AN ON-GRID WIND TURBINE POWER PLANT MODEL AND SIMULATION FOR A PARTICULAR LOCATION IN BANGLADESH

A Project report is submitted in partial fulfillment of the requirements for the award of Degree of Bachelor of Science in Electrical and Electronic Engineering.

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DECLARATION

I hereby declare that this project **“An On Grid Wind Turbine Power Plant Model and Simulation For A Particular Location in Bangladesh”** represents my own work which has been done in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering, and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications. I have attempted to identify all the risks related to this research that may arise in conducting this research, obtained the relevant ethical and/or safety approval (where applicable), and acknowledged my obligations and the rights of the participants.

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APPROVAL

The project entitled **"An On Grid Wind Turbine Power Plant Model and Simulation For A Particular Location in Bangladesh"** submitted by **Swarna Mitra Chowdhury (192-33-5167) & Rifah Tasnim Islam (192-33-5173)** has been done under my supervision and accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** in **January, 2024.**

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Dedicated

To

Our Well Wishers

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SDG	Sustainable Development Goals
BAPEX	Bangladesh Petroleum Exploration and Production Company Limited
NASA	National Aeronautics and Space Administration
MLE	Maximum Likelihood Estimation
MOM	Method of Moments
DPM	Density Power Method
WTG	Wind Turbine Generator
WHS	Wind Hydro & Sun Energy Services
SHS	Solar Home Systems
BMD	Bangladesh Meteorology Department
BCAS	Bangladesh Centre for Advanced Studies
SREDA	Sustainable and Renewable Energy Development Authority
EIA	Environmental Impact Assessments
BNBC	Bangladesh National Building Code
BPDB	Bangladesh Power Development Board
IEC	International Electro-technical Commission

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ABSTRACT

Wind energy is a renewable resource that Bangladesh has, and we should try to use it to meet the country's electricity needs. As a clean energy source, wind power has great potential to contribute to Bangladesh's sustainable development goals. This article gives a thorough analysis contrasting the viability of wind turbine power systems for power generation in a particular area in Bangladesh, as part of the search for sustainable and renewable energy alternatives. Seven different places were looked at to determine which was the most effective. We chose Teknaf as the target area because of its distinctive geographic and climatic features. The HOMER Pro software is used in the study to carry out accurate simulations and economic analyses. The findings show that wind turbines have a greater potential for generating electricity in Teknaf. This area holds high wind speed, especially during specific months of the year, this is the reason for this result. Including installation costs, maintenance costs, and energy output over time are taken into consideration in the simulation and economic analysis. We calculated the economic analysis for the 25-year lifespan of the project at a 50-meter height and assumed about a 10MW load. Our proposed system can generate more than 5810MW of electricity every year. The results imply that wind energy systems help achieve sustainable energy goals and that wind turbines offer an efficient and economically feasible choice for generating power in Teknaf.

***KEYWORDS:* Renewable Energy, Wind energy, HOMER Pro, Teknaf, NASA.**

CHAPTER 1
INTRODUCTION

1.1 Introduction

Bangladesh's reliance on nonrenewable energy sources is significant in its electricity production, particularly natural gas (44.11%), coal (6.8%), HFO (24.13%), HSD (5.15%) [1].The domestic gas supplies are running out, making it difficult to maintain a consistent supply. Bangladesh also depends on imported petroleum products and oil, particularly when demand is at its highest or there is a scarcity of gas. In fuel-based power generation, 5.37% were imported in the year 2013-14, which became 9% in the year 2021-2022 [2]. Due to the nation's nonrenewable energy sector's reliance on imports, problems with price volatility and energy security arise. Bangladesh also imports 1160 MW (4.46%) electricity from India [1, 2]. Not only that, but the country is also planning to import more electricity from Nepal and Bhutan in future to tackle the increasing energy gap [2]. But we can improve energy security and lessen its reliance on volatile international energy markets by putting more emphasis on renewable energy, particularly domestic sources wind.

1.2 Problem Statement

At present Bangladesh is facing huge power crisis for several reasons, which is resulting into load shedding. The primary causes of such a crisis in the power and energy industry are the inability to obtain proper gas supply, and the growth in the price of imported fuel on the international market. The import-dependent planning makes it difficult to provide high-quality power service, even while the production capacity exceeds the demand. From May 24 to May 29, 2023, 4,295 MW of power producing capacity, or roughly 18% of the total capacity, could not be used on a daily average owing to fuel scarcity [3]. The government is under pressure to import gas, coal, and fuel oil because of the country's dollar shortage. As a result, power plants are not getting the fuel they need. Due to a lack of coal, gas, or fuel oil, several power facilities had to be shut down. Gas-powered plants had an output capacity of 11039 MW, but production had been 6221 MW on average in May 2023 [3]. Due to the preference for imports over the country's emphasis on gas development, this situation has developed. The last 20 years have seen no significant gas field discoveries. BAPEX has found a few little gas resources. There has been no improvement to the National

Gas Exploration Agency. A century after the maritime conquest, gas exploration is still producing negative results. Because of unpaid invoices from the currency crisis, Payra, the main power plant, has been unable to purchase coal for a number of months in 2022-2023, and Rampal Power Plant had to be shut down twice. Due to its reliance on foreign energy sources, the country is already facing supply disruptions along with fluctuations in energy market prices. These resources tend to grow more expensive as they become scarcer, resulting in increased energy costs for consumers.

Figure 1.1: Price of Gas from the Year 2016-2021

Fuel Types	Total Center	Fuel Crisis in the Center		
		3 June, 2023	4 June, 2023	5 June, 2023
Gas	64	18	16	17
Furnace Oil	65	28	26	25
Diesel	8	5	5	4
Coal	5	4	4	4
Water	1	1	1	1

Table 1.1: Fuel Crisis in Bangladesh [8]

As we can see gas prices are in 2021-2022, they have increased compared to previous years. Countries like Bangladesh are in a lot of trouble to buy fuel at a high price. From July to December of the previous fiscal year (2021–22), just the import of petroleum products cost 367 million dollars. And it has climbed by 46% during the same time period of the current fiscal year (2022-23). There have been 536 million dollars spent. The central bank is having trouble keeping up with the rising energy import expenses. The country's six power distribution firms, which provide electricity to consumers, reported that load shedding exceeded 2000 MW per day in May 2023, and the maximum loadshedding was around 3000 megawatts in June 2023. Also, there was gas, coal, and fuel oil scarcity affecting around 33% of all power plants [4]. This resulted in load shedding, carried out for up to 10 hours in countryside and three to four hours in Dhaka metropolis in June 2023. When electricity shortages worsen, load shedding is typically concentrated more in rural regions. The figure below gives a list of the number of power plants in energy crisis with dates.

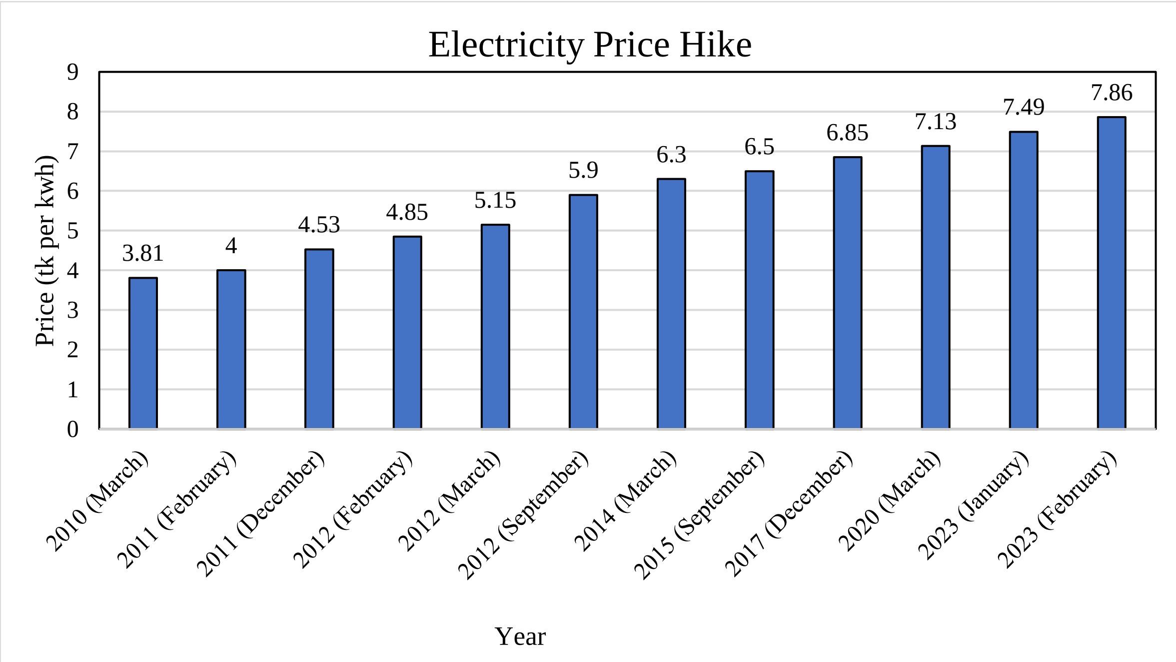

Figure 1.2: Electricity Price Hike from the Year 2010-2023

Bangladesh also experiences environmental problems like air pollution and climate change, much like many other nations. In comparison to fossil fuels, renewable energy sources emit significantly fewer greenhouse gases, making them an essential instrument for lowering carbon footprints and preventing climate change. Bangladesh may support international efforts to reduce global warming and enhance air quality by switching to renewable energy sources, which will have a positive impact on both the environment and public health.

Bangladesh has one of the world's longest sea beaches and is a riverine country. We are aware that coastal and riverine regions are where wind is most prevalent. There will be a lot of wind where there are rivers and the sea because these areas have higher wind speeds than other areas. Therefore, we have the ability to construct wind farms there and provide a significant amount of power within our own nation. By doing this, self-reliance is a possibility for our country.

1.3 Objectives

To overcome the issues mentioned above and the huge energy gap, we need to focus on generating more power from renewable energy sources. We can improve energy security and lessen its reliance on volatile international energy markets by putting more emphasis on renewable energy. Self-reliance is a possibility for our country. Additionally, increasing the use of renewable energy sources like wind can increase energy security and lessen sensitivity to changes in fuel prices.

Bangladesh currently has a relatively little capacity for installing wind energy. A few initiatives and pilot projects have also been conducted to assess the feasibility of wind energy in different areas. Clearly, though, it is insufficient. Just 1195.34 MW, or 4.59%, of the electricity is produced using renewable energy. 80.4% of all renewable energy is produced by solar energy, which accounts for 961.27 MW (off-grid and on-grid). Hydropower accounts for another 19.2% (230 MW). Wind energy accounts for just 0.2% of all renewable energy (2.9 MW) [1]. Bangladesh aims to produce at least 10% of its electricity from renewable sources [2], with a clear preference for solar energy.

Only 10 to 23% of the irradiance can be converted by solar PV under standard testing conditions; the remaining amount is converted to thermal energy, which increases cell temperature and lowers solar PV conversion efficiency [6]. Increased cell temperature results in higher conversion efficiency losses. Research has shown that a 1° C increase in cell temperature results in a 0.35 percent reduction in the power output of PV panels [6]. The bright lighting causes the PV modules' temperature to rise, which lowers their efficiency. Moreover, the efficiency of the panel is affected by additional environmental and operational elements such as wind speed, cloud movement, dust, shadow, humidity, tilt angle, and dust [6]. The cost of installing and purchasing solar panels could be high up first. Furthermore, inadequate training

Wind turbines work best in areas with consistent and strong wind patterns, like wide plains or coastal regions. Bangladesh lies between latitudes 20°34'–26°38' North and longitudes 88°01'–92°41' East. Wind is a reliable and clean energy source, especially for coastal areas. Because of the 724 km long coastal area, the capabilities of wind energy are tremendous here [5]. Wind speeds show strong seasonal fluctuations; they are stronger in the summer (March to August) and lower in the winter (September to February). Wind can generate electricity in a wider variety of wind conditions. A substantial amount of electricity can be produced by wind turbines, particularly in regions with strong, dependable winds. With more installations and technological advancements, wind energy has already surpassed coal and oil in terms of cost. Bangladesh has a sizable rural population, and many isolated regions are still without electricity. Rural electrification can benefit greatly from the use of wind energy, particularly decentralized options like small-scale wind turbines. These off-grid and mini-grid systems can deliver dependable, clean electricity to isolated communities, enhancing their standard of living.

1.4 Brief Methodology

This thesis report focused on analyzing the wind speed data from seven coastal regions in Bangladesh, which was obtained from NASA's data repository. To conduct the analysis and simulations of energy systems associated with these wind resources, we employed Homer Pro software. With the ability to model and simulate a wide range of energy sources, including fuel-based generators, wind, solar, and hydropower, Homer Pro is a very adaptable tool. Grid connectivity and energy storage are also taken into account.

In our research, we specifically focused on the wind energy resources available at a particular location in Bangladesh, utilizing NASA's data. Homer Pro's capabilities were instrumental in this aspect of our work, considering essential factors like climate data, load profiles, and system constraints to generate precise and comprehensive analysis results.

The optimization feature within Homer Pro played a significant role in our research, allowing us to identify the most efficient configuration of energy sources and system components. This optimization process was geared towards cost minimization and meeting specific energy output requirements. In practical terms, this functionality proved invaluable in determining the ideal sizing and operational strategies for renewable energy systems, while factoring in considerations such as capital costs, maintenance expenditures, and energy production.

1.5 Structure of the Report

In this segment we have shown the structure of the report and its description.

Literature Review	Our literature review encapsulates the groundwork of prior research pertinent to our project. We have meticulously traced the evolution of thought and innovation in the field.
Materials & Methods	This chapter serves as a comprehensive guide to the materials and methods employed in our project. Additionally, we've incorporated a detailed NASA data chart illustrating wind speed patterns, offering valuable insights into our methodology. In simulation setup part we have designed a model and assumed load for getting the output of power generation and costing part.
Result & Discussion	In this chapter we have mentioned the output and costing part by using Homer Pro software. We have also showed load vs generation month wise summary graph.
Project management	This chapter shows the project timeline of the report.
Impact Assessment of the Project	We have analyzed the project impact in this chapter where we have mentioned the impact of climate, environment benefits and clean energy source for Bangladesh.
Conclusion	This chapter includes future recommendation for this type of project.

Table 1.2: Structure of the Paper Chapter Wise

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

In previous years, a lot of research has been conducted on wind energy scenario in Bangladesh. In this part we are going to discuss research that is available on present days, their findings, limitations, and viable solutions to mitigate the shortcomings of the existent works.

2.2 Related Research

At present Bangladesh is facing huge power crisis for several reasons. The major reason is the lack of fossil fuels and their increasing prices. More than 40% of our power comes from gas [1]. Due to unaffordable prices of gas in recent days, we are not capable of supplying gas in power plants according to the demand, which has led to a huge energy gap. Soaring prices of petroleum also caused a power generation gap in previous years. We must concentrate on producing more electricity from renewable energy sources in order to address these problems and close the massive energy gap. Wind energy is a dependable and sustainable energy source, particularly for our nation's coastal regions. The 724 km long coastal area contributes to the immense potential of wind energy in this location.

An analysis of Bangladesh's current energy situation and wind energy potential found that the yearly average wind speed at 30 meters is more than 5 m/s. [9]. Bangladesh's north-eastern regions have wind speeds of over 4.5 m/s, while other regions have speeds of about 3.5 m/s [10]. The following areas have a lot of potential for producing electricity from wind. This analysis was done at a height of 50 meters in an onshore location. If it is done at a height of more than 50 meters, it is anticipated that the wind speed will be greater than 7 m/s at an altitude of 80 to 100 meters. Since height increases exponentially, so do wind speeds [9]. The wind speed at 80 meters above sea level is more than 7 meters per second, which is enough to produce power. [9]. In this research, they analyzed wind data from the year 1998-2011.

Here, it was mentioned that in contrast to China, which uses the BeiDou Navigation Satellite System and other methods of measurement, Bangladesh lacks trustworthy wind speed data

[19]. Bangladesh has also lagged in using wind turbines to convert wind energy into power for a while. As the world's first energy producer, China is nearing the end of its multi-year plan for energy technology innovation. The plan specifically mentions wind energy as a focal point and highlights key innovations including wind turbines with a creation limit of between 8 and 10 MW. With over 187 GW, 2018 China led the world, Germany ranked third with 56 GW, while the US ranked second with 89 GW [20]. Before the end of 2018, Bangladesh was expected to request 10283 MW of power. Only 100 MW of that considerable interest was predicted to come from wind control sources, despite the region's enormous coastline and overall size [11]. The lengthy stretch from April to August has breeze speeds greater than 3.2 ms-1 for all time, according to the climatology of wind speed from 2008 to 2018 years, while other months had low breeze speeds. The lengthy period from June through August each year is seen the highest wind speeds. The average breeze speed from April to August from 2008 to 2018 was over 3.2 ms-1 on average, according to the climatology of wind speed, albeit it was low in one additional month [11]. Between the months of March and September, this breeze sweeps over Bangladesh at a regular monthly speed of between 3 and 6 m/s [21].

Understanding the distribution of wind speeds is essential for evaluating the wind potential in windy areas. Topographical and meteorological data for the site under consideration are equally crucial as speed dispersion. If the wind speed distribution in the area is understood, it is easy to assess the power potential and economic viability of any windy site. For this use, the Weibull functions are the most common [12]. The study of analysis of wind characteristics in coastal areas of Bangladesh from March to September 2003 [12] investigated wind data from a few coastal localities in Bangladesh, including Kutubdia, Kuakata, Mongla, Sandwip, and Teknaf. The wind data was gathered at intervals of 10 minutes and then converted to hourly time series.

To investigate and determine the best locations for wind energy generation, statistical analysis based on various models, Weibull Distribution, Maximum Likelihood Estimation (MLE), Method of Moments (MOM), Density Power Method (DPM), and other methods are needed in addition to using simulated wind data [22, 23]. Several studies have been conducted thus far addressing the feasibility study of wind energy along with the analysis of investment, operation, and maintenance costs. There are a few studies that demonstrate the Weibull Distribution Method for analyzing wind speed frequency while using the

Graphical Method, also known as the Weibull Paper Method, to determine the Weibull parameters. They also compared the accuracy of the site by obtaining the Scale parameter (c) and Shape parameter (k) using the Energy Pattern Factor Method, Weibull Paper Method, and Standard Deviation Method. Since Bangladesh's coastal regions had faster winds than other parts of the country, these areas formed the basis for the majority of analyses. To forecast the wind pattern for the places, Weibull and Rayleigh distribution functions have been evaluated in work of data accuracy by comparing between the Weibull and Rayleigh Distribution Function to forecast the wind energy potential for several locations of Bangladesh [13].

In the study of potentiality of wind power generation along the Bangladesh coast, it was depicted a time series of wind speed (0–10 meters mean) from 1990 to 2016 [14]. It was shown that the pattern of wind speed varies significantly from year to year but, on average, did so within 3–4 ms-1. According to the monthly wind speed climatology from 1990 to 2016, the months of April to August are the only ones with consistently high wind speeds (greater than 3.2 ms-1), while all other months have low wind speeds. Each year, the months of June to August see the highest wind speeds [21]. According to the climatology of wind speed from 1990 to 2016, wind speeds of more than 3.2 ms-1 permanently decrease from the months of April to August while being high in other months. The months of June through August are the windiest of the year. Also, it was shown that while the offshore wind speed was consistently high throughout the months of April and August, it is also higher during other months. As a result of the analysis, we can say that Bangladesh will benefit greatly from offshore wind energy, while coastal wind energy can also be useful for power generation from April to August [14].

In wind energy analysis in the coastal region of Bangladesh, through the statistical analysis of actual wind and the use of simulated wind energy mapping for mesoscale and microscale modeling, the coastal and near-coastal wind power potentials of Bangladesh were investigated [15]. The chosen coastal area was subjected to WTGs using various low wind models, such as WinWinD-1/60 for 60 m AGL, GW155-3.3 for 80 m AGL, and GE 1.6-100 for 100 m AGL. It was discovered that two microsites have promising wind speeds, reaching 7.3 m/s at 100 m AGL, indicating that their south-east wind flow can generate significant energy. If a wind power station is listed as generating certified emission reductions, this carbon reduction could play a significant part in carbon trading. This passive method of mitigating carbon through the production of wind energy, along with other renewable energy, is secure for replacing the carbon-emitting source of energy, in contrast to the carbon sequester method, which directly captures carbon from the source of emission before its release into the atmosphere. Bangladesh's coastal wind energy has the potential to increase economic gains by lowering GHG emissions, particularly carbon dioxide. The validation analysis of the meso- and microscale wind resource maps of the same region was made possible with the aid of this research, which calculated the wind power potential of Bangladesh's coastal regions using the most efficient statistical methodologies [15].

According to Wind energy potential in Bangladesh, in 2016, Bangladesh's electrical load peak demand was close to 11,405 MW [16]. By 2015 and 2020, the strategy had established goals for the development of renewable energy resources to supply 5% and 10%, respectively, of the total power demand [25]. It was mentioned that there would be a need for turbines that can produce 225.33 MW of total wind power. The near shore wind farm, with H = 100 m, D = 75 m, and V = 7 m/sec in 4 rows, is thought to have 5104 total turbines. Bangladesh had a solar energy capacity of 15 MW, as evidenced by rural homes. Additionally, Bangladesh produces 37 MW and 230 MW of energy from solid biomass and hydropower, respectively. Using 5104 WT with H = 100 m, D = 75 m, and V = 7 m/sec, 1855.25 MW of power can be produced. With the rise in height, there is a chance that we could anticipate significantly higher wind speeds, which would lead to more electricity generation. Going with renewable energy is crucial to addressing the current energy situation. The production of electricity is now the wind energy usage that occurs most frequently. Based on this study, using a collection of 5104 wind turbines in a close-to-shore wind farm in Bangladeshi coastal areas in 1855.Power generation of up to 25 MW is feasible [16].

In a feasibility assessment for the Wind Home System in Bangladesh's coastal region [17]. It was showed that WHS was far superior to SHS on coastal islands. This system may have an equal impact in some locations. However, due to extremely low wind speeds in October and November, this approach may not be practical for some coastal inlands, such as Patenga and Kuakata [24, 26]. A quantifiable amount of extra energy is available for big variations in wind speed, and it can be used by reducing the peak demand and using other appliances like fans during the heat. Results indicate that the cost of usable energy from WHS fluctuates between 24 and 39 Tk/kWh depending on the location, which is perfectly reasonable for coastal isolated locations [17]. The results from the financial and sensitivity analyses are likewise favorable. As a result, Bangladesh's distant coastal inlands and islands should present a market for WHS.

In a pre-feasibility study of wind resources in Kutubdia Island [18], Bangladesh, it has been discovered that the computed wind speed of BMD from BCAS data and BCAS from BMD data is fairly close to the measured values. Because BCAS has a lower power density than BMD, a wind atlas derived from BCAS data has been taken into consideration for a detailed examination and analysis [24, 26]. If there was a sheltering effect, the speed would be reduced and wind generator locations without significant barriers might be chosen. This investigation and evaluation offered a review of the wind energy over Kutubdia Island.

2.3 Compare and Contrast

A significant drawback observed in prior research on wind energy in Bangladesh pertains to their reliance on outdated wind data. Even in more recent studies, data often stems from the years 1995-1997 or lacks credibility from reliable sources. This is problematic because wind speed varies from year to year, and the wind conditions experienced in 1995-1997 may not accurately represent those of recent years. The root cause of this issue lies in the scarcity of dependable wind data within our region.

Some studies have resorted to using simulated data to predict potential wind speeds instead of utilizing authentic wind data. Our main objective was to address this limitation by focusing on the prediction of potential wind power generation in coastal areas, using the most current and authentic wind speed data available. To accomplish this, we collected wind data from seven coastal regions and conducted calculations to determine the extent to which wind energy could be leveraged to bridge Bangladesh's current energy deficit.

Beside these projects, Bangladesh is also exploring the potential for offshore wind energy development in the Bay of Bengal. Feasibility studies were being conducted to assess the viability and potential capacity of offshore wind farms.

2.4 Summary

This chapter is devoted to reviewing earlier studies conducted in the same field. We scrutinize the inadequacies and limitations prevalent in these earlier studies. Additionally, we outline the innovative elements and solutions that our research introduces, aiming to rectify and overcome the limitations identified in previous works.

CHAPTER 3

MATERIALS & METHODS

3.1 Introduction

Bangladesh has had a delayed adoption of wind energy, primarily as a result of a dearth of reliable wind data. We focused on the data from those locations since recent measurements in some locations in Bangladesh, namely in coastal areas, have showed large wind energy potentials. New onshore wind farms can be built for less money in many locations than new coal or gas plants. We have mentioned here the places in Bangladesh where there is no existing of wind power plant despite the high wind speed. Seven coastal areas are illustrated in this chapter first. Then the methods used to determine how much power will be produced by the wind power plant. We have also used Homer Pro Software for the cost calculation of the highest speed area from seven areas. We have covered the elements of a wind power plant from Bangladesh's standpoint in this chapter. Here is a scenario of the country's first wind firm in Cox's Bazar.

Figure 3.1: 60MW Wind Power Project in Cox's Bazar [27]

3.2 Methods & Materials

In Bangladesh wind turbine power plants can be the prominent renewable energy-based power plant after solar photovoltaic power plant. There are many types and classifications for wind turbines & wind turbine generators but according to the Global Wind Atlas, the most suitable wind turbine type for Bangladesh is a medium-sized, 2-3 MW wind turbine with a hub height of 100 meters. These turbines are usually three-bladed and designed to operate at low to medium wind speeds, which are typically found in many parts of Bangladesh. A wind power plant's wind turbine type in Bangladesh can change based on a number of variables, including the location, wind speed, and required power production. This is the wind turbine power plant's block diagram.

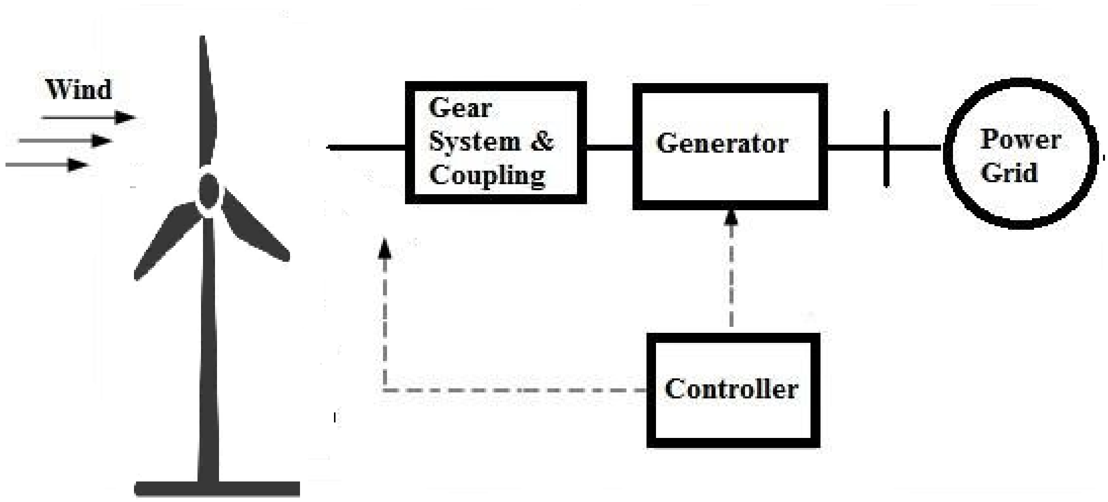

Figure 3.2: Flow Diagram of Wind Turbine System

A wind turbine power plant can be installed using a wide variety of different parts. From figure we can see four components as given below-

1. <u>Wind Turbine:</u> This part uses the turbine's blade to transform wind energy into mechanical energy. Vertical axis wind turbines and horizontal axis wind turbines are the two main types of wind turbines used for turbine work. In Bangladesh, there are wind turbines with three horizontal axis blades in operation.

2. <u>Gear system and coupling:</u> In a wind turbine, a gearbox is usually utilized to boost rotational speed from a low-speed rotor to a faster electrical generator. Through transmission, the generator rotor's speed is raised.

3. <u>Generator</u>: It converts mechanical energy which comes from wind turbines into electrical energy that connects with the national power grid.

4. <u>Controller:</u> Initiates the proper control signals to perform control action after detecting temperature, wind direction, wind speed, and generator output [28].

3.3 System Analysis

Here is the geographical location of seven coastal areas those are useful for wind power generation.is given below-

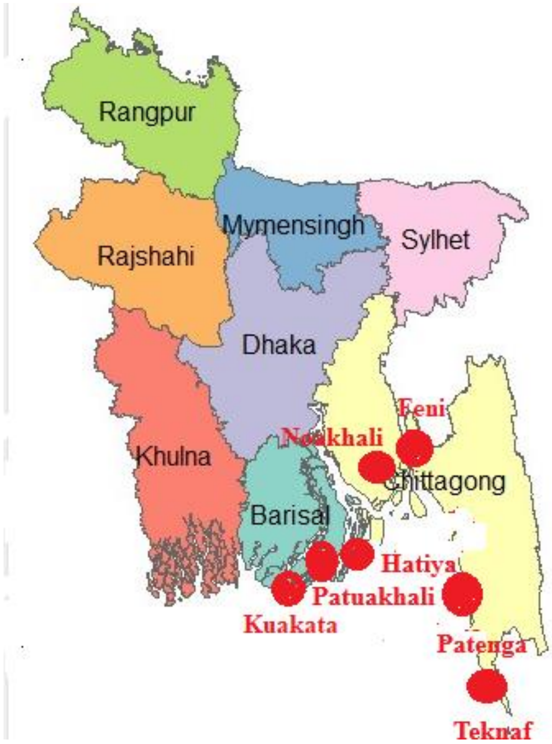

Figure 3.3: Geographical Location of Seven Coastal Regions

Wind speed varies from place to place based on the Bangladesh wind speed map so that we can conclude that the coastal areas have higher wind speed than the other sides of Bangladesh. The above figure shows the location of the seven coastal areas such as Feni, Teknaf, Hatiya, Noakhali, Kuakata, Patenga & Patuakhali. These seven areas data are used to calculate the power output. In the table below, monthly wind speed at different places in Bangladesh are given for the comparison with seven coastal areas that highlighted in the map.

Location	**Year**	**Month**	**Wind Speed at 10m height from sea level (ms^{-1})**	**Wind Speed at 50m height from sea level (ms^{-1})**
Patenga	2022	July	4.073667	5.221333
Patenga	2022	August	3.966129	5.100645
Patenga	2022	September	3.057	3.932333
Patenga	2022	October	2.807742	3.553548
Patenga	2022	November	3.057	3.932333
Patenga	2022	December	2.891935	3.582581
Patenga	2023	January	3.21871	4.103871
Patenga	2023	February	2.693929	3.422857
Patenga	2023	March	2.616774	3.419677
Patenga	2023	April	2.535333	3.131667
Patenga	2023	May	2.989032	3.731613
Patenga	2023	June	4.257333	5.361
Kuakata	2022	July	6.004516	6.672581
Kuakata	2022	August	5.765484	6.414194
Kuakata	2022	September	5.031	5.557333
Kuakata	2022	October	3.805161	4.123226
Kuakata	2022	November	3.613667	3.877
Kuakata	2022	December	3.207097	3.42871
Kuakata	2023	January	3.191935	3.527742
Kuakata	2023	February	3.225714	3.525
Kuakata	2023	March	3.713548	4.077419
Kuakata	2023	April	4.008	4.375
Kuakata	2023	May	4.369032	4.779355
Kuakata	2023	June	5.386	5.954
Feni	2022	July	3.409677	5.186129
Feni	2022	August	3.294516	4.952258
Feni	2022	September	2.586	3.993333
Feni	2022	October	2.252258	3.427742
Feni	2022	November	2.156	3.234
Feni	2022	December	2.070323	3.000968
Feni	2023	January	2.542258	3.813871
Feni	2023	February	2.228571	3.285
Feni	2023	March	2.427097	3.667097
Feni	2023	April	2.242333	3.33
Feni	2023	May	2.641935	3.925161
Feni	2023	June	3.92	5.457
Teknaf	2022	July	5.460323	5.98871
Teknaf	2022	August	5.792581	6.390968
Teknaf	2022	September	4.533667	4.925
Teknaf	2022	October	4.162258	4.515161
Teknaf	2022	November	4.607	4.898667
Teknaf	2022	December	4.705484	4.984516

Teknaf	2023	January	5.8	6.225484
Teknaf	2023	February	4.617857	4.988929
Teknaf	2023	March	3.974516	4.28871
Teknaf	2023	April	3.708667	3.963667
Teknaf	2023	May	4.267419	4.639677
Teknaf	2023	June	5.269	5.811
Patuakhali	2022	July	4.362304	6.012074
Patuakhali	2022	August	3.831982	5.333041
Patuakhali	2022	September	2.980286	4.219714
Patuakhali	2022	October	2.370829	3.294885
Patuakhali	2022	November	2.330905	3.154381
Patuakhali	2022	December	2.513825	3.45023
Patuakhali	2023	January	2.39375	3.31625
Patuakhali	2023	February	2.419336	3.376858
Patuakhali	2023	March	2.866976	3.991734
Patuakhali	2023	April	3.56125	4.82575
Patuakhali	2023	May	3.497903	4.831411
Patuakhali	2023	June	3.948833	5.478208
Noakhali	2022	July	4.492995	6.006959
Noakhali	2022	August	3.935991	5.324378
Noakhali	2022	September	2.966857	4.068286
Noakhali	2022	October	2.313963	3.146175
Noakhali	2022	November	2.067857	2.753
Noakhali	2022	December	2.162995	2.889493
Noakhali	2023	January	2.323427	3.108589
Noakhali	2023	February	2.478584	3.348451
Noakhali	2023	March	2.761532	3.709758
Noakhali	2023	April	3.434875	4.51125
Noakhali	2023	May	3.405806	4.53004
Noakhali	2023	June	4.267833	5.731042
Hatiya	2022	July	4.616267	5.945484
Hatiya	2022	August	4.251843	5.488571
Hatiya	2022	September	3.221286	4.146714
Hatiya	2022	October	2.684839	3.394194
Hatiya	2022	November	2.63319	3.249667
Hatiya	2022	December	2.816959	3.501843
Hatiya	2023	January	2.889315	3.617016
Hatiya	2023	February	2.658584	3.415088
Hatiya	2023	March	2.710806	3.493669
Hatiya	2023	April	3.217583	4.037083
Hatiya	2023	May	3.29746	4.181653
Hatiya	2023	June	4.318375	5.568

Table 3.1: Month Wise Average Wind Speed of Seven Coastal Areas [29].

Wind speed depends on air pressure. The greater the air pressure, faster the air moves, and height above the ground tends to enhance wind speed. So, the wind speed is not constant for power extraction at promising level Wind speed depends on air pressure. The greater the air pressure, faster the air moves, and wind speeds tend during a certain year, rather, it fluctuates in a noteworthy manner. Based on NASA data collected at 50 meters and 10 meters height. It can be said that the 50m height wind energy has more potential than the 10m height wind speed. Here is the graphical representation of seven coastal regions at a height of 50m above the ground.

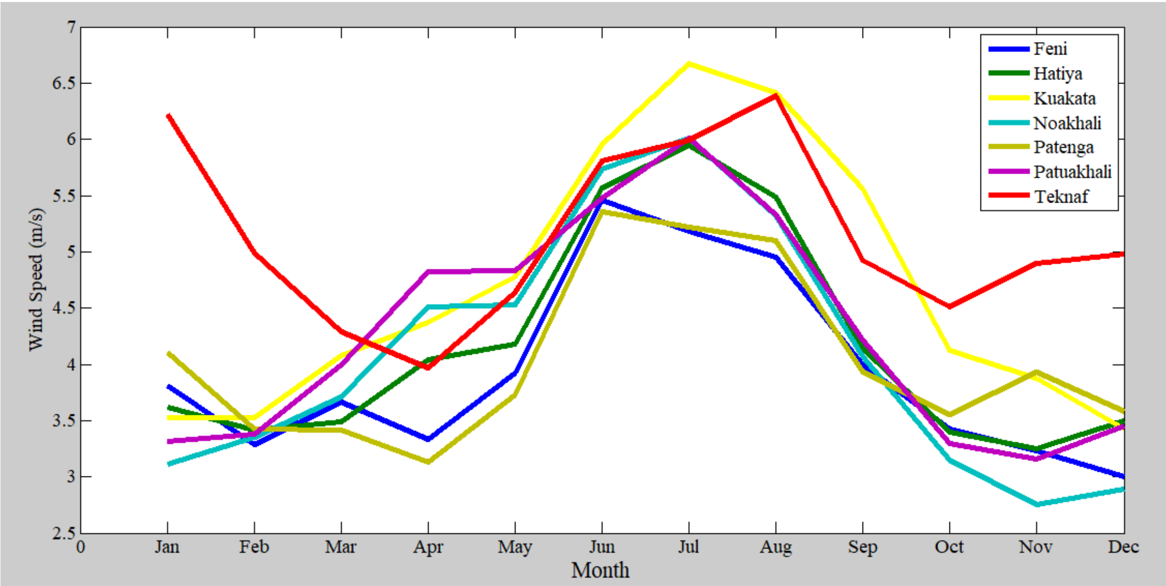

Figure 3.4: Graphical Representation of Average Wind Speed at 50m Height

So, it can be said from figure 3.4 that Teknaf is better suited to harness wind energy. Power generation depends on wind speed where wind speed is the main energy source to produce electrical energy. Wind power is one of the least expensive sources of electricity per unit of energy produced.. Wind power generation in the coastal areas of Bangladesh has significant potential due to the strong winds along the coastline. If we consider any windmill project that might be run in this location, it will be a safe alternative. That's we simulate a model for this Teknaf in Homer Pro Software.

3.4 Simulation Setup

Careful site selection is crucial for wind power generation. Where wind speed is the main factor. Coastal areas with consistent and high wind speeds are typically preferred for wind farms. Here we took Teknaf as this place has high energy potential. We have assumed about a 10 MW load for Teknaf.

Metric	Value	Unit
Scaled Average	2,424.2	kWh/day
Scaled Peak Load	348.08	kW
Load Factor	0.29	
Total Annual Load	884,833	kWh/year

Table 3.2: Assumed Load Demand

For this model we have taken 6 turbines and the lifetime of this project is 25 years.

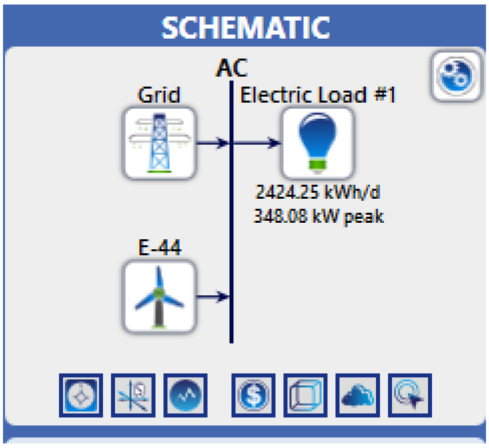

Figure 3.5: Schematic Diagram of Wind Power Plant Model

We created the model of our wind power plant utilizing HOMER Pro Software after considering the graphical view for Tenaf in Figure 3.5 as well as the resource potential throughout the previous five years. Here we have connected our system to the national grid. So that the generated electricity can be distributed, and it can give good support to the main system. Where 2424.25 kWh per day is load and 348.08 kW is peak load.

3.5 Summary

Within this chapter, we elucidate the methodology employed to compute power generation based on wind speed data acquired from NASA. Additionally, we present the configuration of the simulation setup using HOMER Pro software. Furthermore, we include graphical representations of wind speeds in coastal areas, both as a collective overview and on a month-by-month basis. In the subsequent chapter, we delve into the outcomes generated by HOMER Pro resulting from the simulation setup.

CHAPTER 4

RESULT & DISCUSSION

4.1 Result

In this chapter we have discussed about the output part of the simulation that we designed in the previous chapter's simulation setup part.

Quantity	Value	Units
Total Rated Capacity	5,400	KW
Mean Output	663	KW
Capacity Factor	12.3	%
Total production	5,810,241	KWh/year

Table 4.1: Output Results of Selected Wind Turbine

We have used 6 wind turbines of the Enercon E-44[900 kW] model in our proposal. So the estimated maximum capacity of our proposed system will be 900kW X 6= 5400 kW or 5.4 MW. From Table 4.1, we can see the estimated power output from our system. More than 5810 MW of electricity will be produced every year.

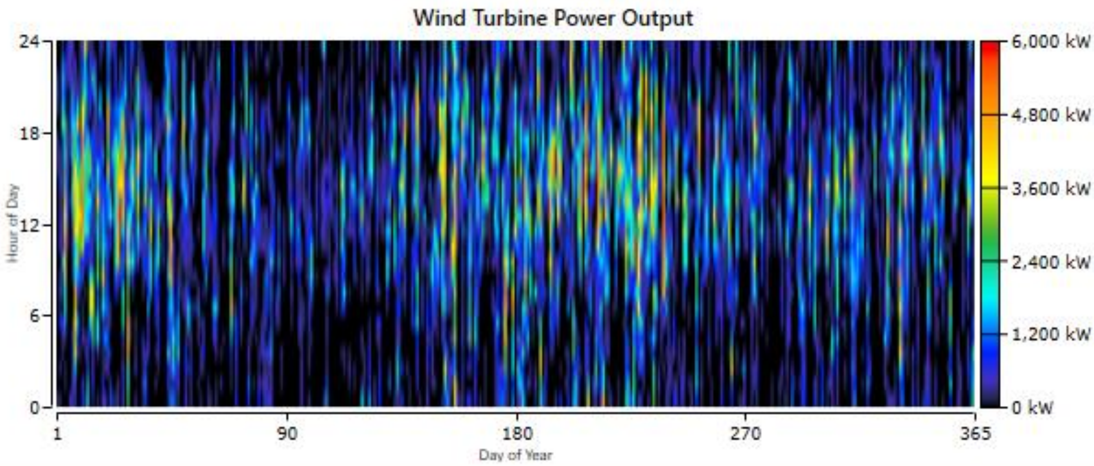

Figure 4.1: Wind Turbine Power Output

The wind turbine's output power is displayed in the simulation's outcome. Here, output power is provided every 24 hours for a year.

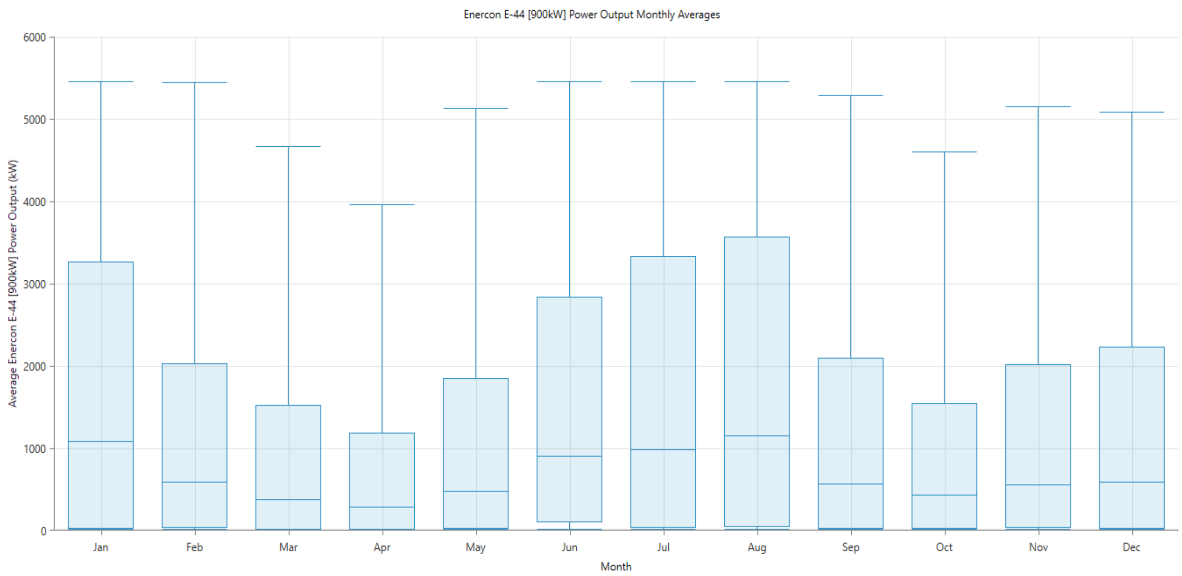

Figure 4.2: Total Wind Power Output Per Year

Figure 4.2 shows us the total yearly power output for our model. We can see there will be an abundant amount of power generated in June, July, and August. The least power will be generated in April because of low wind potential and the amount is less than 1500 kW. On the other hand, around 3500 kW of power will be generated in August.

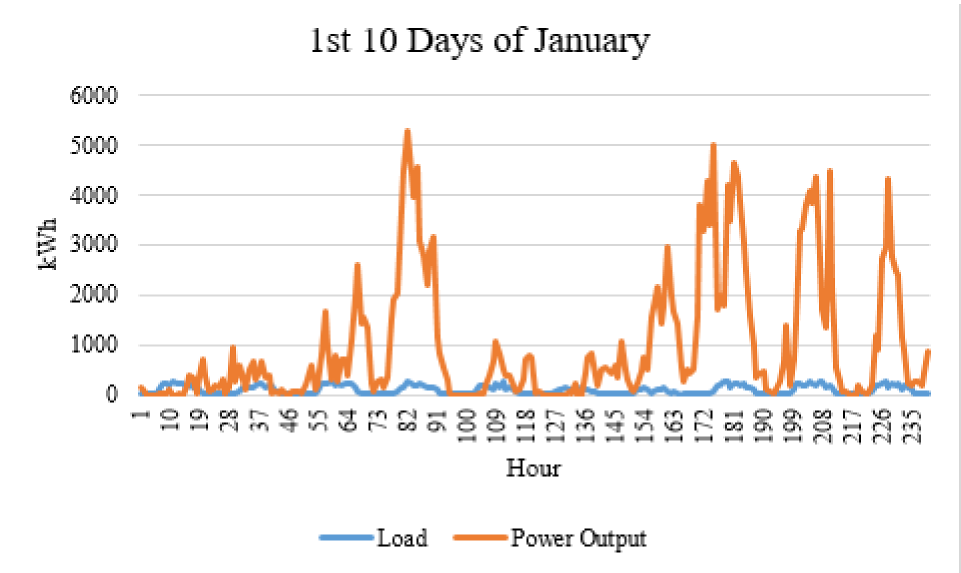

Figure 4.3: Summary of the 1st 10 Days of January

Figure 4.3 provides a brief review of the first 10 days of load demand vs. generation of January. In this month we can get second highest power generation after August month.

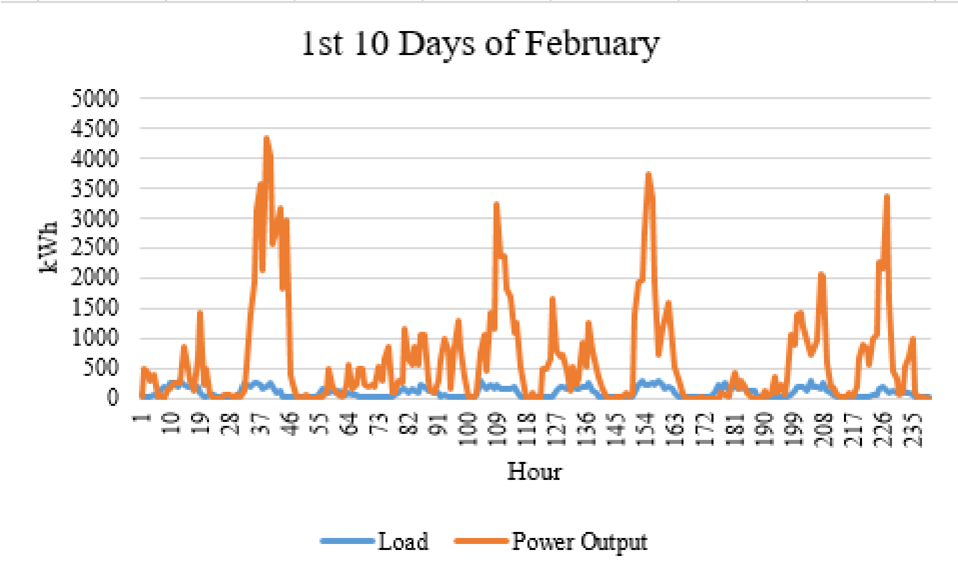

Figure 4.4: Summary of the 1st 10 Days of February

Figure 4.4 provides a brief review of the first 10 days of load demand vs. generation of February. The peak generation around 4400 kWh is on the 7th day of February.

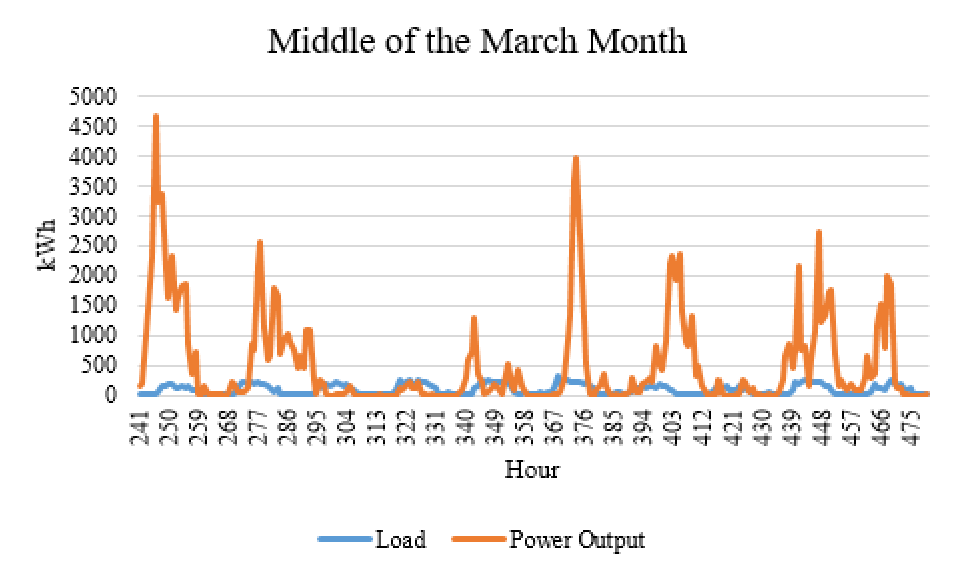

Figure 4.5: Summary of the 2nd 10 Days of March

In the second 48 hours of March, their generation is more than in February. After a brief decline, generation starts to rise once more. This, as we can see by glancing at the Figure 4.5. It is significantly more than the first 10 days of February.

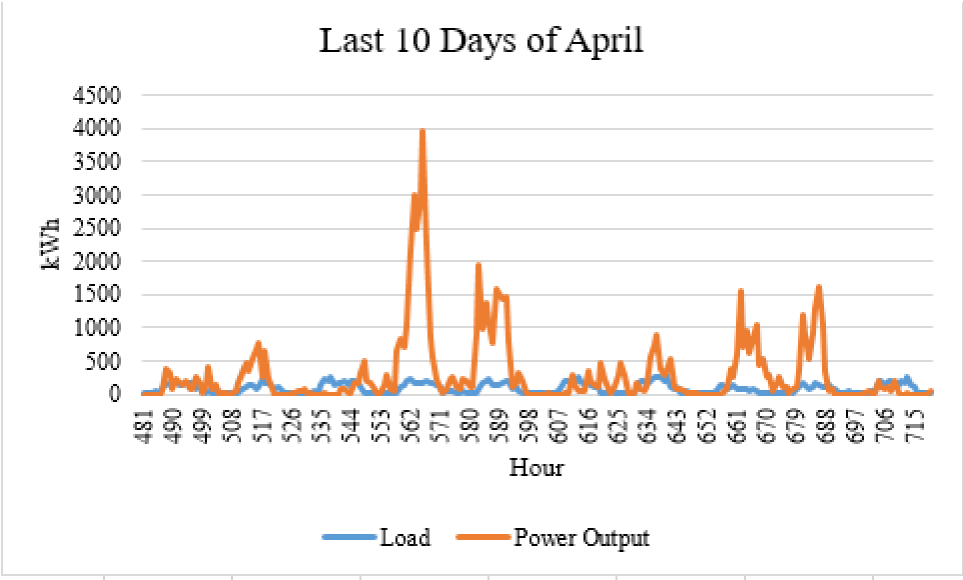

Figure 4.6: Summary of the Last 10 Days of April

Figure 4.6 provides the summary of the last 10 days of April month. Where we can see the power generation quite low than the other month. 22nd & 23rd of April and 28th to 30th of April has lower power generation.

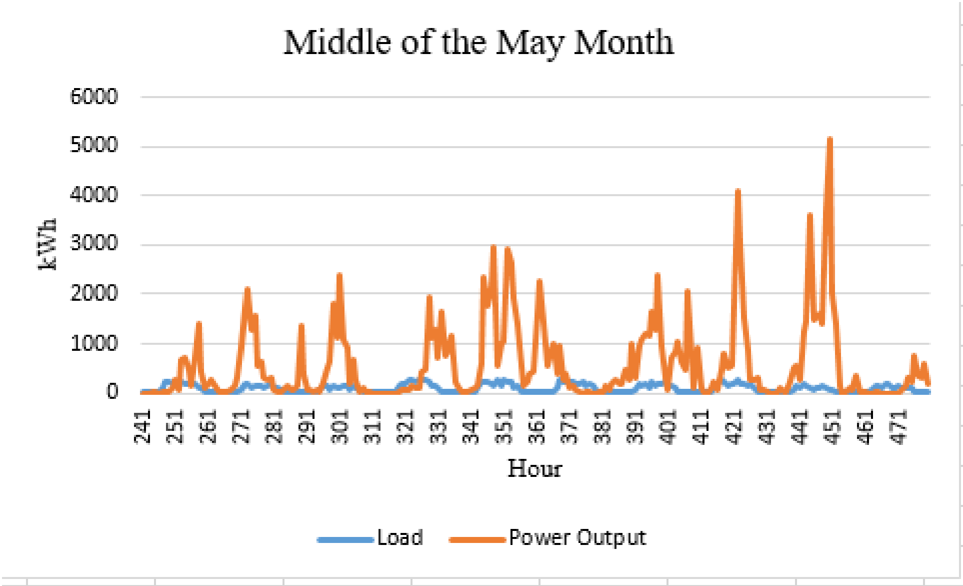

Figure 4.7: Summary of the 2nd 10 Days of May

As we can see by glancing at the Figure 4.7, the power generation in May is significantly more than the last 10 days of April.

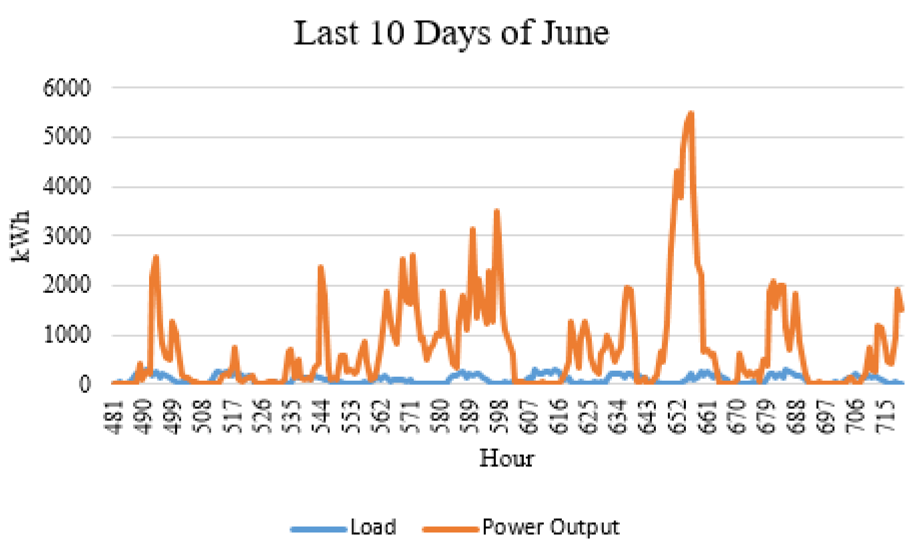

Figure 4.8: Summary of the Last 10 Days of June

The second-highest generation month is June. This month's generation is greater than the load demand. Which will provide the national grid with good assistance.

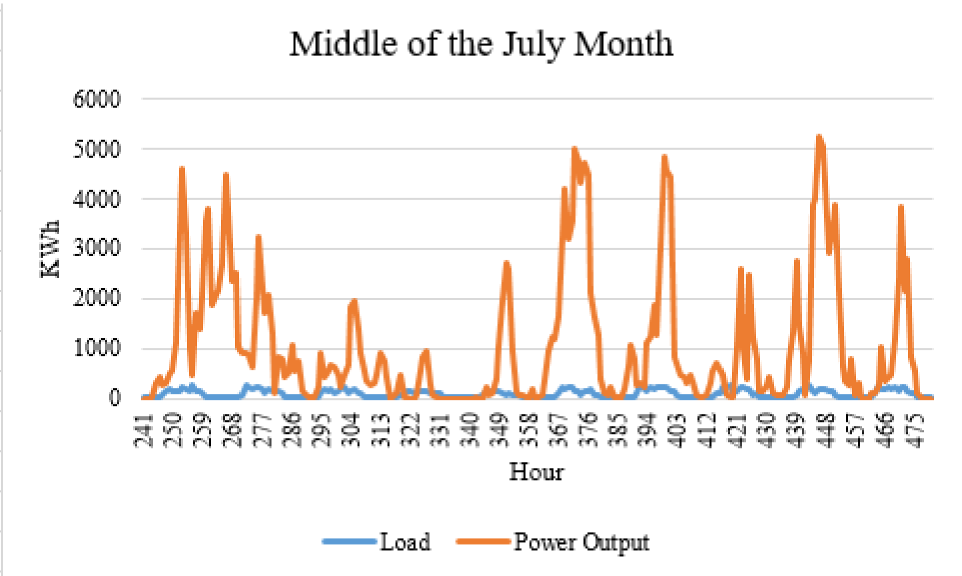

Figure 4.9: Summary of the 2nd 10 Days of July

Comparing to the other months of the year, July has a good amount of generation. The generation is consistently high around 4000 kWh to 5000 kWh in the second 10 days, we can predict that it will continue to be so throughout this month.

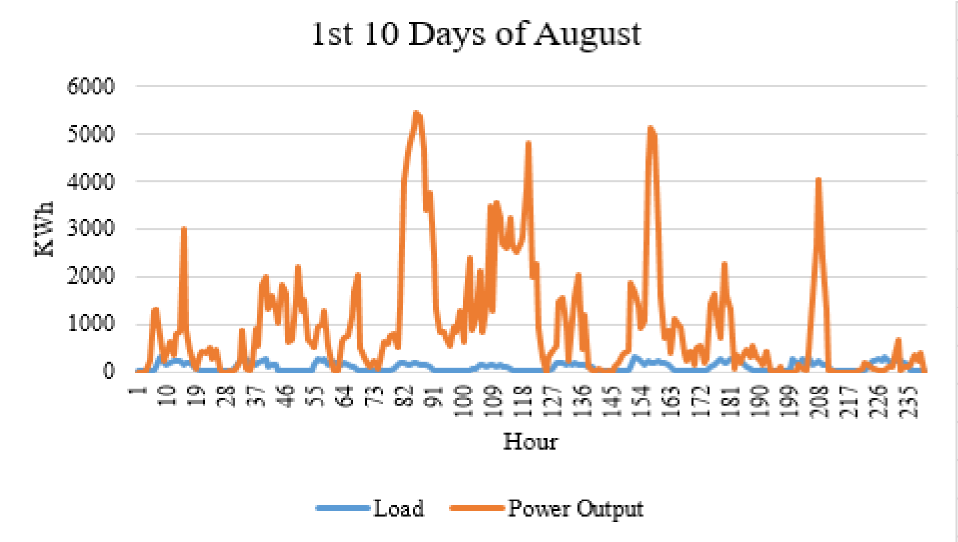

Figure 4.10: Summary of the 1st 10 Days of August

August has the highest generation of the year in comparison to the other months. Because the generation is high around 5000 kWh to 6000 kWh in the first 10 days, we can predict that it will continue to be so throughout this month. The national grid will receive more power from this generation. When comparing February and March, the monsoon season brings more storms and faster winds, which causes August to have higher levels of electricity production than other months.

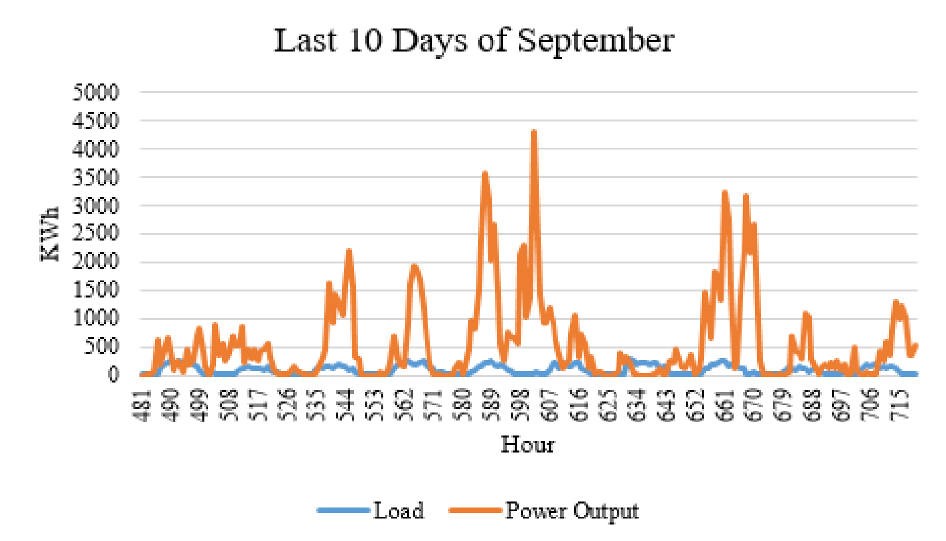

Figure 4.11: Summary of the Last 10 Days of September

Figure 4.11 describes the last 10 days load demand vs generation value of September. The peak generation is over 4400 kWh as we see in the diagram.

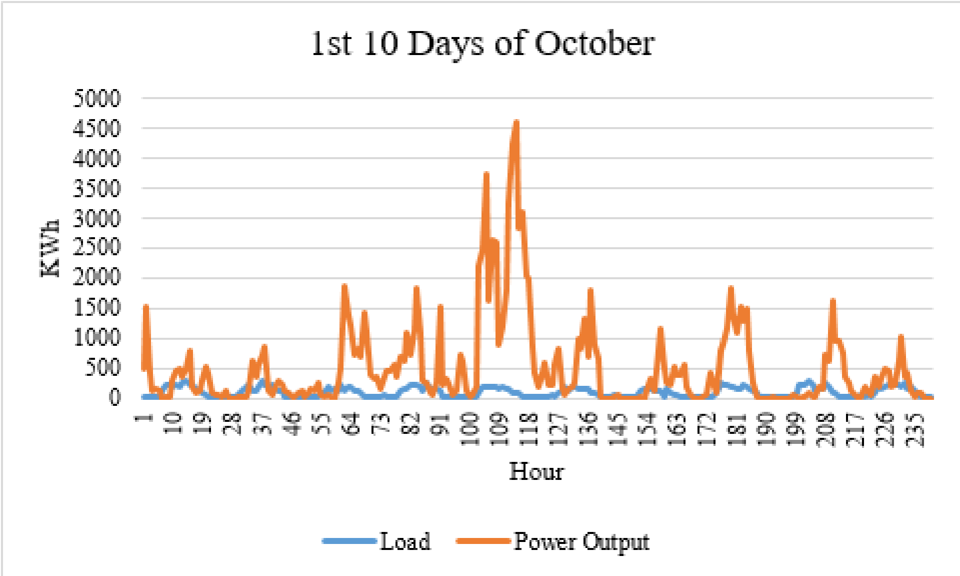

Figure 4.12: Summary of the 1st 10 Days of October

Figure 4.13 describes the 1st 10 days load demand vs generation value of October. The peak generation more than 4500 kWh as we see in the diagram.

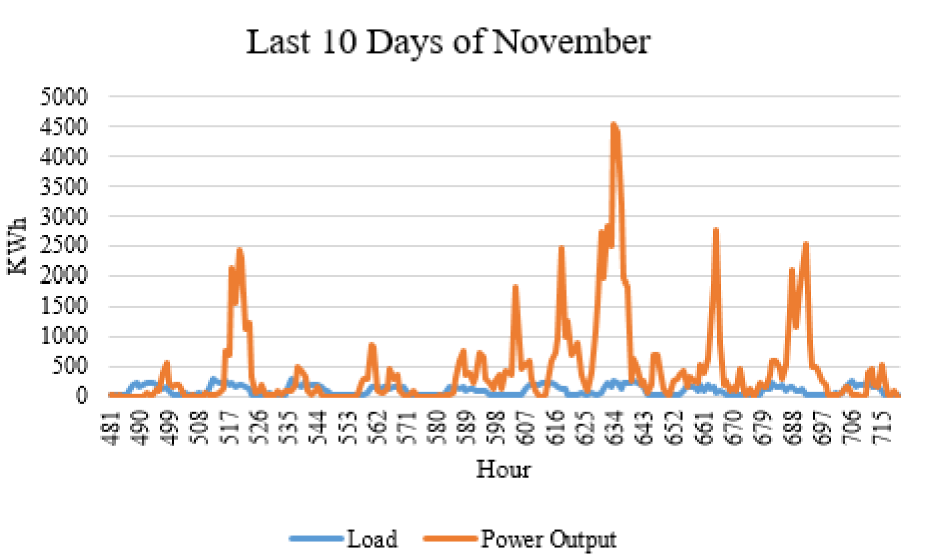

Figure 4.13: Summary of the Last 10 Days of November

November belongs in the winter season. To understand the situation after the month, we have observed the final 10 days of November here. From this, we can observe that the power generation marginally grew as the month ended.

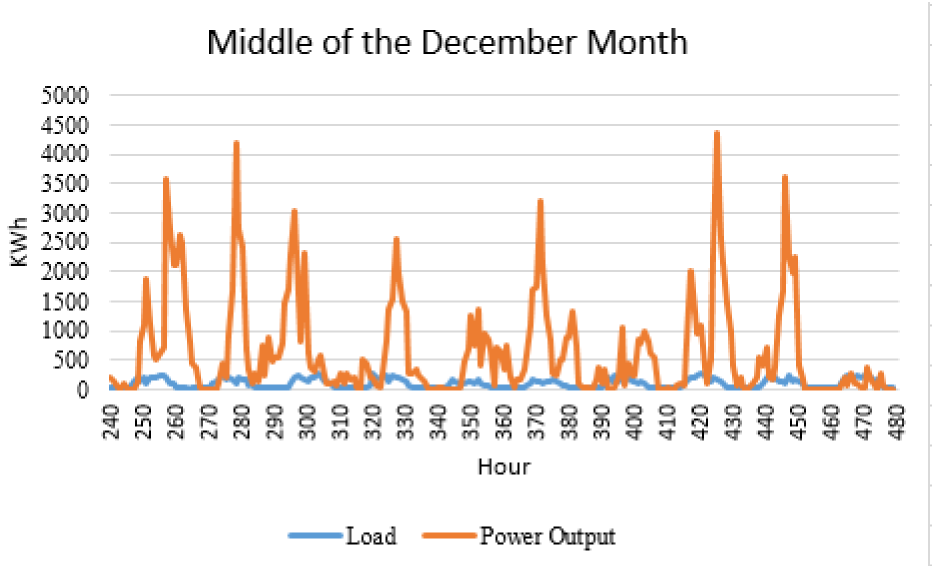

Figure 4.14: Summary of the Last 10 Days of December

We have considered twelve months. It demonstrates that in December, the load demand as well as the generation are minimal. To understand the situation after the month, we have observed the final 10 days of the month.

4.2 Discussion

Components and costing of the model is given below

Component	Capital	Replacement	Operation & Maintenance
Enercon E-44[900 kW]	727,955,580 taka	0.00	855,514,346.19 taka
Grid	0.00	0.00	-337,454,808.96 taka
Total	727,955,580 taka	0.00	518,059,537 taka
In total cost of the system		1,124,015,117 taka	

Table 4.2: Components and Costing of the Model

Table 4.2 describes components with costing. This research was completed based on the current exchange rate for the dollar. Where 109 taka is equivalent to 1 dollar. A 25-year operation and maintenance computation are provided, with a capital investment of approximately 72.8 crores of taka. In its 25 year lifetime there is no replacement cost. Additionally, since we are connecting to the National Grid, there is no additional expense for transmission here; rather, the cost is going down. Together, our proposed model costs around only 112 crore takas, which is a tiny amount compared to other projects in Bangladesh, including the 60 MW power plant in Cox's Bazar under construction with a budget of approximately 1300 crore taka [12].

Furthermore, we designed and distributed a survey form with the aim of gathering insights and opinions from individuals regarding electricity, energy, and its prospective future in Bangladesh. A total of 52 participants took part in the questionnaire, with a predominant number being students, primarily those with an Electrical and Electronics Engineering (EEE) background. The respondents spanned a range of ages, with the majority falling within the 18 to 25 years age group, accounting for approximately 73.5% of participants. The 36 to 45 years age group constituted about 12.2% of respondents, followed by the 26 to 35 years age group at around 10.2%. The participation from individuals aged 46 and above was the least.

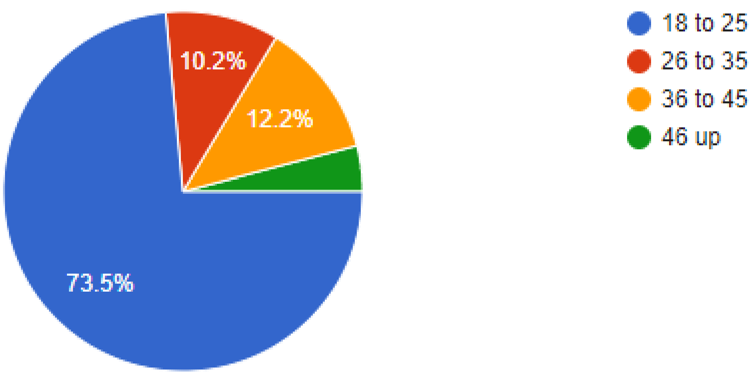

Figure 4.15: Participation According to Age

It's noteworthy that all the survey participants expressed a preference for renewable energy, aligning with a global trend. This inclination is well-founded, given the finite nature of non-renewable energy sources and the detrimental environmental impact associated with fossil fuels. Hence, the consensus emphasizes the urgent need to transition to sustainable energy sources, such as renewable energy, for the betterment of our environment and the long-term sustainability of energy generation.

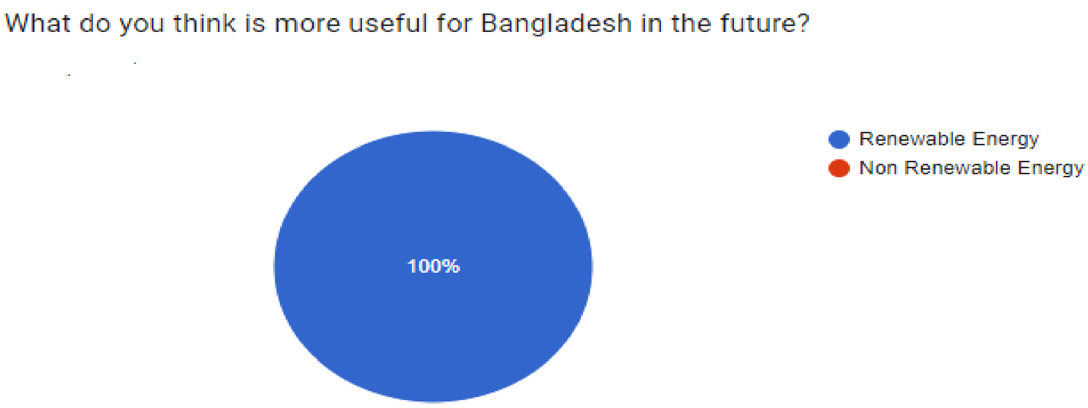

Figure 4.16: Future Energy Resource for Bangladesh

Bangladesh is making commendable strides in the development of its wind energy sector, although it remains in its early stages when compared to more established renewable energy sources like solar power. To gauge public awareness within this domain, we introduced the topic of solar power. Interestingly, a significant proportion, precisely 65.3% of the respondents, recognized wind energy as a viable secondary renewable energy source for Bangladesh, following in the footsteps of solar power. This acknowledgment underscores a growing awareness of wind energy's potential to play a substantial role in Bangladesh's evolving renewable energy landscape.

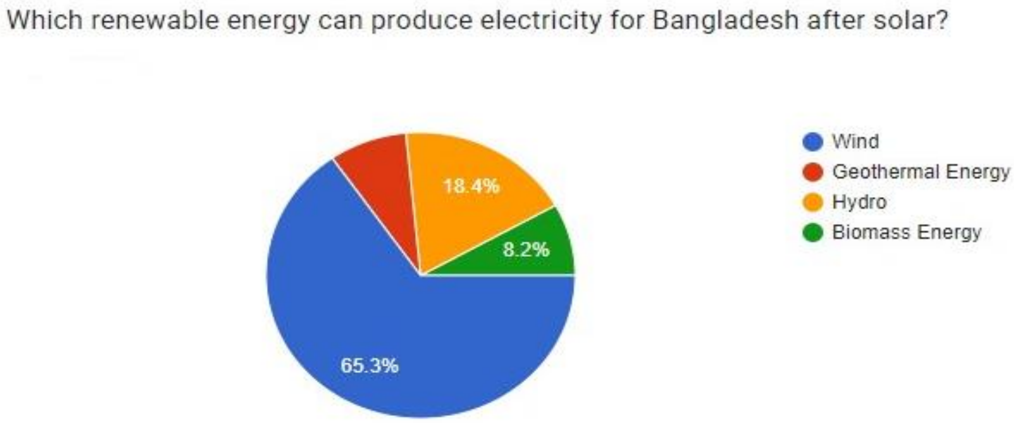

Figure 4.17: Renewable Energy Source after Solar

Our survey analysis methodology employed the Inferential Statistical analysis approach, which centers on deriving meaningful conclusions from the data under scrutiny. The results of our survey analysis led to a compelling conclusion: people's opinions indicate that Bangladesh possesses significant wind energy potential.

CHAPTER 5

PROJECT MANAGEMENT

5.1 Task, Schedule, and Milestones

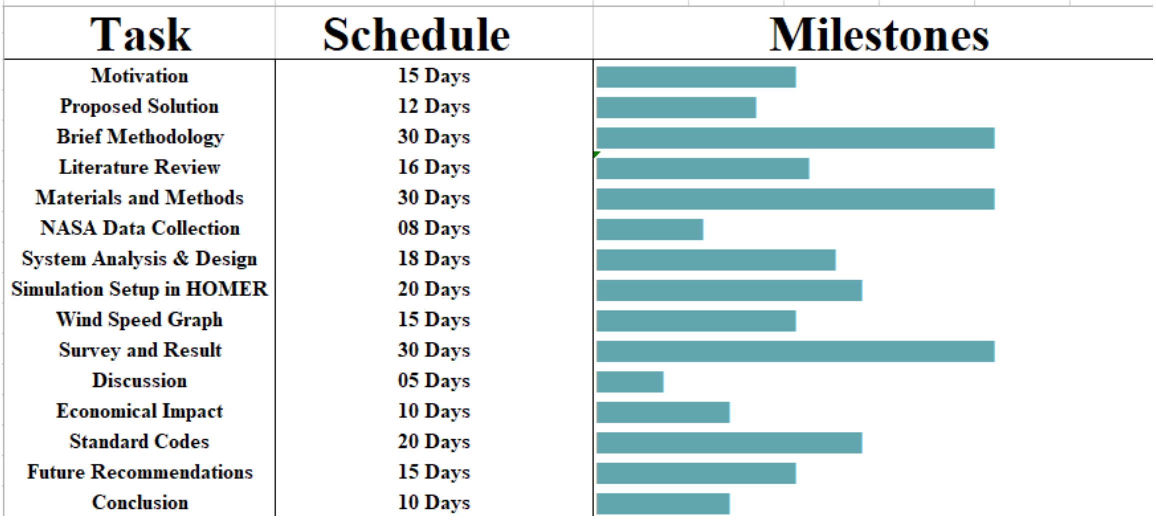

Figure 5.1: Timeline Diagram of Project

The timeline diagram visually illustrates the allocation of time dedicated to constructing the project's main framework and task completion. The representation highlights an extended focus on theoretical components. In total, we invested approximately nine and a half months in the development of this project's foundational structure.

5.2 Lesson Learned

We gained a thorough understanding of the fundamentals of wind energy, including wind physics, wind turbine technology, and power generation procedures. To evaluate the possibility for wind energy projects in particular places, we learned how to evaluate wind resources and do site appropriateness assessments. We learned proficiency in calculating wind farm energy output while considering variables including wind speed, turbine capacity, and wake effects. We also learned to conduct surveys and analyze them using Crosstab analysis. This project also offers insight into local, national, and international laws and policies governing the growth of wind energy. This project enabled us to keep abreast of the most recent developments in wind turbine technology, components, and efficiency enhancements. We researched the effects of wind energy installations on the environment and discovered ways to lessen the harm done to wildlife and local ecosystems. We identified typical issues in the wind energy scenario in our country through research and analysis, and then considered solutions. We learned useful skills and comprehended how our academic work may be utilized to tackle real-world problems by conducting real-world research. Overall, doing this project on wind energy provided us with a multi-faceted learning opportunity that gave us a variety of skills and a deeper comprehension of the advantages and disadvantages of using wind energy for a sustainable future.

This project was also a crucial academic assignment that gave us a life-changing learning opportunity. We obtained a variety of skills during this process, as well as priceless experiences. We gained knowledge of how to carry out thorough research, evaluate the available literature, and create our own research questions. This project helped us overcome obstacles in our research as we developed our problem-solving and time management skills. We gained critical analysis abilities and problem-solving acumen through in-depth research, which prepared us to take on challenging technical issues. By using our knowledge in real-world projects and experimental activities, we developed technical proficiency and practical experience. The project writing process helped us develop our technical writing, communication, and presentation abilities. Our work incorporated ethical research procedures. Additionally, we developed our ability to comprehend and analyze data while being flexible to unexpected outcomes. We also learned about the importance of ethics, professionalism, and intellectual property in the engineering world.

In the end, we believe completing this project helped us develop into competent and creative engineers, as well as well-prepared for careers in industry or academia. Overall, it equipped us for our future employment or further academic endeavors by instilling confidence, expertise, and a profound understanding of our chosen topic.

CHAPTER 6

IMPACT ASSESSMENT OF THE PROJECT

6.1 Economical, Societal and Global Impact

Both direct and indirect effects on Bangladeshi society may result from the creation and use of wind energy systems.

Energy Cost Reduction

Access to Electricity

Job Creation

Investment Opportunities

Environmental Benefits

Climate Change Mitigation

Sustainable Development

I. **Energy Cost Reduction:** In order to improve energy security and lower the nation's energy import costs, developing wind energy resources can assist minimize dependency on imported fossil fuels. By lowering the trade imbalance, this can have a favorable effect on the overall economy. Both direct and indirect effects on Bangladeshi society may result from the creation and use of wind energy systems.

II. **Access to Electricity:** In rural and distant locations with poor grid connectivity, wind energy systems can help increase access to electricity. Wind energy may enhance communities' quality of life by supplying clean and dependable power that makes it possible to access important services like lighting, communication, education, and healthcare.

III. **Job Creation:** Employment possibilities are created as wind energy projects are established, including those in manufacture, installation, operation, and maintenance. By lowering unemployment, raising incomes, and enhancing living conditions, this job development can benefit the neighborhood. Additionally, community involvement, capacity building, and local procurement are frequently included in wind energy projects, which can promote socioeconomic growth in general.

IV. **Investment Opportunities**: The emergence of wind energy has the potential to draw both domestic and foreign investment, spurring economic expansion and advancing the nation as a whole. Investments in wind energy projects provide doors for neighborhood companies, contractors, and service providers, boosting the local economy.

V. **Environmental Benefits:** Wind energy is a clean, sustainable energy source that helps reduce the quantity of greenhouse gases and air pollutants emitted when fossil fuels are used to produce power. Wind energy can enhance air quality by displacing conventional energy sources, lowering the health hazards brought on by pollutants. This may directly improve the health of the populace, resulting in more wellbeing and perhaps cheaper healthcare expenses.

VI. **Climate Change Mitigation:** Wind energy reduces greenhouse gas emissions and the need for fossil fuels, which helps to slow down global warming. Bangladesh can gain from using renewable energy sources like wind power to lower its carbon footprint and comply with international climate pledges because of its vulnerability to the effects of climate change.

VII. **Sustainable Development:** The development of wind energy projects can increase public knowledge of sustainable energy, energy efficiency, and the environment. This may result in educational opportunities, activities to increase capacity, and community-wide promotion of sustainable behaviors. Research and development in renewable energy technology and uses may also be stimulated.

6.2 Environmental and Ethical Issues

Before the development and operation of wind energy projects, thorough environmental impact assessments (EIAs) must be carried out. EIAs assist in identifying possible environmental threats such bird and bat encounters, noise pollution, and aesthetic effects. It is possible to reduce adverse effects on biodiversity, ecosystems, and picturesque landscapes by ensuring optimal placement and mitigation measures.

The lifespan of a wind turbine is roughly 20 to 25 years. To reduce negative environmental effects, wind turbine components must be responsibly decommissioned and recycled after their operating lives are through. To prevent potential disposal concerns, proper waste management and recycling procedures for wind turbine blades, towers, and other components must be developed. For the installation of wind turbines and related infrastructure, wind energy projects need land. It is essential to ensure ethical land use methods, including proper property acquisition and fair compensation for nearby populations. Conflicts can be reduced, and social acceptance can be increased through interacting with communities, listening to their concerns, and including them in decision-making processes.

6.3 Utilization of Existing Standards or Codes

In Bangladesh, there are regulations and standards in place for wind farms. Here are a few significant laws and regulations that are in force at present:

Bangladesh National Building Code (BNBC): The BNBC offers recommendations for several facets of building and infrastructure development in Bangladesh. It contains guidelines for wind loads as well as structural design factors for buildings and other structures, which also apply to wind farms.

Bangladesh Power Development Board (BPDB): The BPDB produced the Bangladesh Grid Code, which is a set of technical requirements and standards. For grid connection, electricity quality, and other operational facets of power plants, including wind plants, it offers rules.

The Bangladesh Environment Conservation Act: This act establishes the country's legislative foundation for environmental conservation. Regulations for environmental impact assessments (EIAs) and environmental approvals are included, which would be relevant to wind power projects.

International Electrotechnical Commission (IEC) Standards: The IEC has several standards specifically to produce wind energy, including the IEC 61400 series for the development and testing of wind turbines. To ensure the secure and dependable operation of wind farms, several nations, including Bangladesh, follow or use these international standards.

6.4 Other Concerns

Although wind energy has several advantages, there are certain issues with its application in Bangladesh. Compared to other nations, Bangladesh has very little wind resources. The geography and location of the nation may not be as ideal for utilizing wind energy to the same degree as some other locations. Energy production may fluctuate due to erratic wind patterns. The instability of the system may be threatened by this unpredictability, necessitating backup energy sources. An infrastructure for wind energy must be built with significant investment. Adoption may be hampered by the expense of building wind farms, transmission lines, and integrating them into the grid, particularly in poor nations like Bangladesh. The absence of comprehensive regulations and financial incentives designed especially for wind energy may limit its development in the nation. A favorable regulatory environment can encourage investment The transmission infrastructure may need to be upgraded and improved in order to integrate wind energy into the current electrical grid. The system must be able to manage the erratic nature of wind energy while effectively distributing electricity throughout the nation.

So, despite its potential, there are a number of issues that must be resolved before wind. These difficulties include the scarcity of adequate wind resource data, a lack of technological know-how, high upfront expenditures, and the erratic nature of wind power. To determine the profitability of wind energy projects in certain areas of the country, thorough feasibility studies must be conducted. These investigations contribute to our understanding of the potential for wind resources, potential locations for wind farms, and wind power's economic feasibility in contrast to other energy sources.

Bangladesh produces relatively little wind energy when compared to solar energy. Although the nation has some potential for wind energy, it hasn’t been utilized as much as solar energy. Although Bangladesh has a few small-scale wind energy plants, they are not yet a substantial part of the country overall energy mix. We should not solely depend on wind energy to reduce the electricity gap between supply and demand. We have to consider other renewable energy sources to fulfil the upcoming increasing electricity demand.

CHAPTER 7
CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This project emphasizes the value of site-specific evaluations when choosing the best technique for producing renewable energy. The study's focus site, Teknaf, Bangladesh, underwent a thorough investigation utilizing the HOMER software platform to contrast wind turbines with solar systems. The results unequivocally show that wind turbines outperform alternative renewable technologies in terms of energy generation potential and economic viability in the context of Teknaf's particular meteorological conditions and geographic features. This result underscores the significance of considering local environmental conditions in the selection of renewable energy technology, which has significant consequences for energy policymakers, stakeholders, and investors. Additionally, given the constant advancement of local circumstances and technology, this research emphasizes the necessity of ongoing monitoring and evaluation of renewable energy sources. While Teknaf now benefits from wind turbines, future energy needs may change due to research and technology developments. Consequently, it is crucial to use a flexible and adaptable approach to energy planning in order to achieve sustainability targets while maximizing financial gains.

7.2 New Skills and Experiences Learned

Undertaking a thesis on wind power plant design and using Homer software offered several key lessons. This academic endeavor demanded rigorous research, underscoring the importance of in-depth data collection and analysis through the utilization of Homer's powerful simulation tools. As we delved into the intricate world of wind energy, we quickly realized that it's an interdisciplinary field, requiring proficiency in engineering, finance, environmental science, and policy.

Moreover, problem-solving skills were honed, as we encountered various challenges associated with optimizing wind power systems and addressing real-world obstacles using Homer's modeling capabilities. This process enhanced our technical knowledge, particularly in areas like turbine technology, tower height, and energy storage solutions, all of which were fine-tuned and optimized within the Homer software.

Our thesis project essentially acts as a microcosm of project management, emphasizing the importance of planning, execution, monitoring, and adaptability in response to unforeseen issues with the support of Homer's simulations. Critical thinking became second nature, as we evaluated design choices, assessed their impact, and drew evidence-based conclusions based on the data and insights using Homer.

Effective communication skills were a must when presenting our findings, whether through well-crafted writing or articulate verbal delivery, showcasing our ability to convey complex technical information. Time management took a central role, as we juggled research, analysis, and writing while adhering to deadlines with the aid of Homer's modeling tools.

Ultimately, our thesis contributes not only to our academic growth but also to the broader conversation about sustainable energy solutions. With Homer Pro as our guide, it highlights and lowering dependency on fossil fuels. This gives us a profound understanding for the importance of our work in the pursuit of a sustainable future.

7.3 Future Recommendations

The fact that Bangladesh's currently installed wind turbines are just 50 meters tall indicates that wind energy is not being effectively captured. A modern wind turbine (MW range) would be the best option for producing wind power with enough wind speed at a height of more than 50 meters. Bangladesh would be better off using wind power and other renewable energy sources to deal with its looming electricity shortage. A comprehensive feasibility assessment on wind power should be carried out in different parts of Bangladesh to identify the best options for different scale wind power mills, making it simpler to take more action.

More recommendations for a future on-grid wind turbine plant project can also be developed as a hybrid power plant using other renewable energy sources, focusing on wind. The project's success hinges on optimizing the hybrid system, integrating it seamlessly with the main grid, and considering its broader impact on energy generation. By utilizing Homer's capabilities, maximize the synergy between wind energy and other renewables to enhance cost-effective energy generation. Additionally, explore advanced energy storage solutions to improve grid stability, particularly in regions with variable wind patterns. Investigate the development of a micro-grid for local energy resilience during grid outages. Prioritize efficient grid interconnection and adhere to standards for seamless energy flow. Maintain rigorous data collection, address environmental concerns, and engage the community. Continuous performance monitoring, the adoption of advanced technology, and a long-term financial plan are also crucial. Finally, staying updated on research and development ensures that the project remains at the cutting edge of technology and efficiency, contributing to a sustainable and impactful project.

The future is very promising for implementation and the prospect of getting a high efficiency, near shore grid connected wind farm with Higher Area Use Efficiency for wider area and more turbines because Bangladesh has vast near shore or open, continuous coastline territory.

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Appendix A

TURNITIN REPORT

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