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Assessment of Wind Energy Alternative in Nigeria from the Lessons of the Katsina Wind Farm

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1.0 Introduction

The harnessing of kinetic energy through the wind has been used for centuries, be it in form of powering sail boats, windmills or furnaces. However it was not until 1979 that the modern wind power industry began in earnest with the production of wind turbines. The use of wind energy as a form of renewable energy gained momentum in the 80s and 90s and there are now thousands of wind turbines operating all over the world (Abdelaziz et al 2011; Fangbele et al 2011).

The modern and most commonly used wind turbine has a horizontal axis with two or more aero-dynamic blades mounted on the shaft. These blades can travel at over several times the wind speed, generating electricity which is captured by a medium voltage power collection system and fed through to the power transmission network.

Wind farms can range from single turbines for domestic use, through to large commercial farm either onshore or off-shore. The energy emitted is measured in watts per hour (kilowatts, megawatts and gigawatts), the turbines currently in manufacture have power ratings ranging from 250kW to 5MW. To put that into perspective, a 10kW turbine will generate enough electricity generation to meet the annual electricity consumption of an average house hold in the US or 10 rural villages in Nigeria. Regardless of the size of the farm, the placement of the turbine is the key to its success.

Wind farms are often opposed and refused planning permission, due to general belief that they ruin the natural environment; in very remote locations, there may be a lack of available transmission lines, protected fauna that may be displaced by the farm, not to mention the difficulties in transporting the turbines to the site in the first instance. Despite its setbacks, wind power is still seen to be cheap, low maintenance form of renewable energy which makes it imperative for Nigeria to adopt among its energy mix (Kwon 2010).

The study area is in Katsina State of Nigeria. Katsina State extends from the arid southern Sahara (where there are important towns such as Jibiya, Katsina, Maiadua and Daura), Southwards through the semi-arid dry lands (with important towns like Dutsin-ma and Kankia) to the semi-arid savannah (with important towns like Malunfashi and Funtua). These settlements mentioned could be placed on an effective wind energy alternative for domestic electricity generation. The Katsina wind project could achieve this but there are several misgivings from the critics of the project. This chapter is intended to review the factors considered necessary in setting such a project i.e project's cost, wind penetration, wind predictability, wind reliability and energy storage. The objective of the research was to assess the extent at which these factors were considered in the project.

2.0 The 10mw Katsina Wind Project

The Katsina wind farm project is owned by the federal ministry of power, this is also the pioneer project aiming to generate 10MW of power through wind turbine with the federal Government desire to improve electricity supply in Nigeria for the actualization of constant power supply.This renewable source (wind) energy project will go a long way in actualizing this target in view of its low cost of maintenance and thereby complementing the already deteriorating non-renewable plants in the country.The contract was awarded to a French contractor Vergnet S.A Engineering company as EPC contractor and also OTIS Engineering /Terrawatts were jointly contracted as consultancy firm to supervise the project. The project is sited at LambaRimi in Rimi local government area of Katsina state in Nigeria where high yield of wind was observed during the feasibility study (Ajayi et al 2011a; Burton et al 2001).

The Katsina 10MW wind farm consists of 37N0 wind turbines with a rated power of 275KW each. The hub height of the turbine is 55M due to two reasons one of which is from the design brief where a medium scale turbines is recommended and the rotor diameter of medium scale ranges from 12m to 45m with a power rated of40KW to 999KW (Gipe 1999).Second reason was from the wind study conducted as it was observed that a height between 50m, 55m to 60m exist a high wind energy yield, and due to these reasons, it was calculated that 55m standard hub height be installed (Yasin et al 2011; Shata 2006).

This certification procedure for the dimensions was carried out by GARRAD HASSAN office. Also VENGNET is an ISO 9001 certified in wind turbine generator manufacturing which is a guarantee of reliability of for the design and manufacture of its products.Preparation for a site location in a mountainous area generally requires a higher capital investment but has a higher average wind speed and capacity factor. Wind generation facilities generally require large amounts of land to allow for sufficient space between the turbines. In agricultural areas, the land surrounding the turbines can still be utilized as farmland. Average wind speeds across the state were measured and Rimi local government area of the state was found to be the best evaluated region for the siting of the project which would be most appropriate for wind generation facilities. The Katsina wind farm project was sited on a large expanse of flat land which was used by the community as a farm and grazing land for their animals. The state government had to settle about four hundred million naira (N400m) in compensation to the communities for the utilization of the land for the project (Akpinar et al 2005b; Fadare 2008; Penelope et al 2006).

The physical arrangement of the turbines within a facility was explored. The exact arrangement of each turbine in a wind generation facility is location-specific; it depends on factors such as wind patterns and land gradients. A general rule of thumb that each column of turbines (spaced perpendicular to the dominant wind direction) should be separated by three rotor diameters and each row of turbines (spaced parallel to the dominant wind direction) should be separated by ten rotor diameters is to be adopted for the project.

The Katsina wind farm turbine positioning was designed following a common rule of 7D x 5d for the fact that the distance between turbines in a row is measured in rotor diameter.Hence a common rule of thumb is to situate with distance of 5 rotor diameter (5d) and the distance between the rows usually is 7 rotor diameter (7d); Where d= rotor diameter = 32m (with respect to Katsina), therefore for katsina project in particular -7D= 7 *32 =224m (in between rows) -5d = 5*32 = 160m (in between turbines). The standard propeller-like turbine most commonly found in wind farms around the world, space the individual turbines around five to seven rotor diameter apart, a recent study found that spacing of at least 15 rotor diameter apart produced the most cost efficient power generation. But even though spreading the turbine out increased the cost efficiency by allowing for fewer individual turbines, it also lowers the power output of a given plot of land.

3.0 Results and Discussion.

3.1Penetration

Wind energy penetration refers to the fraction of energy produced by wind compared with the total available generation capacity. There is no generally accepted maximum level of wind penetration. The limit for a particular grid will depend on the existing generating plants, pricing mechanisms, capacity for energy storage, demand management and other factors. An interconnected electricity grid will already include reserve generating and transmission capacity to allow for equipment failures. This reserve capacity can also serve to compensate for the varying power generation produced by wind plants. Studies have indicated that 20% of the total annual electrical energy consumption may be incorporated with minimal difficulty. These studies have been for locations with geographically dispersed wind farms, some degree of dispatchable energy or hydropower with storage capacity, demand management, and interconnected to a large grid area enabling the export of electricity when needed. Beyond the 20% level, there are few technical limits, but the economic implications become more significant. Electrical utilities continue to study the effects of large scale penetration of wind generation on system stability and economics.

3.2 Predictability

Wind power forecasting methods are used, but predictability of any particular wind farm is low for short-term operation. For any particular generator there is an 80% chance that wind output will change less than 10% in an hour and a 40% chance that it will change 10% or more in 5 hours. However, studies by Graham Sinden (2009) suggest that, in practice, the variations in thousands of wind turbines, spread out over several different sites and wind regimes, are smoothed. As the distance between sites increases, the correlation between wind speeds measured at those sites, decreases. Thus, while the output from a single turbine can vary greatly and rapidly as local wind speeds vary, as more turbines are connected over larger and larger areas the average power output becomes less variable and more predictable. Wind speeds can be accurately forecast over large areas, and hence wind is a predictable source of power for feeding into an electrical grid. However, due to the variability, although predictable, wind energy availability must be scheduled (Ngala et al 2007; Justus 1978; Kumau et al 2011).

3.3 Reliability

Wind power hardly ever suffers major technical failures, since failures of individual wind turbines have hardly any effect on overall power, so that the distributed wind power is highly reliable and predictable, whereas conventional generators, while far less variable, can suffer major unpredictable outages.The combination of diversifying variable renewables by type and location, forecasting their variation, and integrating them with dispatchable renewables, flexible fueled generators, and demand response can create a power system that has the potential to meet power supply needs reliably. Integrating ever-higher levels of renewables is being successfully demonstrated in the real world:

In 2009, eight American and three European authorities, writing in the leading electrical engineers' professional journal, didn't find "a credible and firm technical limit to the amount of wind energy that can be accommodated by electricity grids". In fact, not one of more than 200 international studies, nor official studies for the eastern and western U.S. regions, nor the International Energy Agency, has found major costs or technical barriers to reliably integrating up to 30% variable renewable supplies into the grid, and in some studies much more.

3.4 Energy Storage

In general, hydroelectricity complements wind power very well. When the wind is blowing strongly, nearby hydroelectric plants can temporarily hold back their water, and when the wind drops they can rapidly increase production again giving a very even power supply.Pumped-storage hydroelectricity or other forms of grid energy storage can store energy developed by high-wind periods and release it when needed. The type of storage needed depends on the wind penetration level – low penetration requires daily storage, and high penetration requires both short and long term storage – as long as a month or more. Stored energy increases the economic value of wind energy since it can be shifted to displace higher cost generation during peak demand periods (Yang and Chan 2008).

3.5 Cost of Investment

The potential revenue from this arbitrage can offset the cost and losses of storage; the cost of storage may add 25% to the cost of any wind energy stored but it is not envisaged that this would apply to a large proportion of wind energy generated. For example, in the UK, the 1.7 GW Dinorwig pumped storage plant evens out electrical demand peaks, and allows base-load suppliers to run their plants more efficiently. Although pumped storage power systems are only about 75% efficient, and have high installation costs, their low running costs and ability to reduce the required electrical base-load can save both fuel and total electrical generation costs (Tar 2008; Yu et al 2012; Koeppl 1982).

Wind power has low ongoing costs, but a moderate capital cost. The marginal cost of wind energy once a plant is constructed is usually less than 1-cent per kW·h. This cost has reduced as wind turbine technology improved. There are now longer and lighter wind turbine blades, improvements in turbine performance and increased power generation efficiency. Also, wind project capital and maintenance costs have continued to decline.

The estimated average cost per unit incorporates the cost of construction of the turbine and transmission facilities, borrowed funds, return to investors (including cost of risk), estimated annual production, and other components, averaged over the projected useful life of the equipment, which may be in excess of twenty years. Energy cost estimates are highly dependent on these assumptions so published cost figures can differ substantially. In 2004, wind energy cost a fifth of what it did in the 1980s, and some expected that downward trend to continue as larger multi-megawatt turbines were mass-produced (Ajayi et al 2011b; Babainejd and Keypur 2010).

As of 2012 capital costs for wind turbines are substantially lower than 2008–2010 but are still above 2002 levels. A 2011 report from the American Wind Energy Association stated, "Wind's costs have dropped over the past two years, in the range of 5 to 6 cents per kilowatt-hour recently.... about 2 cents cheaper than coal-fired electricity, and more projects were financed through debt arrangements than tax equity structures last year.... winning more mainstream acceptance from Wall Street's banks.... Equipment makers can also deliver products in the same year that they are ordered instead of waiting up to three years as was the case in previous cycles.... 5,600 MW of new installed capacity is under construction in the United States, more than double the number at this point in 2010. Thirty-five percent of all new power generation built in the United States since 2005 has come from wind, more than new gas and coal plants combined, as power providers are increasingly enticed to wind as a convenient hedge against unpredictable commodity price moves (Chang and Tu 2007).

4.0 Conclusion.

The Katsina wind farm is indeed a pride to Nigeria; if only some few details could be strengthen in order to ensure the sustainability of the project and also to justify the cost involved. It suffices to say that apart from the high cost of the project, the other factors were well articulated in the project.

The persistent shortage of electric power in Nigeria could be remedied through additional wind farms in the locations analysed with the potential of wind energy resources in high volume to warrant a commercial exploitation of the resources. It is imperative to state that there is an urgent need to have an energy mix of Solar, Wind and Hydro resources in the country; in order to meet the demand of over 170 million populace.

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