FABRICATION OF VERTICAL AXIS WIND TURBINE

A PROJECT REPORT

Submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

BY

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2017-2021

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CERTIFICATE

This is to certify that the project work entitled "FABRICATION OF VERTICAL AXIS WIND TURBINE"

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In the partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Mechanical Engineering during the year 2017-2021.

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ABSTRACT

Wind energy systems have been utilized for centuries as a source of energy for mankind. At present, wind power is growing at a rate in excess of 35% per annum. Modern wind turbines are categorized as Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT), which are currently being utilized for diversified remote applications. Most of the wind turbines installed today are HAWT largely due to significant investments made by many countries over the last ten years that have overshadowed progress in VAWT technology. Recently there is a resurgence of interests on different types of renewable energy technologies, including VAWT, because of growing environmental concerns and the demand for more enhanced energy security. The basic theoretical advantages of VAWTs are: they are Omni-directional i.e. they accept the wind from any direction; and the generator, gearbox, etc. can be placed on the ground. Today, there are several commercial VAWT models that have guaranteed performance for diversified end-use applications: The paper outlines the current utilization scenario and the future prospects of these environmentally benign energy converters in remote far-flung areas.

✓ To generate the electricity with the help of vertical axis wind turbine The vertical axis wind turbine is used for generate the 10 watts D.C power & LED is turn on.
✓A vertical axis wind turbine does not need to be oriented into the wind the power transition mechanisms can be mounted at ground level for easy access.
✓ For generating the power it is depend on the velocity of the wind. But we assured the vertical axis wind turbine is generate the fixed DC output which is depend on the velocity of the wind.

INTRODUCTION

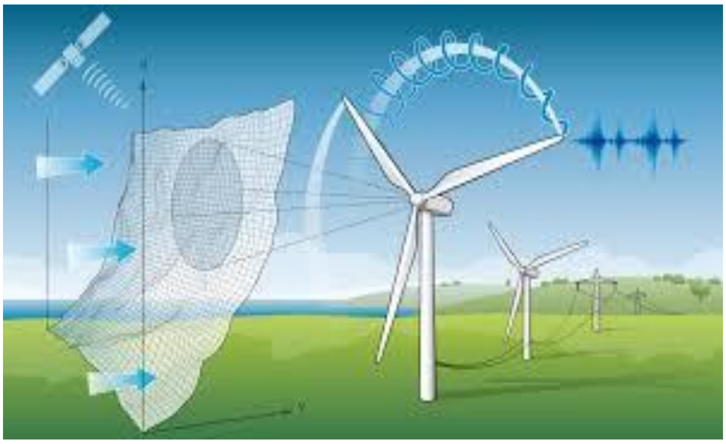
Renewable energy sources have been utilized by mankind since the dawn of civilization through different technologies. Even today, renewable energy sources are playing significant role in the world and supplying more than 14% of the total global energy demand. Over the last three decades (mainly due to oil shocks and environmental concerns regarding greenhouse gas emissions), renewed interest over modern Renewable Energy Technologies (RETS) has opened up the opportunities for applying them in diverse fields for obtaining different energy services. Among all the Renewable Energy Technologies, wind energy is playing a significant role and it has been increasing annually at an average rate of 28% for the last 12 years and, currently it is the world's fastest growing source of energy. According to both the American and European Wind Energy Associations, over 8 billion US$ were invested in wind technology in 2003 and the world's cumulative installation has reached 39,294 MW at the end of 2003.

Commercial wind energy is one of the most economical sources of new electricity available today. Wind turbines can be set quickly and cheaply compared with building new coal-fired generating stations or hydroelectric facilities. Modern wind generating equipment is efficient, highly reliable, and becoming cheaper to purchase. The environmental impact of large wind turbines is negligible compared with an open pit coal mine or a reservoir, and during their operation produce no air pollution. Because of these factors, wind energy is recognized as the world's fastest-growing new energy source. Currently there are two categories of modern wind turbines, namely Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT), which are used mainly for electricity generation and water pumping. Early developments in the 1970-80's demonstrated that though the VAWT are slightly less efficient than their HAWT counterpart, they have some clear advantages. The main advantage is its single moving part (the rotor) and no yaw mechanisms are required, thus simplifying the design configurations significantly performance. Furthermore, almost all of the components requiring maintenance are located at the ground level facilitating the maintenance work appreciably. It is also expected that the maintenance costs will be minimal with VAWTS in comparison to Horizontal Axis Wind Turbines (HAWT) or diesel gensets typically used as a backup or off-grid power source. Under these backdrops, straight-bladed VAWT is expected to be ideal for urban and remote applications in Canada, which has a huge wind energy potential.

1. Wind Energy

The evolution of windmills into wind turbines did not happen overnight and attempts top produce electricity with windmills date back to the beginning of the century. It was Denmark which erected the first batch of steel windmill specially built for generation of electricity. After World War II, the development of wind turbines was totally hampered due to the installation of massive conventional power stations using fossil fuels available at low cost. But the oil crisis of 1973 heralded a definite breakthrough in harnessing wind energy. Many European countries started pursuing the development of wind turbine technology seriously and their development continuing even today the technology involves generation of electricity using turbines, which converts mechanical energy created by the rotation of blades into electrical energy, sometimes the mechanical energy from the mills is directly used for pumping water from well also. The wind power programme in India was started during 1983-84 with the efforts of the Ministry of Non-

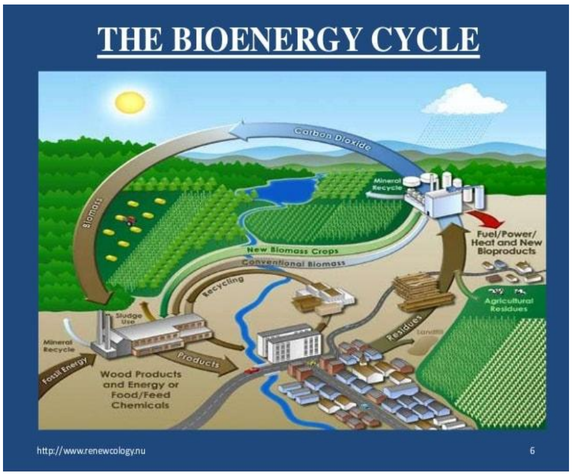
Conventional Energy Sources. In India the total installed capacity from wind mills is 1612 MW, of which, Tamil Nadu has an installed capacity of 858 MW as on 31.03.2002.



Tamil Nadu is endowed with lengthy mountain ranges on its Western side with three prominent passes in its length. These are with wind-potentials: (1) Pal hat Pass in Coimbatore District-1200 MW, (2) Shengottah Pass in Tirunelveli District-500MW and (3) Aralvoymozhi Pass in Kanyakumari District- 300 MW (Total potential-2000MW). The mountainous areas close to Cambium Valley are observed to be having high potential and, though coastal areas, central plains and hilly areas have been observed unsuitable for win power project Rameshwaram is found suitable.

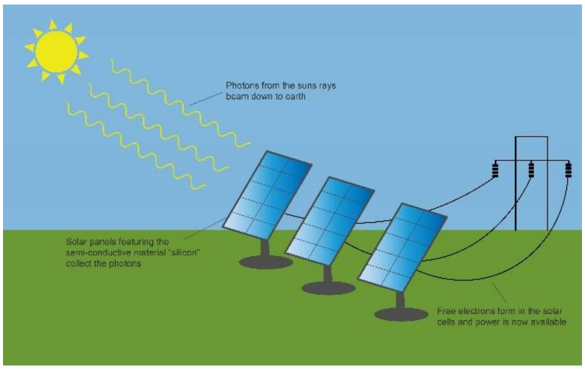
2.Bio Energy

Biomass is yet another important source of energy with potential to generate power to the extent of more than 50% of the country's requirements. India is predominantly an agricultural economy, with huge quantity of biomass available in the form of husk, straw, shells of coconuts wild bushes etc



3.Solar Energy

Solar Power was once considered, like nuclear power, too cheap to meter' but this proved illusory because of the high cost of photovoltaic cells and due limited demand. Experts however believe that with mass production and improvement in technology, the unit price would drop and this would make it attractive for the consumers in relation to thermal or hydel power. The Solar Photo Voltaic (SPV) technology which enables the direct conversion of sun light into electricity can be used to run pumps, lights, refrigerators, TV sets, etc., and it has several distinct advantages, since it does not remote and isolated areas which are not served by conventional electricity making use of ample sunshine available in India, for nearly 300 days in a year. A Solar Thermal Device, on the other hand captures and transfers the heat energy available in solar radiation. The energy generated can be use for thermal applications in different temperature ranges. The heat can be used directly or further converted into mechanical or electrical energy.

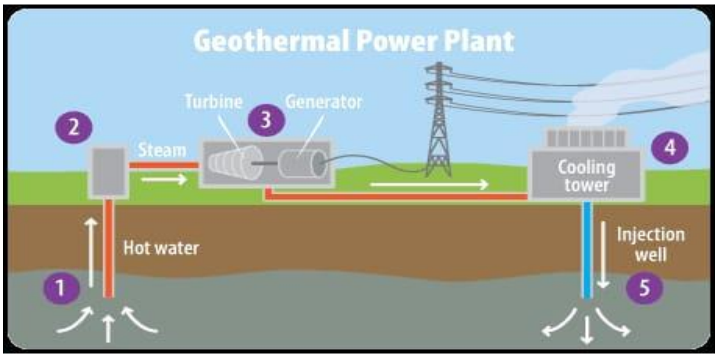


4.Other Sources

The other sources of renewable energy are geothermal, ocean, hydrogen and fuel cells. These have immense energy potential, though tapping this potential for power generation and other applications calls for development of suitable technologies.

(i). Geo-Thermal Energy

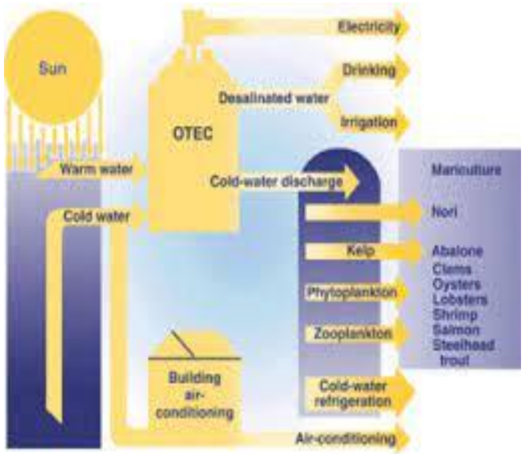
Geo-Thermal energy is a renewable heat energy from underneath the carth. Heat is brought to near surface by thermal conduction and by intrusion into the earth's crust. It can be utilised for power generation and direct heat applications. Potential sites for geo-thermal power generation have been identified mainly in central and northern regions of the country.



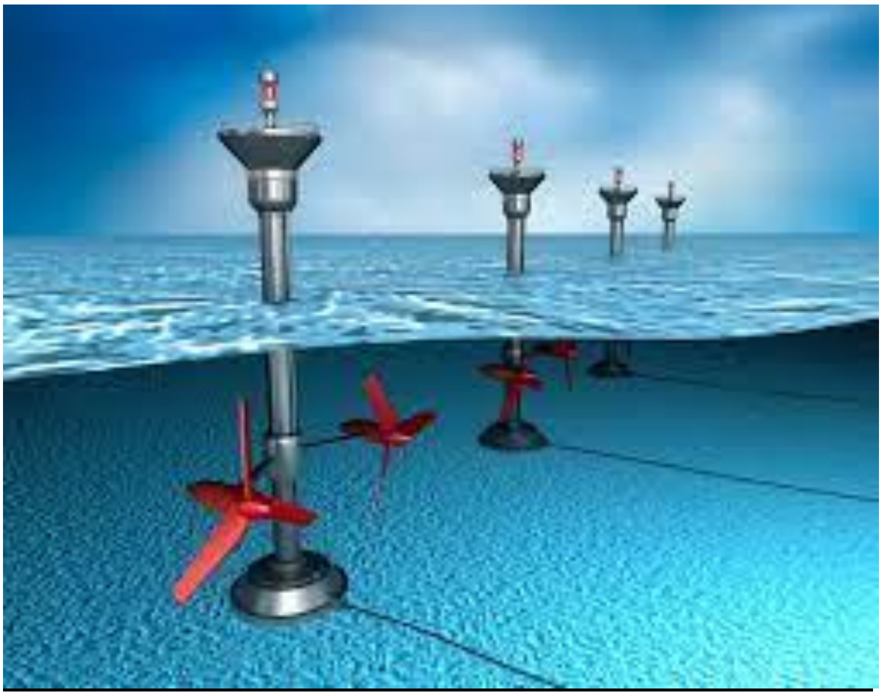
(ii) Ocean thermal and Tidal energy

The vast potential of energy of the seas and oceans which cover about three fourth of our Planet, can make a significant contribution to meet the energy needs. Ocean contains energy in the Form of temperature gradients, waves and tides and ocean current, which can be used to Generate electricity in an environment-friendly manner. Technologies to harness tidal power Wave power and ocean thermal energy are being developed, to make it commercially viable.

OCEAN THERMAL

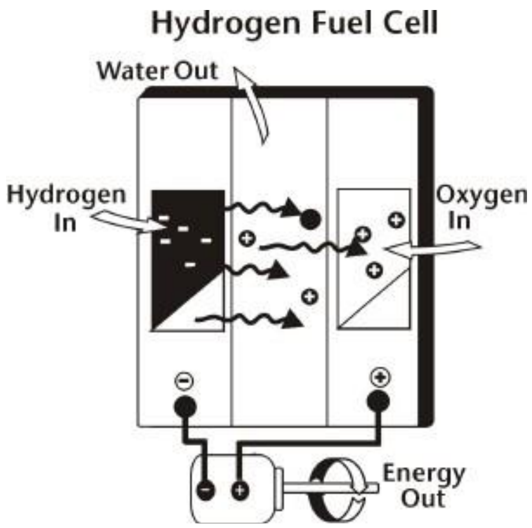


TIDAL ENERGY



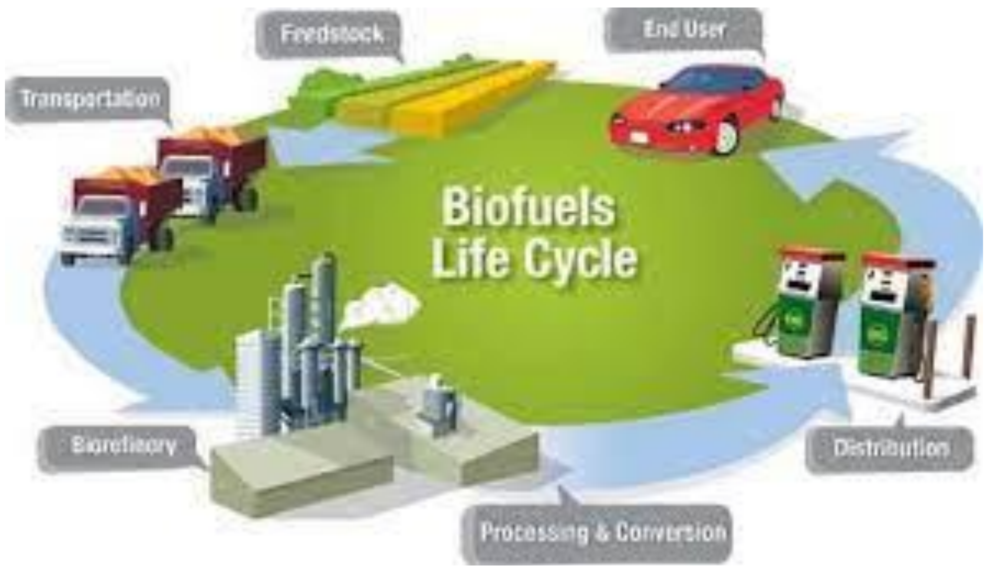
(iii) Hydrogen and Fuel Cells

In both Hydrogen and Fuel Cells electricity is produced through an electro-chemical reaction between hydrogen and oxygen gases. The fuel cells are efficient, compact and reliable for automotive applications. Hydrogen gas is the primary fuel for fuel cells also. Hydrogen can be produced from the electrolysis of water using solar energy. It can also be extracted from sewage gas, natural gas, naphtha or biogas. Fuel cells can be very widely used once they become commercially viable.



(iv) Bio fuels

In view of worldwide demand for energy and concern for environmental safety there is need to search for alternatives to petrol and diesel for use I automobiles. The Government of India has now permitted the use of 5% ethanol blended petrol. Tamil Nadu is one of the nine States in the counter where this programme will commence from January 2003. Ethanol produced from molasses/ cane juice, when used as fuel will reduce the dependence on crude oil and help contain pollution. Further, technology is also being developed to convert different vegetable oils especially non-edible oils as bio-diesel for use in the transport sector. They are however, in R & D stag ONLY



2.COMPARISION OF WIND TURBINES

1-VERTICAL AXIS WIND TURBINE

Advantages of vertical wind turbines:

Vertical wind turbines are easier to maintain because most of their moving parts are located near the ground. This is due to the vertical wind turbine's shape. The air foils or rotor blades are connected by arms to a shaft that sits on a bearing and drives a generator below, usually by first connecting to a gearbox. As the rotor blades are vertical, a yaw device is not needed, reducing the need for this bearing and its cost. Vertical wind turbines have a higher air foil pitch angle, giving improved aerodynamics while decreasing drag at low and high pressures.

Disadvantages of vertical wind turbines

There may be a height limitation to how tall a vertical wind turbine can be built and how much swept area it can have. Most VAWTS need to be installed on a relatively flat piece of land and some sites could be too steep for them while available to HAWTS VAWTs that use guy wires to hold it in place create serious problems for the bottom bearing as all the weight of the rotor is on it and the guy wires Horizontal axis wind turbine (HAWT)

2.HORIZONTAL AXIS WIND TURBINE

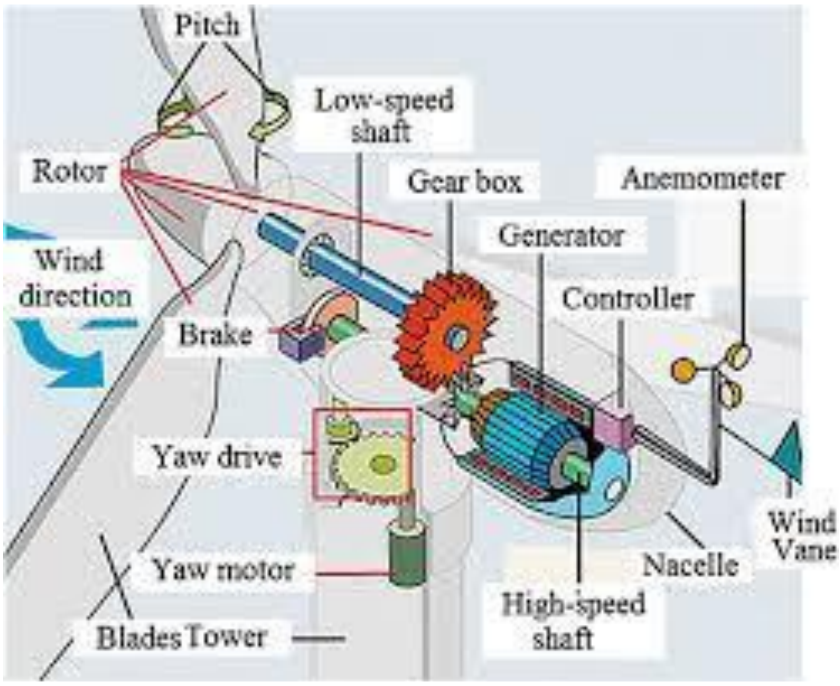
Advantages of horizontal axis wind turbine

In the horizontal wind turbine, the blades are to the side of the turbine's centre of gravity, helping stability. They have the ability to wing warp, which gives the turbine blades the best angle of attack. Allowing the angle of attack to be remotely adjusted gives greater control, so the turbine collects the maximum amount of wind energy for the time of day and season. The blades also have the ability to pitch the rotor blades in a storm, to minimize damage. Tall towers allow access to stronger wind in sites with wind sheer. In some wind sheer sites, every ten meters up, the wind speed can increase by 20% and the power output by 34%. Tall towers also allow placement on uneven land or in offshore locations. These can be placed in forests above the treeline. Most are self-starting. The horizontal wind turbines can be cheaper because of higher production volume, larger sizes and, in general, higher capacity factors and efficiencies, increase downward thrust in wind gusts. Solving this problem requires a superstructure to hold in place the top bearing that also can share the weight of the rotor.

Disadvantages of horizontal wind turbines

HAWTS have difficulty operating in near ground, turbulent winds because their yaw and blade bearings need smoother, more laminar wind flows. The tall towers and long blades (up to 1801 feet long) are difficult to transport on sea and land. Transportation can now account for 20% of equipment costs. Tall HAWTs are difficult to install, needing very tall and expensive cranes and skilled operators. The supply of HAWTs is less than demand and between 2004 and 2006, turbine prices increased up to 60%.

Inside Wind Turbine



Wind Turbine Glossary

Anemometer: Measures the wind speed and transmits wind speed data to the controller. Blades: Most turbines have either two or three blades. Wind blowing over the blades causes the

Blades: Most turbines have either two or three blades. Wind blowing over the blades causes the blades to "lift" and rotate.

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

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 65 mph. Turbines cannot operate at wind speeds above about 65 mph because their generators could overheat.

Gear box: Gears connect the low-speed shaft to the high-speed shaft and increase the rotational speeds from about 30 to 60 rotations per minute (rpm) to about 1200 to 1500 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 exploring "direct-drive" generators that operate at lower rotational speeds and don't need gear boxes

Generator: Usually an off-the-shelf induction generator that produces 60-cycle AC electricity.

High-speed shaft: Drives the generator.

Low-speed shaft: The rotor turns the low-speed shaft at about 30 to 60 rotations per minute.

Nacelle: The rotor attaches to the nacelle, which sits atop the tower and includes the gear box, low and high-speed shafts, generator, controller, and brake. A cover protects the components inside the nacelle. Some nacelles are large enough for a technician to stand inside while working.

Pitch: Blades are turned, or pitched, out of the wind to keep the rotor from turning in winds that are too high or too low to produce electricity.

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

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

Wind direction: This is an “opwind” turbino, so-called because it operates facing into the wind. Other turbines are designed to run “downwind”, facing away from the wind.

Wind vane: Measures wind direction and communicates with the yaw drive to orient the turbine properly with respect to the wind.

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.

Yaw motor: Powers the yaw drive.

The benefits of wind energy Wind energy is an ideal renewable energy because: It is a pollution free, infinitely sustainable form of energy. It doesn’t require fuel. It doesn’t create greenhouse gasses. It doesn’t produce toxic or radioactive waste.

Wind Energy & the Environment

Wind is a clean fuel; wind power plants (also called wind farms) produce no air or water pollution because no fuel is burned to generate electricity. Drawbacks of Wind Machines The most serious environmental drawbacks to wind machines may be their negative effect on wild bird populations and the visual impact on the landscape. To some, the glistening blades of windmills on the horizon are an eyesore; to others, they’re a beautiful alternative to conventional power plants.

3.TYPES OF VERTICAL AXIS WIND TURINE

Wind energy systems have been used for centuries as a source of energy for mankind. Windmills were deployed for pumping water in the ancient China several centuries BC. It is reported that vertical-axis windmills equipped with woven reed sails were used for grinding grains in the Middle East and Persia in 200-100 BC. [5]

There have been many designs of vertical axis windmills over the centuries and currently the vertical axis machines can be broadly divided into three basic types:

1) Savonius type
2) Darrieus type
3) H-Rotor type

Brief descriptions of these VAWT types are given below.

Savonius Wind Turbine

The Savonius type VAWT was invented by a Finnish engineer S. J. Savonius in 1922. [2] It is basically a drag force driven wind turbine with two cups or half drums fixed to a central shaft in opposing directions. Each cup/drum catches the wind and so turns the shaft, bringing the opposing cup/drum into the flow of the wind. This cup drum then repeats the process, so causing the shaft to rotate further, so completing a full rotation. This process continues all the time the wind blows and the turning of the shaft is used to drive a pump or a small generator. These types of windmills are also commonly utilized for wind speed instruments. Modem Savonius machines have evolved into fluted bladed devices, which have a higher efficiency and less pulsation than the older twin cup/drum machines.

Darrieus Wind Turbines

The Darrieus Vertical Axis Wind Turbine was invented by a French engineer George Jeans Mary Darrieus. He submitted his patent in 1931 at US, which included both the eggbeater and Straight-bladed VAWT. [1] The Darrieus type VAWTs are basically lift force driven wind turbines. The turbine consists of two or more aerofoil shaped blades, which are attached to a rotating vertical shaft. The wind blowing over the aerofoil contours of the blade creates acrodynamic lift and actually pulls the blades along.

The troposkien shape eggbeater type Darrius VAWT, which eliminates or minimizes the bending stress in the blades, has been commercially deployed in California of the USA. At present, the largest eggbeater type Darrius VAWT is a 4 MW wind turbine called EOLE (shown in Figure (3)), which is located at Cap-Chat, Quebec, Canada. The height of the EOLE is nearly 100 m and the diameter is 60 m.

In the small-scale wind turbine market, the simple straight-bladed Darrieus VAWT, often called giromill or cyclo-turbine, is more attractive for its simple blade design. At present, several companies are marketing this particular type of VAWT for remote electrification, water pumping and ventilation.

H-Rotors

H-Rotors were developed in the UK through the research carried out during the 1970's – 1980's when it was established that the elaborate mechanisms used to feather the straight-bladed. Darrieus VAWT blades were unnecessary [2] It was found out that the drag/stall effect created by a blade leaving the wind flow would limit the speed that the opposing blade (in the wind flow) could propel the whole blade configuration forward. The fixed straight bladed VAWT or H-Rotor was therefore self regulating in all wind speeds reaching its optimal rotational speed, early after its cut-in wind speed

Future Prospects of VAWT for Remote Applications

From the past experiences, it is evident that wind turbines can compete with conventional sources in niche markets, and lower costs make them affordable options in increasingly large. Markets. Environmentally benign VAWT can be utilized for array of applications, including:

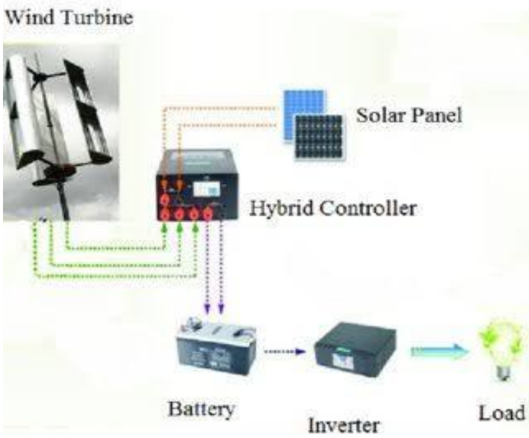
(i) Electricity generation;
(ii) Pumping water:
(iii) Purifying and/or desalinating water by reverse osmosis;
(iv) Heating and cooling using vapour compression heat pumps;
(v) Mixing and acrating water bodies.
(vi) And heating water by fluid turbulence.

In general, VAWT can sensibly be used in any area with sufficient wind, either as a stand alone system to supply individual households and works with electricity and heat, or for the operation of freestanding technical installations. If a network connection is available, the energy can be fed in, thereby contributing to a reduction in electricity costs. In order to maximize the security of the energy supply, different types of VAWT can be supplemented by a photovoltaic system or a diesel generator in a quick and uncomplicated fashion. Through the combination of several VAWT with other renewable energy sources and a backup system, local electrical networks can be created for the energy supply of small settlements and remote locations.

Enabling Applications in The Off-grid Areas in Developing Countries

One of the potential markets for VAWT is remote electrification in the developing countries. According to a World Bank report-about 2 billion people in the developing countries are not connected with the electricity grid. Straight-bladed VAWTs are simple in their design and can easily be manufactured in different developing countries with available materials like wood. Some of the promising
VAWT applications suitable for developing countries are outlined in the subsequent headings.

Household Electrification by Wind Home System: Small Wind Home System (WHS) is an emerging technology and already become commercially viable for certain countries like China and Mongolia. For daily loads as small as one kilowatt-hour per day a wind turbine will be less of China providing expensive than diesels, grid extension, or photovoltaic for virtually any wind resource above 4 m/s For a 10 kW wind turbine a wind resource of only 3.5 m/s will usually make wind the least cost option [1] About 150,000 WHS are currently spinning in the Inner Mongolia of one-third of the non-grid connected households in this region. It has become a glaring example of WHS which has enable Inner Mongolian off-grid residents to adopt modern luxury items like TV, satellite receiver, washing machine, VCD etc. The technical problems faced in the fields were mainly due to batteries rather then micro wind turbines of WHS. Apart from China, WHS can be found in several other countries like Mexico, Argentina, Chile, Morocco and Indonesia. As there are few (two to three) moving parts, WHS does not require much maintenance and can be installed in rugged environment as well.

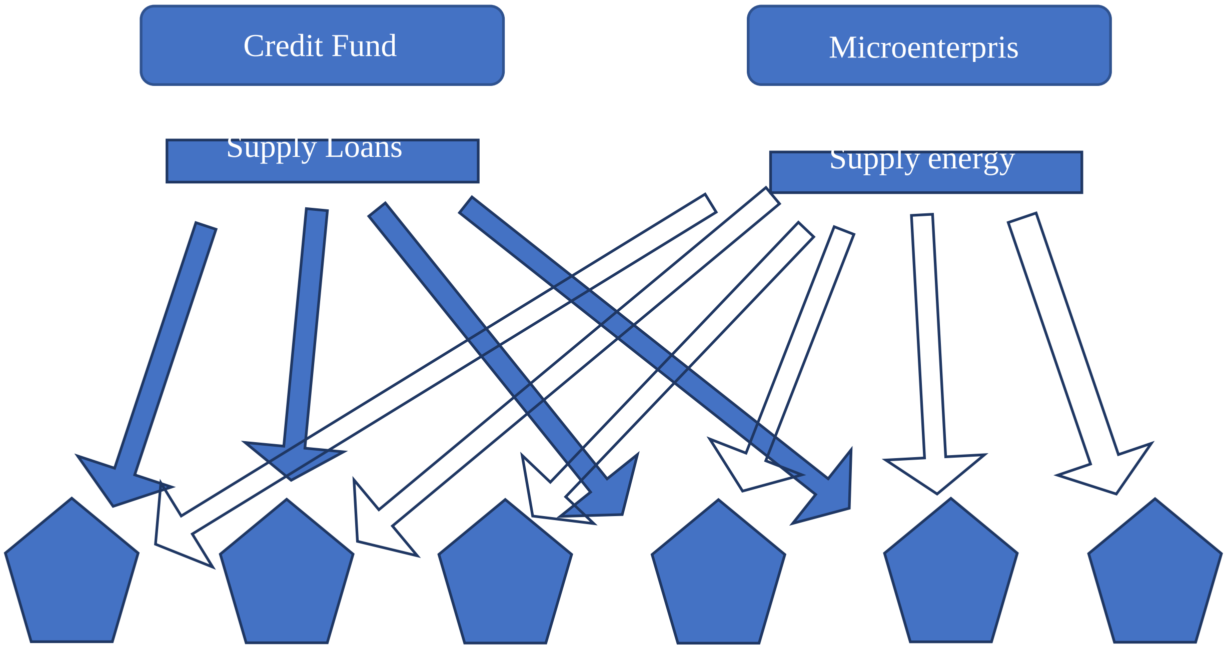


Rural Development Center:

Poverty alleviation in rural areas can be accomplished and the critical role of access to adequate level of energy services, Information Technology (IT) and modern communication facilities in it demonstrated. Solving the unemployment and underemployment problems through skills upgrading, and creating better employment opportunities through these as well as generating income through appropriate village level small industrial enterprises utilizing local renewable energy sources like wind will empower the people for self-help. The production, implementation, operation and maintenance of VAWT will also result in job growth in the village context, preventing VAWT

Micro enterprise Electrification:

Micro enterprises are small and informal business entities (not included in the national tax base) contributing significantly in the national economy with large number of people engaged in this sector. As micro enterprises are small business ventures, their demand is quite low and often. They are home-based. Micro enterprises produce or sell many things, from raw manure to cellular phone call service. Definitely the provision for lighting will extend their working hours in the evening, which in turn increase income as it has been observed in the newly electrified villages in the country. It is expected that if there is provision of electricity through renewable energy technologies (RETs) like VAWT, many diversified types of micro enterprises will emerge. In the coastal regions of the developing countries, scarcity of ice is a big issue, if ice-making plants can be powered with wind energy, micro enterprises will emerge with different fish products.



Health clinic Electrification Developing countries are facing daunting challenge to provide basic health care to the common people. Especially the condition of the rural health clinics are pathetic. These clinics are facing scarcity of all the essential elements including lack of doctors, nurses, medicines, beds, drinking water, sanitation and electricity Health and energy we interdependent factors, which largely determine the progress of rural development in this connection, VAWT can play significant role to providing electricity for some of the basic amenities like refrigerators for vaccines and life saving medicines.

The most essential demand in a health centre is electricity for lighting and refrigeration. incorporating other appliances like medical instruments, fan, communication appliances, water supply, TV, VCR, cassette player, radio etc. will enhance the quality of service which will not only change the face of the health clinic, but also will catalyse for retention of doctors and nurses in the far-flung rural areas. Electrification in an off-grid rural health clinic can be utilized for social services along with the core objective of providing health care, like for health education, family planning advice, evening education, community gathering etc. Income generating services like battery-charging station, Video House etc can be operated for extra.

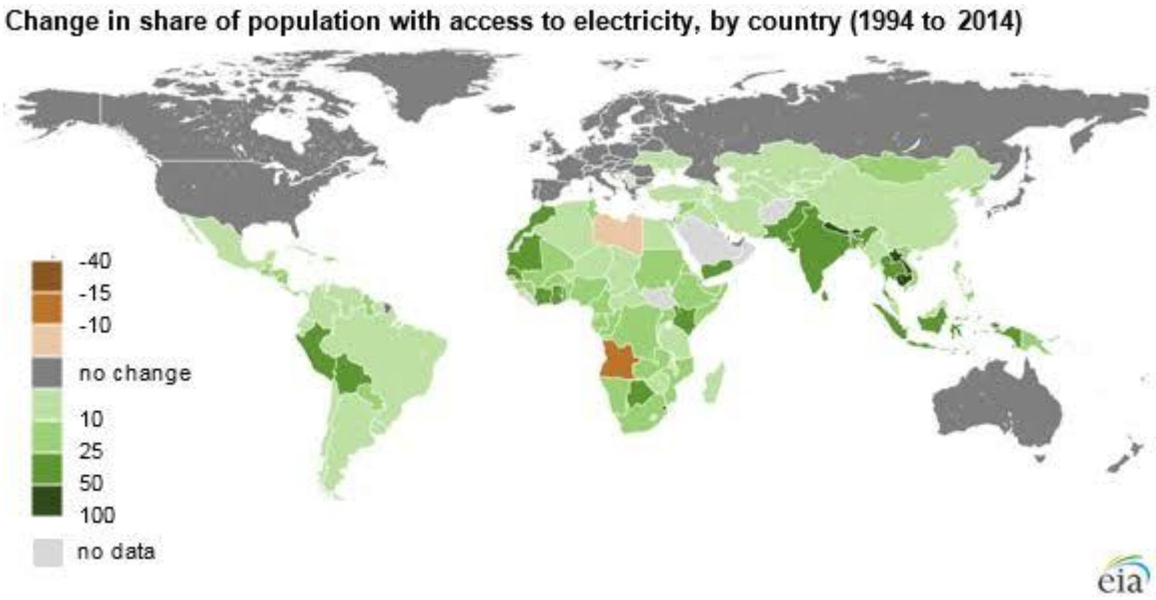
School Electrification:

Education sector in the developing countries are also battered with many difficulties. Most of the rural schools are lacking basic amenities, including electricity, drinking water, sanitation, communication and ete Dropout rate from the primary schools are also alarming Some of these lacking amenities can be provided by wind energy reliably, which can significantly improve the quality of education in the neglected rural off-grid areas.

Like rural health clinics, electrification in an off-grid school can be utilized for social service along with the core objective of providing education, like for health education, family planning advice, evening education, community gathering etc. Income generating services like battery charging station, can be operated for extra income which will ensure money for maintenance and recurring cost (like battery or lamp replacements). This kind of integrated approach will also introduce wind energy technologies into rural areas.

Electrification of Remote Communities in the Developed Countries

At present, there are many remote communities in the developed countries in the Europe and Norrth America that are not connected with the electricity grid. These remote off-grid areas are ideal markets for renewable energy technologics like wind. At present, diesel or propane driven gensets are used for supplying electricity and heat in these locations that are very expensive. In particular, the transport of the fuel to remote areas is costly and labor intensive Solar Photovoltaic installations, on the other hand, are reliable, but they provide very little output in the winter in northern countries like Canada



Commercial VAWT Products for Different Applications

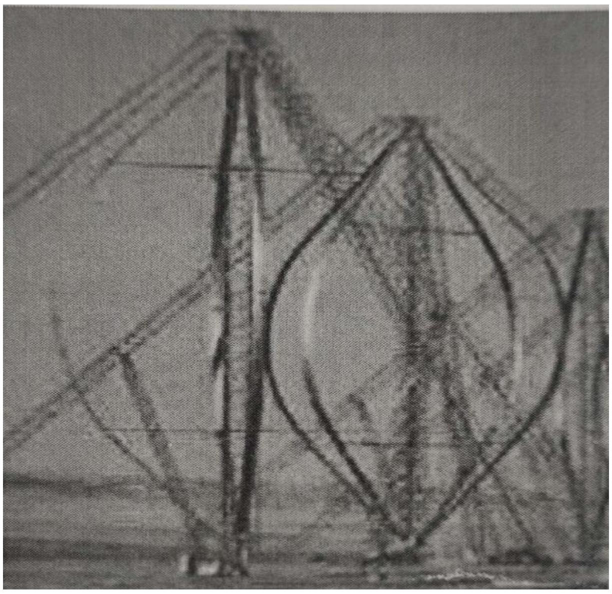
Recently there is resurgence of interests on different types of renewable energy technologies, including VAWT, because of growing environmental concerns and energy security. Today, there are several commercial VAWT models with guaranteed performance for different purposes. Salient features of some of the notable VAWT products are presented below.

Sol wind SW 10/4800 series VAWT are designed to start producing power at a wind speed of only 1.5 m/s and produce approximately 4.8 kW at wind speeds of 10 meters per second. Sol wind Ltd, the developer of the turbine series, claims that they are quiet in operation and due to the ingenious design, the blades do not cause coning noise that occurs with conventional turbines when the blades pass close to the mast

The blades of the SW 10/4800 series wind turbine's are always at the same set distance from the mast and are made from composite fiberglass and lightweight alluminum, making them easy to handle. At the present 'Off the shelf generators are being used with the SW10/4800 series Sol wind Ltd. Is currently designing a magnetic levitation alternator, featuring only one moving part. This keeps the wearing components to a minimum, and so prolongs the longevity of the wind turbine.

Chinook

Developed by Canada based sustainable energy technologies, the Chinook 2000 wind turbine uses a four-bladed, vertical axis rotor. [10] The rated power output of each turbine is 250kW. The design does not require any complicated yaw mechanism or blade pitch control. The blades are supported by a lattice tower constructed of standard structural steel angles. The steel angles are hot-dip galvanized to ensure long life with superior resistance to corrosion Rated wind velocity of the Chinook 2000 is 17 m/s and the cut-in velocity is 4.5 m/s.



Ropatec Wind Rotor

The Ropatec AG is an Italy based company which had developed wind rotor which was conceived for the purpose of providing decentralized power production.[6] available in 500 W, 3000 W and 6000 W performance classes.

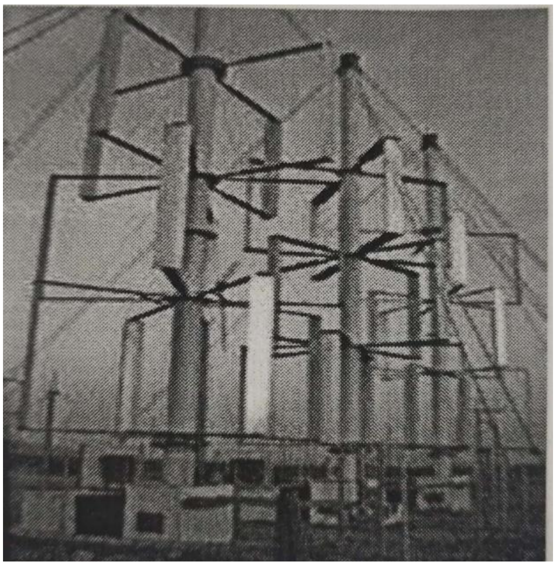
The wind rotor is an innovative and patented high-speed vertical axis wind turbine. Due to the optimal shape of the turbine, the wind rotor activates automatically at wind speeds of 2-3 m/s in any position, even under a torque load.

Wind Side Turbine

Wind side Wind Turbine, developed in 1979 by Risto Joutsiniemi, rotates by two spiral formed vanes. [14] The Turbines have been made to order since 1982, and so far they have been delivered all over the world. Measurements made on the circumstances of the Archipelago of Finland proved that WS-Turbine produced 50% more electricity a year than traditional propellers with the same swept area. The special WS Vane construction makes the turbine able to utilize winds of 1-3 m/s. Developer of the wind side turbine claims that they are totally soundless due to the spiral shape and the fact that the rotation speed does not exceed the wind speed.

VAWTEX

Recently, Ove Arup, an Australia-based company, has developed a wind turbine able to rival electricity as a power source for ventilation. [3] The cost of installing the Vertical Axis Wind Turbine Extractor (Vawtex) is similar to that for conventional ventilation. But it is much less noisy, has no fuel cost and causes no pollution. In some conditions, a building can cool and ventilate itself.
Hot air rises in a room and, as it leavesat the top, drawsin cool air at the bottom



VAWTEX is basically rotating on a vertical axis and driving a fan for ventilation. Vawtex turbines have been installed at Africa University on the Mozambique border and at the Mediterranean Shipping company’s Zimbabwean head quarter. Eight of these are being installed at the Center for Sustainable Construction in Belgium. Anup believes the international market for such devices could easily number thousands per year.

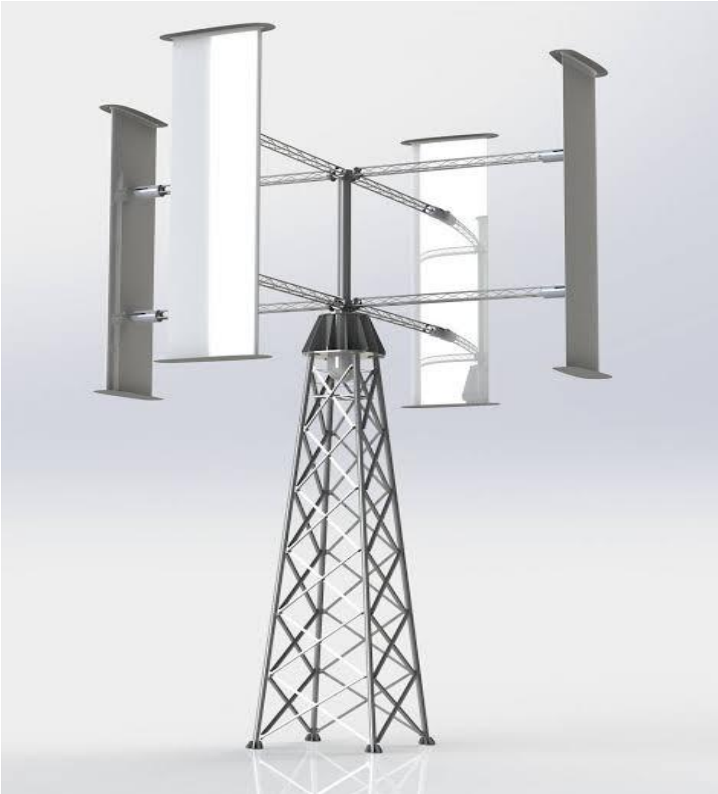
Wind Star VAWT

Wind Harvest is a USA based company, which is developing VAWT since 1975, It has field tested over ten versions of its patented windstar turbines. [12] The company is focusing on commercializing its 15-meter tall, 500kW six-turbine windstar 1400 array for installation beneath tall turbines in high wind resource wind farms. The developer claims that windstar turbines are rugged, easy-to-install and maintain, quiet, low profile, bird-friendly and promise to be among the least expensive per kW machines available when mass production begins.

In 2003 the Company will be installing a 5-turbine array of windstar 1400's in Palm Springs, California. This project will demonstrate the scalability of the proven windstar 530 turbine to this more efficient size. In a 7 m/s wind speed site, this 5 turbine (400 kW) array will produce over 700,000 kWh of energy per year. There is enough energy to meet the needs of over 700 average American households,

Wind Tec

Developed by the German company Neuhauser, wind Tec four commercial models with the capacity of 1 kW, 10 kW, 40 kW and 80 kW. Wind Tec turbines are basically three bladed H-rotor type VAWT. Neuhauser claims their VAWT models to be maintenance free and less noisy.



4. MODEL DESIGNS

EUROWIND WIND TURBINE DESIGN

The concept aims at utilizing an innovative and unique adaptation which allows the turbine to be mounted on industrial chimneys and other similar tall structures without inhibiting their normal use.

The rotor blade design features an asymmetrical airfoil section selected for its high lift and low drag characteristics and is mounted to its supporting cross Arm at a critical angle to optimize its performance. The blades are not twisted and their edges are parallel, unlike the twisted apering blades of borizontal wind turhines. The simple, regular shape of the blade coupled with the lower blade stresses experienced by vertical axis turbines allow the blades to be produced mechanically in sections by extrusion or pultrusion.

A directly coupled slow speed alternator eliminates the need for separate generator sets, gearboxes and clutches.

Figure 17. Eurowind wind mill designs

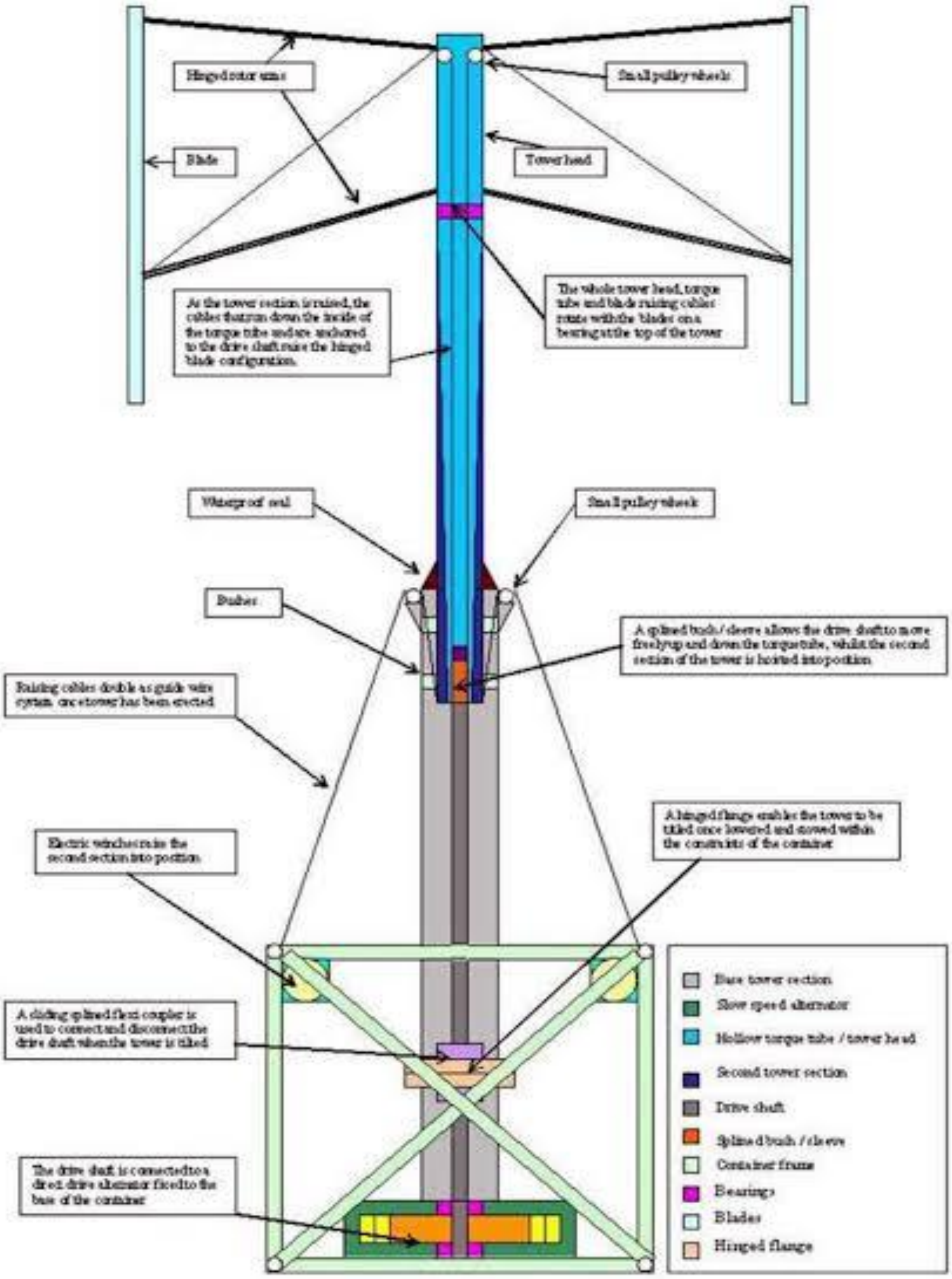


Figure 18. Large Eurowind modular vertical wind mill concept.

The main features of the Eurowind turbines designs are:

1.The turbine is self starting

2.Vertical axis turbines are omni directional and do not require pointing in the direction of the wind.

3.The lower blade rotational speeds imply lower

4. Perceived as being more aesthetically pleasing

5.The increased blade configuration solidity and torque assists the machine in self starting. 6.Elimination the risk of the blades reaching equilibrium during start-up rotation by using 3 blades more.

7.Reduced cyclic loading and power pulsation and fluctuation by using more than 2 blades 8. Easy access to all mechanical and structural elements of the machine.

9.A direct drive, permanent magnet generator is used and there are no gear boxes with the machine having only one moving part.

These machines have been adapted for use in the marine environment such as at harbors, on barges or oil rigs.

Figure 19. Vertical axis wind turbine in a marine environment.

VENTURI WIND TURBINES

INTRODUCTION

In horizontal axis wind turbines the blades rotate and describe a circular surface. The rotor extracts the energy from the air flowing through this rotor surface and has a theoretical maximum efficiency of 59 according to Betz's law.Venturi effect turbines create a wind flow pattern that converges first, like rapids in a river. Within the sphere, a low pressure area is generated which attracts the air in front of the rotor towards the sphere. After the rotor has absorbed energy from the air, the energy poor air is swung radically outwards through the Venturi planes and is carried away by the surrounding airflow.

The air flowing through the turbine and the air surrounding the rotor are used more effectively, resulting into the efficiency of the Venturi turbine being higher than the efficiency of conventional wind turbines.

DESCRIPTION

Venturi turbines create a wind flow pattern that converges first like rapids in a river. This is induced by the unique aerodynamic Venturi characteristics. Therefore the turbine experiences a higher wind speed than other wind turbines would observe. This enables the Venturi turbine to generate electricity at very low wind speeds. Little gusts can be utilized for electricity generation where conventional turbines would use these to start rotating.

TURBY WIND TURBINE DESIGN

DESCRIPTION

This design is advocated for construction in an urban environment. The vibrations, high noise levels and the low efficiency characterizing the Darrieus turbine are caused by the flow of air around the blade. The angle of attack of the apparent wind is kept below 20 degrees. The rotational speed of the turbine is for all parts of the blades is constant. In a Darrieus turbine the distance between blade and shaft varies, accordingly, the blade speed also varies. On the blade parts near the shaft the self generated head wind is low, whereas at the curve of the blade, at the greatest distance from the shaft, its reaches a maximum. The low blade speed close to the shaft results in an angle of attack of the apparent wind that over large parts of a revolution exceeds the allowable limit with stall as a consequence.

There are moments of laminar flow and moments of turbulence resulting in intermittent lift power and drag on the blades and this causes vibrations. The contribution of these blade parts to the driving force of the turbine is negligible. In the curve of the blade, the speed of the headwind is high. The angle of attack of the apparent wind is small, with the consequence that the component of the lift force in the direction of the rotation also nears zero. These parts of the blades do not contribute to the driving force. However given their high speed they do generate a high level of noise. This explains why the Darrieus turbine vibrates heavily, makes a lot of noise and has a low efficiency.

The blades of the Turby concept are designed with a fixed distance to the vertical shaft. To reduce the inevitable vibrations due to the change of the angle of attack between +20 and -20 degrees resulting in a change of the mechanical stress in the blade two times per revolution, its developers chose an odd number of 3 blades of a helical shape, making all changes occur gradually.

Figure23. Turby triple blade wind turbine design on top of a building

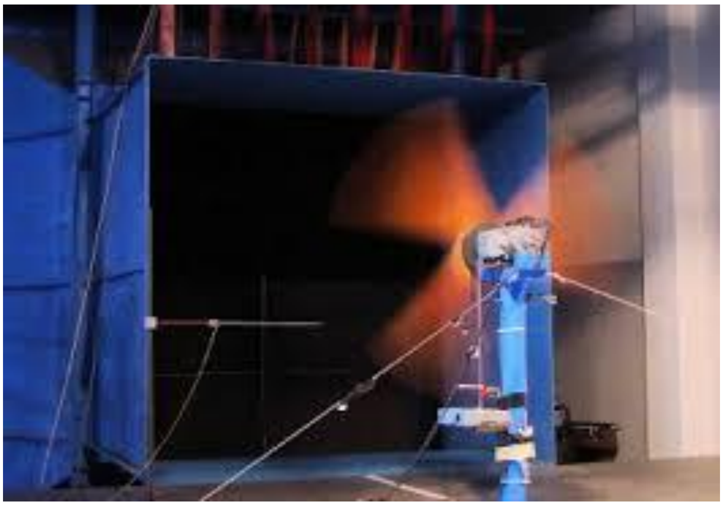


Figure 24. Wind tunnel testing of Turby wind turbine design

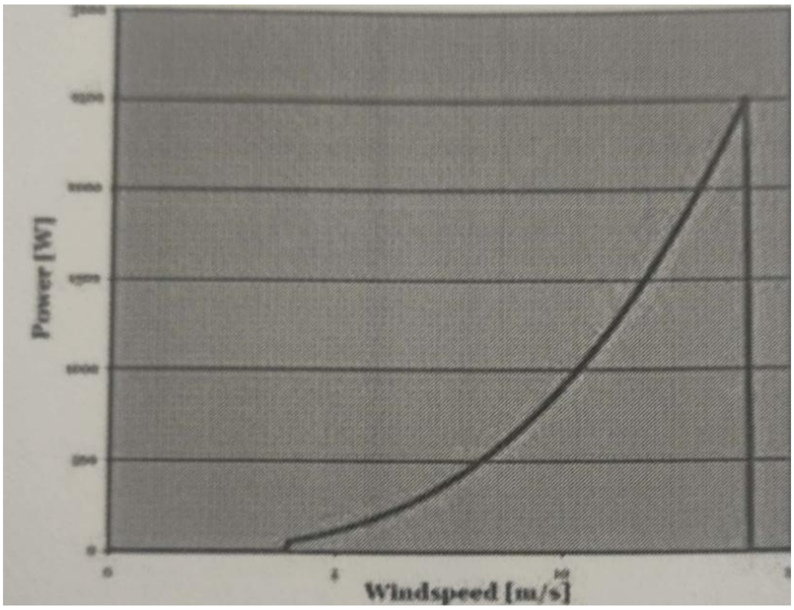


Figure25. Turby turbine power curve

POLES DESIGNS

Two different mast types depending on the required height can be considered. Up to 6 m height, spring supported masts. From 7.5 m and higher freestanding tubular masts are I sed. Both types could be either made of stainless steel or galvanized steel.

HELICAL WIND TURBINES

DESCRIPTION

The Windside Wind Turbine developed in Finland is a vertical wind turbine whose design is based on sailing engineering principles. The turbine rotor is rotated by two spiral formed vanes. It is intended for both inland and marine environments.

Designs are for use in wind speeds of up to 60 m/s.

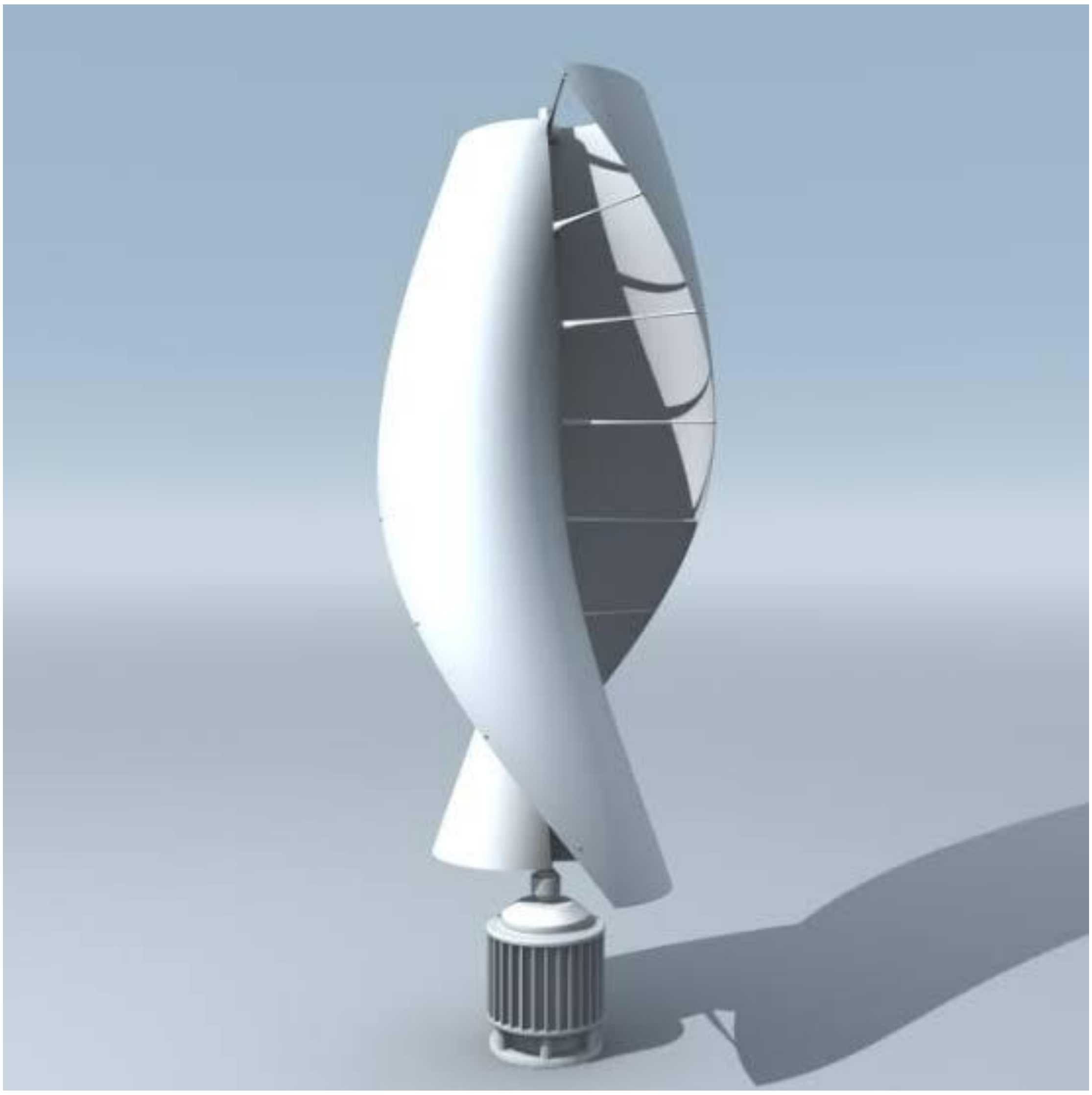


Figure 26, Helical wind turbine with generator at its base.

Figure 27. Manufacturing of helical wind blades.

These designs for battery charging are a unique and ecological solution for energy production in harsh environments under cold or hot conditions, violent storms, as well as low wind speeds.

These turbines generate almost no noise and are safe to use in population centers, public spaces, parks, wildlife parks and on top of buildings. They are also aesthetically appealing and in many cases have been used to combine art and functionality.

QUIETREVOLUTION QR5 WIND TURBINE

DESCRIPTION

The QRS is a wind turbine designed in response to increasing demand for **w**ind turbines that work well in the urban environment, where wind speeds are **l**ower and wind directions change frequently.

It possesses a sophisticated control system that takes advantage of gusty winds with a predictive controller that learns about the site's wind conditions over time to further improve the amount of energy generated. If the control system determines that sufficient wind exists for operation, the turbine is actively spun up to operating conditions at which point it enters the lift mode and starts extrracting energy from the wind. It will self-maintain in a steady wind of 4.0-4.5m/s. The turbine will brake in high wind events of speeds over 12 m/s and shut down at continuous speeds over 16 m/s.

It is constructed using a light and durable carbon fiber structure and is rated at 6kW and has an expected output of 9,600 kWhr per year at an average annual wind speed of 5.9 m/s. This would provide 10 percent of the energy for a 600 m^2 office building. Its design life is 25 years.

Figure 28. Quiet revolution QR5 wind turbine

A direct drive in line electrical generator has auto shut down features and peak power tracking. It is directly incorporated into the mast. The helical design of the blades captures turbulent winds and eliminates vibration.

As a safety feature, it is designed with a high tensile wire running through all its component parts, to minimize the risk of any broken parts being flung from the structure in the unlikely event of structural failure.

AEROGENERATOR VERTICAL OFFSHORE WIND TURBINE CONCEPT

The 144 meters high and V-shaped structure would be mounted offshore and capable of generating up to 9 MW of electricity, roughly three times as much power as a conventional turbine of equivalent size.

Instead of being mounted on a tower with egg whisk blades that bow outwards and meet at the top like a typical Darrieus design, it has two arms jutting out from its base to form a V-shape, with rigid sails mounted along their length at intervals. As the wind passes over these they act like airfoils, generating lift which turns the structure as a whole at roughly 3 rpm.

No matter how high the two main structures are made it is relatively simple to make them with a center of gravity at its bottom. Because of this the technology lends itself to large engineering projects, which is what is needed with wind power.

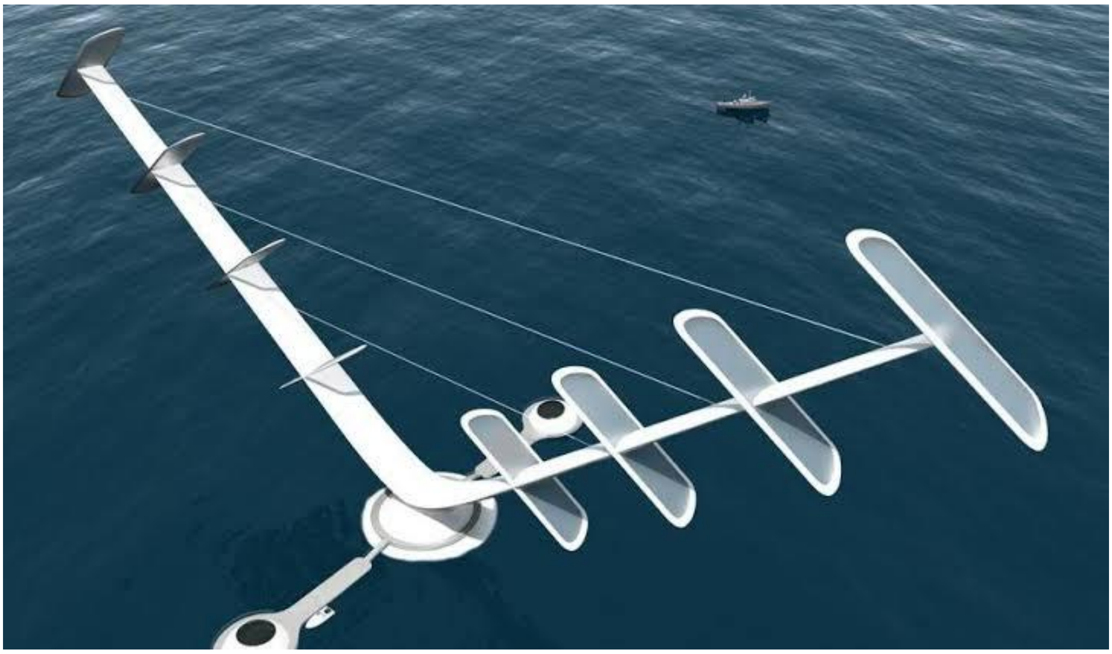


Figure 30. Offshore vertical Acrogenerator concept. Photo: Grimshaw Architects

WINDSPIRE WIND TURBINE

The Windspire design is 30 feet tall and 2 feet in radius. It is equipped with a high efficiency generator, integrated inverter, hinged monopole, and wireless performance monitor.

The slender vertical axis design allows it to operate with a low tip speed ratio, with the edges of the rotor spinning at 2-3 times the speed of the wind, making it virtually silent.

ROTOR

The rotor is a low speed gyromill or a straight-bladed Darrieus design optimized for energy capture efficiency by the Ecole Polytechique de Montréal. The rotor has modified the Darrieus high efficiency configuration into a size and form optimal for small scale power generation. The changes lowered the operating speed, making it nearly silent, while also improving its self-starting capabilities.Constructed from aircraft grade aluminum, the rotor is both high strength and low cost.

At 10 mph wind, the noise level is imperceptible, and it is 8.8 dB above the ambient level in a 50 mph wind; compared with 65-100 dB of other turbine designs.

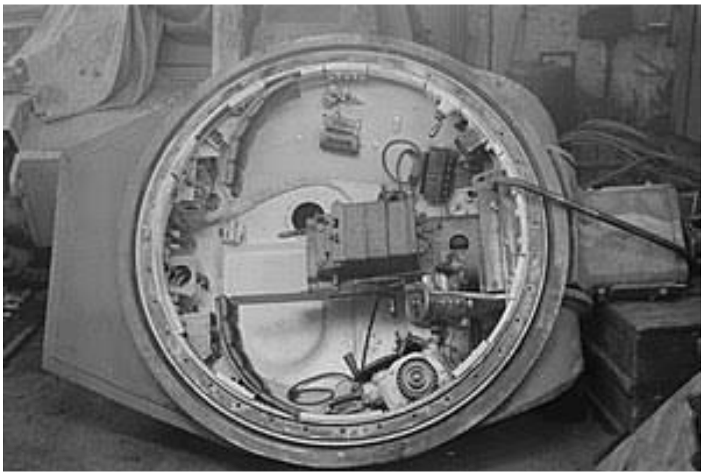
The installation includes a poured concrete foundation without the need for guy wires.

Figure 31. Winsdspire vertical straight blade or gyromill Darrieus wind turbine design

GENERATOR

Double Rotating Air Core motors and generators provide the highest achieved efficiencies ever attaining 98 percent. New manufacturing technology allows them to be produced with both the highest possible efficiency at low cost.

The Windspire generator technology was dynamometer tested and its performance verified by Oregon State University and the University of Nevada, Reno, under a program sponsored by the National Renewable Energy Laboratory (NREL).



INVERTER

The design has its own integrated inverter to convert the raw electrical power from the generator into regulated electricity that ties in with the grid.The high efficiency inverter was designed to optimize operation with the rotor and generator over the encountered range of wind speeds.

WIRELESS MONITORING

The Windspire concept is equipped with a wireless modem that is continuously transmitting the power production information. With the Zigbee dongle modem unit, similar to a flash drive, plugged into a computer's USB drive, one can monitor the performance of the turbine.

POWER CURVE

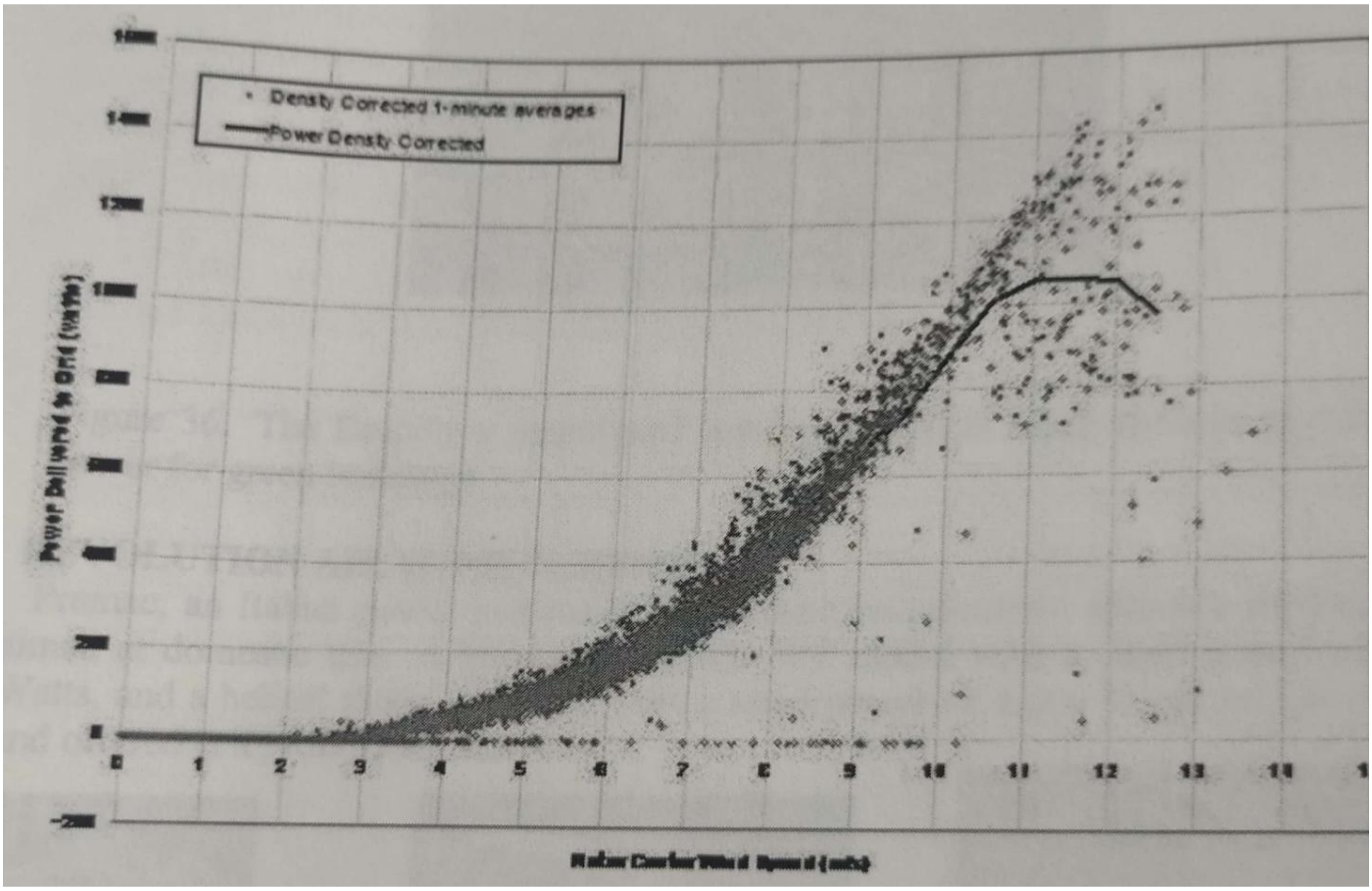
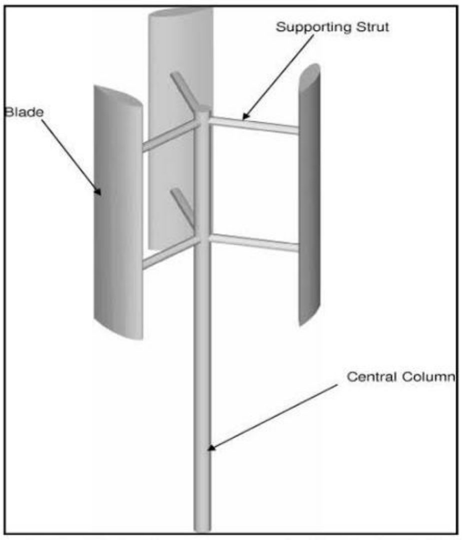


Figure 36. The Beacon: a conceptual design of vertical wind turbines providing power for green buildings,

REVOLUTION AIR WIND TURBINES

Premac, an Italian power generation equipment manufacturer offers wind turbines aimed at domestic use.

A quadrangular 400 WT model with a rated power of 400Watts, and a helical shape 1kW WT with a rated power of 1,000 Watts are produced and offered at a price of $3,500.



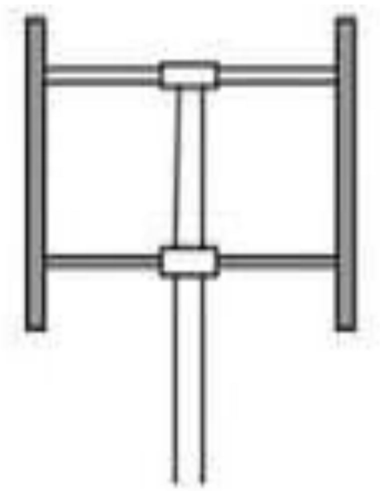


Figure 37, Two and three bladed vertical axis wind turbines. Source: Pramac

SMALL VERTICAL AXIS WIND TURBINES ARRAYS

As the wind passes around and through a wind turbine, it produces turbulence that buffets downstream turbines, reducing their power output and increasing wear and tear. Vertical-axis turbines produce a wake that can be beneficial to other turbines, if they are positioned correctly. Since the blades are arranged vertically, the wind moving around the vertical-axis turbines speeds up, and the vertical arrangement of the blades on downstream wind turbines allows them to effectively catch that wind, speed up, and generate more power.

Small vertical axis wind turbines that are 10 meters tall and generate3-5 kWs are easy to manufacture and cost less than conventional ones if produced on a large scale. The maintenance costs could be less because the generator sits on the ground, rather than at the top of a 100-meter tower, and thus is easier to access. The noise of horizontal axis wind turbines has led some communities to campaign to tear them dswn. These small turbines are almost inaudible and are less likely to kill birds.

Their use on military bases is contemplated because they are shorter and interfere less with helicopter operations and with radar.

Vertical-axis wind turbines are less efficient than horizontal axis wind turbines since half of the time the blades are actually moving against the wind, rather than generating the lift needed to spin an electrical generator. As the blades alternatively catch the wind and then move against it, they create wear and tear on the structure. Adding half a shield against the return stroke would solve the problem.

Figure 39. Vertical axis wind turbines, Los Angeles County, California [3]

HORIZONTAL VS VERTICAL AXIS WIND TURINE

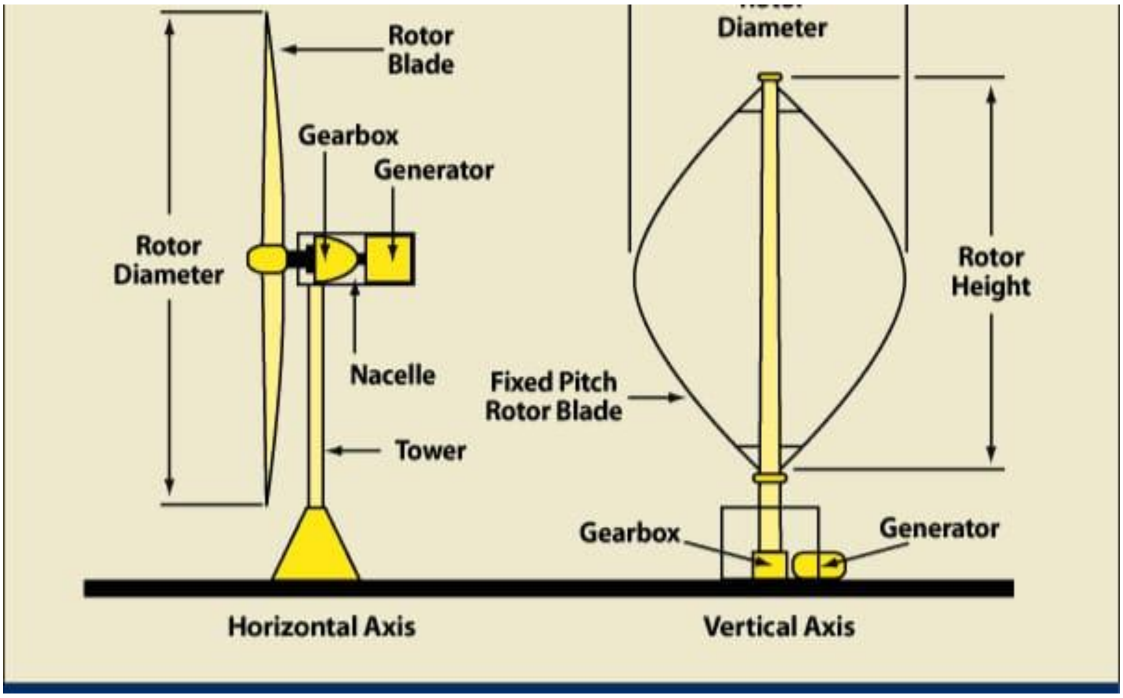


Figure 1.2 HAWT VS. VAWT Design

This project is an extension of previous work at WPI in MQP projects that focused upon VAWTs. The research in this project was intended to improve VAWT efficiency and maximize the energy generation from the wind's available power. This was done by considering alternate turbine designs adding a shroud around the wind turine. The project researched blade designs that performed the best with a 90° enclosure. The enclosure is a shroud that surrounds the turbine and allows wind to enter the area at a 90° angle. The enclosure was expected to increase the turbine's revolutions as compared to a turbine without an enclosure. The project also entailed research into reducing the amount of vibration experienced by a roof caused by wind turbines. This was approached by variations of vibration dampening systems on the roof mounting system. To see how effective a VAWT system would be in Worcester, specifically WPI facilities, a software program called WASP was used with wind speed data collected over the past couple of years. WPI has a few anemometers located on top of Daniels and East Hall as well as the campus center. With these data, the WASP software was used to create plots showing the wind patterns experienced on top of the dormitories.

5.SCOPE OF ADVANCED STUDIES

2 Background

As world population and standards of living increase there is an ever growing demand for energy. This increase in energy creates significant demand for energy created by fossil fuels,which the world has a limited amount of and carbon emissions can lead to global warming The fears of diminishing natural resources and concern of significant climate change as a result of the burning of fossil fuels has created great worldwide interest in clean renewable energy that can meet the electrical demands of the world. One common strategy is to use wind turbines that generatte electricity from wind

2.1 Wind Intro

Wind is generated from solar energy unevenly heating the earth. This uneven beating creates pressure changes in the atmosphere, generating wind. This wind can then be harnessed by a wind turbine. As the wind pushes the blades of a turbine, a generator attached to the axis of the shaft and when spun creates electricity that can be sent to the grid and used in households for electrcity (windies.gov, 2012)
Wind turbines are a clean way to generate power, yet there are many significant problems with them as well One problem is that they are extremely expensive to design and install, and in order to generate enough energy for communities and cities require space wind farms.Another issue is that they have to be created in locations where there is enough wind energy to generate enough clectricity to justify the cost of the machine.(windies gov, 2012)

2.1.1 Power Density

Geography can greatly effect wind speed, and in effect the power from the wind.Knowing this information prior to setting up a wind turbine is imperative. Calculating the average power from wind is a simple equation:

$$Pl={}^{1}pV^{3}\,A$$

Equation 1 indicates the importance of wind speed in power generation because power generation increases proportionally as wind increases to the third power. Knowing the power density will allow wind turbines to be placed in efficient locations for generating electricity. Figure 2.1 shows a scale for power density using equation 1. Wind class one and two contain relatively low amounts of power and have been tested to not be efficient for wind energy generation. Class three does not have sufficient power for large scale energy generation, yet it does potentially have value in personal wind turbine generation. Classes 4.6 have enough energy to be efficient in large scale wind turbine generation intended to power communities and cities

2.1.2 Wind Speed

As figure 2.3 indicates, below 30m in the air the wind velocity increases at a faster rate than the corresponding power density. However, once an altitude of 30m is reached, the power density increases at a faster rate than wind velocities increases. This demonstrates that the higher a wind turbine is, the more energy can be obtained from the turbine.

2.1.3 Power Coefficient

The power coefficient is the percentage of power received by the wind turbine through the swept area of the turbine blades. Equation depicts how to calculate the coefficient of power.

Equation 3

In equation 3, Vu is the velocity of the wind as it approaches the wind turbine and VI is the velocity of the wind as it passes through the swept area of the wind turbine blades. The maximum theoretically possible coefficient of power is called the Betz limit which is 0.593. Most current turbines today have a power coefficient between 0.3 and 04

2.1.4 Tip Speed Ratio

Equation 4 defines the tip speed ratio is the ratio of the tip speed of the blade divided by the wind speed. The equation for tip spoed ratio is described below:

Equation 4

In equation 4, A. is the tip speed ratio, Omegs is the rotor rotational speed in radians per second, R is the rotor radius in meters and Vu is the wind speed.

2.2 Wind Turbine Classification.

The two major classifications of wind turbines are horizontal and vertical axis wind turbines, (HAWT and VAWT). The horizontal axis wind turbines are the most common and have blades rotate on an axis parallel to the ground.

2.3 The Effects of Shrouds on Vertical Axis Wind Turbines (VAWT)

A previous Major Qualifying Project (MOP) report by Julie Eagle (Eagle, 2012) addressed VAWT design, entitled Enclosed Vertical Axis Wind Turbines, shows preliminary research on how a protective shroud affects vertical axis wind turbines placed within it.

The research confirms that a three bladed turbine design with air foil blades outperform and is more efficient at lower speeds then the equivalent flat blade design.

This information is depicted in Figure 2.8.

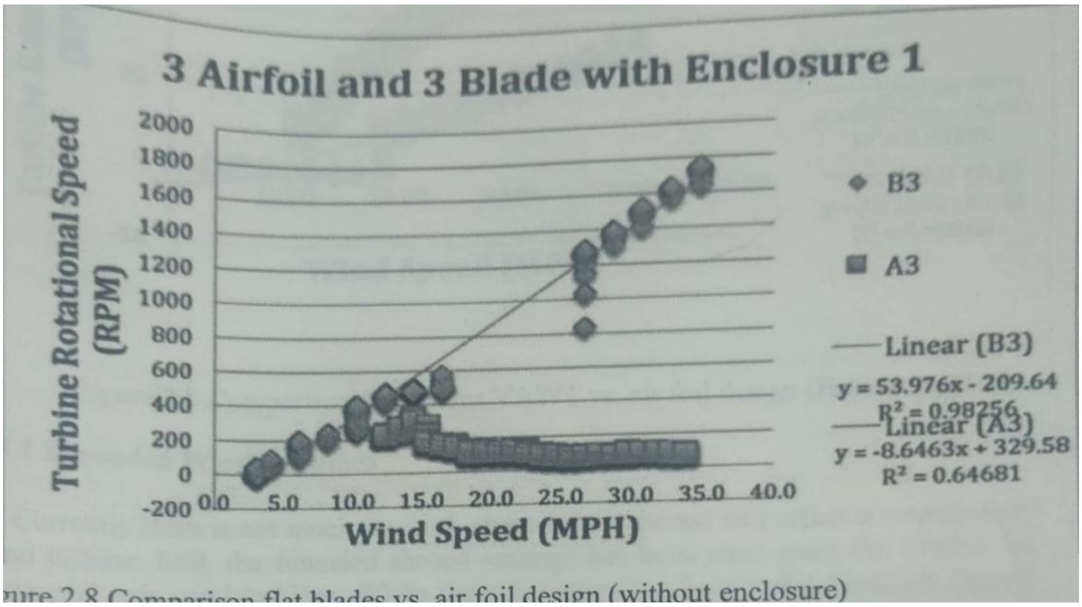


Figure 2.8 Comparison flat blades vs. air foil design (without enclosure)

The results from figure 2.8 demonstrate poor potential for home rooftop wind turbine potential because the airfoil design (labeled as A3) has a cut in speed of 10 miles per hour. The flat bladed design (labeled as B3) takes even higher wind speeds to initiate spinning with a cut in wind speed of 20 miles per hour. The reason these results are poor for a rooftop wind turbine is because in Massachusetts the estimated wind speed that will approach a rooftop wind turbine is 6.24 miles per hour indicating that neither of these designs can be expected to generate significant amounts of energy throughout the year. The results also do not indicate their real performance because there was no load put on the turbine system, such as a generator. The wind speeds indicated to spin the turbine are much lower than actual wind speeds required to rotate a turbine with generator.

Further testing from the same project (Eagle, 2012) compares the previous test with the same turbines, but with a protective shroud and a funnel that accelerates wind speed.

These results are depicted in figure 2.9, The x-axis represents the wind speed that is produced by the wind tunnel and not the accelerated wind speed occurring within the enclosure.

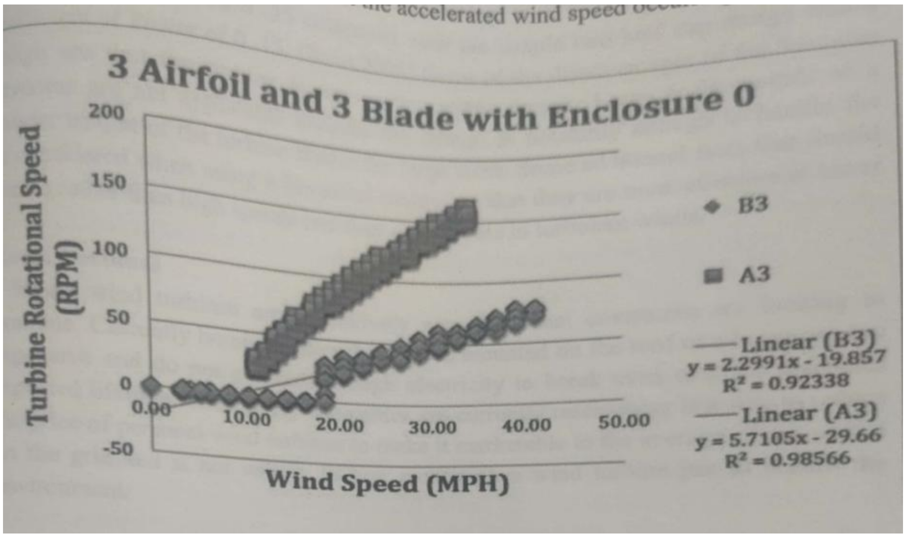


Figure 2.9 Comparison flat blades VAWT vs. air foil design (Enclosure 210”)

2.3.1 Shrouded Wind Turbines

Currently there is not much research about how a shroud will affect a vertical axis wind turbine. Still, the funneled shroud concept has been used since the 1920’s for Horizontal axis wind turbines. While there is supporting facts that a funneled shroud does increase airspeed to the turbine, does also increase the size, weight, and cost of the project. These negative factors deter large wind turbines from having a funnel, as well as the fact that none have been commercially used that can compete with a modern 3 bladed horizontal axis wind turbine. However, current research shows a promising future for shrouded horizontal axis wind turbines with some currently being tested with claims of a 2-5 times increase in power generation in comparison to similarly sized non shrouded horizontal axis wind turbines

2.4 Savonius VAWT

The Savonius VAWT design was created by Finnish inventor S.J. Savonius in the 1920’s. The design utilizes an open overlapping two half cup designs that is very beneficial to wind turbine design. Some of the most appealing benefits of the Savonnas design are it simple and cheap to construct, it has low noise and angular velocity when in use, and it can accept wind from any direction and can withstand extreme weather conditions without significant damage. In addition there are multiple variations to the design that change the performance of the turbine depending on blade configuration.

According to Dept. of Mechanical Engineering at IIT, a split Savonius has a coefficient of power of 0 35 compared with the simple two half cup design with a coefficient of Power of 0.15. (Saha,2008) Some of the disadvantages of the Savonius design are that the turbine is not a very stable design Large scale models of a Savonius are not applicable because the design is notsturdy enough to handle the heavier weight of the turbine blades for large sizes Some additional facts that should be considered when using a Savonius design are that they are most effective at lower speeds rather than high speeds and they can operate in turbulent winds.

Home Turbines

Home wind turbines are a relatively new field that companies are looking to examine Currently home turbines that can be mounted on the roof of a house are too expensive and do not generate enough electricity to break even over the machines expected lifetime. What many companies are currently researching is a way to reduce the price of personal wind turbines to make it marketable to the average citizen who is on the grid and is not willing to lose money on a wind turbine just to benefit the environment.

An example of a home wind turbine is the Bergey 1KW system that has an initial cost of about $6,000 and a 20 year lifespan. An independent study concluded that this system will on average generate 100KW hours a month. At this rate the citizen using the system is essentially paying 26 cents a KW over the course of t 20 years of the system which is more expensive than just purchasing electricity from the grid. The average household uses about 11,500 KWh a month (cia gov, 2012), so this system would only generate 1/12th of the average household system. Even Bergeys 10 KW system with wind speeds at 10mph only generates about 30,000 KWh a year at a much higher initial cost.

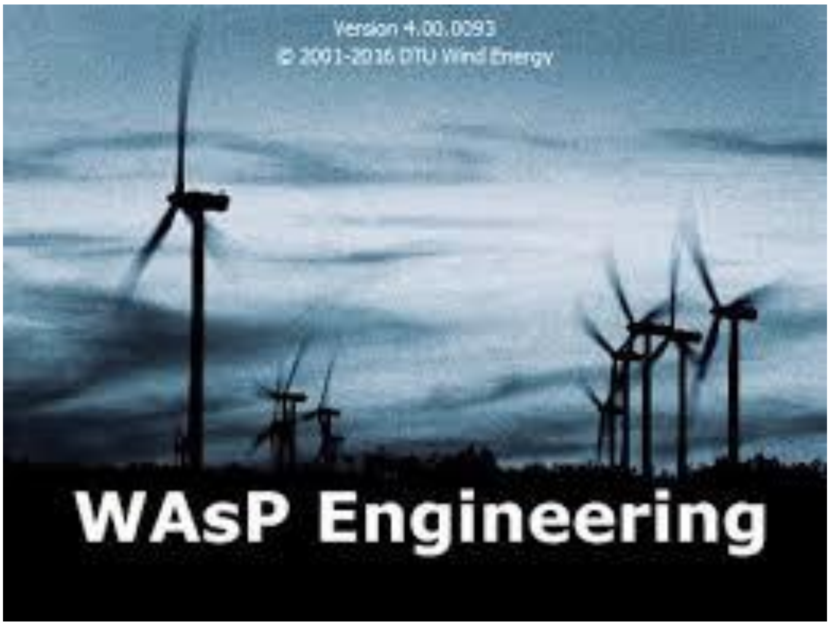
Bergey 1 KW System

There are personal wind turbines that can be attached to a tower in a yard that are cost effective, but they require land space and permits. In many towns and urban communities land space and permits are not an option. (Popular Mechanics,2009) Placing wind turbines on roofs is the solution to most permit and space issues. However, like the Bergey described above, they are not cost efficient and have other issues, this is why only 1% of personal wind turbines have been mounted on roofs.Some of the non-cost related issues of turbines mounted on roofs are vibrations leading to structural damage of the roof and noise that bothers occupants in the house.Solving these issues is the future goal for personal home wind turbine designs.

Background to WASP

WASP is a PC-program for the vertical and horizontal calculation of wind climate statistics. It contains different models to describe the wind flow over different areas and terrains.
This program is mainly for predicting wind climates, wind resources, and power productions from wind turbines and wind farms. The predictions are based on wind data measured at meteorological stations in the same region. The program includes a complex terrain flow model, a roughness change model, a model for sheltering obstacles, and a wake model. The software package further contains a Climate Analyst for creating the wind climatological inputs, a Map Editor for creating and editing the topographical inputs, and a

Turbine Editor for creating the wind turbine inputs to WASP. The fundamentals of WASP and the wind atlas methodology are described in the European Wind Atlas WASP is developed and distributed by the Department of Wind Energy at the Technical University of Denmark, Denmark as shown in figure 2.12.



Mounting system

The most common method for a mounting structure for wind turbines is a monopole design. This consists of some sort of base, usually concrete, with a steel structured pole that extends to the owners desired height. As the progression of turbines has grown there has been desire for roof mounted systems. These roof mounted systems have not had the amount of research as the traditional monopole design. As the growth of roof mounted turbines rises there is an urge to design out the flaws that has been shadowing previous roof mounted systems.

Noise and Vibrations

Wind turbines can create a constant humming noise is considered an annoyance as well as produce vibrations that over time can ruin the integrity of a roof. This has hindered the popularity of consumers wanting to have wind turbines mounted to their roof. This has limited wind turbines to be mounted on poles next to houses but many city ordnance laws prohibit this in residential areas. As a wind turbine is spinning and producing electricity it creates a constant vibration. This constant vibration can damage the shingles around the base as well as damage the trusses around the area where they are mounted. These vibrations are very difficult to prevent, so it is important to have a mounting systern that will disperse the vibrations before reaching the actual structure of the house. Many roofing companies do not put a warrantee on the roof if there is a wind turbine due to the result of the vibrations. This will dissuade a consumer away from having a wind turbine mounted on the roof. Another issue that dissuades a consumer from using wind turbines is the constant humming noise produced when a turbine is generating electricity. A VAWT an opposed to a horizontal axis turbine does not produce as much noise as the traditional turbines due to design differences of the turbines as well as the path of motion of the blade. Another reason that VAWT are more for residential areas is their ability to operate at peak efficiency with turbulence that is produced by roof contours. When wind is traveling over roof peaks and different slopes of roofs they produce a turbulent wind pattern that actually disrupts horizontal axis turbines from producing electricity. This turbulent wind pattern caused by roof peaks does not disrupt the functioning of VAWTs, as well as produce as loud of noise compared to HAWT systems. The rise in popularity of roof mounted VAWTS is opening research into a way to eliminate harmful vibrations from turbines that cause roof damage. This project goes into solving and improving the flaws of roof mounting systems as well as improvements to the overall design of the VAWT blude design in methodical steps that can be seen in the next chapter.

Methodology

The goal of this project was to design a vertical axis wind turbine (VAWT) that could generale power under relatively low wind velocities To accomplish this goal, the objectives were to (1) analyze how different geometry of the wind turbines within various enclosures affect wind turbine power output (2) test how the vibrations caused from the rotations of the wind turbine affect the structural integrity of various aspects housing structures, and (3) compare the operation of VAWTS that are directly placed in the wind with VAWTS that placed within an enclosure.

To meet these objectives, the tasks were to:
Complete background research on wind turbine data

Design turbine blade designs for testing

Design model roof structure

Create experimental set up

Manufacture parts and build model house

Develop future design recommendations

Background Research

Background research included reviewing a previous project, Enclosed Vertical Axis Wind Turbines, by Julie Eagle, which provided a foundation for the current project.Using that information, we then studied new areas in order to complete our research.

Old Projects

Analyzing previous research allowed us to determine that the use of a funneled shroud allowed the vertical axis wind turbine had higher potential to generate more energy than a vertical axis wind turbine without a shroud. The tests also demonstrated that airfoil designs potentially do not perform as well as flat bladed designs perform in to enclosure. The reports indicate that flat bladed designs perform poorly in non-enclosed situations but they have increased performance in enclosures. The report test results state that the flat bladed designs enclosed in 90° shroud perform better than airfoil designs in the 90° enclosure and they also outperform the airfoil design without a shroud.

Additional Research

Research started with basic aerodynamic principles and different blade designs that have potential to work effectively in an enclosure. Research showed that aerodynamically efficient blades have great potential to work for a vertical axis wind turbine (Ponta, Otero,2007) In addition a split Savonius design, which is shown in figure 3.1, is able to operate at peak efficiency with turbulent wind, which meets one of the criteria for roof mounted turbines.

Design turbine blade designs to test

After compiling background research we analyzed the information and decided upon two chosen turbine blade designs that could be tested to demonstrate improved results. The two designs were an adjustable angle S1223 airfoil design and a split Savonius airfoil design.

Adjustable angle S1223 airfoil design

Previous projects used the $1223 airfoil design because it is a low speed airfoil design. However, as stated in the background it did not perform well in the enclosures.Possible solutions could be to use different angles of attack for the blades.

To begin the design process we kept the some of the parameters of the old design, such as turbine height, blade size, and diameter of the VAWT. An additional design parameter was to allow each blade to rotate 360° and provide them with a capability to belocked at any desired angle. The airfoil design was also comprised of three blades because research indicates 3 blades for wind turbines with airfoils is ideal for limiting vibrations and increasing efficiency. To account for the 360 of rotation, with one degree of freedom, the design had two pins that locked in with holes in the top and bottom disk which hold the turbine together. The pin on the bottom of the airfoil design is a threaded bolt that allows the airfoil to belocked in place with a hex nut. The pin on the top of the airfoil is attached to a turning device that holds the blade to the top disk.The turning device also has a compass rose on it that aligns with a compass rose on the top piece allowing for easy angle measurements while adjusting the blade angle.

Design of split Savonius turbine

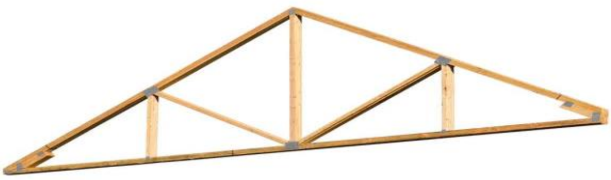
Prior to designing the split Savonius wind turbine, we created parameters in order to allow testing to be assessed in comparison to testing in previous projects. These parameters assured that the turbine blades were of same height, and the total radii of the blades are the same as the flat bladed designs from the reports. After examining different wind turbines we decided that a simple split Savonius design would fit best for our application. The split Savonius we designed had a zero offset; indicating that where the overlapped cusps meet the distance in the y-axis is zero. This can be seen in Figure 3,3 where the red line indicates the zero offset. In addition the overlapping cusps had an offset of 1.5 inches in order to surpass the 0.5 inch rod, located in the center of the blades, without creating interference and allow for wind to pass past therod.

This design, while simple, will give the best indication of whether the split Savonius design is promising for future research with enclosed wind turbines.

Figure 3.4: Split Savonius in enclosure 4 (90)

Scale Model roof structure

To accurately test vibrations a roof would experience from a turbine, we constructed a scale model roof structure. We had to design a blueprint for the structure,construct the scale model house and perform various vibrations testing on the structure. Testing included sending pulses through the vertical shaft attached to the roof and having four accelerometers placed on the structure to detect any acceleration.



Designing Scale Model Roof

To test vibrations associated with wind turbines, we felt the best way would be to actually replicate the vibrations experienced from a turbine onto a structure. We created a plan to build a scale model of a house. There are many possible design alternatives for roof trusses A goal for defining a truss was to have the most popular design that would be able to provide realistic results. We finally came to the conclusion that a double cantilever truss would satisfy our requirements. A double

cantilever truss is shown in Figure 3.5. (roof-truss, 2006) The house was built as a 6:1 scale model with the structure measuring 4 feet by 3 feet at the base. The scale model house is in accordance with Massachusetts building code, with the spacing of wall studs and roof trusses, to ensure reliable testing.

Create experimental set up

After designing the components and structures desired for testing power output for wind turbine designs and the structures desired to be tested, we created the experimental set-ups required to test the prototypes and structures.

Wind turbine set-up

The test set up was in Higgins Laboratory Room 016 Wind Tunnel. When the turbine is set up in the wind tunnel it is located directly in the middle of the cross section of the tunnel. The turbine is attached to a stainless steel rod by using a set screw. At the top, the rod is pressure fitted into a step generator keeping the shaft stable. At the bottom the base is secured into the tunnel as well as being connected to an anemometer. An anemometer is a device that collects the turbines rotation rate in units of rpm. The generator is a 443540 Low RPM Permanent Magnet DC Generator and is attached to the wind tunnel as depicted in figure 3.6. The quarter inch shaft is attached to the generator with a press fit and a set screw to the shaft of the generator.

The anemometer is mensured through a Texas Instrument DAQ box. The generator voltage is measured through a Labview vi. And current is measured by hand with an Ohmmeter. The generator's current is managed by a full wave bridge. The wave ridge is wired as depicted in Figure 3,7

In addition to test the vibrations of the wind turbine we attached an accelerometer at the base of the turbine. The wiring from the accelerometer is attached to a DAQ box in order to record the data on a Labview virtual instruments or vi. The schematics of this can be seen in figure 3.8.

Results

This section describes the results of our testing and shows how we compared our split Savonius design with the previous 4 flat bladed design and airfoil designs. The results also address the use of having funnels attached to shrouds, in hope of increasing power output. Lastly, the results will show the analysis of the vibration testing performed on the model house.

Turbine Data

The turbine data were taken at three different frequencies from the wind tunnel.These were at 22, 25, 30 Hz. The lack of data points and the need to resort to the use of high speeds for testing were a result of our large 12V generator. This made it impractical to accurately relate our power output results with realistic wind speeds that a turbine would expect to encounter. However, it did exhibit differences in each the performance for each set up, whether it was one of the various blade designs or enclosures.

Use of Funnels

The computer simulation indicates a lot about the funneled shroud design. First it reconfirms the theory that the funnel will increase wind speeds into the funnel as the color coded bars representing wind in the system above indicates.

Figure 4.1 also potentially shows why the airfoil design performed poorly in the shroud. As the wind funnels into a smaller area, it creates a higher pressure region as t enters the inlet of the shroud. The outlet of the shroud provides a lower pressure region so the wind dissipates towards the lower pressure region through the center of the shroud and thus not in the direction of the airfoils. This is important because airfoils only operate under certain angles of attack and once the blades are not in this angle the do not generate lift and only continue movement because of momentum rather than the wind moving the airfoil. While these results demonstrate that airfoils in a shroud are not effective, this may not be the case as more outlet positions need to be testes along with various angles of attack of the airfoil that need to be tested as well.

Our testing with various funnels attached to our enclosures was not successful and was not able to turn the generator, even when a load was not applied. The reason for this because the wind accelerated around the funnel rather than flowing through the funnel. This is due to the fact that the funnel creates a higher pressure air system inside the funnel and the wind moved around it. Using funnels in this fashion proved to be an ineffective strategy.

Air Foil Design

The adjustable airfoil design we used was not able to spin the generator under load with or without the enclosure. Even though we tested at speeds 35 percent higher than all other airfoil tests, this design remained unsuccessful. This design proved to be an inefficient design for the vertical axis wind turbine.

Turbine Results

Final testing resulted in effective, informative results using the split Savonius with and without an enclosure. For comparison, we tested a flat four bladed design that had been used in a previous project by Julic Eagle.

Vibration Data

The vibration acceleration data that the vertical shaft experienced when hit by a force with hammer. Each one of the hits is represented at the location where the data spikes on the figures. These four areas are outlined in red boxes. Each of the four hits was taken from a different side of the rod. There is a very obvious difference in the frequency of the hits from the two different mounts. When the rubber vibration isolators are not placed on the mount, the frequency lasts nearly 23 2 times longer. When the vibration isolators are placed on the mount that supports the rod these frequencies experienced are dampened dramatically. This means that the upper portion of the mount that is not directly attached to the house does not experience the normal oscillation frequency that a static rod would experience. The acceleration of the force experienced is quickly returned back to the structures normal frequency. The next area of the structure where accelerometers were placed was the top (horizontal) of the wall studs and on 45° angle of roof trusses.

6. MODEL PREPARATION

Aim: To prepare Vertical Axis Wind Turbine.

Material Required:

- 4” PVC Pipe 30 cm in Length
- ACP Sheet 30cm in Length
- Dynamo 3-5 volt
- PVC or CPVC Fittings 3T’s and 4 Elbows
- Pieces of PVC or CPVC Pipe
- L-Clamp Steel 4
- Plate washer 2” IN Dia-2
- GI Nut that suits Dynamo pulley
- Connecting Wires
- ¾” Cycle screws 30
- Power Bank

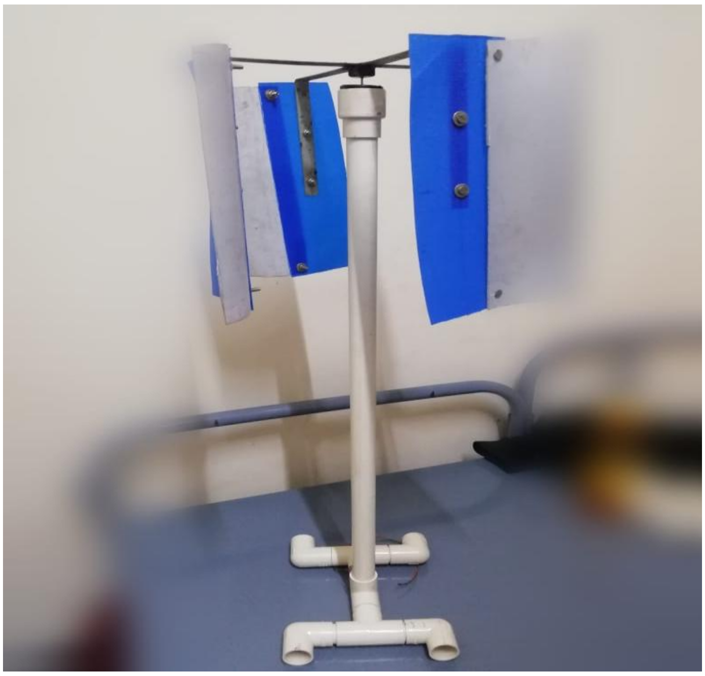
Tools Required:

- Angle grinder
- Drilling Machine
- 6 mm Drill Bit
- Multi meter
- Spanner set
- Welding Machine

Project Design:

Design of Vertical Axis Wind Turbine:

VERTICAL AXIS WIND TURBINE



Procedure:

Step1:

Take PVC Pipe having 4inch diameter and 30cm length. Axially divide it into 4 equal parts using an angle
grinder. Carefully use the grinder make the holes on one side of the PVC using 6mm drill bit.

Step2:

Cut 4 pieces of ACP Sheet having 30 cm in length and 6cm in width. Mark holes on ACP from PVC Pieces and make holes using 6mm drill bit.

Step3:

Buy 4 steel L-clamps and cut it into required length (12cm*6cm) using an angle grinder. Take care and wear glasses while using an angle grinder.

Step4:

Take GI Plate washer 2” in diameter. Take a GI nut that suits dynamo pulley Weld GI Nut at the centre of the plate washer then weld all 4 L-Clamps on the plane washer.

Step5:

Connect ACP Sheets and PVC pieces together using cycle screws. Use a spanner to tighten it. Then connect these propeller blades on propeller frame.

Step6:

Buy PVC or CPVC fittings (4 elbows, 3T’s). Join these components together to make wind turbine base. Connect the wire to dynamo and fix it on wind turbine base.

Step7:

Place propeller on the wind turbine base. Vertical axis wind turbine is ready. Place the wind turbine in front of a fan.

Safety Precautions:

- Weld the Angular Bars correctly
- Wear the glasses while welding
- Put the angular bars correctly on angular round Plate.