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Output Voltage Characteristics of Wind Energy System Considering Wind Speed and Number of Blades

Z. A. MEMON*, A. A. SAHITO*, Z. H. LEGHARI*, P. H. SHAIKH[++]

Department of Electrical Engineering, Mehran UET, Jamshoro

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Abstract: Wind energy offers clean and sustainable form of kinetic energy of air to transform into electrical energy. The efficiency of the wind energy system is dependent on various factors, such as; blade number, wind speed, turbine design and several others (BEWA briefing sheet). Wind turbines with their design are more concerned to bring down the capital cost for renewable energy generation. Therefore, two most important design factors that are wind speed and selection of number of blades have been taken into consideration for this research. In this paper, the relationship for the output terminal voltage with the wind speed and the number of blades has been observed. The lab test setup of wind energy system of heliocentris wind generator was set. The controlled environment with variable fan speed test setup was arranged. It was observed that the output voltage is directly proportional to the wind speed and the number of blades. In future this analysis will be utilized to predict the output power from the wind turbine system and proposed for onsite windmill in the vicinity.

Keywords: Wind, Energy, output voltage, number of blades

1. INTRODUCTION

A major fall in economy has been experienced over last few years. Fossil fuels are also depleting day by day. In this regard concern towards renewable energy resources has been amplified, since it appears to be cost effective and nominal way out. The two major ingredients of renewable energy sources are wind and solar. Wind energy is one of the most crucial ingredients of renewable and sustainable energy resource. A wind energy system is a complex scheme that translates the Wind flow kinetic energy to mechanical energy. That mechanical energy is eventually converted to electrical energy through a generator. The wind generator assembly comprises of wind turbines with aerodynamic blades, gears trains, electrical generators, power electronic converters, storage devices, protection system, measurement and monitoring systems and other auxiliaries, which are necessary for the effective operation and control of wind power plant. The available energy to be converted mainly depends upon the speed of the wind and area swept by the turbine. Unlike the conventional power plants wind energy produce voltage and frequency that vary with the time, so the system should be equipped with such controllers that can maintain the frequency and voltage level.

The efficiency of wind energy system design depends on number of factors. In order to maximize productivity from wind energy, two parameters i.e. (wind speed and number of blades against output voltage) has been spotted on k-00-0410 wind generator heliocentric wind energy set. The wind speed and number of blades are considered as independent variables while output voltage is found to be dependent variable. The wind turbine blades are the significant component of any wind plant; there job is to capture the wind energy and transform it into usable mechanical energy. Over the time, scientists and engineers have experimented with various diverse shapes, designs, materials, and numbers of blades to discover which of these designs provides optimal output. The number of blades in the turbine rotor and its rotational speed must be optimized to extract the maximum energy from the available wind. In U.S. customary units, the power in the wind passing through the cross-sectional area has been given in eq. (1) as,

$$P_w = \varphi A V^3 / 2\, g_c \qquad (1)$$

Where,

P_w=wind Power

V=wind speed

A= cross sectional area

Thus it can also be concluded from the equation that when the wind speed v increases, the wind power Pw also increases. More precisely, the wind power Pw varies with the cube (the third power) of the wind speed v. This paper focuses on effect of variation in wind speed and number of blades on output voltage.

2. METHODOLOGY

Wind turbines at small scale are fabricated with various number of blades, but mostly 3 bladed wind turbines are used. Literature suggest a boost in profit by increasing number of blades, however the cost is not justified. An increase in Coefficient of Power (CP) as

[++]Corresponding Author: Pervez Hameed Shaikh, pervez.hameed@faculty.muet.edu.pk
Mehran University Center for Energy & Development (MUCED) Jamshoro, Pakistan

increasing number of blades and solidity was observed at Clarkson University on horizontal axis wind turbine at small scale. An elevated CP was observed somewhat about a total of 5 and 7 blades. Significant increase in CP was detected at 10 blades as compared to 10 blades, resulting in fading return with enhanced number of blades

The effect of blade number and solidity to evaluate the performance of horizontal axis wind turbine has been considered in (Brown *et. al.* 2007). While designing the direct drive wind turbine obtaining highest efficiency is the main concern. One of the most important components is wind blade in wind turbine. With decreasing number of blades the turbine moves faster

Parametric sweeps of blade number and solidity for straight and augmented blade arrangement were carried out. Outcomes specified suitable blade number for a particular solidity. Wind tunnel tests of 3 and 5 blade rotors at their respective optimum solidities, exhibited similar trends to the numerical predictions. Whereas, the experimental setup was arranged in wind tunnel to observe the effect of number of blades and twist angle (Predescu *et. al.* 2009). The impact of number of blades and blade tip and twisted angle was observed against the power coefficient of rotor. It also presents the view of the extent to which power coefficient depends on the wind speed. Increasing the blade number results in great margin for regulating the cut in wind speed with less impact on output power. Energy production from wind turbine mainly depends on the parameters like wind speed, availability and arrangement of wind turbines

The simulation study of the design of 1kW, 11m/s, 1meter diameter wind turbine has been studied in (Sarkar and Behera, 2012). For a given variation in the tip speed ratios, blades power and efficiency has been evaluated through simulations. Design aspects like blade design, wind power, and output power are focused parameters and were found variations in output power. Two common problems faced by wind energy industry is that the turbines usually run below their specified life and generate less than rated power The two 3*4 scaled down wind farms were examined to know alterations in wind turbine boundary layers (Newman *et. al.* 2015). Turbines were operated at same power output shaving two to three blades. Outcomes indicated that two bladed wind turbines play a crucial role when situated in wind farms first two rows. Parameters taken in account while evaluating performance are tip speed ratio, pitch angle, blade number and wind speed (Jadallah *et. al.* 2014). Simulation results shows relatively lower pitch is proposed for low wind velocity system. It investigates the relationship between power outputs, power coefficient against different pitch angles. The efficiency of wind energy system is labeled in terms of the coefficient of power. The potential of renewable energy system is yet to be exploited. Among the renewable energy systems wind energy holds a good record. However it faces a problem of voltage stability, because moreover induction generators are used in wind turbines which have the disadvantage of reactive power consumption which is one of the main constraint in integration of wind power with electrical power system.

The negative impacts of wind power against voltage stability of power system were studied in (Patel and Joshi, 2015). It was concluded that the type of wind turbine effects voltage stability. Possible solutions leading to the improvement of wind turbine system voltage are proposed. Whereas, the suitability of even number of wind turbine blades were studied. The most crucial reason known is the stability of turbine with a stiff structure. Relative advantages and disadvantages of one, two and three blades are discussed. It has been pointed out that why does wind turbines have more than 3 blades. The reason mentioned is that increased number of blades increases the torque and reduces speed. In order to overcome the reduced speed, numbers of blades are reduced so as to increase the speed for maximum power production. Keeping in view the conflicts on number of blades and their output characteristics leads to conduct this in order scrutinize the possible relationship solution for wind power output. An increase in distributed generation sector have been observed over past decade especially due to the introduction of wind energy system due to the fact that wind energy systems have a short period of return on investment. The other reasons might be low impact on environment, very less construction time and available potential at large scale (Jakus *et. al.* 2011). The optimum design 3 bladed rotors resulted in enhanced Cp with increased solidity and decreased tip speed ratio at the operating point that is optimum. A drop in efficiency and power is observed at constant solidity of 10%, as number of blades increased contradicting numerical predictions at experimental results at flat plate (Duquette *et. al.* 2003). At the areas that are at a distance from main power transmission system, concentration is made on voltage control and reactive power compensation at the time of planning and development of large scale wind power plants (Palsson *et. al.* 2002).

3 EXPERIMENTAL SETUP

In order to drive out the relationship between wind speed and output voltage and other relationship between number of blades and output voltage of the heliocentris wind energy system. Wind in the controlled environment of the laboratory was blown through the pedestal fan. The fan had provision of 3 wind speeds

(i.e. high, medium and low) Wind speeds were measured with anemometer and the DC output voltages were measured with the multi-meter. The distance between pedestal fan and wind generator was kept at 40cm at the time of measurements. It was observed that increasing the wind speed of pedestal fan resulted in elevated voltages. Keeping the distance and wind speed constant (i.e. 15 inches and 16.5 km/h) and by varying the number of turbine blades (3 blades to 6 blades), it was observed that when number of blades were increased, output voltages also increase.

4. (a) RELATIONSHIP FOR WIND SPEED AND VOLTAGE OUTPUT

Two conclusive factors to decide the output of the wind turbine are the wind speed and force. For the greater wind velocity faster will be the rotation and more voltage at the output terminals. Prior to analysis and selection of the optimal characteristics of the wind system it is necessary that the wind speed has variation from region to region. The laboratory setup shows that the output voltage has the direct relation with the wind as depicted in the **(Table 4.1)** and has been graphically shown in 4.1.

Table 1: Wind Velocity against output Voltage

S.No	Mode	Wind speed(km/h)	Output voltage(volts)
1	Low	9	1.6
2	Medium	12	2
3	High	16.5	2.2

The output voltage was found to be dependent on number of blades. As the number of blades increase, the output voltage also increases in a nonlinear manner. The aim of arranging experimental setup was to recognize the number of blades that could produce maximum output voltages. The voltage improvement is little as the number of blades increased from 3 to 4 blades. There after further increase in number of blades drastically improve the terminal voltage. If compromised on cost, 6 bladed turbine exhibit good characteristics as shown in **(Table 4.2)** and graphically depicted in **(Fig. 1and 2).**

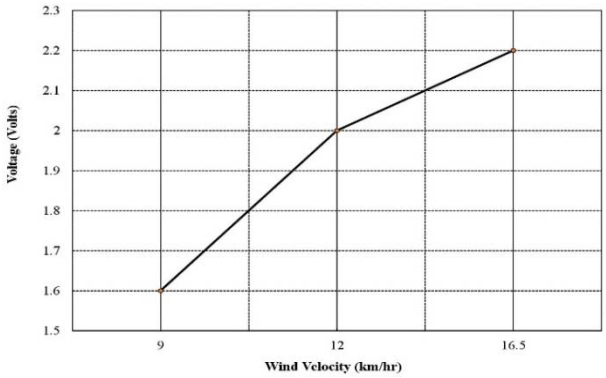

Fig. 1: Wind Speed vs Output voltage characteristics

Table 2: Number of Blades against output Voltage

S.#	Mode	No. of blades	Output voltages(volts)
1	High	3	1
2	High	4	1.1
3	High	5	1.5
4	High	6	2.1

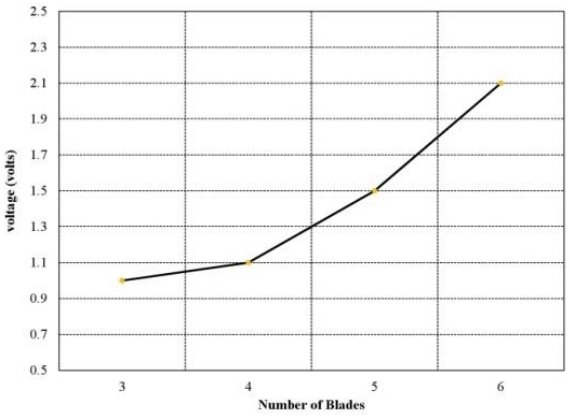

Fig. 2. Number of Blades vs Output voltage characteristics

5. CONCLUSION

The experiment performed on heliocentric wind energy set was used to evaluate voltage output against wind speed and number of blades. The wind speed was regulated from the wind source that is the pedestal fan and it was observed that at high wind speed terminal voltages increased, when focused on number of blades against voltage. Six numbers of blades on the turbine shows relatively satisfactory characteristics in terms of output voltage. Therefore six bladed turbines are proposed in the vicinity where wind blows relatively high. In future this experiment will be enhanced in terms of blade angle for maximum output characteristics.

6. ACKNOWLEDGEMENTS

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