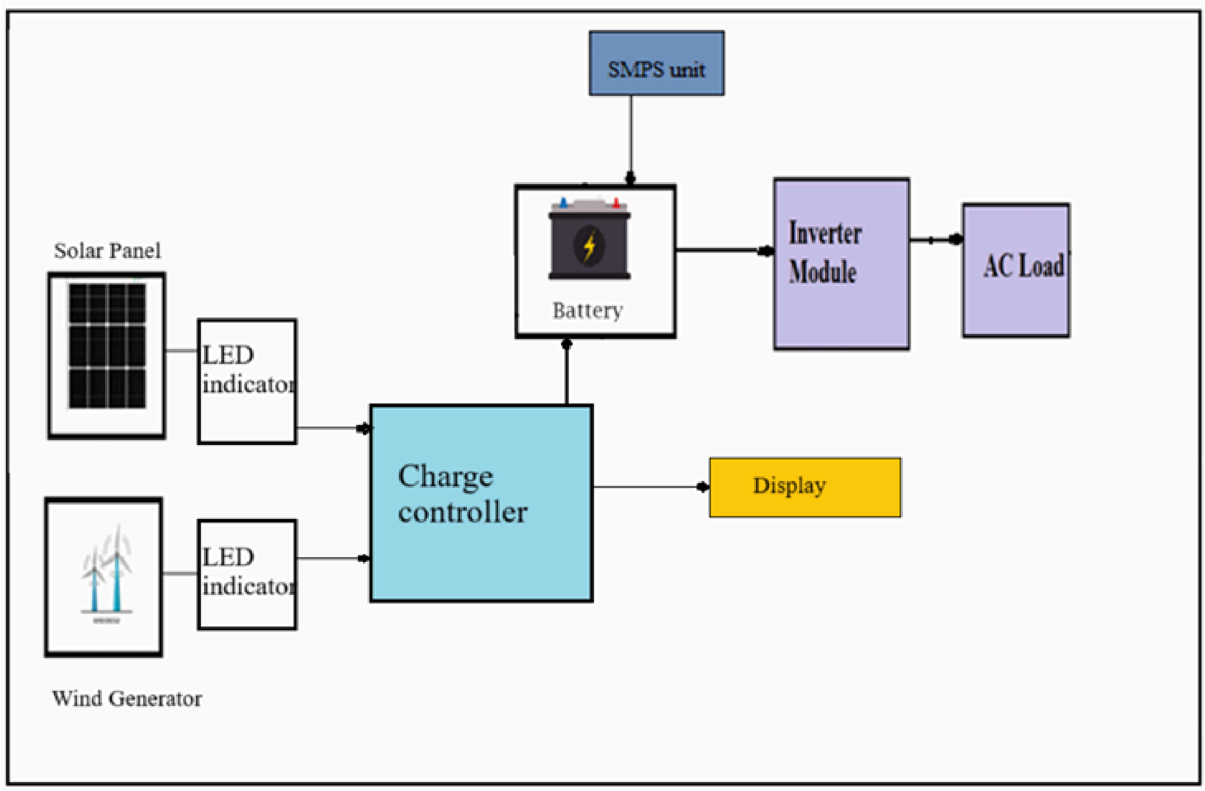
BLOCK DIAGRAM



Working

• Hybrid systems are basically an integration of solar panels and vertical axis wind turbine, the output of this combination is used to charge batteries, this stored energy can then be transmitted to local power stations.
• In this system wind turbine can be used to produce electricity when wind is available and solar energy panels are used when solar radiations are available. Power can be generated by both the sections at the same time also.
• The usage of batteries is to provide uninterrupted power supply. This system requires high initial investment. But the reliability, long-life span and less maintenance make up for that disadvantage. The power output of the wind turbine is DC which is converted to AC with the help of a inverter.
• Now the required amount of electricity can be produced depending on the environmental conditions, by using two systems at the same time or by using only one, according to the conditions pertaining at that point of time.

Hybrid Working Principle

We require electricity for operating almost all the appliances we use in our day to day life. So it has become an indispensable part of our life. Now there are two ways to produce electricity first by using non-renewable sources of energy and second by renewable sources of energy. With increase in population and advancement of technology, consumption of electricity is also increasing exponentially. Simultaneously, we have to increase the production of electricity also in order to meet the demands of growing population. The biggest disadvantage with the usage of conventional resources is that their usage causes pollution due to the production of various pollutants like ash in case of a coal power plant, smoke in case of diesel power plant, radioactive material in case of nuclear power plant. Maintaining these pollutants is not an easy task and it also requires a lot of money. So we have to find some other methods to produce electricity.

The best possible way is by using non-conventional sources of energy. Out of all the possible options available in non-conventional sources of energy, solar and wind are the best methods. As tidal energy can be used only on the sea shores, ocean thermal energy can used in the middle of the sea and its setup is also very difficult. While solar and wind are available in all the areas of the world and setting up their power plant is also not a cumbersome task. The availability of solar energy is a major concern, as it is available for around 8 hours in a day, on the other hand wind is available almost for 24 hours. But we can do one thing to make up for that 15 problem by integrating these two together. During foul weather conditions one of them can be used while during normal weather both can be operated together. So in this paper we will be describing a solar-wind hybrid power system.

● **Solar Energy**

Solar energy is that energy which we get from the sun in form of radiation. It does not cause any kind of pollution, it is inexhaustible. It is available free of cost. Specially, in a country like India where sun shines for almost 300 days in a year, it is therefore a convenient mode of electricity production. Meager amount of investment is involved in setting up a solar power plant and also it is quite easy to maintain. The efficiency of the system is also quite good. Long life span and less emission of pollutants are its major advantages.

● **Wind Energy**

When air flows then it is having some kinetic energy with it which is known as wind energy. This kinetic energy is converted into mechanical energy by the wind turbine, which is used to rotate the shaft of the generator and then electricity is produced. The cost of generation of electricity is quite less. The initial investment of the system varies depending on the type of turbine used. The best part about producing electricity with the help of wind energy is that wind is available for almost 24 hours in day, so there will not be any discontinuous production of electricity. The output varies with the speed of the wind.

● **Hybrid Systems**

Now we have become even more interested in usage of renewable energy sources as an alternative method of producing electricity. Hybrid systems are basically an integration of solar panels and wind turbine, the output of this combination is used to charge batteries, this stored energy can then be transmitted to local power stations. In this system wind turbine can be used to produce electricity when wind is available and solar energy panels are used when solar radiations are available. Power can be generated by both the sections at the same time also. The usage of batteries is to provide uninterrupted power supply. This system requires high initial investment. 16 But the reliability, long-life span and less maintenance make up for that disadvantage. The power output of the wind turbine is DC which is converted to AC with the help of a inverter. Figure 3.2 Hybrid Systems Now the required amount of electricity can be produced depending on the environmental conditions, by using two systems at the same time or by using only one, according to the conditions pertaining at that point of time.

Proposed Calculations
Overall power generated by system is the summation of the power generated by the solar PV panel and power generated by the wind turbine. Mathematically, it can be represented as,After selecting the best position to mount the system, the system was tested and results were obtained for the wind turbine and the solar panel. The results are presented in this chapter and subsequently discussed. Graphs have also been included to put the relationships between relevant variables in perspective.

PT = NW * Pw + Ns * PS
Where,
Total power generated= PT
Power generated by wind turbines= PW
Power generated by solar panels= PS
No. of wind turbine = NW
No of solar panels used= NS

A. Calculations for wind energy:
The power generated by wind energy is given by,
Power = (density of air * swept area * velocity cubed)/2

PW = ½.ρ (AW) (V) 3

Where,
P is power in watts (W)
ρ is the air density in kilograms per cubic meter (kg/m^3) AW is the swept area by air in square meters (m^2) V is the wind speed in meters per second (m/s)

B. Calculations for solar energy
To determine the size of PV modules, the required energy consumption must be estimated. Therefore, the power is calculated as

PS = Ins (t) * AS * Eff (pv)

Where,
Ins (t) = isolation at time t (kw/ m2)
AS=area of single PV panel (m2)
Effpv = overall efficiency of the PV panels and dc/dc converters.
Overall efficiency is given by,

Eff(pv) = H * PR

Where,
H=Annual average solar radiation on tilted panels.
PR =Performance ratio, coefficient for losses.

C. Cost
The total cost of the solar-wind hybrid energy system is depend upon the total no of wind turbines used and total no of solar panels used. Therefore the total cost is given as follows
Total cost= (No. of Wind Turbine * Cost of single Wind Turbine) + (No. of Solar Panels * Cost of single Solar Panel) + (No. of Batteries used in Battery Bank * Cost of single Battery)

CT=(NW*CWT)+(NS*CSP)+(NB*CB)

Where,
CTis the total cost in Rs
CWT is the cost of single wind turbine
CSP is the cost of single solar panel in Rs
CB is the Cost of single Battery in Rs
NW is the number of wind turbine used
NS is the number of solar panels used
NB is the number of Batteries used in Battery Bank.

Analysis :

After selecting the best position to mount the system, the system was tested and results were obtained for the wind turbine and the solar panel. The results are presented in this chapter and subsequently discussed. Graphs have also been included to put the relationships between relevant variables in perspective.

• Wind Turbine Testing

This section provides the result obtained when the wind turbine was tested. To get the wind speed at any given time, an anemometer was used. Also, to get the voltage output corresponding to a particular wind speed, a digital multi-meter was used to measure the voltage generate by the wind turbine for each wind speed. Subsequently, the power output of the wind turbine was calculated for each of the wind speed measurements recorded. These results were taken at five minute intervals for thirty minutes. To enhance better analysis, the measurements were taken in the morning, afternoon and evening. The results of these measurements are presented in table 1. The value of the power output of the wind turbine for any given wind speed was calculated using the formula in equation 1,

$$P = \frac{1}{2} A\rho v^3 C_p \quad \text{....1}$$

where $A = \pi r2$ = 7.07 m2,
air density, ϱ in Osun State = 1.1902 kg/m3,
v = wind speed in m/s, Cp = Betz power coefficient which is assumed to be 0.4 for this wind turbine.

Table 1 Data Collected from Wind Turbine During the Morning Session

Time	Wind Speed (m/s)	Output Voltage (V)
07:30 am	2.3	3.30
07:35 am	1.8	2.75
07:40 am	2.5	3.56
07:45 am	2.6	3.62
07:50 am	1.9	2.92
07:55 am	2.3	3.32
08:00 am	2.0	3.09

Table2 Data Collected from Wind Turbine During Afternoon Session

Time	Wind Speed (m/s)	Output Voltage (V)
01:00pm	2.1	3.15
01:05pm	1.5	2.49
01:10pm	1.3	2.22
01:15pm	1.8	2.73
01:20pm	1.1	2.05
01:25pm	1.7	2.64
01:30pm	0.8	1.53

Table3 Data Collected from Wind Turbine During Evening Session

Time	Wind Speed (m/s)	Output Voltage (V)
06:00pm	3.3	4.23
06:05pm	3.1	4.11
06:10pm	3.7	4.61
06:15pm	3.0	3.97
06:20pm	2.8	3.73
06:25pm	3.4	4.30
06:30pm	3.1	4.11

• Analysis and Discussion of Wind Turbine Test Results

From the results recorded in the tables, graphs were plotted to show the variation of wind with time of the day as well as variation of the voltage and power output of the wind turbine with speed. Figure 1 shows the graph of wind speed versus time, figure 2 shows the plot of voltage output of the wind turbine versus wind speed and Figure 3 shows how the calculated power output of the wind turbine varies with wind speed.

From figure 1, it is observed that throughout the test period, the wind speed never exceeded 4.0 m/s. The highest wind speed recorded was 3.7 m/s which confirms the fact that was stated earlier regarding Ile-ife being an area where wind speed is relatively low.

Furthermore, the graph shows that wind speed was at its highest in the evening between 6:00 pm and 6:45 pm while it was lowest in the afternoon between 1:15 and 1:40 pm. The values for wind speed recorded during the morning session were somewhere in between those for the afternoon and evening.

Figure 2 shows that the relationship between the output voltage of the turbine and the instantaneous wind speed is fairly linear. The graph also indicates that the highest voltage output recorded for the wind turbine was about 4.6 V. However, the hybrid system being designed requires an input voltage of 12 V or even more. This implies that the wind turbine will not be able to supply the required for the system to function. This is a direct consequence of the relatively low speed of wind in Ile-ife. It further implies that the main source of power to the system will be the solar panel.

From figure 3, it can be observed how the power output of the turbine varies with the instantaneous wind speed. From the formula for calculating output power of a turbine, it can be deduced that the output power is proportional to the cube of the instantaneous wind speed and that can be observed from the non-linear of the graph.

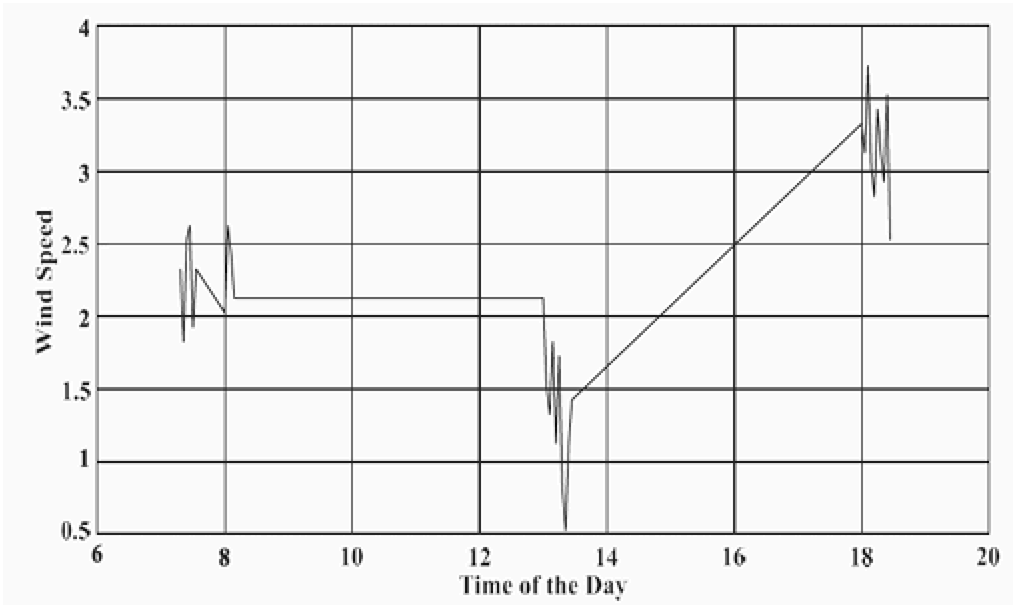
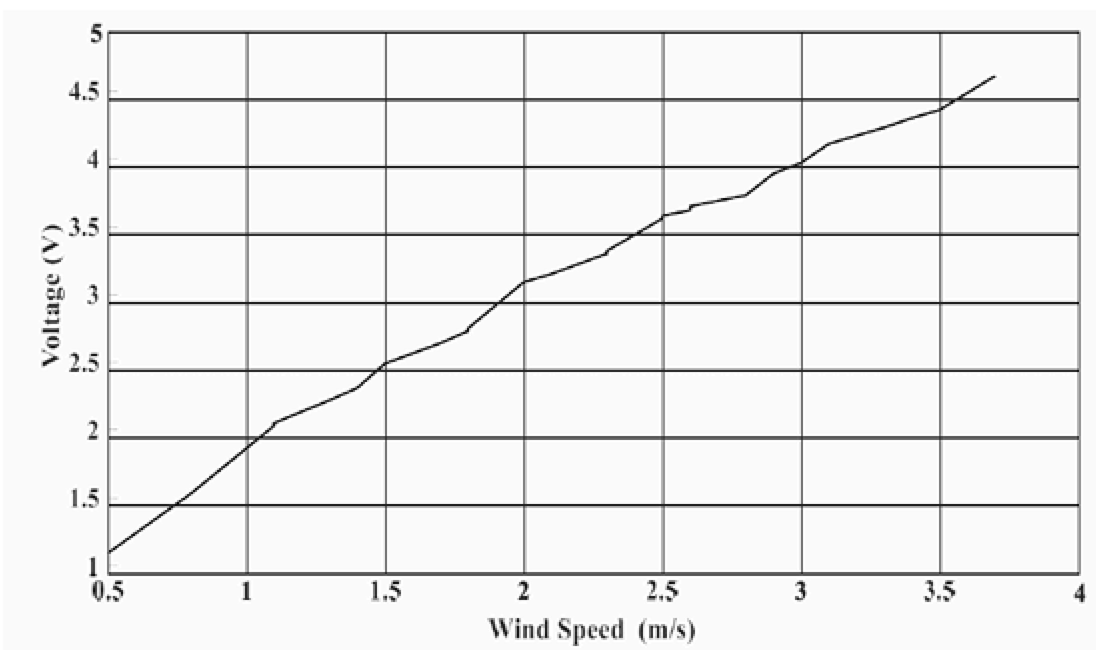


Figure 4.2 Graph of Wind Speed (m/s) Vs Time of the Day



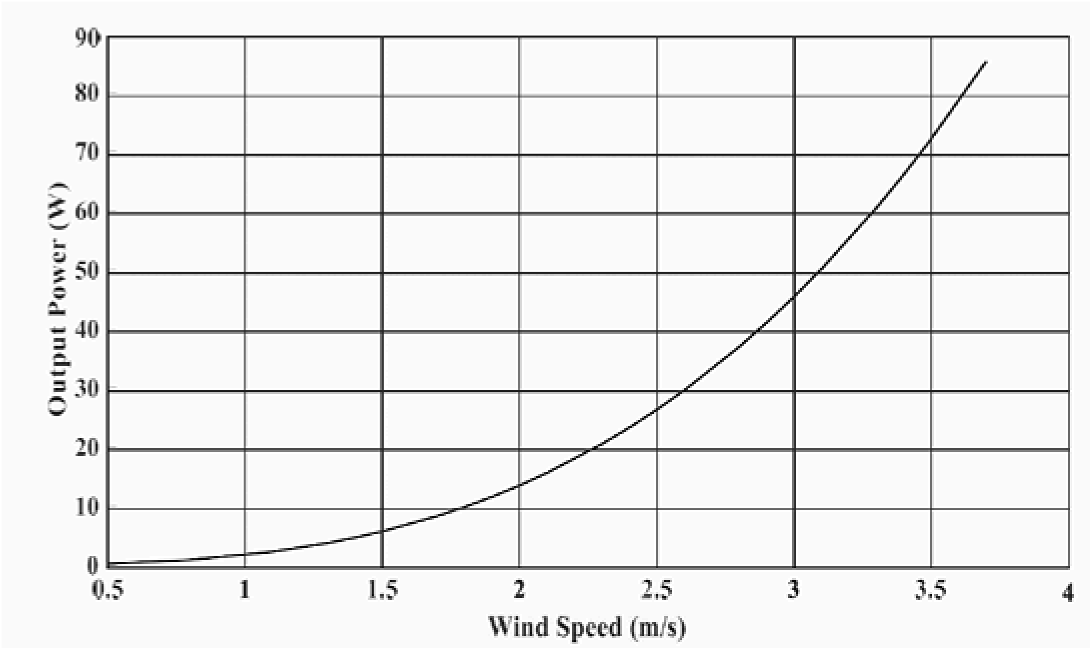


Figure 4.4 Graph of Turbine Power Output Vs Wind Speed

Furthermore, the graph also indicates the highest power output of the turbine throughout the testing period which corresponds to the highest point in the power curve.

• Solar Panel Testing

Just as was done was done for the wind turbine, the solar panel was tested are three different times during the day in order to determine how the output varies with changing weather conditions. The results of the measurements are presented in Table 4. The results recorded for the voltage and current are open-circuit voltage and shortcircuit current respectively. They were measured using a digital multi-meter placed across the two leads of the solar panel. The output power was calculated by multiplying the voltage by the current.

• Discussion of Solar Panel Test Results

From the results recorded in table 4, it can be concluded that the solar panel is capable of giving a voltage output that is greater than 12 V. This implies that the solar panel will be able to power the system in the morning and afternoon conveniently. However, in the evening, when the sun starts to set, the voltage output of the solar panel drops below 12 V and it becomes unable to power the system. From the results gotten from testing the wind turbine, it was concluded that the wind turbine will never be able to provide the voltage needed to power the system at any time of the day. Consequently, at evening time, when the output of the solar panel is not adequate to power the system, the overall input of the system will not be enough to power the system.

Table 4 Data Collected from Solar Panel During Morning, Afternoon and Evening Session

Period	Open-circuit voltage (VOC)	Short-circuit current (A)
Morning	19.91	6.95
Afternoon	21.68	7.53
Evening	11.50	3.57

During this time, the 12 V battery serves as the only power source to the system and ensures that the loads connected to the system receive enough power for a considerable period of time in the evening. Moreover, considering that the project is to be used to power an office where there is little or no activity at night, the problem of insufficient input from the wind turbine and solar panel at evening time will not have much consequence.

• Total Power Output of the Hybrid System

The total power generated by this system is given as the addition of the power generated by the solar PV panel and the power generated by the wind turbine. Mathematically, it can be represented as;

$$P_T = P_W + P_S \qquad (4.2)$$

Where,
PT =Total Power Generated
PW=PowerGenerated by the wind turbine
PS= Power Generated by the solar panel

For the results collected from testing the solar panel and the wind turbine, it can be seen that the highest power outputs of the wind turbine and solar panel are 10 W and 30 W respectively. This implies that the highest power output of the entire system can be calculated as follows;

PT = 10 + 30 = 40W