International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 08 | Aug -2017 www.irjet.net p-ISSN: 2395-0072

Study And Analysis of Savonious Vertical Axis Wind Turbine With Neodymium Permanent Magnet Rotor

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Abstract - *Nowadays, it has been observed that wind energy is the fastest growing area in the renewable energy. The wind turbine by harnessing the wind from atmosphere produces power. The environmental damage due to the non-renewable resources increases enormously which attract the world attention. people start to think the drag type of VAWT has potential to generate power in low wind speed. The HAWT not able to use for commercial household purpose due to its big size and high initial cost. The efficiency of VAWT almost half of the HAWT. The purpose of this research is to develop a VAWT which can rotate at low velocity i.e. 2 m/s -3 m/s by less drag force using Neodymium permanent magnet rotor with the most efficient design of blades which will increase the efficiency of the this VAWT.*

Key Words: **Wind energy, Renewable energy, Savonious VAWT, Neodymium Permanent magnet rotor, Power generation**

1.INTRODUCTION

In recent decades, the prospect of the depletion of fossil fuels has directed attention toward renewable energy sources. so, the dependency on the environment friendly energy sources increases due to its various benefits. Among the renewable energy sources, onshore wind power is one of the most attractive because of its low cost of maintenance of installed systems. Today, wind energy plays an important role for contributing nearly 5% of total power generation in the world. Wind is generated in the atmosphere due to the uneven heat created from sun. The wind turbine by harnessing the wind from atmosphere produces mechanical power. This mechanical power can be used for various tasks (such as pumping water, grain grinding) or can converted into electric energy by using generator.

There is exponential growth in the development of wind energy generation system in recent years due to its modern technology. In recent years due to continuous development and innovative design in wind turbines makes the energy production cost low. Wind energy is cheaper alternative as compared to the other renewable resources which has been proved. So, there is continuous research and development on the improvements of wind energy technology going on. The wind turbine is divided due to its own axis of rotation as HAWT and VAWT. Among the various types of windmills mini windmill model have gained more interest for their excellent adaptability to the urban environment in terms of low maintenance and its low initial cost. The VAWT rotates at its vertical axis in any direction of wind hence there is no need of yaw mechanism. Savonious VAWT is drag type device requires high torque and rotate low speeds.

These wind turbine become good power generating device in rural regions for fulfill the energy demand due to its low initial cost and less maintenance. These turbines have ability to produce continuously power even low wind speed by upgrading permanent magnet rotor into the savonious device. This permanent magnet rotor reduce the required torque for rotor blade by repulsion force of neodymium magnets. The size of these turbines are small than HAWT hence, requires less space for installation. it will become the main power source in peak power grid areas.

1.1 Need for Wind Turbine Technology

Renewable Energy is derived from natural resources such as solar power, wind power, hydropower, geothermal and various forms of biomass. Due to the easily available for use and constantly replenishment, these sources are termed as renewable. The dependency on the Renewable energy sources has experienced a significant upsurge in recent times due to the increasing rates of fossil fuels. The environmental damage due to the non-renewable resources increases enormously which attract the world's attention. The use of renewables is their prime choice for enhancing access to affordable, reliable and environment friendly sources of modern energy services. Technological innovation is a key factor for future wind power development. The HAWT gives the high efficiency in producing power from the wind energy hence, nowadays this turbine widely used in the different regions of the world. The HAWT installation and maintenance cost is high as compare to VAWT. The HAWT not able to use for commercial household purpose due to its big size.[3]

The further development in the VAWT and technological innovations carried out in recent years. The VAWT has simple in design and low maintenance cost compare to HAWT. The

development of VAWT is very important for increase its efficiency in the latest designs of VAWT. The new design in blades that will not help to increase the efficiency of blade but also reduce the overall production cost of the wind turbine. The savonious VAWT required high torque and which can rotate at low speeds. The operation of vertical axis machine is very simple. due to its simplicity of cup shaped blades has the advantages of being a strong starting torque which will help to rotate even with law wind speed.

2. SAVONIOUS VAWT

Savonious VAWT is drag type device requires high torque and rotate low speeds. In 1922 S. J. Savonious was developed this cup shaped VAWT. The efficiency of this type of VAWT is half of the HAWT because of the drag force on the rotor blades. These turbines are simple in construction and require low maintenance. The savonious VAWT can able to rotate at low wind speeds and it not requires external source to start its initial rotation. These types of turbine can be used for low power generation and also for commercial purpose. These wind turbine become good power generating devices for fulfill the increasing energy demand due to its low initial cost and less maintenance. it will become the main power source in peak power grid areas.[2]

2.1 Design of Savonious Rotor

The Savonious rotor blade have high solidity, cup shaped and which is drag based device rotate by wind flow. This rotor blade is simple in construction and reliable. This type of savonious windmill which consist of two, three, or multi blades setup as per requirement for generating power as shown in fig-1. The principle of working of this type of turbine is based on difference between drag forces at concave and convex regions of the rotor blades when they are rotating at vertical axis.

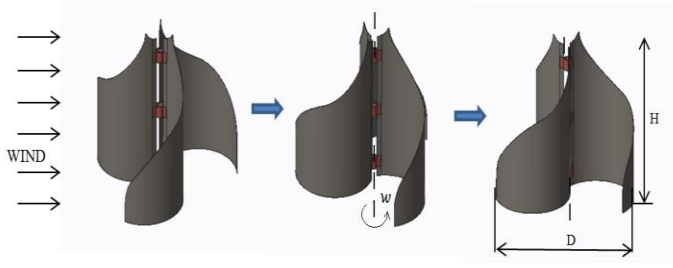

Fig -1: 3D model of Savonious rotor blade angular positions

The major advantages of this newly designed blades are simple, strong, light in construction. The height of the blades are 70 cm and diameter of cup shaped blades are about 50 cm respectively. The angle maintained between two blades are 120.

2.2 Design of Windmill Tower

The base material has been chosen as mild steel. the square shaped pipe which is one inch in size. The height of the base from ground level is about 85 cm. and weight of the base is nearly 20 kg. The structural design of tower as shown in fig-2.

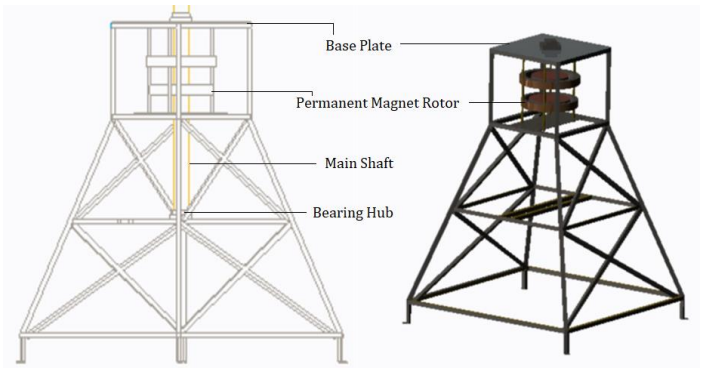

Fig -2: Design of Base model

3.3 Design of Permanent magnet rotor

The purpose of this permanent magnet rotor was to create frictionless bearings and a magnetic levitation design of windmills which is the issue in conventional wind turbines. This permanent magnet rotor consist of two components one is the rotor which is rotating with vertical shaft and second one is the stator which is fixed as shown in fig-3. The cylindrical shaped neodymium magnets are placed on the both components of permanent magnet rotor with specific angle. Neodymium magnets are the powerful earth magnets. The repulsion force of the magnets are very strong. This rotor helpful for instance, these are able to rotate with wind speed as low as 2.0 m/s.

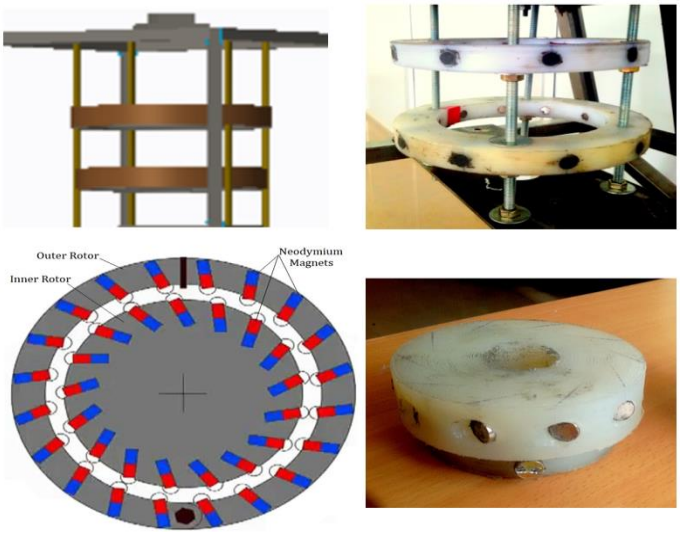

Fig -3: Design of Permanent magnet rotor

3.4 Shaft and Bearing

The shaft chosen for this design is by considering the weight of the shaft and its strength. The high strength aluminium material hollow shaft is used for its light weight and high strength advantage. The diameter of the shaft used in this design is about 2.5 cm or 1 inch and 110 cm long. There are two ball bearings with hub have been used for the particular setup that are primarily centralized with the vertical rotating shaft. This positions of two bearings provides the least amount of friction. The diameter of these two bearings are 2.54 cm.

3.5 Generator

In this VAWT low motor vehicle dynamo is used as electric generator which convert the mechanical energy by rotating shaft to a pulsing direct electric current. Basically, the dynamo which consist of two parts one is the stationary structure called stator which produces magnetic field and the second one is armature which is rotating into the magnetic field.

3.6 Design Specifications

Table-1: Summary of Savonious VAWT design parameters

Wind rotor	Rated power	46.40 W
	Rated speed	3.5 m/s
	Rotor diameter	1.50 m
	Area	1.7671 m^2
Generator	Generator type	DC dynamo
	Electric Transmission	Brushless
Turbine blade	Blade type	cup-type(drag)
	Blade number	3
	Blade material	High strength Aluminium sheet
Blade dimension	Hub material	MS
	Length	70 cm
	Cup radius	50 cm

3.7 Proposed CAD Model

The components of the Savonious VAWT are designed by using the PTC creo 3.0 software with appropriate dimensions as shown in fig-4. This wind turbine is three bladed with angular cup shaped blade sections connected to the generator through vertical shaft. Extra modifications are made in this savonious VAWT compared to old model design by implementing a neodymium permanent magnet rotor to achieve maximum efficiency. The major advantages of this newly designed blades are simple, strong and light in construction. This present research work was undertaken to achieve the savonious VAWT more efficient by implementing the design of this VAWT and upgrading the new component of permanent magnet rotor

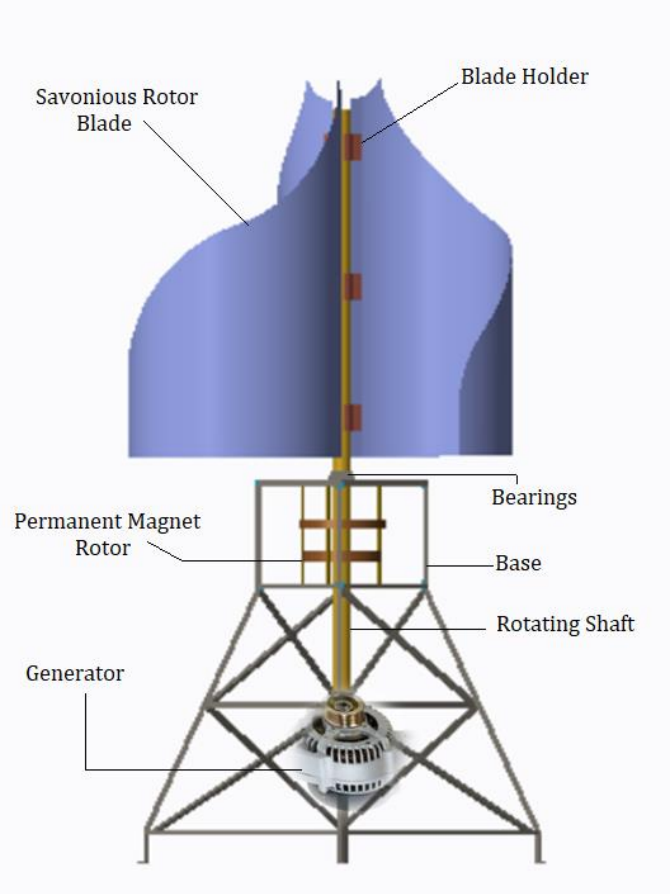

Fig -4: Proposed CAD Model

The main implemented technology in this wind turbine is permanent magnet rotor which operates on the properties of magnetic repulsion. This permanent magnet rotor is helps to cut off the maximum rotating force required to rotate blades in particular wind speed or which can gives repulsion force to driven rotor connected to vertical axis due to which turbine can rotate at low wind speed.

3. ANALYSIS OF ROTOR BLADE

Computational fluid dynamics(CFD) is based on the analysis technique and this method used to analyze and solve the problems related to the fluid flow by numerical approximation method. The complex design surfaces used in the field of engineering can easily analyze the calculations simulated by fluids using the computer based ANSYS software. The main objective of CFD analysis is to study the parameters like pressure and velocity of wind flow on blades as shown in fig-5, fig-6 and fig-7. This analysis gives the approximate results at given boundary conditions.

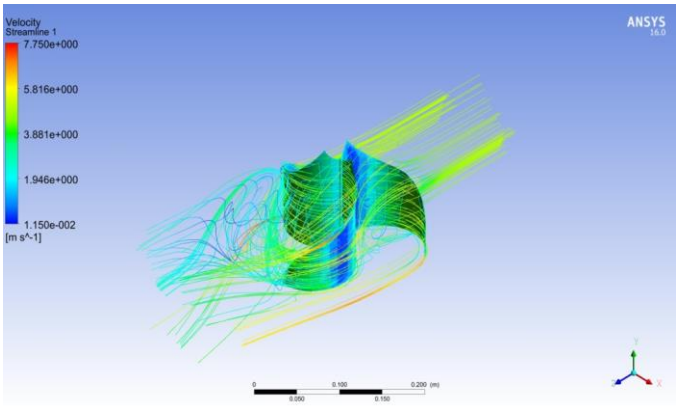

Fig -5 : Streamline flow on blades

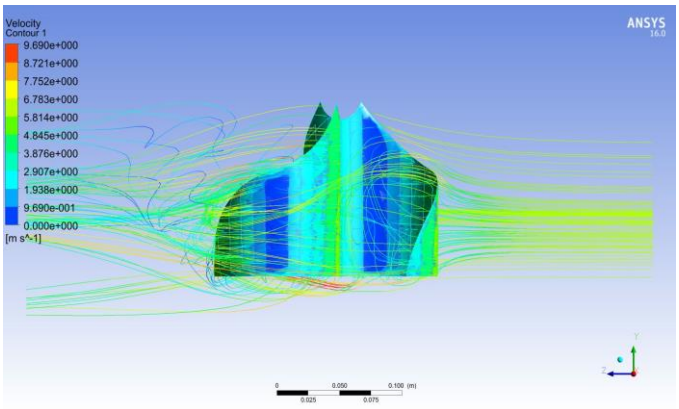

Fig -6: Effect of wind velocity on blades

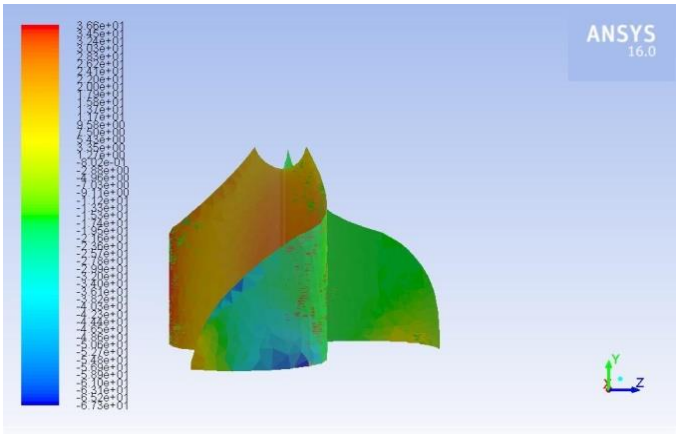

Fig -7 : Contours of static pressure

The computational fluid dynamics (CFD) was performed in order to obtain velocity and pressure forces of wind flow. From CFD analysis, it is found that convex region experiences low velocity and pressure of wind flow, while the concave region experiences high velocity and pressure of wind flow. The maximum velocity of wind flow found in this analysis is 9.690e+00 m/s by given boundary input of 4.0 m/s. and the maximum pressure found in this analysis is 3.665e+01kpa.

5. RESULTS AND DISCUSSION

The results obtain were up to expectations. The efficiency of savonious VAWT is considered about 30% during theoretical calculations, but in this research the efficiency obtained nearly 35%. So, there is increase in efficiency due to permanent magnet rotor which reduces the torque required to rotate the rotor blade and also reduce the friction losses during rotation. This Savonious turbine system with permanent magnet rotor gives better results. For instance, they are able to rotate with wind speed at 2.0 m/s. Also, they can operate in winds up to 20 m/s. It helps to increase power generation by 20% and decrease maintenance costs by 50% as compared to other vertical axis wind turbines. The results have obtained at specific time period using multi-meter and anemometer. The observation of experimental data given in Table 2.

Table -2 : Observation of experimental data

Sl no.	Wind speed (m/s)	Voltage (V)	Current (A)	Power (W)
1	1.7 – 2.1	2.64	1.86	4.910
2	2.2 – 2.5	3.73	2.07	7.721
3	2.6 – 2.9	4.94	2.27	11.213
4	3.0 - 3.3	6.19	2.58	15.970
5	3.5 – 3.9	7.33	2.69	19.717
6	4.0 – 4.3	7.71	2.82	21.742

As seen in scatter chart plotted in Chart-1, it can be easy to conclude that the output voltage increases when the wind speed increases. Here, we observed that minimum voltage of 2.64 V obtained at a speed of 2.0 m/s and maximum voltage 7.8 V obtained at 4.3 m/s . The average voltage of 4V to 5 V obtained at an average speed.

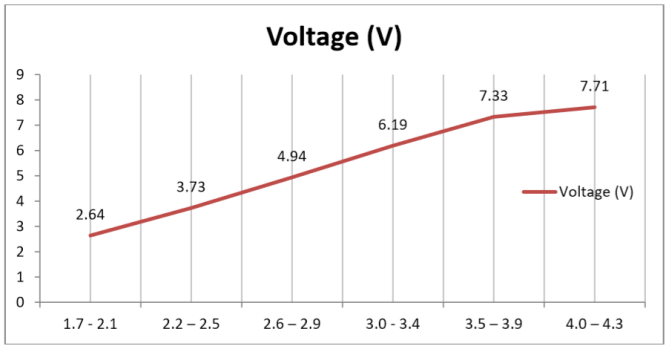

Chart -1: Variation of Wind speed v/s Voltage

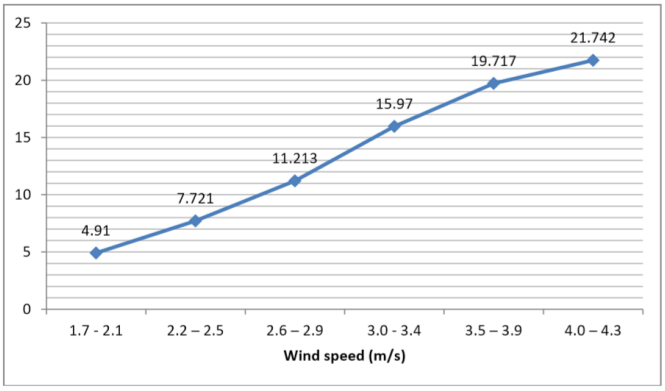

Chart -2: Variation of Wind speed v/s Power

This project succeed to achieve the best result of power output at average wind speed. Initially minimum 2 m/s velocity of air required to rotate the wind turbine and generated 4.91W power as shown in Chart-2. The output power increases with increase in wind speed. Here, the power output obtained nearly 21 W at 4.5 m/s wind speed.

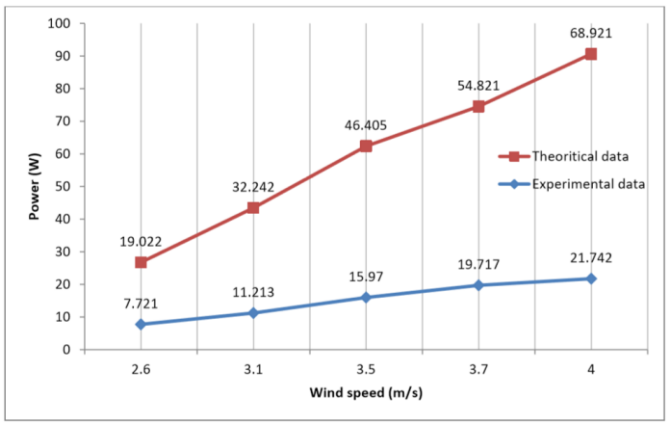

Chart -3: Comparison of power v/s wind speed between the experimental data with the theoretical data.

The Chart-3 shows the comparison of power between the experimental data and theoretical data. At the speed of 2.6 m/s the theoretical calculated power is 19.02W and the experimental data is nearly 7W. The efficiency of savonious VAWT is only 30% due to the high drag force on the rotating blades. but in this research the efficiency obtained nearly 35%. there is increase in efficiency of the VAWT due to permanent magnet rotor which reduces the torque required to rotate the rotor blade.

6. CONCLUSIONS

The savonious VAWT implemented with new design of blades and permanent magnet rotor technology have improved its overall power generation. This permanent magnet rotor is helps to cut off the maximum rotating force required to rotate blades in particular wind speed due to which the turbine can rotate at low wind speed. The result obtain in this project which will benefit the future development of modern VAWT. This turbine will helps to increase the power production in the field of renewable energy. The effective fabrication of this VAWT which helps to minimize the friction losses during the rotation of rotor blades. The newly designed blades are simple, strong and light in construction. It has ability to capture wind from any direction and can withstand any weather condition. A main advantage of this savonious VAWT is that its cost is limited and it can easily affordable for commercial power generation. Considering the all-weather point of view the material used which are noncorrosive.

FUTURE SCOPE

The implementation of rotor blade by using acrylic sheet with solar cell material coating as a solar panels instead of aluminium sheet which will make this wind turbine as hybrid generation system. This will helps to generate power from both solar and wind energy. The efficiency can be increased by precise fabrication of prototype and also by new designing of the blades. The development of gear ratio will also helps to harness wind energy from relatively low wind speed. By increasing the generator capacity and large savonious unit with increased number of generators units which will achieve large power generation with optimized cost.

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