Development and Analysis of Shutter Type Vertical Axis Wind Turbine

Sandip S. Wangikar

Department of Mechanical Engineering, SVERI's College of Engineering Pandharpur

Wind Turbine

A wind turbine is a rotating machine which converts the kinetic energy in wind into mechanical energy. If the mechanical energy is used directly by machinery, such as a pump or grinding stones, the machine is usually called a windmill. If the mechanical energy is then converted to electricity, the machine is called a wind generator, wind power unit (WPU), or wind energy converter (WEC) [1].

Types of Wind Turbines

Wind turbines are classified into two general types horizontal and vertical axis. A horizontal axis machine has its blades rotating on an axis parallel to the ground. A vertical axis machine has its blades rotating on an axis perpendicular to the ground. There are a number of available designs for both and each type has certain advantages and disadvantages. However, compared with the horizontal axis type, very few vertical axis machines are available commercially.

- ### Horizontal Axis Wind Turbine

Horizontal axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower and must be pointed into the wind. Small turbines are pointed by a simple wind vane.

Figure 1: Horizontal axis wind turbine and Vertical axis wind turbine [1]

➢ Vertical Axis Wind Turbine

Vertical axis wind turbines (or VAWTs) have the main rotor shaft running vertically. Key advantages of this arrangement are that the generator and/or gearbox can be placed at the bottom, near the ground, so the tower doesn't need to support it.

Wind power generation in India

The Indian wind energy sector has an installed capacity 18634.9MW (as on 31st Jan 2013).In terms of wind power installed capacity, India is ranked 4th in the world. Today India is a major player in the global wind energy market. According to a recently released report by the Global Wind Energy Council (GWEC), India's wind energy capacity could increase by five times its current installed capacity, if the wind energy sector is supported by aggressive policies. According to the report, India Wind Energy Outlook, even in the absence of any new policies the wind energy capacity is likely to double to about 24 GW by 2020 and further increase to more than 30.5 GW by 2030.

VAWT Work Review

Up to now, different types of vertical axis wind turbines have been utilized in the world for producing electric power. A representative selection of the relevant research in VAWT is discussed below.

Sharma and Madawala [3] were analyzed a smart wind turbine concept with variable length blades &an innovative hybrid mechanical-electrical power conversion system. The variable length concept uses the idea of extending the turbine blades when wind speed fall below rated level, hence increasing the swept area and thus maintaining a relatively high power output. To improve the torque performance of straight bladed vertical axis wind turbine, research work was carried out by Feng and Li et.al. [4] by combining Savonius rotor in SB-VAWT. Aerodynamic analysis was carried out on the static and dynamic torque performance based on the aerodynamic theory and wind tunnel test data based on simulation results, the CSB-VAWT can get a self start and make power out at all tip speed ratio. A three bladed H-rotor VAWT was designed for nominal power production of 1.5KWh for Fadashk station of Khorasan province in Iran by Saeidi et.al. [5]. The designed VAWT was parametrically studied to evaluate its performance and to drive important characteristics of this wind turbine. Although no optimization was sought in aeroelastic design at this stage, the designed VAWT can produce 3.1MWh power annually if it is installed on the mast height of 40m. Pope et.al. [6]. analyzed numerical and experimental studies are presented to determine the operating performance and power output from a vertical axis wind turbine (VAWT). A case study is performed for varying VAWT stator vane (tab) geometries of a Zephyr vertical axis wind turbine (ZVAWT). Yao and Wang et.al [7] analyzed two dimensional vertical axis wind turbines model and two dimensional unsteady incompressible N-S equations and Realizable k turbulence model were solved with software FLUENT. The results showed that the flow structure of vertical axis wind turbines rotational process could be revealed effectively by numerical simulation provided theoretical reference for the engineering design of the vertical axis wind turbine . For the performance improvement of a vertical axis wind turbine, aerodynamic analysis, control mechanism design of 1KW class model was carried out by Hwang et.al. [8]. The aerodynamic analysis shows that the cycloidal wind turbine is possible to generate more power than fixed pitch type VAWT by changing its pitch angle and phase angle according to wind speed and wind direction.

From the above data it is found that India has very large wind energy potential and India is the fourth largest generator of the power in the world. VAWTs have a number of inherent advantages in relation with HAWTs but they also have disadvantages. At present HAWTs are most cost effective and they currently dominate the market but VAWTs may yet prove to be competitive in certain applications. There is lack of definitive data led to present exhaustive investigation of VAWT performance, on which stand-alone applications are practicable.

Construction and Working

Shutter Type Vertical Axis Wind Turbine (STVAWT) consists of four blades (frames) with shutters. These shutters fitted in the frame which is attached to the shaft. The wind energy is used for rotation of this shaft. This shaft is supported with thrust and ball bearings to take the the axial and radial loads. The pulley is mounted at bottom of the shaft. A bevel gear pair is there after the pulley to transmit the rotation at 90^0 . Generator shaft is connected to a bevel gear. This generates voltage of 12V D.C. and stored into Chargeable batteries for further use.

Figure 2: Photograph of experimental setup

Experimentation:

To study the performance of the STVAWT, first the different significant input parameters are to be selected on the basis of their effect on the performance i.e. outputs parameters. Selection of Parameters

- **Output Parameters (Response Parameters):**

  Power: The ultimate outcome of any type of wind turbine is the power generated.

- **Input Parameters (Control Parameters):**

  There are two significant parameters affecting the performance of the Shutter type vertical axis wind

  Turbine as

1. Wind Speed: The wind speed for the experimentation was varied from 5 m/s to 15 m/s with 2.5 m/s interval. (five speeds)
2. Shutter Angle: The shutter angle varied from 12^0 to 48^0 with 6^0 intervals. (seven angles)

All the experiments are conducted and results are recorded.

Results and Discussion:

In Shutter Type Vertical Axis Wind Turbine (STVAWT), the power depends on the torque on the shaft therefore for more power the torque should be always higher, and it is considered as better performance. Therefore, 'HB' for higher torque and was selected for obtaining optimal turbine performance characteristics. Hence the optimal combination of parameters can be obtained by the analysis of variance (ANOVA). The ANOVA tables partitions the variability of the response into separate pieces for each of the effects. It tests the statistical significance of each effect by comparing the mean square against an estimate of the experimental error. At 95% confidence levels in the present experiment, each effect having p-value greater than 0.05 are non-significant and they therefore are eliminated. Thus, the last column in the ANOVA table gives these p-values and thereby shows the significance of each effect. Analysis of experimental data was carried out using MINITAB 15 software.

Results for Power

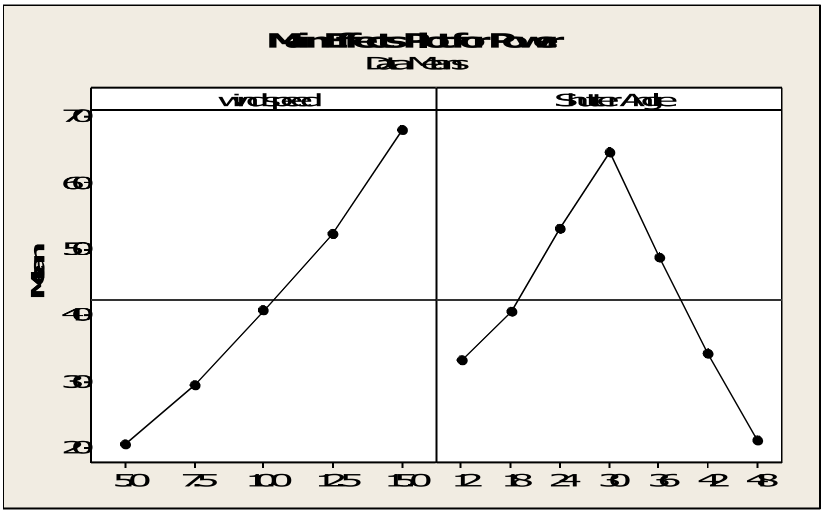
During experimentation power data is collected. and calculations are carried out as shown in table 1.

Table 1 ANOVA Summary Table for Power

Control Factor	Degree of freedom	Seq. SS	Adj MS	F- ratio	*P*- value	Significant (Yes / No)
Wind speed (m/s)	4	3725.47	931.37	36.02	0.000	YES
Shutter Angle (^{0})	6	3655.16	609.19	23.56	0.000	YES
Error	24	620.65	25.86			
Total	34	8001.28				
S=5.08531		R-Sq = 92.24%		R-Sq(adj) = 89.01%		

In order to obtain the effect of the process parameter on turbine performances for each different level, the average response of each fixed parameter are summed up. Table 1 shows the total average response at the levels of three parameters on power. The result shows that the optimum turbine performance for the torque is obtained at wind speed 15 m/s (level 5) and Shutter angle at 30^0 (Level 3). This is the optimum setting obtained under the conditions in which the experiments were performed. The ANOVA for power shows that the effect of all factors namely wind speed and Shutter angle are significant. According to the F-test, both wind speed and Shutter angle are the most significant parameters on power.

The main effect plot and interaction plot for power is shown in figure 3 and 4 respectively. The power increases with increase in wind speed. The power is directly proportional to the cube of wind speed. Therefore it is observed that the maximum value of power is for the higher value of the wind speed (15 m/s).



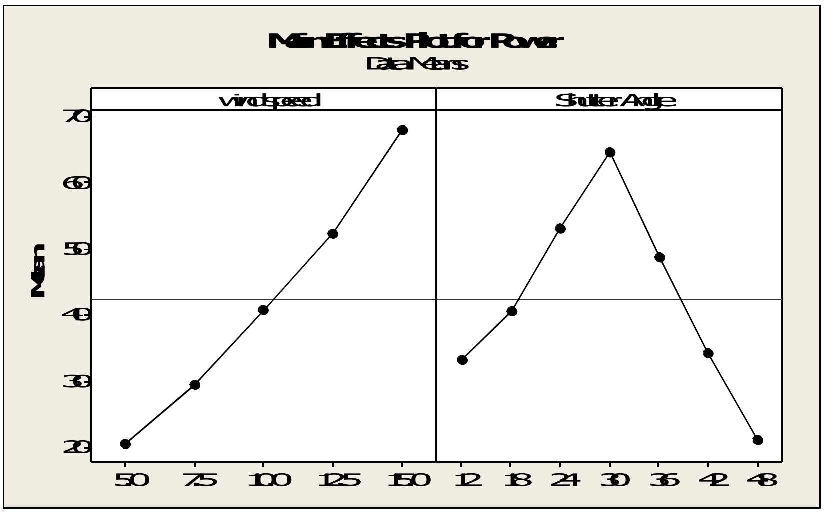
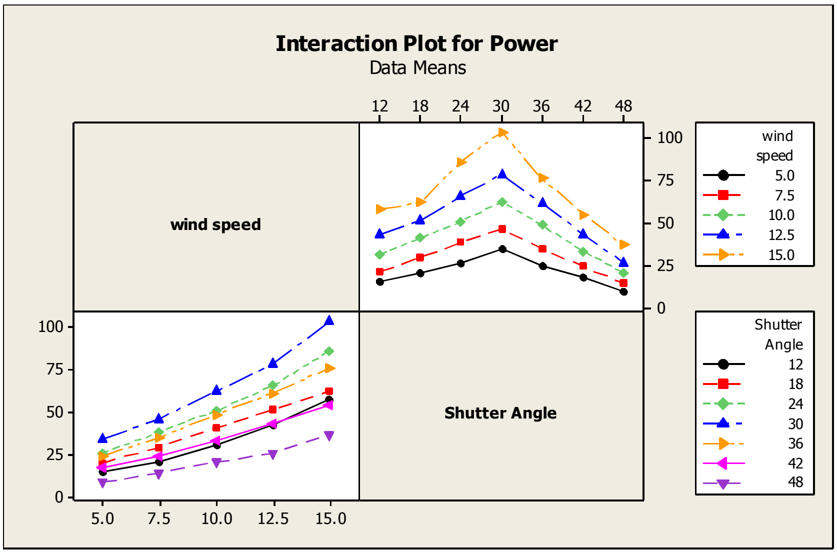


Figure 3: Main effect plots for means Power



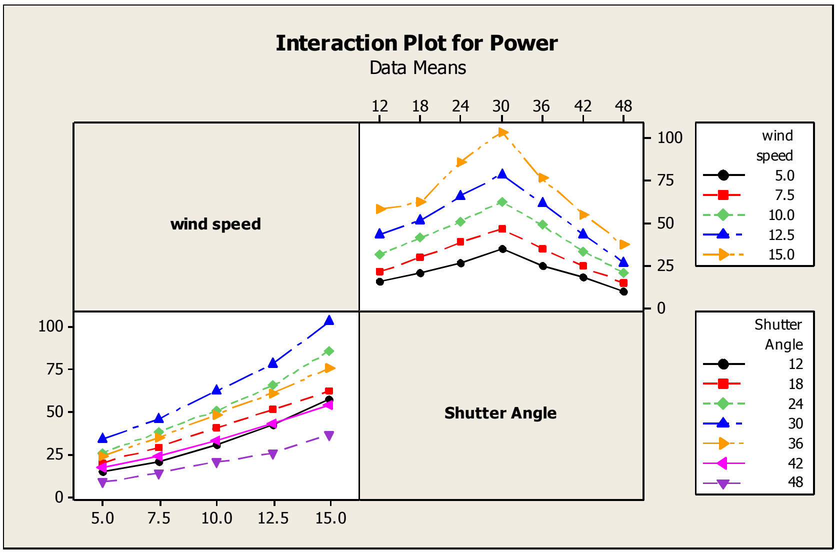


Figure 4: Interaction plots between control factors and Power

The power on the shaft for the STVAWT is found better at 30^0 shutter angle. This is because of the reduction of negative wetted area (opposite to the direction of rotation) which causes negative torque at 30^0 as compared to other shutter angles.

Conclusion

In the present work, a Shutter Type Vertical Axis Wind Turbine (STVAWT) is designed and a model of the same is manufactured. The performance analysis of STVAWT is carried out and the outcomes of the analysis are as below:

- Study and analysis of this work come to conclusion that wind speed and shutter angle affects the performance of turbine significantly.
- Power increases with increase in wind speed and having maximum value at wind speed 15 m/s.

- Power increases with increase in wind speed up to 30^0 shutter opening angle from 12^0 shutter angle and then decreases with increase in shutter opening angle. Comparatively less output was observed at 48^0 shutter opening angle.
- From the above studies, the newly developed shutter type vertical axis wind turbine is working efficiently at 30^0 shutter opening angle.

REFERENCES

1. Davood Saeidi, Ahmad Sedaghat, Pourya Alamdari, Ali Akbar Alemrajabi, "Aerodynamic design & economical evaluation of site specific small vertical axis wind turbines", Applied Energy (2012), pp. 1-2.
2. M. Ragheb, "Vertical Axis Wind Turbine", August 2011 pp.1-10
3. R.N. Sharma, U.K. Madawal, "The Concept of smart wind turbine system", Renewable Energy 39 (2010), pp. 403-410.
4. Fang Feng, Shengmao Li,Yan Li, Dan Xu "Torque characteristics simulation on small scale combined type vertical axis wind turbine", Physics Procidia 24 (2012), pp.781-786.
5. Davood Saeidi, Ahmad Sedaghat, Pourya Alamdari, Ali Akbar Alemrajabi "Aerodynamic design & economical evaluation of site specific small vertical axis wind turbines", Applied Energy (2012), pp.1-3.
6. K. Pope, V.Rodrigues, R. Doyle, A. Tsopela, R. Gravelsins, G.F. Naterer, E. Tsang, "Effects of stator vanes on power coefficients of a zephyr vertical axis wind turbine", University of Ontario Institute of Technology, Faculty of Engineering and Applied Science, 2000 Simcoe Street, Oshawa, Ontario, L1H 7K4, Canada.