VERTICAL AXIS WIND TURBINE PERFORMANCE ENHANCEMENT VIA UTILIZING THE REPULSIVE CHARACTERISTICS OF PERMANENT MAGNETS

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Abstract: Humans have been using wind power for past thousands of years to propel sailboats and ships. But from calendar year 1980s, in the energy sector we can see dramatic development in the form of wind energy. Today in renewable power, other than the hydropower, together with solar power, the wind is also most important source energy. Here the wind energy conversion system; consist of turbine which transforms the kinetic energy available in the wind into the mechanical energy, then the mechanical energy is boosted up with the help of gearbox and then generators are used to transform the rotational mechanical energy into the electrical energy. Now this paper mainly concentrates on the implementation of “magnetic propelling phenomenon” to improve the efficiency of the VAWT system and technology will be implemented between the rotating plane and fixed plane below the turbine, in such way that like polarities facing each other to create magnetic repulsion. The natural property of magnetic repulsion which is created between like poles of magnets can be used as a source of energy. Thus this system will operate with an additional feature like, magnetic repulsion characteristics. The force which is created as the result of the magnetic repulsion will also adds kinetic energy to the turbine while converting the wind kinetic energy into the rotational mechanical energy by the turbines, Hence here our PMP-VAWT system has the ability to operate in the both high & low wind speed environment condition with better efficiency due to the implementation of magnetic repulsive characteristics, and here our choice is to demonstrate the efficiency of PMP-VAWT system as compared to the Traditional VAWT system.

Keywords: Wind Energy, Vertical Axis, Efficiency, Turbine, Magnets, Repulsion.

1. Introduction

In wind energy conversion system, wind energy is harnessed by transforming the wind kinetic energy available in the wind into the rotational mechanical energy. Then this rotational mechanical energy boosted up by using gearbox and then used to turn generators shafts to generate electricity [2]. Here in our paper we mainly concentrated on the implementation of the “permanent magnet’s propelled VAWT system which has potential to run under both the high & low wind environment. Here our course of action is to compare efficiency of both PMP-VAWT system & Traditional VAWT system in the varying wind speed conditions.

2. Wind Sail Outline Composition

Normally the wind turbine system mainly consists of a set of blades, rotor shaft, and generator with gear box. When the air with kinetic energy pass through the turbine blades will result in change in pressure & this causes the rotational force at the turbine rotor shaft. When blade rotates, the kinetic energy available in wind is transformed in terms of rotational mechanical energy, later which boosted up in gear box and used to rotate generator shaft to produce electrical energy. Here the horizontal axis wind turbine & vertical axis wind turbine are the two main types of wind turbines. The horizontal axis wind turbine is like pedestal fan, Rotor shaft is arranged in vertical manner in VAWT, as its plane of rotation is vertical and will spins in a cylindrical in motion, which is older and lesser known in family of wind machines family [4]. The VAWT system provides diverse benefits over the standard HAWT system which is common in world due to its efficiency. VAWT can be classified in to two types: Darrieus & Savonius.

The savonius WT system is a drag based VAWT System, and will operate on principle of paddles. S-Shaped cross section rotors are fabricated in the savonius type rotor system. And the turbine which are based its operation on drag principle will have a much higher torque & little less rotation speed at its
shaft [3]. Hence here after studying both kind of VAWT’s rotors arrangements, finally we marked to support the substructure of our outline on savonius model and the design is visualized in Figure 1. As design was attained with a triangular shape cut out shape from aluminium metal sheet, we implemented a bit different outline in turbine blades, by adapting a curvature design from top of the sail to bottom of the sail at its outer line while resembling the standard outline of savounis models.

![Figure 1: Modified Savonius Turbine](image)

The scoop which was created due to implementation of magnetic propelling section will be eliminated by implementing curvature outline in design and to allow it for smoother torque during turbine rotation.

### 3. Magnetic Propelling Section

Here the magnetic propelling phenomenon implemented based on the repulsive characteristics of permanent magnet. The Nd-Fe-B (neodymium iron born) magnet and substantial supports are used to experience the magnetic repulsion, array type settings is provided in such way that the like polarities of magnets face each other [6]. Hence the magnetic repulsion created and will adds some kinetic force to turbine while transforming kinetic energy available in wind into the mechanical energy.

![Figure 2: Magnetic Repulsion Characteristic to produce circular motion.](image)

In our work, magnetic repulsion technology concept is enacted to cause the higher efficiency of turbine system [8]. The magnets are arranged in array like structure in between the base of the turbine i.e on rotating plane and fixed plane on supper structure when the same polarities face each other in arrangement, the magnetic repulsion will be experienced and this repulsion will give some kinetic energy to the rotary system. This force which was created due to the magnetic repulsion will also adds up some kinetic energy to the turbine while transforming kinetic energy available in wind into rotary mechanical energy and then in to electrical power [5].

### 4. Fact-Finding Methodology

Total power in the main wind stream is corresponding to the air density and the cross sectional area which is nothing but swept area of turbine which is perpendicular to the air flow direction & the wind speed of main wind stream [8]. That which can be written as follows,
Power in main Wind Stream \( \text{W/m}^2 \) = \( P_w \)

Air Density of main wind stream \( \rho = 1.2 \text{ Kg/m}^3 \)

Turbine swept area /cross sectional area which is perpendicular to wind stream = 0.174m\(^2\)

Main wind stream average velocity (m/s) = \( V \)

Table I: Wind power at various wind velocity

| Sl. No | \( V \) = Average Wind Velocity (m/s) | \( P_w = 0.5\rho AV^3 \) (W/m\(^2\)) |
|--------|----------------------------------|----------------------------------|
| 1      | 6                                | 22.55                            |
| 2      | 4.5                              | 9.51                             |
| 3      | 3.2                              | 3.42                             |
| 4      | 2.8                              | 2.29                             |

Now, the turbine mechanical output power \( (P_T) \) can been written by considering the function of tangential force \( (F) \) on wind turbine and Turbine shaft rotational speed per Minute \( (N_r) \) in RPM.

\[
P_T = \frac{2\pi N_r F}{60}
\]

Tangential force \( (F) \) = Mass of the turbine x turbine angular acceleration

Now,

\[
\text{Angular Acceleration} = \frac{\text{acceleration (a)}}{\text{radius of the turbine (r)}}
\]

The change in velocity of the turbine = \( v-u \) (rev/sec)

Angular acceleration = \( \frac{\Delta v}{r} \) (rev/m\(^2\))

Mass of the turbine = 3.1kg

\( N_r = \text{Turbine Revolution per Minute} \)

Now the efficiency of the turbine can be considered as power coefficient \( (C_p) \) which is given by the ratio of mechanical output power of the turbine to the total power which can be accessed from the main wind stream at the cross section area of the wind turbine [6]. Hence Power Coefficient \( C_p \) can be written as follows

\[
C_p = \frac{P_T}{P_w}
\]

The positioning of permanent magnets is experimented with various orientation combinations. The practical experiments are carried out at various wind speed condition.

Table II: Efficiency of PM- Propelled VTWT at different orientation of magnets

| Sl. No | \( V \) (m/s) | Magnets Orientation | \( P_T \) | Efficiency \( = P_T/ P_w \) (%) |
|--------|--------------|---------------------|----------|--------------------------------|
|        |              | Traditional - Vertical Axis wind turbines |          |                                |
| 1      | 6            | Traditional Vertical Axis Wind Turbine without Magnets | 38.52    | 1.71                           |
| 2      | 4.5          |                                     | 13.70    | 1.44                           |
| 3      | 3.2          |                                     | 3.71     | 1.08                           |
| 4      | 2.8          |                                     | 1.75     | 0.76                           |
|        |              | Permanent Magnet Propelled VAWT      |          |                                |
| 5      | 6            | 6 Sets of Magnets are                | 46.48    | 2.06                           |
| No | Magnets | Orientation | Value 1 | Value 2 |
|----|---------|-------------|---------|---------|
| 4  | 6       | Placed in 180° angle Orientation (Parallel to Each other) | 16.48   | 1.73    |
| 5  | 7       | Placed in 180° angle Orientation (Parallel to Each other) | 3.61    | 1.05    |
| 6  | 8       | Placed in 180° angle Orientation (Parallel to Each other) | 1.57    | 0.69    |
| 7  | 9       | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 38.52   | 1.71    |
| 8  | 10      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 13.70   | 1.44    |
| 9  | 11      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 3.71    | 1.08    |
| 10 | 12      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 1.75    | 0.76    |
| 11 | 13      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 42.64   | 1.89    |
| 12 | 14      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 13.70   | 1.44    |
| 13 | 15      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 1.80    | 0.53    |
| 14 | 16      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 1.11    | 0.48    |
| 15 | 17      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 39.40   | 1.75    |
| 16 | 18      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 13.70   | 1.44    |
| 17 | 19      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 3.66    | 1.07    |
| 18 | 20      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 1.67    | 0.73    |
| 19 | 21      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 40.28   | 1.79    |
| 20 | 22      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 16.69   | 1.75    |
| 21 | 23      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 3.76    | 1.10    |
| 22 | 24      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 1.80    | 0.79    |
| 23 | 25      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 45.43   | 2.01    |
| 24 | 26      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 17.51   | 1.84    |
| 25 | 27      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 5.64    | 1.65    |
| 26 | 28      | 6 No's of Magnets are Placed in fixed Plane & 1 No in Rotary Plane in 180° angle Orientation | 3.30    | 1.44    |
| 27 | 29      | 6 Sets of Magnets are Placed in 45° angle Orientation | 67.42   | 2.99    |
| 28 | 30      | 6 Sets of Magnets are Placed in 45° angle Orientation | 24.21   | 2.54    |
| 29 | 31      | 6 Sets of Magnets are Placed in 45° angle Orientation | 6.72    | 1.96    |
| 30 | 32      | 6 Sets of Magnets are Placed in 45° angle Orientation | 3.66    | 1.60    |

4. Simulation

Team Mathwork has been developed an application called MATLAB simulink with additional feature like Simulation & Linking, which offers modeling of a system, and simulation & analyzing the same in a multi domain of a dynamic system under GUI Interface environment. Here the models of multi domain dynamic system are easily constructed by just a click on selection box with suitable customized set of libraries block and these library block will allows matrix operation, creating data
table for analysis and plotting of those functional data’s on graph by implementing the customized algorithm. Hence we have selected MATLAB Simulink software for creating experimental model.

![Figure 3: Simulation counterpart via Simulink MATLAB application](image)

4. Results and Discussions
The attraction and repulsion characteristics of permanent magnets can be considered as a source of energy. The repulsion characteristic of permanent magnets will also add some sort of kinetic energy to the turbine while transforming the kinetic energy available in the main wind stream to rotation mechanical energy [7].

For performance analysis comparison in consider Table 1 & Table 2, and its observed that the Permanent Magnet Propelled- VAWT have an efficiency of 2.99% which is improved when compared to Traditional- VAWT having an efficiency of 1.77%. So now efficiency got increased due to the implementation of magnetic propelling section by using permanent magnets.

5. Conclusions
In the present situation there is no doubt that the energy production in the world must be increased drastically on immediately on continual basis. Un-even heating of the earth surface which caused by earth rotation will create change in air pressure which creats wind energy and in 20th century we are facing a global warming means temperature on earth is increasing rapidly, hence there will be a change in air pressure which will result in air in motion. Hence there won’t be a scarcity in wind energy in future. Here additional option of free energy concept from permanent magnets looks like cutting edge technology, but it’s feasible at given appropriate condition and in future it will become more economical.

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