PROJECT REPORT

ON

Design and Cost Estimation of Wind Power Plant at Deepor Beel

Submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Electrical Engineering of Assam Science and Technology University

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This is to certify that the project entitled "**Design and Cost Estimation of Wind Power Plant at Deepor Beel**" has been carried out and presented by

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students of BTech 8th Semester Electrical Engineering, Assam Engineering College. under my supervision and guidance in a manner satisfactory to warrant its acceptance as a prerequisite for the award of the degree of Bachelor of Technology in Electrical Engineering of the Assam science and technology University. Further, the report has not been submitted/reproduced in any form for the award of any other degree

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ABSTRACT

Energy plays an important role in any country’s economy and infrastructure growth. Wind energy is a renewable form of energy and environment friendly compared to conventional energy resources that pollute the environment. A proper analysis of wind speed data is an important parameter to estimate wind energy potential at a particular site.

In this report we measured the wind speed in different months starting from November 2021 to January 2022 end,from the top of ASTU building,which is at 33ft from the ground. Using the measured speed we calculate the speeds at different heights by using mathematical and graphical analysis. Since the winds near the surface of earth are derived from large-scale movement of atmospheric winds, the location height above ground level at which the wind is measured and the nature of the surface on earth have an influence on the velocity of wind at any given time. By using MATLAB simulink we calculated the power and feasibility of setting a windmill at Deepor Beel.

We have also done some groundwork on what type, specifications, quantity of components will come handy in the setup of a wind power plant and accordingly researched and contacted required authorities and estimated the fixed costs involved during its setup.

CONTENTS

CHAPTER - 1
INTRODUCTION

1.1 Wind flow

Wind results from air in motion. Air in motion arises from a pressure gradient. On a global basis one primary forcing function causing surface winds from the poles towards the equator is convective circulation. Solar radiation heats the air near the equator, and this low density heated air is buoyed up. At the surface it is displaced by cooler, more dense higher pressure air flowing from the poles. In the upper atmosphere near the equator the air tends to flow back towards the poles and away from the equator. The net result is a global convective circulation with surface winds from north to south in the northern hemisphere.

In actuality the wind is much more complex. Earth's rotation which causes a coriolis force resulting in an easterly wind velocity component in the northern hemisphere.
There is further complication of boundary layer frictional effects between the moving air and the earth's rough surface. Mountains, trees, buildings , and similar obstructions impair stream line air flow. Turbulence results, and the wind velocity in a horizontal direction markedly increases with altitude near the surface.

Local winds are caused by two mechanisms. The first is differential heating of land and water. Solar insolation during the day is readily converted to sensible energy of the land surface but is partly absorbed in layers below the water surface and partly absorbed in layers below the water surface and partly consumed in evaporating some of that water. The land mass becomes hotter than the water, which causes the air above the land to heat up and become warmer than the air above water. The warmer lighter air above the land rises, and the cooler heavier air above the water moves in to replace it. This is the mechanism of shore breezes. At night the direction of the breezes is reversed because the land mass cools to the sky morerapidly than the water, assuming a clear sky. The second mechanism of local winds is caused by hills and mountain sides. The air above the slopes heats up during the day and cools down at night, more rapidly than the air above the lowlands. This causes heated air during the day to rise along the slopes and relatively cool heavy air to flow down at night.

1.2 Why renewable energy

Demand for renewable energy has been increasingly justified over the last couple of years as world powers turn to clean, green energy while overdependence on fossil fuel generation is still prominent in developing countries. Nevertheless, there is an expectation that renewable energy sources will play a wider role over the next two decades in energy with wind energy projected to contribute 1.1 trillion - kilowatt-hours (kWh) of a total of close to 4 trillion kWh of renewable energy expected to be generated by year 2030. Furthermore, research suggests that solar and wind energy are currently the most likely to provide economically affordable alternative energy sources, because other renewable energy sources like tidal remain costly and inefficient . It is obvious that wind and solar energy studies will be the center of future renewable engineering efforts.

1.3 Wind energy in India

Wind power generation capacity in India has significantly increased in recent years. As of 30 November 2021, the total installed wind power capacity was 40 GW, the fourth largest installed wind power capacity in the world. Wind power capacity is mainly spread across the Southern, Western and Northern regions.

Wind power costs in India are decreasing rapidly. The levelised tariff of wind power reached a record low of ₹2.43 (3.2¢ US) per kWh (without any direct or indirect subsidies) during auctions for wind projects in December 2017. However, the levelised tariff increased to ₹2.77 (3.7¢ US) per kWh in March 2021. In December 2017, union government announced the applicable guidelines for tariff-based wind power auctions to bring more clarity and minimize the risk to the developers

The Indian government has installed over 800 wind-monitoring stations all over the country through National Institute of Wind Energy (NIWE) and issued wind potential maps at 50m, 80m, 100m and 120m above ground level. The recent assessment indicates a gross wind power potential of 302 GW in the country at 100 meter and 695.50 GW at 120 meter above ground level.

Wind power accounts for nearly 10% of India's total installed power generation capacity and generated 62.03 TWh in the fiscal year 2018–19, which is nearly 4% of total electricity generation. The capacity utilization factor is nearly 19.33% in the fiscal year 2018-19 (16% in 2017–18, 19.62% in 2016-17 and 14% in 2015–16). 70% of annual wind generation is during the five months duration from May to September coinciding with

Southwest monsoon duration. In India, solar power is complementary to wind power as it is generated mostly during the non-monsoon period in daytime.

1.4 Why Deepor Beel

Deepor beel near AEC is a large open water body with a few small buildings nearby. One bank of the beel is located very close to our college and is seen as a potential ground for a wind energy harvesting site. Despite some earlier work being implemented there, no commendable wind project is done at the site. Wind blows almost throughout the year at the site.

The site is open with negligible or very less obstructions and easily accessible for data collection. Wind speed is almost constant.

Thus, we selected Deepor Beel as a potential site for a wind power plant and our project site.

CHAPTER-2
LITERATURE REVIEW

2.1Topic: **Investigation of wind characteristics and wind energy potential in Kirklarel**

AUTHOR**:** Murat Gokceka, Ahmet Bayulkenb ,SukruBekdemira. Turkey Institute of Energy, Istanbul Technical University, Maslak, 34469, Istanbul, Turkey

According to the power calculations done for the site, annual mean power density based on Weibull function is 138.85 W/m2. The results indicate that the investigated site has fairly wind energy potential for the utilization.

Gökçek, M., Bayülken, A. and Bekdemir, Ş., 2007. Investigation of wind characteristics and wind energy potential in Kirklareli, Turkey. Renewable Energy, 32(10), pp.1739-1752.

2.2 Topic: Wind energy feasibility study for city of Shahrbabak in Iran.

AUTHOR**:** A. Mostafaeipour, Ali A. Dehghan, Ahmad Sedaghat, V. Kalantar.

An economic evaluation was done in order to show feasibility of installing small wind turbines. It was concluded that it costs 18 cents for 1 kW h which is 5 cents more than the market price. Each turbine of 10 kW can supply power for icebox, washer, water pump, TV, lighting, electrical fan, charger, and air conditioning units for small houses.

Mostafaeipour, A., Sedaghat, A., Dehghan-Niri, A.A. and Kalantar, V., 2011. Wind energy feasibility study for the city of Shahrbabak in Iran. Renewable and Sustainable Energy Reviews, 15(6), pp.2545-2556.

2.3 Topic: Wind energy potential at different cities of Assam using statistical models

AUTHOR**:**MdZakir Hussain, Dwijendra Kumar Roy, Sabah Khan, Pranjal Kumar Sharma, Rumi Talukdar. International Journal of Advance Research and Innovation.

Analysis shows that there is a possibility of wind power generation in the city of Dibrugarh followed by city Guwahati at these low wind speed region and the vertical axis wind turbines can be installed for power generation in cities Dibrugarh and Guwahati.

Hussain, M.Z., Roy, D.K., Khan, S., Sharma, P.K. and Talukdar, R., 2018. Wind Energy Potential at Different Cities of Assam Using Statistical Models. International Journal, 6(1), pp.38-43.

2.4 Topic: Modeling and simulation of wind turbine generator using matlab-simulink

AUTHOR:Roshen T. Ahmad,Mahdi A. Abdul-Hussain

In this research a mathematical model and its parameters has been studied that affect the electrical output power generated by the wind turbine. These parameters are wind speed which is affected by temperature that cause air density change and that lead to vary wind speed, and power coefficient as a function of pitch angle and blade tip speed.The modeling and simulation technique will play a great role in the design and analysis of these wind turbines.

Ahmad, R.T. and Abdul-Hussain, M.A., 2017. Modeling and simulation of wind turbine generator using Matlab-Simulink. Journal of Al Rafidain University College, (40), pp.282-299.

2.5 Topic: Feasibility study of wind energy potential for electricity generation in the northwestern coast of Senegal

AUTHOR: B. OuldBilala, M. Ndongo, C.M.F. Kebea, V. Samboua, P.A. Ndiayea

The wind characteristics and wind energy potential in eight sites (Kayar, Potou, Gandon, Sakhor, Sine Moussa Abdou, Botla, Dara Andal and Nguebeul) are analyzed using the wind speed data collected during a period of one year for each site. The highest output energy was 4,517,900k Wh/year in Sokhar for the wind turbine Repower, while the lowest output energy was 312 kWh/year observed in Gandon.

Bilal, B.O., Ndongo, M., Kebe, C.M.F., Sambou, V. and Ndiaye, P.A., 2013. Feasibility study of wind energy potential for electricity generation in the northwestern coast of Senegal. Energy Procedia, 36

2.6 Topic: Wind energy: a practical power analysis approach

AUTHOR:Khan, F.H., Pal, T., Kundu, B. and Roy

In this paper an empirical equation using Polynomial Lasso Regression techniques over field data obtained from turkey has been proposed by contrasting and comparing the expected Weibull distribution to the true frequency distribution of the actual wind speed. A detailed overview of the wind energy calculation and improvements is also discussed in this paper with the existing wind power production techniques. Towards the last, inspection of potential wind power applications is carried out in top Indian states.

Khan, F.H., Pal, T., Kundu, B. and Roy, R., 2021, February. Wind Energy: A Practical Power Analysis Approach. In 2021 Innovations in Energy Management and Renewable Resources (52042) (pp. 1-6). IEEE.

2.7 Topic: A study on the wind as renewable energy in Perlis, Northern Malaysia

AUTHOR: Daut, I., Razliana, A.R.N., Irwan, Y.M. and Farhana

Review: Analysis of wind speed and study about the two types of vertical axis wind turbines namely Darrieus type and Savonious types have been done in this paper. A few output power calculations has also been done by using wind speed data in order to check the possibilities and potentialities of wind energy in Perlis.

Daut, I., Razliana, A.R.N., Irwan, Y.M. and Farhana, Z., 2012. A study on the wind as renewable energy in Perlis, northern Malaysia. Energy Procedia, 18, pp.1428-1433.

CHAPTER-3

WORKING PRINCIPLES AND OPERATION

3.1 The nature of the wind

The wind is the vertical and horizontal motion of air masses in the atmosphere.
The circulation of air in the atmosphere is caused by the non uniform heating of the earth's surface by the sun. For example, at the Equator the strong solar radiation warms the ground surface. The air in contact with the ground surface gets warmer and lighter, rising up, generating a low pressure zone.The nature of terrain ,the degree of cloud cover and the angle of the sun in the sky are all factors which influence this process.In general , during the day the air above the land mass tends to heat up more rapidly than the air over water.In coastal region this manifests itself in strong onshore wind.At night the process is reversed because air cools down more rapidly over the land and the breeze therefore blows off shore.

The main planetary wind are cause in much the same way: Cool surface air sweeps down from the poles forcing the warm air over the tropics to rise.But the direction of these massive air movements is affected by the rotation of the and the net effect is large countries clockwise circulation of air around low pressure areas in the northern hemisphere and clockwise circulation in the southern hemisphere.

Wind speed increases with height.They have traditionally been measured at a standard height of ten meters where they are found to be 20%-30% greater than close to the surface.At height 60 m the may be 30%-60% higher because of the reduction in the drag effect of the earth's surface.

3.2 The power in the wind

Wind possesses energy by virtue of its motion.Any device capable of slowing down the mass moving air like a sail or propeller can extract part of the energy and convert it into useful work. Three factors determine the output from a wind energy converter:

1.The wind speed

2.The cross section of wind swept by rotor and

3.The overall conversion efficiency of the rotor,transmission system and generator or pump.

In order to quantify the power available in the wind we need to consider kinetic energy. Therefore, we need to understand how kinetic energy in atmospheric wind is calculated (see equation below).

$KE=\frac{1}{2}mv^2$

m =mass,v=velocity,KE=Kinetic Energy

4. The mass of wind: In order to calculate the mass of air colliding with the swept area of a wind turbine per unit time, consider the diagram : If we take A to equal the swept area of a particular wind turbine's blades, and "l" as the length of the 'tube' of air that collides with the swept area per unit time, we can equate the mass of air to the following:

$m=A\times l\times\rho$

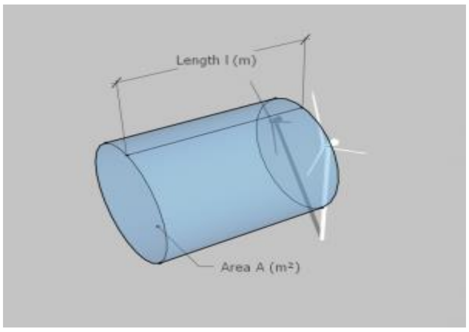


Fig 3.1

Where,

A=Swept Area

,l=Length,

ρ =density

Length can be described in terms of velocity and time:

$l=v\times t$ Where:

t=time

Therefore if we substitute our new equations into the original equation for kinetic energy, we get the following:

$KE=\frac{1}{2}A\rho vtv^2$

If we combine the velocities we get:

$KE=\frac{1}{2}A\rho\, tv^3$

5.Power Available in Wind: Finally if we divide the above formula for kinetic energy by time, we end up with an equation for available Power. As shown in the equation below, the amount of power available is dependent on swept area, density of the air, and wind velocity.

$KE=\frac{1}{2}A\rho\, v^3$

3.3 Wind energy conversion system(wecs)

Traditional windmills were used extensively in the middle ages to mill grain and lift water for land drainage and watering cattle.Wind energy converters are still use for these purposes today in some parts of the world, but the focus of attention now lies with their use to generate electricity.A wind energy conversion system (WECS) is powered by wind energy and generates mechanical energy that sends energy to the electrical generator for making electricity.

(1) Based on axis

(a) Horizontal axis machines

(b) Vertical axis machines

(2) According to size

(a) Small size machines (upto 2k W)

(b) Medium size machines (2 to 100k W)

(c) Large size machines (100k W and above)

(d) Single generator at single site

(e) Multiple generators

(3) Types of output

(a) DC output

i. DC generator

ii. Alternator rectifier

(b) AC output

i. Variable frequency, variable or constant voltage AC.

ii. Constant frequency, variable or constant voltage AC

(4) According to the rotational speed of the area turbines

(a) Constant speed and variable pitch blades

(b) Nearly constant speed with fixed pitch blades

(c) Variable speed with fixed pitch blades

(d) Field modulated system

(e) Double output induction generator

(f) AC-DC-AC link

(g) AC commentator generator

(4) As per utilization of output

(a) Battery storage

(b) Direct conversion to an electromagnetic energy converter

(c) Thermal potential

(d) Inter convention with conventional electric utility guides

3.4 Horizontal axis wind turbines

The horizontal axis wind turbine (HAWT) is a turbine whose rotor rotational axis is parallel to the ground and wind stream . Its primary rotor shaft and electrical generators are at the pinnacle of the tower and must be faced directly to the wind. Micro turbines are directed by a wind vane, with larger turbines utilizing a wind sensor coupled with a servomotor. The gear box is located in the drive train and is used to convert the slow blade movement into much quicker rotation capable of enough energy to drive an electrical generator. Most HAWTs are either two or three blades, but the number of blades has no limit, it depends solely on the designer. HAWT could also be classified as an upwind and downwind turbine.

It is stated that a gear system is used for stepping up the speed of the generator, although designs may likewise utilize an annular generator. Some designs operate at fixed speed, but variable speed turbines have better efficiency and employ a power converter to communicate with the transmission system. All turbines come with protective lineaments for damage limitation during turbulence. In such turbulence the system is also controlled by feathering the blades into the wind hence stalling them, and brought to a halt with the aid of brakes

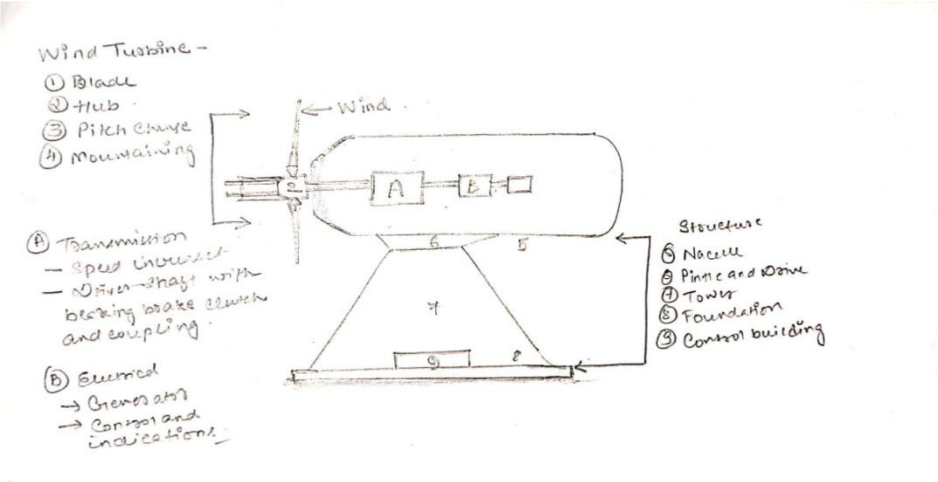


Fig 3.2: Structure and components of horizontal wind mill

3.5 Structure and components of wind mill

The simple structure of the horizontal axis wind turbine (wind mill) shown in above fig.

The following components are used in a windmill.

(1) Anemometer : Measures the wind speed and transmits wind speed data to the controller

(2) Blades: Most turbines have either two or three blades. Wind blowing over the blades causes the blades to “lift” and rotate.

(3) Brake: A disc brake, which can be applied mechanically, electrically, or hydraulically to stop the rotor in emergencies.

(4) Controller: The controller starts up the machine at wind speeds of about 8 to 16 miles per hour (mph) and shuts off the machine at about 55 mph. Turbines do not operate at wind speeds above about 55 mph because they might be damaged by the high winds.

5) Gear box: Gear connects the low-speed shaft to the high speed shaft and increases rotational speeds from about 30 to 60 rotations per minute (rpm) to about 1000 to 1800 rpm, the rotational speed required by most generators to produce electricity. The gear box is a costly (and heavy) part of the wind turbine and engineers are exploiting “direct-drive” generators that operate at lower rotational speeds and don’t need gearboxes.

(**6) Generator:** Usually an off-the-shelf induction generator that produces 60-cyclic AC electricity.

(7) High speed shaft: Drives the generator.

(8) Low-speed shaft: The rotor turns the low-speed shaft 30 to 60 rotations per minute.

(9) Nacelle: The nacelle sits lower and contains the gear box, low-and high-speed shafts, generator, controller, and brake. Some nacelle are large enough for a helicopter to land on.

(10) Pitch :

Blades are turned, or pitched, out of the wind to control the rotor speed and keep the rotor form turning in winds that are too high or too.

(11) Rotor: The blades and the hub together are called the rotor.

(**12) Tower**: Towers are made from tubular steel (shown here), concrete, or steel lattice. Because wind speed increases with height, taller towers enable turbines to capture more energy and generate more electricity.

(**13) Wind direction:** This is an “upwind” turbine, so called because it operates facing into the wind. Other turbines are designed to run “downwind”, facing away from the wind.

(14) Wind vane: Measure wind direction and communicate with the yaw drive to orient the turbine properly with respect to the wind.

(15) Yaw drive: Upwind turbines face into the wind, the yaw drive is used to keep the rotor facing into the wind as the wind direction changes. Downwind turbines don’t require a yaw drive, the wind blows the rotor downwind.

(16) Yaw motor: Power the yaw drive.

CHAPTER-4

MATHEMATICAL FORMULATION OF TURBINE MODEL

Under constant acceleration a, the kinetic energy E of an object having mass m and velocity v is equal to the work done W in displacing that object from rest to a distance s under a force F, i.e,

$E = W = Fs.$

According to Newton's second law of motion F = ma —(1)

thus, the kinetic energy becomes

$E = mas$ — (2)

From kinematics of solid motion, $v^2 = u^2 + 2as$ where u is the initial velocity of the object. This implies that a $= v^2 - u^2$ /2s . Assuming the initial velocity of the object is zero, we have that a $= v^2$ /2s .

Hence from equation (2) we have that E =1/2 mv^2 — (3)

This kinetic energy formulation is based on the fact that the mass of the solid is a constant. However, if we consider wind (air in motion) as a fluid, both density and velocity can change and hence no constant mass. For this reason we formulate the kinetic energy law with a factor of 2/3 instead of 1/2 . Here we shall assume that the density of air does not vary considerably even with variation in altitude or temperature and use the kinetic energy law in the form of equation (3). Hence the kinetic energy(in joules) in air of mass 'm' moving with velocity v(wind) can be calculated from equation (3) above.

The power P in the wind is given by the rate of change of kinetic energy, i.e.

P =dE/dt=1/2dm/dtv^2 m —(4)

But mass flow rate dm/dt is given by dm/dt = ρAv where A is the area through which the wind in this case is flowing and ρ is the density of air. With this expression, equation (4) becomes

P =1\2ρAv^3 —(5)

The actual mechanical power Pw extracted by the rotor blades in watts is the difference between the upstream and the downstream wind powers, i.e.

Pw =1/2ρAv($u_u{}^2 - v_v{}^2$) ----6

where u is the upstream wind velocity at the entrance of the rotor blades in m/s and v is the downstream wind velocity at the exit of the rotor blades in m/s. We shall see later that these two velocities give rise to the blade tip speed ratio. Now from the mass flow rate, we may write

ρAv =1/2ρA($u_u{}^2 - v_d{}^2$) ---(7)

v being the average of the velocities -at the entry and exit of rotor blades of a turbine. With this expression, equation(6) becomes

Pw = 1/2ρA$(u_u - v_d)$ $(u_u + v_d)$/2

which may be simplified as follows:

Pw =1/2[ρA{u/2($u_u{}^2 - v_d{}^2$) +v/2($u_u{}^2 - v_d{}^2$)}]

=1\2[ρA{$v_u{}^3 - v_u v_d{}^2$/2 + $v_d v_u{}^2$/2 -$v_d{}^3$/2}]

=1\2[ρA$v_u{}^3$ {$1 - (v_d/v_u)^2 + (v_d/v_u) - (v_d/v_u)^3$}/2]

or

Pw =1/2ρA$v_u{}^3$Cp — (8)

The expression for Cp in equation (9) is the fraction of upstream wind power captured by the rotor blades. Cp is often called the Betz limit after the German physicist Albert Betz who worked it out in 1919. Other names for this quantity are the power coefficient of the rotor or rotor efficiency. The power coefficient is not a static value. It varies with the tip speed ratio of the wind turbine.

Let λ represent the ratio of wind speed v downstream to wind speed u upstream of the turbine, i.e.

$\boldsymbol{\lambda} = \frac{v_d}{\boldsymbol{v_u}}$ ----(9)

Differentiate Cp with respect to λ and equate to zero to find value of λ that makes Cpmaximum,

$$\frac{dC_P}{d\lambda} = \frac{(1+\lambda)(-2\lambda) + (1-\lambda^2)}{2} = 0$$

i.e. $C_P = \frac{(1+\lambda)(1-\lambda^2)}{2}$ ------(11)

yielding $\lambda = -1$ or $\lambda = 1/3$. Now $\lambda = 1/3$ makes the value of Cp a maximum. This maximum value is 16/27 . Thus the Betz limit says that no wind turbine can convert more than 16/27 (59.3%) of the kinetic energy of the wind into mechanical energy turning a rotor, i.eCpmax = 0.59. Wind turbines cannot operate at this maximum limit though. The real world is well below the Betz limit with values of 0.35 − 0.45 common even in best designed wind turbines.

If the rotor of a wind turbine turns too slowly most of the wind will pass through the openings between blades with little power extraction. If on the other hand the rotor turns too fast, the rotating blades act as a solid wall obstructing the wind flow again reducing the power extraction. The turbines must be designed to operate at their optimal wind tip speed ratio λ in order to extract as much power as possible from the wind stream. Theoretically the higher the λ the better in terms of efficient operation of the generator. There are disadvantages however. High λ causes erosion of leading edges of the blades due to impact of dust or sand particles found in the air. This would require use of special erosion resistant coating material that may increase the cost of energy. Higher λ also leads to noise generation, vibration, reduced rotor efficiency due to drag and tip losses and excessive rotor speeds can lead to turbine failure.

Other factors that impede complete energy conversion in a complete turbine system are things such as gearbox, bearings, number and shape of blades etc. Only 10− 30% of the power of the wind is ever actually converted into usable electricity.

Air density ρ is another flow input quantity at the rotor system. ρ is a function of both air pressure and temperature. When air pressure increases ρ increases. When air temperature decreases ρ increases. This is in accordance with the equation of state

$$P = \rho RT \qquad \text{-----(12)}$$

where R is the gas constant. Both temperature and pressure decrease with increasing elevation. Hence site location is important as elevation has a major effect on power generated as a result of air density variation. At atmospheric pressure, Patm = 14.7psi, temperature is T = 600F and density is ρ = 1.225kg/m3. Temperature and pressure both vary with elevation. This

affects the air density. propose the following relation

$$\rho = \rho_0 e^{-\frac{0.297}{3048}Hm} \qquad \text{-----(13)}$$

where Hm is site elevation in meters. At high elevations the air density corrections can be important.

CHAPTER-5
POWER COEFFICIENT ANALYSIS

Equation (8) relates the parameters that are required in power production by a wind turbine. The power coefficient Cp is the most important parameter in the case of power regulation. It is a non-linear function whose value is unique to each turbine type and is a function of wind speed that the turbine is operating in. Each turbine manufacturer provides look up tables for Cp for operation purposes. Other than looking up tables from turbine manufacturers, models for power coefficient have been developed. For example models Cp as a function of the tip speed ratio and the blade pitch angle θ in degrees as ---

$$C_p(\lambda,\theta) = C_1(C_2\frac{1}{\beta} - C_3\,\beta\theta - C_4\theta^{x} - C_5)e^{-C6\frac{1}{\beta}} \text{----(1)}$$

where the values of the coefficients C1–C6 and x depend on turbine type. θ is defined as the angle between the plane of rotation and the blade cross section chord. For a particular

$$\frac{1}{\beta} = \frac{1}{\lambda+0.08\theta} - \frac{0.035}{1+\theta^3} \text{-----(2)}$$

turbine type C1 = 0.5, C2 = 116, C3 = 0.4, C4 =0, C5 = 5, C6 = 21 and β is defined by

$$C_p = \tfrac{1}{2}(\lambda - 0.022\theta^2 - 5.6)e^{-0.17\lambda} \text{-----(3)}$$

Anderson and Bose suggested the following empirical relation for Cp

where θ is the pitch angle of the blade in degrees, λ is the tip speed ratio of the turbine defined by

$$\lambda \,|= \frac{Vw(mph)}{Wb(rads^{-1})}$$

where ωb is the turbine angular speed.

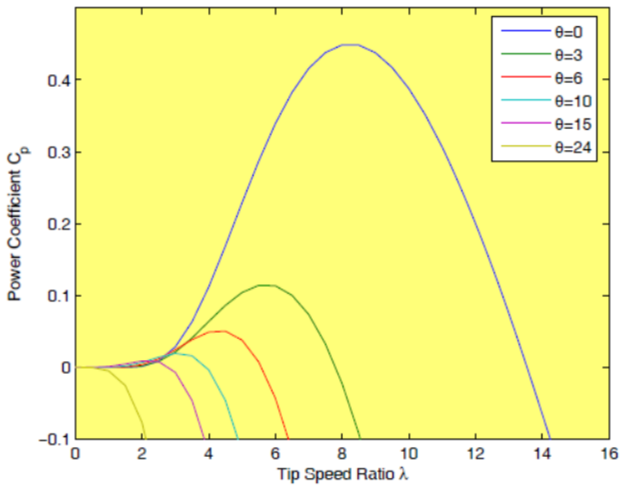
CHAPTER-6

MODELING AND CONTROL OF THE POWER OUTPUT

The power output of a turbine as we have mentioned is determined by the area of the rotor blades, wind speed and the power coefficient. The output power of the turbine can be varied by changing the area and flow conditions at the rotor system and this forms the basis of the control system. Cp is achieved at a λ which is specific to the design of the turbine. Hence the model turbine consists of equations (5), power in the wind, equation (8), power captured by the turbine, equation(10), the tip speed ratio of the turbine and the power coefficient equation (13). Control of output of wind Energy lies in a number of parameters. The rotor area and flow conditions at the rotor system (Vw, ρ,Cp), the rotor torque and pitch angle control. Fixed Speed stall-regulated turbines have no options for control input.

For our simulated turbine, we use the constants suggested with variation in the term 1/1+.08θ becoming 1/1+.08θ+.0001. This additional constant avoids infinity values when $\lambda = 0$. The Cp is plotted for values of $\theta = 00$, $\theta = 30$,$\theta = 60$, $\theta = 100$, $\theta = 150$ and $\theta = 240$. This is depicted in figure 6.1 below. From the figure, it is clear that pitching the blades of the turbine reduces Cp from about 40% when the pitch angle is 0 to about 10% when the pitch angle increases to 30.

This factor is good because it controls power output of a variable wind speed turbine (like the one we are considering) when the wind speed is above the rated one. Another turbine design model has the constant C4 = −0.5. This increases the value of the efficiency Cp and the range of the tip speed ratio, however, at first pitching of 30, the efficiency of the turbine drastically reduces to about 10% as shown in figure 6.2



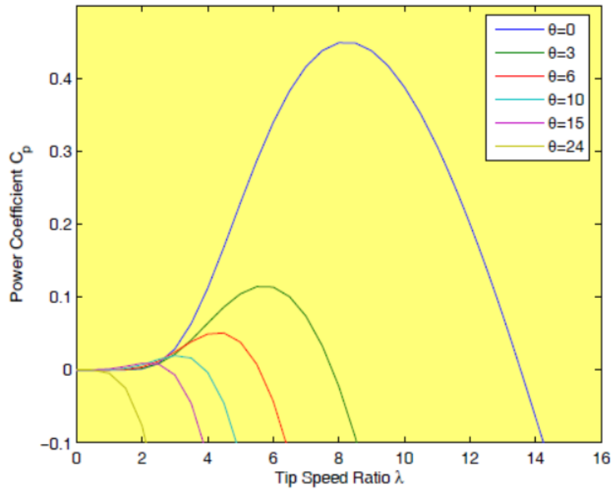


Fig 6.1-simulated power coefficient

Fig 6.2-simulated power coefficient(with variation of C4)

CHAPTER-7

SITE SELECTION

Deepor Bil, also spelt Deepor Beel, is located to the south-west of Guwahati city, in Kamrup Metropolitan district of Assam, India. It is a permanent freshwater lake, in a former channel of the Brahmaputra River, to the south of the main river. It is also called a wetland under the Ramsar Convention which has listed the lake in November 2002, as a Ramsar Site for undertaking conservation measures on the basis of its biological and environmental importance.

Considered one of the largest beels in the Brahmaputra valley of Lower Assam, it is categorized as representative of the wetland type under the Burma monsoon forest biogeographic region

Fig7.1: Satellite photo of the proposed WECS site-Deepor Beel

Some of the main site selection consideration are given below:

7.1 High annual average wind speed

The speed generated by the wind mill depends on cubic values of velocity of wind, the small increases in velocity markedly affect the power in the wind. For example, Doubling the velocity increases power by a factor of 8. It is obviously desirable to select a site for wind energy conversion with high wind velocity. Thus a high average wind velocity is the principle fundamental parameter of concern in initially appraising site.

Till now, the optimum speed found by us at proposed Wind Energy Conversion site is 5.9m/s.

7.2 Availability of anemometry data

It is another improvement sitting factor. The anemometry data should be available over some time period at the precise spot where any proposed WECS is to be built and that this should be accomplished before a sitting decision is made.

Fig 7.2 : Anemometer used during measurement of wind at site

Anemometer: An anemometer is an instrument that measures wind speed. The type of anemometer we are using here is the digital type. This type of anemometer has a spinning wheel. The stronger the wind blows, the faster the wheel rotates. The anemometer counts the number of rotations, which is used to calculate wind speed.

7.3 Availability of wind v(t) curve at the proposed site

This important curve determines the maximum energy in the wind and hence is the principal initially controlling factor in predicting the electrical output and hence revenue return o the WECS machines. It is desirable to have average wind speed ‘V’ such that V>=12-16 km/hr (3.5 – 4.5 m/sec) which is about the lower limit at which present large scale WECS generators ‘cut in’ i.e., start turning. The V(t) Curve also determines the reliability of the delivered WECS generator power, for if the V(t) curve goes to zero there be no generated power during that time.If there are long periods of calm the WECS reliability will be lower than if the calm periods are short. In making such reliability estimates it is desirable to have measured V(t) Curve over about a 5 year period for the highest confidence level in the reliability estimate.

As it is a final year project for our BTech curriculum, we will be collecting the wind speed data for a span of 1 year only.

The data acquired for wind V(t) Curve at the proposed site is given below:

Table- 7.1

SPEED(M/S)	POWER(WATT)
4	1.9
4.5	34.7
5	74.94
5.5	120.3
6	168.4
6.5	216.9

7.4 Wind structure at the proposed site

The ideal case for the WECS would be a site such that the V(t) Curve was flat, i.e., a smooth steady wind that blows all the time; but a typical site is always less than ideal. Wind especially near the ground is turbulent and gusty, and changes rapidly in direction and in velocity. This departure from homogeneous flow is collectively referred to as “the structure of the wind”.

Anemometer Readings:

Table 7.2

No. of readings	Date	Max wind speed (m/s)
1	25-10-21	5.3
2	19-11-21	3.9
3	17-12-21	1.9
4	04-01-22	2.5
5	28-01-22	2.8
6	15-02-22	4.9
7	05-03-22	5.6
8	20-03-22	6.2
9	02-04-22	2.5
10	18-04-22	2.7

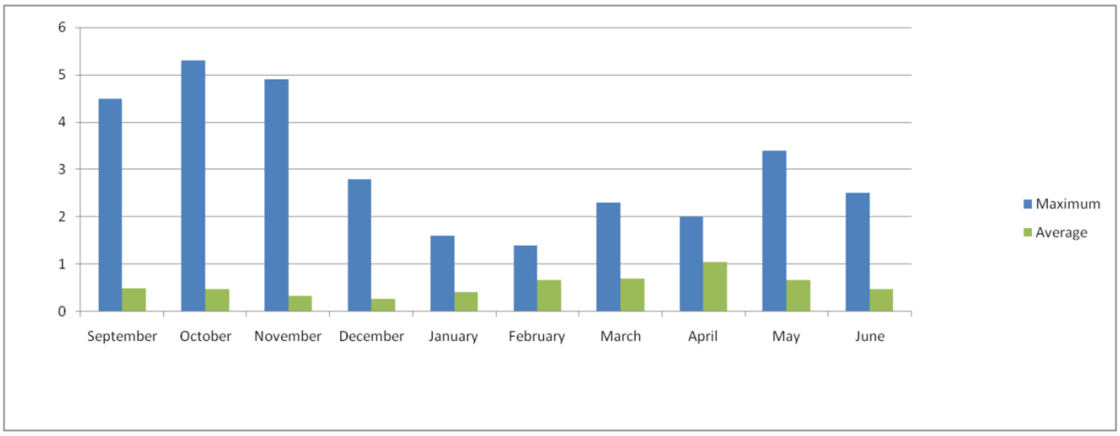


Fig 7.2 Graph showing Maximum speed and Average speed

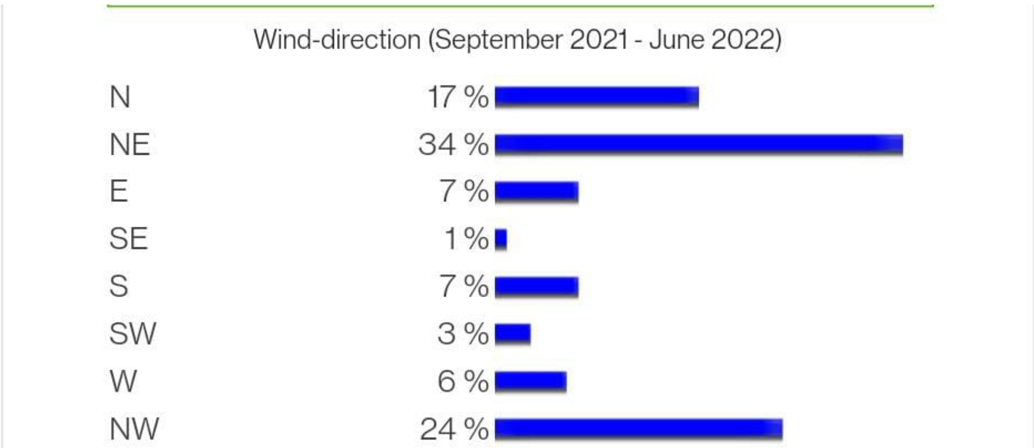


Fig 7.2 : Wind direction at site

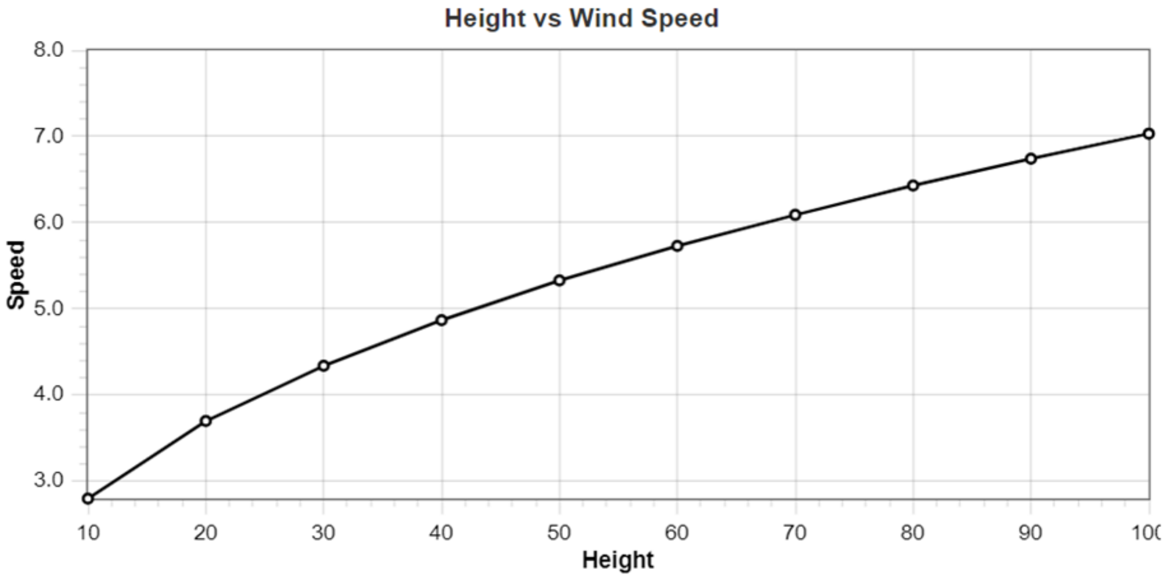


Fig 7.3 : Graph showing variation of speed with height

7.5 Altitude of the proposed site

It affects the air density and thus the power in the wind and hence the useful WECS electric power output. Also, as is well known, the wind tends to have higher velocities at higher altitudes. One must be careful to distinguish altitude from height above ground. They are not the same except for a sea level WECS site.

The relationship between wind speed and altitude can be understood from the data collected from the site in the table below:

Table-7.3

HEIGHT(M)	WIND SPEED(M/S)
15	4.51
20	4.92
25	5.26
30	5.56
35	5.82
40	6.08

7.6 Terrain and its aerodynamic

If the WECS is to be placed near the top but not on the top of a not too blunt hill facing the prevailing wind, then it may be possible to obtain a ‘speed-up’ of the wind velocity over what it would otherwise be. Also the wind here may not flow horizontal making it necessary to tip the axis of the rotor so that the aeroturbine is always perpendicular to the actual wind flow.It may be possible to make use of hills or mountains which channel the prevailing wind into a pass region, thereby obtaining higher wind power.

The beel is bounded by the steep highlands on the north and south, and the valley formed has a broad U-shape with the Rani and Garbhanga hills forming the backdrop. The geologic and tectonic history of the region provide the links to the hydrology and channel dynamics of rivers and pattern, and intensity of land use in the area. It is commonly stated that the beel together with those adjoining it are an abandoned channel of the Brahmaputra system.

While the beel and its lowland fringe are said to be underlaid by recent alluvium consisting of clay, silt, sand and pebbles, the highlands immediately to the north and south of the beel are made up of gneisses and schists of the Archaean age.

7.7 Local ecology

If the surface is base rock it may mean lower hub height hence lower structure cost. If trees or grass or vegetation are present, all of which tend to destructure the wind, the higher hub heights will be needed resulting in larger system costs than the bare ground case.

Temperatures in the beel vary from 10.6^0 to 32^0C. During the winter months, when the size of the lake reduces in area by about fifty percent, the shore area (up to one kilometer) is cultivated with rice paddy when the climate is also relatively cool and dry. The tropical monsoon climate prolongs from May to September when it is humid. Pre-monsoon showers are experienced between March and May.

Table-7.4

MONTH	OCT	NOV	DEC	JAN	FEB	MAR	APRIL
SPEED	5.9	3.9	1.9	2.5	4.9	5.6	2.5
TEMP	78.5 F	72 F	68.3 F	62 F	67 F	74 F	77.1 F
HUMIDITY	82%	78%	80%	79%	61%	57%	68%

7.8 Distance to road or railways

This is another factor the system engineer must consider for heavy machinery, structure, materials, blades and other apparatus will have to be moved into any chosen WECS site.

The proposed WECS site has very good roads and means of communication, which makes it easier for the vehicles to commute to and from the site.

7.9 Nearness of site to local centre/users

This obvious criterion minimizes transmission line length and hence losses and cost. After applying all the previous string criteria, hopefully as one narrows the proposed WECS sites to one or two they would be relatively near to the user of the generated electric energy.

There are many organisations and residential areas near the proposed site which can utilise the power generated.

7.10 Nature of ground

Ground condition should be such that the foundation for a WECS are secured. Ground surface should be stable. Erosion problems should not be there, as it could possibly later wash out the foundation of a WECS, destroying the whole system.

Deepor Beel acts as a natural storm water reservoir during the monsoon season for the Guwahati city with about four meters depth of water during monsoon dropping to about one meter during the dry season. The beel has a perennial water spread area of about 10.1 km^2, which extends up to 40.1 km^2 during floods. However, an area of 414 ha has been declared as "Deepor Beel Sanctuary" by the Government of Assam. As per a Remote Sensing Study the wetland area is reported to have reduced to 14.1% (405 ha) from 1990 to 2002.

11. Other conditions such as icing problem, salt spray or blowing dust should not be present at the site, as they may affect aero turbine blades or the environment is generally adverse to machinery and electrical apparatus.

CHAPTER-8

MATLAB SIMULINK MODELING AND CODING

Using the same exact formulas and values used in “CHAPTER 3: Mathematical formulation of turbine model” a MATLAB SIMULINK model is prepared.

A 5kW turbine was designed and the factors affecting it accordingly are chosen as per convenience:

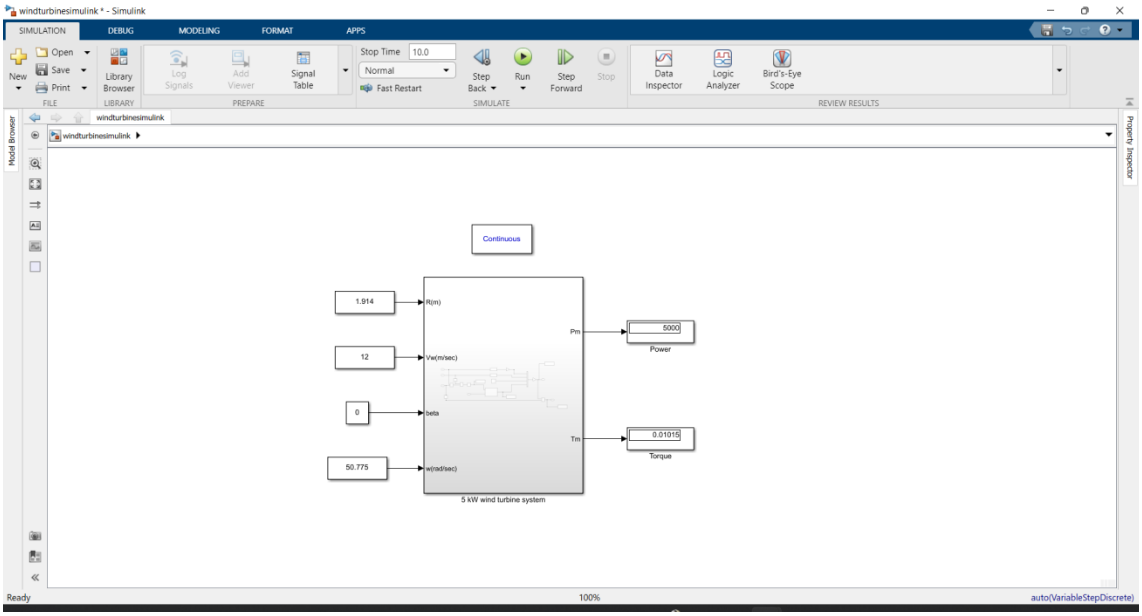


Fig:8.1

Blade radius = 1.914 m

Wind speed = 12m/s

Using these data in the equations we get an output of 5kW.

The interior of the turbine is shown below

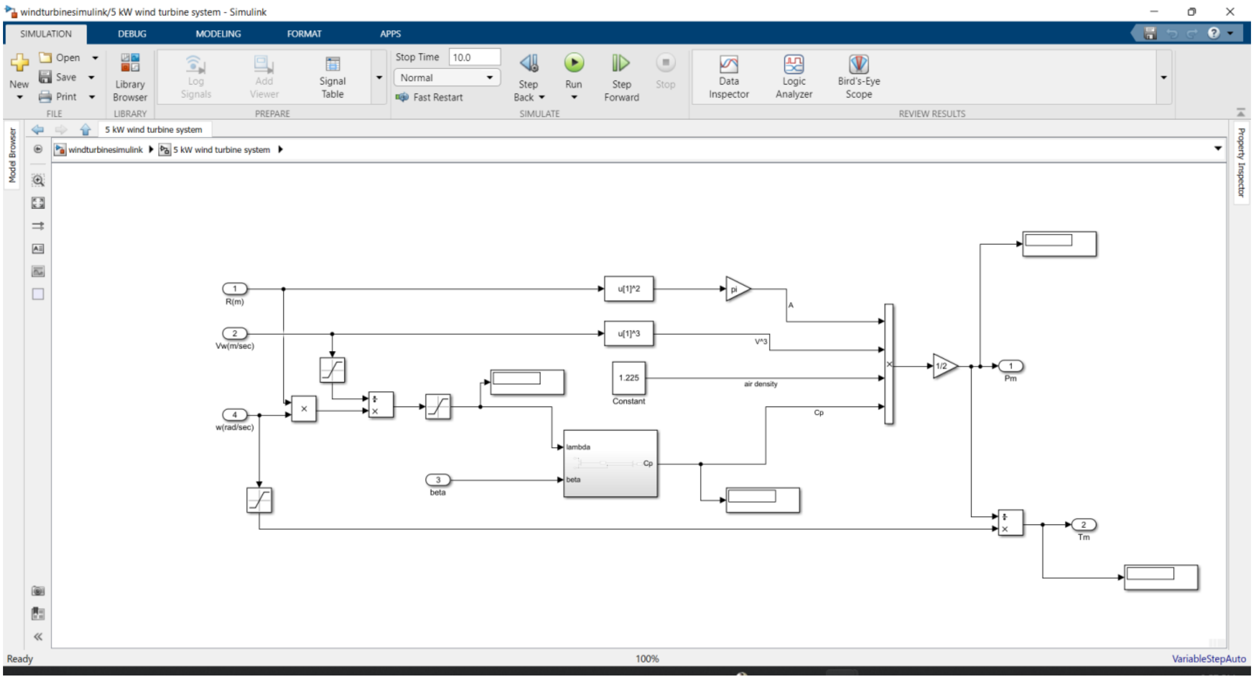


Fig-8.2

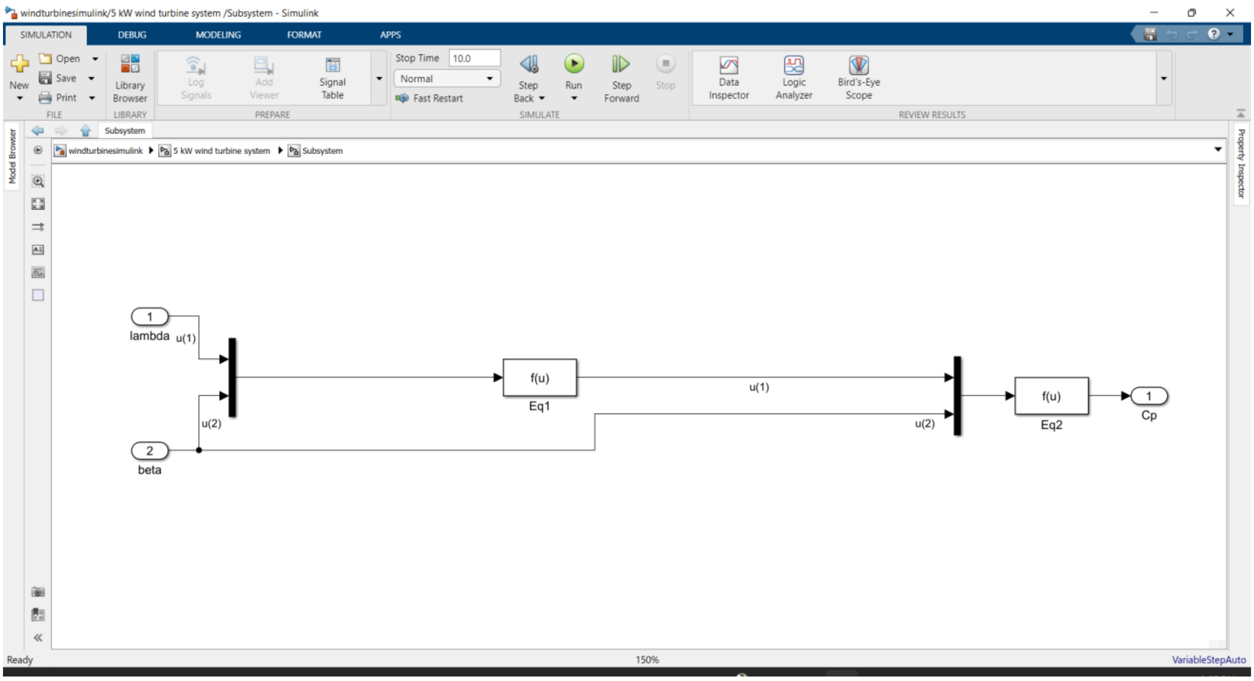


Fig-8.3

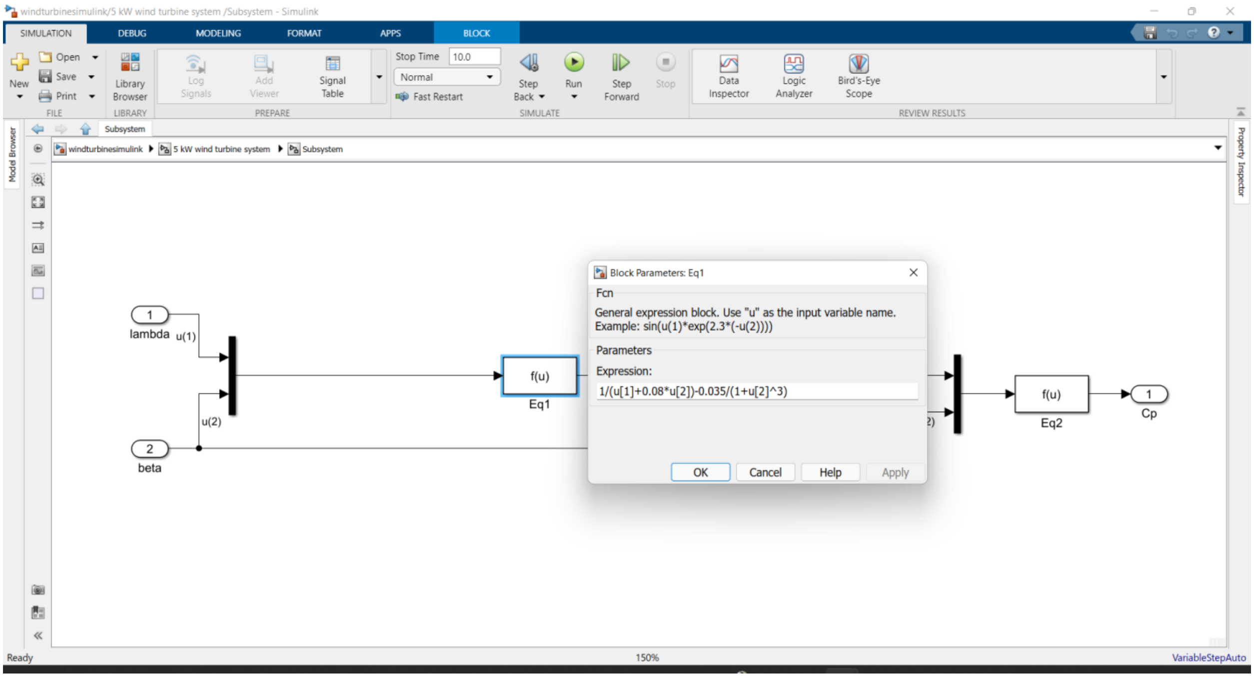


Fig-8.4

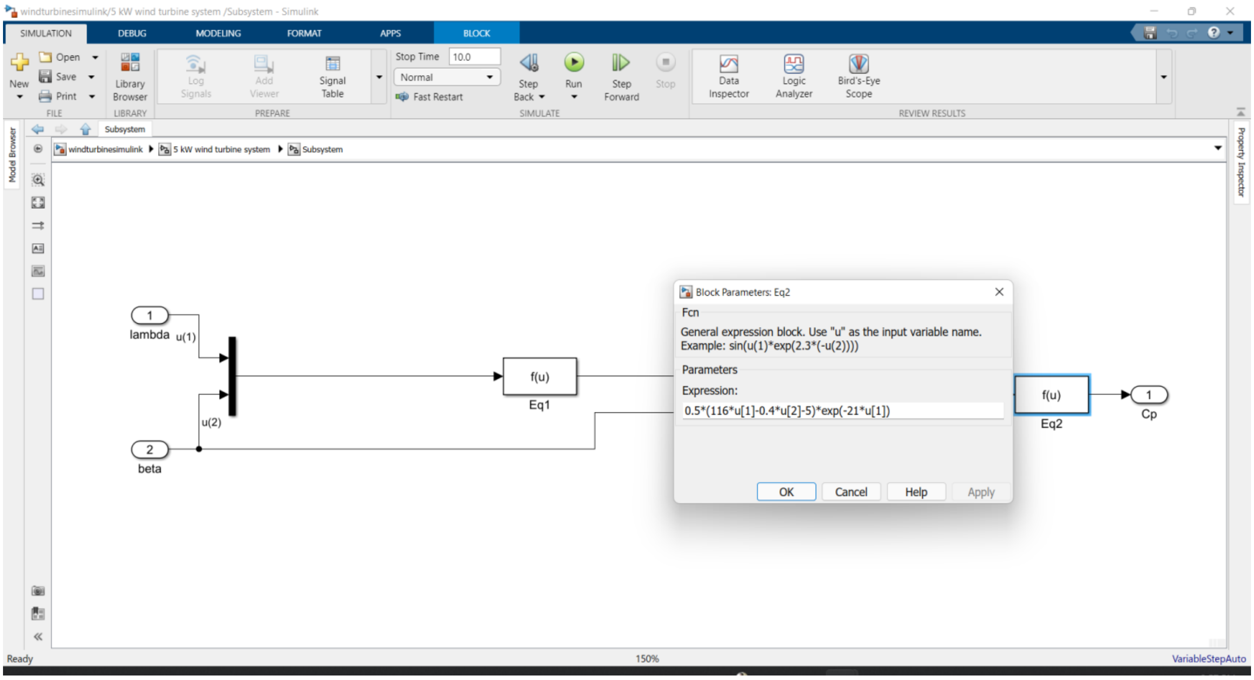


Fig-8.5

As seen above, we get satisfying results using already given values.

Now when we input our practical data

Blade radius = 1 m

Wind speed = 6 m/s

We get an output of 168.4 W

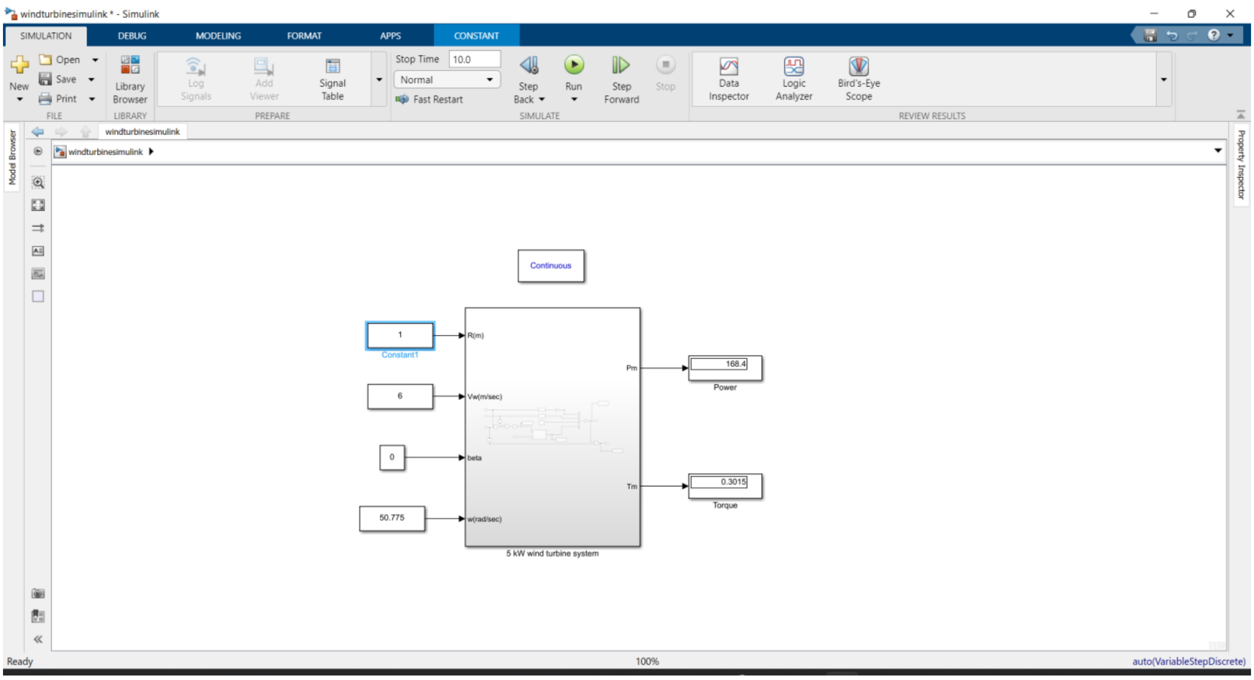


Fig-8.6

Practically, when we input the data of our measurement and observation we get different results. This MATLAB model thus helps us to find outputs for different inputs.

C++ code :

1. To find wind speed at various height

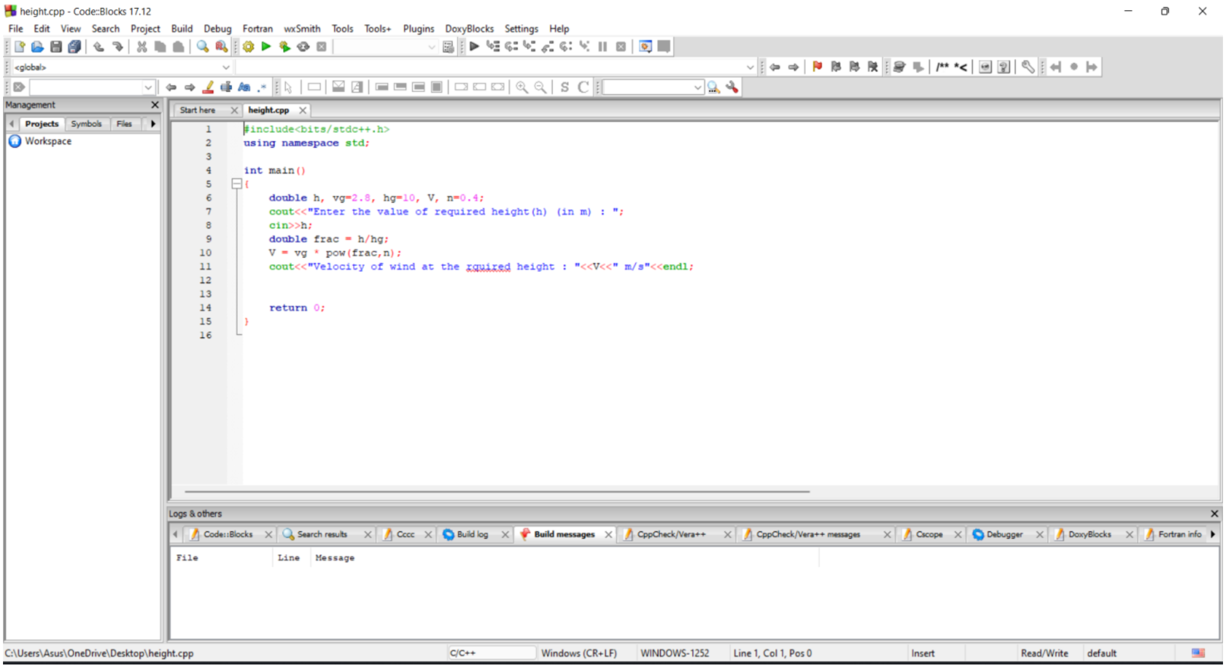


Fig8.7

2. To find power at desired height

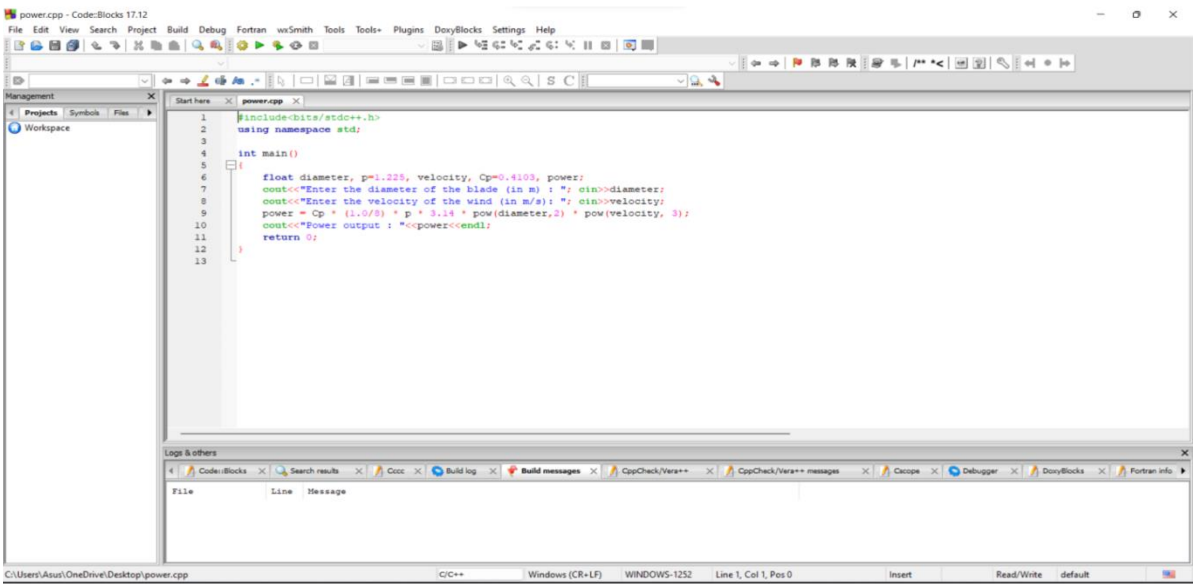


Fig-8.8

CHAPTER 9
COST ESTIMATION

The wind turbines’ cost involves many things, proper negotiations, engineering and other factors. The wind turbine market is relatively small yet; the prices always go down, when there are competitions in the market. As there is no competition in this field, so prices are high.

These turbines come in various sizes and shapes. The cost depends on the following things, turbine size, installation contracts, and kind of turbine, location, freight, utility system upgrades, metering equipment, maintenance, and warranty.

9.1 Turbine price for low wind areas

The wind turbines that are manufactured for low wind localities have had large rotor. The price of low wind turbines is higher than high wind turbines, because the low pressure of wind, they have to perform more efficiently for electricity generation. As Deepor Beel has low wind speed so wind turbine with large rotor will be used.

9.2 Installation cost of wind turbine

Besides purchasing wind turbines, there are some other costs like, ‘wind turbine installation cost. It should be kept in our estimate, when we buy wind turbines, because they could dramatically increase our turbine’ cost. There are some other costs, such as, cables, connections to the grid, turbine foundation, and transportation.

9.3 Operation & maintenance cost

When the wind turbine is new its maintenance cost is low, but when it gets old the operational and maintenance gets so high. It is based on the studies that were done in Europe on about 5000 wind turbines. These wind turbines were installed in 1975. After studies they got on conclusion that every new turbines’ generation had lower maintenance costly than the last generations.

The older wind turbine maintenance cost per annum has been on average 3 percent of the cost of original turbine. The reason is, as, new turbines are generally quite large, you don’t need to service the large turbine comparatively small one. The new turbines are being manufactured with new techniques and materials so, they save our maintenance cost. The new wind turbine cost is in between 1.5 percent to 2 percent, per annum.

9.4 Initial capital cost

The cost of wind energy fell dramatically from the 1980s through 2003, then increased for most of the remainder of the decade. Then, as the recession hit, turbine orders declined and prices with them. Meanwhile turbine technology has significantly improved, so that they are producing energy more efficiently than ever, which is the real bottom line.Specific costs vary considerably from project to project and region to region due to differences in markets, wind resources, and economies of scale.

The initial capital cost is the sum of the turbine system cost and the balance of station cost. Neither cost includes construction financing or financing fees, because these are calculated and added separately through the fixed charge rate. The costs also do not include a debt service reserve fund, which is assumed to be zero for balance sheet financing.

- Primary cost elements tracked in the model include the following:
- Rotor
- Blades
- Hub
- Pitch mechanisms and bearings
- Spinner, nose cone
    - Drive train, nacelle
- Low-speed shaft
- Bearings
- Gearbox
- Mechanical brake, high-speed coupling, and associated components
- Generator
- Variable-speed electronics
- Yaw drive and bearing
- Main frame
- Electrical connections

- Hydraulic and cooling systems
- Nacelle cover
    - Control, safety system, and condition monitoring
    - Tower
    - Balance of station
- Foundation/support structure
- Transportation
- Roads, civil work
- Assembly and installation
- Electrical interface/connections
- Engineering permits

  When evaluating offshore turbines, the following additional components or elements are considered:
    - Marinization (added cost to handle marine environments)
    - Port and staging equipment
    - Personal access equipment
    - Scour protection
    - Surety bond (to cover decommissioning)
    - Offshore warranty premium

9.5 Horizontal axis wind turbine (HAWT)

Upon contacting some of the wind energy enterprises, some idea of prices were known and are as follows :

1. 5kW domestic wind turbine

GSTIN: 33CHXPS8047P1Z3

DIAMOND ENGINEERING ENTERPRISES

Manufacturer, Consultant & Supplier of Solar, Wind & Bio-Gas Plants

Office :
122-D, Kummalamman Koil Street,
Tondiarpet, Chennai-600081, TN.

Cell: 9500012578 / 9087246999
9884927094 / 8925855565
Email: isi23450@gmail.com

http://www.indiamart.com/diamond-engineering-enterprises/

Ref:284(1)/2022-23 Date:24.04.2022

To

M/s. Chennai International Terminals Pvt Ltd
Mr. D. Vinoth Kumar
Regus citi centre
Level 6, Chennai Citi Centre
10 / 11, Dr. Radhakrishnan Salai, Chennai - 600004
Email : madhanj@citpl.co.in, vinothd@citpl.co.in
Mobile: 9003030979

DEAR SIR/MADAM,

SUB: Quotation-supply and installation - wind turbine Energy Systems – reg

We are herewith submitting our competitive rates for supply and installation of 5 k. w. domestic wind turbine as per your requirements, as follows.

No.	DESCRIPTION	Qty	RATE PER QTY	GST @	GST RATE	TOTAL
1.	Supply of 5,000 w domestic wind turbine-1no,(5 year warranty) with hub, tail (furling), nose, brake, 5kw grid tie inverter , including the supply of 12m. high, tilting type, self-supporting tubular tower (HOT DIP G.I.)- 1no. wiring, etc., complete excluding foundation of the tower HSN CODE: 84128030	1 set.	Rs. 3,45,000	5%	Rs. 17,250/-	**Rs. 3,62,250/-** (Rupees Three lakhs Sixty Two Thousand Two Hundred and fifty only)
2.	Installation of 12 m long lattice cum tubular tower, wind turbine on roof top and commissioning charges	1 set	Rs. 36,000/-	18%	Rs. 6,480/-	**Rs. 42,480/-** (Rupees Forty Two thousand Four Hundred and Eighty only)
3.	Foundation and allied civil engineering work	1 set	Rs. 1,00,000/-	18%	Rs. 18,000/-	**Rs. 1,18,000/-** (Rupees One Lakh and Eighteen Thousand Only)

2. 60 meter height wind turbine

Wind Turbine

₹ 56.50 Lakh

Tower Height	200 Feet
Blade Material	Carbon Fibre
Blade Length	7 Feet
Brand	Akshar Electronics
Frequency	60 Hz
Voltage	280-340 V

3. 4.5 meter diameter wind turbine

4.5 M Whisper 500 Wind Turbine

₹ 2.20 Lakh Get Latest Price

Product Brochure

Model	Whisper 500
Rotor Diameter	4.5 m
Rated Wind Speed	12.5 m/s
Swept area	15.89 m2
Weight	80 kg (including blades and tail boom)
Mount	5 inch mounted

GENERAL CONFIGURATION	
Model	Whisper 500
Rotor diameter	4.5 m
Swept area	15.89 m2
Weight	80 kg (including blades and tail boom)
Mount	5 inch mounted
Start-up wind speed	3.1 m/s
Rated wind speed	12.5 m/s
Alternator	PM 3 phase alternator
Alternator efficiency	85 %
Magnets	Ceramic magnets
Insulation class	Class 'H'
Voltage configuration (L.V. model)	24V/48 V nominal
Voltage configuration (H.V. model)	96V/120V/240V nominal

PERFORMANCE	
Average power	2000W at 11m/s (as per IEC 61400 standards)
Number of blades	2
Material of blades	Carbon fiber composite, fiber glass & epoxy bonding
Material of body	Powder coated MS with marination treatment
Survival wind speed	55 m/s
Over-speed protection	Furling, dump load & manual brake switch
Controller	External regulator
Bearings self-lubricated	Low friction, totally enclosed
Controller output	Voltage options : 24 V, 48V DC(LV) 96V,120V, 240VDC(HV) Rated power: 3200 watts
Max. lateral thrust	400 KGF

9.6 Vertical axis wind turbine (VAWT)

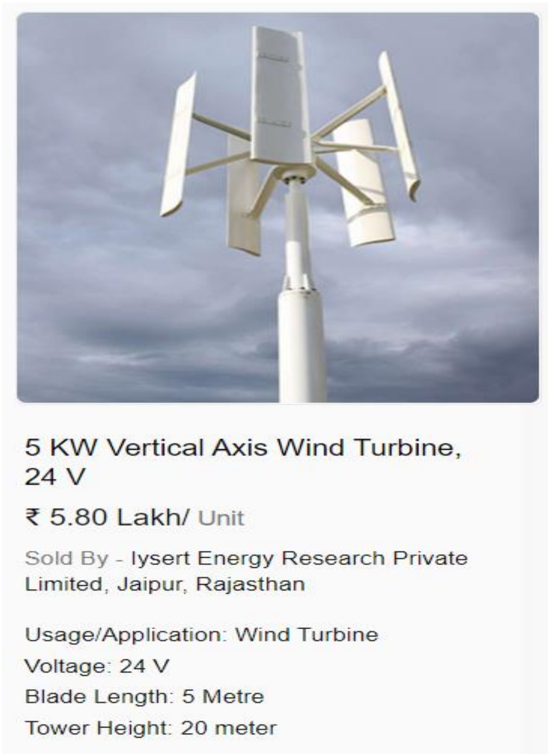
As our plant will have a target output of 5KW and based on the above characteristic we choose a 5 KW Vertical Axis Wind Turbine(VAWT), with a voltage of 24 V, 5 meter Blade length and a tower height of 20m with a cost of 5.80 Lakh/ unit. The overall installation cost which includes the turbine, the tubular tower and commissioning charges is Rs. 36000/-. The foundation and allied civil engineering works which are needed to be done at the location will result in an amount of Rs 18000/-.

As per the recent surveys, it is have found that the transportation of a wind turbine costs around Rs. 50 Lakh/MW. So, in our case it will cost around Rs. 25 Lakh. For the safe transportation of the equipments to the location proper packaging is required. So, there are also the packaging costs, which are around Rs 80000/-.

The competitive rates for the supply and installation of a 5kw VAWT wind turbine at the desired location is given in the table below:

No.	DESCRIPTION	RATE/QTY	GST @	GST RATE	TOTAL
1	Supply of 5,000w VAWT wind Turbine-Ino,(5 year warranty) with hub, tail (furling), nose, brake, 5kw grid tie inverter including the supply of 12m. high, tilting types, self-supporting tubular tower (HOT DIP GI)Ino wiring etc, complete excluding foundation of the tower	Rs. 5,80,000/-	5%	Rs. 29,000/-	Rs. 6,09,000/- (Rupees Six Lakh Nine Thousand only)
2	Installation of 12 m long lattice cum tubular tower, wind turbine on roof top and commissioning charges	Rs. 36,000/-	18%	Rs. 6,480/-	Rs. 42,480/- (Rupees Forty Two Thousand Four Hundred and Eighty Only)
3	Foundation and allied civil engineering works	Rs. 1,00,000/-	18%	Rs. 18,000/-	Rs. 1,18,000/- (Rupees One Lakh and Eighteen Thousand Only)

4	Transportation costs	Rs 25,00,000/-	5%	Rs. 1,25,000/-	Rs. 26,25,000/- (Rupees Twenty Six Lakh and Twenty Five Thousand Only)
5	Packaging costs	Rs 80,000	12%	Rs. 9,600/-	Rs. 89,600/- (Rupees Eighty Nine Thousand Six Hundred Only)



CHAPTER- 10
OVERVIEW

10.1 Scope

Wind is a natural phenomenon and is inexhaustible. The use and scope of wind energy is limitless. With wind energy generators electricity can be generated and put to good use. Remote areas with no supply of electricity but with good wind flow can very much benefit from this. Energy requirement is a basic need of this world and wind energy can help fulfill it to some extent.

10.2 Future works

We are currently focusing on optimum data collection of the various wind characteristics such as wind speed, humidity, direction etc. at Deeporbeel. After we have sufficient number of readings, we will be proceeding to the designing part with components of appropriate ratings, which will lead to a feasible design. Once we are done with the designing, we will be able to calculate the approximate cost of the power plant to be established at Deepor beel.

10.3Pros

- Wind power has a remarkably small impact upon the carbon footprint.
- There is zero carbon emissions associated with the operation of wind turbines.
- The only emissions emitted from wind turbines arise from their manufacture, construction and maintenance.
- Wind energy has one of the lowest water consumption footprints, unlike fossil fuels and nuclear power plants.
- Wind turbines reduce a nation’s demand for imported fuel sources.
- Wind power production meant that Europe managed to avoid fuel costs amounting to €5.71 billion.
- Wind turbines are a great resource to help generate energy in remote locations such as mountain communities or the countryside.
- Wind power can be combined with Solar Energy in order to generate a sustainable energy source in developing countries.

10.4Cons

- Wind turbines depend on a suitable wind speed in order to generate electricity.
- If wind speed is below a certain threshold, turbines depend on other forms of electricity generation in order to operate.
- Planning permission can be hard to get hold of for onshore wind farms due to the visual impact of the turbines.
- The complexity of manufacturing offshore wind farms makes it a much more costly method than onshore wind farms.
- Wind turbines generate a lot less power than the average fossil fuelled power station, requiring multiple wind turbines to be built in order to make an impact.

CHAPTER-11

CONCLUSION

Wind power accounts for nearly 10% of India's total installed power generation capacity and generated 62.03 TWh in the fiscal year 2018–19, which is nearly 4% of total electricity generation. The capacity utilization factor is nearly 19.33% in the fiscal year 2018-19 (16% in 2017–18, 19.62% in 2016-17 and 14% in 2015–16). 70% of annual wind generation is during the five months duration from May to September coinciding with Southwest monsoon duration.

The Wind Potential in India was first estimated by National Institute of Wind Energy (NIWE) at 50m hub-height i.e. 49 GW but according to the survey at 80m hub height, the potential grows as much as 102 GW and 302GW at 100 Meter hub height. Further a new study by NIWE at 120m height has estimated a potential 695GW.

At our proposed site of wind power plant setup, we found the maximum number of observations of wind speed data, may it be at various heights or in various months or in different climatic conditions, to be greater than at least 3.5 m/s. Our main aim to take this matter up was indeed to make use of the untapped renewable resources around the campus, and hence produce a clean form of energy, which can be used as a source of power in various household or industrial establishments etc.

During the survey of the location site, we have found that the wind speed at the desired location is low, also it is not unidirectional and the observations of the wind speeds are not constant. But there is consistency in the wind speed. So, based on the above characteristics of the wind, we have found that to make optimum use of the available wind speed, selecting a vertical axis wind turbine (VAWT) will be of utmost profit. This is because of its following characteristics of VAWT:

1. Produces electrical energy at very low wind speed.
2. Does not need a yaw control because it can produce electricity regardless of the direction of wind.
3. Produces minimum noise.
4. Less vibration than HAWT.
5. Can be installed in urban, residential and commercial areas because of low noise levels.
6. Much shorter than HAWT

So, VAWT will be a wise choice for the implementation of our project at the location site

Overall the future of Wind Energy in India is bright as energy security and self-sufficiency is identified as the major driver. The biggest advantage with wind energy is that the fuel is free, and also it doesn’t produce CO 2 emission. Wind farms can be built reasonably fast, the wind farm land can be used for farming as well thus serving dual purpose, and it is cost-effective as compared to other forms of renewable energy.

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