International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 2 Issue 8 ǁ August. 2013 ǁ PP.28-34

Analysis of Wind Energy Conversion Systems in North East Nigeria Using Present Value Cost Method

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ABSTRACT: *Wind turbines with power ratings of 20, 1000, 2000 and 2300 kW were examined in this study to assess their energy generation and economic analysis for the city of Maiduguri (11.850 N; 13.083 E; altitude 354 m), North-Eastern Nigeria. Costs of electricity were estimated based on the present value cost (PVC) method using wind speed data for9 years. The wind speed, measured at the height of 10 m was obtained from Nigerian Metrological Department. Monthly, seasonal and annual wind characteristics of the site were analysed.The result indicates that the Maximum monthly mean wind speed value of 15.78 m/s was recorded in June while the maximum annual mean wind speed was 11.63 m/s. the monthly mean power output and accumulated annual energy output were obtained as 15.91 MWh and 13.61 MWh/year respectively. The least costs of electricity Production per kilowatt hour was obtained with Avantis AV1010 model at 99-m hub height, while the highest is obtained with P10-20 model at 36.6-m hub height.*

KEYWORDS: *Maiduguri, Wind energy, Wind energy conversion systems, Wind speed*

I. INTRODUCTION

Many local wind sites have been studied by various researches around the country to determine the potentials of wind power for electricity generation, for example [1-8]. As reported in [4,7], annual mean wind speeds in Nigeria was found to vary between 2 and 9.5 m/s with an overall annual mean wind speed of about 4.62 m/s.For Maiduguri, a number of authors have conducted researches on wind energy, indicating the viability for wind harvesting in the region [5, 9]. Ngala et al. [9] carried out an economic assessment on the viability of wind energy as a power source in MaiduguriHowever, in spite of all the numerous work carried out so far on wind analysis in Nigeria, only few research studies have been focused on the economic analysis of wind applications in few sites in Nigeria. For instance, [4, 6,7,8] used the present value cost (PVC) and Levelised Cost of Electricity (LCOE) methods to study the economic feasibility of using wind energy conversions systems for some locations in Nigeria.

In this research, wind energy resource assessment in Maiduguri is presented. Investigation of wind energy generation and the economic analysis of wind turbine applications in this region are carried out using PVC method of analysis for the various wind energy conversion systems (WECS) with power capacities ranging from small to large size. The PVC method takes into consideration the current value of the total cost of energy investment during the entire lifetime of the energy conversion system. This information provided in this paper will be useful to wind energy developers, governments at various levels, and individuals, as well as private organizations that are interested in wind energy developmentNine years (2003-2011) monthly mean speed data were obtained from the Nigerian Metrological department of the Federal Ministry of Aviation (NIMET) Maiduguri, for analysis. The data were measured at a height of 10 m above sea level using a cup anemometer. Maiduguri is located in latitude 11.850 N and Longitude 13.083 E at an altitude of 354 m.

II. WIND SPEED DISTRIBUTION

There are many probability distributions functions that describe wind speed distribution in a particular location. The Raleigh and Weibul distributions are the two most widely used [1]. The weibul distribution is adopted in this study because of its versatility and found to give a better fit with experimental data [1, 2]. The weibul probability distribution function is expressed as:

$$f_w(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} exp\left[-\left(\frac{v}{c}\right)^k\right] \quad (1)$$

Where k and c (m/s) are the Weibull shape and scale factors, respectively and v (m/s) is the wind speed. These parameters can be determined by the mean wind speed-standard deviation method [10] given by equations (2) and (3)

$$k = \left(\frac{\sigma}{\bar{v}}\right)^{-1.086} \quad (1 \leq k \leq 10) \quad (2)$$

$$c = \frac{\bar{v}}{\Gamma\left(1+\frac{1}{k}\right)} \qquad (3)$$

Where $\bar{v}$ is the mean wind speed and computed as:

$$\bar{v} = \frac{1}{n}\left(\sum_{i=1}^{n} v_i\right) \qquad (4)$$

And σ is the standard deviation given by:

$$\sigma = \left[\frac{1}{n-1}\sum_{i=1}^{n}(v_i - \bar{v})^2\right]^{0.5} \qquad (5)$$

$n$is the number of hours in the period of time considered. The parameters can also be computed by other methods as in [2]. However the first method is adopted here.

2.1.Wind speed extrapolation

The wind turbine models selected in this work are designed to operate at different hub heights when compared to the available measured wind data (10 m); it is therefore necessary to extrapolate for the respective turbine hub heights. This can be achieved using log law; whereby the desired speed v at the desired height z is expressed as [11, 12]:

$$v = v_o\left(\frac{\ln(Z/Z_s)}{\ln(Z_o/Z_s)}\right) \qquad (6)$$

$v_o$is the wind speed recorded at standard anemometer height (Z_o). $Z_s$is a local roughness scale. The speed extrapolation can also be done using the power law given in equation (7)

$$v = v_o\left(\frac{H}{H_o}\right)^{\alpha} \qquad (7)$$

Where v is the wind speed at the wind turbine hub height$H$.$v_o$is the wind speed at original height H_o, and α is a surface roughness coefficient. The power law with roughness coefficient of 0.4 is used in this research to compute the speed at the respective turbine hub heights, shown in Table 1.

Table 1: Wind Speed at Different Hub Heights

	36.6 m				**50 m**			
Period	*v*	*σ*	*c*	*k*	*v*	*σ*	*c*	*k*
January	6.95	3.23	7.84	2.30	7.87	3.66	8.88	2.30
February	6.05	3.38	6.82	1.89	6.86	3.82	7.73	1.89
March	9.36	3.70	10.52	2.74	10.60	4.20	11.91	2.74
April	8.60	4.50	9.70	2.02	9.74	5.09	10.99	2.02
May	8.98	4.95	10.12	1.91	10.17	5.61	11.46	1.91
June	10.60	4.21	11.91	2.73	12.01	4.77	13.50	2.73
July	9.74	4.08	10.97	2.57	11.03	4.63	12.43	2.57
August	8.12	2.59	9.03	3.47	9.20	2.93	10.23	3.47
September	6.51	2.78	7.34	2.52	7.38	3.15	8.31	2.52
October	6.42	2.77	7.23	2.49	7.27	3.13	8.20	2.49
November	6.15	2.97	6.94	2.20	6.97	3.36	7.86	2.20
December	6.29	1.94	6.98	3.59	7.13	2.20	7.91	3.59
Whole year	7.81	3.85	8.82	2.16	8.85	4.36	10.00	2.16
Dry Season	7.14	3.40	8.06	2.24	9.90	4.34	11.17	2.45
Rainy Season	8.74	3.83	9.86	2.45	8.08	3.85	9.13	2.24
2003	10.20	4.08	11.47	2.71	11.56	4.62	12.99	2.71
2004	7.56	2.12	8.34	3.97	8.56	2.41	9.45	3.97
2005	10.48	2.86	11.55	4.09	11.87	3.24	13.08	4.09
2006	9.01	2.67	9.98	3.75	10.21	3.03	11.31	3.75
2007	11.01	2.64	12.03	4.72	12.48	2.99	13.63	4.72
2008	4.04	4.43	3.85	0.90	4.57	5.01	4.36	0.90
2009	5.84	3.83	6.51	1.58	6.62	4.34	7.37	1.58
2010	6.78	1.96	7.50	3.84	7.68	2.23	8.50	3.84
2011	5.40	1.48	5.95	4.08	6.11	1.67	6.74	4.08

Table 1 Continued

	80 m				99 m			
Period	*v*	*σ*	*c*	*k*	*v*	*σ*	*c*	*k*
January	9.50	4.42	10.72	2.30	10.34	4.81	11.68	2.30
February	8.28	4.61	9.33	1.89	9.01	5.03	10.16	1.89
March	12.79	5.06	14.38	2.74	13.93	5.51	15.66	2.74
April	11.76	6.15	13.27	2.02	12.80	6.69	14.45	2.02
May	12.27	6.77	13.83	1.91	13.36	7.38	15.06	1.91
June	14.49	5.75	16.29	2.73	15.78	6.26	17.74	2.73
July	13.32	5.58	15.00	2.57	14.50	6.08	16.33	2.57
August	11.10	3.53	12.35	3.47	12.09	3.85	13.45	3.47
September	8.90	3.80	10.03	2.52	9.69	4.14	10.92	2.52
October	8.78	3.78	9.89	2.49	9.56	4.12	10.77	2.49
November	8.41	4.06	9.49	2.20	9.15	4.42	10.34	2.20
December	8.60	2.65	9.54	3.59	9.36	2.89	10.39	3.59
Whole year	10.68	5.26	12.06	2.16	11.63	5.73	13.14	2.16
Dry Season	11.95	5.23	13.48	2.45	10.62	5.06	12.00	2.24
Rainy Season	9.76	4.65	11.02	2.24	13.02	5.70	14.68	2.45
2003	13.95	5.58	15.68	2.71	15.19	6.07	17.08	2.71
2004	10.33	2.90	11.40	3.97	11.25	3.16	12.42	3.97
2005	14.33	3.91	15.79	4.09	15.60	4.26	17.19	4.09
2006	12.32	3.65	13.65	3.75	13.42	3.98	14.86	3.75
2007	15.06	3.60	16.45	4.72	16.40	3.92	17.92	4.72
2008	5.52	6.05	5.26	0.90	6.01	6.59	5.73	0.90
2009	7.99	5.24	8.90	1.58	8.70	5.71	9.69	1.58
2010	9.27	2.69	10.26	3.84	10.10	2.93	11.17	3.84
2011	7.38	2.02	8.13	4.08	8.03	2.20	8.85	4.08

2.2 Power output from turbine models

The electrical power output p_e developed by a wind machine as a function of speed is given by [13]:

$$p_e = \begin{cases} 0 & (v < v_{ci}) \\ a + bv^k & (v_{ci} < v < v_r) \\ p_{eR} & (v_r < v < v_{co}) \\ 0 & (v > v_{co}) \end{cases} \quad (8)$$

$$a = p_{eR} \frac{v_{ci}^k}{v_{ci}^k - v_r^k} \quad (9)$$

$$b = \frac{p_{eR}}{v_r^k - v_{ci}^k} \quad (10)$$

Where v_{ci} is the cut-in wind speed (m/s),v_{co} the cut-out wind speed (m/s) v_r the rated wind speed (m/s) and P_{eR} the rated power (kW).The parameters of interest for assessment of wind power are the mean power output and the capacity factor. The mean power output ($P_{e,ave}$) over a period of time (usually, monthly and annually) can be used to determine the total energy of any installed wind turbine at any location and can be used for total income/cost analysis. The capacity factor C_f, which represents the fraction of the mean power output over a period of time to the rated electrical power p_{eR} of the turbine, can be used for selection of wind turbine among available turbines to be installed in a site with known wind speed characteristics and for identification of sites that are suitable for wind energy development.

The mean power output $P_{e,ave}$ and capacity factor C_f can be calculated using the following expressions based on Weibull distribution parameters [13]:

$$P_{e,ave} = p_{eR} \left\{ \frac{[exp(-Qc) - exp(-Qr)]}{(Qr - Qc)} - exp(-Qf) \right\} \quad (11)$$

$$Qc = \left(\frac{v_{ci}}{c}\right)^k ; Qr = \left(\frac{v_r}{c}\right)^k ; Qf = \left(\frac{v_{co}}{c}\right)^k \quad (12)$$

$$C_f = \frac{P_{e,ave}}{p_{eR}} = \frac{[exp(-Qc) - exp(-Qr)]}{(Qr - Qc)} - exp(-Qf) \qquad (13)$$

The accumulated annual energy output is given by [7, 13, 14]:

$$E_o = P_{e,ave} \times 8760 \text{ (kWh)} \qquad (14)$$

2.3 Cost analysis of electrical generation from a practical wind turbine

In order to produce energy at a low operating cost it is essential to accurately estimate all the costs involved in generating electricity over the life span of a WECS [7, 15]. The cost of a wind turbine varies from one manufacturer to another and dependent on the following factors [8,16]: (i) the rated power, (ii) investment cost (iii) control systems and turbine accessories,(iv) operation and maintenance costs (v) the turbine lifetime, (vi) wind speed regime in selected location, (vii) cost of construction and other infrastructures, and (viii) discount rate. Costs of wind turbine based on rated power are depicted in Table 2 [7, 15].

Table 2: Specific Cost of Wind Turbines based on rated power

Wind turbine size (kW)	Minimum specific cost $(\$/kW)$	Maximum specific cost $(\$/kW)$	Mean specific cost $(\$/kW)$
10-20	2200	2900	2550
20-200	1500	2300	1900
200 and above	1000	1600	1300

According to [7, 16], there are three different ways of quantifying the cost of wind turbines. These are: cost per unit kilowatt, cost per unit rotor area, and cost per unit kilowatt hour of electricity produced. Cost of electricity per unit kilowatt hour is adopted in this work and computed using Present Value Costs (PVC) method to examine the economic analysis of the selected WECS. PVC is computed using the following expression [15]

$$\text{PVC} = \frac{1}{E_{WT}}\left[I + C_{om}\left(\frac{1+i}{r_o+i}\right) \times \left[1 - \left(\frac{1+i}{1+r_o}\right)^n\right] - S\left(\frac{1+i}{1+r_o}\right)^n\right] \quad (15)$$

Where I is the total capital/initial costs, E_{WT} = 8760 $p_{eR}\, C_f$ is the annual energy output of the turbine, C_{om} , n , r_o , i are the operation and maintenance cost for the first year, useful lifetime of the turbine, interest rate, and inflation rate, respectively.

In evaluating the costs of kilowatt hour of energy produced by the WECS at the selected sites, the following assumptions were taken into consideration:

1. Interest rate (r_o) was taken as 16%.
2. Inflation rate (i) was taken as 12%.
3. The lifetime (n) of each turbine is considered to be 20 years.
4. The total capital/initial costs 'I' is the summation of turbine price and other initial costs. These include provisions for civil work, land, infrastructure, installation and grid integration. The actual total of other initial costs depends on a number of factors, for instance the available infrastructure in the selected location. Considering the level argument presented in [17], other initial costs is considered to be 20% of the wind turbine and tower cost.
5. As reported in [18], operational costs are annually recurring and involved in routine operation of wind farms; these costs are fixed and can be estimated in a straight forward deterministic manner. However, maintenance cost cannot be calculated in a straight forward manner as they are not fixed, but only calculated using stochastic variables. It has been reported that the annual operation and maintenance costs vary from about 1% to 7% of the initial system cost [7, 16] and 2% to 16% of the wind turbine cost [16], depending on the rated power and age of the wind turbine. In this study, operating and maintenance cost is assumed to be 25% of the initial capital cost of the wind turbine installation system (system price/lifetime).
6. It has been argued in [7] that assumption of 0% for the scrap value will results in higher unit price of electricity than if non-zero value were assumed. The scrap value, S was therefore taken to be 10% of the turbine price and civil work.
7. In practice, the annual mean wind speed in the selected locations may vary from year to year. However, it will be difficult to estimate the level of variation in the wind speed and, hence, the energy produced over the entire useful life of the wind energy conversion systems. Therefore, it is assumed in this study that the wind turbine produces the same amount of energy output in each year during its useful lifetime.

III. RESULTS AND DISCUSSION

3.1 Energy analysis of wind turbines

Four practical Wind Energy Conversion Systems (WECS) were selected for analysis. The turbines are: AV1010 from AVANTIS group, VESTAS V100, AN BONUS 1 MW and P10-20 [7, 8, 19-20]. The technical details of the turbines are presented in Table 3.

Table 4 and Fig. 1 show the monthly electrical power output, the mean power, the capacity factors and the accumulated annual energy output computed from Equations.(8)–(14),using the three values of the velocities (1, and 1shown in Table 3) and the extrapolated values of Weibull and calculated from equations (2) and (3) at the respective turbine heights. These are computed to assess the monthly, seasonal and year round performance of the four considered wind turbines. It can be observed that the monthly mean power output across the turbine series varied from 0.05 to 15.91 MWh. For both the AN Bonus 1 MW/54 and P10-20,the monthly average power output varied from the lowest in December to the highest in June with values ranging from 0.05 Mwh to 4,75 Mwh. For the remaining turbines, the monthly average power varied from 6.84 to 15.91 Mwh .The highest value of annual energy output among the four turbines was obtained as 13.61MWh/year with AV1010 wind turbine model. This may be attributed to the high turbine hub height. It can be seen that although AN BONUS 1 Mw/54 has higher rated speed than AV1010, the annual energy is lower showing that influence of the hub has significant effect on the on the energy production. AV1010 wind turbine which produces the highest annual energy is therefore best suited for this site.

Another way of comparing the performance characteristics of a wind turbine is by considering the capacity factor of the WECs in a given site. According to [7,] the capacity factor usually ranges from 20% to 70% in practice, is actually affected by the intermittent nature of the wind, the machine availability, and the turbine efficiency. From Table 4, the highest capacity factor is found to be 79% using AV1010 while the lowest is calculated as 9.7% with AN Bonus 1 Mw/54.

Table 3: Selected Wind Turbine Characteristics

Wind Machine characteristics	**AVANTIS AV1010**	**VESTAS V100**	**AN BONUS 1 MW/54**	**P10-20**
Rated power (kW)	2300	2000	1000	20
Cut-in wind speed (m/s)	3	3	3	2.5
Rated wind speed (m/s)	11.2	12	15	10
Cut-off wind speed (m/s)	25	20	25	25
Hub height (m)	99	80	50	36.6
Rotor diameter (m)	100.6	100	54.2	10

Table 4: Electrical Power, Mean Power Output and Capacity Factor for the Selected Wind Turbines

	AVANTIS AV1010			**VESTAS V100**			**AN BONUS 1 MW/54**			**P10-20**		
Period	$P_e(kw)$	P_{eAve} (kw)	$C_f(\%)$	$P_e(kw)$	P_{eAve} (kw)	$C_f(\%)$	P_e (kw)	P_{eAve} (kw)	$C_f(\%)$	P_e (kw)	P_{eAve} (kw)	$C_f(\%)$
January	16.54	12.70	63.06	9.93	9.24	52.77	1.82	2.39	27.24	0.07	0.08	46.31
February	12.53	10.74	53.31	8.94	7.84	44.72	1.66	2.15	24.50	0.06	0.07	38.41
March	37.31	15.91	78.96	21.24	11.53	65.82	3.32	3.89	44.39	0.15	0.12	66.00
April	27.06	13.73	68.14	17.54	9.88	56.37	3.45	3.73	42.58	0.13	0.10	59.20
May	29.20	13.40	66.53	19.26	9.57	54.60	3.95	3.95	45.08	0.14	0.11	60.91
June	52.71	15.85	78.65	29.89	11.09	63.31	4.72	4.75	54.21	0.21	0.13	73.89
July	40.13	15.58	77.33	23.42	11.12	63.47	3.90	4.24	48.44	0.16	0.12	68.29
August	26.39	15.55	77.19	13.47	11.39	65.01	1.58	2.25	25.65	0.08	0.09	52.94
September	13.65	11.98	59.48	8.36	8.51	48.60	1.34	1.84	21.01	0.06	0.07	38.88
October	13.18	11.78	58.45	8.13	8.35	47.66	1.30	1.80	20.54	0.05	0.07	38.02
November	12.31	11.12	55.19	8.13	7.98	45.56	1.40	1.89	21.61	0.05	0.07	37.22
December	10.45	11.10	55.11	5.31	6.84	39.02	0.58	0.86	9.77	0.03	0.05	26.29
Whole year	22.02	13.61	67.55	14.07	9.92	56.61	2.62	3.15	35.93	0.10	0.09	53.55
Dry Season	17.73	12.93	64.19	17.78	10.88	62.11	3.06	3.61	41.17	0.08	0.08	47.27
Rainy Season	29.68	14.99	74.40	11.30	9.44	53.87	2.01	2.59	29.52	0.12	0.11	61.03
2003	47.10	15.91	78.95	26.83	11.26	64.28	4.27	4.50	51.40	0.19	0.13	71.56

2004	20.52	14.67	72.82	9.70	10.07	57.49	0.93	1.38	15.81	0.06	0.07	42.20
2005	78.80	18.29	90.78	36.32	13.69	78.13	3.36	4.13	47.11	0.21	0.13	76.66
2006	39.92	16.97	84.22	19.44	12.78	72.94	2.06	2.85	32.58	0.12	0.11	62.81
2007	122.42	18.93	93.94	51.26	14.27	81.45	3.67	4.42	50.40	0.28	0.14	81.74
2008	6.81	5.74	28.51	9.48	4.34	24.78	1.24	1.59	18.11	0.04	0.04	24.02
2009	12.26	9.95	49.39	9.62	7.32	41.81	1.86	2.28	26.02	0.06	0.07	37.84
2010	13.47	12.59	62.49	6.53	8.00	45.64	0.65	0.97	11.10	0.04	0.05	31.19
2011	5.06	7.04	34.92	2.40	3.50	19.97	0.21	0.32	3.67	0.01	0.02	11.67

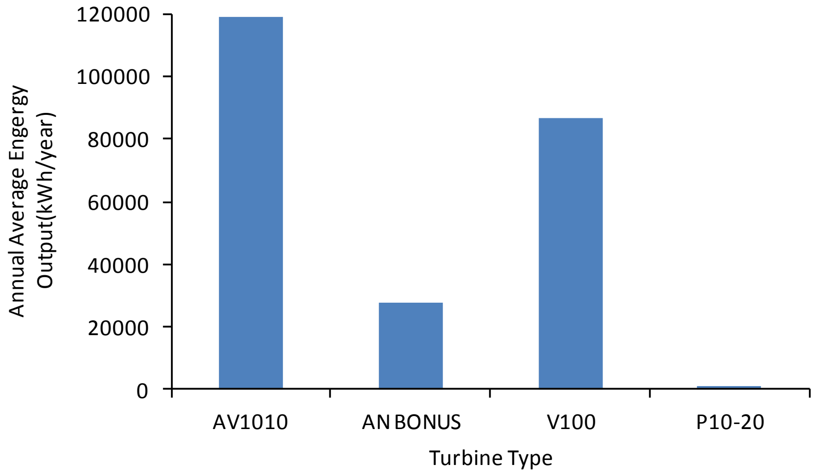

Figure 1: Accumulated Annual Energy Output

3.2 Economic analysis of wind turbines

The characteristics of the four wind turbines discussed in section 2.1 is substituted in equation (15) to compute the cost of energy per kWh. The computed result is shown in Table 5.

The least value of electricity cost is found to be \$0.0196/kWh with the minimum specific cost of wind turbine using AV1010 model. Also, it can be seen from Table 5 that the highest costs of unit energy per kWh using the maximum specific cost of wind turbine, is obtained using P10-20 turbine as \$0.3988. Maiduguri therefore can be considered as economically viable site with respect to average PVC values for AV1010 and V100 wind turbine models because the present cost of electricity as at July ,2013 [21], is 13.63 NGN per kWh(0.0868 USD;1 USD 157.60 NGN; [22]).

Table 5: Costs of Wind Turbines based on PVC Method

Wind turbine	Minimum specific cost ($/kW)	Maximum specific cost ($/kW)	Mean specific cost ($/kW)
AVANTIS AV1010	0.0196	0.0313	0.0255
VESTAS V100	0.0269	0.0430	0.0349
AN BONUS 1 MW/54	0.0847	0.1355	0.1101
P10-20	0.2622	0.5354	0.3988

IV. CONCLUSION

Technical and economic analysis of the four wind energy conversion systems has been carried in the study for the city of Maiduguri. The summary of the observations and findings are as follows: Maximum and minimum monthly mean wind speed values are 15.78 m/s and 6.05 m/s obtained in June and January respectively. The maximum an annual mean wind speed recorded is 11.63m/s. The highest capacity factor was computed as 79%, while the monthly mean power output and accumulated annual energy output were obtained as 15.91 Mwh and 13.61 Mwh/year respectively.

Average minimum cost per Kwh was \$0.0196/kWh with Avantis AV1010 turbine while the highest cost was found to be \$0.388/kWh using P10-20 turbine.

REFERENCES

[1] Asiegbu, A.D. Iwuoha, G.S., Studies of wind resources in Umudike, South East Nigeria – An assessment of economic viability, Journal of Engineering and Applied sciences, 2(10), 2007, 1539-1541

[2] Fagbenle, R.O, Katende, J, Ajayi, O.O. Okeniyi, J.O., Assessment of wind energy potential of two sites in North - East, Nigeria, Renewable Energy, 36 2011, 1277 – 1283

[3] Fadare D.A., The application of artificial neural networks to mapping of wind speed profile for energy application in Nigeria, Applied Energy, 87,2010,pp934 – 942

[4] Adaramola, MS, Paul, SS, Oyedepo, SO: Assessment of electricity generation and energy cost of wind energy conversion systems in North-Central Nigeria. Energ. Convers. Manage 52, 3363–3368, 2011

[5] Aiden J. and J.C Ododo wind speed distributions and Power Densities of Some Cities in Northern Nigeria, Journal of Engineering and Applied Sciences 5(6) pp420-426,2010

[6] Ajayi, O.O. , Fagbenle, R.O ,Katende, J Assessment of Wind Power Potential and Wind Electricity Generation Using WECS of Two Sites in South West, Nigeria International Journal of Energy Science Vol.1 No.2 2011 PP.78-92 www.ijesci.org

[7] Ohunakin S.O., et al., Economic Analysis of Wind Energy Conversion Systems Using Levelised Cost of Electricity and Present Value Cost Methods in Nigeria. International Journal of Energy and Environmental Engineering 4:2, 2013

[8] Ohunakin, S.O., et al., Analysis of cost estimation and wind energy evaluation using wind energy conversion systems (WECS) for electricity.... Energy Policy (2012), http://dx.doi.org/10.1016/j.enpol.2012.05.064

[9] Ngala, GM, Alkali, B, Aji, MA: Viability of wind energy as a power generation source in Maiduguri Borno State, Nigeria. Renew Energ 32, 2242–2246 (2007)

[10] Mustapha Serder Economic analysis of Large Wind Energy Conversion Systems in central Anatolian Turkey, Clean Energy Systems and Experiences 2008

[11] Munkund R. Patel, Wind and Solar power Systems Design, Analysis and Operation, Second Edition, Taylor and Francis, 2006, New York,

[12] Wind Power in Power Systems Thomas Ackermann john Wiley and Sons LTD

[13] Wind Energy Conversion Systems

[14] Akpinar, EK, Akpinar, S: An assessment on seasonal analysis of wind energy characteristics and wind turbine characteristics. Energ. Convers. Manage 46, 1848–1867 (2005)

[15] Gökçek, M, Erdem, HH, Bayülken, A: A techno-economical evaluation for installation of suitable wind energy plants in Western Marmara Turkey. Energ. Explor. Exploit. 25, 407–428 (2007)

[16] Mathew, S: Wind Energy: Fundamentals. Resource Analysis And Economics, Springer, Heidelberg (2006)

[17] Manwell, JF, McGowan, JG, Rogers, AL: Wind Energy Explained: Theory, Design And Application, 2nd edn. Wiley, Chichester (2009)

[18] Ohunakin, O.S., Akinnawonu, O.O., 2011.Assessment of wind energy potential and the economics of wind power generation in Jos, Plateau State, Nigeria. Energy for Sustainable Development http://dx.doi.org/10.1016/j.esd.2011.10.004.

[19] http://www.avantis-energy.com/resources/Technical+data+AV+1010+ +2.3+MW+english.pdf Accessed 19 July 2013

[20] http://nozebra.ipapercms.dk/Vestas/Communication/Productbrochure/V10026MW/V10026MW/ Accessed 19 July 2013

[21] Nigerian Electricity Regulatory Commission (NERC).Consultation Paper for the 2012 Major Review of the Multi Year Tariff Order (MYTO II).Available online: http://www.nercng.org/index.php/document-library/func-startdown/54/ Accessed 26 July 2013

[22] Universal currency converter. Available online: /http://www.xe.com/S.