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(REVIEW ARTICLE)

A review on hybridization of renewable energy resources in Nigeria

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Abstract

The hybridization of renewable energy resources technology is one of the emerging trends in the area of science and technology. The idea is spreading very wide not only within households but industries because of its numerous benefits such as its ecofriendly nature, cost effectiveness, and accessibility. This paper focuses on reviewing the hybridization of wind and solar energy sources in Nigeria. Wind speeds are considerably low during dry season in Nigeria when the intensity of the sun is very high and shines for a long period of time. The wind is stronger during the rainy season when less sunlight is available. Since the maximum operating time for solar and wind systems occur at different times of the day and year, power generation using wind solar hybrid system is likely to be readily available when needed. Wind and solar hybrid system conversion could be large scale connected to the national grid or small scale for stand-alone systems. Different work carried out by researchers' shows that if Nigeria can properly harness 40 percent of her renewable energy resources such as wind and solar, the problem of power failure will be a thing of the past in both remote locations and urban areas of Nigeria. It is recommended that government should as a matter of urgency prioritize the generation of electricity through the integration of the various renewable energy resources.

Keywords: Wind; Solar; Hybridization; Nigeria; Power

1. Introduction

Electrical power is one of the most important factors for agricultural, industrial, and economic development of any country. The main sources of energy in the world today are the fossil fuels such as oil, coal, and natural gas. The over dependence on fossil fuel in this 21st century is drastically depleting the natural reserve and also causing some other harmful effects in the society at large. The increasing threat on the usage of natural gas, coal, and other fossil fuel have propelled scientist and engineers to consider alternative energy sources such as solar photovoltaic, geothermal, biomass, wind and hydro which are the commonly used renewable sources of energy [1]. Renewable energy generation helps countries attain their ecological developments through delivery of secure, reliable, affordable, and quality energy. This is due to the rise in the fuel prices, continuous depletion of fossil fuel and other conventional energy sources, and harmful emissions from the burning of fossil fuels which makes power generation from fossil fuel and other conventional energy resources untenable and non-feasible [2].

Renewable energy resources are considered as a good alternative for remote and inaccessible areas where opportunities of attaining national grid is small because of engineering, technical, and pecuniary limitations and therefore is preferred in most of those areas [3]. Electrical energy generated from renewable energy sources is very important for both personal and economic welfare. Such electrical energy gotten from renewable resources has backup devices like fuel/diesel generator and power bank to satisfy the growing demands. Unlike the general conventional energy sources, renewable energy sources are highly reliable, cost effective, less harmful, and in general can improve the quality of life. Although wind energy and solar energy complement each other, they are both erratic because of rapid variation of wind speed and stellar radiation [1]. However, the scarcity of these renewable energy resources throughout the year has led scientist and engineers to divert their interest towards the aspect of hybrid renewable energy systems (HRES). Over the past few years, so many researches have taken place in the operation, design, control, and optimization

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of the renewable hybrid energy systems. This is evident that optimization of power system is an emerging scenario in science and technology and it is vast in scope.

There are currently about 1.2 billion people in the world without electricity from grid [4]. Majority of these people live in inaccessible areas, like mountain areas, islands, and remote villages. Extending grid to such remote villages is technically and uneconomical demanding as a result of scattered population, rough landscape, and other basic ecological barrier. Fortuitously, most of these remote villages are usually very rich in renewable energy resources, such as wind, solar, hydro energy, and biomass. Exploring these readily available renewable energy resources is possibly the best option to achieve the energy requirement [4]. Depending on the rigidity and nature of the environment, hybrid technologies or single technology may be selected in stand-alone mode or remote area power supply. However, it is a known fact that renewable energy resources are normally irregular and site-specific in nature. Thus, as demand for remote area power supply increases, single technology system becomes very expensive and unreliable. This leads to the introduction of hybrid renewable energy system for power generation in these remote areas to help solve most of the problems associated with single technology system. The conventional diesel generator in some cases can be used as well, since a diesel generator can supply power when the weather conditions are poor over a long period of time. This can increase power supply dependability and considerably decrease storage of renewable energy resources, thus reducing the cost of power supply [5].

Stand-alone renewable energy power generation systems in recent years have become a research focus, and some efforts have been made to improve the hybrid energy technologies for inaccessible area power supply. It is therefore very important to understand the current situation and imminent development of renewable energy storage technologies, power generation technologies, system configuration, sizing and optimization techniques, system modeling and simulation, operation and management, and performance evaluation [6]. This research focuses on reviewing the hybridization of renewable energy resources with a view to optimize power grids in Nigeria. Wind and solar energy are the most important sources of renewable energy which is accessible in Nigeria. The rate of sunshine in a year with solar radiation varies from 7 to 11.5 kwh/m2/day which is about six to seven times its value in Europe (1 kwh/m2/day for most countries in Europe and 1.7 kwh/m2/day in Greece). A wind energy source of about 5 – 10 m/s wind speed is generally accepted as being sufficient and this is readily available in most parts of the country [7].

Towards the late 1980s and early 1990s, there have been numerous explorations of renewable energy resources most especially the photovoltaic (PV) panel solar power in Nigeria. At present, the total electrical power generated in Nigeria is about 7000 MW with only about 70 % available for use. Oil has remained the principal fuel source for electric energy generation followed by natural gas and then hydroelectricity. However, even with Nigeria being one of the highest producers of oil, natural gas, other fossil fuel and having enough water covering a large land mass, the total power output in 2009 was about 2000 MW for a population of about 160 million people [3,4]. On the other hand, South Africa was generating about 43,000 MW of electricity for a population size that is much more less than Nigeria. The demand for electrical power in Nigeria is very high compared to the quantity of electricity she generates. In fact, Nigeria's usage of electric power per capita is considerably low when compared to other neighboring countries such as Ghana, Senegal, Zambia, Gabon, Mozambique, Algeria, Libya, Cameroun, etc. [8]. The current electrical power output of about 7000 MW generated in Nigeria and the minimum target of about 27000 MW by 2020, looks very much untenable. The rate of electrical energy consumption in Nigeria is disturbingly low when compared with other countries with equal energy resources and size of population, notwithstanding being the largest economy and the most populous country in Africa. Due to continuous depletion of fossil fuel and overwhelming environmental problems linked with its usage, it is therefore necessary for the federal government to explore other energy resources. Currently, alternative sources of energy such as renewable energy, nuclear energy, and also coal energy has not been significantly harnessed in Nigeria to boost her power supply. Thus, the need to harness Nigeria's huge natural renewable energy resources has become very imperative and paramount to avoid tripping into an electrical power supply disaster [9].

2. Wind energy in Nigeria

The use of wind energy for optimization of power grids in Nigeria have been neglected over the last decade because of the excess booming of oil and gas in the country within the time frame. Due to the recent hike in the price of petroleum products in the country, several attempts are being made to restructure the wind generator mills. Over the years, the technologies for exploring wind energy have been test-run in Nigeria, especially in the northern region of the country, mainly for electrifying remote areas, pumping of water in open wells, etc. The amount of wind energy generated has increased from about 8.2 MW in 1997 to more than 390 GW in 2017. Presently, most wind turbine generates electricity as much as conventional electrical power plant in most developed countries like China, USA, and Germany. Wind energy is a type of renewable energy resources which uses airflow to generate electrical power. Wind turbines are normally mounted at height more than 100m high and their blades length at about 45m to receive stronger winds [4]. A single

small wind turbine are used to generate electricity for domestic purposes especially for single homes, while a combination of several large turbines wind granges are used to generate electricity for the national grids. The blades of a wind turbine linked to a generator are turned by the wind and the generator thus converts the wind's kinetic energy to electrical energy.

Electricity can be generated from a wind turbine even with wind speed as low as 3 m/s, making wind energy economical, viable, practicable, and a sustainable source of electrical power in Nigeria, especially in the Northern states. The average daily wind speed in Nigeria can be very misleading since in most occasion, it can be very windy in the night time with very little or no wind in the morning or afternoon. Nevertheless, sufficient amount of electricity can be generated with a few numbers of very productive windy hours. This is because electrical power generated is related to wind speed cut up [7]. The available wind speed varies with seasons with higher wind speed recorded from June to September and low wind speed recorded between November to March. Different research carried out shows that there is a great prospect for wind energy exploitation for electricity generation.

Northern part of Nigeria has a very high average wind speed of about 6 - 8m/s. Wind speeds are usually weak in the southern part of Nigeria except for the offshore areas like Akwa Ibom State, Bayelsa State, Delta State, Lagos State, etc. and in the coastal regions which are normally very windy throughout the year. All Nigerians can benefit from wind driven water pump electrical power generated using even wind turbine based on the currently available wind data [9]. Although wind speeds in the southern region are low, Nigeria has very good wind energy resources in most part of the country. The little amount of wind explored in the southern part of Nigeria can however be used for generating stand-alone electrical power using small gauge wind turbines. This will lead to a major development for rural and remote areas which are not connected to national electricity grid.

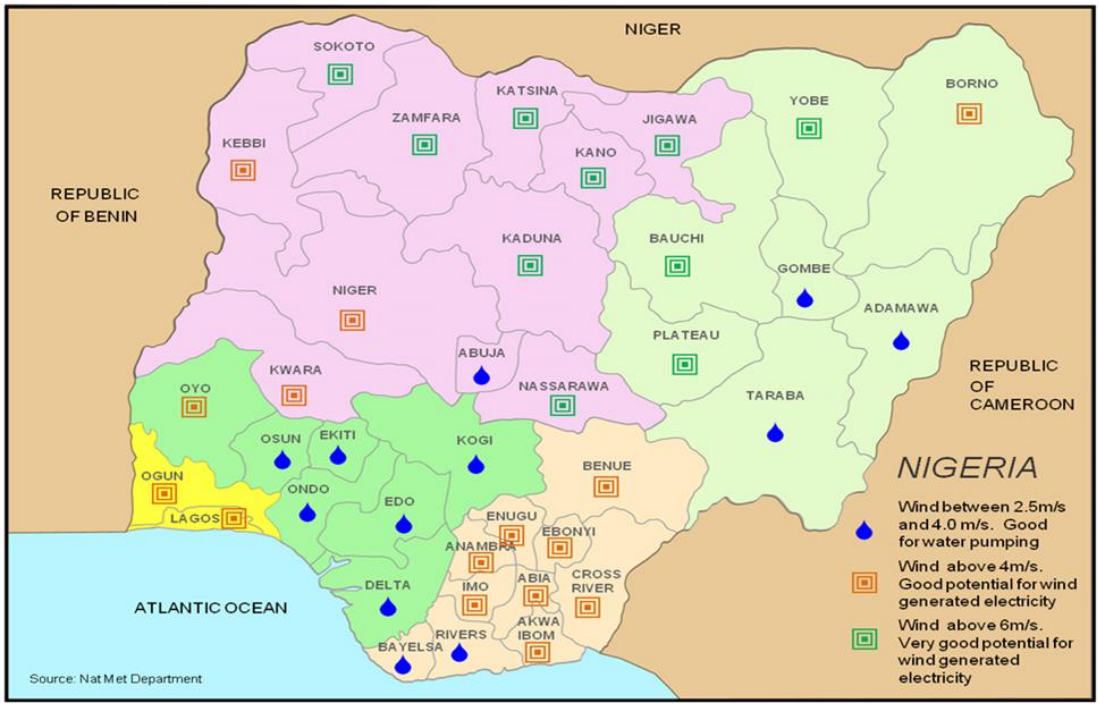

Figure 1 Wind speed across the different states in Nigeria

Source: http://www.neenigeria.com/Nigeria_wind_NEW.png

For efficient and effective generation of electrical energy from wind, some important factors such as availability of considerable amount of wind in the location, knowledge of the nature of wind speed distribution within the location, assessment of the location to ascertain the best position for installation of wind turbine, cost effect of installing wind turbine, and wind power density must be considered. Wind is random in nature; thus, it is very important to develop some models in accessing long term disparity of wind in a given location before concluding on whether the location has the necessary wind resources for electrical power generation [10]. The Federal Government of Nigeria needs to develop a strong policy which regulates and legalizes machineries that would enhance the development of wind energy technology, set standards for wind farm creation and management, and attract both indigenous and foreign investors.

Till date, no serious legal, regulating, and fiscal policy framework exists for wind energy technology. Most potential investors in wind energy will be optimistic to see the level of importance that the government has placed on wind energy technology for the opportunities in place to enhance marketability of the wind energy technology within the country before investing their money. Figure 1.0 shows the amount of wind speed across the different states in Nigeria.

3. Solar energy in Nigeria

Solar energy is the most promising of all the renewable energy resources in Nigeria due to its seeming abundance. Solar energy provides a relatively inexpensive and abundant energy for places whose link to the national grid may not be cheap due to the remote nature of the location from the closest national grid connection point. It is an alternative source of electrical energy in rustic and inaccessible parts of Nigeria. Though Nigeria receives maximum sunlight exposure needed for solar PV implementation, solar energy contributes just a tiny fraction of Nigeria's power generation. The chances for harnessing Nigeria's renewable energies have remained slim and very unrealizable compared to the conventional electricity despite the fact that Nigeria is in the solar tie which increases her solar potentials [11]. The total power demand of Nigeria can be met if only a paltry 5% of the total solar energy radiation across the country is efficiently harnessed. Solar energy emitted from the sun is about 5,000 and 15,000 times the amount of crude oil and natural gas respectively produced daily. Solar radiation is adequately spread in Nigeria with an average solar radiation of about 20.0 MJm–2 per day and average sunshine of about 6 hours a day. Thus, this ranges from 4 hours at the coastal regions to about 8 hours at the northern part. Generally, the total amount of solar energy in Nigeria ranges from about 3.0 KW/m/day to 7.0 KW/m/day. If a solar panel collector is used to cover at least 1% of Nigeria's land mass, it would be possible to generate about 1900 ×103 GWh of solar electrical energy per year which is more than 100 times the current conventional electricity consumption in the country.

Solar electric (photovoltaic) conversion and solar-thermal conversion are the main ways to generate solar energy. Solar-thermal involves the heating of fluids to produce fog which drive turbines for larger electricity generation to the national grids in a centralized manner. A solar thermal system uses solar energy to generate electricity in a different way as with solar cell. Photovoltaic conversion is the direct conversion of sunlight into electrical energy with the aid of a photocell in a decentralized or centralized form. Photovoltaic system comprises of tracking structures, power conditioning equipment, concentrator systems, balance of system (BOS), and storage devices. The BOS consists mostly of some mounting structures for modules. A module is a group of cells connected electrically and packaged into solar panel and may be grouped into larger solar arrays. Solar electric conversion could be large scale connected to the national grid or small scale for stand-alone systems. Solar photovoltaic energy can be obtained with solar panels and high tech solar trackers to provide anticipated and consistent energy throughout the daylight. Some of the solar energy obtained may be stored in batteries for night time usage for lighting and other household uses [3,7]. Solar photovoltaic panels capture sunlight and convert it to direct current electricity with their photovoltaic cells. In addition, several of these cells are placed on each of the panel, which can in turn be connected in series to each other to form higher voltage sources providing more than 230volts direct current. These high voltage cables are delivered directly to an irrigation pump or to solar inverters. Solar trackers are advanced intelligent equipment comprising of different solar panels, and they use global positioning system technology or light sensitive system to turn the panels to ideal path facing the sun and take advantage of energy capture. A well designed tracking system can prolong the operational hours by four hours or more per day and can also increase the total output energy by up to 40 to 50 percent. Different inverters may be connected together serially for larger installations appropriate for homes, hospitals, schools, universities, and industries by using smart inverters that are designed to improve the total output energy from any solar panel arrangement using Maximum Power Point Tracking (MPPT) technology [8].

4. Hybridization of wind and solar energy

Hybridization of renewable energy sources (HRES) consist of two or more renewable energy source, at least one renewable source and a conventional source or a grid and power converters which are used to transform the unregulated power generated from renewable energy sources into very important power at the receiving end. The choice of the energy sources to hybridize should be based on the availability and abundance of such energy resources within the locality. It is, however, preferable to combine or hybridize renewable energy sources because it is readily available and cost effective [5,12]. A very useful advantage of HRES is to obtain greater efficiencies in electrical power than what could be achieved from single power source or from other conventional energy source. It can also provide solution to problems such as effectiveness, fuel flexibility, reliability, economics, and emissions common with the conventional sources of energy such as fossil fuel. Cost effect, reliability, and other conditions such as climate, availability, etc. should be put into consideration when working on hybridization system for electrical power generation.

Consequently, the Federal Government of Nigeria is trying to resolve the power problems by the use of combined energy system which involves an integration of renewable energy with non-renewable energy resources to supply grid energy. Although there is no extensive use of hybridized energy systems in Nigeria, there are mega projects plagued with politicking and vandalism [9]. There are some state governments in Nigeria that have signed memoranda of understanding with foreign and local electrical energy firms to help with energy generation and distributions from renewable resources, especially wind and solar energy. However, most of these mega projects are beleaguered with insufficient funds, vandalism, lack of commitment, and politicking [12]. Some corporate organizations in Nigeria, most especially telecommunication firms like MTN Nigeria and Airtel, are investing greatly in hybrid energy systems involving a combination of solar energy, diesel fuel powered generator, and batteries in order to minimize their reliance on fossil fueled energy system which costs them about $2 million per day.

Therefore, many research works have been carried out by different authors on possible hybridization, optimization, implementation, and challenges of renewable energy sources to solve energy problems in Nigeria. For instance, [13] carried out a study to investigate the economic and technical assessment of using hybrid energy system for electrical power generation in remote communities in the south-west region of Nigeria. They discovered that the hybridization system involving solar photovoltaic, wind, generator, and battery is the most appropriate option for stand-alone electrical power generation in the South-West part of the country. The result of their optimum model shows that the cost of energy for this hybridization energy system are significantly lower than the cost of using diesel generator only without battery or any renewable energy resources. They further observed that there is a drastic decline in emission generated when hybrid energy resources are used instead of conventional energy based system. The challenges and opportunities of renewable energy in mountainous and riverine regions of Nigeria were studied by [14]. They discussed the different sources of renewable energy in Nigeria and their potentials, challenges as well as implementation in line with the renewable energy commission of Nigeria master's plan. They proposed a micro power grid system made of hydro, solar, biomass, and photovoltaic to power a riverine and mountainous region. According to them, the system would not only help to improve the carbon credit and make the environment eco-friendly but will also reduce the cost of electricity. Also, [15] assessed the utilization of wind energy resources in Nigeria. He identified the far northern states, some locations in the southern regions and the mountainous regions as a good area for wind harvest as well as the offshore regions covering Ogun through Lagos and Ondo and rivers to Cross-River along the Atlantic Ocean in the south-south region of Nigeria. Ajayi regretted that despite this great potential and huge prospect of wind energy in Nigeria, the country is still suffering from serious energy shortfall due to her over reliance on hydropower which also is prone to seasonal variation in the quantity of water levels at dams.

5. Implementation of the hres

The renewable resources considered for review in this study is wind and solar energy. The combination of wind and solar energy used for generating electricity is called wind solar hybrid system. This system is designed by using the wind turbines and solar photovoltaic panels' generators for generating electrical power that can be used to charge battery and with the aid of an inverter run alternating current appliances. The key mechanisms of the Wind and Solar Hybrid System are the solar photovoltaic panels, wind aero generator, and tower, cables, batteries, inverter, and charge controller. The wind aero generator is mounted on a mask having a height of about 20 meters from ground level. This enables the generator get wind at a very high speed and thus generates more power. The block diagram of wind solar hybrid system used for power generation is shown in Figure 2.0 below.

The hybrid system is designed to acquire energy in a complementary and combine way. The energy is available through photovoltaic panels during the day time and wind turbine generates energy whenever the wind speed is available. The renewable energy can be stored in the battery bank passed through inverter or used directly. Wind solar hybridization has extended use when grid connection is unavailable and also when grid staggering is a regular problem.

Wind speeds are considerable low during dry season in Nigeria when the intensity of the sun is very high and shines for a long period of time. The wind is stronger during the rainy season when less sunlight is available. Since the maximum operating time for solar and wind systems occur at different times of the day and year, power generation using wind solar hybrid system is likely to be readily available when needed. Engine generator may be used to recharge the batteries and provide power when the wind and the solar system supply are very minimal or significantly low. Even though the addition of a diesel engine generator makes the system more complex, modern electronic microcontrollers operates these systems automatically making the system very reliable and efficient. Wind-solar hybrid system have a general acceptance in terms of nature saving and as a grid energy solution. The system is noiseless and as such can be installed in residential areas, schools, hospitals, and even on roof top.

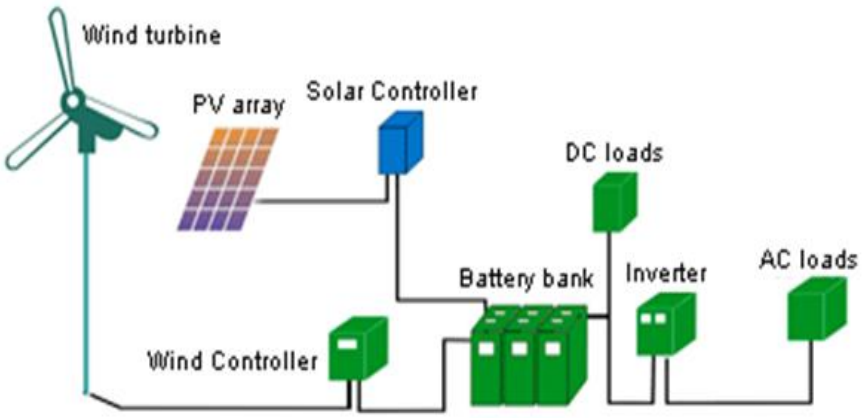

Figure 2 Block diagram of wind solar hybrid system

Source: https://www.mahaurja.com/meda/en/off_grid_power/small_wind_solar_hybrid

6. Conclusion

This paper has provided a review of the prospects and difficulties of power system in Nigeria and the benefit of hybridizing the solar photovoltaic and wind energy sources for electricity generation. The irregular nature of solar photovoltaic and wind sources is responsible for the major problem of stand-alone system and also grid connected system. With hybridizing solar and wind energy resources, the effect of the variation of solar and wind energy resources can be to an extent resolved and the whole system becomes more cheap, efficient and reliable to use especially for a stand-alone system. Different work carried out by researchers' shows that if Nigeria can properly harness 40 percent of her renewable energy resources such as wind and solar, the problem of power failure will be a thing of the past in both remote locations and urban areas of Nigeria. Using only one of the renewable energy resources might not be able to completely satisfy the short fall of electricity supply across the country, thus there is the need for integration of two or more renewable energy resources. On one hand, the hybridization of renewable energy resources for power generation has some challenges such as high initial cost of design and implementation, ignorance of government, and uneven distribution of such renewable sources across the country. On the other hand, the benefits of hybridization range from ecofriendly environment, availability, to cost effectiveness which outweighs those challenges.

Recommendation

It is recommended from this study, that further research be carried out to ascertain the best ways of integrating the available renewable energy sources and also the main barriers in the implementation of solar energy in Nigeria. Also, the federal government of Nigeria should as a matter of urgency prioritize generating electricity through the hybridization of the various renewable energy resources. An effective governing body should be set up by the government with the sole aim of advising both the government and the masses on the benefits of HRES and how to effectively harness them.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors of this article hereby declare that there is no conflict of interest, be it financial, commercial, legal, or any other opposing interests that may affect our study.

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