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A Novel Approach Of Techno-Economical Power Generation By Savonius Type Vertical Axis Wind Generator

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***Abstract* — As power generation demand is being increased in renewable energy sector, power generation from wind energy plays important role in present growing scenario. The design of wind generator is a important parameter to extract the power from wind. In this paper a new approach is explained how maximum power is being obtained. The strong magnets Neodymium magnets N52 were used in this design of wind generator. The vertical type which is most common using now is used in this design. The voltage generated by each coil is presented in this paper. It proves that using two magnetic stator and one coil rotor improves power generation. The modified Savonius vertical axis wind turbine performance can be identified in this paper. The construction design and components details are discussed here.**

***Key words*— Hardware model , Maximum power , Neodymium magnets N52, Savonius type vertical axis wind generator , Two magnetic stators with one coil rotor, Wind energy harvesting**

1. INTRODUCTION

A low rpm electrical generator is used for converting the mechanical rotational power produced by the winds energy into usable electricity to supply our homes and is at the heart of any wind power system. The conversion of the rotational mechanical power generated by the rotor blades (known as the prime mover) into useful electrical power for use in domestic power and lighting applications or to charge batteries can be accomplished by any one of the following major types of rotational electrical machines commonly used in a wind power generating systems. The direct current (DC) machine, also known as a Dynamo. The alternating current (AC) synchronous machine, also known as an AC Generator. The alternating current (AC) induction machine, also known as an Alternator. All these electrical machines are electromechanical devices that work on Faraday’s law of electromagnetic induction. That is they operate through the interaction of a magnetic flux and an electric current, or flow of charge. As this process is reversible, the same machine can be used as a conventional electrical motor for converting the electrical power into mechanical power, or as a generator converting the mechanical power back into the electrical power.

ISSN 2515-8260 Volume 07, Issue 05, 2020

Electricity Generation

A Wind Turbine Generator is what makes your electricity by converting mechanical energy into electrical energy. Let's be clear here, they do not create energy or produce more electrical energy than the amount of mechanical energy being used to spin the rotor blades. The greater the "load", or electrical demand placed on the generator, the more mechanical force is required to turn the rotor. This is why generators come in different sizes and produce differing amounts of electricity. In the case of a "wind turbine generator", the wind pushes directly against the blades of the turbine, which converts the linear motion of the wind into the rotary motion necessary to spin the generators rotor and the harder the wind pushes, the more electrical energy can be generated. Then it is important to have a good wind turbine blade design to extract as much energy out of the wind as possible.

Simple Generator Using Magnetic Induction

Fig.2 Neodymium magnets N52

Then we can see that by moving a magnet past a single loop of wire, a voltage known as and emf (electro-motive force) is induced within the wire loop due to the magnetic field of the magnet. As a voltage is induced across the wire loop, an electrical current in the form of an electron flow starts to flow around the loop generating electricity. But what if instead of a single individual loop of wire as shown, we had many loops wound together on the same former to form a coil of wire, much more voltage and therefore current could be generated for the same amount of magnetic flux. This is because the magnetic flux cuts across more wire producing a greater EMF and this is the basic principal of Faraday's law of electromagnetic induction and an AC generator uses this principal to convert a mechanical energy such as the rotation from a wind turbine or hydro turbine, into electrical energy producing a sinusoidal waveform

Three main requirements for electrical generation:

- A coil or set of conductors
- A magnetic field system
- Relative motion between the conductors and field
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ISSN 2515-8260 Volume 07, Issue 05, 2020

Components Used In Proposed Hadrware Model Design

Neodymium Magnets

Neodymium magnets are the rare earth magnets which are made from an alloy of neodymium, iron, and boron. It is generally represented by “Nd”.

Neodymium magnet characteristics	
Remanance Br	1.43-1.48
Coercive Force HcB	≥860
Intrinsic Coercive Force	≥876
Max.Energy	398-422
Working.Temp	100 ^{0}C

Table.1 Neodymium magnet characteristics

S.NO	MATERIAL	TYPE
1.	Shape	Rectangular
2.	Material	NdFeB
3.	Grade	N52
4.	Plating	Ni-Cu-Ni(Nickel)
5.	Color	Silver
6.	Length	40mm
7.	Width	25mm
8.	Height	5mm

These magnets have been used in both commercial and industrial purposes. These magnets have large dipole moment and high magnetic field strength. The magnetic properties of Neodymium depend on alloy composition, micro structure. Alnico and ferrite magnets are replaced by neodymium in case of industrial purpose due to its high magnetic field strength. Neodymium has magnetic properties like coercivity, energy product, remanance and Curie temperature.

Stator Of The Wind Energy System

Fig.4 Coils Wound on a Wooden board acts as Stator

The stator is made of wood with thickness of 12mm and diameter of 60cm. The armature windings are placed at the edge in order to make the air gap between the coils and magnets as minimum.The stator consists of two plates. Each plate consists of 40 coils with 55 turns each. The two plates are coupled by using nuts and bolts. It looks as shown in the fig below.

ROTOR DESIGN OF PROPOSED MODEL

The rotor is also made of wood with a thickness of 12mm and 56cm diameter .The diameter of rotor is slightly less than that of stator so that windings can be placed in the sides also. It is cut at the edges and magnets are attached to it by using a glue gun. A bearing is fixed at the center of rotor to make sure that it rotates freely about the wind turbine axis.

Fig.3 Magnets fixed on a wooden board acts as Rotor

WIND TURBINE BLADES

- Horizontal Axis Wind Turbines (HAWT):

Horizontal axis wind turbines have the main rotor shaft and electrical generator at the top of a tower, and they must be pointed into the wind. Small turbines are pointed by a simple wind vane placed square with the rotor (blades), while large turbines generally use a wind sensor coupled with a servo motor to turn the turbine into the wind. Most large wind turbines have a gearbox, which turns the slow rotation of the rotor into a faster rotation that is more suitable to drive an electrical generator. Since a tower produces turbulence behind it, the turbine is usually pointed upwind of the tower. Wind turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds. Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted up a small amount. Downwind machines have been built, despite the problem of turbulence, because they don't need an additional mechanism for keeping them in line with the wind.

- Vertical axis wind turbine (VAWT):

Vertical axis wind turbines, as shortened to VAWTs, have the main rotor shaft arranged vertically. The main advantage of this arrangement is that the wind turbine does not need to be pointed into the wind. This is an advantage on sites where the wind direction is highly variable or has turbulent winds. With a vertical axis, the generator and other primary components can be placed near the ground, so the tower does not need to support it, also makes maintenance easier. The main drawback of a VAWT generally creates drag when rotating into the wind.

Fig.5 Vertical axis wind turbine

Comparison between horizontal axis and vertical axis wind turbine:

Sl.no	Horizontal axis wind turbine	Vertical axis wind turbine
1.	Yaw control mechanism is present	Absence of yaw control mechanism
2	Efficiency is high	Low efficiency
3.	They are big size	They are small size
4.	It has high initial installation cost	It has low initial installation cost
5.	High maintenance cost	Low maintenance cost
6.	Self starting	They are not self starting
7.	Difficult transportation	Easy in transportation
8.	They are unable to work in Low wind speed	They are capable of work in Low wind speed
9.	Difficult in transportation	Easy to transportation

ISSN 2515-8260 Volume 07, Issue 05, 2020

10	They are mostly used commercially	These are used for private purposes.
11.	It cannot be installed near human population.	It can be installed near human population.
12.	It is not good for the birds population.	It is good for the birds population.

Table.3 Comparison between horizontal axis and vertical axis wind turbine

In this vertical axis wind turbine there are two types

- Darrieus wind turbine:

Darrieus wind turbines are commonly called "Eggbeater" turbines, because they look like a giant eggbeater. They have good efficiency, but produce large torque ripple and cyclic stress on the tower, which contributes to poor reliability. Also, they generally require some external power source, or an additional Savonius rotor, to start turning, because the starting torque is very low. The torque ripple is reduced by using three or more blades which results in a higher solidity for the rotor. Solidity is measured by blade area over the rotor area. Newer Darrieus type turbines are not held up by guy-wires but have an external superstructure connected to the top bearing.

- Savonius wind turbine:

A Savonius is a drag type turbine, they are commonly used in cases of high reliability in many things such as ventilation and anemometers. Because they are a drag type turbine they are less efficient than the common HAWT. Savonius are excellent in areas of turbulent wind and self-starting.

WIND TURBINE BLADE DESIGN

Fig.6 Savonius type wind turbine blades

There are two types of wind blade design:

- Flat wind turbine:

Flat blades are the oldest blade design and have been used for thousands of years on windmills, but this flat broad shape is becoming less common than other types of blade design. The flat blades push against the wind, and the wind pushes against the blades. The resulting rotation is very slow because the blades that are rotating back on the up stroke after generating power are in opposition to the power output. This is because the blades are acting like huge paddles moving in the wrong direction, pushing against the wind giving them the name of drag-based rotor blades.

- Curved wind turbine design:

So now we are choosing curved wind turbine design because Curved blades are very similar to a long aeroplane wing (also known as an aerofoil) which has a curved surface on top. The curved blade has air flowing around it with the air moving over the curved top of the blade faster than it does under the flat side of the blade, which makes a lower pressure area on top, and therefore, as a result, is subjected to aerodynamic lifting forces which create movement. Also, homemade PVC wind turbine blades can be cut from standard sized drainage pipes having the curved shape already built-in giving them the best blade shape.

ISSN 2515-8260 Volume 07, Issue 05, 2020

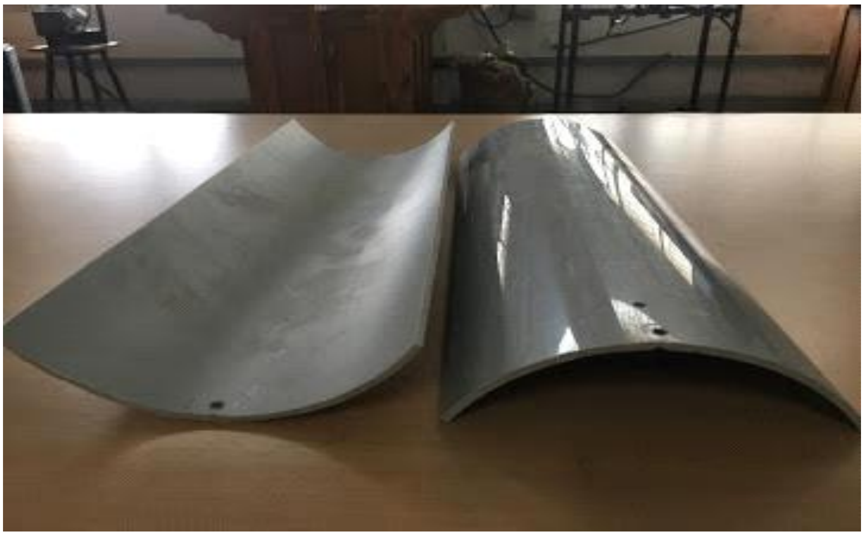


Fig.7 Curved wind turbine design

- Curved Blade Air Flow and Performance:

But curved blades also suffer from drag along its length which tries to stop the motion of the blade. Drag is essentially the friction of air against the blade surface. Drag is perpendicular to Lift and is in the same direction as the air flow along the blade surface. But we can reduce this drag-force by bending or twisting the blade and also tapering it along its length producing the most efficient wind turbine blade design.The angle between the direction of the oncoming wind and the pitch of the blade with respect to the oncoming wind is called the "angle of attack". As this angle of attack becomes larger, more lift is created but as the angle becomes even larger, greater than about 20o, the blade will begin to decrease lift.

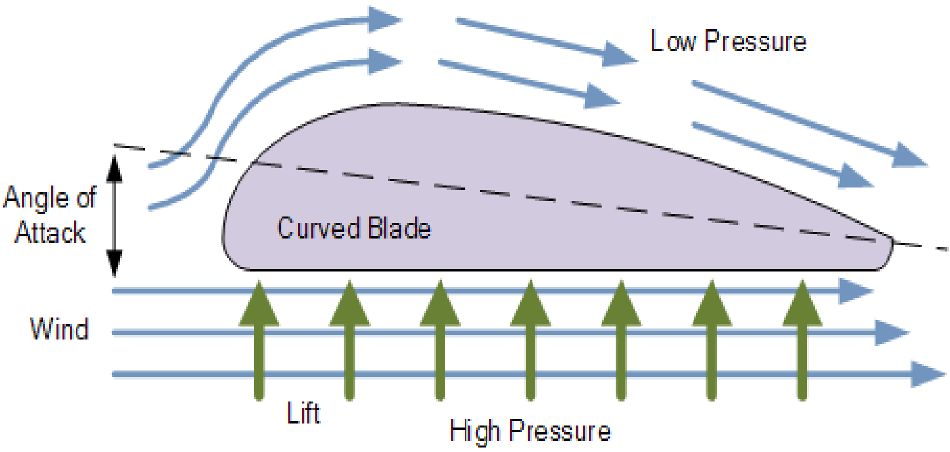


Fig.8 Curved Blade Air Flow and Performance

ISSN 2515-8260 Volume 07, Issue 05, 2020

Copper Wire (Gauge 28)

S.NO	MATERIAL	TINNED COPPER
1.	Diameter	0.0126
2.	Gauge	28
3.	Length(feet)	100
4.	Alloy type	Pure copper(ASTM B3)
5.	Type	Busbar wire
6.	Finish/coating	Bare

Table.4 Copper wire (gage 28)

Fig.9 copper wire used in proposed model

Copper has been used in electrical wiring since the invention of the electro magnet and the telegraph in the 1820.copper wire is the electrical conductor in many categories of electrical winding. Copper wire is used in "power generation, power transmission, power distribution, telecommunication, electronic circuitry, and countless type of electrical equipment". Copper and its alloys are also used to make electrical contacts. Electrical wiring in buildings in the most important market for the copper industry. Roughly half of all copper mined is used to manufacture electrical wire and cable conductors.

Cycle Rims

Fig.10 Cycle Rims

ISSN 2515-8260 Volume 07, Issue 05, 2020

Specification: The Cycle Rims which we are used is having **65 cm diameter steel frames**. Two quantities of cycle rims are used.

Components specifications:

Sl.no.	Components	Specification	Qty.
1.	Cycle rims	65cm diameter steel frame	2
2.	Blades	45cm height 5mm thickness18cm length of circular area	6
3.	Inner blades	40cm diameter 5mm thickness 18cmlength of circular area	3
4.	Permanent magnets	40mmX25mmX4mm N52 neodymium magnets	20
5.	Stator	60cm diameter 55 turns	80
6.	Rotor	60cm diameter	1

Table.5 components specifications

- **BLOCK DIAGRAM OF THE PROPOSED WIND ENERGY SYSTEM**

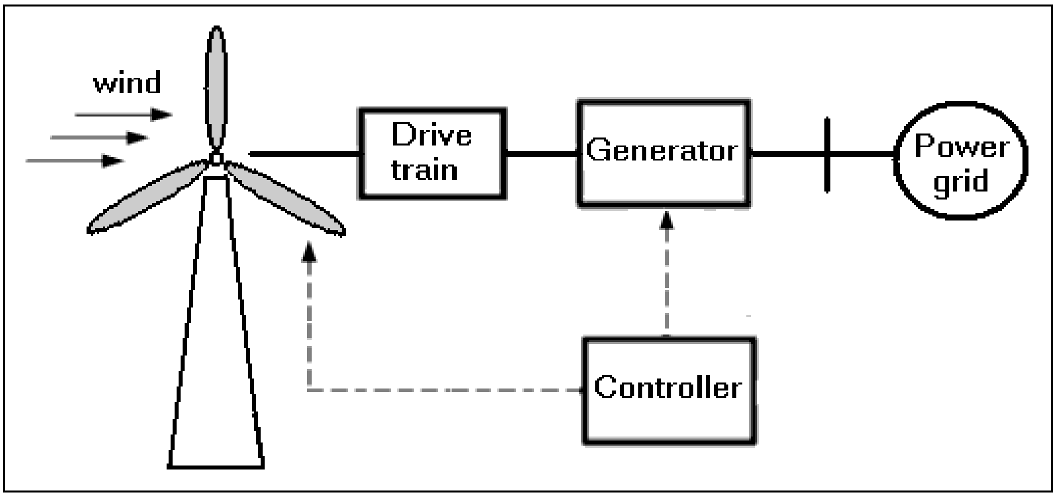


Fig 9. General block diagram of wind power generation

In this, the two stator boards the coupled by nuts and bolts with the rotor placed between them. Fig.10 wind turbine based power generator

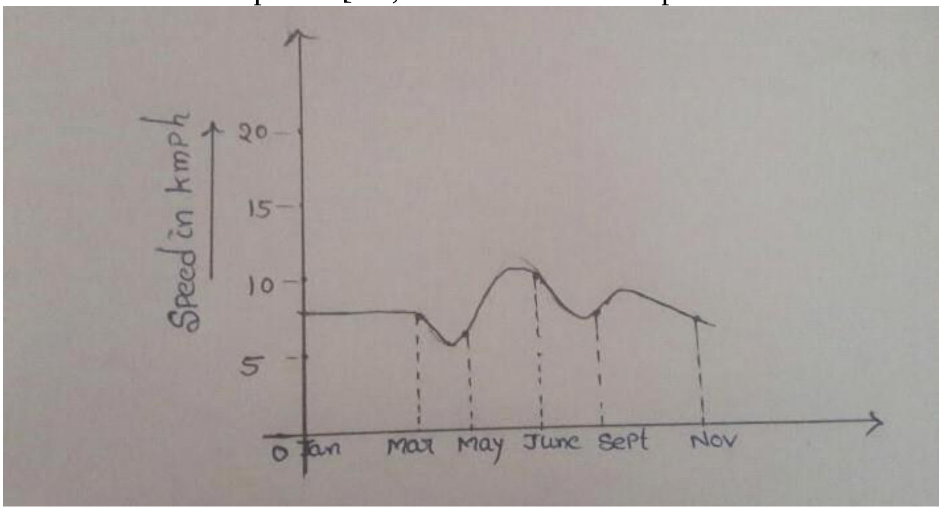
ISSN 2515-8260 Volume 07, Issue 05, 2020

The savonius turbine is coupled to the rotor mechanically. The rotor is placed on a bearing which is fixed to a stand of 2 feet tall. The wind turbine has both inner and outer blades. The outer blades are separated by an angle of 60^0 each and the inner blades are separated by 1200 each with respect to the axis of rotation. The angle between the inner and outer blades is 300 . Each inner blade comes at the exact center of two outer blades so that the wind speed can be fully utilised and the efficiency can be increased. The pitch angle of the wind turbine blade is 120.When the wind flows with sufficient speed, the turbine rotates so that the rotor which is coupled to it also rotates. Thus, the alternating magnetic field is produced. This rotating magnetic flux cuts the stationary armature coils and an emf is induced in it. All the coils are connected in series so that the voltage is increased.

2. RESULTS AND DISCUSSIONS

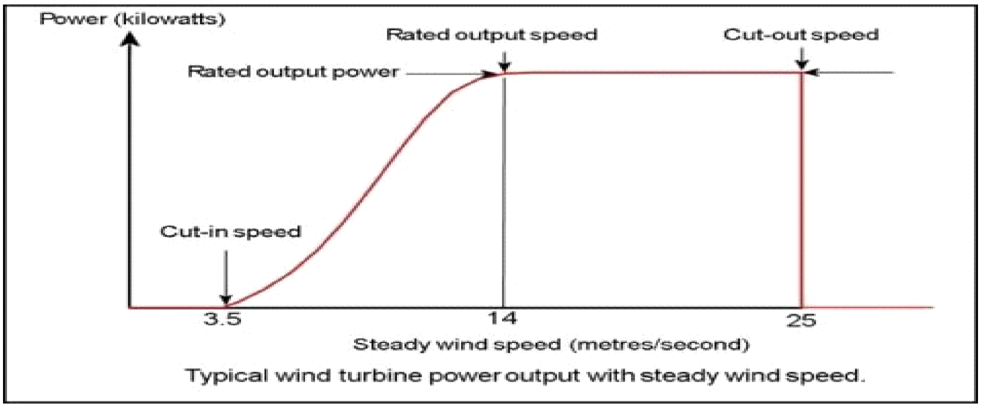
The formula for how to calculate power is:
$P_T = ½ * ρ * A * v 3 * C_p$

Where:
P = Power output, kilowatts
Cp = Maximum power coefficient, ranging from 0.25 to 0.45, dimension less (theoretical maximum = 0.59)
ρ = Air density, lb/ft3=1.225kg/m^3
A = Rotor swept area, ft2 or π D2/4 (D is the rotor diameter in ft, π = 3.1416)
V = Wind speed, mph=8m/s
k = 0.000133 A constant to yield power in kilowatts. (Multiplying the above kilowatt answer by 1.340 converts it to horse- power [i.e., 1 kW = 1.340 horsepower



Wind Speed Data in Rajam

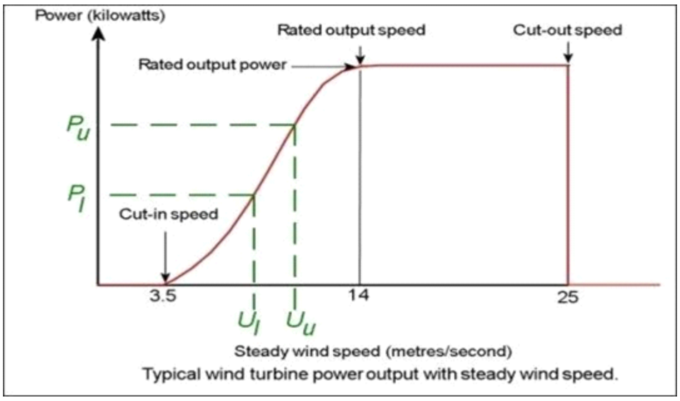
Graph.1 wind speed in Rajam in 2019 year



Graph.2 Wind turbine power output variation with steady wind speed.

Cut in Speed: At very, low speeds, the torque is insufficient to rotate the wind turbine blades. If the wind speed increases the blades start to rotate. The speed at which the turbine first start to rotate and generate power is called cut in speed. It generally lies between 4m/s to 5m/s.

Cut out wind speed: As the speed increases above the rate output wind speed, the forces on the turbine structure continue to rise and, at some point, there is a risk of damage to the rotor. As a result, a braking system is employed to bring the rotor to a standstill. This is called the cut-out wind speed. In general the cut out wind speed is above 25m/s.



Graph.3 Variation of power with the with respect to the wind speed

The main problem with the wind turbine is it is inconsistent. However, the power can be estimated with respect to the variation in the wind speed as shown in the above fig. If we wanted to know the proportion of time that power would be produced between two limits Pu and Pi, it would correspond to the percentage of time that the wind speed lay in range Uu and Ui.

TECHNICAL DATA

Total no. of coils	80
Gauge of the copper wire	28
No. of turns in each coil	55
Coil span	3cm
Air gap	0.5cm
Total no. of magnets	20
Rated current(expected)	0.91 micro amps
Rated power generated	1W

ISSN 2515-8260 Volume 07, Issue 05, 2020

TEST:

No. of coils	1
No. of turns	55
No. of magnets(Nd-Fe-B)	1
Emf induced per coil	2.0mV

Tabular form-6 Tabular form-7

3. CONCLUSION

Since the vertical axis wind turbines are having low efficiency than horizontal axis wind turbines it is not commonly used in our country. But these kinds of wind turbines are highly suitable for small scale domestic purposes at low costs when compared to HAWT. Due to increasing demand for renewable energy it is hoped that these kinds of VAWT plays an important role in every home by assisting the energy needs. The savonius type vertical axis wind turbine is used since it more efficient than the HAWT when it is used near to the ground. This good solution to meet the power demand in the present world moreover it is most efficient renewable energy source.

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