Universal Journal of Renewable Energy **5 (2017), 55-66**
www.papersciences.com

An Analysis & Development of Solar - Wind Hybrid System

Chetan Baseganni[1*], Syed Suhel[1], Mallikarjun Gundur[2], Hanumesha Pujar[1]

[1]Department of Mechanical Engineering, K.L.E.Institute of Technology, Hubballi, India
[2]Department of Mechanical Engineering, Alva's Institute of Engineering & Technology, Moodabidri, India
***Corresponding author: chetancb07@gmail.com**

Abstract
With population increasing exponentially and natural resources being strained by the increasing demand, it is more important than ever to invest in renewable energy since conventional energy is turning more expensive and scarce. Our consumption of fossil fuels as energy has been traced to be a leading cause for environmental degradation. The primary by-product of fossil fuel consumption is carbon dioxide that has been identified to be the primary constituent leading to Global Warming. The need to generate power from renewable sources to reduce the demand for fossil fuels is now well understood. There are only a few types of energy resources that do not contribute carbon dioxide to the environment. Renewable energy sources include wind energy, solar energy, tidal energy, geothermal energy, and biomass energy. Wind and solar energy are amongst the most popular sources of alternative energy because of their eco-friendliness and abundant availability. Wind turbines are used throughout the world to generate electricity from offshore wind farms to residential smaller scale wind turbines. Research on harnessing of solar energy in this trending era has led to many inventions because of its numerous advantages. As a sustainable energy resource, electrical power generation from wind and solar is increasingly important in national and international energy policy in response to climate change. By the present research, an attempt is made to design and develop a wind-solar hybrid energy system which produces electrical energy throughout the day by combining solar and wind energy and thus making it a hybrid system. Wind energy can be harnessed throughout the day depending on wind speed, location and height whereas solar energy can only be harnessed during the daytime. Hence, developing a hybrid model of solar and wind power can be apotheosis for implementation in rural areas since it integrates the potentials of both the systems to provide uninterrupted electric power gneration. The Wind solar hybrid system meets the domestic lighting needs and also produces sufficient energy to meet the minor requirements of agricultural applications.

Key Word and Phrases
Environmental Degradation, Global Warming, Harnessing, Renewable Energy, Solar Energy, Wind Energy.

1. Introduction

Solar and wind energy are deemed clean, in exhaustive, abundant, and eco-friendly. These characteristics have attracted the energy sector to use renewable energy sources on a larger scale. However, all renewable energy sources have their own drawbacks. Wind and solar sources are dependent on unpredictable factors such as weather and climatic conditions. This brings us to the hybrid solar-wind power plant concept for generation of electricity. Hybrid energy stations have proved to be a boon for reducing the depletion rate of fossil fuels and even facilitate energy to remote rural areas without harming the surrounding. Electricity is the major factor for urbanization, industrialization and economic growth of the country [1]. There are various conventional and non-conventional energy sources such as wind, solar, tidal, biomass and geothermal energy which are used to generate electricity. Solar and wind energy system are one amongst the most prominent sources of energy. The utilization of solar and wind energy system has become topical due to modular and eco-friendly nature [2]. The solar–wind energy sector has gained a remarkable progress over the past two decades in its far-flung use of standalone to utility interactive solar–wind systems [3]. Solar and wind energy system usually works in the grid or standalone connected

mode, but efficiencies of these sources are inferior due to the stochastic behavior of solar and wind resources. Hybrid renewable energy source can assist to overcome this drawback of being unpredictable in nature with an aid of grid integration. The hybrid renewable energy system is either the combination of conventional and renewable energy source or combination of two or more renewable energy sources that can operate in standalone or grid-connected mode. The hybrid renewable energy sources combine solar and wind energy and can operate in dual modes i.e., sequential and simultaneous. In sequential mode, it produces electricity alternatively whereas in the simultaneous mode the energy is produced concurrently [4], [5]. The important properties of hybrid renewable energy sources is to unite two or more renewable power generation techniques to establish the adequate use of their operating properties and to achieve higher efficiencies than that which could be attained individually from single power sources. Issues such as modeling, optimization, reliability, power quality and controlling of the system were demonstrated [6]. Nagabhusana et al. [7] carried out a study to reduce the present worth of capital and operating cost by estimating the optimal size by employing linear programming technique.

The main objective by the present research is to design and develop a hybrid system which utilizes both solar and wind energy to generate electric power to serve domestic, agriculture and small-scale industrial purposes. The proposed system constitutes of a Savonius turbine and solar panel where the turbine operates for either direction of wind and solar panel absorbs the UV radiation during the daytime, therefore generating electricity continuously without any interruptions. Fig 1 demonstrates the clear representation of the internal flow and how it is to be achieved. The solar and wind energy available in nature are accepted into the system through direct sunlight and wind currents and solar energy are converted into electrical energy. The kinetic energy of the wind is converted into mechanical energy and further into electrical energy. The electrical energy from both the sources is transferred to a device charge controller to store it and is derived from the storage whenever needed.

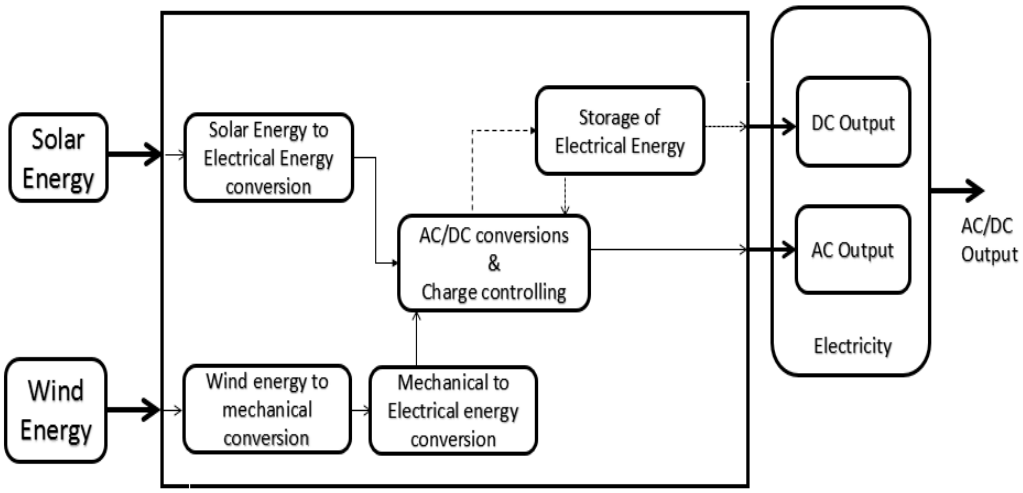

Fig. 1 White Box of Wind Solar Hybrid System

2. Evolution of Proposed Design

This section deals with all the aspects of the product design i.e. concept generation, concept selection through Pugh evaluation and all the calculation involved in the project. It also provides the information about validation of the design calculation through analysis and flow simulation of the product.

2.1 Concept Generation

Once the functions at various levels are known, it is important to find the principle of working

for each of the functions and sub-functions. A working principle must be based on the physical effect needed to achieve the given function based on the flow of materials, energy, and information within each function. Each function may be achieved by numerous ways. One important tool that can be used effectively is a design catalog or morphological chart. This chart gives information about different modes of generation. So the design criterion that we followed is shown below:

Table 1 Morphological Chart

Means → Functions ↓	1	2	3
Solar-Electric Conversion	Photovoltaic Cells	Concentrated Solar Power(CSP)	Seebeck effect
Wind-Mechanical Conversion	Horizontal Wind Turbines	Vertical Wind Turbines	Vortex Wind Turbines
Mechanical to Electric Conversion	AC/DC Generators	Piezoelectric Devices	
Storage	Li-ion Battery	Li-polymer Battery	Lead-acid battery
Conversion	AC-DC convertors	Charge Controllers	

2.2 Pugh Concept Selection

It is necessary to select the best suitable components for the project requirement based on factors such as safety, efficiency, economical, initial torque etc. Initially, Savonius, Dynasphere, Darrieus and Helical rotors were considered and their suitability to the project was evaluated and the results obtained from various tests conducted are tabulated in the pugh chart (Table 2).

Table 2 Pugh Chart

Objectives	Ratings	Savonius	Dynasphere	Darrieus	Helical
Safety	10	0	0	0	0
Efficiency	8	-2	-2	-1	-3
Low Maintenance	8	+3	+3	+1	+2
Initial Torque	9	+2	+2	+1	+1
Constant Speed	9	+1	+1	+2	+1
Economical	7	+2	+1	+1	+1
Total Points		49	42	34	17

From the Pugh chart, it can be concluded that Savonius and Dynasphere are the best wind turbines but it would be still better if these are combined with another turbine on the same shaft. There is an advantage if Savonius and Darrieus are combined because Savonius has a high initial torque but low speed whereas Darrieus has low initial torque and high speed. So the combination of Savonius and Darrieus turbines will result in high initial torque and high-speed. But the manufacturing of Darrieus turbine is complex process. Hence Savonius turbine is selected for the development of hybrid system.

2.3 Design of Turbine

Design of Turbine Blade

Area calculation of Savonius turbine:

In initial stages of concept generation, a small prototype of Savonius model was created with the following dimensions-
Height = 300mm &Diameter = 215mm.

The theoretical power calculation (considering v = 8m/s) is as follows: [8]

$$P = \frac{1}{2} \times \rho \times A \times v^3 \times \eta_m \times \eta_g \times C_p \qquad (2.3.1)$$

= 15.36 W

where,

A=swept area; ρ =density of air (ρ=1.3 kg/m^3); v=wind velocity (v=8 m/s); n_m =mechanical efficiency (n_m =0.9); n_g = generator efficiency (n_g=0.9); Cp=coefficient of power (Cp=0.3)

To generate energy equally from solar and wind, height and diameter of the turbine should be 150cm and 108cm respectively to produce power of 80W for wind speed in the range of 5-8m/sec. The solar panel selected is of 80 watt.

Design of bearings

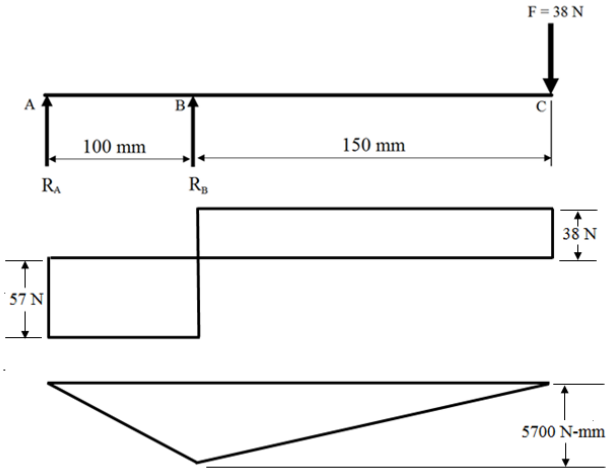

Fig. 2 Representation of loads acting on turbine shaft with shear force diagram and bending moment diagram

Transverse load on the beam=38 N (From Flow Simulation)
M_{max} (at R_B) = 38×150 = 5700Nmm

Maximum deflection at C can be approximated by the relation

$$\Delta_{max} = \frac{Pa^2}{3EI}(1+a) \qquad (2.3.2)$$

=8.47mm

Shaft Calculation

The outer diameter of shaft is calculated by using the formula:

$$d_o = \left[\frac{16}{\pi \times \tau max}\left(\sqrt{(C_m \times M)^2 + (C_t \times T)^2}\right)\left(\frac{1}{1-K^4}\right)\right]^{\frac{1}{3}} \qquad (2.3.3)$$

C_m and C_t are the numerical combined shock and fatigue factors to be applied for the computed bending moment and torsion moment (C_m = 2, C_t=1.5). [10]
T=2000N-mm (From Flow Simulation)
Substituting in Eqn.2.3.3; d_o= 20mm and d_i =16mm
The Deep Groove Ball bearings are selected with inner diameter 20mm and outer diameter 42 mm and thickness 12 mm.

Maximum deflection of fixed horizontal plate is given by:

$$y_{max} = \frac{w \times l^3}{3 \times E \times I} \qquad (2.3.4)$$

= 3.6 × 10^{-6} m

2.4 Solar Angle & Panel Area Calculations

The optimum tilt angle of the solar panel for our location which will produce maximum power output and the area required by the solar panel to produce 80watt of power is determined.

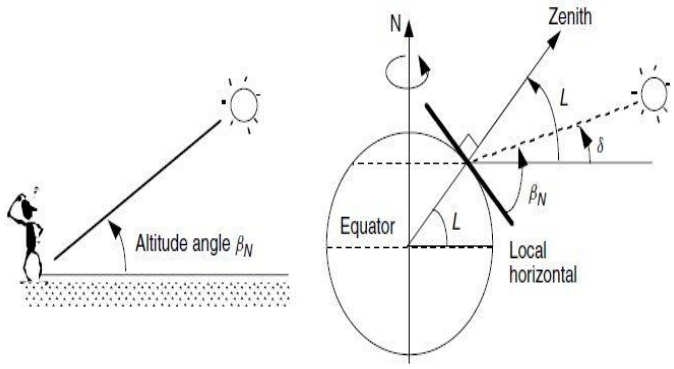

Fig. 3 Tilt angle and declination angle

Declination Angle

The angle made by descending plane with horizontal plane of solar panel is calculated using the

below formula: [10]

$$\delta = 23.45 \sin[\tfrac{360}{365}(n-81)] \quad (2.4.1)$$

where,
81 = 1st equinox day (March 22)
23.45° =maximum inclination of sun to equator [10]

For the day: 23/11/2016
$\delta = -20.4415°$; Change in angle per day = $0.1847°$

Altitude angle of the sun:
$\beta = 90 - L + \delta$; $\beta = 53.8638°$

$$Tilt\ angle = 90° - \beta \quad (2.4.2)$$
$$= \mathbf{36.1362°}$$

Area Calculations of the Panel

The surface area of the solar panel required to generate 80W power is evaluated using the relation:

$$A = \frac{E}{H \times r \times PR} \quad (2.4.3)$$

where,
H= 2000 kWh/m^2/year for India

r= 0.12 (conversion of solar energy to electrical energy through PV cells)

$PR = 0.75$
For 80 W of Solar energy from the photovoltaic panel:
Substituting in Eqn.2.4.3; $\boldsymbol{A = 0.44\ m^2}$

2.5 Analysis of the Design

Considering the above calculations, CADD model is developed and corresponding stress and strain analysis are carried out using ANSYS. Before analysis of any part, meshing is a must, as it relates to the accuracy of results. Finer the meshing better is the accuracy. Initially meshing of developed design is achieved with initial considerations listed below:

Material: Structural Steel
Young's modulus: 200 GPa
Poisons ratio: 0.3
Yield stress: 250 MPa

Analysis of tower is accomplished to check for buckling of tower.

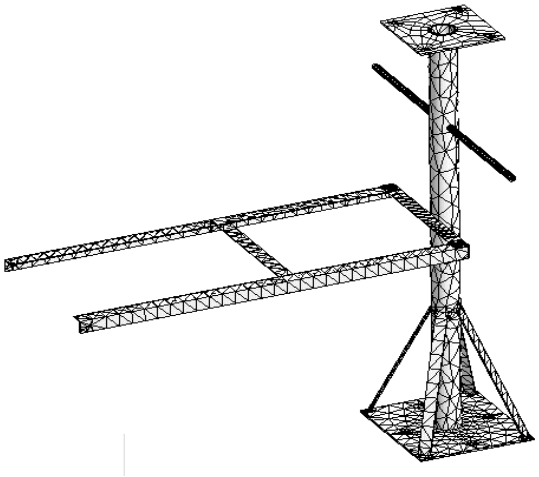

Fig. 4 Meshing of Tower

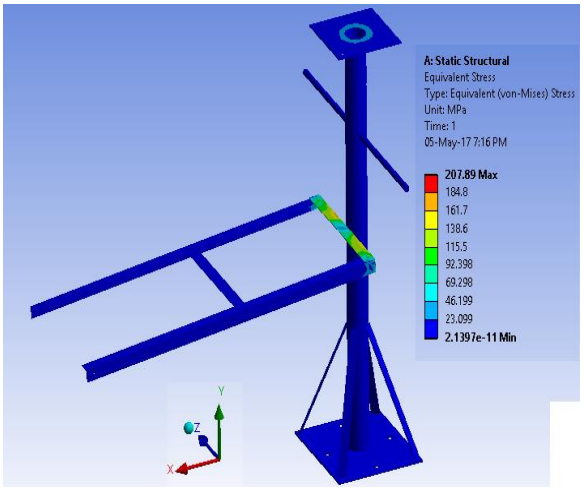

Fig. 5 Stress Variation on System

By Figure 5, it is observed that the maximum stress produced is 208 MPa which is less than the Yield stress of structural steel i.e., 250MPa. Hence the design is safe.

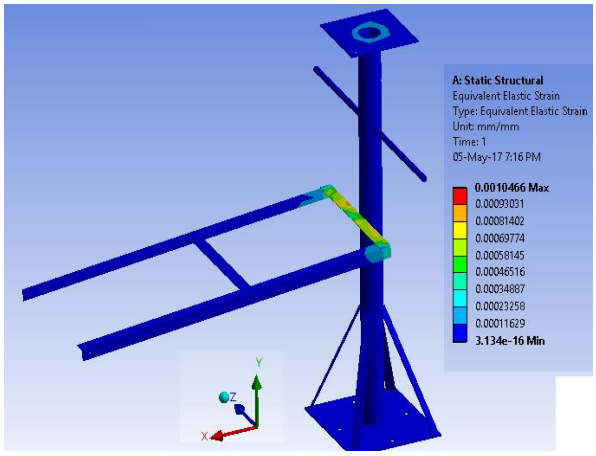

Fig. 6 Equivalent Strain on the System

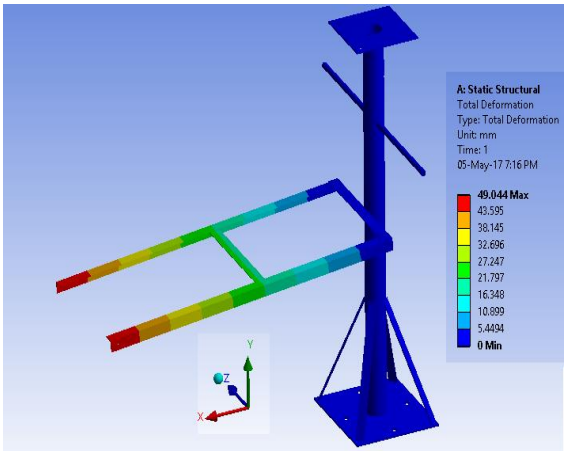

Fig. 7 Total Deformations on the System

Besides, by Figure 6, it is observed that the equivalent strain is 0.0010466 which is very much lower and structural steel can easily sustain it and the maximum deformation is 49mm (Fig.7) which is large and cannot be sustained by the system. Hence to counter this, two inclined supports which act as a base for the solar panel are provided resulting in safer design.

2.6 Flow Simulation

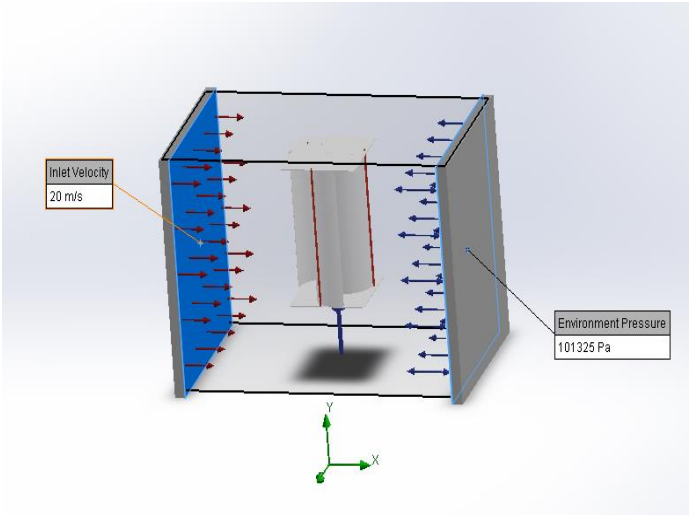

Fig. 8 Flow Simulation of Turbine

The turbine is subjected to flow simulation in solid works with 20m/s of inlet velocity of air and an atmospheric pressure of 101kPa acting on either side of the turbine. The results obtained are used in the design calculations of bearings and shaft. The resulting torque and force values are listed below:

Table 3 Results obtained from Flow Simulation

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
GG Normal Force (X) 1	[N]	28.636	28.629	28.543	28.731
GG Normal Force (Y) 1	[N]	4.535	4.644	4.535	4.804
GG Normal Force (Z) 1	[N]	4.065	4.049	3.971	4.106
GG Force (X) 1	[N]	28.926	28.917	28.833	29.016
GG Force (Y) 1	[N]	4.515	4.626	4.515	4.786
GG Force (Z) 1	[N]	4.117	4.1	4.023	4.157
GG Torque (X) 1	[N*m]	3.841	3.816	3.735	3.879
GG Torque (Y) 1	[N*m]	-2.234	-2.231	-2.24	-2.223
GG Torque (Z) 1	[N*m]	-27.715	-27.694	-27.777	-27.616

3. Experimental Setup

Fig. 9 3D model of the System

Fig. 10 Experimental Setup

Experimental setup consists of Savonius turbine which is coupled to the generator through the shaft. The solar panel is held to the system with the help of solar casing and it is connected to the battery. The developed model is tested for the output of solar panel through pyranometer and testing of the savonius rotor is carried out by Tachometer and anemometer.

4. Results and Discussion

4.1 Checking Solar Panel Output Through Pyranometer

The following results were recorded on 2/5/2017 at 2 pm to 2:12 pm in Hubballi, Karnataka, India.

Table 4 Readings obtained from Pyranometer

Sl.no	Pyranometer readings	solarpanel Voltage (V)	solar panel Current (A)	solar panel Power (W)	% Efficiency of solar panel
1	1044	21	3.73	78.33	11.37
2	1057	21	3.78	79.38	11.56
3	1030	21	3.72	78.12	11.86
4	990	21	3.71	77.91	11.92
5	1026	20	3.9	78	12.35
6	340	20	1.58	31.6	14.08
7	900	21	2.6	54.6	9.19
8	1061	20	3.86	77.2	11.58
9	996	20	3.76	75.2	12.33
10	1028	20	3.82	76.4	11.95
11	1102	20	3.98	79.6	11.26
12	1091	20	3.96	79.2	11.32
13	1082	20	3.92	78.4	11.53
14	287	20	1.34	26.8	14.15
15	290	20	1.45	29	15.15
16	273	20	1.22	24.4	13.54
17	272	20	1.22	24.4	13.59
18	240	20	1.06	21.2	13.38
19	450	21	1.78	37.38	12.59
20	852	22	3.18	69.96	12.44

Results were recorded for a time interval of 30 sec with a gap of 2 minutes since there was no fluctuation in solar intensity. A multimeter is connected to record both current and voltage simultaneously. Pyranometer (irradiance meter) is placed perpendicular to the slab to obtain accurate solar intensity values. From the above results, it can be concluded that the power generated is directly proportional to the intensity of solar radiation. There was no fluctuation observed in voltage but there was variation in current which implies that the time taken by the battery to get charged decreases. i.e., $I \prec \frac{1}{t}$ where 'I' is the current from solar panel; 't' is the time required by the battery to get charged.

4.2 Testing of the Savonius Rotor

The turbine was mounted on a concrete structure and readings of wind velocity, rpm of the turbine and voltage obtained by the turbine were recorded with the help of Anemometer, Tachometer, and Voltmeter.

Table 5 Readings obtained from Anemometer, Tachometer, and Voltmeter.

wind speed (m/s)	RPM	Voltage (V)	Current (A)	Power (W)
4.0	149	2.0	0.20	0.400
4.6	299	2.9	0.30	0.870
4.7	479	4.0	0.35	1.400
3.0	302	2.0	0.20	0.400
3.5	145	3.6	0.40	1.440
4.7	289	2.4	0.20	0.480
4.4	448	5.0	0.60	3.00
7.3	602	7.0	0.80	5.600
5.0	596	5.3	0.60	3.180
4.0	329	5.6	0.60	3.360
4.1	489	6.0	0.70	4.200
5.5	515	6.0	0.70	4.200
4.1	222	5.0	0.60	3.00
6.6	37	5.0	0.60	3.00
3.9	350	3.0	0.25	0.750
2.3	245	2.0	0.20	0.400
3.4	96	2.5	0.20	0.500
3.3	206	2.0	0.20	0.400
5.8	310	3.2	0.27	0.864
4.5	266	4.0	0.35	1.400
3.9	133	3.3	0.30	0.990
5.3	201	5.0	0.60	3.00
6.0	249	6.3	0.70	4.410
4.6	211	5.9	0.70	4.130
4.5	300	4.5	0.30	1.350
3.4	275	5.0	0.55	2.750
2.5	293	2.3	0.22	0.506

The minimum wind speed at which the turbine rotates is 1.8 ms^{-1}. Since designed turbine is Savonious which is a drag type turbine, with the increase in wind speed, the speed of the turbine rotation also increases resulting in higher power output generation. The maximum wind speed attained was 7.3 ms^{-1} causing the turbine to rotate at 600rpm which produced 7 V of voltage and 0.8 A of current generating the power of 5.6 W.

4. Conclusions

Based on exhaustive research on the topic, the following conclusions were drawn. The designed model has a major share of solar in the power production which generates up to 80W power and turbine is capable of generating 30W and hence resulting in 110W power generation approximately which meets the domestic lighting needs and also produces sufficient energy to meet minor requirements for agricultural applications. Hybrid power generation system is a highly efficient solution for power generation than other non-conventional energy resources due to its uninterrupted continuous power generation. It is a reliable source of energy independent of place where it is installed and power can be either be stored or used at the place of generation reducing transmission losses and cost. Through flow simulation and analysis, the model is set to work in all environmental conditions. Compared to horizontal axis turbine, the designed turbine is eco-friendly, produces less noise. By incorporating an electronic system in solar panel, all-time tracking of sunlight can be achieved. For harnessing the wind energy to a greater extent, a tree- like structure can be built with small turbines fixed at every node and should be installed at high altitudes.

References

1. *Khare V., Nema S., Baredar P.,* 'Status of solar–wind renewable energy in India', *Renewable & Sustainable Energy Reviews, **27** (2013), 1–10.*
2. *Elhadidy M. A., Shaahid S. M.,* 'Parametric study of hybrid (wind+solar+ diesel) power generating systems', *Renewable Energy, **21** (2000), 129–139.*
3. *Nema S., Nema R. K., Agnihotri G.,* 'Matlab/Simulink based study of photovoltaic cells/modules/array and their experimental verification', *International Journal of Energy Environment and Economics, **1**(2010), 487–500.*
4. *Elhadidy M.A., Shaahid S.M.,* 'Promoting applications of hybrid power systems in hot regions', *Renewable Energy, **29** (2004), 517–528.*
5. *Notton G., Muselli M., Louche A.,* 'Autonomous hybrid photovoltaic power plant using a back-up generator a case study in a Mediterranean Island', *Renewable Energy, **7** (1996), 371–391.*
6. *Karaki S.H., Chedid R.B., Ramadan R.,* 'Probabilistic performance assessment of autonomous solar–wind energy conversion systems', *IEEE Transactions on Energy Conversions, **14** (1999), 766–772.*
7. *Nagabhusana A.C., Rohini J., Raju A.B.,* 'Economic analysis and comparison of proposed HRES for standalone applications at various places in Karnataka state', *In Proceedings of IEEE PES, **4** (2011), 380–385.*
8. *Johnson Gary L.,* '*Wind Energy Systems*', Manhattan, K.S, *1994.*
9. *Mahadevan K., Balaveera Reddy K.,* '*Design Data Handbook for Mechanical Engineering*', CBS, *2013.*
10. *Masters Gilbert M.,* '*Renewable and Efficient Electric Power Systems*', Stanford University, *2004.*