BACHELOR OF SCIENCE IN ELECTRONIC AND TELECOMMUNICATIONS ENGINEERING

Investigation on Wind Power Generation for Dhaka-Chittagong Highway Based on Vertical Turbine

Submitted by

Md.Bakey Billa

T-151010

Md. Omar Faruk Shawon

T-151039

Supervised by

Engr. Abdul Gafur

Associate Professor

Department of ETE

International Islamic University Chittagong

Department of Electronic and Telecommunications Engineering

International Islamic University Chittagong

Kumira, Sitakunda, Chattagram

DEDICATION

This thesis work is dedicated to all of our honorable teachers and parents. Thanks to almighty Allah that we were able to complete this thesis.

CERTIFICATE OF APPROVAL

The project entitled as “Wind Power Generation With Vertical Turbine Set on Dhaka-Chittagong Highway” submitted by Bakey Billa, bearing ID No: T-151010 and Md. Omar Faruk Shawon, bearing ID No: T-151039, to the Department of Electronic and Telecommunications Engineering (ETE) of International Islamic University Chittagong (IIUC) has been accepted as satisfactory for the partial fulfillment of the requirements for the Degree of Bachelor in Electronic and Telecommunications Engineering and approved as to its style and contents for the examination held on 13th October 2019.

Approved by

Engr. Abdul Gafur

Supervisor

Associate Professor

Department of Electronics and Telecommunications Engineering

Faculty of Science and Engineering

International Islamic University Chittagong

Kumira, Sitakunda, Chittagong.

CANDIDATES DECLARATION

It is hereby declared that the work presented in this thesis has not been submitted elsewhere for the award of any degree or diploma, does not contain any unlawful statement.

Bakey Billa

T-151010

Md. Omar Faruk Shawon

T-151039

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Abstract

Wind power or wind energy is the use of air flow through wind turbines to provide the mechanical power to turn electrical generators and traditionally do other work. Wind power is a sustainable and renewable alternative for burning fossil fuels, and has much less effect on the environment. Electrical energy demand has been continuously increasing. Power generation using wind turbines is becoming viable solution as there is a demand for cleaner energy sources. Vertical axis wind turbines (VAWTs) are more efficient than the horizontal axis wind turbines (HAWTs) for low wind speed applications because of their ability to capture wind flowing from any direction. Therefore, VAWT systems are more suitable for residential and urban applications as they are universally adaptable. Major limitation observed in VAWT is high drag and turbulent force produced by the blade. In this thesis we are utilizing the air force that is generated due to vehicle velocity in Dhaka-Chittagong highway. We are using NACA-2424 as airfoil. NACA-2424 airfoil is selected and analyzed within the required range of Reynolds numbers and wind speeds in Q-Blade software. It is found that the power output is 100W at wind speed of 6 m/s. The estimated price per turbine is approximately 30500 takas only.

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LIST OF SYMBOLS

W	Watt
∞	infinity
α	alpha
m/s	meter per second
MW	mega watt
MT	metric ton
Kgoe	Kilogram Oil Equivalent
Tcf	Trillion cubic feet
MMcfd	million cubic feet per day
Bcf	billion cubic feet
Sq.km	square kilometer
BTU	British Thermal Unit
Lb	pound
GW	giga watt
R	radius
ϖ	omega
ρ	rho
μ	miu

C_l	lift coefficient
C_d	Drag coefficient

LIST OF ABBREVIATIONS

CNG	Compressed natural gas
IEEE	Institute of Electrical and Electronic Engineers
VAWT	Vertical axis wind turbine
HAWT	Horizontal Axis Wind Turbine
GPL	General public license
MSPA	Master Sales Purchase Agreement
TSR	Tip Speed Ratio
BPC	Bangladesh Petro Bangla corporation
SREDA	Sustainable & Renewable Energy Development Authority
REB	Rural Electrification Board
3D	Three Dimension
NGO	Non-Governmental Organization
PV	Photo voltaic
BAEC	Bangladesh Atomic Energy Commission
MOECO	Mitsui Oil Exploration Company Ltd.
BAPEX	Bangladesh Petroleum Exploration & Production Company Limited
NACA	National Advisory Committee for Aeronautics
LNG	Liquid Natural Gas
LPG	Liquefied petroleum gas
SHS	Solar Home System

Chapter 1

Introduction

1.1 Renewable energy overview

As concerns continue to increase over resource availability, energy prices, environmental impacts, and worldwide population growth, renewable energy production becomes paramount in maintaining current energy demands and meeting future requirements. Wind energy has prevailed as the most cost-effective source of renewable energy production.

Wind power or wind energy is the use of air flow through wind turbines to provide the mechanical power to turn electrical generators and traditionally do other work. Wind power is a sustainable and renewable alternative to burning fossil fuels, and has much less effect on the environment. Wind farms consist of many individual wind turbines, which are connected to the electric power transmission network. In modern days there is an increasing demand for power, but unfortunately there is less power generated than demand. As a result, people are using limited resources like fuel, coal etc. to generate power, which in turn produces greenhouse effect, global warming and other various types of problem. Not to mention these resources will come to an end one day. As such people are trying to compensate for that with renewable energy. There are several types of renewable energy that are currently in use to generate power such as, solar energy, tides, waves, geothermal etc. power generation with the help of non-conventional resource such as wind is increasing day by day and this type of power generation is very clean and safe.

1.2 Wind Energy Scenario in Bangladesh

Bangladesh is a mid-income country. Her GDP growth rate is one of the world's largest. For any country, development is the precondition for continued growth of GDP. And the main driving force of the country's development is energy. Proper use of energy is essential to meet the country's growing energy demands as well as to lift up from a mid-income country to a developed country. Energy is playing a vital role in implementing

Vision-2121, Vision-2041 and achieving Sustainable Development Goals. In Bangladesh, about 70 percent of energy demand is met from natural gas. Among other fuels- oil, coal, biomass etc. are vital. There is a huge reserve of coal in our country, but coal is less produced as well as less used here. On the other hand, natural gas reserve is not that substantial, but its production and consumption are the highest among the available resources. Besides those, energy demand is being met through imported oil and LPG. Moreover, the government has already started importing LNG to meet increasing gas demand. Biomass is being used as a lion's share of energy. The energy demand is also being met by importing electricity from India. The use of renewable energy instead of gas, coal and oil has been started in the whole world and is essential for sustainable development and keeping up with the environment by preventing carbon emissions. Many countries in the world like Sweden, Germany, China and USA are currently using renewable energy as a significant part of their energy demand. Bangladesh is also using renewable energy, but it's very less than necessity. The government has taken various steps to increase the use of renewable energy in the future, including solar home system, solar irrigation system, Rooppur nuclear project, etc. Development of energy sector is the key factor for continued development of the country. Bangladesh needs to emphasize on the new exploration activities using latest techniques to explore new mines. Apart from reducing dependence on natural gas, it needs to be coordinated with the imported LNG and enhance the percentage of usage oil and LPG; thereby Bangladesh will succeed in reaching its desired goal of development.[1]

1.3 Current Position of Energy Resources [1]

Known commercial energy resources in Bangladesh include indigenous natural gas, coal, imported oil, LPG, imported LNG, imported electricity and hydro-electricity. Biomass accounts for about 29% of the primary energy and the rest 71% is being met by commercial energy. Natural gas accounts for about 68% of the commercial energy. Imported oil accounts for the lion's share of the rest. Every year Bangladesh imports about 6.6 million metric ton of crude and refined Petroleum Products. Apart from natural gas and crude oil, coal is mainly used as fuel in the brick-fields and Thermal Power Plant. Moreover, power is also being generated by using Solar Home System (SHS) in on-grid and off grid areas. The amount of power generation using solar system is currently about

325 MW. In addition, there are some poultry and dairy farms in which bio-gas plants are being set up and this bio-gas is used for cooking and power generation. The amount of power generation from such plants is currently about 1 MW. Steps have been taken to generate electricity by Bio Mass Gasification Method in the country. Estimated final consumption of total energy is around 47 MTOE. Average increase of energy consumption is about 6% per annum. Per capita consumption of energy in Bangladesh is on an average 293 kgoe (Kilogram Oil Equivalent) and per capita generation of electricity is 464 kWh with an access to electricity 90%, which is lower than those of South Asian neighboring countries.[1]

Table 1.1: Energy calculation for 2017-18. [1]

Name of Fuel	Unit	MTOE
Oil (Crude + Refined + LPG) in K ton	6948	6.9
LPG	554	0.5
Natural Gas in Bcf	961	22.3
Coal (Imported) in K ton	3395	2.1
Coal (Local) in K ton	923	0.6
RE (Hydro) in MW	230	0.2
RE (Solar) in MW	350	0.3
Electricity (Imported) in MW	625	0.5
Sub- total		33.4
Biomass		13.6
TOTAL		47.0

1.4 Natural Gas Organizational Structure

Bangladesh Oil, Gas, and Mineral Corporation, short named Petro Bangla, under the Energy and Mineral Resources Division of the Ministry of Power, Energy and Mineral Resources is entrusted with the responsibility of exploration of oil and gas, and production, transmission and marketing of natural gas in the country.

1.4.1 Natural Gas Reserve

Since first discovery in 1955 as of today 26 gas fields, 24 in the onshore and 2 in the offshore have been discovered in the country. Of them 19 gas fields are in production, one offshore gas field have depilated after 14 years of production while other offshore field has not been viable for production due to small reserve. The estimated proven plus probable recoverable reserve was 28.69 Tcf. As of June 2018, a total of 15.96 Tcf gas has already been produced leaving only 12.72 TCF recoverable reserve in proven plus probable category. Some key information about the natural gas sector is presented in the Table 1.2. [1]

Table 1.2: Gas Sector at a Glance [1]

Total number of gas fields	26
Number of gas fields in production	19
Number of producing wells	110
Present gas production capacity	2750 MMcfd
Avg. gas production rate	2633 MMcfd
Highest Production (6th May, 2015)	2785.80 MMcfd
Total recoverable (Proven + Probabale) reserve	28.69 Tcf
Cumulative Production (June,2018)	15.96 Tcf
Annual Production by NOC	385.34 Bcf (40 %)
Annual Production by IOC	575.43 Bcf (60 %)
Remaining Resurve (Proven + Probabale)	12.72 Tcf
Present Demand	3649 MMcfd
Present Deficit	1016.75 MMcfd
Number of Customer	41.80 lakh (Appx.)

1.5 Natural Gas Consumption

The current average production of natural gas is about 2633 MMcfd. A total 961 billion cubic feet (BCF) of natural gas was produced in 2017-18 which was used by power-40%, fertilizer-5%, captive power-16%, industry-17%, domestic-16%, CNG - 5% and others very small amount. Natural gas accounts for the 66% grid electricity generation while all the 7 urea fertilizer factories are dependent on natural gas for feedstock. Natural gas has made tremendous contribution towards industrial growth in the country as fuel for heating and captive power generation at very favorable price. While the whole nation has been benefitted by this resource, about 7% of the populations have directly been benefitted by using piped natural gas for household purposes. Compressed National Gas is being used as automobile fuel by about 250,000 motor vehicles in the country. Expansion of CNG facilities early last decade dramatically improved air quality in large cities especially in the capital Dhaka as well as lot amount of foreign exchange has been saved due to less amount of oil import.[1]

1.6 LNG import to Supplement Indigenous Supply [1]

- Currently, daily 500 mmcf re-gasified LNG is added to the national grid through installing floating LNG terminal by Excelerate Energy, Singapore at Maheshkhali in Cox's Bazar district.
- SUMMIT LNG Terminal Co. (Pvt) Ltd. has signed the Agreement (BOOT) to set up FSRU at Maheshkhali in Cox's Bazar district with a capacity of supplying daily 500 mmcf re-gasified LNG. More 500 mmcfd re-gasified LNG will be added to the national grid by January 2019.
- The agreement (G to G basis) to buy LNG from Qatar has been signed with RasGas, a state-owned company for a contract period of 15 years.
- 30 organizations have been shortlisted for the purchase of LNG from Spot Market. It is expected that the final Master Sales Purchase Agreement (MSPA) will be signed with these companies soon.

- Land Based LNG Terminal installation projects are underway at Maheshkhali and Kutubdia, each with a capacity of 1000 mmcfd.

1.7 Exploration Activities

The exploration activities in Bangladesh are mostly limited to eastern folded belt and surrounding areas. On the basis of previous geo-scientific study, it seems that the middle part of the country geologically knows as Bengal Fore deep and Eocene shelfal region popularly known as Hinge Zone also have high Potential for hydrocarbon exploration. The objective of 2D seismic survey is to explore remaining potential of the Bengal Foredeep hydrocarbon- geological province in the least explored part of the country. In this regard, two projects on 2D seismic survey being financed by the Gas Development Fund have been approved by the Govt. Besides, with a view to identify new locations for drilling well in the exploration gas fields of structures for mitigating the ever- growing crisis of gas, 3D seismic data were gathered during 2017-2018 field season over Fenchuganj and Rupganj gas fields. Moreover, a joint study with mitsui Oil Exploration Company Ltd. (MOECO), Japan and BAPEX for interpretation of 20 possible leads and prospects in block 8 & 11. [1]

1.7.1 2D seismic Survey Activities [1]

The work programs for carrying out 3600 Line Km of 2D seismic survey has been approved the authority. Areas to over are Khulna and Bagerhat as well as Dhaka, Manikganj, Kishorganj, Narayanganj, Comilla, Faridpur, Gopalganj, Shariatpur, Madaripur, Narail, Netrakona, Kishorganj, Tangail, Gazipur, Jamalpur, Sherpur, Mymensingh and Bagura, of the exploration blocks 2B, 3B, Feni, Chittagong and Khagrachari of exploration

blocks 10, 12, 13, 14 and 15. Seismic data already been collected from the target 3600 Km. About 8-9 prospective leads/prospects have been identified and well proposals have been recommended. Under the 2D Seismic Survey over Exploration Block 3B, 6B & 7 Project of BAPEX, a total of about 2226 LKm 2D seismic data have been acquired by hired international seismic survey contractor during the field season 2017-2018 in Dhaka, Gazipur, Narayangonj, Munshigonj, Tangail, Rajbari, Faridpur, Shariatpur, Madaripur, Gopalganj, Barisal, Pirojpur, Jhalokhati, Patuakhali, Barguna, Bhola and Bagerhat areas under exploration block 3B, 6B & 7. After thorough investigation 20 potential seismic lead have been identified which demands extensive exploration activities to keep up the growing demand of natural gas for the last growing economic development of the country. Under the ‘Vision 2021’ BAPEX has proposed 19 exploratory wells to be drilled under exploration Block-B & Block- 11. In order to accelerate oil and gas exploration activities, BAPEX is expected to find new resource in these areas by conducting highest quality 2D seismic exploration. From the fiscal year 2017-18, a project tilted “Rupkalpa-9: 2D Seismic Project” has been approved by the Energy & Mineral Resources Division in the period of April, 2017 to June, 2019 to conduct 3000 LKm 2D seismic survey financed by gas development Fund (GDF) under Petrobangla. This project has been designed to finalize the Proposed exploratory well location under vision 2021 by conducting regional to semi detail/close gird 2D seismic survey. The Project area includes Kishoreganj, Narsingdi, Gazipur, Tangail, Jamalpur, Sherpur, Mymensingh, Netrakona and Sunamganj districts. During FY 2017-2018, 810 LKm seismic survey has been completed. Processing of acquired data is going on. 3D Seismic Survey: With a view to meeting the growing gas demand of the country and demarcate new well locations in the discovered gas fields or hydrocarbon prolific structures, a project titles “3D Seismic Project of BAPEX” has been approved by the Energy & Mineral Resources Division for the duration of December, 2012 to November, 2019 with an estimated cost of 247.70 crore BDT financed from the Gas Development Fund (GDF). A work plan has been undertaken to acquire 3D seismic data over 2700 sq. km. area of Sunetra, Srikail, Sundalpur,Begumganj, Shahabazpur, Narsingdi, Mubarakpur, Rupganj, Fenchuganj and Semutang gas fields or structures. Data from a total of 500 sq. km. area gas been collected during 2017-2018 field season that includes 300 sq. km. area has been accomplished under this project so far. 3D seismic data interpretation of

Fenchuganj Gas Field and data processing of Rupganj gas field area is in progress. As per the Government directives during this fiscal, two wells were drilled by Gazprom and two wells were drilled as five work overs by BAPEX using its own rigs and crew.

1.7.2 Oil (Petroleum) Sector Organizational Structure

Bangladesh Petroleum Corporation under the Energy & Mineral Resources Division of the government is the nodal organization in the petroleum sectors which deals with import of crude oil and products, oil refining and marketing finished petroleum products. One refining company with lone crude oil refinery in Chittagong is engaged in refining of crude oil while four oil marketing companies are responsible for marketing of finished products across the country.

Oil business used to be government monopoly until 1997 when one private company entered in fractionation of gas condensate extracted from gas fields. Presently, gas condensates, are fractionated by small scale fractionation plants of Petro bangla, BPC and private entrepreneurs. Besides, there two petrochemical plants in the private sector that imported condensate as feed.

1.7.3 Supply and Consumption of Oil [1]

Petroleum products viz. diesel, petrol, octane furnace oil etc., account for about 22% commercial energy supply in the country. Liquid fuel used in Bangladesh is mostly imported. Locally produced gas condensate shares only 6% of total liquid fuel consumption. Bangladesh imports about 1.2 million metric tons of crude oil along with 5.5 million metric tons (approx.) of refined petroleum products per annum. About 4319 thousand BBL per year locally produced gas condensate, which is fractionated mainly into petrol, diesel and kerosene, is the only domestic source of liquid fuel. Major consumer of liquid fuel is transport followed by power, agriculture, industry and commercial sectors. Sector-wise consumption of petroleum products are: transport-49.40%, power-26.94%, agriculture 15.70%, industry4.86%, domestic-2.26% and others 0.85%.

Table 1.3: Petroleum Sector at a Glance (2017-18) [1]

Total Consumption of POL	69.48 Lac MT.
Import of Refined Oil	55.42 Lac MT.
Import of Crude Oil	11.73 Lac MT.
Import of Furnace Oil	13.99 Lac MT
Export of Naphtha	18,584 MT.
Total Storage Capacity	12.21 Lac MT
Domestic Production of LPG	15,936 MT
Production of LPG Under Private	5,37,686 MT
Demand of POL in FY 2018-19	76 ac MT

1.8 Liquefied Petroleum Gas (LPG) [1]

Demand of Liquefied Petroleum Gas (LPG) in Bangladesh is very high. In the public sector 15,936 MT of LPG are bottling every year, out of which 10000 MT is obtained as byproduct from processing of crude oil in Eastern Refinery and 6000 MT from is extracted from natural gas in Kailashtila gas field. LPG is imported by only private sector. Around 537,686 MT of LPG is imported and marketed by private sector entrepreneurs every year. So public and private sector combining do the marketing of 553,622 MT of LPG every year, which is meeting a certain portion of LPG demand of the country. Considering the rising demand for LPG, government has decided to enhance LPG bottling facilities for marketing more imported LPG. For this purpose, two LPG bottling plants, each having capacity of 100 thousand MT per annum, will be set up in the coastal area. Of them, one plant will be installed by Bangladesh Petroleum Corporation (BPC) and the in public private partnership with BPC.

Table 1.4: LPG scenario of last 4 year [1]

Year	Public Sector ProductionMT	Import (Private) MT	Total MT
2014-15	17,574	110,000	127,574
2015-16	14,000	172,792	186,792
2017-18	16,382	307,000	323,382
2017-18	15,936	537,686	553,622

1.9 Coal [1]

In Bangladesh, the reserve of coal (Bituminous Coal) is about 31,00 million tones which is equivalent to 85 Tcf gas in 5 coal fields so far discovered, namely Barapukuria, Khalaspir, Phulbari, Jamalganj and Dighipara. If initiatives are taken for exploration all over the country, there are enough possibilities to discover more coal mines. Out of the discovered mines, coal from 4 deposits (118-509 meters) is extractable at present. Production from Jamalganj may not be viable with present day's technology due to the depth of the deposits.

Table 1.5: Coal Fields of Bangladesh [1]

Place/Field (Discovery Year)	Depth (Meter)	Area (Sq.Km)	Reserve (Million Ton)	Depth (Meter)	Calorific Value (BTU/lb)
Barapukuria, Dinajpur (1985)	119-506	6.68	390	119-506	11,040
Khalaspir, Rangpur (1995)	257-483	12.00	523	257-483	12,700
Phulbari, Dinajpur (1997)	150-240	30.00	572	150-240	11,900
Jamalganj, Jaipurhat (1965)	900-1000	16.00	1,054	900-1000	11,000
Dighipara, Dinajpur (1995)	327	15.00	600	327	13,090
			Total = 3139		

Coal resources can be alternative source of fuel to natural gas. These coals can conveniently serve the energy needs of Bangladesh for 50 years. It is notable that the coal of Bangladesh is considered to be high quality in terms of its high level of heat generation capacity as well as low Sulphur content.

Table 1.6: Coal scenario of last 4 year [1]

Year	Public Sector Production	Import (Private)	Total
2014-15	675,775.50	1,812,030	2,487,806
2015-16	1,021,638	3,812,060	4,833,698
2017-18	1,160,657.81	2,801,407	3,962,065
2017-18	923,276.00	3,394,534.24	4,317,810

Commercial production of Barapukuria Coal Mine commenced from 10 September 2005 using underground mining method with the targeted capacity of one million metric ton per year. Almost 65% of the production is being used by 250 MW (2x 125 MW) Coal fired power station operated by Power Development Board of Bangladesh near Barapukuria coal mine. Remaining 35% coal is being used in brick fields and other domestic purposes which have an impact of reducing deforestation. A total of 67.50 lakh metric ton of coal has been extracted from its inception up to June 2018. At present Barapukuria Coal Mine is producing at an average –2500-3000 MT coal per day.

1.10 New-Renewable Energy Resources [1]

It was mentioned in the Renewable Energy Policy 2008 that 5% and 10% of total electricity would be generated using renewable energy by 2015 and 2020 respectively (GOB 2008). SREDA Act 2012 was enacted for the establishment of Sustainable & Renewable Energy Development Authority (SREDA) for promotion of efficient energy and renewable energy technology. The authority (SREDA) is in the process of institutionalization. Total generation of electricity from new-renewable energy sources (e.g. solar PV, biomass, biogas etc.) up to June 2018 was 339.80 MW. Total generation from RE including hydropower (230MW) was 569.80MW, which was 3% of total electricity generation capacity (18,753 MW) of the country including off grid, RE and Captive. In line with the policy, government has already taken different initiatives in renewable energy development, in which some projects/programs have been completed and some are under implementation.

1.10.1 Solar Energy [1]

Bangladesh is geographically located in a favorable position (within 20034′ to 26038′ north latitude) for harnessing sunlight, available abundantly for most of the year except for the three months June-August when it rains excessively. The amount of Solar Energy available in Bangladesh is high about 4 to 7 kWh/m2/day, enough to meet the demand of the country. There is a fast-growing acceptance of rural people to solar photovoltaic (PV) systems to provide electricity to households and small businesses in rural off grid areas. The Rural Electrification Board (REB), a government agency has been engaged in commercializing solar power electrification of domestic, commercial, irrigation in rural area. IDCOL, a government-owned entity has disseminated some SHS through its partners NGOs. Due to higher cost of its production it has to go a long way to become commercially competitive. However, in remote areas of Bangladesh it is gradually becoming popular and government has undertaken a lot of scheme to subsidize on it. Government has planned to setup solar panel with capacity of 5~10 MW.

1.10.2 Solar Home System (SHS) [1]

Solar Home System (SHS) provides reliable power for lighting and operating low powered appliances such as radio, television, small electric fans. The electricity provided by a SHS can also be used to run Direct Current (DC) driven equipment such as DC shouldering irons, drilling machines etc. and to charge the battery of mobile phones. Larger systems can run computers, refrigerators, pumps etc. IDCOL and BREB are distributing Solar Home System (SHS) to the people living in the off-grid areas. IDCOL through different partner organization has already distributed about 55 lakhs (installed capacity 250 MW) SHS and BREB distributed about 30 thousand SHS throughout the country.

1.10.3 [Solar Irrigation System]

Solar powered irrigation is the breakthrough technology for energy stricken agro-based economy. Solar powered irrigation is the innovative and environment friendly solution for the irrigation system, which currently depends on hugely inefficient electric and diesel pumps. Gradually replacing the electric and diesel pumps for irrigation with solar water pumps could save significant capacity of electricity and huge investment cost. Up to June'18, a 1158 no's solar irrigation pump has been installed by IDCOL.

1.10.4 Bio fuel [1]

Bio fuels can be produced from a variety of plants like rapeseed, mustard, corn, sunflower, canola algae, soybean, pulses, sugarcane, wheat, maize, and palm. The most popular option for producing bio-fuels is from non-edible oilseed bearing trees. The two most suitable species are: Jamal gota (Jatropha curcas) and Verenda (RicinusCommunis). Both of these trees can grow virtually anywhere in any soil and geo- climatic condition. Bio-fuel use is not new in Bangladesh. In the early 20th century, bio-fuel was used for lighting lamps or lanterns. In an agriculturally based country like Bangladesh, bio-fuel can be a better alternative because a 30 percent blend of bio-fuel can be used along with our diesel or petrol. This can also be an excellent fuel to kindle lamps in rural Bangladesh. The use of bio-fuel is increasing in most European countries. Germany has thousands of filling stations supplying bio-fuel and it is cheaper than petrol or diesel. The German government declared that 5 percent of every liter of fuel must be bio-fuel by 2010.

1.10.5 Wind Energy [1]

Bangladesh is exploring the potential of wind power. In the coastal area of Bangladesh, windmills with a capacity of 2.9 MW are in operation. Bangladesh has had to wait for a breakthrough in wind power technology to be competitive against other conventional commercial energy sources. A pilot project to install windmills along the seashore with a capacity of 20 MW has been planned by the government. Based on the results of the pilot project, another 200 MW of power could be harnessed from wind power. Rising fossil fuel and CO2 prices, technological advances and economies of scale with wider deployment are expected to make renewable-based systems increasingly cost competitive in coming decades (IEA 2011).

1.10.6 Tidal Energy [1]

The tides at Chittagong, south east of Bangladesh are predominantly semidiurnal with a large variation in range corresponding to the seasons, the maximum occurring during the south-west monsoon. A strong diurnal influence on the tides results in the day time tides being smaller than the night time. In the year 1984, an attempt was made from the EEE department of BUET, Dhaka to access the possibility of tidal energy in the coastal region of Bangladesh, especially at Cox's Bazar and at the islands of Maheshkhali and Kutubdia. The average tidal range was found to be within 4-5 meter and the amplitude of the spring tide exceeds even 6 meters. From different calculation it is anticipated that there are a number of suitable sites at Cox's Bazar, Maheshkhali, Kutubdia and other places, where a permanent basin with pumping arrangements might be constructed which would be a double operation scheme. Tidal energy might be a good alternative source for Kutubdia Island where about 500 kw power could be obtained. At present there are only 2x73kVA diesel generator sets to supply electricity for 5-6 hours/day for 72,000 people and there is practically no possibility of main grid supply in the future.

1.10.7 Wave Energy

Until to now no attempt has been made by Government of Bangladesh to assess the prospects for harnessing energy from sea waves in the Bay of Bengal. Wave power could be a significant alternative source of energy in Bangladesh with favorable wave conditions especially during the period beginning from late March to early October. Waves are generally prominent and show a distinct relation with the wind. Waves generated in the Bay of Bengal and a result of the south-western wind is significant. Wave heights have been recorded by a wave rider buoy and correlated with wind data. Maximum wave heights of over 2 m, with an absolute maximum of 2.4 m, on the 29 July were recorded. The wave period varies between 3 to 4 sec for waves of about 0.5 m, and about 6 sec for waves of 2 m. In Bangladesh wind speeds of up to 650 kmph (400mph), 221 kmph (138 mph) and 416 kmph (260 mph) have been recorded in the years 1969, 1970 and 1989 respectively. Severe cyclonic storms and storm surge of up to 15 m have been reported. Plant must also be able to survive the exceptional occurrence of very high waves in storm conditions.[1]

1.10.8 River Current [1]

A network of rivers, canals, streams etc. numbering about 230 with a total length of 24140 km covers the whole of Bangladesh flowing down to the Bay of Bengal. Different sizes of boats are the main carriers of people and goods for one place to another. Boatmen usually use the water-sails to run their boasts against the wind direction. But until now no research has been reported to utilize the energy of river current properly.

1.10.9 Waste to Electrical Energy

Dhaka City has been suffering for a long time from a tremendous environmental pollution caused by municipal solid waste, medical waste and various industrial wastes. In order to save the city from environmental pollution the waste management as well as electricity generation from the solid wastes program is being taken by the Government.

1.11 Nuclear Power [1]

Nuclear powers are characterized by very large up-front investments, technical complexity, and significant technical, market and regulatory risks, but have very low operating costs and can deliver large amount of based load electricity while producing almost no CO_2 emissions. Typical construction times are between five and eight years from first concrete poured. Government of Bangladesh has signed a general contract with Russia on December 25, 2015 for the construction and commissioning of the country's first nuclear power plant (2*1200 MW) at Rooppur in Pabna at the cost of $12.65 billion.

Table 1.7: Planned Nuclear Power Reactors [1]

Unit	Type	Capacity	Construction start	Commercial Operation
Rooppur 1	VVER-1200/V-523	1200 MWe	Oct 2017	2023 or 2024
Rooppur 2	VVER-1200/V-523	1200 MWe	2018	2024 or 2025

All fuel for Rooppur is being provided by Rosatom, and all used fuel is to be repatriated to Russia, in line with standard Russian practice for such countries. A draft agreement on used fuel was signed in March 2017, totaling about 22.5 ton/year from each reactor (42 fuel assemblies, each with 534 kg of fuel). A further agreement for repatriation of used fuel for reprocessing was signed in August 2017. The Bangladesh Atomic Energy Commission (BAEC) has taken an initiative to conduct a survey in eight char areas of southern region to select one or two suitable sites to set up the country's second nuclear power plant, aiming to meet the future demand of huge electricity. The study will cover a demographic survey over a 5-km diameter, seismic stability, geological location, and power infrastructure and communication system.

1.12 Electricity sector in Bangladesh [1]

The utility electricity sector in Bangladesh has one national grid with an installed capacity of 21,419 MW as of September 2019. The total installed capacity is 20,000 MW (combining solar power). Bangladesh's energy sector is booming. Recently Bangladesh started construction of the 2.4-gigawatt (GW) Rooppur Nuclear Power Plant expected to go into operation in 2023. According to the Bangladesh Power Development Board in July 2018, 90 percent of the population had access to electricity. However per capita energy consumption in Bangladesh is considered low.

Electricity is the major source of power for most of the country's economic activities. Bangladesh's total installed electricity generation capacity (including captive power) was 15,351 megawatts (MW) as of January 2017 and 20,000 megawatts in 2018.

The largest energy consumers in Bangladesh are industries and the residential sector, followed by the commercial and agricultural sectors.

As of 2015, 92% of the urban population and 67% of the rural population had access to electricity. An average of 77.9% of the population had access to electricity in Bangladesh. Bangladesh will need an estimated 34,000 MW of power by 2030 to sustain its economic growth of over 7 percent.

Problems in 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.

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 investigating team has clarified that the fault was actually due to lack of coordination and poor health of transmission and distribution infrastructure that caused the blackout.

1.13 Overview on Highways

The table 1.8 is representing different features of the highways. The length of Dhaka-North Bengal highway is 657 km, Dhaka-Chittagong highway is 265 km, Dhaka-Sylhet 214 is km and Daulatdia-Khulna highway is 187 km. These are the major highways of Bangladesh. Average vehicle speed is 70-90 km/hr. Average wind speed is about 3.5-9.5 m/s. Moreover, the most important factor is these highways are not disaster prone.

Table 1.8 Showing the different feature of highways related to the vehicle and wind speed [2][3][4]

Highway Name	**Length (Km)**	**Median in Roads**	**Percentage of Vehicle (yearly)**	**Avg. Vehicle speed (Km/hr.)**	**Avg. wind speed (m/s)**	**Disaster prone**
Dhaka - Chittagong	250	Yes	5632798	60~85	3.5 ~ 5.5	No
Dhaka-Sylhet	214	No	2124540			
Dhaka- North Bengal	657	No	2962192			
Daulatdia Khulna	187	No	1800000			

In Dhaka-Chittagong highway there are 4.5+ meter free space which can be used. In field work, we saw that, at average, 11782 vehicles travel by this road everyday with maximum of 85km/h and minimum of 65km/h velocity. By this speed, they generate high speed air flow. In field survey, we observed that the speed of air using anemometer was around 3.00 to 7.00 m/s. In this thesis, we utilize this air velocity by using vertical type wind turbine for producing energy.

Figure1.1**:** Median in Roads of Dhaka- Chittagong Highway

1.13.1 Average Busses & Trucks Move in a Day in Dhaka-Chittagong Highway

The N1 or Dhaka–Chittagong Highway is a main transportation artery in Bangladesh, between Dhaka and Chittagong. Approximately 250 kilometers (200 miles) in length, the road links the country's two largest cities, Dhaka and Chittagong. The highway is known along various stretches as the Chittagong–Cox's Bazar Highway and the Cox's Bazar–Teknaf Highway. Currently two lanes with a four-lane expansion underway, the N1 is the busiest road in the country and a top development priority.

Daily a huge number of busses and truck moves in this highway. Average Busses & Trucks Move in a Day in Dhaka-Chittagong Highway are given below;

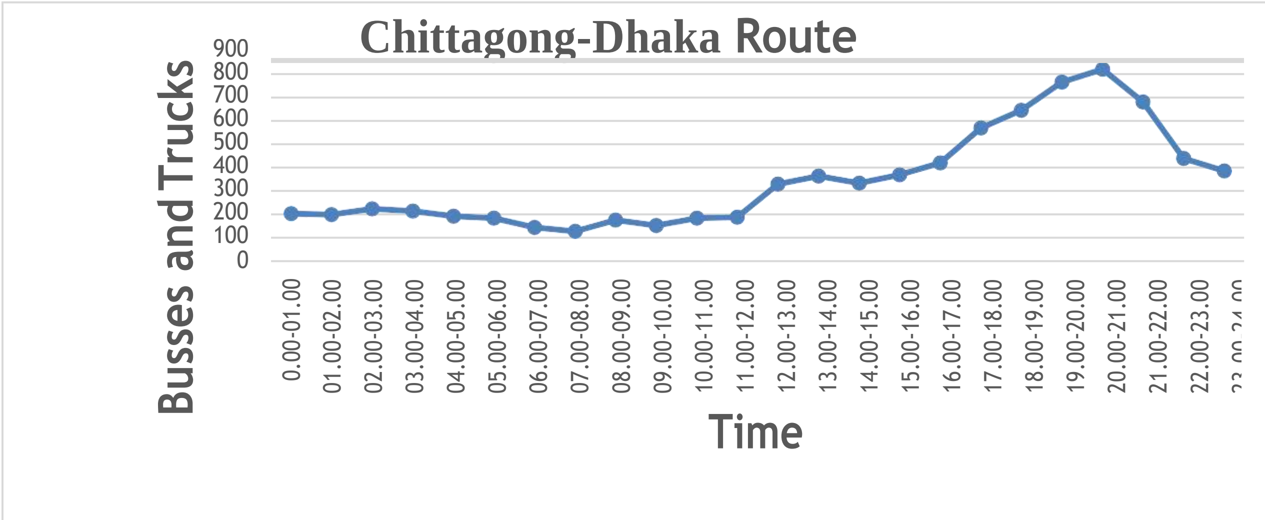


Figure1.2: Busses and Truck moves in a day (Ctg-Dhaka route)

The above figure exhibits vehicles frequency in 24 hours period in the Chittagong to Dhaka route. From the graph we can see that the highest number of vehicles passes in the 20.00 to 21.00 period, around 800 vehicles passes in that time period.

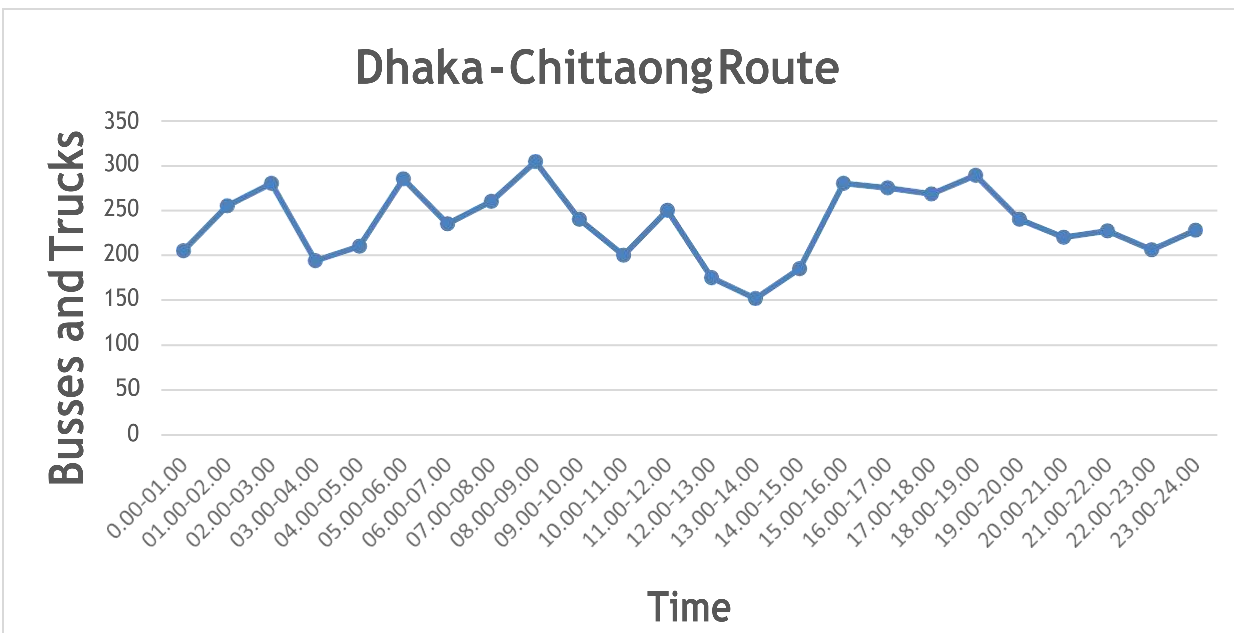


Figure1.3: Busses and Truck moves in a day (Dhaka -Ctg route)

The above figure exhibits vehicles frequency in 24 hours period in the Dhaka to Chittagong route. From the graph we can see that the highest number of vehicles passes in the 07.00 to 08.00 period, around 300 vehicles passes in that time period.

1.13.2 Average Wind speed in a Day at Dhaka-Chittagong Highway

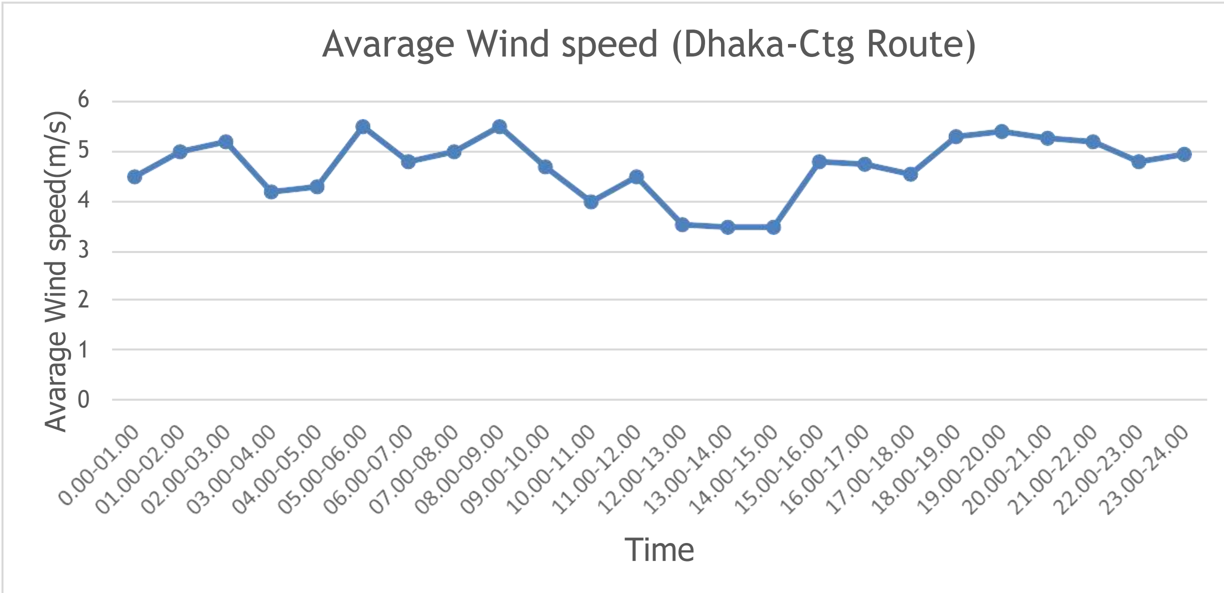


Figure1.4: Average wind speed in a day

We used anemometer to measure the wind velocity generated by the moving vehicles. This graph shows the average wind speed generated by the moving vehicles in a 24 hours period. From the chart we can see that the highest wind power that we got in in the time period of 20.00 to 21.00, and the wind speed in 10 m/s. From the vehicle's frequency chart, we can see that the greatest number of vehicles circulate in this time frame. As a result, more wind is generated. Normally trucks enter and exit Chittagong city at this time as a result an increase in vehicles frequency.

1.14 Types of Wind Turbines

Two major types of wind turbines exist based on their blade configuration and operation. The first type is the horizontal axis wind turbine (HAWT). HAWTs sit atop a large tower and have a set of blades that rotate about an axis parallel to the flow direction. These wind turbine blades operate similar to the rotary air craft. The second major type of wind turbine is the vertical axis wind turbine (VAWT). This type of wind turbine rotates about an axis that is perpendicular to the oncoming flow; hence, it can take wind from any direction. VAWTs consist of two major types, the Darrieus rotor and Savonius rotor. The Darrieus wind turbine is a VAWT that rotates around a central axis due to the lift produced by the rotating airfoils, whereas a Savonius rotor rotates due to the drag force created in blades. There is also a new type of VAWT emerging in the wind power industry which is a mixture between the Darrieus and Savonius designs.

1.14.1 Horizontal Axis Wind Turbines

The blades of a HAWT work to extract energy from the wind by generating lift, resulting in a net torque about the axis of rotation. To accomplish this task efficiently, especially for large HAWTs, active pitch controllers are used to ensure that each blade is adjusted to maintain an optimal angle of attack for maximum power extraction for a given wind speed. However, in HAWT contains more complex parts like control system and it require more moving parts and effort to install than a VAWT assembly where the only moving part is the rotor and the majority of components are located at the base of the turbine.

1.14.2 Vertical Axis Wind Turbines [5]

Now days VAWTs have been gaining popularity due to interest in personal green energy solutions. Small companies all over the world have been marketing these new devices such as Helix Wind, Urban Green Energy, and Wind spire. VAWTs target individual homes, farms, or small residential areas as a way of providing local and personal wind energy. This produces an external energy resource and opens up a whole new market in alternative energy technology. Because VAWTs are small, quiet, easy to install, can take wind from any direction, and operate efficiently in turbulent wind conditions. VAWT is relatively simple its major moving component is the rotor and the more complex parts like the gearbox and generator are located at the base of the wind turbine.

This makes installing a VAWT a painless undertaking and can be accomplished quickly. Manufacturing a VAWT is much simpler than a HAWT due to the constant cross section blades. Because of the VAWTs shows simple manufacturing process and installation, they are perfectly suited for residential applications. An S-VAWT generates electricity through drag force rather than lift force like the D-VAWT.As the wind hits the concave portion of the blade (the bucket), it becomes trapped and pushes the blade around, advancing the next bucket into position. This continues as long as the wind is blowing and can overcome the friction of the shaft about which the blades rotate. A Savonius rotor typically rotates with a velocity equivalent to the speed of the free stream velocity, or a tip speed ratio of one. Because of its lower rotation speed, Savonius rotors shows lower efficiencies and are not capable of providing adequate electricity, but it is used to reduce the overall dependence on other energy resources. However, due to the Savonius wind turbines simplicity, manufacturing is very easy; some have even been built using large plastic blue poly drums with the capability of providing up to 10% of a household's electricity in drag-based wind turbines, the force of the wind pushes against a surface, like an open sail. It works because the drag force of the open, or concave, face of the cylinder is greater than the drag force on the closed or convex section.

1.15 Design Tool

1.15.1 QBlade

QBlade is an open source wind turbine calculation software, distributed under the GPL. The integration of the XFOIL/XFLR5 functionality allows the user to rapidly design custom airfoils and compute their performance polar and directly integrate them into a wind turbine rotor design and simulation. The software is especially adequate for teaching, as it provides a 'hands on' design and simulation capabilities for HAWT and VAWT rotor design and shows all the fundamental relationships of design concepts and turbine performance in an easy and intuitive way. QBlade also includes extensive post processing functionality for the rotor and turbine simulations and gives deep insight into all relevant blade and rotor variables. In addition to that, the resulting software is a very flexible and user-friendly platform for wind turbine blade design. [6]

1.16 Motivation

The motivation for designing a highway wind turbine is to contribute towards the global trend in wind energy production in a feasible way. Wind turbines are traditionally employed in rural areas, the goal of this research is to design a wind turbine that can be used in Dhaka-Chittagong highway. In particular, the turbines will use the wind draft created by vehicles on the highway to generate electricity. The idea is to offset the amount of pollution created by burning fossil fuels by introducing a potential source of clean energy.

Chapter 2

Literature Review

2.1 Paper Review

1. Research paper on "Home-Scale Vertical Axis Wind Turbine Design"

In this research paper, the author portraits the electricity demand in Indonesia. He projected that by the year 2019, electricity in Indonesia rises to 50,530 MW, and by the year 2024, is projected to rise to 74,536 MW. The author designed a Vertical Axis Wind Turbine (VAWT) that is affordable enough to be used in a normal household. He estimated the price to be less than $500 US dollar. The design intended to provide an alternative power source for houses in a remote area with no or limited power source from a power plant.[7]

2. Research paper on "Vertical Axis Wind Turbine for Highway Application"

In this research paper, the authors proposed the highway as the place for turbine placement. The authors will take advantage of the moving vehicles on both sides of the road. In the present work, the turbine is designed and fabricated as per the specifications, the blades used are the semi-circular shape and are connected to the disc which is connected to the shaft. The shaft is then coupled with pulley with the help of bearing, and then pulley is connected to the alternator, which generates the power. The power developed is stored in a battery and then can be used for street light, signal or toll. The aim is to provide maximum output at minimum cost. The average power output was 28.3 watts, where the average wind speed was 6.1 m/s. [8]

3. Research paper on "Highway Power Generation using Low-Cost Vertical Axis Wind Turbine [VAWT]"

In this paper, the fabrication of prototype model of Savonius type Vertical Axis Wind Turbine (VAWT) is made using easily available materials like front wheels of a bicycle with ball bearing, half-cut PVC pipes, wooden base, etc. The Vertical Axis Wind Turbine is placed n the median of the highway to gain maximum wind velocity. The vehicles from both sides of medians accelerate the wind thus increasing its kinetic energy which forces the turbine blades to rotate in a clockwise direction. This drives the rotor which is connected to a DC generator, thus producing electricity. The effort is made to produce electricity at low cost. This electricity can be used for multiple applications like the smart highway system, toll booths, highway lighting, etc. [9]

4. Research paper on “The Development Of Wind Power Energy For Lighting System In The Highway”

In this research paper, the authors selected “Pasir Gudang Highway (FT17)” as the placement for Vertical Axis Wind Turbine. A DC motor will be used to generate power and the power is saved in a 6V battery. The power is then supplied to the highway lighting system. It takes roughly 5 to 6 hours to completely charge the battery. Arduino UNO is used in this project with LabVIEW via LabVIEW Maker Hub. In here maximum output voltage of 6.25V volt was achieved for the wind speed of 32Km/h. The maximum power output was 7.8125W for the current 1.25 Ampere. [10]

5. Research paper on “Power Generation On Highway Using Vertical Axis Wind Turbine And Solar Energy”

In this research paper, the authors focus on the use of air in the highway divider with the help of a Vertical Axis Wind Turbine. The vehicles on the highway produce a considerable amount of air due to its speed. The air then tangentially strikes the blades of the turbine and makes them spin in a single direction. The solar system is installed in a way that helps in directing the air to the turbine blades. The VAWT system together with the solar system produces electricity. This electricity is stored in a battery and then supplied to where necessary. For the VAWT maximum of 9.8 Volt was achieved with a wind speed of 15.33 m/s. The maximum solar panel output was 19.68 volt and together the maximum output was 29.48 Volt. [11]

6. Research paper on “Potential Energy Sources from Highway Wind Turbine and Solar Panel: A review work for the perspective of Bangladesh.”

In this research paper, the author selected the medians of a highway as a place for turbine placement. The highest power of 77 watts was achieved for a wind speed of 10 m/s. The total cost of the design VAWT was 12000 BDT. The average electrical power output obtained was around 28W from a single turbine and its equivalent to 28 KWh/day. For a payback period of 9 years, the per-day cost is 2 takas only.[12]

7. Research paper on “Comparing the calculated coefficients of performance of a class of wind turbines that produce power between 330 kW and 7,500 kW”

The calculated coefficients of performance (CP) of wind turbines that produce power between 330 kW and 7,500 kW were compared using wind speeds that varied from 1 m/s to 25 m/s. The largest coefficients of performance were found to occur with wind speeds between 5 m/s and 10 m/s. Results show that each turbine is capable of producing coefficients of performance of, or near, 0.5; and the turbines studied proved to have essentially the same coefficients of performance when exposed to similar wind speeds. Consequently, turbines with larger rotor diameters are not necessarily more efficient than those with smaller diameters, or vice versa. Therefore, when it comes to energy production, these data indicate that the advantage of turbines with larger rotor diameters is not in their efficiency. Rather, it is in the larger areas swept by their rotors, which expose them to more incoming wind energy. [13]

8. Research paper on “Performance and Productivity Enhancements on Vertical Axis Wind Turbines with a Novel multi-stages Contra-rotating Technique”

Is this research paper the author presents the development of multi-stages and contra-rotating (MSCR) vertical axis wind turbine (VAWT) an attempt to enhance its performance and energy productivity. It is achieved by rising capture capability of the wind energy by additional captured area. The double-stages MSCR technique on a VAWT system that can make almost four times amount of power output if it is compared with a single-stage VAWT. Maximum power of 200W was achieved for a wind speed of

4.5 m/s on a 3SCR system. Whereas a maximum power output of less than 50W was achieved in a normal single VAWT configuration. [14]

9. Research paper on “A system approach to harnessing wind energy in a railway infrastructure”

This paper focuses on a system approach aimed at harnessing the wind potential in railway infrastructure. The key aspect of the proposed system lies in using the mass of air displaced during the movement of a train along a railway track to produce electrical energy. The proposed conversion system to integrate the system consists of a low voltage AC/DC stage and a DC/DC stabilization stage per wind generator, and an isolation stage based on a Solid-State Transformer (SST), which connects all the generators and allows to inject the energy generated to the medium voltage DC catenary. Total energy production of 21.87 KWh/day was achieved. [15]

10. Research paper on “Feasibility of Highway Energy Harvesting Using a Vertical Axis Wind Turbine”

This research presents an experimental study of using a three-bladed helical VAWT specially designed and manufactured for producing electrical energy from wind energy of moving cars on highways for lighting purposes such as the highway lights, traffic signals, and light guidelines. Results show that the VAWT prototype has produced up to 48-Watts of power from vehicles moving on the highway, which produce an average wind speed of 4.4 m/s.[16]

11. Research paper on ” CFD Analysis of a Finite Linear Array of Savonius Wind Turbines”

This paper presents results of Computational Fluid Dynamics (CFD) simulations for an array of Savonius rotors that show a significant increase inefficiency. It looks at identifying the effect on the energy yield of a number of turbines placed in a linear array. Results from this investigation suggest that an increase in the energy yield could be achieved which can reach almost two times than the conventional Savonius wind turbine in the case of an array of 11turbines with a distance of 1.4R in between them.[17]

12. Research paper on “Comparison between solar and wind energy in Lebanon”

In this research, the case of the conversion of photovoltaic and wind energy are studied. In addition, the efficiency of each conversion system is calculated. The cost of the eight solar panels of total power equal to 400 W which had produced energy of 55.175 kWh in 2006 is equal to 6000$. This cost includes the installation price. Adding the batteries prices to this cost, the actual value to have this solar station becomes 6500$. The cost of the wind turbine of 400 W which had produced energy of 55.55 kWh in 2006 is equal to 2000$. This cost includes also the installation price. Adding the batteries prices to this cost, the actual value to have this wind station becomes 2500$.[18]

13. Research paper on “Design and Analysis of Vertical Axis Wind Turbine Rotors”

In this research work NACA 0018 airfoil wind turbine blade is used to modeling the vertical axis wind turbine rotors. The straight three-bladed vertical axis wind turbine rotor is twisted to 45degrees and 90 degrees in order to improve the performance of rotor. The CFD analysis in ANSYS-FLUENT and structural analysis in ANSYS of a straight and twisted three-bladed vertical axis wind turbine rotor was undertaken. It has been observed that the helical blades have an average power output increment equal to 8.75%. This leads the Helical VAWT to a low speed of start-up and then to a higher number of operational hours in similar environmental conditions.[19]

14. Research paper on “Performance Comparison of Vertical Axis and Horizontal Axis Wind Turbines to Get Optimum Power Output”

This paper presents the comparison of power captured by vertical and horizontal axis wind turbine (VAWT and HAWT). According to Betz, the limit of maximum coefficient power (CP) is 0.59. In this case CP is important parameter that determines the power extracted by a wind turbine we made. This paper investigates the impact of wind speed variation of wind turbine to extract the power. The air foil of both wind turbines are NACA 4412. We have found that CP of HAWT is 0.54 with captured maximum power is 1363.6 Watt while the CP of VAWT is 0.34 with captured maximum power is 505.69

Watt. The power extracted of both wind turbines seems that HAWT power is much better than VAWT power.[20]

15. Research paper on "Performance Analysis of Vertical Axis Wind Turbine with Variable Swept Area"

This paper presents optimum power output from vertical axis wind turbine (VAWT's) by changing variable swept area. They used the H-Darrieus type of VAWT's, with extended blade and radius of VAWT's. These turbines response to the wind speed by changing swept area automatically extend outward at low wind speed and retract at excessive wind speed. This action increases the efficiency and get higher power capture at low wind speed. These innovative designs found that the power production increased 260% over the turbines through variable swept area. The maximum power that was captured by this turbine was 4478 W with extendable blade of 150 cm and extendable diameter of 150 cm. [21]

16. Research paper on "On the Improvement of Starting Torque of Darrieus Wind Turbine with Trapped Vortex Airfoil"

In this research paper a notched airfoil (KF-N-21) was incorporated into straight bladed Darrieus rotor as a potential solution to improve the low wind speed performance, and experimentally compared with conventional NACA0021 rotor. The experimental results display the superior performance of KF-N-21 in the low Reynolds number without degrading the performance at the high Reynolds number. The simulation results shows a good agreement with the experimental data endorsing the performance of KF-N-21 airfoil for a wide range of Reynolds number. From the overall perspective, KF-N-21 airfoil displays higher performance gain than NACA 0021 for the simulated Re and can be potential airfoil especially for small wind turbine suffering from poor starting characteristics without degrading the performance at high wind speeds.[22]

17. Research paper on "On the Structural Implementation of Magnetic Levitation Windmill"

In this research paper structural implementation and optimum performance of Vertical Axis Wind Turbine (VAWT) using magnetic levitation technology is observed. By means of property of permanent magnet as an alternate of ball bearings, levitation of the turbine is anticipated with decline in damages while rotation and hence wind turbine blades are positioned on a shaft for attaining stability throughout rotation. Power is then generated with an axial flux generator, which incorporates the utilization of permanent magnets and set of coils. The maximum output voltage for 1000 rpm is 20v and for 1500 rpm it is 25 volt. [23]

18. Research paper on "Modeling of Small Wind Power Plant with Savonius-Darrieus Rotor in the PSCAD"

The paper focuses on the creation of a mathematical model of a small wind power plant with a vertical axis of rotation with a Savonius-Darrieus rotor within the PSCAD. The paper describes the principle of a wind energy source and it brings basic data about this technology and specifies individual parameters and their mutual relations that are needed for mathematical simulation. The improved mathematical model can be also used in finding a new locality, better suited for a wind plant operation. The maximum power output of the wind power plant is 400 W for a wind speed of 15 m/s. [24]

19. Research paper on "Comparison of power electronics lifetime between vertical- and horizontal-axis wind turbines"

In this research paper A comparison has been made of the power electronics lifetime for 5MW horizontal- and vertical-axis wind turbines, based on dynamic models supplied with generated wind speed time series. Both two- and three-bladed stall-regulated H-rotor vertical-axis turbines were modelled, with several different control parameters. The vertical-axis turbine was found to have a lower power electronics lifetime than the horizontal-axis, or require a larger number of parallel switching devices to achieve the same lifetime although this was lessened by running the turbine with a more relaxed speed control, allowing the rotor inertia to partially absorb the aerodynamic torque ripple.[25]

20. Research paper on “Analysis of a micro vertical-axis wind turbine by computational fluids simulation”

This paper presents the performance analysis related to the power output of a micro VAWT with three blades in helicoidal form, based on computacional fluids dynamics simulation (CFD), using Ansys Fluent®. Simulation results indicate that with a solidity of 0.6 and a chord of 0.2 m, the 3-blades turbine presents the best performance, reaching a power coefficient of 0.39, with λ range values from 1 to 3.5. For the same conditions, the mathematical model yields a maximum power coefficient of 0.41, not including turbulence, considered as an acceptable result for modeling values.[26]

2.2 Summery

we can see that several researches were done on Vertical axis wind turbine (VAWT). From the current research it is clear that several factors affect the outcome of the VAWT. Some of this factor are airfoil, blade design, angle of attack, power coefficient. But the most important are blade design and wind speed. Depending on the blade design even at a lower wind speed it is possible to get a satisfactory result.

2.3 Objective

- To produce electricity from high speed vehicles.
- To utilize the free space of Dhaka-Chittagong highway.
- To produce required power for Highway management.

2.4 Comparison Between Horizontal and Vertical Axis wind turbine [27]

Table2.1: Comparison Between Horizontal and Vertical Axis wind turbine

Factors	Horizontal wind turbine	Vertical wind turbine
Power generation Efficiency	50%-60%	Above 70%

Steering mechanism of wind	Yes	No
Blade Rotation speed	Quite large	Quite small
Wind resistance capability	Weak	Strong
Noise	5-60dB	0-10db
Starting wind speed	High	low
Failure rate	High	Low
Maintains	Complicated	Convenient
Rotating speed	High	Low
Effect on birds	Great	Small
Cable stranding problem	Yes	No
Maintenance	No or less	Need Maintenance
Capture wind	Configured to capture wind from any direction without any external control	Requirement yaw mechanism turn turbine blade in direction of wind.
Lifetime	Long life span	Less life span

Chapter 3

Methodology

3.1 Methodology

Methodology is the organized, theoretical analysis of the methods applied to a field of study. It includes the theoretical analysis of the body of methods and doctrines related with a branch of knowledge. Typically, it encompasses concepts such as standard, theoretical model, phases and quantitative or qualitative techniques for a research [28]. Methodology can be said a set of practices or methods. This term may be used to refer to practices which are widely used across an industry or scientific discipline, the techniques used in a particular research study, or the techniques used to accomplish a particular project.

However, a methodology does not set out to afford solutions—it is thus, not the same as a method. Instead, a methodology deals with the theoretical reinforcement for understanding which method or set of methods can be realistic to a specific case.

3.2 Research Design

The framework that has been fashioned to find solutions to the research questions is defined as research design. The design of a research work outlines the research resources such as research question, dependent and independent variables, experimental design, and where applicable, data collection methods and a statistical analysis plan.

3.3 Research Design for this research:

1. Study current energy situation in Bangladesh
2. Study current power demand in Bangladesh.
3. Study literature on vertical axis wind turbine
4. Study procedure on VAWT
5. Study VAWT design in Q-Blade software
6. Calculate necessary parameters to design in Q-Blade
7. Implement the procedure

3.4 Pilot Study

A pilot study, pilot project, pilot test, or pilot experiment is a small-scale introductory study conducted in order to estimate the feasibility, time, cost, hostile events, and improve upon the study design prior to performance of a full-scale research work. It is conducted before the projected study. Pilot studies are usually executed as planned for the intended study. Though a pilot study cannot exclude all systematic errors or unexpected problems, but it lessens so many errors which waste time and effort during the original research study.

Importance of Pilot study:

- To test the research process and/or protocol.
- To categorize variables of concern and elect how to functionalize each one.
- To develop or examine the effectiveness of research instruments and protocols
- To evaluate statistical parameters for later investigations

3.5 Software:

QBlade is an open-source wind turbine calculation software, distributed under the GNU General Public License. The software is seamlessly integrated into XFOIL, an airfoil design and analysis tool. The purpose of this software is the design and aerodynamic simulation of wind turbine blades. The integration in XFOIL allows for the user to rapidly design custom airfoils and compute their performance curves, Extrapolating the performance data to a range of 360°Angle of attack, and directly integrate them into a wind turbine rotor simulation. The integration of QBlade into XFLR's sophisticated graphical user interface makes this software accessible to a large potential user community.[6]

3.6 Design Procedure:

Step 1: Design an airfoil.

Step 2: save the structure and simulate for that airfoil.

Step 3: Save the result if the simulation meets the criteria.

Step 4: if not change the airfoil.

Step 5: see the result

Step 6: if the result meets the criteria then save the result.

Step 7: compare with other existing wind turbines.

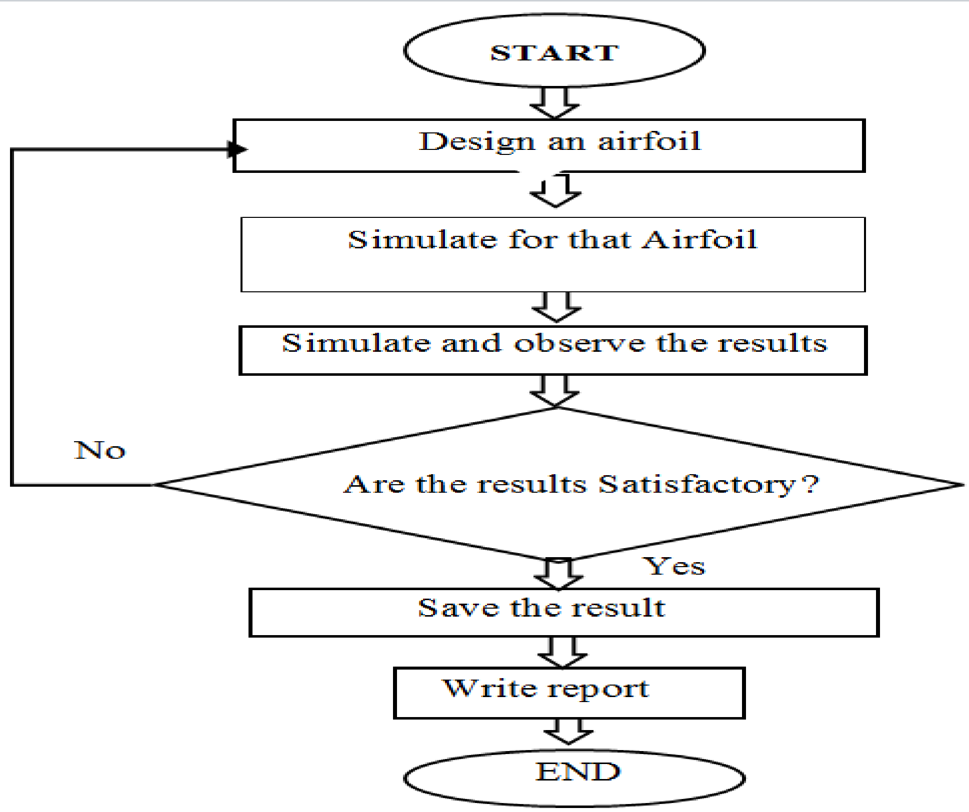


Figure3.1: Flow chart for design procedure

3.7 Equations used for designing wind turbine

3.7.1 Method of operation

The cross section of a VAWT blade is an airfoil producing lift and drag that drive the wind turbine. The force on a blade section depends on both the undisturbed air velocity $V\infty$ and the rotational speed ω of the moving blade. The relative velocity at the blade is [6]

$$W = V_{\infty} - R\varpi \text{ .... } 3.1$$

Where,

V_{∞} = undisturbed air velocity

$R\varpi$ = the rotational speed of the moving blade

3.7.2 Iteration procedure

A rotor simulation is executed for a range of tip speed ratios. The global tip speed ratio is the relative rotational speed of a VAWT rotor and is defined as [6]

$$TSR = R\omega / V\infty \quad \text{.........................} 3.2$$

Where,

R is the radius (of the equator)

ϖ is the angular speed of the blade

V_{∞} is the free stream inflow velocity

3.7.3 Drag coefficient

The drag coefficient C_d is defined as [30]

$$c_d = \frac{2F_d}{\rho u^2 A} \quad \text{..................................} 3.3$$

where:

F_d is the drag force, which is by definition the force component in the direction of the flow velocity

ρ is the mass density of the fluid

μ, is the flow speed of the object relative to the fluid

A, is the reference area.

3.7.4 Power coefficient [31]

The term Power Coefficient is commonly used to designate the efficiency of the entire turbine power system.

$$C_p = \frac{\text{electrical power produced by the wind turbine}}{\text{Wind power into the Turbine}}$$

3.7.5 Output power calculation

$$P_{out} = C_p * P_{in} \quad \text{......................................3.4}$$

Where,

P_{out} is the output power

C_p is the power coefficient

P_{in} is the available wind power for the turbine

3.7.6 Power available from wind for a vertical axis wind turbine (P_{in}) [31]

$$P(in) = \frac{1}{2}\rho s v^3 \quad \text{............................3.5}$$

Here,

P = air density

S = swept area

V = wind speed in m/s

Equation for swept area [31]

$$S = 2RL \qquad (3.6)$$

here,

R = rotor radius in meter

L = length of the blade in meter

Chapter 4

Simulations and Result's Analysis

In this chapter, the results that are obtained after performing simulation of the designed Vertical wind turbine are presented and analyzed.

4.1 Simulation Results of Vertical axis wind turbine

4.1.1 Airfoil Design and Analysis

The DMS algorithms, that are applied to simulate a wind turbine, require tabulated data of lift and drag coefficients over different angles of attack (AoA). This data is either obtained via experiments or through two-dimensional flow simulations. The software XFOIL, developed by Drela and Giles at MIT, is a program to analyze and compute the flow around subsonic isolated airfoils. XFOIL combines a high-order panel method with a fully coupled viscous/inviscid interaction method XFOIL has been validated numerous times and is considered as one of the standard low order airfoil analysis tools.

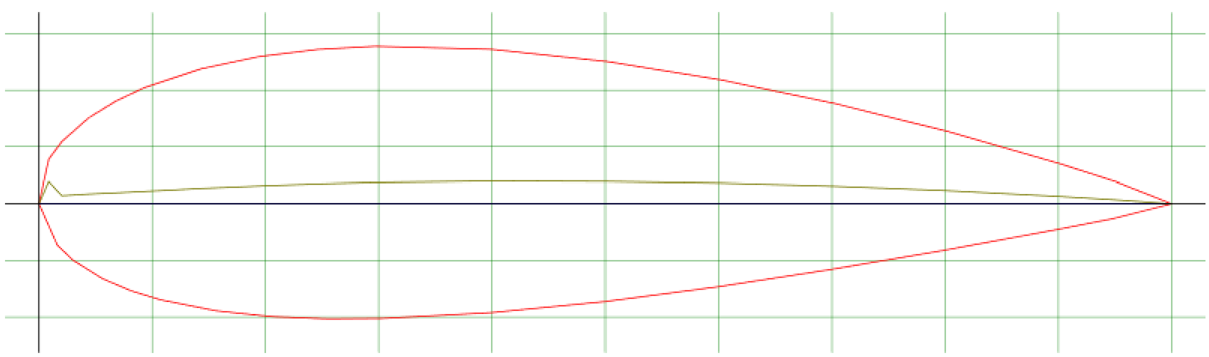
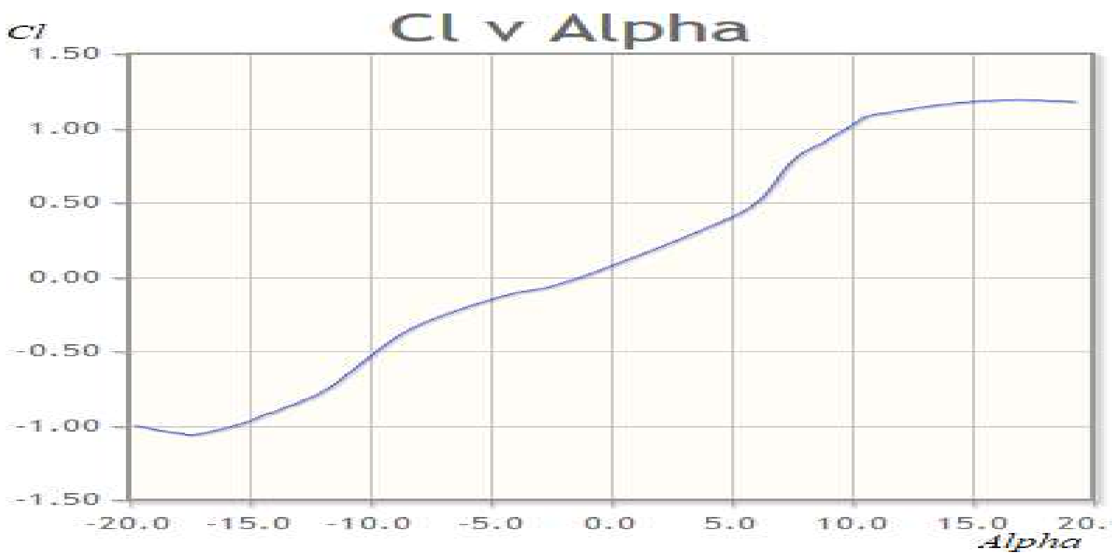


Figure4.1: Airfoil Generation in Q-Blade

4.1.2 360 Extrapolation Graph

X-Foil analysis is performed on the airfoils and C*l* and α graphs are obtained. This can be done by using XFOIL Direct Design button (second red button). Analysis can be defined for variable Reynolds number, angle of attack of the blade with the increment.



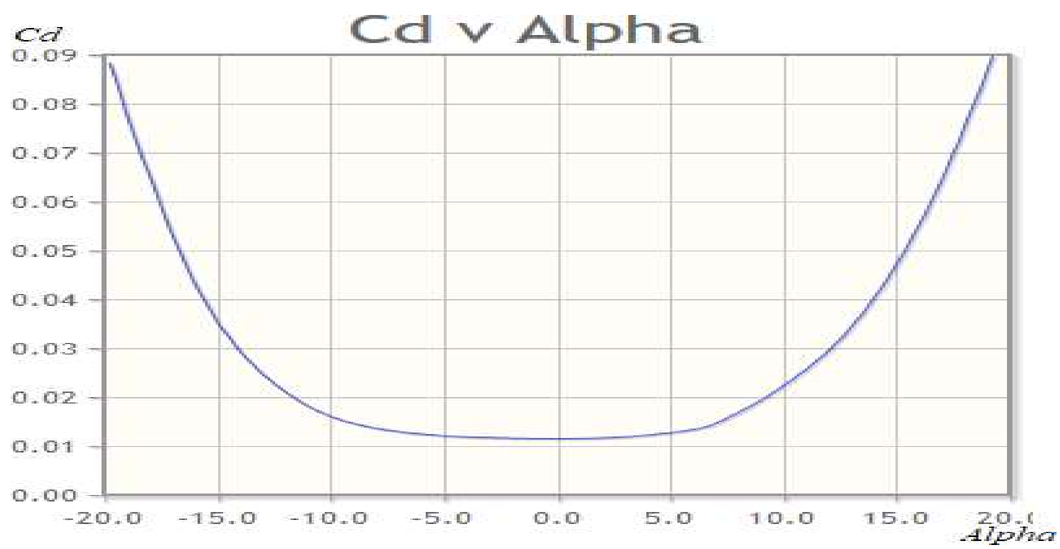


Figure4.2: 360 Extrapolation Graph

The different airfoils are used to generate various lifts at given twist. To generate the maximum power, they are placed at different positions and chords. The airfoils at the tip have less twist when compared to the airfoils from the root since they have to generate more lift. It is considered by the analysis C*l* and α graph. When the air flows on the airfoil, this twist in is sufficient to lift the blade.

4.1.3 DMS Simulation in Q-Blade

Three rotor blades have same design and 3D rotor can be created from the single blade design. Further, power simulation is carried out on the rotor blades. Rotor DMS simulation is used with simulation parameters tip speed and Reynolds number. A rotor simulation can only be defined when any rotor blade is present in the runtime database. When defining a rotor simulation, the user has to select the desired corrections to the DMS algorithm and the simulation parameters. Once a simulation is defined, the user can select a range of tip speed ratios and the incremental step for the simulation. Analysis is performed based on the obtained simulation graphs and blade design is varied for further modeling.

4.1.4 Simulation Result

A. Power coefficient [Cp] Vs Tip Speed Ratio [λ]

Currently available commercial small wind turbines have coefficient of power in the range of 0.2 – 0.45. Significantly less than coefficient of power measured in large scale wind turbines which have high power generation capacity. Value of coefficient of power in wind turbines is mainly dependent on the rotor blade profile. NACA 2424 airfoil is used for rotor blade design. Blade profile can be further optimized to increase the power coefficient. Power coefficient is maximized to value 0.45 for tip speed ratios 4 to 8, as shown in Figure.

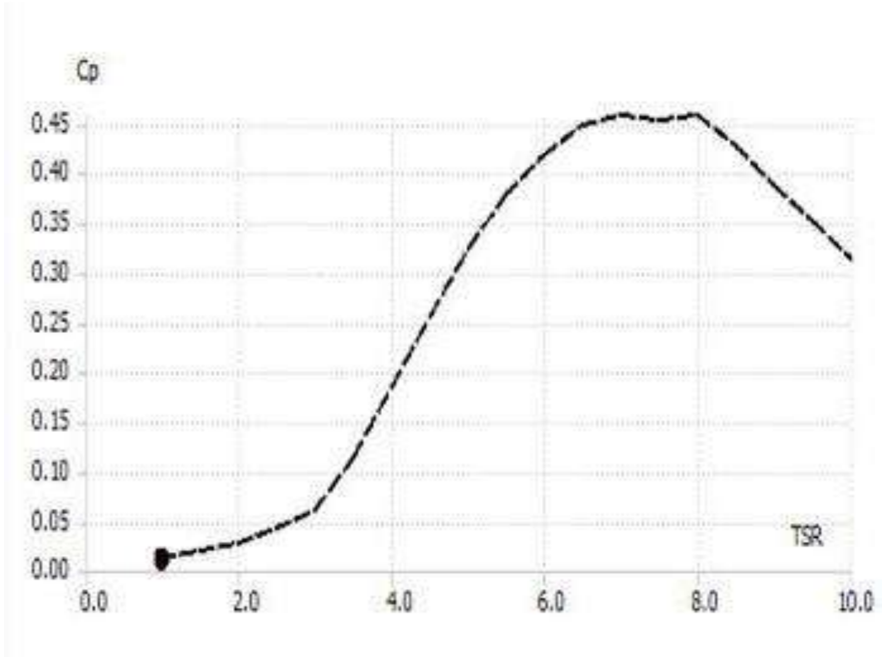


Figure4.3: Power coefficient [Cp] Vs Tip Speed Ratio [λ]

B. Power [P] Vs Tip Speed Ratio [λ]

Rotor blades have optimal tip speed ratio designed, at which they will produce maximum power. Power generated by a wind turbine is proportional to the air mass lifted/ raised by the rotor blades in given time. An increase in tip speed ratio results in decrease in the mass being lifted and affects the power output. The power curve in the Figure4.4 shows the correlation between power output and TSR and power output reaches its maximum values for tip speed ratios of 2 to 4. It is intended that wind turbine be operated in that range of tip speed ratios for maintaining high power output.

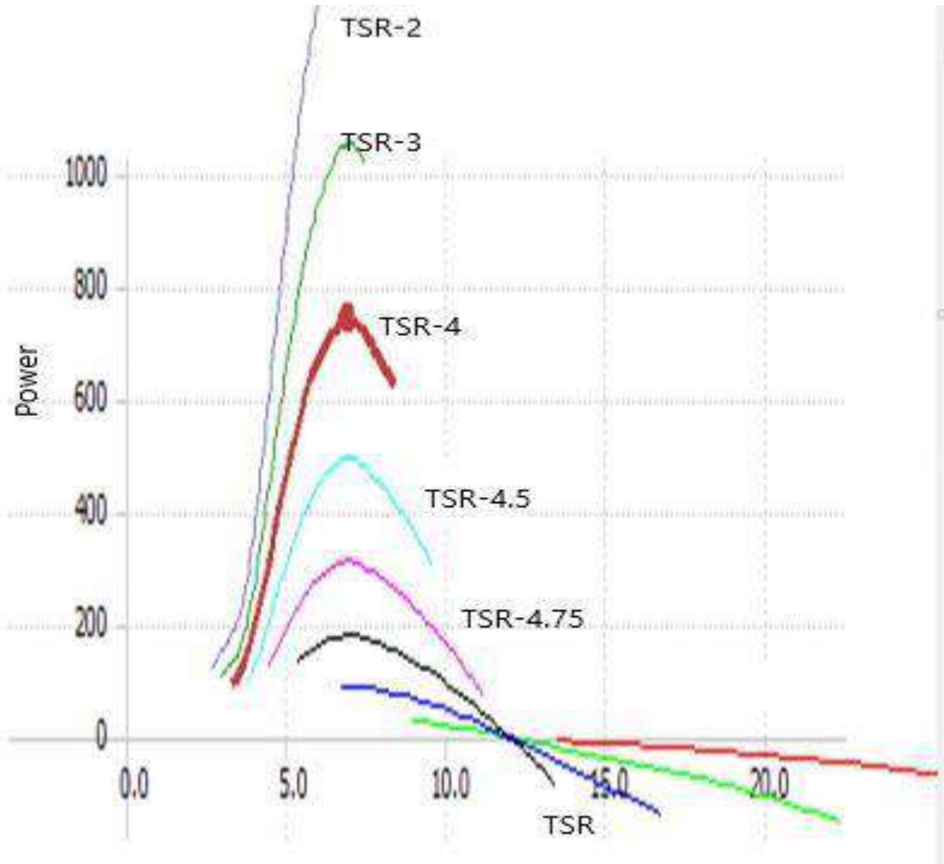


Figure4.4: Power [P] Vs Tip Speed Ratio [λ]

C. Lift and Drag Coefficients

C*l* is the property of airfoils defining the lift force. For VAWT, high value of is C*l* required. Figure 4.5, shows the variation of C*l* with angle of attack [α] and drag coefficient.

C*l*/Cd is an important parameter in airfoil design considerations to minimize drag force and stay elevated. In wind turbines, it is important to maintain high lift coefficient. Figure4.5 , shows the variation of C*l*/Cd with angle of attack [α].

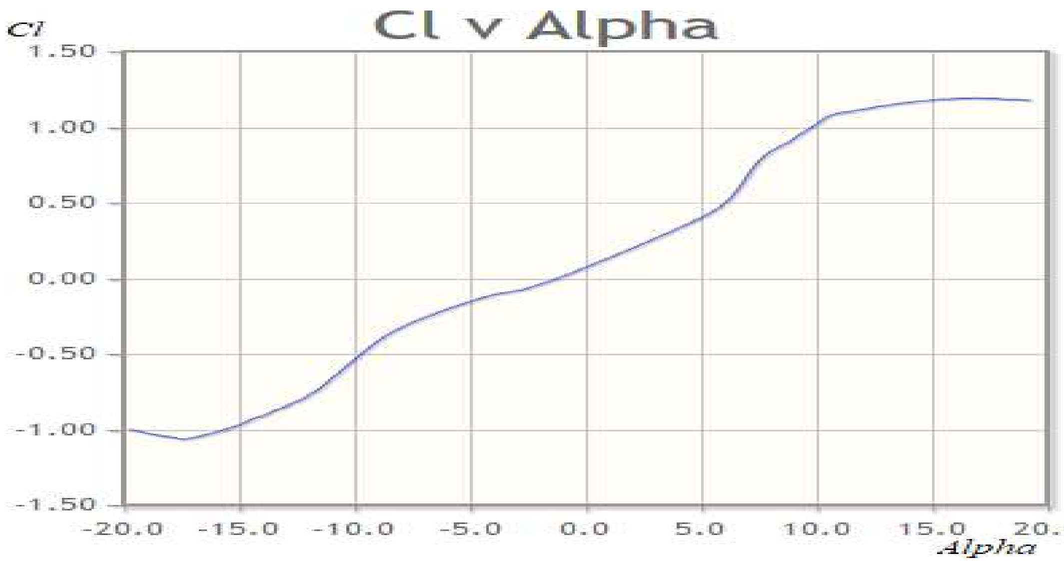


Figure4.5: C*l* vs Angle of attack[α]

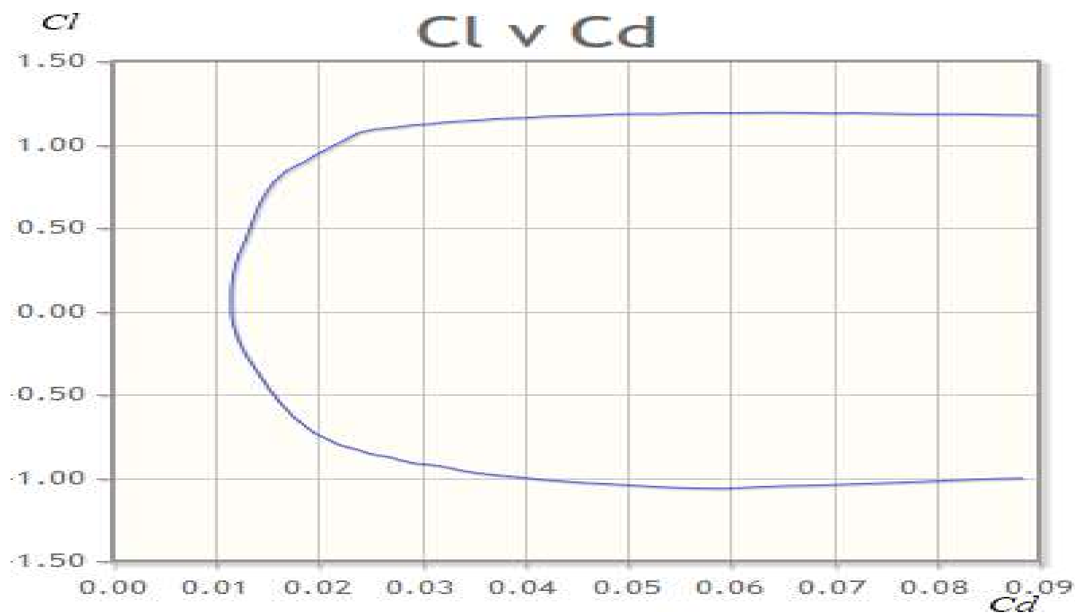


Figure4.6: C*l* vs Cd

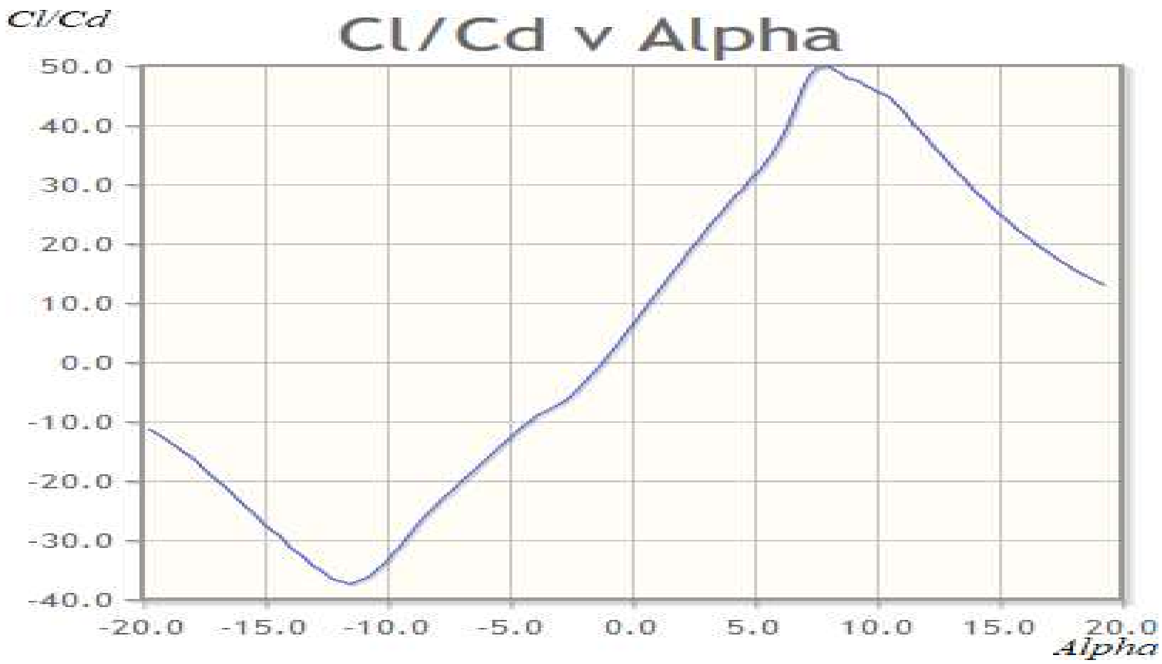


Figure4.7: C*l/Cd* vs Angle of attack[α]

4.2 Calculated polar for: NACA 2424

xtrf = 1.000 (top) 1.000 (bottom)

Mach = 0.000 Re = 0.200 e 6 Ncrit = 5.000

alpha	C_L	C_d	CDp	C_M	Top Xtr	Bot _Xtr
------	--------	---------	---------	--------	--------	--------
-10.750	-0.7044	0.02551	0.01768	-0.0864	0.9259	0.1743
-10.500	-0.6837	0.02475	0.01689	-0.0862	0.9203	0.1783
-10.250	-0.6590	0.02392	0.01607	-0.0869	0.9165	0.1828
-10.000	-0.6367	0.02328	0.01539	-0.0868	0.9110	0.1878
-9.750	-0.6186	0.02270	0.01479	-0.0858	0.9031	0.1920
-9.500	-0.5921	0.02200	0.01410	-0.0865	0.8984	0.1972
-9.250	-0.5575	0.02139	0.01344	-0.0885	0.8951	0.2031
-9.000	-0.5429	0.02095	0.01299	-0.0867	0.8852	0.2075
-8.750	-0.5155	0.02039	0.01245	-0.0873	0.8786	0.2132

-8.500	-0.4759	0.01988	0.01187	-0.0901	0.8743	0.2199
-8.250	-0.4580	0.01946	0.01148	-0.0888	0.8646	0.2248
-8.000	-0.4274	0.01903	0.01103	-0.0898	0.8566	0.2314
-7.750	-0.3840	0.01857	0.01053	-0.0933	0.8511	0.2385
-7.500	-0.3700	0.01827	0.01025	-0.0910	0.8395	0.2440
-7.250	-0.3375	0.01792	0.00985	-0.0923	0.8310	0.2515
-7.000	-0.3160	0.01762	0.00954	-0.0913	0.8210	0.2574
-6.750	-0.2941	0.01734	0.00924	-0.0904	0.8101	0.2644
-6.500	-0.2686	0.01711	0.00894	-0.0901	0.8000	0.2712
-6.250	-0.2522	0.01686	0.00870	-0.0880	0.7886	0.2773
-6.000	-0.2308	0.01664	0.00845	-0.0869	0.7781	0.2846
-5.750	-0.2127	0.01649	0.00823	-0.0849	0.7666	0.2912
-5.500	-0.1950	0.01627	0.00802	-0.0830	0.7562	0.2980
-5.250	-0.1803	0.01613	0.00785	-0.0804	0.7448	0.3052
-5.000	-0.1608	0.01599	0.00764	-0.0788	0.7346	0.3121
-4.750	-0.1500	0.01586	0.00752	-0.0753	0.7232	0.3190
-4.500	-0.1309	0.01574	0.00734	-0.0735	0.7133	0.3269
-4.250	-0.1206	0.01567	0.00725	-0.0699	0.7023	0.3334
-4.000	-0.1044	0.01555	0.00710	-0.0675	0.6926	0.3412
-3.750	-0.0956	0.01550	0.00704	-0.0636	0.6822	0.3486
-3.500	-0.0815	0.01543	0.00693	-0.0607	0.6722	0.3560
-3.250	-0.0693	0.01535	0.00686	-0.0575	0.6631	0.3641
-3.000	-0.0554	0.01531	0.00677	-0.0545	0.6529	0.3724
-2.750	-0.0400	0.01523	0.00668	-0.0519	0.6443	0.3809
-2.500	-0.0292	0.01518	0.00664	-0.0484	0.6349	0.3896
-2.250	-0.0132	0.01513	0.00656	-0.0459	0.6262	0.3987
-2.000	-0.0009	0.01507	0.00652	-0.0426	0.6177	0.4081
-1.750	0.0122	0.01504	0.00647	-0.0395	0.6087	0.4180
-1.500	0.0273	0.01498	0.00640	-0.0368	0.6008	0.4283
-1.250	0.0368	0.01494	0.00638	-0.0330	0.5927	0.4386
-1.000	0.0483	0.01488	0.00635	-0.0295	0.5847	0.4491

-0.750	0.0649	0.01487	0.00630	-0.0271	0.5775	0.4615
-0.500	0.0744	0.01481	0.00632	-0.0233	0.5700	0.4729
-0.250	0.0875	0.01480	0.00630	-0.0202	0.5621	0.4855
0.500	0.1282	0.01477	0.00637	-0.0112	0.5409	0.5261
0.750	0.1445	0.01480	0.00638	-0.0087	0.5343	0.5401
1.000	0.1574	0.01481	0.00645	-0.0056	0.5276	0.5551
1.250	0.1707	0.01483	0.00652	-0.0026	0.5205	0.5695
1.750	0.2019	0.01490	0.00665	0.0025	0.5080	0.6006
2.000	0.2152	0.01494	0.00675	0.0055	0.5009	0.6161
2.250	0.2305	0.01500	0.00683	0.0081	0.4945	0.6327
2.500	0.2479	0.01506	0.00691	0.0102	0.4886	0.6490
2.750	0.2619	0.01512	0.00706	0.0130	0.4818	0.6654
3.000	0.2776	0.01519	0.00718	0.0155	0.4752	0.6831
3.250	0.2958	0.01527	0.00729	0.0174	0.4690	0.7013
3.500	0.3130	0.01535	0.00747	0.0195	0.4626	0.7199
3.750	0.3310	0.01545	0.00765	0.0214	0.4558	0.7400
4.000	0.3529	0.01558	0.00781	0.0225	0.4495	0.7609
4.250	0.3788	0.01572	0.00804	0.0228	0.4430	0.7828
4.500	0.4085	0.01591	0.00832	0.0222	0.4356	0.8047
4.750	0.4454	0.01615	0.00858	0.0201	0.4281	0.8259
5.000	0.4887	0.01645	0.00894	0.0167	0.4206	0.8459
5.250	0.5324	0.01678	0.00931	0.0131	0.4123	0.8640
5.500	0.5862	0.01721	0.00971	0.0075	0.4046	0.8769
5.750	0.6264	0.01761	0.01015	0.0046	0.3960	0.8901
6.000	0.6660	0.01807	0.01059	0.0018	0.3882	0.9005
6.250	0.6985	0.01850	0.01103	0.0005	0.3810	0.9110
6.500	0.7326	0.01899	0.01153	-0.0012	0.3732	0.9198
6.750	0.7585	0.01949	0.01196	-0.0013	0.3664	0.9306
7.000	0.7862	0.01997	0.01249	-0.0018	0.3592	0.9403
7.250	0.8100	0.02049	0.01298	-0.0017	0.3519	0.9506
7.500	0.8307	0.02104	0.01350	-0.0011	0.3453	0.9623

7.750	0.8599	0.02157	0.01405	-0.0022	0.3377	0.9693
8.000	0.8826	0.02222	0.01465	-0.0022	0.3307	0.9782
8.250	0.9128	0.02275	0.01520	-0.0036	0.3236	0.9836
8.500	0.9393	0.02343	0.01586	-0.0045	0.3160	0.9897
8.750	0.9673	0.02411	0.01650	-0.0059	0.3091	0.9951
9.000	0.9978	0.02478	0.01719	-0.0077	0.3010	0.9993
9.250	1.0040	0.02541	0.01777	-0.0051	0.2952	1.0000
9.500	1.0071	0.02597	0.01833	-0.0018	0.2899	1.0000
9.750	1.0101	0.02661	0.01898	0.0014	0.2838	1.0000
10.000	1.0129	0.02735	0.01968	0.0045	0.2784	1.0000
10.250	1.0176	0.02809	0.02042	0.0073	0.2733	1.0000
10.500	1.0227	0.02888	0.02121	0.0098	0.2673	1.0000
10.750	1.0258	0.02981	0.02211	0.0125	0.2619	1.0000

4.3 Power Generation

From the above figure we can see that the highest power the proposed turbine can generate is 1050 W with a wind speed of 13 m/s. But in actuality we have an average wind speed of 6 m/s so the expected power generation per turbine is 100W.

4.4 Cost Calculation

Cost is the most important factor for any kind of process. Implementation of any process is largely depending on the economic feasibility. The design cost of VAWT is represented in the table 4.1.

Table 4.1: Representing the design cost VAWT.

Serial No.	Items	Price (Tk.)
1	Wind Turbine Blade Assembly	20,000.0
2	Charge controller	3,000.0
3	Wiring & Misc.	500.0
4	Battery	4000.0
5	Brick+Sand+ Cement	1500.0
6	Mason and helper	1500.0
	Total	**30,500.0**

4.3 Power Cost

The average electrical power output obtained was around 100w from a single turbine and its equivalent to 2.4 KWh/day in single unit turbine.

$$\text{Payback period} = \frac{Capital\ Cost\ of\ \ Wind\ Turbine}{Electricity\ Cost * Power\ Output\ of\ Turbine} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4.1$$

$$= \frac{30500}{9 * 2.4}$$

=1355.50 days or 3.71 years

Chapter 5

Conclusion

From the above table we can see several other authors works and their achievement. In the reference number [2] the author used semi-circular shaped blades to design a turbine. The author managed to achieve 28.3 watt at a wind speed of 6.1 m/s. In the reference number [5] the author used wind turbine together with solar panel to achieve a power production of 29.48 W where For the VAWT maximum of 9.8 Volt was achieved with a wind speed of 15.33 m/s and the maximum solar panel output was 19.68 volt. But our proposed turbine can generate 100 W of power at a wind speed of 6 m/s.

From this research we can conclude that our VAWT design is more efficient than others. It can generate more power at a relatively lower wind speed. And from cost analysis we can see that it is also cost effective. We can use this generated energy for highway maintenance or we can supply this electricity to the national grid.

5.1 Comparison with another existing turbine

Table 5.1: Comparison with other existing wind turbine

Reference	Wind Speed (m/s)	Output Power (watt)
[2]	6.1	28.3
[5]	15.33	29.48
[6]	10	77
[8]	4.5	50
[10]	4.4	48
[18]	15	400
Proposed	6	100

5.2 Limitation:

The proposed turbine still has some limitation the efficiency of the turbine can be increased. Furthermore, we can add solar panel on top of the turbine to generate more power. From Research paper on “Power Generation on Highway Using Vertical Axis Wind Turbine and Solar Energy” [5] we can see that it is possible to generate more power in combination with solar panel.

5.3 Future Work

a. Further enhancing efficiency.

b. Can add solar panel with turbine.

c. Use different type of turbine.

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