Hybridization energy systems for a rural area in Nigeria

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Abstract. Mankind cannot live without one form of energy or another. Energy (Electrical) is needed to lighten our environment, power our homes, schools, hospitals, offices, businesses, and for industrialization. It is generally known that the economic growth of a nation depends on electricity. This paper is assessing the possibility of hybridizing the various renewable energy sources in Nigeria and evaluating its sustainability, challenges and benefits of hybridizing the combinations of the renewable energy sources (PVs and wind turbine) that are abundantly available in Nigeria. The evaluation of these combinations is to determine the best for the region (rural setting). We are also looking at efforts being put at utilizing these renewable sources for energy generation in Nigeria. The hybrid energy system of a mix of locally available abundant energy resources is a good solution to the persistent epileptic power supply in Nigeria. This will minimize atmospheric degradation as quality of life will be improved.

1. Introduction

In Power Engineering System, the term 'Hybrid' can be defined as a combination of power or energy backup system for the use of mankind. Electrical power producers used in hybrid energy systems are photovoltaic, wind turbines, and different kinds of generators such as diesel, gas and petrol. Hybrid Energy System entails a renewable energy device such as PV solar cells that is balanced through a backup form of generation such as a diesel/gas/petrol generator, wind turbine, fuel cell or battery storage system to ensure continuous supply of electricity.

In Nigeria today, efficient power supply to the populace has been a major challenge which has adversely affected the economy and increased the pressure on the government in terms of energy demand. For a nation to develop technologically, reliable energy is needed. This will attract investors which will in turn boost the economy. The convensional form of power generation (hydro, thermal) can be complemented using a hybrid system (PVs and wind turbines) to generate electrical power as a form of backup in the eventuality of power failure. Efforts made by various administrations/government at addressing this problem (which have included the privatization of its power sector) are yet to yield desirable outcomes [1]. This paper is based on hybridized renewable energy supply system as a feasible alternative to the conventional mode of power generation in a rural area of low energy consumption. It is a fact that Nigeria is blessed with abundant sunshine all year round and there is also large vegetation that covers the country. Maren in (2013), stated that Nigeria was endowed with an annual average daily sunshine of 6.25 hours ranging between 3.5 hours at the coastal region and 9.0 hours in the northern region which receives about 5.08 x 1012 kWh of energy per day from the sun and if solar energy appliances with just 5% efficiency are used to cover only 1% of the country’s surface area then 269.24 MWh of electrical energy can be obtained from solar energy. This amount of electrical energy from the sun is equivalent to 4.66 million barrels of oil per day. This gives rooms for Nigeria to have a greater accessibility and availability of solar energy to develop her solar energy technology [11].

There are a lot of potential for energy generation from the wind. These potential varies with wind...
speed and is available in Nigeria at annual average speeds of about 2.0m at the coastal region and 4.0 m at the northern region of the country with an average annual wind speed of not less than 5 m/s at a height of 10 m above ground level [10]. We need to assess the possibility of hybridizing the various renewable energy sources in Nigeria and evaluating the sustainability of this hybridization in the rural area.

The price of oil has been unstable and for the grid to be expanded there have been the problem of right of way (ROW) non the less it is not a cost effective way out as well. Therefore, the integration of renewable energy source for a rural area becomes an important alternative solution [6].

Nigeria has been blessed with a wealth of natural resources that can be utilized to generate electricity in which the hybridization of solar and wind with proper market and regulatory mechanisms put in place could be utilized to provide a reliable supply of electricity to all residential in the rural area at cost-reflective and affordable tariffs [12]. There are several possible combinations that could be made but the combination of the solar and wind which is based on locally available abundant energy resource [2] was considered here as this often yield greater economic and environmental returns than wind, solar or geothermal stand-alone systems [13].

The condition of living in the rural area is an unhealthy one just because they lack some basic amenities like electricity, water supply, good roads, education etc. Bringing people in this area in mainstream and preventing large scale migration from the rural area to urban area, development of some sources that can fulfill the basic needs among vital classification to be is electricity. Therefore, the hybridization of energy system can prove to be a major cutting edge solution [13].

2. Hybridization of Wind and Solar Electric Systems for rural area

The investigation of Renewable Energy Experts, a hybridization of electric system then combines wind electric and solar PV technologies will offers several merits over a single system. In the United States of America, the speed of wind is low during the summer when the sun shines brightest and longest. Moreover, the wind is strong in the winter when less sunlight is available. As a result of this, the peak operating times for wind and solar energies occur at different times of the day per year [3]. Hybrid power systems produce power as at when needed, this made the integration of wind and solar energy more attractive and been used for the substitution of oil produce [4].

Hybrid electrical systems are stand-alone which operate "off-grid" i.e., it is not connected to an electricity distribution system. When either of the wind or solar system is producing electricity, power can be provided through batteries or engine generator powered by conventional fuel such as diesel, gas and petrol. When the batteries run low, the engine generator can provide power and recharge the batteries. It is essential that the storage capacity must be large enough to supply electrical load demand during non-charging periods. Battery banks should have enough capacity so that it can supply the electric load continuously to the community [7].
2.1. Off-Grid or Stand-Alone Renewable Hybrid Energy Systems for a Rural Area

According to the US Department of Energy, off-grid or stand-alone electrical systems can be more cost-effective than connecting to the grid in remote locations. A rural area of low energy consumption as shown in Figure 2 will benefit and enjoy hybridization of wind and solar. Domestic loads consumers or small businesses using a renewable energy system that is not connected to the electricity grid called a stand-alone system makes economic sense and appeals to their environmental values. Successful stand-alone systems take advantage of a combination of techniques and technologies to generate and distribute reliable power, reduce costs, and minimize inconvenience. Some of these strategies include using fossil fuel or renewable hybrid systems and reducing the amount of electricity required to meet the load demand. In addition to acquire photovoltaic panels or wind turbine, there is the need to invest in some other equipment called **balance-of-system** to safely transmit the electricity to the consumers. This equipment includes:

- Batteries
- Charge controller
- Power conditioning equipment
- Safety equipment
- Meters and instrumentation

Fig 2: Typical load consumption of a rural area
Source: Authors’ Field Survey, 2018

3. Sustainability of Hybrid Energy Systems in rural area

Sustainability is a phenomenon aimed at achieving a “balance between human endeavor such as cost, health, comfort and environmental concerns (resource use and ecological degradation)” [8]. So far so good, there is no formal sustainability analysis of the few existing hybrid energy systems in Nigeria. There have been some reports by the few hybrid energy developers in Nigeria which include that the system has helped them reduce their energy cost, enable them provide stable services and reduce their carbon footprints [5]. However, sustainability evaluation goes beyond the attributes of a system’s perceived benefits. According to Barber (2014), there are some initiatives that have been aimed at resources conservation such as recycling of waste materials that end up having more negative effects on the environment which has contradicted its intended purpose. The overall effects would not be observable or noticed without a
comprehensive analysis of the system. It is therefore expedient to have a critical and quantitative analysis of hybrid electrical system in a way that would enable stakeholders to have a good understanding of the extent to which the system is sustainable [1].

3.1. Challenges of Hybridizing Energy Systems in Nigeria

The few cases of hybrid energy supply projects have shown great potential as a solution pathway to addressing Nigerian energy supply systems [10]. It may be impossible to identify all the problems that could be encountered in the course of developing and operating all types of hybrid energy systems. However, there are some sustainability issues that would need to be considered regardless of the hybrid system. Few of the major challenges of hybridizing energy systems in Nigeria rural area are:

- Integrating the system in such a way that will ensure availability of sufficient amount of energy on a continuous basis with/without interruption.
- Ensuring that the system is simple enough in its design such that it can be maintained/even upgradable by the locally available technicians/artisans.
- Technically, the wind energy system may not be viable because of the low wind speed depending on the location.

3.2. Benefits of Hybrid Energy Systems

It provides assurance of steady supply of energy 24 hours. When either one is not available in insufficient quantity, the other is available to compliment it.

- Since the hybrid system is premised on the abundant local resources, the problem of depending on external supply for energy generation which could be disrupted by vandalism is eliminated.
- It can be utilized at remote locations/terrains where grid connections are difficult or expensive.
- It requires members of the local communities to provide requisite services for its operation and thereby boost business opportunities.
- It increases employment in the locality which in turn would reduce rural urban migration.
- Steady supply of hybrid electric energy would eliminate the need for expensive and polluting fossil fuel powered generators by reducing business operating cost, idleness, and increase productivity.
- It reduces pollution that causes health problems and improve standard of living.
- It enables locally manufactured products to compete on the market.
- It makes local businesses to flourish.
- It increases employment opportunities, reduced social vices, promote peace and economic stability.

4. Conclusion

This discourse has showed that the development of hybrid energy systems in rural area is at an embryonic stage. Hybrid energy systems based on a mix of locally available abundant energy resources seems to be a good solution to the persistent epileptic power supply in Nigeria. For it will improve the quality of life and minimize atmospheric degradation. It will also reduce the migration to the cities thereby reduce overpopulation. Getting it right for the first time would require a balance of human and environmental concerns. This study has provided a balanced criterion for evaluating the sustainability of a proposed/existing hybrid energy system. The next stage would be case studies that utilized the set of proposed criteria in evaluating the sustainability of a number of hybrid energy systems in Nigeria. Hybrid energy systems investors, regulators, researchers and developers would find it useful in their decision making regarding the choice of a hybrid energy systems option (wind, solar, biomass etc.) that are at their disposal.
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