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Decentralization of Power Generation in Nigeria: An Option to Improve Electricity Access Especially in Rural Nigeria

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Abstract

Energy access is vital in improving living standards as well socio-economic and technological development. Access to electricity has been a major challenge in Nigeria especially in rural areas as about 65% do not have access to electricity after much expenditure in the power sector. Electricity can be provided either by centralized grid based means or decentralized methods. Decentralized electrification involves generating electricity at or near the place where it will be used, this eliminates the challenges of high cost of grid extensive transmission network and inadequate generation capacity of the existing centralized power systems. This paper suggests that adopting the decentralized power generation system as done in South Africa, where each state generates its electricity using the prevalent energy source will increase electrification rate in Nigeria. Decentralizing electricity in Nigeria will lead to cheaper power, lower fuel use, reduced energy losses and lower levels of emissions compared to centralized grid.

Key words: Centralized Energy, Decentralization, Electrification, Power grid, Energy access

Introduction

Nigeria is a federal constitutional republic comprising thirty-six (36) states and the Federal Capital Territory (FCT), Abuja. Located in the West African sub-region, the country has a surface of nearly 1 million km^2 and a population of about 186 million people. The country enjoys a tropical rainforest and savannah climate in the south and central belt respectively as well as an arid/semi-arid climate in the north. It is blessed with enormous natural resources; crude oil and natural gas, tin, iron ore, coal, limestone, lead, zinc, arable land, solar, hydropower and wind (www.energypedia.info/wiki/Nigeria_Energy_Situation). Over the past decades successive governments have endeavoured to tackle Nigeria's energy deficit problem by maintaining a monopoly in power provision and pumping money into the poorly managed sector. Since the return to civilian rule in 1999, governments have spent on average about US$ 2bn annually on electricity provision, but with little service improvements to show for it (www.prenuim timesng.com). Nigeria is the largest economy in sub-Saharan Africa, but limitations in the power sector constrain its growth. Nigeria is endowed with large oil, gas, hydro and solar resource, and it already has the potential to generate 12,522 MW (thermal 10,142MW and hydro 2380MW) of electric power from existing plants with an access rate of 45% (rural 35% and urban 55%), but mostly, is only able to generate around 4,000 MW, which is insufficient. Nigeria has privatized its distribution companies, so there is a wide range of tariffs (www.usaid.gov/powerafrica/nigeria)

Provision of electricity is largely supplemented by private producer or use of individual electricity generators powered with fossil fuel for the privileged income groups. Over 90% businesses and companies have private generators leading to high production cost (Omokaro, 2008). The significant gap between demand and supply of electricity, has led to epileptic power supply. The heavy reliance on gas, limited technical/technological know-how, lack of energy efficiency practices and infrastructure maintenance, inadequate regulations and attacks on energy infrastructure contribute to the challenges the sector faces (www.energypedia.info/wiki/Nigeria_Energy_Situation)

Power situation in Nigeria

The Electricity generation began in Nigeria in 1896 and the first thermal power station was built in 1920. By 1968, the first hydro power station Kainji was built which is a large centrally located power plant with grid extension (132KV line) to other locations. The Nigeria Electric Power Authority (NEPA) by virtue of the NEPA Act had monopoly of generation, transmission and distribution of electricity in the country. From 1968 to 1991, the installed capacity for electricity generation in Nigeria increased by a factor of 6 to stand at 5881.6 MW. No further addition to generating capacity was embarked upon by the government from 1990 to 1999 (https://en.m.wikipedia.org/wiki/Electricity_sector_in_Nigeria).

Thus, in 2001, the government started off with reforms, terminating the monopoly status of NEPA and inviting private sector participation in the electricity sector. This reform enabled the development of the National Electric Power Policy in September 2001 and later, National Energy Policy (NEP) was approved in 2003. The Renewable Energy Master plan (REMP) was put in place to provide a roadmap for the effective implementation of the renewable energy component of the NEP. A draft national energy master plan (NEMP) was developed by the Energy Commission of Nigeria with support of the United Nations Development Programme (UNDP) in November, 2005. Several workshops and National Stakeholders Forum on RE Technologies have been held and different Memorandum of Understandings (MOUs) signed with private and foreign companies for technical assistance, training and establishment of demonstration projects. However, their implementation depends on investment (Nnaji*et al*., 2010).

From 2005 to present, the government of Nigeria has implemented several independent power projects (IPPs) to boost energy supply in the country. However, the targets for the projects were never met due to problems encountered, such as corruption, bureaucratic bottleneck; inadequate gas supply and obsolete infrastructures (CREDC, 2007).

Commercial electricity generation in Nigeria currently comes from 9 power stations and various independent Power Projects around the country. Thus, the current nation's available electricity generating capacity is about 4032MW (www.power.gov.ng).

As at November, 2019, the total installed power generation capacity in Nigeria, a country of over 186 million people (www.power.gov.ng), was 7178 MW; 85% of which is gas-fired (thermal) and 15% is hydro-generated. The country achieved its highest peak generation output of 5,074MW in February, 2016 (www.power.gov.ng).

In comparison, South Africa, which has a population of 55.3 million has a total installed capacity of 45,000MW, with an access rate of 86 % (66% rural and 93% urban) and achieved peak generation output of 35,819MW in February 2016 (Reuters, February 27). Currently, they generate about 33,000 MW. Interestingly, South Africa generates about 45% of the electricity used in Africa (http://www.gov.za/about-sa/energy). This shows that Nigeria still has a long way to go in achieving the required generation output to meet the demands of its population. Analysts have projected that about 50,000MW is required to adequately light up Nigeria. However, the generation output in Nigeria as at 27th, November 2019 was 3960 MW (www.power.gov.ng).

South Africa and her decentralized power generation

According to Wikipedia, South Africa with a population of 55.3 million have a total installed capacity of 60,000 MW and produces around 340300000 megawatt-hours electricity annually. Most of this electricity is consumed domestically, but around 12,000 gigawatt-hoursare annually exported to

Swaziland, Botswana, Mozambique, Lesotho, Namibia, Zambia, Zimbabwe and other Southern African Development Community countries participating in the Southern African Power Pool. Most power stations in South Africa are owned and operated by Eskom. These plants account for 95% of all the electricity produced in South Africa and 45% of all electricity produced on the African continent Africa (http://www.gov.za/about-sa/energy)/

The following is a list of electricity generating facilities within South Africa that are larger than 2 MW capacities. It contains currently operational facilities and facilities under construction. As far as possible the net power output in megawatts is listed, i.e. the maximum power the power station can deliver to the grid (https://en.m.wikipedia.org/wiki/Energy_in_South_Africa).

S/No	Type	Capacity [MW]
1.	Coal	40,036
2.	Gas turbine	3,449
3.	Hydro	3,573
4.	Imported Hydro	1,500
5.	Nuclear	1,860
6.	Landfill gas	7.5
7.	Solar CSP	200
8.	Solar PV	1,149
9.	Wind	1,369
	Total	**53,143.5**

Table 1: Electricity generating facilities within South Africa larger than 2 MW capacities

S/No	State	Power station type
1.	Gauteng	Coal
2.	KwaZulu-Natal	Gas and Hydro
3.	Limpopo	Coal, Hydro and Solar
4.	Mpumalanga	Biogas and coal
5.	North West	Gas, Hydro, Nuclear, Solar and Wind
6.	The Eastern Cape	Gas, Hydro and Wind
7.	The Free State	Coal, Hydro and Solar
8.	The Northern Cape	Hydro

Table 2: List of states/provinces in South Africa and their power stations

Centralized vs Decentralised Electrification

Centralized electrification supply involves large-scale generation of electricity at a central power plant. This generated electricity is then transported over a distance to consumers through an electric power grid. It is easier to provide electricity access through grid extension in urban areas due to the concentration of people and the generally higher incomes of potential consumers. While an overwhelming majority of Nigeria's urban population is connected to electricity, the same cannot be said for people living in rural areas. Although some progress in rural areas has been made, significant challenges remain (https://energypedia.info/wiki/Planning_energy_access:_Centralized_or_decentralized_electrification):

i. **High cost of grid extension**: Rural communities have lower population densities than urban areas and have a larger proportion of poor households with lower chances of recovery of investment.

ii. **Inadequate generation capacity**: There is not enough generation capacity to provide a reliable supply.

iii. **Transmission infrastructure issues**: poor transmission and distribution planning or infrastructure, as well as issues such as power theft vandalism, that negatively impact electricity supply.

iv. **Cost**: Rural areas often have low population density and on average have a poorer population. When charges and fees associated with getting electricity connections are perceived to be high

Thus, electrification through grid extension, especially to rural areas, involves huge investment and risk and is usually taken up by governments, rather than private enterprises. Therefore, for grid-connected access to be effective in providing access to the majority of people, there needs to be sustained commitment and a long term vision from the government to plan, regulate, implement and monitor electrification. Electricity also needs to be affordable and dependable for maximum uptake, and thus maximum impact, as providing limited electricity to a limited number of people defeats the purpose of electrification

Decentralized electrification is the production of electricity at or near the point of use, irrespective of size, fuel or technology. Decentralized electrification can be on-gird or off-grid and can be powered by a wide variety of fossil fuels (Ajao*et al*., 2009). It is an energy system that supplies an individual or small group of energy loads. This local generation reduces transmission losses and lowers carbon emission. The security of supply is increased nationally as customers don't have to share supply or rely on relatively few, large and remote power stations. Long term decentralized energy systems can provide more competitive prices than centralized energy. While initial installation cost may be higher, a special decentralized energy tariff creates more stable pricing. This will increase the number of energy providers which will drive competition up and power prices down, enable greater control in communities over the sources of energy they consume. Consumers can sell back power to the grid and it could serve as a way to provide backup power to the national grid. Decentralised electrification can be adopted in Nigerian states without any power station.

S/No	State	Power Generation Potential
1	Anambra	Hydro
2	Adamawa	Solar, Wind
3	Bauchi	Solar, Wind
4	Benue	Hydro
5	Borno	Wind, Solar
6	Cross River	Hydro
7	Ebonyi	Hydro
8	Enugu	Coal, Hydro
9	FCT	Hydro
10	Gombe	Wind, Solar
11	Jigawa	Hydro, Wind, Solar
12	Kaduna	Hydro, Solar
13	Katsina	Solar, Wind
14	Kebbi	Solar, Wind
15	Ogun	Hydro
16	Plateau	Wind, Hydro
17	Sokoto	Solar, Wind,
18	Yobe	Wind, Solar

Table 3: States in Nigeria without any power station

Power generation sources with huge potentials in Nigeria

Hydro Energy

The country is reasonably endowed with large rivers and some few natural falls. Small rivers and streams also exist within the present split of the country into eleven River Basin Authorities, some of which maintain minimum discharges all the year round. Hydropower currently accounts for about 29% of the total electrical power supply. In a study carried out in twelve states and four (4) river basins, over 278 unexploited small hydropower (SHP) sites with total potentials of 734.3 MW were identified (Aliyu and Elegba, 1990). However, SHP potential sites exist in virtually all parts of Nigeria with an estimated total capacity of 3,500 MW. They indicate that Nigeria possesses potential renewable source of energy along her numerous river systems, a total of 70 micro dams, 126 mini dam and 86 small sites have been identified. A private company, the Nigerian Electricity Supply Company (NESCO) and the government have installed eight (8) SHP stations with aggregate capacity of 37.0 MW in Nigeria. Most of these stations are found around Jos at Kwall and Kurra Falls. The total technically exploitable hydropower potential based on the country's river system is conservatively estimated to be about 11,000 MW of which only 19% is currently being tapped or developed (Okafor and Uzuegbu 2010). These rivers, waterfalls and streams with high potentials for Hydropower, if properly harnessed will lead to decentralized use and provide the most affordable and accessible option to off-grid electricity services especially to the rural communities. Potential sites for hydro power generation exist in virtually all parts of Nigeria

Solar Energy

Nigeria lies within a high sunshine belt and thus has enormous solar energy potentials. Solar radiation is fairly well distributed with average solar radiation of about 19.8 MJm –2 day-1 and average sunshine hours of 6hrs per day (Uzoma*et al*., 2011). Analysts have projected that Nigeria could generate 600,000MW by deploying Solar PV panels to cover just 1% of Nigeria's land mass (www. renewableenergy.gov.ng/harnessing-nigerias-solar-power-potential/).

Several pilot projects, surveys and studies have been undertaken by the Sokoto Energy Research Center (SERC) and the National Center for Energy Research and Development (NCERD) under the supervision of the ECN. Several PV-water pumping, electrification, and solar-thermal installations have been put in place. Such Solar thermal applications include solar cooking, solar crop drying, solar incubators and solar chick brooding. Other areas of application of solar electricity include low and medium power application such as: water pumping, village electrification, rural clinic and schools power supply, vaccine refrigeration, traffic lighting and lighting of road signs.

Wind Energy

Wind energy is available at annual average speeds of about 2.0 m/s at the coastal region and 4.0 m/s at the far northern region of the country. With an air density of 1.1 kg/m3, the wind energy intensity perpendicular to the wind direction ranges between 4.4 W/ m2 at the coastal areas and 35.2 W/ m2 at the far northern region (Sambo 2009).

At present, the share of wind energy in the national energy consumption has remained on the lower end with no commercial wind power plants connected to the national grid, Only a few number of stand-alone wind power plants were installed in the early 1960s in 5 northern states mainly to power water pumps and a 5 kW wind electricity conversion system for village electrification installed at SayyanGidanGada, in Sokoto State (Uzoma*et al*., 2011). In recent times, numerous studies have been carried out to assess the wind speed characteristics and associated wind energy potentials in different locations in Nigeria.

Promising attempts are being made in Sokoto Energy Research Centre (SERC) and AbubakarTafawaBalewa University, Bauchi, to develop capability for the production of wind energy technologies.

The technologies for harnessing wind energy have, over the years, been tried in the northern parts of the country, mainly for water pumping from open wells in many secondary schools of old Sokoto and Kano States as well as in Katsina, Bauchi and Plateau States. (Agbetuyi*et al*., 2012)

Other areas of potential application of wind energy conversion systems in Nigeria include electricity production for the rural community and for integration into the national grid system.

In 1998, a 5-kW wind electricity conversion system for village electrification was installed at SayyanGidanGada, in Sokoto State (Mutlu, 2012)

According to the report of Lahmeyer Consultants, 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 between 1.0 and 5.1m/s (1.0 and 6.3m/s) depending on the particular stations, and still confirms that Nigeria falls into the moderate wind regime.

Table 3 shows data of wind energy resources mapping for ten (10) sites in Nigeria including Sokoto collected from on ground measurement carried out between May 2004 and May 2005 also 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) (www.renewableuk.com)

Table 3: Data of wind energy resources in 10 Locations

Site ID	Site Name	State	Measured mean wind speed at 30m height (m/s)
Sok 01	Sokoto/Badaga	Sokoto	5.4
Jos 01	Jos Airport/Kassa	Plateau	5.2
Gem 01	Gembu/Mambila	Adamawa	5.0
Pan 01	South part of Jos/Pankshin Hotel	Plateau	5.0
Kan 01	Kano/Funtua	Kano	4.9
Mai 01	Maiduguri/Maimok	Borno	4.7
Lag 01	Lagos/Lekki beach	Lagos	4.7
Enu 01	Enugu/Nineth mile corner	Enugu	4.6
Gum 01	Gumel/Garki	Jigawa	4.1
Ibi 01	Ibi metrological station		3.6

Coal

Nigeria is endowed with over 2billion tonnes of coal reserves; with several virgin areas yet to be explored. The deposits stretch from Abia state through Enugu, Kogi, Benue, Nasarawa, Plateau, Bauchi, Yobe to Bornu states. Another belt of lignite (brown coal) stretches from Akwa-Ibom state through Imo, Anambra, Delta, Edo, Ondo to Ogun state (Faborode, 2016). Most of these states have virgin areas for detailed exploration, to determine the economic mine ability of the deposits. In 1950, however, the

Nigerian Coal Corporation (NCC) was established by the Federal Government and charged with the responsibility of exploring, developing, and exploiting the country's coal resources. From proven and inferred reserves, Nigerian Coal resources can support medium to large power stations that would generate electricity. According to Faborode, (2016), in the 80s, the then minister, Alhaji Ibrahim Hassan, planned to set up the following power stations:

1. Oji River power station, 120-240 megawatts to use coal, Enugu, Inyi and Ezimo coal fields, to consume 500, 000 1000,000 tonnes per annum.
2. Onitsha power station, 1200 megawatts to use lignite deposits at Agwashi-Ukwu, to consume 2,000,000.00 of lignite per annum.
3. Makurdi power station (600 megawatts) to use coal deposits at Okaba and ogboyoga, to consume 1,500,000 tonnes per annum.
4. Numan power station (150 megawatts) to use coal deposits from Gombe and Lamja.

Were these plans to have been realized, they could have solved the problem of electricity supply in this country. These power stations could be established as additional options to the existing hydro and gas stations. That would provide the necessary impetus and dynamism for steady growth and development.

Biomass

The biomass resources of Nigeria can be identified as crops, forage grasses and shrubs, animal wastes and waste arising from forestry, agriculture, municipal and industrial activities, as well as, aquatic biomass. Crops such Sweet sorghum, maize, Sugarcane were the most promising feedstock for biofuel production (Nnaji et al., 2010). Plant biomass can be utilized as fuel for small-scale industries. It could also be fermented by anaerobic bacteria to produce a cheap fuel gas (biogases). Biogas production from agricultural residues, industrial, and municipal waste does not compete for land, water and fertilizers with food crops like is the case with bioethanol and biodiesel production and, will reduce the menaces posed by these wastes. In Nigeria, identified feedstock substrates for an economically feasible biogas production include water lettuce, water hyacinth, dung, cassava leaves and processing waste, urban refuse, solid (including industrial) waste, agricultural residues and sewage (Akinbami, 2001). It has been estimated that Nigeria produces about 227,500 tons of fresh animal waste daily. Since 1 kg of fresh animal waste produces about 0.03 m^3 biogas, then Nigeria can potentially produce about 6.8 million m^3 of biogas every day from animal waste only. Although biogas technology is not common in Nigeria, various research works on the technology and policy aspects of biogas production has been carried by various scientists in the country. Some significant research has been done on reactor design that would lead to process optimization in the development of anaerobic digesters (Akinbami, 2001). Agro residue can also be densified into briquettes which acts as a solid fuel which can be used for heating and cooking applications in Nigeria, would mitigate problems associated with the use of fuelwood and high cost of petroleum products. Several briquetting studies have been carried out in the country. These studies involved the use of different biomass to produce composite briquettes as well as producing briquettes through variations of process/briquetting equipment parameters such as briquetting pressure, dwell time, particle size, biomass composition etc (Usaka*et al.,* 2019). All these can be utilized and developed to fill energy needs

Conclusion

Decentralizing electricity in Nigeria will lead to cheaper power, lower fuel use, reduced energy losses and lower levels of emissions compared to centralized grid. This is mainly because decentralized electricity is installed at, or near, the point of use, avoiding extensive transmission network investment.

1. There should be a legislation mandating every state in the federation to contribute certain quantity of power to the national grid
2. Government should create an enabling environment by way of friendly policies to attract investors to the power sector.
3. Every state in Nigeria should be mandated to produce certain percentage of the power they consume.

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