2nd International Engineering Conference (IEC2017)
Federal University of Technology, Minna, Nigeria

Wind Energy: The Future for Nigeria

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ABSTRACT
The situation of electricity in Nigeria can be described as erratic with no sign of improvement in the nearest future. This power condition affects the manufacturing, service providers and residential sectors of the economy which in turn affects the country's economic growth; however, there is abundance of untapped wind energy in the country that could help to compensate for the epileptic condition of electricity. This paper tends to address the research question: what is the way forward for the Nigerian poor electricity situation? Wind energy was therefore reviewed and it was discovered that wind speed in Nigeria ranges from 4.0 to 6.0 m/s in the northern part of the country and 2.5 to 4.0 m/s in the southern part of the country. With the amount of wind energy potential in these regions, small scale wind turbine installation could be a viable means to boost electricity.

Keywords: *Economic Growth, HAWT, Renewable Energy, VAWT, Wind Energy, Wind Turbine.*

1 INTRODUCTION

The role of energy on socio-economic life cannot be overemphasized. As the country's population increases and the standard of living set high, there is an ever growing demand for energy (Felix *et al*., 2012). The situation of electricity in Nigeria can be described as unreliable with no sign of improvement in the nearest future. The electricity condition affects the production, service providers and housing sectors of the economy which also affects the country's economic process. In spite of the recent reforms in the power sector, over half of the country's populations still have no access to electric power. This unreliable situation of the power sector can be ascribed to the insufficient and unproductive power plants, poor transmission and allocation facilities, and obsolete metering system used by electricity consumers. In Nigeria, electricity is the backbone of its growth and development with roles in the nation's manufacture of goods and services in the industrial sector as well as agriculture, health and education (Vincent & Yusuf, 2014).

Although hydropower (large and small scale) has been contributing significantly to the total electricity generation among the renewable sources deposited in Nigeria, its contribution to the total energy mix is experiencing a decreasing trend (Ohunakin, 2011) as shown in Figure 1. However, there is abundance of untapped wind energy in the country that could help to compensate for the inconsistent condition of electricity. Wind energy is one of the fastest growing technologies in renewable energy generation industry nowadays. The epileptic state of power in Nigeria and the concern about global warming should be a great concern for all and should drive us into strong demand for wind energy generation. Also, since the price of oil is unstable and fluctuating on a daily basis and grid expansion is not also a cost effective solution, integrating renewable energy sources thus become an important alternative for rural electrification (Olatomiwa *et al.,* 2015). The main advantages of electricity generation from wind are the absence of harmful emissions, very clean and the almost infinite availability of the wind that is converted into electricity (Felix *et al*., 2012). Therefore, this paper tends to address the research question: what is the way forward to the Nigerian unfortunate electricity condition? In order to answer the above question, the paper reviews the current electricity division in Nigeria and compares with the electricity abroad.

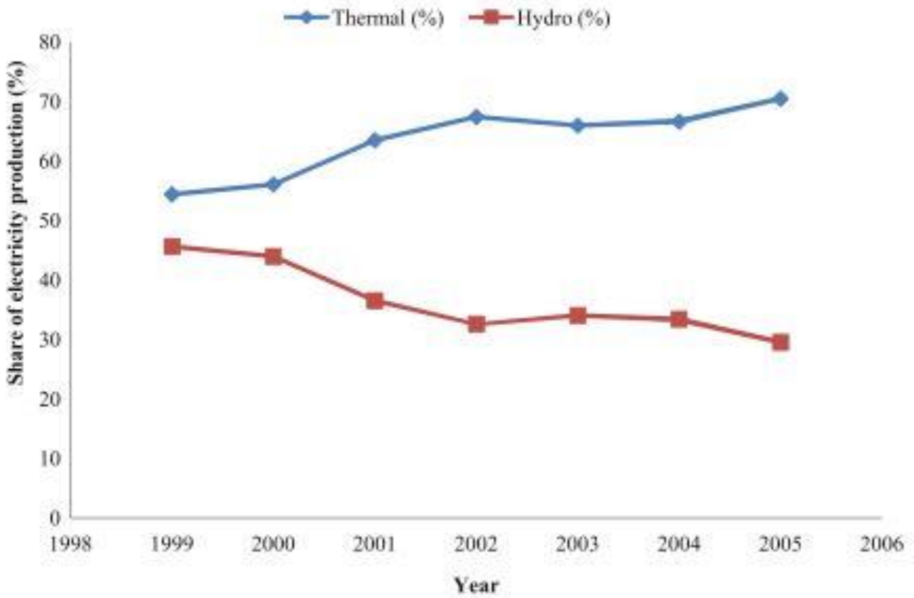


Figure 1: Thermal and hydro-power input to total electricity production in Nigeria between 1999 and 2005. **Source: (Ohunakin, 2011)**

1.1 GEOGRAPHY OF NIGERIA

Nigeria is situated in the western region of Africa and is bordered (as shown in Figure 2) by The Gulf of Guinea to the South, Niger in the Northern part, Cameroon in the East and Benin Republic to the West. Nigeria's land area is 923,768 km^2 (Charles & Meisen, 2014). The most populous country in Africa is Nigeria, with about 170 million people. The climatic condition all through the year is usually favorable but varies, thanks to Nigeria's prime location along the equator. Nigeria is also endowed with abundant deposits of oil, natural gas and other natural resources. She is the largest oil manufacturer in Africa as well as has the largest gas reserve. Petroleum has been the stronghold of Nigeria's economy since its discovery (Charles & Meisen, 2014).

Figure 2: Nigeria Map showing Boundaries. **Source: (Charles & Meisen, 2014)**

Nigeria also has enormous potential in the renewable energy field especially in hydropower generation for the reason of that of her prime location with access to 840 km coastline in the South and two great rivers entering from the Northeast and Northwest. The northern part of Nigeria is also very close to the Sahara, and so the region is exposed to intense sunlight and medium wind for substantial power generation (Charles & Meisen, 2014).

2 HISTORY OF WIND ENERGY

2.1 WIND ENERGY IN EARLY ERA

Wind power was first used to sail ships in the Nile some 5000 years ago. The Europeans used it to grind grains and pump water in the 1700s and 1800s. The first windmill to generate electricity in the rural U.S.A. was installed in 1890 (Patel, 1999). The first wind energy systems (Ancient Civilization in the Near East/Persia) consisted of a vertical-axis wind-mill (as shown in Figure 3a.) connected to a vertical shaft which was usually connected to a grinding stone for milling. In the middles ages, Post mill (Figure 3b.) was first introduced in Northern Europe; this consisted of sails connected to a horizontal shaft on a tower that encases a set of gears and axles, solely for changing horizontal motion into a rotational motion. In the 19th century in US, Wind-rose horizontal-axis water-pumping wind-mills (Figure 3c.) were found throughout rural settlements in America (Kalmikov & Dykes, 2010).

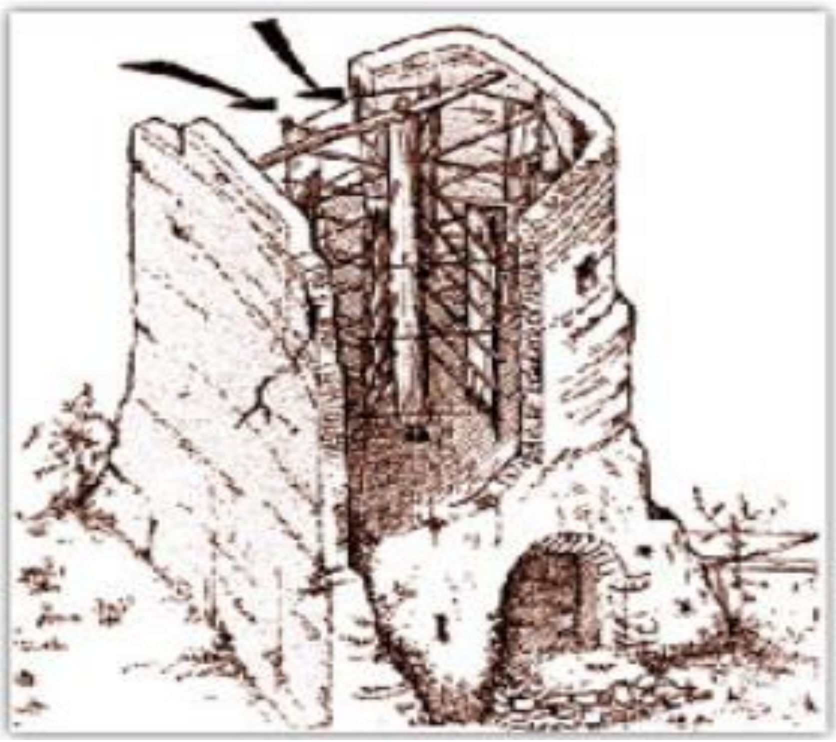


Figure 3(a): Wind-Mill Near East/Persia. **Source: (Kalmikov & Dykes, 2010)**

Figure 3(b): Northern Europe Wind-Mill. **Source: (Kalmikov & Dykes, 2010)**

Wind powered electricity began in the 19th century and had gained popularity by the turn of the century. In 1888, Charles Brush built the first large-wind electricity generation turbine; it was a 17m diameter wind rose configuration with a generating capacity of 12kW. The propeller-type 2 & 3 blade horizontal-axis wind electricity conversion systems became popular in the 1920s-1950s (Kalmikov & Dykes, 2010).

Figure 3(c): 19th Century Wind-Mill in US. **Source: (Kalmikov & Dykes, 2010)**

2.2 WIND ENERGY IN MODERN ERA

This era began in the 1970s shortly after the OPEC (Oil Producing and Exporting Countries) crisis. The key attributes of this period according to (Patel, 1999) includes:

- Increased scale of power output;
- Commercialization;
- Competitiveness;
- Grid integration

The other catalysts for progress during this era apart from the 1970s OPEC Crisis are economics, energy independence and environmental benefits. Turbine designs became standardized—3-blade Upward Horizontal-Axis on a monopole tower—during this period (as shown in figure4). Today, large wind-power plants are competing with electric utilities in supplying economical clean power in many parts of the world (Patel, 1999).

3.0 CURRENT ELECTRICITY SITUATION IN NIGERIA

Commercial electricity generation in Nigeria currently comes from seven power stations and various independent power projects that spread around the country (Obadote, 2009). The problems hindering constant electricity supply in Nigeria are numerous. These problems range from generation to transmission to distribution and marketing.

Figure 4: Modern Era Horizontal Axis Wind Turbine. **Source: (Patel, 1999)**

The problems will be reviewed in the following sub-sections.

3.1 GENERATION

The total installed capacity of the currently generating plants in Nigeria is 10,396.0 MW, but as at December 2013, the available capacity is less than 6056 MW. Seven of the twenty-three generation stations are over 20 years old and the average daily power generation is lower than the peak forecast for the current existing infrastructure (Ajayi, 2010). The current status of power generation in Nigeria presents challenges through the planned generation capacity projects for a brighter future, such as inadequate generation availability, delayed maintenance of facilities, inadequate funding of power stations, outdated equipment, tools, safety facilities and operational vehicles, obsolete communication equipment, lack of exploration to tap all sources of energy from the available resources and low staff motivation (Vincent & Yusuf, 2014).

3.2 TRANSMISSION

The current electricity transmission system in Nigeria contains 5523.8 kilometer of 330 kV, 6801.49 kilometer of 132 kV, 32No. 330/132 kV Substations with total put in transformation capability of 7688 MVA (Shehu & Abdul, 2015). 105No. 132/33/11 kV Substations with total installed transformation capability of 9130 MVA. The typical obtainable capability on 330/132 kV is 7364 MVA and 8448 MVA on 132/33 kV (Patrick, et al., 2013). Due to the very long transmission lines, the Nigeria 330 KV transmission grid is characterized by high power losses. Some of these lines include Benin—Ikeja West (280 km), Oshogbo—Benin (251 km), Oshogbo—Jebba (249 km), Jebba—Shiroro (244 km), Birnin Kebbi—Kainji (310 km), Jos—Gombe (265 km) and Kaduna—Kano (230 km) (Patrick *et al*., 2013). Power losses result in lower power availability to the consumers, leading to inadequate power to operate the appliances. Thus, the high efficiency of the power system is determined by its low power losses (Sunday and Friday, 2010). Increased power demand pushes the power transmission and distribution networks to their upper limits and beyond, causing shortening of the life span of the network or total collapse (Sambo *et al*., 2003). The map of the Nigerian national grid system is shown in Figure 5.

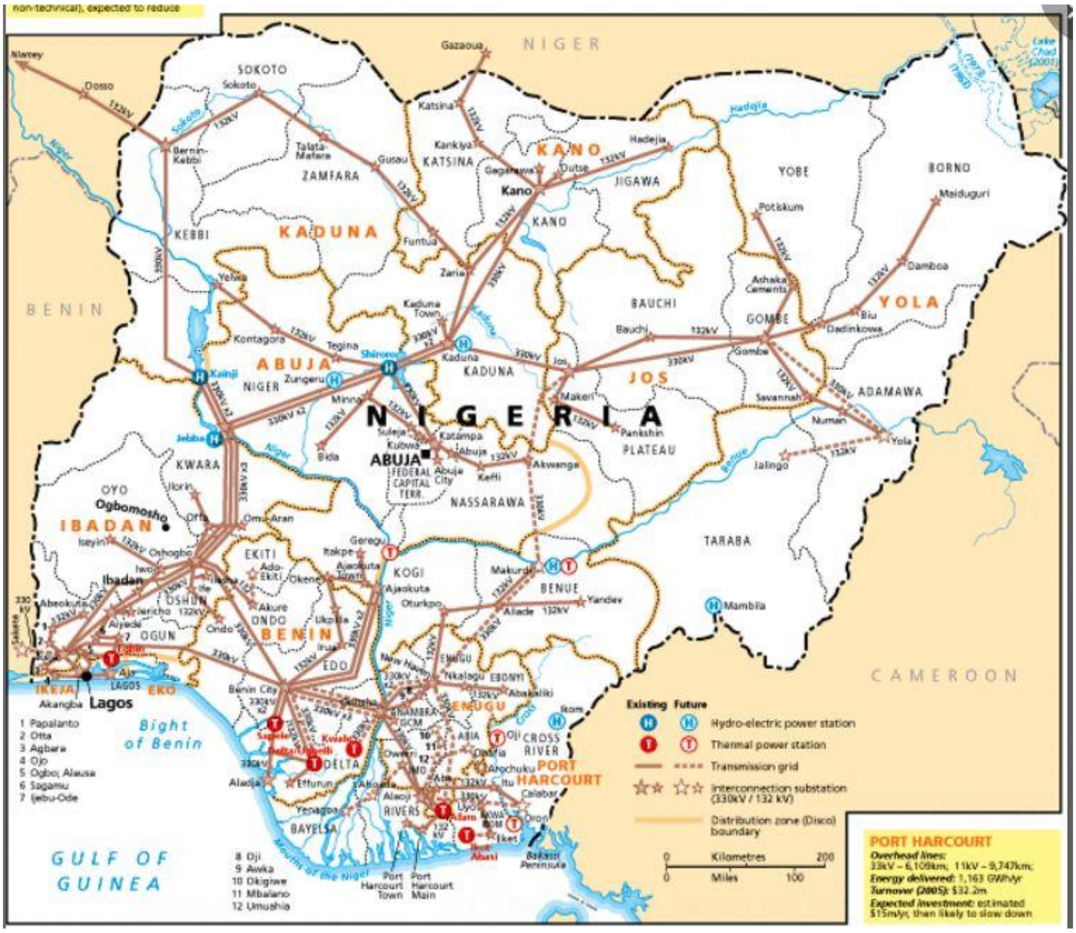


Figure 5: The Nigerian National Grid System. **Source: (Vincent &Yusuf, 2014)**

3.3 DISTRIBUTION AND MARKETING

In most areas in Nigeria, the distribution system and the voltage profile is poor; and the billing is also inaccurate. As the department which interfaces with the public, the need to guarantee sufficient network coverage and provision of excellent power supply, in addition to competent marketing and customer service delivery cannot be over emphasized (Patrick, *et al*., 2013). Inadequate and weak network coverage, congested transformers and bad feeder pillars, inferior distribution lines, poor billing system, questionable practices by staff and very poor customer rapport, to mention a few are some of the challenges associated with distribution and marketing (Vincent & Yusuf, 2014).

4.0 CONNECTION BETWEEN ENERGY AND ECONOMIC GROWTH

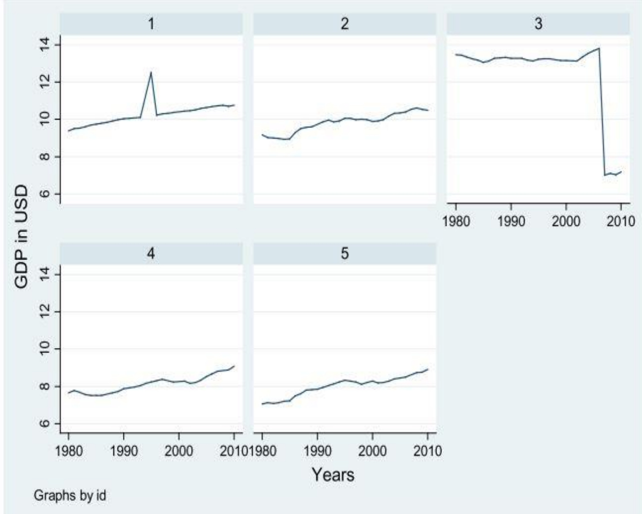
The inflated price of accessing energy and also the effects on economic process (GDP) across regions is one among grave concern (Ojeaga, *et al*., 2014); additionally, the priority over the assembly of adequate and sustainable electricity to drive economic developments may be an international issue. Though the traditional sources of fuel burning are ready to manufacture surplus quantity of energy, its finite nature may be a concern for the longer term (Nze-esiaga & Okogbue, 2014).

An important issue for socio-economic development and economic process of a nation is energy. Energy is typically stored in energy system that provides energy services. Energy services are desired and helpful product, processes or services that result from the employment of energy like lighting, powering of home-based appliances like air-conditioner, refrigerators, and cookers for preparation. The energy chain to deliver these cited services begins with the gathering or extraction of primary energy that is regenerated to energy carriers appropriate for the ultimate customers. These energy carries are utilized in energy end-user technologies to supply the specified energy services. Nigeria's chance to enhance the quality of living for its citizens, making certain socio-economic and political growth depends on the nation's ability to extend energy offer and correct utilization of its energy resources ranging from the grassroots level. Renewable energy technology has great potentials in assuaging the staggering energy situation presently being experienced in Federal Republic of Nigeria (Emodi *et al*., 2014).

4.1 IMPORTANT FACTS ON ENERGY SECURITY IN AFRICA COMPARE WITH OTHER REGIONS

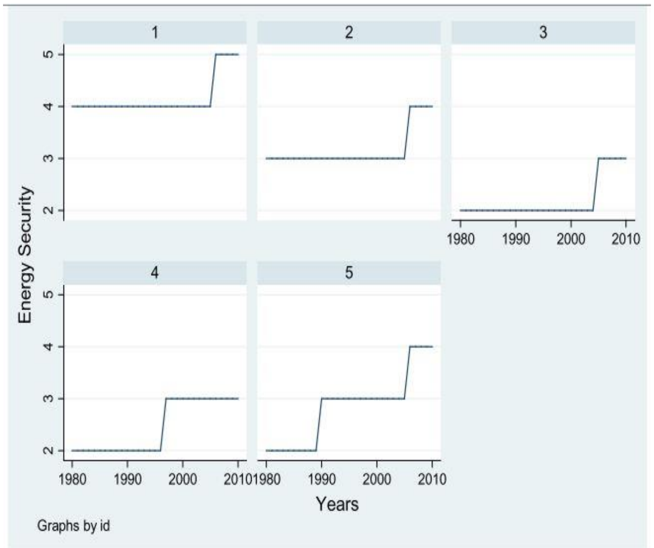
In this section, the stylized facts on energy security and growth across regions are presented. World energy generation capability is on the rise, with output energy in Asia seemingly to surpass total generation in Europe and North America by 2040 that growth across regions is on the rise aside from Africa (as shown in Figure 6), whereas growth is on the rise in North America, European, Union, geographical area and South East Asia (Ojeaga *et al*., 2014). Most countries in Africa stay poor despite Despite been endowed with enormous natural resources, Africa also remains overwhelmed with poor governance and weak institutions making many policies not to have any effect on growth and economic development in the region. Regions which include Europe, Latin America and

sustained commodities high costs within the international market. In several countries that are experiencing growth in Africa the expansion is additionally not inclusive (Ojeaga *et al*., 2014).



Note: The graphs above show trends for North America, Europe, Africa, Latin America and South East Asia respectively.

Figure 6: Trends of Regional GDP. **Source: (Ojeaga *et al*., 2014)**



Note: The graphs above show trends for North America, Europe, Africa, Latin America and South East Asia respectively.

Figure 7: Energy Security Trends across Regions. **Source: (Ojeaga *et al*., 2014)**

South East Asia are experiencing significant growth; Trends also show that energy security is also low for Africa as shown in Figure 7, depicting poor implementation of the Kyoto Protocol as well as an under developed energy sector plagued with high energy supply and distribution disruptions. Issues associated with the cost implications of developing energy plants is also a problem in many African countries with poor income (Ojeaga *et al*., 2014).

5.0 WIND ENERGY RESOURCES IN GEOPOLITICAL ZONES OF NIGERIA

According to National Bureau of Statistics (2013), Nigeria comprises of six geo-political zones (Figure 8) with overall land mass of 923.769 sq. km (98.5% highland and 1.5% lowland). United Nation also observed in 2014, that the proportion of rural inhabitant in Nigeria is about 50.4% with meager 36% of these inhabitants having access to electricity, and the greater part with less than 4 hour/day. Works carried out in the various zones were reviewed.

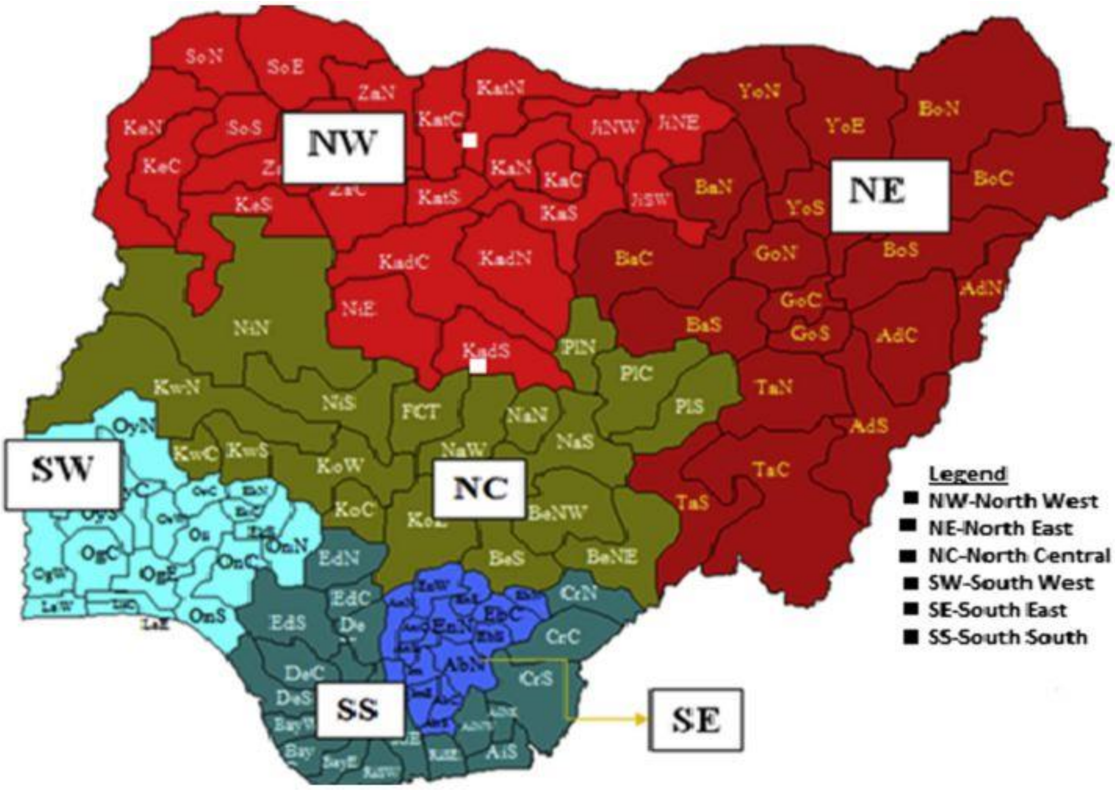


Figure 8: Nigeria Map Displaying Her Six Geopolitical Zones. **Source: (Olatomiwa *et al.*, 2016)**

Wind is associated to the movement of air masses caused by the different solar heating of the earth's surface. Seasoned variations in the energy received from the sun affect the strength and direction of the wind (Ohunakin, 2011). The ease in which aero turbines convert energy within the moving air to rotary energy suggests the utilization of electrical devices to convert wind energy to electricity. For many years, wind has been used for water pumping and milling of grains. Wind speed in Nigeria ranges from 4.0 to 6.0 m/s in the northern part of the country and 2.5 to 4.0 m/s in the southern part of the country (Felix *et al*., 2012), as shown in Figure 9.

In 2011, Ohunakin conducted a research based on wind speed data taken at 10m height, obtained from five (5) meteorological stations (Geographical coordinates given in table 1.) in the North-East geopolitical zone of Nigeria, namely, Bauchi, Nguru, Maiduguri, Yola and Potiskum.

TABLE 1: GEOGRAPHICAL COORDINATES OF NORTH-EAST ZONE. **Source: (Ohunakin, 2011)**

Station	**Latitude ° N**	**Longitude ° E**	**Elevation (m)**
Bauchi	10.17	09.49	609.7
Nguru	12.53	10.28	343.1
Maiduguri	11.51	13.05	353.8
Potiskum	11.42	11.02	186.1
Yola	09.14	12.28	414.8

He then carried out statistical analysis to inspect the monthly and seasonal disparity of the wind characteristics. Wind data at 50m hub height were therefore gotten by extrapolating the 10m data by means of the power law. The results showed Bauchi and Maiduguri to be the most excellent sites amongst the five locations with monthly average wind speeds in the range of 3.96 to 7.04m/s and 4.49 to 6.10m/s respectively; the monthly average power density varies from 61.33 to 299.88W/ m^2 and 63.80 to 173.70W/m^2 in that order, followed by Potiskum recording monthly mean wind speed ranging from 3.92 to 5.68m/s; and an average power density between 53.82 and 150.84W/ m^2 in April and June.

A study was also conducted by Ohunakin *et al.,* in 2011, to statistically examine wind characteristics from seven meteorological stations (Geographical coordinates given in table 2.) within the North-West (NW) geo-political region of Nigeria using 36-year (1971–2007) wind speed data, measured at 10m height and subjected to 2-parameter Weibull analysis.

It was observed that the monthly mean wind speed in this region ranges from 2.64 m/s to 9.83 m/s. The yearly wind speeds ranges from 3.61 m/s in Yelwa to 7.77 m/s in Kano. It was further revealed that Sokoto, Katsina and Kano are appropriate locations for wind machinery installations because of annual mean wind speeds of 7.61, 7.45 and 7.77 m/s, respectively. The results also suggested that Gusau and Zaria should be appropriate for wind energy exploration using taller wind turbine towers due to their particular annual mean speeds and mean power density; while Kaduna was considered as marginal. In addition to this, higher wind speeds were noted in the morning hours than afternoon periods for this location.

TABLE 2: GEOGRAPHICAL COORDINATES OF NORTH-WEST ZONE. **Source: (Ohunakin *et al.*, 2011)**

Station	**Latitude ° N**	**Longitude ° E**	**Elevation (m)**
Yelwa	10.53	04.45	244.0
Zaria	11.06	07.41	110.9
Sokoto	12.28	04.13	220.0
Gusau	12.10	06.42	463.9
Kaduna	10.36	07.27	645.4
Katsina	13.01	07.41	517.6
Kano	12.03	08.12	472.5

Olatomiwa *et al.*, in 2015 and 2016 conducted a study on the assessment of wind energy in six selected locations from each geo-political zone of Nigeria. The locations were: Iseyin, Sokoto, Maiduguri, Jos, Enugu, Port-Harcourt. The research was based on long-term daily meteorological data spanning between 18 and 39 years; and results from the research showed that Sokoto and Jos are situated in the high wind potential regions, while the remaining sites are only suitable for small scale wind applications (Olatomiwa *et al*., 2016).

With this amount of wind energy potential in these regions, small scale wind turbine installation could be a viable means to boost electricity supply and also be integrated into the national grid. Also, a 10 MW wind turbine is currently installed in Katsina state to tap into the wind energy potentials in northern Nigeria; more effort should be put in to adequately harness the wind energy potential in Nigeria (Emodi *et al*., 2014).

The wind potential sites for grid tie electrification in northern region such as Sokoto, Katsina, Nguru, Gusua, Birnin Kebbi, Maiduguri, Zaria, Potiskum, Cashua, Hadejia and Kaduna have been identified and should be explored for medium-scale energy conversion at a higher altitude above ground level (Emodi *et al*., 2014). The geographical locations such as Lagos, Ogun, Oyo, Osun, Ekiti and Ondo states are poor wind regime and unsuitable for wind energy application based on the wind flow study conducted for 10 years period (Olaofe, 2015).

Figure 9: Wind Energy Locations in Nigeria. **Source: (Emodi *et al*., 2014)**

6.0 TYPES OF WIND TURBINE

There are mainly two wind turbine types (related to the rotating axis position in respect to the wind): Vertical Axis Wind Turbine (VAWT) and Horizontal Axis Wind Turbine (HAWT).

Horizontal Axis Wind Turbines (HAWT): The rotating axis of this turbine must be positioned parallel to the wind in order to generate power (see Figure 10). Numerous sources claim a major efficiency per same swept area and the majority of wind turbines are of this type (Castillo, 2011).

Vertical Axis Wind Turbines (VAWT): the rotational axis is perpendicular to the wind direction or the mounting surface as shown in Figure 11. The main advantage is that the generator is on ground level so they are more accessible and they don't need a yaw system. Because of its proximity to ground, wind speeds available are lower (Castillo, 2011).

6.1 COMPONENTS OF A WIND TURBINE

The nacelle contains the key components of the wind turbine, including the gearbox, and the electrical generator (Patel, 1999).

The tower of the wind turbine carries the nacelle and the rotor, as shown in Figure 12. Generally, it is a plus to possess a high tower, since wind speeds increase faraway from the ground. The rotor blades captures the energy from the wind and transfer its power to the rotor hub. The generator does the conversion of mechanical energy to electrical energy. The gearbox increases the rotational speed of the shaft for the generator (Patel, 1999).

Figure 10: Horizontal Axis Wind Turbine. **Source (Patel, 1999)**

Figure 11: Vertical Axis Wind Turbine. **Source: (Patel, 1999)**

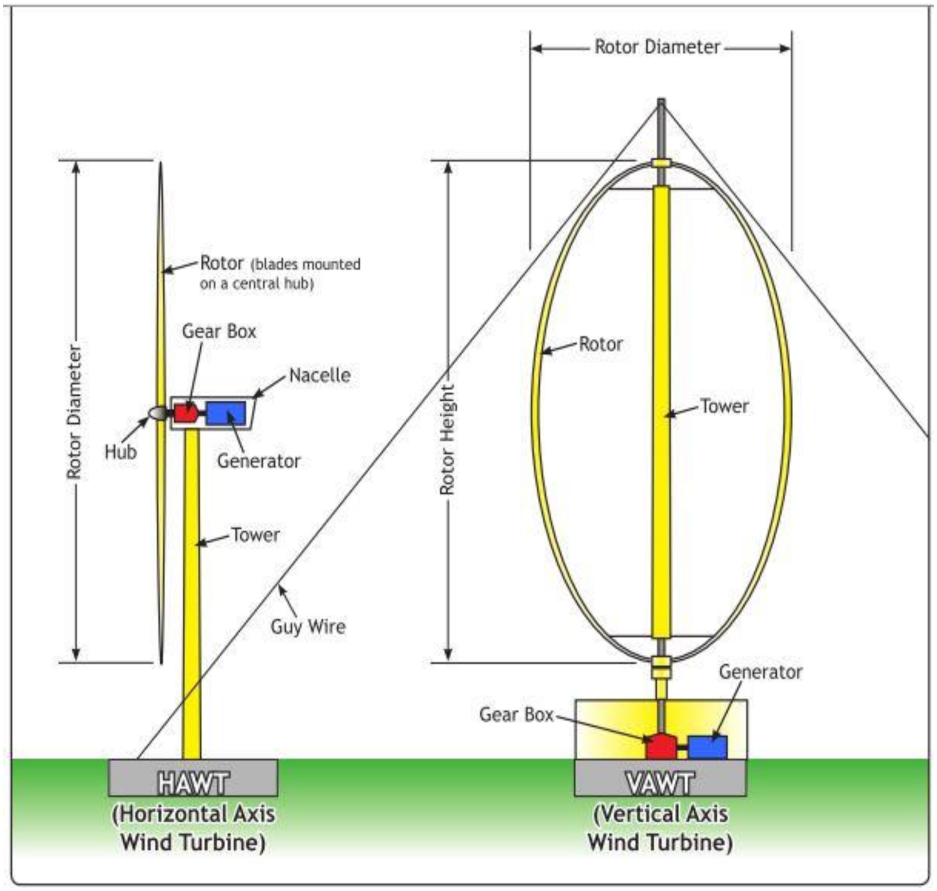


Figure 12: Intricate Parts of Wind Turbines. **Source: (Patel, 1999)**

7.0 CONCLUSION AND RECOMMENDATIONS

Overdependence on fossil supply sources is an issue Nigerian Government should take serious. Developed nations were found to depend more and more on renewable energy sources; this could have strong implications for developing country like Nigeria with low income since renewable energy sources are likely to be cheaper and a more reliable means to generate energy with minimal environmental pollution and degrading consequences. Improving energy security in Nigeria through diversifying generation could also mean improvements in economic growth.

The wind potential sites for grid-tie electrification in northern region of Nigeria such as Sokoto, Katsina, Nguru, etc, have been identified and should be explored for medium-scale energy conversion at a higher altitude above the ground level. The geographical locations such as Lagos, Ogun, Oyo, Osun, Ekiti and Ondo states are poor wind regime and unsuitable for energy application based on the wind flow study conducted over a period of time.

It is highly recommended that both the private and government sector of Nigeria should venture into wind energy as a means of electrification, since improving energy security through diversification of power generation could lead to an improved economy.

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