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Wind power potential and integration in Africa

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Abstract

Wind energy penetration into power networks is increasing very rapidly all over the world. The great concern about global warming and continued apprehensions about nuclear power around the world should drive most countries in Africa into strong demand for wind generation because of its advantages which include the absence of harmful emissions, very clean and almost infinite availability of wind that is converted into electricity. This paper shows the power available in the wind. It also gives an overview of the wind power potential and integration in some selected Africa countries like Egypt, Morocco, South Africa and Nigeria and the challenges of wind power integration in Africa's continent are also discussed. The Northern part of Africa is known to be Africa's Wind pioneers having installed and connected the Wind Energy Converters (WEC) to the grid. About 97% of the continent's total wind installations are located in Egypt, Morocco and Tunisia. Research work should commence on the identified sites with high wind speeds in those selected Africa countries, so that those potential sites can be connected to the grid. This is because the ability of a site to sufficiently accommodate wind generation not only depends on wind speeds but on its ability to interconnect to the existing grid. If these wind energy potentials are tapped and connected to the grid, the erratic and epileptic power supply facing most countries in Africa will be reduced; thereby reducing rural-urban migration and more jobs will be created.

Keywords: Wind power, Power network, Wind potential, Wind integration, Grid, Africa

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1. Introduction

Energy, which is defined as the ability to do work, has a major impact on every aspect of our socio-economic life. It plays a vital role in the economic, social and political development of any nation around the world (www.energy.gov.ng, accessed 14 March 2009). In this 21st century, many countries in Africa continent are still wallowing in abject poverty and have no access to electric power, which has resulted to under-development in most countries in Africa while others are still developing.

The great concern about global warming and continued apprehensions about nuclear power around the world should drive most countries in Africa into strong demand for wind generation because of its advantages which include the absence of harmful emissions, very clean and almost infinite availability of wind that is converted into electricity (Slootweg et al., 2001).

This paper gives an overview of the wind power potential and integration in some selected Africa countries. The challenges of wind power integration in Africa continent will also be discussed.

1.1. What is wind integration?

Wind integration, according to a report on [https://citeseerx.ist.psu.edu Accessed 15 March 2009] is defined as the ability of wind farms to connect to and operate within the distribution supply network in a manner which is compatible with the day-to-day operation of the electricity supply. Wind energy integration is quantified by its penetration and its market share.

1.2. Powers available in the wind

The theoretical power in the wind is given by Muller et al. (2006), Hansen et al. (2002), and Piwko et al. (2005)

$$P_{ae} = \frac{1}{2}\rho\pi R^2 V_{eq}^3 C_p(\theta_{pitch}, \lambda) \quad (1)$$

where P_{ae} is the aerodynamic power extracted from the airflow (Watt), ρ is the air density [typically 1.225Kg/m^3], C_p is the power coefficient which is the fraction of power in the wind captured by a wind turbine, which depends on the pitch angle θ_{pitch} (degree) and on the tip speed ratio, given by

$$\lambda = \omega_{rot}.R/V_{eq} \qquad (2)$$

i.e. it is the ratio between the blade tip speed $\omega_{rot}*R$ and the equivalent wind speed V_{eq} (m/s^2), R is the rotor radius; ω_{rot} *is the rotor speed*. C_p is generally given as 0.59 which means, the 59% of wind power is the maximum power that a wind turbine can utilize.

Equation (1) above shows that the power which a particular wind turbine can extract from wind is a cubic function of the wind speed. This equation also shows that sites with greater wind speeds will generate more power because most wind turbines start generating electricity at wind speeds of around 3-4 meters per second (m/s), (8 miles per hour); they generate maximum 'rated' power at around 15 m/s (30mph); and shut down to prevent storm damage at 25 m/s or above (50mph) [www.bwea.com accessed on 27 June 2009].

2. Current status of wind energy in Africa

2.1. Wind energy integration in Egypt

Egypt is known as the pioneer of wind power integration in Africa. In 2003, a detailed wind atlas was published for Egypt's Gulf of Suez cost, revealed that the region has an excellent wind regime with wind speed of 10m/s. The atlas was expanded in the year 2005 to cover the entire country, indicating that large desert regions both to the east and the west of River Nile, as well as parts of Sinai have average annual wind speeds of 7-8m/s (www.gwec.net, accessed 10 October 2011).

In the mid 80's, a test center with a 52MW demonstration wind farm was built in Hurgada. Since that time to date, wind power integration in Egypt has witnessed a rapid growth. At the end of 2009 as seen from Table 2.1, a total of 430MW wind capacity was installed. A total of 120MW of power was added in 2010 increasing the installed wind capacity to 550MW. This clearly shows that about 57% of the continent's total wind installations are located in Egypt.

Table 2.1. Total Installed wind capacity in Egypt source from [www.gwec.net accessed 10 October 2011].

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
MW	5	5	68	98	145	145	230	310	365	430	550	550

It is very interesting to know that Egypt has the target of producing 20% of its electric power from renewable sources by 2020, and this includes a 12% contribution from wind energy.

2.2. Wind energy integration in Morocco

Morocco has excellent wind resources along the coast line, as well as inland near the Atlas Mountains. Several studies carried out in the past in Morocco, according to gwec.net (accessed 10 October 2011), Benhamou (2006), and medrec.org (accessed 15 November 2011), there are many favourable regions for excellent wind energy potential. The locations with such wind energy integration potentials include regions around Essaouira, Tangier, and Tetouan (with annual average wind speeds between 9.5 and 11m/s at 40m/s) and the areas of Tarfaya Laayoune, Dakhla and Taza (with annual average wind speed between 7.5 and 9.5m/s at 40m height).

It is also important to state here that Saharan trade winds that extend from Morocco through Senegal are known to represent some of the largest wind energy potentials available on earth (Benhamou, 2006). El koudia-El Baida site is also known to have high wind regime, a 50.4-MW wind farm was located at this site and began production in the year 2000. This site has been supplying on average about 1.3% of Morocco's electricity demand (gwec.net, accessed 10 October 2011; Benhamou, 2006).

A smaller 3.5-MW demo wind park called "parc éolien modèle" was built in the same Koudia Al Baida area; 140-MW wind farm was built in the northern part of the country (Tangier); 60 -MW wind farm was built in the center (Essaouira) and 32-MW wind farm was built in Lafarge.

The total wind farm capacity of 286 -MW has been integrated so far in Morocco. The summary of wind energy installed capacity in Morocco between 2004 and 2011 is as shown in Table 2.2.

Table 2.2. Total Installed wind capacity in Morocco Source from [www.gwec.net accessed 10 October 2011].

Year	2004	2005	2006	2007	2008	2009	2010	2011
MW	54	64	64	124	134	253	286	291

2.3. Wind energy integration in South Africa

Wind turbines have been used over many decades in remote areas of South Africa for household electricity generation and agricultural purposes in conjunction with battery storage. South Africa is known to have abundant wind at coast lines. The country wind atlas (iea.org, accessed 28 November 2011) shows the wind speed of 4m/s at 10m height and the west coast has 8.5m/s at a height of 50m. South Africa that has reasonable energy resources which are geographically dispersed to assist security supply, has at present only one 10-MW Darling commercial-scale wind farm in operation. The integration rate of this energy resource is rather too slow in this country. Research works should be on in order to integrate large-scale wind power to the grid most especially in the coastal areas.

2.4. Wind energy potential in Nigeria

Wind Energy has been used in the Northern part of Nigeria to pump water from open well for domestic and irrigation purposes. It has also been used for electricity production for rural community, for example, in year 1998, a 5-kW wind electricity conversion system for rural electrification was installed at Sayyan Gidan Gada, in Sokoto State, Nigeria [www.renewablenigeria.org Accessed 13 July 2009]. This was not connected to the grid!".

This is yet to be connected to the grid! According to [Lahmeyer (International) Consultants 2005 *Report on Nigeria wind power mapping projects, Federal Ministry of Science and Technology Pp 37-51)*], "wind energy reserve in Nigeria at 10m (or 40m) height based on data analyzed for ten wind stations cutting across North West, North East, North Central, South East and South West geopolitical zones shows that some sites have wind regime ranging between 1.0 and 5.1m/s (1.0 and 6.3m/s) depending on the particular stations". This confirms that Nigeria falls into the moderate wind regime.

Table 2.3 shows the data of wind energy resources mapping for ten (10) sites in Nigeria including those from Sokoto collected from on ground measurement carried out between May 2004 and May 2005 by Lahmeyer International. It can be seen from the table that the sites are potential wind farm areas. This is because most wind turbines start generating electricity at wind speeds of around 3-4 meters per second (m/s) (bwea.com, accessed on 27 June 2009). The bar chart corresponding to Table 2.3 is shown in Figure 2.1

It was reported that offshore areas from Lagos State through Ondo, Delta, Rivers, Bayelsa to AkwaIbom states also have potentials for harvesting strong wind energy throughout the year. Detailed wind speed measurements carried out in Nigeria in some hilly and coastal areas have shown an excellent wind potential for implementation of wind farms in those areas. Also in a study carried out in Twenty-two stations on the wind energy density estimate at 25m height showed that Sokoto and Jos respectively have the annual wind energies from wind turbine of 97,035.94 kWh and 94,559.98 kWh (renewablenigeria.org, accessed 13 July 2009). These Figures are also in agreement with Ojosu and Salawu's survey of wind energy potentials in Nigeria (Ojosu et al., 1990).

A number of authors including Sambo (2009), Agbele (2009), and Ogbonnaya et al. (2006) recommended based on the wind speeds, that these potential wind farm areas should be connected to the grid even at distribution level. The Director General of Energy commission of Nigeria in a Paper presented at International Association for Energy Economics Third quarter 2009 (Sambo, 2009) still lamented that these renewable Energy resources most especially wind have not been integrated to the Nigeria grid.

It is very sad, that up till the time of writing this paper, Nigeria, where the wind power prospect is estimated to be high or moderate has not connected this renewable resource to the grid.

Table 2.3. Showing ranking of the wind speed at various measurement stations in Nigeria (Lehmeyer International, 2005).

Site ID	**Site Name**	**Measured mean wind speed at 30m Height (m/s)**
Sok 01	Sokoto/Badaga	5.4
Jos 01	Jos Airport/ Kassa	5.2
Gem 01	Gembu/Mambila plateau	5
Pan 01	South part of Jos plateau/Pankshin Hotel	5
Kan 01	Kano/ Funtua	4.9
Mai 01	Maiduguri/mainok	4.7
Lag 01	Lagos/ Lekki Beach	4.7
Enu 01	Enugu/Nineth mile corner	4.6
Gum 01	Gumel/ Garki	4.1
Ibi 01	Ibi metrological station	3.6

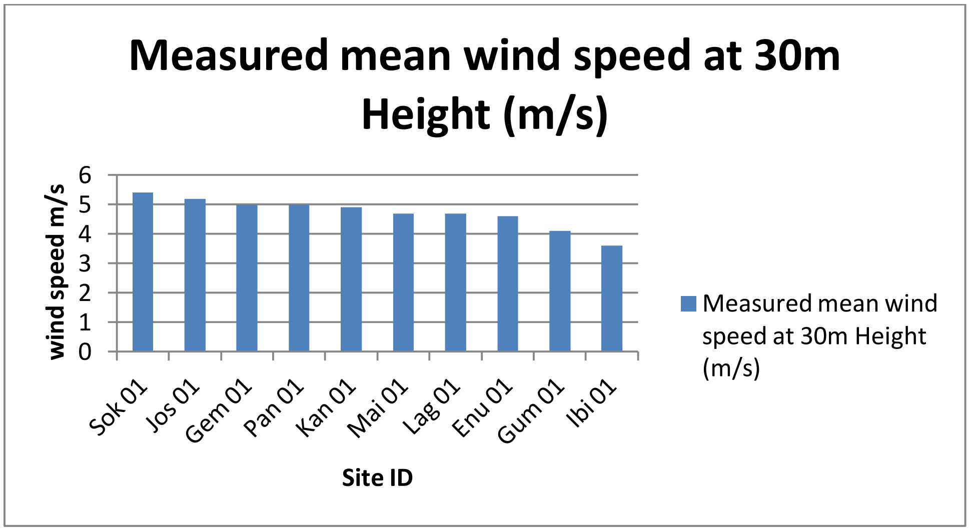

Figure 2.1. Column chart showing the ranking of the wind speed at various stations

At the end of 2010, China for example, is leading the world having installed 44,733MW wind power capacity followed by USA having installed 40,180MW connected both at the Sub-transmission and Distribution levels (www.gwec.net, accessed 10 October 2011).

Table 2.4 below shows the summary of wind power capacities in the Middle East and in Africa at the end of 2011. The column chart of Table 2.4 is as shown in Figure 2.2.

Table 2.4. Operational wind power capacities in the Middle East and in Africa at the end of 2011Source from [www.gwec.net accessed 10 October 2011].

Country/Region	Installed Capacity in MW
Egypt	550
Morocco	291
Iran	92
Tunisia	114
Cap Verde	12
South Africa	10
Israel	8
Kenya	5
Others	4
Total	1086

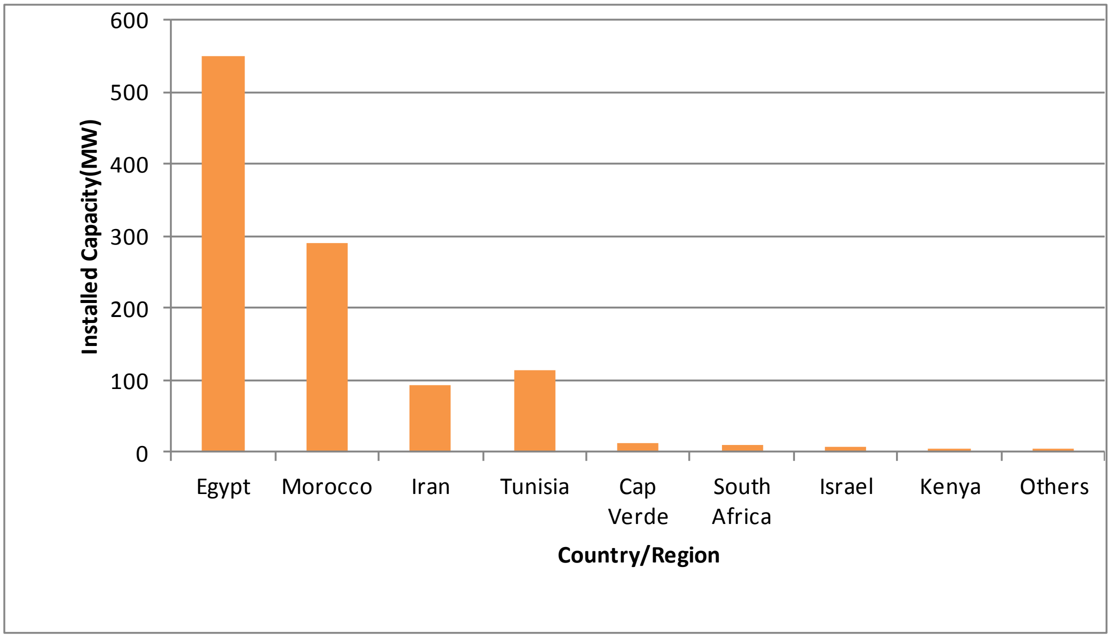

Figure 2.2. wind capacities in Middle East and Africa

3. Remaining challenges

Below are some of the challenges of wind energy in Africa:

- Lack of tailored renewable energy policy, legal and regulatory frameworks in most countries in Africa.
- No adequate financial incentives or funding for renewable energy development in Africa.
- Low capacities and renewable energy knowledge base of key groups in public and private sectors.
- Lack of reliable and detailed wind resources information or wind map.

4. Conclusion

Many countries in Africa continent are endowed with untapped wind energy resources most especially in their coastal areas. Saharan trade winds that extend from Morocco through Senegal represent some of the largest wind energy potentials on earth. Having identified some sites with high wind speeds in those selected Africa countries, research work should be encouraged on how the potential sites can be connected to the grid. This is because the ability of a site to sufficiently accommodate wind generation not only depends on wind speeds but on its ability to interconnect to the existing grid. If these wind energy potentials are tapped and connected to the grid, the erratic and epileptic power supply facing most countries in Africa will be reduced; thereby reducing rural-urban migration and more jobs will be created. Tailored renewable energy policy and regulatory frameworks should be encouraged in most countries in the continent.

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