Electricity Generation Using Wind in Katsina State, Nigeria

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ABSTRACT

This study investigated and presents the Generation of electricity using wind in kastina state. The evaluation/analysis is based on the ongoing project of generating 10MW of electricity in Lambar Rimi Village in Katsina state in which the history of the project, technical specifications, rated capacity, design of turbine spacing was considered. The aim of this research is to investigate the generation of 10MW using alternative wind energy in Katsina.The cut in wind speed was estimated to be 3.5m/s while the cut out wind speed was found to be 25m/s.

SIGNIFICANT OF THE PAPER

One of the bottom lines of this study lies in the inevitable need of harnessing the abundant wind energy using wind turbine, and also assess the development so far with a view to make a preliminary findings available for consideration to proper more technical advises.

1.0 INTRODUCTION

Two main challenges are facing the world in the 21st century (International Energy Network, 2006). One is to meet the exponentially growing demand for energy, particularly in the developing countries, where today 1.6 billion people do not have access to commercial energy. The other is to deal with the global, regional and local environmental impact resulting from the supply and use of energy (Chireke and Igwiro, 2008).

Expanding the use of renewable fuels will lower the long term price of crude oil and reduce carbon dioxide emissions that are contributing to global warming. Nigeria is richly endowed with both energy resources such as crude oil, natural gas, coal, and renewable energy resources like solar, wind, biomass, biogas, etc for many decades, fossil fuels and firewood (conventional energy resources) have continually remained the major energy which account over 90% of the national energy consumption (Archer and Jacobson, 2004).

Consequently, in an effort to explore the wind energy potential in Katsina State, Federal government of Nigeria through the federal ministry of power awarded a contract to a French contractor Vergnet S.A and OTIS Engineering/Terrawalt jointly as consultant firm to the 10MM wind farm project.

In this study, generation of electricity using wind in Katsina Nigeria will be discussed/analyzed.

1.10 METHODOLOGY

The analysis will entail the following under listed steps and procedures:

- Collecting data from the meteorological inspectorate of Umaru Musa Yar'adua Airport Katsina
- Tabulating and comparing of the readings.
- Interviewing the technical/consultant of the project
- Site inspection for direct measurement and counting were necessary
- Assess to project document made available.

2.0 LITERATURE REVIEW

2.1 Definition of Wind

There are many definitions of wind. The 7th edition of the Oxford Advanced Learners Dictionary defines wind as air that moves quickly as a result of natural forces.

In another definition, wind is defined as the horizontal movement of air relative to the earth's surface. Also wind is simply defined as air in motion. This motion can be in any direction with horizontal component of wind flow greatly exceeding the flow that occurs vertically in most cases.

2.2 Sources of Wind

The sun heats up air masses in the atmosphere. The spherical shape of the earth, the earth's rotation, seasonal and regional fluctuations of the solar irradiance cause spatial air pressure differentials. These are the source of air movements. Irradiation over supply at the equator is the source for compensating air stream between the equator and the poles.

Besides, the partial compensation streams, less extensive air currents, exist due to the influence of local areas of high and low pressure. The coriolis force divert the compensation stream between high and low pressure areas. Due to the rotation of the earth, the air masses in the northern hemisphere are diverted to the right and in the southern hemisphere to the left. Finally, the air masses rotation around the low pressure areas.

2.3 Nature and Origin of Wind

"Wind" is flow of air. Air has certain mass (kg) and mass density (Kg/m). Flow of air (wind) results in flow of mass (mass flow: Kg/s). The flowing mass has kinetic energy (KE). Hence wind is a natural source of kinetic energy. The energy in the wind can be converted into useful mechanical energy by means of wind turbine, windmill, sails of ships etc.

As a natural phenomenon in the atmosphere, there are two different origins of wind namely: -

i. ***Planetary Wind:*** - These are caused by daily rotation of earth around the polar axis and unequal temperature, between Polar Regions and equatorial regions.

ii. ***Local Winds:*** - These are caused by unequal heating and cooling of ground surfaces and ocean/lake surface during the day and night.

2.4 Uses of Wind

In human civilization, wind has inspired mythology, influenced the event of history, expanded the range of transport and warfare, and provided a power source for mechanical work, electricity, and recreation. Wind has powered the voyages of sailing ships across earth's ocean. Hot air balloons use the wind to take short trips, and powered fight uses it to increase lift and reduce fuel consumption.

2.5 Wind Speed and Direction

Wind is often described by two characteristic: wind speed and wind direction.

i. ***Wind Speed:*** Wind speed is the velocity attained by a mass of air traveling horizontally through the atmosphere.

ii. ***Wind Direction:*** Wind direction is the direction from where the winds blow 90: East wind 180 south wind 270: West wind. 360: north wind.

2.6 Measurement of Wind Speed and Direction

Wind speed is commonly measured with an instrument called anemometer in km/h, m/h, knots, or m/s. An anemometer consists of three open cups attached to a rotating spindle. The speed of rotation is then converted into a measurement of wind speed, even though wind speed can also be measured without the aid of instrument.

2.7 BRIEF HISTORY OF 10MW KATSINA WIND FARM PROJECT

The 10MW Katsina Wind Farm Project is owned by Federal Ministry of Power. This a pioneer project in Nigeria aiming to generate 10MW of power via wind turbine with the federal government desire to boost electricity generation and have constant power supply. This renewable (wind) energy project will go a long way in actualizing this target in view of its low cost of maintenance. The project was awarded to a French contractor, Vergnet S.A as EPC contractor and also OTIS Engineering/Terrawatt are jointly contracted as consultancy firm to supervise the project.

The project is cited at Lamba Rimi in Rimi Local Government of Katsina State in Nigeria where high yield of wind was observed during the feasibility study.

3.0 TECHNICAL DETAIL

The 10MW Katsina wind farm consists of 37N0 wind turbines with a rated power of 275KW each. The hub height of the turbine is 55M due to two reasons one of which is from the design brief where a medium scale turbines is recommended and the rotor diameter of medium scale ranges from 12m to 45M with a power rated of 40KW to 999KW (Spera, 1994 and Gipe, 1999).

Secondly form the, wind study conducted; it was observed that at a height between 50M, 55M or 60M. There exist a very high yield of wind energy and due to these, reasons the turbines was designed to have a standard hub height of 55M.

It is worthy to note that the certification procedure for its dimension was carried out by GARRAD HASSAN designed office, which is internationally recognized for its technical expertise on wind turbine generators. Couple with the fact that, the contractor, VENGNET is a ISO 9001 certified wind turbine generator (WTG) manufacturer, which is a guarantee of reliability for the design and manufacture of its product.

Thanks to a tiltable guyed tower of 55M, the turbine can be quickly and easily lowered, in order to facilitate assembly and maintenance, and in case of hurricane this way reducing the risks of destruction of the equipments, each turbine has a step up transformer at its ground base which will step up.(see the general layout presentation of GEV MP turbine. Appendix 1).

3.1 DESIGN OF TURBINE SPACING

The Katsina wind farm turbine positioning was designed following a common rule of 7D x 5d for the fact that the distance between turbines in a row is measured in rotor diameter. Hence a common rule of thumb is to situate with distance of 5 rortor diameter (5d) and the distance between the rows usually is 7 rotor diameter (7d).

Where d= rotor diameter = 32m (with respect to Katsina)

Therefore for katsina project in particular

-7D= 7 *32 =224m (in between raws)

-5d = 5*32 = 160m (in between turbines)

The standard propeller-like turbine most commonly found in wind farms around the world, space the individual turbines around five to seven rotor diameter apart, a recent study found that spacing of at least 15 rotor diameter apart produced the most cost efficient power generation. But even though spreading the turbine out increased the cost efficiency by allowing for fewer individual turbines, it also lowers the power output of a given plot of land.

To compensate for the energy loss resulting from the wake generated from the turbine interfering aerodynamically with neighboring turbines, HAWT wind farms also resort to using bigger blades and taller towers that are capable of taking advantage of the more powerful gusts of wind found at greater height. But these large structure result in increased production and maintenance cost, visual, acoustic, and radar signatures problems, as well as more bat and bird impacts.(see Katsina wind farm delivery substation base on the spacing desgned, Appendix 2)

3.2 WIND RESOURCES ASSESSMENT

For a project of such magnitude obviously Wind energy assessment most have been carried out as an integrated analysis of the potential wind energy resources of katsina. Such as arrangement begins with the understanding of the general wind pattern of the area and progress to the collection and analysis of data.

3.3 Mean Wind Speed

Mean wind speed (MWS) is the most commonly used indicator of wind production potential. The mean wind speed is defined as:

$$MWS = \frac{1}{N}\sum_{i=1}^{i-N} V_i \qquad [1]$$

Where N is the sample size and V_i is the speed recorded for i^{th} observation.

3.4 Wind Speed Variation with Height

Wind speed near the ground changes with height. This requires an equation that predicts wind speed at one height in term of the measured wind speed at another. The most common expressed for the variation of wind of speed with height is the power law expressed as follow:

$$\frac{v_2}{v_1} = \left(\frac{h_2}{h_1}\right)^{\alpha} \qquad [2]$$

Where v_2 and v_1 are the mean wind speed at height h_2 and h_1 respectively. The exponent α depends on factor such as surface roughness and atmospheric stability. For Katina the value is 0.214 (Enabureken, 2007).

3.5 Wind Power Density

The power of the wind P(v) at speed v through a blade sweep area A increase the cube of its velocity and given as (Ahmed S. Et al, 2005):

$$P(v) = \frac{1}{2}\rho A v^3 \text{ Watts} \qquad [3]$$

Where ρ is the mean air density (1.225 kg/m^3) at average pressure of sea level and at 15^0C.

3.6 Annual Capacity Factor

The annual capacity factor is defined as the ratio energy generated in a time period to the energy produced if the wind turbine had run at rated power over that period:

$$\text{Annual capacity factor} = \frac{\text{Energy generated per year (kwh)}}{\text{Turbine rated power (kw) x 8760}} \qquad [4]$$

4.0 RESULT AND DISCUSSIONS

Eleven years of monthly mean wind speed data (1996-2006) measured at 10m height were obtained from Meteorological Inspectorate of Katsina Airport as shown in Table

Table 1: monthly katsina wind speed data for 11yrs

Month/ Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Jan	3.125	3.563	3.250	5.060	3.813	4.813	5.063	4.313	4.874	4.875	3.375
Feb	3.563	3.500	3.500	4.375	3.625	4.750	3.875	4.125	4.813	3.813	3.188
March	3.688	3.875	3.938	4.688	3.875	4.500	4.188	4.813	5.188	3.313	3.438
April	3.625	3.563	3.688	4.875	3.688	4.835	4.563	5.000	4.375	4.313	3.500
May	3.750	3.500	3.875	4.938	3.813	5.188	5.188	4.313	5.188	4.438	3.750
June	3.688	3.688	3.688	5.313	3.750	5.063	5.250	4.500	5.000	4.563	3.625
July	3.813	3.875	5.750	5.625	3.688	5.375	5.313	4.563	5.000	3.125	3.563
Aug	3.563	3.688	5.750	5.188	3.750	5.125	5.063	4.313	4.688	2.813	3.688
Sept	3.688	3.625	3.625	4.938	4.688	5.063	4.813	4.125	4.438	2.750	3.375
Oct	3.750	3.620	4.873	4.813	4.438	4.125	3.313	3.750	3.875	3.188	6.938
Nov	3.750	3.688	4.313	3.625	3.938	3.813	3.688	4.563	3.563	3.563	3.750
Dec	3.875	3.870	8.813	3.875	4.938	4.250	3.875	4.750	3.688	6.625	3.875

Using equation (2), the mean monthly wind speed at 30m, 55m and 70m were computed as shown in Table 2(see Appendix 4 for a copy of the data form)

Table 2: Computed mean monthly wind speed at 30m, 55m and 70m heights.

MONTH	WIND SPEED m/s		
	30m	55m	70m
January	5.300	6.034	6.354
February	4.949	5.634	5.932
March	5.219	5.941	6.257
April	5.294	6.027	6.347
May	5.505	6.267	6.599
June	5.533	6.299	6.633
July	5.708	6.498	6.843
August	5.470	6.227	6.558

September	5.179	5.896	6.209
October	5.487	6.246	6.577
November	4.852	5.524	5.816
December	5.218	5.940	6.256

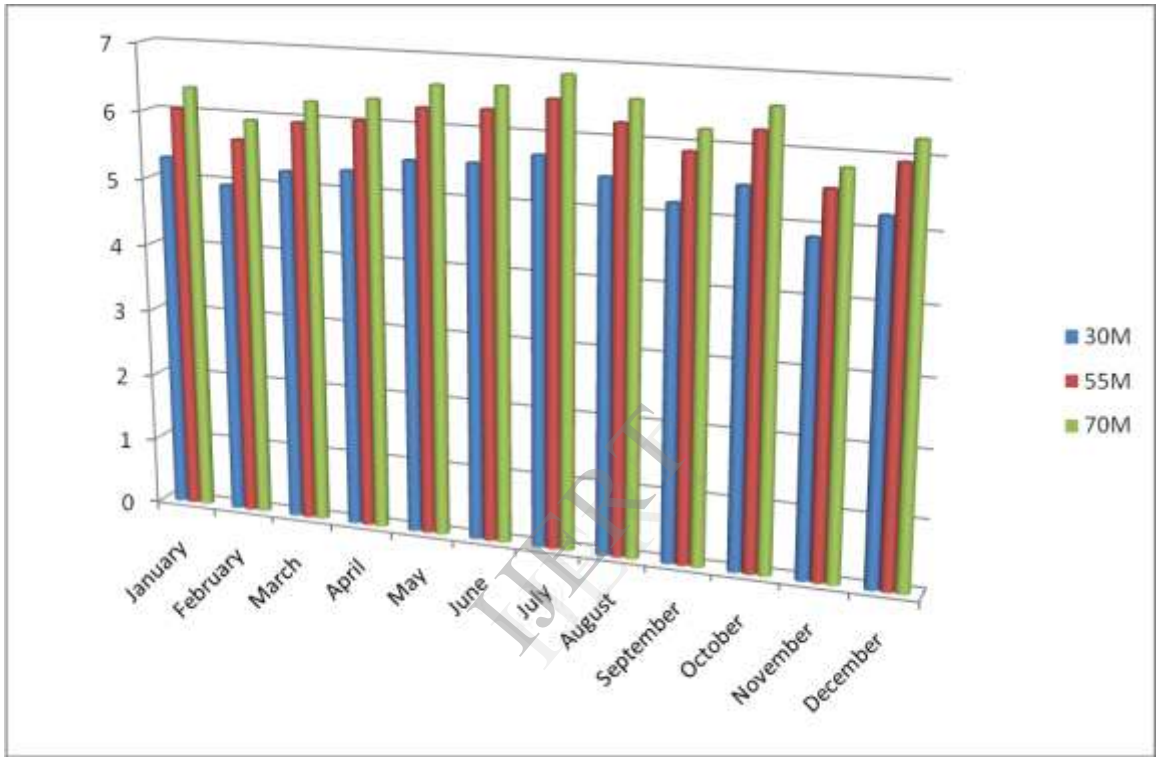

Figure1: Representation of mean monthly wind speed at both 30m, 55m and 70m heights.

Characteristics of Vergnet Gev Mp wind turbine generator

Rated Power	275kw
Hub height	55m

Rotor diameter	32m
Swept area	804.25m^2
Number of blades	2
Cut in wind speed	3.5 m/s
Cut out wind speed	25 m/s

Source: GEV MP Operation and maintenance manual (DO & M/IN/139 – 500).

The average annual mean monthly wind speed at 55m height for Katsina from Table [2] is 6.044m/s.(see Appendix 3 for rotor diameter and hub height)

5.0 CONCLUSION

In view of the enormous wind energy potential in the country, Government has took a great decision by embarking in a pilot project of generating electricity using alternative wind energy, even though not without both technical, political and administrative ill-preparedness.

It is worthy to note that, even though the farm has an installed rated/theoretical capacity of 10,175Kw (10MW) but the actual power to be generated will never exceed 8,140MW (8MW). The aim of this research is to investigate the generation of 10MW using alternative wind energy in Katsina. The average annual mean monthly wind speed at 55m height for Katsina from Table [2] is 6.044m/s.(see Appendix 3 for rotor diameter and hub height)

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