SONARGAON UNIVERSITY

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ANALYSIS ON SUITABILITY OF HORIZONTAL AXIS WIND TURBINE (HAWT) USAGE IN PROSPECT OF DHAKA CITY.

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BSc. Engineering Thesis

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ANALYSIS ON SUITABILITY OF HORIZONTAL AXIS WIND TURBINE (HAWT) USAGE IN PROSPECT OF DHAKA CITY.

DECLEARATION

We hereby declare that the study reported in this thesis entitled as above is our own original work has not been submitted anywhere for any degree or other purposes. Further, we certify that the intellectual content of this thesis is the product of our own work and that all the assistance received in preparing this thesis and sources have been acknowledge and cited in the reference section.

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Abstract As energy consumptions by human societies are increasing rapidly over the years, more energy is needed to fulfill the requirement of daily life usage. On the other hands, sources of energy such as gas & coal are decreasing at high speed. The only alternative available is using renewable energy that can be made from various natural sources like wind, sunlight etc. Among them wind energy can be obtained by using mechanism such as wind turbine. There are generally two different types of wind turbines. One type is built with the aim of generating electricity from wind with high speeds. On the other hand, the other type is built especially for areas with low wind speeds, such as Bangladesh.

Wind turbines consist of a set of blades attached to a rotor hub, which together form the rotor; this rotor deflects the airflow, which creates a force on the blades, which in turn produces a torque on the shaft and the rotor rotates around a horizontal axis, which is mainly attached to a gearbox and generator. The generator generates electricity. We have undertaken a project to design a wind turbine and tests its suitability of usage in aspect of Dhaka city. The design process includes the selection of the wind turbine type and the determination of the blade airfoil, pitch angle distribution along the radius, and chord length distribution along the radius. The pitch angle and chord length distributions are optimized based on conservation of angular momentum and theory of aerodynamic forces on an airfoil. The objective it is expected that the present work will provide a good piece of findings with valuable information and results to be used by academicians as well as industrial engineers.

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Chapter 1

INTRODUCTION

1.1 Preamble

As a source of energy, green energy often comes from renewable energy technologies such as solar energy, wind power, geothermal energy, biomass, and hydroelectric power. Each of these technologies works in different ways, whether that is by taking power from the sun, as with solar panels, or using wind turbines or the flow of water to generate energy. To be deemed green energy, a resource cannot produce pollution, such as is found with fossil fuels. This means that not all sources used by the renewable energy industry are green. For example, power generation that burns organic material from sustainable forests may be renewable, but it is not necessarily green, due to the CO_2 produced by the burning process itself. Green energy sources are usually naturally replenished, as opposed to fossil fuel sources like natural gas or coal, which can take millions of years to develop. Green sources also often avoid mining or drilling operations that can be damaging to ecosystems. [1]

Among renewable sources of energy, the wind is the most widely used resource due to its commercial acceptance, low cost and ease of operation and maintenance, relatively much less time for its realization from the concept to operation, creation of new jobs, and least adverse effect on the environment. The fast technological development in the wind industry and availability of multi-megawatt sized horizontal axis wind turbines has further led to the promotion of wind power utilization globally. It is a well-known fact that the wind speed increases with height and hence the energy output. [2]

1.2 Notable Properties and Types of Wind Turbines

Wind flow patterns and speeds vary greatly and are modified by bodies of water, vegetation, and differences in terrain. Humans use this wind flow, or motion energy, for many purposes: sailing, flying a kite, and even generating electricity.

The terms "wind energy" and "wind power" both describe the process by which the wind is used to generate mechanical power or electricity. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity. Wind turbines work on a simple principle, instead of using electricity to make wind—like a fan—wind turbines use wind to make electricity. Wind turns the propeller-like blades of a turbine around a rotor, which spins a generator, which creates electricity. Wind is a form of solar energy caused by a combination of three concurrent events:

1. The sun unevenly heating the atmosphere
2. Irregularities of the earth's surface
3. The rotation of the earth

A wind turbine turns wind energy into electricity using the aerodynamic force from the rotor blades, which work like an airplane wing or helicopter rotor blade. When wind flows across the blade, the air pressure on one side of the blade decreases. The difference in air pressure across the two sides of the blade creates both lift and drag. The force of the lift is stronger than the drag and this causes the rotor to spin. The rotor connects to the generator, either directly (if it’s a direct drive turbine) or through a shaft and a series of gears (a gearbox) that speed up the rotation and allow for a physically smaller generator. This translation of aerodynamic force to rotation of a generator creates electricity.

Modern wind turbines can be categorized by where they are installed and how they are connected to the grid:

1. Land-based wind turbine
2. Offshore wind turbine
3. Distributed wind turbine

Wind turbines generally fall into one of two categories:

1. Horizontal axis wind turbines (HAWT) and
2. Vertical axis wind turbines (VAWT).

HAWTs, the more common type, consist of propeller-like rotors fixed around a central hub and facing into the wind, like a windmill. Both types use bladed rotors of various designs driving a shaft to a generator that uses electromagnetic induction to produce a voltage.

1.3 Objective:

The objective of the project is to design a horizontal axis wind turbine and measure its efficiency in the prospect of Dhaka city. The design process includes the selection of the wind turbine type and the determination of the blade airfoil, pitch angle distribution along the radius, and chord length distribution along the radius. The pitch angle and chord length distributions are optimized based on the conservation of angular momentum and the theory of aerodynamic forces on an airfoil.

The project was carried out with the intentions of following outcomes-

- To find out daily wind speed
- To plot change in daily wind speed from collected data
- To derive rpm of wind turbine for different wind speed
- To derive value of generated power for different wind speed

Chapter 2

BACKGROUND STUDY

2.1 Current Scenario:

The growing awareness of the adverse effects of the changing climatic conditions on global, regional, and local scales has led people from all walks of life to utilize clean and renewable sources of energy to combat the increasing environmental pollution. The renewable sources of energy that are being promoted these days include the wind, solar photovoltaic, solar thermal, geothermal, big, and small hydro, biomass, and municipal waste, to name some. Among these energy sources, wind power has been realized as the major source of energy globally due to fast technological development and the availability of all sizes of wind turbines covering almost all types of applications starting from home to grid-connected large utilities. Wind power is clean, renewable, and available round the clock intermittently. However, it is a highly fluctuating meteorological parameter and changes with location, time of the day, day of the month and month of the year, and lastly from year to year.

Global wind power capacities have been on the rise for almost the last two decades. The continuously encouraging international trends are a clear indication of an increasing role of renewable energy sources in general, and wind power in particular meeting the current and future electricity demands. [3]

The cumulative wind power installed capacity was 17 GW in 2000 and reached 194 GW in 2010 GWEC [4], an average annual growth of around 104% over 10 years, as shown in Figure 1. From 2010 onwards, on average, the global wind power installed capacity growth was 24.64%. The cumulative capacity was 238 GW in 2011 while reaching 283 GW in 2012, corresponding to an increase of 18.90%. In 2016 the global wind power installed capacity rose by 12.5% compared to 2015. The annual wind power addition on a global scale is provided in Figure 2. China with 23.328 GW wind power capacity addition in 2016 remained on top of the world while the USA with 8.203 GW capacity additions stood in second place. Next Germany, India, and Brazil took third, fourth, and fifth place in terms of annual wind power capacity additions of 5.443, 3.612, and 2.014 GW in

2016; respectively. It is worth mentioning that India took fourth place whereas new wind power capacity addition concerned in the year 2016.

Technological development and availability of all sizes of wind turbines covering almost all types of applications starting from home to grid-connected large utilities. The wind power is clean, renewable, and available round the clock, though intermittently. However, it is a highly fluctuating meteorological parameter and changes with location, time of the day, day of the month and month of the year, and lastly from year to year. Global wind power capacities have been on the rise for almost the last two decades.

A great effort has been put into wind turbine performance optimization. In 2006, around 100 research papers were published on this topic, around 200 alone in 2009, and more than 600 in 2013. Keeping in view the limitations on hub-heights and at the same time increasing the energy output from the wind turbines, blade design needs to be modified in terms of decreasing the cut-in speed and/or the rated speed. Reducing the cut-in speed means that a wind turbine can start producing power at a lower wind speed. On the other hand, reducing the rated wind speed means that more power can be produced at a lower rated speed. This paper provides a comprehensive review of both theoretical and experimental techniques and methods used for the efficient design of horizontal-axis wind turbine blades.

2.2 Literature Review:

As per the data provided by Md. Tajnin Amin in his article ‘Prospects of Wind Energy in Bangladesh’, [7] May to August is the most suitable period for extracting wind energy. During this period, the average monthly wind speed varies from 3.68 m/s to 7.03 m/s. Kuakata has the best-suited place among the six spots. Besides Kuakata, Patenga, Kutubdia, and Char Fashion have a good probability to be the sites for installing a wind turbine. The study proved that it will not be a good decision to establish a windmill in Teknaf. But wind energy is extractable from all the places from the six spots around the year.

Alongside the paper by Md. Sabbir Alam, Md. Helal Hossain, Rokhsan-Ara Hemel, Md. Tauhedul Azam regarding 'Investigating the Prospect of Rooftop Flapping Wind Turbine in Bangladesh [8] proves that flapping wind turbine has the advantage on noise, pollution, and aviation mortality rate, it has the potential to install in residential areas like Dhaka and Cox's Bazar cities. In their analysis, they found that the wind velocities are not the same in all the months of the year in Bangladesh. Wind velocities are high in April, May, June, and July and low in September, October, November, and December. Wind velocities remain medium in January, February, and March. Therefore, we investigate the average wind velocities of Dhaka and Cox's Bazar stations for the previous ten years for each month and find a suitable range of wind velocities, which is our research interest to operate wind turbines with slow flapping motion.

The above mention research papers prove the suitability of wind turbine usage in Dhaka city. Based on the above citation, this paper will prove the suitability of the Horizontal Axis Wind Turbine in the prospect of Dhaka City.

2.3 Research Methodology:

To successfully design an efficient wind turbine, the blade contour will take advantage of aerodynamic considerations while the material it is made from provides the necessary strength and stiffness. By investigating the aerodynamic characteristics of a wind turbine blade, the parameters that make up the blade contour are optimized, and the loads that test its structural adequacy will be calculated. Only aerodynamic principles will be analyzed in this project.

To define the power extracted from the wind by the wind turbine, conservation of linear momentum and Bernoulli's principle will be used to arrive at the Betz limit. Schmitz developed a more comprehensive model of the flow in the rotor plane based on the conservation of angular momentum. After completion of the set-up of the wind turbine, the power generation data will be collected from various locations of Dhaka City depending on height and airspeed. The driven data will be used for studying the efficiency and suitability of the designed horizontal axis wind turbine for Dhaka City.

2.4 Motivation: Among renewable sources of energy, the wind is the most widely used resource. Based on the present energy crisis scenario in Bangladesh, wind turbine has the most efficiency in resolving following crisis:

a. Shortage in electrical power supply
b. Suitability of operation and maintenance
c. Shortage in fuel supply
d. Commercial acceptance
e. Creation of new jobs
f. Adverse effect on the environment i.e. global warming.

Based on the above mentioned scenario, installation of single use wind turbines appeared to be one of the best alternative renewable energy resources.

2.5 Significance of Present Study:

Bangladesh has initiated the program of utilizing wind power in its existing energy portfolio. Accordingly, a wind power resource assessment campaign, wind farm design, optimization, and power grid system integration studies have already been initiated by the government. The present effort of understanding the nature of wind power technological developments, existing performance enhancement methodologies, and developing local expertise and facilities is an initiative to contribute to the national wind energy development and deployment program. More than 150 research papers, reports, books, and material from different sources have been collected and reviewed. It has been noted that wind power technology is fully matured and commercially acceptable by many nations whether developed or developing. Design and performance enhancement, theoretical, analytical, numerical, and experimental approaches have been used widely and hence be adopted here in Bangladesh as well. It has been observed that wind turbine performance optimization has been performed based on a single objective basis such as maximization of annual energy yield; minimization of blade loads, cost of energy, root moment; etc. Here is an urgent need to develop methodologies to measure the performance of wind turbines based on multi-objective issues as mentioned. However, with limited literature on the multi-objective analysis of wind turbine blade efficiency improvement, concurrent-hybrid non-dominated sorting genetic. The algorithm is being used for the optimization of the annual energy production, flap-wise root-bending moment, and flaps the wind-turbine blade. The data provided in this paper will be very useful to researchers, academicians, students, and consultants who are planning to work on wind turbine efficiency enhancement, optimization, and overall performance evaluation for further research in Bangladesh.

Chapter 3

MODULE PREPARATION

3.1 Preamble:

Module preparation is one of the crucial part of analysis which influences the reliability and accuracy of results. It is said that approx. 66% of errors in analysis comes from wrong sampling. So, to find more precise data & experimental accuracy of results, sample preparation must be well balanced & accurate.

The project design & make a prototype like horizontal axis wind turbine (HAWT) is quite difficult in Bangladesh. Unavailability of raw materials, instruments & unskilled workers are main reason of not to making a well project like HAWT. Procedure of making turbine blade, rotor, bearing housing, shaft alignment, gear arrangement & connecting to generator is bit complicated & time consumed.

3.2 Preliminary design:

The design process includes the selection of the wind turbine type and the determination of the blade airfoil, blade length and pitch angle distribution along the radius, chord length distribution along the radius, bearing housing, shaft, gear & placement of whole module of turbine. The pitch angle and chord length distributions are optimized based on conservation of angular momentum and theory of aerodynamic forces on an airfoil. Three blade were used to make this (HAWT) project & descriptions are mentioned bellow.

1. **Length of turbine blade:** The distance between the center of rotor and outer most point of tip of blade is considered as the length of turbine blade.
2. **Chord Length and Blade Pitch:** Chord refers to the imaginary straight line joining the leading and trailing edges of an aero foil. The chord (C) length is the distance between the trailing edge and the point on the leading edge where the chord intersects the leading edge.

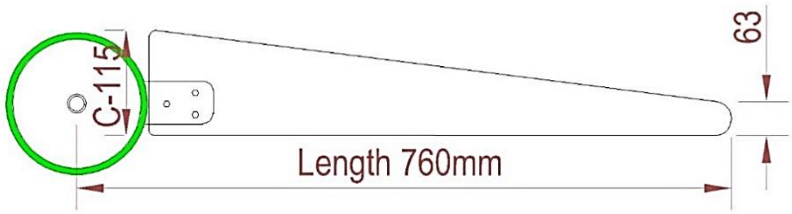


Figure 3.1: Turbine Blade

Blade pitch refers to turning the angle of attack of the blades of rotor into or out of the wind to control the production or absorption of power. It is used to adjust the rotation speed and the generated power for wind turbine.

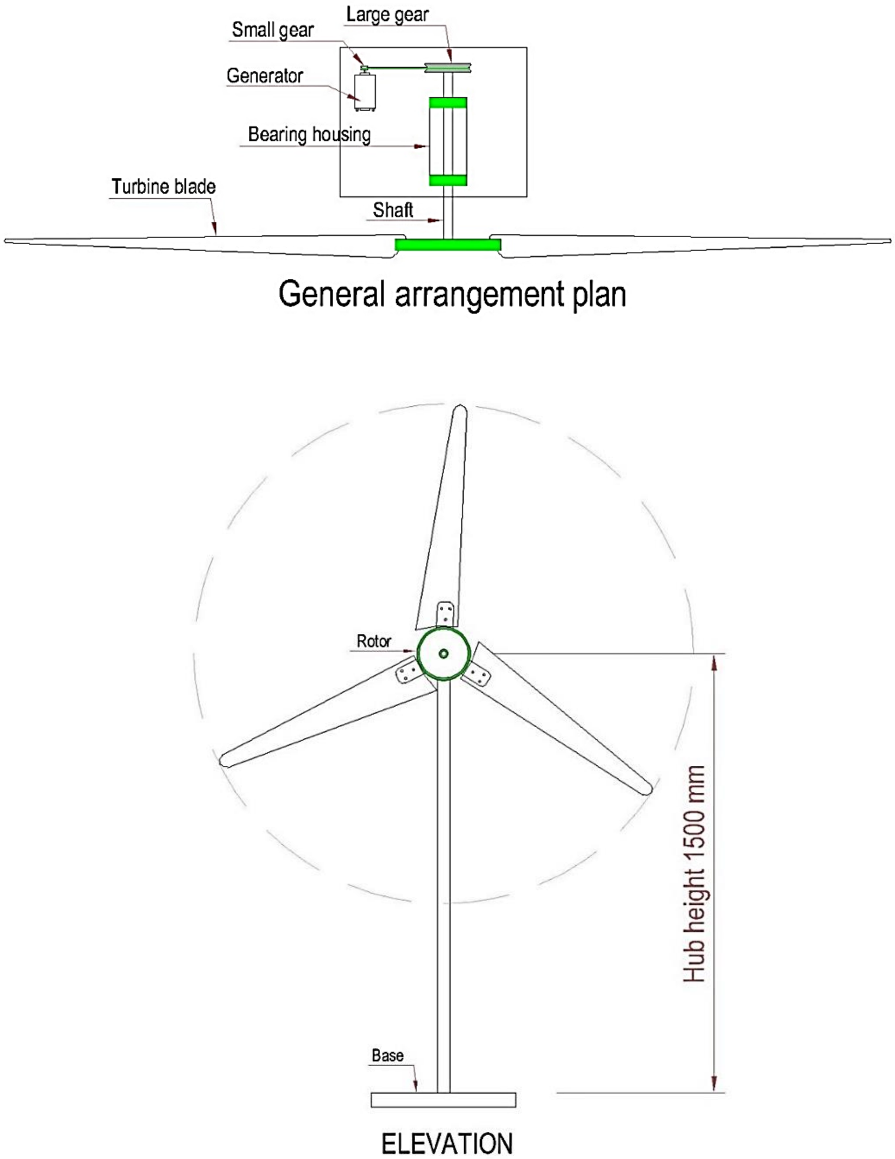


Figure 3.2: Wind Turbine

Hub height: Hub height is defined as the distance from the ground/base to the center of rotor of turbine.

Rotor hub: The rotor hub is the component that usually holds the blades and connects them to the main shaft of the wind turbine. It is a key component not only because it holds the blades in their proper position for maximum aerodynamic efficiency, it also rotates to drive the generator.

Generator: A DC generator is an electromechanical energy conversion device that converts mechanical power into DC electrical power through the process of electromagnetic induction. DC generator operates on the principle of electromagnetic induction i.e. when the magnetic flux linking a conductor changes, an EMF is induced in the conductor. If a conductor turn clockwise between N & S poles of a magnet, electromotive force will be generated.

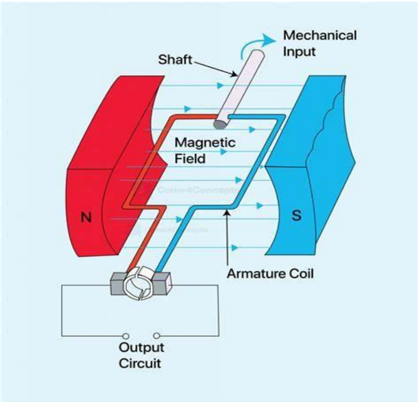


Fig 3.3: DC generator diagram

Voltage: The electric potential difference between two points. In a static electric field, it corresponds to the work needed per unit of charge to move a test charge between the two points. In the International System of Units, the derived unit for voltage is named. It's measured in Volts (V).

Current: Electric Current is the rate of flow of electrons in a conductor. The electric current is measured in amperes, which is the amount of charge passing a point per second. One ampere is equal to 6.24 x 10^18 electrons per second. There are two types of electric current: alternating current (AC) and direct current (DC). AC changes direction periodically, while DC flows in one direction only. In this experiment DC current were found which one directional flow of electric charges.

Voltage $V=IR$ eq.1

Current $I=V/R$ eq.2

Electric power: Electric power is the rate at which electrical energy is transferred by an electric circuit. The SI unit of power is the watt, one joule per second. The electric power P is equal to the energy consumption E divided by the consumption time t, P is the electric power in watt.

$$\text{Power } P = VI \qquad \text{eq.3}$$

$$P = I^2R \qquad \text{from eq.1}$$

$$P = V^2/R \qquad \text{eq.4}$$

By using these basic formula, Current *I* & power *P* produced from generator can be easily determined.

Watt (W): The SI unit of power, equivalent to one joule per second / ($1\ kg{\cdot}m^2{\cdot}s^{-3}$) corresponding to the rate of consumption of energy in an electric circuit where the potential difference is one volt and the current one ampere.

Ampere (A): An ampere is a unit of measure of the rate of electron flow or current in an electrical conductor. One ampere of current represents one coulomb of electrical charge (6.24 x 10^{18} charge carriers) moving past a specific point in one second.

3.3 Turbine blade particulars & Project specification:

ITEMS	DIMENSION
Blade length	760 mm
Chord length	115 mm
Tip width	63 mm
Large gear (Attached with shaft) diameter	60 mm
Small gear (Attached with generator) diameter	20 mm
Gear ratio	1:3
Hub height	1500 mm
Height clearance of turbine	2300 mm
Width clearance	1600 mm
Bearing inner diameter	17 mm
Bearing outer diameter	48 mm
Generator	12 V DC (500W)

3.4 Assembling and installing wind turbine prototype:

3.4.1 Collection of raw material & Instruments: After completing preliminary design of turbine, collection of raw materials & instrument started. Aluminum sheet (1.5mm) metal were collected for turbine blade, rotor hub (Al), shaft (MS), bearing, Anemometer, Clamp meter and DC generator from Nawabpur market, Dhaka, Bangladesh. Had to visit dozens of different types of materials & electric foundry shop & market especially Al Karim market for turbine blade, HT Electric market for Electrical meter to collect these instruments & materials. Mild steel pipe, base frame & others MS plates were collected from local mechanical workshop.

Fig: Aluminum sheet

Fig: Bearing

Fig: DC generator

Anemometer: Anemometer is an instrument that measures wind speed and wind pressure. It measures wind speed by the amount of wind pressure against a surface, such as a cup or a propeller, or by using sonic pulses. Anemometers are important tools for meteorologists, who study weather patterns.

Fig: Anemometer

Clamp meter: A clamp meter is an electrical test tool that combines a basic digital multi-meter with a current sensor. It is a clothespin-shaped instrument that can be clamped around a live wire in order to measure the current it's carrying. As a measurement principle, clamp meters detect the magnetic field emitted by current flowing in a wire in order to measure the current value.

Fig: Clamp meter

3.4.2 Making & assembling:

1. Turbine blade:

Collected aluminum sheet having thickness of 1.5mm was used to make turbine blade. To make this blade, some fan blade making workshop were visited in Nawabpur, Doyaganj, Dhaka. Who actually make industrial exhaust fan, fan blade & supply it to wholesale market. This blade actually made at an exhaust fan making workshop at Distillery road, Doyaganj, Gendariya, Dhaka. At first aluminum sheet were cut according to blade dimensions & shape as per it’s designed. Then blade was bend in manual metal sheet roller machine.

Fig: Manual roller machine

Fig: Turbine Blade

2. Shaft & bearing housing:

A mild steel solid shaft diameter of 17mm is shaped & resized in lathe machine in accordance with inner diameter of bearing & rotter hub. The shaft is carried by two sets bearing in a bearing housing. One end of shaft is connected with rotor hub & other end is with large gear (pulley). Bearing housing is made with steel pipe wherein bearing is placed & prepared solid shaft is placed through the bearing. Bottom outer part of bearing housing is welded to a solid steel plate. Generator (DC 12V) & other system module is placed on the solid steel plate.

Fig: Lathe machine operation

Fig: Shaft & bearing housing

3. Stand & Tower making:

L shaped MS frame size of 50x50x4mm and each length of 450mm were welded together to make rectangular base stand of turbine. A steel pipe of 50mm diameter were used as tower height of 1500mm from base. Two ends of pipe are threaded and connected to base and upper bearing housing plate. Pipe was threaded with lathe machine. All of these making & assembling were performed in a local mechanical workshop located at Meghna ghat, Narayanganj.

Fig: Base stand

Fig: Threaded pipe

4. Refining & assembling prototype:

After preparing and making all parts of turbine, all parts were assembled & set up initially. Turbine were trialed and tested. During trial & test session, we found some problems in turbine blade & in shaft bearing housing. Problems in blade wasn't well weight balanced, rotor of turbine with bearing wasn't revolving smoothly. To solve these problem, we re-weighted the blade until angular momentum of rotor was neutral. Bearing & rotor shaft in bearing housing were realigned, pitch angle of blade was modified. Then we were succeeding to fix the problems. Turbine blade were fitted with nut-bolt. After found all satisfactory, painting was completed.

Fig: Drill machine operation

Fig: Welding operation

5. **Final wind turbine prototype:**

All parts of turbine were re-arranged & set-up. Base stand connected with tower to rotor hub module, shaft gear connected with flexible round belt to generator gear (pulley) etc. Positive and negative terminal of generator is connected with wire to light indicator and main switch board. Everything were installed properly. Finally, part of module preparations were completed and found project of HAWT.

Fig: Wind turbine prototype

Chapter Four

EXPERIMENTAL DATA COLLECTION & ANALYSIS

4.1 Preamble:

Wind speed data was collected three times in a day-morning, noon & night from several places & floors. Data was taken for about 2-3 minutes to determine average and maximum wind speed from the roof of 8th, 12th & 20th floors in Motijheel, Paltan residential & commercial area. Collected data was plotted in table successively and placed for graphical analysis. Wind speed is typically reported in miles per hour, knots or meter per second. Here in this research, wind speed is measured in meter per second.

4.2 Data Table:

4.2.1 Wind Speed Data in December (8th Floor):

Dec-22	Avg. Speed at 8th floor			Max. Speed at 8th floor		
Day	Morning	Noon	Night	Morning	Noon	Night
14	1.12	1.02	1.24	1.54	1.63	1.85
16		1.22	1.18		1.62	1.76
18	3.74	1.3	1.24	4.06	1.5	1.55
20	1.96	1.52	1.74	2.77	2.34	3.18
22	1.22	1.38	3.08	3.04	3.52	3.86
24	3.62	2.36	1.77	4.1	3.42	3.52
26	1.2	1.14	1.21	1.66	1.61	1.66
28		1.12	1.46		1.43	2.42
30		1.72	1.64		2.25	2.31

Table 4.1: Average & Maximum wind speed data

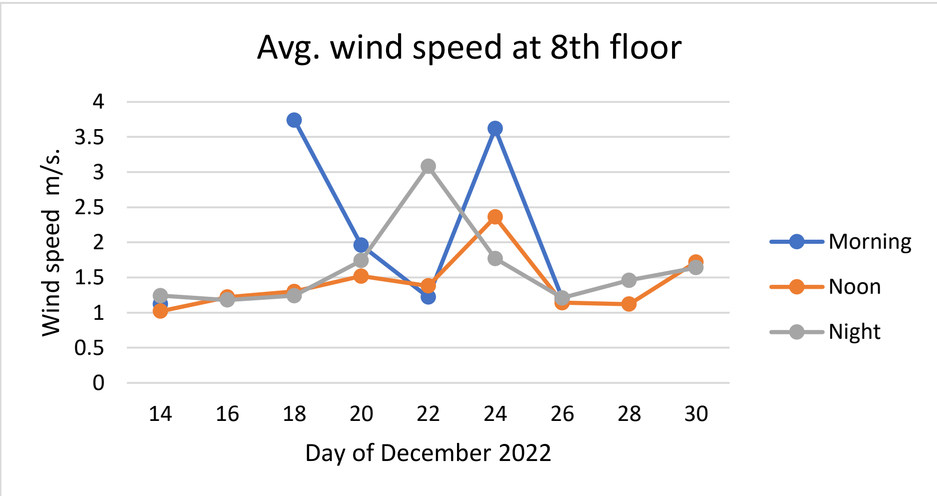


Figure 4.1: Average wind speed data

Figure 4.1 shows that the average value of wind speed with respect of the day of December 2022. Variation of wind velocity was small throughout the month and it remains between 1.00 m/s. -2.36 m/s. except 18th morning, 22th night and 24th morning. Highest wind velocity was 3.74 m/s. on 18th December in morning and lowest velocity was 1.12 m/s. in noon on 28th December.

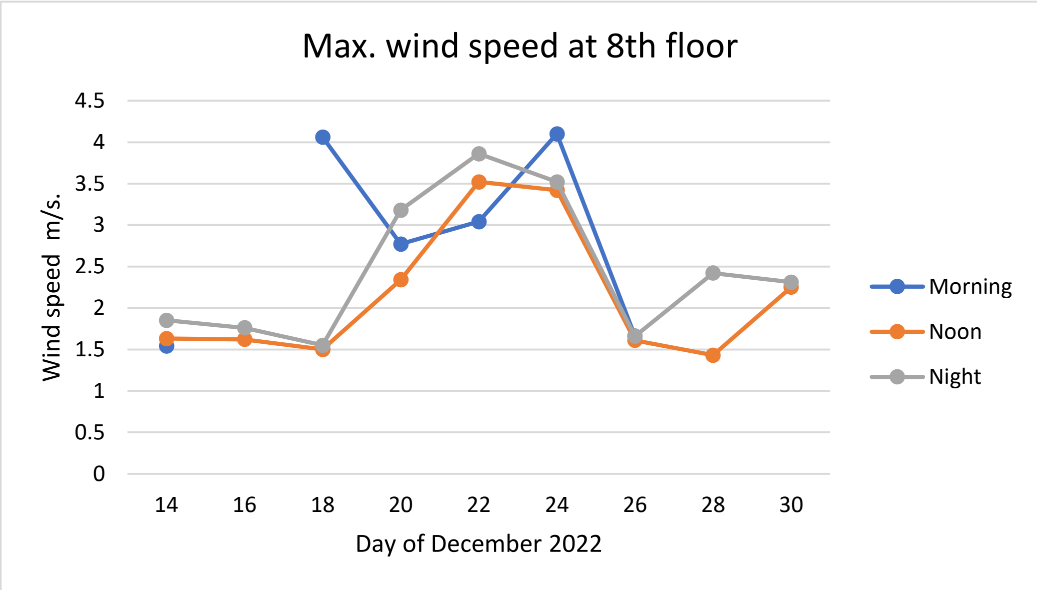


Figure 4.2: Maximum wind speed data

Figure 4.2 shows maximum wind speed with respect of the day of December 2022. It shows that wind speed level was above 2.34 m/s. on 20th to 24th December and maximum velocity was 4.1 m/s. on 24th morning. Wind velocity was relatively low on the others day of December and it remains between 1.5 m/s.-2.5 m/s.

4.2.2 Wind Speed Data in January (8th Floor):

Jan-23	Avg. Speed at 8th floor			Max. Speed at 8th floor		
Day	Morning	Noon	Night	Morning	Noon	Night
2	1.44	1.21	1.45	2.72	1.55	2.31
4	1.52	1.22	1.34	3.11	3.31	2.2
6	0.86	1.02	1.05	1.33	1.26	1.54
8	1.22	1.26	0.34	1.45	1.44	0.86
10	1.4	1.28	1.12	1.65	1.93	1.76
12	1.76	1.2	1.22	2.5	1.96	1.84
14	1.1	1.04	1.11	1.37	1.33	1.52
16	1.52	1.54	1.52	2.59	2.94	2.44
18	1.28	1.11	1.58	1.88	1.8	2.1
20	0.88	0.75	0.64	1.33	1.12	1.18
22	1.26	1.35	0.76	2.04	2.26	1.14
24	1.22	1.42	0.77	1.92	1.86	1.2
26	1.24	1.22	0.64	1.58	1.55	1.18
28	1.91	1.44	1.8	3.74	2.62	3.11
30	1.45	1.41	1.36	2.32	2.34	2.3

Table 4.2: Average & Maximum wind speed data

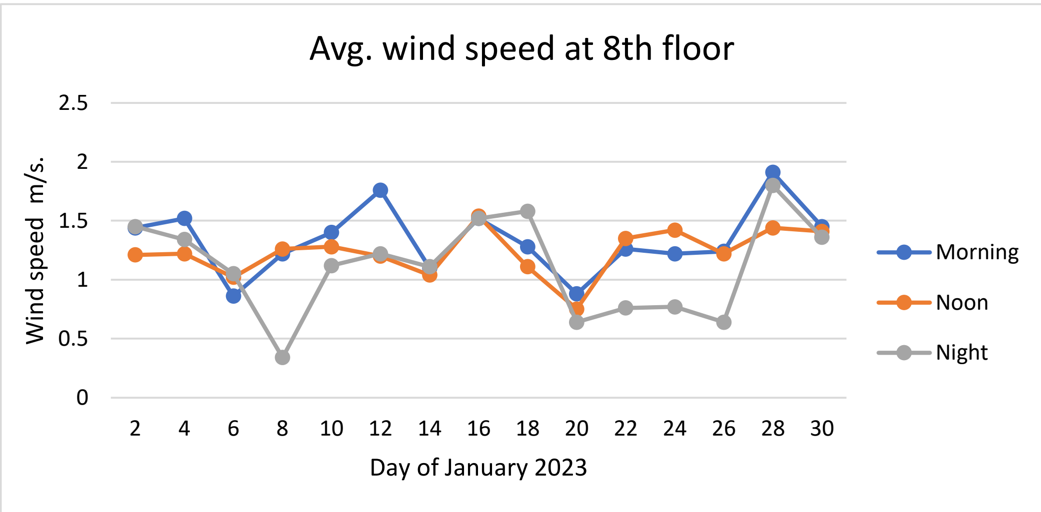


Figure 4.3: Average wind speed data

Figure 4.3 shows that the average value of wind speed with respect of day of January 2023 and variation of wind velocity was irregular throughout the month. Highest wind velocity was 1.8 m/s. on 28th January in morning and lowest velocity was 0.34 m/s. on 8th January at night. It also shows that wind velocity was relatively low at night than morning and noon on 20th January-26th January.

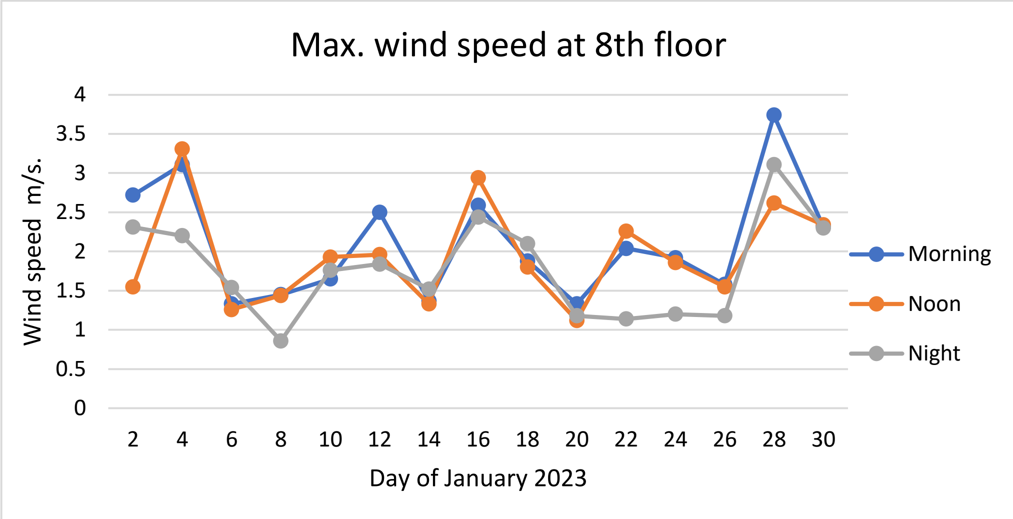


Figure 4.4: Maximum wind speed data

Figure 4.4 shows maximum wind speed with respect of the day of January 2023. It shows that rhythmic change of wind speed by day throughout the month. Wind velocity low in morning, also low in noon & night or vice versa and it happens most of the day. Such as 12th January high, 14th January's velocity was low and 16th January was high. Wind speed at night was comparatively lower than morning & noon over the month. Wind speed level was above or around 2.00 m/s. most of the day and maximum velocity was 3.74 m/s. in morning on 28th January, lowest was 0.86 m/s. on 8th at night.

4.2.3 Wind Speed Data in December (12th Floor):

Dec-22	Avg. Speed at 12th floor			Max. Speed at 12th floor		
Day	Morning	Noon	Night	Morning	Noon	Night
14	1.12	1.06	1.19	1.56	1.64	1.88
16		1.24	1.2		1.6	1.77
18	3.83	1.87	1.37	4.19	2.13	1.66
20	2.23	1.74	3.19	2.85	2.45	3.43
22	1.28	1.44	3.13	3.16	3.61	3.93
24	3.83	2.44	1.87	4.19	3.56	3.68
26	1.2	1.15	1.18	1.66	1.63	1.68
28		1.12	1.61		1.43	2.4
30		1.7	1.66		2.28	2.36

Table 4.3: Average & Maximum wind speed data

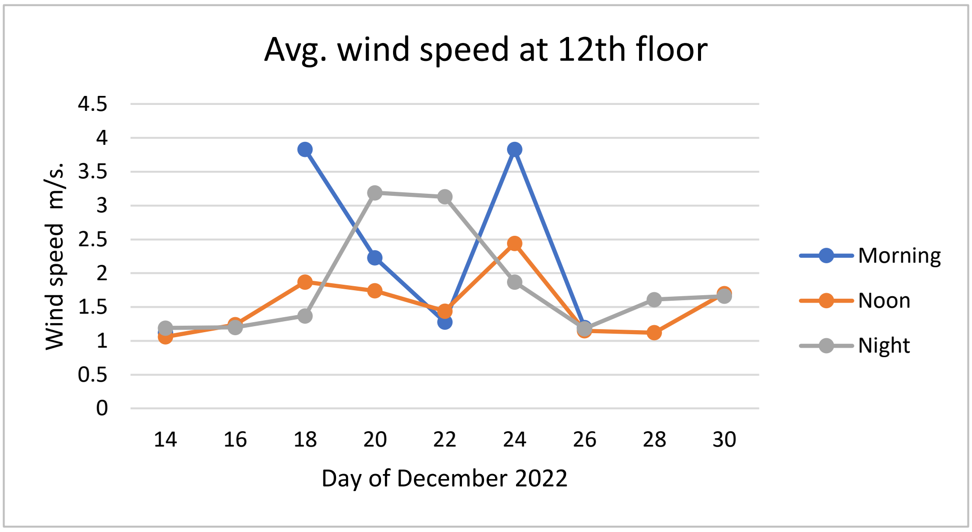


Figure 4.5: Average wind speed data

Figure 4.5 shows that the average value of wind speed with respect of day of December 2022 at 12th floor and variation of wind velocity was irregular throughout the month. Highest wind velocity was 3.83 m/s. on 18th and 24th December in morning and lowest velocity was 1.06 m/s. on 14th December in noon. 20th & 22th December's velocity was high at night in this month and others day's velocity was relatively low.

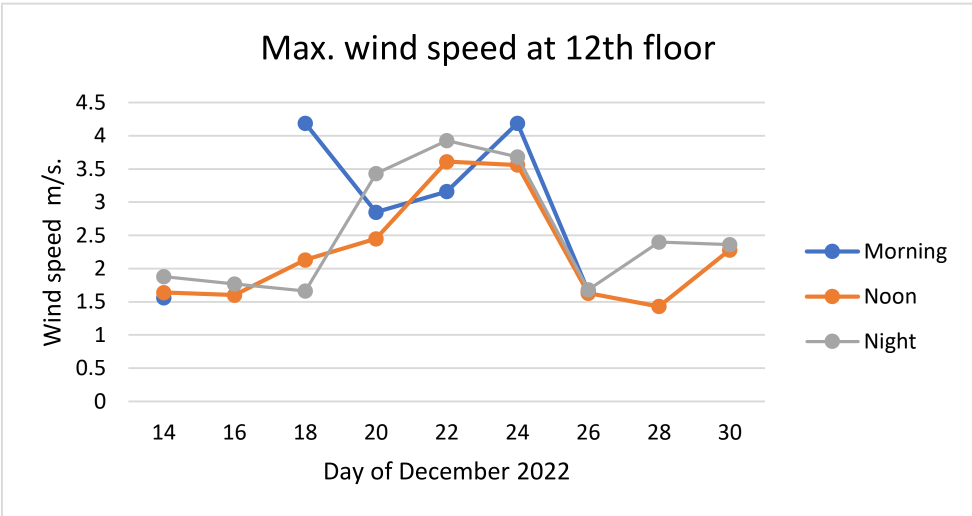


Figure 4.6: Maximum wind speed data

Figure 4.6 shows maximum wind speed with respect of the day of December 2022 at 12th floor. It shows that wind speed level was above 2.85 m/s. on 20th to 24th December and maximum velocity was 4.19 m/s. on 18th & 24th morning. Wind velocity was relatively low on the others day of December and it remains between 1.5 m/s. -2.5 m/s. Night velocity was comparatively high with respect of morning & noon throughout the month.

4.2.4 Wind Speed Data in January (12th Floor):

Jan-23	Avg. Speed at 12th floor			Max. Speed at 12th floor		
Day	Morning	Noon	Night	Morning	Noon	Night
2		1.54	1.52		3.02	2.41
3	1.52	1.53	1.46	3.11	3.02	3.1
4	1.54	1.24	1.54	2.96	2.77	2.92
6	0.79	1.11	1.02	1.16	1.38	1.4
8	1.22	1.52	0.78	1.47	2.04	1.09
10	1.48	1.34	1.22	1.88	2.09	1.82
12	1.74	1.25	1.24	2.52	2.04	1.88
14	1.08	1.1	1.09	1.38	1.38	1.54
16	1.54	1.55	1.49	2.6	2.96	2.44
18	1.32	1.24	1.62	1.96	1.88	2.22
20	0.85	0.77	0.72	1.3	1.24	1.25
22	1.32	1.38	0.8	2.1	2.3	1.12
24	1.2	1.44	0.76	1.96	1.78	1.22
26	1.3	1.24	0.7	1.66	1.68	1.11
28	2.01	1.56	1.74	3.82	2.7	3.44
30	1.44	1.42	1.41	2.36	2.41	2.38

Table 4.4: Average & Maximum wind speed data

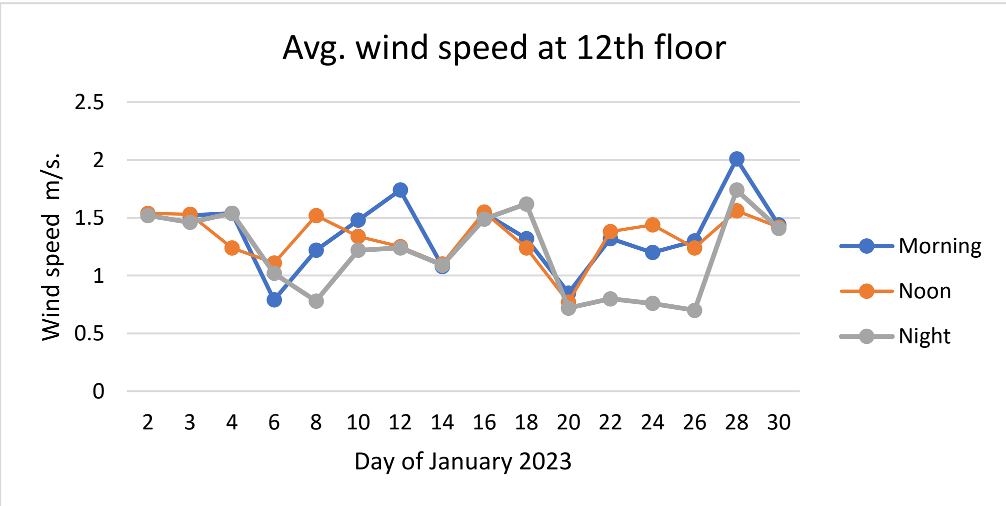


Figure 4.7: Average wind speed data

Figure 4.7 shows that the average value of wind speed with respect of day of January 2023 at 12th floor and variation of wind velocity was irregular throughout the month. Highest wind velocity was 2.01 m/s. on 28th January in morning and lowest velocity was 0.70 m/s. on 26th January at night. It also shows that wind velocity was relatively low at night than morning and noon almost over the month.

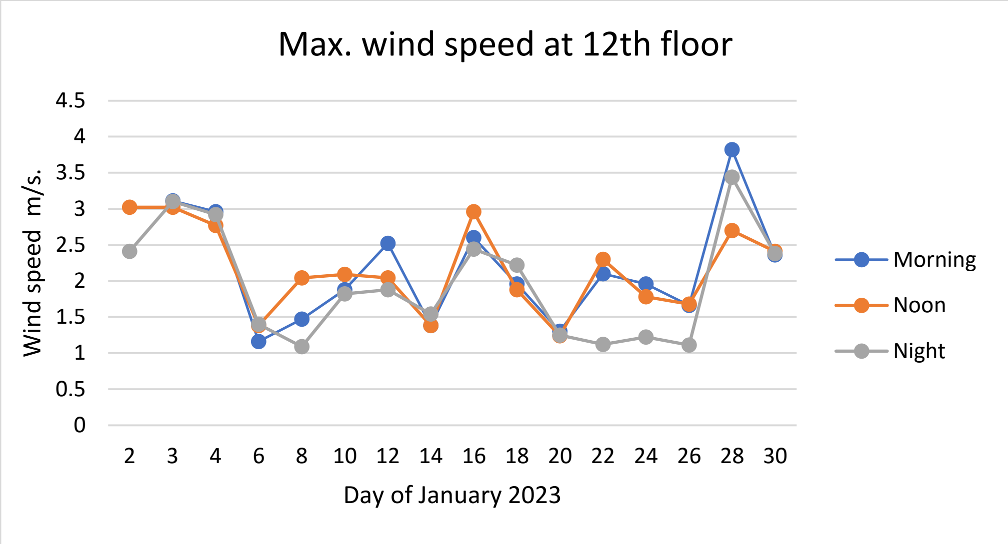


Figure 4.8: Maximum wind speed data

Figure 4.8 shows maximum wind speed with respect of the day of January 2023 at 12th floor. It shows that rhythmic change of wind speed by day throughout the month. Wind velocity low in morning, also low in noon & night or vice versa and it happens most of the day. Such as 12th January high, 14th January's velocity was low and 16th January was high. Wind speed at night was comparatively lower than morning & noon over the month. Maximum wind velocity was 3.82 m/s. in morning on 28th January, lowest was 1.09 m/s. on 8th at night.

4.2.5 Wind Speed Data in December (20th Floor):

Dec-22	Avg. Speed at 20th floor			Max. Speed at 20th floor		
Day	**Morning**	**Noon**	**Night**	**Morning**	**Noon**	**Night**
18	3.88	1.81	1.33	4.24	2.16	1.64
20	2.22	1.72	3.2	2.86	2.48	3.44
22	1.3	1.42	3.06	3.11	3.66	4.02
24	3.84	2.44	1.8	4.2	3.66	3.72
26	1.08	1.12	1.2	1.68	1.66	1.62
28		1.11	1.66		1.43	2.38
30		1.71	1.65		2.32	2.41

Table 4.5: Average & Maximum wind speed data

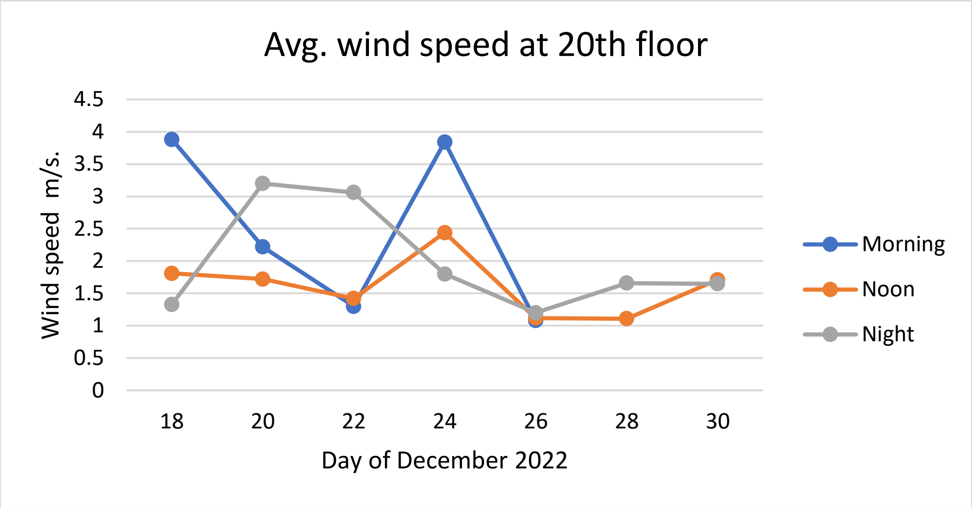


Figure 4.9: Average wind speed data

Figure 4.9 shows that the average value of wind speed with respect of 7 days of December 2022 at 20th floor. Highest wind velocity was 3.88 m/s. on 18th December in morning and lowest velocity was 1.08 m/s. on 26th December in morning. 20th & 22th December's velocity was high at night in this month and others day's velocity was relatively low.

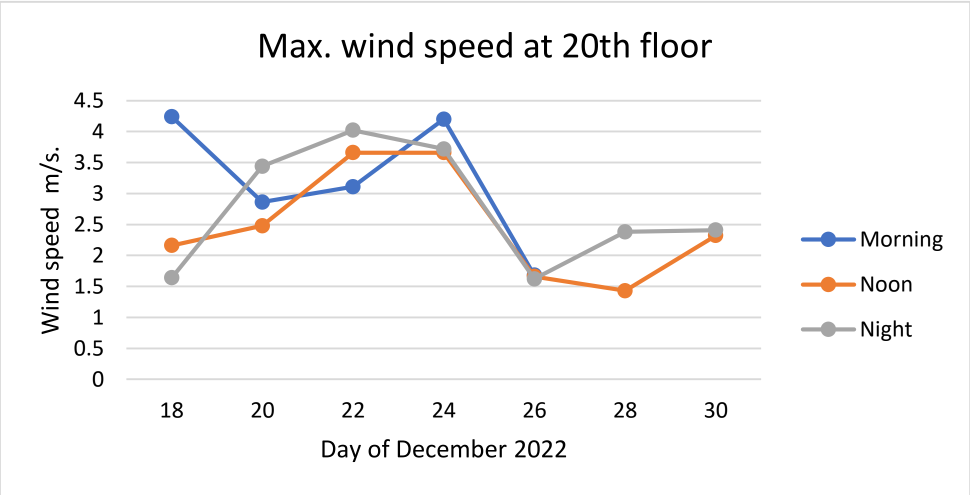


Figure 4.10: Maximum wind speed data

Figure 4.10 shows maximum wind speed with respect of the day of December 2022 at 20th floor. It shows that wind speed level was above 2.86 m/s. on 20th to 24th December and maximum velocity was 4.24 m/s. on 18th morning. Wind velocity was relatively low on the others day of December and it remains between 1.5 m/s. -2.5 m/s. Velocity was comparatively high in middle of the month.

4.2.6 Wind Speed Data in January (20th Floor):

Jan-23	Avg. Speed at 20th floor			Max. Speed at 20th floor		
Day	Morning	Noon	Night	Morning	Noon	Night
`	1.44	1.46	1.72	2.72	2.18	2.54
4	1.51	1.26	1.8	3.06	3.38	3.01
6	0.8	1.1	1.08	1.42	1.4	1.44
8	1.29	1.51	0.96	1.58	2.4	1.11
10	1.36	1.25	1.18	1.74	2.12	1.89
12	1.78	1.24	1.25	2.64	2.11	1.94
14	1.14	1.08	1.14	1.44	1.4	1.52
16	1.54	1.55	1.52	2.61	2.86	2.46
18	1.32	1.24	1.64	1.96	1.88	2.2
20	0.82	0.84	0.7	1.28	1.22	1.26
22	1.28	1.33	0.72	2.14	2.33	1.18
24	1.28	1.44	0.92	2.04	1.88	1.26
26	1.3	1.36	0.64	1.78	1.65	1.22
28	1.94	1.58	2.4	3.92	2.74	4.18
30	1.48	1.44	1.42	2.38	2.36	2.36

Table 4.6: Average & Maximum wind speed data

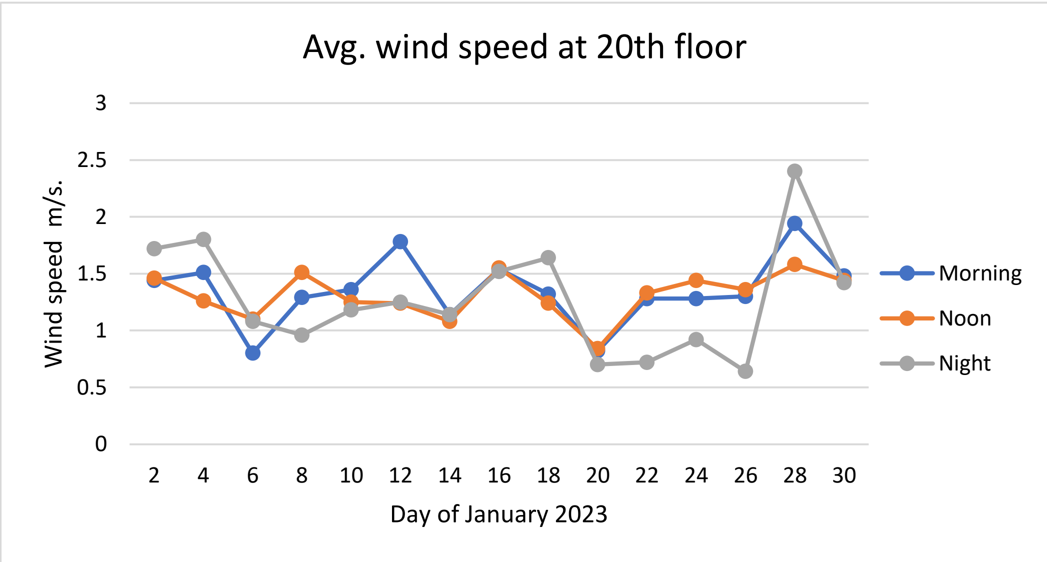


Figure 4.11: Average wind speed data

Figure 4.11 shows that the average value of wind speed with respect of day of January 2023 at 20th floor. Highest wind velocity was 2.40 m/s. on 28th January and lowest velocity was 0.64 m/s. on 26th January at night. Wind speed variation was low in noon throughout the month and variation was around 0.5 m/s. lowest night wind speed was 20th -26th January and it was below 1.00 m/s.

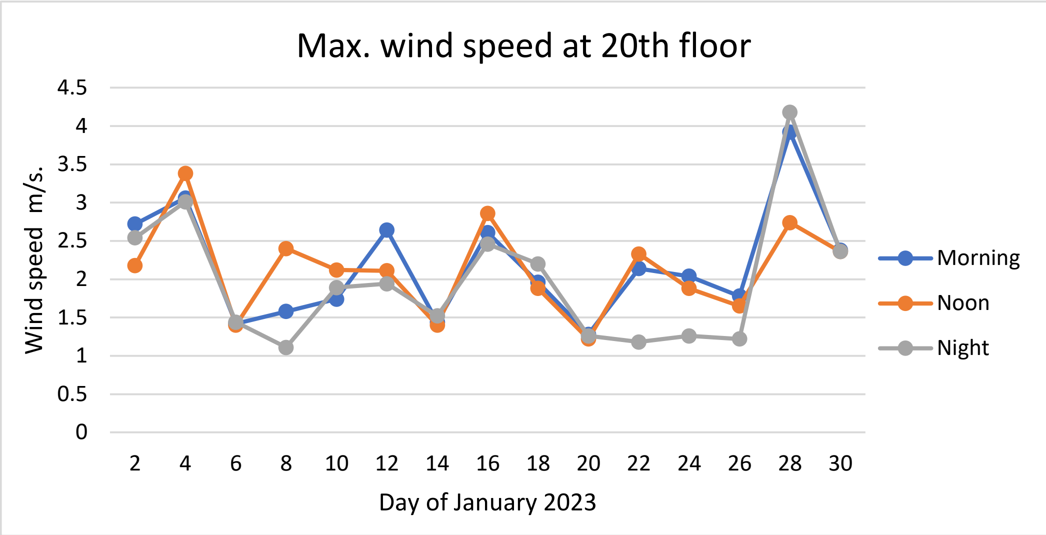


Figure 4.12: Maximum wind speed data

Figure 4.12 shows maximum wind speed with respect of the day of January 2023 at 20th floor. It shows that rhythmic change of wind speed by day almost throughout the month. Wind velocity low in morning, also low in noon & night or vice versa and it happens most of the day. Such as 12th January high, 14th January's velocity was low and 16th January was high. Wind speed at night was comparatively lower than morning & noon over the month. Maximum wind velocity was 4.18 m/s. at night on 28th January, lowest was 1.11 m/s. on 8th at night. From 20th to 26th January wind velocity was below 1.3 m/s. at night.

By studying these data, it is clear that wind speed increases with respect of increase number of floor. These graphs shows that maximum wind velocity was found at 20th floor and velocity was relatively low at 8th floor.

4.3 Data Analysis:

4.3.1 Experimental work & performance analysis:

Wind turbine performance analysis is a bit complicated but critical issue and has to be dealt carefully. This section deals with this issue by reviewing the experimental studies and analytical approaches reported in the literature. We performed our HAWT experiment in an almost open place. An axial stand fan was introduced to supply air in different wind speed to the turbine rotor. A speed sensor (Anemometer), Load module & clamp meter were used to determine different experimental parameters. The speed of air is measured by using anemometer placed along the turbine. Turbine is placed along perpendicular to axial fan. The rotational speed of turbine rotor was measured manually. The clamp meter is to measure the value of voltage produced by the electrical generator. Obtain RPM & producing voltage from generator with respect to wind speed plotted in graph.

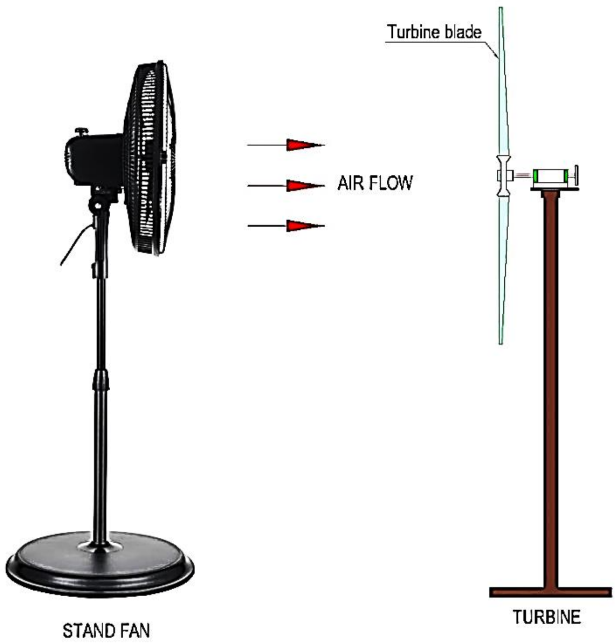


Fig: Schematic diagram of experiment

The output power of any power producing device is maximum when it is operated at the optimum conditions. Similar is the case for wind turbines. They produce maximum power if the rotors are driven at the optimum rotational speed for a particular wind speed.

Turbine started to rotate at wind speed of 1.52 m/s. At initial stage of rotation of turbine, voltage meter shows the value 1V. Producing voltage increases with respect to increase of rpm. We found maximum 104 rpm at wind speed of 2.42 m/s. and voltage measured 2.48V. Wind speed, rpm and voltage were measured successfully during session of experiment. Obtained data from experiment is plotted in table & in graph.

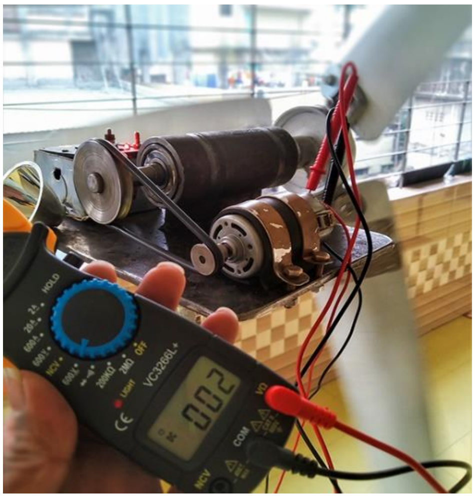


Fig: Produced voltage from generator

Wind speed	RPM
1.76	75
1.84	88
2.16	92
2.2	100
2.42	104

Table 4.7: Wind speed VS RPM of turbine

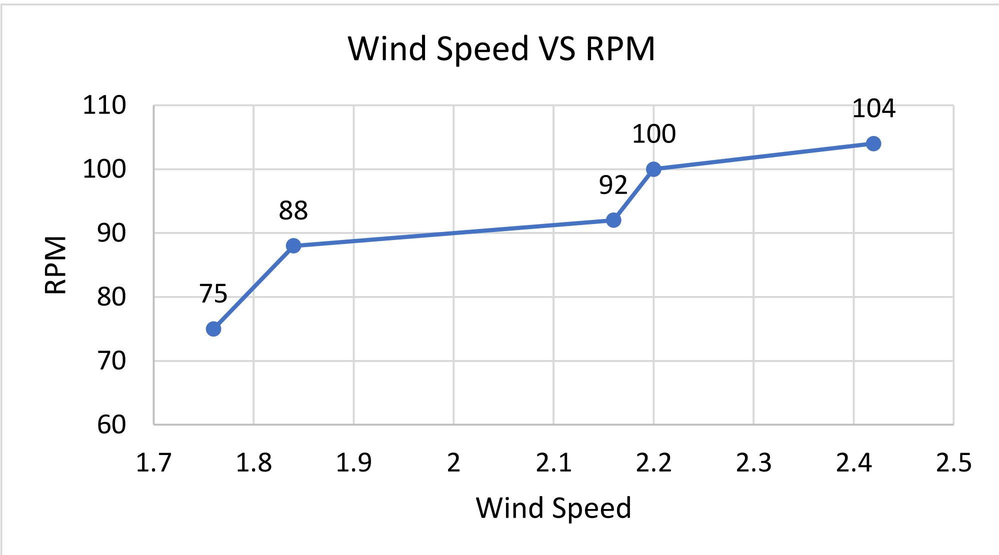
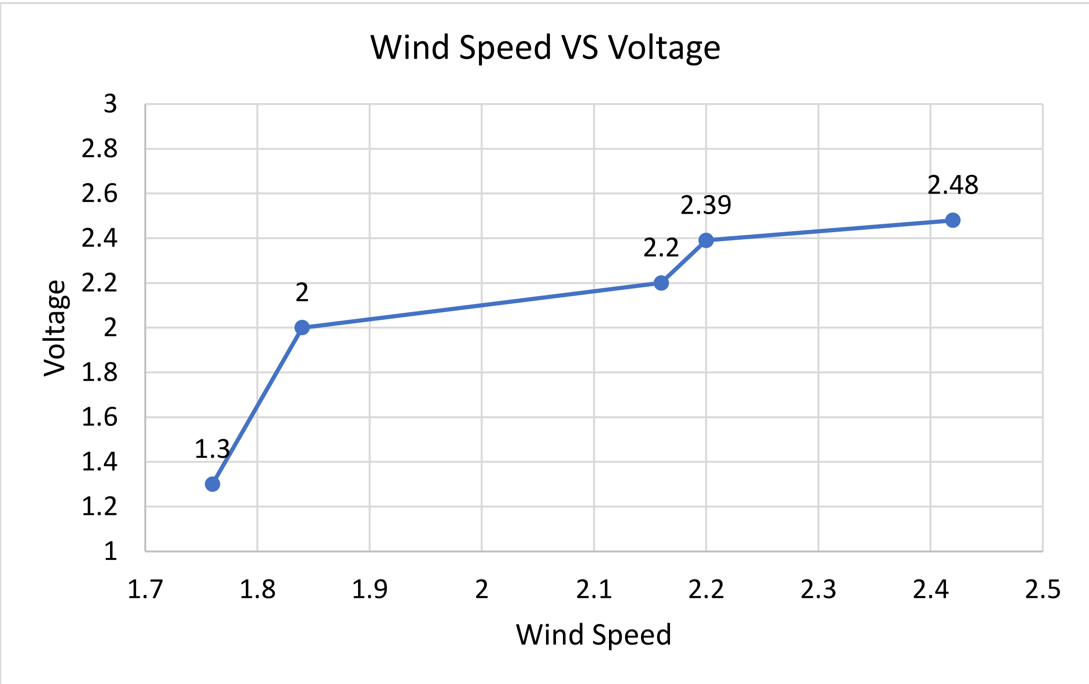


Figure 4.13: Wind speed VS RPM

Figure 4.13: Shows the relation between the measured values of rotational-speed of the wind turbine with different wind velocity. In general, the rotational-speed of the wind-turbine increases when the increase of wind velocity & wind pressure. Its shows that minimum rotational speed 75 rpm at wind velocity of 1.76 m/s. and maximum rotational speed 104 rpm at wind velocity of 2.42 m/s.

Wind speed	Voltage
1.76	1.3
1.84	2
2.16	2.2
2.2	2.39
2.42	2.48

Table 4.8: Wind speed VS voltage



Graph 4.14: Wind speed VS Voltage

Figure 4.14: shows the relation between the wind velocity and producing voltage. The predicted results of the experiments indicated that the voltage increases when the wind-speed increase. Also, it shows that the maximum voltage is 2.48V at 2.42 wind speed.

Chapter Five

Results & Discussion

5.1 Preamble:

This study was focused on find out the daily wind speed at different height of floors in the morning, noon & night of over the year. But only two month's (December & January) data was collected & which is not enough for experiment & analysis. November-January month is regarded as off session of wind flow in Bangladesh. Pick time of wind velocity in Dhaka is April-August and average speed is 3.2m/s-4.21 m/s.[8] It is shown that, wind velocity increase with increase of height form ground. As we took data from 8th, 12th & 20th floor, we see wind velocity is maximum on 20th floor then 12th floor & comparatively low on 8th floor due to surrounding obstacle. But most of the building in Dhaka city is 10-12 storied. So we prefer 12th floor to install the project. Based on two months collected data, experimental performance study of a horizontal axis three bladed wind-turbine was conducted to estimate the wind power and the generated electrical power. From experiment, we found generated rpm from different wind speed and generated electrical power.

RPM	Voltage (V)
75	1.3
88	2
92	2.2
100	2.39
104	2.48

Table 5.1: RPM VS Voltage

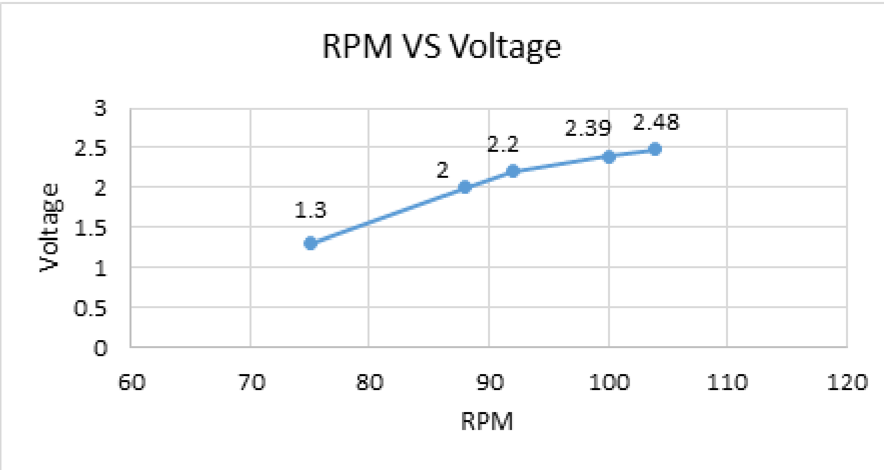


Figure 5.1: RPM VS Voltage

Figure 5.1 shows the relation between RPM & generated voltage. It is clear in this figure that no notable voltage is produced before 75 rpm. Voltage increases with respect increase of rpm of generator.

So, we can say that more rpm more power. But if we increase turbine rpm, significant vibration will occur. So solution is; as the required torque to revolve turbine blade is same and swept area of turbine unchanged, so increasing of gear ratio will increase generator rpm also increase power output without increase vibrations.

5.2 Limitation:

1. **Local made wind turbine**: As the turbine was made locally, turbine blade, pitch angle, bearing housing etc. was not well enough & accurate. So it has some issues like create vibration & noise as a results of low efficiency.
2. **Limited data for analysis**: Previously mentioned that only two month's data was collected instead of whole year. Which is inadequate for analysis. Wind speed data will be needed over the year to find more accuracy of analysis.

5.3 Future work:

As data is needed throughout the year, Automated *Arudino* system may be introduced in this project. Automated *Arudino* system will give us daily basis live data like wind velocity, wind temperature, wind pressure, rotor rpm, generated voltage, electricity etc. The accumulated data from Arudino system will help us in analyzing and obtaining more accurate results for our project and will be trusted resources for future research on wind turbine.

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   Neel S. Patel1 Denish C. Patel2 Rushabh A. Shah3 Nayan K. Desai4 Kuldeep H. Nayi5 P.G. Student Department of Mechanical Engineering Dr.S. & S.S. Ghandhy GEC-Surat, Gujarat, India 2BITS-Pilani, Rajasthan India 5Government Engineering College-Valsad, Gujarat, India
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