Lappeenranta University of Technology
School of Energy Systems
Degree Program in Electrical Engineering

ONI, ABIODUN TAOFEEK

NIGERIA ENERGY SECTOR CRISIS AND RENEWABLE ENERGY SOLUTIONS

Examiners: Professor Jarmo Partanen

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ABSTRACT

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Master's Thesis

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This study concentrates on power generation, transmission and the renewable energy investment opportunities in the Nigeria power sector. It beams light on various failed energy policies by the past government administrations as well as current energy reforms with special attention to the alternative renewable energy solutions. The study was born out of a passion to find suitable and a sustainable lasting, solution to decades of power generation problems which have crippled Nigeria's industrialisation being Africa's economic engine room despite the huge amount of investment which has gone to the sector since her independence in 1960 up till date. In order to achieve the set objective, a critical searchlight will be beamed on the power sector with the view of examining various challenges facing the sector as well proffer long lasting solutions. The bureaucracy in obtaining the power generation data from the generation companies for the purpose of this study led to the delay

of its completion, despite the current energy reforms which mandated periodical release of power generation to the public. OMOKU 150MWe gas turbine power plant located in River State, the south-south oil-rich region in Nigeria was used as a case study.

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Special thanks to Professor Jarmo Partanen for his patient and guidance towards the completion of this thesis work. I am very grateful for your guidance and inestimable contributions toward the success of this project report.

Special thanks to my wife – Oluwakemi Oni, and children: Morireoluwa and Mofifoluwa Oni.

Table of Contents

LIST OF SYMBOLS AND ABBREVIATIONS

MW	Mega Watt
kW	Kilo Watt
PPAs	Power Purchased Agreements
GENCOs	Electricity Generation Companies
NIPP	National Independent Power Projects
SEA	Sustainable Energy for All
LCOE	Levelised Cost of Electricity
PVC	Photovoltaic Cell
NERC	Nigeria Electricity Regulation Commission
NIMET	Nigeria Meteorological Agency
IPP	Independent Power Project
O&M	Operation and Maintenance
TCN	Transmission Company of Nigeria
NpoPC	National Population Commission
iWIN	Independent Energy Watch Initiative
FILP	First Independent Power Limited
GDP	Gross Domestic Products
R	Resistance of the conductor
ι	Length of the conductor
ρ	Proportionality constant
s =	Cross sectional area

1 INTRODUCTION

1.1 Background

Due to its vast land mass, waterways, population index, the largest economy in Africa as well as the availability of human capital, Nigeria has become the preferred global investment destination in Africa over the past decades. However, the constant downward trend in power generation has crippled its economic growth, reducing its gross domestic product (GDP) growth rate from 5.3% in 2011 to -0.36% in 2016 Q1, which has subsequently had a drastic effect on its unemployment rate which stands at 12.1% as at 2016 (Wijeratne David, 2016). Despite the large volume of natural resources such as crude oil, coal, solar energy, hydropower and other sustainable renewable energy resources which can be used to generate abundant electricity, as at date, the country total power generation capacity is 7000MW, while the average generation stands at 5,000MW according to an independent power generation monitoring organisation (iWin, 2018) against 160,000MW needed to meet the nation's electricity demands (Salau, 2016). It is rather pathetic that the current power generation cannot support the ever-growing population. According to the world bank report under the Sustainable Energy for All (SEA) initiative in conjunction with the International Energy Agency, only 57.7% Nigerians have access to electricity (Sustainable Energy for All, 2017) leaving over 90 million Nigerians without access to electricity and the people who actually have access to power, constantly experience blackouts 60% of the time (Sadik, 2015). This has crippled the country's industrialisation growth because most companies depend on generators and other independent power sources to ensure uninterrupted supply of electricity to keep the business running. This has led to the high market price of most commodities in the country. According to the Africa Progress Report 2015, despite numerous wealth and manpower development in Nigeria, the country has the highest number of populations without access to electricity supply in Africa.

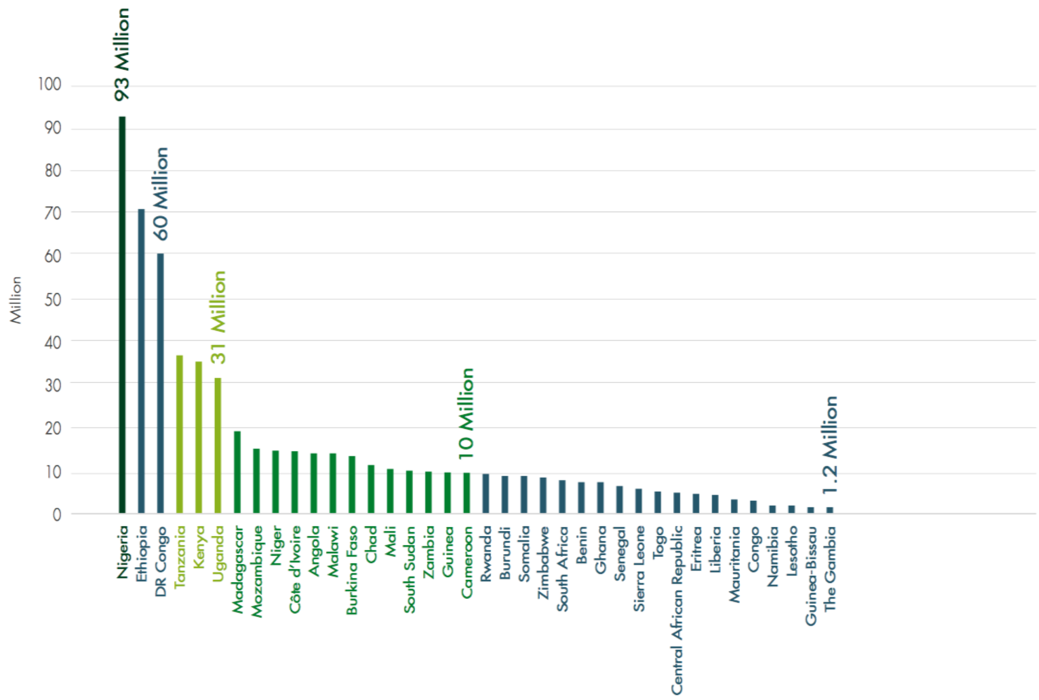

Figure 1: The Missing Millions: Nigerians without access to Electricity-2012

Source: (African Progress Report, 2015)

Apart from various challenges in the power generation, the transmission sector also faces numerous setbacks; chief of them is the ageing power transmission equipment, inadequate capacity as well as vandalisation. Despite the shortfall in power generation, the transmission and distribution system cannot absorb the amount of power being currently generated in the country. Between January and March 2017, according to the generating companies of Nigeria (GENCOs), there were more than ten power collapses during transmission from generating station to the final consumers, this was attributed to ageing equipment which was installed decades ago. From inception up till now, the power transmission has been monopolised by the federal government through the Transmission Company of Nigeria (TCN). Energy transmission expansion has been hampered by poor funding as well as obsolete equipment.

1.2 Goals

The purpose of this research work is to under-study the history and the present situation of electricity generation in Nigeria, West Africa with the view of finding the best solutions to the current power crisis being experienced in the country. The present transmission network structure will be briefly discussed. However, the main focused would be on the latter being the foundation of the power system structure. In other to achieve the set goal, the 12 months of electricity generation data from a natural gas powered 150MWe mini plant located in Omoku community in River State, South-South region of Nigeria would be analysed and used as case study. The possibility of harnessing the abundant renewable energy resources such as wind, solar and hydropower energy in Nigeria to solve the lingering power generation crisis will be considered. Finnish energy privatisation and distribution model mechanism will be briefly examined with the view of possibility in adopting the models to solve decades of power generation problem in Nigeria. The project work also intends to allow the Finnish electricity power investors to consider investing in Nigeria renewable energy power sector due to high electricity demand and return on investment as a result of its large population, high gross domestic products (GDP index) as the current government leadership now have the political will in solving the decades' problem facing the power sector.

1.3 **Thesis Structure**

Section one contains the thesis background, objectives and goals, while chapter 2 contains the brief history of Nigeria and its power generation, the structure of electrical power system, historical trend of Nigeria Electricity generation, Power sector reform, the challenges of electricity power generation, Power transmission network structures. Chapter 3 deals with the analysis of 150Me hydropower generation data located in Omoku community in Port Harcourt, Nigeria, with a view of examining the plant productivity, load analysis, simple calculation on power consumption per capital and forecasts on the amount of energy needed in Nigeria. Chapter 4 discusses the alternative to the current power generation problem as well as analysis of the amount of abundant renewable energy such as solar and wind energy. Detailed recommendation on how to expand the current power generation through renewable energy sources with main the focus on solar energy due to its low start-up capital, environmentally friendly nature as a result of non CO_2 emission, easy and cheap maintenance, abundant availability among others and wind energy which possess most of the latter futures as well. Chapter 5 deals with the summary of the project and conclusions.

2 NIGERIA AND THE ENERGY REFORM STRUCTURES

2.1 Nigeria at a glance

Nigeria is the most populous black nation and the seventh largest in the world with an estimated population of 184 million people according to the National Population Census data (NpopC, 2017) with 2.5% per annum average growth rate. According to the United Nations reports, in twenty years' time, the population will grow to nearly 230 million (Akinsoji, 2016).

It is located in the West Africa sub-region with a total land area of 923,700km^2. The southern part of the country is surrounded by the Atlantic Ocean. It belongs to the African Union (AU), the body which is responsible for Africa economy integration, co-existence and bilateral relations among its member states. It is an oil-producing country which boasts of 2.7 million barrels daily production and it is the eleventh largest oil producing country in the world. (NNPC, 2017). The oil revenue forms 90% of total export commodity and 75% of government revenue yearly. Before the advent of the oil boom in the 1970s, agriculture was the primary source of its income. It boasts of 71 million hectares of land which represents 71% of the total land mass. The southern part of the country is surrounded by water which is one of the most sustainable sources of electricity power generation if it is well utilised. (FAO, 2017). Figure 1 below shows the vivid illustration of Nigerian geographical location and population distribution while figure 2 shows the numerous untapped natural resources endowment which can be used for electricity generation.

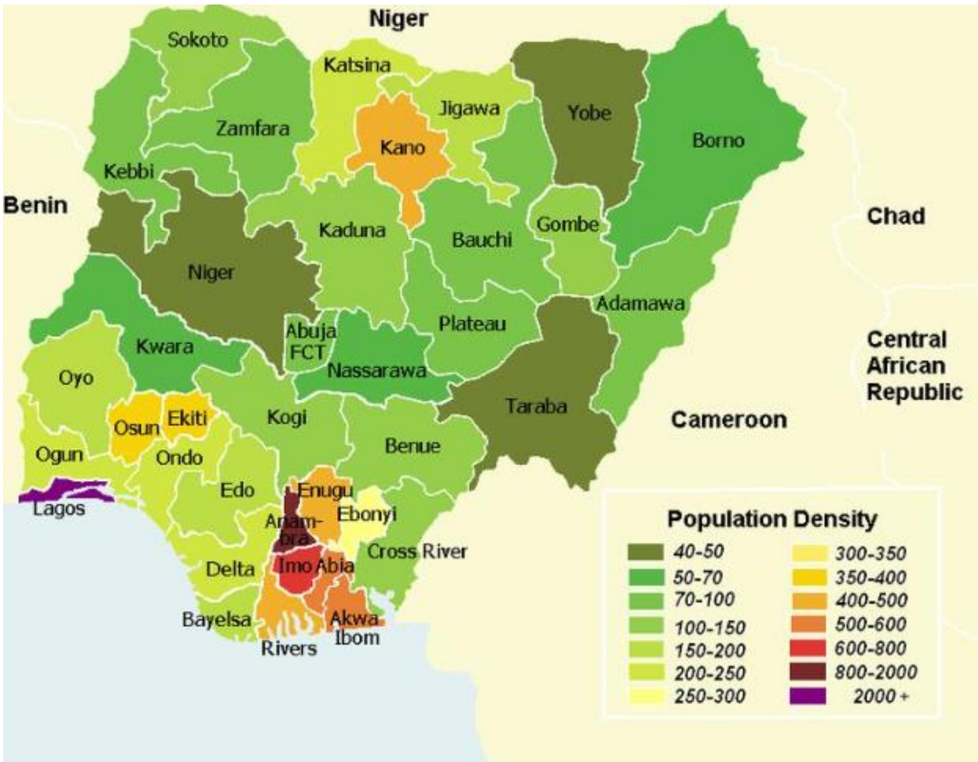

Figure 2: Map of Nigeria geographical location and Population distribution
Source: (Akinsoji, 2016)

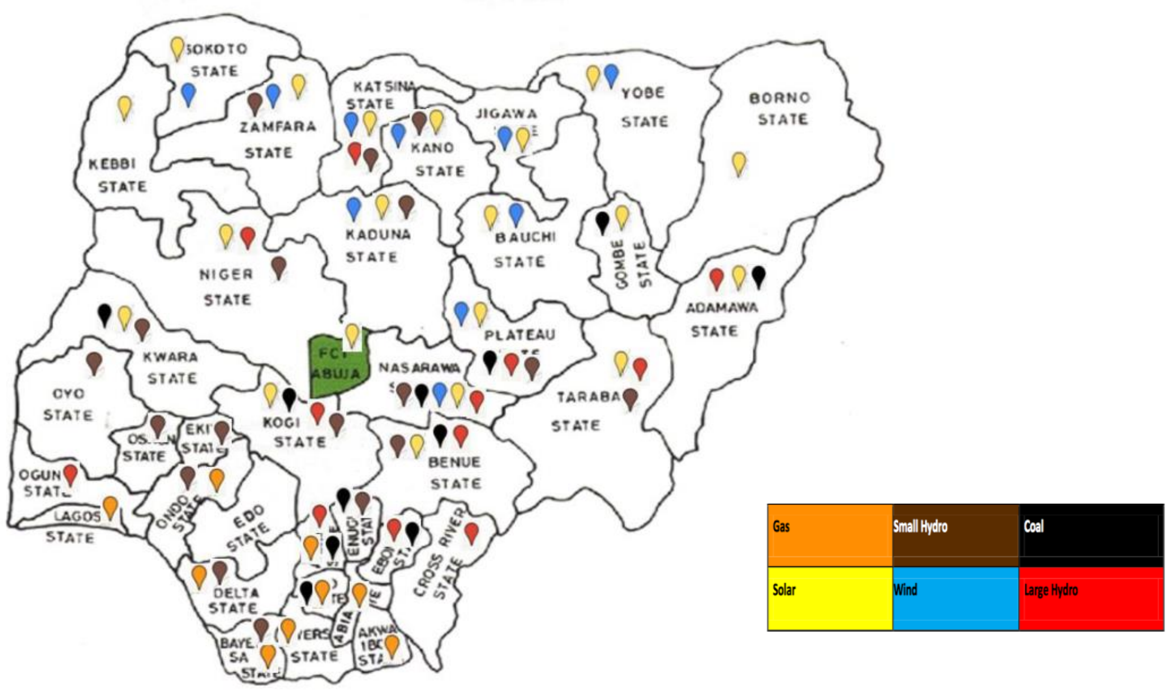

Figure 3: Nigerian Natural Energy resources distribution map

Source (Akinsoji, 2016)

2.2 Power Generation

Electrical energy can be generated from different sources such as: coal, natural gas, hydro, nuclear power, as well as renewable energy sources like: wind, sunlight, biomass, wastewater sludge et. al which are new technology being currently researched all over the world due to their high sustainability and environmentally friendly nature. Conventionally, electrical energy is generated in bulk and the power stations are usually located outside the residential area far from the consumers due to the extreme power voltages, hence the need for large a network of conductors and step down transformers between the power stations and the consumers. The network is classified into two parts:

1. Transmission

2. Distribution

2.3 Structure of Electrical Power System

The structure of electrical power system outlines the flow of electrical power from the generating stations to the final consumers (primary and secondary consumers). The generating stations, transmission network and distribution network are the three major components of electrical power system structure. They are connected to each other across several thousands of kilometres with the help of electrical conductors as well as several step up and step down transformers in other to deliver the desired regulated voltage at the consumers' end. (Bakshi U.A, 2009) . Secondary consumers are usually fed from the step down distribution sub-stations with voltages between 4kV - 35kV (phase-to-phase) while the phase-to-neutral is typically 2.4kV - 20kV. Primary consumers are fed via the service main with a single line low voltage typically 220V in Nigeria.

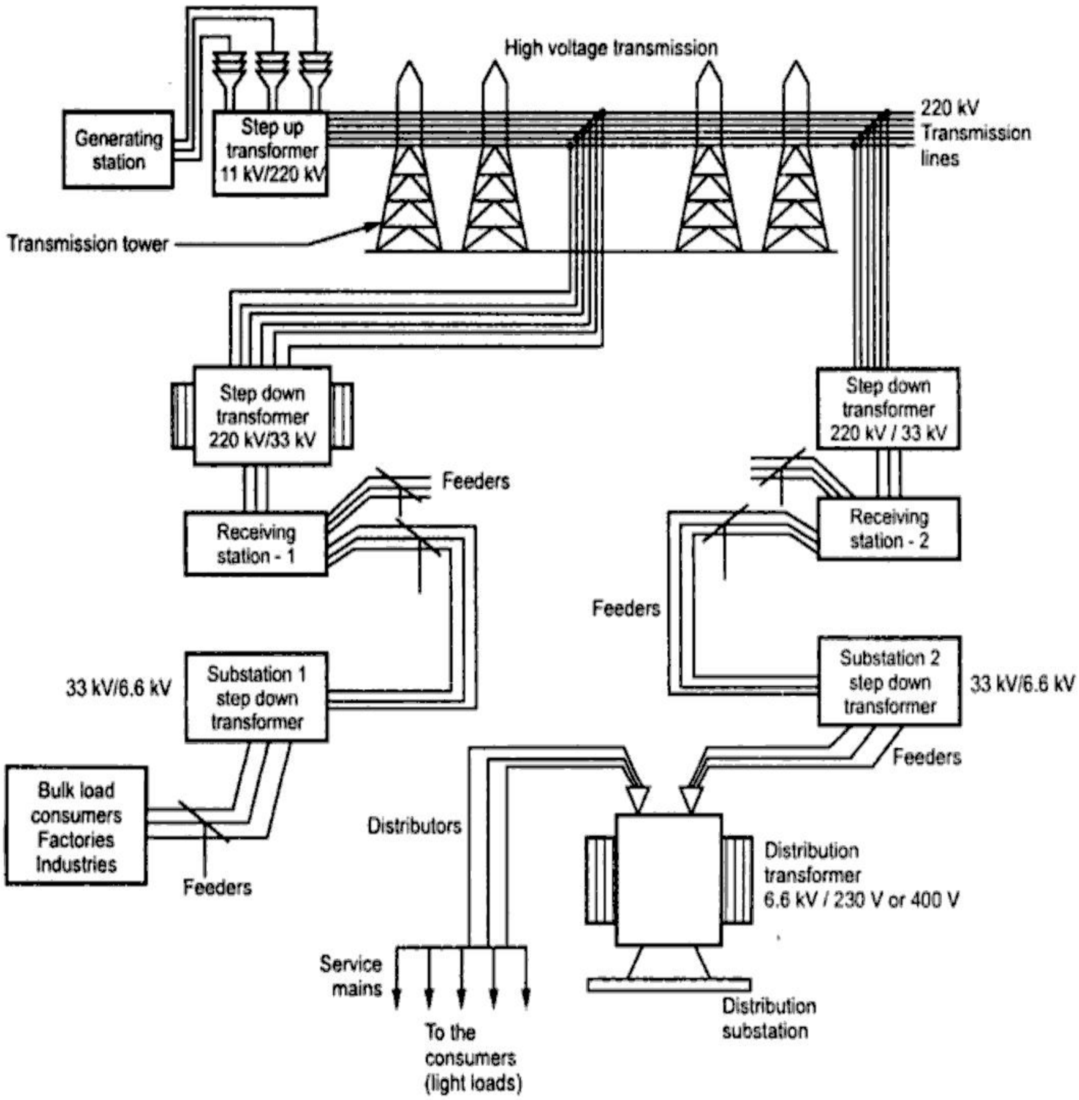

Figure 4: Schematic diagram of an electrical Power Structure

Source: (Bakshi U.A, 2009)

The generating stations are usually located outside the residential area with power output typically 11kV, 22kV, 33kV depending on the generation capacity. However, due to transmission purposes, step-up transformer is required immediately after generation to increase the voltage to 132kV or 220kV base on the requirement. The high voltage power is transmitted over a long distance with help of transmission lines and towers, insulators et. al. The transmission lines must possess the following features: Relative constant voltage across the transmission line, the small line lost must be ensured for high transmission efficiency, small copper losses must be maintained in other not to overheat the transmission conductors. As seen in the figure above, the power is transmitted to the substation via the 220V/33kV or 220V/22kV step-down transformers. The power is then transmitted to the distribution substations usually consist of a step-down transformer which steps down the voltage from 33kV to 6.6kV or 3.3kV for bulk consumers (Bakshi U.A, 2009). At the other substation, the power is further reduced to 230V or 400V with the help of step down distribution transformers before it is supplied to the individual consumers via distribution lines and service mains. For simplicity, the line diagram of a typical transmission line is shown below. It shows a complete flow of power energy from the generating station to the consumers' end.

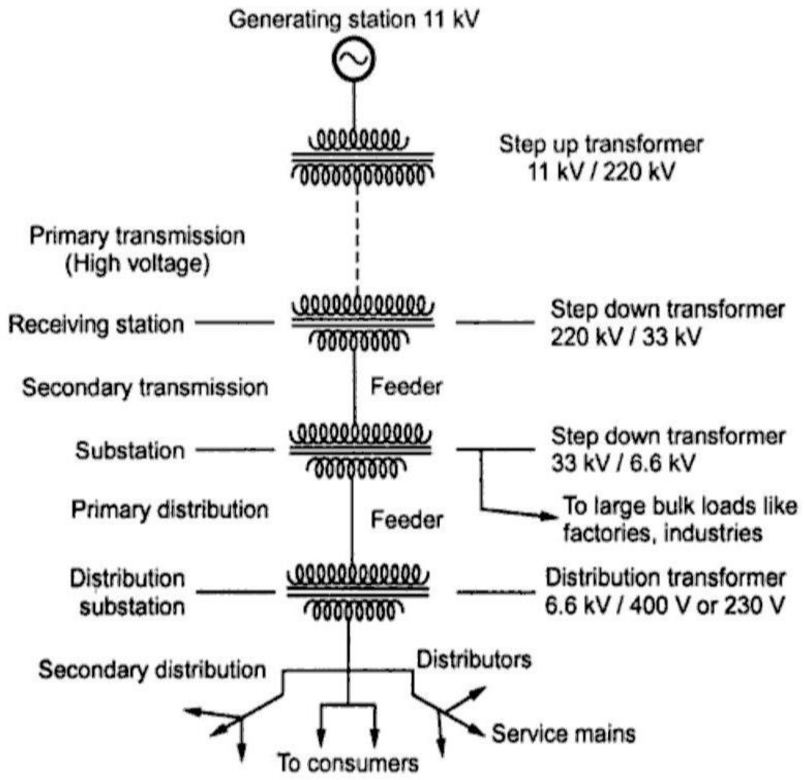

Figure 5: A simplified line diagram of an Electrical Power Structure

Source:https://grieteee1317.files.wordpress.com/2014/12/power-systems-by-bakshi.pdf

As shown in the line diagram figure above, there are four main stages of transmission and distribution between the generating station and the final consumers.

2.4 Primary and Secondary Transmission:

Extreme high voltage is involved in primary transmission. At this stage, the generating voltage power coming from generating station is fed into the primary transmission station with high voltage covering a long distance and increase to 132kV, 220kV or more with the help of step-up transformers. A 3-phase, 3-wire system is used. According to the Nigeria Electricity Regulation Commission, the primary transmission lines must be located in a remote area outside the metropolis and offset of 700 meters must be given between the power line and any public or private property. The voltage from the primary transmission line usually reduces to 3.3kV,11kV or 33kV with the help of a step-down transformers. The power is then transmitted to various substations using overhead 3-phase, 3-wire system.

2.5 Primary and Secondary Distribution

Primary distribution is also called a low voltage distribution with voltage ranges from 11kV - 132kV. At the primary distribution substation, the high voltage coming from the secondary transmission station is further reduced to 3.3kV, 6.6kV depending on the capacity. At this point, large consumers like manufacturing companies, factories are connected to the grid. The power is also further transmitted to the distribution centers. At the main substations, the transmission line connector is terminated from which the power is then distributed to the secondary substations placed throughout the load area.

In Nigeria, the line voltage to neutral is typically 230V The low voltage coming from the primary distribution stations are further step down to 400V with the help of step down distribution transformers with output voltage of 230V supplied to the final household consumers using the underground or overhead service mains and distribution poles which are usually concrete or wooden. The line to line voltage is usually 400V.

2.6 Transmission Powerlines

Power is transmitted at high voltages over a long distance due to losses and cable resistance. For a given amount of power, a higher voltage reduces the amount of resistance in the conductor as well as the current as illustrated in the given equation:

$$R = \frac{\rho l}{s} \qquad \text{(i)}$$

Where R=resistance of the conductor

ι =length of the conductor

ρ = proportionality constant

s = cross sectional area

The design of a power line majorly depends on the following factors among others: the amount of transmitting power required, the distance between the generating station and the step down distribution stations, the total cost of the power line, urban congestion, ease of installation and the expected load growth et.al. Basically power lines are classified according to the voltage class they belong as enumerated below:

2.6.1 Extreme High -Voltage Lines (EHV)

The extreme high-voltage lines are used to transmit power with voltage up to 800kV depending on the country specifications. In Nigeria, it is owned by the Federal government and operated by the Transmission Company of Nigeria (TCN). The EHV is carried by large lattice pylons steel of 70m average height situated at 150m apart. (TheodoreWildi, 2002). In Pylon towers, conductors can be arranged in three ways: Single level, two level- circuits are arranged in two levels on two crossbars, and Three-level - here, conductors are arranged in three crossbars with three levels arrangements.

2.6.2 High-Voltage Lines

The high voltage lines are sometimes used to transfer energy from one generating station to the other in the to increase the network stability. It also transports electrical power to the main substations from the generating station. The lines are composed of area conductors or underground cables at operating voltage typically below 230kV. (TheodoreWildi, 2002).

2.6.3 Medium-Voltage Lines (MV)

It is used for power distributions in both urban and rural areas with a voltage between 2.4kV-69kV. Radial distribution systems are chiefly used in large cities where transmission lines are spread from one or more substations into various load centres (TheodoreWildi, 2002).

2.6.4 Low-Voltage Lines (LV)

The service mains cables are used to provide electric power to low voltage to consumers who required low voltage supply for their operation such as in factories, commercial and residential buildings et.al. The lines may be overhead or underground cable system. The lines are insulated conductors which are usually made of aluminium materials.

2.7 Historical Trend of Nigeria Power Generation

Decades, before Nigeria gained independence from its colonial master – the United Kingdom in October 1960, the country generated its first electricity under the British authority in 1886 to power homes of the then sizeable population when two generating set were installed in Lagos colony. The Electricity Corporation of Nigeria (ECN) was created to build and provide constant electricity supply to its citizens by the act of parliament in 1951 shortly before the independence. In other to further strengthen the commission, a hydropower company was created and named Niger Dams Authority (NDA) in 1962. Ten years after, in 1972, the two companies were merged and renamed as National Electric Power Authority (NEPA) with the primary responsibility of ensuring generating, transmitting and distribution of electricity supply to both rural and urban communities across the states of the Federation. However, due to inability to provide a constant power supply to the yearly geometric population growth, the government embarked on power sector reform process and the Electricity Power Sector Reform (EPSR) Act was signed into law in March 2005 which gave birth to renaming of the regulatory body to Power Holding Company of Nigeria (PHCN).

The reform law paved way for both local and foreign investors to participate in Nigeria electricity generation, transmission and distribution. (NERC, 2006). The power generation was fully privatised and allowed to run by both foreign and local investors in other to create a competitive market and ensure a significant rise in power generation. Presently, apart from the three Independent Power Plants (IPP) which include: Afam VI with 642MW generating capacity operated by Shell Petroleum Development Company (SPDC), Okpai - 480MW operated by Agip oil, and Ibom Power and NESCO with 270MW capacity which were built largely by private oil companies for their operations, there are six Generating Companies (GenCos), eleven electricity Distribution Companies (DisCos) and one Transmission Company (TCN) which is still being run by the government due to heavy investment cost involved in running a parallel transmission line in the country. In other to further boost the power supply, the government established Niger Delta Power Holding Company (NDPHC) with the primary aim of identifying and building critical infrastructure in all the three stages of power supply namely: generation, transmission and distribution through the National Integrated Power Projects (NIPP) scheme (NERC, 2006).

Below are the names, currently installed capacity, fuel types and the privatisation status of all the generating power stations that were privatised after the 2005 power reform as well as the list of PHCN successor companies after the privatisation and policy reform was signed into law in 2015.

GenCo	Installed Capacity (MW)	Type	Privatisation Status
Afam Power Plc	**776MW**	Gas	100% Sold
Sapele Power Plc	414MW	Gas	51% Sold
Egbin Power Plc	1,020MW	Gas	100% Sold
Ughelli Power Plc	900MW	Gas	100% Sold
Kainji Power Plant	760MW	Hydro	Long Term Concession
Jebba Power Plant	578MW	Hydro	Long Term Concession
Shiroro Power Plc	600MW	Hydro	Long Term Concession

Figure 6: Main Privatised Power Generation Companies and their Capacity Excluding the IPP

Source: http://www.nercng.org/index.php/home/nesi/403-generation

Generating company (Genco)	Transmission company (Transco)	Distribution company (Disco)
Kainji Power Plc	Transmission Company of Nigeria	Eko Electricity Distribution Co. Plc
Shiroro Power Plc		Ikeja Electricity Distribution Co. Plc
Ughelli Power Plc		Ibadan Electricity Distribution Co. Plc
Sapele Power Plc		Benin Electricity Distribution Co. Plc
Afam Power Plc		Abuja Electricity Distribution Co. Plc
Geregu Power Plc		Port Harcourt Elect. Distribution Co. Plc
		Enugu Electricity Distribution Co. Plc
		Kaduna Electricity Distribution Co. Plc
		Kano Electricity Distribution Co. Plc
		Jos Electricity Distribution Co. Plc
		Yola Electricity Distribution Co. Plc

Figure 7: List of PHCN Successor Companies

Source: (Titus Koledye Olugbenga, 2013)

2.8 The Nigerian Power Sector Reforms

According to the African progress report 2015, over 90 million Nigerians are living without electricity supply. Out of this figure, 73 million are living in rural areas across the country while 17 million are living in cosmopolitan areas yet they do not have access to electricity, despite the huge number of natural resources in Nigeria. In 2013 alone, the country earned USD89B from the sales of petroleum, yet a total of 93 million of her citizens lack access to electricity. Hence, the power sector is characterised by huge a gap between the power demand and supply. The Larger percentage of non-electrified are living in an off-grid area where the grid connection is not economically viable due to the high cost of transmission equipment infrastructures. (African Progress Report, 2015). In other to achieve the targeted goals of generating 10.2MW of electricity by 2019, a huge investment of USD 3.5 billion is needed annually in power generation sector alone from 2016 while a large investment is also needed in other supply chain network of power system such as power transmission and distribution network sector (Akinsoji, 2016).

In other to attract the much needed private investment to bridge the gap of the huge deficit between the power demand and supply and rescue the nation power sector, series of continuous reforms and transformation is needed. The foundation of the reform began in 2015 with the Electricity Power Sector Reform (ESPR) Act which allowed private local and foreign investors to participate in the Power generation, transmission and distribution.

As shown in figure 7 below, according to the ESPR 2015 Act, the power generation is completely privatised and sub-divided into three main categories, namely: the successor privatised GENCOS (Electricity Generating Companies), NIPP (National Integrated Power Projects) GENCOS as well as Private IPP (Independent Power Project) GENCOS. The transmission and distribution sector are being managed by National Electricity Regulatory Commission (NERC) which is an independent body. They also oversee the electricity regulatory enforcement laws, testing and certification through the Nigeria Electricity Management Service (NEMSA) (Akinsoji, 2016).

2.8.1 Power Sector Post Reform Structure

The figure below shows a vivid break down analysis of electricity regulation post-reform structure. The electricity generation sector is further sub-divided into three groups namely: seven GENCOS companies (emerged after the privatisation of PHCN in 2013) as listed in figure 7 above with 5,048MWe maximum generating capacity, NIPP GENCOS and Private IPP GENCOS which licenses were issues to mega multinational companies that required large bulk of electricity for their productions. The payment of bulk power sent to the national grid is regulated and settled by Nigerian Bulk Electricity Plc (NBET). The transmission and distribution sector are being managed by National Electricity Regulatory Commission (NERC) which is an independent body. They also oversee the electricity regulatory enforcement laws, testing and certification through the Nigeria Electricity Management Service (NEMSA) (Akinsoji, 2016).

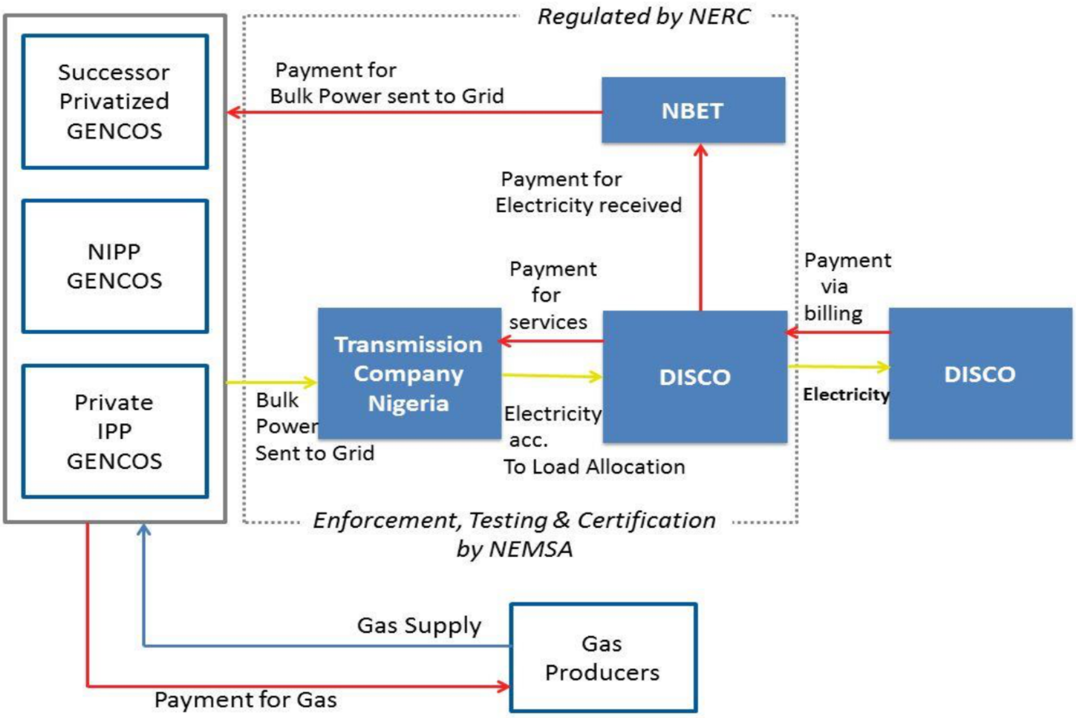

Figure 8: Post Reform Structure of Power Sector

Source: (Akinsoji, 2016)

2.9 The Challenges of Power Generation and Transmission in Nigeria

The Nigeria electricity power generation has been on the decline despite the rapid population growth. Several factors are responsible for this decline, aside from the corruption which has eaten deep into the fabric of the country's system of governance, this has, in turn, led to the economic decline of the country. According to (Titus Koledye Olugbenga, 2013) in the journal published in 2013, the Bureau for Public Enterprises listed the below factors among others as critical problems which are presently confronting the power sector:

a) Insufficient use of electricity by the consumers
b) Lack of capital investment
c) Inappropriate industries and market structure
d) Limited access to infrastructure
e) Inadequate power generation capacity
f) Ineffective regulation
g) High technical losses and vandalism

h) Poor maintenance of existing power system

The above-mentioned factors are major roadblocks that limit the growth of power sector in Nigeria. The consistence transmission line vandalisation by militants has also hindered the distribution of few power generations. Inadequate maintenance of existing power stations has also become a norm and has resulted in the continuous epileptic supply of electricity to the final consumers despite the occasional rise in power generations. The companies only engage in reactive maintenance(RM) in the event of any major fault, while the preventive planned maintenance (PPM) which increases the life span of the infrastructures is non-existence (Titus Koledye Olugbenga, 2013).

2.9.1 Power Transmission

Transmission of electricity from the power stations to the final consumers is done over a long distance with high voltage, usually from 132-kilovolts or above in order to reduce power losses that usually occur along the transmission line. Aside the numerous problems associated with the Nigeria power sector, the ageing and the complexity of our transmission network make it difficult to supply a constant and uninterrupted electricity to customers. There is a big correlation between the standard of living and the available power supply in a nation because electricity is essential to the economic growth of any country. (Francis Akpojedje, 2016). Transmission Company of Nigeria (TCN) is saddled with the responsibility of ensuring the electricity power transmission and maintenance across the country. It was established in 2004 as a business unit from defunct National Electric Power Authority (NEPA). The company main responsibility is to ensure effective electricity transmission, system operation and trading (TCN, 2017). The transmission company has three operational departments and their operational roles are enumerated below:

2.9.1.1 System Operations (SO):

The primary responsivity of the system operator (SO) is to ensure the smooth transmission of generated power from the power plants (GENCOs) to the Distribution companies (DISCOs). They are saddled with the responsibility of allocation of power loads in the event of an insufficient generation. They enforce the grid core and all operational procedures, they control the grid voltage as well as the frequency of transmission, and they design, install and maintain the communication facilities such as Supervisory Control Data Acquisition (SCADA) software for effective grid operations among others. (NERC, Nigerian Electricity Regulatory Commission, 2017).

2.9.1.2 Transmission Service Provider (TSP)

Transmission and Service Provider is saddled with the responsibility of maintenance and development of over 20,000km transmission line infrastructure across the length and breadth of the country. They provide open access transmission services for all the stakeholders (GENCOs) for effective power transmission to the substation distribution station via the transmission line. (NERC, Nigerian Electricity Regulatory Commission, 2006) (NERC, Nigerian Electricity Regulatory Commission, 2017).

2.9.1.3 Market Operations (MO)

The market Operation department of the Nigeria Electricity Regulatory Commission (NERC) ensures the market rules of the Nigerian Electricity Supply Industry (NESI) is strictly followed by drafting and implementing the market procedures, ensures that the market settlement system is administered, administration of payment system and commercial agreement of the market system among others (NERC, Nigerian Electricity Regulatory Commission, 2017).

2.10 **Current Transmission Network Structure**

The Nigeria transmission network comprises of 330kV lines covering a distance of 6,680km with a substation capacity of 10,238MVA and 9,161km of 132kV lines with a substation capacity of 11,721MVA while the wheeling capacity is 5,300MW against the presently required capacity of 12,000MW (Akinsoji, 2016). Another 132kV transmission network covering a total distance of 705.3km is under construction in other to boost the current capacity (Francis Akpojedje, 2016). However, the sector still faces with numerous challenges such as insufficient transmission network coverage, long distance lines, technical issues, few mesh network, line losses, equipment theft and vandalisation, issues with the host communities among others. The transmission losses stand at approximately 7.4% which is higher than the country's benchmark losses of 2-6%. The Nigerian transmission network system is facing a critical operational and infrastructure challenges. The figure below shows the existing power transmission network across the country. (NERC, Nigerian Electricity Regulatory Commission, 2017)

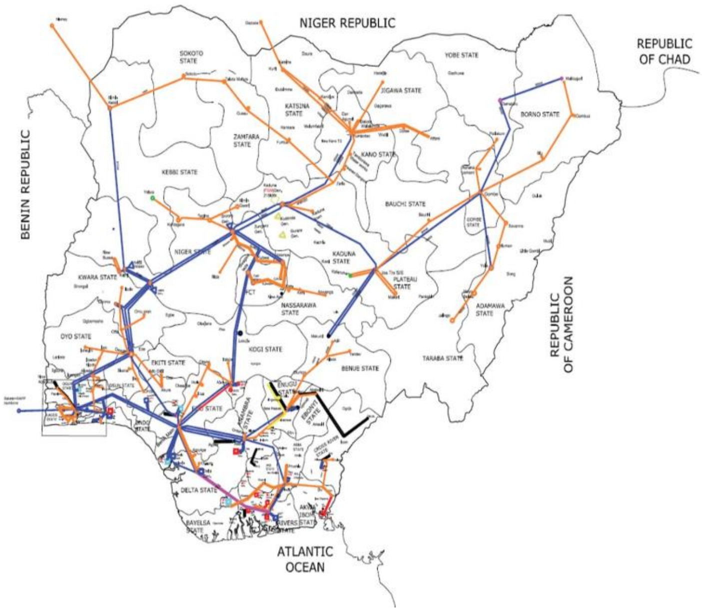

Figure 9:The Nigerian Map Showing the Existing 330kV and 132kV Transmission line

Source: (Akinsoji, 2016)

3 OMOKU POWER PLANT

3.1 150MW Omoku Gas Power Station

The 150MW gas power plant which 2016 power generating data is used for this research work is located in Omoku community with a total population of 33, 000 inhabitants in the Northern part of River State, the south-south oil reach state in Nigeria. It is one of the power stations under the National Integrated Power Project (NIPP) scheme being managed by the Niger Delta Power Holding Company. Due to the remote nature of the community, the city is not connected to the national power grid, hence 132kV switchyard is being used to distribute electricity to the various consumers. Natural gas is used to fire the power station due to it nearness raw materials- the presence of oil producing companies such as Shell Petroleum and Development Company (SPDC), TOTAL Oil Exploration Company and Nigerian Agip Oil Company (NAOC).

3.1.1 Plant Description

The plant has six (6) generating 25MW GE heavy duty gas turbines with a total installed capacity of 150MW. The installation began in 2011 when three 25MW Nuovo Pignone gas turbines were installed while the 4th unit was installed in 2002 and commission in 2006. The plant was later upgraded with additional two units 2x25MW Nuovo Pignone gas turbines in 2005 and finally commissioned in 2008. The power plant is equipped with 6x35MWA transformers, 132kV switchyard by Schneider Electric, 2x1MW caterpillar black start generators, fire protection unit, 132kv switching facility among others (FIPL, 2105).

3.1.2 Power Generation Analysis

Omoku plant is a mini power plant designed with an installed capacity of 150MWe to serve the oil reach community and its environment with an average of 100, 000 homes. However, according to the summary of the power generation in figure 7 below which was extract from 2016 daily power generation data sheets as attached in the appendix 1, the peak power generation was in December 2016 which stood at 49,396.30MWe while the plant recorded its low power generation of only 8,867.90MWe in February of the same year due to natural gas supply shortage from the Escravos oil well refinery, hence only two out of six units 25MW GE duty gas turbine were operational, leaving GT1, GT2, GT4, GT6 out of operation. According to the data obtained, from the cumulative summary analysis done, the average power generation was 19,643MWe during the year under review against 150MWe installed capacity. Further investigation reveals that only three out of installed six (6) units of 25MW GE heavy gas turbine work during the period under review as shown in appendix 1- power generation power sheet.

DATE: 10-Jan-2018

2016 EXTRACT SUMMARY OF POWER GENERATION OF 150MWe OMOKU PLANT

Month	GT1(MWh)	GT2 (MWh)	GT3 (MWh)	GT4 (MWh)	GT5 (MWh)	GT6 (MWh)	Aerage Montly Generation(MWh)	Total Gen (MWh)
January	5521.4	0.00	0	0	8356.3	4569.2	3074.48	18446.9
February	7271.50	0.00	0.00	0.00	9317.30	0.00	2764.80	16588.80
March	6448.80	0.00	3987.20	0.00	3348.50	0.00	2531.11	13784.50
April	4518.40	0.00	5364.80	0.00	3130.20	0.00	2168.90	13013.40
May	6337.10	0.00	0.00	0.00	6295.40	0.00	2105.42	12632.50
June	4612.30	0.00	3828.10	0.00	4983.40	315.90	2289.95	13739.70
July	3178.90	0.00	1890.00	0.00	2214.40	2392.60	1612.65	9675.90
August	248.80	0.00	5293.40	0.00	1594.40	1731.30	1477.98	8867.90
September	0.00	0.00	9370.90	0.00	9543.20	6941.20	4309.22	25855.30
October	1526.70	0.00	9369.20	0.00	10061.70	2158.40	3852.67	23116.00
November	2518.00	0.00	8958.60	0.00	10203.00	8919.20	5099.80	30598.80
December	9131.80	2734.90	11242.70	0.00	14101.30	12185.60	8232.72	49396.30
Total	**51313.70**	**2734.90**	**59304.90**	**0.00**	**83149.10**	**39213.40**	**39519.69**	**235716.00**
Monthly Average	**4276.14**	**227.91**	**4942.08**	**0.00**	**6929.09**	**3267.78**	**3293.31**	**19643.00**

Table1: Omoku 2016 Power Generation Monthly Summary

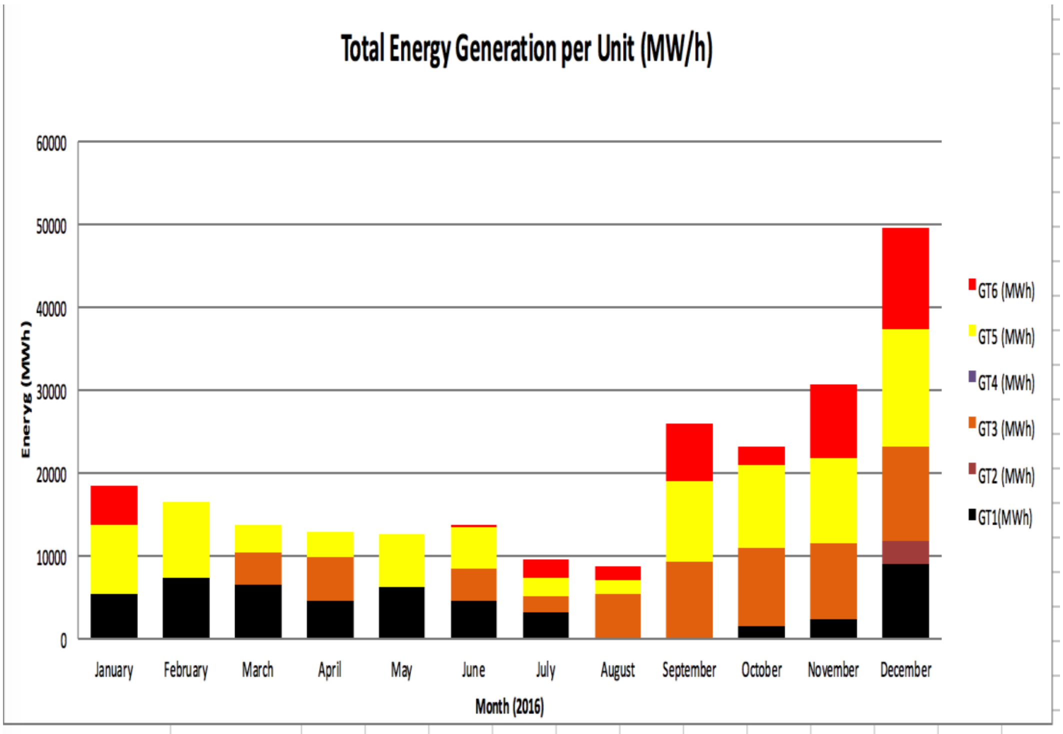

Figure 10: The Total Energy Per each Unit

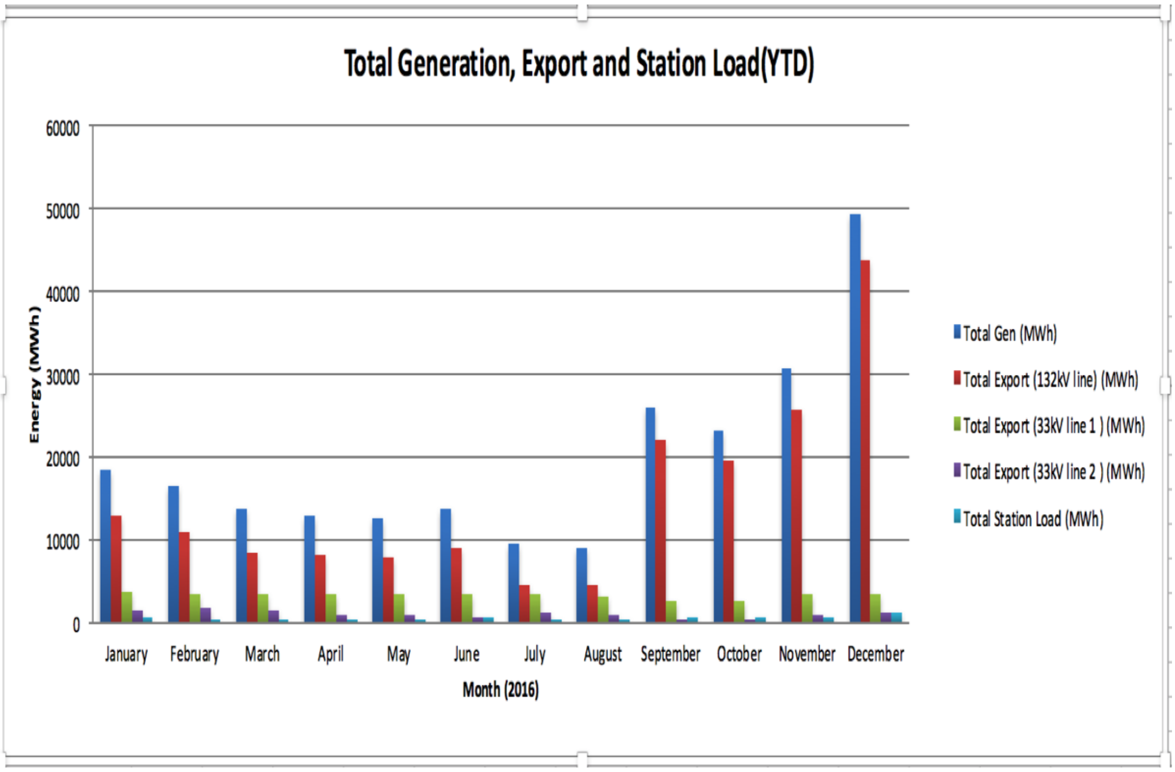

Figure 11: Bar Chat Showing the Amount of Power Generation and Export

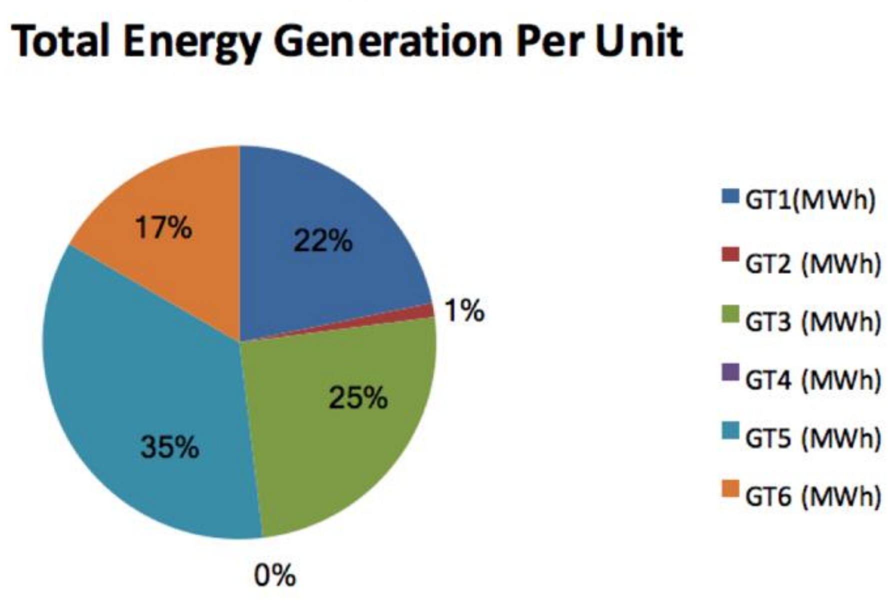

Figure 12: Total Energy Generation Per Unit

Figure 11 above shows the graphical illustration of the amount of power generation on the monthly bases and the total export despite the shortfall in power generation to meet the demand of the consumers in the community. The month of December the witnessed highest amount of energy exported, this was due to high the amount of electricity generated. The higher the amount of electricity generated, the higher the exported energy and vice versa. Figure 12 also shows the pie chart which illustrates the percentage of electricity generated per unit. As seen in the figure, unit 5 generated the highest amount of electricity while unit 2 generated 2,734.90MWe throughout the whole year which represents 1% of the total generation capacity as a result insufficient supply of natural gas to the station and equipment vandalisation. Hence all the gas turbines cannot be operational simultaneously. Lack of preventive maintenance is the key constraints to the plant capacity utilisation also contributed largely to the plant under performance, as seen in the plant power generation performance computed in table 1 above, the 25MW turbine in unit 4 was not in operation throughout the year under review.

According to the estimate, Omoku Power plant 150Me electricity generation capacity was designed to feed the community and the neighboring communities with an average population of 297, 000 inhabitants (100,000 homes) excluding the companies.

According to an independent energy watch initiative in Nigeria, an average power consumption in Port Harcourt, Nigeria is 0.4kW/hr per capital where the power plant is located.

=0.4kW/hr x24hours = 9.6kW/hr/day per capital consumption

=0.4kW x 297,000 population

= 85.2MWe

As shown in the equation above, the power plant is expected to deliver an average of 85.2MWe/hr when fully operational, but according to the 2016 power generation data obtained, the plant delivered maximum capacity of 49,396.30MWe which represents 32.93% of its installed capacity despite the amount of investment on the project, this is unconnected with the pipeline vandalisation, equipment theft, engagement in corrective maintenance instead of preventive planned maintenance, inadequate supply of natural gas from Escravos thermal as a results of oil well vandalisation among others.

All the Power plants in Nigeria are performing 35% below their installed capacity due to the aforementioned constraints among others. The power generation datasheet of this plant was used as a case study in other to understand why all the all the power generation plant are performing below capacity. Therefore, it is a clear evidence that the present sources of energy generation are not sustainable hence alternative sources need to be sourced in other to find a lasting solution to the current energy crisis in Nigeria.

3.2 25MW Nuovo Pignone Gas Turbine Specification

The 25MW pignone gas turbine was manufactured by GE Oil & gas company in the USA. It has 75million total operating hours with maximum power output ranges from 22-34MW. It has its application in oil and gas, marine and power generation applications. It incorporated the latest aerodynamic design which has a wider application not only in power generations. it has a high rotational speed of 11,000rpm (revolution per minute) with 4.7kg/s mass flow rate. It has a high compressor performance with eleven- stage axial flow design with a combine pressure ratio of 15.5:1 which was derived from aircraft engine transonic flow technology. In 2015, according to the research done in the mechanical engineering department at the River State University of Science and Technology, the plant underwent a complete improvement by incorporating a heat recovery steam generator with the main aim of improving the system performance and reducing the environmental emission impact. The gas turbine efficiency increased from 26.6% to 48.8% after the modification (Lebele-Alawa, 2015).

3.2.1 Gas Turbine

Basically, the MS6001B pignone gas turbine has a fuel flexibility usage capacity, it can be operated with either the natural gas or liquefied natural gas (LNG). However, natural gas is being used to fire the gas turbine at Omoku plant. It has a single shaft which was specifically built by the manufacturer for power generations. According to the manufacture, the device is equipped with an integrated control cab which helps to eliminate control room civil works and any related wiring. It is equipped with the annular combustion chamber of 13 fuel nozzle. (GEOil, 2011)

3.3 **Root Causes of Plant Under Performance**

As stated above, several factors such as over dependency on natural gas, a man-made natural disaster which could be controlled, equipment vandalisation among others are major common root causes hindering the installed capacity perform of all the generating power stations in Nigeria. Two of these root causes are briefly discussed below:

3.3.1 Over Dependency on Natural Gas

The over dependency on natural gas from the oil exploration to power most of our Power plants is one of the main problems confronting the power generation sector because the power plants are usually located hundreds of kilometres from the oil refinery location, hence the Niger Delta militants usually take advantage of the shortfall to blow off the gas pipelines and vandalise other equipment.

3.3.2 Natural Disaster and Equipment Vandalisation

Although, the country has not recorded any major natural disaster for decades due to its geographical location on the world map. However, some natural 'man-made' disasters such as fire accidents as a result of non-compliance with the international safety and standard rules and regulations has affected the power sector industry in no small measure. The nation witnessed another nationwide total power collapse for 16 hours on the 2nd of January, 2018 when fire gutted the major pipeline on its Escravos pipeline system operated by the Nigeria Gas Processing and Transportation Company Ltd (NGPTC) which supply gas to four major thermal generating plants comprises of Egbin Power plant(1,320MW), Olorunsogo NIPP (676MW, 450MW and 338MW), as well as Paras 60MW power stations. (Fashola Babatunde, 2018).

4 DISCUSSION AND RECOMMENDATIONS

4.1 Energy Investment Opportunity in Nigeria

Due to the vast growing population of 184 million (NNPC, 2017), the government energy policies, the availability of human capital, favourable demographics, potential for economic growth, the gap between the energy demand and supply as well as abundant and availability of renewable and non-renewable energy resources such as :coal, natural gas, solar energy, wind, hydro power. Nigeria is the Africa heavyweight, hence, investment in Nigeria power sector is very attractive with high Return on Investment (ROI) within the shortest period of time. According to Central Intelligence Agency (CIA) world fact book, Nigeria is the 9th largest gas reserve in the world with estimated 5,284,000,000,000 cubic meters (cu m) natural gas as at 2017 (CIA, 2017).

The table below shows the various type of abundant renewable energy available in Nigeria and their capacity.

Table 2: Renewable Energy Resources and Capacity in Nigeria

RESOURCES	POTENTIAL	REMARK
Large Hydropower	11,250MW	1,900MW Exploited
Small Hydropower	3,500MW	64.2MW Exploited
Solar	4.0kWh/m^2/day-6.5kWh/m^2/day	15MW dispersed solar PV installations(estimated)
Wind	2-4m/s @10m height in mainland	Electronic Wind Information System(WIS) available; 10MW windfarm in progress in Kastina State

Biomass (Non-fossil organic matter)	-Municipal Waste	-18.5 million tonnes produced in 2005 and now estimated 0.5kg/capita/day
	-Fuel wood	43.4 million tonnes/year fuel wood consumption
	Animal Waste	245 million assorted animals in 2001
	-Agricultural Residue	91.4million tonnes/year produce
	-Energy Crops	28.2 million hectares of arable land out of which 8.5% is being cultivated

Source: (ECN, UNDP, 2012)

Figure 11 below shows the existing gas well locations from different crude oil refinery sites and the laid pipelines infrastructure routes across the length and breadth of the country.

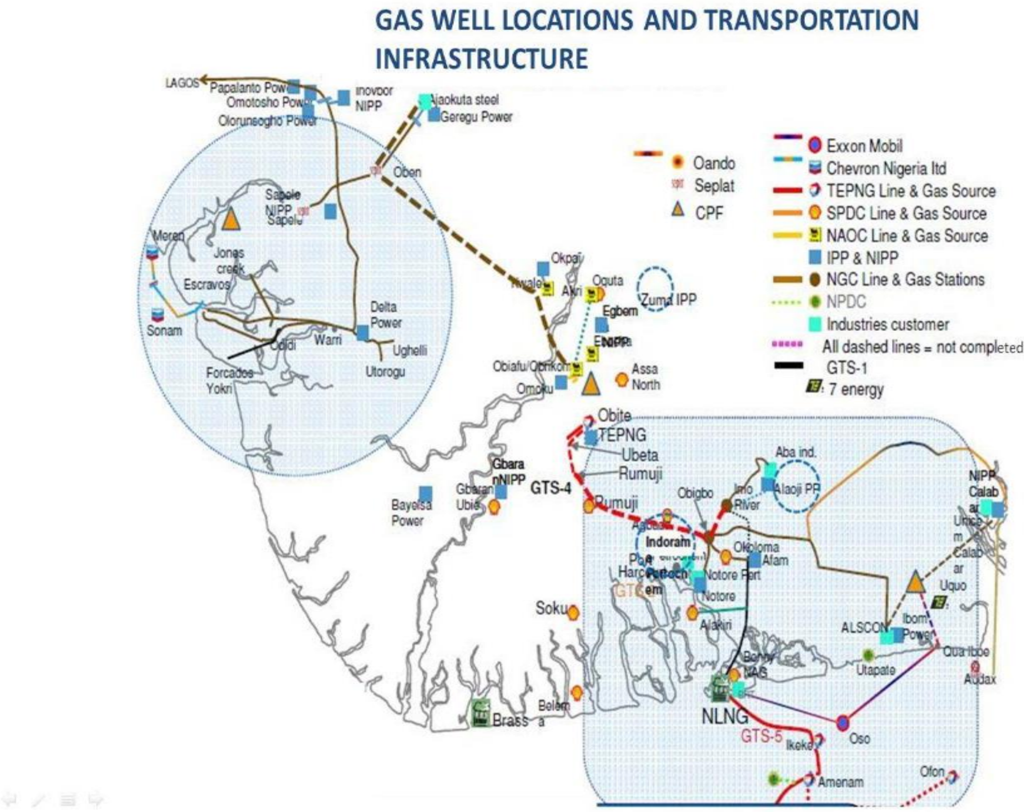

Figure 11: Map showing both existing and planned location pipeline infrastructure

Source: (Akinsoji, 2016)

4.2 Renewable Energy Investment

Due to high carbon contents, a high cost of fossil energy and the negative environmental impacts such as climate change, global warming, fossil fuel is gradually losing its popularity, the world is now shifting attention to a more sustainable and renewable energy due to its low carbon energy contents and environmentally friendly nature. Nigeria is vast reach in renewable energy resources, such as wind, hydropower, solar energy, and biomass.

4.2.1 Solar Energy Investment

The use of solar energy technology aids the capture of solar energy by using photovoltaic cells (PV) which helps in converting sunlight into electricity.

However, studies have shown that this technology has a huge potential in reducing the country's over-dependency on fossil fuels like crude oil and natural gas for power generation. Nigeria falls within the tropics of cancer and Capricorn where the renewable solar energy is in abundant. At present, with an average of 6 hours of sunshine, depending on the weather condition, the solar radiation is approximately 19.8MJm^2/day with the highest concentration in the northern geographical location which has 2200kWh/m^2 average solar radiation has shown in figure 13 below. This is capable of generating 1850x10^{3}GWh of electricity per year. (Charles, 2014). With sunshine period of 5-7 hours per day, the solar energy capacity ranges between 12.6MJ/m^2 per day in the coastal latitudes (southern part of the country) to 25.2MJ/m^2 per day in the Northern part (EzugwuC.N, 2015). Technically, with the average solar radiation level of approximately 5.5kWhm^2/day and the prevailing efficiencies of commercial solar-electric generators, if solar modules or collectors were used to cover 1% of Nigeria total land mass area of 923,773km^2, it is possible to generate 1850x10^{3}GWh (6.6x10^{11}MJ) of solar electricity per year. According to the experts, the solar PV systems off grid is estimated to cost an average of USD0.047/kWh (N18.00/kWh) as against the conventional fossil fuel power generation which presently cost N21.80/kWh (USD 0.058/kW) in Nigeria.

Due to the market size, the populations and the wide gap between the demand and supply of electricity, coupled with the Federal government of Nigeria energy policy with special attention to harnessing the renewable energy resources, indigenous Finnish energy companies can tap into this great opportunity by investing in the Nigeria Power sector.

Figure 12 below shows the projected cost of different energy resources between 2010 -2035 with the cost of solar energy (kW/h) reducing drastically, this shows the future potential of solar energy.

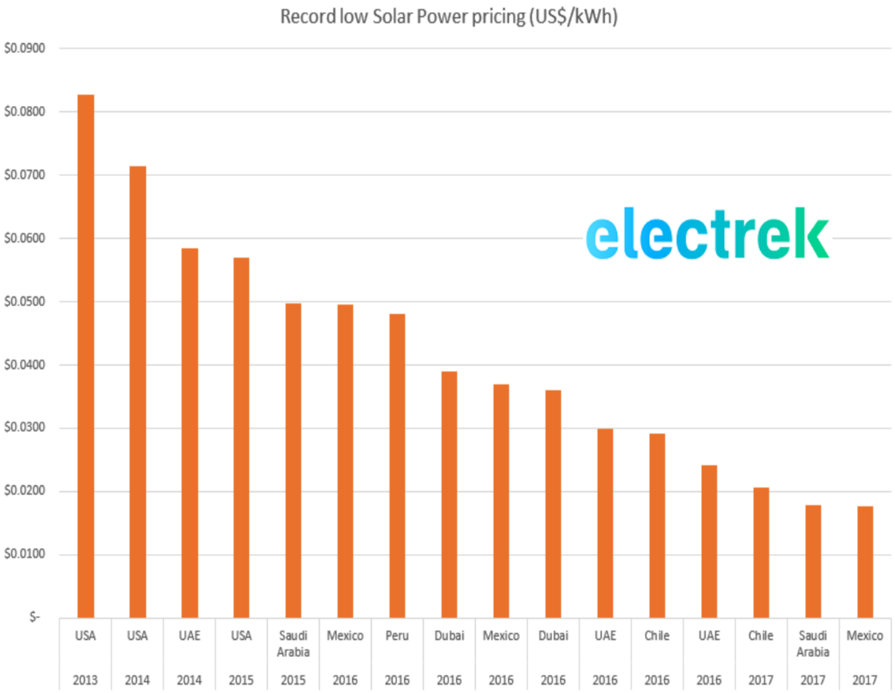

Figure 12: Record low Solar Power Price (kWh)

Source: (Electrek, 2017)

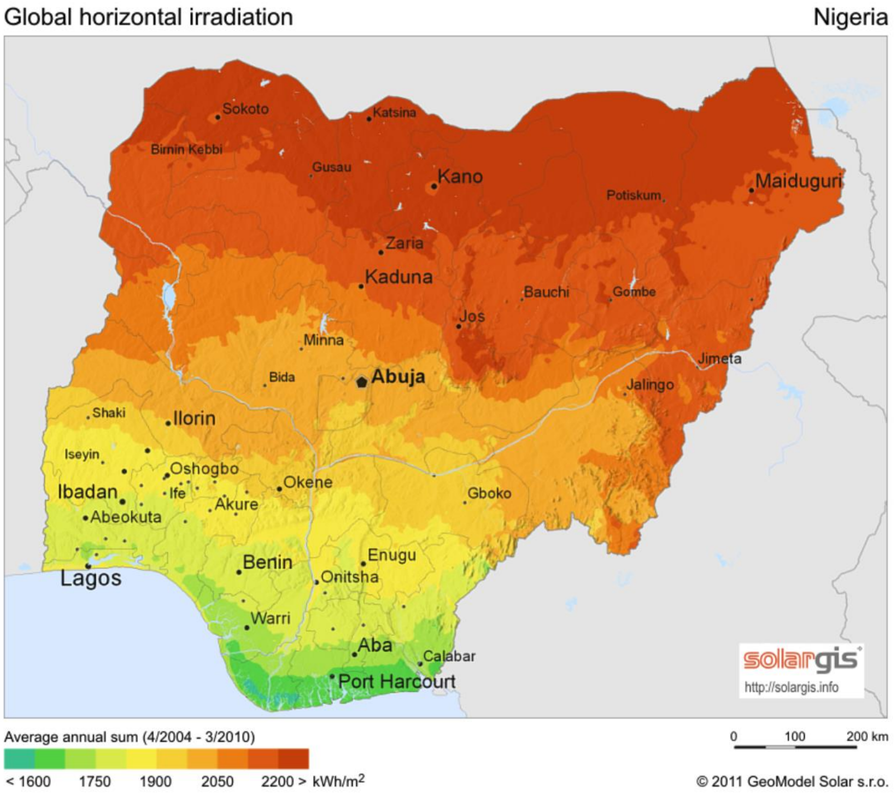

Figure13: Nigerian Map Showing Average Solar Radiation

Source: (SolarGis, 2017)

4.2.2 The Unit Cost of Solar Energy Generation

Solar energy is one of the most promising renewable energy resources in Nigeria due to its abundant in nature with the estimated 1850x10^3GWh of electricity production per year. At present, there is no significant solar energy utility price in Nigeria, but in 2016, the federal government signed the power purchased agreements (PPAs) with the new solar energy investors at USD 0.047/kWh being the maximum expected unit cost which electricity must be sold to the customers. This price is competitive because, as at 2015, the global average levelised cost of electricity (LCOE) for newly installed utility-scale solar PV was USD 0.013/kWh in the developed countries (NESG,Maria Yetano, Nnanna Ude, 2017). According to the projection, the unit cost of solar energy is expected to fall in Nigeria as more investment is being injected into the system which helps in creating a healthy competition as being witnessed in Germany with poor solar energy radiation where the solar PV utility scale was auctioned at average cost of USD 0.07kW/h in 2017. The global price downward trend is expected to continue as shown in Figure 12 where the unit price is expected to fall close to USD 0.05kW/h by the year 2035

Parameters	Unit	NERC 2015	IEA WEO 2016	AEO 2017	Lazard 2016	PV IPP1
Currency and year		Not stated	2015 USD	2016 USD	Not stated	Not stated
Installed capacity	MW	5	Not stated	150	30	100
Capital Cost	$/kW	1500	2400	2277	1450	1150
Technical lifetime	yr	20	20	20	30	20
Capacity Factor	%	19%	21%	19%	23%	19%
Fixed O &M	$/kW/yr	30,00	24,00	21,66	12,00	17,30
Variable O & M	$/kWh	0,0001	0	0	0	0
sLCOE (11% WACC)	**$/KWh**	**0,131**	**0,177**	**0,185**	**0,089**	**0,097**
World Bank 2013 LCOE	$/KWh	0,245				

(Newsom, 2012).

Figure 14: PV Utility –Scale Analysis

Source: (NESG,Maria Yetano, Nnanna Ude, 2017)

4.3 Wind Energy Investment

The wind energy potential is enormous in Nigeria with its abundant nature majorly stretching from the middle belt to the Northern part of the country. The wind energy has experienced a massive growth worldwide since 1980 when the average power generated by a 25m height wind turbine pole was 0.055MW, now with a constant speed, a 100m height wind turbine power plant can generate up to 3.0MWe depending on the wind speed. Like other renewable sources of energy, wind energy is environmentally friendly because it does not emit greenhouse gasses emission, hence, it produces no nuclear waste. (Gasch R, 2002). The research has shown that wind speed of 6m/s and above is good potential to generate electrical energy. Despite the aforementioned potential and abundant availability, Nigeria is yet to take advantage of this free natural resources. However, with the current energy policy and the government readiness to encourage the foreign investors to harness the great opportunity in renewable energy, the Finnish power generation investors can make use of this investment opportunity. According to the research, the Northern part of the country has the highest wind speed at an average of 7.0m/s at 10m height (Charles, 2014). According to the survey sponsored by the Federal government to access the wind energy potential, using Weibull distribution function for a period of 10 years between 1995-2004, it was discovered that in Oyo state, the southern part of Nigeria, the average wind speed and power density was 2.947m/s and 15.48W/M^2, this is not economically viable for wind turbine, However, in Umidike town, South-East part of Nigeria, at 65m hub height above the natural ground, the wind speed was 5.36m/s, this is economically profitable for a commercial wind turbine power generation. A 4- year wind data was also obtained across the seven major cities in Nigeria– Abuja, Enugu, Warri, Jos, Ikeja, Calabar and Sokoto, where the average yearly wind speed3.0 -7.5m/s in the South and Northern part of the country respectively (Adaramola, 2011). Hence, the Northern part of the country would be the best location for the wind turbine power plant. Figure 14 &15 showed the wind distribution and wind speed across the country respectively.

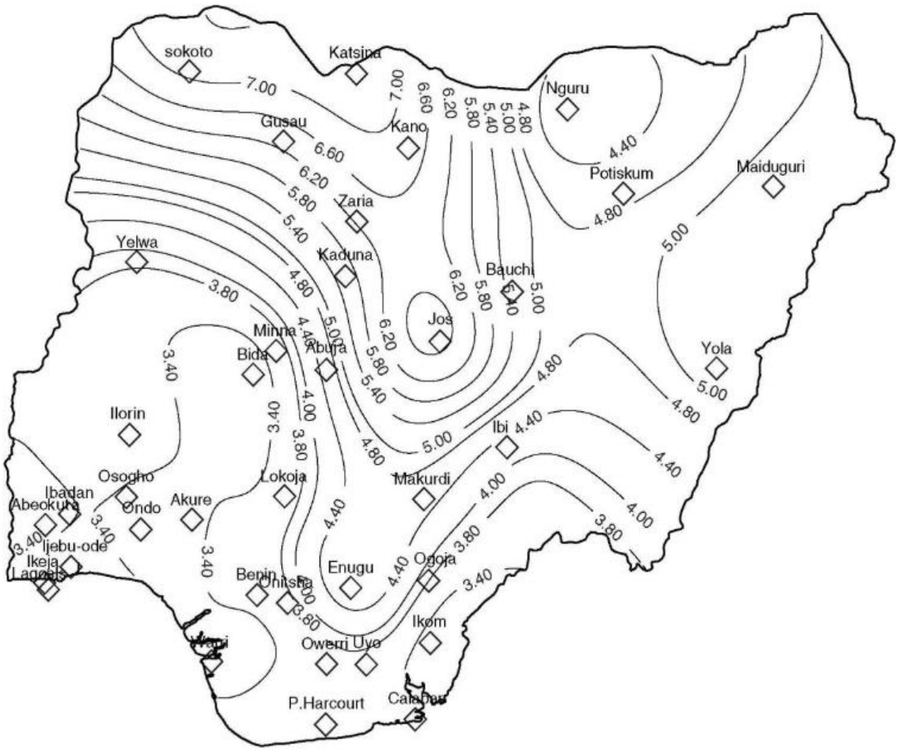

Figure 15: Map Showing the Wind Speed Across Nigeria

Isovents in m/s determined from 40 years' measurements at 10m height obtained from Nigeria meteorological dept. (NIMET), Oshodi, Lagos Nigeria. Source: (NIMET, 2010)

4.3.1 The Unit Cost of Wind Energy Generation

Although the technology and the investment are still relatively new in Nigeria. However, research has shown that the unit cost of wind energy per kilowatt is very competitive with the prevailing unit cost of USD 0.09/kWh. The total cost (kWh) of electricity produced can be calculated by discounting the levelising investment and O&M (operation and maintenance) cost over the lifespan of the turbine and then dividing them by the total sum of annual electricity production. Consequently, the unit cost (kWh) is calculated as an average over the lifespan of the turbine. However, practically, the unit cost will be lower than the calculated average cost at the beginning of the power plant due to the low operational and maintenance cost (O&M). The figure below shows the projected unit cost (kWh) of electricity generated from the wind energy in Nigeria. The price is seen to be USD 0.057/kWh (N20.48) as at 2016, including the cost of transmission and distribution. This price is very competitive as the present unit cost of electricity is USD 0.059/kWh (N21.80) in Nigeria

Parameters	Unit	NERC 2015	IEA WEO 2016	AEO 2017	Lazard 2016
Currency and year		Not stated	2015 USD	2016 USD	not stated
Installed capacity	MW	10	not stated	100	100
Capital Cost	$/kW	1760	1880	1686	1475
Technical lifetime	yr	20	20	20	30
Capacity Factor	%	32%	24%	32%	47%
Fixed O &M	$/kW/yr	18,50	48,00	46,71	46,71
Variable O & M	$/kWh	0,0015	0	0	0
sLCOE (11% WACC)	**$/KWh**	**0,087**	**0,135**	**0,092**	**0,057**
World Bank 2013 LCOE	$/KWh	0,186			

Figure 16: Price Analysis of Wind Energy in Nigeria

Source: (NESG,Maria Yetano, Nnanna Ude, 2017)

4.4 Recommendation

Presently, the prevailing power generation is not sustainable for national growth, because the current generation stands at an average of 5,000MW which represents 3.13% of 160,000MW needed to meet the estimated electricity demand for sustainable growth according to the experts. All the power stations are running below their installed generating capacity. The daily power generation capacity of 150MW gas turbine station used as a case study in this report showed a common factor to all the power stations across the country, hence the need to annex the abundant renewable energy resources available in the country. After carefully analyzing the root causes of power generation and transmission problems in Nigeria and identified abundant renewable resources, the under listed technical solutions are recommended to solve the age-long problem in the Nigeria power sector. However, some of the viable solutions such as the use of nuclear energy which has proven to be one of the best solutions to electricity generation despite its shortcomings is beyond the scope of this report.

4.4.1 Renewable Energy off Grid Distribution System

Nigeria needs to make use of the advanced and vibrant energy technologies to solve its ageing electricity problem. After carefully examined the country energy crisis and the amount of potential renewable energy resources available in the country, renewable energy off grid distribution system is strongly recommended. The amount of renewable energy generated by individuals in various categories can be utilized by them and the excess can be sold to the eligible customers within the same distance proximity without connecting it to the national grid. This system will ensure rapid access to electricity and enhance industrialization. Renewable power generated between 5kW - 0.75MW should be distributed to the final consumers via off grid system and be real-time monitored by the Nigeria Electricity Regulatory Commission for record purposes, monitoring and regulations. The price of the distributed electricity per kilowatt should be regulated using the current price of N21.8/kW (€0.058/kW) as a benchmark by the appropriate regulatory bodies. This will ensure flexibility and competitiveness. The system will encourage effective power supply to the consumers, boost the economy and ensures Nigeria meets up with the amount of energy needed for energy sustainability.
This report proposes three categories of investors under this technical innovative idea: category A: Solar Renewable power generation between 5kW-15kWe and category B: Solar Renewable power generation between 15kW - 0.75MWe. Category C: Medium Solar and Wind Renewable power generation between 0.75MWe – 4MWe.

4.4.2 Category A: Solar Renewable Power Generation between 5kW-15kWe

The category A is for average individual income earners who want to invest in solar renewable energy. They can generate solar power between 5kW -15kW of electricity and sell the excess to their neighbours by means or independent distribution means or via the existing distribution means owned by the local electricity distribution companies (Discos). This category is for three or four-bedroom apartment owners that consume little amount of electricity. This will earn the investors extra income and boost the nation's economy while providing solution to the problem. The solar panels can be placed on the roof top while the inverters, batteries, power controllers, AC panel mains, disconnectors et.al can be warehoused in a rack or small enclosed unit as illustrated in figure 16 below. The individual investors should be made to register the amount of electricity they wish to generate for record and monitoring purposes and obtain an electricity generation permit without necessarily paying a fee under this category in other to encourage the investors. The amount of electricity in kilowatts should be regulated by the regulatory authority. In other to pilot the project, ten thousand individual mini investors can generate an average of 7.5kWe/h of solar energy at the comfort of their homes in each of the 36 states, a minimum of 75MW/h of electricity will be generated in each state under this category, which will bring about average of 2,7000MW/h of electricity generation if such is replicated in all the 36 states in Nigeria. This represents 54.0% of 5,000MW/h current electricity being generated nationwide as at 2017, the generation statistics showed the sum of electricity generated across all the existing power stations in Nigeria was 10,192GW/h. This is too little when compared with the population.

= 7.5kW x 10,000 investors in each state x 36 states
= 2,700MW/h of electricity will be generated across the country under this category

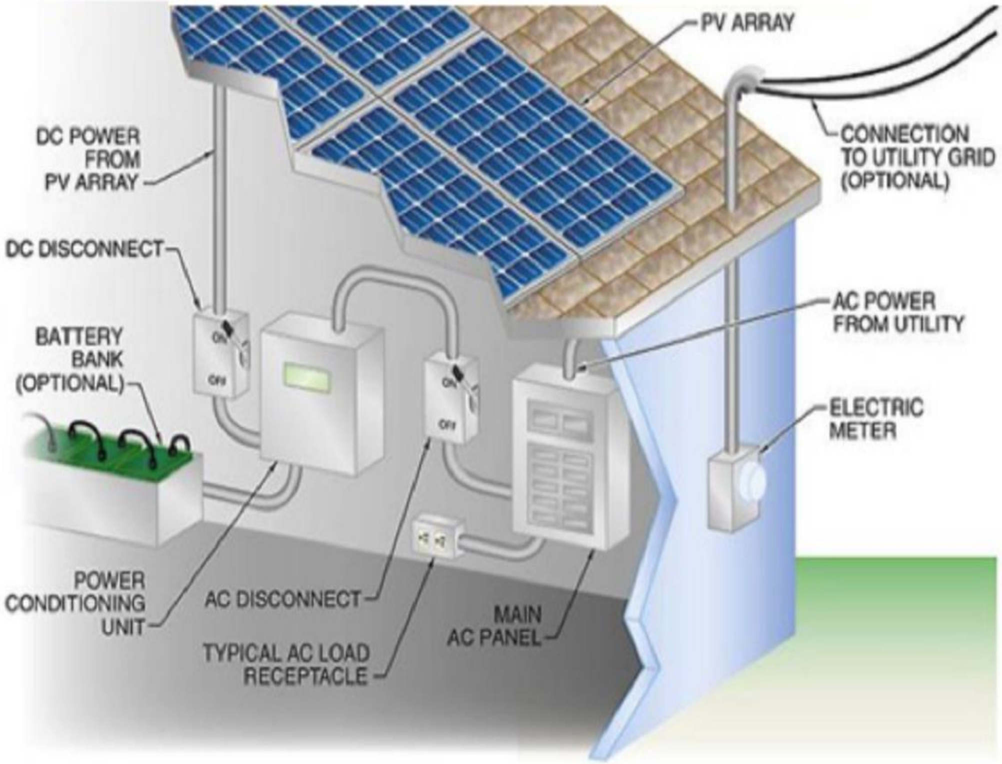

Figure 17: A typical mini Solar Energy set –up
Source (NHEnergyChoices, 2015)

4.4.3 Category B: Solar Power Generation between 15kW-0.75MWe.

The second category focuses on small investors who are stakeholders in power industry and individuals who can invest in solar renewable power generation up to 0.75MWe. Under this category, both generating and distribution permits will be obtained from the relevant authorities. The authorities will also monitor the instantaneous amount of power generation for the record purposes as well as the regulating the unit price of electricity per kilowatt (kW) to be sold to the prospective customers. The investors should be allowed to choose the type of renewable power they want depending on the economic viability of the resources available in the location.

At the beginning of the pilot project, licenses can be issued to a maximum of 500 investors and this should be proportionally allocated across the 36 states in the country to generate an average of 0.65MW/h of electricity. With this system, an average of 325MW of electric power, which represents 6.5% of the current power generation(5,000MW/h) will be conveniently generated and added to the existing generation capacity.

4.4.4 Category C: Medium Solar and Wind Renewable Power Generation between 0.75MW – 4MW

The third category investors are the medium stakeholders both local and foreign investors who are capable of investing in renewable solar or wind energy medium Power Project depending on their choice. The power generated can be distributed to the customers through the existing service mains of the licensed distribution companies. The investors should pay statutory distribution fees to the existing licensed distribution companies, which should be regulated by the Nigeria Electricity Distribution company. Incentives can be given by reducing the equipment import duty, electricity generation permit fee and value-added tax (VAT) among others in other to attract prospective investors. With 100 investors generating an average of 3.5MW/h of electricity in this category, 350MW/h can be added to the existing capacity.

Finnish electricity power generation investors like Fortum Energy, Wasilla, et.al who are experts in renewable energy can partner with the Nigerian government to invest in solar or wind energy due to its abundant nature.

4.5 Finnish Energy System; A Case Study for The Nigeria Energy Reform

With a population of a little over 5 million, in 2016, Finland average electricity production was 66.2 terawatts hours (TW/h) out of which renewable energy sources contributed for 45% of its total production (FinlandStatisitc, 2017). However, Nigerian with an average population index of over 184 million is nowhere near Finland energy production per capita index, hence the Nigerian government needs to holistically study the Finnish power sector with the view of analysing the possibility of adopting the system, most especially in the power generation and distribution sector. Finnish privatization policy gives room for private investors to generate and distribute electricity to both individual consumers and cooperate bodies without government interference as against the occasional interference by the regulatory authorities in Nigeria despite the fact that sector has been fully privatised. The regulatory body only serves as a regulator and monitor the power generation while holding on to only the power transition through the FINGRID oyj.

In Finland, the unit price of electricity (in kilowatts) is not fixed, hence customers are allowed to choose the energy companies they wish to purchase electricity from without any restriction, this gives room for a healthy competition between the distribution companies, but in Nigeria, government fixes the amount of electricity unit (N21.8/kWh or €0.058/kWh) for consumers and they are compelled to buy electricity only from the distribution companies (Disco) allocated to their states.

5 SUMMARY

It is a clear evidence that the present power generation and national grid transmission capacity cannot sustain Nigeria ever growing population and industrialization. Basically, the crisis in power sector can be summarized under two broad categories: technical issue and non-technical issues. Non-Technical issues are mainly due to misappropriation of funds, lack of political will by the past administrations since independence. The latter has eaten deep into the Nigerian economy. The country lost about N11Trillion (approximately €31.7B) to misappropriation of funds in the energy sector between 1999 till date due to government unwillingness to fully privatise the sector, this has remained the major source of the problem in the sector.

Insufficient natural gas to constantly power the power station, equipment vandalisation, lack of a well-structured planned preventive maintenance (PPM), among others are the major technical issues confronting the sector as analysed in this project report. The present transmission network system is no doubt ageing and cannot absorb the current power generation capacity despite the low generating capacity. Hence, the entire sector needs a total transformation and restructuring.

This project work seeks to find the practical lasting solutions to the energy crisis in the country by analysing the amount of solar and wind energy availability in Nigeria. With an average of 6 hours of sunshine and 19.8MJm^2/day of solar energy radiation and the 7.0m/s average wind speed at 10m height, wind and solar energy resources can significantly contribute largely to solve the energy crisis. The solar and wind renewable energy power generation roadmap was simplified and categorized into three main categories with a practical workable approach analysis. Under the category A, with 360,000 individuals mini investors generating 7.5kW of solar power and reselling the un-used energy to the neighboring houses usually three or four-bedroom apartment low energy consumers via the independent or existing service mains in all the 36 states of the federation, an average 2,700MW of electricity can be added to the current 5000MW generation capacity while category B will contribute 325MW to the system as analysed above. Lastly, category C which is for medium investors who can generate an average of 3.5MW solar or wind power will also add an average of 350MW of electricity which is a significant amount of power generation to the system. Nigeria power generation sector will witness additional 3,375MWh of renewable power accounting for 67.5% of 5,000MW/h being the current power of generation capacity.

In the future, other sustainable renewable energy resources such as waste residues, wastewater sludge, agricultural wastes and other bio-degradable energy resources can be further studied in other to boost the power generation sector. However, for now, due to security challenges, technological know-how et.al the use of nuclear energy resources for power generation is not feasible in Nigeria.

In other for this proposed recommendation to work, the government must also ensure enabling environment and right energy policy framework to ensure the sustainability of the proposed alternative renewable energy reform. The power generation allocation under the category A, B and C must be evenly allocated based on the geographical locations and the electricity demand.

6 BIBLIOGRAPHY

Adaramola, e. M. (2011, February 2). Wind Speed distribution anc charactersitics in Nigeria. *ARPN Journal of Engineering and Applied Sciences*, 83.

African Progress Report. (2015). *Power People and Planet-Sizing Africa's Energy and Climate Opportunities.* Kenya: Africa Progress Panel.

Akinsoji, O. (2016). *The Nigerian Power Sector Investment Opportunities and Guidelines.* Abuja: Federal Republic of Nigeria.

Bakshi U.A, B. M. (2009). *Power System 1* (1st Edition ed., Vol. 1). Shaniwar Peth, India: Technical Publications Pune.

Charles, A. (2014). *How is 100% Renewable Energy Possible in Nigeria?* Global Energy Network Institute. Califonia: Global Energy Network Institute.

CIA. (2017, January 01). *Central Intelligence Agency , USA*. Retrieved January 11, 2018, from https://www.cia.gov/library/publications/the-world-factbook/rankorder/2253rank.html

ECN, UNDP. (2012). *Renewable Energy Master Plans.* Energy Commission of Nigeria. Abuja: Energy Commission of Nigeria.

Electrek. (2017, November 16). *Electrek*. Retrieved March 08, 2018, from Electrek: https://electrek.co/2017/11/16/cheapest-electricity-on-the-planet-mexican-solar-power/

EzugwuC.N. (2015, January). Renewable Energy Resources in Nigeria: Sources, Problems and Prospects. *Journal of Clean Energy Technologies, 3*(3), 2-3.

FAO. (2017, 11 28). *http://www.fao.org/nr/water/aquastat/countries_regions/NGA/*. Retrieved 11 28, 2017, from Food and Agriculture Orgaisation of the United Nations.

Fashola Babatunde. (2018, January 03). *Federal Minsitry of Power Work and Housing.* Retrieved January 10, 2018, from http://www.pwh.gov.ng/read_02?columes=dGl0bGVfc2hvd19lY2hvXzAxenoqXDAxKjRmNjJhNGFhMDc2YjkwMWZkOThlNzQzMDdhYWI0NjBk&whaters=MSpcMDEqZWZiMTQzNWMwNjYyMTAxODIxN2RkZmFiNzE3ZDYyNzE%3D&rtsdfgh=OTM0KlwwMSozYTZkMzE5YzE2NjRjZjk1Y2IzNmIyYjdjNWZiYTQ4Zg%3D%3D&pageNum_Recordset1=MCpcMDEqYjkxMmE2ZDE5YjY0ZTVkMWJlYTk5NGMwNjBkNmJiMjk%3D

FinlandStatisitc. (2017, November 2017). *Renewable Energy Sources produced 45 per cent of electricity*. Retrieved Feb. 13, 2018, from https://www.stat.fi/til/salatuo/2016/salatuo_2016_2017-11-02_tie_001_en.html

FIPL. (2105, April). (FIPL-First Independent Power Limited) Retrieved January 10, 2018, from Omoku Power Plant: http://fipl-ng.com/omoku-plant/

Francis Akpojedje, M. E. (2016, January). A comprehensive Review of Nigeria Electric Power Transmission Issues and Rural Electrification Challenges. *International Journal of Engineering Trends and Technology (IJETT), 31*(1), 2-9.

Gasch R, T. J. (2002). *Wind Power Plant- Fundamentals,Dessign, Construction and Operation.* (P. D.-I. Gasch, Ed.) London: Solarpraxis AG, Germany , James &James Science Publishers Ltd.

GEOil. (2011, Decmeber). *Gas Turbine.* Florence: GEOil &Gas.
iWin. (2018, January 16). *Indepdent Energy Watch Initiative*. Retrieved January 19, 2018, from http://iwin.org.ng
Lebele-Alawa, B. T. (2015, August). Improved Design of a 25MW Gas Turbine Plant usinf combined Cycle Application. *Journal of Power and Energy, 3*, 1-14.
NERC. (2006). *Nigerian Electricity Regulatory Commission*. Retrieved November 15, 2017, from http://www.nercng.org/index.php/home/nesi/403-generation#
NERC. (2017, 09 22). *Nigerian Electricity Regulatory Commission.* Retrieved 11 28, 2017, from http://www.nercng.org/index.php/home/nesi/404-transmission
NESG,Maria Yetano, Nnanna Ude. (2017). *Comparison of Cost of Electricity Generation in Nigeria.* Nigerian Economic Summit Group & Heinrich Böll Stiftung Nigeria. Abuja: Nigerian Economic Summit Group.
Newsom, C. (2012, June 04). *Renewable Energy Potential in Nigeria.* Retrieved January 12, 2018, from http://pubs.iied.org/pdfs/G03512.pdf
NHEnergyChoices. (2015, Sept 02). *NH Energy Choices*. Retrieved January 09, 2018, from http://www.nhenergychoices.com/solar-works-nh/
NIMET. (2010). *Nigerian Meterological Agency*. Retrieved 12 02, 2017, from http://www.nimet.gov.ng/rtc-lagos
NNPC. (2017, 11 28). *Nigerian National Petroleum Corporation*. Retrieved 11 28, 2017, from http://www.nnpcgroup.com/PublicRelations/NNPCinthenews/tabid/92/articleType/ArticleView/articleId/380/Nigerian-Crude-Oil-Production-Hits-27-Million-Barrels-As-NNPC-Benue-Pledge-to-Resuscitate-Makurdi-Depot.aspx
NpopC. (2017, 11 27). *National Population Commsion , data for national planning and development*. Retrieved 11 27, 2017, from http://population.gov.ng
Oluseyi, A. (2010). The Potential of Wind Energy in Nigeria. *Wind Engineering, 34*(3), 303-312.
Osibanjo, P. (2017, Oct 10). Nigeria Power Generation Capacity. (I. Adeyemo, Interviewer) Abuja, Nigeria: Premium Times.
Sadik, P. O. (2015). *Energy Crisis in Nigeria: Sustainable Option Using Nanotechnology as a Way Forward.* Sustainable Nanotechnology Organisation. Omowunmi Sadik.
Salau, S. (2016, January 08). *The Guardian.* Retrieved November 14, 2017, from https://run.edu.ng/media/6182273564112.pdf
SolarGis. (2017, May 23). *SolarGis*. Retrieved February 17, 2018, from https://solargis.com/products/api/?_ga=2.258122954.150505794.1520097095-180914625.1520097095: https://solargis.com/products/api/?_ga=2.258122954.150505794.1520097095-180914625.1520097095
Sustainable Energy for All, W. B. (2017). *https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?name_desc=false*. Retrieved November 2017, 2017, from Sustainable Energy for All- World Bank: https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?name_desc=false
TCN. (2017, 11 27). *Transmission Compnay of Nigeria*. Retrieved 11 28, 2017, from http://www.tcnorg.com/index.php/find-tickets/258-about-transmission-company-of-nigeria
TheodoreWildi. (2002). Electrical Machines, Drives and Power Systems. In T. Wildi, *Electrical Machines, Drives and Power Systems* (pp. 664-667). 2002, New York: Pearson Education International.

Titus Koledye Olugbenga, P. D. (2013, 03). The current and future challenges of electricity market in Nigeria in the face of deregulation. *Africa Journal of Engineering Research, 1*(2), 35-37.

Tribune, N. (2017, May 11). *The Power Transmission Challenge.* Retrieved November 27, 2017, from http://www.nigeriaelectricityhub.com/2017/05/11/the-power-transmission-challenge/

Wijeratne David, P. O. (2016). *Powering Nigeria for the Future.* Retrieved November 14, 2017, from https://www.pwc.com/gx/en/growth-markets-centre/assets/pdf/powering-nigeria-future.pdf

WorldBank. (2014, May 19). *World Bank Group.* Retrieved Januay 10, 2018, from https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC?end=2014&locations=NG-FI&start=1971&view=chart