Design of a Vertical Axis Micro Wind Turbine to Re-Use Foul Air through an Exhaust Fan

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Abstract – *Wind energy is often referred to as the more efficient way of reproducible energy. Across the wild world wind turbines are highly revered and wind energy is often referred as the future of energy generation. But yet, only around 10% of the entire energy generated across the world is the product of wind energy. In a lot of cases kinetic energy of the wind/air just goes to waste. This thesis hence aims to use the wind energy that is expelled as waste air from the homes by exhaust fans and convert the kinetic energy of the wind to electrical energy using a Vertical-Axis Micro Wind Turbine. In this setup a vertical axis micro wind turbine is placed at back of a exhaust fan that faces inside the home.*

***Key Words*: WIND ENERGY, VERTICAL AXIS WIND TURBINE, RENEWABLE ENERGY, EXHAUST FANS, ENERGY EXTRACTION, ENERGY REGENERATION, CLEAN ENERGY**

1. Introduction

A wind turbine, or alternatively referred to as a wind energy converter, is a device that converts the wind's kinetic energy into electrical energy. Wind power has become one of the fastest emerging renewable energy technologies for electricity generation, and the total installed capacity has reached 487 GW (about 4% of the global electricity) by the end of 2016. The development of an effective wind turbine (WT) design, especially for an urban area, is critically needed to increase the penetration of wind power technology in cities and semi-urban areas. Wind turbines are largely categorized into two types based on their axis of rotation.

1. Horizontal Axis Wind Turbine (HAWT)
2. Vertical Axis Wind Turbine (VAWT)

The orientation of the shaft and rotational axis determines the classification of the wind turbines. A turbine with a shaft mounted horizontally parallel to the ground is known as a horizontal axis wind turbine or (HAWT). A vertical axis wind turbine (VAWT) has its shaft normal to the ground. [1]

Vertical-axis wind turbines are becoming more and more common these days and are often referred to as omnidirectional wind turbines because the vertical axis wind turbines do not need to change their orientation with respect to the direction of the wind. This acts as major advantage over horizontal axis wind turbines as HAWTs require to change their orientation with respect to the direction of the wind. This causes HAWTs to lose efficiency in energy generation when compared to VAWTs.

Exhaust fans are widely used globally for variety of operations, one of which, is their primary household application to drive out foul air produced majorly in kitchens if homes. The foul air is sucked in by the exhaust and let out at the other end of the exhaust fan which is usually located at the exterior of the house.

The VAWT is placed the at the face of the exit path of the exhaust fan. The foul air sucked in by the exhaust fan is blown towards the VAWT which used the kinetic energy of wind and generates electricity.

The idea of production of minimal yet significant units of electricity, from foul waste air, might feel rather wasteful. But even the minimal amounts of energy generated when summed up, account to a large amount of energy when done on a large scale.

2. LITERATURE SURVEY

Wind energy extraction can be maximized when the rotor efficiency operates at maximum. This maximum should occur at reasonable costs and ideal situations.

Energy (P) carried by moving air is expressed as a sum of its kinetic energy

$K.E = \frac{1}{2}\rho A V^3$

Where,

V - Air Velocity

A – Turbine Swept area

ρ- Air Density

A physical limit exists to the quantity of energy that can be extracted, which is independent of design. You can only convert 59.3% of the kinetic energy by the wind to mechanical energy, as stated by the Betz's law. This is because the wind on the back side of the rotor must have a high enough velocity to move away and allow more wind through the plane of the rotor. 'C' is known as the betz's co-efficient which is equal to 16/17. [3]

3. Design

For this setup, a VAWT was chosen due to the novelty of current VAWT designs as well as due to the higher efficiency it provides over HAWT.

The advantages of the VAWTs are that they can accept the wind from any direction. This simplifies their design and eliminates the problem imposed by gyroscopic forces on the rotor of a convectional machine as the turbine tracks the wind. The vertical axis of rotation also permits mounting the generator and drive train at ground level.

The design intended that the turbine should have low cut-in wind speed, lightweight, and can be easily moveable. The drag-based machine should be capable of harnessing energy from the non-directional wind at low cut-in speed, which makes it a better choice for many urban applications. For a VAWT, efficiency depends on the airfoil chord, number of blades, rotor radius and height of the blades. In the design process of a vertical-axis wind turbine it is crucial to maximize the aerodynamic performance. [2]

The VAWT is installed exactly 500mm away from the exhaust at the exterior of the house so that it doesn't accidentally come in contact with the exhaust fan while keeping the wind losses low.

3.1 **Exhaust**

Exhaust fans are mainly used to suck in foul air while circulating the clean air. To be implemented in residential houses the exhaust fans need to be compact that can fit into one corner of the room. The blades are curved to improve the efficiency of circulation of air while keeping the entire exhaust assembly at a lower weight.

For this experiment the radius of the exhaust fan was kept at 300mm and was made to rotate at a speed of about 1400rpm so that the air sucked in can be at a usable velocity to drive the VAWT.

FIG. 1: Isometric View of the Exhaust Fan Design

FIG. 2: Front View of the Exhaust Fan Design

3.2 **Vertical-Axis Wind Turbine**

The wind turbine has been given sufficient clearance from the unit as too large a distance would create a disruptive pattern of flow due to interference of regional air and also incessantly occupy a larger space, on the contrary if the turbine is placed at a seemingly close distance from the unit back pressure might be generated, having a knock on effect on the turbine.

The blades of the VAWT have an approximate diameter of 500mm and each blade has a height of approximately 800mm. The VAWT is placed upon a 1000mm cylindrical casing which houses the generator. The shaft that connects the blades and the generator is connected through a series of gears to increase the speed of rotation for increasing the energy production of the VAWT.

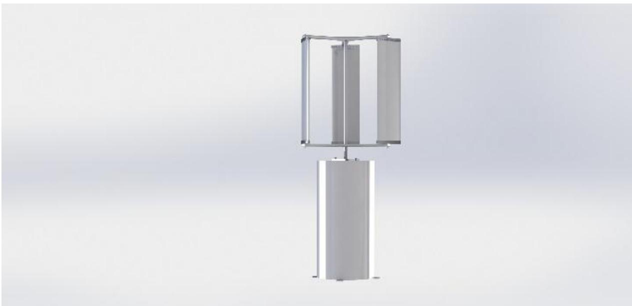

FIG. 3: Front View of VAWT Design

FIG. 4: Top view of VAWT Design

3.3 **Setup**

The turbine will be a 3-blade vertical axis wind turbine placed right behind the exhaust fan at the exterior of the house leaving a gap of 500mm between the exhaust fan and the VAWT. This will lead to a better wind flow and optimal use of space.

Theoretically, the efficiency of the wind turbine can be said to be directly proportional to the number of blades of the turbine. However, when we take into consideration a turbine which has a relatively small swept area then the relationship between efficiency and no of blades as mentioned above changes. This happens due to the fact that if the rotor has too many blades then the flow of the wind through it is disrupted due to small clearance and aerodynamic interferences. Due to this overall efficiency decreases.

FIG 5 – Setup Design

4. Working

To determine the energy that can be produced through this experimental setup the following calculations are made:

$K.E = \frac{1}{2}mv^2$ (1)

Where, K.E = kinetic energy
m = mass
v = velocity

M is equal to its Volume multiplied by its density ρ of air i.e $M = \rho AV$ (2)

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

We get, $K\,E = \frac{1}{2}\rho AV.V^2$

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

Where,
A= swept area of turbine
ρ= density of air (1.225 kg/m3)
V=wind velocity.

We consider the velocity of wind coming out of a exhaust fan rotating at a speed of 1400 to be around 6 m/s (Generic value of velocity of air through fans)

1. Velocity of the wind coming out of the air compressor (V) = 6 m/s
2. Density of air coming out of the Air conditioner (ρ) = 1.23 kg/m^3.
3. Diameter of blades of the wind turbine (D) = 500mm = 0.5 m
4. Height of the blades (H) = 800mm = 0.8 m
5. Swept area of the wind turbine (A) = [π*D*H]

A = $1.256m^2$

You can only convert 59.3% of the kinetic energy by the wind to mechanical energy, as stated by the Betz's law. This is because the wind on the back side of the rotor must have a high enough velocity to move away and allow more wind through the plane of the rotor. 'C' is known as the betz's co-efficient which is equal to 16/17.

C = 16/17 = 0.593, Betz's Co-efficient.

Now we can write the revised formula as,

$$P = \frac{1}{2}\rho AV^3C$$

The power hence obtained from the term given will be in watts (W).

Substituting the obtained values into the aforementioned formula, we can calculate the power production in the given modeled setup, the power that will be obtained here, will be the theoretical maximum amount for the turbine.

$$P = 0.5*1.23*1.256*(6)^3*0.59$$

P = 98.439 Watts

Considering turbine efficiency as 35% and Generator efficiency as 85%

P = 98.439*0.35*0.85

Therefore,

P = 29.28 Watts (Approximately 30 Watts)

30 Watts may not be as much as much as the power generated in regular wind turbines, but this energy can be used for a large number of non-power intensive applications in the household. Below are the ways the energy generated can be utilized:

- To run a 22-inch LED TV
- To run an air purifier

- Small appliances like amazon echo, google home, apple tv or chromecast
- To run a radio on power rather than batteries
- To charge various household appliances [3]

5. Conclusions

The main purpose of this thesis was to develop a portable and efficient system that can be used to generate small amounts of electricity which in turn could be used for domestic non-power intensive applications. Solidworks was used to design both the exhaust fan and the VAWT.

Foul air extracted by the exhaust fan which was considered to be useless has been utilized to generate power capable enough of running everyday appliances. Other than that, these wind mills can be used to store energy in case of emergencies at provide energy at once at a larger scale. This would be possible if a homes start adopting such technologies and improving waste energy utilization at a higher level

There's a lot of scope in the field of micro turbines and there will definitely be future advances in the technology that'll help generate more amounts of power and reduce our dependency on non-replenishable fuels. This thesis hopes to be the stepping stone that clean energy future.

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