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Development and Effective Utilization of Offshore Wind Turbine

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Abstract:- The prospectus needs to generate energy by the development of an offshore wind machine and the subsequent utilization of the energy is a key issue. Meteorological data was obtained and analyzed for two states in the Niger-Delta region of Nigeria. Theoretical analysis confirmed that the average wind speeds produced are sufficient enough for the generation of offshore wind energy. 25meter diameter (which can be more) of offshore wind turbine was used at different depth and distance from shore. Offshore wind speed data for eleven years (1993 - 2003) were sourced from meteorological center Mushin. The results showed that wind power output of 106. 22kw (25m diameter wind turbine) may be a reality for only a state.

Keywords:- *Prospect, Development, utilization. Offshore, Turbine, Energy.*

I. INTRODUCTION

The current interest in wind energy for electricity generation can he traced back to the oil crisis of the 1970’s. A number of Government funded research and development programs were initiated during period internationally. Nigerian not an exception. Many of the countries focused on the development of large machines (with rotor diameters around 50/60 meters. 1 MW power output). The reasoning behind this strategy was that fewer machines would be needed and hence the environmental impact would be minimized. Even at this early stage it was recognized that onshore development might eventually he constrained and that the offshore resource offered good winds and a very large energy potential. (1)

Nigeria, which is located approximately between 4º& 14º North and 3º& 14º East, its territory extends about 650 miles (1.050 KM) from North to South and 700 miles east to west, consists of several eroded surfaces, occurring as plateaus, at elevations of 2.000ft (610 meters). 3.000ft and 4.000ft above sea levels. The coastal areas including the Niger-Delta are covered with young soft rocks and partly enclosed by offshore resources. (6)

Based on these attribute, the need for utilizing the large mass offshore winds is then obvious, especially around the coastal areas.

II. MATERIALS AND METHOD

A. *OFFSHORE WIND ENERGY*

Studies of offshore wind energy have been in progress for around 30 years. As a result the key issues associated with the resource, the offshore environment and the necessary adaptations of wind turbine technology are well understood. Early studies focused on the use of megawatt (MW) size wind turbines, frequently in large arrays, whereas early demonstration wind farms used modest numbers of specially adapted versions of commercial machines around the 500KW mark.(2)

Early global offshore wind energy studies, carried out during the late 1970s and early I 980s, generally concentrated on assessments of three key interrelated issues: Wind speeds and wind characteristics, the magnitude of the energy resource and the feasibility and cost of building wind turbines offshore. (4)

Most of the studies looked at the feasibility of using machines with ratings in the range 2 to 5MW, Arranged in clusters of up to a hundred or more machines.

Although there were no commercial machines of this type in operation, there were a number of land-based prototypes and experimental machines, and the expectation was that commercial designs would soon follow. (2)

B. *OFFSHORE WIND TURBINE*

Offshore development in practice has proceeded in a more evolutionary manner, initially with relatively small machines sited close to the shore. Nevertheless, they identified many of the key issues involved in the exploitation of offshore wind energy. The increased wind speeds at offshore sites were, and are, a key issue and the importance of water depth and sea-bed condition was also recognized.

C. *DEVELOPMENT AND EFFECTIVE UTILIZATION OF OFFSHORE WIND TURBINE*

It was clear that adequate information above wave conditions was needed, partly to ensure that there were no problems with machine dynamics and partly to ensure that the turbine blades were clear of the waves at all times. The cost of the grid connection to the shore showed up as a significant proportion of the total typically around 25 percent. (4)

III. THEORY

A. CALCULATING THE ENERGY AVAILABLE FROM THE WIND

The total power available from a wind is

$$P = \frac{KE}{mass} \times m = \frac{1}{2} \cup_w{}^2 \rho \cup_w A$$

$$P = \frac{1}{2} \rho A \cup_w{}^3 \text{ ......} (1)$$

Where, KE = Kinetic energy
m = mass flow Kg/s
p = density of air, Kg/m^3
A = area normal to the wind, m^2
$\cup_w =$ Wind velocity m/s

The density of air varies with altitude and atmospheric conditions. At STP conditions, 100 mbar (29.53 in. Hg) and a temperature of 293 °K (68 t), the density is I .20Lkg'm^3. (5)

Although the density does decrease slightly with increasing humidity, the decrease is small and is usually neglected in calculations. The density of dry air can be calculated for any temperature and barometric pressure by means of the ideal gas law. By the use of air properties, this simplifies to,

$P = dencity(kg/m^3) =$ 0.349 atmospheric pressure (mbar)…………………… (2)

Temperature (°K)

Since some proposed sites are at altitude of 1000ff or more. Both pressure and temperature variations occur and the density correction is necessary. Changes of 10 to 15% in air density are usual at any given site.

The maximum fraction of the wind energy that could be converted to useful energy by an ideal aerometer (such as a wind turbine) was 1627 or 59.3%. This is analogous to the Carnot cycle efficiency for steam power cycles. Thus the maximum, theoretically obtainable power output of a wind device is

P = 0.2965 pAU^3_w. ……………………………………………………………. (3)

(A. Betz of Gottingen Limit)

B. WIND TURBINE THEORY

Consider a control volume around the wind turbine as shown in fig. 1. The variables shown in this figure are:

$\cup_w =$ Wind speed, m/s

a_1 = Interference factor

$R_{th} =$ Turbine blade radius, m

The actual thrust on the turbine. F_{th}, derived from a momentum balance is equal to,

$$F_{th} = 2\pi R_{tb}{}^2 \rho \cup_w{}^2 a_1(1-a_1) \text{ ………………… ………………………………….. } (4)$$

From a momentum and energy balance on the control v' (me in fig I. the turbine power would be

$$P = 2\pi R_{tb}{}^2 \rho \cup_w{}^3 a_1(1-a_1)^2 \text{ ………………..…………………………………….. } (5)$$

The power coefficient for a wind turbine is defined as the ratio of electric power output to the power available in the wind.

The power coefficient. P is then obtained by division of equation

(6) By (2). Hence

$$P_c = \frac{2\pi R_{tb}{}^2 a(1-a_1)^2 \cup_w{}^2}{\frac{1}{2}\rho A \cup_w{}^3} \text{ ………………………………………………………. } (6)$$

By replacing A with $\pi R_{tb}{}^2$, we have

$$P_c = 4a_1(1-a_1)^2 \text{ …………………………………………………………… … } (7)$$

Note that P_c will be a maximum at $a_1 = \frac{1}{3}$

This maximum value of $(P_c = 0.593)$ leads to a maximum value for

P of 0.2965 $\rho A U_w{}^3$, thus confirming equation (3)

Blade element theory is used to provide a relationship between the blade properties, the power produced by the turbine, the axial thrust and the interference factor, a_1 No closed form solutions have been developed that relate all these factors and the usual procedure is to solve the theoretical equations by numerical analysis techniques. (5)

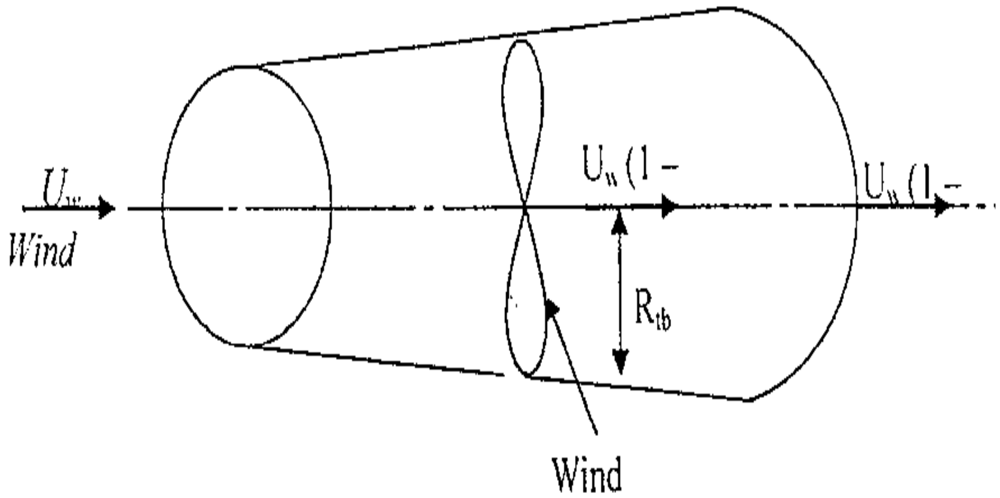

Fig 1: Wind turbine

Turbine tip speed ratio $\left(\frac{wR_{tb}}{U_w}\right)$………………….
…………………………. **(8)**

The actual turbine rated power output may he up to 10% less than predicted due to frictional (mechanical) losses and electrical losses. The output that can be obtained from a well-designed wind turbine is approximately 70% of the Betz limit of 0.2965 pAU^3_w or

$$P_{act} = 0.21\rho A U_w{}^3$$
……………………………………………………………. (9)

C. EXPERIMENTAL PROCEDURES

Wind Speed datum established for eleven years (1993 – 2003). [3,7.8]

Visitation to Federal Meteorological Center. Mushin, World Meteorological Organization, and Shell-Nigeria Web Sites for datum and necessary comparison.

Average wind speed calculated for coastal an offshore area.

Total wind speeds for each year were summed and the average found for twelve month period. Finally the average wind speed for the eleven year period was calculated of both coastal and offshore areas—as shown on pages 9 & 10.

Determination of power output in the wind which is analogous to turbine power.

Equation (3) was used in the calculation of wind power output, which is confirmed by equation (9) turbine power output.

Assumed turbine diameter as 25meters.

- **Costal Area**

YEA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOT	AVR
1993	4.0	4.0	4.0	4.0	4.0	4.0	6.0	5.0	4.0	3.0	3.0	0	48	3.75
1994	4.0	4.0	4.0	4.0	5.0	5.0	4.0	5.0	4.0	4.0	3.0	3.0	48	4.01
1995	4.0	4.0	5.0	4.0	4.0	4.0	5.0	5.0	4.0	4.0	3.0	3.0	49	4.08
1996	4.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0	49	4.08
1997	3.1	3.9	4.5	5.0	3.5	4.0	3.1	3.3	4.0	3.5	2.9	2.9	43.7	3.64
1998	3.6	4.1	3.7	4.1	3.3	4.2	3.7	3.4	4.0	3.1	2.9	2.9	43.0	3.58
1999	3.9	3.7	4.0	3.8	3.6	3.4	2.4	3.0	3.7	3.2	2.4	2.6	39.7	3.31
2000	4.0	4.3	4.0	3.3	3.4	2.7	2.3	4.4	2.9	3.5	3.3	2.1	40.3	3.36
2001	3.7	3.5	3.9	3.6	2.5	2.5	1.5	5.2	2.2	2.0	1.5	2.3	34.4	2.87
2002	1.7	2.4	4.0	3.5	2.5	2.5	2.2	2.5	2.6	2.1	1.3	1.2	20.5	2.39
2003	1.7	2.1	2.2	2.5	2.3	2.3	2.1	2.9	3.1	2.5	2.0	1.6	27.7	2.27

Table 1: Average Wind Speed (m/s) data for Port-Harcourt

- **Offshore area (25 – 40km from shore (3))**

YEA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOT	AVR
1993	6.5	6.7	6.7	6.5	6.6	6.6	7.8	7.7	7.0	5.8	5.8	5.0	85.3	7.10
1994	6.8	7.0	6.7	6.7	6.8	6.8	6.8	7.3	7.0	7.0	5.5	6.5	87.9	7.31
1995	5.6	7.3	7.4	7.0	6.8	6.9	7.2	7.2	7.0	7.1	5.6	6.0	88.3	7.35
1996	6.7	7.5	7.3	7.3	6.5	6.5	6.1	6.1	6.6	6.0	5.8	5.8	78.2	6.52
1997	5.7	6.7	7.2	7.2	6.5	6.5	6.4	6.4	7.0	6.0	6.0	6.0	77.6	6.47
1998	6.6	6.5	6.5	7.0	6.5	7.0	6.9	6.9	7.0	6.0	5.9	59.	85.6	7.13
1999	6.8	6.5	7.0	6.5	6.9	6.6	6.0	6.3	6.3	6.3	5.7	5.6	76.5	6.38
2000	7.1	7.0	7.0	6.4	5.8	5.8	6.8	6.0	7.0	5.7	6.0	5.1	74.7	6.22
2001	5.9	6.9	6.9	6.6	5.8	6.0	6.0	8.1	6.0	6.0	5.5	5.5	75.2	6.27
2002	4.8	5.3	6.9	6.6	5.5	5.5	5.2	6.5	6.0	6.0	5.0	5.1	68.4	5.70
2003	4.6	5.0	4.8	5.2	4.9	5.2	5.2	5.8	51	5.1	4.8	4.8	61.5	5.16

Table 2: Average Wind Speed (m/s) data of Bayelsa

- **Coastal Area**

YEA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOT	AVR
1993	6.0	6.0	6.0	7.0	7.0	6.0	6.0	6.0	5.0	5.0	5.0	6.0	71.0	5.92
1994	6.0	6.0	7.0	7.0	6.0	6.0	6.0	7.0	6.0	5.0	4.6	6.0	72.6	6.05
1995	7.0	7.0	6.2	6.5	6.0	5.0	4.2	5.0	5.0	5.0	4.0	5.0	65.9	5.49
1996	5.4	6.8	6.2	7.5	6.7	6.1	6.1	6.1	5.5	4.5	4.5	4.5	72.1	6.01
1997	6.1	6.7	6.9	6.1	5.1	5.9	5.0	5.9	4.7	4.6	3.4	6.1	66.5	5.54
1998	7.2	5.9	5.1	4.6	4.2	4.5	5.6	7.1	5.2	4.8	5.6	5.8	65.6	5.47
1999	6.7	5.5	7.1	6.7	5.3	5.2	6.2	5.4	4.6	4.6	4.6	5.9	67.8	5.65
2000	6.1	3.9	7.0	5.9	4.9	5.3	5.8	6.0	5.1	4.2	4.9	7.2	66.3	5.53
2001	5.8	4.8	6.3	5.6	4.7	5.4	5.4	4.6	4.7	4.5	5.5	4.5	61.8	5.15
2002	5.8	4.8	6.3	5.6	4.7	5.4	5.4	4.6	4.7	4.5	5.5	4.5	61.8	5.45
2003	5.1	6.8	5.6	5.6	4.6	5.2	6.5	5.6	5.4	4.7	3.9	5.0	64.0	5.33

Table 3: Average Wind Speed (m/s) data for Port-Harcourt

- **Offshore area (25 – 40km from shore (3))**

YEA	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOT**	**AVR**
1993	8.3	8.5	8.5	8.5	9.2	7.9	7.9	8.3	7.9	8.0	8.0	7.3	98.3	8.19
1994	8.6	9.0	9.0	9.2	8.3	8.3	8.6	8.8	8.5	8.1	7.8	7.9	102.1	8.51
1995	9.2	9.2	9.2	9.5	8.5	8.2	7.9	8.3	8.3	8.5	7.8	7.9	102.3	8.53
1996	8.6	8.8	9.6	9.6	9.2	9.0	9.0	8.3	8.5	8.2	7.7	7.7	104.2	8.68
1997	8.7	8.9	9.3	8.8	8.5	8.8	8.0	8.2	7.9	8.0	7.8	9.0	101.9	8.49
1998	9.6	9.0	8.3	8.0	7.8	7.9	8.5	9.3	8.4	8.2	8.0	7.9	100.9	8.41
1999	9.0	8.6	9.1	9.0	7.8	7.8	8.9	8.3	8.1	8.4	8.4	8.8	102.2	85.2
2000	8.6	7.2	9.6	9.0	7.9	8.5	8.8	9.1	8.4	8.0	8.3	9.0	102.4	8.53
2001	8.4	7.9	9.0	8.7	7.9	8.4	8.6	8.1	8.2	8.2	8.7	8.3	100.3	8.36
2002	7.9	8.4	9.4	9.6	9.1	8.9	8.3	8.7	8.2	8.1	8.1	7.6	102.3	8.53
2003	7.8	9.2	9.0	9.0	7.9	8.3	8.9	8.4	8.4	8.2	7.6	8.0	100.7	8.39

Table 4: Average Wind Speed (m/s) data of Bayelsa

IV. RESULTS/DATA ANALYSIS

- **Port- Harcourt**
- Average coastal wind speed $U_{wc} = 3.39m/s$
- Average offshore wind speed $U_{wo} = 6.51m/s$

- **Bayelsa**
- Average coastal wind speed $U_{wc} = 6.07m/s$
- Average offshore wind speed $U_{wo} = 8.47m/s$
- Density of air, $\rho = 1.201kg/m^3$ (5)
- Area normal to wind, $A = \pi d^2/4$
- Wind turbine diameter, d = 25m (assumed)
-

Using equation (3)

Power output of wind, P = 0.2965 $\rho A U^3$

Port-Harcourt

A. COASTAL POWER OUTPUT

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$$P_{cst} = 0.2965\rho \frac{\pi d^2}{4} U_{wc}{}^3$$

$$= \frac{0.2965 \times 1.201 \times 3.142 \times (25)^2 \times (3.39)^3}{4}$$

$$P_{cst} = 6.81KW$$

B. OFFSHORE POWER OUTPUT

$$p_{off} = 0.2965\rho \frac{\pi d^2}{4} U^3{}_{off}$$

$$= \frac{0.2965 \times 1.201 \times 3.142 \times (25)^2 \times (6.51)^3}{4}$$

$$P_{off} = 48.23KW$$

C. BAYELSA

$$P_{off} = \frac{0.2965 \times 1.201 \times 3.142 \times (25)^2 \times (6.07)^3}{4}$$

$$P_{off} = 39.09KW$$

D. OFFSHORE POWER OUTPUT

$$P_{off} = \frac{0.2965 \times 1.201 \times 3.142 \times (25)^2 \times (8.47)^3}{4}$$

$$P_{off} = 106.22KW$$

States	Costal		Offshore		Area Normal wind (m^2)
	Wind speed (m/s)	Power output (KW)	Wind Speed (m/s)	Power output (KW)	
Port Harcourt	3.39	6.81	6.51	48.23	625
Bayelsa	6.07	39.09	8.47	106.22	625

Table 5: Summary of Results Offshore Area Normal

V. DISCUSSIONS

Base on the results shown on table 3 above, the highest power output of 106.22kw (offshore) is from Bayelsa. This coincides with the 10mIs wind speed of power output 174.3kw. (2). in our calculations which may not be accurate, we therefore neglected all losses and other short coming. The power output calculated for PI-l (48.23kw) may be good enough depending on the size of offshore wind turbine used. The higher the size of turbine, the higher the output power of wind. We are therefore convinced that, wind power produced for Bayelsa is good for the 25m diameter wind turbine assumed and if 50meters diameter is used, the power output in the wind can be double or increased to at least minimum requirement. Graph one shows that wind speed is intermittent with the highest speed at 1996, and graph two shows highest output power at the offshore level of 106.22kw.

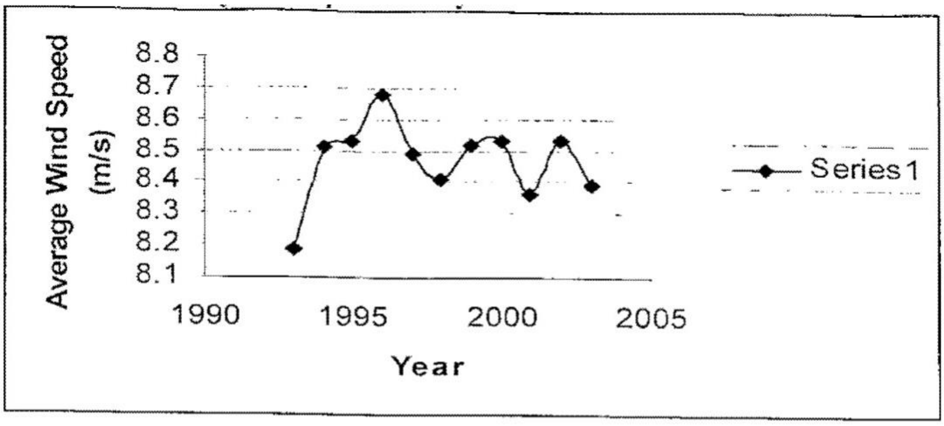
VI. CONCLUSION

Offshore wind farms are possible in areas where the wind capacity is substantial, and all the necessary wind requirement/characteristics are achieved. In the Niger-Delta region, the two sample states experimented shows that energy can be generated using offshore wind mechanism generating substantial amount. Thereby improving the quantity generated by National electric power Authority (NEPA). The cost of Energy can equally be reasonable, depending on the availability of necessary parameters to he used in its determination.

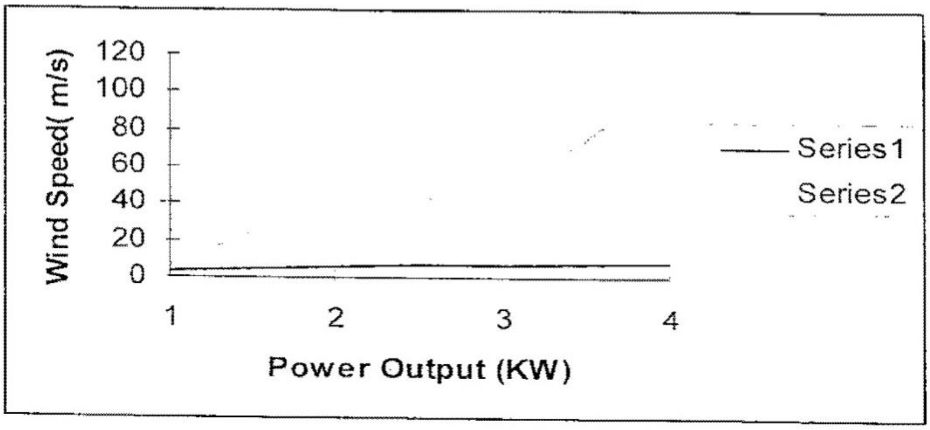
VII. RECOMMENDATION

The energy research institutes in Nigeria should look into the possibility of conducting more and extensive research in order to exhibit accurate experimental results.

Government should allocate special budget in an effort to see to the emergences of offshore wind farm in Nigeria.



Graph 1: Yearly wind speed for bayelsa



Graph 2: Power Output to Wind Speed

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