EXPERIMENT STUDY ON ROTATIONAL BEHAVIOUR OF A SAVONOUS WIND TURBINE FOR TWO-LANE HIGHWAY APPLICATIONS

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Abstract - *The objective of this work is to understand the behavior of a Savonius wind turbine (SWT) on two-lane highways located in Coimbatore district, India. Experiments were conducted by placing a Savonius wind turbine (SWT) on the sides of the highway during the south-west monsoon season in three different directional roads, i.e., south-west to north-east, south to north and west to east. Vehicles moving on the highway at varying speeds modify the velocity of air locally, which in turn results in varying the drag forces on the blades of SWT, setting it in motion. An economical SWT was designed, fabricated and tested in a wind tunnel and on the highways, and the angular rotational speeds were measured. Based on the data obtained, further analysis was done to understand the behavioral patterns of SWT. Data obtained from the experiments show a "negative drag force", which is created in two-way lanes by the vehicles moving in opposite direction, affecting the rotational speed of SWT by a significant proportion. These conditions have been studied and the results have been discussed*

Key Words: **Wind behaviour Savonius, wind turbine Highway applications, Low-rise wind Monsoon, Solar mill**

1. INTRODUCTION

The main aim of this work is to design, fabricate, and test a wind turbine for power generation applications in rural areas. Vertical Axis Wind Turbines were selected to harness the energy from wind through the drag forces induced due to vehicular movements. Various parameters were analysed for the design of a low-cost wind turbine. A Savonius blade was selected for the design, which could be accommodated on the median of the highways. By using recycled materials, a low-cost wind turbine was fabricated at a cost of $117.5 approximately. The wind turbine was placed on the houses and on the highway medians to test the power output at various operating conditions. Average electricity consumption at selected rural houses were calculated. The calculated average electricity demand during power cuts in the selected rural houses was around 0.2–0.6 kWh/day. Average generated electricity from the turbine at highways was observed to be around 0.67 kWh/day. The Level zed cost of electricity (LCOE) of the generated electricity from the proposed SWT on highways is around $0.04/kWh. The LCOE of the proposed design is relatively cheaper when compared with the conventional horizontal axis wind turbines. The energy demand during power cuts was met completely when the SWT was placed on the highways number in the running text. The order of reference in the running text should match with the list of references at the end of the paper.

1.1 The rotational behavior of a Savonius Wind turbine in low rise highways during different monsoons

This work describes the behavior of a vertical axis Savonius Wind Turbine (SWT) in Four-way lane highways during South-West and North-East monsoons. A vertical axis SWT was designed and fabricated using low-cost materials. Starting behavior of the SWT was studied by measuring and calculating the starting torque coefficient. The proposed SWT's cut-in speed was achieved at a velocity of 3.5 m/s. Experiments were carried out on a four-way lane highway through the placement of turbine at two different positions (middle and sides of the highway). Also, the experiments were repeated during different monsoons to understand the behaviour under different wind directions. Error analysis was performed on the data obtained by considering possible measurement errors and instrument accuracies. The obtained experimental data clearly illustrates that the SWT's nominal rotational speed varies at different monsoons, when located at the sides of the road. From the data analysis, it can be understood that the wind directions play a key role for harnessing maximum amount of energy in highway wind-energy generation. Maximum augmented rotational speed of around 64% was achieved by placing the SWT at the median of Four-way lane highways in different monsoons

1.2 Wind tunnel test and results

The experimental setup was fabricated and tested in a wind tunnel to determine the behaviour at uniform wind speeds. The schematic view of the wind tunnel setup is shown in Fig. 3. The self-starting potential was tested by measuring the starting torque at constant wind velocities.

During starting torque measurement, the alternator was coupled with the SWT's shaft. The torque coefficient is calculated using Eq. (1). The starting torque coefficient at different rotor angles is depicted in the Fig. 4. The starting torque coefficient value was highest when the angle of attack was 30°. From the obtained wind tunnel data, the torque coefficient does not fall below the negative values. Thus, from the Fig. 4 it is inferred that the proposed SWT has good self-starting capability. From better starting capability and angular stability, better dynamic torque of the rotor is also expected.

2. EXPERIMENTAL SETUP

The block diagram of the system has shown in the Fig (1) and the fabricated model has shown in the Fig (9). Here the stand size has selected at 1 m height. And the GI sheet has been selected with the thickness of 1 mm for the SWT blade. The end plate has been made by teak wood and its thickness of 5 mm. The painting has done overall the setup to avoid corrosion and damage. Here the turbine has been connected with alternator with the alternator with gear arrangement and without gear arrangement. Here the guide vanes have been used to increase the rotational speed of the turbine at the available wind speeds.

Fig. 1: Experimental Set-up

Table -1: specification of wind turbine

PARAMETER	DIMESION
Board diameter	600 mm
Blade diameter	140mm
Blade angle	30^0
Blade height	290 mm
Base board	600mm
Leg height	830 mm
Shaft diameter	15 mm

Table – 2 Specification of the selected solar panel

MODEL	KL010
Maximum power	10W
Cell size	26×78
No of cells	36
Dimension (mm)	345×285×22
Weight(Kgs)	1.2

Table 5- Specification of the controller

Rated voltage	6V/12V/24 V	Voltage of stop power supply	*54V/10.8V/21.6`V
Rated charging current	10Amps	Voltage of resume power supply	*6.3V/12.6V/25.2V
Rated load current	10Amps	Voltage of stop charging	*7.2V/14.4V/28.8V
Working temperature	-20~+60 ºC	Temperature coefficient of voltage stop charge	-3mV/ºC /cell
Dimensions(L*W*H)	103×95×38 mm	Net weight	110g~140g

3. RESULTS AND DISCUSSION

Fig-2 shows the relation between the velocity and power without gear arrangement. It can be seen that the rated power output was considerably affected by the direct coupling of alternator and SWT.

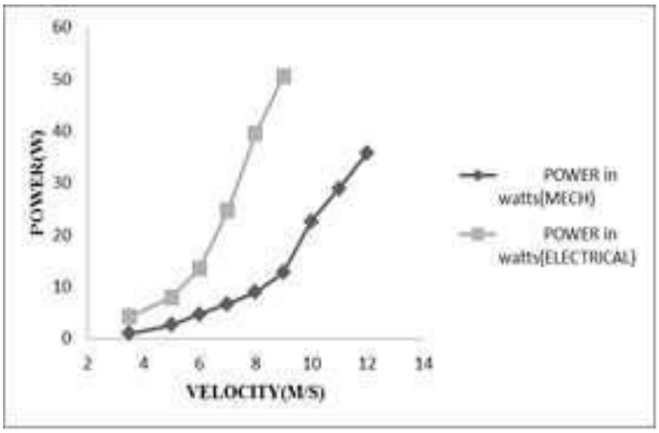

Fig. 2: Velocity vs power (without gear)

Fig-3 shows the relation between velocity and power with gear arrangement. It can be seen that the increase in electrical efficiency compare than without gear arrangement. The mechanical power output values were shoes the gradual increase in power with respect to the velocity. The experimental values were shows the gradual increase in power with respect to the Velocity.

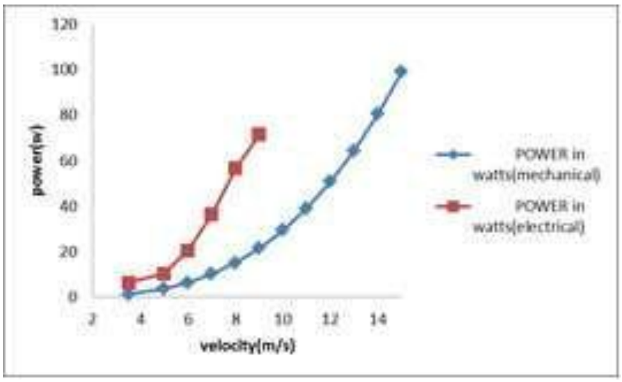

Fig. 3: Velocity Vs Power (With Gear)

In experimental, power output was calculated by the electrical output of the alternator. Voltage is kept constant and the different wind velocities, the current I (Amps) value is obtained.

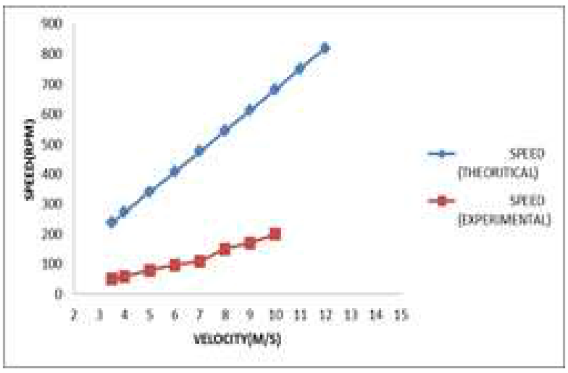

Fig. 4: Velocity Vs Speed

Fig-4 shows the relation between the velocity and speed of the both theoretical and experimental. The theoretical value was shows the gradual increase in speed with respect to velocity. Theoretical calculation shows the peak value at 800RPM.

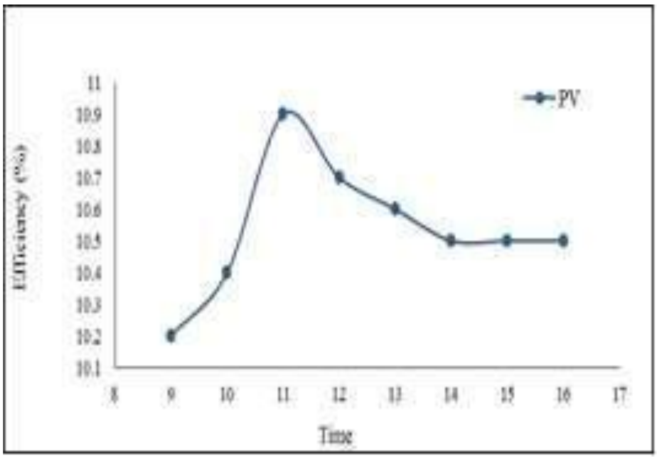

Fig. 5: Efficiency Vs Time

The experimental value was shows the gradual increase in speed with respect to velocity. Experimental value shows the peak value at 210RPM.

Fig (5) shows the relation between efficiency of PV and Time. At different time the power output of the PV varies with respect to time because of suns radiation change every 15mins

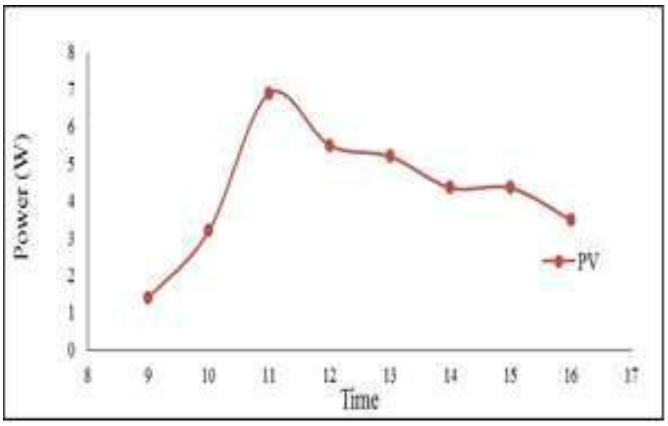

Fig. 6: Power Vs Time

Fig (6) shows the relation between Power output and Time. At different time the power output of the solar panel differs. It mainly depends on the solar radiation. Voltage and Current values differs it depends on the solar radiation.

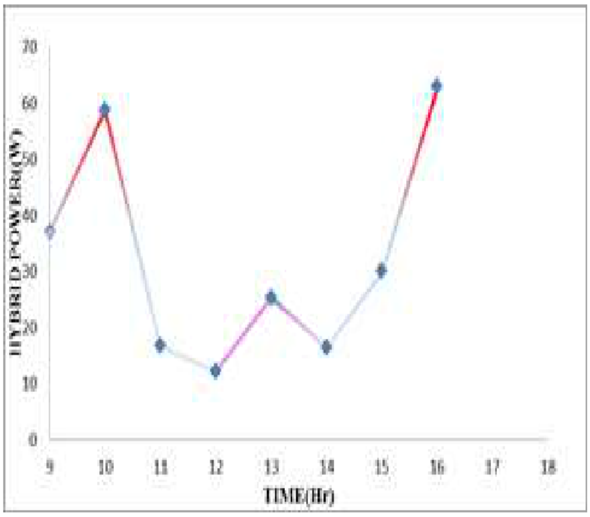

Fig. 7: Time Vs Hybrid Power

Fig-7 shows the time vs. hybrid power of the proposed system. The fig-7 shows the peak power production which obtained between 9.30 to 10.30AM.and 3.45pm to 4.15pm because of the high wind velocity. The below curve in the Fig (7) shows that the sudden decrease of power production during the period of 10.45AM to 12.00PM and 1.00PM to 1.45PM.

Here the wind turbine contributes more during the time period of 9.00am to 10.45pm and also during the 3.00pm to 6.00pm. The solar power contributes the power production throughout the day time from 9.00am to 6.00pm but their contribution more at the 12.00 to 2.00pm.The maximum power production by the hybrid 60W to 70W when both the wind turbine and solar participation were more at this time. The lower power was produced 11.00am to 2.00pm on that particular date.

3. CONCLUSION

The hybrid power system shows the comparatively better performance than the individual performances of both wind turbine and solar panels the solar power system produces the power constantly throughout the day time and the wind turbine produces the power and whenever the wind speed gained by it the peak value produced by the designed hybrid system is 70W and the lower value produced will be 12W so the hybrid power system will show the huge impact in the energy conservation. These Solar-wind energy systems can considerably be reducing of our power requirement in rural areas. The power generation through Vertical VASWT and PV hybrid system achieved the overall efficiency of 22% for the stand alone system for electricity generation due to the selection of wind turbine and the hybrid system.

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