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Design, Analysis & Fabrication of Maglev Vertical Axis Wind Turbine

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ABSTRACT: Magnetic levitation is a method by which an object is suspended with no support other than magnetic fields. Magnetic pressure is used to counteract the effects of the gravitational and any other accelerations. The principal advantage of a maglev windmill from a conventional one is, as the rotor is floating in the air due to levitation, mechanical friction is totally eliminated. That makes the rotation possible in very low wind speeds, which is the new direction to improve the performance of wind turbines. In this project work, magnetically levitated (maglev) wind turbines are designed and developed. It is the self-starting turbine. 3D Designing is done using Solidworks 2015 software and Finite Element Analysis is used to study effect of air flow on the Turbine blade using ANSYS FLUENT. The choice for this model is to showcase its efficiency in varying wind conditions as compared to the traditional horizontal axis wind turbine and contribute to its steady growing popularity for the purpose of mass utilization in the near future as a reliable source of power generation. Power will then be generated with an axial flux generator, which incorporates the use of permanent magnets and a set of coils. Inverter circuit is used to convert DC voltage to AC voltage by rectifying it. Vertical axis wind turbines offer promising solution for smaller ruler areas or medium sized residential spaces.

KEYWORDS: Magnetic Levitation, Power Generation, Magnets, CAD Design, CFD Analysis.

I. INTRODUCTION

A wind turbine is device that converts the winds kinetic energy into electrical energy. The blades of wind turbine turn between 13 and 20 revolutions per minute, depending on their technology, at a constant velocity, where the velocity of the rotor varies in relation to the velocity of the wind in order to reach a greater efficiency. Rapid evolution of wind technology has led to an increase in the durability of wind turbines. Wind turbines are manufactured in a wide range of vertical and horizontal axis types. The smallest turbines used for applications such as battery charging, for auxiliary power for boats or to power traffic warning signs. Slightly larger turbines can be used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electric grid.

A) Renewable Energy

Renewable energy is generally electricity supplied from sources, such as wind power, solar power, geothermal energy, hydropower and some others. The need for the renewable energy is high from last few decades due to the exhaustion of conventional power generation methods. The use of renewable energy is the only thing that reduces the dependency of human on fossil fuels. Among all the other renewable energy sources Wind Energy is one of the fastest growing energy sources which is growing at the rate of 30% annual graph. The wind speeds in Asian countries is very low, especially in the cities, and this much amount of wind speed is not enough to start the wind mill. This paper introduces structure and

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principle of the proposed magnetic levitation wind turbine for better utilization of wind energy. In Maglev Wind turbine there is no friction, and therefore it can work on low speed.

B) Maglev Wind Turbine

The problem with the traditional structure of VAWT is that weight from the VAWT makes bearings bear larger axial force; makes bearings frayed largely and shorten the life. At the same time, due to the increase in friction, the system loss mechanical energy and reduce the efficiency. Its main advantages are that it uses frictionless bearings and a magnetic levitation design and it does not need to vast spaces required by more conventional wind turbines. It also requires little if any maintenance. The Maglev wind turbine was first unveiled at the Wind Power Asia exhibition in Beijing 2007. The unique operating principle behind this design is through magnetic levitation. Magnetic levitation is supposedly an extremely efficient system for wind energy. The vertically oriented blades of the wind turbine are suspended in the air replacing ball bearings.

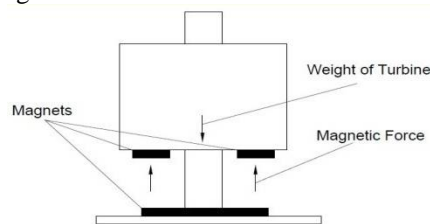


Fig -1: Schematic Diagram of Maglev VAWT

Fig-1 shows free body diagram of Maglev VAWT where weight of rotor is acting downward and magnetic force acting upward. Using the effects of magnetic repulsion, wind turbine blades will be fitted on a rod for stability during rotation and suspended on magnets as a replacement for ball bearings which are normally used on conventional wind turbines.

II. LITERATURE REVIEW

Vishal D Dhareppagol, Maheshwari M Konagutti, the objective of this thesis work is to design and implement a magnetically levitated vertical axis wind turbine system that has the ability to operate in both low and high (1.5m/s to 40m/s) wind speed conditions. The no of blades used for this turbine is 6 which are placed such that the angle between two adjacent blades is 60 degree. Each blade is fixed between the two discs with 30degree deviated. The length to diameter ratio is kept as 1 for better performance of turbine. Producing 20% more energy than a conventional turbine, at the same time decreasing operational costs by 50% over the traditional wind turbine. [1]

Pravesh K. Sahare, Tanveer A. Hussain, Sangita N. Kakde, Sujata R. Ingle, Ambikaprasad O. Chaubey, the objective of this paper is to write a review on all the parameters important for designing of Maglev Vertical axis wing turbine. Disc type Neodymium magnets are considered which are developed rapidly and applied widely due to their perfect characteristics. The author concluded that the design of the blades and rotors are capable enough to rotate at low wind speed and give the output. The magnets are levitated properly while working which gives smooth rotation and hence there is negligible friction. [2]

Chinnu Sara Thomas, Dhanya Varghese, Jayalakshmi S, Sonu SavyThomas George, Rini Varghese P, the aim of this project work is to design a Vertical axis magnetic levitated wing turbine as an alternative for conventional wind turbine. Author has considered Two ring type neodymium (Nd-Fe-B) magnets of grade N52 of outer diameter 28 mm, inner diameter 10 mm and thickness 12.5 mm are placed at the shaft, by which the required levitation between the rotor and the base is obtained. The Experimental result shows that maglev wind turbine rotate at minimum wind energy of 1.45m/s as compared to conventional turbine which required 4.475m/s. [3]

Shubham Patil, Pratik Kumbhar, Oslaniya Siddhartha, Patil Rohit, C.S.Wagle, the objective is to compare the experimental testing of the Vertical wind turbine with bearing and magnetic assistance at the supports. Neodymium

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magnet with dimensions 15*8*3mm having capacity to repel 9.81 force can be used for levitation between stator and rotor to maintain air gap. The Magnetic bearing will produce 29.7% more RPM than conventional Design. The experimental Results shows that the Magnetic Vertical Axis Wind Turbine has lower starting speed and the arrangement of magnets so proposed assists the turbine in lowering the starting speed. [4]

Andrea Alaimo, Antonio Esposito, Antonio Messineo, Calogero Orlando and Davide Tumino, the Objective of the paper is to analyze the complex and unsteady aerodynamic flow associated with wind turbine functioning, using computational fluid dynamics an attractive and powerful method. The applicative goal of this study is the comparison of the performance between a straight blade vertical axis wind turbine and a helical blade one. Analyses are carried out through the use of computational fluid dynamic ANSYSR Fluent software, solving the Reynolds averaged Naiver–Stokes (RANS) equations. [5]

Rosario Nobile, Maria Vahdati, Janet F .Barlow, Anthony Mewburn-Crook, a 2D computational investigation of an augmented wind turbine is proposed and analyzed in this project work. Three parameters are carefully investigated: mesh resolution; turbulence model; and time step size. It appears that the mesh resolution and the turbulence model affect result accuracy, while the time step size examined, for the unsteady nature of the flow, has small impact on the numerical results. It is found that the power and torque coefficients of the augmented wind turbine are independent of the incident wind speed considered. [6]

S. Jagadish Venkata Sai, T. Venkateswara Rao, this paper presents the design and analysis of vertical axis Savonius wind turbine to generate electrical energy from wind energy. The 3D model of Savonius rotor blade was made by utilizing SolidWorks software. Computational Fluid Dynamics (CFD) analysis and structural Finite Element Analysis are presented in this paper. It is found that the concave blade regions have high pressure and convex region have low pressure for the two blade Savonius rotor. The maximum and minimum pressures from external flow analysis were 101.496 Pa and 101.296 Pa respectively. [7]

N. Dibakara Reddy, Surender Singh, N. Tejeshwar Reddy, the aim of the paper is to propose a CFD analysis of the Vertical axis wind turbine using mild steel as blade material. CREO 2.0 is used a 3D Modelling software to design a VAWT blade and Computational Fluid dynamics analysis is performed in ANSYS 15.0.The CFD analysis proves that all types of pressure calculated are less than the material maximum value and thus Savonius turbines made of mild steel can be used as they provide strength as well as good electrical output. [8]

III. OBJECTIVE

- To design a Vertical axis magnetically levitated wing turbine for low wind application.
- To study the Performance of the turbine in terms of Electric Power Generated.
- To harness wind energy in more efficient way by elimination friction.
- To analyse rotor in different pressure condition.
- To fabricate the prototype.

IV. PROBLEM DEFINITION

The conversion efficiency of wind energy to electrical energy from the available conventional wind turbines is less than 30 % and the minimum wind velocity required to run these turbines is 20 km/h. Also they are noisy at high speed, requires regular maintenance, friction leads wear and tear.

It is found that to improve the performance of the wind turbines most of the work is carried out on the wind turbine blade profile modification. Therefore increasing the efficiency of the wind turbines is the present need. This can be achieved by reducing the contact friction of the rotor at its supports by providing the contact free frictionless magnetic

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bearings. It is the new direction to improve the performance of wind turbines. Also magnetic levitation increases life of rotor.

V. METHODOLOGY

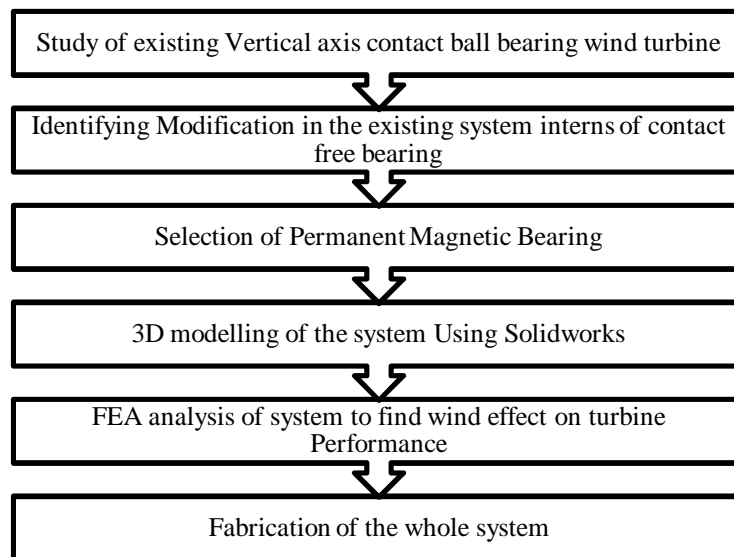


Fig -2: Methodology

Fig -2 shows applied procedure for Maglev VAWT.

VI. THEORETICAL CALCULATIONS

A) POWER CALCULATION

The wind turbine works on the principle of converting kinetic energy of the wind to mechanical energy. The kinetic energy of any particle is equal to one half its mass times the square of its velocity,

$$K.E = \frac{1}{2}Mv^2 \quad \dots\dots\dots (1)$$

Where,

K.E = kinetic energy

M = mass

v = velocity,

$$M = \rho AV \quad \dots\dots\dots (2)$$

Substituting eq. (2) in eq. (1)

$$K E = \frac{1}{2}\rho AV^3 \text{ watts.}$$

Where,

A= swept area of turbine.

ρ = density of air (1.225 kg/m³)

V=wind velocity.

Therefore power developed by wind turbine= $\frac{1}{2}\rho AV^3$ watts.

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Coefficient of power (C_p)

Coefficient of power is the ratio of mechanical power developed by the turbine to power of wind.

$$C_p = .593$$

Power of Turbine (P_T)

$$P_T = \frac{1}{2} \rho A V^3 * C_p \text{ watts}$$

To find dimensions of turbine:

Assume: Power to be generated = 20 watt

Average wind speed = 6 m/s

$$P_T = \frac{1}{2} \rho A V^3 * C_p$$

$$20 = \frac{1}{2} * 1.225 * A * 6^3 * .59$$

$$A = .2562 \text{ m}^2$$

$$\text{Considering aspect ratio} = \frac{H}{D} = 1$$

Where,

H: Height of turbine

D: Diameter of turbine

$$A = D * H$$

$$.2562 = D * D$$

$$D = .506 \text{ m}$$

$$H = .506 \text{ m}$$

B) MAGNETIC LEVITATION

Magnetic Levitation accrued when the two similar pole are repelled without each other.

The ring shaped permanent magnets of grade N35 are used for the levitation.

Dimensions: Outer diameter = 40 mm

Inner diameter = 20mm

Thickness = 10mm

The force between this two like magnetic pole are to be calculated as,

$$F = \frac{M q_{m1} q_{m2}}{4\pi r^2}$$

Where,

q_{m1} & q_{m2} = magnitudes of magnetic poles (Amp- mtr)

μ = permeability of intermediate medium as air, $4\pi * 10^{-7} \text{ N/A}^{-2}$

r = Distance between two magnetic pole.

$$q_{m1} \text{ \& } q_{m2} = H_{C1, C2} * A = 900 * 10^3 \text{ A/m}$$

$$F = \frac{\mu_0 H_{C1} H_{C2}}{4\pi r^2}$$

According to equilibrium forces;

$$\sum F = 0$$

$$Mg - F = 0$$

$$F = Mg$$

Where,

F is magnetic force, N

M is total mass of rotor to levitate, kg

g is gravitational acceleration m/s^2

Therefore total weight of the turbine is around 4 kg.

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$$F = 4 \times 9.81 = 39.24 \text{ N}$$

Available Neodymium magnet with dimensions **40*20*10mm** having capacity to repel **39.24 N** force can be used for levitation between stator and rotor to maintain air gap

Drag force is given by;

$$F_d = \frac{1}{2} \rho A V^2 C_d$$

Where;

$$C_d = \text{coefficient of drag} = 1.42$$

$$F_d = \frac{1}{2} \times 1.225 \times 0.2562 \times 6^2 \times 1.42$$

$$F_d = 8.02 \text{ N}$$

C) COILS

Copper wire of 42 gauges 500 turns each are used as coil for power generation. Total 10 such coils are used in this prototype. The axial flux generator, which we are designing, utilizes the changing magnetic field produced by the magnets to induce a voltage. The rotating magnets pass over a number of coils each producing their own voltage.

Faraday's law of electromagnet induction states that, the induced electromotive force equal to the change in magnetic flux over the change in time.

$$\text{emf} = N \frac{d\Phi}{dt} \text{ volt}$$

VII. CAD MODELING

A) Modification required in new concept of contact free bearing

Replacement of Frictional Contact Ball with Frictionless Contact Free Magneto Bearing. Selection of optimized Blade Angle Design and Number of blades to get optimized electric power generation.

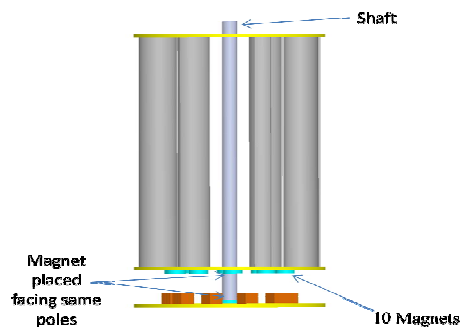


Fig -3: Selected Concept Design of VAWT

Fig -3 shows concept design, which represents the design team's initial response to the project brief. The main advantage of the design concept is to reduce the friction, improved visibility and reduce initial losses.

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B) CAD- Solidworks Design

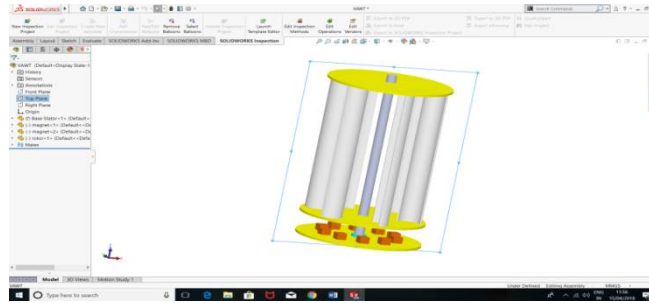


Fig -4: Solid Model Design in CAD

Fig -4 shows CAD model, based on the dimensions obtained from the calculations, the model of the VAWT blades was created and all other parts were assembled with the help of the 3-D modeling CAD software Solidworks 2015.

VIII. SPECIFICATIONS OF PROTOTYPE

Table-1: Specification of wind turbine

SL. NO	Parts	Dimension				Material
		Outer	Inner	Height	Thickness	
1	Base stator	500mm	50mm	-	15mm	Plywood
2	Shaft	50mm	-	800mm	3mm	Metal
3	Turbine blade	100mm	-	500mm	3mm	PVC pipe
4	Magnet on shaft	75mm	50mm	-	12mm	Neodymium
5	Magnet on base stator & rotor	30mm	-	-	5mm	Neodymium

Table -1 shows all parts of wind turbine containing all their dimensions with the materials associated with it.

IX. CFD SIMULATION OF MAGLEV VAWT USING FEA

Finite element analysis helps predict the behaviour of products affected by many physical effects. Applying various pressure difference conditions to analyse system.

A) Pressure Difference of 1 Pa
B)

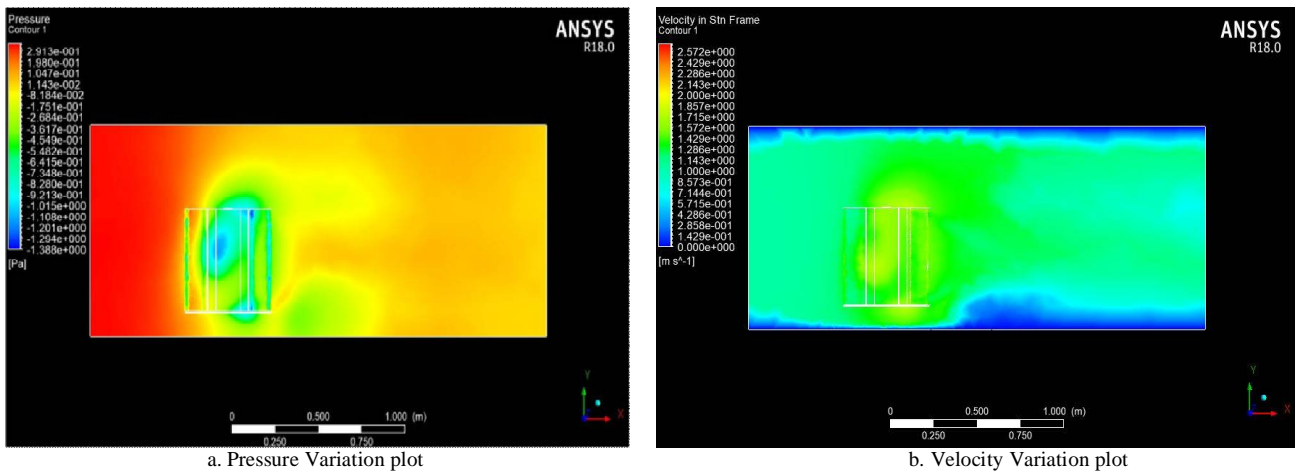
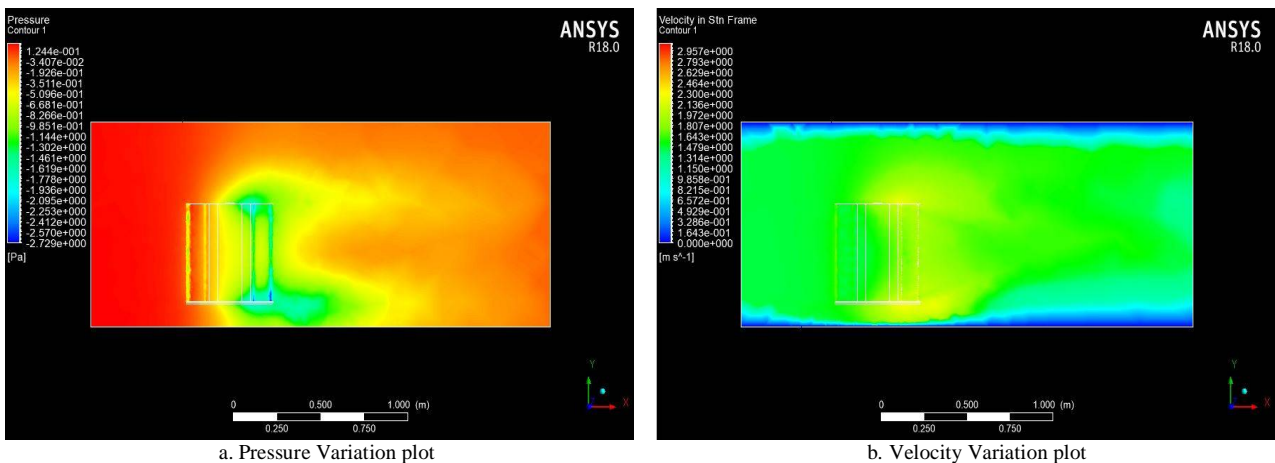


Fig -5: Pressure difference of 1 Pa

Fig -5 shows pressure variation plot, velocity variation plot and torque generated for pressure difference of 1 Pa viewed by a contour cut plot from front view.

B) Pressure Difference of 1.5 Pa



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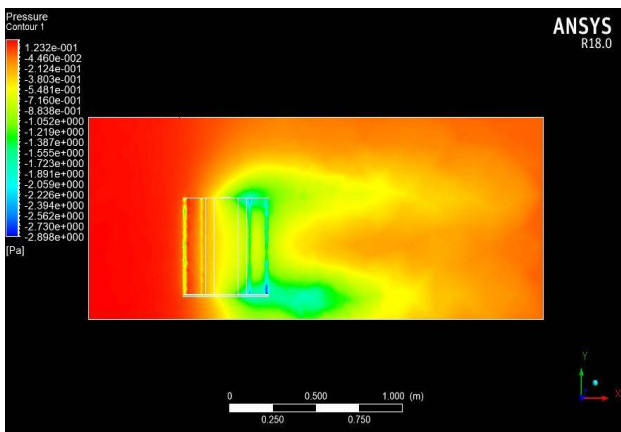


c. Torque generated

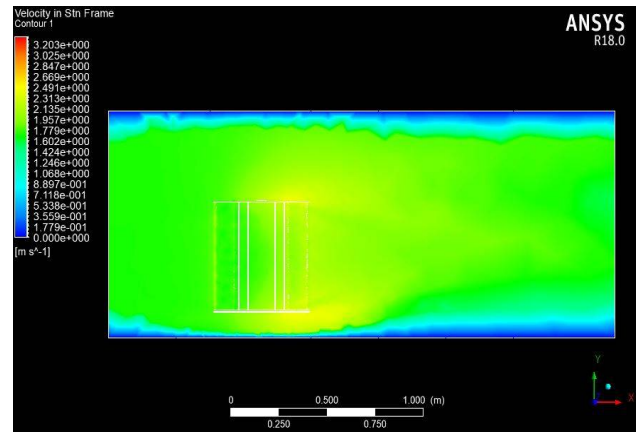
Fig -6: Pressure difference of 1.5 Pa

Fig -6 shows pressure variation plot, velocity variation plot and torque generated for pressure difference of 1.5 Pa viewed by a contour cut plot from front view.

C) Pressure Difference of 2 Pa



a. Pressure Variation plot



b. Velocity Variation plot



c. Torque generated

Fig -7: Pressure difference of 2 Pa

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Fig -7 shows pressure variation plot, velocity variation plot and torque generated for pressure difference of 2 Pa viewed by a contour cut plot from front view.

X. PROTOTYPE

A) Magnet placement

Ten magnets each having dimensions of diameter=30mm, thickness=6mm of disk type are arranged with alternate pole to each other in outer periphery. Also neodymium magnet is placed at centre for levitation. This is part of rotor.

B) Coil arrangement

Copper wire of 42 gauges 500 turns each are used as coil for power generation. Total 10 such coils are used in this prototype. These coils are arranged in such a way that coils are exactly below disc magnet of rotor. Coils are connected in series. This is part of stator.

C) Rotor

Rotor contains 6 blades of PVC material cut exactly through middle and are arranged at an angle 60 degree to each other. The disc of rotor has centre through hole of 18 mm diameter to support shaft (rod). Rotor downward disc is provided with 10 disc magnets of size 30 *6 mm.

D) Magnetic levitation

Magnetic levitation is the use of magnetic fields to levitate an object. Here stator and rotor are separated by some centimeters in air due very high repulsive force between two neodymium ring magnets placed on shaft. Two neodymium ring magnets of grade N35 having dimensions outer diameter=40mm, inner diameter=20mm, thickness=10mm are used. It replaces the use bearing hence reduces the friction. So it rotates at even low starting speed.

E) Inverter Circuit

An inverter converts the DC electricity from sources such as batteries or fuel cells to AC electricity. The transistors used in the circuit are CTC1351. Step up transformer, Capacitor and Inductor, Silicon Diode. A resistor of 220 ohms and a MOV (metal oxide varistor) is used to protect the other components of the circuit.

F) Final prototype

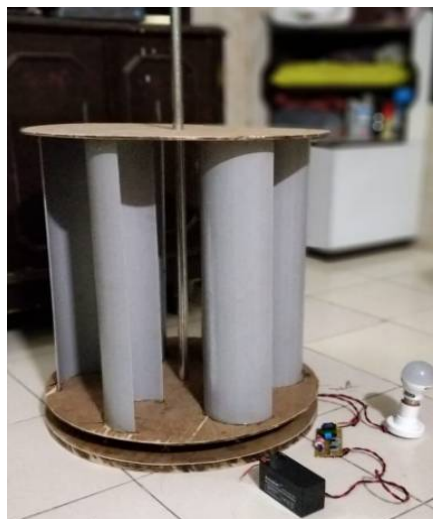


Fig.8 Final prototype

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Fig -8 shows assembly containing rotor, stator, shaft and other extra parts such as inverter circuit, rechargeable battery of 12 V, 1.3 Ah and LED bulb.

XI. RESULTS

A) Analytical results

Table 2- Results of FEA.

Case no.	Pressure Difference (Pa)	Rotation Developed (RPS)	Torque Developed (N-mm)	Power (W)
1	1	1	330.646	2.077
2	1.5	1	513.44	3.226
3	2	1	823.23	5.1725

Table -2 shows results of FEA in which pressure difference is varied keeping rotations developed as constant to find out torque and power.

B) Experimental results

To find output of wind turbine, generator was connected to multimeter where readings observed was .49 mA. Generator output was connected to a rechargeable battery when sufficient voltage is available, it starts charging battery while there is no load acting. LED bulb of 5 watt was connected with inverter circuit, when battery is removed from charging.

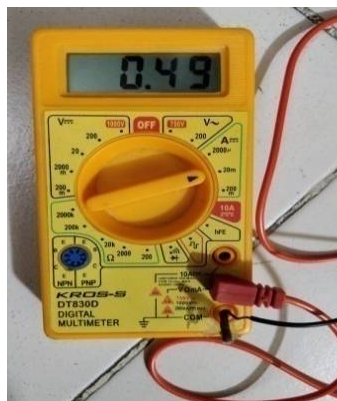


Fig.9 Multimeter reading

Fig -9 shows multimeter reading, where dial is set for voltage indication with red wire as positive connection and black wire as negative connection (common).

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XII. CONCLUSION

Magnetic levitation for wind power generators, represent a very promising future for wind power generation. Maglev wind turbines will require lower wind velocity for start-up and also they show better performance at lower wind velocities. The wind turbine rotors and stator levitated properly using permanent magnets which allowed for a smooth rotation with negligible friction. At moderate wind speeds the power output of the generator satisfied the specifications needed to supply the LED load.

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