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Power Generation Through VAWT Implementation on Highways & Stabilization the Output Voltage by Controlled Buck-Boost Converter

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***Abstract*—** There is abounded wind available to entertain our energy requirements if it could be utilized in an effective manner.Wind turbines are able to generate enough power thus decreasing the need for expensive power generators that cause pollution. In comparison to horizontal axis wind turbines (HAWTs) the vertical axis wind turbines (VAWTs) are much more efficient and reliable because of its simplisity and cost effectiveness.This study in vestigates that wind energy is able to cope with the energy crisis we are currently having all over the globe. Although the use of Horizontal Axis Wind Turbine (HAWT) in today's world is more than the Vertical Axis Wind Turbine (VAWT) but they have some issues as they require higher wind speed as compared to VAWT to generate enough mechanical work to produce electrical power. Peshawar highways wind profile was implemented in this experiment. The wind on highways is not constant all the time as it is dependent on the moving vehicles and varies time to time. The project can be theoretically implemented in the light of Peshawar highways wind profile. Wind energy could be valuable source of energy because of its importance of environmental friendly and free of cost once it is installed. The main goal of this research is to model such type of VAWT for high-ways to get kinetic energy produced by the air flow of moving vehicles and to transfer that energy into mechanical energy furthermore that mechanical energy will be converted to electrical with the help of generator. This vertical axis wind turbine is feasible on high ways due to its unique structure. It can capture the wind in both directions on highways. The project is tested in both theoretically and experimentally and it outclassed all previous models.

***Keywords*—** Vertical axis wind turbine, Buck boost converter, Stepper generator.

I. Introduction

FOSSIL fuels are considered to be one of the main sources to cope with the energy requirements around the world., however going with it for long-term can cause some serious damage, these resources can be adequate for the next few generation. Governments and higher authorities should take this matter serious and should give a chance to other sources of energy as a replacement of conventional resources that are environmental friendly and feasible.[6] The expeditious growth in global economy has accorded to our rapidly increasing demand for energy. However, the environmental unfriendly resources like fossils fuels such as coal, oil, and natural gas, which are considered to be the main energy source since the world's revolution are not only dealing with its exhaustion but is also slowly becoming a serious threat to our environment.[1] Among the renewable resources that we have wind energy seems to be the best option to replace the conventional resources. [2] The history of wind power is older than 3000 years, and utilizing this power to generate electrical power has started about 100 years ago. [3] Germany, USA, Denmark and Spain were among the first few countries who implemented this idea of converting wind energy into electrical energy on larger scale, similarly other countries like China and Turkey have done considerable work to register their names in the list of countries using wind energy as a source for running their industries.[1,3,4] It is expected that wind energy will supply 5 percent of the world's energy requirements by the end of 2020 [5]. This paper aims at the production of electricity in a clean, green and environmental friendly way by utilizing the wind energy and converting it into electrical energy through VAWT.

A. Related Work

In 2010, Kooiman and Tullis [7] did an experiment to evaluate the effects of unreliable wind on the aerodynamic performance of the vertical axis wind turbine. All the variations in wind speed were noted and were compared to a test case wind tunnel performance. Hara et al [8] examined the effects of changing wind speed on the performance of vertical axis wind turbine and the change in rotor's moment of inertia because of this varying wind. In 2012, Scheurich and Brown [9] presented their work on a numerical model of VAWT aerodynamics for fluctuating wind. The average speed of the pulsating wind was 5.4m/s with a varying frequency of 1Hz. Experiment was done for three types of designs including straight, curved and helical and different amplitudes were recorded. The rest of this research is structured as follows. In Section II, the designing of vertical axis wind turbine is presented. In Section III, Power Analysis of the VAWT is presented, followed by the numerical results and discussion in section IV. At the end in Section V conclusion of the whole work is given.

II. SYSTEM MODEL LAYOUT

A. Designing of Vertical Axis Wind Turbine

A Wind Turbine is a device that converts the kinetic energy of the wind into mechanical energy which is being converted into electrical energy by an alternator. The components of the full-scale VAWT are support structure, Blades, Shaft, DC generator, converter and battery.

TABLE I NOTATION SUMMARY

S. NO.	Parameter	Description
1	ρ	Air density
2	$K.E_w$	Kinetic energy of wind
3	P_w	Available wind power
4	V_w	Wind speed
5	A_s	Rotor swept area
6	L_b	Length of blade
7	D_r	Diameter of rotor
8	R_r	Radius of rotor
9	D	Duty cycle
10	V_i	Input voltage
11	V_o	Output voltage
12	L	Inductor
13	I_L	Inductor current

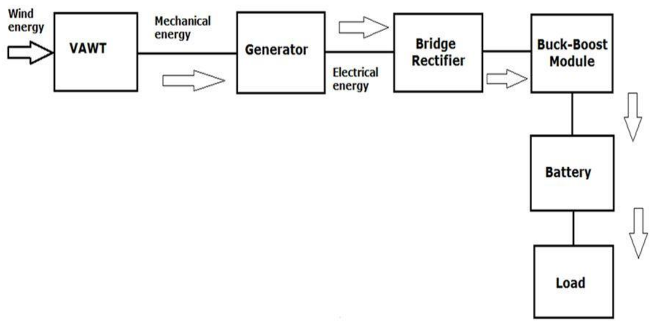

Figure 1. Block diagram

The project will check the feasibility of implementing vertical axis wind turbine on highways. For this purpose, clear areas of the Peshawar will be analyzed for mean wind speeds and traffic conditions. Data were collected through an anemometer on highway for different times of the day keeping in mind the rush traffic hours when there were heavy traffic flow and normal traffic routine when there were light traffic on the highway. The turbine rotation also depends on the light vehicle speed and heavy vehicle speed. Putting all those assumptions and after calculations and theoretical work we designed a VAWT that would best harnessed the wind energy that is present on the highways. The design of the vertical axis wind turbine (VAWT) allows making use of the wind energy on the highways in effective way as it has the ability to rotate on wind flowing on both sides of the divider on highways. The two most important advantages of installing vertical axis wind turbines on highways are that there will be no need of searching for land as highway dividers will be used for the implementation of project and there will be no noise problem as residential areas are normally far away from highways. Previously the best use of wind turbines was in areas where the wind is available in excess like hilly areas, seashores, river banks etc. But with this project we are presenting the idea of installing these wind turbines on the dividers of highways in order to utilize the wind produced by moving vehicles in an effective way. The main reasons why a VAWT are as follows:

- Starting speed is low about 3-4 m/s.
- Less maintenance is required.
- Configured to capture wind from any direction without any external control.
- No massive and tall towers are required.
- Long life span.

1) SUPPORT STRUCTURE:

For making the whole structure strong enough to sustain high pressure winds and extreme weather conditions we have used an iron stand for this turbine which will also provide support to the main rotatory part of the turbine. The height can be adjusted according to the need in our case 2-3 feet are enough because the normal height up to which the wind blows on highways is 4-5 feet.

2) DESIGN OF BLADES:

For the designing of blades of a VAWT PVC pipes were used. keeping in mind the cost, size and wight of the blades while designing a VAWT because of it significance. The reason why we used PVC pipes in our project for the making of blades for the wind turbine is that it is lighter in weight as compared to carbon fiber etc. These blades have the ability to sustain high pressure air and rain. The cost of these blades is very low as compared to other blades available in the market. Eight blades from PVC pipes are used in this prototype, the height of each blade is 2.6 ft. The angle of each blade is 65 degrees. It makes easy for the other blades located behind of the respected blade so if the first blade moves through wind so the other blade comes in the position of first blade and rotate so the speed increases.

$A_s = Lb*Dr$
where,
$L_b = 0.79$ m
$D_r = 0.70$ m
$A_s = 0.79*0.70$
$A_s = 0.55$ m

Figure 2. Blades of VAWT

3) DESIGN OF ROTOR:

The rotor of the turbine should be well designed to sustain the extreme conditions. In this project a bicycle rim is working as a rotor. I have used it by considering the width of the highway divider so that maximum amount of wind can be utilized. I have attached a gear system of 1 ratio 15 at the bottom of the rotor in order to achieve the required power. The shaft of the rotor is easy to rotate to slow winds.

Figure 3. Rotor of VAWT

4) DC GENERATOR:

The stepper generator is mechanically connected to the shaft of the turbine which will convert the mechanically energy produced by turbine to electrical energy. As the electrical power produced by stepper generator is in the form of AC so it should be converted into DC first for this purpose we have connected a bridge rectifier circuit which will convert AC into pulsating DC and a capacitor is also used in the circuit which will convert that pulsating DC into pure DC.

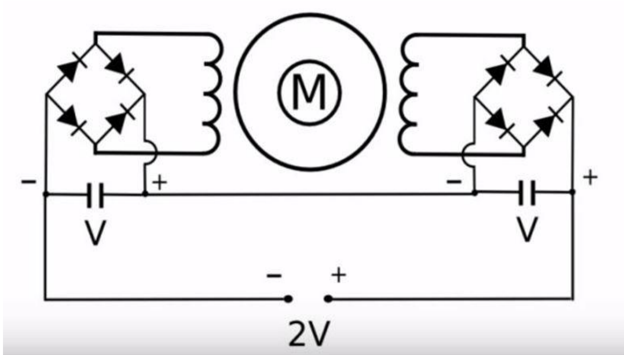

Figure 4. Bridge rectifier circuit

We have used stepper motor as a generator for this turbine because of the following reasons:

• Stepper generator generates power at low RPM.

• Stepper generators are brushless so the only wearing parts should be the shaft against the bearings.

• They are cheap as compared to DC generators.

• Can get enough power with simple gear system rather than a complex and noisy gear system required for dc generator.

5) STORAGE:

For storage purposes a storage battery is used to store the output of the VAWT. A rechargeable lead acid type battery was used of capacity 12 V for this project. Output of the generator is connected to this battery through a reversed biased diode in order to stop the reverse flow of current from the battery towards generator.

B. Controlled Buck-Boost Converter: For Stabilizing the Output Voltage

A buck boost converter is a DC converter that is widely used for its specification of converting higher input voltages to lower output voltages by stepping down or converting lower input voltages to higher output voltages by stepping up. it does the same operation of conventional transformers but for DC. By changing the value of duty cycle we can get our required output.

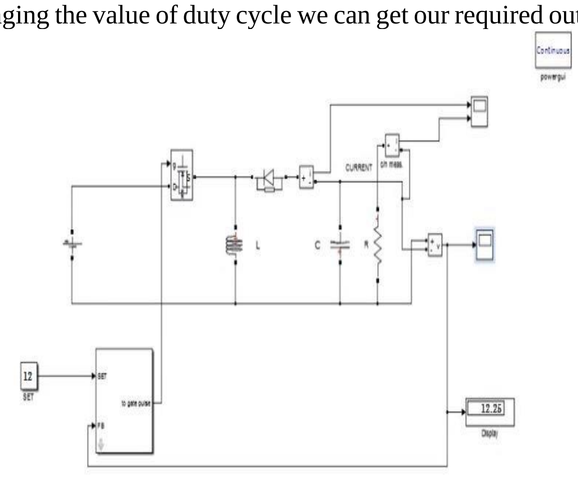

Figure 5. Controlled buckboost model

The output power produced by the generator is in the form of DC which cannot be supplied directly to the load because of the variations as the output power depends on wind speed thus it should be stabilized first by using a controlled buckboost convertor which will keep the voltage at a specific level which is 12 V.
when the switch is closed;

$$I_{L_{On}} = \int_0^{DT_S} \frac{V_i}{L} dt = \frac{V_i DT_S}{L}$$

when the switch is opened;

$$I_{L_{Off}} = \int_0^{(1-D)T_S} \frac{V_O}{L} dt = \frac{V_O\,(1-D)T_S}{L}$$

The sum of the variations of inductor current I_L during the on and the off states must be zero:

$$I_{L_{On}} + I_{L_{Off}} = 0$$

Substituting $I_{L_{On}}$ and $I_{L_{Off}}$ by their expressions yields:

$$\frac{V_i DT_S}{L} + \frac{V_O\,(1-D)T_S}{L} = 0$$

$$\frac{V_O}{V_i} = \frac{-D}{1-D}$$

$$D = \frac{V_O}{V_O - V_i}$$

III. Power Analysis of the Vertical Axis Wind Turbine

The working principle of a VAWT is that it converts the wind energy into mechanical work and then this mechanical work is converted into electical power.

The kinetic energy of the wind is given as

$$K.E_\omega = \frac{1}{2} m_\omega V_\omega^2$$

Where m_ω denotes mass and V_ω denotes velocity.

$$m = \rho \text{ As } V_\omega$$

Where ρ denotes density of the air and As denotes rotor swept area.

$$K.E_\omega = \frac{1}{2} \rho \text{ As } V_\omega^3$$

TABLE II: WIND SPEED VS RPM READINGS

S.NO.	Wind speed (m/s)	Turbine Rotation (rpm)
1	4	225
2	6	255
3	8	315
4	11	345
5	14	375
6	16	450

(1:15 gear system)

Available wind power is given by,

$$P_\omega = \frac{1}{2} \rho \Pi D_r^2 V_\omega^3$$

IV. NUMEICAL RESULTS AND DISCUSSION

$$P_\omega = \frac{1}{2} \rho \Pi D_r^2 V_\omega^3$$

Where, Density of air: $\rho = 1.225 kg / m^3$ Diameter of rotor: $D_r = 0.70\ m$

For Velocity: $V = 4\ m/s$

$$P_\omega = \frac{\frac{1}{2} \rho \Pi D_r^2 V_\omega^3}{4}$$

$$P_\omega = \frac{\frac{1}{2} * 1.225 * 3.14 * 0.70^2 * 4^3}{4} = 15W$$

For Velocity: $V = 6\ m/s$

$$P_\omega = \frac{\frac{1}{2} \rho \Pi D_r^2 V_\omega^3}{4}$$

$$P_\omega = \frac{\frac{1}{2} * 1.225 * 3.14 * 0.70^2 * 6^3}{4} = 51W$$

For Velocity: $V = 8\ m/s$

$$P_\omega = \frac{\frac{1}{2} \rho \Pi D_r^2 V_\omega^3}{4}$$

$$P_\omega = \frac{\frac{1}{2} * 1.225 * 3.14 * 0.70^2 * 8^3}{4} = 120W$$

For Velocity: $V = 11\ m/s$

$$P_\omega = \frac{\frac{1}{2} \rho \Pi D_r^2 V_\omega^3}{4}$$

$$P_\omega = \frac{\frac{1}{2} * 1.225 * 3.14 * 0.70^2 * 11^3}{4} = 313W$$

For Velocity: $V = 14\ m/s$

$$P_\omega = \frac{\frac{1}{2} \rho \Pi D_r^2 V_\omega^3}{4}$$

$$P_\omega = \frac{\frac{1}{2} * 1.225 * 3.14 * 0.70^2 * 14^3}{4} = 646W$$

For Velocity: $V = 16\, m/s$

$$P_\omega = \frac{\frac{1}{2}\rho \Pi D_r^2 V_\omega^3}{4}$$

$$P_\omega = \frac{\frac{1}{2} * 1.225 * 3.14 * 0.70^2 * 16^3}{4} = 965W$$

TABLE III: WIND SPEED VS RPM VS POWER READINGS

S.NO.	Wind speed (m/s)	Turbine Rotation (rpm)	Power (Watts)
1	4	225	15
2	6	255	51
3	8	315	120
4	11	345	313
5	14	375	646
6	16	450	965

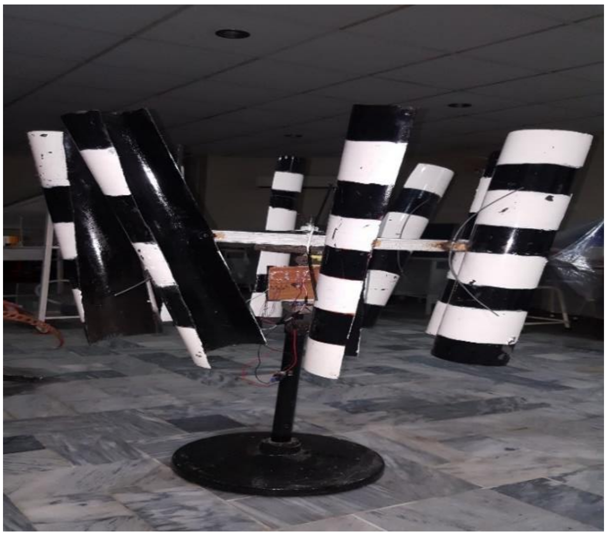

Figure 6. Fabricated model of vertical axis wind turbine

CONCUSLION

It is concluded that by installing wind turbines on dividers of the highways electrical energy can be generated in environmental friendly and cost effective manner. In this project i have installed a vertical axis wind turbine on highway's divider for the generation of electrical power. i have succeeded in generating electrical power upto 965 watts from the design we suggested for this project. Wind energy seems to be one of the best solution to meet the energy requirements of today's world. it's a free of cost source of energy only the initial construction cost is what you have to bear. Unlike coal, wind energy is a green and environmental friendly energy it does not harm the environment neither it produces any harmful gases. it is the believe of most of the people that wind energy could be the replacement for fossil fuels in the near future.

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