energy’s workforce includes the economist in addition to engineer who originally designed the HOMER software though at NREL, along having professional managers, analysts along with business professionals with practical knowledge in entrepreneurial ventures, electric power systems, and renewable strength. Our collective vision is usually to empower people world wide with tools, services, and information as a way to accelerate the adoption connected with renewable and distributed strength sources.

1.6.2 Simulation

Simulation HOMER simulates your operation of a system by simply making energy balance calculations for every one of the 8, 760 hours in a very year. For each hours, HOMER compares the power and thermal load inside hour to the energy that this system can supply in this hour. For systems which include batteries or fuel-powered generation devices, HOMER also decides for each and every hour how to work the generators and no matter whether to charge or eliminate the batteries.

1.6.3 Optimization

After simulating each of the possible system configurations, HOMER displays a directory of feasible systems, sorted by simply lifecycle cost. We can easily obtain the least cost system presents itself the list, or you can scan the list pertaining to other feasible systems.

1.7 Outline Of the Study

Our study basically shows the cost optimization for hybrid mini off grid system. Designing a proper hybrid mini off-grid system is also a part of this study. Cost optimizing is basically the most important part for any projects. Everything depends on it. Sometimes project success depends on the cost. So our study contains a full hybrid system model by using HOMER software and also the cost analysis for this system.

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction

This paper presented comparative analysis between an off grid and a grid connected Hybrid power system. Grid connect hybrid (PV/Wind) system is more efficient and economic compared to the traditional Hybrid system. In the same load. As its result present cost of the proposed model is less than off grid model. Although off grid model needs extra-large battery bank [2]. It is not feasible to use only diesel as a source of energy generation nowadays. Hybrid energy system can be feasible and optimized solution in this regard (PV-Diesel-Wind-Battery Hybrid) [3]. The maximum wind power depends upon greatly on the wind velocity. Again the velocity is greatly depending upon the determine site location [4]. Result deduced by ABC algorithm have been compared with results obtained by software tool HOMER and PSO. The proposed algorithm proved better results as compared to HOMER and PSO [5]. Variable size of PV array, no. of Wind turbine, AC-DC Converter. They require minimum civil construction, small reservoir and considering all environment factor [6]. The effective effort maintaining the power supply reliability of renewable energy sources related to the combination of multiple power plants in different energy sources, namely is hybrid power system [7]. The rise of energy demands are increasing the dependence on renewable energy sources. It will also reduce the pressure on the national grid. Reduces the emission of gases and reasonable COE [8]. Technical configuration and business analysis case of a hybrid mini-grid system for a remote non-electrification village are considered [9]. Renewable resources hydropower, solar PV, wind, bio-diesel generator the paper identifies the optimal off-grid option and compares this with conventional grid extension. A hybrid combination of renewable energy at off grid location can be cost effective and sustainable, techno-economically viable and environmentally sound [10]. Different types of optimization techniques used in PV-Wind based hybrid energy system. The hybrid optimization techniques are found best than single optimization methods [11]. PV, Wind turbine, Diesel generator with battery and inverter system is also a very good alternative solution having little higher cost of electricity and net present cost. COE is higher than the cost grid electricity but environment protection [12]. Renewable energy source is better energy

source for cost reduction [13]. Main focus on grid and stand-alone mode operation of micro-grid. The model developed some variety of load those all connected to the grid through bidirectional converters to maintain the reliable and stable system under constant loads considered [14]. This paper study conventional and non-conventional energy resource for off grid system. Electricity generation due to the favorable daily average solar radiation which varies but diesel price is almost same. The diesel generation only situation would decrease the operating hours [15]. Bangladesh has great opportunity of wind energy at Various Location. This energy source will be the most cost effective source of electrical power in the near future. Bangladesh is looking for renewable energy sources to join the total power demand in country. Huge amount of wind energy in coastal line of 574km in Bangladesh. By 2020, possible to produce power more than 10% of the total power demand from renewable energy sources [16].

2.2 Mini-Grid of Hybrid power system

Hybrid power are combinations between different technologies to produce power. It contribute different types of energy sources, some PV sources, Wind sources, Diesel sources and Battery system for backup, converter. PV, Wind, Diesel Generator, Battery and Converter system is effective alternative solution than having little higher cost of electricity. This system optimization analysis of cost and Environment effect.

2.3 Summary

Day by day increase of electricity demand. That have to do search of alternative resource for produce in electricity.Likewise, Hybrid power system of mini grid is medium for electricity produced.Hybrid power system depend on conventional and non-conventional energy sources.Mini-grid hybrid power system analysis between an off grid and on grid system.Off grid hybrid power system design for remote location because grid connected is not possible.Day by day,Renewable energy based power plant will increased.Bangladesh has great opportunity of Solar Radiation, Wind Energy and Biogass etc.She has 724 km long coastline along the beautiful bay of bengal.This area we can get large amount of wind energy.Solar System, Wind Turbine system, Diesel Generator system and Battery System grid day by day increased.Renewable based electricity contributing in Grid system.That being decrease conventional based electricity produced.

CHAPTER 3

SITUATION OF BANGLADESH POWER SECTOR

3.1 Situation of Bangladesh power sector

Bangladesh is a Developing country-economically and socially in March, 2018.Bangladesh has achieved all the three conditions that were needed to be a developing country. Bangladesh is most densely populated nations because of its 180 Million people in a land mass of 147570 km. In 1971, just 3% of Bangladesh population had access to electricity. Today has increase of number of population for this increases demand of electricity.

Electricity Generation in the Country by 2013-8,500MW

Electricity Generation in the Country by 2015-11,500MW

Electricity is the major source of power for most of the country's economic activities. Bangladesh's total installed electricity generation capacity (including captive power) was 15,351 megawatts (MW) as of January 2017[17]. As 2015, 92% urban population and 67% rural population have the access to the electricity for their source of light. An average of 77.9% of the population have the access to electricity in Bangladesh [18]. Bangladesh will need an estimated 34,000 MW of power by 2030 to sustain its economic growth of over 7 percent [19]. Bangladesh has planned to produce 5% of total power generator By 2015& 10% by 2020 from Renewable energy Sources like air, waste & solar energy. In general, rapid industrialization and urbanization has propelled the increase in demand for energy by 10% per year. What further exacerbates Bangladesh’s energy problems is the fact the country’s power generation plants are dated and may need to be shut down sooner rather than later.

There was clearly no institutional framework regarding renewable energy before '08; therefore the renewable vitality policy was adopted from the government. According to the particular policy an institution, Sustainable & Renewable Energy Development Authority (SREDA), was being established as a center point for the promotion and also development of sustainable vitality, comparison of renewable vitality, energy efficiency and vitality conservation. Establishment of SREDA remains under process. Power division is always to facilitate the development regarding renewable energy until SREDA will be formed.

The last year or two, many success developed stories inside the Power Sector in Bangladesh. Yet, the road that is situated ahead is dotted together with innumerable challenges that be a consequence of the gaps that are present between what's planned versus what the energy sector has been capable of deliver. There is undoubtedly that the demand regarding electricity is increasing rapidly with all the improvement of living common, increase of agricultural creation, progress of industries along with overall development of the united states.

3.2 Present Structure of power sector

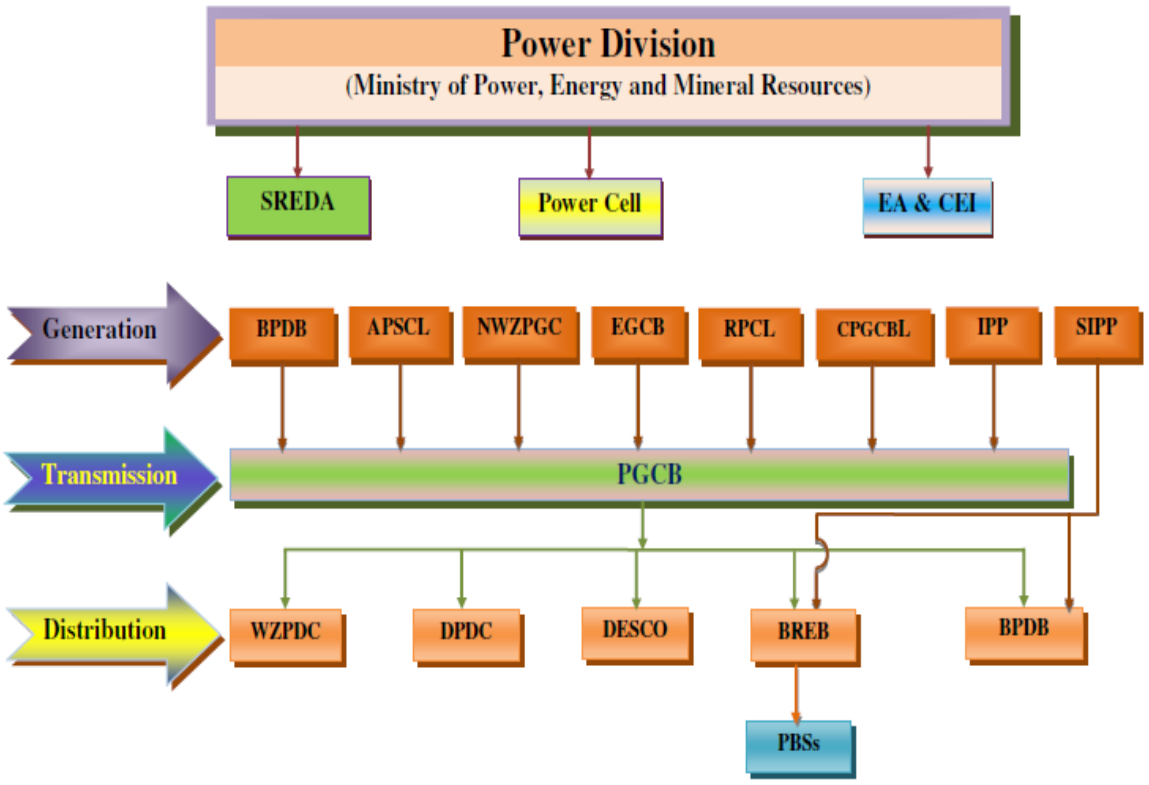


Figure 3.1: Present Structure of Power Sector

- **Top Institution**

  Power Division, Ministry of Power, Energy & Mineral Resources (MPEMR)

- **Generation**

  Bangladesh Power Development Board (BPDB)

  Ashuganj Power Station Company Ltd. (APSCL)

  Electricity Generation Company of Bangladesh (EGCB)

North West Power Generation Company Ltd. (NWPGCL)

Independent Power Producers (IPPs)

- **Transmission**

  Power Grid Company of Bangladesh (PGCB)

- **Distribution**

  Bangladesh Power Development Board (BPDB)

  Dhaka Power Distribution Company (DPDC)

  Dhaka Electric Supply Company Ltd. (DESCO)

  West Zone Power Distribution Company (WZPDC)

  Rural Electrification Board (REB) through Rural Co-operatives

3.3 Energy Sector

In 2018, Bangladesh has installed capacity in 20,000MW. Share of government financing 56% and Share of Private financing 46%.Electricity coverage 95% [20].Bangladesh has huge the possibility of power sector in produced electricity.Energy sector depends on a country of development. Bangladesh government has proposed 100% electricity reach in people.Now, electricity reach in 95% of people.This sector has contributed in private sector and government sector.Private sector are huge amount of electricity produced combination conventional and non-conventional energy.

3.3.1 Natural Gas

As of 2011, 79 natural gas wells are present in the 23 operational gas fields which produce over 2000 millions of cubic feet of gas per day (MMCFD). It is well short of over 2500 MMCFD that is demanded, a number which is growing by around 7% each year. In fact, more than three-quarters of the nation's commercial energy demand is being met by natural gas. This influential sector caters for around 40% of the power plant feedstock, 17% of industries, 15% captive power, 11% for domestic and household usage, another 11% for fertilizers, 5% in compressed natural gas (CNG) activities and 1% for commercial and agricultural uses.

In Bangladesh, Natural gas is used as primary energy in most of the existing power plants. Now 88% of total electricity is produced from gas- based power plants. Beside, gas a small amount of electricity is produced using diesel, furnace oil and coal.

3.3.2 Coal

Natural gas is the main source of produce of energy. But it's going to run out day by day. So find the alternative way. There are provisions of potential renewable energy resources like the solar, wind, tidal etc.; but the initiatives are very slow. Coal reserves and their prospects could not assure the nation as there are proven coal reserves of about 4,750 Mt (equivalent to 975 GM3 of gas, which is around 3 times greater than the present gas reserve in Bangladesh). Bangladesh has coal fired power station in Matarbari, Cox's Bazar, Chittagong. It is Proposed 12,00MW coal Fired Power Station. Now Proposed Coal fired based power station in Rampal Power station. It energy Produce to 1320MW [21].

3.3.3 Oil

Oil is the Second step to energy produced. Bangladesh has small amount of oil Reserve. Bangladesh has discovered oil in two old gas fields in the country's northeastern region with an extractable reserve worth $5.5 billion, the chairman of state-owned Petrobangla said [22].

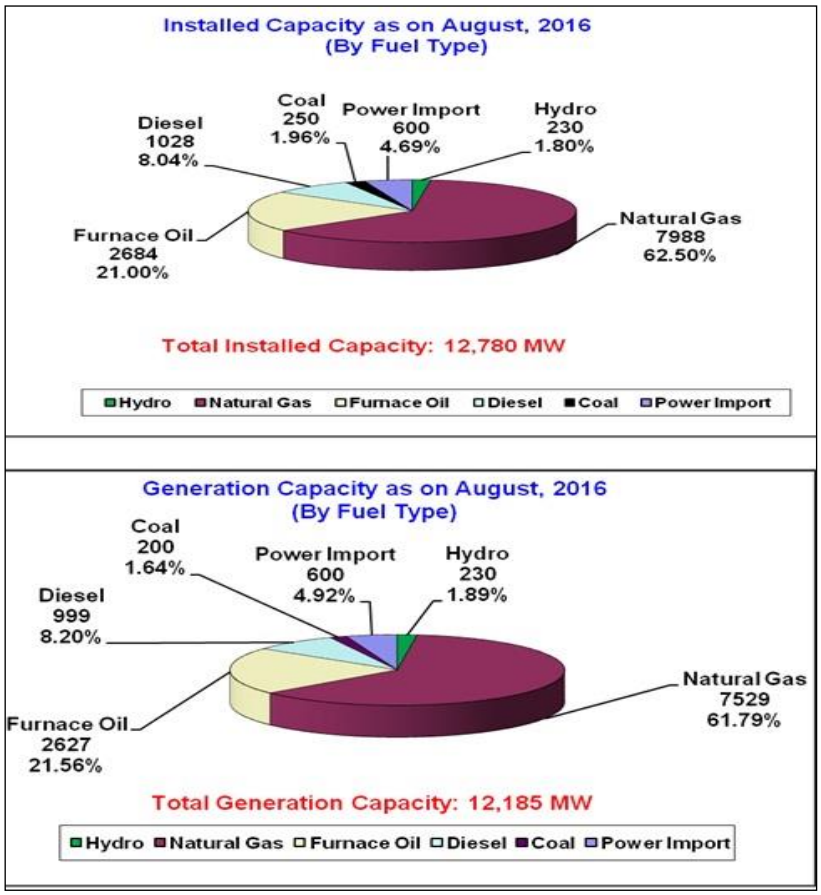


Figure 3.2: Energy generation by Fuel (%)

3.4 Master plan of Power Sector in Bangladesh

The government is formulating the Power System Master Plan (PSMP)-2016 with the year 2041 in mind where the demand of power will shot up to over 57,000MW. Out of that envisaged amount, around 35 % would be generated from gas as well as from coal and the remaining 30% from regional connectivity, renewable and nuclear energy, as chalked out in the PSMP.

The meeting of the steering committee to finalise the PSMP-2016 was organised by the Power Division on Saturday at Bidyut Bhaban.

Japan International Cooperation Agency (JICA) which is aiding the Power Division to formulate the PSMP presented the plan in front of the stakeholder.

In the PSMP, JICA extensively focuses on energy balance, power balance and tariff strategies following Bangladesh`s aspiration to become a high-income country.

JICA also put its emphasis on future necessity of power, fuel, transmission of generated power and efficient use, developing able human resources, mode of renewable energy production and financing by 2041 for the sector [23].

Under this plan, the coal (indigenous or imported), power trade from India, the limited gas, nuclear power will be used for the base load power plant, and LNG will be used to complement the gas shortage. Limited gas, liquid fuel and LNG will be used for the peak load power plant. The government has also taken efficiency improvement program for reduction of the growing power demand.

She said a target has been set to raise the power generation from renewable energy to 5 percent by 2021 and to 10 percent from renewable energy out of the overall power generation as per the Renewable Energy Policy. "To materialise this goal, a plan has been taken to generate some 3,100 MW of power by 2021 based on renewable energy. "The system loss in power distribution has now been reduced to 10.96 percent which was 15.67 percent in the past".

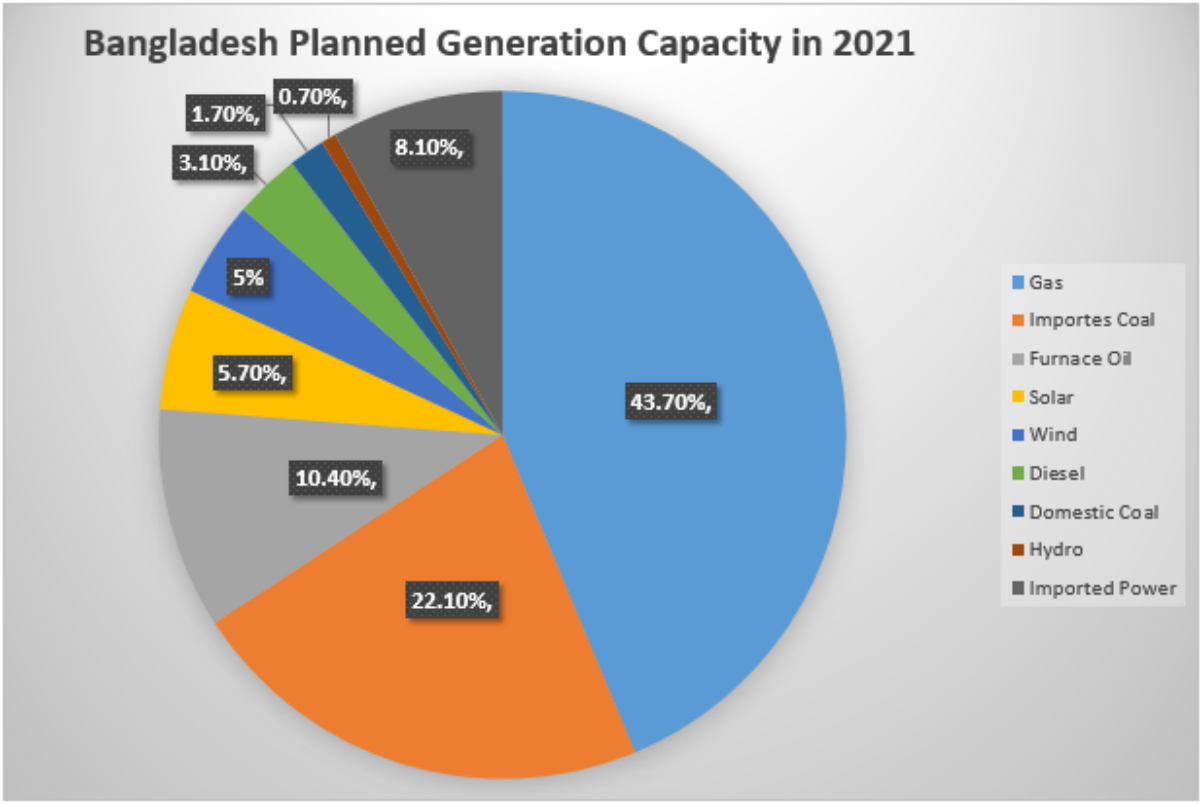


Figure 3.3: Bangladesh Planned Generation Capacity in 2021

Untilnow, gas based electricity generation is much higher compared to other fuels like hydro, Coal, Gas supply is the major constraint for gas based power generation projects.

3.5 Renewable Energy

Renewable Energy likes Solar, Wind, Tidal, Hydroelectric energy, geothermal power, Biomass. This type of energy to produce electric energy and reduce to Environment Effect. So, it is better option produce to electricity.Bangladesh huge potential of Renewable Energy.

3.5.1 Solar Energy

Bangladesh has big opportunity to produce electricity of solar energy. NGOs and Private Organizations implementing solar energy program. There is a strong potential for solar energy within the country. A large - Scale of solar home systems (SHSs) is implement. Solar photovoltaic (PV) systems are in use throughout the country with over 2.9 million household-level installations having a capacity of 122.2 MW (April 2014) [24].

3.5.2 Wind Energy

There is a strong Potential for Wind Energy because has 724km long coast line and many small islands in the Bay of Bengal. Bangladesh has two Wind Turbine Generation Power sector. 1.9MW Wind Power in Kutubdia and Feni. Power curves of wind turbines with two different installed capacities from two different manufacturers have been used to calculate energy generation. The estimated annual energy outputs for Kutubdia and Kuakata are 133 MWh and 160 MWh for a 150 KW wind turbine; while the outputs are about 200 MWh and 230 MWh respectively from a 250 KW station at these places [25].

3.5.3 Bio Energy

Biomass is biological material resulting from living, or recently located organisms. It most often means plants or plant-derived materials which might be specifically called lignocellulosic biomass. For energy source, biomass can either double directly via combustion to provide heat, or indirectly after renovating it to various sorts of biofuel. Conversion of biomass to biofuel can be achieved by different methods which might be broadly classified into: arctic, chemical, and biochemical approaches. Wood remains the largest biomass energy source today; examples include forest residues - like dead trees, branches in addition to tree stumps -, property clippings, wood chips and in some cases municipal solid waste. From the second sense, biomass includes plant or animal matter which might be converted into fibers or maybe other industrial chemicals, as well as biofuels. Industrial biomass is usually grown from numerous sorts of plants, including miscanthus, switchgrass, hemp, hammer toe, poplar, willow, sorghum, sugarcane, bamboo bedding and sheets, and a variety connected with tree species, ranging by eucalyptus to oil side (palm oil) [36]. Bangladesh possesses huge potential of biography energy. Bio energy can produce 37m3 of merely one ton of dung. Bangladesh make 400MW electricity to Rice husk.

3.6 Summary

Bangladesh energy produce to various types of fuel,Renewable energy source. Electricity increase dependency on renewable energy. Because of conventional energy day by day getting lost.Now, has many working of mega projects.Such as, Ruppur Neuclear plant, Matarbari coal plant,Rampal coal plant etc. This projects to huge amount of electricity produced. Our demand of electricity fulfil in this project.So, Bangladesh are no poorest country. Now Bangladesh is developing country in this world.

CHAPTER 4

ANALYSIS AND SIMULATION

4.1 HOMER Software

4.1.1 Methodology

It is a tool for modelling and optimization system for renewable and non- renewable energy of both off grid and a grid connected power system for variety of application. HOMER is reduce the analysis problem and design of micro-grid, arising due to number of design option. This software involve also all costs such as the initial capital and maintenance costs including pollution penalties. HOMER performs to ensure the best possible matching between supply and design in order to design the optimization system. It simulates the energy balance calculations for each of the 8760 hours in a year. After simulation, all of the possible system configurations, displays HOMER that can be used to compare system design option.

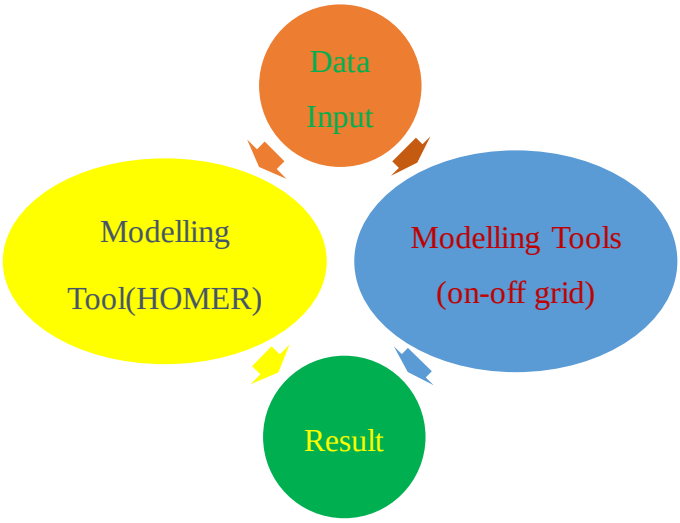


Figure 4.1:Optimization process of HOMER Software

4.1.2 Optimization Process

Feasibly designed with regard to economy, reliability and ecological measures the subject of various operational and physical constructions on the location. The overall objective is usually to identify a microgrid configuration that's low TNPC (total net present cost). For that, different system configurations in addition to technical constraints are simulated. This Forms Various Combining of system components upon which the engineer has control to pick out. Finally, list of setup is sorted out in addition to compared.

4.2 Load Profile

In a very remote rural village the demand for electricity is just not high compared to urban areas. Electricity is demanded pertaining to domestic use like Celling Supporter, Light and TV. At nighttime hours, the power consumption to the residential unit comes along where only basic electro-mechanical appliances are consuming electrical power.

The load demand decrease during Morning hours when everybody leave pertaining to schools, service or Preparing food. Throughout the noon a long time, the load demand quantities are minimum as almost all of the family members are outside the house.

Again, during the evening hours when all the family members are present, the electricity consumption rises as anyone switches on various Weight appliances. The average energy utilization of electrical appliances of the residential unit is presumed (80 kWh/day). The Peak Load is 18KW.

For this thesis we have taken a village of Patenga upazila.Patenga sea beach is Tourist Spots. Here maximum people are Service man.So maximum people work all day long.So this region is Electricity Consume a Small Amount .

This region 80 Households has been considered. This load is based on 3 energy efficienent lamps(15W each) , for summer we considered 2 fans(40W each) and Winter we considered 1 fan(40W) and 1 television (20W) for each family.Annual Peak load 18KW and Primary load to 80KWh/day.

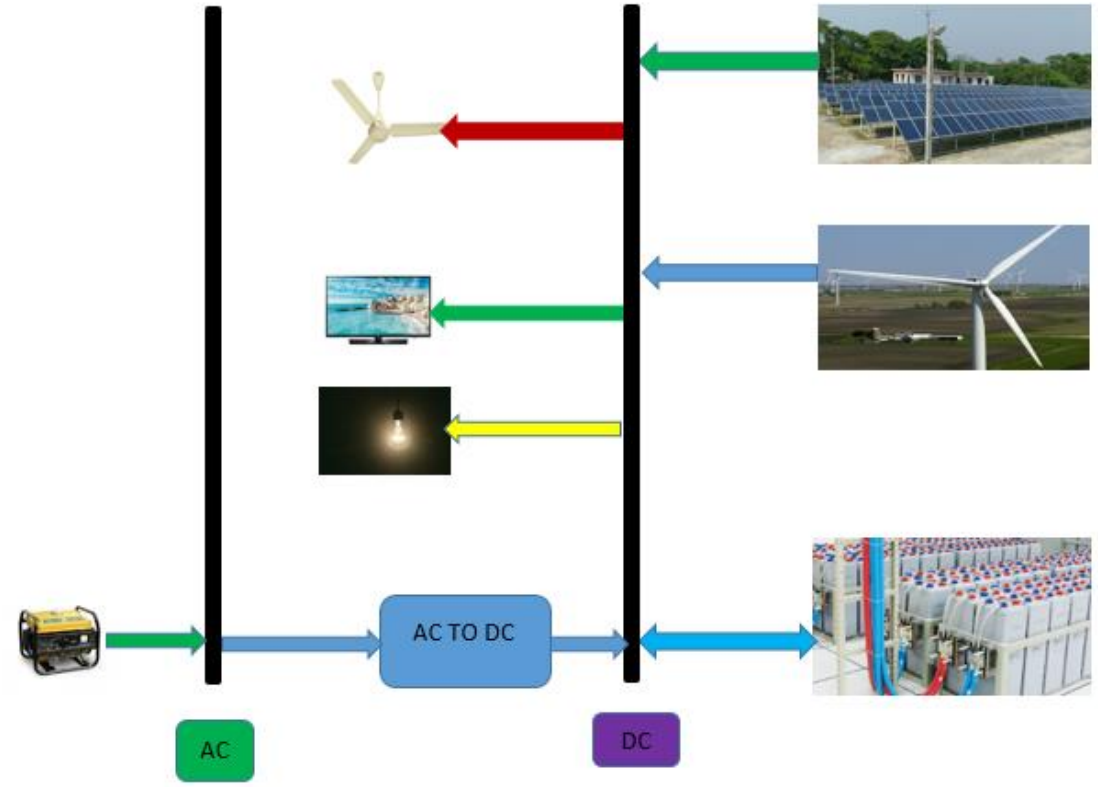


Figure 4.2: Load Profile

4.3 Hybrid Energy System

Standard energy systems for Nowadays position. Hybrid energy system depend on renewable energy source.This system are most effect in energy sector because of it is connected in grid connected and off grid connected. This system is off grid connected system. Grid connected system has benefit extra energy given in grid.So system is effective our energy sector. Among the renewable energy sources, solar and wind energy have been utilized with diesel engine in this study.Energy demand is DC Load. Maximum source connected in DC bus and Load is DC. The hybrid generation system consists of an electrical load, renewable energy sources and other system components such as PV, wind turbines, battery.Diesel Generator and converter. Fig.4.3 shows the hybrid energy system.

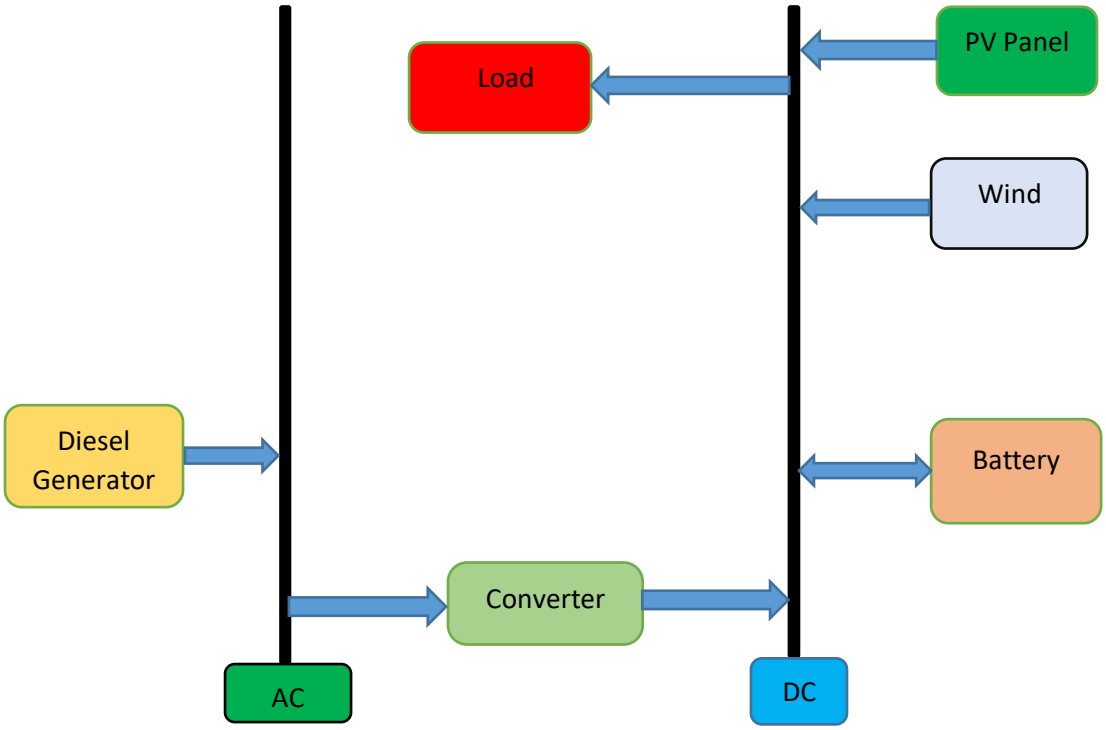


Figure 4.3: Hybrid Energy System

4.4 Economic Input Analysis

A mini-Grid system are very important part system fixed capital cost and system fixed Operation and Maintainance cost . This cost is input give in HOMER Software. A mini-Grid system of fixed capital cost are Land, Infrastrucer and associated building,Distribution equipment and materials cost etc.And system fixed operation and maintainance cost are salary. Considered 1.5 Km area for this mini-grid hybrid power system.A mini-grid system are produce electricity. This electricity distribution consider area in 80 household.Electricity distribution included material are wire,poles,circuit breaker,energy meter,multipole breaker and labor salary.So, total system fixed capital cost are $5675 considered in this Location and system fixed O&M cost is $192 for salary.

4.5 Summary

Hybrid power system are combination of conventional and non-conventional energy source and technology. Mini-grid and Micro-grid are provides hybrid power system.Hybrid power system is very important of power sector.Because this technology use to do huge amount of produce electricity.As a developing country of very important part of power sector. Electricity based industry, vecholes,mega project day by day increased.So that developing in power sector. Hybrid power system to optimization of cost and environment analysis usin HOMER Software.This is technology contributed in power sector.

CHAPTER 5

INFORMATION OF HYBRID POWER SYSTEM COMPONENTS

5.1 Information of Hybrid Power system Components

The Hybrid generation system mix PV panels, Wind turbines, Diesel generator, Batteries and Converters.

5.1.1 Solar Photovoltic

The cost of PV module including in Capital cost, Replacement cost, O&M cost have to be provided to the software for the simulation and Modeling purpose. This PV module life time has 25 years. Here 1kw to 25kw PV modules are Considered[31].
1$(USD)=83.93Taka(BDT) [27]

Table 5.1: Solar Panel Specification

Parameter	Unit	Value
Capital cost	BDT/1KW	29375.5
Replacement cost	BDT/1KW	25179
O&M cost	BDT/1KW/yr	84
Tracking System	No tracking system	0.05
Life time	Years	25

5.1.2 Diesel Generators

Diesel generator cost depends on its Size. Here has been 1kw to 20kw used in diesel generator. Because of our system peak is 18kw. For this system a slope and the intercept are 0.25 L/hr/KW and 0.08 L/hr/KW respectively [32].

Table 5.2: Diesel generator Specification

Parameter	Unit	Value
Capital cost	BDT/KW	32733
Replacement cost	BDT/KW	32733
Operational Life time	Hours	15000
Minimum load ratio	Percent	30
Fuel curve intercent	1/h/kw rated	0.08
Fuel curve slope	1/h/kw output	.25
Fuel price	BDT	65

Diesel fuel price = BDT 65.0 [28]

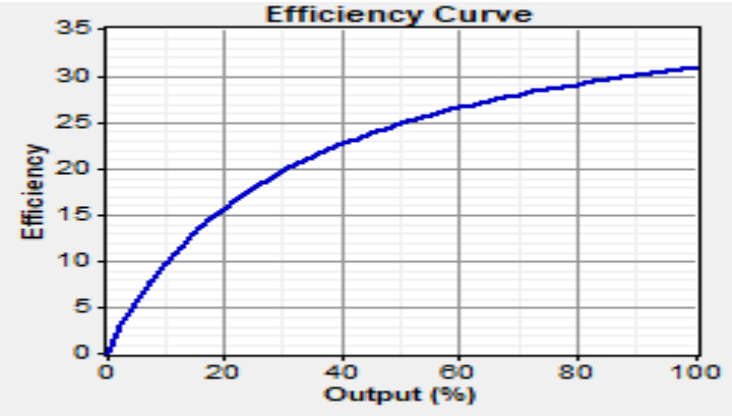


Figure 5.1: Efficiency curve of 18KW diesel generator

5.1.3 Wind Turbine

Wind Turbine cost depends on Wind Height.For the Hybrid system Generic 3KW Wind Turbine can be Considered. Generic 3KW wind turbine starting wind speed is 3m/s in this study. Rated DC voltage 24/48V. Rated wind Speed 12.5m/s.Shown Table 5.1.3 has technical parameters and cost asumptions [33].

Table 5.3: Wind Turbine Specification

Parameter	Unit	Value
Rated Power	KW	3
Starting Wind Speed	m/s	3
Rated Wind Speed	m/s	12.5
Security wind Speed	m/s	40
Capital cost	BDT/KW	47925
Replacement cost	BDT/KW	47925
O&M cost	BDT/KW	4197
Life time	Years	20

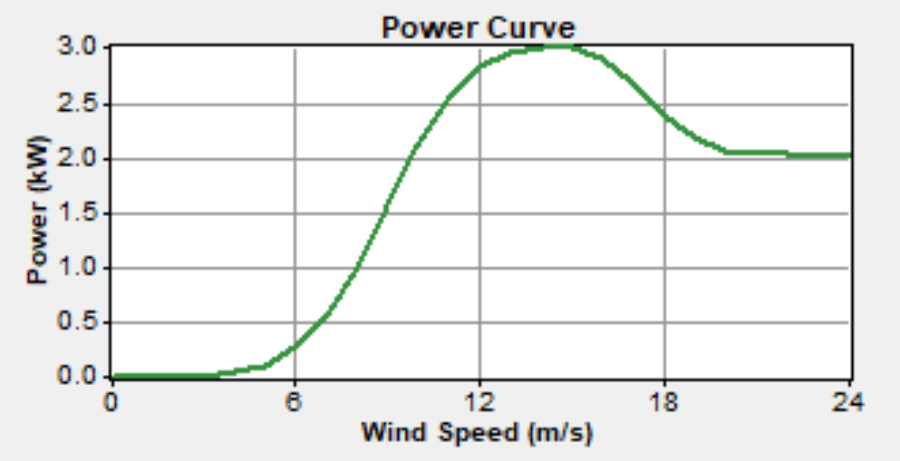


Figure 5.2: Power curve of Generic 3KW Wind Turbine

5.1.4 Battery

The Hybrid system are considered in The Vision 6FM200D storage batteries. This Battery Available in Bangladesh. Batteries System connected in hybrid power system for backup system. Considered batteries are nominal voltage 12V and nominal Capacity 200Ah.[34].

Table 5.4: Specification of Battery

Parameter	Unit	Value
Nominal Voltage	Volt	12
Nominal Capacity	Ah	200
Maximum Charge Current	A	60
Round Trip Efficiency	Percent	80
Capital cost	BDT/KWh	12590
Replacement cost	BDT/KWh	10072
O&M cost	BDT/KWh/yr	25

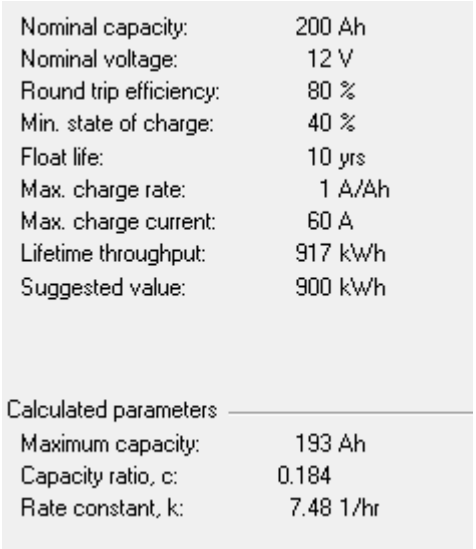


Figure 5.3: Specification Vision 6FM200D Battery

5.1.5 Power Converter

Here this system connected in DC Load. As the electricity generated from the PV or Wind turbine is DC. DC current into AC current used it Inverter. When AC current into DC current used it Rectifier Converter.Considered Converter Range 1KW to 25KW. Shown Table 5.5 the technical and Economical parameters of the Converter [35].

Table 5.5: Specification of Converter

Parameter	Unit	Value
Capital cost	BDT/KW	3861
Replacement cost	BDT/KW	3861
Life time	Years	15
Efficiency	Percent	90
Rectifier capacity	Percent	100
Rectifier Efficiency	Percent	85

5.2 Summary

This Chapter is discuss specification of hybrid power system. Hybrid power system to do establish requirement various types of equipment.Now, that equipment details prices is discussion. My preferable value use to do searching various site. Here acceptable value is use. Solar panel,Wind turbine,Diesel Generator,Battery and Converter are specification in discuss.

CHAPTER 6

OPTIMIZATION RESULT OF THE MINI-GRID HYBRID POWER SYSTEM

6.1 Area of Patenga

Patenga is a sea beach Located 14 km south of the port city of Chittagong , Bangladesh. It is near the mouth of the Karnaphuli River.

Patenga Thana (Chittagong metropolitan) area 22.34 sq km, located in between 22°13' and 22°18' north latitudes and in between 91°46' and 91°50' east longitudes. It is bounded by bandar thana on the north, anowara thana on the south, karnafuli thana and karnafuli river on the east, bay of bengal on the west.

Population Total 140223; male 74308, female 6591; Muslim 130827, Hindu 7471, Buddhist 100, Christian 1748 and others 77. Water bodies Bay of Bengal and Karnafuli river are notable. Administration Patenga Thana was established on 27 May 2000 comprising part of Chittagong Bandar thana. Access to electricity All the wards of the thana are under electrification net-work. However 84.40% of the dwelling households have access to electricity [26].

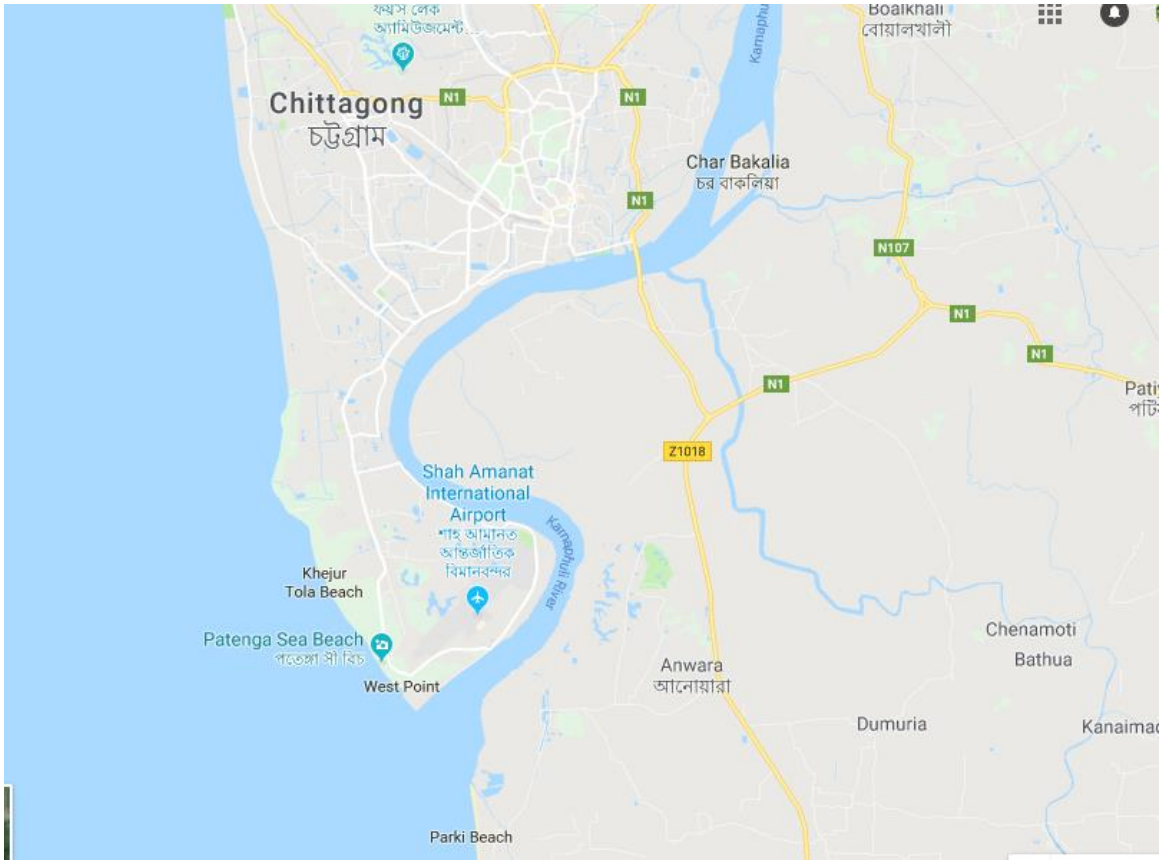


Figure 6.1 : Patenga Upazila Map

6.2 Load Assesment Profile

6.2.1 Summer Season Load Profile (March –September)

At maximum energy consumption is summer seasonal because that time use is two celling fan,three light and one TV. Using by here maximum energy consumption of Celling Fan.Here, celling fan operation hours 13.30hr and Power Rating 40W. Light operation hours 6hr and Power Rating 15W ,TV operating hours 4.30hr and Power Rating 20W.The households load demand variation considered as 15 % day-to-day random variation. The summer peak load of the system with 80 household considered as 10.48 kW and daily energy demand about 101.12 kWh/day.

Here,

Electricity Demand for Each Family

Three Light =15W(Power rating)*3(no.of light)*6(hours of operation)=270Wh

Two Celling Fan =40W(Power rating)*2(no. of fan)*13.30(hours of operation)=1064Wh

One Television=20W(power rating)*1(no. of TV)*4.30(hour of operating)=86Wh

Table 6.1: Summer Load (March-September)

Duration	Light(15W)	Fan(40W)	TV(20W)	Watt	(Watt*80)/1000
0-1	0	1	0	80	6.4
1-2	0	1	0	80	6.4
2-3	0	1	0	80	6.4
3-4	0	1	0	80	6.4
4-5	0	1	0	80	6.4
5-6	.30	.30	0	37.5	3.00
6-7	.30	0	.20	17.5	1.40
7-8	0	.30	0	24	1.92
8-9	0	0	.30	6	.480
9-10	0	.25	0	20	1.6
10-11	0	0	.30	6	.480
11-12	0	0	.20	4	.320
12-13	0	.35	.20	32	2.56
13-14	0	.20	0	16	1.28
14-15	0	0	.30	6	.480
15-16	0	.40	0	32	2.56
16-17	.15	0	0	6.75	.540
17-18	.45	0	1	40.25	3.22
18-19	1	.30	.15	72	5.76
19-20	1	1	.15	128	10.24
20-21	1	1	.30	131	10.48
21-22	1	1	0	125	10.0
22-23	0	1	0	80	6.4
23-24	0	1	0	80	6.4
	6hr	13.30hr	4.30hr	1264W	101.12KW

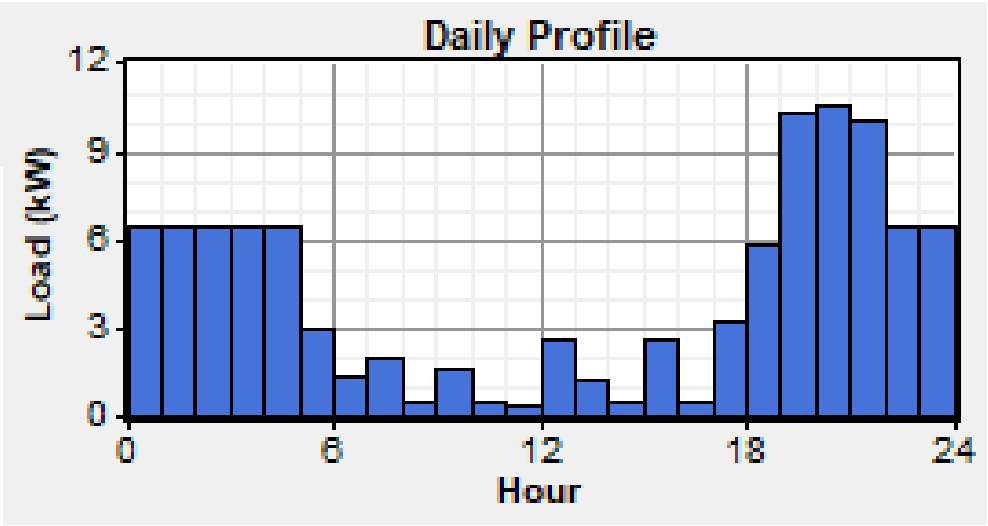


Figure 6.2: Summer Load Profile

6.2.2 Winter Season Load Profile (October-February)

The winter energy consumption half of the summer energy consumption due to use of one celling fan.The winter load has considered half of the summer load due to absence of one ceiling fan not in operation.The winter peak load of the system with 80 household considered as 5.04 kW and daily energy consumption as 56.44kWh/day.

Table 6.2: The winter load (October-February)

Duration	Light(15W)	Fan(40W)	TV(20W)	Watt	(Watt*80)/1000
0-1	0	1	0	40	3.2
1-2	0	1	0	40	3.2
2-3	0	1	0	40	3.2
3-4	0	1	0	40	3.2
4-5	0	1	0	40	3.2
5-6	.30	.30	0	25.5	2.04
6-7	.30	.30	.20	29.5	2.36
7-8	0	1	0	40	3.20
8-9	0	0	.30	6	.480
9-10	0	.25	0	10	.80
10-11	0	0	.30	6	.960
11-12	0	0	.20	4	.320

12-13	0	.35	.20	18	1.44
13-14	0	.20	0	8	.640
14-15		0	.30	6	.480
15-16	0	.40	0	16	1.28
16-17	.15	0	0	2.25	.180
17-18	.45	0	1	40.25	3.22
18-19	1	.30	.30	63.0	5.04
19-20	1	.30	0	27	2.16
20-21	1	.30	.30	63	5.04
21-22	1	1	0	55	4.40
22-23	0	1	0	40	3.2
23-24	0	1	0	40	3.2
	6hr	13.30hr	4.30hr	699.5W	56.44KW

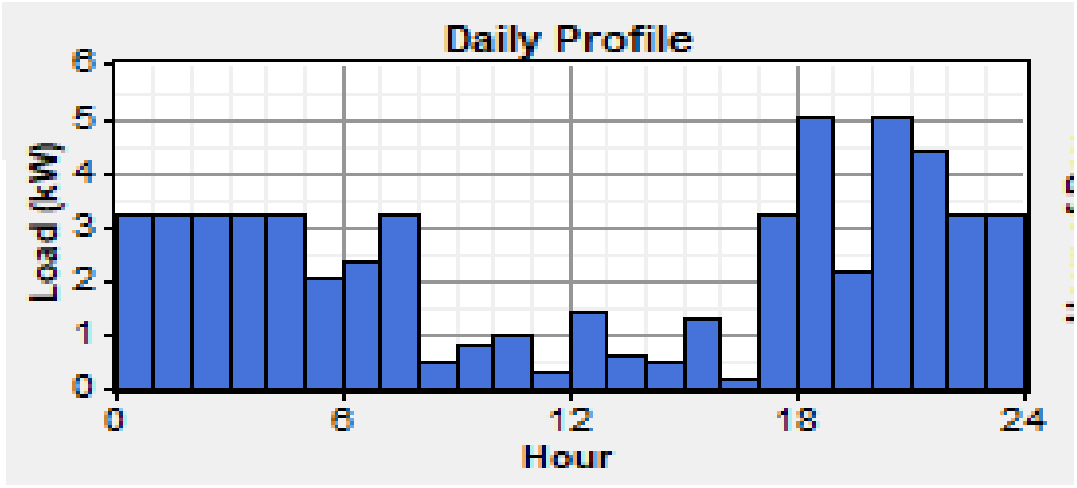


Figure 6.3: Winter Load profile

6.3 Various Types of Off-Grid system Optimization Result for DC Load

1.PV+ Diesel Generator+Battery+Converter

2.Wind turbine+Battery

3.PV +Wind Turbine+Battery

4.PV +Wind Turbine +Battery+Converter (Proposed System)

Shown here four energy generation systems. This system simulated by using HOMER software. HOMER software by find out various optimization result. We will choose the Correct result from inside.

6.4 Photovoltaic(PV)

Photovoltaic is a term which covers the conversion of light into electricity using semiconducting materials that exhibit the photovoltaic effect,a phenomenon studied in physics, photochemistry, and electrochemistry[29].

A typical photovoltaic system employs solar panels, each comprising a number of solar cells, which generate electrical power. PV installations may be ground-mounted, rooftop mounted or wall mounted. The mount may be fixed, or use a solar tracker to follow the sun across the sky.[28]

Photovoltaic has specific advantages just as one energy source: its operation generates no pollution with out greenhouse gas emissions after installed, it shows simple scalability according of power needs along with silicon has large availability inside Earth's crust. PV systems contain the major disadvantage that the electricity output is dependent on sunlight, so about 10-25% is lost if the tracking system is certainly not used, since the cell are not directly facing the sun always. Dust, clouds, and other pursuits in the atmosphere also diminish the electricity output. Another main issue will be the concentration of the production inside hours corresponding to major insolation, which don't usually match the peaks widely used in human activity menstrual cycles. Unless current societal habits of consumption and electrical networks mutually accommodate this scenario, electricity still should be made up by various other power sources, usually hydrocarbon. [29]

The figure 6.4 shows a solar panel arrangement:

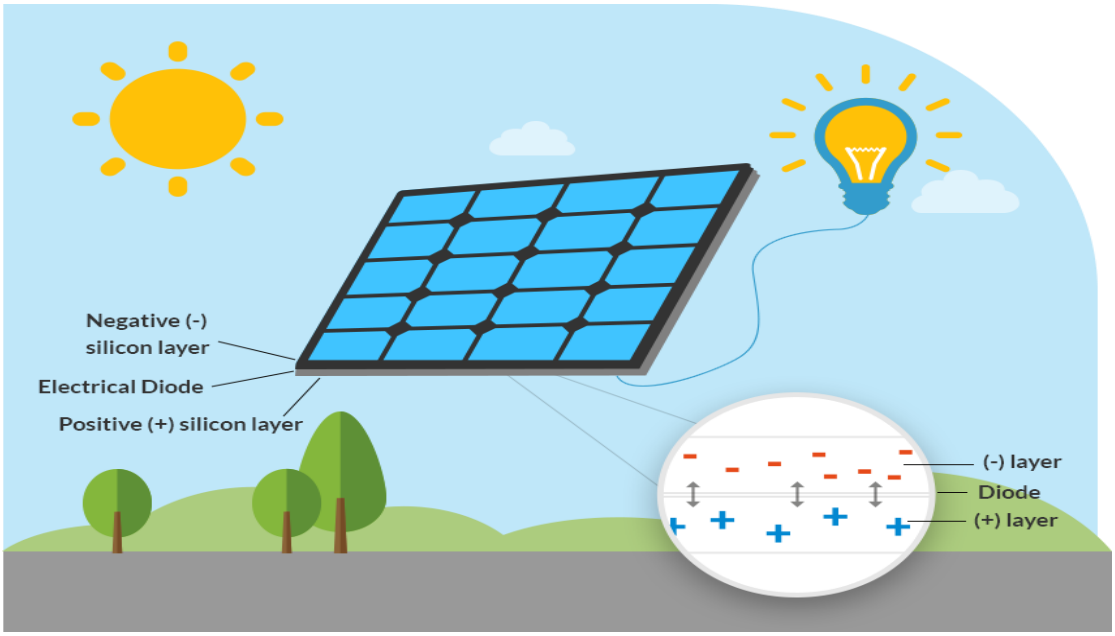


Figure 6.4: Solar panel Arrangement system

6.5 Diesel Generator(DG)

A diesel generator is the combination of a diesel engine with an electric generator (often an alternator) to generate electrical energy. This is a specific case of engine-generator. A diesel compression-ignition engine often is designed to run on fuel oil, but some types are adapted for other liquid fuels or natural gas. Diesel generating sets are used in places without connection to a power grid, or as emergency power-supply if the grid fails, as well as for more complex applications such as peak-lopping, grid support and export to the power grid. [30]

The below figure 6.5 shows a common diesel generator model.

Figure 6.5: Diesel Generator

6.6 (PV+Diesel Generator+Battery+Converter)Energy Generation System

6.6.1 System Components Assessment

The energy system components are PV Modules,Diesel Generator,Battery and Power Converter. The cost, number of units to be used, operating hours, etc. need to be specified in HOMER software for each of this equipment.This information details involved in previous section.

In this system,the main component is renewable energy component its PV Panel. Further alternative energy component which Diesel Generator(DG).DG produce to AC current but Load is DC ,So use Rectifier.Rectifier will change AC to DC Current.Here,use is Large amount of PV Panel component,PV Panel component have the other component involved such as a battery(vision 6FM200D model) [33].

The PV panel to produced is DC and PV connected DC bus so,this current is not converted because load is DC. Batteries System has for backup system.

Shown figure 6.6 (PV+Diesel Generator+Battery+Converter) energy generation system

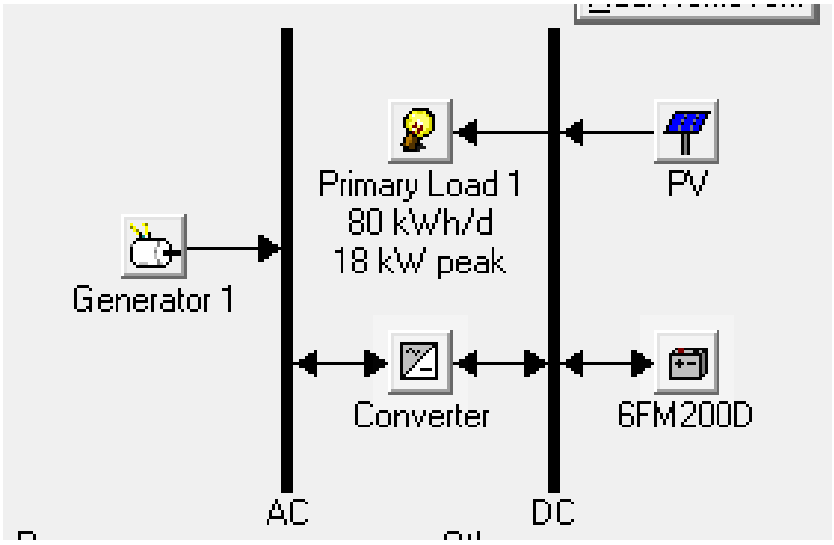


Figure 6.6: (PV+Diesel Generator+Battery+Converter) energy generation system

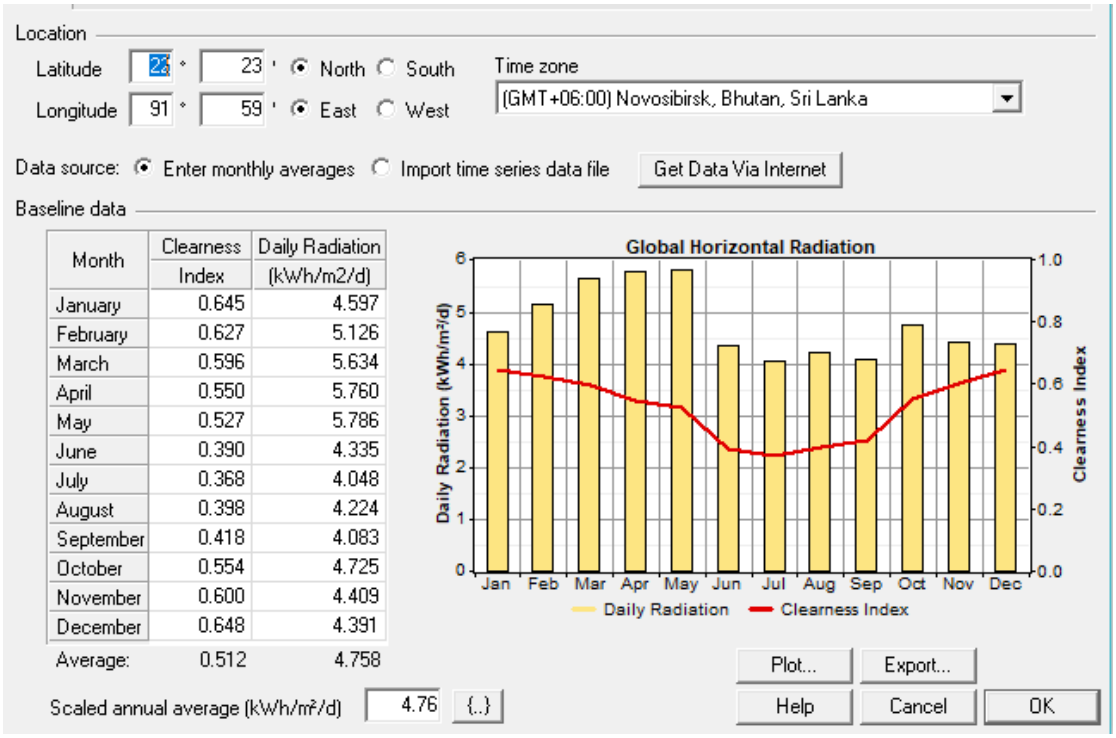
6.6.2 Photovoltaic array Model

Solar Panel installation cost is $.35/W. This case, considered a 24KW solar energy system. A 24KW solar energy system's installation and Replacement cost are taken as $8400 and $7200.

There are different sizes are considered, such as 1KW to 25KW. This PV array lifetime is 25 Years and 25 years output come here. This PV array is no tracking system [31].

6.6.3 Solar Resource Data

Bangladesh is very good for the purpose of electricity generation from the solar irradiance,measure of incoming solar radiation.This has been Location consider is Patenga.Patenga Latitude and Longitude are 22°23 North and 91°59 East .Patenga monthly averaged global radiation data has been taken from NASA(National Aeronautics and Space Administration).This Location to Annual Average radiation is 4.76KWh/m2/d and average clearness index is 0.512[26].



Month	Clearness Index	Daily Radiation (kWh/m2/d)
January	0.645	4.597
February	0.627	5.126
March	0.596	5.634
April	0.550	5.760
May	0.527	5.786
June	0.390	4.335
July	0.368	4.048
August	0.398	4.224
September	0.418	4.083
October	0.554	4.725
November	0.600	4.409
December	0.648	4.391
Average:	0.512	4.758

Figure 6.7: Annual Solar Global Horizontal Radiation

6.6.4 Diesel Generator Model

Diesel generator connected in AC bus. For remote electrification commonly used in Diesel Generator.Because it is low cost,easy to install and electric opertating system.There are various range of diesel generator,choose in appropriate model for this Location.This case use is 4KW diesel generator and cost is taken $624.The minimum load ratio 30%.The lifetime rating is taken 15000hr.The diesel price per liter BDT65 taka [32,28].

6.6.5 Battery Model

Batteries carry major cost in power system. In every case different number of batteries are used.This battery model are available in Bangladesh.The battery model is Vision 6FM200D (12V.200Ah). This Battery service are Long life. An Warranty 1 years. The cost of one is ($150) with a replacement cost of ($150) while the maintenance cost is expected at ($.29/year). The battery to be considered in this simulation is range from 1to 62 units[34].

6.6.6 Power converter Model

A power electronics converter is used to convert AC to DC and DC to AC. The simulation range of power converter are 1KW to 25KW. We use 5KW converter in this case. A lifetime of a unit is considered to be (15 years) [35].

6.6.7 Simulation Results

The project's lifetime is considered to be 25 years .The optimal combination of power system components for our case study is a 24kW PV-Array,vision 6FM200D, and 5kW rectifier. This system is considered at ($ 0.774/L) of diesel cost. The total net present cost, capital cost and the cost of electricity (COE) for such a hybrid system are $153,988, $52,129 and $0.415/kWh, respectively [34,28]

The figure 6.8 shows the simulation result of (Diesel Generator +PV+ Battery+ Converter) energy generation system.

Sensitivity Results | Optimization Results

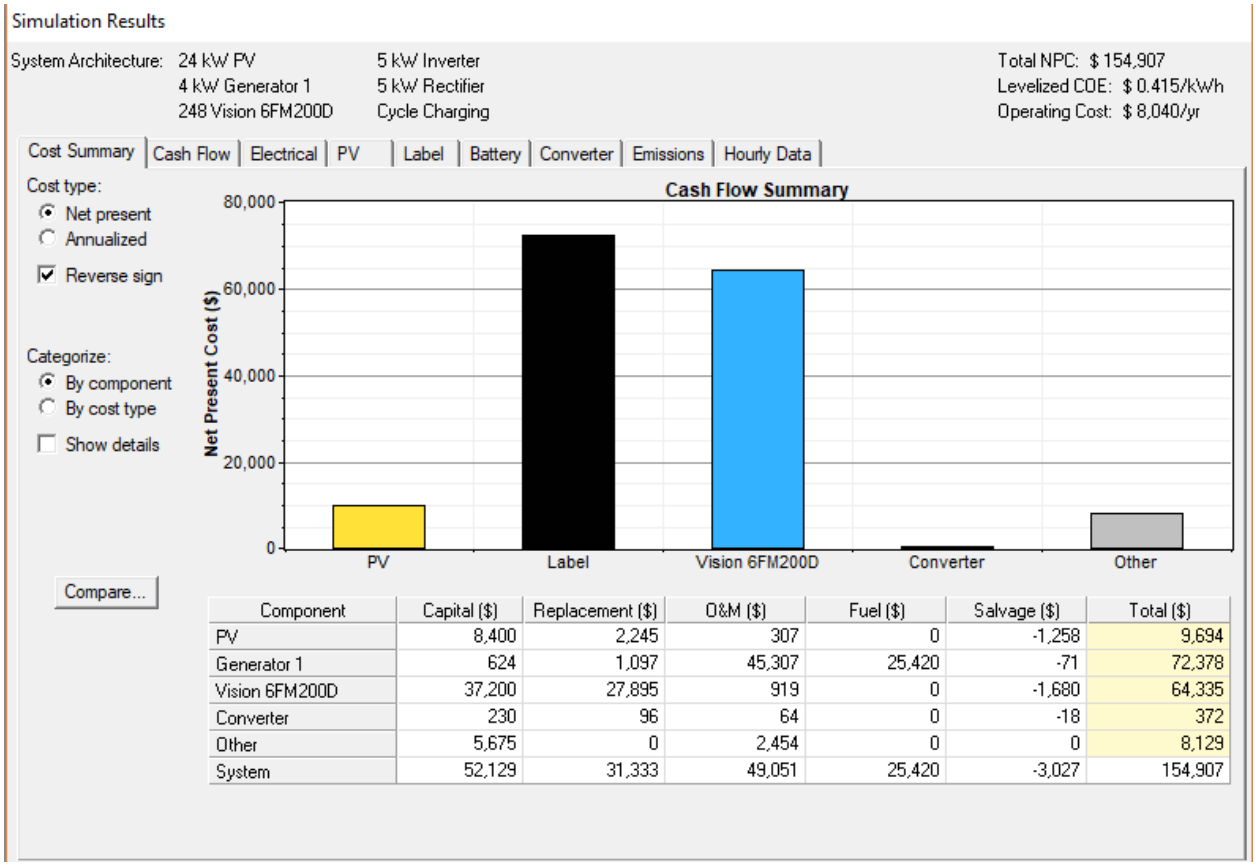
Double click on a system below for simulation results.

PV (kW)	G3	Label (kW)	6FM200D	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)
12	6		104		$ 31,111	1,996	$ 56,625	0.152	1.00		
	10		160		$ 39,363	2,024	$ 65,238	0.175	1.00		
5	6	2	120	1	$ 31,627	3,205	$ 72,598	0.194	0.98	479	1,416
	10	2	160	1	$ 39,929	3,117	$ 79,771	0.213	0.99	376	1,170
24		4	248	5	$ 52,129	8,040	$ 154,907	0.415	0.85	2,486	2,685

Figure 6.8: Simulation Results

6.6.8 Cost Summary

The whole project cost summary shown in below figure . However once PV installed,the maintainance and operating cost become very cheap then Diesel generator system.Fixed capital cost of this project are $52,129.And the operating and maintainance cost is estimated to be $4,9051.The replacement cost is $31,333.The system fixed capital costs include various civil constructions, labor, logistics wages, required licenses, administration and government approvals and other miscellaneous costs.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	8,400	2,245	307	0	-1,258	9,694
Generator 1	624	1,097	45,307	25,420	-71	72,378
Vision 6FM200D	37,200	27,895	919	0	-1,680	64,335
Converter	230	96	64	0	-18	372
Other	5,675	0	2,454	0	0	8,129
System	52,129	31,333	49,051	25,420	-3,027	154,907

Figure 6.9: Cost Summary

6.6.9 Cash Flows

The below figure,we can see that ,the total NPC is $154,907.And the levelized COE is $0.415/kwh. Finally the operating cost is $8,040/yr.

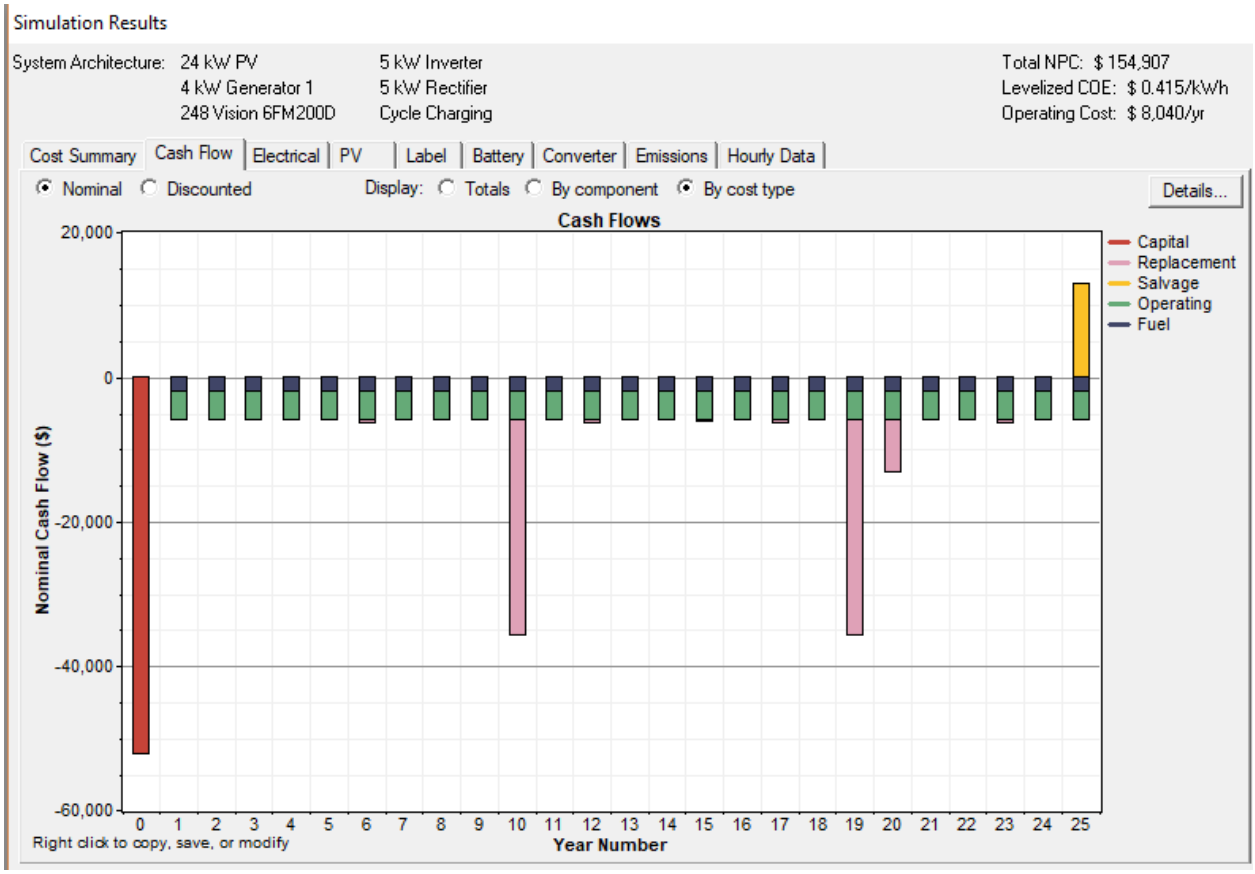


Figure 6.10: Cas Flows

6.6.10 Monthly Average Electric Production

The below figure shown the monthly distribution of the electricity produced in kW by the (PV) and (DG). From April to September, the PV is mostly used combined with Diesel generator(DG). Also, from April to May the peak load is met by (PV) and (DG).Lack of solar radiation during winter month, We get most of the power from diesel generator.

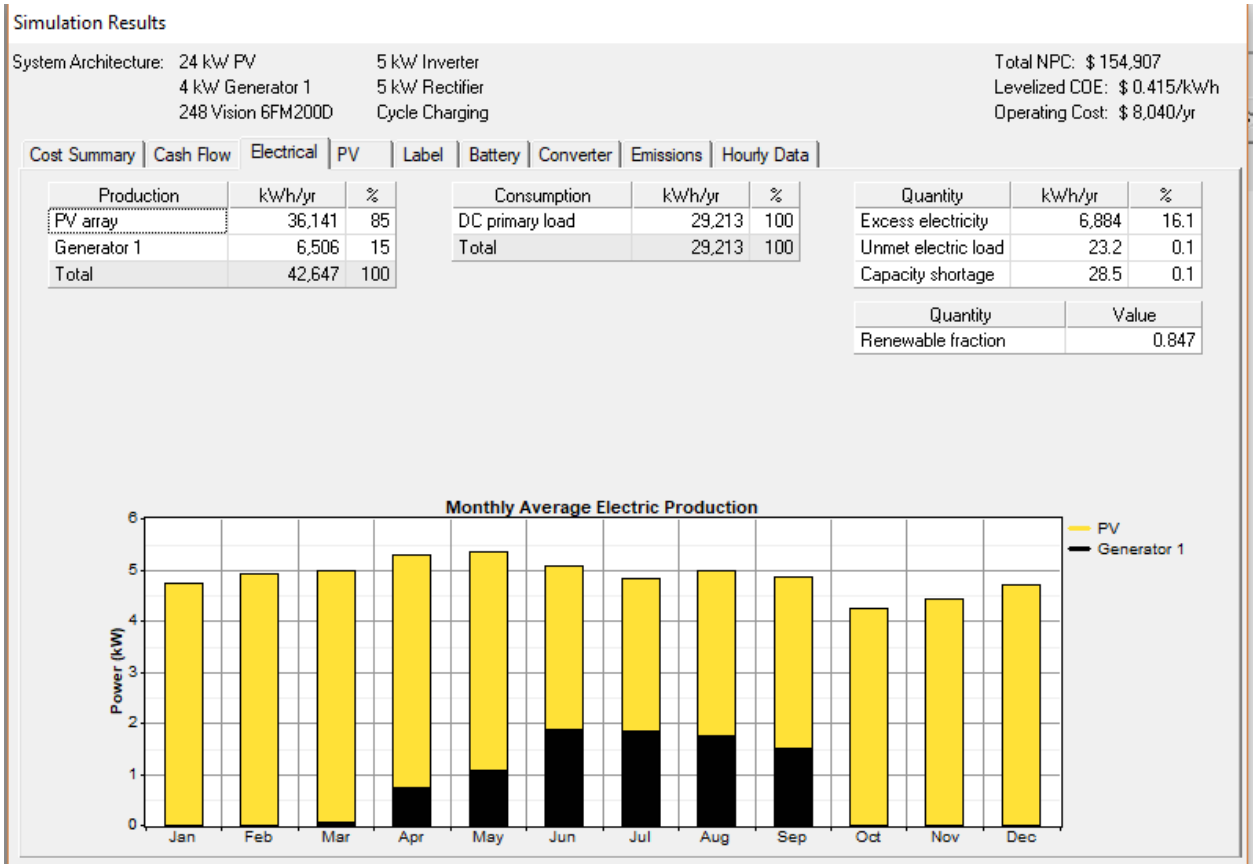


Figure 6.11: Monthly Average Electric Production

The below table shows the electricity production of the system components.

Table 6.3: Electricity production of the system components

Production	KWh/yr	%
PV Array	36,141	85
Generator 1	6,506	15
Total	42,647	100

6.6.11 Sensitivity and Optimization Results

This case consist of three sensitivity variables like (PV size, battery size and power converter size) are considered in this analysis. The area load at 80 kWh/d, 18 kW peak, this system might majority consist of 24 kW PV array, arrange 4kW of the generator, 248 unit of batteries and 10KW of the power converter.And those case simulates HOMER Software.

For this case optimization result are consist of initial capital, total net present cost (NPC), cost of energy (COE), renewable fraction, diesel in litter and generator in hourly working in this system. This system of COE $.415/KWh.The total Net present cost $154,907.For this project

this COE is highest. Beside,excess electricity produce 6884KWh/yr of 16.1%.And unmet electric load 23.2KWh/yr of 0.1%.Also capacity shortage 28.5KWh/yr of 0.1%.Further renewable fraction value 0.847.

So the Sensitivity result of this case,the (PV, diesel generator, battery and converter) based hybrid system is not suitable due to huge cost .The cost is very large greater than grid connected cost around study area.

6.6.12 Emission

We can see below this figure the major emission comes from carbon dioxide.

Pollutant	Emissions (kg/yr)
Carbon dioxide	6,546
Carbon monoxide	16.2
Unburned hydrocarbons	1.79
Particulate matter	1.22
Sulfur dioxide	13.1
Nitrogen oxides	144

Figure 6.12: Emission

6.7 Wind Turbine

A wind turbine is a device that converts the wind's kinetic energy into electrical power.Wind turbines are manufactured in a wide range of vertical and horizontal axis types.The main component of wind turbine are,blade,Nacelle,rotor,Tower,Hub etc.This case we use horizontal axis type wind turbine.The wind turbine working principle are when wind are available,the turbine blades start to rotate and we get electrical power from kinetic energy. The turbines are used for applications like battery charging for additional power for boats or caravans so they can power traffic warning signals. Slightly larger turbines can be employed for making contributions into a domestic power supply though selling unused power here we are at the utility supplier by using the electrical grid. Arrays connected with large turbines, known seeing that wind farms, are becoming an increasingly important cause of intermittent renewable energy and are also used by many countries during a strategy to lower their reliance on fossil heats up. The below fig. shows the structure of a wind turbine.

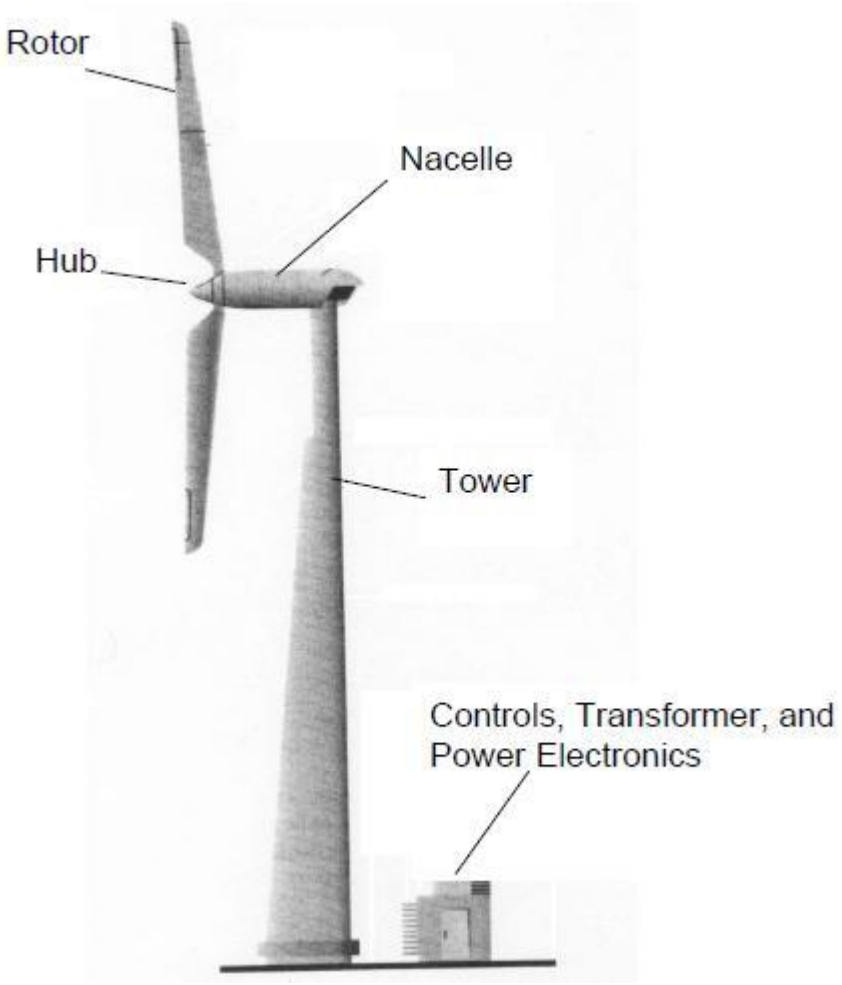


Figure 6.13:Structure of wind turbine

6.8 Battery Design

Battery is a energy stored system.A mini-grid hybrid power system are included source PV,Wind Turbine and Diesel generator.Here,PV and Wind are Renewable energy Produced.This energy produce vary are seasonal and environment chance.So,this energy are needed stored.There are two types Battery design.Such as, Parallel and series design.We used 12V 200Ah Battery.Batteries per String 4, Bus 48V.

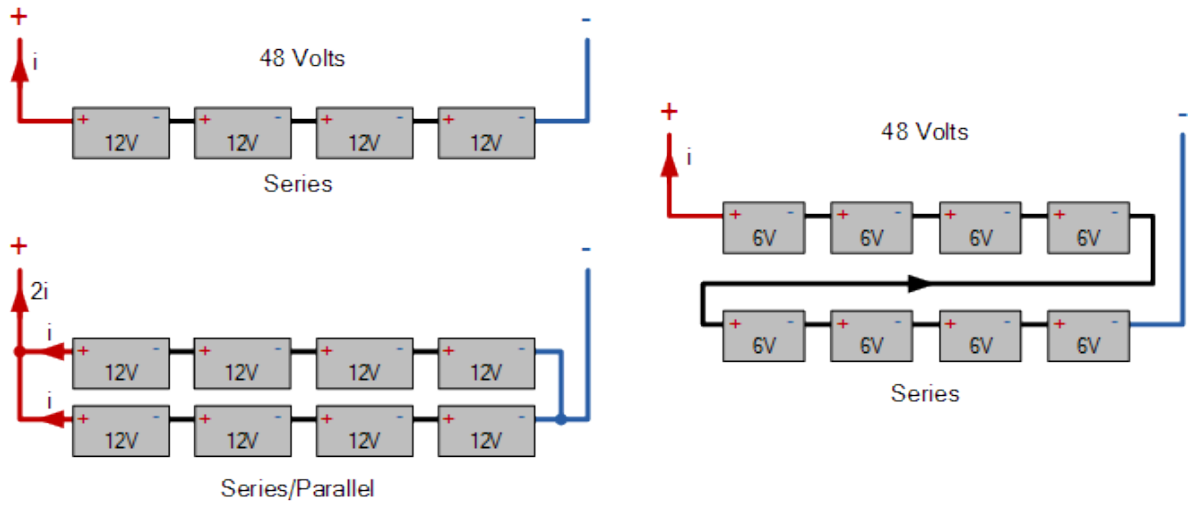


Figure 6.14: Battery Design

6.9 (Wind Turbine+Battery) Energy Generation System

6.9.1 System Components Assessment

The energy system components are Wind turbine and Battery. The cost, number of units to be used, operating hours, etc. need to be specified in HOMER software for each of this equipment.This information details involved in previous section.

In this system,the main component is renewable energy component its Wind Turbine.

The Wind turbine is to produced DC and connected to DC bus so,this current is not converted Ac because load is DC. And the Batteries System has for backup system.

The below figure shows the model of Wind Turbine +Batteries Energy Generation System.

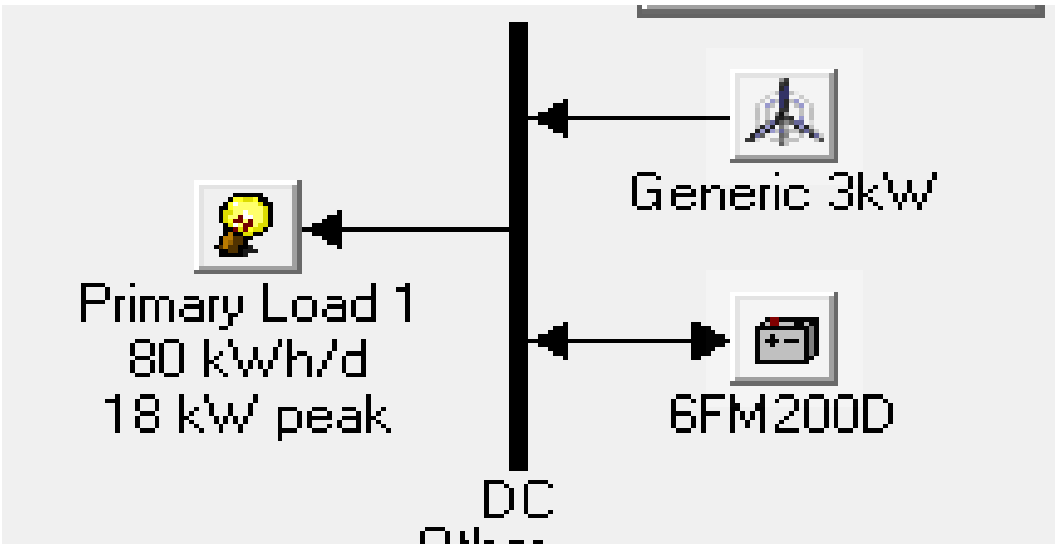


Figure 6.15:Wind Turbine+ Battery Energy Generation System

6.9.2 Wind Turbine Model

Availability of energy from the wind turbines depends greatly on wind variations. Therefore, wind turbine rating much lower compared to the average electrical load. In this analysis,we considered Generic 3kw model with hub height (25 m) is considered. It provides (DC) voltage as an output.The capital ,replacement and maintenance costs of 30 kw are taken as ($9,688) ,($5,785) and ($500/year).A lifetime of a turbine is taken to be (15 years).[33,26]

The below table shows wind speed data of Patenga upazila.

Table 6.4:Wind speed data of Patenga

Month	Wind Speed (m/s)
January	6.220
February	6.340
March	7.370
April	7.920
May	8.470
June	8.690
July	9.200
August	8.540
September	7.480
October	6.930
November	6.710
December	5.910
Annual average:	7.489

From the above table we can see that there are various wind speed for 12 months.The average annual wind speed is 7.489 m/s.[37]

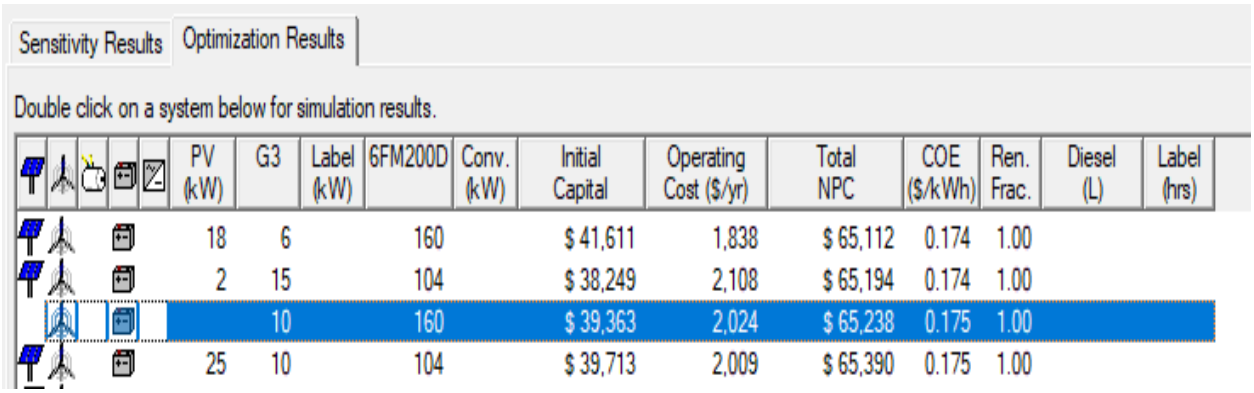
6.9.3 Battery Model

.Batteries carry major cost in power system. In every case different number of batteries are used.This battery model are available in Bangladesh.The battery model is Vision 6FM200D (12V.200Ah). This Battery service are Long life. An Warranty 1 years. The cost of one is ($150) with a replacement cost of ($150) while the maintenance cost is expected at ($.29/year). The battery to be considered in this simulation is range from 1to 62 units[34].

6.9.4 Simulation Results

The project's lifetime is considered to be 25 years .The optimal combination of power system components for our case study is a 30KW wind turbine,vision 6FM200D. The total net present cost, capital cost and the cost of electricity (COE) for such a system are $65,238 , $39,363 and $0.175/kWh [33,34].

The below fig shows the simulation result of Wind Turbine and Batteries Energy Generation System.

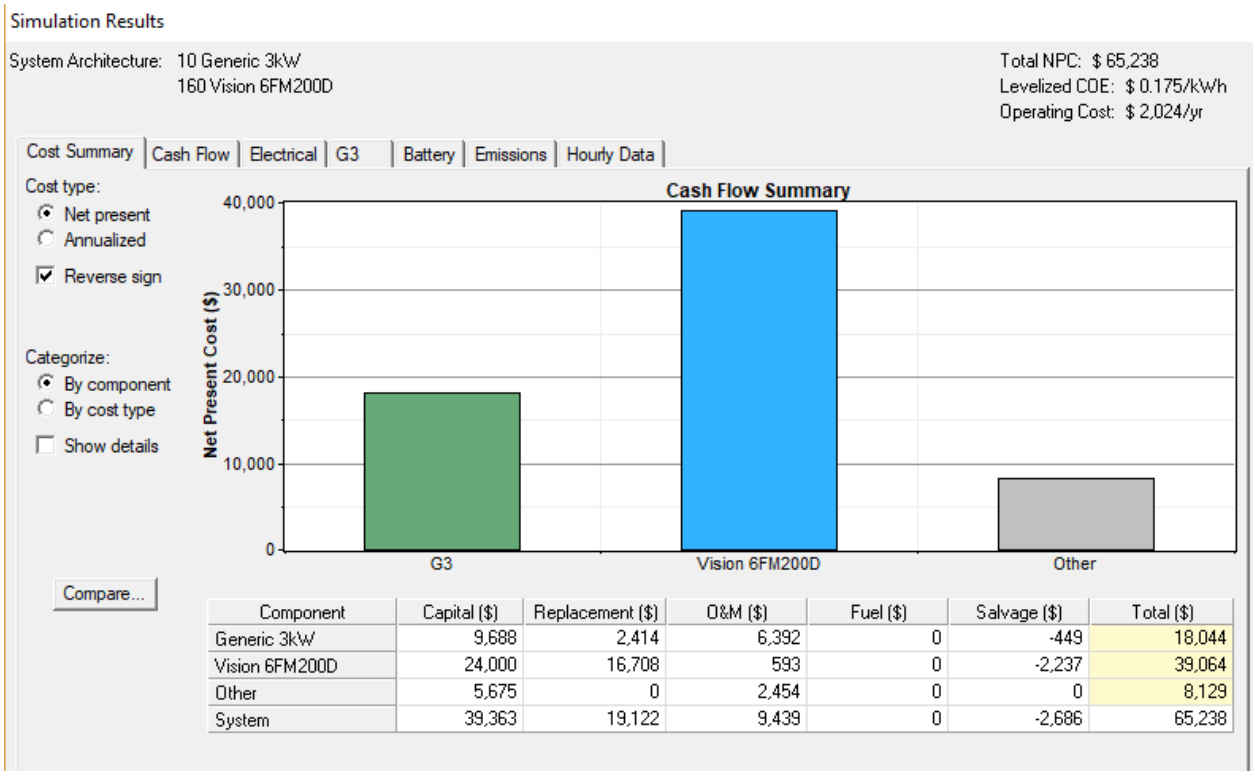


PV (kW)	G3	Label (kW)	6FM200D	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)
18	6		160		$ 41,611	1,838	$ 65,112	0.174	1.00		
2	15		104		$ 38,249	2,108	$ 65,194	0.174	1.00		
	10		160		$ 39,363	2,024	$ 65,238	0.175	1.00		
25	10		104		$ 39,713	2,009	$ 65,390	0.175	1.00		

Figure 6.16: Simulation results

6.9.5 Cost Summary

The whole project cost summary shown in below figure . However once Wind Turbine installed,the maintainance and operating cost become very cheap .Fixed capital cost of this project are $39,363.And the operating and maintainance cost is estimated to be $9,439.The replacement cost is $19,122.The system fixed capital costs include various civil constructions, labor, logistics wages, required licenses, administration and government approvals and other miscellaneous costs.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic 3kW	9,688	2,414	6,392	0	-449	18,044
Vision 6FM200D	24,000	16,708	593	0	-2,237	39,064
Other	5,675	0	2,454	0	0	8,129
System	39,363	19,122	9,439	0	-2,686	65,238

Figure 6.17: Cost Summary

6.9.6 Cash Flows

The fig. shows the cash flows graph.The total NPC is $64,645.The levelized COE is $0.175/kwh.And the operating cost is $1,978/yr.

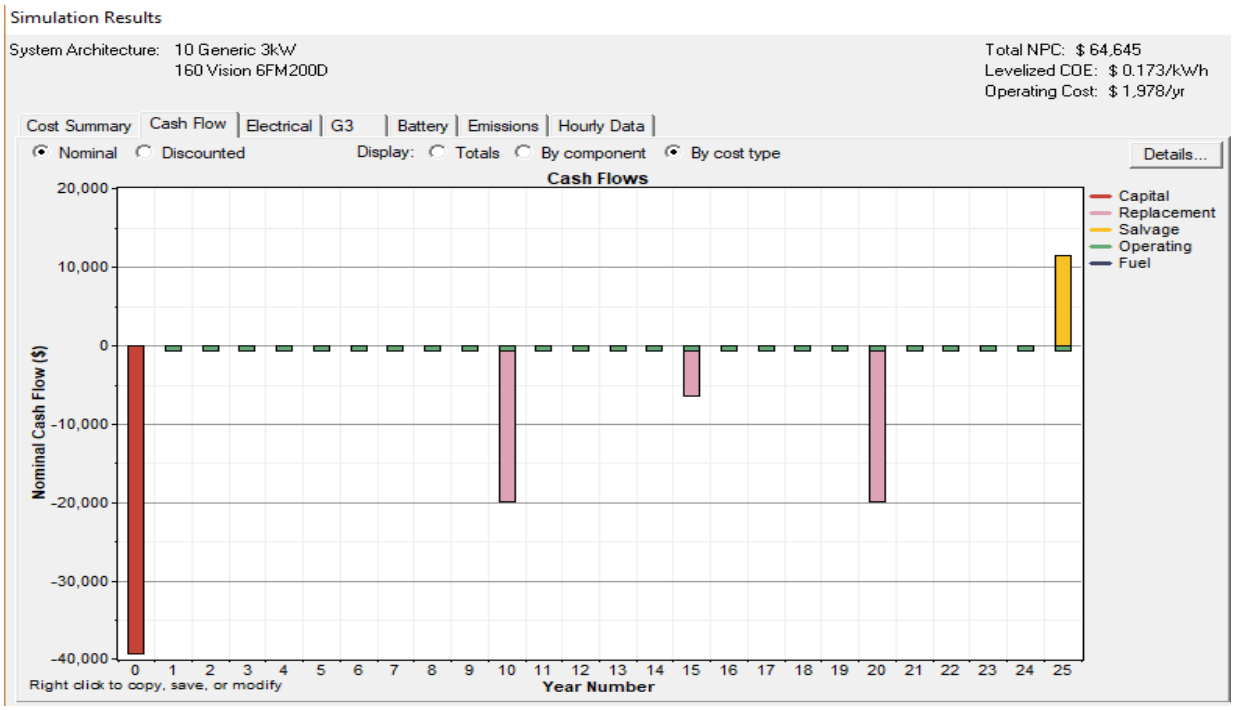


Figure 6.18 :Cash Flows

6.9.7 Monthly Average Electric Production

The below figure shown the monthly distribution of the electricity produced in kW by the Wind Turbine. From march to September, the Wind Turbine is mostly used. Also, from june to August the peak load is met by Wind Turbine . Lack of Wind speed in various month,We get power From storage in Batteries.

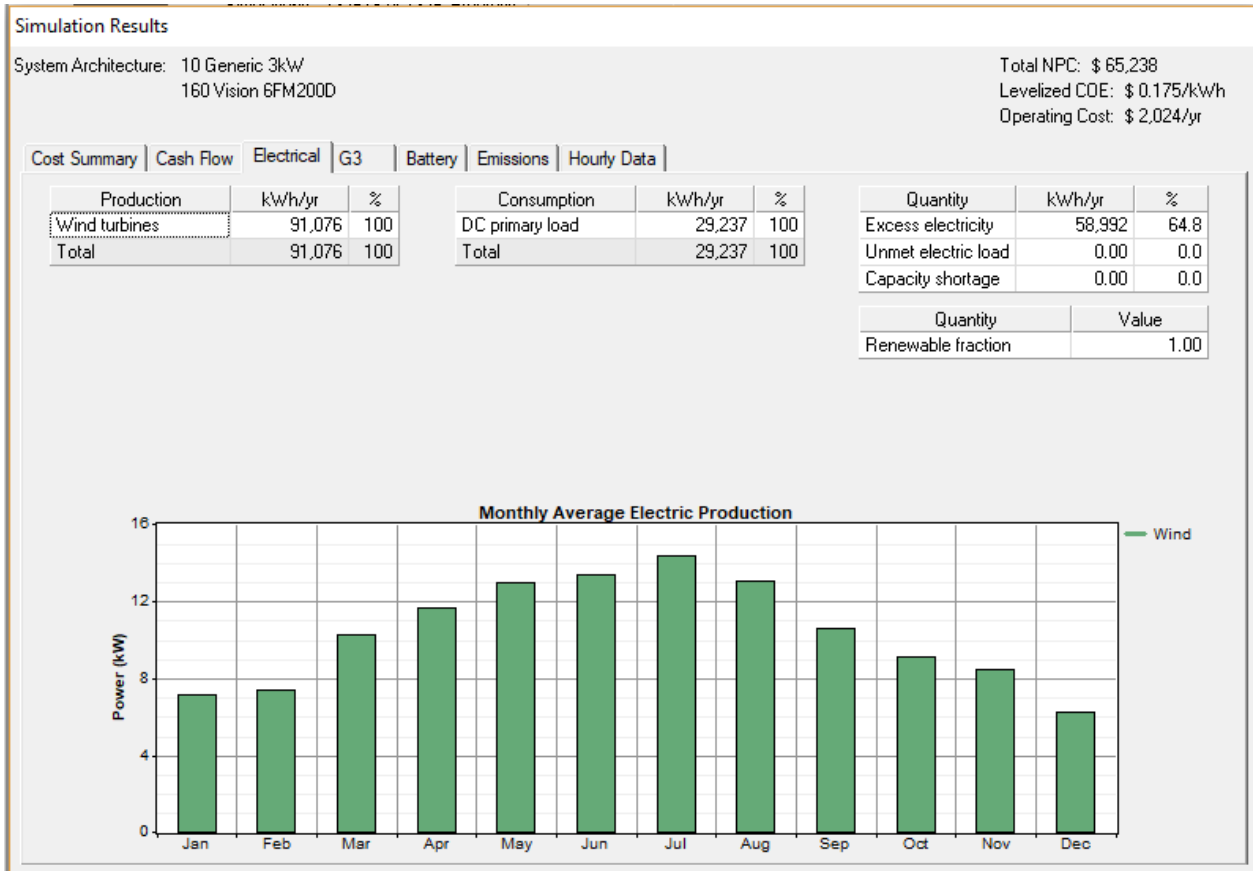


Figure 6.19:Monthly Average Electricity Production

The below fig. shows electricity production of the system components.

Table 6.5 :Electricity production of the system components

Prduction	KWh/yr	%
Wind Turbine	91,076	100

6.9.8 Sensitivity and Optimization Results

This case consist of sensitivity variables like (Wind Turbine size, battery size) are considered in this analysis. The area load at 80 kWh/d, 18 kW peak, this system might majority consist of 30 kW Wind Turbine , 160 unit of batteries .And those case simulates HOMER Software.

For this case optimization result are consist of initial capital, total net present cost (NPC), cost of energy (COE), renewable fraction, diesel in litter and generator in hourly working in this system. This system of COE $.175/KWh.The total Net present cost $65,238.Excess electricity produce 58,992KWh/yr of 64.8%.And unmet electric load 0.0KWh/yr of 0.0%.Also capacity shortage 0.0KWh/yr of 0.0%.Further renewable fraction value 1.0.

So the Sensitivity result of this case,the (Wind Turbine and Batteries) based system is not suitable Because we can not provide 100% power energy of consumers.it has no alternative source and also the storage power from Battery can not back up the whole system.

6.10 (PV+Wind Turbine+Battery) Energy Consumption System

6.10.1 System Components Assessment

The energy system components are PV Modules,Battery and Power Converter. The cost, number of units to be used, operating hours, etc. need to be specified in HOMER software for each of this equipment.This information details involved in previous section.

In this system,the main component is renewable energy component its PV Panel and Wind Turbine Load is DC ,.Here,use Large amount of PV Panel and medium amount of Wind Turbine.Both have the other component involved such as a battery(vision 6FM200D model) [34].

The PV panel and Wind Turbine are produced DC and PV ,Wind Turbine connected DC bus so,this current is not converted because load is DC.

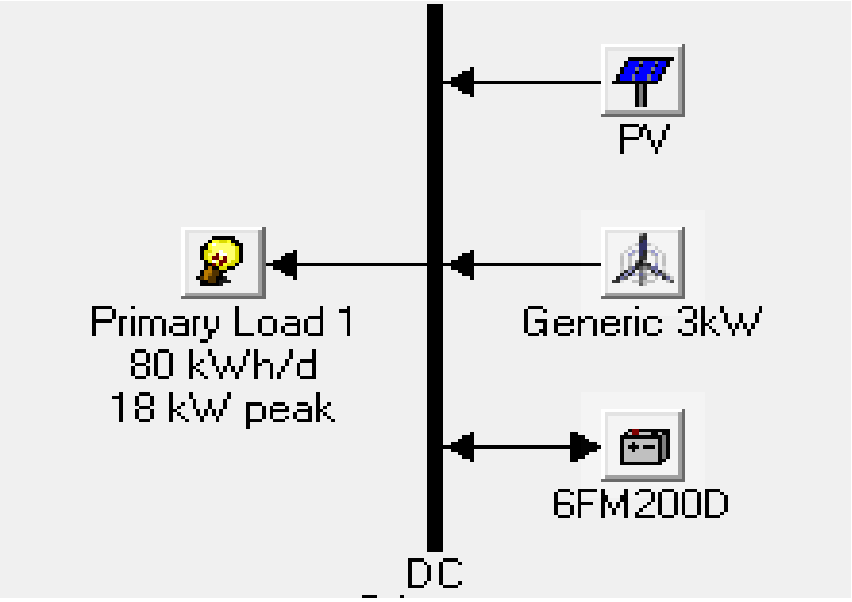


Figure 6.20: (PV+Wind Turbine+Battery) Energy Consumption System

6.10.2 PV Array Model

Solar Panel installation cost is $.35/W. This case, considered a 20KW solar energy system. A 20KW solar energy system's installation and Replacement cost are taken as $7000 and $6000. There are different sizes are considered, such as 1KW to 25KW. This PV array lifetime is 25 Years and 25 years output come here. This PV array is no tracking system [31].

6.10.3 Wind Turbine Model

Availability of energy from the wind turbines depends greatly on wind variations. Therefore, wind turbine rating much lower compared to the average electrical load. In this analysis,we considered Generic 3kw model with hub height (25 m) is considered. It provides (DC) voltage as an output.The capital ,replacement and maintenance costs of 6 kw are taken as ($1584) ,($1150) and ($100/year).A lifetime of a turbine is taken to be (15 years)[33,26,37].

Wind speed fig.6.21 shown in below

Month	Wind Speed (m/s)
January	6.220
February	6.340
March	7.370
April	7.920
May	8.470
June	8.690
July	9.200
August	8.540
September	7.480
October	6.930
November	6.710
December	5.910
Annual average:	7.489

Figure 6.21: Wind Speed

6.10.4 Battery Model

Batteries carry major cost in power system. In every case different number of batteries are used.This battery model are available in Bangladesh.The battery model is Vision 6FM200D (12V.200Ah). This Battery service are Long life. An Warranty 1 years. The cost of one is ($150) with a replacement cost of ($150) while the maintenance cost is expected at ($.29/year). The battery to be considered in this simulation is range from 1to 62 units[34].

Nominal capacity:	200 Ah
Nominal voltage:	12 V
Round trip efficiency:	80 %
Min. state of charge:	40 %
Float life:	10 yrs
Max. charge rate:	1 A/Ah
Max. charge current:	60 A
Lifetime throughput:	917 kWh
Suggested value:	900 kWh
Calculated parameters	
Maximum capacity:	193 Ah
Capacity ratio, c:	0.184
Rate constant, k:	7.48 1/hr

Figure 6.22: Vision 6FM200D Battery Specification

6.10.5 Simulation Results

The project's lifetime is considered to be 25 years .The optimal combination of power system components for our case study is a 20kW PV-Array,6 KW Wind Turbine,220 unit vision 6FM200D. The total net present cost, capital cost and the cost of electricity (COE) for such a hybrid system are $73,174, $47,259 and $0.196/kWh[].

The figure 6.6.7 shows the simulation result of (Wind Turbine+PV+ Battery) energy generation system.

Double click on a system below for simulation results.

PV (kW)	G3	Label (kW)	6FM200D	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)
15	3		220		$ 46,522	2,072	$ 73,003	0.195	1.00		
18	5		200		$ 46,598	2,068	$ 73,029	0.195	1.00		
5	6	2	120	5	$ 31,811	3,231	$ 73,109	0.196	0.98	524	1,390
8	6	2	120	1	$ 32,677	3,163	$ 73,111	0.196	0.99	463	1,380
20	2		220		$ 47,259	2,027	$ 73,174	0.196	1.00		
8	6	2	104	3	$ 30,369	3,355	$ 73,259	0.196	0.98	549	1,441

Figure 6.23: Simulation Results

6.10.6 Cost Summary

The whole project cost summary shown in below figure . However once PV panel and Wind Turbine installed,the maintainance and operating cost become very cheap .Fixed capital cost of this project are $47,259.And the operating and maintainance cost is estimated to be $4,804.The replacement cost is $25,324.The system fixed capital costs include various civil constructions, labor, logistics wages, required licenses, administration and government approvals and other miscellaneous costs.

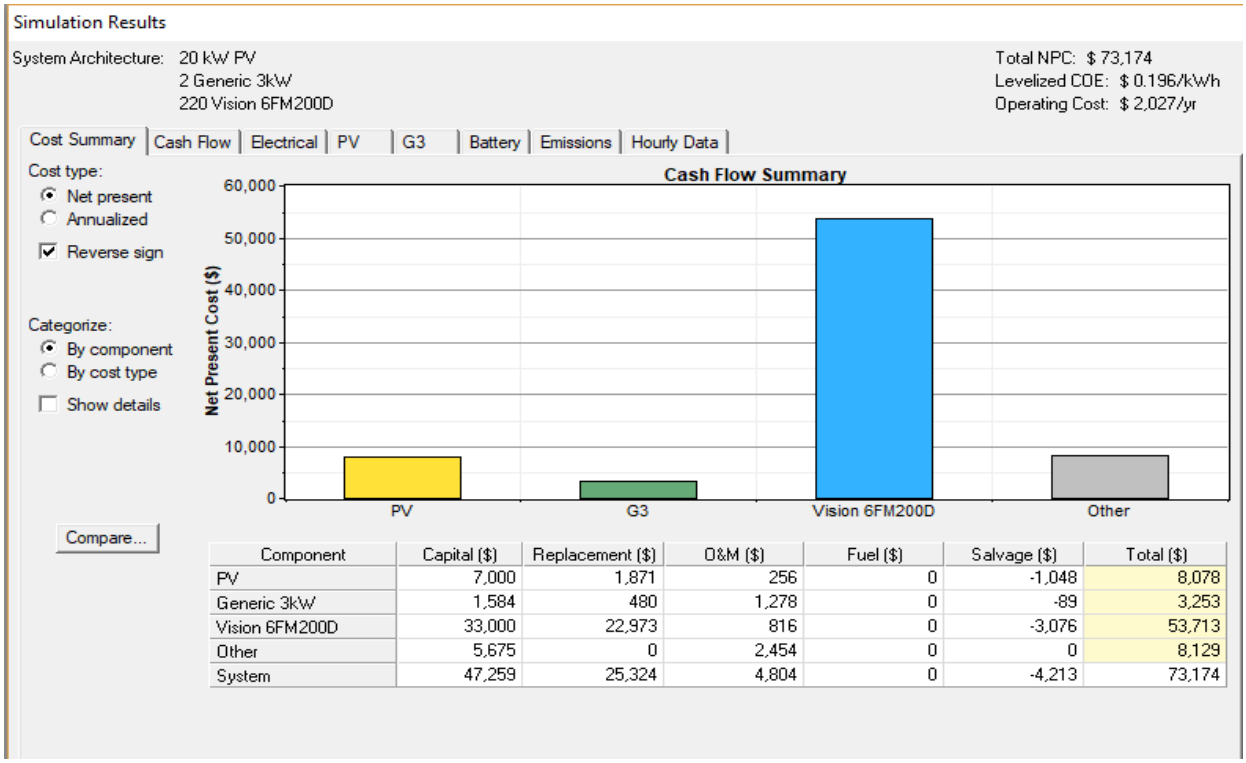


Figure 6.24: Cost Summary

6.10.7 Cash Flows

The fig. shows the cash flows graph.The total NPC is $73,174.The levelized COE is $0.196/kwh.And the operating cost is $2,027/yr.

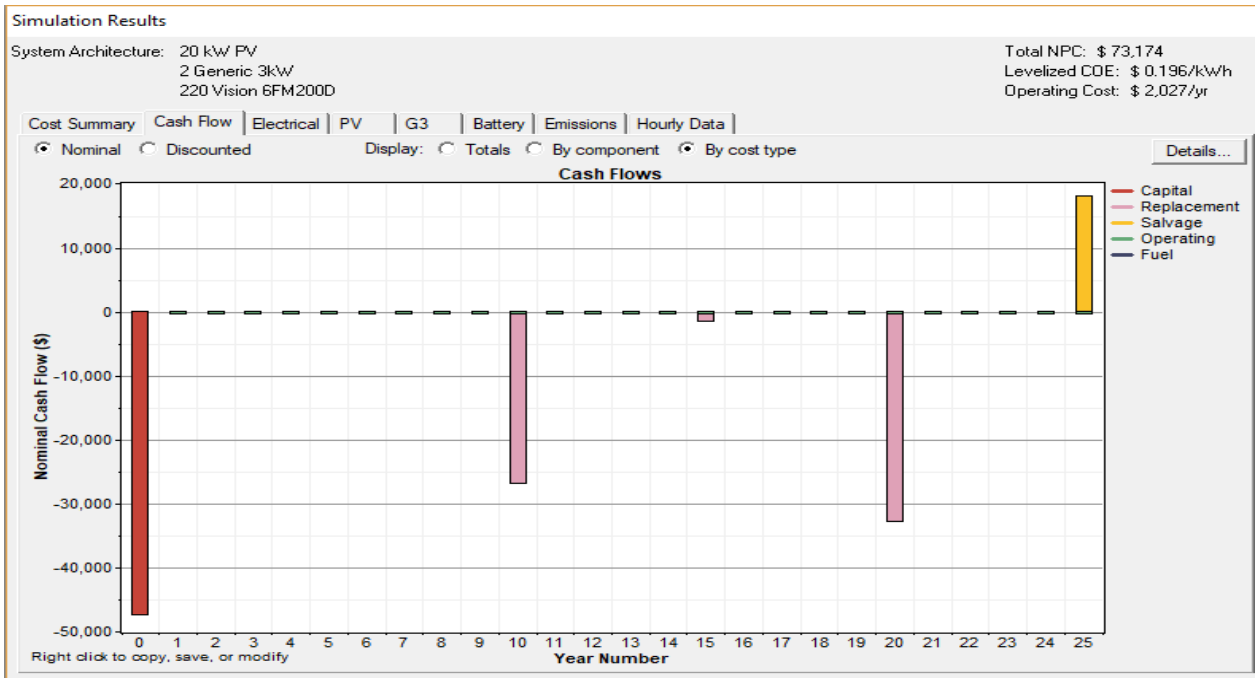


Figure 6.25: Cash Flows

6.10.8 Monthly Average Electric Production

The below figure shown the monthly distribution of the electricity produced in kW by the (PV) and (Wind Turbine). From October to April, the PV is mostly used combined with Wind Turbine. Also, from March to May the peak load is met by (PV) and (Wind Turbine).Lack of solar radiation and Wind speed in various month, We can use Batteries as a back up in this system.

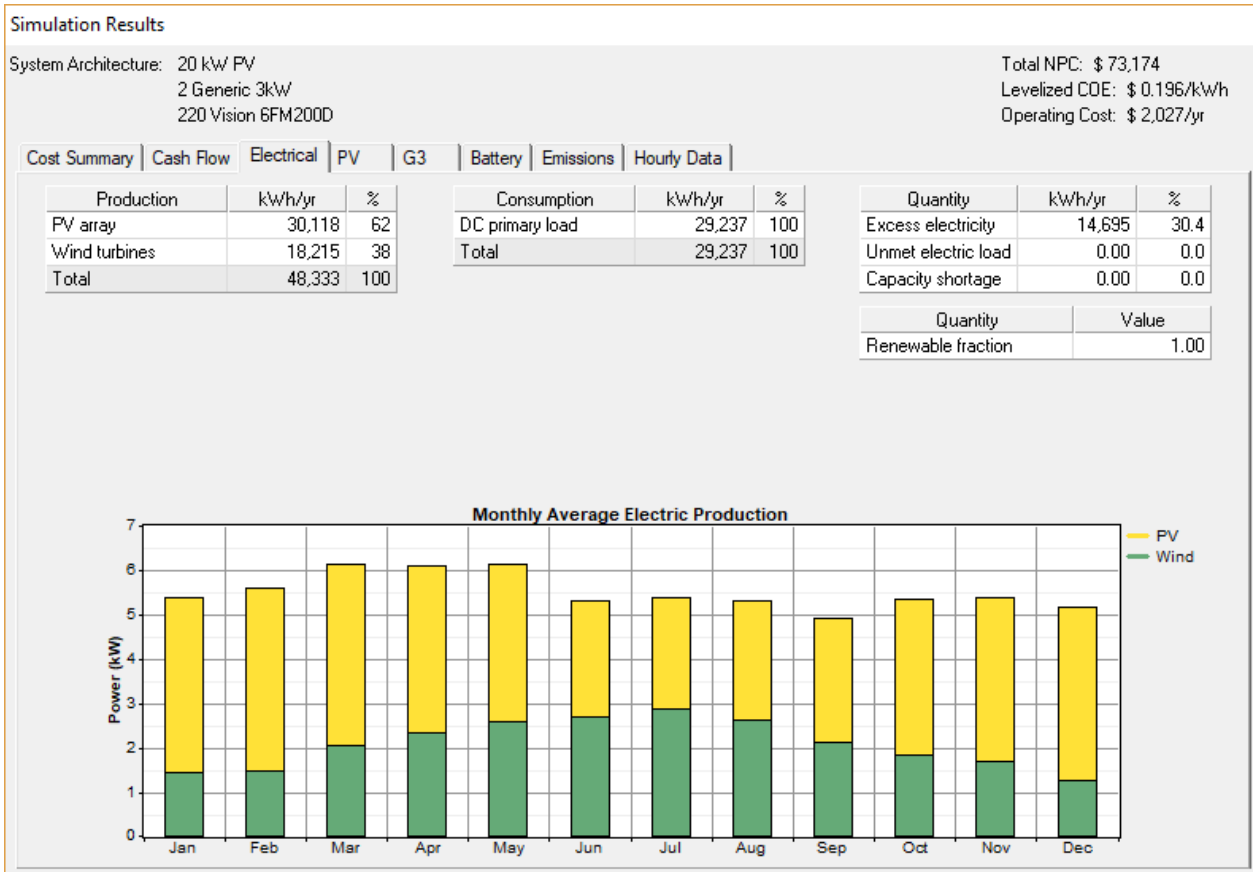


Figure 6.26: Monthly Average Electric Production

Table 6.6: Electric Production of the system Components

Production	KWh/yr	%
PV Array	30,118	62
Wind Turbine	18,215	38
Total	48,333	100

6.10.9 Sensitivity and Optimization Results

This case consist of sensitivity variables like (PV size,Wind Turbine size, battery size) are considered in this analysis. The area load at 80 kWh/d, 18 kW peak, this system might majority consist of 20 kW PV array,6 KW wind Turbine, 220 unit of batteries.And those case simulates HOMER Software.

For this case optimization result are consist of initial capital, total net present cost (NPC), cost of energy (COE), renewable fraction, diesel in litter and generator in hourly working in this system. This system of COE $.196/KWh.The total Net present cost $73,174. Excess electricity produce 14,695KWh/yr of 30.4%.And unmet electric load 0.0KWh/yr of 0.0%.Also capacity shortage 0.0KWh/yr of 0.0%.Further renewable fraction value 1.0.

So the Sensitivity result of this case,the (PV, Wind Turbine, battery) based hybrid system is not suitable due to Alternative source .Beacuse without alternative source like Diesel Generator those whole system can give 100% surety to provide electrical energy to consumers.

6.11 Mini- Grid Hybrid Power System

Mini Grid Hybrid system consists variable component such as(Solar,Wind, Biogas,Diesel,Battery and converter).The figure of Mini grid system shown in below

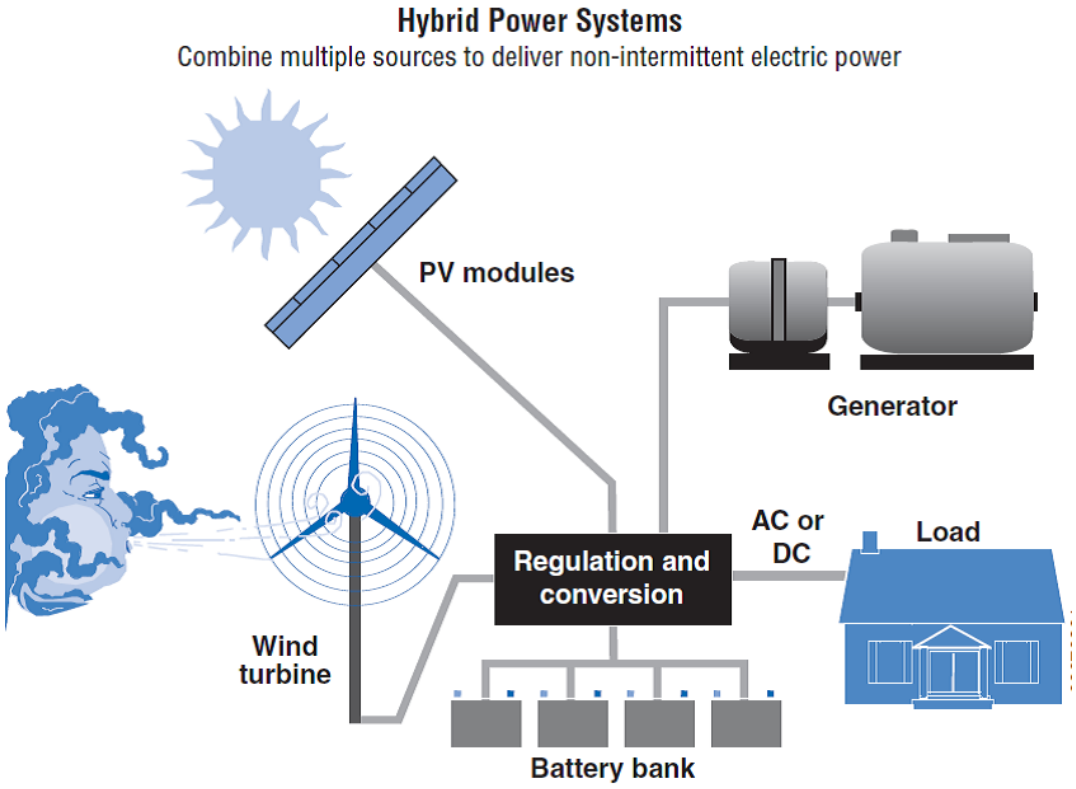


Figure 6.27: Mini-Grid Hybrid Power System

6.12 The Proposed Mini-Grid Hybrid Generation System

6.12.1 Proposed Hybrid System Modeling

We have considered a combination of the following technologies, namely solar (PV) system, wind turbine, batteries, a diesel generator (DG) and converter . In the hybrid system, the demand from the area is (DC) coupled, the (DG) are connected to the (AC) side of the network and the (PV) system,Wind Turbine and the batteries are connected to its (DC) side. Usually, a conventional back-up diesel generator (DG) is used to supplement the hybrid power system for peak loads and during unavailable of renewable resource period.

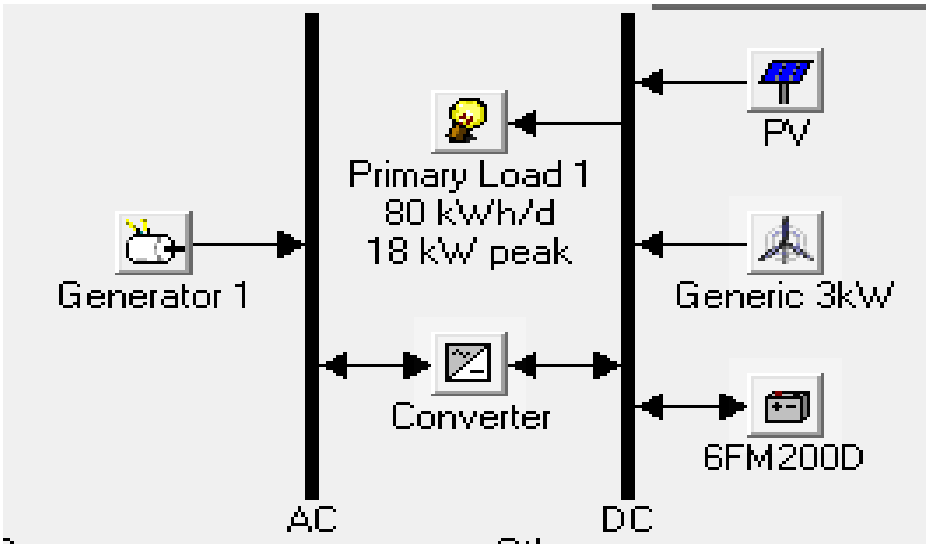


Figure 6.28:Proposed Hybrid power system

6.12.2 System Component Assessment

The energy system components are PV Modules,Wind Turbine,Battery and Power Converter. The cost, number of units to be used, operating hours, etc. need to be specified in HOMER software for each of this equipment.This information details involved in previous section.

In this system,the main component is renewable energy component its PV Panel and Wind Turbine.The Load is DC .and back up source Diesel Generator and Batteries.

The PV panel and Wind Turbine are produced DC and PV ,Wind Turbine connected DC bus so,this current is not converted because load is DC.

6.12.3 Photovoltaic Array Model

Solar Panel installation cost is $.35/W. This case, considered a 8KW solar energy system. A 8KW solar energy system's installation and Replacement cost are taken as $2800 and $2400. There are different sizes are considered, such as 1KW to 25KW. This PV array lifetime is 25 Years and 25 years output come here. This PV array is no tracking system [31].

6.12.4 Wind Turbine Model

Availability of energy from the wind turbines depends greatly on wind variations. Therefore, wind turbine rating much lower compared to the average electrical load. In this analysis,we considered Generic 3kw model with hub height (25 m) is considered. It provides (DC) voltage as an output.The capital ,replacement and maintenance costs of 18 kw are taken as ($5,636) ,($3,467) and ($300/year).A lifetime of a turbine is taken to be (15 years).[33,26,37]

6.12.5 Diesel Generator Model

Diesel generator connected in AC bus. For remote electrification commonly used in Diesel Generator.Because it is low cost,easy to install and electric opertating system.There are various range of diesel generator,choose in appropriate model for this Location.This case use is 2KW diesel generator and cost is taken $520.The minimum load ratio 30%.The lifetime rating is taken 15000hr.The diesel price per liter BDT65 taka [32,28].

6.12.6 Battery Model

Batteries carry major cost in power system. In every case different number of batteries are used.This battery model are available in Bangladesh.The battery model is Vision 6FM200D (12V.200Ah). This Battery service are Long life. An Warranty 1 years. The cost of one is ($150) with a replacement cost of ($150) while the maintenance cost is expected at ($.29/year). The battery to be considered in this simulation is range from 1to 62 units[34].

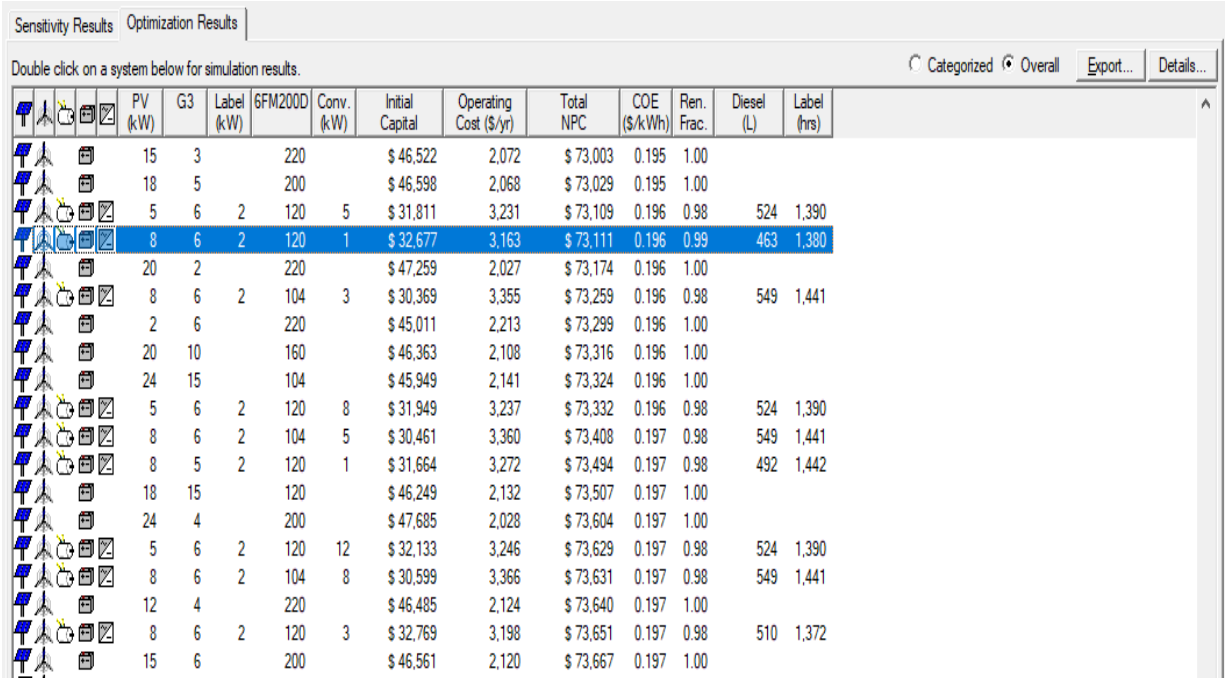
6.12.7 Power Converter

A power electronics converter is used to convert AC to DC and DC to AC. The simulation range of power converter are 1KW to 25KW. We use 1KW converter in this case. A lifetime of a unit is considered to be (15 years) [35].

6.12.8 Simulation Results

The project's lifetime is considered to be 25 years .The optimal combination of power system components for our case study is 8KW Pv panel,18KW wind turbine,120 unit vision 6FM200D. The total net present cost, capital cost and the cost of electricity (COE) for such a system are $73,111 , $32,677 and $0.196/kWh.

The below fig shows the simulation result of PV Panel,Wind Turbine,Converter and Batteries Energy Generation System.

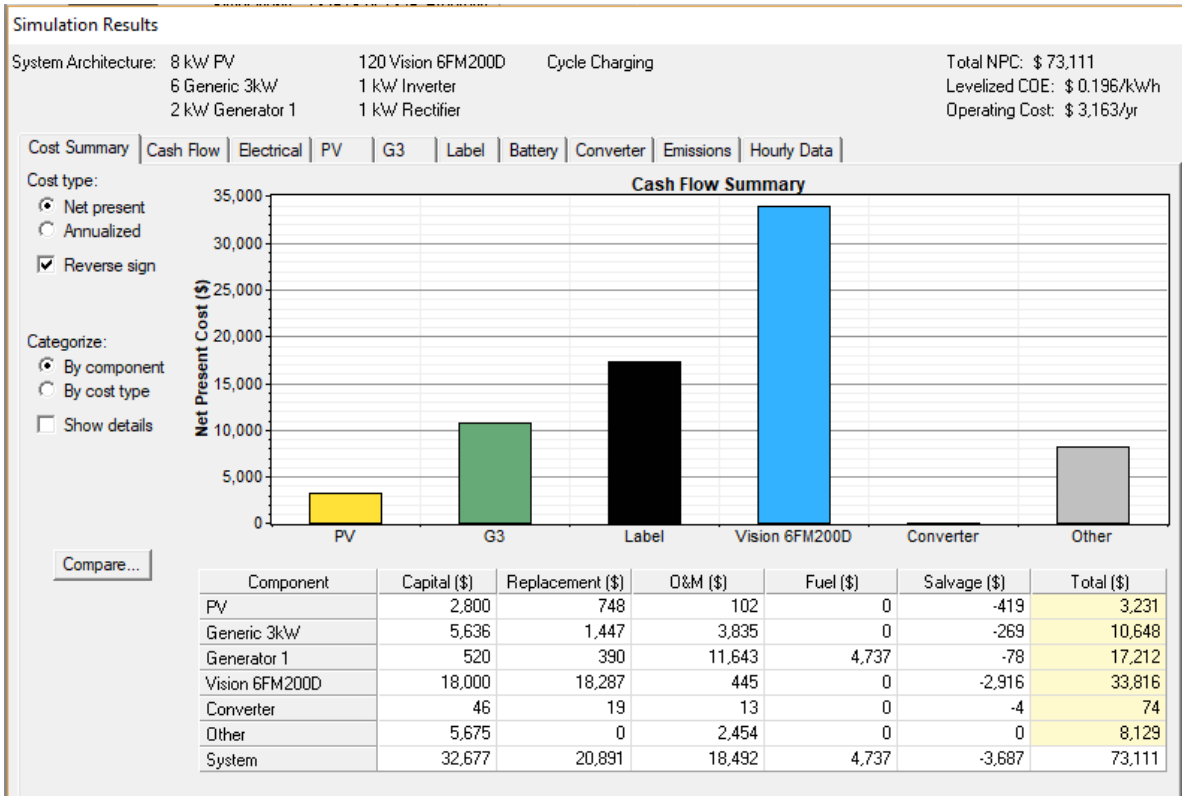


PV (kW)	G3	Label (kW)	6FM200D	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)
15	3		220		$ 46,522	2,072	$ 73,003	0.195	1.00		
18	5		200		$ 46,598	2,068	$ 73,029	0.195	1.00		
5	6	2	120	5	$ 31,811	3,231	$ 73,109	0.196	0.98	524	1,390
8	6	2	120	1	$ 32,677	3,163	$ 73,111	0.196	0.99	463	1,380
20	2		220		$ 47,259	2,027	$ 73,174	0.196	1.00		
8	6	2	104	3	$ 30,369	3,355	$ 73,259	0.196	0.98	549	1,441
2	6		220		$ 45,011	2,213	$ 73,299	0.196	1.00		
20	10		160		$ 46,363	2,108	$ 73,316	0.196	1.00		
24	15		104		$ 45,949	2,141	$ 73,324	0.196	1.00		
5	6	2	120	8	$ 31,949	3,237	$ 73,332	0.196	0.98	524	1,390
8	6	2	104	5	$ 30,461	3,360	$ 73,408	0.197	0.98	549	1,441
8	5	2	120	1	$ 31,664	3,272	$ 73,494	0.197	0.98	492	1,442
18	15		120		$ 46,249	2,132	$ 73,507	0.197	1.00		
24	4		200		$ 47,685	2,028	$ 73,604	0.197	1.00		
5	6	2	120	12	$ 32,133	3,246	$ 73,629	0.197	0.98	524	1,390
8	6	2	104	8	$ 30,599	3,366	$ 73,631	0.197	0.98	549	1,441
12	4		220		$ 46,485	2,124	$ 73,640	0.197	1.00		
8	6	2	120	3	$ 32,769	3,198	$ 73,651	0.197	0.98	510	1,372
15	6		200		$ 46,561	2,120	$ 73,667	0.197	1.00		

Figure 6.29: Simulation Results

6.12.9 Cost Summary

The whole project cost summary shown in below figure . However once PV and Wind Turbine installed,the maintainance and operating cost become very cheap then Diesel generator system.Fixed capital cost of this project are $32,677.And the operating and maintainance cost is estimated to be $18,492.The replacement cost is $20,891.The system fixed capital costs include various civil constructions, labor, logistics wages, required licenses, administration and government approvals and other miscellaneous costs.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	2,800	748	102	0	-419	3,231
Generic 3kW	5,636	1,447	3,835	0	-269	10,648
Generator 1	520	390	11,643	4,737	-78	17,212
Vision 6FM200D	18,000	18,287	445	0	-2,916	33,816
Converter	46	19	13	0	-4	74
Other	5,675	0	2,454	0	0	8,129
System	32,677	20,891	18,492	4,737	-3,687	73,111

Figure 6.30: Cost Summary

6.12.10 Cash Flows

The fig. shows the cash flows graph.The total NPC is $73,111.The levelized COE is $0.196/kwh.And the operating cost is $3,163/yr.

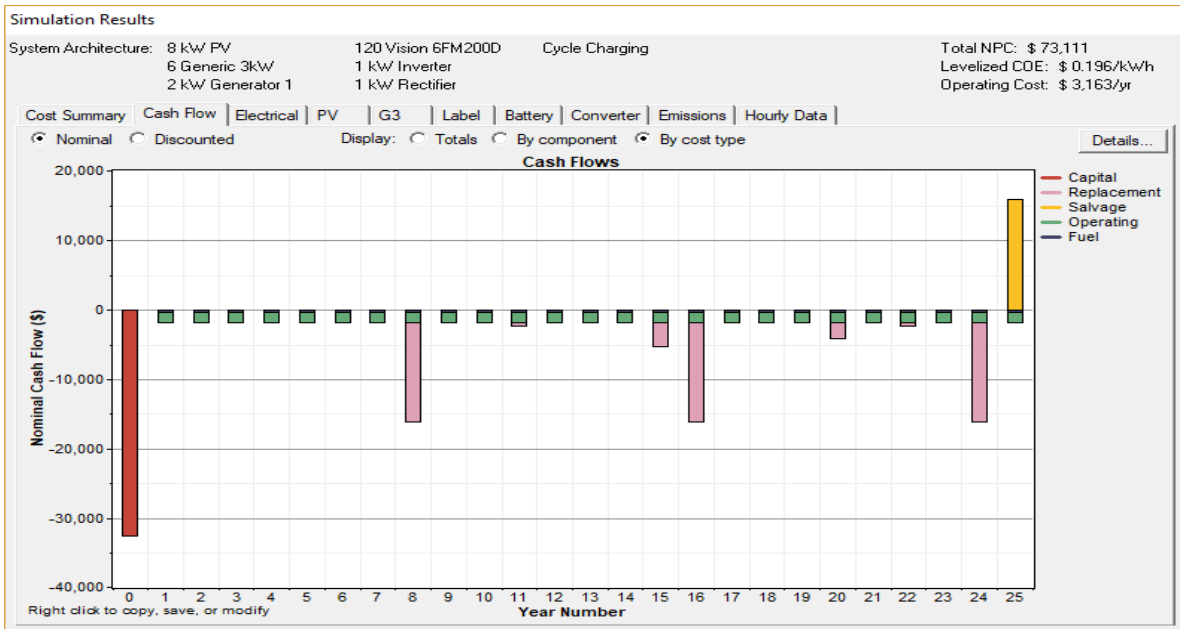


Figure 6.31:Cash Flows

6.12.11 Monthly Average Electric Production

The below figure shown the monthly distribution of the electricity produced in kW by the (PV), Wind Turbine and Diesel. From April to August, the Wind is mostly used combined with PV and Diesel Generator. Also, from May to July the peak load is met by (PV) and (Wind Turbine). The Wind operates at full load along the year and produces (54,646KWh/year), achieving a capacity factor of 81% . In various month when solar radiation are inadequate and wind are inavailable ,Diesel generator becomes the dominant producer. For the selected system the Diesel generator operates for 1,380 hours (capacity factor 1%), produces (970 kWh/year) and consumes 463 liter of fuel.The solar produces(12,047/kwh),achieving a capacity factor of 18%.

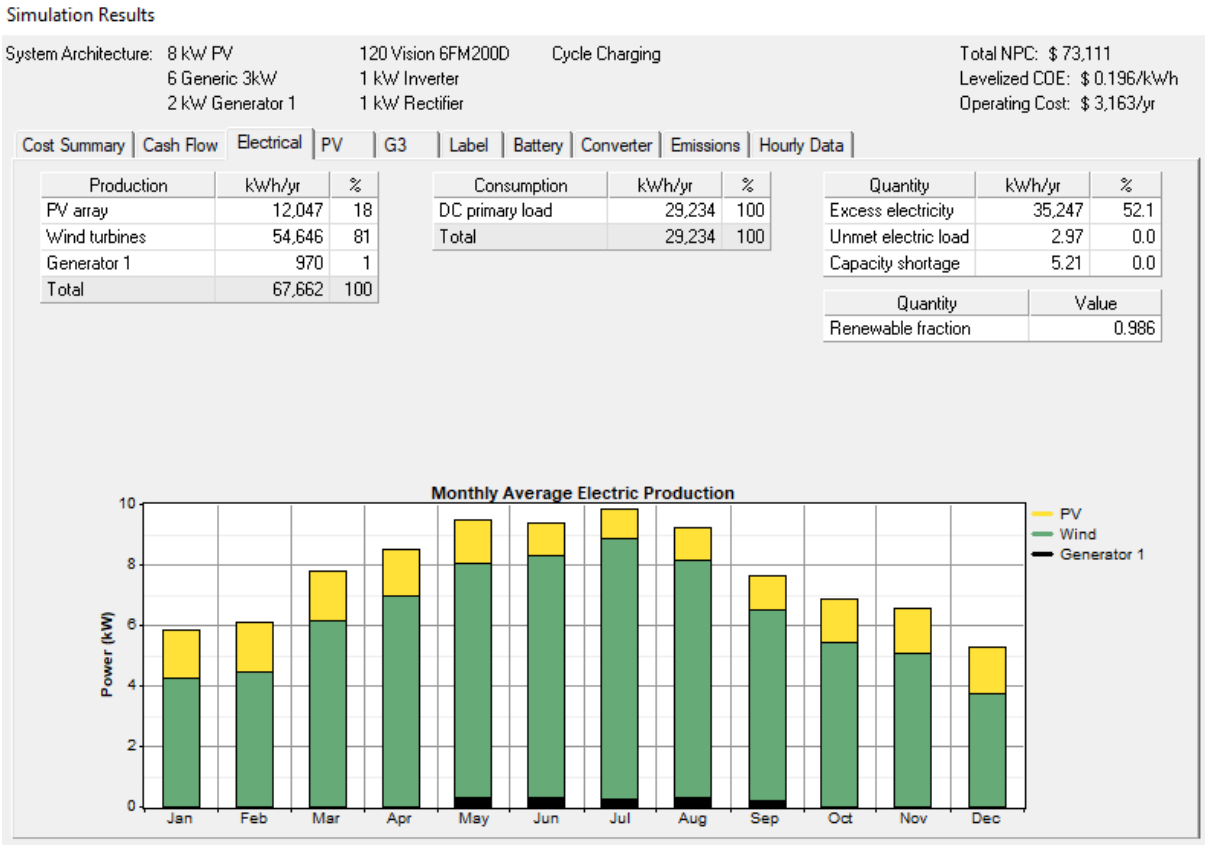


Figure 6.32: Monthly Average Electric Production

Table 6.7: Electric Production of the system components

Production	KWh/yr	%
PV Array	12,047	18
Wind Turbine	54,646	81
Generator 1	970	1
Total	67,662	100

6.12.12 Sensitivity and Optimization Results

This case consist of sensitivity variables like (PV size,Wind Turbine size, battery size and converter size) are considered in this analysis. The area load at 80 kWh/d, 18 kW peak, this system might majority consist of 8 kW PV array,18KW wind Turbine, 120 unit of batteries and 1KW converter.And those case simulates HOMER Software.

For this case optimization result are consist of initial capital, total net present cost (NPC), cost of energy (COE), renewable fraction, diesel in litter and generator in hourly working in this system. This system of COE $.196/KWh.The total Net present cost $73,111. Excess electricity produce 35,247KWh/yr of 52.1%%.And unmet electric load 0.0KWh/yr of 0.0%.Also capacity shortage 0.0KWh/yr of 0.0%.Further renewable fraction value 1.0.

So the Sensitivity result of this case,the (PV, Wind Turbine,Diesel generator,converter and battery) based hybrid system is suitable for stand alone.Beacuse with alternative source like Diesel Generator those whole system we can give 100% surety to provide electrical energy to consumers.

6.12.13 Emission

We can see below this figure the major emission comes from carbon dioxide.

Pollutant	Emissions (kg/yr)
Carbon dioxide	1,220
Carbon monoxide	3.01
Unburned hydrocarbons	0.334
Particulate matter	0.227
Sulfur dioxide	2.45
Nitrogen oxides	26.9

Figure 6.33: Emission

CHAPTER 7

DISCUSSION AND CONCLUSION

7.1 Conclusion

Optimization of wind-solar-Diesel generator hybrid power system connected to DC load is presented in this study. The cost of diesel fuel is increasing day by day. On the other hand, the amount of non renewable energy sources is decreasing day by day. It is not feasible to use only diesel as a source of energy generation nowadays. Hybrid energy generation system can be feasible and optimized solution in this regard. In HOMER shows that component sizes, cost summary, cash flow summary, electrical production and cost of PV-Wind-Diesel Generator hybrid system.In this study, a PV-diesel-wind-battery hybrid generation system was found most feasible and optimized.For our Proposal Model 8KW solar-PV modules , 6KW Wind Turbine (each of 3KW), 2KW diesel generators,120 batteries (each of 200 Ah) and 1KW converter is found to be the best configuration in terms of Cost of Energy (COE), environmental conditions and Renewable Fraction (RF). The Cost of Energy (COE) $0.196/KWh The renewable fraction of this system is found 99%.This Project Lifetime 25years.

7.2 Limitations

There are some major limitations.

1.Cannot give exact diagram.

2.It works on a fixed fuel price, but fuel price is not fixed at all.

3.Solar radiation is not same always, but Homer doesn't calculate it.

4.Wind speed is not same always,but Homer software doesn't calculate it.

5. GHG (Greenhouse gas) analysis is not available, but Carbon Emission (tone/year) can be obtained.

6.The obtained result is found from the HOMER software .The actual calculated result may vary.

7.3 Scope for future work

1. Ethanol,Gasoline, Methanol,Propen can be added to the proposed hybrid energy generation
2.Hydro energy can be added to the proposed hybrid energy generation
3.Biogas energy can be added to the proposed hybrid energy generation
4. Liquefied Natural Gas can be added to the proposed hybrid energy generation.

Reference:

1. https://whatis.techtarget.com/definition/microgrid
2. Md. Nurnnabi, N.K. Roy, " Grid connected hybrid power system design using HOMER", Proceedings of 2015 3rd International Conference on Advances in Electrical Engineering 17-19 December, 2015, Dhaka, Bangladesh.
3. Nasif Mahmud, Asif Hasan, Md Shaminur Rahman," Modelling and cost analysis of hybrid energy system for St. martin Island using HOMER", 2013 2nd International Conference on Informatics, Electronics and Vision (ICIEV 2013) (2013).
4. Suman Chowdhury, Swapan Kumar Saha," Height analysis for site selection of wind potentiality in bangladesh", INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 3, ISSUE 1, JANUARY 2014.
5. Shakti Singh, Mukesh Singh,"Feasibility study of an Island micro-grid in rural area consisting of PV, Wind, Biomass and Battery energy storage system", Energy Conversion and Management Volume 128, 15 November 2016, Pages 178-190.
6. Kandula Murali Krishna," Optimization analysis of micro-grid using HOMER", India Conference (INDICON), 2011 Annual IEEE.
7. R. Nazir, H. D. Laksono," Renewable energy sources optimization: A micro-grid model design", 2013 International Conference on Alternative Energy in Developing Countries and Emerging Economies.
8. Sk. A. Shezan, M. Farzana," Techno-Economic Analysis of a Hybrid PV Wind-Diesel Energy System for Sustainable development at Coastal Areas in Bangladesh", 2016 4th International Conference on the Development in the in Renewable Energy Technology (ICDRET).
9. Subhes C. Bhattacharyya," mini-grid based electrification in Bangladesh: Technical configuration and business analysis", Renewable Energy Volume 75, March 2015, Pages 745-761.
10. Rohit Sen, Subhes C. Bhattacharyya," off- grid electricity generatio with renewable energy technologies in india: An application of HOMER" Renewable Energy Volume 62, February 2014, Pages 388-398.
11. Sunanda Sinha, S. S. Chandel," Review of recent trends in optimization techniques for solar photovoltaic–wind based hybrid energy systems", Renewable and Sustainable Energy Reviews, Elsevier, vol. 50(C), pages 755-769.

12. Vinod Srivastava, Vinod Kumar Giri," optimization of hybrid renewable resources using HOMER" INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH R. Srivastava and V.K.Giri, Vol.6, No.1, 2016.
13. Vikas Khare, Savita Nema," Status of solar wind renewable energy in india", Renewable and Sustainable Energy Reviews Volume 27, November 2013, Pages 1-10.
14. Muhammad Taheruzzaman," Design, Planning, and Modelling of Renewable Energy Integrated Microgrid for Rural Electrification in Bangladesh".
15. Alam Hossain mondal, Manfred Denich, " Hybrid system for decentralized power generation in Bangladesh", Energy for Sustainable Development Volume 14, Issue 1, March 2010, Pages 48-55.
16. A. Z. A. Saifullah, Md. Abdul Karim, Md. Raisul Karim," Wind Energy Potential in Bangladesh".
17. "Key Statistics". Bangladesh Power Development Board. Retrieved 3 November 2014.
18. "Source of Light in Bangladesh : 2015". Retrieved 8 June 2017.
19. "Govt plans to sign energy pact with Bangladesh". The Himalayan Times. 2018-04-16. Retrieved 2018-05-09.
20. https://en.wikipedia.org/wiki/Electricity_sector_in_Bangladesh.
21. https://www.sourcewatch.org/index.php/Matarbari_power_station.
22. http://mole.my/bangladesh-finds-oil-reserves-worth-5-5-billion/.
23. http://energynewsbd.com/details.php?id=622
24. https://energypedia.info/wiki/Bangladesh_Energy_Situation#Wind_Energy
25. http://www.sdnbd.org/wind.htm
26. http://en.banglapedia.org/index.php?title=Patenga_Thana
27. https://www.google.com/search?q=1+dollar+to+taka&rlz=1C1GGRV_enBD805BD805&oq=1+dolar+&aqs=chrome.1.69i57j0l5.6983j1j7&sourceid=chrome&ie=UTF-8
28. http://www.bpc.gov.bd/contactus.php?id=39
29. https://en.wikipedia.org/wiki/Photovoltaics
30. https://en.wikipedia.org/wiki/Diesel_generator
31. https://www.alibaba.com/product-detail/Cheap-price-hot-selling-top-quality_60783235106.html?spm=a2700.7724857.normalList.18.22d669c5S9XXRJ&s=p
32. https://www.alibaba.com/product-detail/1kw-2kw-low-price-diesel-generator_60035448850.html?spm=a2700.7724857.normalList.6.28bf18400hL4xR&s=p
33. https://www.alibaba.com/product-detail/600w-1kw-2kw-3kw-5kw-10kw_1706128678.html?spm=a2700.7724857.normalList.46.125d49aemud7zN
34. https://www.alibaba.com/product-detail/Reliable-Quality-12v200ah-lead-acid-battery_60621388034.html?spm=a2700.7724857.normalList.58.366819d0nsOoCu
35. https://www.amazon.com/Adjustable-Converter-110V-220V-Switching-Transformer/dp/B0777MH681?ref_=fsclp_pl_dp_3
36. https://en.wikipedia.org/wiki/Renewable_energy
37. Md.Robiul Islam,Md.Nazibur Rahman,"STUDY OF WIND POWER IN DIFFERENT PARTS OF BANGLADESH",page-1292,volume:03.