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Research article

Design and fabrication of Wind Turbine on car: Simulation using ANN approach

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Abstract

One of the most widely used renewable energy across the world is Wind energy. The Kinetic energy present in the wind is trapped by the blades and that convert mechanical energy into electrical energy to produce power. This paper deals with the Fabrication of new model Savonius wind turbine and installing it on the car. The potential wind power generated by moving car is trapped to rotate the wind turbine. The power generated from this turbine is stored in the battery and can be used in various applications. This method is carried out to experiment the wind turbine installation on car to obtain a desired output and efficiency. It is found that the Savonius wind turbine is self starting and more efficient at high speed of the car.

Keywords: Wind energy; Savonius wind turbine; wind power

Introduction

The demand for renewable energy is increasing widely. Out of various renewable energy sources solar, wind, hydro and biomass have the major share in the world. The wind energy is extracted by using wind turbines for electricity, wind pumps for pumping water, wind mills for mechanical works. Apart from standard methods used to extract wind energy, new economical methods are invented.The Wind Turbine Generator Systems are classified as the horizontal axis wind turbine (HAWT) and the vertical axis wind turbine (VAWT) based upon the axis of rotation is parallel or perpendicular to the ground. There has been raising trend in installing wind turbine in urban areas to increase the usage capacity. The specific objective of the wind turbine is to test the wind turbine and determining the nominal wind power and operation characteristics of the system. The efficiency of the turbine is based on the capacity factor and tip speed ratio. There are other few wind turbines based on the different blades profiles like Darreius and Savonius. The present work deals with the Savonius turbine rotor. There are various studies with different Savonius rotor designs and performances, a three stage with 120-degree bucket phase shift with adjacent stages Savonius rotor to reduce initial torque [1]. The efficiency of the Savonius turbine by using a double-stepped Savonius rotor with two paddles and two end-plates [2]. The twisted bladed rotor of Savonius turbine and observed a higher efficiency and self-starting capability as compared to that of the other conventional bladed rotors [3]. As the car moves, it displaces the air in that area and moves over the body of car with the particular velocity [4]. This produces a wind velocity all over the surface of the car [5]. The objective of our project is to harnessing this wind energy, by installing a wind turbine along the top surface of the car, and produce electric power from it. And store it in a battery. This wind turbine is of Savonius without overlapping type, which rotates in drag force on horizontal axis.

Materials & Methods

Design of wind Turbine

The basic formulas to design the Savonius wind turbine Figure 1 are given below. The output power (P_T) from a turbine rotor and the wind kinetic energy per unit time (P_W) are given by Equations (1) and (2). The rotor power coefficient (Cp) is defined as the ratio between the rotor output power and the dynamic power of the air as shown in Equation (3).wind turbine is designed to operate within the tip speed ratio to achieve the highest rotor efficiency.

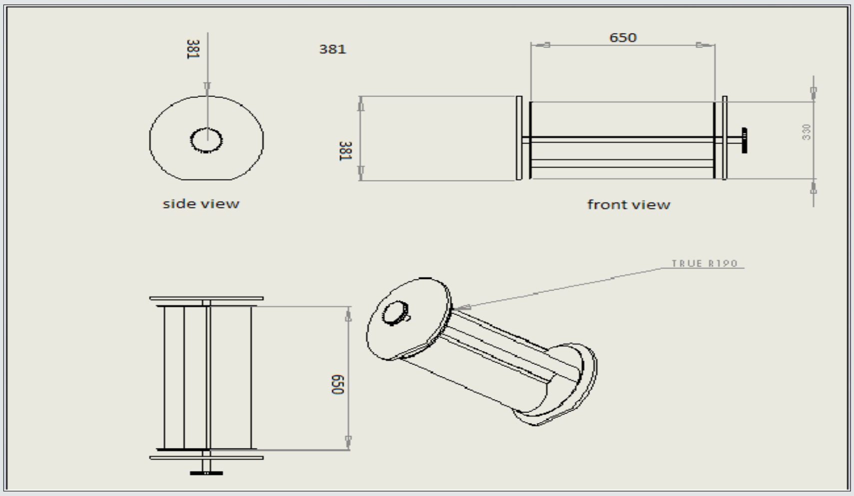

Figure 1: The side view, front view, top view, and isometric view of the Turbine.

$P_T = T\times w$ 1

$P_W = 0.15*\text{Air density}*H*D*v^3$ 2

$C_p = P_T/P_W = \dfrac{T\times w}{0.15*\text{Air density}*H*D*v^3}$ 3

Tip speed ratio $= W_r * r_r / v$ 4

Rotational speed of rotor = $(60*ʎ*v)/(\pi*D)$ 5

Aspect ratio (z) = H/D 6

The equation (4) represents the tip speed ratio of the the turbine is the ratio of angular velocity (W) and radius (r) of the rotor to the Velocity of wind speed (v). equation (5) shows the rotational speed of rotor and equation (6) defines the aspect ratio of the turbine, the ratio of height of the blade (H) to the diameter of the rotor (D).

Wind turbine consists of following parts:

a. Shaft

b. Blades

c. Stand and bed

d. Gear assembly

e. Alternator.

Shaft

The shaft made up of hollow stainless steel of 75cm long. The blades and gears are attached to this shaft. The thickness of the shaft is of 1.2cm, it is chosen such that it can withstand the weight of the blades even it is rotating at high speed.

Blades

Blades are the main part of the wind turbine, through which wind is harnessed and convert it into useful energy. The blade profile of the turbine is hollow cylindrical structure with a length of about 65cm and a diameter of about 15cm. the thickness of blade is 0.5 cm. Necessary drag force is created by the hollow cylindrical structure of the blade. There are three blades; each blade is kept at an angle of 120° from the other blade. These blades are connected to the centre shaft by four bolts and it is tightly attached to it so that the shaft rotates with the rotation of blade with wind speed. The blades are made up of PVC materials of 15cm diameter and 65 cm in length. The purpose of selecting PVC material for blade is that it has less weight, durability is high it can withstand high stress and force and is easily available

Wood arrangement

Plywood with two different thicknesses is used in the fabrication of the turbine. One with 0.4cm thickness, diameter of 33cm.Which is connected to two ends of the blade to give an extra mechanical support to the blades when it rotates at high speed. And also to cover bottom end of the blades so that maximum amount of air is passes out along the length, with increase in speed. This helps in producing more power [6]. Second one with 1.5cm in thickness and 38cm diameter is kept after the inner wood. The whole assembly stands on this wood. Bearings are fixed at the centre of the outer woods. The centre shaft is inserted into this bearing on both the sides.

Gear assembly

Two helical girth gears are used .Gear assembly is used for converting the low speed of the shaft into high speed.car alternator needs 900rpm to charge 12v battery. Turbine rotates at a speed of about 580rpm. to obtain a speed more than 900rpm (900/580=1.5), 1.5 step up is needed. Thus two gears with a gear ratio of about 1:3 is used.

Alternator

A car dynamo of rating 12v and 40 amps is used for producing power. This works on the principle of faraday's law of magnetic induction. This is connected to the rotor shaft through gear assembly. The dynamo kept is over a bed, to balance the weight of the wind turbine.

ANN Simulation

The ANN simulation was carried out using MATLAB with input as the power and output as the experimental data using function nntool. The application of feed forward propagation model was applied in the simulation with Levenberg marquardt algorithm with Tansig function. Figure 2 shows the input and neural network layers of the simulation experiments.

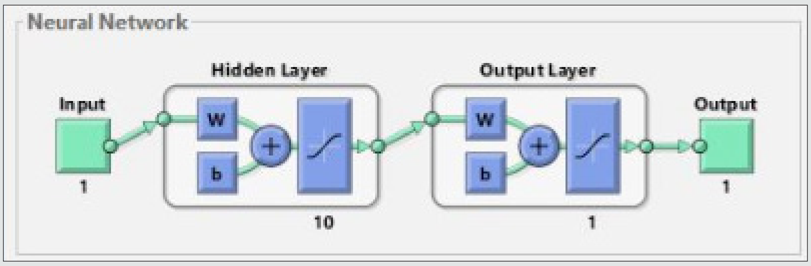

Figure 2: ANN modelling.

Results and Discussion

Working principle

Wind turbine is mounted on top of the car. As the car moves with necessary velocity, the wind hit the blade. This creates the high pressure air inside the hollow surface of the blade and low pressure air behind the blade. Due to Pressure Gradient force (PGF), the air movement from high pressure area to low pressure area creates a sufficient drag force. At a moment one concave surface and one convex surface will be facing the wind [7]. The drag force coefficient of concave surface is more than the convex surface. Hence semi circular hollow cylinder with concave surface facing the wind will experience more drag force than convex surface, thus pushes the blade backwards. Thus blades begin to rotate and the shaft holding the blades will also rotate Figure 3. The motion is transferred to the gear assembly attached on the shaft to the alternator. This in turn rotates the rotor of dynamo and which cuts the stator magnetic field and e.m.f is generated. This generated D.C power is given to battery and it is stored for future use. From the performance analysis of wind turbine Figure 4 It is observed that the aspect ratio is above the required value so rotor rotates with more efficiency and high power is generated from it. The tip speed ratio of the turbine falls exactly to 1 by theoretical calculation which is the default value for Savonius type [1]. The power curve and wind speed curve are drawn and analysed this shows the power increases with increase in wind speed and alternator produces its rated value at a speed of about 80km of car by theoretical calculation the rotational speed will have maximum value of 860rpm which is stepped up three times so that rated power of 480w is produced.

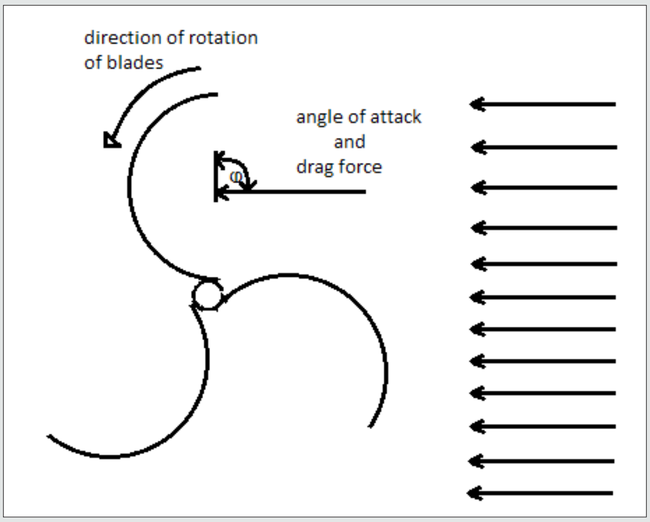

Figure 3: Rotation of turbine due to wind flow.

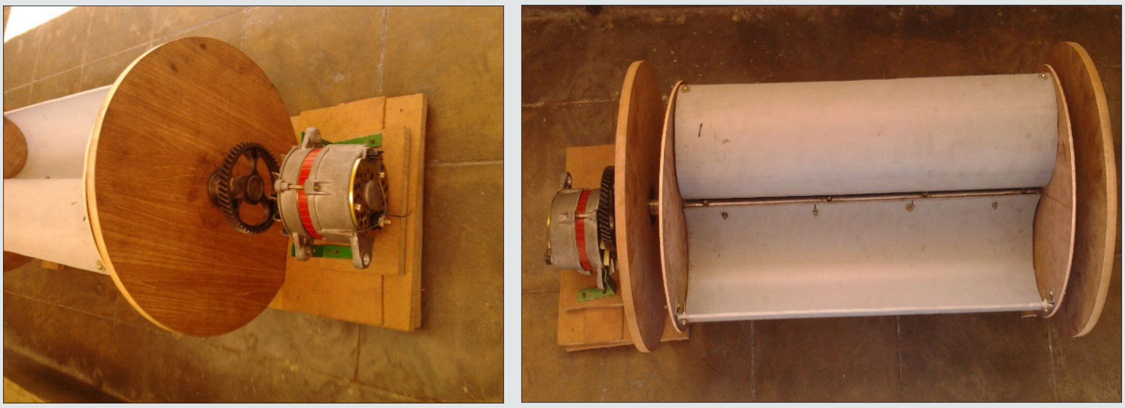

Figure 4: Fabricated Wind turbine model.

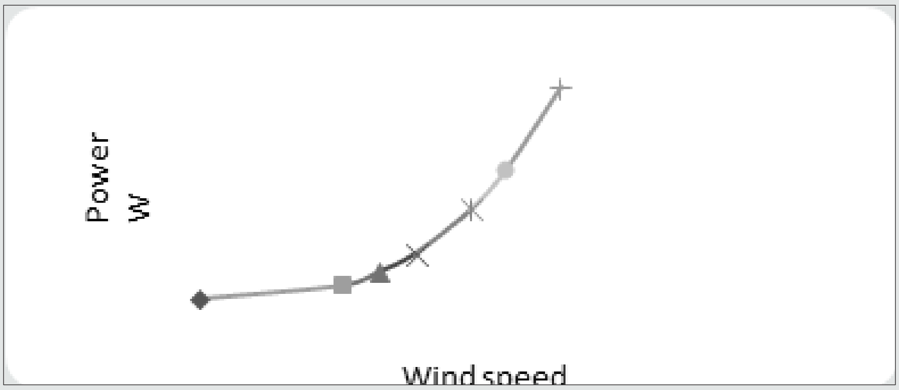

Figure 5: Power curve of the installed wind turbine.

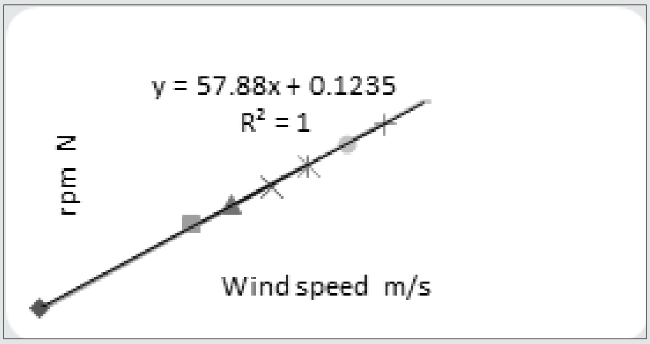

Figure 6: Wind speed (m/s) Vs rpm (N).

Aspect ratio

Aspect ratio (z) = H/D

= 0.66/0.33

= 2.

For a wind turbine to have more efficiency, aspect ratio should be greater than 1[Khan et al., 2007]. This wind turbine have aspect ratio of 2. so the efficiency is high.

Power output

The maximum power out of wind turbine = 0.15*Air density*H*D*v^3

Where H =0.66m; D =0.33m; v =15m/s

Maximum power = 0.15*1.225*0.66*0.33*$(15)^3$ = 132 watts.

Power obtained from turbine corresponding to the wind speed is shown in (Table 1).

Table 1: Power at varying velocity of car

Velocity of wind m/s	Power output from turbine in watts
8	20.5
10	40.2
12	69.1
15	135
17	196.6

Rotor speed:

The rotational speed of rotor $= (60*\lambda*v)/(\pi*D)$

$= (60*1*15)/(3.14*0.33)$

$= 860$ rpm.

Tip speed ratio:

Tip speed ratio $= W_r*r_r/v$

$= 2\pi n* r_r/v*60$

$= 2*3.14*580*0.165/10*60 = 1$.

Power output at different rpm (Table 2).

Table 2: Power output at different rpm.

Wind speed (while travelling in car) m/s	Rpm N	Power W
10	580	20.5
12	694	40.2
14	810	69.1
16	926	135
18	1042	196.6
20	1158	320

ANN Modelling analysis

Artificial neural networking model has been applied to the power output experimental data in order to simulate and validate the output. The simulated results is shown in the Table 3 Along with the experimental and theoretical data. It is clear that the ANN modelling values was significant with the experimental data. Based on the analysis Figure 7 The simulation were stopped at epoch 1 with R value of 0.92 which is close to 1 indicating the applicability of model yielded satisfactory results.

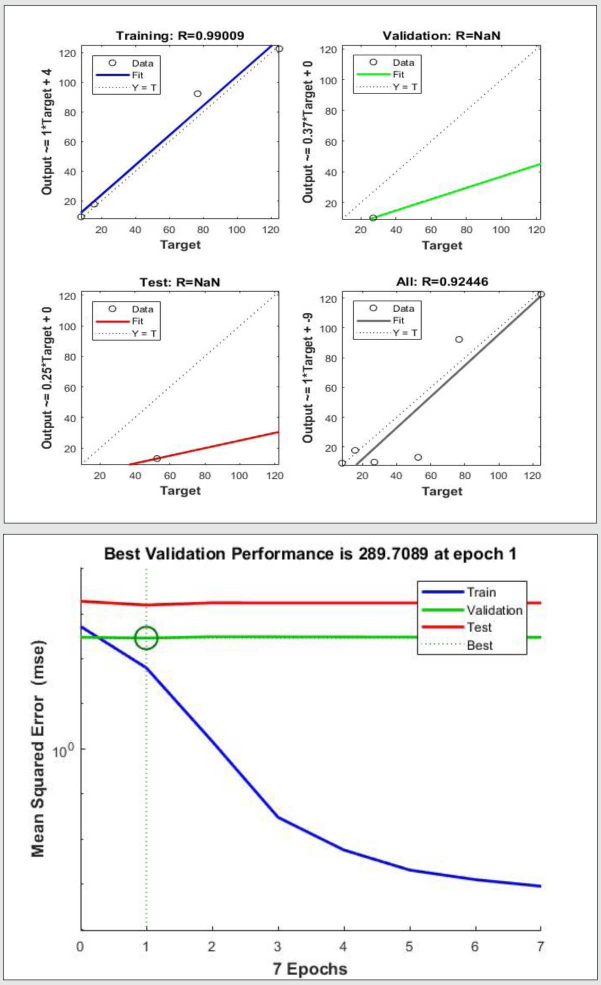

Figure 7: ANN Simulation of power curve.

Table 3: Comparison of both theoretical and experimental.

Wind speed m/s	Power output Theoretical	Power Output Experimental	ANN Modelling
	W	W	Predicted
8	20.5	7.995	9.2068
10	40.2	15.678	17.7885
12	69.1	26.949	9.9282
15	135	52.65	13.1379
17	196.6	76.674	92.2339
20	320	124.8	122.5674

Conclusion

The prototype of Savonius wind turbine was successfully tested in the car and their performance behaviour at different wind speeds are observed. The results showed that new model Savonius wind turbine reaches rated speed at 23m/s and produces maximum power of 480W. The produced power can be stored in the battery and used as a backup power for car multimedia, alternative for car battery when it is discharged, can be connected in parallel to increase power of the battery. By increasing the angle of twist, the performance of the Savonius rotor is increased in its performance. The future works for authors are to make it efficient by changing the blade profile and to increase the wind speed by attaching a diffuser to the turbine.

Nomenclature

D_E - End plates diameter of the rotor

D - Rotor diameter

d - Diameter of each cylinder paddles

A - Swept area of the rotor, πR^2

Cp - Power factor

D - Diameter of rotor, m

H - Height of rotor, m

F - Effect of external forces

M_0 - Air mass flow rate, kg s

P - Power, watt

Z – Aspect ratio.

λ - Tip speed ratio. (for Savonius it is =1)

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