Frequency Distribution Analysis of Available Wind Resources in Umudike, Abia State, Nigeria, for Wind Energy Conversion System Design

C.I. Oriaku*, J.C. Osuwa, A.D. Asiegbu, G.U. Chukwu, and C.O. Kanu

Department of Physics, Michael Okpara University of Agriculture,
Umudike, PMB 7267, Umuahia, Abia State, Nigeria.

ABSTRACT

Frequency distribution of ten-year wind speed data measured in Umudike has been analyzed. The results revealed a 98% probability of having 2.0 m/s hourly wind speed available for the period of time studied. The maximum extractable wind power has been estimated as 11.3 kw, which occurred in August, and the least wind power of 6.50 kw in November. It is expected that this preliminary result will help in the selection and design of efficient Wind Energy Conversion System (WECS) that will boost energy supply in the area.

(Keywords: Umudike, frequency distribution, wind speed, wind power, wind energy conversion, WECS)

INTRODUCTION

In Nigeria today, a great percentage of the general population reside in rural areas where they do not have the access to the nation's electric power source. In view of this, people have resorted to migrating back to the urban areas, where they receive the benefits of such amenities.

The major source of electricity in Nigeria is hydropower, which is usually restricted to the generation of shaft power from falling water (Medugu and Malgwi, 2005). The Power Holding Company of Nigeria (PHCN) is charged with the responsibility of managing the nation's Hydroelectric Power (HEP) station across the River Niger in Kainji. However the company has been noted for unreliable power supply characterized by low voltage and incessant power cuts, often without warning or even apologies to consumers (Uchendu, 1993). The unreliability of this situation has of course led to search for a more viable energy source for Nigeria. The adoption of power generating sets has rather worsened the situation due to high costs and incessant fuel scarcity characterizing the entire system, year-round. Moreover, most of these generating sets constitute environmental noise and pollution.

Wind energy has been noted as an alternate source of energy that can be exploited to meet of the needs of Nigeria and other developing nations (Syed, 2004). Umudike is a town in Abia State, Southeastern Nigeria, located at latitude 05^0 29^l North and longitude 07^0 33^l East. It is an important town in the region, hosting the nation's University of Agriculture and the National Root Crop Research Institute (NRCRI). It is endowed with an average wind speed of 2.6 m/s (Iwuoha, 2004). For effective harnessing of this renewable resource, it is important to evaluate the frequency distribution of the available resources. This is owing to the fact that the speed of the available wind is changing continuously; the knowledge of the frequency of occurrence is needed for proper wind system design.

MATERIALS AND METHODS

Wind Speed Data

The wind speed data was collected from the Department of Agrometeorology and Statistics, National Root Crop Research Institute (NRCRI), Umudike, Nigeria. The daily average wind speed data available in Beaufort number were converted to meter per second (m/s). The data collected was a ten year data set measured between 1994 and 2003.

Theory and Computations

Since wind speeds are measured in integer values, which are observed many times during recording, the number of observation of specific wind speed U_i will be defined as m_i. The average wind speed U can be computed (Justus, 1985) as:

$$\overline{U} = 1/n \sum_{i=1}^{r} m_i U_i \qquad \textbf{(1)}$$

Where n is the total number of observation and r is the number of different values of wind speed.

The relative frequency (probability) of which speed occurrence is given as:

$$P(U_i) = m_i/n \quad \textbf{(2)}$$

The cumulative of the frequencies is required to sum up to unity as:

$$\sum_{i=1}^{r} P(U_i) = 1 \quad \textbf{(3)}$$

Also the annual total observed wind speed frequency M_i is given as:

$$M_i = \sum_{i=1}^{k} m_i \quad \textbf{(4)}$$

Frequency Distribution of Wind Speed

The computed frequency of wind speed (m/s) in Umudike area, by month and by percentage are shown in Tables 1 and 2.

Wind Power

Theoretically, a wind machine rotor can extract at most 59% of the power. The available power in any wind speed may be estimated (Alnaser, 1993) as:

$$P = \tfrac{1}{2} \rho U^3 \quad \textbf{(5)}$$

Equation (5) can be modified to give:

$$P = \tfrac{1}{2} \rho A U^3 \quad \textbf{(6)}$$

Where:
P = wind power in watts.
ρ = Air density (for Umudike, $\rho \cong 1.21 Kg/m^3$)
A = swept rotor area (m^2)

$$\text{But } A = \pi R^2 \quad \textbf{(7)}$$

Where R = rotor radius (R = 20m).

Table 1: Computed Cumulative Frequency of Wind Speed (m/s) in Umudike Area.

Wind Speed	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
01	309	282	309	300	310	300	310	310	300	310	301	310	3650
02	309	282	309	300	310	300	310	310	300	310	301	310	3650
03	305	279	302	294	308	290	306	306	295	303	293	298	3579
04	117	094	136	113	106	118	139	139	110	067	034	064	1237
05	001	004	002	002	002	002	003	001	001	002	-	008	0028
06	-	-	001	-	-	-	-	-	-	-	-	-	0001
07	-	-	001	-	-	-	-	-	-	-	-	-	0001
08	-	-	001	-	-	-	-	-	-	-	-	-	0001

Table 2: Computed Cumulative Frequency (in percentage) of Wind Speed in Umudike.

Wind Speed	Umudike
1	100.00(3650)
2	098.05(3579)
4	000.76(0028)
5	000.03(0001)
6	000.03(0001)
7	000.08(0001)
8	000.03(0001)

Table 3 and Figure 1 show the annual variation of wind speed and available wind power in the Umudike area. Table 4 shows the average yearly wind speed the wind power in the Umudike area.

RESULTS AND ANALYSIS

Table 2 shows the cumulative frequency of Umudike expressed in percentage. This was extracted from the frequency distribution in Table 1. The last column of Table 2 represents the annual cumulative frequency of occurrence of a particular wind speed. The available annual wind power was calculated from the wind speed using equation (6).

Table 3: Annual Variation of Wind Speed and Available Wind Power in Umudike Area.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean wind speed (m/s)	2.34	2.28	2.39	2.37	2.37	2.38	2.44	2.46	2.31	2.20	2.04	2.17
Available power (KW)	9.74	9.01	10.38	10.12	10.12	10.25	11.05	11.32	9.37	8.10	6.46	7.77

Table 4: Average Yearly Wind Speed and Available Yearly Wind Power in Umudike Area.

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Av. Yearly wind speed (m/s)	2.52	2.39	2.34	2.16	2.02	2.21	2.37	2.46	2.31	2.37
Yearly available wind power (KW)	12.17	10.38	9.74	7.66	6.27	8.21	10.12	11.32	9.37	10.12

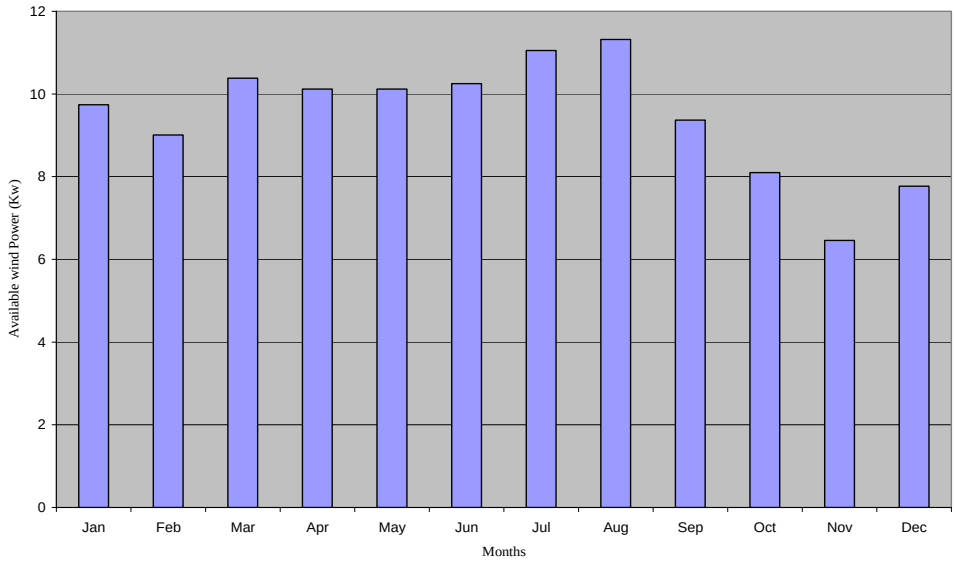

Figure 1: Annual Variation of Wind Speed and Available Wind Power in Umudike Area.

CONCLUSION

The frequency distribution of the available ten year data set of wind speed measured in NRCRI Agrometereological and Statistics Department have been analyzed. The results revealed a 98% assurance of hourly wind speed, which is up to 2.0 m/s throughout the years considered. This light wind (Madugu, 2005) resource can be harnessed by using appropriate Wind Energy Conversion System (WECS) to capture the available energy from the wind.

Also the maximum available extractable power from the wind has been estimated for Umudike as 11.30 KW occurring in August.

With this preliminary study in Umudike Weather Station, it is expected that the results of the frequency distribution analysis of the measured data will be considered in the design of efficient wind energy conversion systems (WECS). This will at least help to supplement the efforts of the Power Holding Company of Nigeria (PHCN) in resolving the energy crisis facing the entire nation.

REFERENCES

1. Medugu, D.W. and D.I. Malgwi. 2005. "A Study of Wind Potential: Remedy for Fluctuation of Electric Power in Mubi, Adamawa State Nigeria". *Nig. Journ. Phys*. 17:40-45.

2. Le Guarieres, D. 1982. *Wind Power Plants: Theory and Design.* Pergamon Press: Elsford, NY.

3. Iwuoha, G.S. 2004. "Modeling of Average Wind Power in Umudike Area for Industrial and Domestic Applications". Unpublished B.Sc. Project. Department of Physics, M.O.A.U. Umudike.

4. Syed, Z.I., S.M. Nasir, and T. Bodshah. 2004. "Frequency Distribution of Wind Speed of Quetta, Pakistan". *Journal of Research (Science)*. 15(4):391-394.

5. Justus, C.G. 1985. *Wind and Wind System Performance.* Franklin Institute Press: Philadelphia, PA.

6. Uchendu, O.A. 1993. "Economic Cost of Electricity Outages: Evidence from Sample Study of Industrial and Commercial Firms in the Lagos Area of Nigeria". *CBN Economic and Financial Review*. 31:183-195.

SUGGESTED CITATION

Oriaku, C.I., J.C. Osuwa, A.D. Asiegbu, G.U. Chukwu, and C.O. Kanu. 2007. "Frequency Distribution Analysis of Available Wind Resources in Umudike, Abia State, Nigeria, for Wind Energy Conversion System Design". *Pacific Journal of Science and Technology*. 8(2):203-206.