Design of vertical axis wind turbine as an emergency power source

Sanket Kamble[#1], Ajay Ingole[#2], Rishikesh Kodak[#3],Shivam Mirajkar[#4]

Department of Mechanical Engineering, Savitribai Phule Pune University

Abstract

Wind power has always been promising for production of energy. Though horizontal wind turbines have already been in use with advanced technology some development is required in vertical type of wind turbines. Small development in VAWT will show great potential of theirs in future.In this project our aim is to design and manufacture a savonius type vertical axis wind turbine which can be used as an power source during emergency. Our main areas for use of this turbine will be at camping sites and household activities. This paper will show you the design of a savonius type VAWT and its analysis. Also the project aims at making the turbine as portable as possible. The various proposed conceptual designs for VAWT are described and their working principles are outlined.

Historical Background

Wind energy systems have been used for centuries as a source for energy gor mankind. According to historic sources in early17th century BC the Babylonian Emperor Hammurabi used windmills for irrigation project. Later Persian developed a more advanced wind power machine than the Babylonian. The Arab geographer travelling in Afghanistan in the 7th century have a written description of windmills which resembeled our modern doors. Vertical windmills were used in some parts of Iran and Afghanistan and it was estimated it could generate 75 hp and can can grind a ton of wheat in 24hours. With such use of wind energy in historic culture a little advancement in modern world has definitely helped us.

Introduction

Renewable energy is the energy which is available through natural resources like sun, wind, tides, etc. With growing concern about global warming from the emission of green house gases has provided a strong impetus for engineers and scientists worldwide to research alternative renewable and clean energy. If this increase in global warming is not controlled soon mankind will be pushed to death from dirty burning of gas and coal. With increase in demand for energy many countries have already found out alternatives for production of energy. Countries like Denmark, Netherlands, Germany, USA, UK, etc are some countries which have renewable energy as their major energy production source. They have always focussed on development of renewable energy. Elon Musk CEO of Tesla SpaceX has always worked on using renewable energy and protect the environment from disasters in upcoming years.His tweets always shows him urging us everyone for use of renweable energy as soon as possible and not after the tea spills the cup.

As we know horizontal axis wind turbines have already made a remarkable place in production of energy at larger levels. Though they have some disadvantages. They require high speed winds for energy production which is not possible in countries like Thailand which have low wind speeds. Also they are huge structure so requires large space and also the nearby areas are to be evacuated. The noise created by turbines is very loud and causes noise pollution. For production of energy at high levels HAWT are the best but at smaller levels for production of energy at household activities VAWT can be used. If a major focus on VAWT is kept for its development surely it will not fail to replace HAWT.

Comparison of VAWT and HAWT

VAWT's are commonly smaller in height and function nearer to ground so the heavy equipments can be placed near to ground and not in the nacelle. This allows easy maintenance of the turbines and helps in easy replacement of any failed component. However the wind are slower at ground level so the amount of energy generated at same wind speed will be lower.

Another benefit of a VAWT over the HAWT is that it does not need a yaw mechanism, because it can harness the wind from all directions. This benefit is outweighed by numerous other limitations, such as: time varying power output because of change of power in a single blade rotation, the requirement for guy wires to support the main tower.

VAWT' are smaller in size and hence can be packed together inside wind farms and this allows more in any space. They are quiet, omni-direction and they also generate lower force on support structure. They also don't require as much wind in order to produce power, therefore permitting them nearer to ground where speed of wind is lower. Because they are near to ground they can easily controlled and implemented on tall structures.

A great deal of research at Caltech has revealed that cautiously designing the wind farms using VAWT's may result in generation of power output that is ten times greater than a HAWT wind farm that is same size.

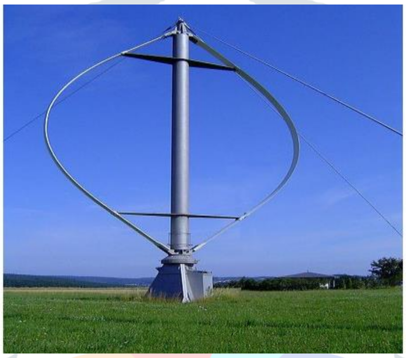
Also VAWT's are more quieter than HAWT, with dB level at a ground level measured from ten meters away from tower recorded 95 dB for a HAWT this about the sound of a highway with cars passing by as compared to about 38dB for a VAWT which is about the sound of whispered conversation.

VAWTs sometimes do not function properly under winds that are gusty. They generate extremely low starting torque, and also have dynamic stability issues. The VAWTs are also very sensitive to the off-design conditions and possess a low installation height that limits operation to the environments with a low wind speed. The blades that are attached to VAWT are vulnerable to types of fatigue because of the broad variation in applied forces with every rotation. The vertical types of blades implemented in early models became bent with every spin, and this caused them to have cracks. With time, blades broke, and this led failure of the turbine. This makes VAWTs less reliable.

TYPES of VAWT's

Darrieus Type

The Darrieus wind turbine is a type of vertical axis wind turbine (VAWT) used to generate electricity from the energy carried in the wind. The turbine consists of a number of curved aerofoil blades mounted on a vertical rotating shaft or framework. The curvature of the blades allows the blade to be stressed only in tension at high rotating speeds. There are several closely related wind turbines that use straight blades. This design of wind turbine was patented by Georges Jean Marie Darrieus, a French aeronautical engineer; filing for the patent was October 1, 1926. There are major difficulties in protecting the Darrieus turbine from extreme wind conditions and in making it self-starting.



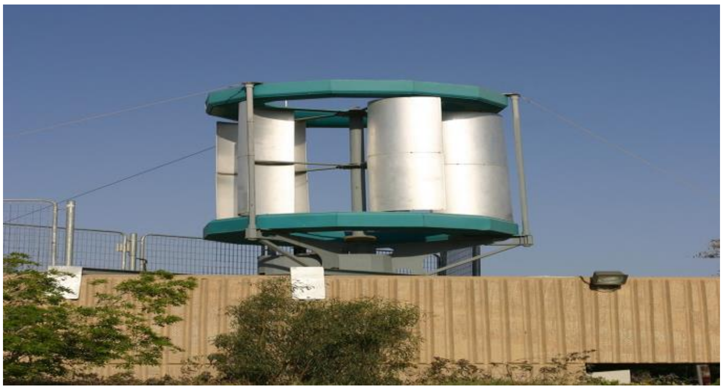
Darrieus Type

Savonius Type

Savonius wind turbines are type of vertical-axis wind turbine (VAWT), used for converting the force of the wind into torque on a rotating shaft. The turbine consists of a number of aerofoils, usually but not always vertically mounted on a rotating shaft or framework, either ground stationed or tethered in airborne systems.

TheSavonius wind turbine was invented by the Finnish engineer Sigurd Johannes Savonius in 1922. However, Europeans had been experimenting with curved blades on vertical wind turbines for many decades before this. The earliest mention is by the Italian Bishop of Czanad, Fausto Veranzio, who was also an engineer. He wrote in his 1616 book 'Machinae novae' about several vertical axis wind turbines with curved or V-shaped blades.

The Savonius turbine is one of the simplest turbines. Aerodynamically, it is a drag-type device, consisting of two or three scoops. Looking down on the rotor from above, a two-scoop machine would look like an "S" shape in cross section. Because of the curvature, the scoops experience less drag when moving against the wind than when moving with the wind. The differential drag causes the Savonius turbine to spin. Because they are drag-type devices, Savonius turbines extract much less of the wind's power than other similarly-sized lift-type turbines. Much of the swept area of a Savonius rotor may be near the ground, if it has a small mount without an extended post, making the overall energy extraction less effective due to the lower wind speeds found at lower heights.



Savounis Type

Design and Calculation

Due to starting torque problems in Darrieus type turbine we have selected savonius type of turbine for our designing and manufacturing. Energy carried out by wind is given by kinetic energy

Hence,

$KE=1/2*m*V^2$

$KE=1/2*\rho*A*V^3$

Where

A= Swept Area

ρ= Air Density

V= Wind Speed

A physical limit is exists known as Betz limit.

It is the hypothetical maximum energy which can be extracted from a volume of moving air. It was independently discovered by three different scientists between 1915 and 1920, but as per Stiglers Law it wasn't named after the person who discovered it first but after Alfred Betz who discovered it in 1920.

The limit is 16/27, typically represented as the approximation 59.3%.

It is based on a hypothetical disk with an infinite number of blades with no drag and no hub. This is obviously different than any real world device.

The principle is simple. At a certain point, the back pressure of air makes the air move around the device instead of through it. Obviously, if all of the energy was taken from the moving volume of air, the air would be still behind the device. In that case, all the rest of the air would simply move around it for no generation. Note that this has been the fatal flaw with every concentrator / Venturi effect / funnel wind turbine since the 1920's, up to and including the Sheerwind Invelox.

Commercial utility-scale wind turbines with horizontal axes and three blades don't achieve 59.3% of course but they approach 90% of that and have been proven globally as the best set of compromises for economically harvesting energy from the wind. That's why utility scale wind generation is the cheapest form of new generation out there.

That last bit is important. Efficiency of harvesting of a free resource doesn't matter when the free resource is so abundant that there are multiples of the energy flowing through it at any given time. What does matter is the economics of harvesting the energy.

As savonius type of turbine is considered the betz limit is considered as 0.26

Power to be generated is 125 watts

$125=0.26*1/2*1.225*A*10^3$

$A=0.784m^2$

H=0.784m

D=0.9m

.References

[1] Net Power Coefficient of Vertical and Horizontal Wind Turbines with Crossflow Runners Toni Pujol , Albert Massaguer , Eduard Massaguer, Lino Montoro and Martí Comamala ,2018

[2] Aerodynamic models for Darrieus-type straight-bladed vertical axis wind turbines Mazharul Islam, David S.-K. Ting, Amir Fartaj,2006

[3] Vertical Axis Wind Turbine development Guilherme Silva.,2008

[4] Design and construction of vertical axis wind turbine Piyush Gulve , Dr S B Barve.

[5] Vertical axis wind turbine design load cases investigation and comparison with horizontal axis wind turbine Christos Galinosa, Torben J. Larsena, Helge A. Madsena, Uwe S. Paulsena,2016