PARAMETRIC ANALYSIS AND PROSPECTS OF WIND TURBINE STATION IN OWERRE-EZUKALA, ANAMBRA STATE

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ABSTRACT

Energy is the basic necessity for the economic development of any country. Many indispensable functions for present-day living grind to halt when the supply of energy stops, or when the generating power stations are operating below installed capacity. The impetus to undertake this task was got because of the elusive nature of energy from existing electricity companies which has kept Owerre-Ezukala in darkness for nearly seven years. Also, the rated or perceived wind velocity in this area and the effects it had produced was an added drive. This research discussed the parametric analysis and prospects of wind turbine station in Owerre-Ezukala, Anambra State. The wind speed data collected from some sites in this area averaged 5.6 m/s; indicating that the community has good prospects for the installation of wind energy conversion systems. The paper recommends that the implementation of this design, will not only solve the energy need of Owerre-Ezukala, but will as well benefit nearby communities.

Keywords: Wind Energy, Electrification of Owerre-Ezukala, Wind Energy Data.

1.0 INTRODUCTION

One of the problems that confront the nation of Nigeria is inadequate power generation and supply. A country that claims to be the great *Giant of Africa* cannot boast of meeting up with the energy demands of her citizens. This looming problem had affected productivity in every facet of her economy. At one point or the other, government brings out scheme to better the efficiency of power and energy supply. These programmes often fail to materialize, perhaps, because of either poor management or inadequate generation of energy to satisfy the need of the teaming Nigerian populace. Manufacturing and pharmaceutical industries, suffer serious regression in their operation, as a sequel. Moreover, rural areas like Owerre-Ezukala become trapped by the inferno of darkness thereby making life unbearable for the autochthonous people. The quest to resolve the above identified problem set the researcher into thinking of an alternative energy source that can adequately satisfy the electricity need of the designated geographical area. However large Nigeria's energy resource of fossil fuel may be, it is being consumed at a high rate, and one day, the fuel resource will become so depleted that the normal existence of energy-dependent firms will be seriously disrupted, unless other energy sources have become available on the scale necessary to meet the country's energy demand. Many warnings have been given over the years about Nigeria's rate of fuel refining and consumption, and the prospects of future fuel shortage. Nevertheless, each time the crisis has passed and the nation has continued on its unrealizable strategies. There is a renewed awareness of the importance of harnessing other energy sources, and the need for a long-term planning for the country's future energy supply. Wind energy is basically the harnessing of wind power to produce electricity. The kinetic energy of the wind is converted into electrical energy. The relationship between the kinetic energy and electrical energy is a direct or linear one. Taking other mechanical factors for granted, the higher the speed of the wind, the higher the electrical energy.

1.1 Wind Electricity Economics

Wind generator power costs are heavily linked to the characteristics of a wind resource in a specific location. The cost of supplied power declines as a wind speed increase, and the power supplied increases in proportion to the cube of the wind speed. The proportionality relation is represented mathematically as:

$$\mathbf{P \propto AV^3} \quad (1)$$

where P = Power generated by the turbine; A = Swept area of the rotor; V = Wind velocity.

Matching available energy and load requirements is also important in wind energy economics. The correct size of wind generator must be chosen together with some kind of storage or co-generation with an engine or a grid to obtain the best economy. The ideal application is a task that can utilize a variable power supply, e.g., ice making or water purification.

Regarding the economics, the choice of interest rate, obviously, has a major effect on the overall energy cost. With low interest rates, capital intensive power sources such as solar and wind are favoured. Other factors bearing a strong influence on the economics of wind electricity are the standard of maintenance and service facilities and the cost of alternative energy supplies in the particular area.

1.2 Problems in Operating Wind Power Generators

The operation of wind power generators entails the following problems:

1. Location of site: The most important factor is locating a site big enough which has a reasonable average high wind velocity. Okegbe and Ogba-ukwu regions in Owerre-Ezukala, are promising areas.
2. Constant angular velocity: A constant angular velocity is a must for generating A.C. (alternative current) and this means very sensitive governing.
3. Variation in wind velocity: The wind velocity varies with time and varies in direction and also varies from the bottom to top of a large rotor. This causes fatigue in blade.
4. Need of a storage system: At zero velocity conditions, the power generated will be zero and this means some storage system will have to be incorporated along with the wind mill.
5. Strong supporting structure: Since the wind mill generator will have to be located at a height, the supporting structure will have to be designed to withstand high wind velocity and impacts. This will add to the initial costs of the wind mill.
6. Occupation of large areas of land: Large areas of land will become unavailable due to wind mill gardens (places where many wind mills are located). The whole area will have to be protected to avoid accidents.

In spite of all these difficulties, interest to develop wind mills is sustained since this is a clean source of energy. Wind possesses high kinetic energy, and windmills have been used for many years to drive mill mechanism, in developed countries. No wonder, these developed economies continue to enjoy uninterrupted power supply across many decades. The search for and quest for the development of wind energy technology (WET), that can satisfy the energy need of small communities, in South-Eastern part of Nigeria, gave rise to this paper. A lot of speculations had been going on among engineers about the prospects of having a functional wind power plant (WPP) in the South-East. These initiatives fail to come to light, maybe, because, the idea is cut short in the intellectual level, or simply because of political reasons. It will be the primary concern of this *corpus* to investigate the available wind regime in different locations, at 10 m altitude, and the possibility of improving a sustainable wind speed that can generate electricity for use in Owerre-Ezukala. Achieving this aim is actually targeted through the following objectives:

- To identify and map out research areas that would be explored for sustainable wind regime
- To determine the wind speed characteristics of research sites
- To ensures that an existing power cables are in place to convey electrical energy to the consumers.

The term wind energy or wind power describes the process by which wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity. Wind turbines operate on a simple principle. The energy in the wind turns the propeller-like blades around a rotor. The rotor is connected to a main shaft which spins a generator to create electricity. Wind flow patterns and speeds vary greatly across Anambra State; and are modified by bodies of water, vegetation, and differences in terrain.

2.0 APPARATUS AND PROCEDURES

Data gathering was commenced on 18th December 2015 and ended on 15th March 2017. Data collection and collation was perfected in collaboration with expatriate engineers (Canadian trained Engineers), who were sponsored by a foreign agency, to do the research in the designated areas. The electronic digital anemometer was used to measure the average wind velocity. The kinds of device used here, are improved technology. The first category is altitude free and insensitive. A researcher only needs to key-in the required altitude or height, in meters, at which the device is to operate. This is done standing on the ground. If, for instance a 10 m height is preferred, the device is kept on a place with minimal disturbance, where it can record the wind speed at the designated height. The recording of the wind velocity is done every 2 hours. These readings are collated every 2 days, and the process continues. This anemometer has a special lithium cell (battery) that has a life expectancy of about 3 years. The other type of digital anemometer has a powerful bluetooth-like feature that can cover an ambience of 50 – 100 m. It finds application by the use of high rising communication masts and tall building in the designated areas. After a successful pairing with a cell-phone or personal computer that has in-built bluetooth facility, the device is mounted in a 10-metre-high mast or tall-building. A periodic reading of the wind velocity is recorded on one's cell-phone or computer. This is a low cost method. The instruments are reliable and have to be in good working order. They have to be correctly sited. Fig. 1 shows the pictorial diagrams of these devices.

Fig. 1a: Type 1 Anemometer

Fig.1b: Type 2 Anemometers

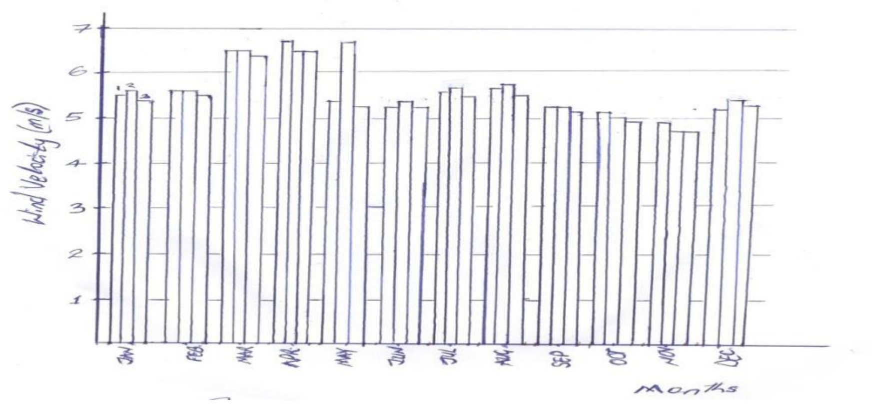
2.1 Methodology

Owerre-Ezukala is in Orumba-South local government area of Anambra State. It is a border town located at the South-East of the capital territory. The town is surrounded in the north by Awlaw in Enugu State; in the east by Isuochi in Abia State; in the south by Nneato also in Abia State. The closest town in Anambra State to Owerre-Ezukala is Ogbunka. Its geographical coordinates are: longitude 6^{o} 1′ 0″ North, and latitude 7^{o} 19′ 0″ East. (www.maplandia.com/ng/owerre-ezukala), akin to that of Enugu in Enugu State. The town, also, is on the same geographical location as Isuikwuato in Abia State, and Okigwe in Imo State.Table-1 shows the average values of wind speed taken over a 12-month periods using a high-tech anemometer. These readings were obtained at various times of the day, and different seasons, at an altitude of 10m.

Table-1: Wind Speed Distribution Parameters at 10m (Personal Research)

Region	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Avg.
Ugwu-Osu	5.5	5.6	6.5	6.7	5.4	5.3	5.6	5.7	5.3	5.2	5.0	5.3	67.1	5.6
Okegbe	5.6	5.6	6.5	6.5	6.7	5.4	5.7	5.8	5.3	5.1	4.8	5.5	67.4	5.6
Ogba-ukwu	5.4	5.5	6.4	6.5	5.3	5.3	5.5	5.5	5.2	5.0	4.8	5.4	65.8	5.5

This is represented in a bar chart in Fig. 2. According to Nigerian Metrological Agency (NIMET), Oshodi, the mean wind speed (velocity) V_{mean} of this geographical coordinate, at an altitude of 10m, approximates to 5.5 ± 0.6. This point to a close knitted correlation between the measured parameters and the predicted data.



Key: Bar 1. Ugwu Osu Bar 2. Okegbe Bar 3. Ogba-Ukwu

Fig. 2: Bar Chart of Wind Speed Distribution

2.1.1 Calculation of Mass Flow Rate of Wind

To do this, recourse is made to the equation below:

$$\dot{m} = \rho A V_{wind} \quad (2)$$

2.1.2 Calculation of Theoretical Power of the Wind Turbine

This is usually done using the energy equation:

$$P_{wind} = \frac{1}{2}\rho A V_{wind}^3 \quad (3)$$

2.1.3 Calculation of the Actual Power of the Wind Turbine

This corresponds to the maximum power that can be delivered by the turbine. The extractable or actual power of the wind turbine can be computed using the equation:

$$P_{max} = \frac{16}{27}\left(\frac{1}{2}\rho v^3 A\right) \quad (4)$$

2.1.4 Calculation of the Rotor Power Coefficient of Wind Turbine

The rotor power coefficient is a measure of the rotor efficiency and is obtained by applying the equation:

$$C_p = \frac{Extracted\ power}{Power\ in\ wind} = \frac{P_{rotor}}{P_{wind}} \quad (5)$$

2.1.5 Calculation of the Performance of the Wind Turbine, C_p

The wind that passes through the rotor, V_{out} can be determined using equation, thus:

$$V_{out} = 2/3V_{in} \qquad (6)$$

Similarly, V_r is got by applying equation:

$$V_r = V_{out}/V_{in} \qquad (7)$$

It follows that one can calculate the performance of the wind turbine. This is achieved using the equation:

$$\frac{(1 + V_r)(1 - V_r^2)}{2} \qquad (8)$$

3.0 RESULTS AND DISCUSSION

Although the power equation above (cf. equation 2.2) brings to the fore the power in the wind, the actual power that could be extracted from the wind is significantly less than this figure suggests. The actual power will depend on several factors, such as the type of machine and rotor used, the sophistication of blade design, friction losses, and the losses in the other equipment connected to the wind machine. There are also physical limits to the amount of power that can be extracted realistically from the wind. A German physicist Albert Betz concluded in 1919 that no wind turbine can convert more than 16/27 (59.3%) of the kinetic energy of the wind into mechanical energy turning a rotor. To this day, this is known as the *Betz Limit* or *Betz' Law*. The practical or actual maximum power efficiency of any design of wind turbine is 0.59 (i.e. no more than 59% of the energy carried by the wind can be extracted by a wind turbine). This is called the "power coefficient" and is defined as:

$$C_{pmax} = 16/27 = 0.59 \qquad (9)$$

Also, wind turbines cannot operate at this maximum limit. The C_p value is unique to each turbine type and is a function of wind speed that the turbine is operating in. Once the various engineering requirements of a wind turbine are incorporated into the design - strength and durability in particular – the real world limit is well below the *Betz Limit* with values of 0.35 - 0.48, common even in the best designed wind turbines. Hence, the power coefficient needs to be factored in equation 2.2, and the extractable power from the wind is given as in equation 2.3, by:

$$P_{avail} = 1/2\rho AV^3C_p \qquad (10)$$

Wind power, it must be echoed, depends on: Amount of air (volume), Speed of air (velocity), Mass of air (density), flowing through the area of interest (flux). The proportionality relation is represented mathematically as:

$$P \ \alpha \ AV^3$$

A graph illustrating the variation of wind power with wind speed is given in Fig.3 below. From equation 4, the following inferences can be drawn:

- Power ~ Cube of velocity

- Power ~ Air density
- Power ~ Rotor Swept Area

High power output is possible with: high tower for high wind speed; and long blades for large swept area. The fact that wind power is proportional to the cube of the wind speed is very significant. This can be demonstrated by pointing out that if the wind speed doubles, then the power in the wind increases by a factor of eight. It is, therefore, worthwhile finding a site which has a relatively high mean wind speed.

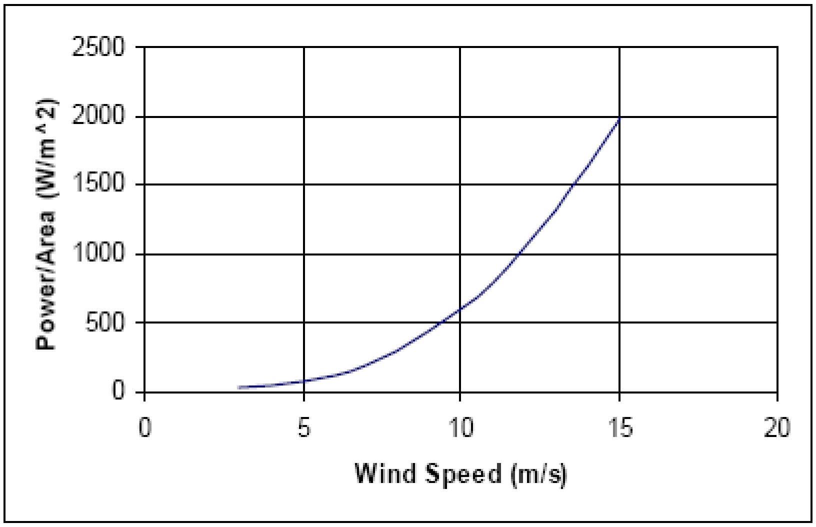


Fig. 3: Wind Power vs. Wind Speed

CONCLUSION

Wind possesses high kinetic energy, and wind mills have been used for many years to drive mill mechanisms. The search for alternative power sources has led to the rediscovery of wind power. Consequently, many wind driven power stations – large and small – have been built and are generating power, in developed countries. The modern wind-mills are much more technically sound than their historical counter-parts, and have benefited from established knowledge of aerodynamic blade design. Such areas of improved engineering knowledge include automatic control of the rotor position to suit changing wind directions, and for adjustment to the blade pitch. Besides, the behaviour of the unit can be controlled and monitored by computers.

The present work does not, in any way, claim to be the final word in the area of aerodynamic design. Rather, it has painstakingly, presented the findings of a conducted field research that can be translated into useful appliance. Constructing an affordable and efficient wind turbine that would serve the electricity need of Owerre-Ezukala people in Anambra State becomes an imperative as the community has been cut-off for more than five years from supply from Electricity Company. The construction, if realized, will in no small measure, enhance the living conditions of the autochthonous people of this geographical area; which is one of the objectives of the Millennium Development Goals (MDG) of the previous Nigerian government, and the Sustainable Development Goals (SDG) of the present administration (especially goal 7: affordable and clean energy).

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