Electric Power Industry Restructuring In Nigeria

Oseweuba Valentine Okoro

Abstract: This paper presented a general overview of Electric power generation in Nigeria, with a special focus on the restructuring attempts made by the Federal Government to facilitate the provision of a more stable power supply for her people as well as an investigation into the basis of the Nigerian energy mix. During the course of this investigation, there was an extensive consideration of the history of power generation in Nigeria, the current state and the future trends while establishing that the non-sustainable nature of the current power systems remains the major catalyst for the electricity restructuring drive. The paper also identified the various plant types that will adequately meet the demands for peak, intermediate and base load requirements. The economics of electricity generation via the utilisation of the Levelised Cost of Energy (LCOE) was explored in an attempt to fully explain the Nigerian energy mix while establishing the role of economics and resource availability in the determination of the Nigerian energy mix. Possible social and environmental concerns of electricity generation were also explored and mitigation measures identified from literature. The paper also provided recommendations that will assist in the achievement of a more sustainable and revitalised electric power sector within the country Nigeria.

Keywords: power sector, Independent Power Producers, Nigerian energy mix, restructuring drive, privatization

I. INTRODUCTION

The availability of energy is pivotal for poverty alleviation and facilitates services in the areas of health and communication thus constituting a vital ingredient for socio-economic and technological development as well as paramount in determining the country's level of economic development [1]. Thus, an absence of a reliable energy source significantly hinders economic growth and development. Indeed the significance of energy as a major consideration in both domestic and foreign policies was established in a lecture for Energy and Power Supply Systems (CE1199A), presented on 22 October 2013 at the University of Abertay Dundee by C.S. Özveren. Unfortunately Nigeria operates a centralised energy system were over 160milion individuals living in both the urban and sparsely distributed rural communities are dependent on a common energy source. This results in many communities living without electricity due to the high cost of connecting to this centralized source thus contributing to the existing scenario where over 70% of the population do not have access to electrical power [2].

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II. BRIEF OVERVIEW OF POWER GENERATION IN NIGERIA

Power generation in Nigeria effectively began in 1896 with the 20MW power station at Ijora, although no coordinating entity for nationwide electricity generation and supply existed until 1951 when the Electricity Corporation of Nigeria (ECN) was established. The Niger Dam Authority (NDA) was subsequently set up to build and manage dams in Nigeria in 1961, with the country operating at a total installed generation capacity of a little above 50MW, with the first 132KV line constructed in 1962. In 1972, the Federal Government of Nigeria effected the unification of both entities, leading to the formation of the National Electric Power Authority (NEPA), a power utility responsible for generation, transmission, and distribution and trading of electricity in Nigeria. However, this exclusive monopoly of NEPA over the generation, transmission, distribution and sales of electricity ceased in 1998 in line with the privatisation drive of the federal government with the entity undergoing a name change to PHCN (Power Holding Company of Nigeria) in 2005 [3],[4],[5]. Reference [6] emphasised the significance of thermal systems in the national energy mix establishing that electricity in Nigeria was from predominantly thermal systems before the advent of hydro-generated electricity. It is also curious to note that the hydro system that began with Kainji in the early 1970s was gradually displaced by the thermal dominated systems again some years later because of persistent water-flow problems of the River Niger at Kainji as well as increasing costs of establishing hydro-plants and their long gestation delays.

III. THE ELECTRICITY GENERATION IN NIGERIA PAST AND PRESENT

Nigeria currently generates a significant proportion of the total National power via Government owned power stations that operate far below the installed capacity; Table 1 shows the government owned generating stations and plants in Nigeria.

TABLE I
GOVERNMENT OWNED GENERATING STATIONS AND PLANTS IN NIGERIA [7]

Power station	Type	Year commis sioned	Installed capacity (MW)	Availabl e capacity (MW)
Ughelli Power Plc	Gas-fired thermal plant	1966	900	300
Shiroro Hydro Power Plc	Hydro electric plant	1989	600	450
Sapele Power Plc	Thermal Plant	1978	1020	90
Oji River Power Station	Coal-fired steam power station	1956	10	nil
Kainji/Jebba Hydro Electric Plc	Hydro plant	Kainji : 1968 Jebba : 1985	Kainj : 760 Jebba : 540	480 450
Calabar Thermal Power Station	Thermal Plant	1934	6.6	nil
Afam (i-v)Power Station	Thermal Plant	1963-2001	726	60
Ebin power Plc	Thermal	1986	1320	1100
Geregu Power PLC	Thermal Plant	2007	414	276
Omotosho Power PLC	Thermal Plant	2007	304	76
Olorun-shogo Power PLC	Thermal Plant	2008	304	76

A critical consideration of Table 1 will show that the available capacity is significantly less than the installed capacity with the most conservative projections indicating continuous increase in the future energy demand in the country as illustrated in Figure 1.

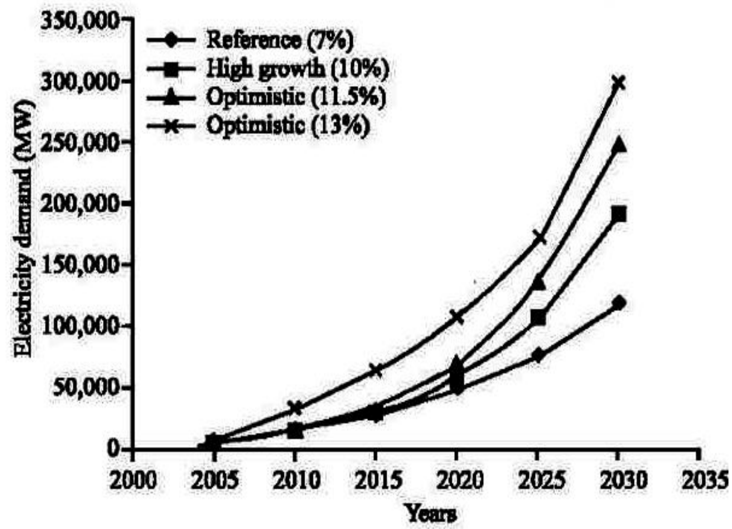

Fig 1: The projected electricity demand between 2005 and 2030[8]

Apparently an appreciation of the dire situation of energy supply as well as a recognition of the obvious non-sustainability of the prevailing power systems due to growing demand led to the introduction of Independent Power Producers.

A. The Independent Power Producers

These Independent Power Producers are entities, which own and operate facilities that generate electric power for sale to end users. In some cases, Independent Power Producers may also be capable of transmitting excess energy into the distribution or transmission grid system [9]. In an attempt to streamline the operation of these Independent Power Producers the Electric Power Sector Reform Act was enacted in 2005 which transferred the electricity sector in Nigeria from a government controlled heavily subsidised system to a largely market-driven project [10].Currently Nigeria has eight (8) fully functional Independent Power Producers with corresponding capacities as shown in table II.

TABLE III

INDEPENDENT POWER PRODUCERS [11]

S/No	Station	Capacity (MW)
1	Geregun Kogi	414
2	Omotosho, Ondo	335
3	Papalanto, Ogun	335
4	Alaoji, Abia	346
5	Geometric , Aba	140
6	Chevron JV, Agura, Igbin, Lagos	750
7	Total Fina, Obite, Rivers	500
8	Exxon Mobil, Bonny , Rivers	500

B. National Integrated Power Project (NIPP)

The National Integrated Power Project (NIPP) was originally initiated 2004 in a bid to increase generation as well as stabilise Nigeria's electricity supply system while the Electric Power Sector Reform Act (EPSRA) of 2005 took effect[12].Reference [13] identified additional factors that prompted the introduction of NIPP:

- Unreliability of existing generation plants due to poor maintenance of aging parts leading to frequent, breakdowns, and process inefficiencies due to losses, leading to a largely unsustainable process,
- Under investment in the power sector which resulted in significant deficiencies in the capacity available
- The surplus availability of gas as a fuel for power generation.

The current National Integrated Power Project (NIPP) in Nigeria are shown in table III

TABLE IIIII

EXISTING NATIONAL INTEGRATED POWER PROJECT (NIPP) IN NIGERIA [14]

Project	Location	Designed capacity(MW)
Calabar	Cross River State	563
Egbema	Egbema , Imo State	338
Sapele	,Sapele , Delta Stae	451
Ihovbor	Ihvbor , Edo State	451
Omoku	Omoku , River State	225
Gbarain	Gbarain Bayelsa State	225
Alaoji	Alaoji, Abia State	961
Olorunsogo - Phase 2	Olorunsogo, Ogun State	676
Omotosho - Phase 2	Omotosho, Ondo State	451
Geregu	Geregu Kogi State (supporting the IPP station)	434

IV. The electricity generation in Nigeria – Future Trends

The energy 'cocktail' in Nigeria will expect to exploit alternative energy sources in her attempt to meet the ever-increasing energy demand of the population. Reference [15] stated that vast amounts oil and gas as well as renewable energy resources existed within the country thus providing possibilities for domestic electricity generation via the exploitation of these renewable sources. The exploitation will lead to a decentralised utilisation, promoting sustainable rural socio-economic development via self-reliance through the exploitation of local natural resources [16]. In an effort to exploit this renewable energy sources the Federal Government of Nigeria recently launched Nigerian Renewable Energy Master Plan (REMP), called "a visionary step in developing renewable energy sources in Nigeria" through the Council for Renewable Energy in Nigeria (CREN) . It is expected that a successful implementation of the Renewable Energy Master Plan will lead to the installation of 2,945 MW capacity from alternative sources such as wind, solar photovoltaic, solar thermal, small-scale hydro and biomass by 2025[17]. Another possible but significantly controversial future energy source that may be considered is energy from nuclear sources. The expression of interest in generating energy from Nuclear sources began since the 1970s, although concrete attempts towards commissioning its first nuclear power plant has only just began. However, with the IAEA assessment framework for states pursuing nuclear power for the first time it is most unlikely Nigeria that any nuclear power plant construction will begin before 2020 [18]

V. The Nigerian Energy Mix

Currently the energy mix is Nigeria energy is dominated by an over overdependence on biomass, particularly fuel wood as shown in figure 2. A consideration of figure 2 will show that the Nigerian energy mix is predominated by energy from oil, natural gas, traditional biomass and hydro sources; the reason for this becomes clearer when there is an appreciation of considerations that determine a country's energy mix which according to [19] include:

- Economic consideration; refers to the availability of cheap local resources or cheap imports as well as a reduced production cost.
- Political and social considerations; refers to global energy considerations with particular reference to energy security and political groupings
- Environmental considerations; refers to the consideration of the environmental impacts of utilising energy from a particular source

In addition to these factors identified, [20] established that since less than 40% of the entire population is connected to the grid, alternative readily accessible energy sources will ultimately be exploited.

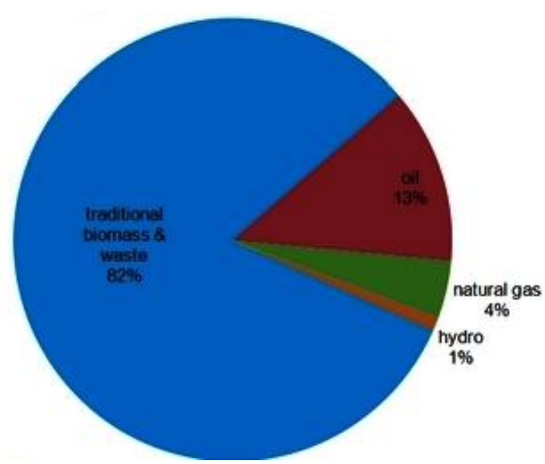

Fig 2: Total energy consumption in Nigeria 2010 [21]

A. The economics of energy generation in Nigeria

Reference [22] defined the Levelised Energy Cost as the price charged for electricity produced from a specific source for the plant to attain profitability and is calculated over 20 to 40 year periods. In very simplified terms the equation translates to the ratio of the Net cost of the system (£) to the Power Production guaranteed over the system life (Kwh) as shown in the Figure 3.

$$LCOE = \frac{\sum_{i=0}^{N}\left[\frac{I_i + O_i + F_i - ITC_i - PTC_i}{(1+r)^i}\right]}{\sum_{i=0}^{N}\left[\frac{E_i}{(1+r)^i}\right]}$$

- I_i Investment costs in year i
- O_i O&M costs in year i
- F_i Fuel costs in year i
- ITC_i Investment tax credits in year i
- PTC_i Production tax credits in year i
- E_i Energy generated in year i
- r wacc
- N Lifetime of project (years)

Fig 3: The Levelised Cost of Energy equation [23]

Figure 4 shows the variation of the Levelised Cost of Energy for different sources. A consideration of the Levelised Cost of Energy (LCOE) will show that that natural gas, traditional biomass and hydro power have a comparatively lower Levelised energy cost. A critical consideration of Figure 4 clearly shows the reason behind the observed trends of Levelised Cost of Energy .In general a reduced cost of production (Capital and operational cost) compared to the energy supplied over time will lead to a significantly lower Levelised Cost of Energy. This is aptly illustrated by hydropower generation which has relatively static net cost overtime due to its significantly lower operational and maintenance cost [24].

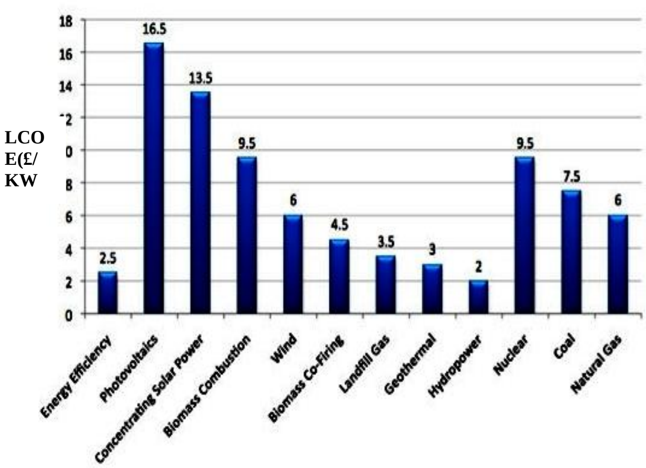

Fig 4: Levelised Cost of Energy for various power and energy efficiency option c/KWH [25]

A hydropower plant presents a scenario in which the quotient of the Levelised Cost of Energy remains relatively constant compared to an ever increasing divisor leading to a significantly reduced Levelised Cost of Energy. However, it is also clear from Figure 4 that the economics of power generation is not the sole factor in the determination of the Nigerian energy mix. This is because it can be observed that other electricity sources such as geothermal and wind power has comparatively low Levelised Cost of Energy. The lack of the adequate technical knowhow, availability of the resource as well as the political-will may be other determining factors to be considered.

VI. LOAD VARIATION AND THE NIGERIAN POWER INDUSTRY

Reference [26] established that the demand for power varies consistently and subsequently identified three (3) major types of power stations based on these load variations:

- Base-load power station operates most of the time at full power is responsible for available steady power supply for 24 hours a day, seven days a week.
- Peak-load power stations are required to account for unpredictable fluctuations in demand and usually operate for significantly shorter intervals compared to base-load power stations.
- Intermediate-load power station, designed to fill the gap in supply between base- and peak-load power and it usually operates during the daytime.

Figure 5 shows a simple illustration of a typical load variation curve

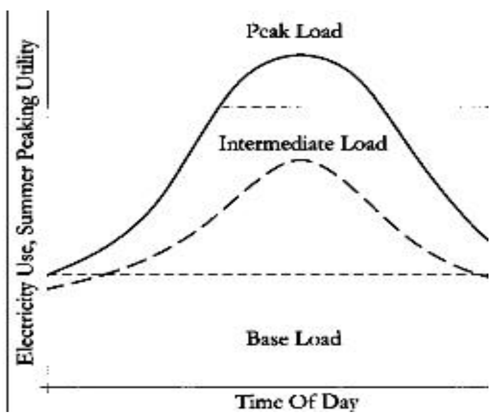

Fig 5: Typical Electric Load Curve [27]

A consideration of Figure 5 will show that different plants can be used to meet different load demands; table IV establishes the appropriate power source for each load type identified based on the Nigeria energy mix

TABLE IVV

LOAD TYPE AND THE APPROPRIATE POWER SOURCE [28], [29]

Load Type	**Appropriate power source**
Base Load	Thermal, Hydroelectric power plants as well as Biomass co-firing.
Peak Load	Hydroelectric power plants and natural gas combustion turbines
Intermediate load	Combustion turbines, combined cycle turbines

V. ENVIRONMENTAL CONCERNS ELECTRICITY GENERATION IN NIGERIA

As established earlier electricity in Nigeria is generated mainly via the utilisation of fossil-based plants(mainly thermal), which utilise fossil fuel in converting water to steam to turn the turbine, as well as via hydroelectric power plants, which exploit the force of flowing waters.

A. Thermal Plants

Reference [30] considered thermal generating stations as plants that convert the energy in fossil fuel or biomass into electricity via combustion. This combustion of fossil fuels (mainly coal) in thermal plants will lead to the production of carbon dioxide (CO_2) and sulphur dioxide (SO_2) indeed when coal containing about 2.5 percent sulphur is used to produce the electricity for per person per year about 9 tonnes of CO_2 and 120 kg of SO_2 are subsequently produced [31]. These gases together with methane gas (natural gas) which is also utilised in the Nigerian energy mix are considered as anthropogenic greenhouse gases which are recognised as the major drivers of world climate change [32] The contribution of electricity generation to the climatic change was aptly emphasised by [33] when it was recognised that electricity generation is by far the fastest growing and largest source of green house gases table V shows the greenhouse gases generated per kWh of electricity produced from Fossil Fuel Plants. Having established the role of thermal plants in global warming and climate change, a hierarchy of resource utilisation was established in a lecture for Energy and Power Supply Systems (CE1199A), presented on 22 October 2013 at the University of Abertay Dundee by C.S. Özveren. It established that conservation attempts should precede efficient utilisation of resource, renewable energy utilisation, natural gas, Nuclear energy use and clean coal technologies respectively in minimising the negative impacts of fossil fuel use in power generation.

TABLE V

THE GREENHOUSE GASES GENERATED PER KWH OF ELECTRICITY BASED ON THE FOSSIL FUEL USED [34]

Plant Type	CO	NOX	SO2	CO2
Coal	0.11	3.54	9.26	1090
Oil	0.19	2.02	5.08	781
Gas	0.20	2.32	0.004	490

A. Hydroelectric power Plant

Reference [35] established that although hydroelectric power generation has low emission of CO_2 and other air pollutants its utilisation in the Nigerian energy mix also brings about its peculiar environmental and social concerns. Reference [36] established the effect of hydropower generation on aquatic population such as the interference with migrating aquatic life as well as the deposition of sediments, leading changes in the ecological make up of the downstream environment. Reference [37] proposed that these impacts can be mitigated by the installation of fish ways such as fish ladders and elevators as well as utilization of trap-and-haul operations as well as emphasising that researches on techniques to pass gravel through a reservoir so that it would be available to support downstream spawning are ongoing. Other possible environmental concerns and possible mitigation measures identified include:

- Fish mortality due to passage through the turbine, which can be mitigated by the use of advanced turbine concepts which are under development to reduce mortality of turbine-passing fishes
- Alteration of water temperature which can be mitigated by the aeration of the reservoir fore-bay waters with air or oxygen and constructing aeration weirs in the tailrace below the dam

Reference [38] also considered the gas bubble disease that arises due to gas super saturation, which is a direct consequence of rapid water flows and falls as a major impact on aquatic life. However, she proposed the use of advanced turbine technology and improved designs which guarantee that a downstream dissolved oxygen concentration of at least 6mg/L is maintained in accordance with water quality standards. During the Seminar presentation of 3 December 2013 for Energy and Power Supply Systems (CE1199A) at the University of Abertay Dundee C.S. Özveren also identified the loss of settlements and agricultural land which can be minimised by conducting adequate impact assessment to determine the level of displacements and land losses thus, avoid site selection if losses are beyond acceptable levels.

VI. CONCLUSIONS AND RECOMMENDATIONS

This paper has investigated the past and present state of the Nigeria electric power sector while establishing the future trends as presented by the power sector reform programme of the Federal Government of Nigeria. The non-sustainability of existing power systems was established as the major driver for the attempts by the government to reposition and restructure the electric power sector. The paper elucidated the major social and environmental impacts of electricity generation based on the current energy mix while identifying the possible mitigation measures. The paper also presented a multifaceted approach to the energy problem in Nigeria while applauding the Federal Government on strides taken it may be necessary to consider the following recommendations in the electricity restructuring drive:

- The government must be committed to fair play by presenting a level playing field for all genuine power investors
- There may be a need introduce a more directed subsidy scheme such that it benefits the segment of the population that actually needs it
- It is clear that other sources of electricity must be explored if any form of economic development is to be sustained.
- Transmission costs can also be reduced by promoting the distributed generation concept

Above all it is clear that the although the present electricity restructuring drive of the Federal Government of Nigeria is a step in the right direction very little will be achieved if the drive is not matched with technocrats who possess the sincerity of purpose and will to effectively serve as catalysts in restructuring the power sector and ultimately improving the life of every Nigerian.

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