OPTIMIZATION, SIMULATION AND CONTROL STRATEGY OF HYBRID RENEWABLE POWER SYSTEM FOR BASE TRANSCEIVER STATION (BTS) IN BANGLADESH

BY

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RECOMMENDATION

This is to certify that Md. Emran Hossain (ET 101036) & S.M. Shahnewaz Siddiquee (ET 101072), students of International Islamic University Chittagong (IIUC) under the department of Electrical & Electronic Engineering (EEE), had carried out the thesis titled "Optimization, Simulation And Control Strategy Of Hybrid Renewable Power System For Base Transceiver Station (BTS) In Bangladesh" successfully under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

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June 2014

CANDIDATES DECLARATION

It is hereby declare that the work have been done by us under the supervision of **Engr. Md. Aasim Ullah ,** Lecturer, Department of Electrical and Electronic Engineering, International Islamic University Chittagong (IIUC). The thesis has not been published anywhere in full, or in a part. All items and sub items that appear on the thesis are referenced, where needed. The thesis has been completed by our individual effort which has not been copied from anywhere.

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ABSTRACT

Base Transceiver station (BTS) is a set of telecommunication network that organized as tower with transmitter and receiver antennas. The function of BTS is power amplification so it can connect the telecom operator networking with customers. Power is the main issue for telecom operators to set up cellular network coverage in remote or isolated areas. Power generation by combining both renewable and conventional sources known as hybrid power generation, can be the most efficient way for electrification of Base transceiver station (BTS). The aim of this thesis is to determine the optimized system configuration of PV based renewable hybrid system for remote off-grid BTS sites as well as grid connected BTS sites in Bangladesh. The possibility of supplying electric energy from solar-wind resources to the BTS is also investigated. For this analysis three case study is considered. We analyzed the possibility of using renewable source for both off-grid and grid connected BTS taking Chittagong as reference site. The final optimization of the renewable based hybrid system is carried out through Hybrid Optimization Model for Electric Renewable (HOMER) software to find out that whether the system is feasible or not for proper electrification in the BTS.

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LIST OF ABBREVIATIONS

GHG	Green house gases
HOMER	Hybrid optimization model for electric renewable
HPS	Hybrid power system
NPC	Net present cost
NREL	National renewable energy laboratory
PV	Photovoltaic
RESs	Renewable Energy Sources
SOC	State of Charge
DOD	Depth of Discharge
BTS	Base Transceiver Station
DOA	Days of Autonomy
UTMS	Universal Mobile Telecommunication System
GSM	Global System for Mobile Communication
CDMA	Code Division Multiple Access

CHAPTER 1

INTRODUCTION

1.1 Background :

Telecommunication Networks have got changed the method people reside, function and have fun with. Since several people around the globe are linked by telecommunication systems, the problem to supply dependable and cost efficient power options to these expanding systems is essential for telecom operators. In remote locations, grid electric power is not really accessible or can be accessible in restricted quantities. In the former, diesel generators with backup battery had been utilized for running these sites. These techniques, usually situated in locations with hard accessibilities need regular upkeep and are usually characterized by their higher fuel intake and higher transportation price. Also, credited to the quick depletion of fossil fuel reserves and increasing requirement of clear energy technology to decrease the greenhouse gas emission immediate lookup for alternate options for powering these sites is required.

Thus renewable resources can end up being an achievable answer for running these sites. The numerous RES like as solar power, wind power, fuel cells, biodiesel and therefore are usually utilized for telecommunications sector in the building nations.

The disadvantage of standalone power systems using renewable energy is that the availability of renewable energy sources has daily and seasonal patterns which results in difficulties of regulating the output power to cope with the load demand. Also, a very high initial capital investment cost is required. Combining the renewable energy generation with conventional diesel power generation will enable the power generated from a renewable energy sources to be more reliable, affordable and used more efficiently.

There are many remote places, especially in developing countries, where grid supply has not reached yet but still with more availability of PV-wind hybrid systems. Over and above, the dependence of economy on depleting fossil fuels and the adverse environmental effects of conventional power generation systems created renewed interest in renewable energy sources toward building a sustainable energy economy. As stated in PV-wind hybrid energy is the world’s fastest growing energy sources, expanding globally at a rate of 25–35% annually over the last decade. In recent years advance materials, the capacity to be interconnected with the utility throw net-metering programs and better manufacturing processes have decreased their capital costs making them more attractive. Another way to attempt to decrease the cost of these systems.is by making use of hybrid designs that uses both wind/photovoltaic. The question is which configuration will be the most cost effective while supplying demand. This thesis present an optimization procedure capable to design hybrid removable energy systems using HOMER in order to find the most effective way to use wind and solar energy at the lowest cost possible. Then economic analyses were made over a period of 20 years, to determine the project viability.

1.2 Objective of thesis :

The thesis main objective is the analysis of hybrid energy system using photovoltaic modules and wind turbines technologies for powering base transceiver station in Bangladesh. The intent behind this thesis is to recognize a suitable methodology to design and analyze the hybrid solar wind energy system with limited meteorological data such as the monthly average of solar energy, wind energy and temperature so that it provides adequate answers to the installation and operation of a base transceiver station (BTS). These renewable energy produces electricity with a irregular manner that has made them untrustworthy in terms of power reliability. The inclusion of energy storage is a solution to this problem. However, the amount of energy storage required is typically enormous resulting in a huge implementation cost. Thus, the thesis outlines the associated storage technology for designing the hybrid PV and wind energy system. In addition, it provides the selection of appropriate manufacturers to meet the load in terms of technical and economical viability.. The specific objectives of the thesis are

i. To find the optimized system configuration of PV based renewable hybrid system for remote off-grid BTS sites as well as grid connected BTS sites.
ii. To study the feasibility of Wind-PV hybrid system configuration for off grid BTS sites.
iii. To study the environmental benefits of renewable sources powering BTS.

1.3 Thesis layout :

The thesis is divided into seven chapters.

Chapter one provides the background and the objective of the thesis.

Chapter two covers the literature survey of various feasibility assessment of hybrid renewable power system by different authors. This chapter also provides a general outlook of present status of Bangladesh’s telecom sector. The methodology of analysis of renewable hybrid system and. the simulation software (HOMER) used in this analysis are also discussed.

Chapter three provides a good outlook of the power system architecture of base transceiver station.

Chapter four provides the methodology of analysis of PV based hybrid system configuration for off-grid and grid connected roof top base transceiver station. Chittagong is selected as reference site.

Chapter five includes the result and discussion found from the analysis of PV base hybrid system..

Chapter six provides the methodology of analysis of wind based renewable system configuration for off-grid base transceiver station in Bangladesh. The analysis is done by taking Chittagong as reference site. This chapter also includes the result and discussion found from this analysis.

Chapter seven provides conclusive discussions for the work. Some scopes for the future works in relation with the limitations are also presented in the chapter.

CHAPTER 2

LITERATURE REVIEW

The solar energy are omnipresent, freely available, inexhaustible, environmental friendly and are considered as promising technologies to deliver power supply to remote telecommunication applications. The combination of renewable energy technology with existing conventional system results in hybrid systems which consists of PV array, wind turbine, inverter, storage system and other accessories. There are various researches carried out on hybrid renewable energy system with respect to performance and optimization and other several parameters needed. For the purposes of this study, The individual components of hybrid renewable energy system should be modeled and analyzed to meet the reliability for the effective performance of the hybrid system since its design depends on the performance of the individual components. The individual system performance and other losses will affect the overall performance of the system, which normally results in the over sizing of renewable energy system. However, the energy system should delivered optimum power at the minimum cost if the energy generation predicted from these individual components is accurate.

2.1 Stand-alone hybrid renewable system :

A standalone power system is defined as an self-generating system that provides electricity without connections to the electricity grid lines. It is also called remote areas power system because they are mostly located in the remote and inaccessible areas. Thus, standalone hybrid renewable power system is a system that consists of renewable sources to supply electricity to the load without access to the grid electricity. Due to the irregular nature of the renewable energy, it is difficult to regulate the output power generated from these sources to meet the load. There are various factors that affect the standalone systems as time and location, energy resources, climate, environment, physical laws and so on. Various authors consider these several factors in the design and analysis of standalone hybrid renewable power system for powering base transceiver stations. This section reviews the literature of standalone hybrid renewable energy system for telecommunication applications.

Pragya et al. [2] proposed a standalone PV/wind hybrid energy system with diesel generator as a backup for a mobile base station site located in isolated areas of Central India. They used HOMER simulation for economic analysis of standalone system and stated that the fuel consumption is also reduced to approximate 80% and this standalone system payback period is

2-4 years in a good sunny and windy location. However, this system used diesel generator as a backup system. In some cases transportation and refueling of this diesel generator is not feasibly and economically viable at the remote telecom station.

Kazuhiro et al. [3] described a large 250kW hybrid system consisting of wind turbine, PV modules, inverter and battery storage to supply power to the telecommunication equipment at the radio relay station at a small island in the south-west of Japan. They used large hybrid system to provide power to telecommunication relay station and power grid by reversing power flow method.

Banu and Orhan [4] proposed the sizing of a PV/wind hybrid energy system with battery storage using response surface methodology for the mobile communications (GSM) base station at Urla, Turkey. They used an hourly mean solar radiation and wind speed data for 2 year period to simulate the hybrid energy systems. However, this method does not consider the sizing procedure using limited resources and selection of appropriate manufactures.

The mentioned above authors [2-4] simulated, designed and analyzed the hybrid renewable power system for a remote telecommunication station using various methodologies to find the optimal solution based on hourly meteorological data which was given. The purpose of the thesis is to do a comparative study to find the best solution among different hybrid renewable energy system configuration with few meteorological data and select the appropriate manufacturers with lowest value of cost function definition in terms of reliability and system cost.

2.2 Assessment and selection of renewable resources :

The designing of any standalone renewable energy sources consists feasibility analysis and system design. Feasibility analysis concerns with the selection of renewable energy technology at the particular site and system design deals with the overall specifications of the components based on the technical and economic viability. Feasibility assessment, moreover, includes both technical and economic potential at the given sites. The assessment of appropriate renewable energy technology should be done by considering the precise data and information of all possible renewable energy system such as through meteorological, wind, solar radiation, and other RES measurements. This however can be a time consuming task for long term data and information. For instance, the duration of the process of collecting relevant data and information of wind-based renewable energy system is one year [5]. Thus, this feasibility analysis should give the idea of selection of renewable energy technology of the particular site.

After selecting the most appropriate renewable energy the next step is the assessment of the appropriate size, i.e. dimensioning of the isolated electrical system based on renewable energy sources. Selection of the appropriate topology is another fundamental task which includes a margin for the expected future increase in load [6]. The sizing of appropriate technology, moreover, depends on cost as reliability and Investment. Reliability is the most important technical factor to evaluate the different systems to guarantee within its limit to meet the load demand according to the available generated and stored electrical energy.

Dalton et al. [7] carried a feasibility analysis of stand-alone renewable power systems for a large tourist hotel over 100 beds located in a subtropical coastal area of Queensland, Australia. HOMER and HYBRIDS software were used as assessment tools in terms of net present cost(NPC), renewable factor and payback time. The results shown by both modeling software provided the different configurations of similar standalone power system for replacement of conventional thermal energy supply considering renewable resources potential and cost factors. However with HYBRIDS, the average production had a higher NPC than that of HOMER.

Haidar et al. [8] studied the energy generation from wind, solar and diesel for the different regions of Malaysia. They used HOMER software to study the potential and cost of production from these resources. Their result was compared with the total energy production and cost of energy from the diesel generator. They found that the cost of energy from these resources is cheaper than diesel generator.

Bekele and Palm [9] studied the possibility of supplying electricity from solar-wind hybrid system to a remotely located community of 200 families with approximately 1000 people isolated from the grid in Ethiopia through HOMER software. The results were compared from the list of feasible renewable power sources based on net present cost and found that hybrid solar and wind system is only the promising technology for power generation to these communities.

From this review it is seen that HOMER is widely used for most of the renewable based systems. Thus, based on the above literature reviews, HOMER software is taken for the purposes of this study to carry the feasibility assessment.

2.3 Review of hybrid concept:

We attempted to match the least costly off-grid and on-grid electricity generation technologies with the resources available in Bangladesh. The various off-grid power generation technologies in Bangladesh was analyzed by various institute in Bangladesh. Potential areas for off- grid power generation systems in remote areas of Bangladesh were tagged in-depth study on electricity access. Some have been installed in the fields for further studies. Similar studies for all kinds of off-grid electricity generation have been carried out, examining their unit capital cost. A study on REB was conducted by BPDB. They supplied heat and electricity from various RES available with the help of hybrid optimization modeling. BPDB tried to find the optimal combination of components for a hybrid power generation system for a typical on-grid location of Chittagong, Bangladesh. To compute the optimal size of each component with regard to achieving the lowest possible total LCC. Their aim was to reduce the total annual cost of power generation.

2.4 Review of electrification of Base transceiver station by renewable sources around the world:

The China Mobile has one of the world's largest deployments of green station powered by alternative energy. China Mobile had 2,135 base stations. Of these 1,615 were powered by alternative solar energy, 515 by solar and wind energy and 5 by other alternative sources. According to a study low-carbon telecommunications solutions saved China 48.5 million metric tons of direct carbon dioxide emissions in 2008 and 58.2 million metric tons in 2009 and projected to deliver as much as 615 tons in carbon savings by the year 2020 [9].

Indonesian operator PT Telekomunikasi Selular (Telkomsel) is using latest generation low power consumption RBSs which are powered by solar technology from Ericsson to provide macro coverage in Sumatra and rural areas of Indonesia [9].

In India, have around 310,000 telecom towers of which about 70% are in rural areas. Presently 40% power requirements are met by grid electricity and 60% by diesel generators. The diesel generators are of 10-15 KVA capacity and consume about 2 liters of diesel per hour and produce 2.63 kg of CO2 per liter. The total consumption is 2 billion litres of diesel and 5.3 million litres of CO2 is produced. For every kWh of grid electricity consumed 0.84 Kg of CO2 is emitted. Total CO2 emission is around 5 million tons of CO2 due to diesel consumption and around 8 million tons due to power grid per annum.[9].

Jordan Telecom implement solar energy project for telecom tower in Karak area is a hybrid system that contains solar panels, wind turbine and diesel engine generator. Also there are 15 projects for telecom sites with stand-alone solar systems are installed and support GSM telecoms equip. Jordan Telecom are installing solar systems for outdoor sites where there is no need for a/c units and the average load is 300W to 1400W including the consumption of fans [10].

2.5 Current status of Bangladesh telecom sector :

Bangladesh telecoms sector‘s growth has exceeded all expectations and had a transformative impact on the economy in terms of aggregate investment, FDI. This impact was the same like Readymade Garments and Remittances. There are likely to be public private partnership (PPPs) opportunities for telecoms to partner up with the Government of Bangladesh in service delivery across the areas of e-education, e-health and e-commerce. The liberalization of Bangladesh‘s telecommunications sector began with small steps in 1989 with the issuance of a license to a private operator for the provision of inter alia cellular mobile services to compete with the previous monopoly provider of telecommunications services the Bangladesh Telegraph & Telephone Board (BTTB). Significant changes in the number of fixed and mobile services deployed in Bangladesh occurred in the late 1990s and the number of services in operation has subsequently grown exponentially in the past five years. The incentives both from government and public sectors have helped to grow this sector. It is now one of the biggest sector of Bangladesh. As a populous country, it's huge market has attracted many foreign investors to invest in this sector. Currently there are six telecom operators in Bangladesh. Those are:

i. Telenor Bangladesh Ltd.: Branded as Grameenphone
ii. Axiata Bangladesh Ltd: Branded as Robi
iii. Pacific Bangladesh Telephone Ltd.: Branded as Citycell
iv. Orascom Telecom Ltd.: Branded as Banglalink
v. Teletalk Bangladesh Ltd.: Branded as Teletalk
vi. Airtel Bangladesh Ltd. Branded as Airtel, formerly known as Warid Telecom

Now the total number of Mobile Phone subscribers has reached 106.934 million at the end of July 2013[10]. Currently there are over 33000 BTS sites in Bangladesh by six operators. The annual energy requirement for these sites are 453 million kWh. Bangladesh government has a target of converting 5% of total BTS site to renewable solution within 2015.A survey shows that from these sites 3622 sites have the potential to be converted to renewable site[12].

2.6 Hybrid optimization model for electric renewable (HOMER) :

HOMER micro power optimization software is a computer model that was developed by NREL in the U.S.A. HOMER simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications[13]. When we design a power system, we must make many decisions about the configuration of the system: What components does it make sense to include in the system design? How many and what size of each component should we use? The large number of technology options and the variation in technology costs and availability of energy resources make these decisions difficult. HOMER's optimization and sensitivity analysis algorithms make it easier to evaluate the many possible system configurations. HOMER can be of significant use for the designing of the system due to its flexibility. Its analysis is based on the technical properties and the LCC of the system. The LCC is comprised of the initial capital cost, cost of installation and operation costs over the system’s life span.

Simulation, Optimization and Sensitivity analysis are the three major actions run by HOMER[14].

2.6.1 Simulation :

HOMER simulates the operation of a system by making energy balance calculations in each time step of the year. For each time step, HOMER compares the electric and thermal demand in that time step to the energy that the system can supply in that time step, and calculates the flows of energy to and from each component of the system[15]. For systems that include batteries or fuel-powered generators, HOMER also decides in each time step how to operate the generators and whether to charge or discharge the batteries. HOMER performs these energy balance calculations for each system configuration that we want to consider. It then determines whether a configuration is feasible, i.e., whether it can meet the electric demand under the conditions that we specify, and estimates the cost of installing and operating the system over the lifetime of the project. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel, and interest [16].

2.6.2 Optimization :

After simulating all of the possible system configurations, HOMER displays a list of configurations, sorted by net present cost (sometimes called lifecycle cost), that we can use to compare system design options [17].

2.6.3 Sensitivity Analysis :

When we define sensitivity variables as inputs, HOMER repeats the optimization process for each sensitivity variable that we specify. For example, if we define wind speed as a sensitivity variable, HOMER will simulate system configurations for the range of wind speeds that we specify Figure 2.1 shows how simulation, optimization and sensitivity analysis are interrelated. The oval figure enclosed in another oval figure shows that one optimization consists of multiple simulation and one sensitivity analysis consists of multiple optimizations[18].

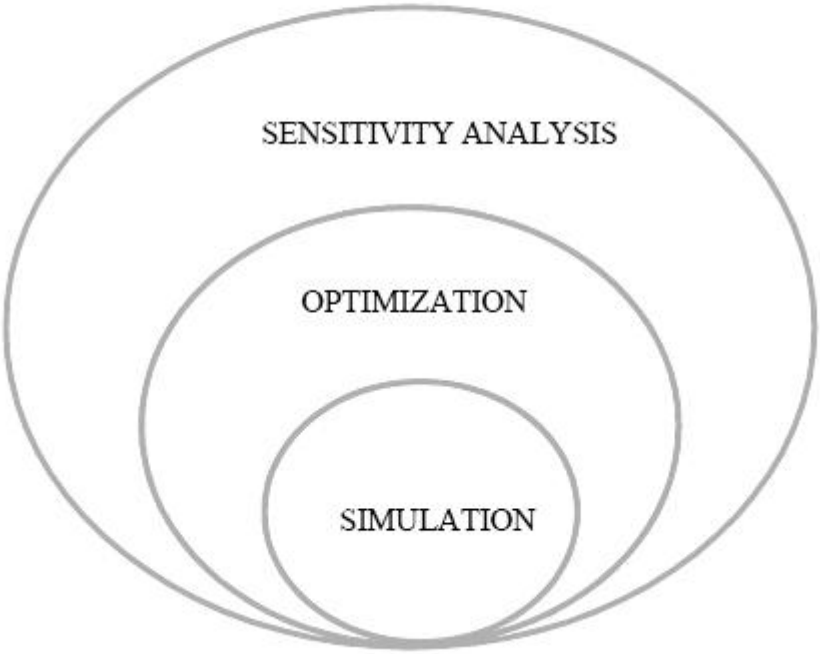


Figure 2.1 Relationship between simulation, optimization, and sensitivity analysis (Courtesy : NREL)

2.6.4 Modeling using HOMER :

To model the hybrid power systems using HOMER, the following step must be develops [19].

Firstly, obtain the information data about the renewable energy sources (RESs) available at those hybrid system locations such as the average monthly solar energy, wind speed and diesel power uses to supply the load demand. Also, it was necessary to know about the daily load profile for that locality.

Next, define the characteristics and specifications of the hybrid power systems. The information that necessary to obtain is the type of PV module, wind turbine, diesel generator, battery, and converter.

For each of the system components, define the maximum power generated, life time, price, replacement and their maintenance period.

2.6.5 Selection of HOMER :

The main strength of HOMER is that it helps to determine how variable resources such as wind and solar can be optimally integrated into hybrid systems. It also determines the economic feasibility of a hybrid energy system, optimizes the system design and allows users to really understand how hybrid renewable systems work [20]. So HOMER is preferred as the best tools to simulate the hybrid power systems. HOMER is more simple and easy to be used for simulation purpose. The main drawback is that in case of solar energy optimization , it does not give the number of panels and their type as a solution, only a PV array power, from ones chosen by the user. For storage system the user must select the type of battery, and no optimization between different types of battery is made.

2.7 Methodology :

Optimum designing is very important for any renewable power system, which can ensure battery bank working at the optimum conditions as much as possible, therefore prolonging its lifetime and reducing cost of energy production. Nowadays commercial software packages for simulating PV and hybrid generating systems have been developed. By using computer simulation techniques, the optimum system configuration can be found by comparing the performances and energy production costs of different system configurations. This study requires various other factors, to be considered.

2.7.1 Power flow strategy :

The following figure shows the power flow decisions for renewable hybrid system consists of different renewable source.

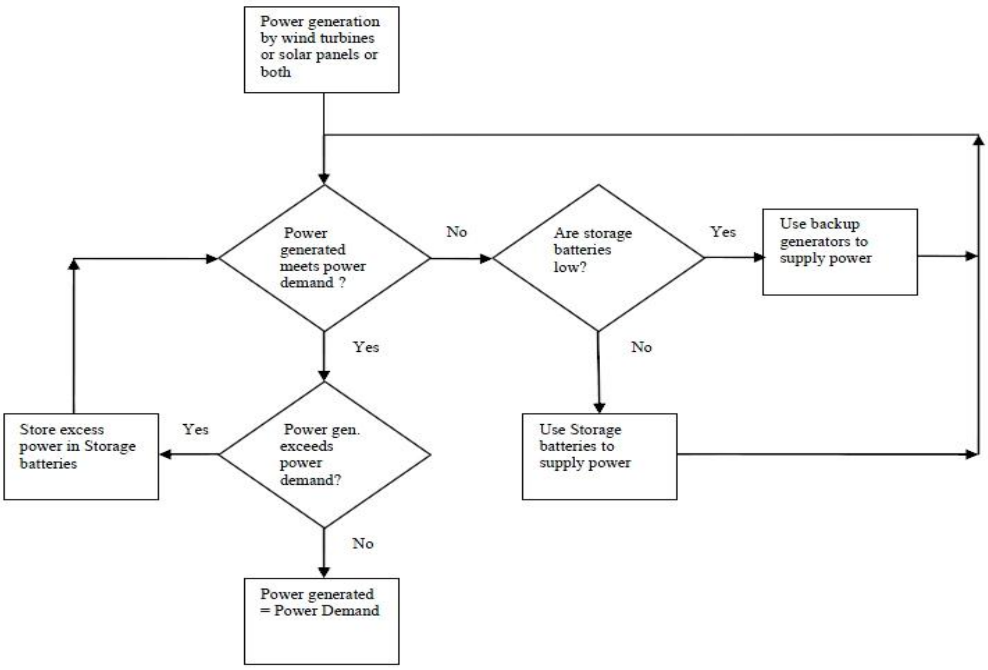


Figure 2.2 : Power flow strategy for BTS electrification

The system operates such a way that it tries to reduce the diesel generator runtime in remote BTS or reduce the grid dependency of grid connected BTS. Battery storage increases the over all system reliability.

2.7.2 Method of analysis :

The steps involved for choosing the optimal system size are as follows:

i. Determination of the average power demand of the BTS site.
ii. Determination of the average hourly solar insolation of location under study. Depending upon the available data, the number of PV panel and wind turbines should be selected such that the power generated by these devices should match the actual power demand of the site.
iii. The number of solar panel should be kept as minimum as possible because the area required for installation is limited in roof top sites.

For selecting various combination of devices, following three cases are consider:

i. Case I: Analysis of different hybrid system configuration for powering off-grid BTS. In this analysis we considered three configurations. As off-grid BTS's generally powered by diesel generator, PV-diesel configuration is taken for analysis.
ii. Case II: Analysis of different hybrid system configuration for powering grid-tie BTS. In this analysis we considered three configurations. PV-grid configuration is taken for analysis.
iii. Case III : Possibility of power generation with wind turbine in integration with PV-diesel system for off-grid areas is also investigated.

CHAPTER 3

POWER SYSTEM ARCHITECTURE OF BASE TRANSCEIVER STATION

The evolution of technologies has led to rapid growth in the use of mobile telephony and hence the need to have reliable transmission network across the globe. This has necessitated the need for network providers to guarantee unlimited access virtually everywhere in their geographical areas of operation.. In this chapter we studied the basic power system architecture of Base Transceiver Station (BTS).

3.1 Power Consumption by Telecommunication System:

Core Network, Base Station and Mobile Station are the main components of telecommunication network [21]. The maximum energy consumption in network is given by the above three basic components. The following figure shows total power consumption in cellular communication network.

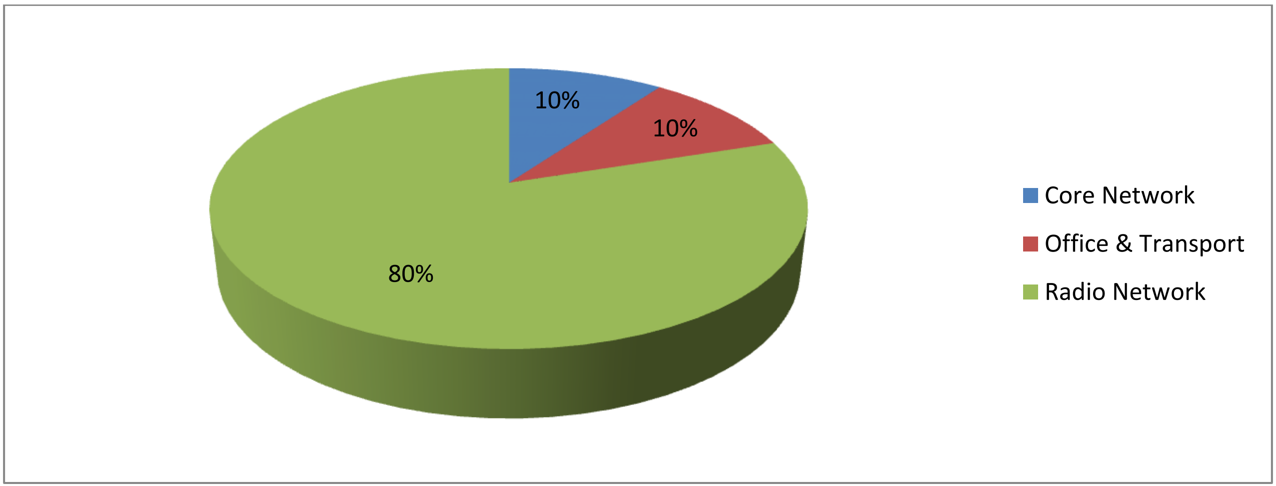


Figure 3.1 : Power consumption by cellular communication system

3.1.1 Core Network :

Basic element of telecommunication network is core network that maintain various services to subscriber that are linked by the access network. Core network could be split into two categories-one Mobile application part (MAP) that is using for Global system for mobile communication (GSM) and Universal mobile telecommunication System (UMTS).Secondly the IS-41 core network developed in USA which are employing for D-AMPS (time division multiple access) [21].CDMA-one and CDMA2000.Core network are performing switching task between MSC and User end. In addition, it established the interface to fixed network and billing system. Amount of core network component is relatively less . Normally power consumption by the core network components is low[21].

3.1.2 Mobile Station :

Mobile station commonly refers to cell phone or mobile phone a electronics device which is used to transfer the voice or data information over Telecommunication network. Nowadays mobile phone are providing various additional service and accessories The power consumption of mobile terminal is relatively low as compare with other component of the cellular communication system. After all, Because of demanding various application services accessories the energy consumption due to the mobile phone is too significant [23].

3.1.3 Base Transceiver Stations :

Base Transceiver Stations are commonly refers to Base stations. Mainly two types of base stations are deployed through out the world based on technology. First is GSM base station and second is CDMA base stations [24]. Base Station is conveying between clients mobile through the air interface.

One base station site is called as one cell, which is used, by Omni directional transmission and receiver antenna and when consider as two cell sites that is called two –sector that is using wide beam directional antenna and with three cell sites that is called 3-sector, which is using narrow beam directional antenna. One cell site Base Station is rarely used because it gives less coverage area. Two sector BTS are using for road coverage and three sector BTS are using for large area like urban suburban and rural area because of having the largest coverage area. The basic function of BTS is to send and receive voice signal and data message to MS and from Mobile station through the radio interface.

The following tables show the power consumption estimation for GSM and CDMA macro base station, which operates on a medium, or high capacity sites for urban area and other deployment on a low capacity sites for rural area[25].

Table 3.1: Power consumption by GSM macro base station

Power Consumption By macro base station		
	Urban Area (High/Medium Traffic)	Rural Area (Low Traffic)
Accessories	Rated Power (W)	Rated Power (W)
Base Band	300	200
TRX40W Power Amplifier	2000	700
AC-DC Converter	370	130
Cooling System	1000	600
Lighting & Alarm	300	100
Total Power Consumption	4070	1730

Table 3.2: Power consumption by 3G micro base station

Power Consumption By 3G macro base station	
Accessories	Rated Power (W)
Base Band	400
TRX40W Power Amplifier	800
AC-DC Converter	150
Cooling System	400
Lighting & Alarm	100
Total Power Consumption	1850

3.2 Power consumption in various base station equipment :

Base station is the most power consuming element in telecom system. It consume more than 80% power of the overall network. Power consumption of BTS depends on types of base station such as macro , micro or pico base station. It also depends on number of sectoring. It can be one ,two or three sector cell. Normally macro base station requires more power than micro and pico base stations. A base station consist of few elements such as DC power supply , cooling system , radio unit and base band unit. The figure 3.2 show a block diagram which represents the power system architecture of a typical base station.

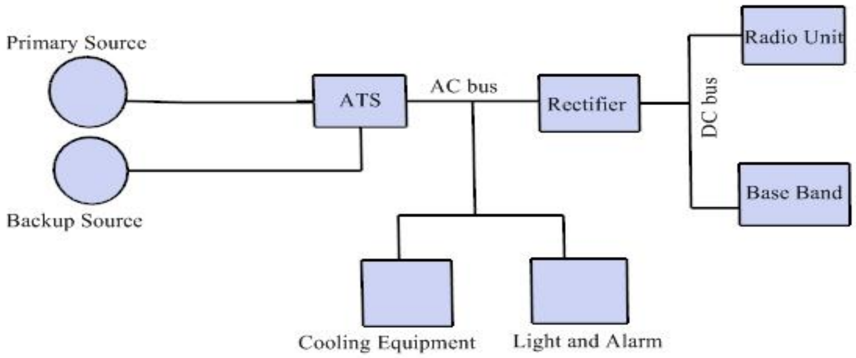


Figure 3.2 : Power system architecture of a base station

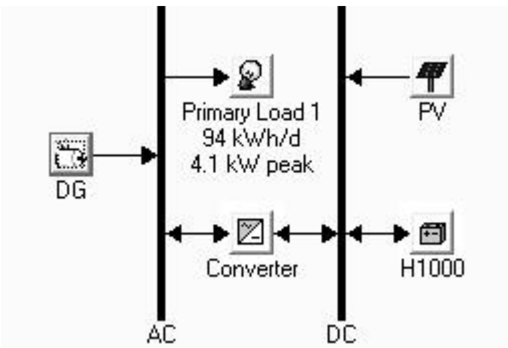
CHAPTER 4

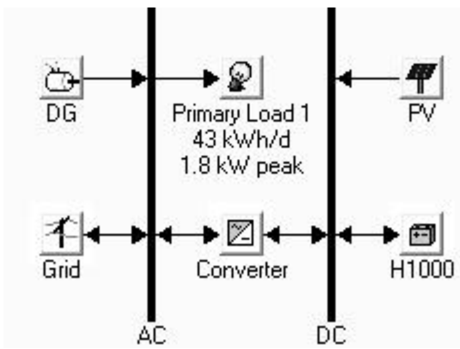
OPTIMIZATION OF HYBRID RENEWABLE SYSTEM FOR BASE TRANSCEIVER STATION

There are many renewable resources which can be added in joint operation with different conventional power source. Diesel generator is the most common power generating device in base stations. Renewable sources like solar, wind ,biomass etc can be used to produce power to run a base station site. Till date conventional energy sources are mostly used to generate power for base transceiver station situated in city areas. But keeping in mind the various drawbacks related to conventional sources and to reduce the grid dependence of private telecom sectors, we are now analyzing the techno-economical aspects of renewable system for powering base transceiver stations. This is to promote renewable technology as the most effective power generation technology for coming future. Chittagong is selected as reference site for solar and wind energy resource.

4.1 Hybrid system configuration :

Stand alone renewable system is not reliable because of its dependence to certain factors such as solar energy depends on presence of sunlight. However these renewable sources can be used reliably in hybrid system configuration. In this case study we considered solar photovoltaic energy system with diesel generator and battery as backup for diesel powered BTS and solar photovoltaic energy system with grid electricity and small diesel generator and battery bank as backup for roof top BTS. Figure 4.1 shows two different hybrid system configuration for powering BTS.





(a) **(b)**

Figure 4.1 : (a) PV-Diesel configuration (b) PV-Grid configuration

4.2 Study area :

Chittagong is chosen as the study area. It is situated in 22.30° N longitude and 91.42° E latitude. Due to its geographical location the solar potential of Chittagong is very rich. For being situated in coastal region it has also some potential for small scale wind generation . For our study here we considered the clearness index and daily solar radiation of Chittagong for a span of one year. Figure 4.2 shows the satellite image of Chittagong.

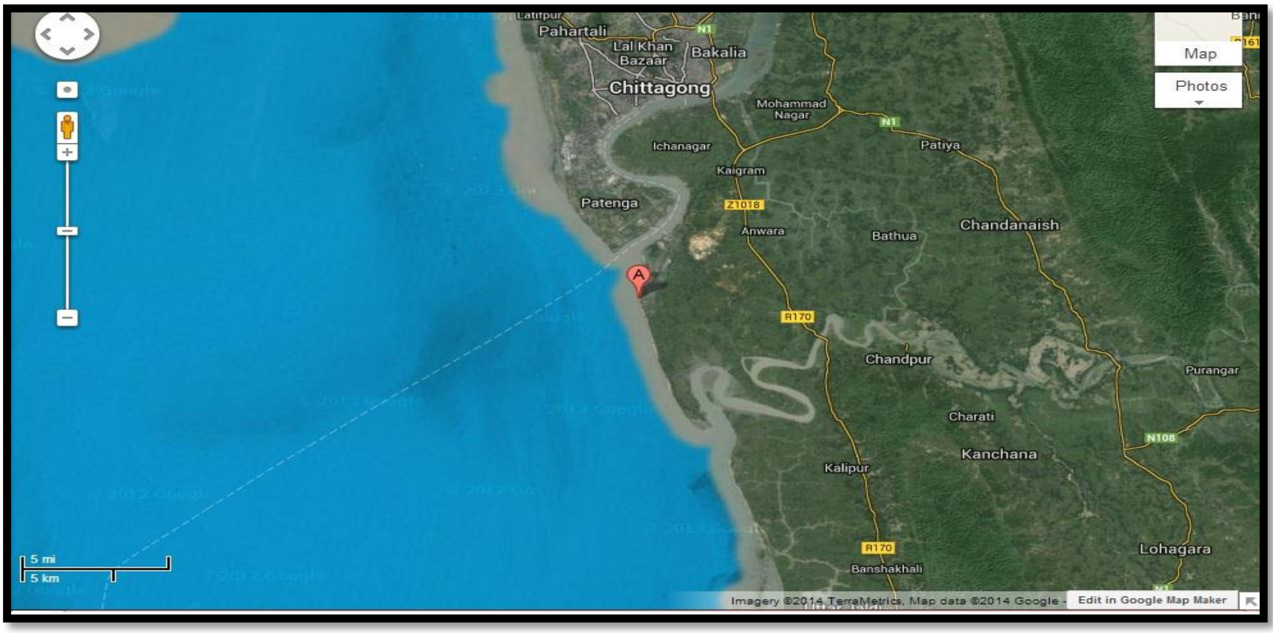


Figure 4.2 : Chittagong (Courtesy : Google earth)

4.3 Physical modeling by HOMER :

This section provides the details about the physical operation that HOMER models for its simulations. The subsections describe the various input parameters HOMER requires to model the system: The energy load demand that the system has to serve, the selected energy components to generate electricity, the various energy resources associated to the selected components, and how this hybrid combination operates to serve the loads. The figure 4.3 shows that the types of loads and the number and types of components selected for the system in this study. They also show that this simulation is selected to run as an off grid renewable hybrid system for BTS as well as for roof top grid tie BTS.

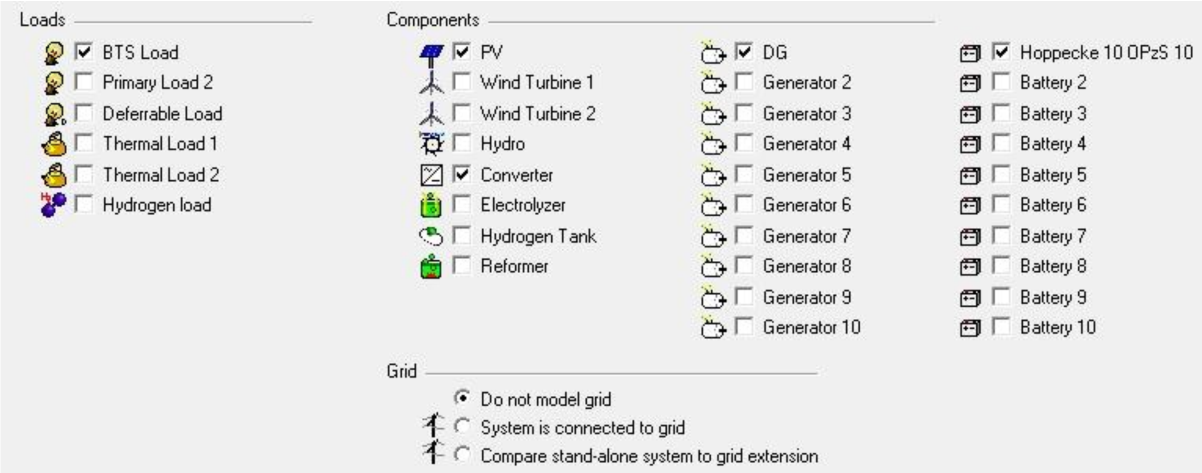


Figure 4.3 a : The selected load and components of PV- Diesel hybrid system

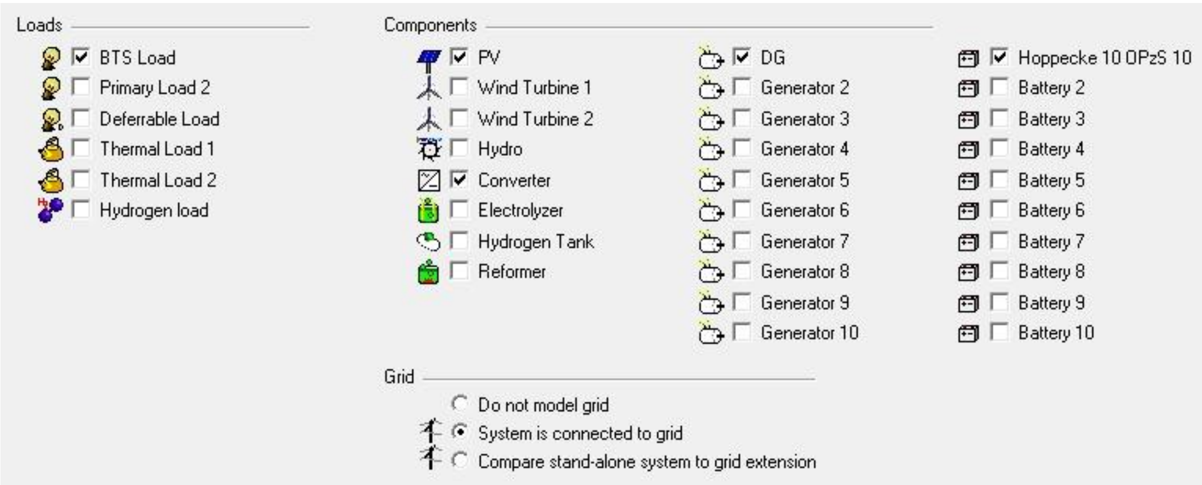


Figure 4.3b : The selected load and components of PV-Grid system

4.4 Load Assessor :

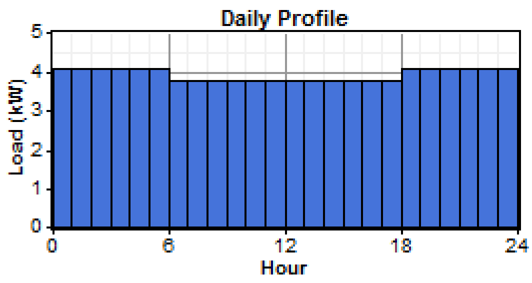
Primary load is electrical load that the system must meet immediately in order to avoid unmet load. Unmet load is electrical load that the power system is unable to serve. It occurs when the electrical demand exceeds the supply. For each system, HOMER calculates the total unmet load that occurs over the year, as well as the unmet load fraction. By default, HOMER considers infeasible any system that experiences unmet load.

In a base station loads are mainly radio transmission unit , base band unit , power amplifier ,cooling system and other accessories such as light , alarm etc [26]. In this study two load profile is considered. Table 4.1 shows the hourly load distribution of a diesel powered BTS.

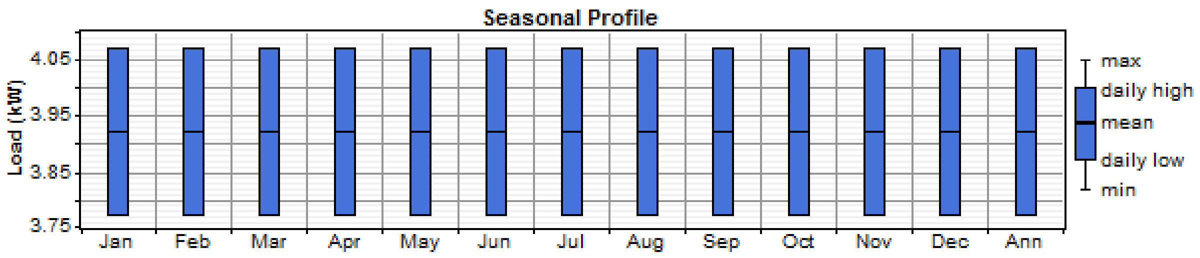
Table 4.1: Hourly Load distribution of BTS

	Load distribution by major components					
Hour	Base Band(W)	TRX40 amplifier(W)	Converter (W)	Cooling system(W)	Others(W)	Total (W)
0:00-1:00	300	2000	370	1000	300	4070
1:00-2:00	300	2000	370	1000	300	4070
2:00-3:00	300	2000	370	1000	300	4070
3:00-4:00	300	2000	370	1000	300	4070
4:00-5:00	300	2000	370	1000	300	4070
5:00-6:00	300	2000	370	1000	300	4070
6:00-7:00	300	2000	370	1000	300	4070
7:00-8:00	300	2000	370	1000	-	3770
8:00-9:00	300	2000	370	1000	-	3770
9:00-10:00	300	2000	370	1000	-	3770
10:00-11:00	300	2000	370	1000	-	3770
11:00-12:00	300	2000	370	1000	-	3770
12:00-13:00	300	2000	370	1000	-	3770
13:00-14:00	300	2000	370	1000	-	3770
14:00-15:00	300	2000	370	1000	-	3770
15:00-16:00	300	2000	370	1000	-	3770
16:00-17:00	300	2000	370	1000	-	3770
17:00-18:00	300	2000	370	1000	-	3770
18:00-19:00	300	2000	370	1000	300	4070
19:00-20:00	300	2000	370	1000	300	4070
20:00-21:00	300	2000	370	1000	300	4070
21:00-22:00	300	2000	370	1000	300	4070
22:00-23:00	300	2000	370	1000	300	4070
23:00-00:00	300	2000	370	1000	300	4070
Total daily load						94380

So the load required by the BTS is 94,380 W/day. The load of BTS remain fixed in all time step. Hence the day to day load variability and time step to time step load variability is 0%.The average load in HOMER is 3.92 kW . The figure 4.4 shows the daily load demand and annual load profile.



(a)



(b)

Figure 4.4 : (a) Daily load demand (b) Sessional load profile

For grid-tied BTS the power requirement is relatively low due to less power consumed to cooling system and amplifier. Table 4.2 shows the he hourly load distribution of a Grid-tied BTS

Table 4.2: Hourly Load distribution of Grid-tied BTS

	Load distribution by major components					
Hour	Base Band(W)	TRX40 amplifier(W)	Converter (W)	Cooling system(W)	Others(W)	Total (W)
0:00-1:00	400	800	150	400	100	1850
1:00-2:00	400	800	150	400	100	1850
2:00-3:00	400	800	150	400	100	1850
3:00-4:00	400	800	150	400	100	1850
4:00-5:00	400	800	150	400	100	1850
5:00-6:00	400	800	150	400	100	1850
6:00-7:00	400	800	150	400	100	1850
7:00-8:00	400	800	150	400	100	1850

8:00-9:00	400	800	150	400	100	1850
9:00-10:00	400	800	150	400	100	1850
10:00-11:00	400	800	150	400	100	1850
11:00-12:00	400	800	150	400	100	1850
12:00-13:00	400	800	150	400	100	1850
13:00-14:00	400	800	150	400	100	1850
14:00-15:00	400	800	150	400	100	1850
15:00-16:00	400	800	150	400	100	1850
16:00-17:00	400	800	150	400	100	1850
17:00-18:00	400	800	150	400	100	1850
18:00-19:00	400	800	150	400	100	1850
19:00-20:00	400	800	150	400	100	1850
20:00-21:00	400	800	150	400	100	1850
21:00-22:00	400	800	150	400	100	1850
22:00-23:00	400	800	150	400	100	1850
23:00-00:00	400	800	150	400	100	1850
Total daily load						4300

From the table 4.2 it is seen that the daily load requirement of a grid-tied BTS is 43 kWh. The average load is 1.85 kW. The figure 4.5 shows the daily load profile and annual load data for roof top grid-tied BTS.

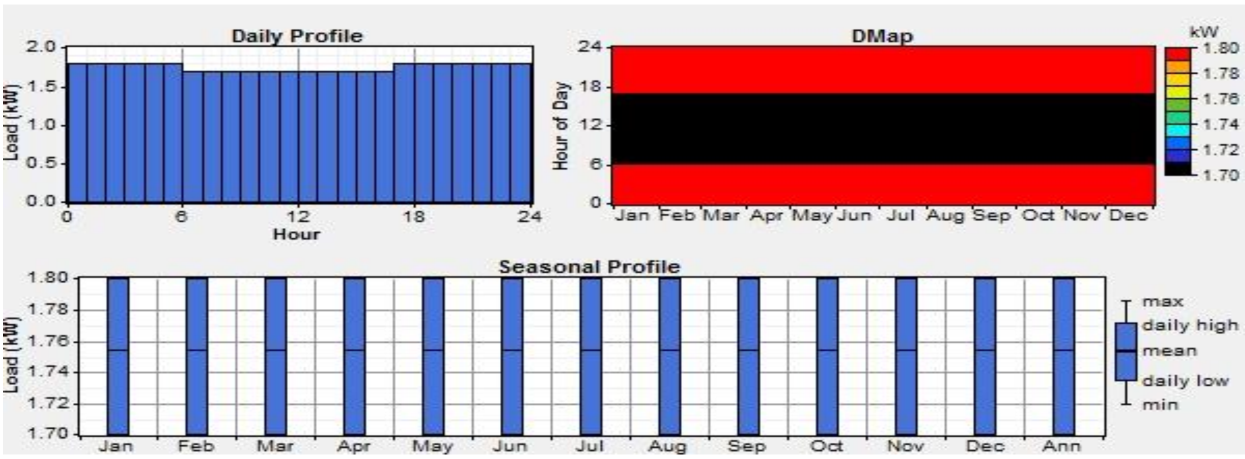


Figure 4.5 : Daily load demand and Sessional load profile

4.5 Meteorological data :

Renewable energy resource available at a location can differ considerably from site to site and this is a vital aspect in developing the hybrid system. As RES like solar, wind and SHP are naturally available and intermittent, they are the best option to be combined into a hybrid system. All of these resources depend on different factors – apart from seasonal or even hourly changes: Whereas the amount of solar energy available is dependent on climate and latitude, the hydro resource depends from the location's topography and its rainfall patterns; the wind resource is influenced by atmospheric circulation patterns and geographic aspects. The resources dependence of various factors in turn influences when and how much power can be generated and thus the behavior and economics of the hybrid system. As a consequence, successful system modeling significantly depends on the accurate modeling of the RES. This section describes the modeling of the selected RES by HOMER.

4.5.1 Solar Resource :

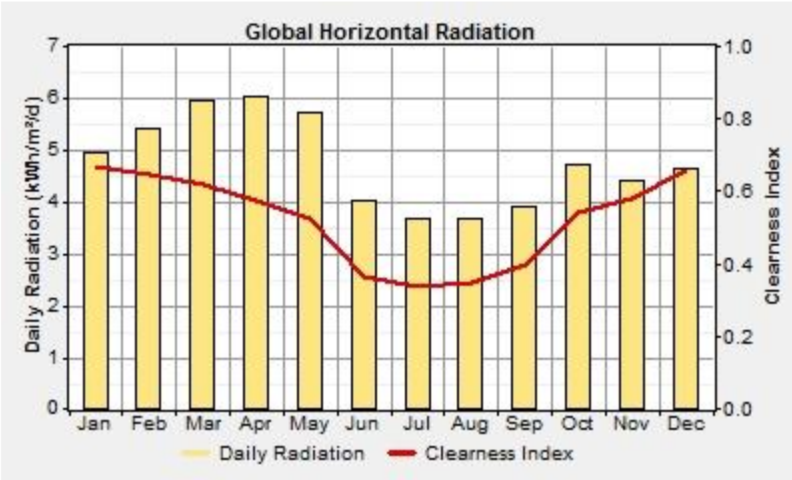
The solar energy resource is taken from SWERA for Chittagong at 22 ° 30′ N latitude and 91° 42′ E longitude. The table 4.3 shows the annual solar radiation and clearness index of St. Martin Island [27].

Table 4.3 : Annual solar radiation and clearness index

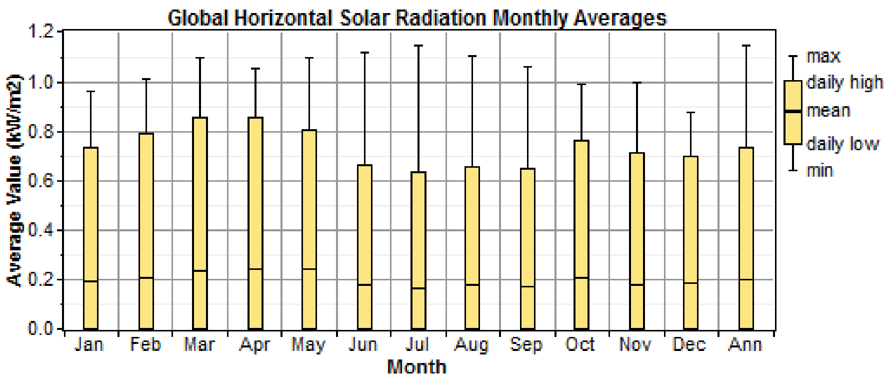
Month	Daily Radiation (kW/m2/day)	Clearness index
January	4.940	0.667
February	5.414	0.644
March	5.963	0.621
April	6.031	0.574
May	5.708	0.522
June	4.017	0.365
July	3.663	0.335
August	3.685	0.357
September	3.916	0.397
October	4.702	0.539
November	4.411	0.580
December	4.653	0.659
Average	4.572	0.488

Table 4.3 shows the solar resource profile considered over a span of one year. The annual average solar radiation was scaled to be 4.527kWh/m2/day and the average clearness index was

found to be 0.488. The graph plot in the figure 4.6 shows that solar radiation is available throughout the year; therefore a considerable amount of PV power output can be obtained.



(a)



(b)

Figure 4.6: (a) average daily radiation and clearness index (b) Global solar data through out the year

4.5.2 Diesel resource :

Classifications for diesel generator are based on its efficiency and its fuel consumption (hourly and specific fuel consumptions). The definition for the specific fuel consumption (l/kWh) is the amount of fuel required in producing 1 kWh of energy. In other words, it was the amount of fuel consumed by generator to supply energy to the specified loads in duration of one hour.

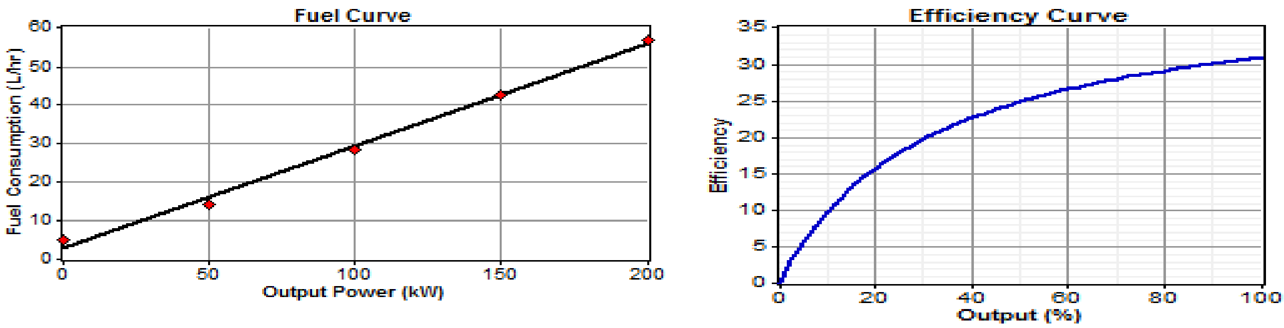


Figure 4.7 : Fuel curve and efficiency curve for diesel generator

Normally, the manufacture will provide the users with the spreadsheet that listed units or fuel type and other diesel generators parameters. The intercept coefficient is 0.085 L/hr/kW and the slope is 0.2535 L/hr/kW. HOMER will enter those values into the appropriate input boxes on the Generator Inputs window. The price of 1L diesel is 68 BDT as local market rate . Taking 77.6 BDT = 1USD, the price of 1L Diesel is 0.876$

4.6 Component assessor :

As mention earlier, HOMER software was used to simulate the hybrid power systems, for purpose to determine the operational and economic characteristics. In this section we initially describe the dimensioning of the components of the systems including size, cost and their lifetime. In this system, a component generates, delivers, converts and stores energy. In this HOMER analysis, SPV and wind turbines are the intermittent RES selected with a Generator for backup. Batteries and Converter are for storing, respectively converting, electricity.. The performance and cost of each of the system's components is a major factor for the cost results and the design. Thus, the development of these data was carried out with much diligence. A different set of performance and cost parameters is used by HOMER to characterize each of these different components. The component's technical and cost parameters for this study are based on data collected from online market and previous published literatures, information from personal sources of Bangladeshi manufactures and assumptions.

4.6.1 Solar Photovoltaic :

The information about PV array including the capital, replacement and O&M costs, as well as component lifetime are specified in details in the HOMER software. In this study Solarworld sun module SW 260 panel is considered, the installation costs for a stand-alone photovoltaic array range from 700 to 3000 $ kW−1 [30]. A cost of 1800 $ kW−1 was used. As there is very little maintenance required for PV, only $10/year is taken for O&M costs. Life time of solar photovoltaic panel is taken as 20 years. After some preliminary runs, we can conclude that most suitable PV sizes to be considered were 2kW, 3kW, 4kW, 5kW and 7 kW

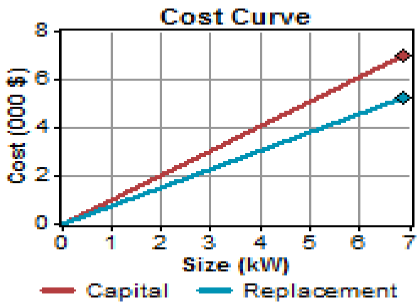


Figure 4.8 : Cost curve of SPV

4.6.2 Diesel generator :

The capital cost, replacement cost, O&M costs of a 10kW isuzu diesel are taken as $5300, $3975, and $0.3/hr respectively. The following figure shows the cost curve of the generator, connected to an AC output with a lifetime of 2,62,800 operating hours. The minimum load ratio is taken to be 10% of the capacity; moreover, HOMER requires the partial load efficiency to simulate this component. HOMER calculates the total operating cost of the generator based on the amount of time it has to be used in a year [30].

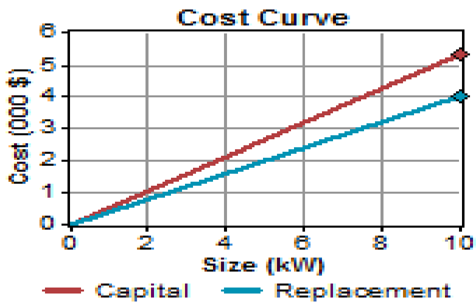


Figure 4.9 : Cost curve of isuzu diesel generator

4.6.3 Battery :

Batteries are used as a backup in the system and to maintain a constant voltage during peak loads or a shortfall in generation capacity. HOMER models a number of individual batteries to create a battery bank connected in series-parallel connections. The battery chosen for this study is Hoppecke 10 OPzS 1000 as shown in figure 6.7.4. It is a 2V battery with a nominal capacity of 1000 Ah (2 kWh) [30]. It has a lifetime through put of 3,438kWh. The capital cost, replacement cost and O&M costs for one unit of this battery were considered as $700, $500, and $5/year respectively. HOMER models the batteries on charging and discharging cycle.

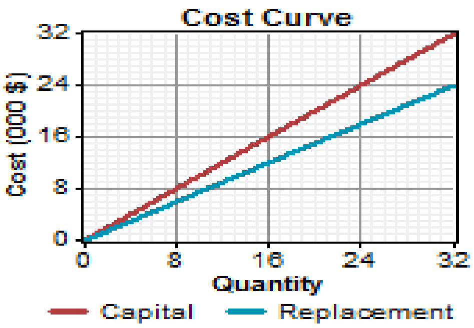


Figure 4.10 : Cost curve of H100

4.6.4 Converter :

A converter is an electronic power device that is required in a hybrid system to maintain the energy flow between AC and DC electrical components. It has an inverter and a rectifier to do the conversions from DC to AC and vice versa.

Two types of converter considered here is mainly off-grid converter and grid connected converter used for off grid and grid connected system [29]. The capital cost, replacement cost and O&M costs for 1kW systems, which were considered as $100, $75, and $10/year respectively. The following shows the cost analysis curve. The lifetime of the converter is 20 years, inverter efficiency of 90% and rectifier efficiency of 85% is considered . In this hybrid system HOMER simulates the system with the inverter and AC generator to operate simultaneously whenever required.

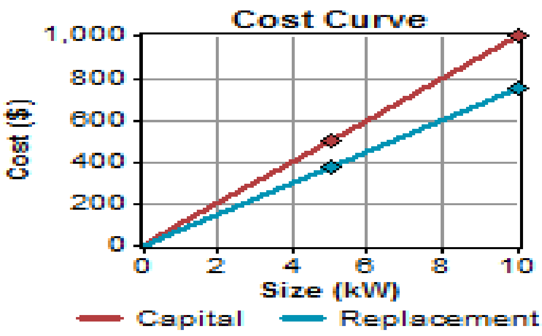


Figure 4.11 : Cost curve of converter

4.7 Grid :

The main advantage of grid-tie renewable system is that the excess power can be send to the grid in the same way when there is excess load demand, the power can be bought from the grid [30]. The net purchase and sellback unit is calculated by an electric meter which is connected to the hybrid system. The per unit rate is different during 24 hours. Those are as follows:

4.7.1 Peak hour :

In a peak hour the load demand is maximum. During this time the power generation cost is high. In peak hour the purchase price 0.1$/KWh and sellback price 0.035$/KWh is considered. The peak hour start from 5 pm to 11pm.

4.7.2 Off peak hour :

In off peak hour the purchase price 0.06$/KWh and sellback price 0.035$/KWh is considered. The off peak hour start from 11 pm to the next day of 5 pm.

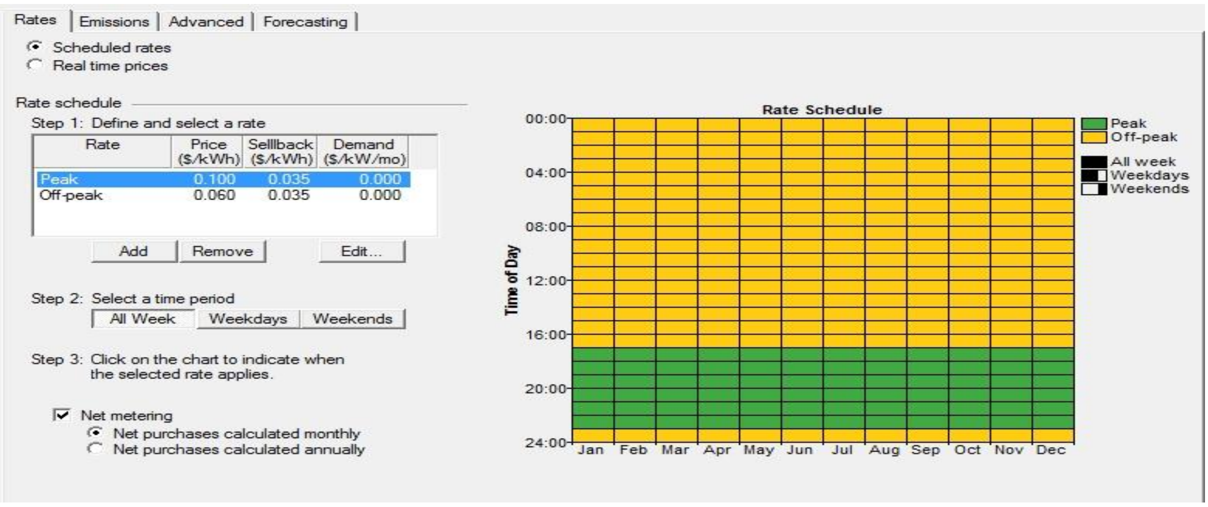


Figure 4.12 : Grid scheduling

4.8 Generator Scheduling for roof-top BTS :

To simulate the optimal renewable system for roof top grid-tie BTS's two hours of grid electricity failure is assumed and according to the system requirement the diesel generator is programmed to force on condition. First two hours of peak tariff is considered for generator scheduling. Figure 4.13 shows the generator forced on timeline.

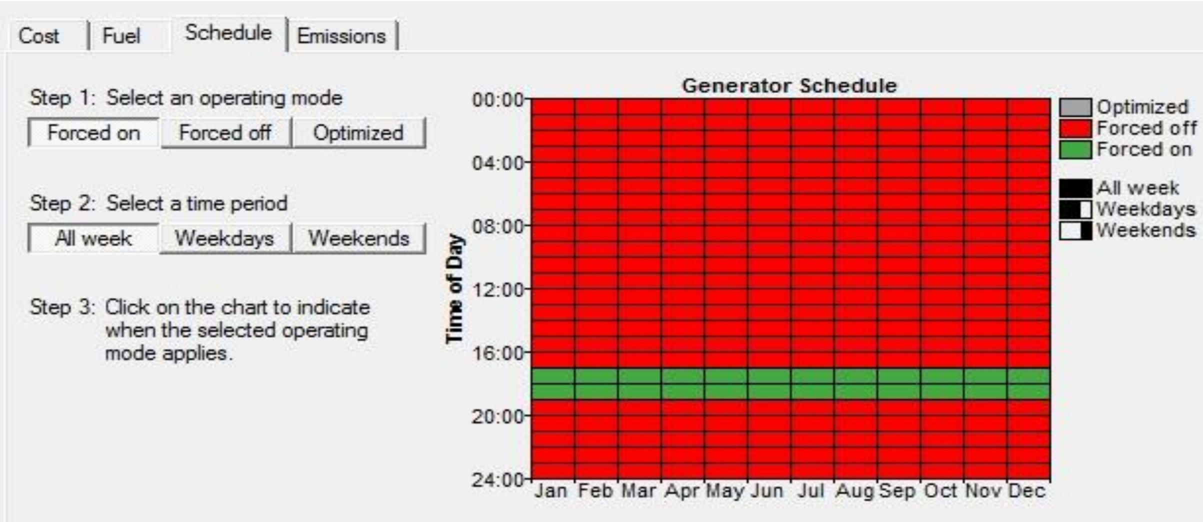


Figure 4.13 : Generator scheduling

4.9 System Economics :

As it is HOMER's aim to minimize the total net present cost (NPC) both in finding the optimal system configuration and in operating the system, economics play a crucial role in the simulation.

The project's lifetime is considered to be 20 years with an annual interest rate of 6%. The nominal interest rate minus the inflation rate gives the real interest rate. As it is a small system a fixed capital cost of $1000 and a fixed operating cost of $500 is considered. The fixed capital cost includes cost of structure for PV installation , metering equipment cost and monitoring cost. Annual capacity shortage is considered 0% and a minimum of 20% energy will come from renewable source.

4.10 Equipment to consider :

Figure 4.14 and Figure 4.15 show the equipment size considered for HOMER analysis.

This table displays the values of each optimization variable. HOMER builds the search space, or set of all possible system configurations, from this table and then simulates the configurations and sorts them by net present cost. You can add and remove values in this table or in the Sizes to Consider table in the appropriate input window.

Hold the pointer over an element name or click Help for more information.

	PV Array (kW)	DG (kW)	H1000 (Strings)	Converter (kW)
1	1.000	0.00	1	1.00
2	2.000	10.00	2	2.00
3	3.000		3	3.00
4	4.000		4	4.00
5	5.000			5.00
6	6.000			
7	7.000			
8				
9				
10				

Figure 4.14 : Equipment consideration for PV-diesel system

This table displays the values of each optimization variable. HOMER builds the search space, or set of all possible system configurations, from this table and then simulates the configurations and sorts them by net present cost. You can add and remove values in this table or in the Sizes to Consider table in the appropriate input window.

Hold the pointer over an element name or click Help for more information.

	PV Array (kW)	DG (kW)	Grid (kW)	H1000 (Strings)	Converter (kW)
1	1.000	2.00	4.000	1	1.00
2	2.000			2	2.00
3	3.000			3	3.00
4	4.000			4	4.00
5	5.000				5.00
6	6.000				
7	7.000				
8					
9					
10					

Figure 4.15 : Equipment consideration for PV-grid system

CHAPTER 5

SIMULATION OUTPUT OF OPTIMIZED HYBRID RENEWABLE SYSTEM

Optimal system sizing is very important for commissioning renewable energy based power system. In this chapter the optimized output of PV based hybrid renewable system is discussed. The economic analysis and environmental impact for both diesel based and grid connected rooftop BTS is shown in this chapter.

5.1 Optimization of PV-Diesel hybrid power system for BTS :

HOMER can simulate each system based on power production and levelized cost of energy. The main operational characteristics namely annual electrical energy production, annual electrical loads served, excess electricity, renewable energy fraction, capacity shortage (limit to maximum 10%), unmet load and others are obtained from simulated system. The environmental impact parameters of the system such as carbon emissions, annual diesel consumption are also studied. The optimized results of PV-Diesel system for powering BTS is given below

PV (kW)	DG (kW)	H1000	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	DG (hrs)
7	10	24	5	$ 36,200	9,679	$ 147,219	0.374	0.26	11,526	5,853
6	10	24	5	$ 34,400	10,094	$ 150,178	0.381	0.22	12,066	6,155
7	10	48	5	$ 53,000	9,771	$ 165,077	0.419	0.26	11,530	5,857
6	10	48	5	$ 51,200	10,208	$ 168,290	0.427	0.22	12,066	6,152
6	10	24	1	$ 34,000	12,385	$ 176,054	0.447	0.21	14,895	8,760
6	10	24	2	$ 34,100	12,395	$ 176,269	0.447	0.21	14,895	8,760
6	10	24	3	$ 34,200	12,405	$ 176,484	0.448	0.21	14,895	8,760
6	10	24	4	$ 34,300	12,415	$ 176,698	0.449	0.21	14,895	8,760
7	10	24	1	$ 35,800	12,370	$ 177,682	0.451	0.23	14,876	8,760
7	10	24	2	$ 35,900	12,380	$ 177,897	0.452	0.23	14,876	8,760
7	10	24	3	$ 36,000	12,390	$ 178,112	0.452	0.23	14,876	8,760
7	10	24	4	$ 36,100	12,400	$ 178,327	0.453	0.23	14,876	8,760
7	10	72	5	$ 69,800	9,891	$ 183,254	0.465	0.26	11,530	5,857
6	10	72	5	$ 68,000	10,328	$ 186,466	0.473	0.22	12,066	6,152
6	10	48	1	$ 50,800	12,505	$ 194,230	0.493	0.21	14,895	8,760
6	10	48	2	$ 50,900	12,515	$ 194,445	0.494	0.21	14,895	8,760

Figure 5.1: Optimized system configuration for PV-Diesel hybrid system

5.1.1 Energy output :

For PV-Diesel system 26% energy comes from PV panel and 74% from diesel generator. The system has annual electricity production of 36949 KWh/yr where 9574 KWh/yr from PV and

27325 KWh/yr from diesel generator. The system has excess electricity of 72 KWh/yr and unmet electrical load of 0 %. Figure 5.2 shows the monthly electricity production of PV-Diesel system.

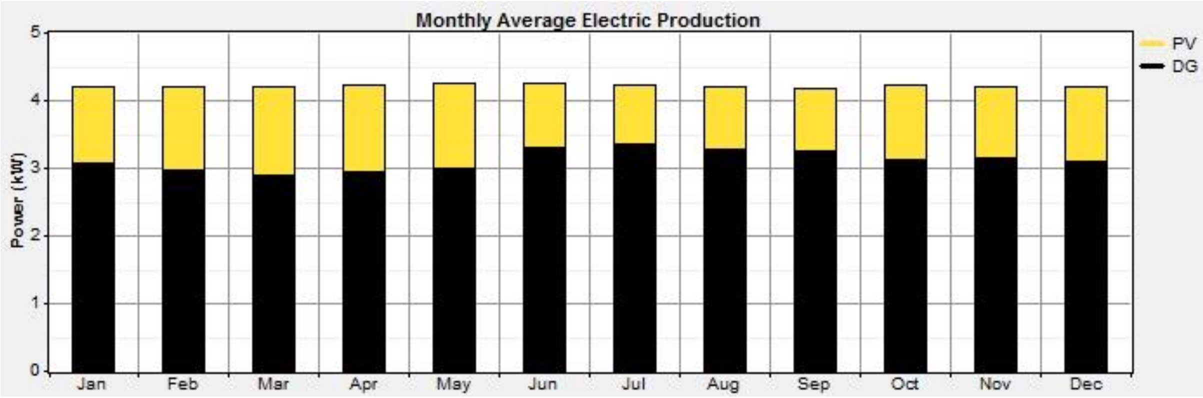
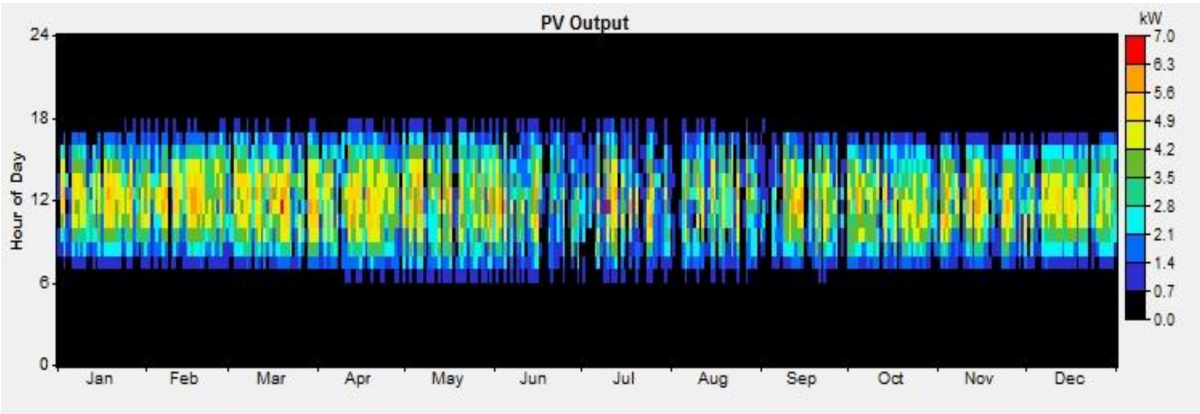


Figure 5.2 : Monthly average electric production of PV-Diesel hybrid system



. Figure 5.3 : Monthly PV output

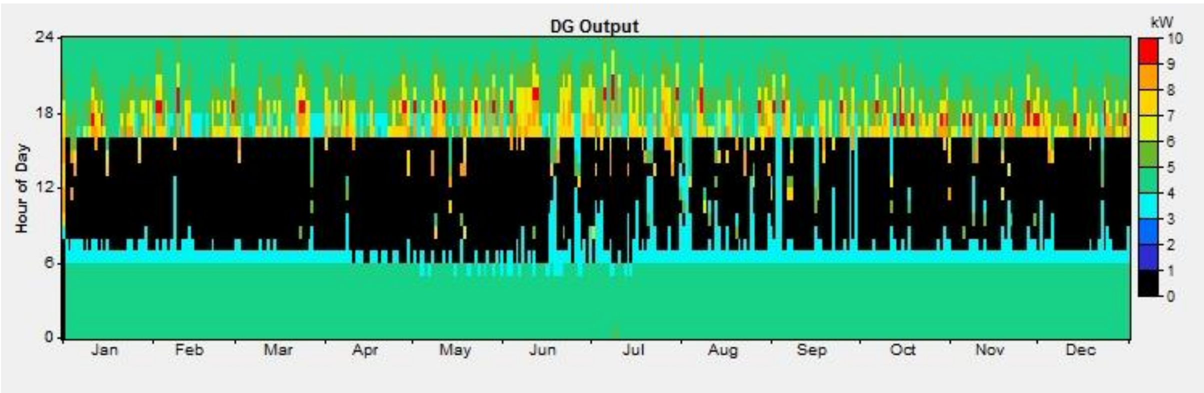


Figure 5.4 : Monthly Diesel generator output

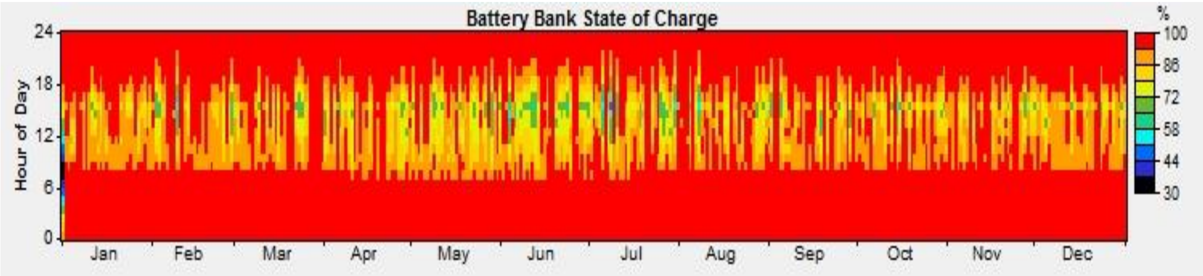


Figure 5.5 : Charge state of Battery Bank

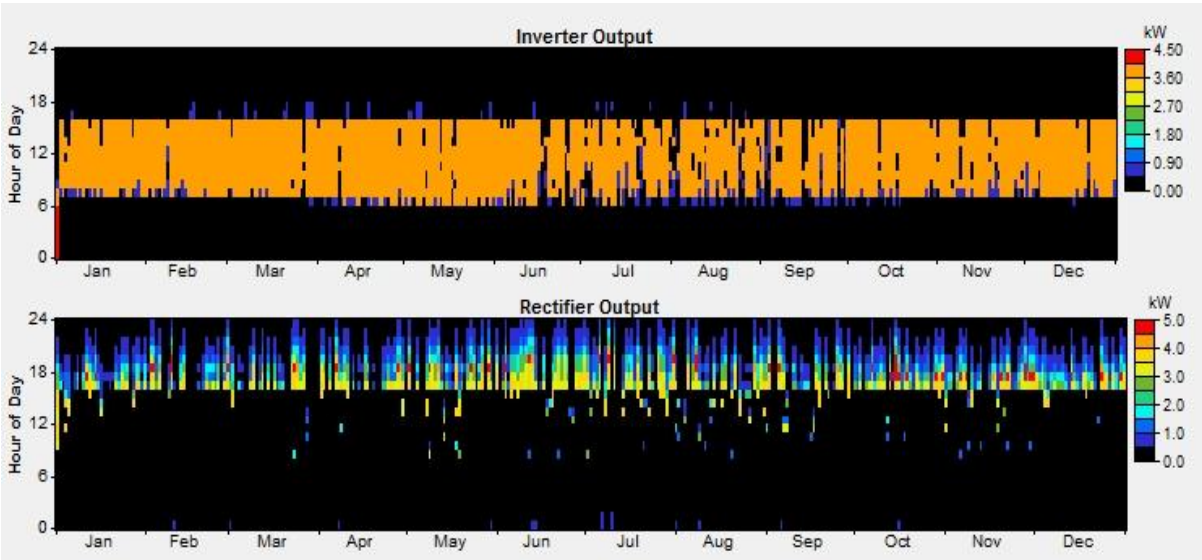


Figure 5.6 : Monthly converter output

5.1.2 Economic analysis :

The system is analyzed in HOMER according to the cost of electricity (COE) of the system. Other factors which influence the analysis are capital cost, operating cost, renewable energy factor, total Net present cost (NPC) and diesel consumption rate. Table 5.1 shows the annualize cost of each component of the hybrid system.

Table 5.1 : Net annualized cost of optimum PV-diesel system

Component	Capital Cost($)	Replacement Cost($)	O&M ($)	Fuel($)	Total ($)
PV	12600	0	149	0	12749
DG	5300	0	1343	105764	11719
H100	16800	3942	1376	0	22018
Converter	500	0	573	0	1073

The PV-diesel energy system has a net present cost of $ 147219. The operating cost per year is $ 9679. Cost of energy is found $ 0.37/kWhr. The battery bank needs to be replaced several times during the project, resulting in a high-annualized cost within those durations. O&M for other component costs are also not-significant. Figure 5.7 show the yearly cash flow summary of hybrid system configuration.

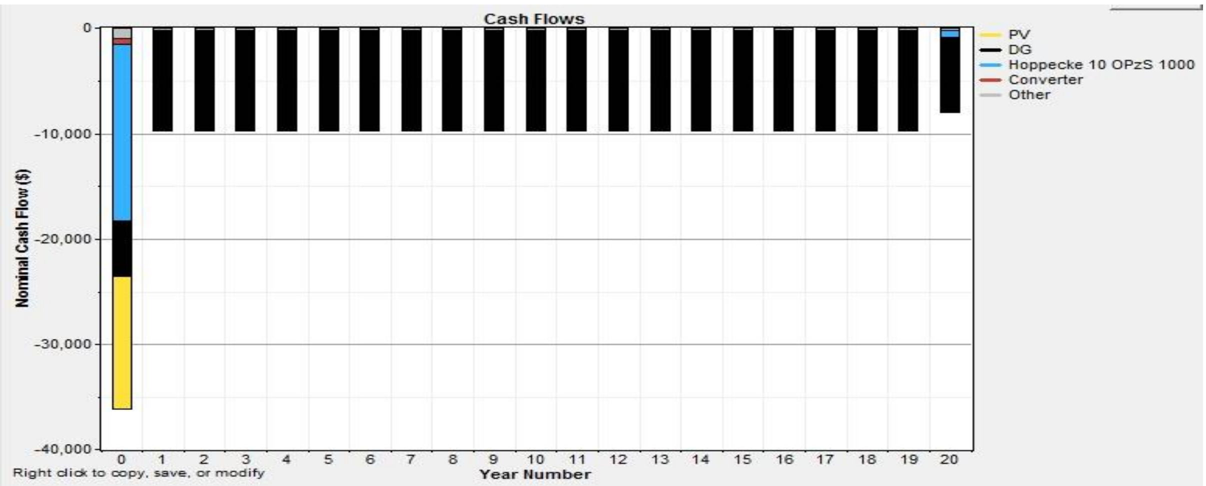


Figure 5.7 : Yearly cash flow of PV-diesel system

5.1.3 Environmental Emission :

Using renewable sources the emission of GHG is reduced significantly. Table 5.2 shows the total green house gas emission from the system.

Table 5.2: Total emission from the system

Pollutant	Emissions (kg/yr)
Carbon Di-Oxide	30352
Carbon mono Oxide	74.9
Unburned Hydro-Carbon	8.3
Particulate matter	5.65
Sulfur Dioxide	61
Nitrogen Oxide	669

5.2 Optimization of PV-Grid Hybrid system for roof-top BTS :

PV-grid system consists of PV panel and grid electricity as primary source and diesel generator and battery as backup source. Diesel generator is scheduled to operate only two hours daily. HOMER finds the optimal system configuration based on cost of energy per unit. The optimal system size found by HOMER is 3kW of PV panel , 4kW from grid , 2kW of DG , 24 H100 battery and 2kW of converter. Figure 5.8 shows the optimal system size for roof-top BTS.

PV (kW)	DG (kW)	H1000	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	DG (hrs)
3	2	24	2	4	$ 23,800	1,369	$ 39,500	0.218	0.25	226	730
3	2	24	3	4	$ 23,900	1,377	$ 39,693	0.219	0.25	226	730
3	2	24	1	4	$ 23,700	1,411	$ 39,887	0.221	0.24	226	730
3	2	24	4	4	$ 24,000	1,387	$ 39,908	0.221	0.25	226	730
3	2	24	5	4	$ 24,100	1,397	$ 40,122	0.222	0.25	226	730
4	2	24	3	4	$ 25,700	1,303	$ 40,640	0.225	0.32	226	730
4	2	24	2	4	$ 25,600	1,315	$ 40,687	0.225	0.32	226	730
4	2	24	4	4	$ 25,800	1,312	$ 40,852	0.226	0.32	226	730
4	2	24	5	4	$ 25,900	1,322	$ 41,067	0.227	0.32	226	730
4	2	24	1	4	$ 25,500	1,392	$ 41,469	0.229	0.30	226	730
5	2	24	3	4	$ 27,500	1,237	$ 41,691	0.231	0.39	226	730
5	2	24	4	4	$ 27,600	1,238	$ 41,798	0.231	0.39	226	730
5	2	24	5	4	$ 27,700	1,248	$ 42,012	0.232	0.39	226	730
5	2	24	2	4	$ 27,400	1,279	$ 42,068	0.233	0.39	226	730
6	2	24	4	4	$ 29,400	1,167	$ 42,786	0.237	0.44	226	730
6	2	24	3	4	$ 29,300	1,188	$ 42,923	0.237	0.44	226	730
6	2	24	5	4	$ 29,500	1,173	$ 42,957	0.238	0.44	226	730
5	2	24	1	4	$ 27,300	1,379	$ 43,120	0.238	0.35	226	730

Figure 5.8 : Optimized system configuration for PV-Grid hybrid system

5.2.1 Energy output :

For PV-Grid system 25% energy comes from PV panel and 72% from grid and 3% from diesel generator. The system has annual electricity production of 16274 KWh/yr where 4103 KWh/yr from PV and 11733 KWh/yr from diesel generator. The system has excess electricity of 35 KWh/yr and unmet electrical load of 0 %. Figure 5.9 shows the monthly electricity production of PV-grid system.

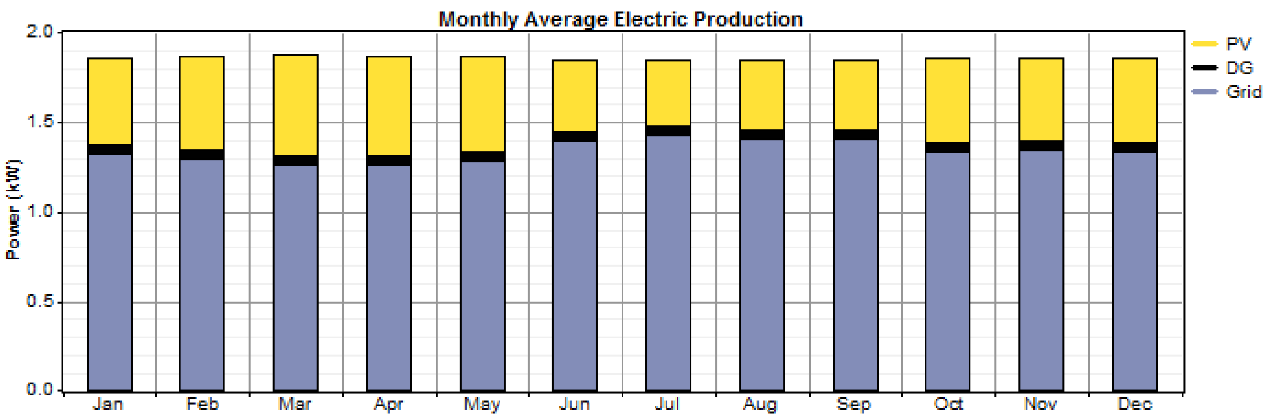


Figure 5.9 : Monthly average electric production of PV-grid system

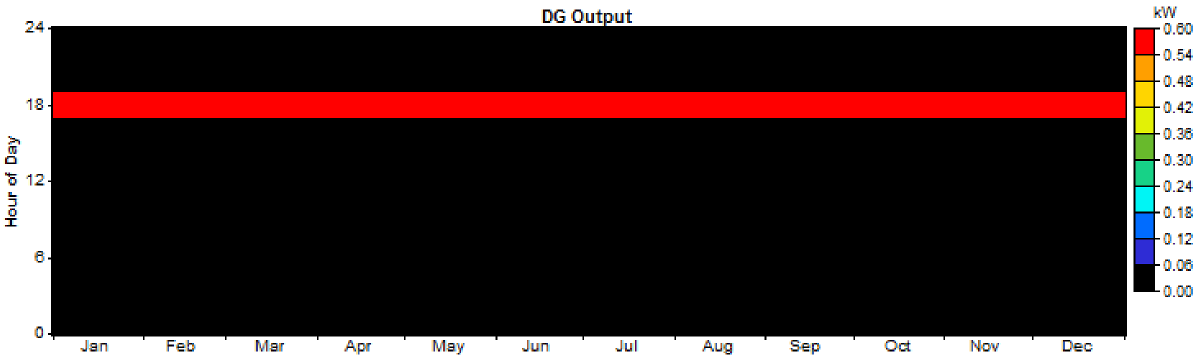


Figure 5.10 : Monthly average output of diesel generator

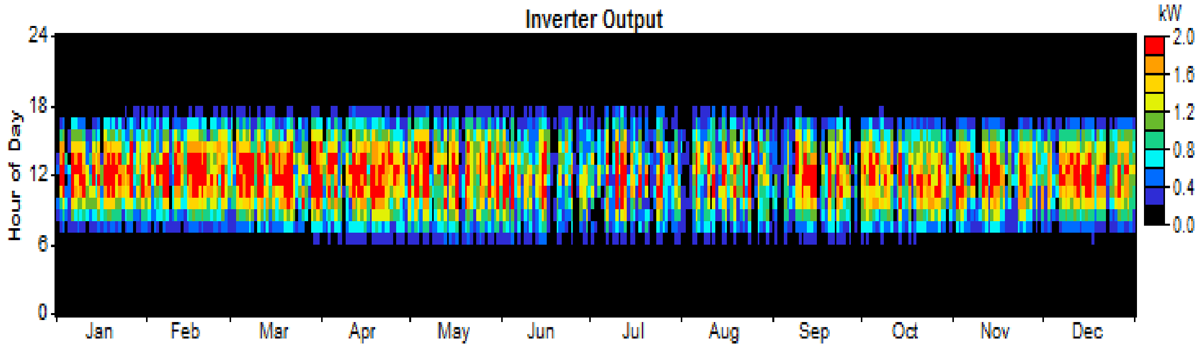


Figure 5.11 : Monthly average output of inverter

Table 5.3 shows the net grid purchase to the system .

Table 5.3: Net grid purchase

Month	Energy Purchased (kWh)	Energy Sold (kWh)	Net Purchases (kWh)
Jan	988	6	982
Feb	870	7	862
Mar	939	9	930
Apr	911	6	905
May	952	7	945
Jun	1,004	3	1,001
Jul	1,059	4	1,055
Aug	1,045	4	1,041
Sep	1,013	3	1,009
Oct	991	3	988
Nov	970	5	965
Dec	990	3	987
Annual	11,733	63	11,670

5.2.2 Economic analysis :

The system has a total NPC of $39500 .The total operating cost is $ 1369 per year. The levelized cost of energy is found $0.218 per kWh. This grid connected system offers surplus energy tobe sold to grid which can reduce some operating cost. Again this also need some extra equipment which can increase the net present cost. Table 5.4 shows the net annualized cost of the system and figure 5.12 shows the yearly cash flow

Table 5.4 : Net annualized cost of optimum PV-grid system

Component	Capital Cost($)	Replacement Cost($)	O&M ($)	Fuel($)	Total ($)
PV	5400	0	100	0	5500
DG	400	0	167	2077	2585
H100	16800	0	1376	0	18176
Converter	200	0	229	0	429
Grid	0	0	9615	0	9615

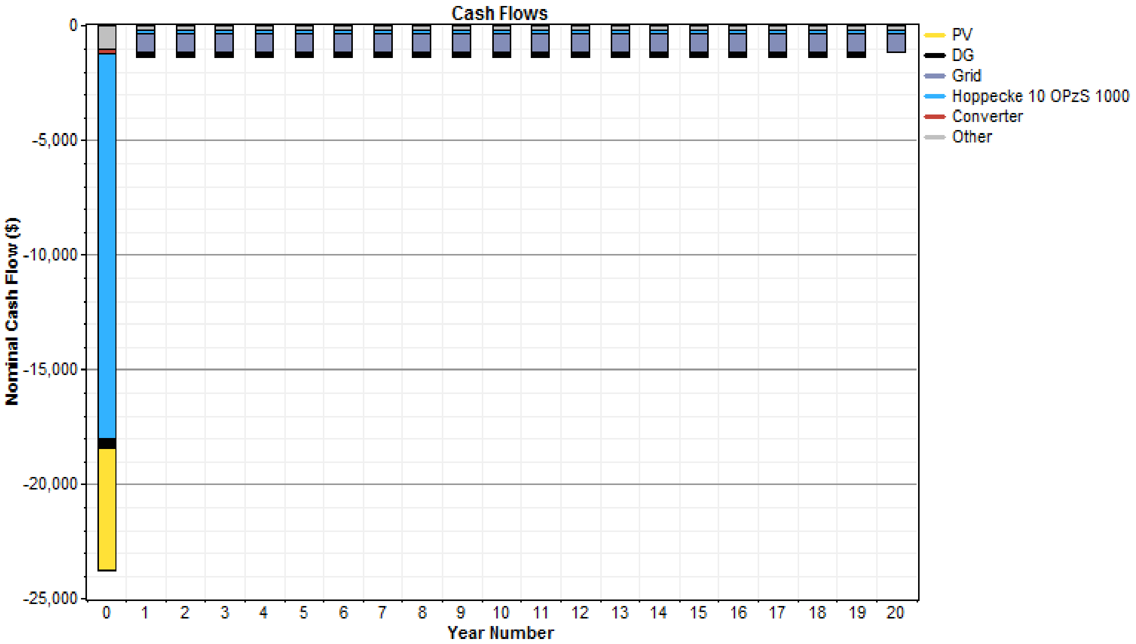


Figure 5.12 : Yearly cash flow of PV-grid system for roof top BTS

5.2.3 Environmental Emission :

The system has significantly low carbon emission which makes it more eco-friendly than other conventional system. Table 5.5 shows the total GHG emission by the system.

Table 5.5: Total emission from the system

Pollutant	Emissions (kg/yr)
Carbon Di-Oxide	7972
Carbon mono Oxide	1.47
Unburned Hydro-Carbon	0.163
Particulate matter	0.111
Sulfur Dioxide	33.2
Nitrogen Oxide	28.8

5.3 Size required by PV panel :

The total area required by a PV based plant depends mainly on total shade free area and PV panel efficiency. Total area will need to be assessed for incidence of shadows through the year to determine the extent of shade free area available. Shadow effect the PV plant performance in two ways.

When shadow falls on PV panel the output of the PV panel reduced and when shadow falls on a part of panel that part turns into a resistance and starts heating up. As a result that portion of the panel eventually burns out and the whole panel needs to replace. So when designing a PV based plant it is important that no shadow falls on to the panel. Building ,trees etc can cast shadow on a PV plant. Even one row of the panel can cast shadow on the row behind them.

Panel efficiency influences space requirement because efficiency calculated with respect to the area occupied by the PV panel. Higher efficiency panel required less space than a lower efficiency panel.

5.3.1 Calculation of size required by PV panel for roof top BTS :

From HOMER simulation it is seen that 25% load is satisfied from PV panel. Taken this into account we will calculate the total area required to produce 25% electricity from PV with a panel efficiency of 16% [27].

The total daily load is given as 43000 watt-hours/day. Hence 25% of the daily load is 10750 watt/day

$E_{(daily)}$ =10750 watt-hours/day.

Let the electronic efficiency and the battery depth of discharge is 90% and 60% respectively. Using the following equation the total amount of PV power that need tobe generated to satisfy the load is calculated

$E_{(PV)} = E_{(daily)}$ / (electronic efficiency × battery DOD)

= 10750 / (90% × 60%) watt-hours/day

= 19907.4 watt-hours/day

Now we calculate the amount of solar radiation that PV panel need to collect each day. PV panel efficiency is considered 16%.

$E_{(solar\ radiation\ needed)} = E_{(PV)}$ / panel efficiency

= (19907.4 Watt-hours/day) / 16%

= 124421.3 Watt-hours/day

The average monthly solar radiation in Chittagong is 4.527 kWh/m2/day.

Now the total shade free area required to produce 10750 Wh of electricity can be calculated using following equation.

Panel area required = $E_{(solar\ radiation\ needed)}$ / Daily solar radiation.

= (124421.3 Wh/day) / (4527 Wh/m2/day)

= 27.48 sq meter.

= 295.79 sq ft

This is the module size needed for providing 25% of the load. Arrangement of the panel and the mountings require additional spacing.

CHAPTER 6

WIND BASED HYBRID SYSTEM FOR BASE TRANCEIVER STATION (BTS) : BANGLADESH PERSPECTIVE

Of the several available option of renewable energy, wind systems have captured interest for a long time. The modern development of wind turbines was started from 1973 and the main achievement of this development lies in the improvement of aerodynamic efficiency and reliability, leading to lower costs per kWh generated. A great deal of information has been gathered in the past two years on the wind energy potential along coastal Bangladesh. The potential of wind energy in the coastal areas of Bangladesh is very high but this cannot be determined accurately until sufficient good quality data on wind speeds over at least twelve months of the year are available in different location. In this chapter the prospect of wind energy in Bangladesh and potential use of wind system with PV for powering BTS is discussed.

6.1 Wind energy in Bangladesh:

For geographical position of Bangladesh wind power has a good potential Bangladesh power development board and local government engineering department have done a lot of research work on wind power system. There is a project in ‘Muhuri’ which shows that it has a potential of 100MW wind power capacity [29] .In Bangladesh wind are mainly available during monsoon and one or two month before and after the monsoon. From September to late December the wind is too low to be used by any conventional windmill. Except for those month , a wind mill if properly designed and located can provide enough energy to be marketable. Figure 6.1 shows the energy density of wind in Bangladesh. From the figure 6.1 it is seen that most of the places in Bangladesh wind energy density of 80-120 W/m2 at a height of 20m.But in the coastal belt of southern Bangladesh and Northern Rangpur region has 200-250 W/m2 wind energy density at 20m height. Figure 6.2 shows the average wind speed across Bangladesh at 20m height.

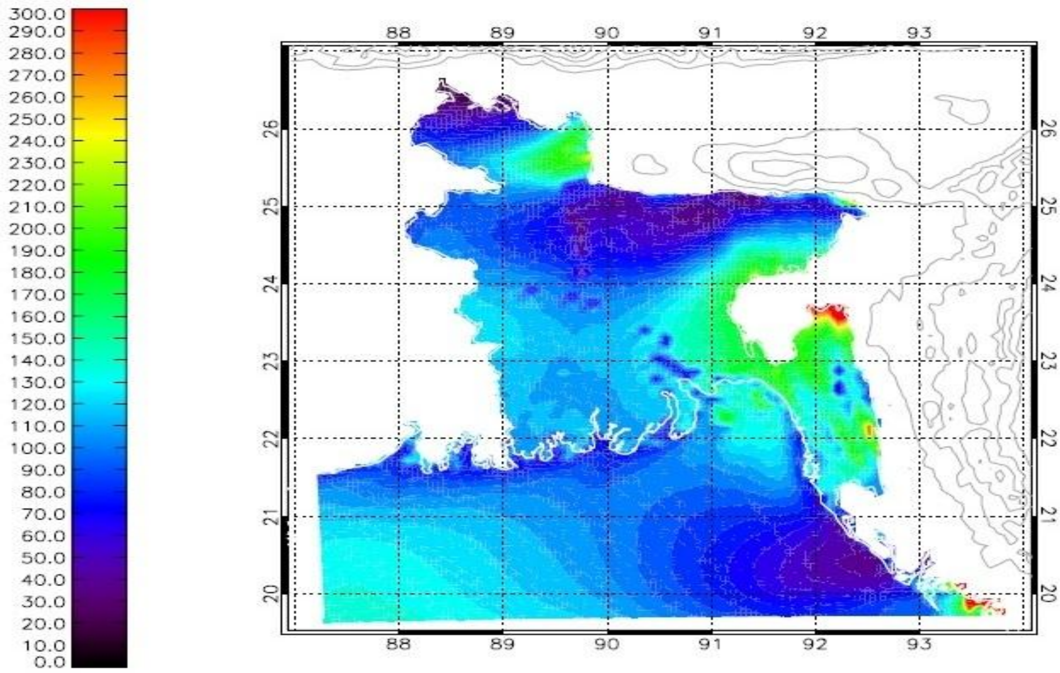


Figure 6.1 : Wind energy density (W/m2) in Bangladesh at 20m height (Courtesy : BUET)

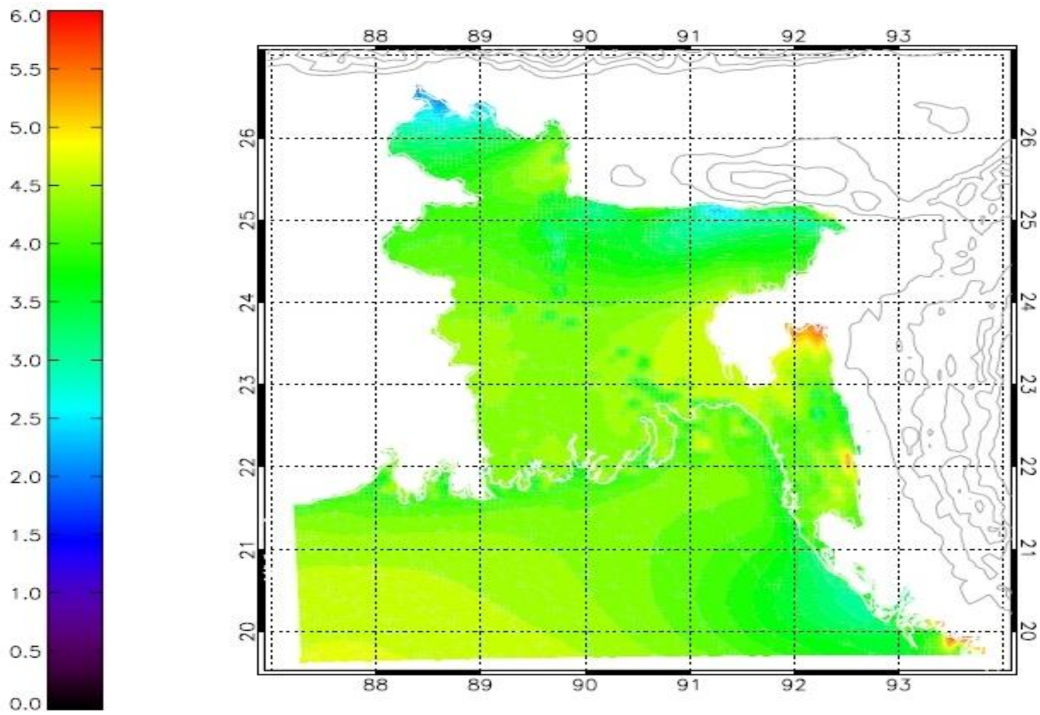


Figure 6.2 : Wind speed (m/s) across Bangladesh at 20m height (Courtesy : BUET)

From the figure 6.2 the average wind speed is found 3-4.5 m/s at 20m height. Though it is not enough speed to run large scale wind mill, low rated wind turbine can be deployed to generate power for small load.

6.2 PV-Wind hybrid system for BTS :

Standalone wind system can not be used to generate power for base transceiver station due to the random variation of wind speed and low wind energy density. For this reason we considered PV with wind turbine to supply power to BTS. In day time there will be enough solar power to run the BTS and in night time a significant amount of wind can produce enough power to backup diesel generator. So our total system will be PV and wind as primary source and Diesel generator as backup. Using HOMER we will evaluate the system response and the economic viability of the system. Figure 6.3 shows the analyzed system configuration. Here Generic 1kW wind turbine is selected for simulation. The net capital cost of Generic 1kW wind turbine ranges from $8000-to $11000. A capital cost of $9600 is considered for each turbine

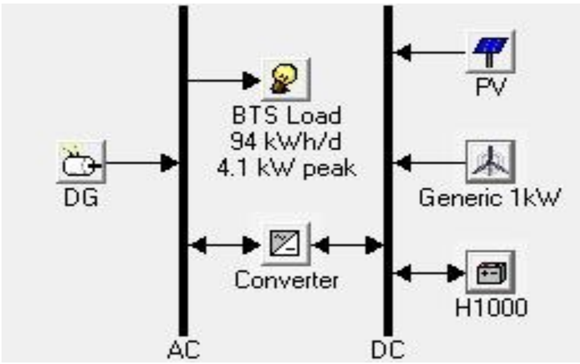


Figure 6.3 : System configuration

6.2.1 Wind energy resource :

The wind speeds at Patenga , Chittagong has measured for this study. The monthly variation of wind speed for Patenga is shown in Figure 6.5. It was observe that the diurnal variation of wind speeds is low and fluctuate. In practice, the suitable range of wind speeds for good performance of wind energy system is between 3 m/s– 4m/s, and being less practical when the speed decreases [31].

Table 6.1 : Annual average wind speed data (m/s)

Month	Wind speed at 20m height (m/s)
January	3.96
February	3.84

March	3.70
April	3.36
May	3.70
June	3.60
July	3.30
August	3.42
September	3.40
October	3.20
November	3.00
December	3.45
Average	3.48

For HOMER simulation results, the diurnal pattern strength is set to be 0.25. It is considered that there are 15 hours of peak wind speed. and the randomness in wind speed (autocorrelation factor) is 0.85.

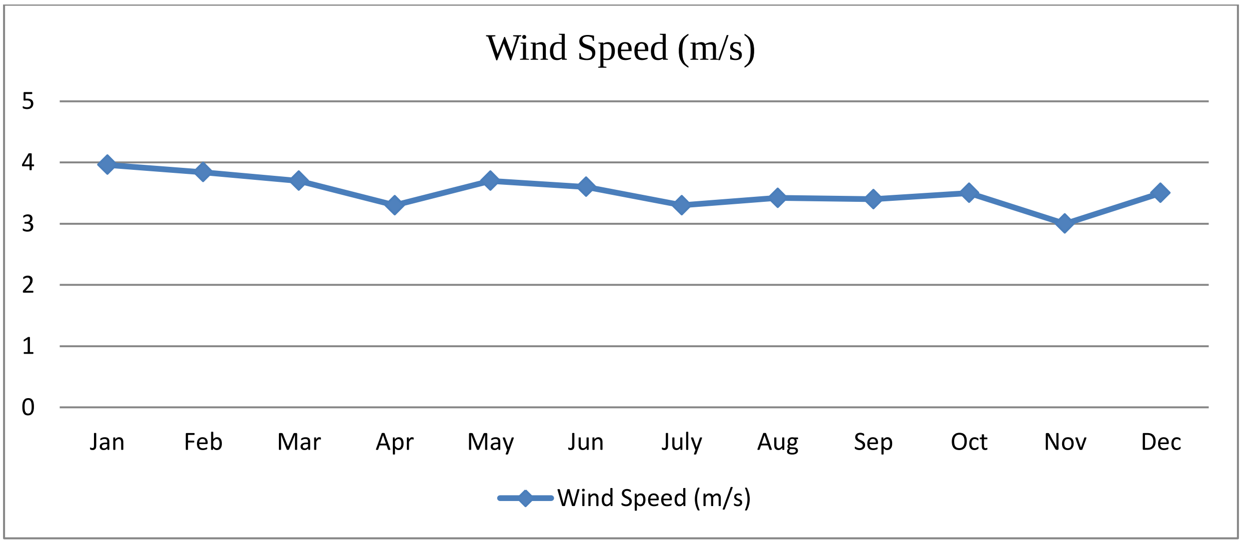


Figure 6.4 : Wind speed at Chittagong at 20m height

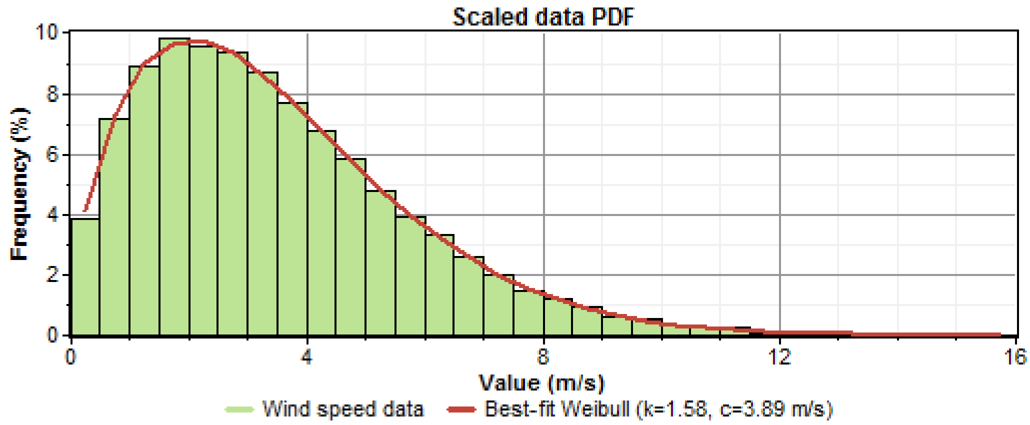
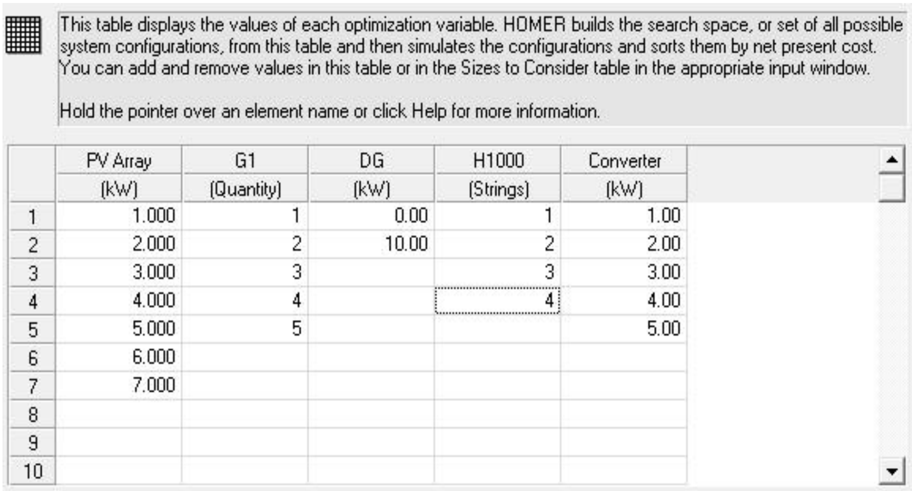


Figure 6.5 : Wind probability distribution

6.2.2 Equipment to consider :

Figure 6.6 shows the size of equipment considered for HOMER optimization.


This table displays the values of each optimization variable. HOMER builds the search space, or set of all possible system configurations, from this table and then simulates the configurations and sorts them by net present cost. You can add and remove values in this table or in the Sizes to Consider table in the appropriate input window.

Hold the pointer over an element name or click Help for more information.

	PV Array (kW)	G1 (Quantity)	DG (kW)	H1000 (Strings)	Converter (kW)
1	1.000	1	0.00	1	1.00
2	2.000	2	10.00	2	2.00
3	3.000	3		3	3.00
4	4.000	4		4	4.00
5	5.000	5			5.00
6	6.000				
7	7.000				
8					
9					
10					

Figure 6.6 : Equipment consideration for simulation

6.3 Optimization Result :

The optimization result obtained by HOMER shows that the system has a NPC of $156139 and a levelized energy cost of 0.396 $/kWh. The initial capital investment is $45800 and operation cost is $9620. Figure 6.7 shows the optimized system configuration,

PV (kW)	G1	DG (kW)	H1000	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	DG (hrs)	Batt. Lf. (yr)
7	1	10	24	5	$ 45,800	9,620	$ 156,139	0.396	0.28	11,266	5,699	17.8
6	1	10	24	5	$ 44,000	10,012	$ 158,834	0.403	0.24	11,801	6,019	18.9
5	1	10	24	5	$ 42,200	10,488	$ 162,501	0.412	0.20	12,360	6,302	18.4
7	2	10	24	5	$ 55,400	9,580	$ 165,276	0.420	0.29	11,003	5,498	16.2
6	2	10	24	5	$ 53,600	9,945	$ 167,671	0.426	0.26	11,528	5,837	17.5
5	2	10	24	5	$ 51,800	10,401	$ 171,104	0.434	0.22	12,078	6,127	17.3
7	1	10	48	5	$ 62,600	9,656	$ 173,353	0.440	0.28	11,266	5,699	20.0
7	3	10	24	5	$ 65,000	9,539	$ 174,413	0.443	0.31	10,761	5,318	15.0
6	1	10	48	5	$ 60,800	10,094	$ 176,574	0.448	0.24	11,802	6,021	20.0
6	3	10	24	5	$ 63,200	9,888	$ 176,612	0.448	0.28	11,268	5,651	16.3
5	3	10	24	5	$ 61,400	10,318	$ 179,749	0.456	0.24	11,802	5,950	16.4
5	1	10	48	5	$ 59,000	10,548	$ 179,990	0.457	0.20	12,361	6,302	20.0
7	2	10	48	5	$ 72,200	9,546	$ 181,689	0.461	0.29	11,010	5,508	20.0
4	3	10	24	5	$ 59,600	10,799	$ 183,466	0.466	0.20	12,341	6,204	15.6
7	4	10	24	5	$ 74,600	9,501	$ 183,578	0.466	0.33	10,533	5,158	14.2
6	2	10	48	5	$ 70,400	9,970	$ 184,754	0.469	0.26	11,529	5,839	20.0
6	4	10	24	5	$ 72,800	9,836	$ 185,622	0.471	0.29	11,023	5,479	15.3
6	1	10	24	1	$ 43,600	12,423	$ 186,091	0.472	0.22	14,817	8,760	20.0

Figure 6.7: Optimized system configuration

The total electricity output from the system is 37113 kWh /yr where 26% from PV , 72% from DG and only 2 % from wind turbine. The wind turbine only has 710 kwh/yr generation. Figure 6.8 shows the hourly generation by wind turbine throughout the year. From the figure it is seen that the wind power generation in our selected place is too random and highly unpredictable which is no suitable for powering a BTS site.

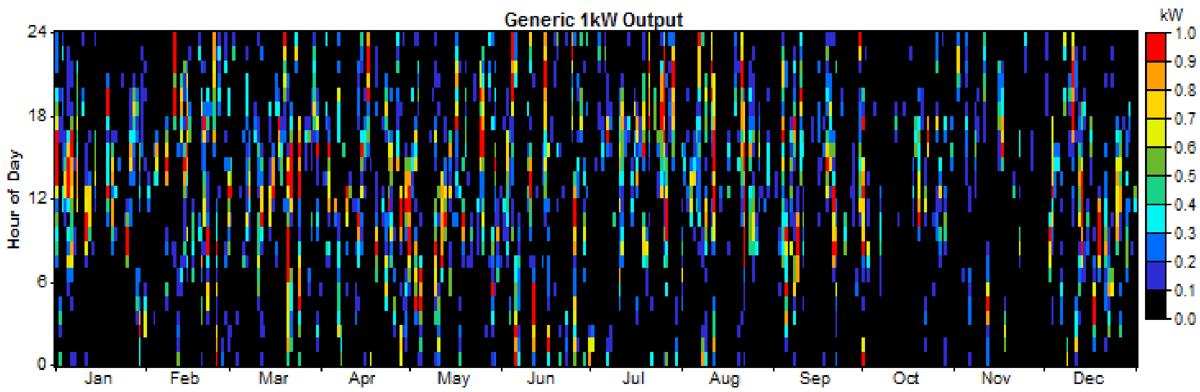


Figure 6.8: Hourly wind energy generation through out the year

From the figure 6.7 it is seen that adding extra wind turbine increases the renewable fraction and wind based generation but also the cost of energy and the net present cost also increased. Figure 6.9 shows the increase of cost of energy with an additional wind turbine keeping other equipment constant.

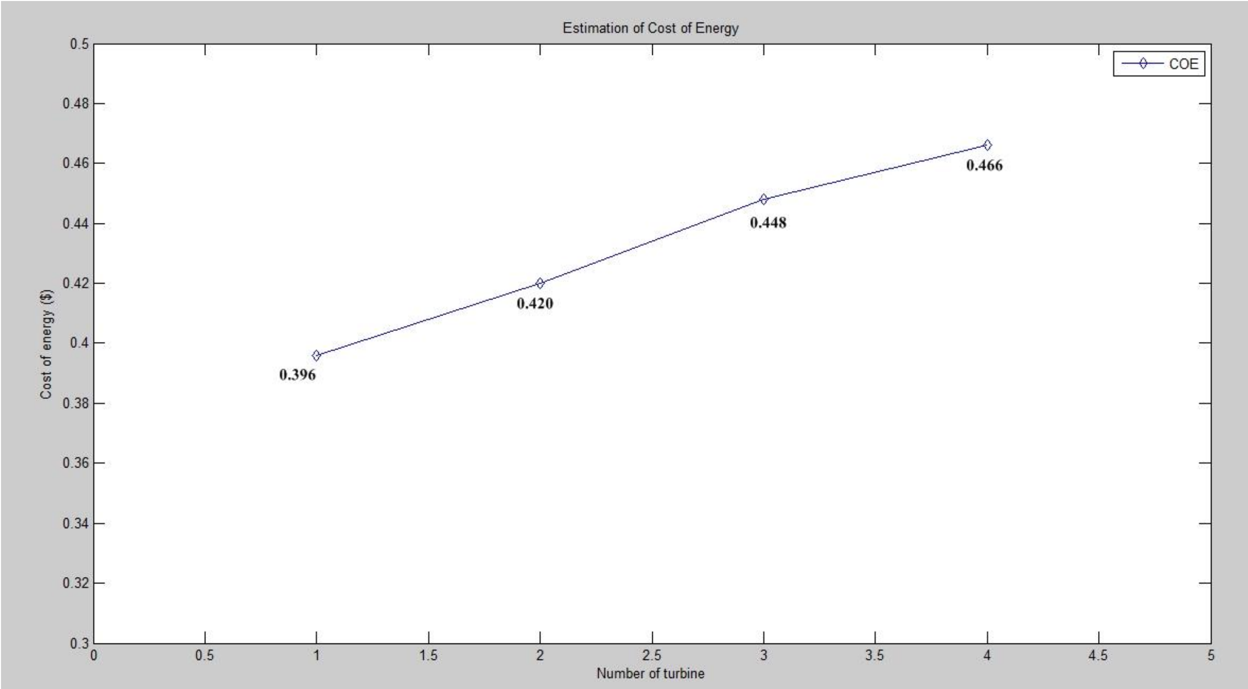


Figure 6.9: Estimation of cost of energy

So from HOMER analysis we can conclude that wind based hybrid system is not very reliable to generate power for BTS because of low wind power generation. Due to high capital cost of wind turbine, it is suggested to exclude from hybrid system.

CHAPTER 7

CONCLUTION

This study concludes that using a renewable hybrid system to power base transceiver station sites is far better than the conventional system, especially in areas where there is no utility power. The economic analysis of hybrid renewable systems carried out in this paper verifies the predictions for the brilliant future of hybrid energy technology for network operators in Bangladesh. The results show that the cost of hybrid PV based hybrid systems, though very high during installation have lower overall costs throughout the lifespan of the system for both off-grid and grid connected BTS. Wind based hybrid system is not feasible due to low wind speed and high NPC.

To finance the implementation of such systems, the initial investment cost can be carried with the help of public and private grants; after this costs can be covered firstly by user tariffs and secondly, if required, by a cross subsidy raised from the users of network or through any other international support. The main drawback of renewable systems are the high initial capital cost and the unreliability of RES. However, these obstacles can be expected to be removed by technological progress. Additionally, there are many factors making the use of renewable sources attractive, such as relatively short payback times, low O&M costs and the ability of renewable systems to respond to rising power demands. With time, technological progress will lead to a fall in prices, while at the same time the prices for conventional fuels are constantly rising.

From an environmental standpoint, in terms of pollutant emission, the hybrid renewable system is preferred over the existing system. The power flow strategy takes full advantage of the solar & wind energy when it is available, and minimizes fuel consumption, thereby reducing pollution. If the diesel-only generator is continued to be used by network operators in Bangladesh, the CO_2 generated in each base station location will possibly cause global warming in the near future. From the simulation results (costs and emissions), it is demonstrated that the use of a hybrid PV-wind system achieves significantly lower NPC and reduction on CO_2, as compared to a standalone system. Therefore, the suitability of hybrid renewable system in the telecommunications industry was determined in the perspective of technical and economical analysis. Thus, the use of hybrid systems will become even more attractive, especially since they are environmentally friendly, reliable and can be operated continuously.

The main challenge to implement such system will be the assessment of suitable sites where sufficient renewable resource is present. The telecom operators should consider this to deploy renewable sources. City and area's where wind speed is not sufficient, solar solution can be a reliable option. The wind power generation in Bangladesh mainly restricted to coastal areas. So this also be an option for telecom operators to power their BTS's.

As a conclusion, the hybrid renewable system has potential use for power generation at BTS sites in Bangladesh.

Future work :

As future work we will investigate feasibility of other sustainable sources such as micro-hydro , bio-fuel and fuel cell powering telecom industry. We intend to study the availability of roof top space in the city area for deployment of PV based renewable resources for the electrification of roof top base transceiver station . GIS system will be used to determine probable roof top space where through out the cities specially in Dhaka and Chittagong for deployment of PV system for BTS electrification

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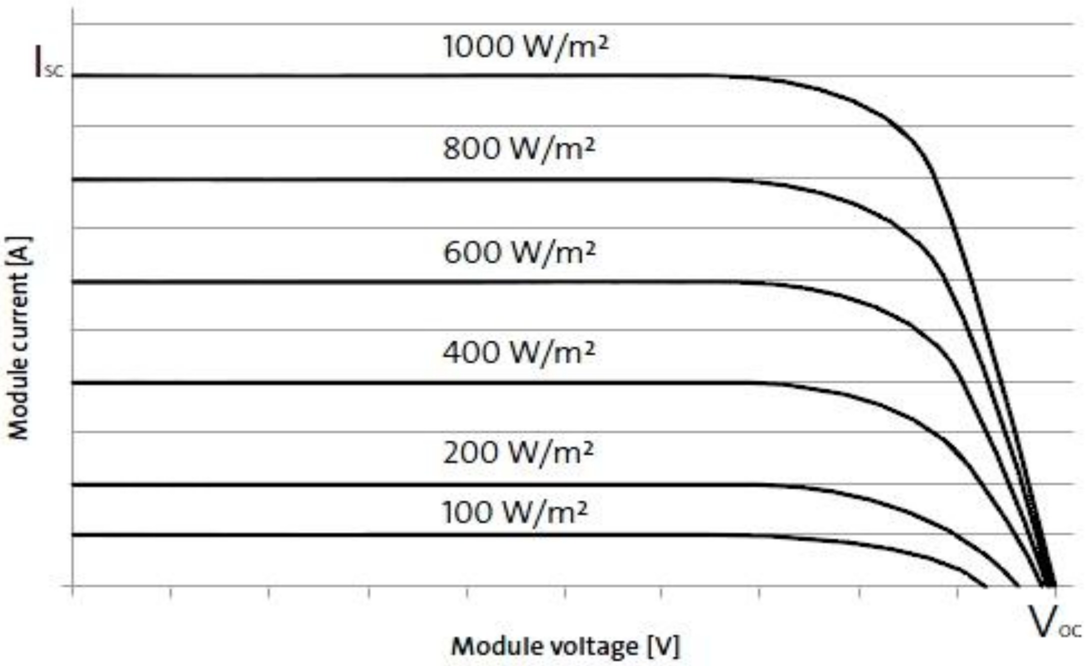
APPENDIX A

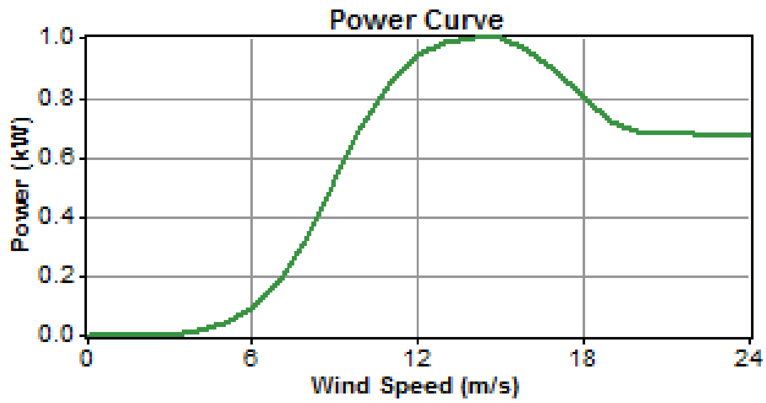
SUNMODULE SW260 specification :

Maximum Power under Standard Test Condition (Pmax)	260 Wp
Open Circuit Voltage(V)	38.9 V
Maximum Power Point Voltage (Vmax)	30.7 V
Short Circuit Current (I)	9.81A
Maximum Power Point Current (Imax)	8.56 A
Cell per module	60
Cell type	Mono Crystalline
Efficiency	16%

V-I characteristics of SW260 :



Power curve of Generic G1 wind turbine :



Hoppecke 10 OPzS 1000 battery specification :

Nominal Capacity	1000Ah
Nominal Voltage	2V
Round trip efficiency	86%
Min State of Charge	30%
Max. charge current	202A

Hoppecke 10 OPzS 1000 battery depth of discharge :