WIND SPEED DISTRIBUTION AND CHARACTERISTICS IN NIGERIA

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ABSTRACT

The aim of this paper is to review wind speed distribution in Nigeria and discuss the potential of using this resource for generation of wind power in the country. The power output from a wind turbine is strongly dependent on the wind speed and accurate information about the wind data in a targeted location for wind turbine is essential. The wind speeds in Nigeria range from about 2 to 9.5 m/s based on recent reported data and the trend show that wind speeds are low in the south and gradually increases to relatively high speeds in the north. The areas that are suitable for exploitation of wind energy for electricity generation as well as for water pumping and small scale applications were identified. Also some of the challenges facing the development of wind energy and suggested solutions were presented.

Keywords: wind speed, power density, electricity, Nigeria.

1. INTRODUCTION

Nigeria is endowed with huge resources of conventional energy resources (crude oil, tar sands, natural and coal) as well as reasonable amount of renewable energy resources (e.g. hydro, solar, wind and biomass). According to the OPEC annual statistical bulletin 2009, Nigeria proven crude oil reserves and natural gas are 37.2 billion barrels and 5,292 trillion standard cubic metres, respectively. In addition, the estimated reserve of tar sands and proven reserves of coals are about 30 billion barrels of oil equivalent and 639 million tons (with inferred reserves of about 2.75 billion tons), respectively (ECN, 2003). The estimate of renewable energy resources in Nigeria are presented in Table-1.

Table-1. Renewable energy resources and estimated reserves in Nigeria.

Hydropower (large/small scale)	14,750 MW
Solar radiation	3.5 - 7.0 $KWhm^2$/day
Wind	2-4 m/s at 10m height
Biomass	144 million tons/year
Wave and tidal energy	150,000 TJ/year

Source: Ibitoye and Adenikinju, 2007

By the end of 2008, Nigeria was expected to have been generating 15000 MW of electricity (Ibitoye and Adenikinju, 2007) however as at the time of preparing this article the electricity generation from all the available power stations is about 3100MW, which is about 50% of installed electricity capacity as at 2004 and 20% of the 2008 projected capacity. The shortage in electricity production from thermal stations (which accounted for about 70% of installed electricity capacity), is surprisingly, attributed mainly to lack or shortage of gas supply. The overall targets of renewable energy and total electricity generation are presented in Table-2. This table shows that Nigeria is already behind these values as regard to wind energy contribution. Surprisingly, the hydropower reserve data (as shown in Table-1 and supported by other sources e.g. Manohar and Adeyanju, 2009; Sambo, 2006) is far less than the long term target (Table-2) for this resource. This disparity can be linked to insufficient and inaccurate information or over ambition on the part of Nigeria government agency that make these projections.

Due to recent development in wind energy mostly in developed countries (especially in Europe) with desire to reduce environmental impacts of the convectional energy resources, there is a general growing interest in the wind energy development in Nigeria. The global cumulative installed capacity of wind power gradually increases from 6,100 MW in 1996 to 158,505 MW in 2009 (GWEC, 2010). In Africa, Egypt, Morocco and Tunisia are the leading countries with installed capacity of 430 MW, 253 MW and 54 MW, respectively, at end of 2009 (GWEC, 2010).

The questions are: can Nigeria benefit from the global development in wind energy resource? Can investment by government at all levels and private organizations in this resource help to ease electricity crisis in Nigeria? To answer these questions, knowledge about the availability and distribution of wind speed across this country are essential. The general notion is that Nigeria has enough wind energy resource and therefore, investment in it can help in solving her electricity crisis. The focus of this review article is to survey some of the papers that reported wind speed and wind energy potential in Nigeria and discuss the potential uses of this resource. This information will be helpful to government and any organization to make an informed decision regarding investment in wind energy resource.

Table-2. Targets for renewable electricity generation (MW) in Nigeria.

Resource	Short term 2008	Medium term 2015	Long term 2030
Hydro (large)	1930	5930	48000
Hydro (small)	100	743	19000
Solar PV	5	120	500
Solar Thermal	-	1	5
Biomass	-	100	800
Wind	1	20	40
All Renewable	2,036	6,905	68,345
All Energy Resources	15,000	30,000	190,000

Source: Sambo (2006).

2. WIND SPEED DISTRIBUTION

Reasonable amount of work have been carried out to investigate the characteristics and pattern of wind speed across Nigeria and thereby, identify areas that are best suited for wind power generation. Due to accessibility to wind speed data information, some researchers reported wind speed data in one city (e.g. Anyanwa and Iwuagwu, 1995; Medugu and Malgwi, 2005; Ngala *et al*., 2007; Oriaku *et al*., 2007; Fadare, 2008) while others reported wind speed data across the country (e.g. Fagbenle *et al*., 1980; Ojosu and Salawu, 1990a, b; Adekoya and Adewale, 1992; Fagbenle and Karayiannis, 1994; Fadare, 2010). Most wind data presented by these authors were measured at different heights (varied from about 5 to about 15 m) but were adjusted to a common height of 10m. This allowed comparison to be made among different locations.

Based on the wind data information from 1951 to 1960 and from twelve meteorological stations, Fagbenle *et al*., (1980) reported that average wind speed across Nigeria is about 3 m/s. In addition, they found that wind speeds are generally higher in the northern part of Nigeria than in the southern part with the highest wind speed of about 3.6 m/s in the Jos area. Also, they derived a third-degree polynomial expression for power density (W/m^2) for Nigeria as a function of average wind speed across these meteorological stations:

$$\frac{P}{A} = -47.8 + 74.2U - 34.5U^2 + 5.1U^3 \qquad \frac{W}{m^2}$$

where P is the power (W), A is the rotor swept area (m^2) and U is the average wind speed (m/s).

Ojosu and Salawu (1990a) reported wind speed data from 1951-1975 from 22 stations across the country and they concluded that Sokoto area (in northern part) have highest wind speed of about 5.12 m/s in June and annual average of 3.92 m/s. Furthermore, they reported wind speed of about 2 m/s or less in the middle and southern areas. Further study by these authors (1990b) that was based on another set of wind speed data (1968-1983) classified wind speeds across Nigeria into four different regimes: 1.0-2.0 m/s (e.g. Oshogbo, Minna and Yola), 2.1-3.0 m/s (e.g. Lagos, Makurdi and Port Harcourt), 3.1-4.0 m/s (e.g. Enugu, Kano, Maiduguri) and > 4.1 m/s (e.g. Jos, Nguru, Sokoto). These wind regimes are shown in Figure-1. In general, the findings of Ojosu and Salawu (1990a, b) are similar to that of Fagbenle *et al*., (1980).

Further studies on the wind speed pattern across Nigeria by Adekoya and Adewale (1992) based on wind data from 30 meteorological stations and Fagbenle and Karayiannis (1994) based on wind data for 18 stations and from 1979-1988, are consistent with previous studies mentioned above. Fagbenle and Karayiannis (1994) specifically mentioned that average wind speeds in Nigeria range from about 2 m/s to about 4 m/s with highest average speeds of about 3.5 m/s and 7.5 m/s in the south and north areas, respectively.

Most recent study by Fadare (2010) make use of artificial neural networks to predict the wind speeds distribution across Nigeria and compared the predicted wind speeds with measurements data from 28 stations that span between 1983 and 2003. This analysis predicted monthly average wind speed ranging from a minimum of 0.8 m/s for Ondo (in south region) to maximum value of about 13.1 m/s for Kano (in north region) with both values occurred in December. The overall average annual wind speed of 4.7 m/s was predicted for Nigeria. The measured data presented in this study indicated that maximum average annual wind speed of 9.47 m/s was recorded in Jos (closely follow by 9.39 m/s in Kano) while minimum value of 1.77 m/s was recorded in Ondo. Samples of the monthly isovents for selected months using the predicted values are presented by this author (see Figure-2, for the month of June). Both the monthly measured and predicted mean wind speeds reported by this author are generally higher than previous studies. However, the trend of the average annual wind speeds is in agreement with other previous studies.

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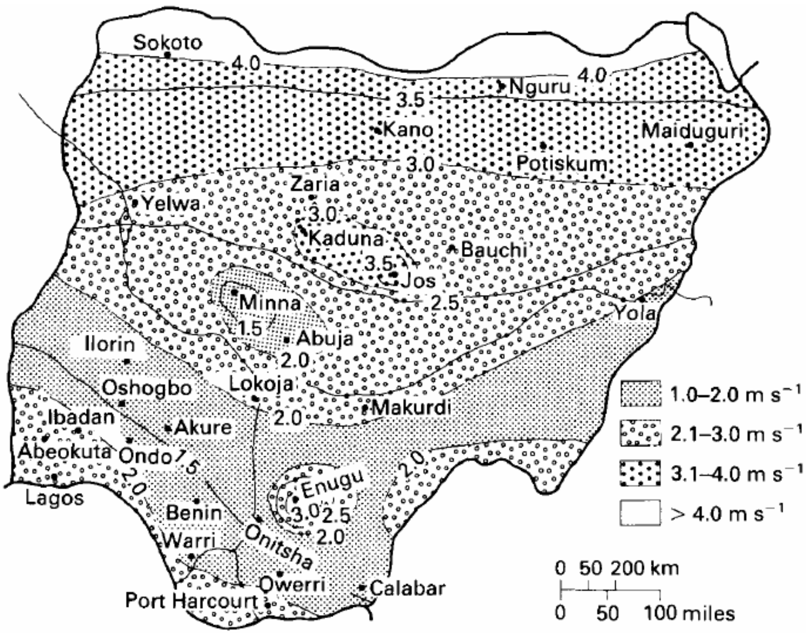

Figure-1. Nigeria annual average wind speeds distribution (isovents at 10 m height) showing four different wind speed regimes (Source: Ojosu and Salawu, 1990b).

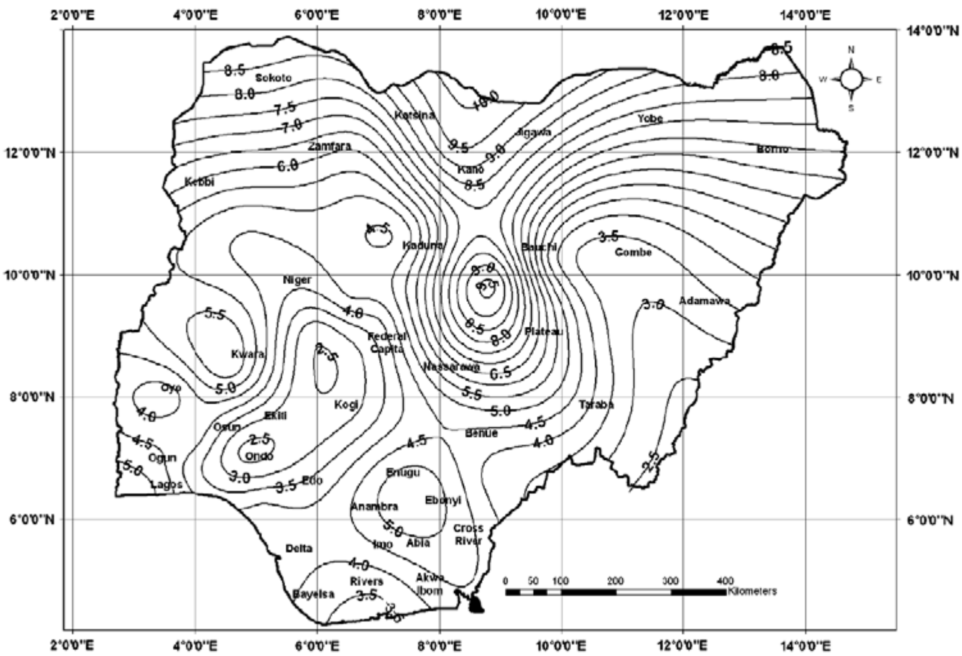

Figure-2. Predicted monthly average wind speeds (m/s) distribution (isovents at 10 m height) in Nigeria for the month of June (Source: Fadare, 2010).

Anyanwa and Iwuagwu (1995), Medugu and Malgwi (2005), Ngala *et al*., (2007), Oriaku *et al*., (2007) and Fadare (2008) are other researchers that reported wind speed data in Nigeria. However, the scope of these studies was limited to single city which are Owerri, Mubi, Maiduguri, Umudike and Ibadan, respectively. Their findings are similar and consistent with studies that reported wind speed distribution across the country.

3. COMMENTS AND CONCLUDING REMARKS

The energy from wind is strongly dependent on the average wind speed in the location where the wind energy conversion system is to be sited. In addition, the availability and consistency of this wind speed are essential in order to determine the economy viability of wind energy. In siting wind energy conversion system, the first major step is to determine the characteristics of the wind speed at the targeted site and estimate the amount of energy that can be derived from such wind speed. For investment on wind energy conversion system to be cost effective, the site average wind speed should be between 4 - 6 m/s (Adekoya and Adewale, 1992; Mathew, 2006). This wind speed range can however be use for small wind turbine to generate electricity. For a modern wind turbine, the minimum wind speed (cut-in wind speed) require in order for turbine to generate electricity is generally in the range of 4-5 m/s and depend on the size of the turbine, peak power output can be attained when the wind speed is in range of 10-15 m/s. For water pumping, wind turbine can be operated at lower wind speed; however they can be functioned effectively when the wind speed is more than 3 m/s.

From the Section 2, it is clear that Nigeria has low wind speed regimes and this is understandable due to location of Nigeria. The wind speed varies in general from low regime in the south of the country to relatively high speed regime in the north. The variation is related in part to the latitude which increases from the south to north and vegetation distribution that change from forest region in the south to savanna region in the north. However, some areas (scattered across the country) have unusual low or high wind speeds that does not follow this general trend of wind speed distribution across the country.

On the average, while researchers like Adekoya and Adewale (1992) and Fagbenle and Karayiannis (1994) reported the average wind speed from that ranges 2 to 4 m/s, however Fadare (2010) reported the annual average wind speeds that range from about 2 m/s to 9.5 m/s. The different in the range of wind speeds reported by these authors may be related to the period in which the wind data were recorded. The higher measured wind data reported by Fadare (2010) may be due to increment in wind speed as a result of deforestation across the country. In addition, the higher wind speed reported by Fadare (2010) may be due to the ability of the artificial neural networks used by this author to correctly predict the wind speeds.

On a nationwide scale, utilization of wind energy resources for electricity generation can only be achieved and be cost effective in limited locations such as Gausa, Jos, Kano and Sokoto. These areas have average annual wind speeds of more than 6 m/s according Fadare (2010). Other potential areas for electricity generation are Kaduna, Potiskum, Maiduguri, Ilorin, Minna and Enugu with wind average annual wind speeds in the range of 5-6 m/s. Except for Enugu which is in the south, all these locations are in the northern part of the country. The wind speeds in the other locations indicated that, wind turbine can effectively be used for pumping of water and other low capacity applications. In general, most of the wind data (as presented in Section 2) indicated that potential uses of wind power are limited to water pumping, small scale electricity generation, providing intermittent power requirements for a variety of purposes that needs low energy capacity, slow-running high torque wind turbines with multi-blade (Ojosu and Salawu, 1990(a,b); Adekoya and Adewale, 1992; Fagbenle and Karayiannis, 1994; Anyanwa and Iwuagwu, 1995). So in nutshell, there is good potential for utilization of wind energy in Nigeria depend on the end use of the generated power. To use wind energy resources for electricity generation in Nigeria, Ojosu and Salawu (1990b) suggested a wind turbine system with a cut-in wind speed of 2.2 m/s.

Investment in wind turbine is a capital intensive venture and with limited life span of wind turbine when compared with hydro and thermal stations, it is understandable that active government roles at all levels are crucial for the development of wind energy resource in Nigeria. In the developed countries where the wind energy technology have been fully established, the government played and still playing important roles in providing the financial support, incentive to encourage private and government agencies to invest in wind energy, and most importantly, they provide policy frameworks and back-up them with actions to encourage the exploitation of wind energy resources.

In Nigeria, there are well established policies on development of renewable energy resources but there are many hindrances and challenges to the development of these resources in Nigeria. Some of these problems are reluctance of government and its agencies to encourage wind energy technologies, low government financial support and not availability of fiscal incentives, lack of awareness, inadequate institutional framework and resource assessment, and technical ineptitude and limitation (Sambo, 2006 and Ajayi, 2009) as well as lack of government actions to follow-up available policies. Deliberate actions with strong political will by government at all levels particularly at state and federal levels are needed for realization of renewable resources (especially wind energy) contribution to the energy mix in this country.

Currently, Nigeria is producing her electricity from hydro and gas (thermal) stations which are scattered across the country. As discussed by Ibitoye and Adenikinju (2007) and Gbadebo and Okonkwo (2009), Nigeria electricity crisis are associated with many problems which includes aging of power plants and heavily overloaded equipments, poor utility performance, weak transmission and distribution systems, poor funding and lack of preventive and routine maintenance electricity facilities. Due to these problems, electricity generation and supply, are characterized with poor quality, unpredictability and limited availability. Unless there is a change of attitude especially in the area of maintenance, investment in wind energy may encounter similar problems. There is a need for policy on maintenance of electricity infrastructures that would make it mandatory for government agencies that are involve in electricity generation and distribution to carry out regular maintenance on these infrastructures. This can be done by establishing an electricity infrastructure commission with authority to regularly inspect electricity facilities (including wind energy infrastructures) across the country to make sure that maintenance procedures are follow strictly.

In our opinion, in order to fully exploit the wind energy resource in Nigeria and meet the projected wind energy contribution of 20 MW and 40 MW to total electricity generation by 2015 and 2030, respectively, lots of preliminary works have to be done in the areas of education and training. To our knowledge, there is no accredited academic programme in any Nigerian universities and polytechnics that can provide training and produce experts in the field of wind energy technology. Therefore, government need specific policy that relate to development of skilled knowledge in wind energy resource. This can be achieved by establishing training and research centers in selected universities and polytechnics across the country.

In addition, serious attention will need to be given to construction of roads (to provide accessibility to remote sites that have wind energy potential) and the issue on how to transmits and connect the generated power to national grid need to be addressed. In addition, it is necessary to thoroughly carry out intensive and detailed measurements of the wind conditions (temperature, speed and direction) on the targeted site over a period of at least 3-5 years and the nature of the topology of the site will need to be studied. All these studies will require state-of-the-art measuring instruments which are generally expensive and scarce available in Nigeria. The information reported by Fadare (2010) is encouraging and further investigation to supplement his study and analysis will be helpful. This will require serious huge financial commitment from the government and its agencies and as well as contribution from private and multinational companies.

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