American Journal of Energy and Natural Resources (AJENR)

ISSN: 2835-9186 (ONLINE)

VOLUME 4 ISSUE 1 (2025)

PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Energy and Natural Resources (AJENR)

Volume 4 Issue 1, Year 2025
ISSN: 2835-9186 (Online)
DOI: https://doi.org/10.54536/ajenr.v4i1.4157
https://journals.e-palli.com/home/index.php/ajenr

Design and Installation of a Solar and Wind Hybrid System in Kano State, Nigeria

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Article Information

Received: December 19, 2024

Accepted: January 24, 2025

Published: April 07, 2025

Keywords

Hybrid Power System, Renewable Energy, Solar Energy, Wind Energy, Wind Speed

ABSTRACT

This project aims to design and install a hybrid power system that combines two renewable energy sources, namely solar and wind energy, to produce reliable and sustainable electricity. Three solar panels and a wind turbine were installed in order to transform solar and wind energy, respectively, into electrical energy. Additionally, a hybrid charge controller was added to "multiplex" the inputs from the solar panel and wind turbine and give an output voltage sufficient for the 12 V battery. A charge controller was also added to avoid overloading the hybrid controller. A 1kVA inverter also transformed the battery's DC output to usable AC. For this study, ten-year wind data was analyzed using Weibull distribution through the standard deviation method. According to the results, the test period's wind speed in Kano at 4.2 m/s for a height of 10 m yielded a turbine output of 72.3 watts. It was less than what the turbine needed to create the system's 12 V DC output. However, the test results revealed that the solar panels could create or generate at least 12 V for several hours, particularly during the day. The study concluded that, the battery in the system was mainly for stability and backup for use at night. The turbine generated 1.104 kWh and the Solar generated 2.335 kWh.

INTRODUCTION

Energy constitutes an essential requirement, akin to sustenance and hydration. All entities within our environment necessitate energy. Throughout the years, there has been a marked escalation in the global population, which correlates directly with the consumption of energy. All conceivable devices and apparatus require some form of energy to operate effectively. Given the diminishing reserves of fossil fuels, it is imperative to ascertain sustainable renewable energy sources that can mitigate reliance on fossil fuels.

For any nation aiming for industrialization and higher levels of technological growth and national development, the production of electricity is without a doubt a necessary requirement. Undoubtedly, a vital necessity that must be met in order to improve the comfort and enjoyment of daily life is the constant supply and availability of energy. As a result, various nations around the world work towards providing reliable electricity.

According to Ingole and Rakhonde (2015), there are two ways of electricity generation; either by conventional/non-renewable energy resources or non-conventional/renewable energy resources. Nowadays, electricity is generated from conventional energy resources. These energy resources include coal, petroleum, wood fuel, Natural gas, nuclear energy, etc. On the other hand, non-conventional resources include wind, solar, tidal energy, Bio-energy, Hydropower, etc. These non-conventional energy resources are usually pollution-free and economical. They are also naturally replenished, thus, unlike conventional energy resources, they are inexhaustible.

One of the many unconventional energy sources that can be used to produce power is wind, as was previously mentioned. It is employed to produce electricity in many developed or sophisticated nations worldwide. Airflow through the wind is used to generate this wind power, which is then used to mechanically power electrical generators. The mechanical energy is subsequently transformed into electrical energy by these generators. As an alternative to burning fossil fuels, wind power is abundant, clean, renewable, widely available, emits no greenhouse gases while in operation, and requires little land (Fthenakis & Kim, 2009).

Despite the abundance of energy resources in Nigeria, the country is still short in supply of electrical power. Only about 55.4 percent of the nation of over 200 million has access to grid electricity according to World bank, (2020). Even electricity supply to consumers that are connected to the grid is erratic. Due to this, citizens and businesses have over time turn to the usage of conventional sources of generating electricity which is harmful to the environment. However, independent or stand-alone renewable energy sources will only generate the necessary energy when that specific resource is accessible. For instance, solar energy is only available when the sun is shining, whereas wind energy is only available when the wind is blowing. Furthermore, because solar panels, batteries, and an inverter are expensive, installing a solar system is a capital-intensive task for low-income earners.

Therefore, how can the issue of an inadequate, costly, unsustainable, and unstable electrical supply be resolved? There is a need for new energy sources, and Ingole *et al.* (2015) state that these sources should be affordable, dependable, and pollution-free.

Only when that specific resource is accessible can renewable energy resources functioning as a stand-alone or autonomous unit generate the necessary energy. For

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instance, solar energy is only available when the sun is shining, whereas wind energy is only available when the wind is blowing. Therefore, if just one of these renewable energy supplies is used at a time, there may be a low availability issue (the likelihood of carrying out the necessary function at a specific time). For instance, if a solar panel is the only mechanism used to generate electricity, it will not function as intended on wet or stormy days or at night. In fact, such a stand-alone system will do very little or nothing in the bid to satisfy the desire for sustainable, reliable electricity in Nigeria.

Therefore, to maximize the available resources and provide a stable and consistent electricity supply, hybrid systems that combine two renewable energy resources would be designed. The project at hand is to combine energy from wind and solar together to generate electricity. One source will serve as the complement of the other and thus ensure that there is always energy to be harnessed and converted to electrical power. The system is also equipped with a battery to store the power obtained from wind and solar energy. This means that, if both wind and solar energy happen to be unavailable at the same time, we can still have electricity. Hence, the research at hand has the potential to solve the problem of unreliable, unsustainable, and erratic power supply in Nigeria.

Aim and Objectives of the Research

The aim of the research is to design and install a solar-wind hybrid power system in Kano State, Nigeria.

The objectives of this project include the following;

1. To analyse ten years wind data in Kano.
2. To reduce the number of backup batteries.
3. To provide sustainable electricity irrespective of changes of weather condition

Scope of the Research

As mentioned earlier, the research work involves the design and installation of a hybrid power system made up of wind and solar power. The Mechanical Engineering Department Level 5 of Bayero University in Kano has been used as a case study in this research.

In this study, the wind speed characteristic of the site where the hybrid power system will be situated, will be examined using a digital anemometer. The solar characteristics of then area will also be accessed. These will be carried out to determine whether the area experiences enough wind speed and solar radiation that will ensure the smooth operation of the system.

Subsequently, the hybrid power system will then be designed and implemented by a combination of a solar panel and wind turbine. A hybrid charge controller will also be included to serve as a multiplexer of the outputs from the wind turbine and solar panel. A battery is also included to serve as auxiliary power source when the wind and solar energy are simultaneously.

LITERATURE REVIEW

Hybrid Power System

Hybrid power systems are systems that combine two or more renewable sources of energy together to provide increased system efficiency as well as greater balance in energy supply. A very common example of a hybrid power system is that involving the combination of solar and wind energy.

In this system, a photovoltaic array is coupled with a wind turbine. This creates more output from the wind turbine in the cold season, whereas during the hot season, the solar panel produces its peak output. Generally, hybrid energy systems often yield greater economic and environmental returns than wind, solar or geothermal stand-alone systems by themselves. Before reviewing the past works and studies involving hybrid power systems as a whole, it is vital to describe the key subsystems in the hybrid system at hand, the solar panel and wind turbine.

Review of Past Works and Studies Involving Hybrid Power Systems

A survey of the body of research showed that numerous academics and engineers from all around the world had worked extremely hard to create dependable hybrid power systems. Nearly all of the evaluated papers serve a variety of functions, including socioeconomic research, analysis, modeling, optimization, and off-grid application design.

In a study on standalone solar and hybrid systems, Akikur *et al.* (2013) examined the viability and importance of solar energy (both standalone and hybrid form) in global electrification, as well as the solar-wind hybrid, solar-hydro hybrid, and solar-wind-diesel-hydro/biogas hybrid. Ismail *et al.* (2013) conducted a techno-economic analysis and feasibility study of a photovoltaic system that uses microturbines and batteries as a backup power source. Iterative methods have been used for component size and optimization in order to reduce the production cost of energy (COE).

Prabhakar and Ragavan (2013) talked about battery-assisted PV-wind-hydro hybrid systems' power management techniques. They created a control method that uses drop control, dc-link voltage control, and the energy-balance model to predict the load.

Menshsari *et al.* (2013) talked about applying the ant colony algorithm to optimize a hydro-wind-solar-fuel cell hybrid. Saha *et al.* (2013) presented a fictitious hybrid system that uses a diesel generator as a backup source in addition to wind, solar, biogas, and microhydro hybrid as its primary energy sources.

Kumar and Garg (2013) used SIMULINK software to develop a solar-wind hybrid system. All of the system's realistic components were included in the simulation, and the power output of each individual component of the system as a whole was compared. In order to electrify Malaysia's rural areas, Fadaeenejad *et al.* (2014) investigated PV-wind-battery and PV-wind-diesel-battery hybrids.

Review of Wind Energy Characteristics and Potential in Nigeria

Nigeria's wind profile was first described in the middle of the 1990s when Fagbenle *et al.* (1980) investigated the country's wind potential and discovered that the 1951–1960 surface wind data at 10 m height from twelve meteorological sites was characterized by a modal class of roughly 3.0 m/s. Additionally, research demonstrated that mean wind speeds in the North were twice as high as those in the South, with the maximum mean wind speed of almost 3.6 m/s recorded at the high-altitude Jos station in Plateau State.

Ojosu and Salawu (1990) examined average yearly wind data from 22 weather sites between 1951 and 1975. With an annual mean wind speed of 3.92 m/s and a monthly average of 5.12 m/s in June, they determined that the high altitude Sokoto station had the strongest winds. The study also revealed that wind speeds in the southern regions and middle belts were just 2.0 m/s at most.

Review of Solar Energy Characteristics and Potential in Nigeria

Oghogho *et al.* (2014) came to the conclusion that since solar energy is free and almost endless, it can be thought of as the perfect energy source. Nigeria's geographic location—the equatorial region, which receives a lot of solar radiation—is one of her major advantages for facilitating the production of solar energy in the country. Nigeria has a somewhat evenly distributed amount of solar radiation, with an average of 19.8 MJm-2day-1 and six hours of sunshine per day, with the extreme northern boundary receiving 9.0 hours and the coastal parts receiving roughly 3.5 hours (Adebayo, 2014). Nigeria gets 4.851×1012 kWh of solar energy every day. The intensity of solar radiation varies between 3.5 and 7.0 kWh per square meter each day. (Oseni, 2012).

According to Nnaji and Unachukwue (2010), Nigeria, which is in the tropics and receives a lot of sunshine, could have access to 1500PJ (roughly 258 million oil equivalent) of solar energy annually if solar appliances with a 5% conversion efficiency were installed across just 1% of the nation's total land area during the six months of the year.

MATERIALS AND METHODS

In this research work, primary resources acquired from The Nigeria Meteorological Agency NiMet were adopted in the use of the wind speed data analysis and Weibull distribution was used to determine the probability that the turbine will work as well as estimating the velocity of the wind speed which was used as a criterion for the selection of the turbine.

Description of the Research Work

The Savonious Vertical Axis Wind Turbine was used in

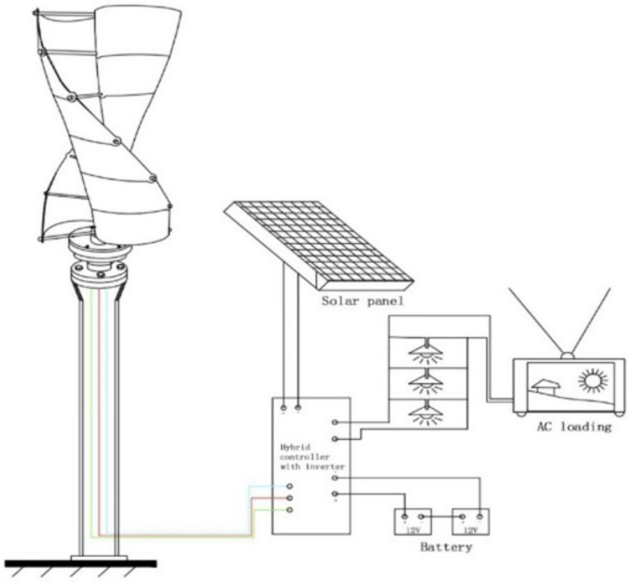

Figure 1: Solar wind hybrid design model

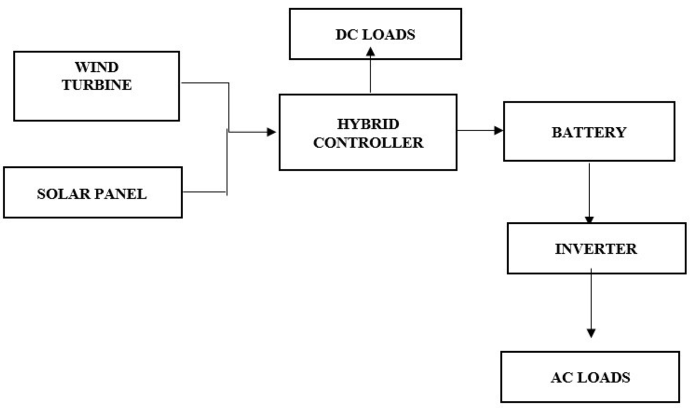

Figure 2: Block Diagram of the Device

this research. Figure 3.0 shows the Hybrid Solar Wind Design Model and Figure 3.1 shows the block diagram that highlights subsystem blocks in the project. These include, the solar panel, wind turbine, charge controller, battery, inverter as well as the loads, either DC or AC loads. As shown in the diagram, the outputs from the wind turbine and solar panel are multiplexed and fed in as input to the hybrid controller

System Design

(a)The hybrid system consists of the following:
(b)Load Estimate
(c)Wind Analysis and selection of Wind Turbine
(d)Sizing and selection of Solar panel
(e)Sizing and selection of Battery
(f)Sizing and selection of Inverter
(g)Sizing and selection of Charge Controller

Load Estimate

The power expended by the appliances in the area of interest was estimated with respect to their operation time to yield the total energy that will be consumed by these appliances.

The Energy requirement = Total Power × Operation Time in (Hrs) = 3,475 Wh/day, has been estimated that the total power consumed by these appliances is 615W and the total corresponding Energy consumed by these appliances gives 3.475 Kwh

Percentage Scale down = (Scale down Estimate)/(Total Estimate) × 100% = 3475/9125× 100% = 38%

Wind Analysis and Selection of Wind Turbine

Although the use of wind turbines has become necessary in many parts of the world, the actual developments in the turbine do not concern countries where the average wind speed is low. Vertical axis wind turbines are the growing type of wind turbine in the small wind energy market, they prove to be very promising as in the case of the new rotor design. Vertical axis wind turbines (or VAWTs) have the main rotor shaft arranged vertically. Key advantages of this arrangement are that the turbine does not need to be pointed into the wind to be effective. This is an advantage on sites where the wind direction is highly variable. In this project to select the turbine to be used, we need to carry out wind energy data analysis.

Wind Data Analysis

However, precise prediction of wind is not an easy task since wind, like many other meteorological parameters often exhibits significant variability over a range of scales, both spatially and temporally. In the view of wind power development, the variation of wind speed at a given location is generally characterized by a probability distribution, which indicates the likelihood that a given wind speed will occur. Most commonly used for wind energy assessments is the two-parameter Weibull distribution, which has been shown to accurately capture the skewness of the wind speed distribution, then other statistical functions and has been used in a number of studies.

The Weibull Distribution

Various mathematical tools have been used for the analysis of wind speed data. Among several tools, the two parameter Weibull distribution is extensively used function for analyzing measured wind speed data in a given location over a given time period. The two parameter Weibull distribution is a special case of the generalized gamma distribution. For the analysis of wind speed data, the two parameter Weibull probability distribution function is the most suitable, accepted and recommended distribution function as it gives a better fitting and high accuracy for monthly probability density distributions of measured wind speed than any other distribution functions. The Weibull probability density function is expressed as,

$F(v)= (K/C)\ (V/C)^{(k-1)}\ \exp\{-(V/C)^{k}\}\quad (v>0;K,C>0)$

Source: Journal for Renewable and Sustainable Energy University of Birmingham

Where f(v) is the probability of wind speed, k is shape parameter and c is the scale parameter (in m/s).

Wind Speed Data

For this research study, the metropolis of Kano was selected for our wind turbine deployment. However, ten years wind speed data of Kano city were gotten from Nigeria Metrological Agency (NIMET) in Knot for the wind data analysis. Conversion was made from knot to m/s while weekly, monthly and yearly wind average were calculated in m/s.

Statistical Analysis

Statistical analysis includes calculation of shape parameter, scale parameter and most probable wind speed for the ten years will be calculation.

In this study, Standard deviation method will be used for our analysis

To get our shape Factor (k);

$k = (\sigma/Vm)^{-1.086}$

Source: Journal for Renewable and Sustainable Energy University of Birmingham

where k= Shape Factor, σ= Standard Deviation and Vm = Mean velocity

After k, then we find scale factor, to get the scale factor (c);

$C/V_M = (0.568+ 0.433/k)^{(1/(-K)})$

Source: Journal for Renewable and Sustainable Energy University of Birmingham

Where c = Scale factor (m/s), V_m= Mean of the wind speed.

Probability density functions of Weibull distributions (F(v))

Future and available wind potential is very important to build of wind energy conversion system. For this reason, estimation parameter results of distribution are studied monthly. Optimum model can be chosen according to performance criteria

$F(v) = (K/C)(V/C)^{(k-1)} \exp\{-(V/C)^k\}$ (v>0;K,C>0)

However, our average Shape parameter for the ten years is approximately 2.92 and the average Scale parameter for the ten years is approximately 5.83m/s. Therefore, we are working with these values for Turbine selection in in Kano state.

Table 1: Weibull Distribution with Shape Parameter and Scale Parameter for ten years

V(m/s)	K	c	k/c	v/c	(V/C) k-1	(k/c) (v/c)^k-1	(v/c)^k	(-(v/c) k)	Exp	f(v)
1	2.92	5.83	0.500858	0.171527	0.033877892	0.016968001	0.005811	-0.00581	0.994206	0.01687
2	2.92	5.83	0.500858	0.343053	0.128201754	0.064210827	0.04398	-0.04398	0.956973	0.061448
3	2.92	5.83	0.500858	0.51458	0.279247429	0.139863206	0.143695	-0.1437	0.866152	0.121143
4	2.92	5.83	0.500858	0.686106	0.485144998	0.242988575	0.332861	-0.33286	0.71687	0.174191
5	2.92	5.83	0.500858	0.857633	0.744627006	0.37295212	0.638617	-0.63862	0.528022	0.196927
6	2.92	5.83	0.500858	1.02916	1.056736664	0.529274624	1.087551	-1.08755	0.337041	0.178387
7	2.92	5.83	0.500858	1.200686	1.420707299	0.711572095	1.705824	-1.70582	0.181623	0.129238
8	2.92	5.83	0.500858	1.372213	1.835900541	0.919524799	2.519246	-2.51925	0.08052	0.07404
9	2.92	5.83	0.500858	1.543739	2.301770358	1.152859253	3.553333	-3.55333	0.028629	0.033005
10	2.92	5.83	0.500858	1.715266	2.817840293	1.411336819	4.833345	-4.83335	0.00796	0.011234
11	2.92	5.83	0.500858	1.886792	3.383688149	1.694746037	6.384317	-6.38432	0.001688	0.00286
12	2.92	5.83	0.500858	2.058319	3.998935205	2.002897221	8.231084	-8.23108	0.000266	0.000533
13	2.92	5.83	0.500858	2.229846	4.663238322	2.335618508	10.3983	-10.3983	3.05E-05	7.12E-05
14	2.92	5.83	0.500858	2.401372	5.376284016	2.692752886	12.91046	-12.9105	2.47E-06	6.66E-06
15	2.92	5.83	0.500858	2.572899	6.13778388	3.074155906	15.7919	-15.7919	1.39E-07	4.26E-07
16	2.92	5.83	0.500858	2.744425	6.947470983	3.479693871	19.06682	-19.0668	5.24E-09	1.82E-08
16	2.92	5.83	0.500858	2.744425	6.947470983	3.479693871	19.06682	-19.0668	5.24E-09	1.82E-08
18	2.92	5.83	0.500858	3.087479	8.710429793	4.362685248	26.89327	-26.8933	2.09E-12	9.12E-12
19	2.92	5.83	0.500858	3.259005	9.663251631	4.839913338	31.49259	-31.4926	2.1E-14	1.02E-13
20	2.92	5.83	0.500858	3.430532	10.66335742	5.340823959	36.58099	-36.581	1.3E-16	6.93E-16

Source: Journal for Renewable and Sustainable Energy University of Birmingham

Estimation of monthly and annual parameters for Kano region are implemented by using average monthly wind speed data between 2011 and 2020. The Standard Deviation Method was used for determining Weibull parameters. Below is the Weibull distribution function graph;

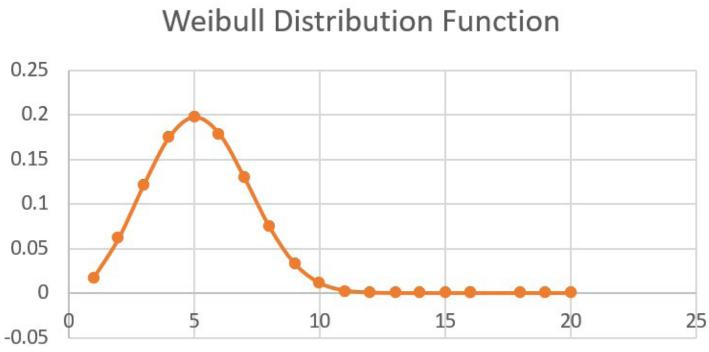

Figure 3: Graph: Weibull distribution function

The probability that the selected wind turbine will work is

$P(V_c < V < V_f) = \exp\{-(V_c/C)^k\} - \exp\{-(V_f/C)^k\}$

Where;

V_c = Cut-in wind speed

V_f = Cut-off wind speed

C = Scale factor

K = Shape factor

Source: Journal for Renewable and Sustainable Energy University of Birmingham

After substituting the specifications of the selected turbine, the probability that the turbine will work is;

$P(V_c < V < V_f) = \exp\{-(2.5/5.83)^{2.92}\} - \exp\{-(45/5.83)^{2.92}\}$

$P(V_c < V < V_f) = 0.9190 \cong 0.92$

Therefore, the probability is 92%.

Capacity Factor of the Selected Wind Turbine

Capacity Factor is an indicator of how much energy a particular wind turbine makes in a particular place.

$CF = (\exp\{-(V_c/C)^k\} - \exp\{-(V_r/C)^k\})/((V_r/C)^k - (V_c/C)^k) - \exp[(V_f/C)^k]$

Source: Journal for Renewable and Sustainable Energy University of Birmingham

However, after substituting the wind turbine parameters, the capacity factor of the wind turbine in Kano region is

$CF = (\exp\{-(2.5/5.83)^{2.92}\} - \exp\{-(8/5.83)^{2.92}\})/((8/5.83)^{2.92} - (2.5/5.83)^{2.92}) - \exp[(45/5.83)^{2.92}]$

$= 0.344.$

Therefore, the capacity factor is 34.4%

Based on the capacity factor of 34.4%, the total energy gotten from the turbine could be

$100 \times 12 \times 0.92 = 1104$Wh/day

Which is about 32.8% , therefore the wind turbine will contribute about 32.8% to the hybrid system.

Sizing and Selection of Solar Panels

The solar will contribute about 67.2% to the system

Panel wattage = (total energy × 1.25)/(peak sun hours)

Panel wattage = (2335 × 1.25)/5 = 583.75W

Using 180W panels, the number of panels required is given by;

No. of panels = (panel wattage)/180

No. of panels = 583.75/180 = 3.25 ≈ 3 panels

Sizing and Selection of Battery

For stability and energy demand during the night, the battery has been sized as follows;

Day of autonomy = 1

Depth of discharge (DOD) = 0.5

Storage capacity = (energy required to be stored× 1.25 × days of autonomy)/(depth of discharge × system voltage)

Storage capacity = (800 × 1.25 × 1)/(0.5 × 12) = 166.67Ah

Using a 220Ah tubular battery

No. of Batteries = 166.67/220 = 0.76 ≈ 1 battery

Sizing and Selection of Inverter

Based on the scale down load estimate, total power requirement of the system (615), a 1kW Fami-care intelligent power inverter was selected.

Charge Controller Sizing and Selection

Based on the maximum load that the hybrid controller can carry, a charge controller was selected to compliment the hybrid controller, for the whole system two charge controller was used in which the hybrid controller carries the turbine and one solar panel while the other charge controller carries the remaining two panels. Both the charge controllers are PWM charge controllers.

Selection of Turbine

Base on the wind data analysis, we selected a vertical axis wind turbine with the specifications below;

Table 2: Turbine Specifications

Model	
Rated Output	300W
Peak Output	310W
Rated voltage	12v AC
Start-up wind speed	2.0 m/s
Cut-in Wind Speed (V_c)	2.5 m/s
Rated Wind Speed (V_r)	8 m/s
Cut-off wind speed (V_f)	45 m/s
Number of blades	10
Rotor Diameter	0.46m
Blade Material	Casting aluminum alloy
Generator type	3-phase Maglev with high performance Neodymium Magnet
Generator case	Casting aluminum alloy
Net weight	14kg
Tower Connector	Flange
Flange Size	DN25
Working temperature range	From -40°C to 60°C
Product life	15 years

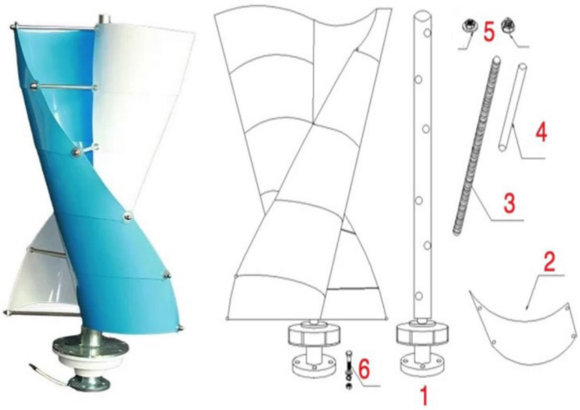

Figure 4: Savonius Vertical Axis Wind Turbine

Table 3: Accessories

No.	Accessories	Qty
1	Main Generator	1
2	Blades	12pcs
3	Blade shaft	7
4	Shaft	12
5	Blades screw	28
6	Flange screw	4

RESULTS AND DISCUSSION

After selecting the best position to mount the system, the system was tested and results were gotten for 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 output current corresponding to a particular wind speed, a digital multi-meter was used to measure the current generated by the wind turbine for each wind speed based on a known load. Subsequently, the power output of the wind turbine was calculated for each of the wind speed measurements recorded. These results were taken at ten minutes intervals for thirty minutes. To enhance better analysis, the measurements were taken in the morning, afternoon and evening. Having the system voltage to be 12V and applying a load of 100W, the output currents over different wind speeds were calculated using the relations below;

$P = I \times V$

Where;

P: power (Watts)

I: current (Amps)

V: voltage (volts)

The results of this measurements are presented below;

Data Collected from the Wind Turbine in the Morning Session

Table 4: Data Samples

Time	Wind Speed (m/s)	Output current (A)	Power (W)
7:20 am	2.24	3.63	43.56
7:30 am	1.22	2.30	27.6
7:40 am	3.82	5.02	60.24
7:50 am	2.76	3.93	71.16
8:00 am	2.12	2.68	32.16

Data Collected from the Wind Turbine in the Afternoon Session

Table 5: Solar Panel Specifications

S/N	Characteristic	Rating
1	Maximum Power	180W
2	Open Circuit Voltage	24.01V
3	Maximum Voltage	19.71V
4	Short Circuit Current	9.51A
5	Maximum Current	9.13A
6	Dimensions	1480 x 670 x 25mm

Data Collected from the Wind Turbine in the Evening Session

Table 6: Data Samples

Time	Wind Speed (m/s)	Output current (A)	Power (W)
6:00 pm	3.3	4.74	56.88
6:10 pm	4.2	6.03	72.36
6:20 pm	3.96	5.83	69.96
6:30 pm	4.25	4.00	48.00
6:40 pm	3.9	5.84	70.08

Data Collected from the Wind Turbine in the Morning Session

Table 7: Data Samples

Time	Wind Speed (m/s)	Output current (A)	Power (W)
7:20 am	2.24	3.63	43.56
7:30 am	1.22	2.30	27.6
7:40 am	3.82	5.02	60.24
7:50 am	2.76	3.93	71.16
8:00 am	2.12	2.68	32.16

Data Collected from the Wind Turbine in the Afternoon Session

Table 8: Data Samples

Time	Wind Speed (m/s)	Output current (A)	Power (W)
1:20 pm	1.12	3.62	43.44
1:30 pm	2.04	3.86	46.32
1:40 pm	1.86	2.03	24.36
1:50 pm	2.43	2.23	26.76
2:00 pm	2.15	2.00	24.00

Data Collected from the Wind Turbine in the Evening Session

Table 9: Data Samples

Time	Wind Speed (m/s)	Output current (A)	Power (W)
6:00 pm	3.3	4.74	56.88
6:10 pm	4.2	6.03	72.36
6:20 pm	3.96	5.83	69.96
6:30 pm	4.25	4.00	48.00
6:40 pm	3.9	5.84	70.08

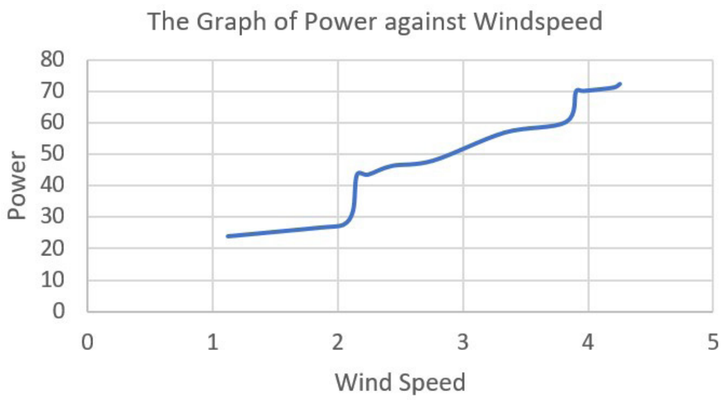

Figure 5: Graph of Power against Windspeed

From the graph the highest turbine output power yields 72.3 Watts at a velocity of 4.2 m/s while the corresponding lowest turbine output yields a value of 24.00 Watts. This shows that power output varies proportionally with the wind speed at a height of 10m.

The graph of the Wind speed was also plotted against Time. Readings were taken at 10 minutes interval during the morning, afternoon and evening session of the day. It was observed that the wind speed varies significantly for the different time intervals without a regular pattern. The graph clearly shows that the wind is erratic in nature.

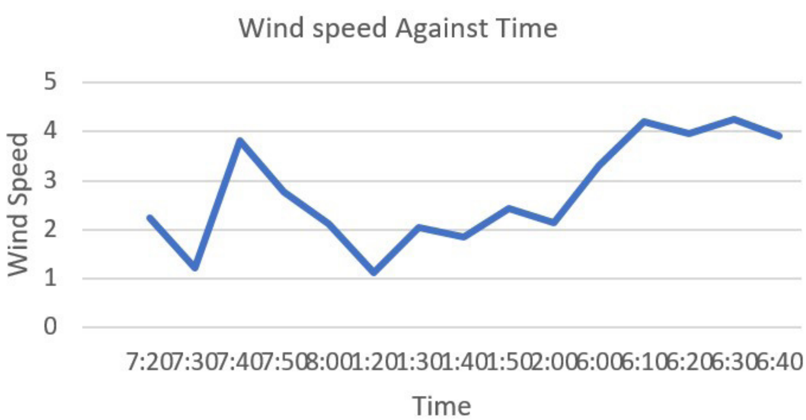

Figure 6: Graph of Windspeed against Time

CONCLUSION

The parameters obtained from the analysis carried out with the Weibull distribution function were used in the turbine selection. The probability of the turbine working in the selected area in Kano State was 92%. The capacity factor of the wind turbine was analyzed using the wind turbine parameters to give 34.4%. According to the results, the test period's wind speed in Kano was at 4.2 m/s for a height of 10m, which yielded a turbine output of 72.3 watts. In conclusion, the Solar wind Turbine generated a total of 3.439 kWh where the wind turbine generated 1.140 kWh/day and the Solar generated 2.335 kWh/day.

Recommendation

Average daily Analysis was carried out in the Weibull distribution function for a 10-year wind data. For future research work on Solar-Wind System deployment in Nigeria. It is highly recommended that hourly average data be analyzed when using statistical model for increased accuracy of the probability function and the capacity factor. Also, Solar Irradiance analysis should be carried out on the proposed location for installment. This would give more insights to possible locations with high solar energy that can be harnessed for the Solar-Wind System.

Acknowledgement

Our special gratitude goes to Sirius-X Energy the sponsor of this research article. Sirius-X Energy have provided both material, human and financial resources towards the successful publication of this research work. Also, our profound appreciation goes to professor Abdullahi Adamu for his guidance and technical support throughout the course of this research study.

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