PRINCE MOHAMMAD BIN FAHD UNIVERSITY

College of Engineering

Department of Mechanical Engineering

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Senior Design Project Report

DESIGN OF WIND TURBINE GENERATOR

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering

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Chapter 1: Introduction

1.1 Project Definition

This chapter entails creating a simple wind turbine generator that can use multiple energy sources. The wind turbine generator changes kinetic wind energy into electricity. The goal of creating the wind turbine generator is to reduce overreliance on fossil fuels, which contribute to greenhouse gases and global warming, as well as to reduce the associated costs. The assumption is that the wind turbine generator has lower carbon footprint, with lower greenhouse gas emissions and less water consumption. Wind turbine generators have many applications, including the production of additional power for battery charging in boats and carnivals, desalination of water, and powering streetlights and traffic signs.

1.2 Project Objectives

1. Design and construct a wind turbine to generate electricity.
2. Examine the change between wind energy to electrical energy.
3. Improve the maximum efficiency of the wind turbine by using the optimum design and good selection materials.
4. Minimize the energy cost spent over the power system.

Polinder, Henk, et al. "Trends in wind turbine generator systems." IEEE Journal of emerging and selected topics in power electronics 1.3 (2013): 174-185.

Henk Polinder, Senior Member, IEEE, J. Abraham Ferreira, Fellow, IEEE, Bogi B. Jensen, Member, IEEE, Asger B. Abrahamsen, Kais Atallah, Richard A. McMahon

1.3 Project Specifications

Figure1(wind turbine generator).

The project entails designing a 100 watts wind turbine generator that operates at a wind speed of 10 m/s, generating 12 volts. The generator will consist of 3 blades, each with a diameter of 1.2 m. The proposed product is a small generator weighing up to 9 kg. The generator will use kinetic energy of the wind to produce electricity. Using kinetic energy will reduce the cost of electricity generation using fossil fuels. Wind is a renewable and environmentally friendly source of energy.

Using wind energy can reduce environmental pollution, contribute to mitigation of climate change, and help to solve the global energy crisis.
This project creates an opportunity for excellent power generation when the wind turbine generator is positioned in a suitable location. The plan is to position the generator in clean, strong, and laminar wind. The turbine can start working at 2 m/s wind speed. The blades will be made of Nylon fiber because it has desirable characteristics like good elastic recovery, fatigue resistance, and high strength. The body will be made of diecast aluminum alloy because it provides the requires strength and the powder coating provides weather and corrosion protection.

1.4 Applications

1.4 Applications

The idea of the proposed wind turbine is to use renewable wind energy for generation of clean electricity. Small wind turbine is an economic and environmentally friendly project using clean renewable energy. This project can be installed in an open place where the wind is strong, clean, and laminar. As high as this project installed the wind will be stronger so it can generate more energy.

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Chapter 2: Literature Review

2.1 Project background

Wind energy has emerged as one of the popular sources of green energy. For over a decade, wind energy had been used for various applications. However, the use of wind energy to produce electricity is a more recent application. Currently, large fields of windmills, known as wind farms, are found in different regions of the world. One of the notable trends is the use of wind power on a small scale. Individuals and organizations can purchase or build small wind turbines to generate electricity and meet domestic and commercial energy needs. There is an opportunity of supplying generated electricity to the grid and allows companies to buy it to meet their needs.

(Brinkman, Robert, Introduction to Sustainability p.74). The conventional "Wind turbine generator system (WTGS)" rotates on the horizontal axis and consists of a three-blade wind wheel, with fast speeds of up to 1500/750 rpm and gearboxes with a ratio greater than 60 (See Fig 2.1.). Asynchronous machines offer many benefits, such as simple designs, ability to work under different operating conditions, and low capital and operating costs. Asynchronous generators are usually used together with induction motors like squirrel-cage and slip-ring motors. The slip-ring rotors are places on the rotor side of the machine connecting power converters or resistors that control the flow of electric current for the machine to operate at different speeds.

[Lubosny Z. (2003) Wind Turbine Generator Systems. In: Wind Turbine Operation in Electric Power Systems. Power Systems. Springer, Berlin, Heidelberg.]

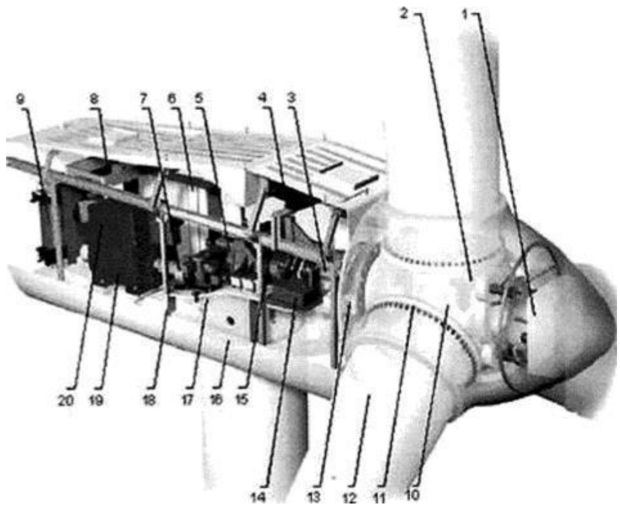


Fig. 2.1. WTGS with asynchronous generator (V 80-2.0 MW; 1 — hub controller, 2 — pitch cylinder, 3 — main shaft. 4 — oil cooler. 5 — gearbox, 6 — generator controller with converter, 7 parking brake, 8— service crane. 9 step-up transformer, 10 blade hub, 11 blade bearing, 12 — blade, 13 — rotor lock system, 14 — hydraulic unit, 15 — hydraulic shrink disk, 16 — yaw ring, 17 — machine foundation, 18 — yaw gears, 19 — generator, 20 — generator cooler).

The purpose of using wind turbines

With unabated climate change and global warming, the priority in almost all industries to reduce environmental pollution and develop renewable energy sources. Wind energy is one the clean energy sources being looked to replace fossil fuels and enhance energy security. There is growing awareness that using renewable and environmentally friendly energy sources would mitigate climate change and ameliorate the global energy crisis. The real benefits of wind energy is the rationalization of greenhouse gases like CO_2, SO_2, NO, and other harmful emissions from power plants that use the conventional energy like coal-fuel and radioactive nuclear power plants. Wind turbine can reduce the dependence on fossil fuel and mitigate the emerging concerns over the fluctuating prices of oil and gas. Wind energy can also enhance global environmental protection. There has seen an increase in the use of wind power across the world recently. The global annual installed capacity of wind generation reached 37 GW in 2009, taking the total global capacity to 158 GW. Since wind power is a promising source of sustainable, clean, and reliable electricity, it is anticipated that wind power will account for much greater proportion of power generation in the coming years. This chapter aims to provide background information on what entails wind power generation and the design of modern wind turbines.

2.2 Previous Work

Wind has been used as a source of energy for over hundred years. Some of the known historical designs of windmills were made of wood, cloth, and other materials. The historical windmill designs were used mainly for pumping water or grinding corn. With technological improvements in the 19^{th} century, fossil fuel engines replaced the traditional bulky and inefficient designs. The same period also experienced widespread connection of national power grids. Wind energy became popular again towards the late 20^{th} century, with better knowledge of aerodynamic properties of different designs and advances in material science driving the demand for more sustainable energy sources. Wind power is currently a common source of power. Wind turbines are classified into two types depending on the direction of the column and the axis of rotation. The first type of the "Horizontal Turbine Wind Turbine Axis (HAWT)", which consists of a turbine with a horizontal composite column running parallel to the earth. The second type is called the "Vertical Axle Wind Turbine (VAWT)" and consists of natural pole on the ground.

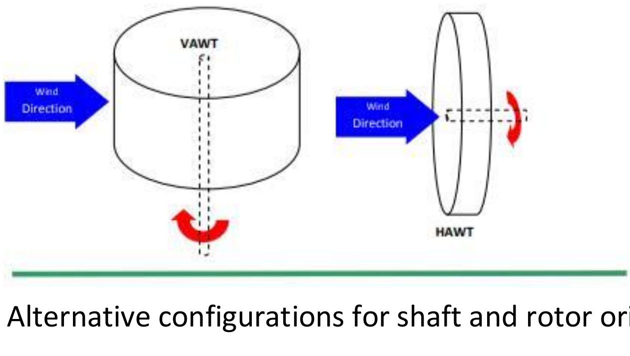
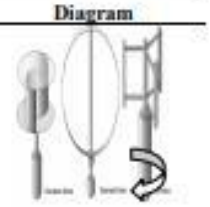


Figure 1. Alternative configurations for shaft and rotor orientation

Although wind turbines have been use for a long time, no design has ever reached the maximum theoretical efficiency. The earliest designs were made of wood and cloth sails, like the Persian windmills. Many designs have been used over the years. Although there have been improvements of VAWT designs, they have never matched the efficiency of modern HAWT designs. However, HAWT designs are sensitive to blade profile changes and design adjustments. Table 2 summarizes the major parameters influencing the performance of HAWT blade designs.

Table 2. Modern and historical rotor designs.

Ref No.	Design	Orientation	Use	Propulsion	* Peak Efficiency	Diagram
1	Savonius rotor	VAWT	Historic Persian windmill to modern day ventilation	Drag	16%	
2	Cup	VAWT	Modern day cup anemometer	Drag	8%	
3	American farm windmill	HAWT	18th century to present day, farm use for Pumping water, grinding wheat, generating electricity	Lift	31%	
4	Dutch Windmill	HAWT	16th Century, used for grinding wheat.	Lift	27%	
5	Darrieus Rotor (egg beater)	VAWT	20th century, electricity generation	Lift	40%	
6	Modern Wind Turbine	HAWT	20th century, electricity generation	Lift	Blade Qty / efficiency: 1 — 43% 2 — 47% 3 — 50%	

* Peak efficiency is dependent upon design, values quoted are maximum efficiencies of designs in operation to date [1].

The BEM method defines an ideal HWAT rotor blade design. However, several theories exist on how to calculate the optimum chord length. The Betz method provides the basic conformation of the modern wind turbine blade, although more advanced method of optimization is commonly used.

Betz optimization Equation:

$Copt = \frac{2\pi r}{n}\frac{8}{9C_L}\frac{U_{wd}}{\lambda V_r}$ where $Vr = \sqrt{V_w^2 + U^2}$

r = radius (m)
n = blade quantity
C_L = lift coefficient
λ = local tip speed ratio
V_r = local resultant air velocity (m/s)
U = wind speed (m/s)
U_{wd} = design windspeed (m/s)
C_{opt} = optimum chord length

The performance of blades design.

The optimum dimensioning of the wind turbine blade is based on variations in wind speed conditions for a site. The turbine runs at off-design conditions, which includes higher than rated wind velocities. One of the consideration in creating an optimum wind turbine is to limit the rotational speed and prevent unnecessary loading of components. Limiting the rotational speed increases the lift in conditions that are lower than rated. This approach also prevents overseeding of the rotor, which can lead to an overload or failure of the blades under excessive load. One would expect the gearbox to become obsolete in future turbine designs.

[Schubel, Peter J.; Crossley, Richard J. 2012. "Wind Turbine Blade Design" *Energies* 5, no. 9: 3425-3449. https://doi.org/10.3390/en5093425]

2.3 Comparative Study

1	Senior design project – to design a unique single blade wind turbine
2	Cedarville University students design and test a single blade windmill based on a concept originally introduced by Raymond Holland. included four students in mechanical engineering. The students carried out structural analyses, assessed design aerodynamics, and collected data to guide the final production. The team tested the prototype and determined its capabilities and limitations.
3	A design team at Cedarville University developed a single blade windmill. The design is based on a concept originally introduced by Raymond Holland in 1986.
4	Walters, Steven and Hegna, Harwood A., "A Unique Single Blade Wind Turbine Senior Design Project" (2006). *Engineering and Computer Science Faculty Presentations*. 59. https://digitalcommons.cedarville.edu/engineering_and_computer_science_presentations/59

The project achievement result:

- During the testing stage, measurements from the potentiometer and slip rings demonstrated variation in the blade angle of attack.
- On releasing the brake, the blade rotated slowly at about 20-25 rpm and the windspeed remain below 13 mph.
- The wind speed increased about 145 seconds after starting the test and the blade's angle of attack (AOA) began to adjust automatically.
- The blade angle increased significantly within 6-8 seconds from 10 degrees to about 60 degrees.
- The AOA was measured between the horizon and the angle of the blade at the root.
- The self-adjusting blade angle gave the turbine an easier startup while allowing higher efficiencies at greater rotational speeds.
- This concept relates to the Tip Speed Ratio (TSR) of the blade which is the ratio of the velocity of the blade tip to the velocity of the incoming wind.
- A lower TSR of 1-3 produced better starting torque, but at lower efficiency.
- For conventional windmills, the blades are designed to operate at a specific TSR, with a balance between establishing good starting torque and good efficiency.
- During startup, the blade had a TSR <2, until the AOA increased.
- The blade speed accelerated rapidly at this point from about 25 rpm to over 200 rpm in less than 40 seconds.
- During the interval, the TSR increased from 2 to 6, taking advantage of the increased efficiency at high tip speed ratios.
- The blade slowed down on applying the brake after about 185 seconds.
- As the blade speed decreased, the AOA readjusted itself automatically to the initial 10 degrees.

Angle of Attack Varies with RPM and Wind Speed

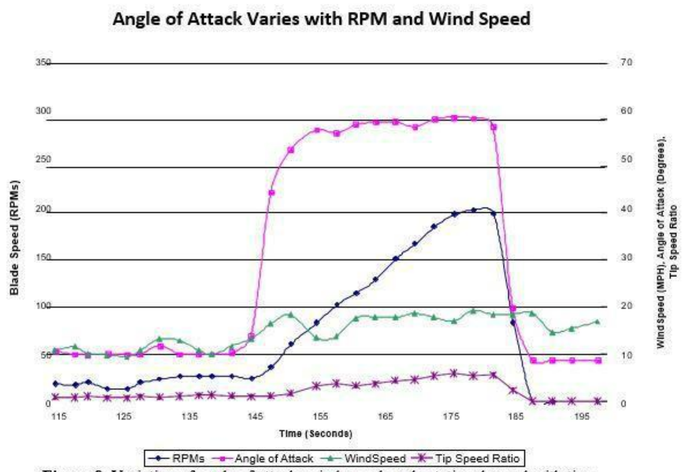
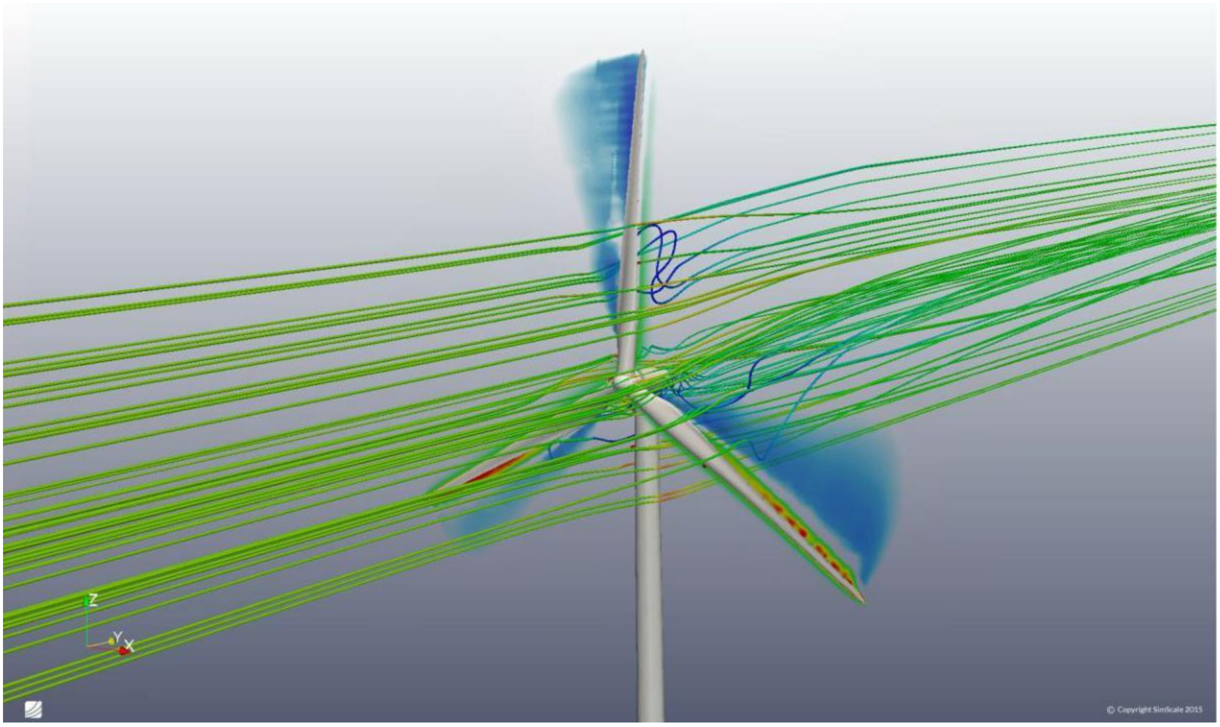


Figure 8. Variation of angle of attack, wind speed, and rotational speed with time.

Discussion:

I will make a brief comparison of our project with this project and discuss some details. In our project, we adopted a three-blade turbine design to give higher efficiency to the opposite of this design. The single-blade turbine rotates slowly 20 to 25 rpm/s and we will increase the rotation altogether to 750 rpm/s. These are the most significant differences that will affect our project positively. The aerodynamic design of three-blade turbines will improve the airflow.



Chapter 3: Constraints and Methodology

3.1 Design Constraints and Design Methodology

Wind Turbine Generator

The use of wind energy plays a crucial role in establishing an environmentally sustainable economy low in carbon. Wind energy is generated using a wind turbine, a machine that revolves and converts the wind's kinetic energy into usable mechanical energy. The mechanical energy generated is then converted to electrical energy used in the power grid (Aono et al., 2020). A generator and a rotor are the main components of the turbine used for energy conversions. The paper's focus is on the design constraints and design methodology used to implement and verify a wind turbine generator. The following figures show the wind turbine generators

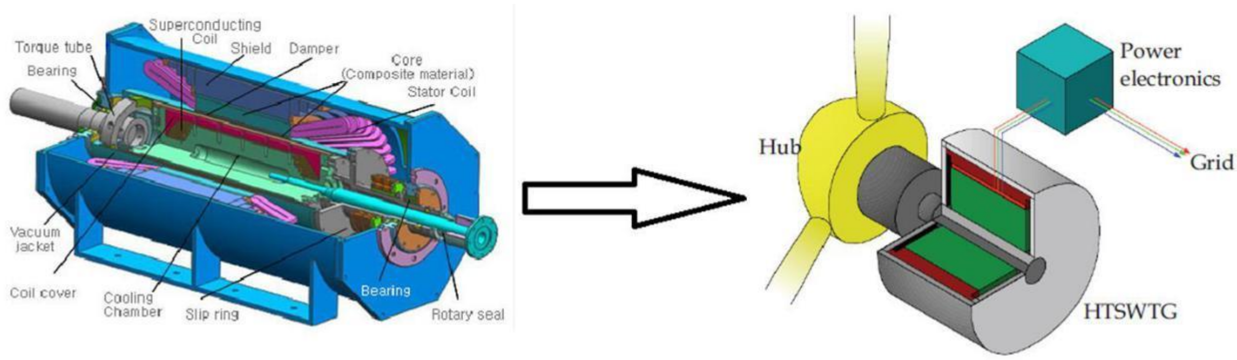


Figure 1: Diagram of a wind turbine generator

Wind turbine generators rotate electrical machines designed to convert the rotating rotor's mechanical energy into electrical energy. For big and more conventional power plants, the wind generators' design is different. The electric generators designed to have higher efficiency, higher reliability, and higher power rating (Madonna et al., 2018). However, a generator that delivers the lowest cost of energy is preferred. Therefore, a generator is a crucial component in producing renewable energy. To create a generator with an advanced configuration for use in wind turbines, we have several methods and strategies that have to be implemented. One is the choice of the generator type to be used. We can consider three types of generators for use as wind turbine systems, such as AC synchronous, direct current, and AC asynchronous generators (Rathish et al., 2021). They can be run by varying their speed or using it fixed at a specific rate. Another design strategy that we should consider is the site to be implemented. This should affect other factors such as protective casing in offshore use and the generator's cooling arrangement. Another strategy in designing the generator will be coming up with the wind turbine's basic parameters and determining the speed range of the generator. The concept behind the working of the generator is then illustrated and defined. The winding of the generator is then presented for analysis. The wind turbine generator's electromagnetic design is then given, and all its losses are evaluated. Most importantly, the plan about the cooling systems' Estimations and the torque used are exposed. Finally, the generator parameters' calculations are given to finish the design.

Key Design Constraints

Geometrical constraints.

The reference design and the optimization of the blades should be factored in about the geometry of the turbine. The blades of the fan should have high tensile and compressive strength. The tip of the blade should be optimized to deflect at the rated angle and speed. The turbine should be designed to deliver optimal gravity load to avoid fatigue during operation.

Engineering Standards

Due to noise issues for small turbines, the turbine's tip speed should not exceed 70m/s. The tip speeds should be within the range of 65-70 m/s for variable speed machines. The maximum rotor output power should also not exceed 14000W to avoid overloading the generator (Meghni et al., 2018). The wind turbine's tip speed ratio should approximately be 7 for optimum performance. The design speed should be around 8m/s for the best performance. If it is too low, the rotor will not achieve the best power output to operate.

Sustainability.

When used optimally, a wind turbine generator can be used to sustain energy or an entire household. Wind is non-polluting energy, and it’s a renewable energy source, which makes wind turbine generator use sustainable. Wind energy is also clean and does not contain harmful chemicals.

Environmental

Generators' general use affects the environment mostly during the productions and collection of raw materials to build generators. This is because the raw materials needed to develop them lead to the destruction of the mines' environment where they are dug.

Social.

Some of the best wind farms are constructed in the most remote places of the country. It is here where the optimum wind energy can be utilized. However, some of these regions have some people not used to this technology can possibilities of tampering with the physical equipment’s is often experienced. Therefore, when selecting a site for a wind farm, there is need to consider the social criteria’s on how to approach this by actively involving all the stakeholders.

Economic.

Economics aspect of a wind turbine generator is a crucial aspect to consider when buying or setting up a wind farm. However, the costs of the generator differ with the location of the site, the turbine size, and the dimensions of the whole project. The total prices of using a wind turbine generator will fall under the project completion costs and the generator's costs.

Manufacturability

The technique and skill of manufacturing wind turbine generators is a unique set of unknown knowledge to many. The right design for such a generator requires a certain level of expertise that is not common to many. This makes its manufacturing costly. Economic. Generators are usually large and contain heavy materials of copper and iron. Purchasing these materials is expensive in the market. The total cost of manufacturing and acquiring a generator is therefore costly. This increases the overall cost of using renewable energy systems.

Safety.

Wind energy helps to reduce climate change which is a global solution. However, wind turbine blades have been said to kill some birds and bats and also interfered with people living around them through noise pollution. The use of wind power can however be utilized in the est ways without having to affect wildlife and the people living around the wind farms. Its advantaes of reducing climate change by use of the natural resource has however argued that it will save more wildlife and humans if people adopted use f renewable energies instead of fossil fuels.

Ethical.

Wind energy is ethical because it helps in providing clean renewable energy and maximizes on the use of land. Unlike the fossil fuels, wind energy does not produce any harmful gases to the environment.

A sample design of the wind turbine generator is shown below.

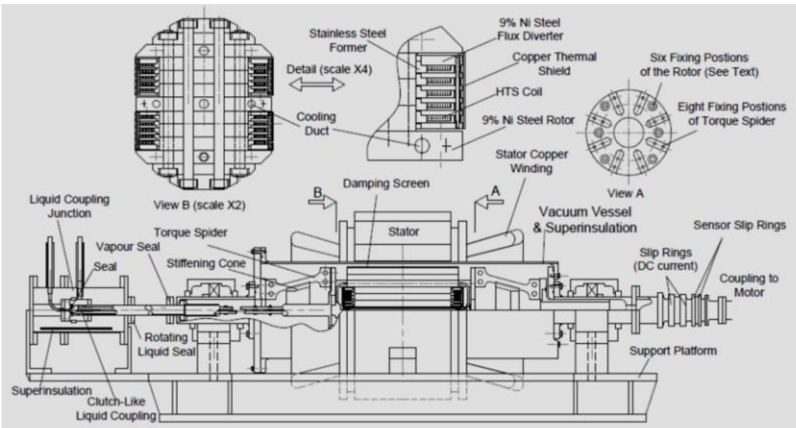


Figure 2: Exploded design of the wind turbine generator.

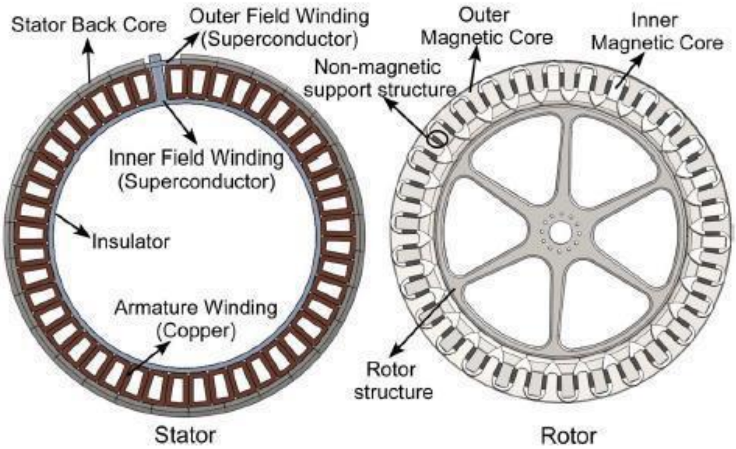
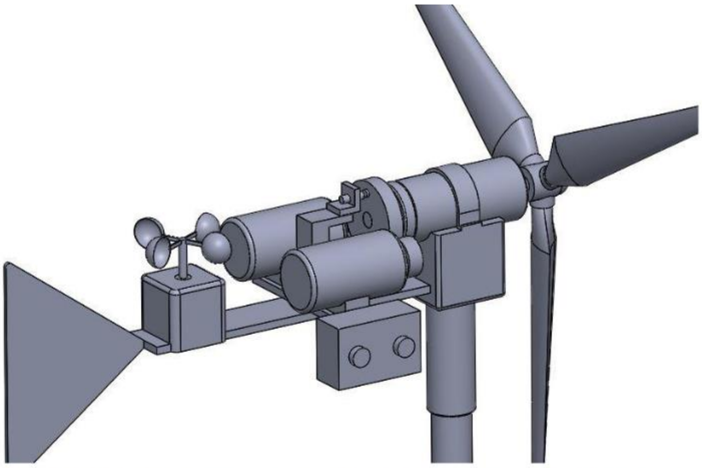
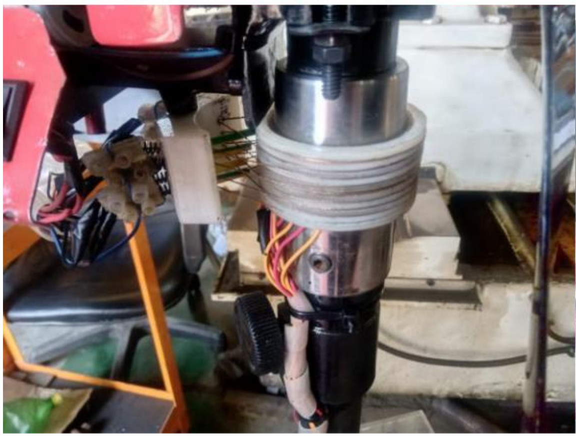
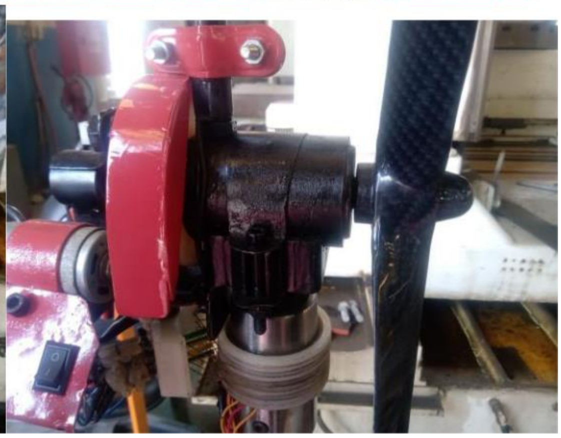


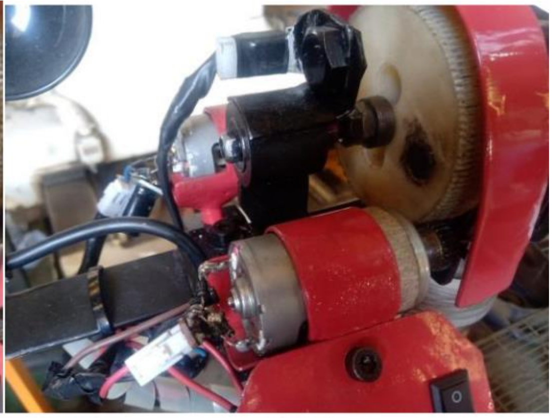
Figure 3: Design parts of the generator stator and rotor.

Wind Turbine 3D Model:








Video 3d Model:

References.

Aono, H., Fukumoto, H., Abe, Y., Sato, M., Nonomura, T., & Fujii, K. (2020). Separated flow control of small horizontal-axis wind turbine blades using dielectric barrier discharge plasma actuators. *Energies*, *13*(5), 1218.

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3.2 Engineering Design standards:

Design standards ensure the quality, reliability, and safety of the development project. Spouse we consider climate change in our design. We must consider the trade-off between risk and sustainability when planning projects and developing the built environment: too weak. The system will fail; too strong will lead to excess energy, Wasted and concretized energy. This compensation is usually handled by defining and complying with building codes and regulations. A method of accurately measuring design parameters based on environmental measurements (such as wind speed, wave height, high water level, and other environmental variables). In addition, these requirements allow the use of historical data when analyzing design parameters. Predicting the future conditions in many situations, and therefore using historical data to design the parameters of the future long-term infrastructure may increase the risk of inadvertently deviating from the trade-off between risk and flexibility. The most common standards focus on the design of horizontal wind turbines. The number of blades, blade material, blade shape, tower and base materials, machine control, and direct drive gears or generators. This is stable. When it comes to energy efficiency, a leaf is an ideal choice. One, another similarly, two blades produce more power than three blades, but this has its own problem: the result is vibration. This also directly affects the turbine components, causing them to wear out for a long time and lose their efficiency. Any turbine with more than three blades has more excellent wind resistance than a three-bladed turbine, reducing power generation and power. Material defects: Most of the material characteristics of the blade are high strength, lightweight, fatigue resistance, and corrosion resistance. Weight gains more power. The blades rotate too fast in strong winds and generate energy. It will turn when the wind is not blowing for the reasons mentioned above; carbon fiber is strong and durable due to its weight, making it an excellent choice for use on blades. Blade shape: There are two types of blades: flat and curved. The blades rotate backward in the upstroke after power generation, which is opposite to the power output, resulting in prolonged rotation. Curved edges are more efficient than flat blades with flat sides, which creates a lower pressure area at the top and is therefore affected by the aerodynamic lift that causes movement. To avoid warpage, doubling the tower's height requires an increase in the diameter of the tower, which requires more material. The area where the wind turbine blades rotate and the moment due to low wind speed constitute the largest part of the tower load. The material that makes it possible to support and stabilize the wind turbine. Direct drive generator: A direct drive wind turbine (without a gearbox) is a direct drive generator that can operate without a gearbox. These turbines have many advantages, including smaller size than traditional turbines, slightly lower operating costs, and gearless turbines, and there is no need to replace gearboxes. The main idea of the generator is to generate electricity and replace gears when the blades rotate. The power created depends on the speed of the blades and therefore the power of the generator.

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Direct drive (gearless) wind turbine market, by permanent Magnet (pmsg) & ELECTRICALLY Excited (EESG) Generator Technology, TURBINE Size/Capacity Range. (2012, October). Retrieved March 21, 2021, from https://www.marketsandmarkets.com/Market-Reports/direct-drive-gearless-wind-turbine-market-805.html

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3.3 Theoretical calculation of the power of wind turbine

1. Preliminary

The power of this turbine is

$$P_k = F\ V\ = [\frac{C_k}{a}\ \frac{1}{2}\ \rho\ S\ V_{fluid}^2]\ V = C_k\ \frac{1}{2}\ \rho\ S\ V_{fluid}^3$$

$$with \quad V\ =\ a\ V_{fluid}$$

Pk the kinetic turbine Power,
Ck the kinetic power coefficient, ρ the fluid density,
Vfluid the fluid velocity.
V the fluid velocity at the position of the turbine.

According to the work, a kinetic energy approach shows that the maximum power coefficient C_T can not exceed a maximum of $\frac{16}{27}$

$$C_{T\ maxi} = C_{k\ Betz} = \frac{16}{27} \qquad C_k \leq C_{T\ maxi} \qquad P_{T\ maxi} = C_{k\ Betz}\ \frac{1}{2}\ \rho\ S\ V_{fluid}^3$$

The theory of the Betz limit is correct, it is based on the calculation of the kinetic energy. The objective to increase the efficiency of the turbine is to transform the potential energy into kinetic.

2. Theoretical preliminary

2.1 continuity equation :

The mass flow rate is the same everywhere along the streamtube and so

ρSfluidVfluid = ρSV = ρSwakeVwake

ρ the fluid density (constant),
V_{fluid} the fluid velocity.
V the fluid velocity at the position of the turbine. V_{wake} the streamwise velocity in the far wake.

2.2 kinetic energy :

k index for kinetic

$$E_k = \frac{1}{2}\, m\, v^2$$

$$P_k = \frac{dE_k}{dt} = \frac{1}{2}\, \frac{dm}{dt}\, v^2 + \frac{1}{2}\, m\, \frac{dv^2}{dt} \qquad \frac{dv}{dt} = 0$$

$$P_k = \frac{dE_k}{dt} = \frac{1}{2}\, \dot{m}\, v^2 = \frac{1}{2} \rho\, S\, v^3$$

2.3 Potential energy :

p index for potential

$$E_p = m \frac{p}{\rho}$$

$$P_p = \frac{dE_p}{dt} = \frac{dm}{dt}\, \frac{p}{\rho} + m \frac{1}{\rho}\, \frac{dp}{dt} \qquad \frac{dp}{dt} = 0$$

$$P_p = \frac{dE_p}{dt} = \dot{m} \frac{p}{\rho} = Svp$$

3. Power calculation

3.1 Power calculation from kinetic energy :

Force applied by the fluid on the rotor.

$$F_k = m \frac{dV}{dt} = \dot{m} \Delta V \ = \ \rho S V$$

Power

$$P_k = F_k V \ = \ \rho S V^2 \left(V_{fluid} \ - \ V_{wake}\right)$$

$$P_k = \frac{\Delta E_k}{\Delta t} = \frac{1}{2} \ \rho S V^2 \left(V_{fluid}^2 \ - \ V_{wake}^2\right)$$

From theses equalities

$$V = \frac{V_{fluid} + V_{wake}}{2}$$

defining $a = \frac{V}{V_{fluid}}$ $\quad 0 \le a \le 1$

$$V_{wake} = V_{fluid}(2a - 1) \quad V_{wake} \ge 0 \quad a \ge \frac{1}{2}$$

$$F = \ \rho S V \left(V_{fluid} \ - \ V_{wake}\right) \ = \ \frac{1}{2} \rho S (V_{fluid}^2 \ - \ V_{wake}^2)$$

$$P = F V \ = \ \rho S V^2 \left(V_{fluid} \ - \ V_{wake}\right)$$

defining $a = \frac{V}{V_{fluid}}$

$$V_{wake} \ = \ V_{fluid} \ (2 \ a \ - \ 1) \quad as \quad V_{wake} \ge 0 \quad a \ge \frac{1}{2}$$

$$P_k = \ 4 \ a^2 \ (1 - a) \ \frac{1}{2} \ \rho S V_{fluid}^3$$

defining power coefficient $C_k = \frac{P_k}{\frac{1}{2} \rho S V_{fluid}^3} \ = \ 4 \ a^2 \ (1 - a)$

Search of maximum power coefficient

$$\frac{dC_k}{da} = 0 \quad a\,(2 - 3\,a) = 0 \qquad or \qquad a = \frac{2}{3}$$

$$a = \frac{2}{3} \qquad C_k = \frac{16}{27} = 0.593$$

$a = 0$

The maximum power coefficient C_{kmaxi} is defined by Betz

$$C_{kmaxi} = C_{kBetz} = \frac{16}{27} \approx 60\%$$

3.2 Power calculation from potential energy :

The pressure difference is equal to

$$p_{fluid} - p_{wake} = \frac{1}{2}\,\rho\,(V_{fluid}^2 - V_{wake}^2)$$

this pressure difference creates on the surface of the turbine a force.

$Fp = (pfluid - pwake)S$ The power of this force is equal to

$$P_p = (p_{fluid} - p_{wake})SV = a(p_{fluid} - p_{wake})SV_{fluid} = 4\,a^2\,(1-a)\,\frac{1}{2}\,\rho SV_{fluid}^3$$

defining potential power coefficient $C_p = 4\,a^2\,(1 - a)$

3.3 Coefficient of power of a turbine with a conversion system :

Moving fluid creates stresses on rotor.Energy conservation can be applied Energy conservation : the total energy remains constant see JOULE

Total energy is equal to the sum of kinetic energy and potential energy.

$ET = Ek + Ep$

The variation of the total energy during the time is zero.

$$\frac{dE_{total}}{dt} = 0 \qquad \frac{dE_{kinetic}}{dt} = -\frac{dE_{potential}}{dt}$$

The variations of energy kinetic and potential vary simultaneously and in opposite sense.

$$\frac{dE_{kinetic}}{dt} = P_k = \frac{1}{2}\rho s v^3 \qquad \frac{dE_{potential}}{dt} = P_p = svp$$

$$\frac{dE_{kinetic}}{dt} = -\frac{dE_{potential}}{dt} \qquad P_k = -P_p \qquad p = -\frac{1}{2}\,\rho\,v^2$$

Pressure variations vary with variations in speed the pressure difference creates stresses on the turbine.

The stresses are maximum when the forces due to the kinetic energy are maximum.

The coefficient C_p can not be greater than or equal to C_k.

3.4 Total power of the turbine :

At the power level, taking into account the differential of kinetic energy and the differential of the potential energy, the power coefficient is

$$C_T = C_k + C_p$$

$$C_T = C_k + C_p$$

$$P_T = C_T \frac{1}{2}\rho S V_{fluid}^3 = (C_k + C_p) \frac{1}{2}\rho S V_{fluid}^3$$

3.5 Balance sheet of the powers

In the case of horizontal wind turbines (HAWT, fast wind turbine type), the power coefficient $C_{T\ HAWT}$ is

$$C_{T\ HAWT} = C_k = 4a^2(1-a) \quad C_p = 0$$

In the case of vertical axis turbines (VAWT, Darrieus type) the power coefficient $C_{T\ VAWT\ Darrieus}$ is

$$C_{T\ VAWT\ Darrieus} = C_k = 4a^2(1-a) \quad C_p = 0$$

In the case of vertical axis turbines (VAWT with conversion) with convert, these stresses into additional energy, the power coefficient $C_{T\ VAWT\ with\ conversion}$ is

$$C_{T\ VAWT\ with\ conversion} = C_k + C_p = 8a^2(1-a)$$

At the level of Powers

$$P = C_T \frac{1}{2}\rho S V_{fluid}^3$$

$$P_{T\ HAWT} = 4\ a^2\ (1-a)\ \frac{1}{2}\rho S V_{fluid}^3$$

$$P_{T\ VAWT\ Darrieus} = 4\ a^2\ (1-a)\ \frac{1}{2}\rho S V_{fluid}^3$$

$$P_{T\ VAWT\ with\ conversion} = 8\ a^2\ (1-a)\ \frac{1}{2}\rho S V_{fluid}^3$$

Conclusion :

Betz had the maximum power coefficient $C_{k\ Betz}(=\frac{16}{27})$ of a wind turbine or tidal turbine from the calculation of kinetic energy.

Taking into account the kinetic energy and the potential energy, the coefficient of maximum power becomes $C_{T\ maxi}(=\frac{32}{27})$:

Transforming potential energy into kinetic energy greatly increases turbine performance.

$$P_{T\ maxi} = C_{T\ maxi}\ \frac{1}{2}\ \rho\ S\ V_{fluid}^3 \quad with \quad C_{T\ maxi} = \frac{32}{27}$$

$$E_k = \frac{1}{2}\, m\, V^2$$

$$\frac{dE_k}{dt} = \frac{1}{2}\,\frac{dm}{dt}\,V^2 + \frac{1}{2}\,m\,\frac{dV^2}{dt} \qquad \frac{dV}{dt} = 0$$

$$\frac{dE_k}{dt} = \frac{1}{2}\,\dot{m}\,V^2 = \frac{1}{2}\rho\,S\,V^3$$

V Wind speed at the turbine level

Force applied by the wind on the rotor

$$F = m\frac{dV}{dt} = \dot{m}\Delta V \ = \ \rho SV\,(V_{fluid} \ - \ V_{wake})$$

V_{wake} streamwise velocity in the far wake

$$P = FV \ = \ \rho SV^2\,(V_{fluid} \ - \ V_{wake})$$

$$P = \frac{\Delta E}{\Delta t} = \frac{\frac{1}{2}mV_{fluid}^2 - \frac{1}{2}mV_{wake}^2}{\Delta t}$$

$$P = \frac{\Delta E}{\Delta t} \ = \ \frac{1}{2}\dot{m}(V_{fluid}^2 \ - \ V_{wake}^2) = \ \frac{1}{2}\rho SV(V_{fluid}^2 \ - \ V_{wake}^2)$$

From theses equalities

$$V = \bar{V} = \frac{V_{fluid} + V_{wake}}{2}$$

$$F = \ \rho SV\,(V_{fluid} \ - \ V_{wake}) \ = \ \frac{1}{2}\rho S(V_{fluid}^2 \ - \ V_{wake}^2)$$

$$P = FV \ = \ \rho SV^2\,(V_{fluid} \ - \ V_{wake})$$

defining $a = \frac{V}{V_{fluid}}$

$$V_{wake} \ = \ V_{fluid}\ (2\ a \ - \ 1) \quad as \quad V_{wake} \geq 0 \quad a \geq \frac{1}{2}$$

$$P = \ 4\ a^2\ (1-a)\ \frac{1}{2}\ \rho SV_{fluid}^3$$

defining power coefficient $C_k = \frac{P}{\frac{1}{2}\rho SV_{fluid}^3} \ = \ 4\ a^2\ (1-a)$

Search of maximum power coefficient

$$\frac{dC_k}{da} = 0 \quad a\ (2 \ - \ 3\ a) \ = \ 0 \qquad a = 0 \qquad or \qquad a = \frac{2}{3}$$

$$a = \frac{2}{3} \qquad C_k = \frac{16}{27} = 0.593$$

The maximum power coefficient C_{kmaxi} is defined by Betz

$C_{kmaxi} \ = \ C_{p\,Betz} = \frac{16}{27} \approx$ 60%

The maximum power of the fluid is

$$P_{fluid} = \frac{1}{2}\rho S_{fluid}V_{fluid}^3$$

$S_{fluid} \ = \ \frac{S\ V}{V_{fluid}} \ = \ a\ S$

The power of the turbine is

$$P = \frac{C_k}{a}\ P_{fluid} \ = \ C_k\ \frac{1}{2}\rho\frac{S_{fluid}}{a}V_{fluid}^3 \ = \ C_k\ \frac{1}{2}\rho SV_{fluid}^3$$

The maximum power of the turbine is

$$P_{max} = \frac{C_{p\ Betz}}{\frac{2}{3}}\ P_{fluid} \ = \ \frac{8}{9}\ P_{fluid} \ = \ C_{p\ Betz}\ \frac{1}{2}\rho SV_{fluid}^3 \ = \ \frac{16}{27}\ (\frac{1}{2}\rho SV_{fluid}^3)$$

$$P_{max} \ = \ C_{p\ Betz}\ \frac{1}{2}\rho SV_{fluid}^3 \qquad (1)$$

Additional recovery power (from potential energy)

The fluid creates stresses in the blade. They are due to thrust force.

The energy of this force is

$$E_p = m \frac{f_s}{\rho}$$

f_S thrust force

For HAWT horizontal wind turbines (fast wind turbine type), the thrust force F_s are constant.

$$\frac{dE_p}{dt} = 0$$

For a VAWT, the thrust force depends on the time or the rotation angle $F_s(t)$ or $F_s(\beta)$ $\beta = \omega t$

$\omega = \frac{d\beta}{dt}$ angular frequency

$$\frac{dE_p}{dt} \neq 0 \quad and \quad \frac{1}{2\pi}\int_0^{2\pi} E_p(\beta) d\beta = \epsilon \quad (\epsilon \ small)$$

As

$$F_s = f_s S = C_x \frac{1}{2} \rho S V_{fluid}^2$$

$$E_p = m C_x \frac{1}{2} V_{fluid}^2$$

V fluid speed at the level turbine

The power is

$$P_p = \frac{dE_p}{dt} \quad dm = \rho S V dt$$

$$P_p = \frac{dE_p}{dt} = \frac{dm}{dt} C_x \frac{1}{2} S V_{fluid}^2 + m C_x \frac{1}{2} S \frac{dV_{fluid}^2}{dt} \qquad \frac{dV_{fluid}}{dt} = 0$$

$$P_p = a C_x \frac{1}{2} \rho S V_{fluid}^3 \quad with \ a = \frac{V}{V_{fluid}} \tag{2}$$

$$\frac{1}{2\pi}\int_0^{2\pi} E_p(\beta) d\beta = \epsilon \quad (\epsilon \ small) \quad E_{p-max} \approx -E_{p-min}$$

the power depends on a potential energy difference

$$P_p = \frac{\Delta E_p}{\Delta t} \quad T = \frac{2\pi}{\omega} \quad P_p \leq \frac{E_{p-max} - E_{p-min}}{T} \quad P_p \leq \frac{E_{p-max}}{\pi} \omega$$

for a half-turn

$E_p(\beta) R \, d\beta = dE_p \pi R$

in particular

$$E_{p-max} = \frac{dE_p}{d\beta}\pi = \frac{dE_p}{dt} \frac{\pi}{\omega}$$

As

$$\frac{dE_p}{dt} = a C_x \frac{1}{2} \rho S V_{fluid}^3 \quad and \quad P_p \leq \frac{E_{p-max}}{\pi} \omega$$

$$P_p \leq a C_x \frac{1}{2} \rho S V_{fluid}^3$$

Variation of energy in opposite sense

Along a streamline, the Bernoulli's equation is see BERNOULLI

((1738))

$$\frac{p}{\rho} + \frac{v^2}{2} = constant \quad with \quad z = 0$$

By multiplying by m

$$m\,\frac{p}{\rho} + m\,\frac{v^2}{2} = constant$$

The differential of this equation is

$$d(\frac{1}{2}\,m\,v^2) = -d(m\,\frac{p}{\rho}) \qquad (3)$$

the variations of energy vary simultaneously and in opposite sense.

3.4 SELECTION OF COMPONENTS

3.4.1 Arduino Uno

Techinical Specifications

Operating Voltage: 5 Volts

Input Voltage: 7 to 20 Volts

Digital I/O Pins: 14 (of which 6 can provide PWM output)

UART: 1

I2C: 1

SPPI: 1

Analog Input Pins: 6

DC Current per I/O Pin: 20 mA

DC Current for 3.3V Pin: 50 mA

Flash Memory: 32 KB of which 0.5 KB used by bootloader

SRAM: 2 KB

EEPROM: 1 KB

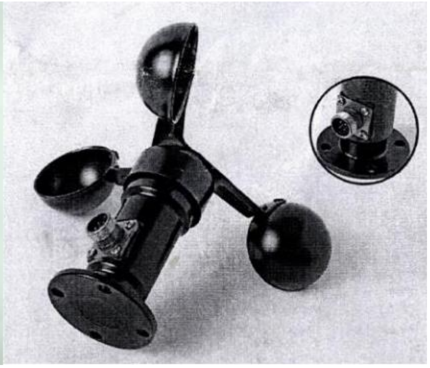
Clock Speed: 16 MHz

Length: 68.6 mm

Width: 53.4 mm

Weight: 25 g

3.4.2 Wind Speed sensor



Wind Speed sensor

1.Functional characteristics

The wind velocity sensor is a professional Meteorological tool for measuring the horizontal pace of the wind. The shape of the conventional three air cup wind velocity sensor is adopted.

The aluminum alloy material is used in the wind cup. It has suitable anti clothing and high strength, and it is well started with the smooth bearing system of the interior, which ensures Accuracy of information collection. The built-in signal processing unit in the cup body can provide pulse signals widely used in meteorology, ocean, environment, airports, ports, laboratories, industry and agriculture, and transportation.

2.Technical parameters

Measurement range : 0-32. 4 s/m.

Precision : +0.3m/s

Start wind speed : <0.8m/s

Temperature : -40ºC-80ºC

Humidity : Less than 90%

Length of lead line : 2.5 meters (customizable)

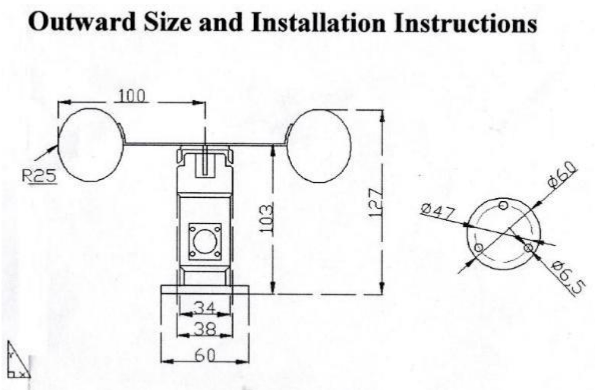
Pulse output Type

Supply voltage : 5-24v DC

Output signal : pulse

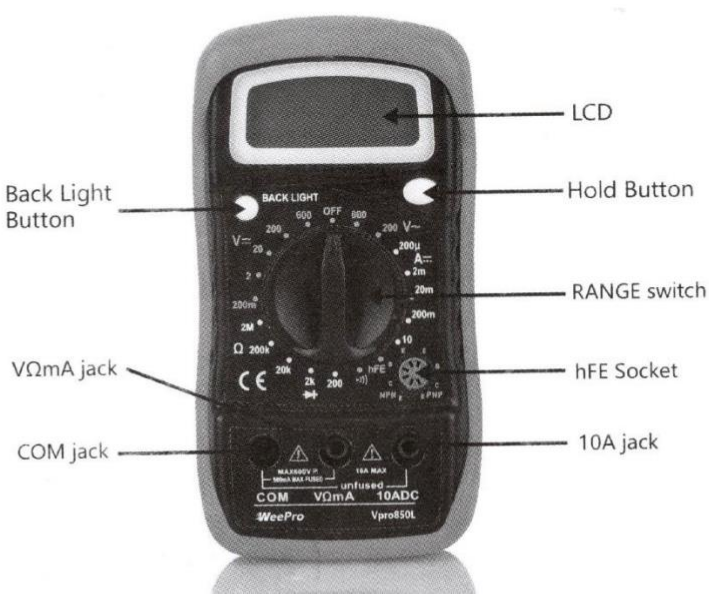
Wind speed value + frequency * 0.83m/s

3.Connection instructions.



Model specification	Aerial explanation	Line color description
Voltage Output Type	1 (V+) : Positive power supply 2 (G) : Power source 3 (Vo) : Output Voltage Signal 4 empty	Brown (V+) : Power supply positive Yellow (G) : Power source Blue (Vo) : Output Voltage Signal
Current Output Type	1 (V+) : Positive power supply 2 (G) : Power source 3 (Vo) : Output Voltage signal 4 empty	Brown (V+) : Power supply positive Yellow (G) : Power source Blue (Vo) : Output Voltage Signal
RS485 Interface Type Modbus protocol	1 (V+) : Positive power supply 2 (G) : Power source 3 (T+) : RS485+/A/T+ 4 (T-) : RS485-/B/T-	Red (V+) : Power supply positive Black (G) : Power source Yellow (T+) : RS485+/A/T+ Green (T-) : RS485-/B/T-

3.4.3 Multimeter Vpro850L



1.Safety Instructions

Meet these guidelines to prevent physical injuries or potential harm to the meter or the equipment being tested:

1. Before using the meter, inspect the case.
2. If the meter is broken, if the case (or part of the case) is inspecting holes or missing plastic, do not use it.
3. Pay close attention to the connectors' insulation.

Examine the test leads for any corrosion or exposed wire. Examine the test's consistency. Between the terminals or the earth link, do not add more than the nominal voltage defined in the measuring unit. To prevent injury and electric shock, the rotary switch should be adjusted to the proper location, and the range should not be altered during the calculation. For your measurements, use the appropriate clamp, function, and range. Please avoid using or storing the meter in areas with high temperatures, humidity, explosive, flammable materials, or heavy magnetic fields. If the meter gets damp, its efficiency will suffer. Hold the fingertips behind the finger guards by using the test leads. Until measuring resistance, continuity, diodes, or hEF, disconnect the transistor from the circuit and discharge any high voltage capacitors. As soon as the power symbol shows, replace the battery. Because of the meter's poor batteries, it will provide false readings, resulting in electric shock and personal injuries.

Until opening the case of the test instrument, disconnect the test leads from the circuit under test and power of the test tool. Spare parts are available. To prevent injury to the measuring instrument and injuries, the internal circuit of the measuring device must not be manipulated at will. The surface of the meter should be cleaned with a soft cloth and mild detergent during repair. Corrosion, injury, or injuries must not be covered against the measuring instrument. When you are not using the meter, turn it off and uninstall the battery if you're not going to need it for a longer time. Keep an eye on the battery because repeated use will cause it to leak. If a leak happens, replace the battery as soon as possible. A leaking battery would harm the meter.

2.General Specifications

Max display : LCD 31/2 digital (1999 count) 0.6" High
Polarity ; Automatic , indicated minus, assumed plus,
Measuring method : double integral A/D switch implement
Sampling speed : 2 Times per second
Over-load indication ; "1" is displayed
Operating environment : 0ºC-40ºC, at < 80% RH
Storage Environment : -10ºC-50ºC, at < 85% RH
Power : 9V NEDA 1604 or 6F22
Low battery indication symbol
Product Size : 135 x 67 x 33 mm
Product net Weight : 145g (including battery)

3.Techinical Specification

Accuracies are guaranteed for 1 year, 23°C±5°C, less then 80% RH

4.1 DC VOLTAGE

RANGE	RESOLUTION	ACCURACY
200mV	100uV	±(0.5% of rdg +
2V	1mV	±(0.8% of rdg + 5D)
20V	10mV	
200V	100mV	
600V	1V	±(1.0% of rdg +

Over load protecion : 220V rms AC for 200mV range and 600V DC or 600V rms for all ranges.

4.2 AC Voltage

RANGE	RESOLUTION	ACCURACY
200V	100mV	±(2.0% of rdg + 10D)
600V	1V	

Response ; Average respondin, calibrated in rms of a sine wave.

Frequency Range : 45Hz-450Hz

Over load protection : 600 V DC or 600V rms for all range.

4.3 AUDIBLE CONTINUITY

Range	Description
	Built-in buzzer sounds if resistance is less then 30±20Ω

4.4 DC Current

RANGE	RESOLUTION	ACCURACY
200uA	100nA	±(1.8% of rdg + 2D)
2mA	1uA	
20mA	10uA	
200mA	100uA	±(2.0% of rdg + 2D)
10A	10mA	±(2.0% of rdg + 10D)

Over load Protection : 500 mA /250V fuse (10A range unfused). Measuring voltage drop ; 200mV **4.5 Resistance**

RANGE	RESOLUTION	ACCURACY
200Ω	0.1 Ω	±(1.0% of rdg + 10D)
2K Ω	1 Ω	±(1.0% of rdg + 4D)
20K Ω	10 Ω	
200KV	100 Ω	
2M Ω	1K Ω	

Maximum open circuit voltage : 3V.

Overload Protection : 15 seconds maxi – mum 220Vrms.

3.4.4Turbine Fan

Technical Specification:

Swing Diameter : 750 mm

Material : Correction resistance coated Aluminum alloy

Weight : < 1 Kg

No of Blade : 3

Cross section area of blade : Max 55 mm

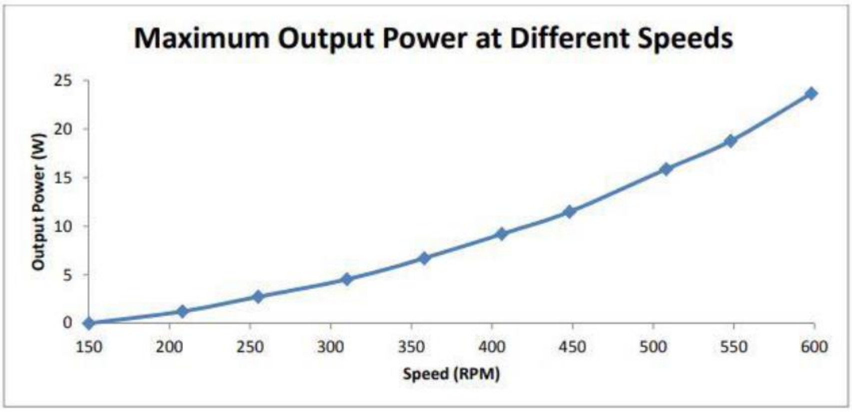
Min 25 mm

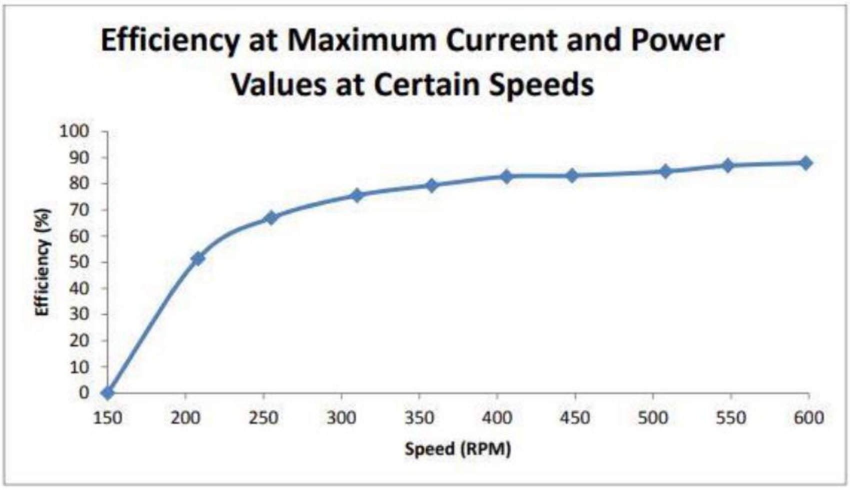
3.4.6 Support Stand

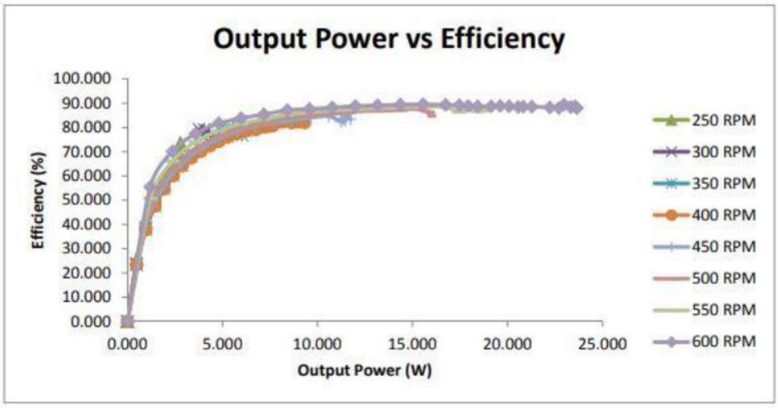
Technical Specification:
Size : 1.1 Mtr
Load Capacity : <50 Kg
Material : Steel Pipe
Weight per meter : 0.24 kg
Coating: Corrosion resistance painted

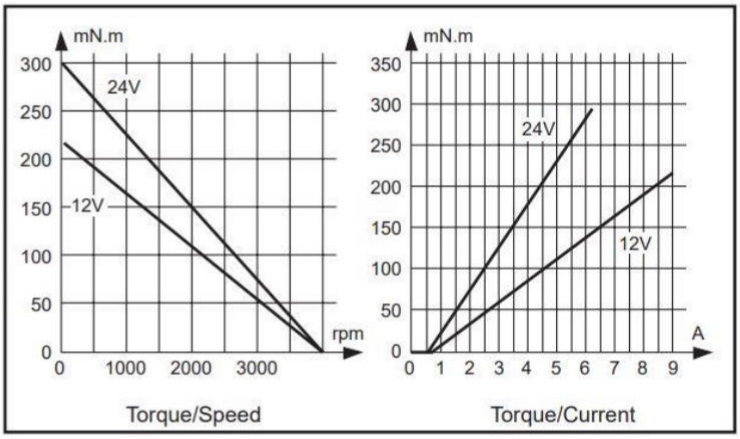
3.4.7 Generator

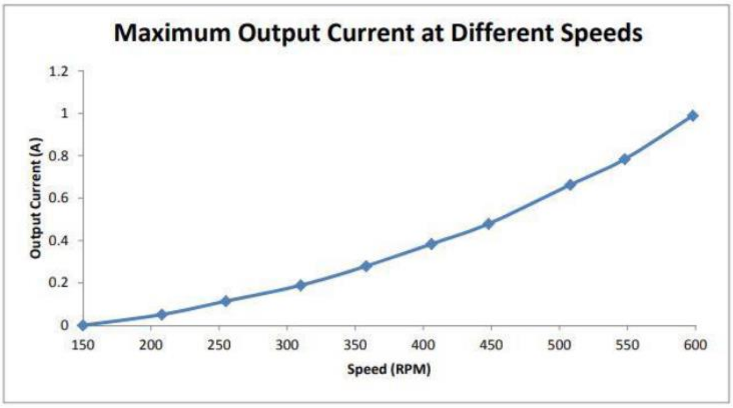
Technical Specification :











3.5 . ASSEMBLY PROCEDURE

Abstract:

The paper analyzes the various urban-specific turbine designs. In relation to the house, we are exploring different options for installing wind turbines. Valid samples of wind turbines installed on homes, sporting fields, roads, etc., are considered an insight into actual indicators. However, the reliability and the payback time of these turbines are inferior, and the noise they emit may be the concern. Thus, the wind turbines built in the building have a more lucrative reputation than profitable investment for individual owners and architects.

Key words: wind turbines, buildings.

1 Introduction

At the moment, arguments and discussions are taking place about the feasibility of wind power. According to experts, wind turbines are cost-effective and reliable whether they are mounted on high poles or combined with a plant in conjunction with any renewable energy source.
Engineers came up with the concept of putting wind turbines on top of buildings because wind speed rises with height. As a result, the turbines can be mounted on buildings as separate structures, increasing the use of wind currents generated by their height. The second scenario is the incorporation of wind turbines into the design of systems (for example, opposite a hotel), in which the building itself is equipped with wind turbines. The construction of wind turbines between two tall buildings is the third choice. Facilities will speed up the wind velocity at the wind turbine's location and cause a lot of turbulence in this situation. Wind turbines situated in areas with high wind speeds

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Buildings are referred to as Constructing Augmented Wind Turbines (BAWT) because the wind turbine uses the structure as a wind concentrator. Only small wind turbine dimensions relative to building dimensions can produce a concentrator effect. This restricts BAWT proportions to no more than 20% of the typical building scale.

We generate electricity where it is required by installing wind turbines in houses, and there is no transmission failure. Turbines will only satisfy about 15% of the building's overall energy consumption, so the rest must come from other outlets.
The paper is divided into four sections: section 2 discusses wind turbine architecture for urban environments, section 3 discusses proposed wind turbine placement on structures, and section 4 discusses examples of wind turbines built into buildings and potential issues. Conclusions are presented in Section 5.

2 Suitable wind turbine designs

A wind turbine's aerodynamic performance is determined by how wind energy is transformed (lift or drag type wind turbine). Lift-driven wind turbines will achieve high aerodynamic efficiency (up to the Betz limit of 59 percent). Airfoils were used to produce the driving force/lift in these wind turbines, and they used very little material (Fig. 1). Drag-driven wind turbines, on the other hand, have lower aerodynamic efficiencies (up to 15 percent) and use more material. For economic considerations, the lift-driven wind turbine is preferred over the BAWT.

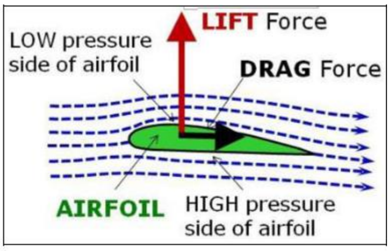


Fig. 1 Lift based wind turbine concept

Many lift-driven winds turbines could be used to power the structure. Wind turbine blades can be vertical (VAWT) or horizontal (HAWT) depending on the direction of the axis of rotation. There's some controversy over whether HAWT or VAWT is better for urban environments and building mounting. VAWT has the advantage of not having to be guided towards the wind in the built area where the wind flow is often chaotic. VAWT also produces fewer waves and makes less noise. HAWT, on the other hand, is more powerful and cost-effective in converting wind energy to electricity. According to some estimates, a building with an incorporated HAWT may achieve at least a 25% boost in annual energy yield over a freely yawing stand-alone turbine in a standard urban environment. As a result, all kinds of turbines are being used in homes. Other standards for urban wind turbine construction include:

• Good wind efficiency,

• Safe urban area operations,

• Low level of noise,

• Simple, robust design;

• Servicing reduced,

• Aesthetic look.

3 Positioning of the turbine

Locating between diffuser shaped buildings

Buildings are designed in this situation to serve as a wind turbine diffuser. Numerous experiments were performed in ring-shaped diffusers on the horizontal wind turbines. Comparing with other options, this mixture leads to high aerodynamic effectiveness. To produce significant aerodynamic performance, the diffuser needs to belong. The typical form of the wind turbine with diffuser amplification is not ideal for the built environment. This is why a mixture of

Other applications are also "diffuser" and "duct."

Locating in building facades

Several designs have developed engineered wind turbines that merge splendid façades like sculptures to increase wind flows on turbines and produce more electricity than is historically feasible. At the same time, these artistic wind-generating façades solve such conventional challenges such as noise and distortion with this kind of dynamic façade. Many of these advanced wind systems use the Wind Assisted Rotor Platform model (WARP). The turbines are compact and have an aerodynamic appearance on the outside of a house. The modules shaped by a saddle ridge roll around the building and intensify wind flows (Fig 2).

Fig. 2 Wind turbines integrated into a Chicago parking (via Flickr)

The disadvantage of alongside location is evidently that the performance will be strongly dependent upon the direction of the wind.

Locating on the building rooftop

To locate on the roof, it should be remembered that the leading edge of the roof separates the flow and the angle to the horizontal roof is around 45 degrees. This effect is less significant for a Darrius turbine. The blades undergo a near-horizontal flow for average tip speeds. On a HAWT, the tilt has a more substantial impact. The airfoils are stagnating, the aerodynamic performance is decreasing, and the rotor load is uniform. The Darrius turbine, therefore, appears preferable for the building roof.

4 Examples of wind turbines integrated in buildings

Man uses wind power from ancient times by building integrated systems.
The public and industry were at first very cautious about the concept of installing wind turbines on houses, particularly in view of investment feasibility and potentially negative effects in the event of an accident.
But over time, investors dream about constructing advanced wind turbines, and the prices of fossil fuels increase.

We, therefore, see the first buildings with their wind turbine power source.
The World Trade Center in Bahrain is one of them (Fig. 3, Fig. 4).

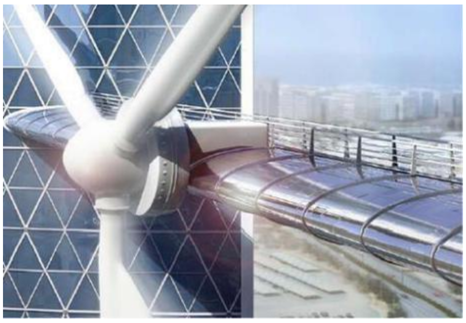


Fig. 3 Detail of Bahrain World Trade Center

In this building, it is possible for analyzing all the arguments for and against the wind turbine integrated into the building.

Fig. 4 Bahrain World Trade Center

The noise produced by turbines is not just low effectiveness and a long payback period. Whatever material from the blades and the shaft bearing makes, the wind flow produces an unpleasant noise regardless of the frequency. The buildings with incorporated wind turbines are also unoccupied on the floors.

But any wind blowing makes the racket if we look at the laypeople. The size of the noise caused by hitting objects which are in their way depends on their strength (buildings, trees, etc.). There has been many research on the effect on the human well-being of wind noise. Reviewing the evidence available for wind turbine noise risks concludes that it poses no risk to human health. When issues occur, they are on a particular basis and do not apply to the general inference that wind turbine noise is harmful. The concept of designing buildings, which will be equipped to generate renewable energy sources for their use, began after the completion of the building in this picture. The best known to be constructed in China is Zero Energy Tower (Fig. 5).

The Guangdong Tobacco Company's investors have agreed to build renewable energy scrapers, They have also hired Skidmore, Owings & Merrill LLP, and the prestigious firm was designing such buildings for this mission. The enterprise has established the idea that the building system and wind turbines can be flowed by the wind. And on the building façade, solar cells can also be installed. The building remains under construction, and we await the first feedback on the skyscraper's energy independence.

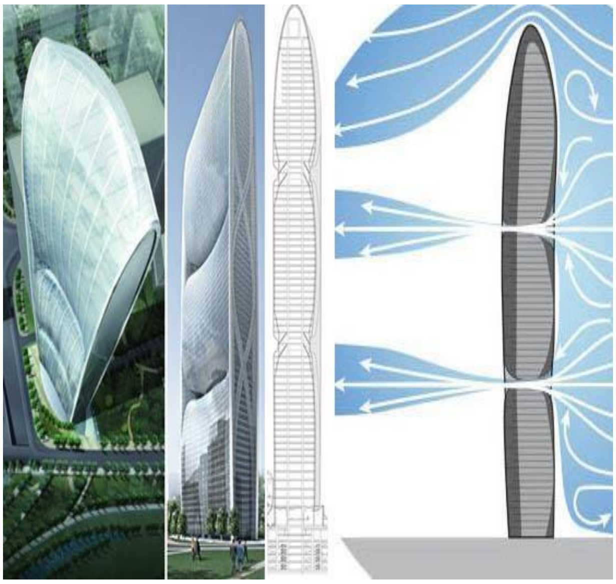


Fig. 5 Guangdong Tobacco Tower in China

Architects began the age of building skyscrapers that are required to generate electricity from their own properties, with the construction of Bahrain's WTC and Zero Energy Tower. The new proposal is the "Castle House" or "Strata SE1" skyscraper project in London (Fig. 6, Fig. 7).

Fig. 6 Detail of the Castle House

Fig. 7 The Castle House, Elephant and Castle in Southwark, London

The controversy has long been over the cost-effectiveness and reliability of such systems, which have three integrated wind turbines in their configuration that can generate illumination electricity and ventilation electricity.

In addition to the skyscrapers in the megalopolises, wind turbines are gradually placed in large sports centers. This can be because such stadiums need a tremendous need for electricity, and many people visit them. This reduces operational costs and raises awareness of clean energies, and also educates people. However, wind turbines pose possible risks. An example is the Manchester City football club which demanded permission in 2006 to set up wind turbines on its stadium but was denied the permit because of reasons of safety (ice on the blades and its threat). The other example of this is the North Texas University stadium, which supports wind turbines and provides about 6% of the electricity needed. As soon as the wind turbines were put on their stands in other US colleges and sports clubs such as the Cleveland State University Baseball Stadium (CSU), "The Lincoln Financial Field," Philadelphia (Fig. 8, Fig. 9), a football stadium "The Riverside Stadium."

Fig. 8 Lincoln Financial Field, Philadelphia

Fig. 9 Detail of Lincoln Financial Field

In addition to wind turbines being integrated into homes and sports fields, designers and developers consider more choices. Thus, wind turbines on roads and bridges have recently been built. Students at the University of Arizona have suggested that a group of wind turbines run by wind tribulation from the cars be operated over a motorway (Fig. 10). Each turbine can generate approximately 9600 kWh of electricity per year and transmit it through the power grid. Besides this definition, there is an idea of building bridges and viaducts with constructing wind turbines. The bridge between Italy and Scilla Bagnera is to be one of these terms. (Fig. 11).

Fig. 10 Horizontal wind turbines on the highway

Fig. 11 Wind turbine in bridge, Bagnera Scilla in Italy

If you consider the concept of building new wind turbines for efficiency and energy independence in any possible structure, it is challenging to neglect all their issues. Over and above the long payoff time and noise, embedded wind turbines in the buildings have been blamed for posing a danger to the environment by blades. Since the blades sometimes measure 30 feet in length and plunge from tens of meters, if any mounting protection device fails, all homes, roads, and passengers are theoretically threatened within a range of several hundred yards. So far, there hasn't been a confirmed event (or, if any of these instances, suppliers and owners at least don't want it to be public), but a possible danger exists.

The fourth and greatest challenge is that the blade movement produces vibrations. The building and its construction are conveyed by vibrations and create an extra strain. Many construction planners address this issue and how it can be solved by offering various shapes and locations of wind turbines, but the problem still persists. The overall result is that constructing buildings with assembled turbines must be based on vibration stress. Unless you take this into account during the construction of the structure, structural stress can be close to an earthquake and building destruction. Today we will see a significant number of wind turbines made from diverse materials with the advancement of innovative technology and materials on the market. Increasingly, a wind turbine with carbon fiber blades and fiberglass blades can be seen on the market, which is much simpler, flexible, louder, cleaner, and more costly as compared with various aluminum alloys.

Each wind turbine maker (unabhängig of the building mounted) says they have an efficiency which seems good on paper. However, as you begin to calculate the electricity produced, these findings decrease significantly as wind turbine investments become feasible as independent energy producers. Let's look at constructing integrated wind turbines (BAWT and HAWT) rather than a small amount of energy produced. We find costly estimates that require various long-term efficiency and test model calculations. If the findings of such studies validate our return on investment, the issue remains whether this is, in fact, the same in the sector. Since the laboratory conditions are far from on the floor, usually, these turbines are paired with another form of renewable energy.
We also much meet wind turbines for publicity purposes, which illustrate how businesses are eco-friendly or attract passengers to learn about renewables. Thus, turbine advertising has been set up in Florida along the entire road to promote wind turbines (Fig. 12). But the most frequent comment, though, is that in most cases, the lambs don't spin, and their inference is that it may not fit at all, considering the environmental assessments, i.e., the transients.

Figure 12 The commercial wind turbine, Florida 5. Conclusions

Wind turbines designed for buildings that use higher wind speeds must be prepared for various flow modes. The most appealing choice is to put the turbines up or next to a building in the light of the required changes in the building to allow good flow properties for the wind turbine. Compared with the winds off-shore, a vertical axis wind turbine may be preferable for the ceilings due to different wind conditions as a lower overall wind speed and greater turbulence strength.

In addition to the skyscrapers in the megalopolises, wind turbines are gradually placed in large sports centers. This reduces operational costs and raises awareness of clean energies, and also educates people.

If you look at the concept of building wind turbines in the urban world, all of the problems which surround them cannot be ignored. Besides the long payback time, noise and turbulence, integrated wind turbines are often blamed for the risk posed in the atmosphere by blades.

3.6 Economic Evaluation

Abstract

We look at different facets of the construction and operation of small wind turbines. First of all, an extensive literature review considers the specifications of wind turbines, industry figures, the smart grid, prosumer principles, and the main criteria influencing wind turbine performance.

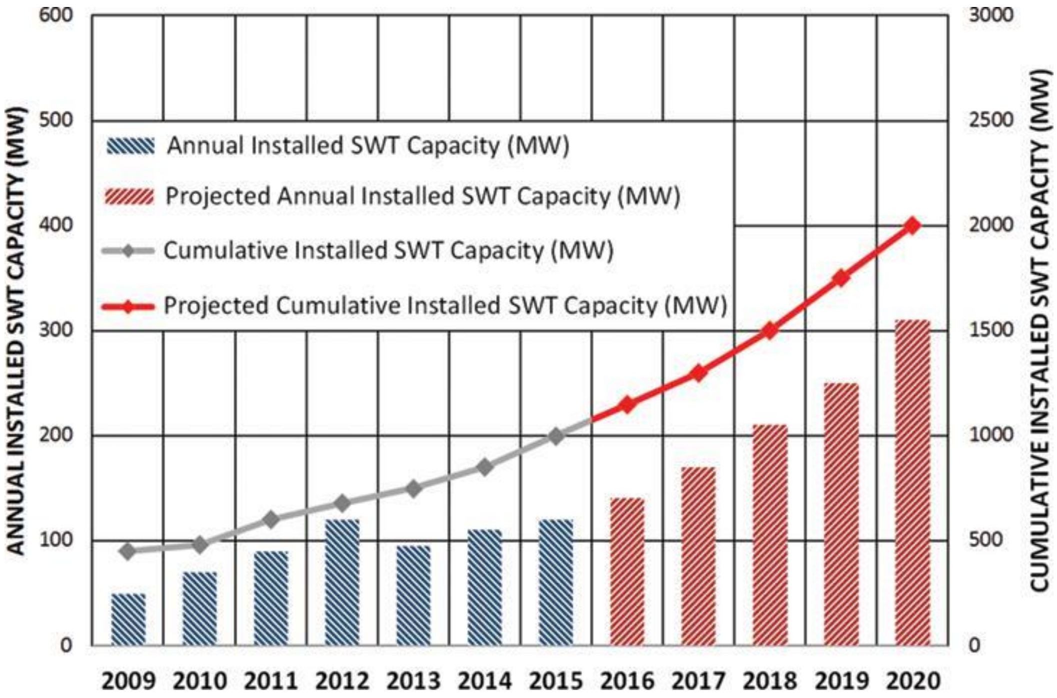
Subsequently, the literature review and series of combined numerical simulations was conducted to investigate the effect on small wind turbines of the selected design solutions.

Objective assessment of various design methods permitted the systematic recognition of current limits and the possibilities for specific wind turbine design solutions:
Finally, based on the numerical analysis carried out, a number of design priorities for the next wind turbine are proposed.

1. Introduction

A different category of devices built in the wind energy industry is small wind turbines (SWT's). SWT's Wind turbines in this segment are typically suitable for small and individual customers, including homes, mills, wind farms, road signage, and publicity programs. In several remote electric applications, SWTs provide a viable solution, where wind resources can be defined as provided a set of site assessment parameters.

Beneficial in conjunction with other energy conversion systems such as photovoltaic, hydro, or diesel engine as independent applications. With a growth of about 10 percent, the number of SWTs working worldwide increases per year. It is unfortunate given the immense promise of wind power (best around the coasts and in the highlands of the continent). A global outlook for installed capacity SWTs is proposed in the years 2009–2020.



Dumat Al Jandal will be in future the first wind farm in Saudi Arabia and, once built, the largest in the Middle East.

By the arrival in Duba Port of 20 wind turbines, Dumat Al Jandal's wind farm in Saudi Arabian has marked a key building milestone. A consortium led by EDF Renewables, in collaboration with Masdar, is developing the 400-megawatt MW Wind Power Project.
At the Dumat Al Jandal location, 900 km north of Riyadh in the Al-Jouf area of Saudi Arabia, wind turbines consisting of towns, blades, and nacelles will be installed.

There are a total of 99 wind turbines from Vestas V150-4.2MW mounted with a hub height of 130 m and a rotor diameter of 150 m.
Vestas is also responsible for the engineering, manufacturing, and maintenance contracts for the project, while the plant balance is maintained by TSK, while the Al Babtain Contracting Company provides the project substations and high voltage solutions.

Dumat Al Jandal going to be the first wind farm in Saudi Arabia and, once built, the largest in the Middle East. Construction started last August, and in the first quarter of 2022, commercial activities could commence.
The wind farm will fuel up to 70,000 Saudi households until fully operational, thus displacing around 988,000 tons of carbon dioxide a year.

In January 2019, after a competition tender in which it submitted the lowest offer in the region of US$21,3 per megawatt-hour, the Renewable Energy Projects Development Office of the Saudi Ministry of Energy awarded US$500 million Dumat Al Jandal wind farm to the EDF Renewables-masdrar consortium.
At the financial closure, the tariff further increased to USD 19.9/MWh, making Dumat Al Jandal the world's most economical wind plant.

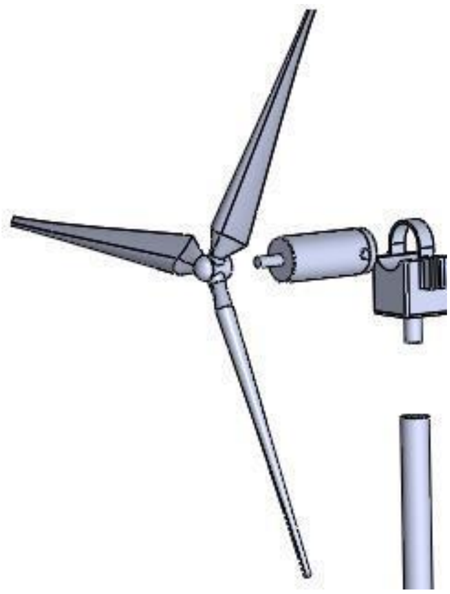
The wind farm Dumat Al-Jandal will provide power to Saudi Power, a subsidiary of Saudi Electricity, a Saudi power generation and distribution corporation, under a 20-year power purchases deal. The wind farm will supply electricity.
"Dumat Al Jandal is our first wind power project to produce power at scale and is a major project under the King Salman Renewable Energy Initiative and has a key role to play in the lasting diversification of Saudi Arabia's power mix," said Osama bin Abdulwahab Khawandanah, CEO of the Saudi Power Procurement Company, which manages the entire production of the Dumat al Jandal project.

"Dumat Al Jandal represents our close relationship with the private sector and the economic viability of wind power, allowing us, in line with our Vision 2030 reduction, to develop a sustainable renewable energy sector in the Kingdom."

"This main construction landmark at the largest wind farm in the Middle East highlights the progress made by the consortium and its suppliers in the project delivery phase, thanks to supporting from the Kingdom authorities and from the entities responsible for implementing the National Renewable Energy Programme. Frédéric Belloy, EDF's International Executive Vice President, said in his turn.

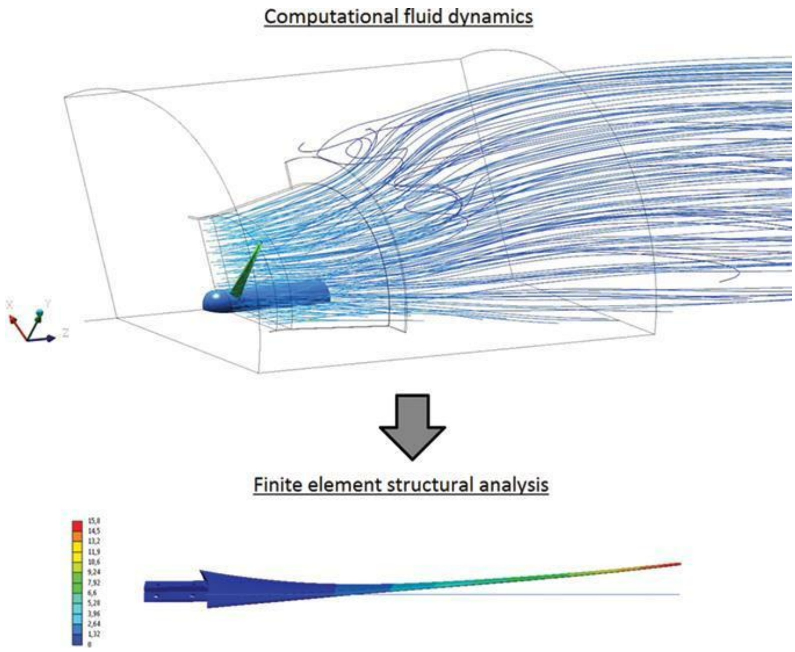
2. SWT design solutions

2.1. Shrouded SWTs



2.2. Other SWTs designs

Aerodynamics improves performance with the amount of blade. The primary driver for the construction of multiblade turbines (up to three). A rise of six percent in aerodynamic Efficiencies of one to two blades, although an increase of just three percent inefficiency of two to three blades.



SWT blade deflection

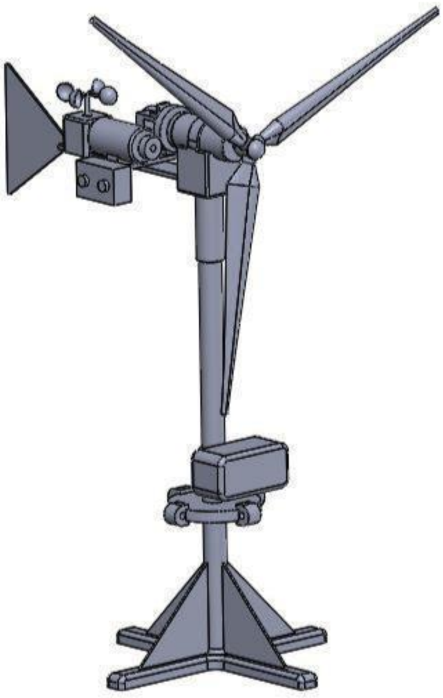
2.3. SWT's generators

SWTs normally come with synchronous generators with varying angular velocities dependent on permanent magnets (e.g., neodymium magnets). It is a design approach that can help achieve effective operational requirements. Many other facets of wind turbine operation include, for example, a considerably greater yearly output of electricity compared to the equivalent power of fixed pitch, fixed speed turbines, are determined by the working principles of the variable speed generator.

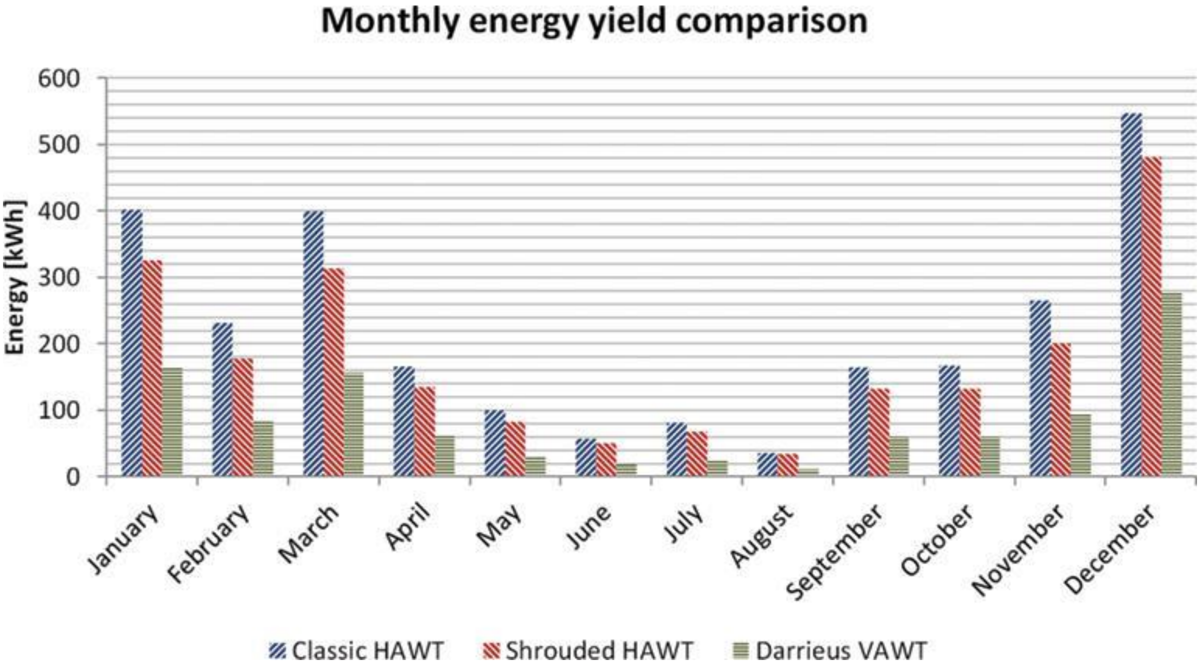
The potential cost for linking the SWT to the power grid increases the normal financial gains from the potential revenue generated from the sale of electricity. The other factor is that SWTs are normally simplistic machines and hardly have advanced control structures, such as blade pitch mechanisms.

This form of generator generates alternating current (AC) to be adjusted by a single bridge rectifier to direct current (DC). The DC voltage enables the use of these battery charging turbines, similar to the Solar Photovoltaic (PV) devices. A charge controller is introduced for in-battery charging systems to avoid overcharging of the battery. To avoid overvoltage of the inverter and the turbine from over-speeding, the dumping load is necessary.

2.4. SWT's supporting structures



3. SWT's economic evaluation



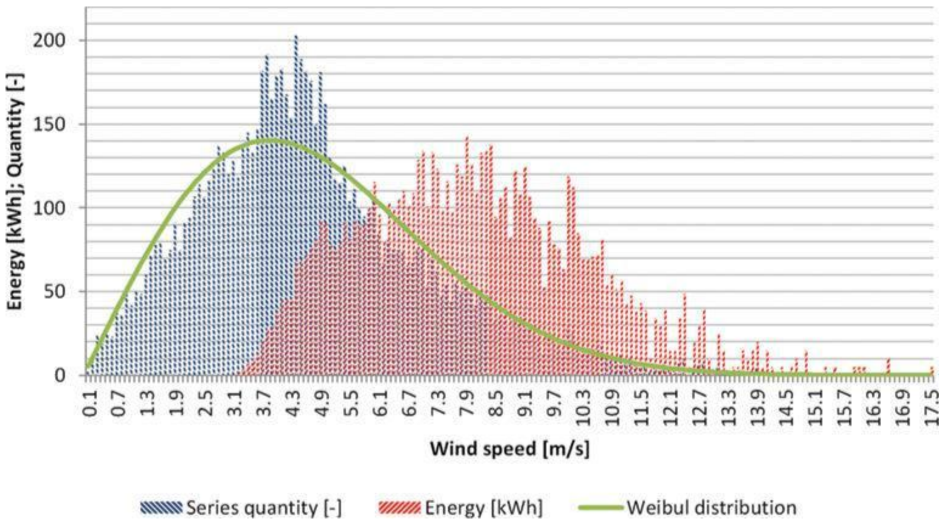
Every month for the turbines, they are selected.

With most electricity generated during windy winter periods, the gap in monthly power production is readily apparent. Maintenance or regular inspections needed.

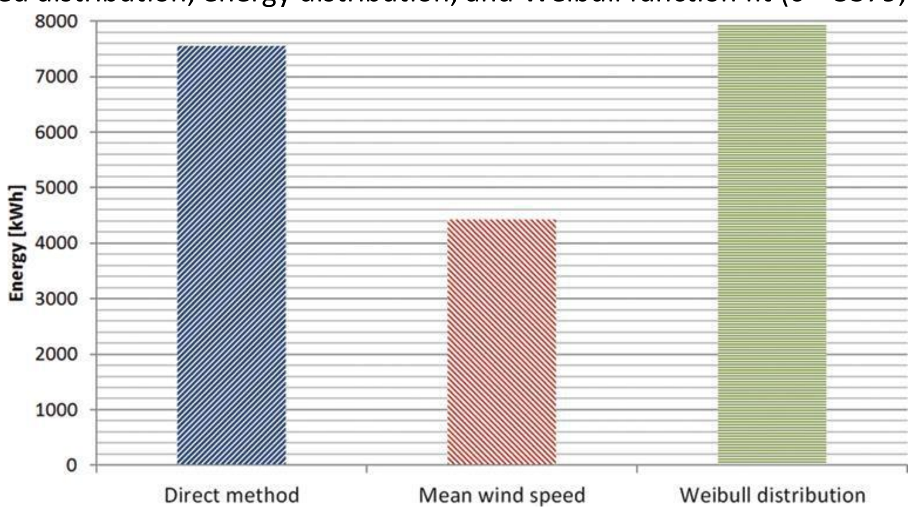
During the quiet summer months should be performed. The dilemma of continuous power supply arises from such a disparity of energy generation.

Although it's the lowest-rated strength for the selected place, the classic three-blade HAWT proved to be considered the most economical construction. In principle, high theoretical efficiency was achieved by the advanced development of the shut HAWT turbine. In operation, it proved somewhat less than the classic configuration of a larger rotor because of the limited rotor diameter. In addition, because of extra mass and increased aerodynamic drag, the jackets are likely to place additional pressure on the frame, which will raise maintenance costs. Snowfall and freezing could reduce operating availability and make deicing necessary. In terms of cost efficiency, the selected Darrieus vertical wind turbine was the worst build. The return time was unacceptably long due to high machine costs and the poor performance in comparison with the rotor capacity.

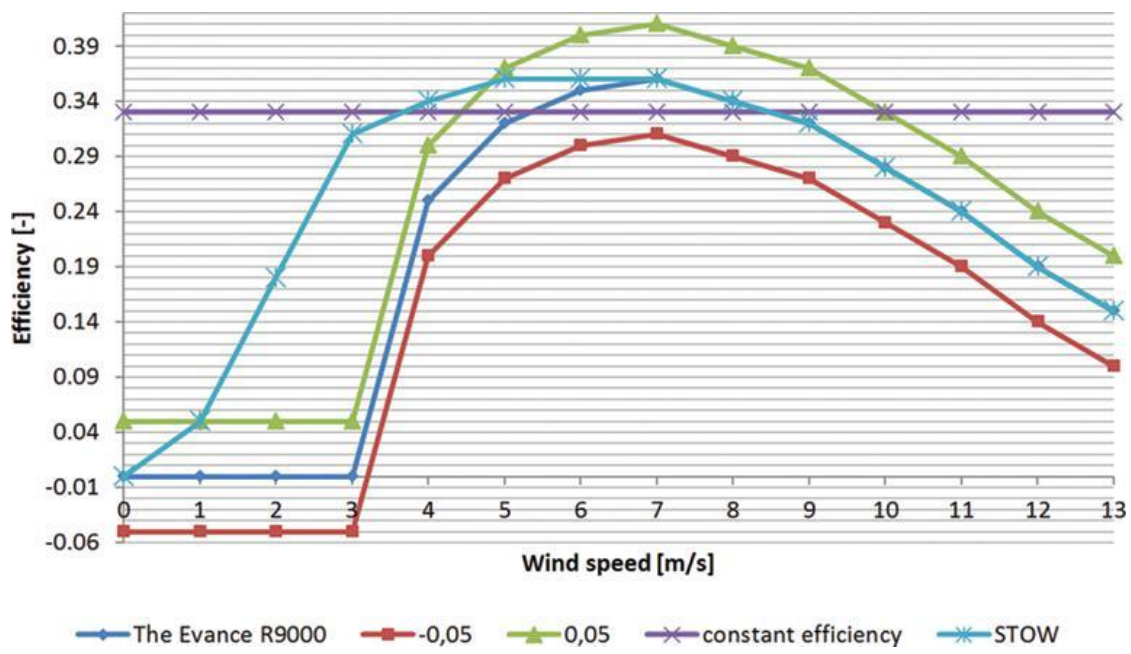
3.1. Investigation of parameters influencing the efficiency of SWTs



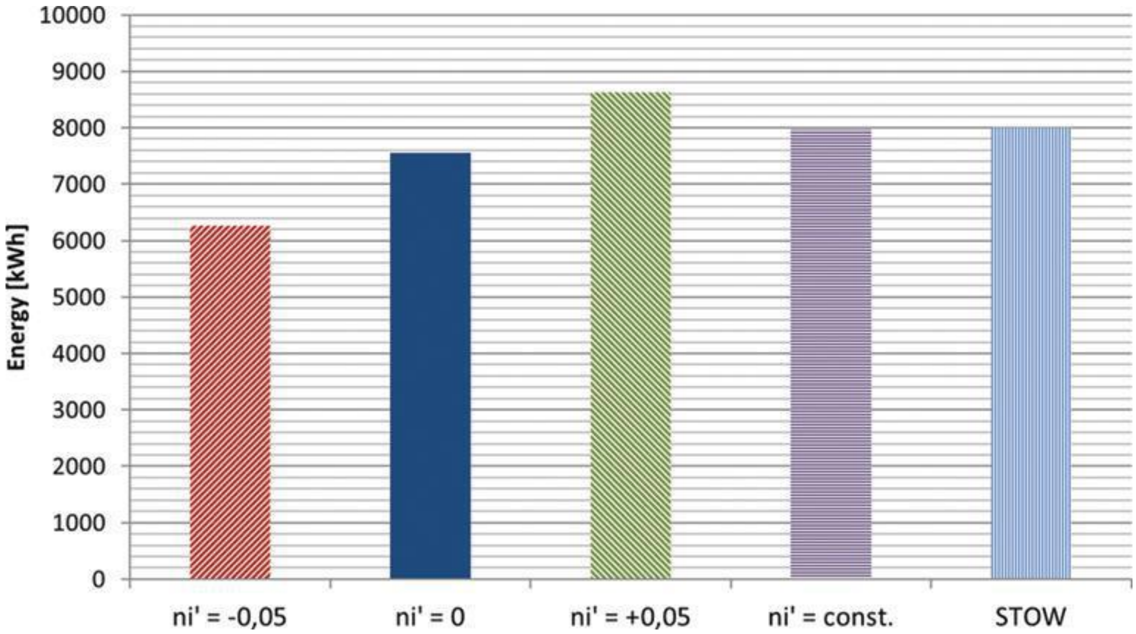
Wind speed distribution, energy distribution, and Weibull function fit (c = 5379; k = 2023).



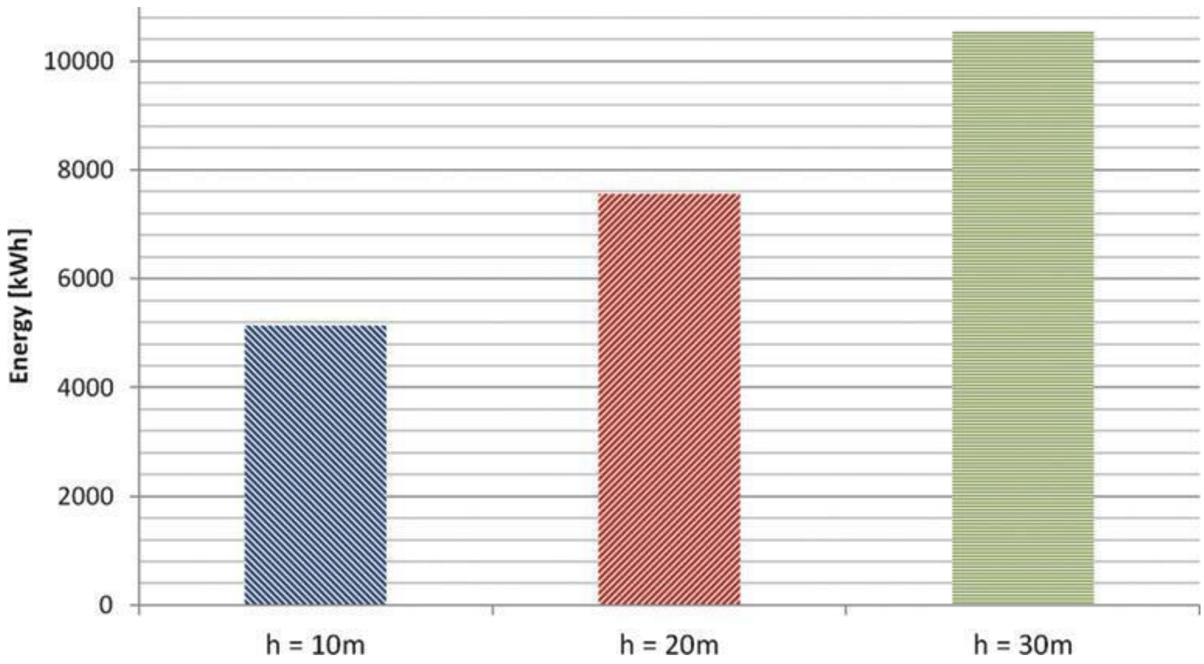
Energy production estimates based on three different wind speed data types.



Efficiency curves used for the energy calculations.

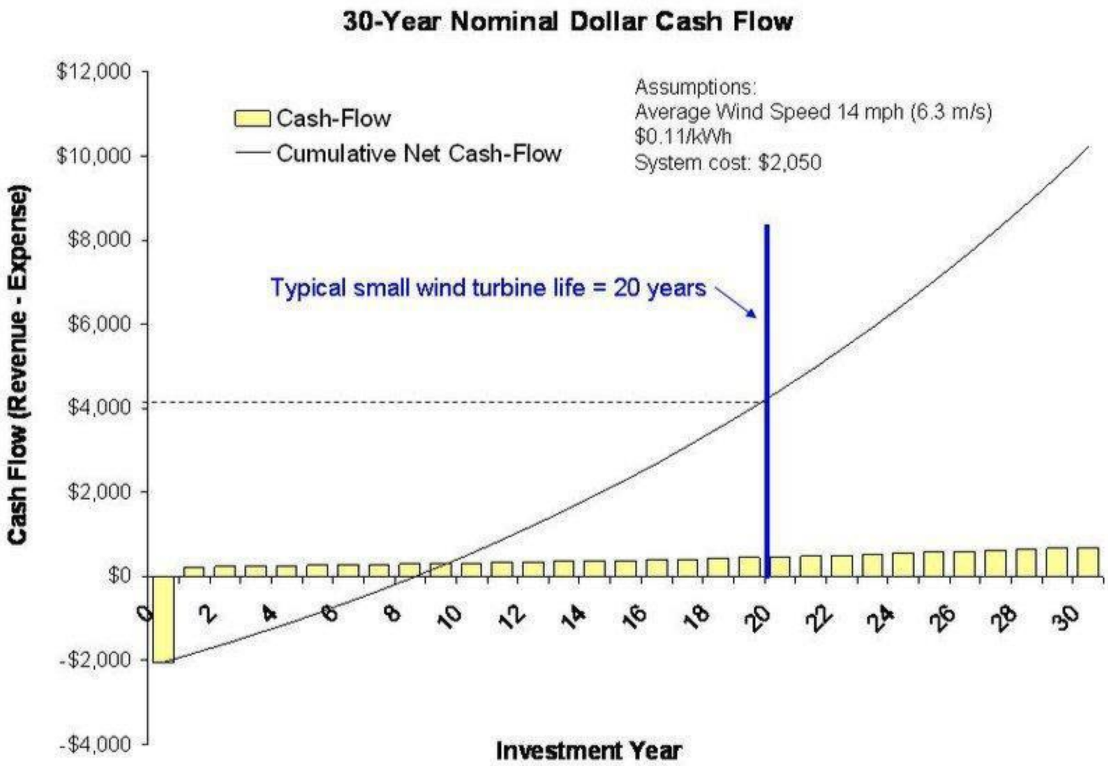


The energy produced by a turbine of 5 kW with different curves of efficiency; the series is linked to the curves shown in Figure 11. The tower height was the final parameter of the small wind turbine. At the height of 10 m, data on wind speed were obtained. According to the power-law, the wind speeds have been recalculated for the whole year at 20 and 30 m heights with the field dependency parameter $\alpha = 1/7$. The wind speeds obtained have been used to approximate the power generated with the standard power curve and are shown in the figure.

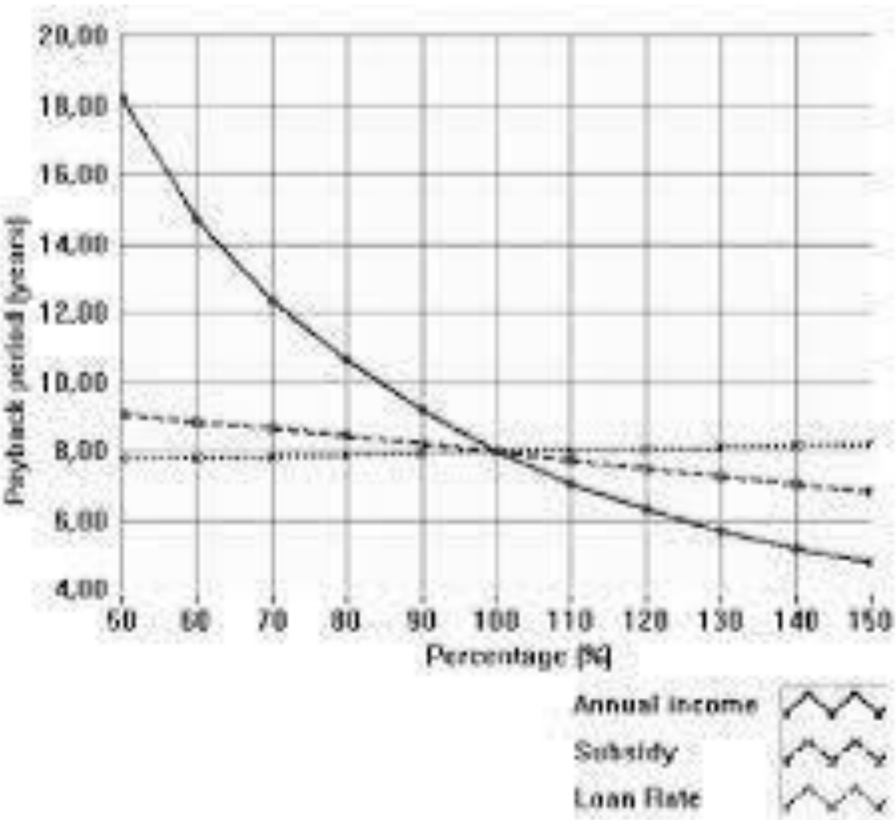


Estimated wind speed provided by the empirical power law for different tower height variants (10, 20 and 30 m)

Cash flow diagram (expenses, revenues, profits)



Payback period chart



A large number of parameters should be considered when measuring a small wind turbine's return on investment.

First of all, lifetime risks must be calculated. They generally consist of the initial price of small wind turbines, transport costs, installer cost, and repair expenses (foundation price plus real work) (yearly maintenance fee multiplied by small wind turbine lifetime, usually around 20 years).

Secondly, you have to quantify the annual benefit, the price of electricity generated (Extracted from the kWh yearly generation of electricity by a total of one kWh of grid price and feed-in tariff per kWh). It should also be considered the price of power increases per year, which should also be included in the measure.

The outcome is divided into annual earnings, revealing how many years it takes for the tiny wind turbine to pay and start profiting. Anything under ten years is reasonable with a 5-7-years return time and a strong wind conditions position with a large feed rate, and power price will go as low as three years. Anything beyond the ten years is acceptable.

Operation and Maintenance Costs of Wind Generated Power

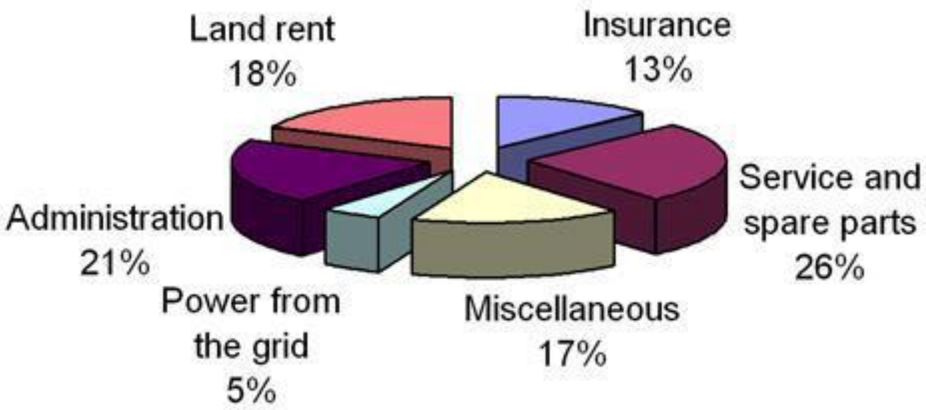
Operating and maintaining (O&M) expenses are a significant proportion of the wind turbine's gross annual costs. O&M costs will easily account for 20 to 25 percent of the level of the overall cost of a new turbine per kWh produced over the turbine's lifetime. If the turbine is equal

New, the share may only be 10-15%, but by the end of the turbine's life, it may rise to at least 20-35%. As a result, O&M costs increase, as manufacturers are dramatically reducing these costs by developing new turbine designs that require less frequent service visits and less turbine downtime. O&M fees apply to a few cost components, including O&M costs

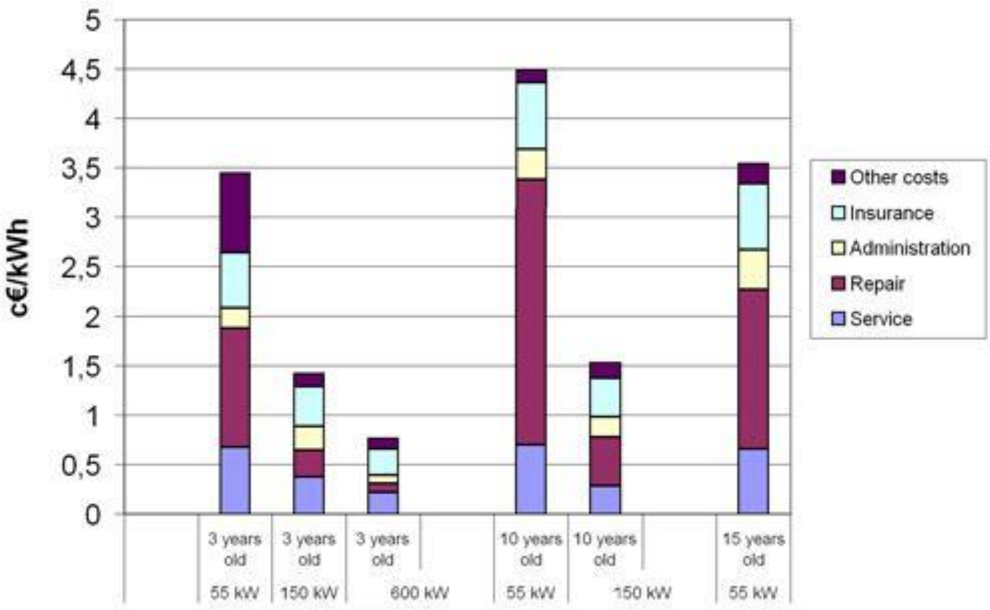
Insurance; and;

Maintenance regularly; repair;

Spare bits and management.



Different Categories of O&M costs for Turbines



O&M Costs as Reported for Selected Types and Ages of Turbines

4. Summary

Due to the long ROI cycle (even for standard and established designs), installation in areas with more than normal wind conditions is very important. It is advisable to use the produced energy immediately to prevent energy loss on an AC/DC/AC electricity conversion.
The use of power banks increases investment costs enormously and is environmentally dangerous since the batteries used are tough to recycle.

Above all, however, it has been seen that even a significant improvement in turbine aerodynamics and total efficiencies would provide no more power than an increase in tower height. The beneficial effects of aerodynamic rotor optimization, the use of advanced, light materials, etc. in turbine operation and power output;
With regard to all of the above, consideration should be given to minimizing the price of the finished product and mounting configuration on the tower as economically and lawfully as is realistically clear from the point of view of the aeromechanical and operational safety as a critical aspect of the development of modern small wind turbine solutions.

Risk Assessment of Hazards Due to the Installation and Maintenance of Wind Turbines

The following terminology used in the risk evaluation process is described as follows in accordance with the standard "Occupational health and security – risk recognition and elimination and risk appraisal and control":
The chance is the combination of the likelihood of a harm occurs and

The harm's severity.

The ultimate hazard recognition process, risk analysis, and risk management is risk assessment.
Risk evaluation requires an understanding of threats, factors, effects and

Odds with them.
Danger recognition is the mechanism by which hazards are identified, listed, and characterized.

Risk identification is a method to understand and determine the existence of hazards.

The danger levels.

Risk assessment the comparison between the expected risk and the risk parameters is a procedure.

To assess the risk's importance.

A risk assessment is used to minimize or monitor risk as to the basis for a decision. This move is called risk management.

The level of risk must be calculated to assess which danger to begin treatment before adopting risk management steps. The Risk Matrix displayed in Table I is one of the common strategies employed for ranking or priority risks, where the vertical column indicates the probability of risk, and where it occurs, the horizontal line demonstrates a risk magnitude.

In this qualitative process, the mixture of probability and magnitude decides.

Risk level; it must be decided accordingly which steps to monitor and minimize risk should be taken—risk level.

The following sections address different risk categories during the construction, service, and maintenance of wind turbines.

Table I. Risk matrix showing the risk likelihood and severity

	A	B	C	D	E
E	Low Med	Medium	Med Hi	High	High
D	Low	Low Med	Medium	Med Hi	High
C	Low	Low Med	Medium	Med Hi	Med Hi
B	Low	Low Med	Low Med	Medium	Med Hi
A	Low	Low	Low Med	Medium	Medium

Fig. 1. Risk assessment process

RISK OF WORKERS SLIPPING, TRIPPING AND FALLING

A. Hazard Identification.

Any sections of a wind turbine are in use for a long time, while others are subject to extreme weather conditions. The wind turbine must be well monitored to ensure that it remains working. Regular wind turbine servicing involves air filters, brake pads, tower bolts and lubrication. The key parts found in the body of the tower, such as the rotor, gearbox, laying mechanism etc, have the most maintenance needed. Maintenance teams may cause such forms of dangers, such as sliding, triggering and dropping for the maintenance of these components.

B. Risk Analysis.

High resistance is required to climb a wind turbine. This means staff ought to climb high altitudes using the internal wind turbine tower-mounted ladders. Modern wind turbines can, however, also have electrical lifts that may minimize specific hazard categories. In scaling towers of wind turbines, maintenance crews face the danger of stumbling and tripping. If the wind turbine tower's cross-sectional area becomes somewhat smaller in height, the risk becomes more pronounced. However, whether they were fitted with a cage as well, the ladders would have landing platforms every 30 feet. However, if the cages or the wells are not fitted, the landing platform shall be every 20 feet as required by the rules on occupational health and safety (OSHA).

In addition, during the construction and maintenance of wind turbines, staff are subject to decreasing risk. For the welding, fitting, maintenance, and installation of test equipment and electric cables, they may need to access separate wind turbine parts in heights above 100 feet. Consequently, protective precautions became compulsory to prevent a chance of high altitudes coming down. This ensures proper, stable, strong, and routine maintenance of the machinery. Workers should still be trained to only function while they have health and psychological problems.

C. Risk Evaluation / Likelihood.

If the appropriate safety precautions and rules are taken into consideration, the probability of sliding, trickling, and falling should not be too high. This means using the right tools, training, fitness and personal protective equipment for staff (PPE).

D. Risk Evaluation / Severity.

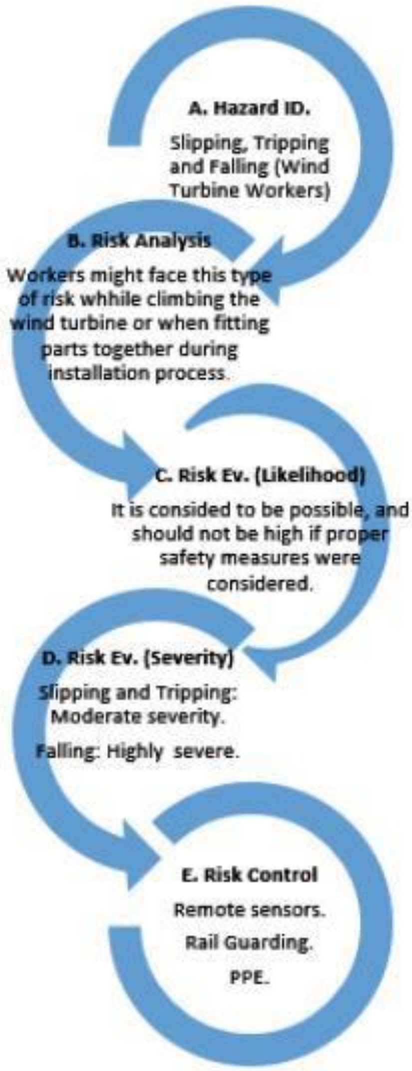
Series of slips and tricks need not be strong when scaling wind turbine ladders. The chance of the wind turbine collapsing while doing the necessary

Parts are heavy in repairs or installation. But the true level of severity depends on the situation and can be determined after all prevailing circumstances and causes have been studied.

E. Risk Control.

In wind turbine servicing, the issue becomes more evident in the case of wind farms because it is not possible to send maintenance teams to check on each wind turbine manually. Therefore, it is practical and effective to use remote monitoring technical instruments to provide information on the functionality of the wind turbine. It decreases the risk and costs of manually inspecting the wind turbines by dispatching staff. According to OSHA guidelines, railings must shield construction teams who operate in certain environments and are exposed to drop hazards up to 4 feet. In case such a railing is not accessible, staff must wear the correct EPP, for example, a personal drop-off or safety net. Fig. 2 demonstrates the stumbling, tripping, and sinking employees' risk study.

Fig. 2. Risk analysis of workers slipping, tripping and falling.



RISK OF ICE ACCRETION AND IRREGULAR SHEDDING ON WIND TURBINES
A. Hazard Identification.

The cold climate influences the functioning of wind turbines and, through the ice accretion on wind turbine blades, raises significant problems for the wind energy sector. The accreted ice isn't spread evenly on wind turbine blades, compared with the root areas. It is found that more ice accretes around blades. The annual depletion of ice power varies from 20 to 50 percent. Wind turbine ice fragments can harm people and destroy the environment, including nearby turbines.

B. Risk Analysis.

A load of accredited ice will exceed up to 50% of the weight of a structural bladder, which puts the structural stability of the wind turbine and the surrounding areas at serious risk. Irregular ice accretion and blades dumping will lead to imbalances in the load, increased fatigue loads, vibrations in wind turbines. There is also a potential risk of accumulated ice being cast away as the blades melt while the centrifugal force is spinning.

C. Risk Evaluation / Likelihood.

Wind turbine blades would likely be hung and irregularly dumped due to harsh weather in the Arctic, particularly in this area. The precise probability depends on certain aspects, including the application of de-icing technology.

D. Risk Evaluation / Severity.

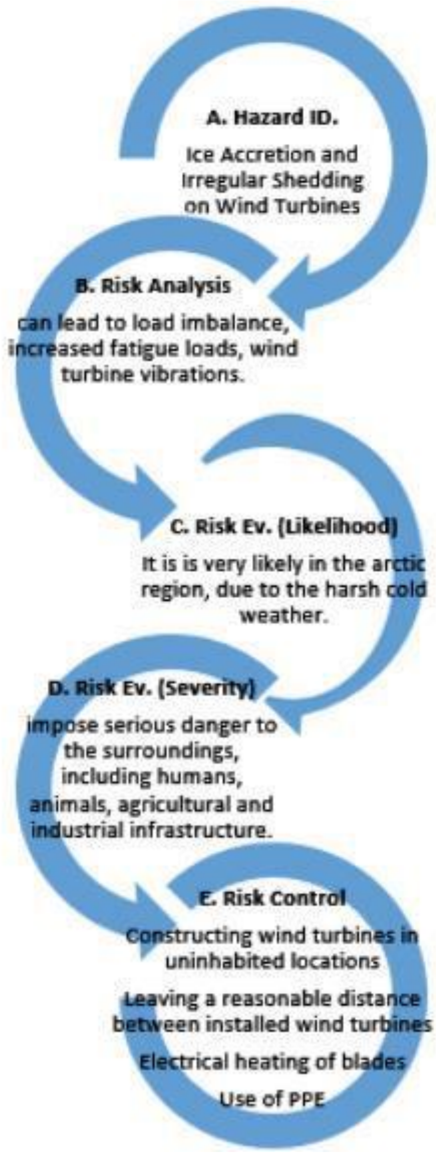
In the event that ice is fallen by the blades of the wind turbine, the ice accretion imposes grave dangers to the region. Ice removal can cause human and animal injuries. The construction of housing complexes, farm infrastructure, and manufacturing facilities, as well as wind turbine blades, are susceptible to ice removal.

E. Risk Control.

Safety steps should require wind turbine construction in uninhabited areas, away from highways, agriculture, and industrial infrastructure. Furthermore, wind turbines with a reasonable gap must be designed to prevent each other from suffering damages. It should be left approximately 250 m from the wind turbine to minimize the chance of dropping ice in service and 50 m from the blades. Electric blade heating can help eliminate or reduce ice build-up and shedding. This suggests, however, that any strength is lacking to resolve the glacial situation

The issue. The thermal anticipation device has been reported to require a power sum equal to at least 25% of the maximum rated capacity for wind turbine ice build-up. Fig. 3 indicates an ice accretion risk study and intermittent wind turbine shedding.

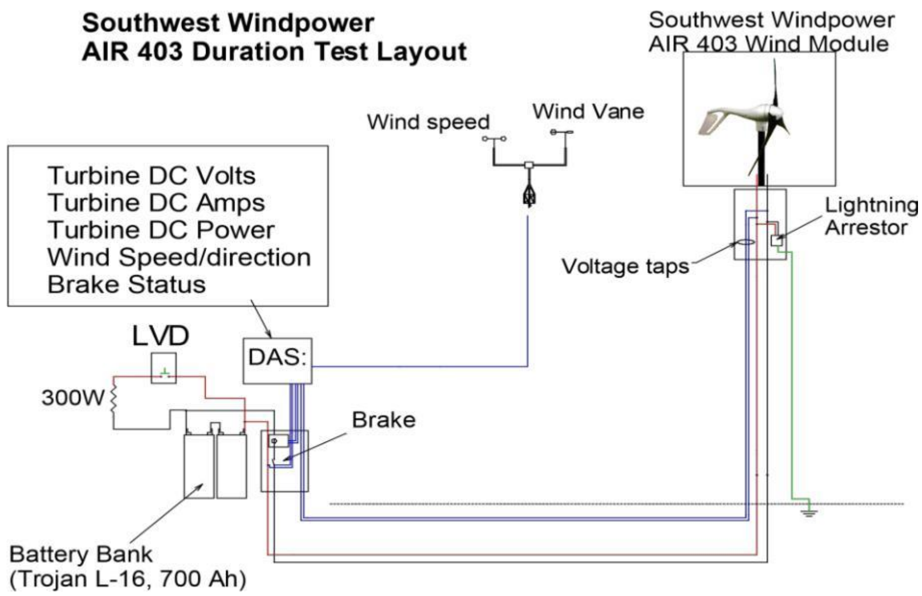
Fig. 3. Risk analysis of ice accretion and irregular shedding on wind turbines



This paper presents an evaluation of various types of threats related to the use of wind turbines. The study incorporates a comprehensive risk management approach to determine the necessary actions to avoid and mitigate risks.

Chapter 4: Constraints and Methodology

4.1 Experimental Setup, Sensors and data acquisition system

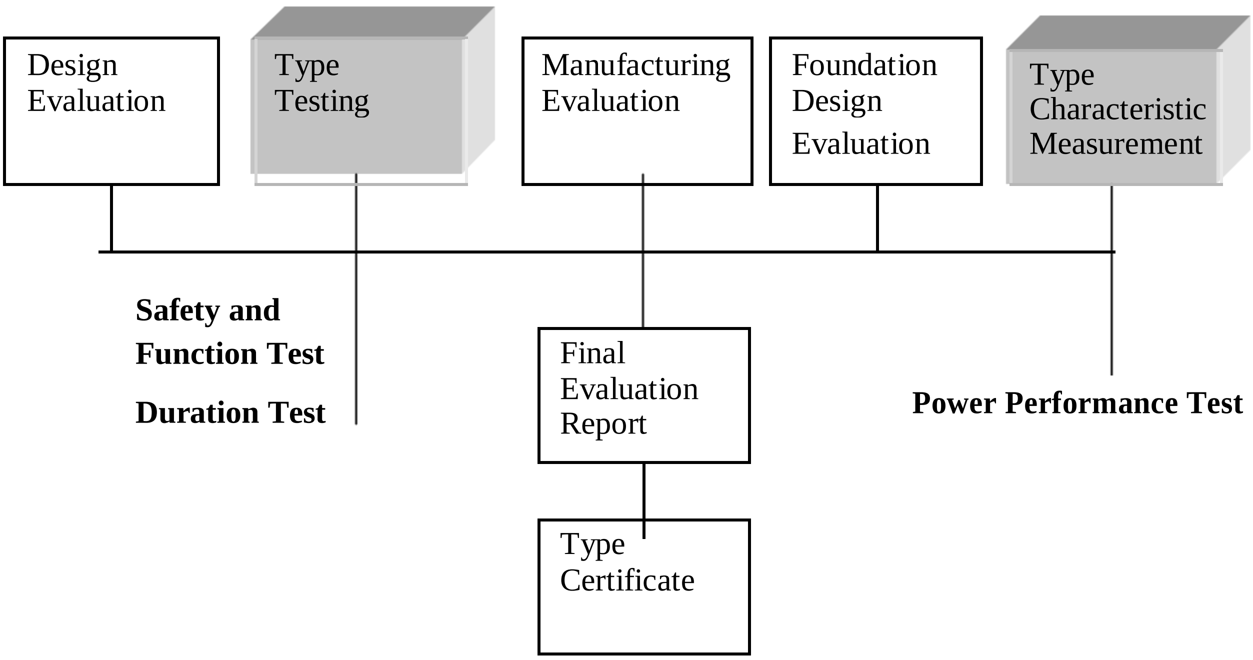


AIR 403 DURATION TEST SCHEMATIC

	Test Turbine
General Configuration	
Make, Model, Serial Number	Southwest Windpower AIR 403, #19825
Rotation Axis (H / V)	H
Orientation (upwind / downwind)	Upwind
Number of Blades	3
Rotor Diameter (m)	2 ft
Hub Height as tested (m)	10 ft
Operation	
Rated Electrical Power (W)	12
Rated Wind Speed (m/s)	12.5 (28 mph)
Cut-in Wind Speed (m/s)	2.7 (6 mph)
Rotor	
Swept Area (m^2)	1.8 (19.4 ft^2)
Blade Pitch Angle (deg)	2.5

Direction of Rotation	Clockwise
Control and Electrical System	
Controller: Make, Type	Arduino
Electrical Output Voltage	Nominal 12 volts

4.2 Results, Analysis and Discussion



Safety and Function Test

The aim of the safety and function test is to ensure that the turbine is equipped to work safely in any situation. This testing focuses on the turbine's control mechanism. Small turbine control systems, on the other hand, are also simple and passive.

The study findings are used in the savings and security tests of the Wind 403 turbine:
Service of an emergency shutdown. Perform a brake checks to confirm that the turbine fails once the brake is applied in high winds.

Controlling the amount of power and rpm. Check that the blades' aero-elastic stall function restricts speed and power in high winds, and that the charge controller limits current when the battery voltage is greater than or equal to the charge controller voltage set-point.

Balance the yaw. A test plan will be established if issues are discovered during the visual inspection.

Loss of grid attitude. The open circuit test involves a 4 Hz current sampling to ensure that the turbine controller's internal braking function reduces current to zero.

Defense against going too far. Check that the "aeroelastic stall" of the blade decreases current performance.

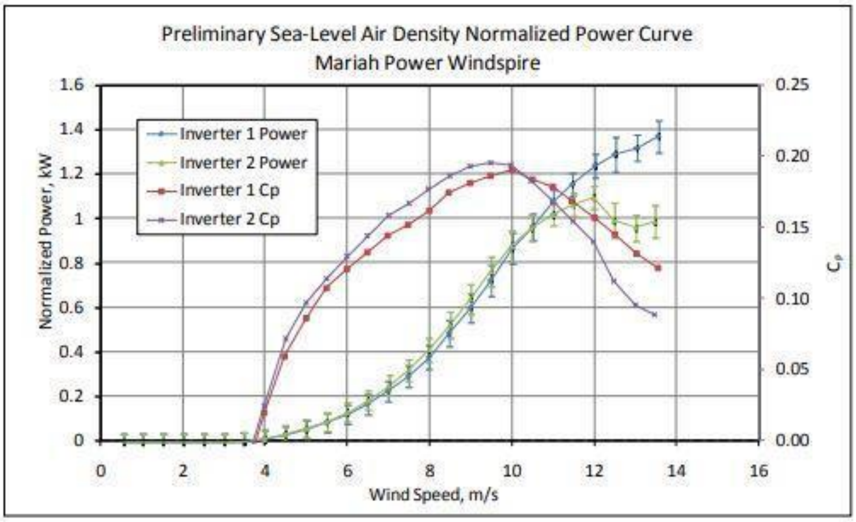
Test Method	Comment	Complies with Design
Power control	Turbine controls power output per design	Yes
Rotor speed control	Turbine controls rpm to 61, per design	Yes
Normal start-up	Turbine starts after several motor pulses in design wind speed and above, and below cut-out; over-speed error on start-up after manual shutdown	Partially
Normal shutdown	Turbine shuts down normally in winds less than cut-in and greater than cut-out	Yes
Emergency stop	Turbine stops within 2 to 3 seconds of pressing emergency stop button	Yes
Loss of grid	Turbine brakes immediately and stops within 2 to 3 seconds of load loss	Yes
Undervoltage / overvoltage	In an overvoltage simulation the turbine brakes immediately	Yes
High wind speed shutdown	Turbine stops in winds greater than 25 m/s and waits for start-up per the design	Yes
Rotor overspeed	Turbine brakes immediately in simulated 10% overspeed and deploys tip brakes at 15% simulated overspeed	Yes
Generator overcharge	Turbine brakes immediately in simulated generator overcharge	Yes
Excessive vibration	Vibration error registers on turbine controller after activating vibration sensor	Yes
Cable twist	Cable-twist error registers on turbine controller after lifting cable-twist arm	Yes

Duration Test

As previously stated, the period test can be used to replace the blade tests and load measurements used for small turbine type testing. Since a period, test is normally simpler to perform than blade and load tests, this deviation from the large turbine norm can help minimize the cost of testing small turbines.

The turbine must be tested for 1,500 hours of power generation over a six-month period, as well as 250 working hours in winds greater than 10 m/s (22 mph) and 25 hours of operation in winds greater than 15 m/s (33 mph). The turbine must perform at least 90% of the time to meet the operating requirements.

Power Performance Test

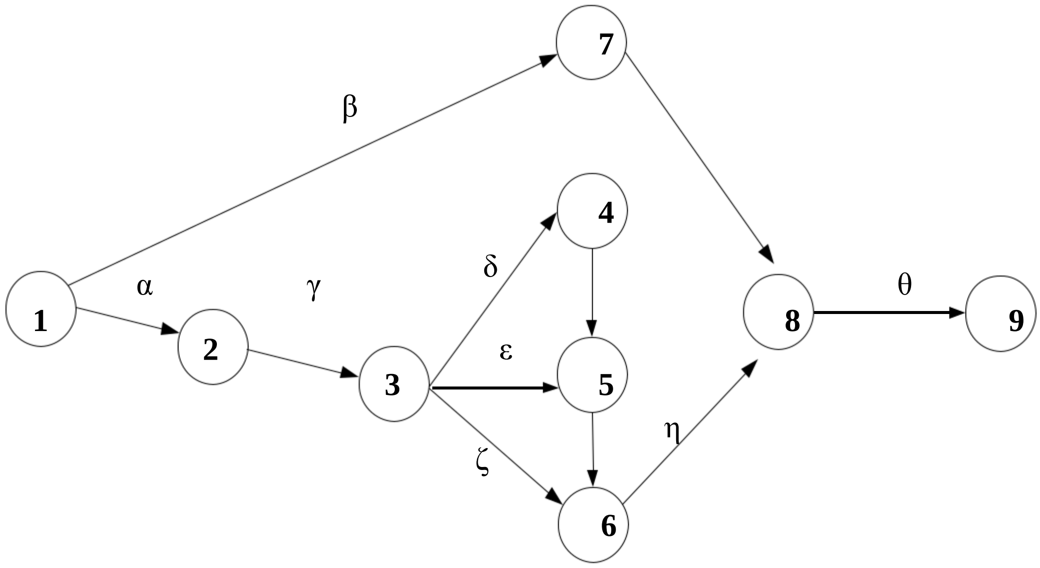


The significant productivity assessment is based on the IEC 61400-12 standard, with a few tweaks to account for the effect of battery state-of-charge for example load voltage difference on output power. The electrical load is operated at voltages corresponding to a battery SOC of approximately 40%, 70%, and 100%, with each SOC voltage requiring 60 hours of service. In fact, each 0.5 m/s (1 mph) wind speed bin needs 30 minutes of data for each of the three voltage settings. The variation of the power curve as a function of voltage will be tested to assess the sensitivity of the power curve to battery SOC since this is the first power output test for a small wind turbine certification.

The final power curve would be an average of the three voltages if the voltage difference has a slight effect on the power output. If voltage has a major impact on the performance of the power curve (e.g., greater than 5%), the power curves for the three voltage settings can be shown separately.

Chapter 5: Project Management

5.1 Project Plan



list of tasks & time duration for each task

Activity Code	Activity	Duration Time (Day)
α	Foundation	8
β	Generator and cable network	4
γ	Control Equipment	3
δ	Tower	3
ε	Nacelle	5
ζ	Rotor blade set	8
η	Wind turbine completion	8
ϑ	Trial operation	3

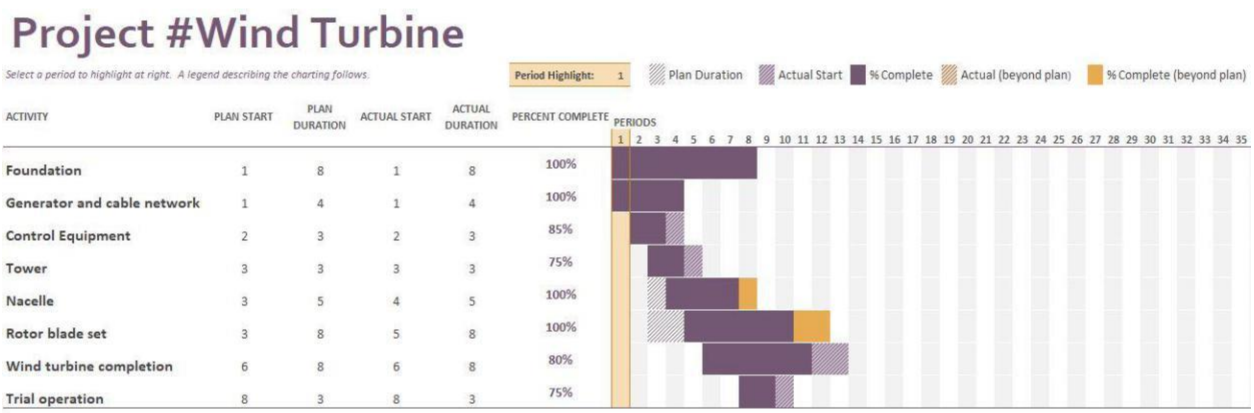
5.2 Contribution of Team Members

Activity	Detailed Description of Every Task
Foundation	The construction of wind turbine using Steel foundation & Support beams.
Generator and cable network	A power grid is made up of devices outside of the wind turbine, such as a generator, capacitor, diode, leap transformer, ground transformer, and power station. The cable trenches and cable design are two other operations. .
Control Equipment	The installation of control cabinets and appliances, as well as contact and power connections, in the tower's basement.

Tower	The tower parts are mounted on the base. On-site, several individual tower parts must be linked.
Nacelle	The Nacelle, which includes generating components such as a generator, gearbox, shafts, and brakes, is installed on the tower.
Rotor blade set	Trying to attach turbine blades to a ground hub is linked to as rotor blade fixation.
Wind turbine completion	To complete the wind turbine, the rotor blade set is mounted on the Nacelle.
Trial operation	The final test of the wind turbine operation and the relation of the generator system to the wind turbine.

5.3 Project Execution Monitoring

Project executed as per our project plan. As per critical Path Diagram Task to be assigned and monitered.



5.4 Challenges and Decision Making

List of Challenges Faced	Previous Design	Alternative Design
Power Transmission to Generator	Directly connected to Generator	Gear box connected to increase speed
No of Generators	1	2
Generator usage	Single generator for Control system & output power	One Generator for Control system. Other generator for Output power
Power Flexivation	Direct out put from Generator	Bridge circuits and capasitors used for reduce Power Flexivation.

Generator Capasity	Single 24 v	Dual 12 v generators
Wind direction Control	Cone type	Blade type
Micro Controller	Without Ardino	With Ardino

5.5 Project Bill of Materials and Budget

Bill of Materials and Budget

DESCRIPTION OF FINISHED GOOD: DESIGN OF WIND TURBINE GENERATOR

PART NO.	MATERIAL	DESCRIPTION	QTY	UNIT COST	TOTAL COST
2021001	Electric	Generator	2	350.00	700.00
2021002	Aluminum Alloy	Turbine Fan	1	500.00	500.00
2021003	MS	Stand	1	300.00	300.00
2021004	Plastic	Gears	3	30.00	90.00
2021005	Electrionic	Ardunio	1	900.00	900.00
2021006	Electric	Electric wires	1	100.00	100.00
2021007	Electric	Lamps	4	25.00	100.00
2021008	Electrionic	Speed Sensor	1	600.00	600.00
2021009		Bearings	1	80.00	80.00
2021010		Safety Stickers	1	50.00	50.00
2021011	Fabrication of Mechanical Item Spare		1	600.00	600.00
2021012	Fabrication of Electric Item Spares		1	500.00	500.00
				TOTAL MATERIAL COST	**4520.00**
				LABOR COST	**-**
				% TRANSPORTATION COST	**-**
				TOTAL COST in SAR	**4520.00**

Chapter 6: Project Analysis

6.1 Life-long Learning

Experts conclude that at the present pace of growth, the earth will not last long. Natural resources that appeared limitless only a few years ago are now displaying symptoms of depletion.

Simultaneously, the amount of waste generated grows by the day. Each Brazilian generates 0.6 kg of waste per day on average. This equates to over 120,000 metric tons of waste every day. Landfills and landfills are running out of capacity, necessitating the implementation of a more effective recycling scheme.

Learn about the different types of green energy and how they perform. Find out which ones are the most promising, as well as their key benefits and drawbacks. Learn more about solar, wind, geothermal, biofuels, and other renewable energy sources.

6.2 Impact of Engineering Solutions

Like all energy sources, wind energy can harm the ecosystem by reducing, fragmenting, or degrading habitats for animals, fish, and plants. Additionally, rotating turbine blades can endanger flying animals such as birds and bats. Because of the potential for wind power to harm ecosystems and because these concerns could impede or prevent wind production in high-quality wind resource areas, impact minimization, siting, and licensing issues are among the wind industry's top priorities.

WETO participates in programs that aim to characterize and recognize the effect of wind on ecosystems on land and offshore to solve these concerns and promote environmentally sound production of wind power in the United States. Furthermore, through integrated knowledge centers like Tethys, WETO engages in activities to gather and disseminate objectively rigorous peer-reviewed data on environmental impacts. The office also participates in technical analysis that allows for the advancement of cost-effective technology to reduce biodiversity impacts onshore and offshore wind farms.

WETO aims to promote interagency cooperation on wind energy effects and siting analysis to ensure that taxpayer dollars are used wisely to solve sustainability challenges associated with wind deployment in the United States.

Listed below are a few of WETO's investments:

The office has funded peer-reviewed research for more than 24 years, thanks to strategic partnerships with the wind industry and environmental groups.

The National Wind Coordinating Collaborative (NWCC) and the Bats and Wind Energy Cooperative are two examples of such organizations.

The NWCC was established in 1994 by the DOE's wind office in collaboration with the National Renewable Energy Laboratory to address a wide range of issues related to wind energy production, such as transmission, power markets, and wildlife impacts. The NWCC's emphasis has changed over the last decade to discussing and disseminating high-quality knowledge about environmental effects and solutions.

In May 2009, the Department of Energy's wind office released approximately $2 million in environmental testing grants to reduce the threats of wind power production to critical ecosystems and ecosystems. Researchers from Kansas State University and the NWCC's Grassland Community Collaborative published a study in 2013 that showed wind growth in Kansas had no significant impact on the population and reproduction of greater prairie chickens.

The Bats and Wind Energy Cooperative has been involved in several research projects funded by DOE's National Renewable Energy Laboratory since its inception in 2003, including studies evaluating the impact of changing the cut-in-speed of wind turbines (the minimum wind speed at which wind turbines begin producing power) and the use of ultrasonic acoustic deterrents to reduce impacts to bats.

WETO also invests in research and development programs that help to advance the industry.

Via a sustainable funding incentive, bat effect prevention and minimization solutions would be ready. The Energy Department is in favor of it.

Bat Conservation International, Frontier Wind, General Electric, Texas Christian University, and the University of Massachusetts will field test and analyze near-commercial bat impact reduction systems, which will provide regulators and wind facility owners-operators with feasible and cost-effective resources to mitigate bat impacts.

WETO chose six teams in 2016 to improve technology that would shield eagles that share airspace with wind turbines. More than **$3 million** was distributed among the six organizations.
Eagle-impact-minimization technology research and development teams for innovative, vital eagle-impact-minimization technology research and development programs the study funded by this grant would provide wind farm owners and operators with practical and cost-effective resources for mitigating future eagle impacts. This critical study builds on the Energy Department's efforts to facilitate wind energy implementation while ensuring species coexistence by resolving siting and environmental concerns. If the research is successful, it will conserve biodiversity while also offering new strategies for the wind industry to reduce regulatory and financial risks.
WETO is a supporter of studies into biological associations with offshore wind turbines. With this funding, researchers gather essential data on aquatic life, offshore bird and bat activity, and other factors that influence the implementation of offshore wind projects in the United States. The Biodiversity Research Institute and a diverse group of partners, for example, performed the largest ecological survey ever undertaken in the Mid-Atlantic to produce a clear image of the landscape in Mid-Atlantic Wind Energy Areas, which will aid permitting and environmental enforcement for offshore wind projects.

WETO also collaborates with other federal agencies to provide standards to help developers comply with legislative, regulatory, and administrative criteria for wildlife protection, national security, and public safety. The Wind Energy Technologies Office, for example, collaborated with the Department of the Interior on the Land-Based Wind Energy Guidelines and Eagle Conservation Plan Guidance.

6.3 Contemporary Issues Addressed

ISSUES AND CHALLENGES

A. Design issues

One of the most significant problems is proper wind turbine construction. Wind turbines must be appropriately designed in terms of blade loading (for lighter blades) and aerodynamic stability. Inertial, magnetic, and aerodynamic stresses are all applied to wind turbines. For better construction of horizontal axis and vertical axis wind turbines, several researchers have developed mathematical models to measure material and structural stresses. Ernesto and his associates for the design of the HAWT, a multi-objective optimization approach based on the coupling of an aerodynamic model (blade element theory) and an evolutionary algorithm was developed. Bier booms used a probability-based system to calculate the extreme response of wind turbines powered by pitch angle variation. This allowed wind turbine manufacturers to build more efficient turbines by better describing extreme conditions in them.

And wind turbines that have been optimized Using an adaptive neuro-fuzzy inference scheme, Petkovic and Shamshirband investigated multiple parameters that affect wind energy generation (ANFIS). Blade pitch angle was found to be one of the most influential parameters.
The 'aero foil' shape is a critical design parameter for understanding the blade's aerodynamics. New' aero foils' have been created to improve the energy capture capability of wind turbines. For measuring the strength of fibrous composite materials, Padgett established a multiplicative damage model. It was used to figure out how strong these products were when they failed. Fug sang and colleagues. They have defined the design and verification of the RISO-131 aerofoil family. Slender blades were created to maximize airfoil lift coefficient while also reducing fatigue and intense loading. Via science, modern blades have grown to their current form, resulting in a higher lift-to-drag ratio. Several experiments on design improvements, such as diffuser enhanced wind turbines (DAFT), have also been conducted. Building Augmented Wind Turbines (BAWT) have also been studied, in which the form of the building is optimized to maximize wind energy.

B. Location Issues

Wind energy farms require a vast amount of land, which a developer must own or protect. Wind energy farms are typically situated in rural areas where land is available and can be used for other purposes such as forestry, livestock activities, etc. The power produced by a wind turbine is primarily determined by wind speed. Obstacles such as houses and topography have the most significant impact on wind direction. Wind energy plants must be built in remote areas at adequate heights to guarantee sufficient wind energy supply.

Although the above parameters can select a specific location, the actual supply of wind will never be consistent. Seasonal changes, hurricanes, and other climatic changes may cause variations in wind speed. The generation system is unable to provide constant electricity due to the inconsistency in wind speed/energy. As a result, energy generation can fluctuate, influencing power system operations. Power system regulators should create comprehensive scheduling schedules and reserve resources for wind energy systems to address this problem. However, maintaining continuity is an expensive substitute. Furthermore, reliable forecasting approaches are needed to reduce the need for reserve capacity and increase wind power penetration. The Weibull probability density function with two parameters is often used to predict wind speed distributions. Shamshirband and colleagues the shape and scale factors of the Weibull process were computed using the Extreme Learning Machine (ELM), and it was found that using ELM gave more reliable and precise results for measuring these factors. Other approaches for forecasting wind speed distributions include Support Vector Machine (SVM), Genetic Programming (GP), Artificial Neural Network (ANN), and generalized adaptive neuro-fuzzy.

C. Grid connection issues

As previously stated, wind turbines are typically located in rural areas due to land supply, higher wind speeds, and the likelihood of other activities such as farming. When it comes to wind energy generation and the grid, there are two major issues. For starters, grid infrastructure in many rural areas is limited, and even though there is a reliable grid in place, integrating wind energy into the grid will cause technological problems such as voltage fluctuations and other issues due to wind energy variations.

The majority of the energy produced (if not transmitted effectively) is lost due to grid infrastructure limitations. Owing to weather patterns, vast water sources, clouds (preferential heating), day & night periods, storms/turbulence, and other factors, wind availability varies. However, although the energy generation from wind farms/mills is affected by these variables, the market is unaffected. In practice, it is often the case that when the power supply is at its highest (at night), the demand is very low. Batteries, power regulators, and other devices can help to reduce these losses however, it would be an expensive substitute. High financing costs are also impeding the development of the wind energy market in many developed countries. Even if the majority of wind power projects can be funded with a 70:30 debt-to-equity ratio, rising interest rates along with challenging macroeconomic dynamics make this technology difficult to introduce. As a result, wind energy needs a strong grid infrastructure.

Even if a grid is present, due to the erratic existence of wind, integration of electricity produced in wind farms presents many technological challenges, impacting power quality. Voltage spikes, power system transients and harmonics, reactive power, low power factor, electromagnetic interference, synchronization, and other factors all influence power efficiency. Variations in voltage and grid frequency make wind farm activities complex and reduce the likelihood of wind energy being successfully integrated into the grid. Due to differences in wind energy production, some of the key power quality issues faced in wind farms include:

1) Uncontrollable reactive power and low power factor
2) Power fluctuations and voltage distortion
3) Voltage fluctuations & significant line losses

To address future wind power grid integration, we would focus on power system architecture and service challenges, such as demand side control and energy storage strategies, grid infrastructure problems (network reinforcement and upgrade), the implementation of more scalable frameworks, and other concerns. The conventional management strategy necessitates the addition of a backup power plant to guarantee supply at all times. This is done to compensate for wind energy's unpredictability by choosing a more controllable source such as hydro, diesel, or thermal power plants, for example. Grid connectivity can also be solved by adding it to energy storage facilities to provide an integrated infrastructure.

Additional energy reserve that will serve as a buffer between the manufacturer and the user Power electronics principles can also be used to address the issue of grid convergence. There is a surplus of electrical power (frequency destabilization) during strong wind cycles, so it is possible to restrict the power generated by wind turbines by using electronic components or adjusting the pitch angle of the blades to minimize the rotor's output. However, many scientists and researchers around the world are researching and studying this subject. In addition, the reactive power produced by a wind turbine can be varied using inverters connected to the generator. It is possible to consume or supply reactive power when controlling the grid's voltage level. Many wind turbines with doubly fed induction machines have incorporated this alternative.

D. Impacts on environment

Wind energy has both positive and negative environmental effects. Pollutants such as carbon dioxide, nitrogen oxides, sulfur dioxide, and other gases are not emitted by wind turbines. A 2.5 kW wind energy system is expected to save 1–2 tons of CO2, while a 6 kW system will save 2.5–5 tons of CO2. It does, however, have a host of drawbacks. As a result, it's critical to consider the worst-case scenario in order to limit the harm. There are serious consequences for animals and human lives (noise and vision).

1) **Impacts on wildlife**

The actual and indirect effects of wildlife can be divided into two groups. The mortality rate caused by collisions with wind turbines is a direct one, while indirect effects include habitat destruction and others. Wind turbines, on the other hand, have a lower effect on biodiversity than other energy sources. According to Sovacool, traditional power plants (fossil fuelled) kill twenty times more birds per GWh than wind turbines. Table 1 shows the major causes of bird mortality in the United States from multiple sources (as reported by researchers). Researchers and industry leaders are working to develop strategies for the safety and prevention of wind turbine-related incidents. Several studies have found that the location of wind turbines has no substantial impact on bird mortality rates. However, in order to maximize wind energy penetration, wildlife effects must be minimized.

TABLE I. LEADING CAUSES OF BIRD KILLS IN UNITED STATES:

Human-related causes	Number of birds kill per year (million)
Cats	1000
Buildings	100
Hunters	100
Vehicles	60-80

Communication towers	10–40
Pesticides	67
Power lines	0.01–174
Wind turbines	0.15

Via careful architecture and planning, it is necessary to reduce the effect on biodiversity. It has been determined through studies that turbines with lower hub heights, shorter rotor diameters (higher revolution rate), and closer turbine spacing kill more birds. The recently built tubular steel tower turbines are safer and deliver twice as much energy as prop-style turbines. Avian radars are used to track birds in areas such as Texas in the United States. If moving birds are in danger, the machine will shut down the wind turbines automatically and restart them after the birds have safely passed the wind farm.

2) **Noise impact**

One of the most serious environmental concerns when introducing wind energy is noise emissions. Noise emission can cause land prices to drop within a certain distance of a construction and is therefore dangerous to humans (up to some extent). As a result, prior to constructing a wind turbine, it is necessary to research the various forms of noise emitted by wind turbines. The relationship between wind speed and wind turbine noise is depicted in Figure 1. The L90 metric, which is often used to characterize the constant sound from a wind turbine, is used to reflect the sound frequency.

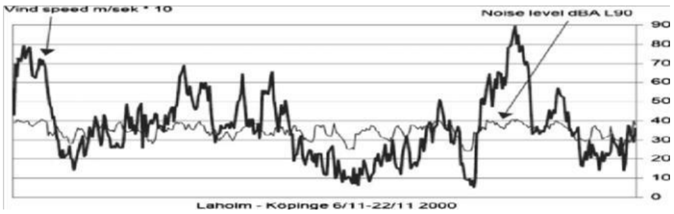


Fig. 1. Wind speed and noise level in dBA L90 versus time.

A wind turbine's noise can be classified as either aerodynamic or mechanical. The flow of air over and past the blades of a turbine produces aerodynamic noise, which increases with the rotor's rpm. Higher blade tip speed results in lower noise levels, according to research. When a wind turbine deals with atmospheric turbulence, it makes a distinctive "whooshing" sound. The blades can be carefully designed to reduce aerodynamic noise. Moving elements such as the gearbox, engine, and bearings generate mechanical noise. The amount of mechanical noise emitted can be affected by wear and tear, incorrect designs, and a lack of preventive maintenance. Mechanical noise can be reduced by careful construction, collection, and maintenance, among other things. Anti-vibration support footings and sound insulation curtains will also help to mitigate it.

3) **Visual impacts**

The form, colour, and architecture of the wind turbines have the greatest visual effects. Person experiences, which are almost impossible to quantify, frequently determine the scope of the issue. People's views of the aesthetics of wind farm installations are usually improved by grouping same-size turbines in clear & uniform rows of light color columns. To examine visual impacts in various contexts, the Quiche Test, Multicriteria Analysis (MCA), and the Spanish system were used. Turbines in service have lower visual impacts than stationary turbines, according to the findings. Residents living nearby can be disturbed by shadow flickering caused by spinning blades and the reflection of the sun's rays from the wind turbine. However, by improving the smoothness of the rotor blade surface and covering the turbine with a less shiny rubber, this can be minimized. Other effects include interference with television or radar transmission due to magnetic forces produced by the wind turbine, as well as a greater risk of being struck by lightning. However, by taking the appropriate precautions, each of them may be reduced to a minimum. Tremeac and Meunier concluded that wind energy has less harmful environmental effects than other energy sources.

It is critical to reduce harmful environmental effects so that wind energy projects can be used as a long-term power source in the near future. To analyze environmental effects, the Life Cycle Assessment (LCA) method is commonly used .It is thought to be a more robust method for integrating environmental aspects into industry and economy than most environmental management schemes (EMS). For floating offshore wind turbines or wind-fuel cell hybrid systems, life cycle tests may be used. Manufacturers may use LCA research as a guide to improve the consistency of their goods to earn an eco-label.

E. High capital investment

Since the majority of the investments are made at the time of investment, wind energy is a capital-intensive technology. The initial costs of a project will account for up to 80% of the final expense. The wind turbine itself is the most expensive part, followed by grid connection and other costs. The cost of a modern wind turbine is broken down in Fig. 2. Capital costs (turbines, foundations, and grid connection), variable costs (operation and maintenance, land rent, insurance, and taxes), and the investment's economic lifetime are only a few of the factors that influence wind power costs.

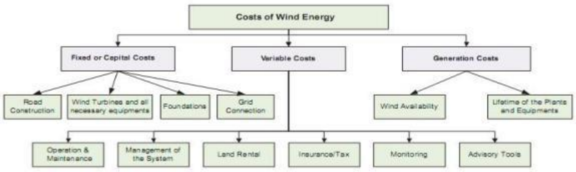


Fig. 2. Typical breakup of overall cost of a large scale wind energy system

The majority of the funds (around 80%) would be needed during the development process for effective wind energy deployment. As a result, it is important to have favorable repayment terms. Many green energy ventures in countries like India will take advantage of a 70:30 debt-to-equity ratio. Lower interest rates, on the other hand, are needed to support wind energy. Wind power is inconvenient due to its erratic existence (lower plant energy factor). The payback times for programs are longer. As a result, even though it may be the cheapest alternative, harnessing this energy may not be successful due to inappropriate funding conditions during the initial phases. The net present value (NPV) and internal rate of return (IRR) are relevant criteria to consider when determining the feasibility of a project investment. Petkovic devised a model for determining the most cost-effective and optimum wind farm configuration, taking into account the relationships between turbines, different costs, and wind regimes.

F. High production cost

Power generated, fixed costs (interest, land rent, insurance), and variable costs (maintenance/repair, miscellaneous) are used to calculate the manufacturing cost. Because of the erratic nature of wind and the high investment needed, it is not always feasible to incorporate wind energy on a wide scale. Power generation is a critical parameter for lowering production costs, and it is further dependent on wind speed, which is easily affected by barriers (buildings), geography (plain, mountains), and other factors. Turbine construction is another critical factor to consider.

& grid availability, as well as range. The production cost is a broad metric used to measure a project's progress or failure. It can be reduced to a minimum with good preparation and intervention. Power system regulators are used to make comprehensive scheduling schedules and set reserve space for proper energy use in order to increase the consistency of wind power generation. Accurate forecasting approaches are used to reduce the reserve capability requirement (as stated earlier). Owing to the frequent differences in the outputs of each wind turbine (despite the fact that they are all powered from the same wind energy), power production (wind farms) varies as well, resulting in a lower plant capability factor .Lower plant volume means lower yields, resulting in higher average production costs. It is critical to expand wind power penetration in order to reduce manufacturing costs, which would potentially result in further electricity output. This can be accomplished by careful configuration and selection, the use of power regulators, and modular AC transmission systems (grid), among other things. However, it will come at a premium price, which will boost manufacturing prices to some degree. As a result, only a limited amount of wind power plant optimization is feasible.

Chapter 7: Conclusions and Future Recommendations

7.1 Conclusions

Wind energy has a lot of promise, and it encourages more attention, particularly in large-scale systems. The benefits of wind energy in terms of climate change reduction and the ability to reduce energy dependence are undeniable. In developing countries like India, it not only helps to reduce greenhouse emissions and power shortages, but it also helps to increase job opportunities. Wind energy programs in countries such as the United States, Germany, Australia, China, Canada, Denmark, Turkey, and Japan have effectively incorporated this energy into their structures. Wind energy policies in many countries provides incentives such as more appealing funding options (lower interest rates), tax exemptions, discounts, and participation of academic agencies, among others. In a few countries (including India), the concept of a Renewable Energy Certificate (REC) has been adopted to encourage renewable energy.

The current research looks at the potential of wind energy as well as the major problems and difficulties that come with harnessing it. Any of these problems may have potential solutions (based on research); however, these alternatives/solutions would necessitate further investments, making wind energy less feasible (financially). As a result, an efficient wind energy strategy is needed for this energy to be integrated. Grid integration has been described as a key factor in improving the deployment of wind energy systems. Recent advancements in the field of power electronic devices have accelerated the industry's overall expansion. Because of technological limitations in turbine and generator technology, turbine blade capacity, generator size, and the erratic existence of wind, high altitude wind energy systems have become increasingly appealing. The below are certain research and development (R&D) goals that the wind energy industries/institutions must pursue:

1) New wind farms, which would lower overall costs.
2) Improved component design and reliability
3) Large-scale turbines to go further into the ground
4) Appropriate capital evaluation and preparation
5) Appropriate urban planning based on social and environmental factors (life cycle analysis etc.)
6) Effective grid infrastructure and wind energy system integration

7.2 Future Recommendations

Modern Wind Turbines

A traditional wind turbine has a turbine tower, rotor, gearbox, generator, and other components. Three rotor blades and a nacelle are used on most modern wind turbines. The gearbox, engine, brake mechanism, and control systems are all housed in the nacelle. Fiber Reinforced Polyester is often used for blades because it is lightweight and has excellent mechanical properties. To reduce vibrations, gearboxes are typically installed over dampers. Most current wind turbines also have instruments to calculate wind speed and direction, such as anemometers and wind wane.

New wind turbines now have power management systems as standard equipment. Wind turbines are designed to harvest as much energy as possible from the wind and provide as much electricity as possible. When a wind turbine is built, however, power outputs due to very high winds (which are uncommon) are not taken into account. To prevent damage to wind turbines during high winds, a portion of the wind's excess energy is wasted through power control devices. There are two kinds of power management systems used in modern wind turbines. First, an electronic controller is used to control the blade pitch system, which controls the output power. Secondly, for a stall regulated wind turbine, a speed regulation and suitable torquespeed characteristic is intrinsic in the aerodynamic design of the rotor.

There have been many improvements to traditional wind energy technologies. Each one needed cutting-edge research and production of cost-effective solutions/alternatives. Regardless of technological advances, many choices must be taken. For example, one of the key parameters is determining the number of blades, which includes design considerations (aerodynamic efficiency), component cost, system stability, and aesthetics. According to study, raising the number of blades from one to two results in a 6% improvement in aerodynamic performance, whereas increasing it from two to three only results in a 3% increase in efficiency. However, the decisive factor in eliminating one or two bladed wind turbine from the commercial market has been the visual impact. Three bladed wind turbine is a good compromise because it does not involve too much air disturbance for the following blade and reasonable amount of energy is gathered.

Recent trends in wind turbine technology

Interest in VAWT faded after it was discovered that HAWT are more effective for large-scale wind energy generation than VAWT. In comparison to VAWT, HAWT are highly optimized and readily available in the modern period. VAWT are aerodynamically more powerful than HAWT and are more suitable in broad scale (10 MW) wind energy generation, according to research a few years ago. As a result, VAWT has regained popularity, and several studies have been conducted since then. VAWT has also shown improved efficiency in terms of flow isolation, reducing the negative impact on energy generation. Wind does not have to be blowing in a certain direction for VAWT to work. As a result, no yawing mechanism is needed. As a result, it has been suggested that VAWT can be more successful in harnessing wind energy in complex urban terrains.

A. Relationship between the Fish-Schooling Concept and VAWT farm

‘‘A school of fish can be characterized as a provisional group of individuals, generally from the same genus, same age, and within the same biological period, unified by mutual attraction, and showing different degrees of synchronization of their swim capacity within a focused group," Soria and Dagom established the fish schooling principle. They retain continuous touch, mostly through sight, but also through acoustics and olfactory means. These people will come together at any moment and take coordinated action that employs the same biological abilities for all members of the community. Person activity inside the school is found to be synchronized.” When swimming across the sea, a fish releases vortices from its tail into its wake. Though HAWT makes up the majority of modern wind farms, VAWT farms have turbines that rotate in the same direction. Dabiri investigated the hydrodynamic interaction between the fish's clockwise and anti-clockwise vortices. It was concluded that VAWT could benefit from similar positive hydrodynamic interference to improve overall performance. It was also discovered that using VAWT instead of HAWT, with optimum positioning, it is possible to get 10 times more electricity from the same wind farm. The inter-relationship between the shed-vortices from fish and VAWT when arranged in a specific array is seen in Fig. 3. Due to the partnership (fish schooling) among the VAWT, Whittlesey et al. predicted significant benefits of putting VAWT in a strategic array.

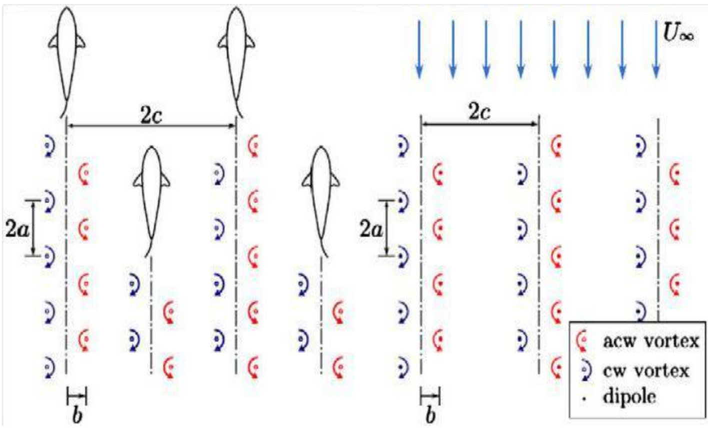


Fig. 3. Inter-relationship between the shed vortices from fish-schooling and arrangement of VAWT [50].

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