Hybrid Energy Generation Through Vertical Axis Savonius Wind Turbine and Solar Panel

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Abstract

The power demand in our country is increased so that there is a consistent power cut in rural areas. This is because of high power consumption by factories and also due to less availability of non-renewable energy resources. So it is a known fact that the application of hybrid renewable energy system to generate power at economic, quick, reliable answer to the rural household's need for power. This Solar-wind energy system can be considerably reducing of our power requirement in rural areas. But, the wind speed is varying both day and night time the produced electricity through horizontal axis wind turbine. To overcome this, issue the vertical axis Savonius Wind Turbine (SWT) with guide vanes has been introduced for producing electricity at low wind speed (cut in speed approximately 3m/s) by combining both SWT and solar photo-voltaic (PV), the hybrid design had been fabricated. The hybrid controller has been selected for the rated power output of the proposed system. In this study, the power generation through Vertical VASWT and PV hybrid system achieved the overall efficiency of 22% for the stand alone system for electricity generation. In this study the optimized design of VASWT has been selected and the performance study has been done with addition of PV panel and modified automobile car alternator.

Keywords: Hybrid energy, Photovoltaic, Wind Energy, Energy Demand

I. INTRODUCTION

Electricity is most needed for our day to day life.[1]-[5] There are two ways of electricity generation either by conventional energy resources or by non-conventional energy resources. Electrical energy demand increases in world so to fulfill demand we have to generate electrical energy. Nowadays electrical energy is generated by the conventional energy resources like coal, diesel, and nuclear etc. The main drawback of these sources is that it produces waste like ash in coal power plant, nuclear waste in nuclear power plant and taking care of this wastage is very costly. [2]And it also damages the nature. The nuclear waste is very harmful to human being also. The conventional energy resources are depleting day by day. Soon it will be completely vanishes from the earth so we have to find another way to generate electricity. The new source should be reliable, pollution free and economical.[4]-[5] The non-conventional energy resources should be good alternative energy resources for the conventional energy resources. There are many non-conventional energy resources like geothermal, tidal, wind; solar etc. the tidal energy has drawbacks like it can only implemented on sea shores. While geothermal energy needs very lager step to extract heat from earth. Solar and wind are easily available in all condition. The non-conventional energy resources like solar, wind can be good alternative source.[3] Solar energy has drawback that it could not produce electrical energy in rainy and cloudy season so we need to overcome this drawback we can use two energy resources so that any one of source fails other source will keep generating the electricity. And in good weather condition we can use both sources combine.

A. *Wind Energy*

If the efficiency of a wind turbine is increased, then more power can be generated thus decreasing the need for expensive power generators that cause pollution.[2] This would also reduce the cost of power for the common people. The wind is literally there for the taking and doesn't cost any money. Power can be generated and stored by a wind turbine with little or no pollution. [6] If the efficiency of the common wind turbine is improved and widespread, the common people can cut back on their power costs immensely. The types of wind turbines are Horizontal axis wind turbine, Vertical axis wind turbine. The vertical axis wind turbines are purely operates based on the drag force. But in horizontal axis wind turbines, lift and drag forces plays the roles to operate the wind turbines. The vertical axis wind turbines have less efficiency than horizontal axis wind turbines. But it has high maintenance cost and investment cost. To overcome these issues the vertical axis wind turbines are the best choice for wind energy generation at low cost.

B. Solar Energy

"Photovoltaic" is a marriage of two words: "photo", meaning light, and "voltaic", meaning electricity.[9] Photovoltaic technology, the scientific term used to describe what we use to convert solar energy into electricity, generates electricity from light. We use a semi-conductor material which can be adapted to release electrons, the negatively charged particles that form the basis of electricity. The various types of PV Panels are single, poly, thin film amporous silicon panels

C. Hybrid Energy System

Hybrid energy system is the combination of two energy sources for giving power to the load. [8] In other word it can defined as "Energy system which is fabricated or designed to extract power by using two energy sources is called as the hybrid energy system." Hybrid energy system has good reliability, efficiency, less emission, and lower cost.

In this proposed system solar and wind power is used for generating power. [12] Solar and wind has many advantages than other than any other non-conventional energy sources. Both the energy sources have greater availability in all areas. It needs lower cost. There is no need to find special location to install this system.

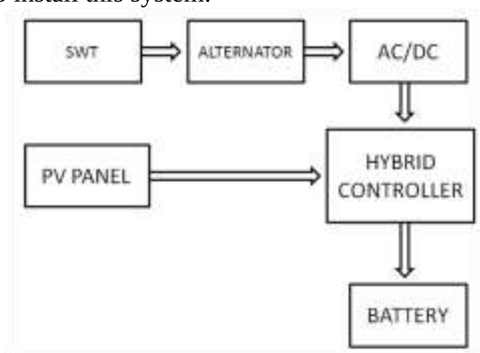

Fig. 1: Block Diagram Of Hybrid System

II. EXPERIMENTAL SETUP

The block diagram of the system has shown in the Fig (1) and the fabricated model has shown in the Fig (2). 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. [7]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 [10].

Fig. 2: Experimental Set-up

The specifications of the SWT, PV panel and the selected hybrid controller have discussed in the Tables (1-3)

Table - 1
Specification of Wind Turbine

PARAMETER	*DIMESION*
Board diameter	*600 mm*
Blade diameter	*140mm*
Blade angle	*30^{O}*
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 – 3
Specification Of The Controller

Rated voltage	*6V/12V/24V*	*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)*	*103×95×38mm*	*Net weight*	*110g~140g*

Here the modified car alternator (maruti 12V 55A) has been selected for electricity generation. The modifications are done in the coil windings in the alternator. The number of turns 11 to 44 have been raised and the coil thickness reduced by half of the actual thickness which is available in the standard alternator. The purpose of doing this is to generate the electricity at low rotational speed of the wind turbine. [1] The gears are made in plastic to reduce the load to the turbine while rotating. [2] 1:2 gear ratios have been used in this arrangement. Initially the turbine output shaft has connected directly to the alternator and both the mechanical and electrical power have been found as per the Fig (3) shown.

The Polycrystalline silicon has selected as a PV material. A hybrid controller has used to charge the 12V battery at the rated power. [8]The hybrid controller has been selected depending upon the solar and wind power outputs.

III. ANALYSIS

The various measuring instruments used in this project. The wind velocity and speed of the wind turbine are measured by digital anemometer and digital tachometer with the range of 0 – 30 m/s and 20 – 75000 RPM. The wind and solar power outputs were measured by the two separate multi-meters (0-600V & 0-10Amps). Similarly, the separate multi-meter was used to find the total power output from the hybrid controller. In this work, the solar irradiation data have been collected from the Tamil Nadu Agriculture Weather Network (TAWN). The PV panel temperature has measured by thermocouples with the range of (-272ºC – 1260ºC).

The PV panel has been faced towards South direction at the latitude of 11.03ºN, 77.13ºE and the altitude of 1125 feet.

A. Theoretical Calculation for Wind Turbine

Vertical axis wind turbine power calculation: [6]

$$P = 0.5\rho A C_p V^3$$

Where,
P-power,
ρ - 1.225 Kg/m^3 density of air at sea level and 15ºC;
A-Swept Area m^2;
V-wind velocity in m/s;
C_p-power Coefficient;

1) Swept Area

$\text{Savonius area} = \text{Swept area} = A_S = H \times D$

Where,
H = the rotor height in m.
D = the rotor diameter in m.

$A_S = H \times D$

= 0.29 × 0.28

As = 0.0812 m^2

2) The Tip Speed Ratio (λ)

$$TSR = \lambda = (\omega \times d)/V$$

Where,
ω = the angular velocity of Savonius rotor (rad/sec).
d = the diameter of the semi-cylindrical Savonius rotor (m).
V = the wind speed (m/sec)
Assuming wind velocity as 6 m/s

$\lambda = (\omega \times d)/V$

For a Savonius VAWT **λ** is approximately equal to unity. **λ**=1

1 = (ω×0.14)/6
ω = 42.85 rad/s
λ = (42.85×0.14)/6
λ = 0.99(Equal to unity)

3) Speed of the Rotor

$\omega = 2\pi N/60$
$N = \omega \times 60/2\pi$
N = 409.18 rpm

4) Power

$$P = 0.5\rho A C_p V^3$$

P = 0.5×1.225×0.0812×0.59×6^3
P = 6.33 watts.

B. Solar Power Calculation

Efficiency in PV panels is measured by the ability of a panel to convert sunlight into usable electrical energy conversion. [9]

$$\eta_{max} = P_{max}/A_C \times G_t$$

Where,
P_{max} = Maximum power output in watts
A_c = Area of collector in m^2
G_t = Incident radiation flux in W/m^2

$$\eta = P/A_C \times G_t$$

= 10/ (0.098325×1000)
= 0.1017
= 10.17%

The Experiment has been conducted during the period of November and December.

Table – 4
Time Vs. Hybrid Power

S.NO	TIME	HYBRID POWER
1	9.00	37.2
2	10.00	58.8
3	11.00	16.8
4	12.00	12.3
5	13.00	25.34
6	14.00	16.56
7	15.00	30.05
8	16.00	63

Fig (1) shows the relation between solar radiation and time. The radiation measured in the day time (8.00 am to 6.00 pm).In the Morning session radiation increases gradually and peak at afternoon and it's slowly reduces on the evening.

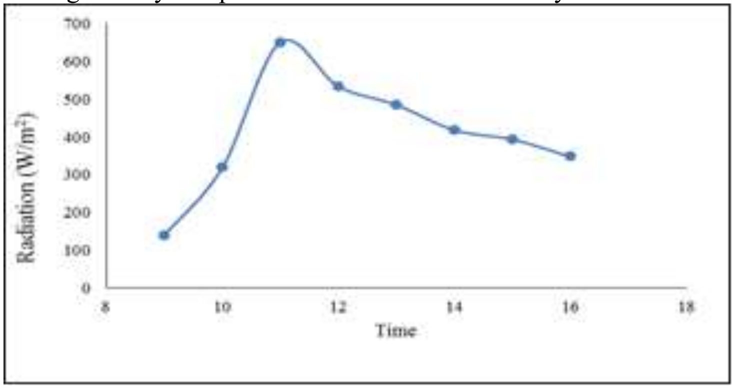

Fig. 3: Time Vs Solar Radiation

C. Experimental Calculation of Wind Turbine

P = V×I
P = 12*1.7
P = 20.4 watts.

D. *Experimental Calculation of Solar Panel*

Power (P) = Voltage (V) ×Current (I)
= 12×0.58
= 7watts
= 7/ (0.098325) × (650.84)
= 10.9%
During the data collection the obtained maximum efficiency of the solar panel was 10.9%

E. *Total Power*

Although the power generated in both wind turbine and PV panel, there is power fluctuations occur due to the insufficient wind speed and solar irradiation.[9] To overcome this interrupted power output to charge battery is avoided by the uninterrupted power output of hybrid charge controller. So the total power was calculated with respect to time from the hybrid controller.
P = V×I
= 12×5.25
= 63 watts

IV. RESULT & DISCUSSION

Fig(2) shows the relation between the velocity and power without gear arrangement.it can be seen that the rated power output was considerabely affected by the direct coupling of alternator and SWT.

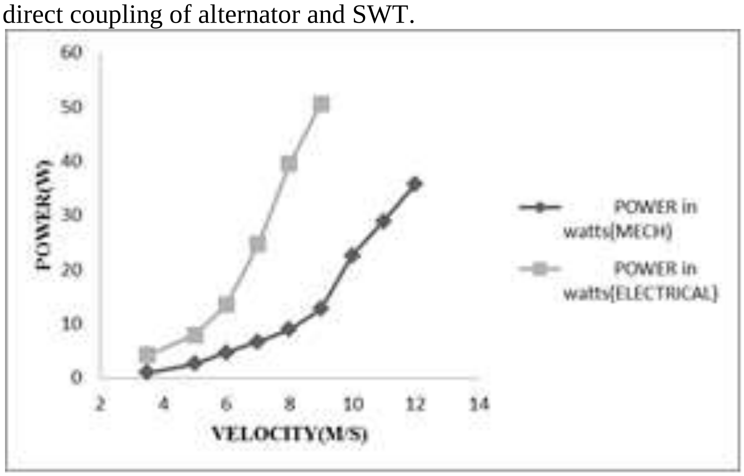

Fig. 4: velocity vs power (without gear)

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.

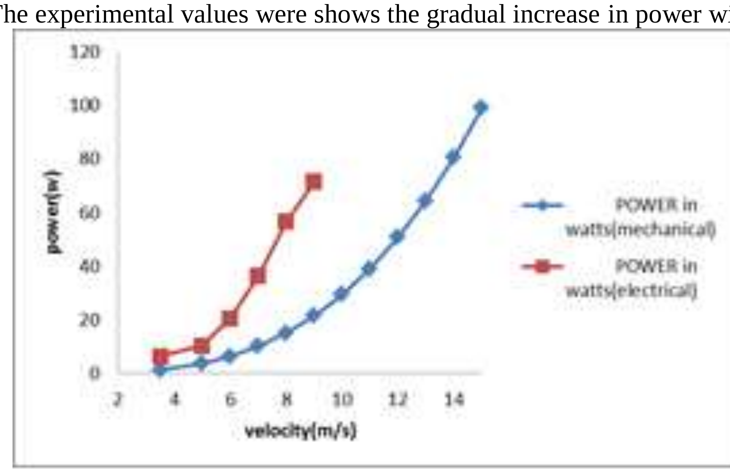

Fig. 5: Velocity Vs Power (With Gear)

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.

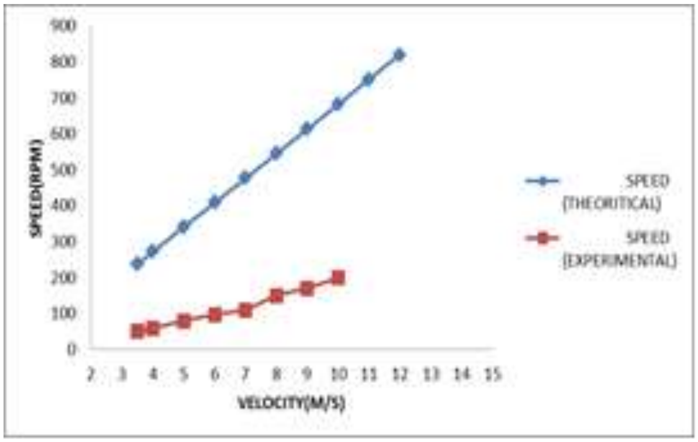

Fig. 6: Velocity Vs Speed

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.

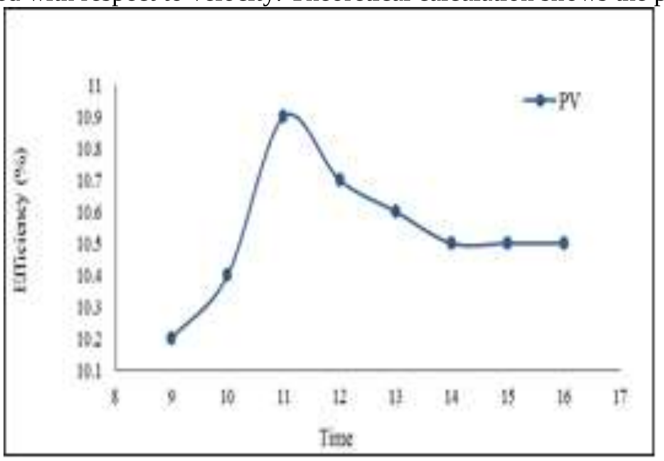

Fig. 7: Efficiency Vs Time

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

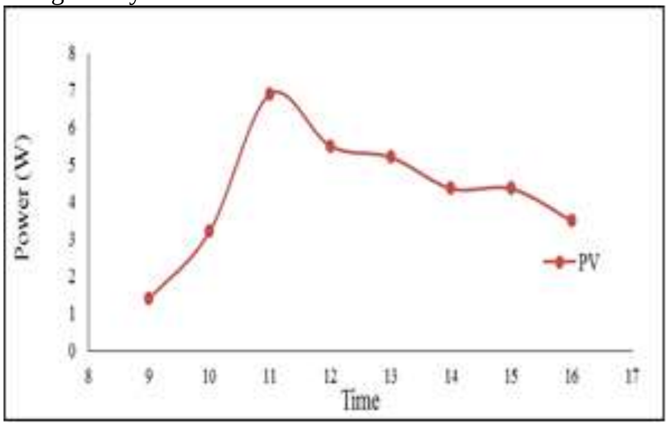

Fig. 8: Power Vs Time

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.

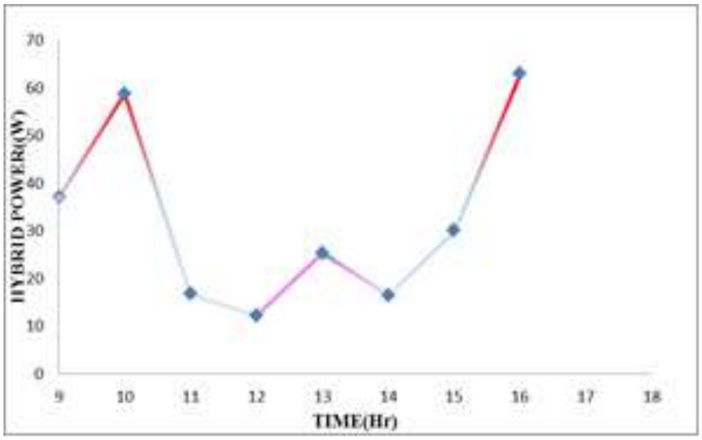

Fig. 9: Time Vs Hybrid Power

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.

V. 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.

Nomenclature

- A Area, m^2
- A_c Collector area, m^2
- C_p Power Coefficient, (-)
- D Rotor diameter, mm
- D Blade diameter, mm
- G_t Solar Irradiation, W/m^2
- H Height of rotor, mm
- I Current, Amps
- N Speed, RPM
- P Power, W
- P_{max} Maximum power output of solar, W
- V Velocity, m/s
- ω Angular velocity, rad/s
- λ Tip speed ratio, (-)
- η Efficiency, %
- η_{max} Maximum Efficiency, %

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