A REVIEW OF RENEWABLE ENERGY SYSTEM IN BANGLADESH AND PERFORMANCE ANALYSIS OF MINI HYBRID ENERGY GENERATION MODEL TO COPE WITH THE SYSTEM

A Project & Thesis
By

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SEPTEMBER, 2022

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Declaration of Authorship

We, Md. Alamgir Hossain, Md. Zahurul Haque, Shamim Reza, Billal Khan and Md. Nazmul Islam declare that this thesis titled, “A REVIEW OF RENEWABLE ENERGY SYSTEM IN BANGLADESH AND PERFORMANCE ANALYSIS OF MINI HYBRID ENERGY GENERATION MODEL TO COPE WITH THE SYSTEM” and the work presented in it are our own and has been generated by me as the result of my own original research.

We confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University.

2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.

3. Where we have consulted the published work of others, this is always clearly attributed.

4. Where we have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely our own work.

5. We have acknowledged all main sources of help.

6. None of the part of this work has been published before submission.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOTATIONS

A	Cross-Sectional area of front view of the blade, m^2
C	Coefficient of performance
ρ	Density of Air, kg/m^3
V	Velocity of Air, m/s
P_{wind}	Wind Power, watt

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ABSTRACT

The demand of electricity is increasing day by day, which cannot be fulfilled by only non-renewable energy sources. Bangladesh is a developing country. In 2041 Bangladesh will be developed country which is the vision of Bangladesh government. For the development of country electricity is the major fact. After certain time non-renewable energy such as Coal, Natural gas etc. in Bangladesh will be finished. Renewable energy is another option for producing electricity. Renewable energy sources such as solar & wind are available everywhere & environmentally favourable. For the availability of solar power and wind and also to meet up the little amount of electricity compared with the national grid we choose the wind-solar hybrid power generation system. This paper discusses about the design, fabrication & performance analysis of a wind-solar hybrid power generation system by varying blade angle, distance of blade from shaft and height of shaft from base of wind turbine.

CHAPTER 1

INTRODUCTION

1.1 Background

In the present world, every country is giving important place on energy security and sustainable development; hence role of renewable energy has become ever more significant. With the expectation of promoting electricity generation based on non-conventional renewable energy, the government of Bangladesh introduced an energy policy to achieve a 5% target of power generation through non-conventional renewable energy by year 2015 and 10% by 2020.[1]

To achieve this target, government of Bangladesh is looking for various options preferably Renewable Energy resources. Under the existing generation scenario of Bangladesh, Renewable Energy has a very small share to the total generation. The share of Renewable Energy exceeds more than 1% till now. The present Government is placing priority on developing Renewable Energy resources to improve energy security and to establish a sustainable energy regime alongside of conventional energy sources. Government has already launched *"500 MW Solar Power Mission"* to promote the use of Renewable Energy to meet the increasing demand of electricity.[2]

Fig. 01 Map of Bangladesh[3]

The People's Republic of Bangladesh is a developing country in the Bay of Bengal in South Asia, surrounded by India and Myanmar. Three large rivers run through this country; the Ganges, the Brahmaputra and the Meghna, together forming the Bengal Delta. With over 170 million inhabitants and a total surface of 147,570km$_2$, Bangladesh is one of the most densely populated countries in the world with the two largest cities being the capital Dhaka and the harbour city of Chittagong.[4]

The utility electricity sector in Bangladesh has one National Grid with an installed capacity of 15,379 MW as on February' 2017. Bangladesh's energy sector is booming. Recently, Bangladesh started construction of 2.4 GW Rooppur N4uclear Power Plant expected to go into operation in 2023. But still the per capita energy consumption in Bangladesh is considered low. Bangladesh has small reserves of oil and coal, but very large natural gas resources. Commercial energy consumption is mostly natural gas (around 66%), followed by oil, hydropower and coal. Electricity is the major source of power for most of the country's economic activities. Bangladesh's total installed electricity generation capacity (including captive power) was 15,351 MW as of January 2017. As 2015 92% urban population and 67% rural population have the access to the electricity for their source of light. Average 77.9% population have the access to the electricity in Bangladesh. Problems in the Bangladesh's electric power sector include, high system losses, delays in completion of new plants, low plant efficiency, erratic power supply, electricity theft, blackouts, and shortages of funds for power plant maintenance. Overall, the country's generation plants have been unable to meet system demand over the past decade. Non-commercial energy sources, such as wood fuel, and crop residues, are estimated to account for over half of the country's energy consumption. On 2 November 2014, electricity was restored after a day-long nationwide blackout. A transmission line from India had failed, which "led to a cascade of failures throughout the national power grid," and criticism of "old grid infrastructure and poor management." However, in a recent root-cause analysis report the investing team has clarified that fault was actually due to Lack in electricity management & poor Transmission & Distribution health infrastructure that caused the blackout.[5]

Ensuring energy security, energy resources used in the country in the future need to be diversified. Also, to ensure the continuity of supply, energy mix need to be rationalized considering important factors, such as economic cost, environmental impact, reliability of supplies and convenience to consumers.

The hybrid renewable power generation is a system aimed at the production and utilization of the electrical energy stemming from more than one source, provided that at least one of them is renewable.

Through this thesis it is expected to give concern about development of the wind-solar hybrid power generation systems where wind solar potential is high in Bangladesh.

Wind-solar hybrid system has numerous advantages. One of the advantages is reliability, when solar and wind power production resources are used together, reliability is improved and the system energy service is enhanced. What this mean is that in the absence of one type of energy, another would be available to carry out the service. Other advantages are the stability and lower maintenance requirements, thus reducing downtime during repairs or routine maintenance. In addition to these, as well as being indigenous and free, renewable energy resources contribute to the reduction of pollution emissions.

1.2 Problem Identification & Inspiration

With the world oil crisis, dangers of overdependence on oil pushed for the development of alternative energy sources. Current international trend in electricity generation is to utilize renewable energy resources. Solar, wind, biomass, micro hydro systems can be seen as suitable alternatives to conventional power. With the expectation of promoting electricity generation based on non-conventional renewable energy, the Government of Bangladesh introduced an Energy Policy to achieve a 5% target of power generation through non-conventional renewable energy by year 2015 and 10% by 2020.[1]
So far, these vast renewable energy resources, wind and solar, are not sufficiently harnessed for electricity generation in Bangladesh. Thus, in this thesis a hybrid renewable power generation system integrating the available solar and wind resources

will be investigated in detail for a specific location. It is not possible to generate large amount of electricity by wind-solar hybrid system. Wind-solar hybrid system is used for production a small amount of electricity. Considering the different situation, we choose wind-solar hybrid power generation system.

1.3 Objective of the Thesis

The main objective of the thesis is to design, fabrication and assess the performance analysis of a wind-solar hybrid power generation system in our project.

Specific Objectives of this thesis are:

- To discuss about energy market in Bangladesh.
- To discuss problems of energy sector and need for renewable energy in Bangladesh.
- To study the Wind – Solar potential in different locations by analysing data from different sources.
- To design and fabrication of a wind – solar and hydro system model for a selected suitable location.
- To analyse the performance of a wind – solar and hydro system indifferent condition.

CHAPTER 2

2.1 Literature Review

To get a better insight about the different energy resources, energy supply, wind and solar potential in Bangladesh and hybrid power generation system, an elaborated literature study was carried out. Wind energy has been used for thousands of years for milling grain, pumping water and other mechanical power applications. Wind power is not a new concept. The first accepted establishment of the use of windmills was in the 10^{th} century in Persia. New ways of using the energy of the wind eventually spread around the world. By the 11^{th} century, people in the Middle East used windmills extensively for food production. Returning merchants and crusaders carried this idea back to Europe. The Dutch refined the windmill and adapted it for draining lakes and marshes in the Rhine River Delta. When settlers took this technology to the New World in the late 19th century, they began using windmills to pump water for farms and ranches and later to generate electricity for homes and industry.[6]

Wind energy was the fastest growing energy technology in the 1990s, in terms of percentage of yearly growth of installed capacity per technology source. The growth of wind energy, however, is not evenly distributed around the world. By the end of 1999, around 69% of the worldwide wind energy capacity was installed in Europe, a further 19% in North America and 10% in Asia and the Pacific.[7]

With the recent rise in energy costs many people have been looking to alternative sources of energy. One of the greatest energy sources is sun which is readily available for the taking. We just need to be able to harness its power. Solar technology isn't new. Its history spans from the 7th Century B.C. to today. We started out concentrating the sun's heat with glass and mirrors to light fires. Today, we have everything from solar-powered buildings to solar-powered vehicles. In 7th Century B.C. "Magnifying glass used to concentrate sun's rays to make fire and to burn ants." In 1921 Albert Einstein wins the Nobel Prize for his theories explaining the photoelectric effect.[8]

2.2 Methodology

Initially, literature review was done to get better understanding about the energy situation and problems of energy sector in Bangladesh. Design consideration of wind-solar and Hydro hybrid system and modelling are main concept. Hence related literature was studied. In order to identify wind and solar potential of SU-Dhaka, Bangladesh. Previous study was analysed that has been carried out in. The following steps are

performed during completing project:

- At first design a vertical axis wind turbine with a solar system.
- Then construct it according to the design.
- Some parametric experimental studies carried out to make it more efficient.
- Several blade configurations experimented for improving efficiency of the turbine.
- Several instruments like Tachometer, Voltmeter, Ammeter and Anemometer are used to evaluate the performance.
- The setup of wind-solar & hydro hybrid power generation system are shown in chapter 5.

2.3 Outline of the Project & Thesis

This thesis is organized in 7 chapters. General introduction about the thesis on “Design of wind solar hybrid power generation system” is described in Chapter 1. Besides problem statement and inspiration, objective of the study, methodology & the literature review of the thesis are included. Chapter 2 covers introduction about energy sector of Bangladesh and problems of energy sector in Bangladesh. Chapter 3 and Chapter 4 contain basic background theory of wind and solar energy resources & previous assessments of wind and solar resources of Bangladesh are presented. Chapter 5 describes the design details of wind-solar hybrid power generation system. Chapter 6 presents the result & discussion of the thesis. Finally, In chapter 7 conclusions and recommendations are described

CHAPTER 3

ENERGY SECTOR IN BANGLADESH

3.1 Energy Resources

Bangladesh is satisfied with several forms of renewable energy resources. Some of them are used and developed to supply the energy requirement of the country. Others have the potential for development when the technologies become advanced and economically feasible for use. Following are the main renewable resources available in Bangladesh. [1]

Hydro Power
Solar Power
Wind Power.
Also, Obtainable of
Tidal Power
Wave energy
Waste to electric energy
Geothermal energy

In addition to the above indigenous renewable resources, the availability of petroleum within the country territory is being investigated.

Petroleum, Coal, Natural Gas, Nuclear Energy are the most common energy sources globally available for electricity supply purposes. However, In Bangladesh petroleum and nuclear energy are imported in large scale into the country as a source of energy while coal is founded very recently for electricity generation. The use of other energy sources is still being studied.

To combat the rapid growth in electricity demand, the government adopted a phased approach to power generation. A 6-12 months program to generate electricity through liquid fuel based rental and quick rental power plants was followed by a short term (18-24 months) option of liquid fuel based peaking plants. The role played in the short term by small IPPs, contingency plants, and quick rental plants gave necessary relief for the interim period of three to five years until large base-load projects and major plants can be installed and become operational. Natural gas is the main energy source of Bangladesh and the power generation sector is heavily dependent on that. In 2014 FY, 8,340 MW were generated using 337.4 BCF natural gas. According to the Power System Master Plan 2016, the gas production from the domestic gas field will reach its peak in 2017. The Government is trying to meet the growing demand of natural gas by importing LNGs. The projection of primary energy for Bangladesh is shown in Table 1. As can be seen from the table that coal will be used extensively for power generation in future.[9]

Table 2.1

Bangladesh Power Sector at a Glance

	2009	**2017**	**8 Years' Addition**
Power Plants (No)	27.0	111.0	84.0
Expired Plants	0.0	3.0	3.0
Grid Capacity (MW)	4,942.0	15,821 (Including Captive)	10,879.0
Highest Generation (MW)	3,268 (6 Jan 2009)	9,507 (18 Oct 2017)	6,239.0
Power Import (MW)	0.0	660.0	660.0
Total Consumers (million)	10.8	26.7	15.9
Transmission Line (Ckt Km)	8,000.0	10,436.0	2,436.0
Distribution Line (Km)	260,000.0	412,000.0	152,000.0
Grid sub-station capacity (MVA)	15,870.0	30,993.0	15,123.0
Access to Electricity (%)	47.0	80.0	33.0
Per Capita Generation (KWh)	220.0	433 (Inc. captive) (30 June 2017)	213.0
ADP allocation (BDT in bn)	26.8	225.8	199.0
System Loss (%)	16.9	12.2	-4.7

3.2 Hydro Power

At present only 230 MW of hydro power is utilized in Karnaphuli, Rangamati hydro station, which the only hydro-electric power plant operated by BPDB. Micro hydro and mini hydro have limited potential in Bangladesh, with the exception of Chittagong and the Chittagong hill tracts. Hydropower assessments have identified some possible sites from 10 kW to 5 MW but no appreciable capacity has yet been installed. [10]

3.3 Biogas or Biomass

The potential of biogas as a renewable energy source for Bangladesh is relatively well-documented. In 1997, GTZ's Bangladesh Country study of biogas stated: 'The cattle dung available from 22 million cows and buffaloes million of the 8.5 million households who own 'bovines' have 3 to 4 cows, and a further million have more than 5 cows is nearly 0.22 million tons / day. Similarly, Islam et al. In 2008 estimated that animal dung available from 24.48 million cattle and buffalo is nearly 0.186 million tons / day. One ton of dung can produce 37 m3 of biogas. Available cattle dung can therefore produce between 2.5 to 3.0 x 109 m3 of gas per year which is the energy equivalent of between 2.5 to 3 million tons of coal. In addition, Islam et al. Mention that a substantial amount of biogas can be produced from human and other animal excreta (particularly poultry), garbage and water hyacinth.' The 2006 SNV report outlines a number of other reasons why biogas is an attractive option for Bangladesh. According to BCAS, the Chinese fixed dome biogas plant has proven to be the 'most suitable for Bangladesh', and a local variant is the 'only design that is being applied in the country' now. [10]

3.4 Solar Power

Solar energy presents a huge, almost limitless resource of effectively free renewable energy. It is also the largest renewable resource that Bangladesh has access to with no major risks or uncertainties in technology readiness. Rooftops present an opportunity to avoid land use changes in rural areas and represent a wasted resource in urban areas. Daily average solar radiation varies between 3 and 6.5 kWh m-2 day-1, with maximum radiation in March and April and the minimum in December and January. [11]

3.5 Wind Power

Electricity generated by wind turbines can feed to the central grid or be locally consumed using small stand-alone wind turbines. Generation of electricity from wind energy becomes very much promising where speed and wind power density are sufficiently high. Wind power generating capacity growth accelerated to 31% in 2009 through the whole world, with capacity increasing by a record 38 GW to reach 160 GW by the end of 2009. This was the sixth consecutive year of accelerating growth, a remarkable achievement in a year of global economic recession. Wind turbines for grid-connected systems are the most highly demanded on the market and the rate of capacity growth is 28% per year between 1999 and 2009. [10]

3.6 Tidal Power

The tides at Chittagong Division are predominantly semidiurnal with a large variation in range corresponding to the seasons, the maximum occurring during the south-west monsoon. In 1984, an attempt was made by mechanical engineering department of KUET to assess the feasibility of tidal energy in the coastal regions of Bangladesh, especially at Cox's Bazar and at the islands of Maheshkhali and Kutubdia. The average tidal range was found within 4-5 meter and the amplitude of the spring tide exceeds even 6 meter. From different calculations, it is anticipated that there are a number of suitable sites at Cox's Bazar, Maheshkhali, Kutubdia and other places where permanent basins with pumping arrangements might be constructed which would be a double operation scheme. [1]

3.7 Wave energy

Bangladesh has favourable conditions for wave energy especially during the period beginning from late March to early October. Waves generated in Bay of Bengal and a result of the southwestern wind is significant. Maximum wave height of over 2 meters with an absolute maximum of 2.4 meter were recorded. The wave periods varied from 3 to 4 seconds for waves of about 0.5 meter and about 6 seconds for waves of about 2 meter. [1]

3.8 Waste to electric energy

In order to save the large cities from environment pollution, the waste management as well as electricity generation from the solid wastes programme is being taken by the government. [1]

3.9 Geothermal energy

Geothermal potential of Bangladesh is yet to be determined. Different studies carried out by geologists have suggested possible geothermal resources in the northwest and southeast region. Among the studied areas of northwest region, Singra-Kuchma-Bogra area, Barapukuria coal basin area, and the Madhyapara hard rock mine area − with temperature gradient above 30°C/km and bottom hole temperature in excess of 100°C− meet the requirements of binary cycle power plants. But to reach a foregone conclusion on exploiting the resource in a viable, feasible and economically profitable way, extensive research is required. In 2011, Anglo MGH Energy, a Dhaka-based private company announced the construction of 200 MW geothermal plant, first ever of such kind, in Thakurgaon district. But for some unknown reasons, this project never commenced, and no development in this field has been announced afterwards.[1]

3.10 Production of Electricity

Demand for electricity in Bangladesh is projected to reach 34,000 megawatts (MW) by 2030 and the Government of Bangladesh has plans to increase power generation beyond expected demand to help propel growth in the export-oriented economy and to meet the demands of a growing middle class. Total investment in the sector over the next 15 years is estimated at $70.5 billion. While installed generation capacity is 13,846 MW as of February 2018, shortfalls exist due to poor distribution infrastructure and a mismatch between the types of energy plants and fuel mix available. Private power production units are approaching half of total installed capacity. Only two-thirds of Bangladesh’s population is currently connected to the electricity grid. This indicates an untapped potential market of up to 60 million people connecting to the national grid in coming years as Bangladesh continues its growth trajectory. The fuel mix of Bangladesh’s power plants is heavily based on natural gas. The Government of

Bangladesh plans to reduce dependence on natural gas and move towards coal with plans to generate 50 percent of total electricity using coal-based power plants by 2030. Other solutions include importing electricity from neighbouring countries, importing liquefied natural gas (LNG), and expanding use of renewable resources, including solar and wind. [12]

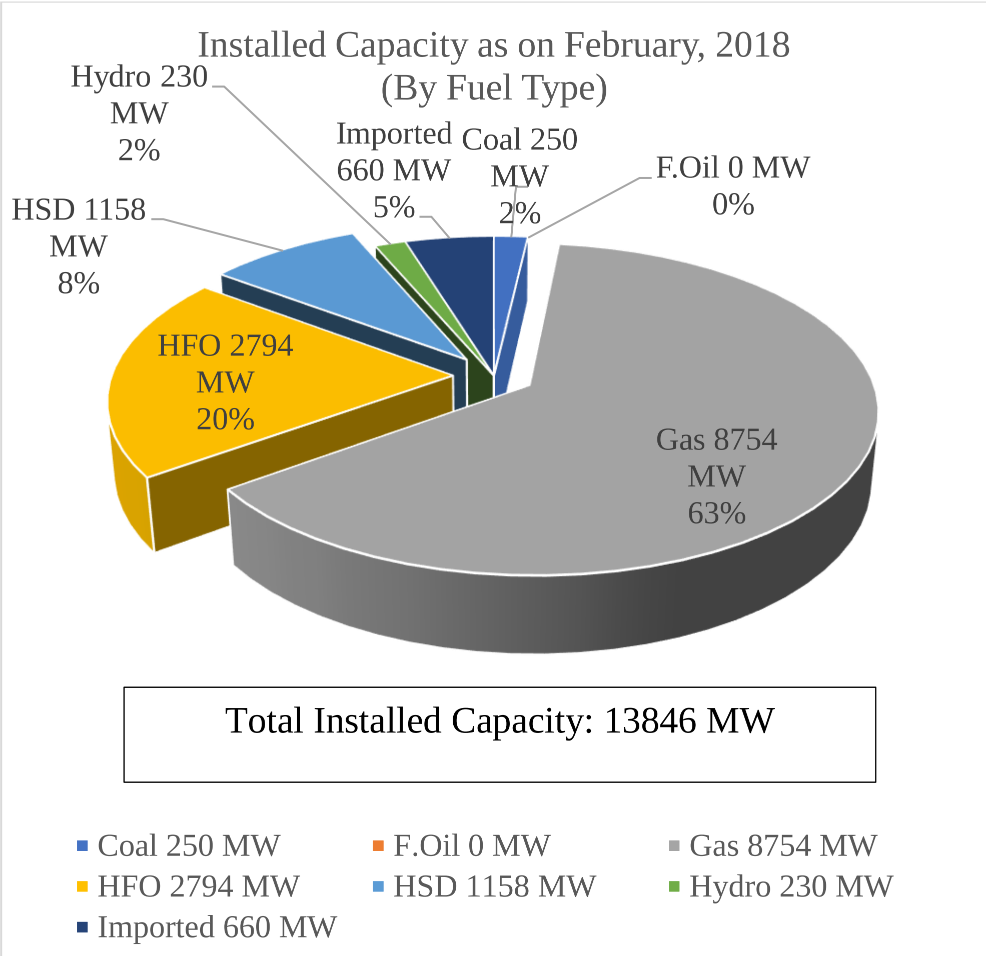

Fig. 0.1 Installed energy capacity in Bangladesh. [13]

CHAPTER 4

WIND ENERGY

4.1 Introduction

Wind energy is converted solar energy. The sun radiates energy on to the Earth and the Earth is heated unevenly. The atmosphere heats up much more quickly in the equator regions than in the rest of the globe. Lands heat up (and cool down) more quickly than the oceans do. This differential heating of the earth drives a global atmospheric convection system and resulting different air pressure fluctuations.
Wind is the movement of air caused by pressure difference within the atmosphere. This pressure difference exerts a force that causes air mass to move from a region of high pressure to one of low pressure. That movement of air is referred to wind. Wind power is the transformation of wind energy into more utilizable forms, typically electricity using wind turbines.

4.2 History of the Wind Energy

Harnessing the wind is one of the oldest methods of generating energy. Since ancient times man has used the help of windmills to grind the harvest and to pump water. With the appearance of electricity at the end of the nineteenth century, the first prototypes of modern wind turbines were built, using technology based on the classical windmill. Since then it has been a long process until wind energy was accepted as a serious and commercially sound method to generate energy. [13]

The oil crisis of the 70s, and even more the anti-nuclear power movement of the 80s, raised interest in alternative energies and the search for new ecologically and commercially viable ways of generating power intensified. The wind turbines built at that time were mainly for research, and extremely expensive. With the help of government financed international research and funding programs, as well as the creation of research institutes in the 80s, new methods of renewable power generation continued to be researched, developed and implemented. [13]

Research institutes such as the German Wind Energy Institute (DEWI) and the Danish Research Institute Risø, as well as various research programmes and international co-operatives in the wind energy sector, were instrumental for the industrial and technological breakthroughs of professional wind energy pioneers. Thanks to close co-operation between the research institutes and the wind energy pioneers, international standards, strict regulation and increasingly efficient designs were developed and implemented to result in modern, commercially viable wind parks. [13]

With the development of the 55-kW wind power station in 1981, the early high costs of wind energy were dramatically reduced. Wind energy is now one of the cheapest energy sources when all external costs (e.g. environmental damage) are taken into account. [13]

Modern wind power stations increasingly generate a major proportion of global energy. Germany is one of the biggest wind energy markets, with the second largest amount of installed wind power capacity (23,903 MW in 2008) after the USA. Alongside Germany and the US, Spain, France, Denmark, China and India are the biggest users of wind energy to generate electricity. [13]

The wind energy industry, with its continuously growing export volume, has become an important global growth market and economic factor. [13]

4.3 Future of Wind Energy

International climate and environmental experts agree that the atmosphere of our planet is warming up and that we are running short of resources. Furthermore, all power stations built in the 60s or 70s will soon have to be replaced. Political and economic requirements have changed dramatically since those stations were built; global environmental problems can no longer be ignored. International environmental treaties, such as the Kyoto Protocol, establish legally binding commitments for the reduction of greenhouse gas concentrations in the atmosphere and industrialised countries agreed to reduce their collective GHG (greenhouse gas) emissions. International, standardised applications for renewable energies, regardless of national regulations or climate conditions, are more and more likely to be put into place. The wind energy industry's future looks optimistic. [13]

Wind power Energy available in wind is basically the kinetic energy of large masses of air moving over the earth surface. Blades of the wind turbine receive this kinetic energy, which is then transformed to useful mechanical energy, which is then transformed further to mechanical or electrical energy depending on the end use. [13]

A wind rotor of cross sectional area A in m_2 is exposed to wind stream with velocity V in m/s as depicted in figure 3.1 below

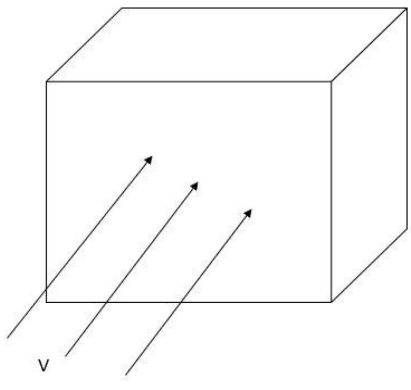

Fig. 0.1 Air moving with velocity V m/s towards area A m^2

Wind is air in motion. An air mass flowing through an area A(m_2) with a Velocity V(m/s) represents mass flow rate,

$$m = pAV$$

Kinetic energy per second or the power possessed by moving air is, therefore,

$$P_{wind} = \frac{1}{2} mV^2$$

Substituting for mass flow rate in the equation for power in the wind,

$$P_{wind} = \frac{1}{2} C\rho AV^3$$

As shown in the equation above, the power of the wind is proportional to the cube of the wind speed.

The most accurate estimate for wind power density is given by following equation.

$$P = \frac{1}{2} A \ \frac{1}{n} \sum_{j=1}^{n} (p_j V^3{}_j)$$

Where n is the number of wind speed reading and ρ_j and V_j are the j_{th} reading of the air density and wind speed.

As shown in the equation output power is related to the area intercepting the wind, i.e. area swept by the wind turbine rotor. For horizontal axis turbine, the rotor swept area is,

$$A = bh$$

Where, b & h are breath and height of the blade respectively in meters. Relatively small increases in blade length or breath produce a correspondingly bigger increase in the swept area, and therefore in power.

4.4 Wind Energy Scenario in Bangladesh

With its sub-tropical climate, with monsoon and typhoon seasons, Bangladesh is confronted with large amounts of rainfall and periodically high wind speeds (gusts) during typhoon season. The mean annual wind speeds in Bangladesh are not well documented and few data is available. The readily available data shows that low wind speeds predominate on the Bangladeshi lands. Next to onshore wind speeds, no (extensive) data is readily available concerning (far) offshore wind speeds. [4]

The 'Solar and Wind Energy Resources Assessment' initiative also calculated the annual wind speeds in Bangladesh, this at a height of 50 meter. The data is shown in figure 3.2. The maximum annual onshore wind speeds at 50 meters in Bangladesh do not outreach 5 meters per second, and 6 meters per second for offshore wind. These can be considered as low wind resources. During the typhoon season however, there can be wind gusts with speeds well over 35 meters per second (>126 km/h). [4]

The international program Enhancing Capacity for Low-Emission Development Strategy (ECLEDS) is part of the USAID LEAD program, which supports and complements the US Government's Enhancing Capacity for Low Emission Development Strategies (EC-LEDS) initiative. EC-LEDS supports developing countries' efforts to pursue long-term, transformative development and accelerate sustainable, climate-resilient economic growth while slowing the growth of greenhouse gas emissions. Through this initiative, a current operational wind mapping project is funded. This project consists of 9 sites where a two-year wind speed metering programme is in progress at heights between 20 and 200 meters (with a met mast at 20, 40, 60 and 80 metres and two SODAR's up to 200 meters). See appendix F for a short description of the program. The preliminary results of the measurement campaign are still under embargo with the Ministry of Power. Final results of the measurement campaign are expected to become public in 2018. In appendix D a rough map of the wind resources of Bangladesh is included to give an impression of the wind climate. Also, Vestas, a Danish wind turbine manufacturer, has been performing wind monitoring and site assessments in Bangladesh; these results are not made public. [4]

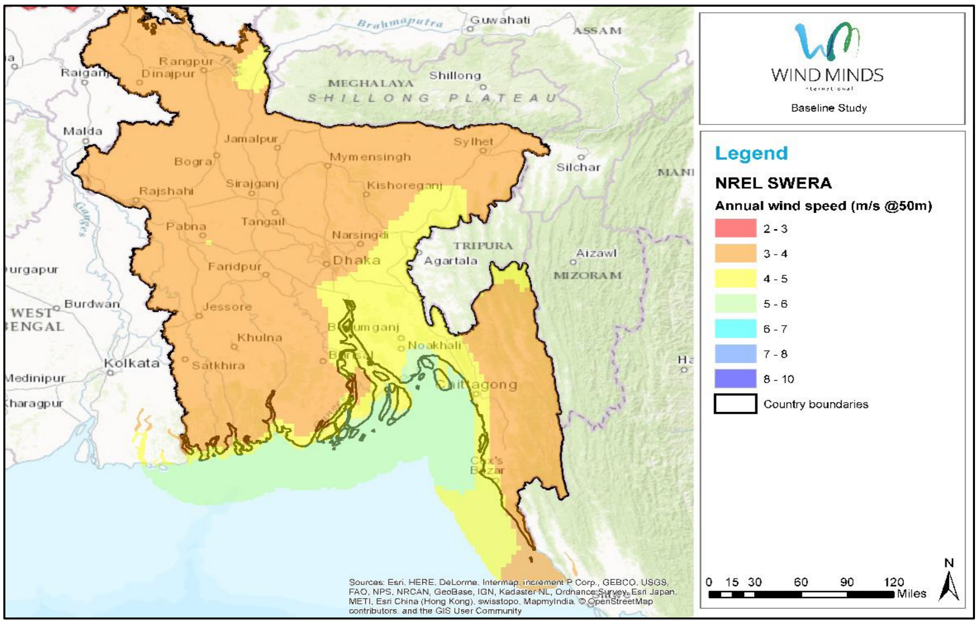

Fig. 0.2 Annual wind speeds in Bangladesh (source: NREL, 2007)

4.5 Available space for wind farms

4.5.1 Onshore

Bangladesh is a densely populated country and being situated in the Bengal Delta, which makes large areas not usable for most activities, results in land being a scarce commodity. Figure 3.3 shows the land use of Bangladesh. As can be seen (light blue in the map), the vast majority of the country is used for agricultural purposes (maintained by irrigation processes).

Bangladesh consists mainly of flat lands. Three-quarters of the land has no elevation higher than 30 meters. The north and southeast are more elevated, in which the division of Chittagong is the most elevated land of the country (figure 3.3). [4]

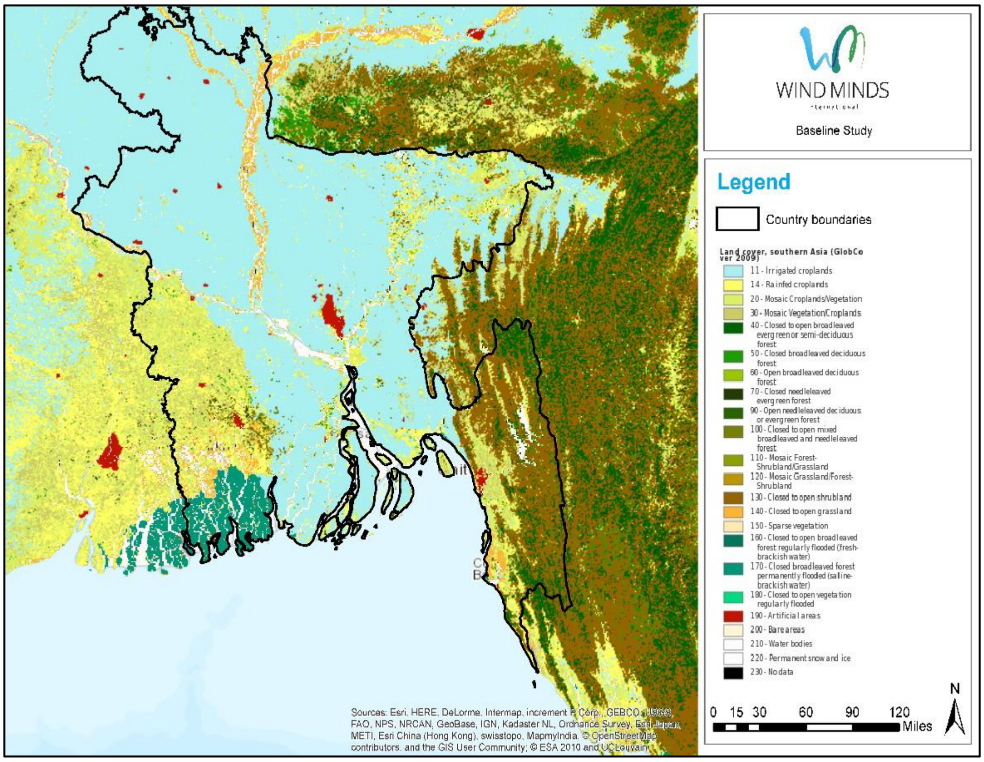

Fig. 0.3 Land use (Glob Cover, 2009) [4]

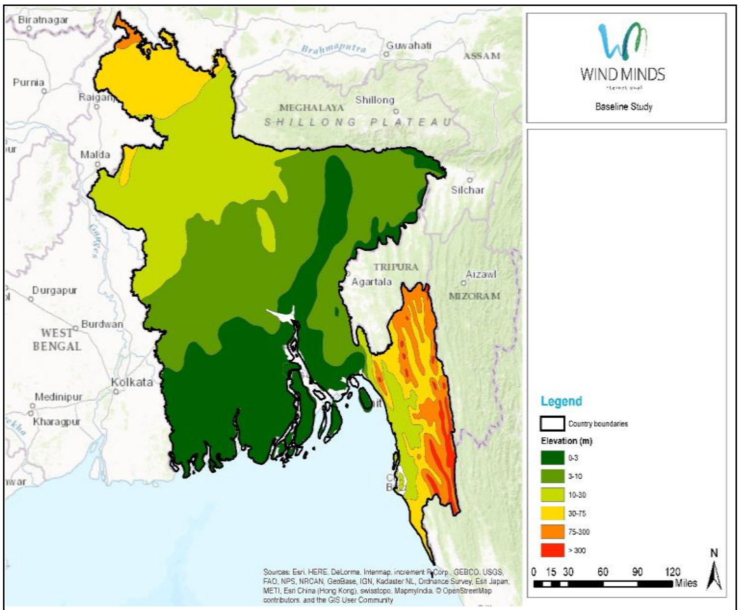

Fig. 0.4 Generic land elevation of Bangladesh. [4]

4.5.2 Accessibility of the terrain

Large parts of Bangladesh are not well accessible with large trucks to transport modern wind turbine parts, due to infrastructure limitations. An advantage is however the presence of rivers that might be usable for transportation of heavy and large components. [4]

4.5.3 Offshore

With the active Ganges, the Brahmaputra and the Meghna rivers, fluvial sedimentation Processes are current throughout the coastal line, with an exception off of the Chittagong coast. Partly by these processes, the first kilometres from the coast are relatively shallow.

The 20-meter depth line is at its farthest ca. 110 kilometres from the coast of Patuakhali (see figure 3.5). Being fluvial sedimentation, it is anticipated that the soil of the seabed mainly consists of mud and loose sand. Offshore form the Chittagong division, the sedimentation processes seem to be of a lesser strength, but therefore the seabed is deeper, closer to shore. Next to this presumed solid seabed, the harbour of the City of Chittagong is also nearby, which can be a useful base for offshore contractors. [4]

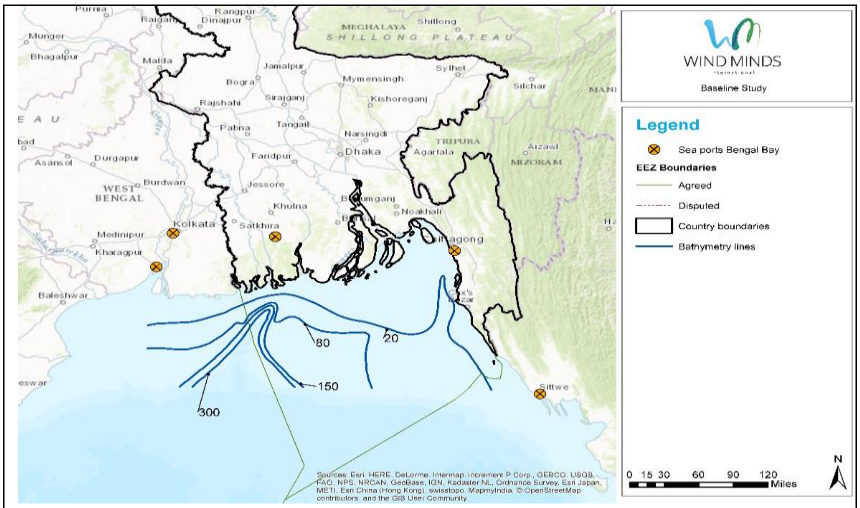

Fig. 0.5 Bathymetry lines of Bangladeshi Bengal Bay (source: USGS, 2001) [4]

CHAPTER 5

SOLAR ENERGY

5.1 Introduction

The sun is the largest energy source of life, at the same time it is the ultimate source of all energy. The sun is a star with surface temperature is about 5800 Kelvin. This temperature derives from reactions which were based on the transformation of hydrogen to helium, the process called Nuclear Fusion, which produce high temperature of the sun and the continuous emission of large amount of energy. Solar energy is emitted to the universe mainly by electromagnetic radiation and approximately one-third of energy radiated from sun is reflected back. The rest is absorbed and retransmitted to the space while the earth reradiates just as much energy as it receives and creates a stable energy balance at a temperature suitable for life.

Solar radiation provides a huge amount of energy to the earth. The total amount of energy which is irradiated from the sun to the earth surface equals approximately 10,000 times the annual global energy consumption.

There are normally two ways to generate electricity from sunlight, through photovoltaic (PV) and solar thermal systems. In this thesis is used photovoltaic power system. The light of the sun, which reaches the surface of the earth, consists mainly of two components, direct sunlight and indirect or diffuse sunlight, which is the light that has been scattered by dust and water particles in the atmosphere. Photovoltaic cells not only use the direct component of the light, but also produce electricity when the sky is overcast. To determine the PV electricity generation potential for a particular site it is important to assess the average total solar radiation received over the year.

5.2 History of Solar Panels

The development of solar energy goes back more than 100 years. In the early days, solar power was used primarily for the production of steam which could be used to drive machinery. But it wasn't until the discovery of the "photovoltaic effect" by Henri Becquerel that would allow the conversion of sunlight solar electric energy. Becquerel's discovery then led to the invention in 1893 by Charles Frits of the first genuine solar cell which was formed by coating sheets of selenium with a thin layer of gold. And from this humble beginning would arise the device we know today as the solar panel. [15]

Russel Ohl, an American inventor on the payroll of Bell Laboratories, patented the world's first silicon solar cell in 1941. Ohl's invention led to the production of the first solar panel in 1954 by the same company. The new-fangled solar panels found their first mainstream use in space satellites. For most people, the first solar panel in their life was probably embedded in their new calculator - circa the 1970s!

Today, solar panel and complete solar panel systems are used to power a wide variety of applications. Yes, solar panels in the form of solar cells are still being used in calculators. However, they are also being used to provide solar power to entire homes and commercial buildings, such as Google's headquarters in California.

5.3 Benefits of Solar Panels

Using solar panels is a very practical way to produce electricity for many applications. The obvious would have to be off-grid living. Living off-grid means living in a location that is not serviced by the main electric utility grid. Remote homes and cabins benefit nicely from solar power systems. No longer is it necessary to pay huge fees for the installation of electric utility poles and cabling from the nearest main grid access point. A solar electric system is potentially less expensive and can provide power for upwards of three decades if properly maintained. [14]

Besides the fact that solar panels make it possible to live off-grid, perhaps the greatest benefit that you would enjoy from the use of solar power is that it is both a clean and a renewable source of energy. With the advent of global climate change, it has become more important that we do whatever we can to reduce the pressure on our atmosphere from the emission of greenhouse gases. Solar panels have no moving parts and require little maintenance. They are ruggedly built and last for decades when properly maintained.

Last, but not least, of the benefits of solar panels and solar power is that, once a system has paid for its initial installation costs, the electricity it produces for the remainder of the system's lifespan, which could be as much as 15-20 years depending on the quality of the system, is absolutely free! For grid-tie solar power system owners, the benefits begin from the moment the system comes online, potentially eliminating monthly electric bills or, and this is the best part, actually earning the system's owner additional income from the electric company. How? If you use less power than your solar electric system produces, that excess power can be sold, sometimes at a premium, to your electric utility company!

There are many other applications and benefits of using solar panels to generate your electricity needs - too many to list here. But as you browse our website, you'll gain a good general knowledge of just how versatile and convenient solar power can be.

5.4 Photovoltaic Power Generation

Photovoltaic power system is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. PV power generation uses solar panels comprising a number of cells containing a semiconducting material. As long as light is shining on the solar cells, it generates electric power. When the light stops, the electricity stops.

5.5 Solar Cell Work

Solar cells are composed of various semiconducting materials. Semiconductors are materials, which become electrically conductive when supplied with light or heat, but which operate as insulators at low temperatures.

Over 95% of all the solar cells produced worldwide are composed of the semiconductor material Silicon (Si). As the second most abundant element in earth`s crust, silicon has the advantage, of being available in sufficient quantities, and additionally processing the material does not burden the environment. To produce a solar cell, the semiconductor is contaminated or "doped". "Doping" is the intentional introduction of chemical elements, with which one can obtain a surplus of either positive charge carriers (p-conducting semiconductor layer) or negative charge carriers (n-conducting semiconductor layer) from the semiconductor material. If two differently contaminated semiconductor layers are combined, then a so-called p-n-junction results on the boundary of the layers.[15]

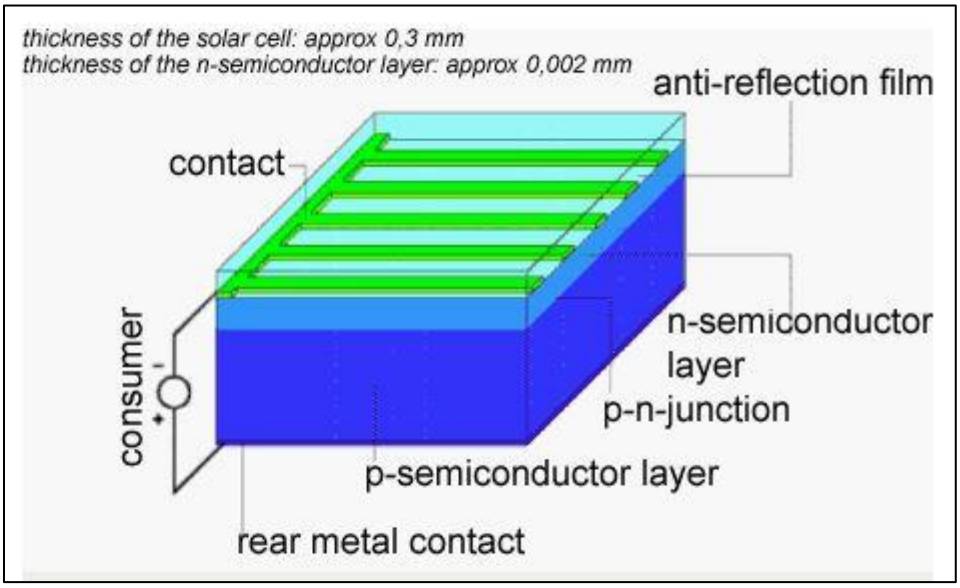

Fig. 0.1 Model of a crystalline solar cell. [15]

At this junction, an interior electric field is built up which leads to the separation of the charge carriers that are released by light. Through metal contacts, an electric charge can be tapped. If the outer circuit is closed, meaning a consumer is connected, then direct current flows.

Silicon cells are approximately 10 cm by 10 cm large (recently also 15 cm by 15 cm). A transparent anti-reflection film protects the cell and decreases reflective loss on the cell surface.

5.6 Characteristics of a Solar Cell

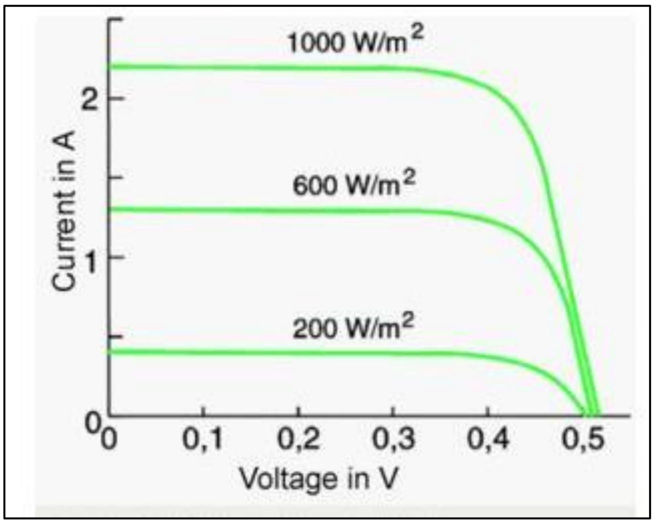

Fig. 0.2 Current-voltage line of a si-solar cell. [15]

The usable voltage from solar cells depends on the semiconductor material. In silicon it amounts to approximately 0.5 V. Terminal voltage is only weakly dependent on light radiation, while the current intensity increases with higher luminosity. A 100 cm^2 silicon cell, for example, reaches a maximum current intensity of approximately 2 A when radiated by 1000 W/m^2.

The output (product of electricity and voltage) of a solar cell is temperature dependent. Higher cell temperatures lead to lower output, and hence to lower efficiency. The level of efficiency indicates how much of the radiated quantity of light is converted into useable electrical energy.

4.7 Different Cell Types

One can distinguish three cell types according to the type of crystal: monocrystalline, polycrystalline and amorphous. To produce a monocrystalline silicon cell, absolutely pure semiconducting material is necessary. Monocrystalline rods are extracted from melted silicon and then sawed into thin plates. This production process guarantees a relatively high level of efficiency.

The production of polycrystalline cells is more cost-efficient. In this process, liquid silicon is poured into blocks that are subsequently sawed into plates. During solidification of the material, crystal structures of varying sizes are formed, at whose borders defects emerge. As a result of this crystal defect, the solar cell is less efficient. If a silicon film is deposited on glass or another substrate material, this is a so-called amorphous or thin layer cell. The layer thickness amounts to less than 1µm (thickness of a human hair: 50-100 µm), so the production costs are lower due to the low material costs. However, the efficiency of amorphous cells is much lower than that of the other two cell types. Because of this, they are primarily used in low power equipment (watches, pocket calculators) or as facade elements. [15]

Material	Level of efficiency in % Lab	Level of efficiency in % Production
Monocrystalline Silicon	approx. 24	14 to17
Polycrystalline Silicon	approx. 18	13 to15
Amorphous Silicon	approx. 13	**to7**

5.8 Natural Limits of Efficiency

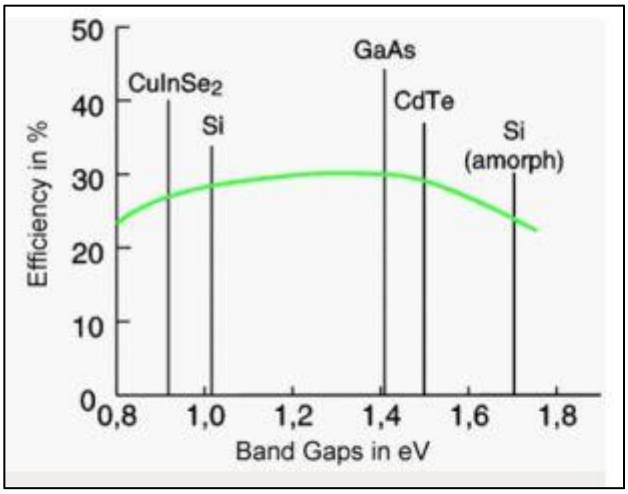

Fig. 01 Theoretical maximum levels of efficiency of various solar cells at standard conditions. [15]

In addition to optimizing the production processes, work is also being done to increase the level of efficiency, in order to lower the costs of solar cells. However, different loss mechanisms are setting limits on these plans. Basically, the different semiconductor materials or combinations are suited only for specific spectral ranges. Therefore, a specific portion of the radiant energy cannot be used, because the light quanta (photons) do not have enough energy to "activate" the charge carriers. On the other hand, a certain amount of surplus photon energy is transformed into heat rather than into electrical energy. In addition to that, there are optical losses, such as the shadowing of the cell surface through contact with the glass surface or reflection of incoming rays on the cell surface. Other loss mechanisms are electrical resistance losses in the semiconductor and the connecting cable. The disrupting influence of material contamination, surface effects and crystal defects, however, are also significant. Single loss mechanisms (photons with too little energy are not absorbed, surplus photon energy is transformed into heat) cannot be further improved because of inherent physical limits imposed by the materials themselves. This leads to a theoretical maximum level of efficiency, i.e. approximately 28% for crystal silicon. [15]

5.9 PV Cell

PV cells are made up of semiconductor material, such as silicon, which is currently the most commonly used element in semiconductor industry. Basically, when the light strikes the cell, a certain potion of it is absorbed within the semiconductor material. When energy knocks semiconductor electrons loose, allowing them to flow freely. PV cells have one or more electric fields that act to force electron that are freed by light absorption to flow in a certain direction. This flowing of electron is a current and by placing metal contacts on the top and bottom of the PV cell can draw that current off to be used externally. This current, together with the cell's voltage which is a result of its built-in electric field or fields, define the power in Watts that the solar cell can produce.[13]

5.10 PV module and array

The solar cell is the basic building block of the PV power system. However, it rarely used individually because it is not able to supply an electronic device with enough voltage and power. For this reason, many photovoltaic cells are connected in parallel or in series in order to achieve as higher voltage and power output as possible. Cells connected in series increases the voltage output while cells connected in parallel increase the current. The solar array or panel is a group of several modules electrically connected in series-parallel combination to generate required current and voltage and hence the power. [13]

5.11 Solar Resource in Bangladesh

The long-term average sunshine data indicates that the period of bright sunshine hours in the coastal regions of Bangladesh varies from 3 to 11 hours daily. The insolation in Bangladesh varies from 3.8 kWh/m^2/day to 6.4 kWh/m^2/day at an average of 5 kWh/m^2/day. These indicate that there are good prospects for solar thermal and photovoltaic application in the country. [1]

With an estimated 40% of the population in Bangladesh having no access to electricity, the government introduced a scheme known as solar home systems (SHS) to provide electricity to households with no grid access. The program reached 3 million households as of late 2014 and, with more than 50,000 systems being added per month since 2009, the World Bank has called it the fastest growing solar home system program in the world.

The Bangladeshi government is working towards universal electricity access by 2021 with the SHS program projected to cover 6 million households by 2017.

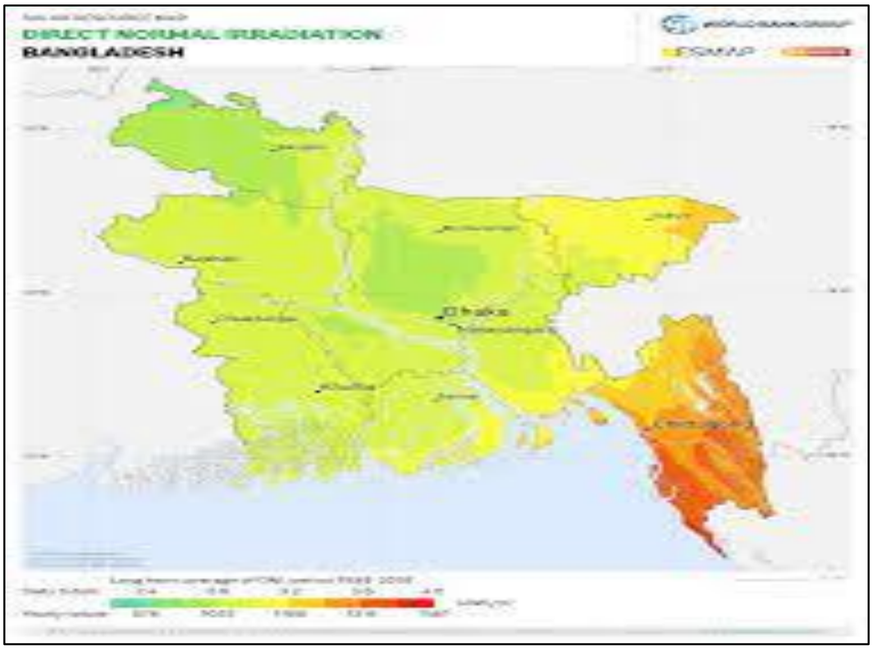

Fig: 4.3 ; Map of Bangladesh DNI.[16]

CHAPTER 6

HYDRO ENERGY

6.1 Introduction

Hydro Electric power (HEP) is a major renewable energy source used all over the world today to produce electricity. It utilizes the basic laws of Physics. Falling water under high pressure has high kinetic energy. In an HEP station, the falling water turns the turbines. Through magnetic induction, the generator converts the mechanical energy of the turbines to electricity.

6.2 History of Hydro Power Energy

Some of the first innovations in using water for power were conceived in China during the Han Dynasty between 202 BC and 9 AD. Trip hammers powered by a vertical-set water wheel were used to pound and hull grain, break ore, and in early paper-making.

The availability of water power has long been closely associated with kick-starting economic growth. When Richard Arkwright set up Cromford Mill in England's Derwent valley in 1771 to spin cotton and so set up one of the world's first factory systems, hydropower was the energy source he used. [7]

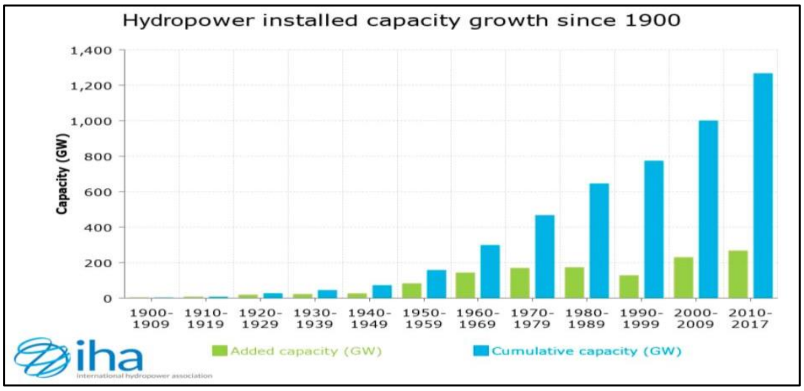

Fig: 5.2 ; Hydropower installed capacity growth [7]

6.3 Resources of Hydro power energy in Bangladesh

The climate in the country follows a four-season cycle: winter (December-February), summer (March-May), monsoon (June-September) and autumn (October-November). In winter, the average maximum and minimum temperatures are 26.5 and 13.5°C, respectively, whereas the corresponding respective values in summer are 33.3 and 22.2°C (Hossain, A.K. and O. Badr, 2007; Sustainable Development Networking Programme accessed on August 19, 2007). Average annual temperature is 26 C and while rainfall is 2540 mm (Hossain, A.K. and O. 0 Badr, 2007; Bangladesh Bureau of Statistics. accessed on August 19, 2007). The sectors of the country's economy are agriculture and forestry, fishing, mining and quarrying, manufacturing, construction, electricity and gas, transport and communication, wholesale and retail trade, financial services and other services (e.g. tourism, real state business). During the last 5 years, Bangladesh averaged over 5% growth in the GDP (Hossain, A.K. and O. Badr, 2007; Energy Information Administration. accessed on August, 2007. The national currency of the country is Taka, its exchange rate is US$1 = Taka 69.04 (as on 20/08/2007). Table 1 gives some of the national statistics of Bangladesh (Bangladesh Bureau of Statistics; Rofiqul Islam, M. et.al. 2008; World Bank. accessed on August. 22, 2007; Government of the People's Republic of Bangladesh, Bangladesh economic review 2007. [9]

Table 5.3 : National statistics of Bangladesh. [9]

Indicators	1991	1995	2003	2005	2006
Population (million)	111.45	119.8	135	138.6	140.6
Urban population (%)	17.20	22.00	23.10	24.17	NR
Population in below poverty level (%)	47.00	45.80	44.30	40.00	NR
Land area (km)	147,570 2				
GDP (US$ in billion)	26.50	32.06	54.00	60.00	67.71
Industrial GDP (%)	22.14	24.18	27.80	27.2	27.91
Services GDP (%)	49.45	50.98	49.37	52.6	52.48
Agriculture GDP (%)	28.13	24.83	22.83	20.1	19.61
GDP per capita (US$)	241	336	363	463	476

Life expectancy at birth (years)	56	58	64.9	65.1	NR
Literacy rate (%)	38.8	43.2	48.8	50.0	NR

NR- Not reported

6.4 Future of Hydro power energy

Due to its multiple services and benefits, hydropower is expected to remain the world's largest source of renewable electricity for years to come and with significant untapped hydropower potential; much of the sector's future growth is expected to come from Africa and Asia.

In 2018, IHA, in its annual Hydropower Status Report, reported worldwide hydropower installed capacity to have risen to 1,267 GW, with a record 4,185 TWh estimated to have been generated in 2017.

According to the International Energy Agency, in order to meet the main energy-related components of the Sustainable Development Goals, including the below two degrees Celsius commitment of the Paris Agreement, an estimated 800 GW of additional hydropower will need to be brought online over the next two decades. [10]

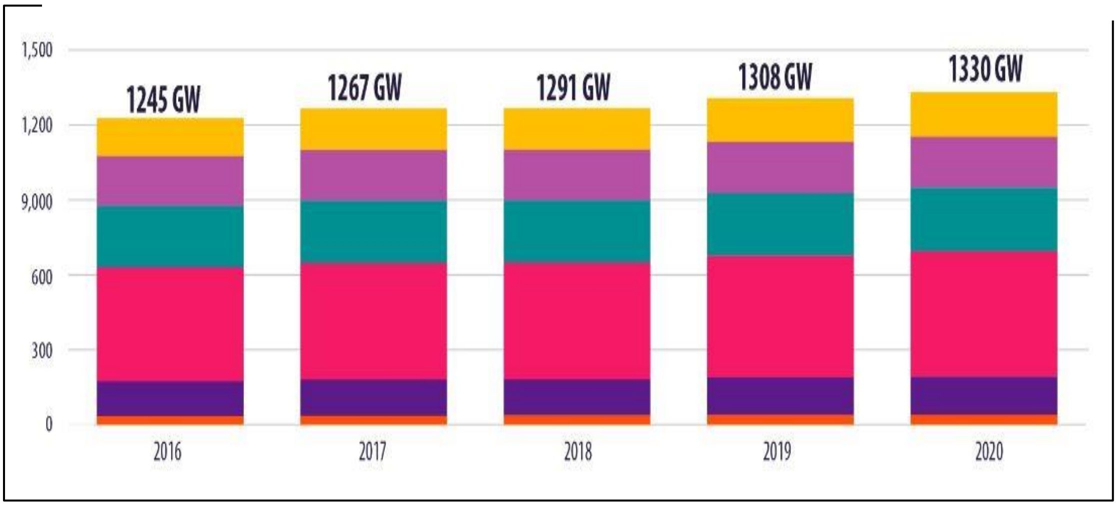

Fig: 5.4; Future Hydropower generation growth [9]

CHAPTER 7

COMPONENTS OF MINI HYBRID POWER SYSTEM

7.0 Components name with description

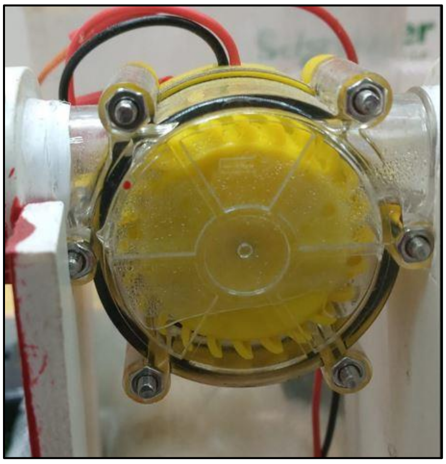

Fig: 7.1: Pelton Turbine

7.1 Pelton Turbine:

The operation of a Pelton turbine is fairly simple. In this type of turbine, high speed jets of water emerge from the nozzles that surround the turbine. These nozzles are arranged so the water jet will hit the buckets at splitters, the centre of the bucket where the water jet is divided into two streams.

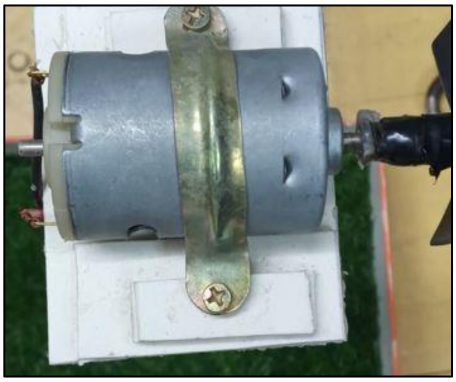

Fig: 7.2: DC Motor

7.2 DC Motor:

A DC motor is any of a class of rotary electrical motors that converts direct current (DC) electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current in part of the motor.

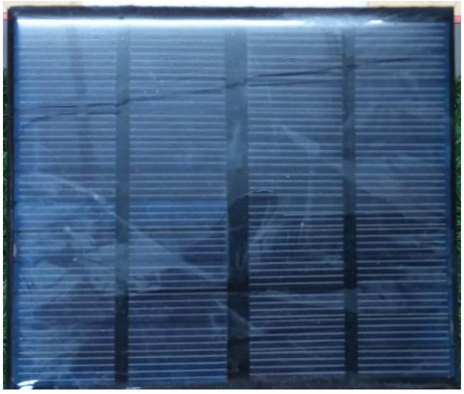

Fig: 7.3: Solar Panel

7.3 Solar Panel:

In a nutshell, a solar panel works by generating electricity when particles of sunlight, or photons, knock electrons free atoms, setting them in motion. This flow of electrons is electricity, and solar panels are designed to capture this flow, turning it into a usable electric current.

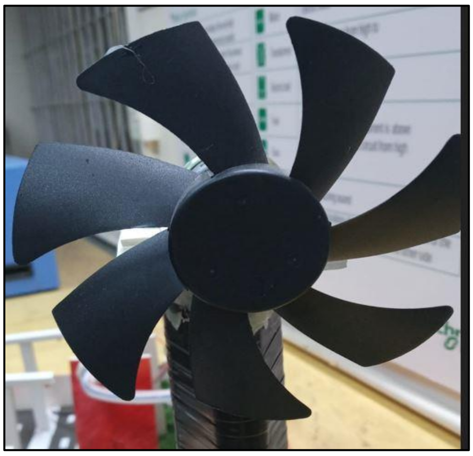

Fig: 7.4 : Fan

7.4 Fan:

Slanting the blades pushes air in a perpendicular direction to the plane of rotation, the air filling up the vacuum behind comes in the same direction as the one pushed, so an overall draft is established. The direction of the wind depends on the direction of the slant with respect to the direction of rotation.

Fig: 7.5: Hose pipe

7.5 Hose pipe:

Hoses can be used in water or other liquid environments, or to convey air or other gases. Hose are divided into two categories based on their use:-

i) Suction hose and

ii) Delivery hose

Fig: 7.6: Hose clip

7.6 Hose clip :

A hose clamp (hose clip, hose lock or jubilee clip) is a device used to attached and seal a hose onto a fitting such as a bard or nipple.

Fig: 7.7: Plastic channel

7.7 Plastic channel:

These polycarbonate U-channels are durable, impact-resistant, and virtually unbreakable. They have a continuous-use temperature range of up to 265°F (129°C), and keep their physical properties over a range of temperatures.

Fig: 7.8: Mini water pump

7.8 Mini water pump:

A mini centrifugal pump relies on quick impeller rotation to create a powerful centrifugal force that pushes the water to the edges of the cavity This action creates a vacuum in the middle of the impeller. Which sucks more water in through the inlet pipe, then pushes it out to the outlet pipe at the edge.

CHAPTER 8

RESULT AND DISCUSSION

8.1 Wind power generation result analysis (Data Table)

Exp. No.	Air flow speed, km/h	Distance, feet	Current, mA
1	7.7	1	70
2	7.3	1.5	40
3	5.5	2	25

Description: First we apply air km/h with the help of blower machine at a distance of 1 feet then we have got result air flow speed 7.7 km/h and measured electricity is 70 mA. When completing three times of experiment as a result it is seen that speed decreases as distance increases also current decreases.

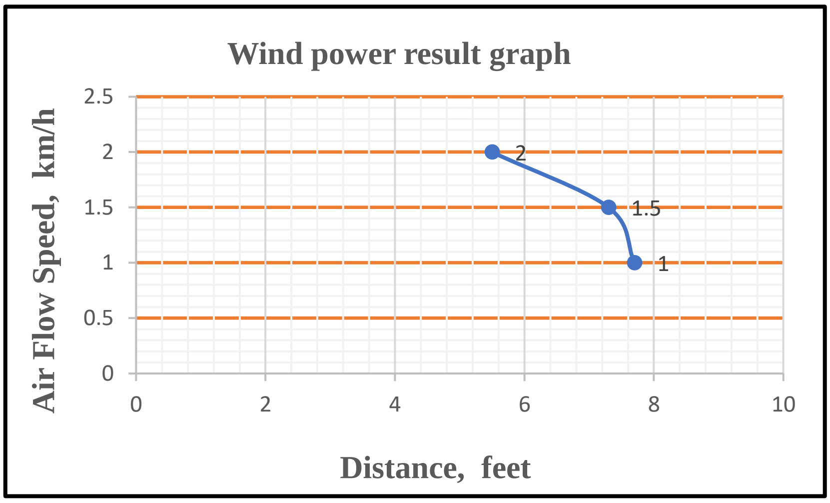

Fig: 7.9 Distance Vs Air flow speed graph

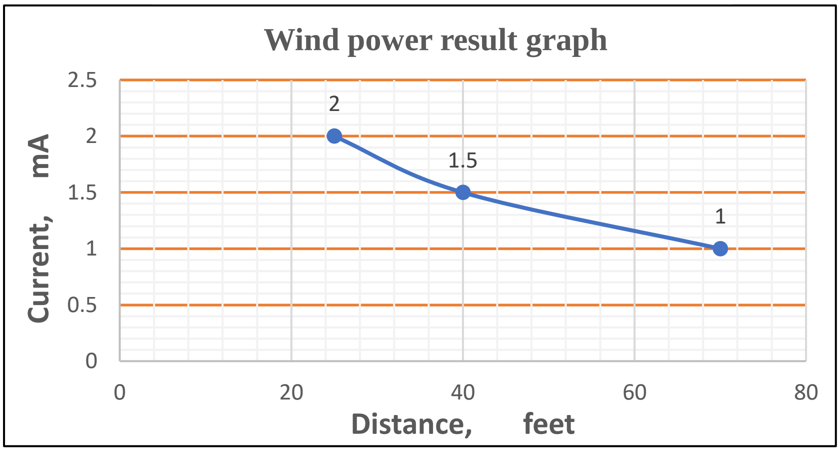

Fig: 7.10 Distance Vs Current graph

8.2 Solar power generation result analysis (Data Table)

Exp. No.	Lux (lx)	Distance, Inch	Current, mA
1	5500	1	10
2	2500	3	5
3	1200	6	1.5

Description: First we apply light on solar panel with the help of torch light at a distance of 1 inch then we have got result light 5500 lx and measured electricity is 10 mA. When completing three times of experiment as a result it is seen that light decreases as distance increases also current decreases.

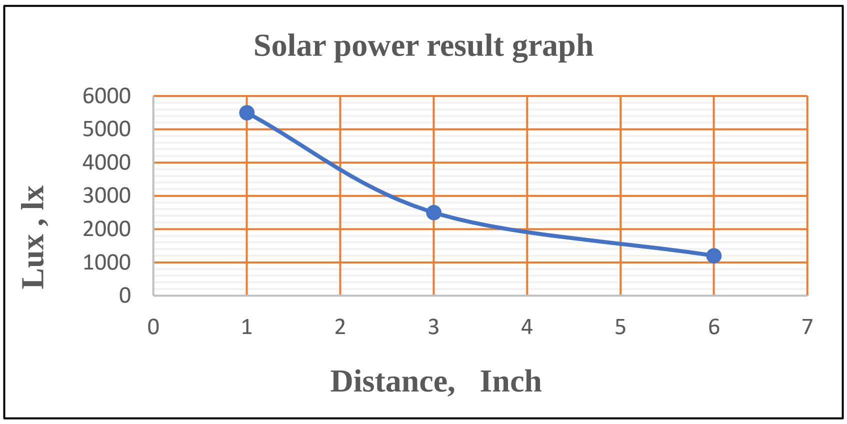

Fig: 7.11 Distance Vs Lux graph

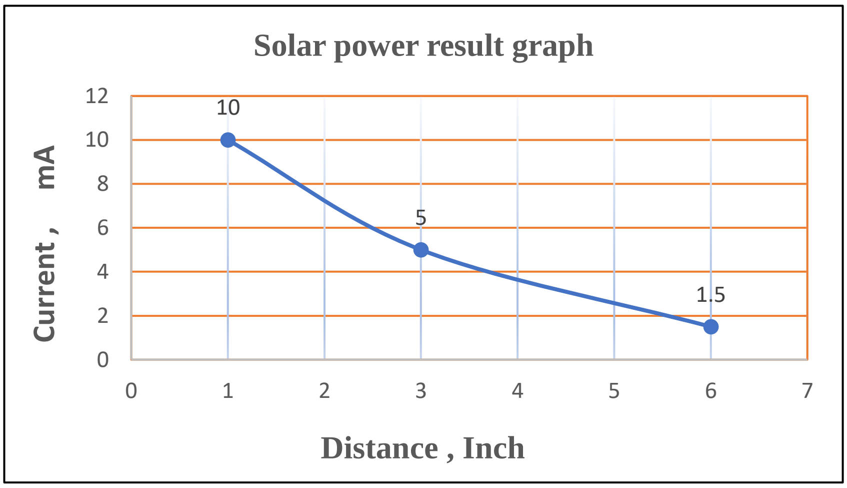

Fig: 7.12 Distance Vs Current graph

CHAPTER 9

COST ANALYSIS

Table: 9.1 Cost analysis for the mini hybrid power generation system break down:

Sl. No.	Component Name	Specification	Required Quantity	Unit	Unit Price	Total Price
01	Solar panel	5x5 inch	1	S. inch	22	550
02	DC Motor	12 volt	1	Nos	240	240
03	Fan	APS	1	Nos	230	230
04	Hose pipe	PVC	3	Feet	65	195
05	Hose clip	MS	2	Nos	20	40
06	Water turbine	Pelton wheel	1	Nos	900	900
07	Water pump	12 volt	1	Nos	320	320
08	Plastic channel	PVC	10	Feet	55	550
09	Plastic pipe	PVC	2	Feet	45	90
10	Adapter	12 volt	1	Nos	150	150
11	LED	3 volt	20	Nos	5	100
12	Ebonite board	PVC	25	SFt	35	875
Grand Total (BDT)						4240

CHAPTER 10

10.1 Conclusion

In this thesis work, a hybrid model of Solar/Wind/Hydro energy system is developed. We have also seen that this model is more effective and more reliable as compared to the earlier one.

The power delivered by hybrid model of Solar/Wind/Hydro is much higher and economical than the current system.

The system is more environmental friendly and the waste products of this system do not contain any harmful gases/products, this model use all the renewable energy sources for electric generations which are the need of the time.

The combination of the three technologies in a common frame will ensure advantages of three techniques and at the same time, it will reduce their individual limitations.

This paper has attempted to present a hybrid energy model which has considered these three prominent renewable energy sources for an increase in reliability and continuity of the resultant system.

This paper suggests a model which has a wide scope for future research in the area of hybrid energy. Our nation has been suffering from power failure and irregularities especially in remote areas and the implementation of this framework at any given location can be of great use as our country has been blessed by the locational and demographic advantages for both the resources.

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