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SHORT COMMUNICATION

Design and Construction of Vertical Wind Turbine

G. Divya[1*], M. Gayathri Devi[2], Sanjay Kumar Suman[3] and M. Yogesh[4]
[1, 2,3]Course of Embedded System Technologies, Velammal Institute of Technology, Panchetti-601204, Thiruvallur District, TN, India
[4]Dept. of Mechanical Engg., Anna University, Chennai -600025, TN, India
divyasathishg@gmail.com*; +91 9171160800

Abstract

Effective lift and drag forces for a vertical axis wind turbine design is based on averaged torque per cycle. Vertical Axis Wind Turbine (VAWT) produce torque by both lift and drag using a semi-airfoil shape; allow air to flow through a cavity connecting the two blade halves resulting in decreased turbulence and friction. In this study, this metric is used to characterize the relationship between overall optimum aerodynamic performance and design. The study found that for modest momentum coefficients, significant net power augmentation can be achieved with relatively simple aerofoil geometry if blowing is controlled through the blades rotation.

Keywords: Wind turbine design, semi-airfoil shape, aerodynamic performance, momentum coefficients.

Introduction

The increase in the emission of greenhouse gases and other pollutants with the increase in the demand for electricity is a cause of concern worldwide. India, with the rapid economic growth which leads to the rapid industrialization coupled with urbanization has been responsible for the increasing demand of electricity ever since independence. There has been a large gap between the supply and demand of electricity. The production of electricity is mainly based on fossil fuels such as coal; oil and natural gas are known as non-renewable resources. It took millions of years to be formed in the crust of earth by natural processes. Once they were used (burnt) to produce electricity, they are gone forever and we cannot replace it. Beside the slow extinction of our non-renewable fossil fuel, it also has another devastating face which costs for the environment. They emit toxic pollutants such as sulphur-di-oxide, nitrous oxide and carbon which have deleterious effect on both our environment as well as our health systems. The repercussions due to the use of fossil fuels have shifted our focus towards renewable sources for the generation of electricity (Global wind energy market, 2006).

One way of generating electricity from renewable sources is to use wind turbines. Wind turbine is a device which extracts power from moving wind (mechanical energy) and delivers it as a useful electrical energy. Two types of wind turbines viz., Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT) are being commonly used. Although HAWT is the most commonly used wind turbine, VAWT with some new and improved technology couple with the decreased production cost will have a great impact in actual market (Kasmi and Masson, 2010).

The reduced space consumption of VAWT is the biggest advantages which in turn, term them as ‘Urban Windmill’. The increasing trend towards the use of wind turbine for the production of electricity worldwide has opened a new way to achieve our electricity needs. In near future, wind turbines may start to influence the behavior of electrical power systems. Therefore, adequate models to study the impact of wind turbines on electrical power system behavior are needed. In this study, a modified vertical wind turbine is proposed which works on lift and drag mechanism involving aerodynamic force. This vertical wind turbine has its axis of rotation about y-axis. Here the moving wind is allowed to flow through blades which act as a prime mover. The prime mover helps to rotate the rotor which contains the magnets (Jha, 2010). Keeping the above facts in view, the aim of the present study is to design and construct a vertical wind turbine and assess its usefulness for the production of electricity especially in household set-up.

Materials and methods

Proposed system: In existing Darrieus design, the angle of attack changes as the turbine spins, so each blade generates its maximum torque at two points on its cycle (front and back of the turbine). This leads to a sinusoidal (pulsing) power cycle that complicates design. In existing savonius, there is a presence of pulsating torque. This might affect the output (Khan, 1998). In existing giromill there is no self-start. In this study, the airfoil is introduced where the torque is uniform without any changes in various points. As the airfoil in this turbine forms a cup shaped structure, there is no need of another resource to start the turbine, it is a self-starting process.

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Fig. 1. Working principle of newly designed turbine.

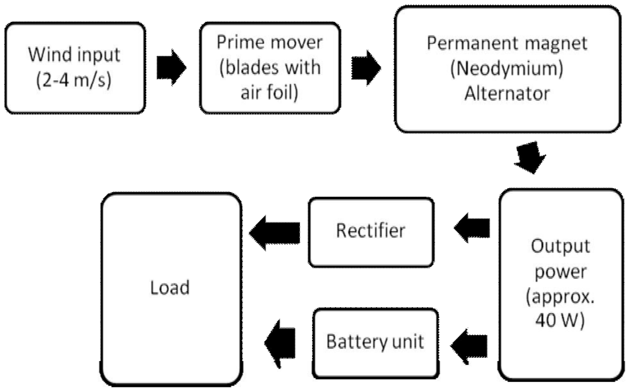
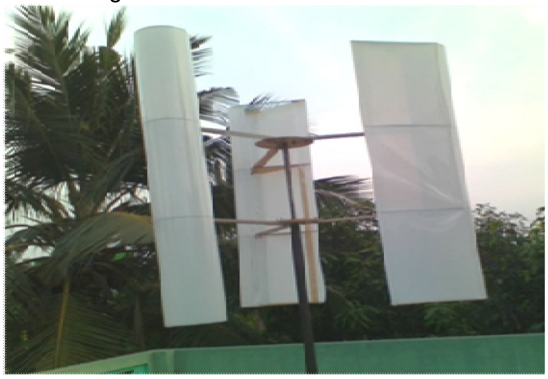


Fig. 2. Airfoil arrangement.

Fig. 3. Blade design.

Fig. 3. Over all view of the turbine.



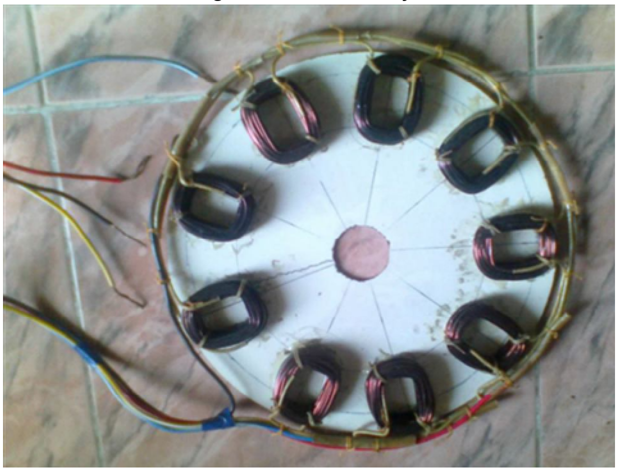
To overcome the disadvantages of those turbines, a unique, mixed Darrieus-Savonius-Giromill type is implemented here. The main benefits obtained are improved performance at lower wind speeds and a lower rpm regime at higher wind speeds resulting in a silent turbine suitable for residential environments (Ali, 2009). The working principle of newly designed turbine is shown in Fig. 1.

Airfoil: In this blade design, the aerofoils are arranged in such a way that they are symmetrical and have zero rigging angle, that is, the angle that the aerofoils are set relative to the structure on which they are mounted (Fig. 2). This arrangement is equally effective, no matter which direction the wind is blowing-in contrast to the conventional type, which must be rotated to face towards the wind. When the rotor is spinning, the aerofoils are moving forward through the air in a circular path (Fig. 3). Relative to the blade, this oncoming airflow is added vectorially to the wind, so that the resultant airflow creates a varying small positive angle of attack (AoA) to the blade. This generates a net force pointing obliquely forward along a certain 'line-of-action'. This force can be projected inwards past the turbine axis at a certain distance, giving a positive torque to the shaft, thus helping it to rotate in the direction it is already travelling in. The aerodynamic principles which rotate the rotor are equivalent to that in autogiros and normal helicopters in autorotation. As the aerofoil moves around the back of the apparatus, the angle of attack changes to the opposite sign, but the generated force is still obliquely in the direction of rotation, because the wings are symmetrical and the rigging angle is zero. The rotor spins at a rate unrelated to the wind speed and usually many times faster. The energy arising from the torque and speed may be extracted and converted into useful power by using an electrical generator.

Permanent magnet alternator: This type of generator uses permanent magnet for self-excitation that is made without energy supply, thus the efficiency is higher than the induction machine. Power can be generated at any speed and if provided with a large number of poles, it can have a slow rotational speed if compared to conventional generators (Fig. 4).

Fig. 4. Rotor assembly with permanent magnet.

Fig. 5. Coil assembly.



Rotor: There are 12 magnets on each disc, they have to be positioned every 30° in an opposing layout. So one magnet will go down with its North facing and the next one will have its South facing up.

- Number of magnets used: 12 (Neodymium)
- Coil segments: 9
- Size of magnet: 30 X 20 X 15
- Neodymium permanent magnet (magnetized through) used as flux material which produces the required flux.

Stator: The stator is a basic 9 coil single layer arrangement, one of the simplest ones to do and it is 3 phase wired in star (Fig. 5).

- Dimension of coil: 50 X 40 X 40 (Copper coil)
- Angle b/w magnets: 300
- Angle b/w coils: 400
- Tip speed ratio

Power calculation of voltage production by alternator: A permanent magnet alternator is simply a set of magnets moving relative to wires. Electric current is induced in the wires in a phenomenon that has been known since the days of Faraday. The voltage produced is alternating current (hence-alternator-‖) and follows a classic wave pattern.

The level of maximum (peak) voltage production is approximate by the following equation:

$$Vmax = \frac{NARPB}{2}$$

Where N is the number of loops of wire, A is the area enclosed by a loop of wire, in square meters, R is the rotational velocity of the magnets, in cycles per second, P is the number of magnet poles per cycle and B is the strength of the magnetic field of each pole in Tesla.

Results and discussion

The magnets that are being used in vertical wind turbine have an intrinsic strength of about 0.8 Tesla. However, there is an air gap between the magnets and the wire loops. The magnetic field intensity drops off quickly in an air gap. If the air gap is around a quarter inch, then the field would be approx. 0.65 Tesla. The area enclosed by a loop of wire in vertical wind turbine is about 3 cm by 2 cm, or about 1 x 10^{-3} sq.m. Vertical wind turbine has 12 magnetic pole changes per cycle. It has 780 loops of wire. Let's say vertical wind mill spins at 4 cycles per sec. Then, an estimate of the peak voltage would be:

$$V_{max} = \frac{(780)\times(1\times10^{-3})\times(12)\times(4)\times(0.65)}{2} = 18.72 \text{ Volts}$$

Power output:

Watts output = 0.00508 × $Area \times windspeed^3 \times efficiency$
(Area in sq.ft (height x width), Wind speed in mph).
The 3 x 3 described above in a 15 mph wind and an alternator of around 75% efficient would have a power output of:
0.00508 × (3 × 3) × 15^3 × (.41 × .75) = 46.29 watts
Efficiency would vary depending on the alternator and building techniques. The turbine as tested will function at 41% efficiency at the shaft.

Specific power output:

0.00508 × (3 × 3) × 15^3 × (.41 × .75) = Total sq. feet of area.
If we want 63 watts in a 15 mph wind using the number from above:
$\frac{46\ watts}{(0.00508\times15^3\times(0.75\times0.41))}$ = 8.72 sq.ft (or a 3 ft dia x 3 ft tall)

Advantages of vertical axis wind turbine: VAWT can extract power from wind coming from all directions, easy to build, slow speed of rotation, so parts do not wear easily. Alternator is near ground level, renewable source of energy, low cost power and power can be extracted in inaccessible areas. VAWT is flexibility in various locations, ease of installation, strong and durable and minimal maintenance and it can withstand harsh environment. VAWT can be applicable in several areas such as; remote facilities, residential, end of the line power, oil rigs and off-shore platforms, ships, island, commercial buildings, communication towers, tall bridges and over passes and electric hybrid automobiles.

Conclusion

From this study, we infer that the green energy can be utilized to fulfill the needs of increasing power demands. Due to its compact design, VAWT can be implemented for domestic use as well as commercial requirement. A three-bladed design is more efficient than a four-bladed rotor; airfoil arrangements keep the torque of the turbine high as possible, so it can give the high efficiency at lower speeds and there is no self-starting problem. It is expected that this kind of project will be encouraged as well as taken into consideration for meeting power demands.

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