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Design and Fabrication of a Rooftop Mounted Vertical Axis Wind Turbine

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Abstract - Renewable energy projects have gained attention due to the lack of resources for conventional energy generation. It is highly effective for power generation from the participation of the general public in small-scale renewable energy generation for individual household appliances. As an initiation, promoting vertical axis wind turbines (VAWT) for the altitude of rooftops with low cost, simple maintenance, and fewer impacts compared to horizontal axis wind turbines (HAWT). The VAWT is designed with symmetrical blades of NACA (National Advisory Committee for Aeronautics, US) airfoil with concluded chord length, circular angle, twist angle, radius, and height to maintain maximum wind-harnessing efficiency. The turbine shaft is connected to the generator along with the system controller through appropriate control and supply functions of the turbine with battery storage system and an inverter to supply household appliances.

Keywords: Renewable Energy Generation, VAWT, NACA Airfoil

I. Introduction

Energy is a critical component of both social and economic development. Fossil fuels are the "principal source" of electricity generation in many countries. In Sri Lanka, electricity is mainly produced by imported fossil fuels. Nevertheless, Sri Lanka has a tropical environment with renewable resources [1]. Within the country, wind is a precious source and can be harnessed as electrical energy through turbines. The conventional wind turbine design is the horizontal axis wind turbine (HAWT). These turbines require steering control, yaw control, and rotor control [2].

The unconventional vertical axis wind turbine (VAWT) turbines rotate parallel to the ground and the direction of wind through aerodynamic or drum blades, using lift force or drag force respectively. In particular, VAWTs are the first known wind chargers. VAWTs are most suitable for small-scale generations since they are omnidirectional. As advantages, VAWTs are possible to place together, they are quiet in operation, do not require much wind to generate power, have low noise and vibration to the basement, and are easily installed and maintained [3].

By means of its catching method, there are two major types of VAWT blades, which are the drag type and the lift type. Moreover, drag mechanisms are conceptually simple, but they have some drawbacks compared to the lift mechanism. On the rooftop, the wind is relatively low in speed but frequent in flow. The VAWT is effective in the comparison of wind-harvesting turbines. There are a lot of research studies carried out based on the VAWT model with its different rotor types, catching methods, numbers of blades, and covering methods [4].

Further, the aerodynamic performance is ably studied with CFD (Computational fluid dynamics) simulations considering the flow around airfoils. Typically, low-speed airfoils are used for wind turbine applications. NACA (National Advisory Committee for Aeronautics, US) airfoils are used for simulations. The airfoils are differed by symmetrical/ asymmetrical, maximum camber thickness, and distance from the leading edge. The airfoil, chord length, circular angle, twist angle, radius, and height of the blade affect the power output of the turbine [5].

II. Methodology

A. Turbine Blade

The NACA0012 airfoil was chosen as the cross-section for the final turbine blade. The other specifications of the blade were, chord length of 15cm, a circular angle of 10°, a twist angle of 5°, a rotor radius of 30cm, and a blade height of 25cm. These decisions were concluded and impacted by the performance and cost analysis of turbine blades. Eventually, blades were fabricated through the 3D printer.

Assembly of the turbine is carried out as per Figure 1: Design of the turbine. The blade angles were maintained as 120° for effective harnessing mannerism.

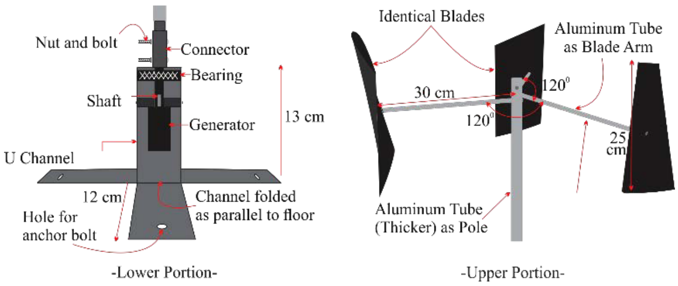

Figure 1: Design of the turbine

B. Generator, Battery and Inverter

The generator is a permanent magnet and 12V DC geared motor with 80 rpm. The battery is sealed lead acid 12V with a 7AH capacity for daily consumption of 20W LED bulbs for 4 hours. In order to convert DC into 220V AC, used a 25W booster inverter module with overload and overheat protection.

C. System Controller

The system controller is used to control and monitor the VAWT system. Within the control circuit, there are sub-systems such as analog sensing for both current and voltage, a charge pump, and three pulse-controlled switches.

The charge pump is a DC-DC converter circuit which is added to harness the slow and frequent wind. It boosts the output voltage by storing energy in a capacitor through a PWM (Pulse Width Modulation) signal. The voltage divider method is used to measure the voltage up to 15V from the calculated resistor ratio. The current is calculated from Ohm's Law Equation using a known resistor. The pulse switching is designed using a combined switching circuit of a transistor and a MOSFET while taking flow current and switching frequency into account.

The system is programmed in endless loops between several functions. The function charge pump was declared with a 120 duty cycle analog output. Three separate sensing with defined calculations within the reading function to determine generated current, generator, and battery voltages. A parameter is sensed a couple of times and averaged before its calculations. The power and energy are calculated from previous read function outputs. And that data is displayed on an LCD display and a serial monitor, with emergency notifications provided by LEDs and buzzers.

III. Results and Discussions

The turbine blade is the primary component used to harness energy from wind power. The lift force mechanism was further developed for the blade by referring to previous studies. As VAWT design, the three-bladed helical rotor setup was used. Furthermore, QBlade was chosen for turbine design, which is a wind design and simulation software. The simulations followed after designing the turbine with appropriate entities of airfoil, chord length, circular angle, and twist angle. Table 1: Constant parameters of the air were defined before simulation are listed.

Table 1: Constant parameters

Parameter	Value	Remarks
Wind Speed	2 m/s^2 – 12 m/s^2	From weather analysis
Rotational Speed	70 – 85 rpm	From specification of generator
Air density	1.16 kg/m^3	From weather data analysis
Viscosity	0.00001511kg/ms	Kinematic Viscosity at 25°C
Mach number	0.01	The ratio of flow velocity; value from minimum wind speed
Reynolds number	20000	Predicted flow pattern of fluid; value from minimum wind speed
Ncrit value	9	Measure of free flow turbulence; value of average wind tunnel

Airfoil is the most important specification of turbine blade. The NACA 4-digit airfoil series were considered for airfoils in both symmetrical and asymmetrical genres, and compared the speed vs. power graphs for selection. From the peak power outcome of the turbine, NACA 0012 airfoil was chosen. The next following entity is chord length, which increases with output power but also influences a negative torque in the 360° rotation of the turbine. Nevertheless, the negative torque is under control through circular and twist angles.

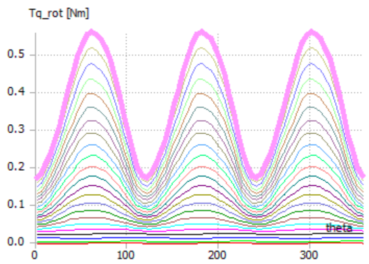

Figure 2: Azimuth angle vs. rotor torque graph

The circular angle acts around the center point of the turbine, and the twist angle adds a twist at the edges, corresponding to the middle of the blade height. Further, change of twist angle acts quite similar to change of circular angle, but the higher increments interfere with the balance of the turbine. Therefore, the combination is more effective in order to maintain the positive torque with stability. For this case, power vs. speed graphs are quite similar among the collections since the cross-section matters most for those variations. But as shown in Figure 2: Azimuth angle vs. rotor torque graph for the final combination on behalf of peak net positive torque.

The increase in turbine height and radius had a direct effect on harnessing wind energy and torque, but this was limited by considering the strength of the turbine pole. Theoretically, for defined specifications and parameters, the acquired peak power output is 5W for 12 m/s wind speed and cutoff wind speed is 1 m/s from the final turbine simulation.

IV. Conclusion and Future Developments

The rooftop-mounted VAWT power generation helps to involve ordinary people in sharing their contribution to green energy. Furthermore, it will be a complete integrated system for consumers with a user-friendly system controller. The project was an initiation of the VAWT system by delivering power to household appliances. For future development, the efficiency of the system can be increased further, by replacing the DC motor with a synchronous motor along a multi-step converter to convert whatever AC input to 12V DC. Therefore, the turbine rotation speed is no longer a limitation for the system.

References

[1] A. Withanaarachchi, J. Nanayakkara and C. Pushpakumara, “An approach to analyse key renewable energy technologies: A case from Sri Lanka,” IEEE International Conference on Industrial Engineering and Engineering Management, pp. 570-574, 2014.W. Woo, H. Choo, M. B. Prime, Z. Feng, and B. Clausen, “Microstructure, texture and residual stress in a friction-stir-processed AZ31B magnesium alloy,” Acta Mater., Vol. 56, No. 8, Pp. 1701–1711, May 2008.

[2] M. Hyams, “Wind energy in the built environment,” 27 March 2014.

[3] OzerIgra, “Research and development for shrouded wind turbines,” Energy Conversion and Management, vol. 21, no. 1, pp. 13-48, 1981

[4] J. F. Manwell, J. G. McGowan and A. L. Rogers, “WIND ENERGY EXPLAINED: Theory, Design and Application,” USA, A John Wiley and Sons, Ltd, Publications, 2009, pp. 33 – 34, 46.

[5] NACA Airfoil Database, http://airfoiltools.com