Increasing Energy Mix in Nigeria's Electric Grid Through Renewable Energy Development

CLETUS U. OKOYE[1], I. A. ADEJUMOBI[2]

[1] *Department of Electrical / Electronic Engineering, The Federal Polytechnic, Ilaro, Ogun State, Nigeria.*

[2] *Department of Electrical/Electronic Engineering, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria.*

Abstract- ***Nigeria's electricity supply is grossly inadequate, irregular and unreliable. Total available daily generation varies from time to time but usually ranges from about 3,000 MW to 4,000 MW. This is far from meeting the national power demand of 40,000 MW (connected and suppressed demand). The result is that many industries have closed down their businesses or relocated to neighbouring countries resulting in high rate of unemployment and cost of goods and services. Manufacturers are forced to depend on self-generation for survival. This paper posits that complete dependence on Nigeria's total installed grid capacity of 12,954.40 MW (as at December 2019) portends a great danger to the largest economy in Africa as there is no grid-connected renewables in the country. Besides ensuring future low-carbon energy development, it draws attention to the huge renewable energy potentials of Nigeria ready for exploitation to mitigate the current energy crisis.***

Indexed Terms- ***Renewable Energy, Energy Mix, Installed Capacity, Grid, Self-Generation.***

I. INTRODUCTION

Energy deficit has been a major issue slowing down socio-economic development in Africa, with particular reference to Nigeria. Nigeria is blessed with abundant natural resources which can be exploited to generate electricity for the nation and for export. Yet, energy shortage has degenerated into a major crisis in the country that must be tackled now if we as a nation must emerge stronger economically.

NESP (2015) reveals that the overall electrification rate for Nigeria is barely 45% compared with 32% average electrification in Sub-Sahara Africa. It further discloses that that the urban and rural electrification rates in Nigeria are 55% and 35% respectively. Besides, the World Bank in February 2017 ranked Nigeria second only to India with the highest electricity access deficit with an estimated 75 million people unconnected to the grid, (TEMPLARS 2018). Similarly, the UNDP and Oxford Poverty and Human Development Initiative (Adepegba, 2019) reiterate that the Global Multi-dimensional Poverty Index (MPI) had indicated that multi-dimensionally poor Nigerians increased from 86 million to 98 million between 2007 and 2017.

One of the major reasons why poverty and unemployment rate is high in Nigeria is because energy/power supply from the grid is grossly inadequate. This has caused many multinational companies such as Michelin and Dunlop to relocate to neighbouring countries and so many other industries to shut down operations (Okoye, et al, 2020; Okoye and Omolola, 2019). The economic transformation agenda, otherwise known as Nigeria Vision 2020, aims at making Nigeria one of the 20 most developed and largest economies in the world in the year 2020. Unfortunately, year 2020 has come and gone without any critical sustainable achievement in power generation output. Rather, we are presented with an average daily power generation below 4500MW which is far below the peak load forecast of 14,630MW expected in April 2018, for example (NCC, 2018).

Of the 12954.40MW total installed generating capacity in Nigeria as at December, 2019, hydro power plant, the only source of renewable energy in the country's power mix has a total installed capacity of 1938.40 MW; representing 15% of the total installed capacity (NCC, 2019). The rest of the plants (85%) are thermal that use natural gas as fuel.

Emphasis should now be on how to diversify energy base to include other grid-connected renewable sources. Meanwhile, the existing large-scale grid-connected renewable is in form of large-scale power plants (Kainji hydro, Jebba and Shiroro hydro). Apart from hydro, there is no real commercial large-scale exploitation of other renewable energy sources at present. If this is done, more grid-connected energy will be available to consumers with less danger to the environment.

Good enough, according to NESP (2015), Power Africa, the USAID-funded energy initiative, some time ago, disclosed plans to invest One billion US dollars to help Nigeria diversify her energy/power mix. Since it is technically the responsibility of the Federal Ministry of Power (FMP), the National Electricity Regulatory Commission (NERC) and the Transmission Company of Nigeria (TCN) to see to the inclusion of electricity generated from renewables into energy mix, one would expect a follow up from here. After all, the Economic Growth and Recovery Plan (2017 – 2020) of Nigeria lays emphasis on significant development of power.

II. METHODOLOGY

Part of the requirements for graduation at Higher National Diploma (HND) level in the Department of Electrical/Electronic Engineering (Power & Machines Option) is an educational visit/excursion to

(i) The National Control Centre (NCC), Osogbo, Nigeria.
(ii) At least, one major power station (hydro or thermal), and
(iii) An Injection substation.

This is in line with the Engineering Curriculum developed and approved by the National Board for Technical Education (NBTE), the Regulatory Body of all technical/vocational programmes in Nigeria as run or administered by the Polytechnics, Monotechnics and Technical Colleges.

Consequently, several visits were made over a period of time with the students to the NCC, Olorunsogo 750MW power Station, Olorunsogo 335.00MW Power Station and an Injection Power Substation situated along Powerline Road, Ilaro, Ogun State. In the course of the visits, the students and the researchers were taken through the crucial processes involved in generation, transmission and distribution of electrical energy with particular reference to frequency control. Technical questions bordering on these processes were asked and appropriate answers supplied by the engineering personnel concerned at the departments, units, and places visited.

At the end of the visits, relevant data were collected from the stations, and the National Control Centre (NCC). This is also complemented with data from other relevant literature.

The data were classified as shown in Tables 1.0 to 4.0.

Table 1.0: Nigeria's Power Plant Capacity and Grid Generation as at March 01, 2021

Station Type	Power Plant A	Installed Capacity (MW) B	Average actual generation (MWH/H) C	Installed capacity Utilisation C_n/B_n (%)	Peak Generation (MW) 01/03/2021 D	Energy generated (MWH)	% Contribution to System energy Generation
Hydro	Kainji G.S.	760.00	364.29	47.93	342.00	8,743.00	7.49
	Jebba G.S.	578.40	339.92	58.77	456.00	8,158.00	6.99
	Shiroro G.S.	600.00	254.42	42.40	435.00	6,106.00	5.23
	Dadin-Kowa	40.00	16.03	40.08	15.90	384.80	0.33
	SUB-TOTAL	1,798.40	974.66	49.26	1,248.90	23,391.80	20.05
Thermal	Egbin G.S. St	1,100.00	772.92	70.27	833.00	18,550.00	15.90
	Sapele Steam	720.00	47.16	6.55	56.00	1,131.90	0.97
	Delta II-IV G.S.	900.00	323.83	35.98	344.00	7,771.90	6.66
	Afam IV & V	351.00	48.44	13.80	50.00	1,162.49	1.00
	Geregu G.S.	435.00	346.90	79.75	399.00	8,325.70	7.14
	Omotosho G.S.	335.00	153.33	45.77	152.60	3,680.00	3.15
	Olorunsogo	335.00	187.00	55.82	185.00	4,487.90	3.85
	SUB-TOTAL	4,176.00	1,879.58	45.01	2,019.60	45,109.89	38.67
	Sapele NIPP	500.00	131.59	26.32	197.90	3,158.26	2.71
	Alaoji NIPP	500.00	0.00	0.00	0.00	0.00	0.00
	Olorunsogo NIPP	750.00	0.00	0.00	0.00	0.00	0.00
	Geregu NIPP	435.00	129.77	29.83	235.00	3,114.50	2.67
	Omotosho NIPP	500.00	20.38	4.08	111.40	489.00	0.42
	Ihovbor NIPP	500.00	0.00	0.00	0.00	0.00	0.00
	Odukpani	625.00	349.99	56.00	533.10	8,399.87	7.20
	Gbarain	120.00	0.00	0.00	0.00	0.00	0.00
	SUB-TOTAL	3,930.00	631.73	16.07	1,077.40	18,161.63	13.00
	Okpai G.S. IPP	480.00	357.38	390.00	390.00	8,577.00	7.35
	Afam VI G.S. IPP	650.00	286.23	300.00	300.00	6,869.54	5.89
	Asco IPP	110.00	0.00	0.00	0.00	0.00	0.00
	Ibom G.S. IPP	190.00	0.00	0.00	0.00	0.00	0.00
	AES IPP	294.00	0.00	0.00	0.00	0.00	0.00
	Trans-Amadi IPP	100.00	86.50	84.70	84.70	2,076.02	1.78
	Rivers IPP	180.00	144.49	154.00	154.00	3,467.70	2.97
	Azura IPP	461.00	407.75	436.00	436.00	9,786.10	8.39
	Omoku G.S. IPP	150.00	39.39	38.10	38.10	940.50	0.81
	Egbin St6	220.00	0.00	0.00	0.00	0.00	0.00
	Paras Energy IPP	95.00	53.14	52.90	52.90	1,275.40	1.09
	SUB-TOTAL	2,930.00	1,374.68	1,455.70	1,455.70	32,992.26	28.28
	GRAND TOTAL (WEIGHTED AVERAGE)	13,014.40	4,860.65		5,801.60	116,655.58	100.00

Source: National Control Centre (NCC), Osogbo, Nigeria
IPP: Independent Power Plants

Table 2.0: Small Hydro Potentials in Surveyed States in Nigeria

S/No.	State	River Basin	Total Sites	Potential Capacity (MW)
1	Sokoto	Sokoto-Rima	22	30.6
2	Katsina	Sokoto-Rima	11	8.0
3	Niger	Niger	30	117.6
4	Kaduna	Niger	19	59.2
5	Kwara	Niger	12	38.8
6	Kano	Hadeja-Jama're	28	46.2
7	Borno	Chad	29	20.8
8	Bauchi	Upper-Benue	20	42.6
9	Gongola	Upper-Benue	38	162.7
10	Plateau	Lower-Benue	32	110.4
11	Benue	Lower-Benue	19	69.2
12	Cross River	Cross River	18	28.1
	Total		278	733.6

Source: Esan (2003); Okoye (2010)

Table 3.0: Nigerian's Major Renewable Energy Potential

S/No.	Resource Type	Potential
1	Large hydropower	11,500MW
2	Small hydropower	734MW
3	Solar	3.5 – 7.0KW/m/day
4	Sun shine	4 – 8 hours/day
5	Wind	2 – 6m/s at 10m height
6	Animal waste	61 million tones/year

Source:
1) Federal Republic of Nigeria: Investment opportunities in the Nigerian Power Sector
2) The Nigerian Institution of Electrical/Electronics Engineers, 13th Distinguished Annual Lecture

Table 4.0: Estimated Electricity Generation from $1KW_P$ PV module in selected Nigerian Cities

City	Horizontal/Optimal Inclination Angle (degrees)	Yearly average daily radiation ($KWh/m^2/day$)	Annual electricity generation (KWh)
Sokoto	0	5.21	1426
	15	5.34	1462
Maiduguri	0	6.22	1703
	16	6.4	1752
Abuja	0	5.26	1440
	15	5.39	1476
Ilorin	0	5.13	1404
	14	5.23	1432
Ibadan	0	4.61	1262
	14	4.71	1289
Enugu	0	4.75	1300
	12	4.82	1319
Port-Harcourt	0	4.26	1166
	11	4.31	1180
TOTAL		71.64	19,611

Source: Akorede, M. F. et al (2017)

RESULTS AND DISCUSSION

From Table 1.0, though Nigeria's total installed generation capacity as at March 2021 was 13,014.40MW, the installed capacity utilization was only 37.35% (NCC, 2021). The 13,014.40MW installed capacity is a far cry from Nigeria's power sector Road Map aspiration of 40,000MW by 2020. Besides, of the 13,014.40 MW capacity, hydro (a renewable source of energy) contributed 14% of the total installed capacity while the thermal source accounted for 86%. The Independent Power Plants (IPP) constituting 2930.00MW (22.5%) are all thermal. Thus, there is no grid electricity contribution from renewable other than from the large hydropower plants.

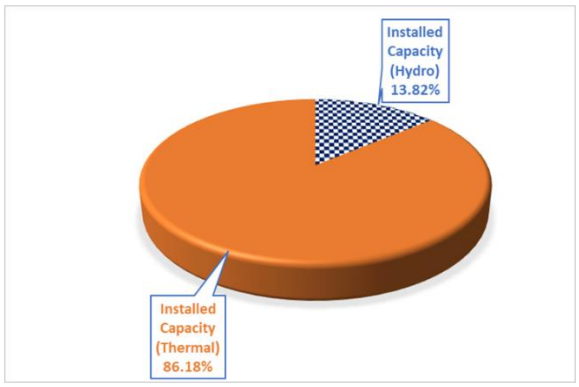

Fig. 1.0. Chart showing composition of energy mix in Nigeria's power grid.

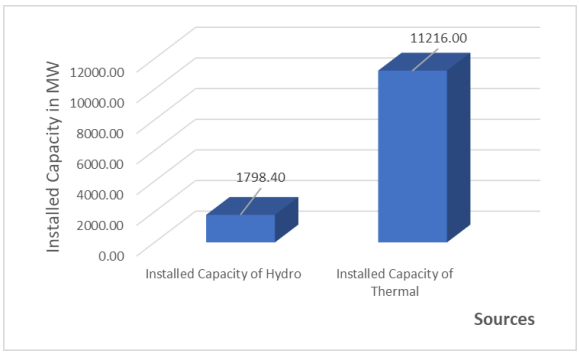

Fig. 2.0. Chart showing Hydro-Thermal composition in Nigeria's grid power mix.

However, Nigeria has over 27.8 potential small hydropower sites capable of generating 733.6MW of electricity (Table 2.0).

Comparatively, China has installed more than 87,000 small-scale hydropower schemes since 1968 (Andrews, 1992). These are producing 5000MW of electricity (the equivalent production of ten coal-fired power stations). In 1998, the Indonesian government announced its intention to electrify 18600 villages using small and micro-hydro schemes. According to Inversion (1986), and Okoye (2010), the University of Science and Technology in Peshawar in Collaboration with the Appropriate Technology Development Organisation in Pakistan has developed and implemented a programme of micro-hydropower plants to generate electricity. According to Ekpo (2017), at present, only about 25 countries of the world depend on hydropower for 90% of their electricity need while 12 countries are 100% dependent on hydropower.

Nigeria has a huge potential for large-scale generation of power/energy from other renewable sources, especially solar and wind (Table 3.0). Apart from hydro, solar and wind power have not been exploited on commercial basis such that they can be grid-connected for wider use. In all, wind power generation is not yet well understood in Nigeria as in the case of solar PV system (Newsom, 2012). The two, solar and wind hold a great hope for large scale exploitation in Nigeria. Worldwide, electricity generation from renewable as at the end of 2015 was about 23.7% made up of hydropower (16.6%) wind (3.7%) and 3.4% from other new renewables (Akorede, 2017; Olaoye et al, 2016).

Wind speeds for various geo-political zones in Nigeria have been established (Akorede, et al, 2017; Akinwale & Ogundavi, 2017; Emodi & Ebele, 2016). For instance, the North-West zone with wind speeds in the range of 3.88m/s to 9.39m/s has the highest wind speeds. The North-East has wind speed of 9.47m/s while in South-East, wind speed of 5.73m/s was recorded for Enugu site only. For South-South, wind speed records are as follows: Calabar (4.65m/s, highest) and Port-Harcourt, is least with 3.30 m/s wind speed. Ondo in South-West of Nigeria has wind speed of 1.77m/s (the least obtainable) and speeds 4.5m/s and above are present in Lagos Island, Lagos Mainland and Shaki. In North-Central zone, Minna has the highest wind speed of 5.36m/s while Bida has the least with 2.46m/s. All these are very useful information for development of grid-connected wind power plants in Nigeria.

Similarly, studies (EC JRC, 2013; MESOR, 2013; Akorede, 2017) show the solar radiation data for different regions of the world, geo-political zones and selected cities in Nigeria in particular, Table 4.0 shows the estimated solar energy that can be generated in some Nigerian cities for both horizontal and optimal inclined solar PV modules.

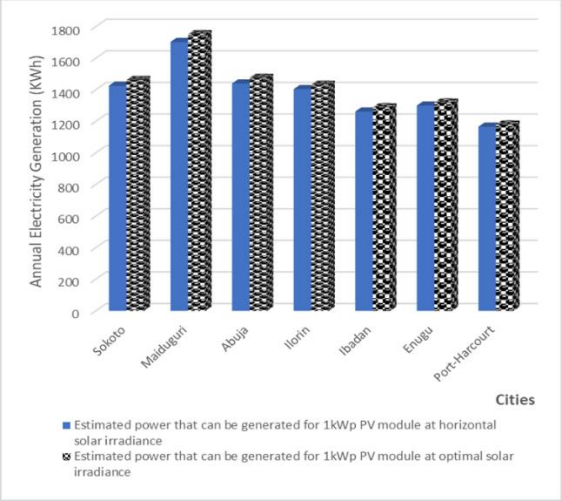

Fig. 3.0. Chart showing estimated annual electricity generation from 1KWp PV module in Nigerian cities.

The northern part of Nigeria has the most outstanding potential for generating solar power since from table 4.0, and for a $1KW_p$ PV module at horizontal solar irradiance, the annual sum of estimated power that can be generated is high for most northern cities: 1703 and 1426 KWh in Maiduguri and Sokoto respectively. Compare this with values in far Southern part of Nigeria such as Ibadan (1289 kwh), and Port-Harcourt (1180 kwh) respectively. All these attributes and more are what made solar and wind power generation attractive for grid-connected electricity. Besides, they are environment friendly when compared with electricity generation from fossil fuel (gas, oil and coal).

Burning of fossil fuels releases greenhouse gasses (e.g., carbon dioxide, nitrous oxide and methane) that cause depletion of ozone layer and consequent global warming. That is why many nations of the world are today banning or restricting investments in fossil fuels and Nigeria is protesting against it (ASU, 2021). In fact, seven European countries such as Germany, United Kingdom and France announced their intension to stop public funding for certain fossil fuel-driven projects overseas.

CONCLUSION

Nigeria's grid electricity is generated by 25 thermal power plants and three large-scale hydropower plants. Of the 12954.40 MW installed capacity as at December, 2019, hydropower plants account for a mere 15% while gas-fired (thermal) plants are responsible for 85%. This means that Nigeria's energy mix is in favour of fossil fuel sources with attendant negative environmental consequences.

This is because the burning of fossil fuels is accompanied by the release of greenhouse gasses such as carbon-dioxide, methane and nitrous oxide (among others) which deplete the ozone layer; thus increasing global warming. Besides, due to inadequate power supply in Nigeria, the cost of electricity in production and manufacturing accounts for as much as 40% of the operational expenses of Micro, Small and Medium Scale Enterprises (MSMES); the economic mainstay of any nation. Consequently, there is this lack of competitiveness and a reduction in profit margin. At present, Nigeria's daily electricity generation revolves around 3500 MW in a nation of about 200 million people.

The paper thus encourages massive investments (public and private) in renewable energy technologies with particular interest in solar and wind power. The North-East, North-West and North-Central geo-political zones of Nigeria record high wind speed in the range of 9.39 m/s to 3.88 m/s. For Southern part of Nigeria, wind speeds of 5.73 m/s, 4.65 m/s and 4.5 m/s can be observed in Enugu, Calabar and Lagos respectively. Also, solar radiation is liberally distributed across Nigeria but with higher intensity in most northern cities such as Sokoto and Maiduguri.

RECOMMENDATIONS

In order to accelerate the development and integration of renewable energy into the energy mix, the following solutions are recommended.

- The government should declare a state of emergency in energy sector and then prepare itself for planned, deliberate and systematic investment in renewable energy technologies with particular reference to solar and wind resources. It is embarrassing and visionless for the entire nation of over 200 million people to depend on the mere 3500 to 4500MW per day for her existence and critical infrastructural development.
- Having psychologically so attuned itself, the government should seek for partnership for

financing large-scale renewable energy development. It should strengthen its business relationship with Power Africa – a U. S. government-led initiative consisting of 12 U. S. government Departments and Agencies and a diverse coalition of more than 140 public and private-sector partners. In this way, more help could come for renewable energy exploitation.

- Government should seek for more finance mechanisms to boost and sustain investment in renewable energy development. For instance, Norway supports Mozambique's first large-scale solar power plant – the 40MW Mocuba Solar-power plant (Power Africa, 2017). The construction of the grid-connected solar plant commenced in 2017 and it is planned to meet the energy needs of 175,000 households.
- The government should ensure that the Grid code issued by the National Electricity Regulatory Commission (NERC) in November 2017 is strictly adhered to. The code was designed to ensure a safe, reliable and efficient operation of electricity transmission system and recognizes and makes provision for integration of renewable energy resources into the grid. This provision must be utilized by diversifying the country's energy mix to bring in solar and wind power plants.
- As the nation successfully grows her grid-connected renewable technologies, the distribution network should also be upgraded to enhance its distribution capacity.
- Sometime ago, the Bank of Industry launched a one-billion-naira solar Energy Fund to "Finance access to alternative and renewable energy for Micro, Small and Medium Scale Enterprises" (Power Africa, 2017). Besides, in 2017, the Rural Electrification Agency (REA) announced that the Federal Government of Nigeria planned to generate 3000MW of electricity by the year 2020 through 10,000 community-based mini-grids for under-served rural areas. Good policies and intentions such as these should always be monitored and evaluated closely to ensure that they are ultimately actualized and in good time too. The government is too weak in this direction.

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