DESIGN AND FABRICATION OF VERTICAL AXIS WIND TURBINE

A project report submitted

in partial fulfillment of the requirement for the award of the degree of

BACHELOR OF ENGINEERING

IN

MECHANICAL ENGINEERING

by

N.BHAVANI **(314126520107)**

K.UMAMAHESWARARAO **(314126520077)**

P .LEKHANVITHA **(314126520118)**

R.ABHIRAM **(314126520139)**

Under the esteemed guidance of

Sri.M.RAMAKRISHNA,M.TECH

(Assistant Professor),

DEPARTMENT OF MECHANICAL ENGINEERING

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES

(Approved by AICTE, Permanently Affiliated to A.U., &
Accredited by NBA and NAAC with 'A' Grade)

Sangivalasa, Bheemunipatnam Mandal,

VISAKHAPATNAM-531162

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY &SCIENCES (Autonomous)

(Approved by AICTE, Permanently Affiliated to A.U., &
Accredited by NBA and NAAC with 'A' Grade)

PRAGNANAM BRAHMA

ANITS

CERTIFICATE

This is to certify that the project report entitled *"DESIGN AND FABRICATION OF VERTICAL AXISWINDTURBINE"*is a bonafide work carried out by **NARTHU.BHAVANI (314126520107), KARROTHU.UMAMAHESWARARAO(314126520077),PATNALA.LEKHANVITHA(314126520118),RUTTULA.ABHIRAM(3141265201390)**during the year 2017-2018 under the guidance of **Sri. M.RAMAKRISHNA,** in partial fulfillment of requirements for the award of the degree of Mechanical Engineering In Department of Mechanical Engineering, Anil Neerukonda Institute of Technology And Sciences, Affliated To Andhra University, Visakhapatnam.

PROJECT GUIDE

22/4/18

(Sri.M.RAMAKRISHNA)
Assistant professor
Dept of Mechanical Engineering
ANITS, Sangivalsa
Visakhapatnam

APPROVED BY

(DR.B. NAGARAJU)
Head of the Department
Dept of Mechanical Engineering
ANITS, Sangivalsa
Visakhapatnam

PROFESSOR & HEAD
Department of Mechanical Engineering
ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCE
Sangivalasa-531 162 VISAKHAPATNAM Dist AP

THIS PROJECT IS APPROVED BY THE BOARD OF EXAMINERS

Dr. B. Naga Raju
M.Tech,M.E.,Ph.d
Professor & HOD
Dept.of Mechanical Engineering
ANITS, Sangivalasa,
Visakhapatnam-531 162.

INTERNAL EXAMINER:

EXTERNAL EXAMINER:

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N. BHAVANI	(314126520107)
K.UMA MAHESWARA RAO	(314126520077)
P.LEKHANVITHA	(314126520118)
R.ABHIRAM	(314126520139)

DECLARATION

We N.Bhavani, K.UmaMaheswara rao, P.Lekhanvitha, R.Abhiram bearing the University Registered No's: 314126520107,314126520077, 314126520118, 314126520139 respectively do hereby declare that this project work entitled "DESIGN AND FABRICATION OF VERICAL AXIS WIND TURBINE" was carried out by me under the guidance of Sri.M.RAMAKRISHNA, Assistant professor Department of Mechanical engineering, Anil Neerukonda Institute of Technology and science.this project is submitted to Andhra university, Visakhapatnam in partial fulfilment of requirement for the award of bachelor of technology Degree in Mechanical engineering during the academic year2017-2018. I hear by declare that the project is an original work done by me and not submitted earlier for the award of any degree in any other institute.

N.BHAVANI- 314126520107

K.UMA MAHESWARA RAO-314126520077

P.LEKHANVITHA- 314126520118

R.ABHIRAM-314126511025

ABSTRACT

The use of wind energy for energy generation is one of the oldest methods for harnessing renewable energy. Use of renewable energy is an essential ingredient of socio-economic development and economic growth. Renewable energy sources such as wind energy, tidal energy etc. is abundant and can help in reducing the dependency on fossil fuels. With increased concern for environment now days led to the research for more environment friendly sources of energy and with this considerations wind energy can be considered as a viable option in this regard. Different configurations of wind turbines such as horizontal axis wind turbine and vertical axis wind turbines are mainly used for energy extraction. Horizontal axis mainly used in large scale applications and thus its implementation is generally a concern due to huge installment setup and initial cost; whereas vertical axis wind turbines offer promising solution for smaller ruler areas or medium sized residential spaces. The project work focuses on various stages for design and development of optimized vertical axis wind turbine which will studies various parameters such as general wind energy scenario, design and aerodynamic performance analysis of vertical axis wind turbines.

The variations of power with the change in wind velocity and density respectively are drawn from the study.

CONTENTS

CHAPTER-1
INTRODUCTION

1. INTRODUCTION

Energy is a basic requirement for economic development. Every sector of Indian economy i.e. Agriculture, Industry, Transport, commercial and domestic needs input of energy. The economic development plans implemented. Since independence has necessarily required consumption of energy has resulted in the country becoming dependent on fossil fuels. Such as Coal, Oil, Gas.

Rising prices of oil and gas in future lead to concerns about the security of energy supply need to sustain our economic growth. Increased use of fossil fuels results in environmental problems both locally and globally. Because of these reasons, there is a need to develop a sustainable path of energy development. Promotion of energy conservation and use of renewable energy sources are twin planks of a sustainable energy supply. India has variety of renewable energy sources such as biomass, biogas, solar, wind etc. India ranks second in the world in biogas utilization and 5^{th} in wind power & photovoltaic production.

Advantages of Renewable energy sources:

- Decentralized power generation
- Rapid installation of modular generation equipment
- Reduction of poverty through improved energy access
- Free abundant and theoretically boundless fuel source
- Low generation period which is not possible in conventional power plant
- Reduction in foreign exchange, Improves standard of living of rural areas
- Stability of grid system, Employment generation

1.1 WIND ENERGY:

Wind, which is an erratic and dilute in nature, is an important energy source. It has been estimated that 1% of daily wind energy available on the earth is equivalent to the present annual world total energy consumption.

Wind has a potential energy source was recognized as far back as 200B.C. in the early 1900's wind mills were being used for pumping water and to some extent for generating electricity in remote areas, in U.S., in Northern Europe and in some other places. The purpose of this wind energy is to provide that kind of information and reference in compact and easily accessible form. It provides information on several aspects of importance to wind energy development. Areas covered include wind structure, characteristics, wind measurement and site selection, basics of aerodynamics, design characteristics, performance. Thus, it will serve several functions. It will serve as a checklist reference for the actual implementation of wind energy activities to reduce the chance of pitfalls.

Traditionally, wind energy has been used primarily to pump water for human or cattle consumption or for Irrigation, Sailing, Grinding and other mechanical applications. Since 1981, wind turbines have been used to generate electricity competitively and it is environmentally benign and does not emit green house effect.

1.2 WIND POWER GENERATION:

Generation of electricity has been emerged as the most important application of wind energy in the world. The concept is flowing wind, rotates the blades of a turbine and causes electricity to be produced in generator unit. The blades and generator housed in a unit called as nacelle are mounted at the top of the tower.

There is stand alone mode in addition to grid mode to generate electricity. In case of stand alone system the battery bank is utilized to store the energy and will be utilized by inverting from DC to AC. The capacity of the system is to be designed based on the wind availability, application etc., Generally, installations carried out in India are grid mode and the power is fed to the grid network to supplement the conventional sources of energy. The fore going Chapters will give details on various parameters to establish wind power projects.

1.3 ABOUT WIND:

Due to increase in the oil prices and with the depletion of fossil fuels, the Government of India identified various alternative sources of energy to meet the power requirement in various sectors like lighting, pumping, power generation etc.

Out of the available renewable sources of energy like solar, biomass, wind, mini hydel, geothermal etc, wind energy offers more promising due to availability in abundance and can be generated with least cost.. The world's wind energy resources are highly dispersed and prevalent mostly at sites where it is difficult to harness for example at seas and altitudes or in the form of storms and hurricanes. Winds result because the areas closer to the equator receive more energy than the areas closer to the two regions.

This difference produces large scale convection currents in atmosphere which we know as wind. The wind distribution is based on the difference in temperature. In the costal areas there shall be winds from land to sea and vice versa and also the K.E. in the wind shall be strong enough to harness the potential. Though A.P. has 1050KM length of coast line, the winds are low when compared to the Tamilnadu coast, where close to 4000Mw of wind power projects are installed and are in operation. The study of the Government Department indicates that there is no much potential in the coastal areas of Andhra Pradesh.

The Nodal Agency (NEDCAP) installed met mast in the coastal areas at Bheemilipatnam, Sullurupeta of Nellore District and also in Cherala of Guntur District from which it is revealed that the potentially coastal Andhra is not encouraging. Whereas, the met mast installed in coastal belt of Tamilnadu in places like Kanyakumari, Netturu, Palladam etc., has very strong winds when compare to any other site in the country. The factor that influenced strong winds is due to Palghat gaps. In the case of Karnataka state, most of the wind potential exists in Inland sites which are mountain zones like Andhra. In the case of Gujarat, most of the windy sites are in the coastal belt.

In India, sites are identified in Govt., Forest & Private lands by installing met mast at heights varying from 50mtr to 100mtr towers to examine the wind velocity and direction.

1.4 CHARACTERISTIC OF WIND:

Wind is an erratic and dilute in nature. Wind has some well known characteristics, of which principal one is its variability. There are two basic types variations i.e. average speed variations between LOCATION & TIME. The variability between locations can be divided into two distinct components.

1. Differences in wind regimes between sites
2. Differences in wind speed at different heights for any particular sites

Variability of wind speed over a particular time generally increases as the unit measurement period per observant decreases. It is probably intuitive to most people that the distribute of average daily wind speed for any particular site would have a greater variance than that of average monthly or year wind speeds. The time series data is required at fixed intervals to analysis the wind pattern.

This characteristic makes wind as a source of energy more acceptable situations where short run variability in energy output would not catastrophic i.e. where the total energy out put from the wind system over, say a year, must have a rather high level of predictability where output variability from day to day does not matter too much.

Besides its variability over time and from site to site as mentioned above, the wind speed generally also tends to increase with altitudes, at most sites. This happens for the principal reason that as altitudes increases, the influence of surface roughness created by geographic structures and manmade ones becomes less in reducing wind speeds.

For purpose of study and analysis, the atmosphere has been divided into three altitude segments having distinct wind characteristics. Ranging from 50-100m above ground is known as the region of constant shearing stress i.e. the influence on the wind speed due to the surface roughness is constant. Ranging 500-1000m is known as the region of transition having variable shearing stress and above 1000m wind movements become similar to that of a fluid with zero viscosity not affected at all surface characteristics.

It is not always true that wind speed increases based on the altitude of a site, the influence of the shape and terrain features will affect and mostly in the case of complex terrain which can be cited Ramagiri site in Andhra Pradesh.

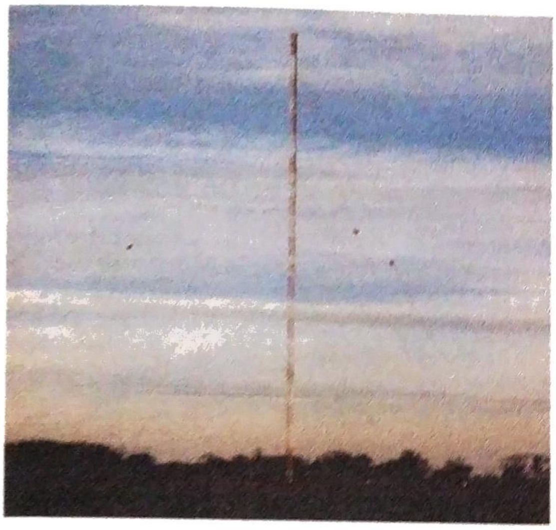
1.5 INSTRUMENT FOR WIND MEASURMENT:

Wind speed measuring instruments are known as Anemometers it keep track of two principal components speed and direction in addition to that air temperature and pressure is also monitored.

The first known anemometer was swinging plate by hanging plate with swing from a horizontal rod intensity of the wind was measured by the extent to which any of the plate deviated from perfectly perpendicular position to it during still position. Now a days propeller type are used it is a two or three blade propeller calibrated such that it measures r.p.m of wind. Anemometer consists of several components: Sensor, Transducer, Date processor. The transducer (generator or potentiometer) will translates wind speed into electric signals, processor collects data. Outer part of the wind vane (sensor) is made of corrosion resistant material. The output is of 4-20mA analog signal2.

1.6 METMAST FOR WIND RESOURCE:

A Wind Turbine without Wind is like a Dam without Water. To identify the windy sites by collecting wind data, direction and other parameters, to design the wind farm layout and Micro sting to achieve optimal generation, to estimate the expected generation from the project metmast is important.



1.1 Metmast installation at a windy site

1.2 Anemometer

1.3 Sensor

1.4 Data logger

A Metmast is a temporary structure installed for a period of 2 years and may be removed after study. A series of identical conventional and reliable cup anemometers has been arranged on booms. The anemometers measure the wind-speed at eight different height levels. The lowest level is at 18m, the highest level is at 95m. Registration of the wind direction is implemented by means of conventional wind vanes.

Furthermore, the wind is measured three-dimensionally by two ultrasonic anemometers. Data concerning atmospheric humidity, air temperature and air pressure and temperature difference complete these figures The wind speed data is collected in several altitudes. The height difference between successive measuring levels is approx. 10 m. This permits determination of wind speed gradients. In order to exclude systematic errors, measuring instruments of different types or with different measuring procedures are used. Only well proven measuring instruments are utilized. The principles of redundancy and diversification were implemented for all essential measuring equipment. The principal descriptive parameter of a wind regime is the annual average wind speed. It is usually given in meters per second or miles per hour but it is also provided in terms of watts per m2 i.e. power density.

Power density (PD) = $0.62*V^3$

Wind resource measurement is known as Anemometry, concern with quantifying the amount, variability and other characteristics of the wind. With the increasing interest in the wind energy the need for wind data has gone beyond its aviation and weather forecasting needs. Because of the cubic relationship which exists between the power in the wind and the wind speed small change in wind speed can have significant effect on the total power. Kinetic energy = ½ MV^2

M = Mass in Kgs, V= Velocity in meter Square

The Kinetic Energy in the Wind will influence on the extraction of wind from the site for generation of electricity. The velocity in the wind has large bearing on the power generation has "P" is proportional to the cube of velocity and also proportional to swept area of the rotor. Any variation in the wind speed will increase or decrease the power in KW and also increase or decrease in the diameter of the rotor has also influence on the power. In view of this a good windy site is to be identified through the process of site selection.

1.7 COMPONENTS OF WIND TURBINE GENERATORS:

The main components of the wind turbine generator are

- Aero turbine
- Nacelle
- Tower

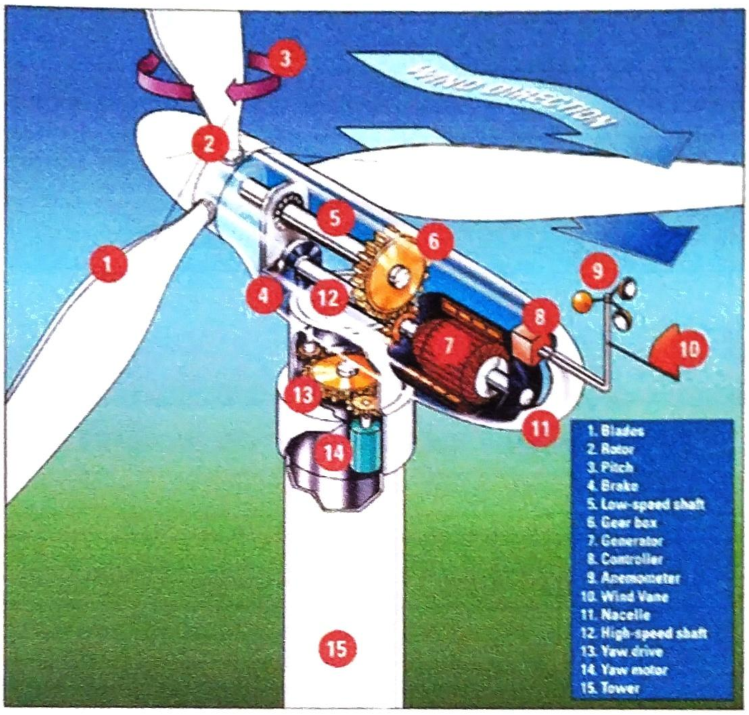


Fig: 1.7 Components of Wind Turbine Generator

1.8 AERO TURBINE:

The combination of rotor blades, Hub, Pitch mechanism is called aero turbine. Aero turbine converts energy in moving air to rotary mechanical energy.

1.8 (a) Rotor:

Rotor accounts for 20% of cost of turbine. If blades stress is kept constant as the size increases then the blade loads and required strength will both scale as the cube of diameter implying that geometric similar blades are feasible in a given material and that blade mass will then also scale as cube of diameter. As the blade turns it has to support its own weight and thus bending becomes a dominant loading. The material used is glass polyester or glass epoxy. The blades are mounted on slew. Bearing which in turn are mounted on spheroid graphite (SG) iron hub, Rotor is mounted on rotor shaft, with through whole pitch wiring.

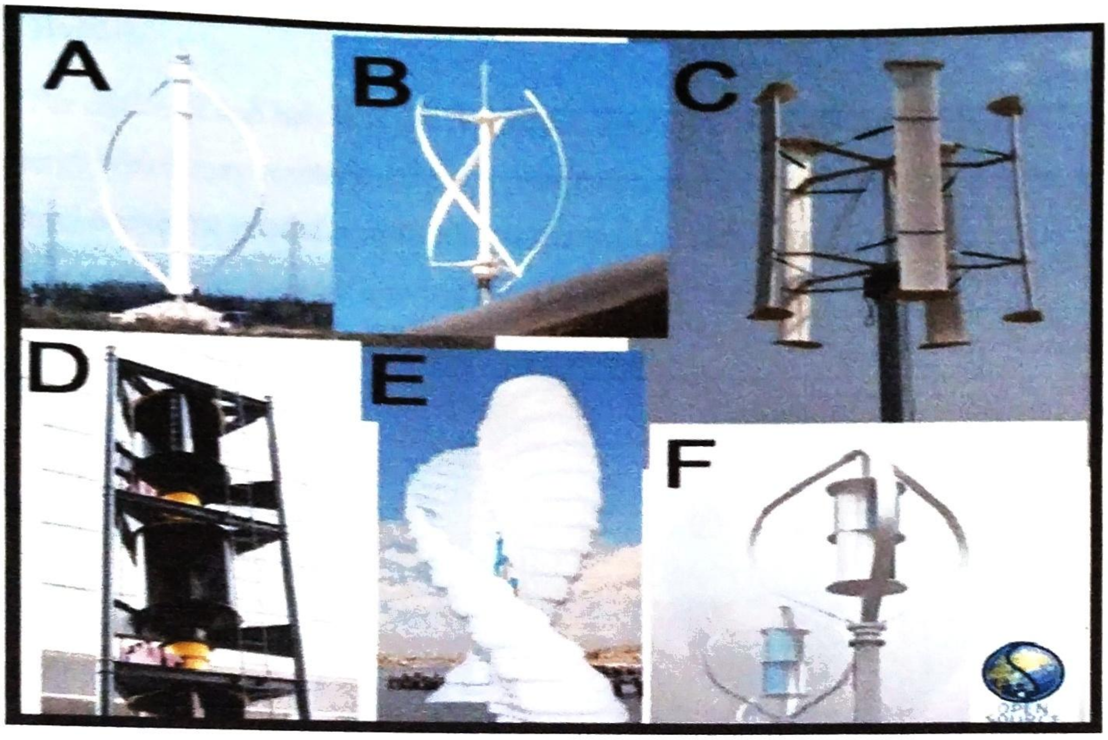
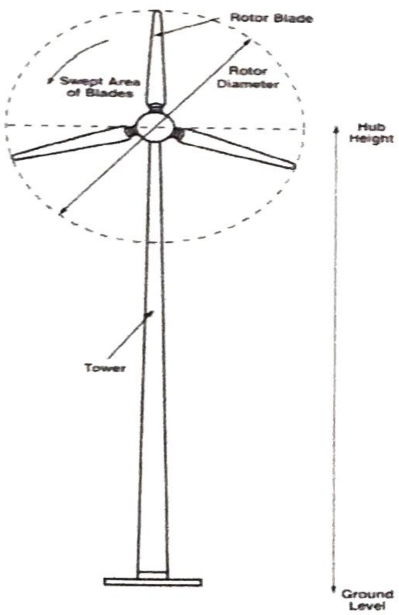


Fig1.8 Diagram of a Vertical Wind Turbine



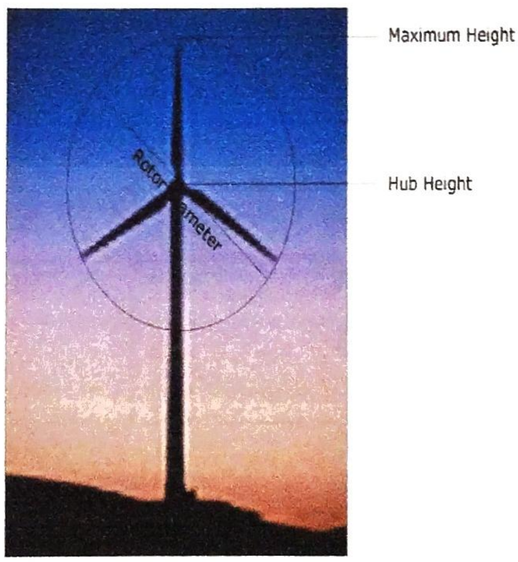


Fig: 1.8 (a) Schematic Diagram of a Wind Turbine

1.8 (b) Hub:

The choice of hub height is site dependent. There is a tradeoff between the benefits of the extra energy which may results from placing the rotors in the higher wind speeds to be found at higher level above the ground against the extra cost of making tower larger. Hub height equal to diameter is a good descriptive of courage trend of the larger turbine.

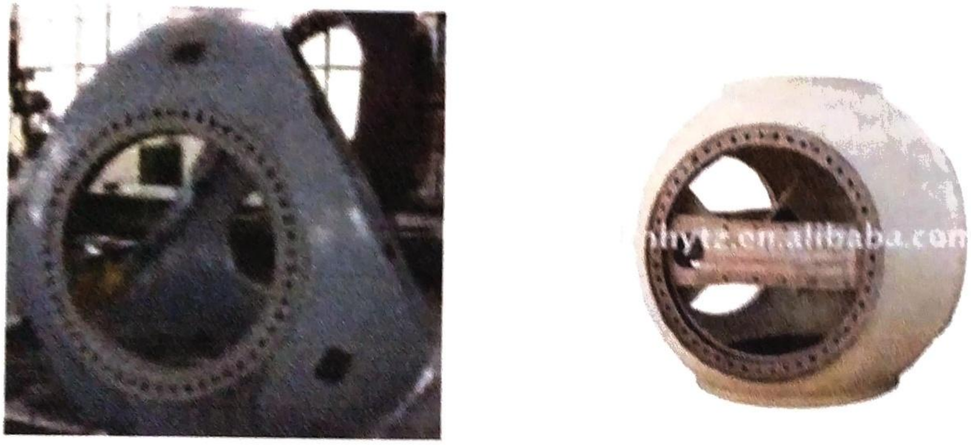


Fig: 1.8(b) Rotor Hub

PARAMETERS	MULTI MEGAWATTS TURBINE	SUB MEGAWATTS TURBINE
Hub Height	80 mts	65mts
Rotor Diameter	77	70
Maximum tip height	118.5	88.5

1.8(c) Pitch System:

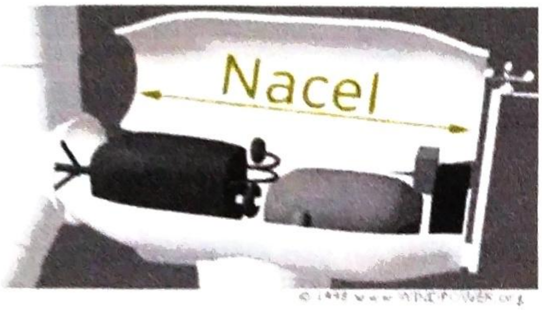
The pitching mechanism has in-built intelligent system which consists of frequency drives controlled by microprocessors.

- These intelligent frequency drives have real time measurement with a response time of just 30ms.
- Electrically driven, geared AC motor and feedback System to achieve required pitch Angle with digital accuracy from the controller.

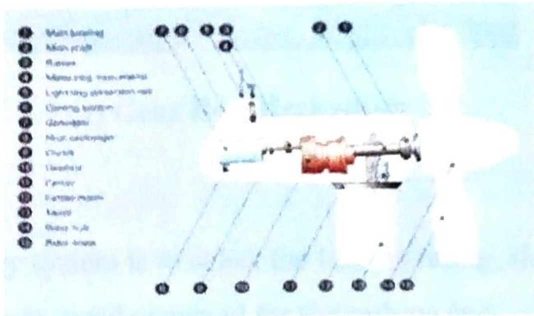
- Micro-pitching control mechanism achieves unmatched fine pitching with 0.1° Resolution.

1.9 NACELLE:

Nacelle houses rotor shaft with main bearings, gearbox, generator wind measuring instruments and control system.



1.9(a) Nacelle



1.9 (b) Parts of Nacelle

1.9 (a) Gear box:

Gear connects the low speed shaft to the high speed shaft and increases the rotational speeds from about 30-60 rotations per min (r.p.m) to about 1200-1500 r.p.m., the rotational speed required by most of the generators to produce electricity. Typically it can increase the speed of the main shaft up to a maximum of 6:1 per stage.

Most of the medium sized wind turbines use two storage transmissions, although larger turbines will use three stages. The no of stages influences cost and efficiency. A 3 stage gearbox- 1st stage planetary and other two helical is used. 1st stage – planetary takes up the slow rotor speed/ movement & distributes the high torque to the subsequent planetary gears.

Helical shape helps in noise dampening. Multi-stage, planetary and helical gears ensure highest possible mechanical efficiency and power. A permanent in-built, mechanically driven oil pump supplies oil to the gearbox and all shaft bearings with pressure lubricants. A separate oil-cooling unit with micro-filter system is provided for cooling the oil in the gearbox. Generator is connected to the gearbox by H-spacer and Axial dampers.

1.9 (a) Gear Box

1.9 (a) Gear Box Mechanism

1.9 (b) Generator:

An important step for installation of wind energy system is to select the turbine rating, the generator and distribution system. Based on the maximum speed expected for the turbine and taking into account the cubic relationship between the wind speed and the generated power the designers must select the generator and the gear box.

Induction generator are used for this because of the way it works as a motor or generator, the possibility of variable speed operation and its low cost induction machine offers advantages for rotating power plant. It has very same construction as induction motor with small change; the rotor speed is faster with respect to stator magnetic field rotation.

1.9 (b) Asynchronous Generator

Doubly Fed Induction Generator:

A very important machine, typically used for high power applications, is the doubly fed induction generator (DFIG). The DFIG is a wound rotor machine where the rotor circuit is connected to an external variable voltage and frequency source via slip rings and the stator is connected to the grid network. There is also a possibility of altering the rotor reactance by effectively modulating some inductors in series with the original rotor reactance. Adjusting the frequency of the external rotor source of current controls the speed of the doubly fed induction generator, which is usually limited to a 2:1 range. Doubly fed machines were not very popular in the past due to the maintenance required for the slip rings.

More recently, with the development of new materials, powerful digital controllers and power electronics, the doubly fed induction generator became a solution in power generation for up to several hundreds of KW ratings.

1.9 (c) Hydraulic System:

High quality hydraulic system similar to those found in jet planes supplies the mechanical braking devices. Motor & pump assembly – draws oil from reservoir & pushes it via high efficient filters ensuring cleanliness of oil & extended service level.

1.9 (c) Hydraulic Systems

1.9 (d) Yaw System:

The nacelle is actively yawed to the wind by the four electrical servomotors which are thyristor controlled. The yaw brake consists of a larger disk brae activated by hydraulic brake calipers. The complete system ensures a smooth yawing procedure, and that the nacelle is fixed when the yawing is inactive. An anemoscope (wind vane) gives signals to the master computer, which controls the yawing procedure of the turbine. The system ensures that the turbine is positioned correctly in the wind at all times, thereby resulting in the optimal power production and minimum stress on the turbine drive train.

1.9 (d) Yaw Base

1.9(d) Yaw Base Mechanism

1.9 (e) Control System:

Controller has two independent computers. The master computer is located in the switchboard in the bottom of the tower, and a slave is located in the nacelle. It has 24 bit digital signal processor & Micro controller based programming is used.

Sensors:

- Vibration (Osi) Switch
- Vibration Analyzer
- Rotor speed Sensor
- Incremental encoder (Gen. Speed Sensor)
- Yaw Sensor and North Position Sensor
- Twist Stop Sensor
- Anemometer, Wind Vane
- Pressure Switch, Hygrostat
- Brake ON/ OFF & Pad Wear Sensor, PTC (Positive Temperature Coefficient)

1.9 (e) Control Systems

1.10 TOWER

The tower of wind turbine carries Nacelle and Rotor. Two types of towers are used in wind mills.

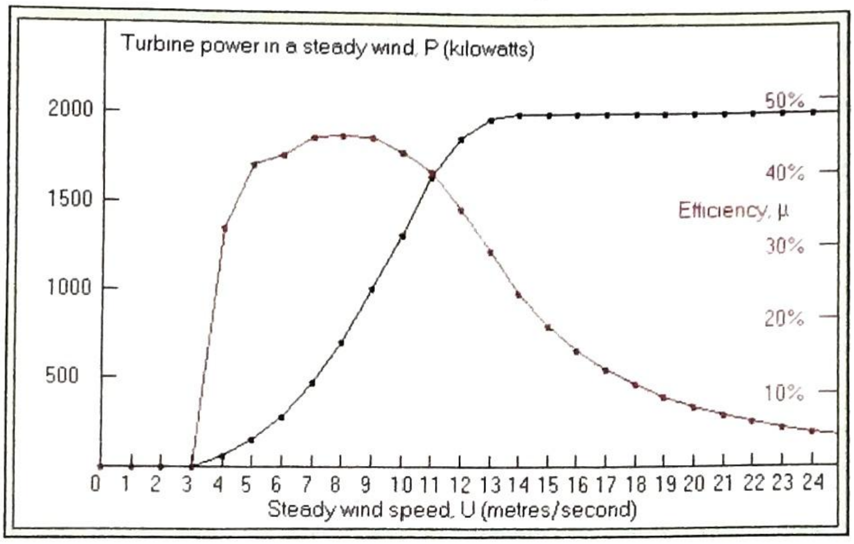
- Lattice type
- Tubular type

The tower must have the following features to have the good project.

- Better load carrying capacity
- Designed to eliminate critical natural frequencies
- Designed to reduce the dynamic stresses to minimum
- Better stability and load distribution
- Better lighting system.
- Epoxy coating on Tubular Tower
- Ultrasonic and Radiography tests.

1.11POWER CURVES:

When wind speeds are low the wind machine will stand idle. As wind speeds rise to what is known as the "Cut in speed", the machine will begin operating. The cubic relationship which exists between power and wind speed means that power increases at an accelerating rate as the wind speed increases up to a point where the rated o/p is approaching wind speed above to "rated wind speed" generally do not produce power output levels.



Graph 1.11: Power Curve Table of WTG's

1.12 RATED POWER:

Rated Power: $P = \frac{1}{2} \rho A V^3 Cp$

As said that the power will depends on three parameters: Air density 'ρ' (1.225 kg/m$^{3)}$, Swept area 'A' & Velocity 'V'. Cp is Betz co-efficient (0.593). Now we can see how these parameters affect the power.

1. **Density:**

   Wind generates because air molecules are moving past them. The more molecules we can move past the blades, the faster the blades will spin and the more electricity the wind system will produce.

2. **Swept Area:**

   Area of the rotor is included in the power equation because the rotor is in essence, the collecting device for the wind generation. The rotor captures the power in the molecules that moving past it. Larger the collecting device, the more electricity we can produce.

3. Velocity:

Increasing wind velocity increases the number of air molecules passing the rotor, so increasing wind speed will also have an effect on the power output of the wind system. But, because the velocity increases, the power increases by cubic times the velocity. So velocity is the important parameter for wind power generation.

$$Cp = \frac{\text{Power Output from wind machine}}{\text{Power available in wind}}$$

Depending on the power curve data of different manufacturing companies and average wind speed obtained at the selected site (2 years) will determines the rating of wind turbine. Different Power- Velocity curves of companies are given below.

1.13 SPACING OF WIND TURBINES IN A WIND FARM:

1.13 Spacing of Wind Turbines

1.14 SITE SELECTIONS:

The site choice for a single or a spatial array of WTG's is an important matter. If the WECS sites are wrongly chosen the net wind electric generated energy per year may be sub-optimal with resulting high cost. Some of the main considerations are given below

1. **High annual average speed:**

The wind velocity is the critical parameter power in the wind in the wind through a given cross sectional area for a uniform wind velocity is given by

$$P_w = KV^3$$

For the most accurate assessment of wind, anemometer data must be there. Strategy for sitting consist of

- Visit of sites based on historical data if available (IMD, Satellite data)
- Survey of historical wind data
- Top sheet for identifying the terrain
- Contour maps of terrain and wind are correlated
- Macro level study to identify site in broad
- Installation of met mast for identifying the site
- Collection of data timely and analyzing the data
- Summary data sheet
- Selection of windy site

2. **Availability of anemometer data:**

The anemometer data must be available over some time (for a minimum period of one to two year) at the precise spot where any proposed WTG's is to be built and that this should be accomplished before siting decisions is made.

3. **Availability of wind curves at a proposed site**:

This important curve determines the maximum energy in the wind and hence is the principal initially controlling factor in predicting the electrical out put. It is desirable to have average wind speed V such that V>12-16km/hr or 3.5-4.5m/s.

4. Altitude of the proposed site:

It affects the air density and thus the power in the wind. Also as is well known that winds tend to have higher velocity at higher altitudes.

5. Terrain and its aerodynamic:

One should know about the terrain of sites. If the WTG's 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 wind 'speed up'.

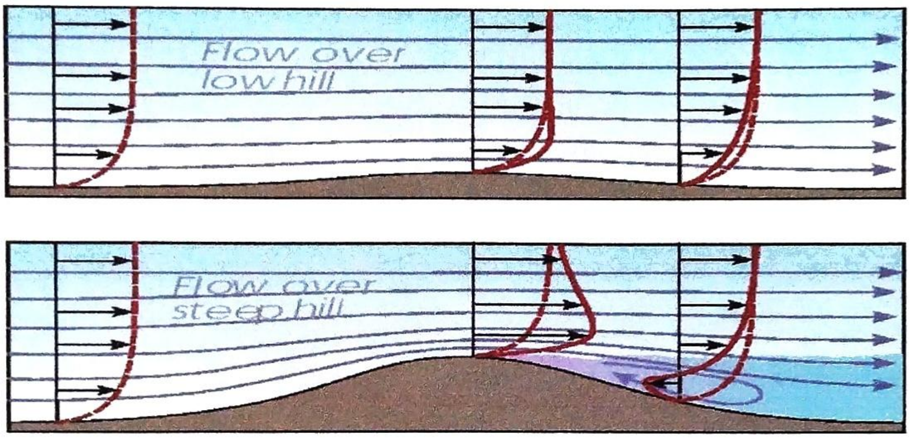


Fig 1.14 Flow of wind

6. Local Ecology:

If the surface is bare rocks 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 speed then wind hub height must be increased, the cost increases than bare ground case.

7. Distance to roads:

For heavy machinery, structures materials blades and rotors transport is necessary.

8. Nearness to site to local centers:

This obvious criterion minimizes the transmission line length and hence losses and costs.

9. Nature of ground:

Ground condition should be such that the foundation for WTG's is secured. Ground surface must be stable

10. Least land cost& Machine cost:

Land cost can be minimal to reduce project cost. A right machine at a right place i.e. selection of a suitable machine to a suitable site to optimize the generation to make the project viable.

The site selection is the major activity in identifying a windy site to make the project viable and to carry out micrositing analysis is utmost important for the success of the project which provides input for economic evaluation. There are institutions in the world at Netherlands (ECN) & Germany, USA and over a period of time, an institute was developed in India known as Center of Wind Energy Technology, to analysis the wind data, after wind resource assessment, notification on sites, testing and for issuing of type approvals in Chennai with test facility at Kayathar. While preparing pre-feasibility report, the other factors listed above shall also be taken into consideration to arrive the final conclusion on the site.

RISO LABORATORIES, DENMARK is one of the leading institutions in the world for certification on type approval, testing of machinery, R&D activities etc. This institution developed WASP programmer to examine the wind power density of different location in a given site if above mentioned parameters are known. This tool is being used in India to identify windy pockets at macro level to install met masts to identify a windy site and then take up analysis at micro level to estimate the potential of a site.

CHAPTER-2

LITERATURE REVIEW

2.1 Literature review:

Young-Tae Lee [1] in article —Numerical study of the aerodynamic performance of a 500 W Darrieus-type vertical-axis wind turbine‖ studied characteristic and the performance of a Darrieus-type vertical axis wind turbine with NACA airfoil blades. The performance of Darrieus-type turbine this can be characterized by torque and power. Various parameters especially related to blade design affect performance of turbine, parameters such as chord length, helical angle, pitch angle, and rotor diameter. To estimate the optimum shape of the Darrieustype wind turbine in accordance with various design parameters, aerodynamic characteristics and the separated flow occurring in the vicinity of the blade, the interaction between the flow and the blade, and the torque and power characteristics is examined in this work. In this study analyse through, wind tunnel experiment and numerical analysis concluded that Darrieus-type wind turbine with a NACA airfoil blade produces maximum output power with optimized design parameters. Additionally, variations of flow and performance characteristics which appear while design parameters are varied were derived numerically. The results of study can be summarized as follows. The thickness ratio of the airfoil blade makes no significant difference in the performance of the wind rotor and turbine considered. However, similar to solidity, a thick airfoil is applied by a higher drag force, which leads to a low power coefficient from turbine. In terms of power performance at varying pitch angles of blades, the highest efficiency occur pitch angle of 2 degree. The optimum pitch angle is predicted to change in accordance with the angle of attack.

Bavin Loganathan [2] investigated a domestic scale vertical axis wind turbine considering blade geometry with semi-circular shaped blades under a range of wind speeds during operation. A 16-bladed rotor was initially designed and its torques and angular speeds were measured over a range of wind speeds using a wind tunnel. Additionally, a new concept of cowling device was developed to enhance the turbine efficiency by directing air flow from the rear blades into the atmosphere. Another 8-bladed rotor was also manufactured to investigate the effect of blade number on the maximum power generation from turbine. The aerodynamic performance of the cowling device was also investigated in this study. Maximum power curves as a function of wind speeds were established for each configuration. The results indicated that the 16-bladed wind turbine can be used for domestic scale wind power generation also the results show that the cowling device has positive effect to increase the rotor speed to a significant amount. With the use of the cowling device, the average rotor speed increased by about 26% for the 16-bladed rotor compared to the baseline configuration. A significant increase about 40% of rotor speed was also found for the 8-bladed rotor with the implementation of cowling device. The results of article also indicated that the cowling device can be used to increase the power output of this cyclonic type vertical axis wind turbine especially with a reduce number of blades. Results show that the wind turbine device has positive effect to increase the rotor speed to a significant amount. The average rotor speed increased by about 26% for the 16-bladed rotor Compared to the baseline configuration with implementation if new cowling devise. An energy and exergy analysis is performed on four different wind power systems considering especially blade performance, including both horizontal and vertical axis wind turbines. Significant variability in turbine designs and operating parameters are encompassed through the selection of systems. In particular, two airfoils that is blade geometries, commonly used in horizontal axis wind turbines are compared with two vertical axis wind turbines. This paper analyzes each system with respect to both the first and second laws of thermodynamics for analysis. The aerodynamic performance of each system is numerically analyzed by computational fluid dynamics software in this case FLUENT. Key design variables are analysed and the predicted results are discussed during study. The exergetic efficiency of each wind turbine is studied for different geometries, design parameters and operating conditions, thereby providing a useful design tool for wind turbine blade power development. Work concludes that the first and second laws were used to compare the performance of a variety of wind power systems. Exergy analysis was shown to allow a diverse range of geometric and operating designs to be compared with a common metric. Exergy is a useful parameter in wind power engineering, as it can represent a wide variety of turbine operating conditions, with a single unified metric. Through exergy methods, better site International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 National Conference on Emerging Research Trends in Engineering and Technology (NCERT- 02nd & 03rd November 2015) Dr. Sau. Kamaltai Gawai Institute of Engineering & Technology 160|P a g e selection and turbine design can improve system efficiency, decrease economic cost, and increase capacity of wind energy systems.

Research work by Robert Howell [3] presents a combined experimental as well as computational study into the aerodynamics and performance of a small scale vertical axis wind turbine blades. Wind tunnel tests were carried out to ascertain overall performance of the turbine and two- and three-dimensional unsteady computational fluid dynamics models were generated to help and to understand the aerodynamics of this turbine performance. Wind tunnel performance results are presented for cases of different wind velocities, tip-speed ratio and solidity as well as rotor blade surface finish. It is shown experimentally that the surface roughness present on the turbine rotor blades has a significant effect on performance of turbine. Below a critical wind speed (Reynolds number of 30,000) the performance of the turbine is degraded by a smooth rotor surface finish but above it, the turbine performance is enhanced by a smooth surface finish of blade. Both two bladed and three bladed rotors were tested and a significant increase in performance coefficient is observed for the higher solidity rotors (three bladed rotors) over most of the operating range. Dynamic stalling behaviour and the resulting large and rapid changes in force coefficients and the rotor torque are shown to be the likely cause of changes to rotor pitch angle that occurred during early testing. This small change in pitch angle of blade caused significant decreases in performance. A small model research VAWT turbine has been manufactured as prototype and tested over a range of operating conditions. The straight turbine rotor blade, with an aspect ratio of 4:1, operates at relatively low tip speeds and its performance shows a clear dependence on the rotor blade surface finish. Below a critical Reynolds number (30,000), the performance is enhanced by having the surface of the turbine roughened, but above this Reynolds number the power coefficient is observed to be degraded. Computational predictions of the performance coefficient of this turbine were carried out and the 3D simulations were shown to be in reasonably good agreement with the experimental measurements, considering errors and uncertainties in both the CFD International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 National Conference on Emerging Research Trends in Engineering and Technology (NCERT- 02nd & 03rd November 2015) Dr. Sau. Kamaltai Gawai Institute of Engineering & Technology 161|P a g e simulations and the wind tunnel measurements. The 2D simulations of flow showed a significantly increased performance compared to the 3D simulations and this was shown to be mainly due to the presence of the large tip vortices present in the real turbine and the 3D simulations. Simulations illustrated the periodic pulsing nature of the tip vortices caused by the changing lift generated by the rotor blades as they travel through each rotor revolution. At phases considered where higher amounts of lift are generated, stronger tip vortices are present, whereas at phases where little lift is generated, the vortices are observed to be significantly reduced as per work carried out.

2.2 SUMMERY:

Vertical axis wind turbine offer economically viable energy solution for remote areas away from the integrated grid systems. In order to spread the use of VAWT, the problems associated with various configurations, i.e. poor self-starting and low initial torque, low coefficient of power, poor building integration should be overcome. Furthermore, following conclusions can be drawn from the present review: Sufficient wind energy potential is available in the world. In order to make best use of it efficient designs of wind turbines need to be developed. Various vertical axis wind turbines can offer solution to the energy requirements with a reasonable payback period. Coefficient of power can be maximized by selecting a suitable operating range for various configurations. Remarkable advances in wind turbine design have been possible due to developments in modern technology. The advanced wind turbine technologies have been reviewed as follows considering overall performance point of view The factors such as selection of site, height, choice of wind generators, wind velocity, wind power potential have been considered as an objective function of probabilistic models. Selection of windy site for wind power generation requires meteorological data for installation of wind generator. Experimental and theoretical methods are used to analyze vibration problems of wind turbines. Aeroaccoustic tests are used to find noise in the aerofoil. Wind field modelling is an important part of a structural analysis of wind turbines. In aerodynamic modelling blade element moment theory is used for calculation of aerodynamic forces acting on the rotor blade. Control system modelling is used to keep the operating parameters of the wind turbine within the specified limit. These developments and growing trends towards wind energy signal is a promising future for the wind energy industry. With this improved technology wind turbine can be designed for its optimum power production at less cost.

CHAPTER-3

METHODOLOGY

3. METHODOLOGY

Here, we could see how the prototype is made.

Take pvc pipe having 4 inch diameter and 30 cm length .Axially divided into 4 equal parts using an angle grinde. Carefully use angle grinder make holes on one side of the pvc using 6 mm drill bit

Cut four pieces of ACP sheet having 30 cm length 6 cm in width. Mark holes on ACP from pvc pipes and make holes using 6mm drill bit.

Take 4 steel L-clamps and cut it into required length 12 cm*6cm using an angle grinder.

Take GI plate washer 2 inches in diameter take GI nut that suits dynamo pully then weld GI nut at the centre of plate washer then weld all 4 L-clamps on the plate washer now proppller frame is ready.

Connect ACP sheets and pvc pipes together using cycle screws use a spanner to tighten it then connect these proppller blades on proppler frames. Now wind turine proppller is ready.

Take pvc fittings join these components together to make wind turbine base. Connect the wire to the dynamo and fix it on wind turbine base.

Place proppller on wind turbine base. Finally vertical axis wind turbine is ready. place the wind turbine in front of a fan.

Fig: 3.1 WIND TURBINE-MODEL

Fig:3.2 L-Clamps

Fig:3.3 ACP-Sheets and PVC Blades

CHAPTER-4
ANALYTICAL METHOD
(WEIBULL-RAYLEIGH METHOD)

4.1 WIND SPEED DISTIBUTION:

One of the characteristics of wind is that its speed at any one moment cannot be estimated based on its speed some moment earlier i.e. wind follows a basically random pattern from one moment to next. Nevertheless, measured over longer periods of time, wind speed tends to display a generally predictable frequency distribution. The Weibull distribution has been found to conform well to the distribution of observed wind speeds.

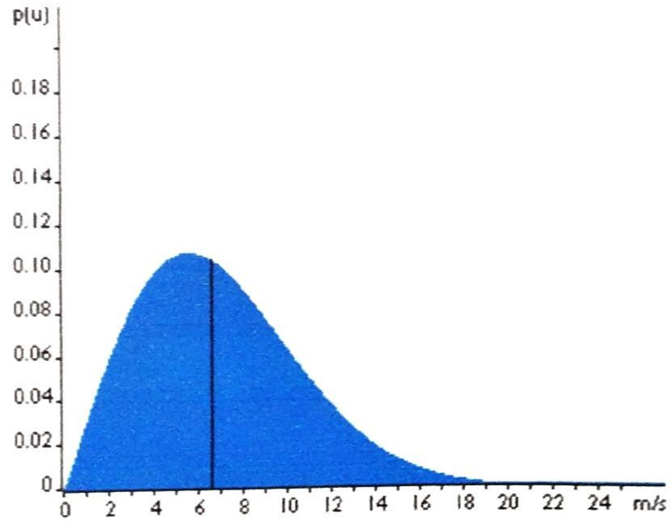
$$P(v) = (k/c)[(v/c)^{k-1}\exp(-(v/c)^{k})]$$

V is ratio of any wind speed to mean wind speed

C is site parameter (1.15-1.18)

K is shape parameter (1.7-2.5)

For k=2 the weibull distribution becomes Raleigh distribution.



Graph 4.1 shows the shape of the weibull curve

Thus given that wind profile tends to follow the Weibull distribution and more specifically the Ralyiegh distribution. This is useful trick because if often happens that reliable information on average wind speeds over considerable periods of time. Below table shows the practical readings to analysis distribution curves

TABLE 50

STATION : JAMALAMADUGU 1

PERCENTAGE FREQUENCY DISTRIBUTION OF WIND SPEED

Class Interval (kmph)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
0 - 2	2.4	1.3	1.8	0.6	1.0	0.1	0.4	0.6	1.9	8.5	6.4	5.8	2.6
2 - 4	2.4	2.0	2.6	0.9	2.2	0.4	0.6	1.2	2.4	8.6	5.5	4.2	2.7
4 - 6	4.9	5.1	3.9	3.4	3.5	1.3	0.5	1.2	2.7	10.5	9.7	5.2	4.2
6 - 8	7.8	8.5	8.0	7.9	5.3	1.8	0.9	1.8	4.5	12.9	12.0	8.2	6.6
8 - 10	10.3	9.5	8.3	10.4	7.0	1.8	1.3	2.6	5.0	12.7	14.9	12.7	8.0
10 - 12	13.4	12.6	10.0	10.9	7.0	2.7	1.7	2.0	5.7	11.9	15.4	14.9	9.0
12 - 14	14.1	11.9	10.3	10.1	7.4	3.0	2.6	3.2	6.8	9.5	12.0	16.9	9.6
14 - 16	14.7	12.7	10.3	9.7	7.8	4.2	4.2	3.7	6.7	6.9	8.6	13.1	8.5
16 - 18	12.1	12.2	11.0	10.0	7.7	5.4	3.8	5.3	7.2	6.4	6.6	10.7	8.2
18 - 20	8.1	9.9	10.0	9.9	7.7	5.6	5.0	6.2	7.7	2.9	4.4	4.4	5.9
20 - 22	5.6	8.2	9.1	9.1	7.7	6.0	6.2	6.5	7.9	2.5	2.7	2.9	6.2
22 - 24	2.7	4.4	7.3	6.6	6.1	7.4	5.9	6.8	6.8	1.4	0.7	0.7	4.7
24 - 26	1.2	1.7	3.7	4.7	4.4	6.4	6.9	7.8	5.9	1.5	0.5	0.4	3.8
26 - 28	0.3	0.7	1.9	2.6	3.4	6.5	7.0	7.0	5.3	1.1	0.4		3.0
28 - 30	0.0	0.2	1.0	1.9	3.3	5.6	7.5	8.7	5.1	0.8	0.2		2.9
30 - 32	0.1		0.3	0.2	3.3	6.0	7.1	7.6	5.6	0.6	0.1		2.4
32 - 34	0.0		0.3	0.1	2.7	5.5	7.3	8.5	4.7	0.5	0.0		2.[illegible]
34 - 36			0.1	0.2	2.6	5.3	7.8	7.4	3.1	0.4			2.3
36 - 38		0.0	0.0		2.1	6.1	6.7	5.3	2.7	0.3			2.0
- 40			0.0	0.0	1.7	5.5	5.4	3.0	1.9	0.1			1.5
40 - 42			0.0	0.1	1.4	4.7	4.9	2.1	1.2	0.0			1.2
42 - 44					1.2	2.3	2.6	1.5	0.6	0.0			0.7
44 - 46					0.8	1.6	1.6	0.7	0.2				0.4
46 - 48					0.8	1.8	0.7	0.2	0.2				0.3
48 - 50					0.6	1.3	0.8	0.1	0.0				0.2
50 - 52					0.4	0.7	0.4		0.0				0.1
52 - 54					0.3	0.4	0.2						0.1
54 - 56					0.2	0.2	0.0						0.0
56 - 58					0.2								0.0
58 - 60					0.2								0.0

Based On Data January 1993 December 1995

Sensor Height : 25 M
Range 0-2 Extends From 0.0 To 1.9 Kmph
2-4 Extends From 2.0 To 3.9 Kmph
And So On

Table: 4.1.a Frequency distribution of wind speed at station

TABLE 81

STATION : JAMALAMADUGU 2

PERCENTAGE FREQUENCY DISTRIBUTION OF WIND SPEED

Class Interval (kmph)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
0 - 2	0.3	0.2	0.7	0.7	0.4	0.2	0.2	0.1	0.3	2.2	0.9	0.2	0.5
2 - 4	0.5	0.7	1.3	0.5	1.5	0.3	0.3	0.4	0.8	4.1	1.5	0.9	1.1
4 - 6	2.1	2.8	2.6	2.2	3.0	0.6	0.5	0.8	2.1	7.4	3.3	2.5	2.5
6 - 8	3.7	4.8	5.4	5.8	4.9	1.2	0.5	1.3	4.1	10.7	7.6	5.2	4.6
8 - 10	8.0	7.7	7.6	8.8	6.0	1.7	1.3	1.9	5.0	14.0	13.1	9.7	7.1
10 - 12	10.4	10.1	9.2	10.2	7.3	2.0	1.8	3.0	5.6	13.9	15.8	15.0	8.7
12 - 14	14.4	11.0	10.2	10.2	6.3	2.9	2.5	3.5	7.2	13.6	17.4	19.7	9.9
14 - 16	18.5	14.6	10.4	9.6	8.1	4.8	3.8	4.1	7.5	10.5	14.0	17.7	10.3
16 - 18	16.5	14.0	11.2	10.2	8.0	5.2	4.3	5.0	8.8	7.5	11.3	13.1	9.6
18 - 20	12.0	12.8	11.4	10.6	7.9	5.5	5.5	6.9	9.3	5.0	7.1	9.4	8.6
20 - 22	7.7	11.2	10.9	10.0	7.7	6.5	6.7	7.8	8.0	3.2	4.2	4.0	7.3
22 - 24	3.8	5.6	8.5	8.6	6.0	7.3	7.3	8.8	6.6	2.2	1.5	1.6	5.8
24 - 26	1.6	2.9	5.4	6.0	4.5	8.3	8.7	8.3	7.0	1.5	0.6	0.3	4.6
26 - 28	0.5	1.0	3.2	3.3	3.8	6.5	7.0	7.8	5.6	1.4	0.6	0.1	3.4
28 - 30	0.0	0.2	1.0	1.8	3.9	6.8	8.6	8.2	5.6	0.8	0.2	0.0	3.1
30 - 32	0.1	0.1	0.6	0.7	3.2	7.4	7.8	8.6	3.9	0.4	0.2		2.8
32 - 34		0.0	0.2	0.4	3.0	6.4	7.6	7.6	2.4	0.3		0.2	2.3
34 - 36			0.1	0.1	3.3	5.2	7.3	5.2	2.9	0.3	0.0		2.0
36 - 38			0.0	0.1	2.5	6.4	5.9	3.9	2.5	0.2	0.1	0.0	1.8
38 - 40			0.0	0.1	2.3	3.1	3.8	2.7	2.1	0.1	0.1	0.1	1.2
40 - 42			0.1	0.0	1.7	2.7	3.5	2.0	1.0	0.1	0.0	0.1	0.9
42 - 44					1.4	2.7	2.2	1.5	0.5	0.3			0.7
44 - 46					0.8	1.8	1.5	0.5	0.6	0.1			0.4
46 - 48					0.9	2.0	0.8	0.2	* 0.2	0.0			0.3
48 - 50					0.6	1.5	0.5	0.0	0.1	0.1	0.0		0.2
50 - 52					0.4	0.5	0.1		0.0	0.0			0.1
52 - 54					0.4	0.4	0.1						0.1
54 - 56					0.2	0.1							0.0
56 - 58					0.1	0.1							0.0
58 - 60					0.1								0.0

Sensor Height : 25 M
Range 0-2 Extends From 0.0 To 1.9 Kmph
2-4 Extends From 2.0 To 3.9 Kmph
And So On

Based On Data January 1993 - December 1995

Table: 4.1.b Frequency distribution of wind speed at station

TABLE 1

STATION : JAMALAMADUGU 1

SUMMARY OF WIND DATA

Month	Monthly Mean Wind Speed (Kmph)		Monthly Standard Deviation (Kmph)		Hourly Maximum Wind Speed (Kmph)		Peak Wind Speed (Kmph) (Date/Year/Time of Occurrence)		Lull in Hours		Prevailing Wind Direction	
	(10m)	(25m)	(10m)	(25m)	(10m)	(25m)	(10m)	(25m)	(10m)	(25m)	(10m)	(25m)
JAN	10.12	12.99	2.97	3.11	26.55	32.18	48.27 (6/94/16:09)	49.07 (6/94/16:09)	329	198	SE	SE
FEB	11.17	13.84	2.56	2.91	32.18	37.41	53.90 (28/93/19:20)	56.31 (28/93/19:23)	252	165	SE	SE
MAR	12.15	14.87	2.58	2.94	34.59	41.03	52.29 (20/94/07:22)	57.12 (20/94/07:12)	253	175	SE	SE
APR	12.88	15.43	2.43	2.92	33.39	40.63	65.97 (30/94/19:00)	71.60 (28/94/03:15)	221	156	SE	SE
MAY	16.18	19.91	3.27	3.97	53.10	62.35	89.30 (7 /94/01:03)	98.15 (7 /94/01:03)	127	137	NW/W	W
JUN	22.05	27.31	2.75	3.10	47.87	55.91	92.52 (2 /93/03:52)	98.15 (2 /93/03:52)	79	48	W/NW	NW/W
JUL	22.63	28.18	1.68	2.22	45.86	54.30	94.13 (13/94/16:17)	99.76 (13/94/16:17)	64	31	NW	NW/W
AUG	20.29	25.57	1.63	1.78	41.83	49.07	74.01 (2 /95/01:23)	76.43 (10/93/17:54)	95	55	NW	NW/W
SEP	16.20	20.23	2.35	2.68	43.85	51.89	71.60 (1 /93/15:48)	71.60 (2 /95/12:13)	181	121	NW/W	NW/W
OCT	7.98	10.37	1.85	1.79	35.40	42.24	62.75 (3 /93/01:37)	66.77 (3 /93/01:55)	472	370	SE/NW	SE/W
NOV	7.92	10.28	2.89	2.95	27.35	32.58	52.29 (17/94/15:29)	57.92 (17/94/15:29)	454	324	SE	SE
DEC	8.85	11.35	3.05	3.32	22.53	25.74	42.64 (7 /93/14:03)	46.66 (2 /95/12:44)	392	262	SE	SE
ANNUAL	14.04	17.53	5.13	6.20	53.10	62.35	94.13 (13/7/94/16:17)	99.76 (13/7/94/16:17)	2091	2022		

Based on Data January 1993 - December 1995

Table: 4.1.c Estimation of wind data

4.2 POWER RELATIONSHIP:

Power Relationship is given by

$V(h_2)/V(h_1) = (h_2/h_1)^a$

Where v (h1), v (h2) are the wind velocity at specific heights

h1, h2 are the specific heights, a -is the power law index=1/7

The power law index of a site decides on the height of the machine as higher the power law index the upper winds are stronger and vise-versa. After taking the wind data for two years life time or mortality of wind is analyzed. This can be done by using Weibull-Raleigh method. In this we can observe speed distribution over a specified period & frequency distribution. Fore coming chapter will explain about this analysis.

CHAPTER-5

PROCEDURE FOR POWER CALCULATION

PROCEDURE FOR POWER CALCULATION:

Based on metrological wind data, the hourly electricity production for a certain amount of wind power will be modeled. However, to model the hourly wind power production one also needs information about the site of the wind turbines, the types of wind turbine they are used the station that provides the meteorological data of interest and about the ways of transforming the measured wind speed to wind turbines sites and hub height and converting wind speed to power production.

Therefore, the general methodology for modeling the hourly wind power production data for a specific amount of wind power consist of the following steps

- Selection of suitable location where wind turbines can be placed
- Selection of meteorological measuring stations which can be used to describe the wind climate at a certain wind turbine location
- Selection of wind turbine types each being representing for a certain class of wind turbines
- Calculation of the wind speed at a location and the hub height of each wind turbine using the measured wind speed data
- Calculation of the hourly wind power production for each wind turbine and for all wind turbines together gives the total power generated for a period.

RATED POWER:

Rated Power: $P = \frac{1}{2} \rho A V3$

As said that the power will depends on three parameters: Air density 'ρ' (1.225 kg/m3), Swept area 'A' & Velocity 'V'. Cp is Betz co-efficient (0.593). Now we can see how these parameters affect the power.

1. Density:

Wind generates because air molecules are moving past them. The more molecules we can move past the blades, the faster the blades will spin and the more electricity the wind system will produce.

2. Swept Area:

Area of the rotor is included in the power equation because the rotor is in essence, the collecting device for the wind generation. The rotor captures the power in the molecules that moving past it. Larger the collecting device, the more electricity we can produce

When the number of blades is even the formula to calculate the swept area is enumerated by multiplying the blade length (l) by the rotor diameter (d):

$$S=d*l$$

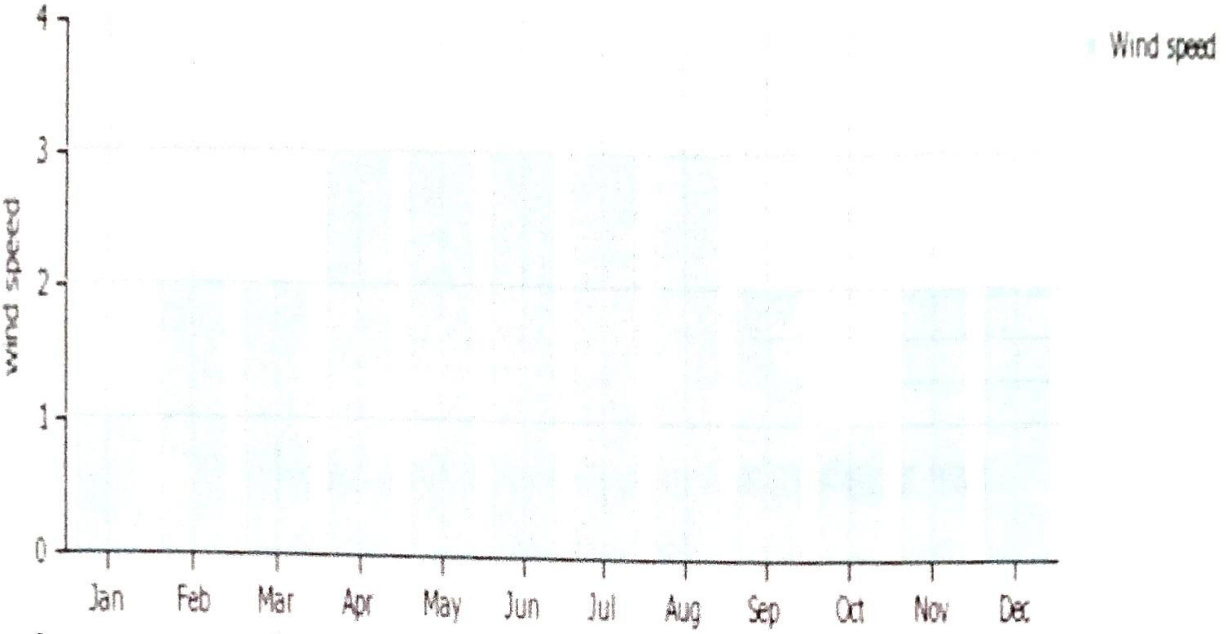
3. Velocity:

Increasing wind velocity increases the number of air molecules passing the rotor, so increasing wind speed will also have an effect on the power output of the wind system. But, because the velocity increases, the power increases by cubic times the velocity. So velocity is the important parameter for wind power generation.

CHAPTER-6
RESULT ANALYSIS

RESULTS:

The mean monthly wind speed over the year in visakhapatnam,India (meters per second)



Data from nearest weather station: Vishakhapatnam, India(4.4Km)

The variation of power with the change in wind velocity is shown in the graph plot below:

Rated Power: $P = \frac{1}{2} \rho A V^3$

As we know, density= P/RT

where P = Pressure

R = Universal gas constant = 0.287J/kg K

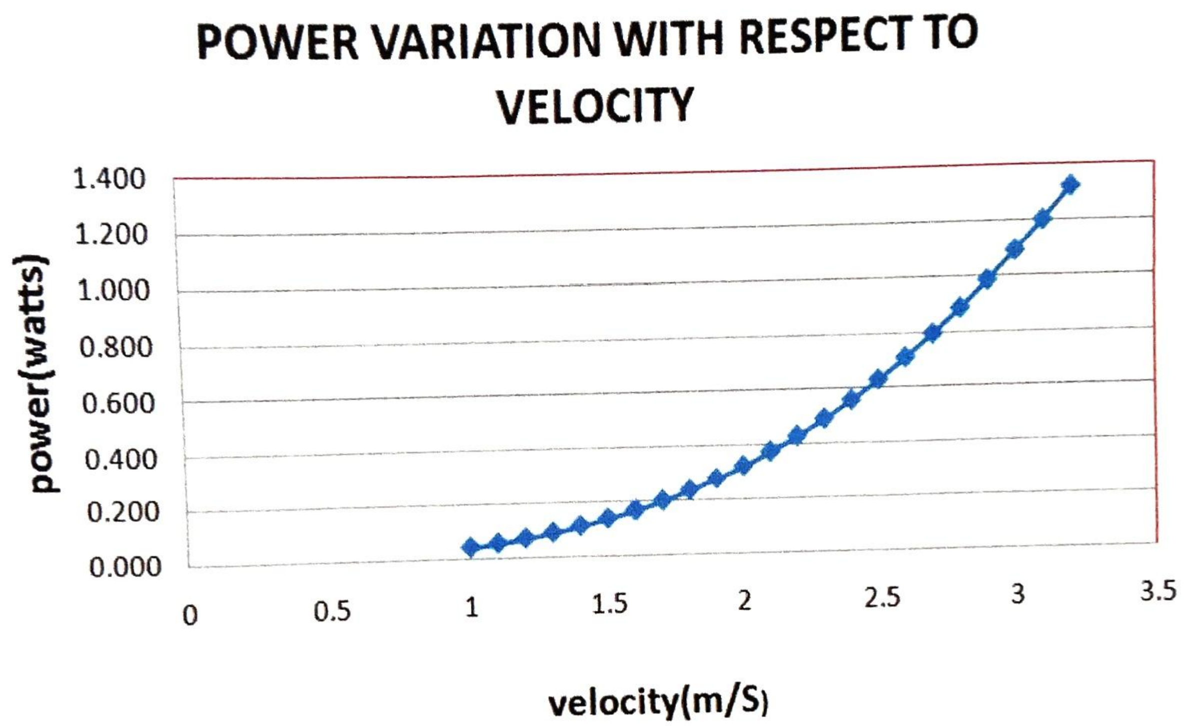
T = Temperatur

With change in velocity power values changes

Here we have taken constant desity

velocity (m/s)	power (W)
1	0.040
1.1	0.054
1.2	0.070
1.3	0.089
1.4	0.111
1.5	0.136
1.6	0.165
1.7	0.198
1.8	0.235
1.9	0.277
2	0.323

2.1	0.374
2.2	0.430
2.3	0.491
2.4	0.558
2.5	0.631
2.6	0.709
2.7	0.794
2.8	0.886
2.9	0.984
3	1.090
3.1	1.202
3.2	1.323



The variation of power with the change in density:

Rated Power: $P = \frac{1}{2} \rho A V^3$

As we know, density= P/RT

where P = Pressure

R = Universal gas constant = 0.287J/kg K

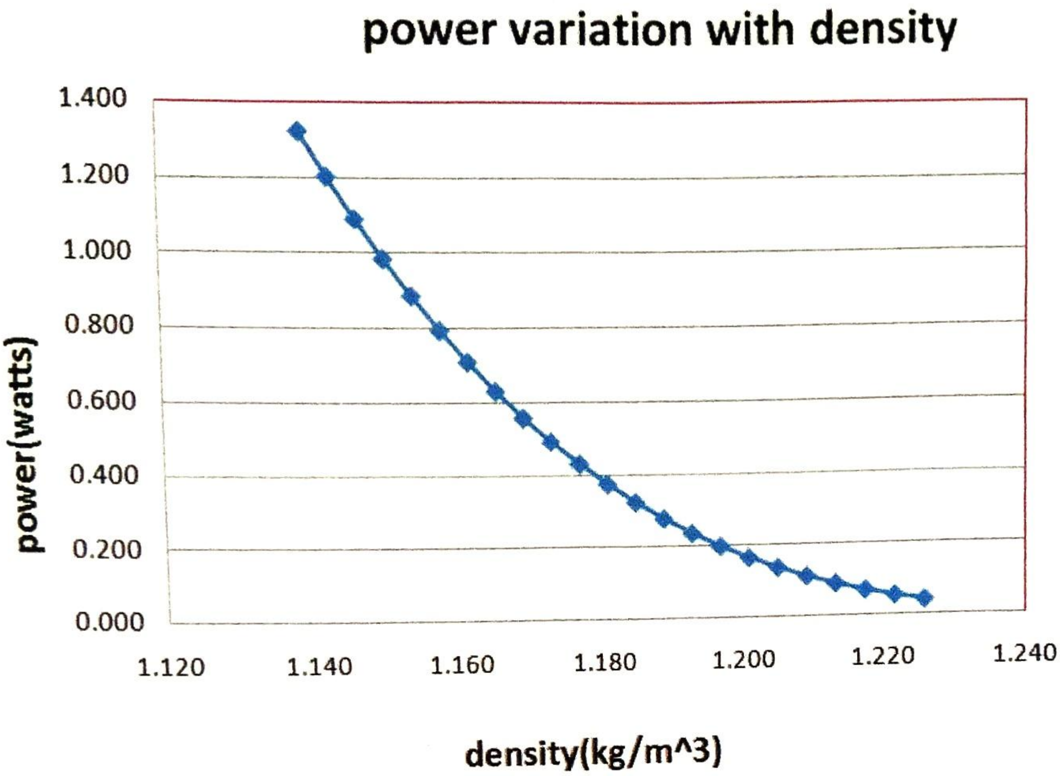
T = Temperature

With the change in temperature, density value changes.

Therefore with the change in density, there is variation in power as shown in the graph plot shown below

Here we have taken change in velocity

Velocity(m/s)	Power(watts)	Density(kg/m^3)	Temperature(K)
1	0.048	1.226	288
1.1	0.064	1.222	289
1.2	0.083	1.217	290
1.3	0.105	1.213	291
1.4	0.131	1.209	292
1.5	0.160	1.205	293
1.6	0.194	1.201	294
1.7	0.232	1.197	295
1.8	0.274	1.193	296
1.9	0.322	1.189	297
2	0.374	1.185	298
2.1	0.431	1.181	299
2.2	0.494	1.177	300
2.3	0.563	1.173	301
2.4	0.638	1.169	302
2.5	0.718	1.165	303
2.6	0.805	1.161	304
2.7	0.899	1.158	305
2.8	0.999	1.154	306
2.9	1.106	1.150	307
3	1.221	1.146	308
3.1	1.343	1.143	309
3.2	1.472	1.13	310


power variation with density
power(watts)
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
1.120
1.140
1.160
1.180
1.200
1.220
1.240
density(kg/m^3)

CHAPTER-7
CONCLUSION

CONCLUSION:

Vertical axis wind turbine offer economically viable energy solution for remote areas away from the integrated electricity grid systems. Blade design plays critical role for performance and energy extraction from turbine. In order to spread the use of VAWT, the problems associated with various configurations, i.e. poor self starting and low initial torque, low coefficient of power, poor building integration should be overcome. With the assumption of placing the turbine in a location with moderate wind availability with optimized blade parameters and design specifications, high power generation is achieved with vertical axis wind turbine and can be serving as energy generation unit for remote areas.

CHAPTER-8
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