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Determination of Annual Energy Capture Potential for Wind Power System: A Case Study

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Abstract: Annual mean wind speed in Ogbomoso was calculated to be 127.517ms^{-1} through the monthly wind speed and direction data collected for 5 years from Nigeria Meteorological Agency (NIMET), Ilorin. The data were collected from Ilorin (Lattitude $8^0 32^1$ N and Longitude $4^0 34^1$E), which is very close to Ogbomoso (Latitude $8^0 05^1$ S and Longitude $4^0 12^1$ W). The determined annual mean wind speed was then applied in the Weibull Probability distribution function using c^{++} Programming Language. Weibull Probability distribution of 1.3030×10^{-54} at sea level is obtained which shows the wind speed variation over the period and thus indicates the probability distribution of annual mean wind speed being 127.517ms^{-1}. Digital Data Logger is employed to compute the power potential for wind turbine. The annual energy capture potential of 5562.69MJ is obtained for wind power system. The obtained equivalent power potential of 635.01kW is a considerable amount when compared with power consumption of 956.25kW utilized in Ladoke Akintola University of Technology, Ogbomoso. We then realize that the annual energy capture potential for a single wind turbine is 66.4% of the power consumption in LAUTECH through conventional energy source.

Key words: Renewable energy, wind turbine, wind speed, conventional energy, power potential, digital data logger

INTRODUCTION

Wind energy is one of the renewable energy sources, which is also known as non-conventional energy source. Wind energy has not been fully harnessed in developing countries due to many factors such as low awareness, lack of technology know how, high cost of wind turbine among many others. Recently, the awareness is increasing in both the developed and developing countries with the use of wind as another source of generating electricity in addition to the trivial conventional sources such as nuclear and fossil fuel or as an alternative.

Wind energy is a converted form of solar energy. It is simply air in motion, which is caused by the uneven heating of the earth's surface by the sun. The sun's radiation heats different parts of the earth at different rates, most notably during the day and night. Different surfaces such as land, water, desert and forest areas absorb or reflect sun at different rates.

During the day, the air above the land heats up more quickly than the air over water. The warm air over the land, which is less dense, expands and raises, then the heavier, cooler air over the water which is more dense rushes in to take its place, creating winds. At night the movement of air or winds are reversed because the air cools more rapidly over land than over water. In the same way, the large atmospheric winds that circle the earth are created because the land near the earth's equator is heated more by the sun than the land near North and South poles.

Freris (1990) had shown that air has more energy when it is in motion. It contains the energy of their motion (kinetic energy). Some portions of that energy can be converted to other forms of energy.

Sayigh (1991) disclosed that the energy that the windmills produce can be used in many ways, traditionally for grinding grain or spices, pumping water, sawing wood, hammering seeds, sailing and flying a kite.

Today, wind energy is mainly used to generate electricity. Wind is called a renewable energy source because the wind will blow as long as the sun shines.

Schwartz declared that good sites for wind plants are the tops of smooth rounded hills, open plains or shorelines and mountain gaps that produce wind tunneling due to their low friction coefficients.

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Gupta (1997) stated that India is one of the largest producers of wind energy in the world of about 1,800MW capacity. And her government has identified 77 sites for economically feasible wind-power generation, with a generating capacity of 4,000MW of grid-quality power. So, it is estimated that India has about 20,000MW of wind power potential out of which 1,000MW has been installed as of 1997.

Hammons *et al.* (1997) reiterated that the Department of Energy and United States national laboratories also have a number of programs to promote the wind hybrid technologies throughout the developing world with particular emphasis on Latin America and the Pacific Rim countries. These activities include feasibility studies and pilot projects, project financing and supporting renewable energy education efforts.

Gijs (1998) explained that wind turbine work in the opposite of an electric fan. Instead of using electricity to generate wind, like a fan, wind turbine use wind to generate electricity. The wind turns the rotor, which spins a shaft and connects to a generator that produces electricity.

The operation of a wind power plant is not as simple as just building a windmill in a windy place. Wind plant owners must carefully plan where to locate their machines. It is important to consider how fast, how much of the wind blow and how much energy can be generated which form the essence of this research.

Mukund (1999) shows that the specific power density, P, of a site depends on the cube of the wind speed, V.

$$\text{Thus, } P_{max} = \tfrac{1}{4}\,\rho\, V^{3}.$$

Where,

P_{max} : Is the maximum specific power density.
ρ : Is air density in Kgm^{-3}
V : Is the velocity of the air in ms^{-1}.

Auxiliary (2001) reviewed that wind speed increases with altitude and over open areas with no windbreaker because of the drag of the surface (sea or land) and viscosity of the air. He continued that the variation in velocity with altitude follows the $^{1}/_{7}{}^{th}$ law, which predicts that wind speed rises proportionally to the seventh root of altitude. He further stated that doubling the altitude of a turbine increases the expected wind speeds by 10% and the expected power by 34 %.

MATERIALS AND METHODS

In this research, a monthly average of the wind speed was obtained from Nigeria Meteorological Agency (NIMET), Ilorin for the period of 5 years 2001, 2002, 2003, 20004 and 2005.

In 2001, the wind speed ranges between 102.19 ms^{-1} and 184.32 ms^{-1}. The year 2002 had wind speed between 88.62 ms^{-1} and 149.42 ms^{-1}. The wind speeds between 115.25 ms^{-1} and 179.53 ms^{-1} were experienced in 2003, 100.41 ms^{-1} and 189.65ms^{-1} in the year 2004. Also, in the year 2005, the wind speed ranges between 83.37 ms^{-1} and 146.42 ms^{-1}.

Weibull Probability distribution function,

$$h(v) = (^{k}/_{c})\,(^{v}/_{c})^{k-1}\, e^{-(v/c)k}$$

(Where, k is the shape parameter, c is the scale parameter) is employed to determine the probability of mean wind speed.

C++ Programming language was written to solve equivalent digital data logger equation of Weibull Probability distribution function to determining power potential and consequently energy capture potential in LAUTECH, Ogbomoso.

$$V_{rmc} = 3\sqrt{1/n\sum_{i=1}^{n} V_i^3}$$

RESULTS AND DISCUSSION

The obtained annual wind speed average for the year 2001, 2002, 2003, 2004 and 2005 are 135.7175 ms^{-1}, 113.5292 ms^{-1}, 141.3008 ms^{-1}, 133.6217 ms^{-1} and 111.0033 ms^{-1} respectively. The annual wind speed average for the 5 years is calculated to be 126.189 ms^{-1}.

The wind speed sharply increases from the months of March. The maximum value of 189.65 ms^{-1} wind speed is obtained in April 2004 from a wind, which blew from south direction. The minimum wind speed of 83.37 ms^{-1} in December, 2005 from a wind, which blew South West direction.

It could be seen from Fig. 1 that the months of April produce the highest monthly average wind speeds while the lowest monthly average wind speeds are obtained in the months of December for each year. This can be attributed to the higher uneven heating of the earth surface causing air blowing from ocean through land during the month of April compared to the month of December.

These results imply that the maximum power production of a wind power system can be obtained in the month of April, most especially when the wind blow in south direction and the minimum power production in December.

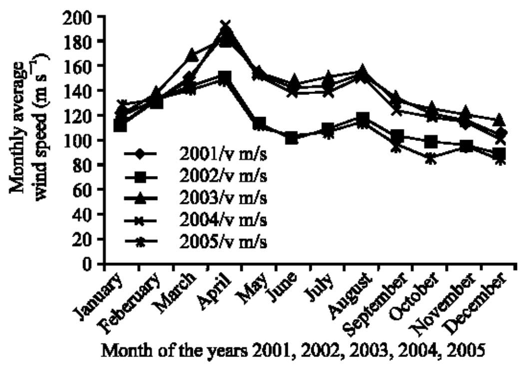

Fig. 1: Graph of monthly average wind speed against months of the year, 2001-2005

This noticeable effect is seen in the months of March and April in Ogbomoso where wind blows off many roofs of buildings, breaks up and uproots trees and sometimes causes collapse of buildings and structures.

Using random values for shape parameter, $k = 2.5 - 3.0$ and scale parameter, $c = 5\text{-}10$ in the Weibull Probability distribution function with the aid of c++ Programming Language, the probability gives 1.303×10^{-54} at sea level. This probability distribution expresses the wind speed being 126.189 ms^{-1}.

C++ Programming Language written on digital data logger equivalent formula for Weibull probability distribution function gives root mean cube wind speed, V_{rmc} of 127.517 ms^{-1} which was consequently used to determine the annual energy capture potential.

This study resulted into the annual power production potential of 635.01kW and annual energy capture potential of 5562.69MJ which is consistent with trend published (Ezekanyi, 2001) for wind power system of a single turbine.

Figure 2 shows the graph that compares the power potential between conventional energy source and wind energy source in LAUTECH, Ogbomoso.

Figure 3 shows the pie chart depicting the percentage of wind power potential to conventional energy source presently in use at LAUTECH, Ogbomoso.

The annual power production of 635.01kW through a single wind turbine is enormous in generating electricity for a particular site.

Presently, the annual power consumption in Ladoke Akintola University of technology, Ogbomoso through conventional source of energy is 956.25kW. Our study results into the annual power production of 635.01kW, which is a considerable amount of energy production from a single turbine.

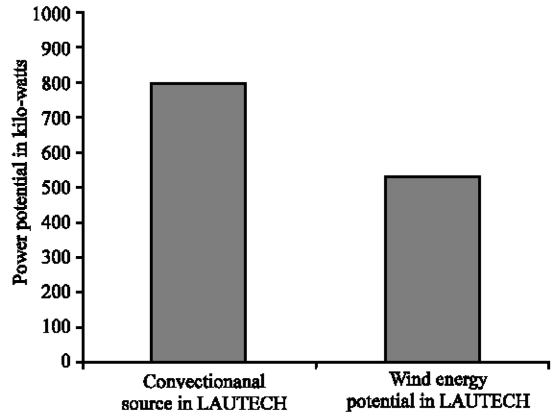

Fig. 2: Graph of comparism of power potential between conventional and wind energy source in LAUTECH

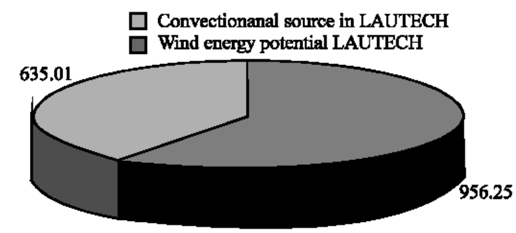

Fig. 3: Graph comparing of wind power potential in LAUTECH and conventional energy source

We realize that the annual energy capture potential for wind turbine is 66.4% of the power consumption in LAUTECH through conventional energy source as shown in Fig. 3.

This emanated as a result of enormous kinetic energy possesses by wind, which is then converted into electrical energy through wind turbines.

The root mean square cube equivalent of the digital data logger equation in its limitation does not take into account the variation in the air mass density, which is also a parameter, although of second order, in the wind power density.

However, it could be seen from this result that combination of many turbines would undoubtedly produce power that can exceed the needed power consumption in LAUTECH.

CONCLUSION

In essence, due to erratic power supply, low output generation and incessant hike in petroleum prices among many other factors that characterize the environment in generation of electricity, we then conclude that wind power system could be used to complement the present source of generating electricity in LAUTECH and possibly in Ogbomoso Township. This would undoubtedly improve the generation and distribution of electricity in Ogbomoso most especially when a wind farm is built.

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