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PROSPECTS AND CHALLENGES OF OFF-GRID POWER GENERATION FOR RURAL COMMUNITIES IN NIGERIA – THEORETICAL PERSPECTIVE

*[1]Dangana Audu & [2]Ikechuku A. Diugwu

[1,2]Department of Mechanical Engineering. Federal University of Technology Minna. Niger State. Nigeria.

*Corresponding Author Email address: danganaaudu@@gmail.com

ABSTRACT
Rural area electrification in developing countries is vital for socio-economic growth. However, these small settlements also face erratic, and in worst scenarios no supply of power; just like in some urban cities. Only about 29% of rural communities have access to electricity as against 77% in urban settlement. These figures are relatively low as compared to developed countries and some other African countries. A lasting solution to these protracted problems could be the adoption and design of off-grid power generation for remote areas facing difficulties of on-grid extension reach. This paper therefore seeks to explore the prospects and challenges of adopting off-grid power generation for rural communities in Nigeria. Efforts made by the government to deploy off-grid power generation as an alternative source has been faced with challenges. Amongst these include; planning, gap in existing technology, operational issues, and political instability. The study recommends that; all tiers of government be duty-bound to implement off-grid projects to make the country attain its long-term plans of sustainable power supply, collaboration with the World Bank, United Nations (UN), NGOs and other institution to develop the power sector.

Keywords: *Generation, Power, Nigeria Off-grid, Renewable Energy*

1 INTRODUCTION

Generally, electricity is considered as a vital component and instrument for development. Nigeria being among the world's largest electricity access deficit account for about 77 Million people without access (The World Bank, 2017). The role of electricity in our everyday lives is enormous and the derivable benefits are countless. Adequate power supply is a mandatory precondition to any nation's development. Energy access policies are steadily yielding significant progress, as the number of people without access to electricity fell below 1 billion in 2017 (IEA, 2017). According to a recent report shown in table 1 below, North African countries are able to achieve 99% electricity access for rural communities, while Chine has a 100% access for both urban and rural settlements.

However, despite significant steps forward in Kenya, Ethiopia, Tanzania and Nigeria, rural communities still have very low access. In Nigeria, only about 29% of rural communities have access to electricity as shown in table 2 below (IEA, 2018). A significant amount of the economy is powered largely by small-scale generators, and about 50% of the population have limited or no access to the grid. As a result Nigerians and their businesses spend almost $14 billion (₦ 5 trillion) annually on inefficient generation that is expensive, of poor quality, noisy, and polluting (REA, 2017)

Table 1: Electricity Access, summary by region

Electricity Access, Summary by Region

	Rate of access						Population without access (million)
	National				Urban	Rural	
	2000	2005	2010	2017	2017	2017	2017
WORLD	73%	76%	80%	87%	95%	76%	992
Developing Countries	64%	69%	74%	83%	93%	73%	992
Africa	35%	39%	43%	52%	74%	36%	603
North Africa	90%	96%	99%	100%	100%	99%	<1
Sub-Saharan Africa	23%	28%	32%	43%	67%	28%	602
Developing Asia	67%	74%	79%	91%	98%	85%	351
China	99%	99%	99%	100%	100%	100%	-
India	43%	58%	66%	87%	98%	82%	168
Indonesia	53%	56%	67%	95%	100%	89%	14
Other Southeast Asia	68%	76%	84%	88%	97%	82%	44
Other Developing Asia	38%	45%	58%	76%	88%	68%	125
Central and South America	86%	90%	94%	96%	98%	86%	20
Middle East	91%	80%	91%	92%	98%	78%	18

Source: IEA, World Energy Outlook-2018

Table 2: Electricity Access, in West Africa

Electricity Access in Africa

	Rate of access						Population
	National				Urban	Rural	without
	2000	2005	2010	2017	2017	2017	2017
West Africa	33%	37%	42%	51%	77%	29%	182
Nigeria	40%	47%	50%	60%	80%	40%	77
Benin	22%	23%	27%	30%	54%	9%	8
Cote d'Ivoire	50%	49%	59%	60%	88%	31%	10
Ghana	45%	51%	61%	84%	97%	69%	5
Senegal	30%	35%	54%	65%	90%	43%	6
Togo	9%	18%	28%	36%	64%	16%	5
Burkina Faso	13%	9%	15%	18%	58%	1%	16
Cape Verde	59%	65%	70%	96%	100%	89%	<1
Gambia	18%	27%	35%	45%	66%	13%	1
Guinea	16%	18%	20%	17%	46%	1%	11
Guinea-Bissau	10%	11%	12%	10%	14%	8%	2
Liberia	0%	1%	2%	10%	16%	3%	4
Mali	12%	14%	17%	38%	83%	6%	11
Mauritania	15%	17%	19%	30%	56%	1%	3
Niger	7%	8%	9%	12%	68%	1%	19
Sao Tome and Principe	53%	55%	57%	68%	87%	22%	<1
Sierra Leone	9%	11%	12%	20%	19%	20%	6

Source: IEA, World Energy Outlook-2018

Events have shown that access to electricity through the grid can no longer sustain increasing population, especially in developing economies of the world. For instance, in a study by Perez (2006), an estimated 1.7 Billion people live off- grid worldwide.

Off grid technologies can generally be explained as an affordable decentralized energy designed for homes, villages, dispersed settlements islets; which can be made up of solar home systems, wind systems, biogas digesters, biogas gasifiers, micro-hydro power plants, etc. Alliance for Rural Electrification (2013). In addition, off-grid systems are able to support the incorporation of decentralized renewable power generation into the grid and provide power reliability and stability.

Thus, major objectives of this study are to;

1. Explore prospects and challenges of off-grid power generation
2. Recommend policies for increased adoption of the system.

The system of off-grid power generation will go a long way to address the recurring issues facing the Nigerian Power sector over the years. This sustainable and renewable system has been fully implemented in some countries and is yielding excellent results. Subsequent sections of the paper further discourses power generation; off-grid power generation and will further address issues of prospects and challenges hindering full adoption of this system.

2 LITERATURE REVIEW

2.1 POWER GENERATION IN NIGERIA

According to Claudius (2014), the history of electricity generation in Nigeria can be dated back to the end of the 19th century, when the first generating power plant was installed in Lagos in 1898, fifteen years after its introduction in England. The total capacity of the generators used then was 60Kw due to the low demand then (Onochie *et al.*, 2015). In 1946, the public works department ceased to have control over the operation of the electricity generating plants and distribution system in the country. As a result of this, the Nigeria Government Electricity Undertaking (NGEU) was established under the jurisdiction of the Public Works Department (PWD) to take over the responsibility of electricity supply in Lagos state. Five years later, a central body was established to take over all the various electricity supply outlets within the country.

The body is referred to Electricity Corporation of Nigeria (ECN), and was established by act of parliament in 1951 (Olugbenga *et al*., 2013). With the increase in demand for electricity, some projects were carried out in Ijora, Oji River, Kano, and Ibadan power stations to further compliment the availability and quality of power delivery in the country (Claudius, 2014).

In 1962, a decade after the establishment of ECN, Niger Dams Authority (NDA) was set up, which was responsible for dam construction after discovering the countless benefits that would generate from the dam. This led to the construction of Kainji Dam in 1962 and was completed in 1968 (Claudius, 2014).

The electricity produced by NDA was sold to ECN for distribution and sales at utility voltages. However, a merger of the two was made in 1972 to National Electricity Power Authority (NEPA). According to Olugbenga *et al.* (2013), electric power demand increasingly overshoots available supply as population increases and this resulted in a decline in electricity generation capacity. As a result of the Government effort to revitalize power sector, NEPA was renamed to Power holding company of Nigeria (PHCN) by electricity power sector reform (EPSR) Act of 2005. In addition, the study stated that by the act, NEPA was translated into the newly corporated PHCN plc comprising of 18 separate successor companies that took over the assets, liabilities and employees of NEPA, and responsibilities for the generation (6 companies), transmission (1 company) and distribution (11 companies). Sambo *et al*(2010) states that electricity generation in Nigeria over the last 40 years varied from gas –fired, oil – fired, hydroelectric power stations to coal-fired with hydroelectric power system and gas – fired system taking precedence.

The study further posits that Nigeria has 14 generating plant (of the which, 3 are hydro and 11 are thermal (gas/steam)) supplying electricity to the National Grid. The national grid is made up of 4,889.2km of 330kV line, 6,319.33km of 132kV line, 6,098MVA transformer capacity at 330/132kV and 8,090MVA transformer capacity at 132/33kV.

2.2 OFF-GRID POWER GENERATION

Over the past few years, the Nigerian government had expanded its focus on exploring other sources of power generation through off-grid to reduce pressure on grid supply due to the recurrent problems facing the sector. Apart from irregular and unreliable supply, high cost of connection, recurrent vandalism of the transmission lines, pressure on the national grid has led to constant system collapses; all these necessitates the provision of electric power through off-grid option. Furthermore, these problems have led to; those who play in the industrial sector and a number of residential power consumers to solely disconnect from grid supply to rely on self-generated power for their operations (Ugwuanyi, 2018). Off-grid generation can be described as stand-alone power generation systems or mini-grids, which typically provide smaller communities with electricity through independent electricity distribution network systems (Financial Nigeria, 2016). Off -grid supply is power supply that does not go through the national grid. They are usually low capacity generations.

The broad difference between off-grid and centralized grids is the latter is larger in size, produces several hundred megawatts (MW) or thousands of gigawatts (GW) that can cover larger area and rely on centralized power stations to meet electricity demand. While the former is smaller in size, producing lesser, and has a (semi)-autonomous capability to satisfy electricity demand through local power generation. According to Elusakin, Ajide, and Diji (2014), off-grid technologies are majorly linked with renewable technologies such as solar and hydro.

According to the IEA (2017), annual per capita electricity consumption was 140 kWh in 2015, or roughly 12 kWh per capita per month. An online publication by Punchng (2015) shows that the total off-grid generation capacity as approved by the Nigerian Electricity Regulatory Commission (NERC) is still less than 500MW. There is need for significant investments in off-grid power generation; considering Nigeria's plans to increase power generation capacity in the coming years. Off-grid supply meant for solar home systems (SHS) and comes in small systems of between 10W and 500W and mainly for rural communities while SHS of larger systems of between 500W and 15KW for urban and semi-urban. Off-grid systems for SMEs and businesses are between 500KW and 1MW and perfectly runs the rural electrification agency (REA) energizing economy, while mini grids can range from 15KW to 10MW for industries, estates, educational institutions and markets, solar agriculture, solar irrigation (Ugwuanyi, 2018). For instance, the figure below shows a schematic diagram of an off-grid PV system. Here, the solar panels become generates the needed energy by one's home or any energy dependent system. There may be no option other than to go with an off-grid solar system.

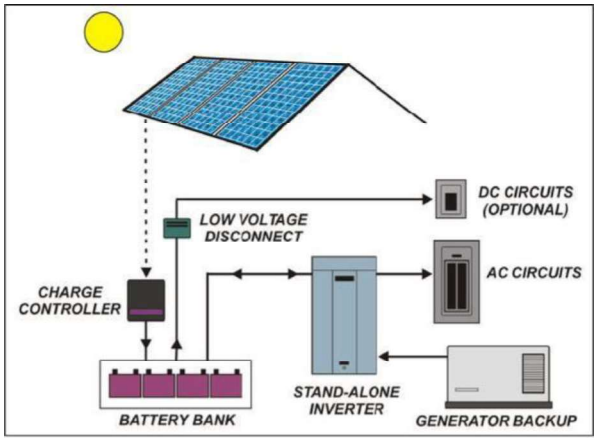

Figure 1: Off-grid PV System Schematic
Source: Ammar & Noor (2018)

2.3 OFF-GRID POWER GENERATION IN RURAL COMMUNITIES

The government through the ministry of power, works and housing in partnership with the private sector operator, has been developing solar and wind projects to feed the population that does not have access to grid supply. The rural electrification agency (REA) is another major vehicle the government is using to drive the off-grid generation project in the rural areas of the country (Ugwuanyi, 2018).

The Nigerian Rural Electrification Agency (REA) was created by the Electric Power Sector Reform Act in 2005 to facilitate the provision of affordable power supply for residential, commercial, industrial, and social activities in the rural areas. The agency is dedicated to supporting off-grid development to enable people function without the support of remote grid infrastructure. According to a report by Source: Ben *et al, 2015,* about 31 million people may be living in an area where electricity is available, yet do not have access. Nearly three-quarter (72%) of under-the-grid Nigerians live in rural communities, and just about 30% live within 10Km 0f a high voltage transmission line- as shown in the figure below.

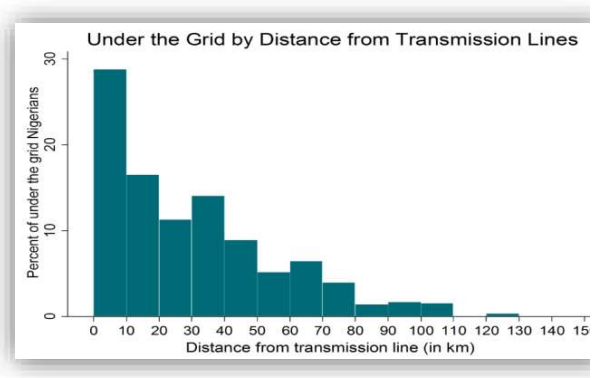

Figure 2: "Under the Grid" population distance from Transmission line (Km)
Source: Ben *et al, 2015*

According to (ARE, 2015; IRENA 2015), there are majorly two approaches to conduct rural power generation in an effective way; one of the approach is mini-grid or isolated grid which generates between 10KW – 10MW to serve limited number of consumers (rural communities, institutional buildings and commercial/industrial plants and buildings).

The other approach is through stand-alone system which provides electricity to individual appliances, homes or a small business. For instance, Bangladesh is one of the world's most densely populated countries with a population of over one hundred and fifty eight million and has made a success story from implementing off-grid power solutions. The government of Bangladesh initiated the solar home system (SHS) based rural electrification programme in 2003 through development company limited under a microcredit scheme. In 2002, only 7000 Bangladeshi households used solar panels, but as of today, the programme has installed about 2 million SHS in the country (Financial Nigeria, 2016).

3.0 PROSPECTS OF OFF-GRID POWER GENERATION

According to the Minister for Power, Works and Housing in Nigeria, Mr. Babatunde Fashola (2016), Elusakin, Ajide, and Diji (2014) the following are some of the prospects for off-grid power generation in the country:

Potential to grow industrial clusters and small cottage industries

Most industrial groups and some small businesses require uninterrupted power supply to function optimally. This could be generated through fully off-grid power plants or embedded within distribution networks. This could potentially transform the economy of these areas; increase profitability for the existing businesses; create jobs; and breed a crop of customers who are willing to pay for electricity supplied.

Opportunity to expand and refurbish distribution networks of the DISCOs

In line with the NERC Regulation for Independent Electricity Distribution Networks (IEDNs), 2012, off-grid generation plants require Independent Electricity Distribution Networks (IEDNs) to supply electricity to end users, except for eligible customers upon declaration by the Minister of Power, who can be supplied to directly. This creates opportunities for investors who may wish to create off-grid projects with their own IEDN. This could potentially be a win-win situation for DISCOs who could either collaborate with developers to expand or refurbish their network; add to their number of paying customers; or acquire the developer assets given the right regulatory framework.

Access to other fuel alternatives

Most of the power plants in Nigeria are gas fired thermal plants. Given the current constraints with gas, off-grid power plants could be an alternative, taking advantage of diverse and hybrid fuel sources like renewables (solar, wind, biomass). This would be particularly more useful in areas where there is limited gas supply, e.g. the northern part of Nigeria where solar, wind, and hydro sources are prevalent.

Opportunity for rural electrification

Off-grid solutions are also useful in the area of topographical or geographical challenges in rural areas which have made it uneconomical to extend the grid to such areas. Rural electrification in Nigeria is currently in a weak and ramshackle state; hence there is a dire need for investments in the area.

Technology development

Positive passion for improved technological development on the side of the government will go a long way to foster the development of this system. Government should invest more in science and technology as well as creating enabling environment for foreign technology companies to train and develop our engineering graduates.

4.0 CHALLENGES OF OFF-GRID POWER GENERATION IN RURAL COMMUNITIES

Technology gap

Due to the fact that many of the off-grid equipment are sophisticated and advanced, there is need to develop the

adequate technological know-how for installation, operation and maintenance. It is common to find that many solar PVs (photovoltaic) installed fail shortly after installation. Also, renewables such as wind and biomass have not been fully explored in Nigeria, and would require adequate know-how. The country needs to strive hard to close these gaps in technology for improved practices.

Objections from existing Monopolies.

There are possibilities that there would be objections to the granting of off-grid licenses from electricity distribution companies (DISCOs) over the areas where their DISCO licenses currently cover. NERC also maintains a balance to ensure that the DISCO's market share will not be destroyed by the grant of an off-grid license (Financial Nigeria, 2016).

Improper planning

Inadequate planning is an impediment to the success of off-grid development in Nigeria. Off-grid projects are not well planned such that the viability of the projects are not being considered in each location before the implementation. Planning and design proceed any sustainable off/grid power project which is the beyond the challenges of technology type and availability (Elusakin, Ajide, and Diji, 2014)

Lack of monitoring the implementation of off-grid projects

Off-grid projects when awarded to contractors are not effectively monitored. Due to corruption in the REA, project fund are alos misappropriated which leads to non-implementation of off-grid projects (Alao and Awodele, 2018).

Political Instability

Another major challenge hindering the full implementation of off-grid power generation in rural communities is the frequent political instability faced in the country, as well as change in government policies

5.0 CONCLUSION

There is the urgent need to strategically increase the rate of electrification for rural communities to promote socio-economic development in the country. The main aim of this study was to examine the prospects and challenges facing the adoption of off-grid power generation in rural communities. This was achieved through theoretical review of relevant literature. One of the constraints encountered in the course of this study is the limited literature in the area of off-grid system in Nigeria. Hence, as a recommendation, further research should be done to breach the existing gap between Nigeria and other countries.

5.1 RECOMMENDATION

- To encourage further investments in off-grid solutions, it is important that the government ensures that the environment is welcoming enough to elicit tax support from the government in terms of tax reforms
- Projects for rural electrification should be adequately funded as well as strategy to ensure sustainable growth in the projects
- Collaboration with the World Bank, United Nations (UN), NGOs and other institution to develop the power sector.
- All tiers of government be duty-bound to implement off-grid projects to make the country attain its long-term plans of sustainable power supply.

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