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# IMPACT OF THE INDEPENDENT POWER PRODUCERS AND NATIONAL INTEGRATED POWER PROJECTS ON THE DEREGULATION OF THE NIGERIAN ELECTRICITY SECTOR

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## ABSTRACT

In Nigeria, the Independent Power Producers (IPPs) and the National Integrated Power Projects (NIPPs) were established because of the deregulation of the electricity sector, in order to achieve the objectives of constant electricity supply and reduced gas flaring in the Niger Delta region. This move was to foster sustainable development in the oil rich region of the country, through the use of the available natural resources. This paper presents the impact of these projects on the existing Nigerian electricity system since their inception. The outputs of the power plants after their inception were presented with respect to the existing Nigerian grid network. It was found that the power plants account for about 25% of the total electricity generated. It was also established that because of the shortage of gas supply, the NIPP power plants accounted for about 54% of the total constrained electricity generation. The proposed power projects failed to achieve their objectives due to mainly gas pipeline destruction in the region. However, their presence contributed significantly to the improvement of electricity supply in Nigeria. Some opportunities and challenges in the deregulation of the Nigerian electricity sector were also highlighted.

*Keywords: Generation capacity, Nigerian electricity sector, Independent power producers, National integrated power projects, Gas, Electricity supply.*

## INTRODUCTION

Nigeria is the most populous country in Africa with a population of over 180 million people (NPCN, 2016). The country has numerous natural resources for electricity generation (ECN, 2015). In spite of the abundance of these natural electricity potentials in Nigeria, the grid network still suffers insufficient and epileptic electricity supply (Uhunmwangho and Okedu, 2014). The country has not been able to sustain its development through the use of the plenty natural available resources for electricity generation, rather, still rely and seek aids from foreign countries with regards to constant electricity generation. It has been estimated that only 40% of the Nigerian population has access to grid-connected electricity (Loi, 2002). Also, only 18% of the rural areas in the country which form a major part of the population has access to the national grid network (Momoh, 2000).

According to the World Bank, in the year 2005, the population of Nigeria was estimated 139.6 million, with a per-capita electricity consumption of 128.64 kWh. It was reported that only about 40% of this population had access to electricity supply (KPMG, 2013). In August 2005, from a total installed generation capacity of 6,000MW, only about 3,774MW was achieved as a peak value (Oyeneye, 2004). The grid was down with constant electricity outage, thus, electricity supply was unreliable in general. As a result, in 2005, it became necessary to establish and enact the Electric Power Sector Reform Act (EPSRA), in order to legalize the Nigerian Electric Power Policy (NEPP) of 2001. This formed the basis for the framework of the Independent Power Producers (IPPs) scheme and the National Integrated Power Projects (NIPPs).

The IPPs and NIPPs were originally designed to boost electricity generation in phases, starting with about 10,0000 MW while at the same time significantly reduce gas flaring in the Niger Delta region through the efficient use of flared gas in the area to power the proposed plants. The plants are mainly simple cycle gas turbines which have the facility to be upgraded to combined cycle engines (with the exception of Alaoji and Olorunshogo II, which are already combined cycle gas turbines). There were originally six power plants under the IPP scheme and eleven power plants under the NIPP, including a new power plant, proposed to be sited in Akwa-Ibom state. This plan was overtaken by the construction and commissioning of the 191 MW Ibom Power Plant in 2009, thus reducing the total number of the proposed power plants to ten. The estimated cost of the IPPs and NIPPs since their inception shows that over 8.26 billion US Dollars have been spent (Jonathan, 2015).

Currently, twenty-three generating plants are tied to the Nigerian grid network with a total installed and available capacities of 12,067 MW and 6,840 MW respectively (Ibe and Okedu, 2009). The bulk of the generation is thermal with an installed capacity of 8,457.6 MW (81% of the sum) and an available capacity of 4,996 MW (83% of the sum). The other generation type is hydropower emanating from three stations and contributing 1,938.4 MW of the total installed capacity (and an available capacity of 1,060 MW) (News report, 2017). It is obvious from the available data that electricity demand in Nigeria far surpasses supply. On the NIPP website (NIPP website, 2017), it was forecasted that this demand would grow from 33 terawatt hours in 2011 to between 56 and 95 terawatt hours by 2020. Consequently, peak load demand would rise from 5,000 MW in 2011 to between 9,000 MW and 16,000 MW by 2020.

This paper presents the analysis of the current situation of electricity supply in Nigeria with respect to various electricity policies and reforms that have been embarked upon in a bid to improve power supply in the country. A further investigation of the various contributions of the IPP and NIPP projects based on current available energy reports, data and analysis using simple statistical methods was also carried out. The presented results help to ascertain whether the main goals of the IPP and NIPP have been achieved and if it was justifiable to set up the programs. Some of the opportunities and challenges in the deregulation of the Nigerian electricity sector were also highlighted.

## AIM AND OBJECTIVES

The aim of this paper is to present the impact of the IPP and NIPP schemes in the Nigerian electricity sector as a result of its recent deregulation, in order to promote sustainable development in the country. The following are some of the objectives of this work.

(1) To give a chronological description of the infrastructure development plans and implementation in the Nigerian electricity sector.
(2) To review the components of the Nigerian Electricity Sector.
(3) To analyse the electricity generation in Nigeria prior to the IPP and NIPP schemes.
(4) To have the idea of the mathematical correlation of electricity generated with respect to the growing population.
(5) To study the various state of the Independent Power Producers (IPPs) and the National Integrated Power Projects (NIPPs) in Nigeria.
(6) To highlight the reasons for the various delays and socio-economic factors in implementation of the electricity projects.
(7) To give the description, site location and gas supply of the various NIPP plants.
(8) The performance evaluation of the IPP and NIPP schemes in the Nigerian grid system.
(9) To evaluate the various constraints like turbine gas supply to the various electricity projects.
(10).To highlight some of the benefits and weak points of the deregulation of the Nigerian electricity sector.

## METHODOLOGY

In order to access the level of sustainable development in the Nigerian electricity system, the following criteria were used to achieve the set aim and objectives of this work.

(1) Before the inception of the IPPs and NIPPs projects, what was the installed and available generating capacity of the country?
(2) After the inception of the IPPs and NIPPs projects, what is the installed and available generating capacity of the country?
(3) What percentage of the generation is constrained due to gas supply shortage, pipeline destruction in the Niger Delta region or geography?

## INFRASTRUCTURE DEVELOPMENT PLANS AND IMPLEMENTATION

The Federal Government of Nigeria (FGN) in 1972, created the National Electric Power Authority (NEPA) in line with Decree No. 24 as a step in the evolution of the electricity industry in Nigeria (Ministry of power and steel, 2006). NEPA was formed from a merger of the Electricity Corporation of Nigeria (ECN) and the Niger Dams Authority (NDA). In September 1990, the appointment of a director to oversee NEPA led to the partial commercialization of the corporation, with the creation of four autonomous divisions headed by separate directors. These divisions were Generation and Transmission; Distribution and Sales; Engineering; and Finance and Administration.

The FGN made further efforts towards the restructuring of the Nigerian electricity sector, with an intent to implement electricity supply solution which was efficient, reliable and cost-effective for sustainable development of the nation, while at the same time attract private investment (Loi, 2002). In April 2001, the National Electric Power Policy (NEPP) was approved (NEPA, 2001). This policy outlined plans for the Federal Government to improve the electric power sector and grow the industry through private sector participation. However, this policy was not implemented until 2005, when the EPSRA was established (Momoh, 2000).

The purpose of the EPSRA was to provide the legal backing required for the NEPP to be implemented (Momoh, 2000). Part of the intentions of the NEPP/EPSRA was to transfer the public monopoly of NEPA to the Power Holding Company of Nigeria (PHCN) in 2003, in order to create an attractive, competitive, efficient and well robust sustainable developed responsive electricity market in Nigeria. Prior to this period, electric power generation, transmission, and distribution in Nigeria were the sole responsibilities of the federal government. The NEPA was the vehicle driving this program for the government and exercised total control of the electricity market. The services of the NEPA were so poor that new industries for the importation, sales, distribution, installation and maintenance of petrol and diesel generating sets sprang up and has continued to flourish (Afolabi, 2015 and Okafor, 2015). In 2004, the National Integrated Power Projects (NIPPs) were established to boost the electricity supply in the country under the control of the Niger Delta Power Holding Company of Nigeria (NDPHC). The NIPPs were expected to be completed by 2015.

In 2005, EPSRA, along with other policies and programs were established in order to create an enabling sustainable developed environment to increase the total power generation capacity of the country by approximately 11,000 MW (Awosope, 2014).

The Power Sector Reforms which were made possible by the EPSRA of 2005 became necessary due to the following challenges:

- Constrained access to electricity infrastructure, which resulted in low connection rate
- Insufficient generation of electricity
- Misuse of generated electricity capacity
- Poor investment fund monitoring
- Ineffective regulation
- Large technical losses and vandalism of facilities in the industry
- Lack of adequate transmission and distribution facilities
- Widespread electricity theft and inefficient use of electricity by consumers.

However, the major objective of this reform in the Nigerian electricity sector is to establish an Electricity Supply Industry (ESI) that meet the following requirements (KPMG, 2013 and Oyeneye, 2004):

- Provide unfettered access to clean, reliable and efficient power supply on demand
- Maintain a high standard of customer service delivery and transparency in billing
- Create and maintain a competitive and viable electricity market that can attract and keep private investors.

The Nigerian Electricity Regulating Commission (NERC) was reconstituted to provide the regulatory framework needed to protect the interests of private investors and consumers in 2010. Also, the Nigerian Bulk Electricity Trading

Company (NBET) was established to provide a security for the facilities in the industry. Manitoba Hydro International (MHI) of Canada was employed to reorganize the Transmission Company of Nigeria (TCN) into a more vibrant and market driven company to encourage the sustainable development of the nation.

In 2011, the PHCN was unbundled into eighteen successor companies for privatization. The reasons were to achieve more efficient, reliable, affordable and quality services to foster electricity growth in the country. The eighteen companies were made of six generating companies (GENCOs), one transmission company (TCN) and eleven distribution companies (DISCOs) (PHCN, 20011, 2012, 2014 and NERC, 2011, 2013, 2015).

The progress made with the reforms so far show that the Nigerian government was actually making serious efforts to improve the electricity supply to the populace and to make the country more sustainably developed through the use of the available resources. Some changes that have taken place in the ESI since the introduction of the EPSRA include (NERC, 2016):

- The NEPA has been unbundled into the 18 companies of the PHCN
- The Unbundled entities are now operated and maintained by private investors with the exception of the TCN which is still wholly owned by the FGN.
- The NERC is now established and fully functioning as a regulatory body for the Nigerian ESI on behalf of the FGN
- The Rural Electrification Agency (REA) is now fully funded and operational across the country.
- A Consumer Assistance Fund (CAF) is now being created to enable low-income earners to get access to electricity.
- Private investors are now building new power plants in Nigeria, in addition to the recently privatized ones.
- Information about the daily performance of the Nigerian ESI is now available on the internet for everyone to see.
- There is now more transparency in consumer billing and the use of pre-paid metering by consumers has greatly increased.
- There is an increased awareness of the need for efficient use of electricity by consumers, as most Nigerians now use energy efficient lighting in their buildings.

The reform of the NEPP and the EPSRA gave room for the sustainable development of the Nigerian electricity market by creating an opportunity for the IPPs to invest in the industry (Income Electrix, 2015 and JICA, 2007).

## REVIEW OF THE COMPONENTS OF THE NIGERIAN ELECTRICITY SECTOR

The current structure of the Nigerian electricity sector, with the eleven distribution companies and the six generation companies being run by private investors in a public-private partnership arrangement with the FGN is shown in Table 1(NERC, 2013).

Table 1: PHCN incorporated successors (NERC, 2013)

| Generating Company(GENCO) | Transmission Company(Transco) | Distribution Company (Disco) |
|---|---|---|
| Kainji Power Plc<br>Shiroro Power Plc<br>Ughelli Power Plc<br>Sapele Power Plc<br>Afam Power Plc<br>Geregu Power Plc | Transmission Company of Nigeria | Eko Electricity Distribution Co. Plc.<br>Ikeja Electricity Distribution Co. Plc<br>Ibadan Electricity Distribution Co. Plc<br>Benin Electricity Distribution Co. Plc<br>Abuja Electricity Distribution Co. Plc.<br>Ikeja Electricity Distribution Co. Plc<br>Port Harcourt Electricity Distribution<br>Enugu Electricity Distribution Co. Plc<br>Kaduna Electricity Distribution Co.Plc<br>Kano Electricity Distribution Co. Plc<br>Jos Eectricity Distribution Co. Plc<br>Yola Electircity Distribution Co. Plc |

The Nigerian power sector transmission is around 5,523.8 km of 330kV, and 6,801.49 km of 132 kV, transmission lines respectively. There are 32 Nos. 330/132kV substations having a total of 7,688 MVA (6,534.8 MW) installed transformation capacity; 105 Nos. 132/33/11 kV substations of 9,130 MVA (7,760.5 MW) with total transformation capacity. The capacity that could be availed on all the 330/132kV Bus is 7,364MVA (that is, 95.8% Capacity) and 8,448MVA (that is, 94.1% Capacity) on all the 132/33kV Bus (NDPHC, 2015), with an average transmission loss of 8.5% (Olugbenga, et al, 2012). The major two arms of the TCN are the market and system operators with duties of providing a platform for wholesale electricity market, increasing efficiency and making the market competitive. The specific responsibilities of the system operator are:

- Enacting the grid codes/requirements
- Enacting standard measures for the proper working of the controlled grid
- Enforcing the system planning
- Implementation of forecast demands
- Maintenance of outages and operations
- Tie lines coordination

The specific responsibilities of the Market Operator are:

- Market strategy administration
- Market rules implementation

These unbundled companies (except the TCN) were sold to private owners through a competitive bidding process. The Nigerian government on September 30, 2013, reduced its shareholding portion to 40% in the distribution companies and 20% in the generation companies while retaining 100% shareholding of the TCN. Thus, the Nigerian ESI is now led by private investors, with the NERC maintaining regulatory oversight. The various percentage of the network allocated to each distribution company in the Nigerian electricity sector is shown in Table 2 (Labo, 2010) and Figure 1 respectively.

Table 2: Electricity Distribution Companies in Nigeria (Labo, 2010)

| S/N | DISCO | PERCENTAGE OF THE NETWORK ALLOCATED |
|---|---|---|
| 1 | Abuja Distribution Company | 11.5% |
| 2 | Benin Distribution Company | 9% |
| 3 | Eko Distribution Company | 11% |
| 4 | Enugu Distribution Company | 9% |
| 5 | Ibadan Distribution Company | 13% |
| 6 | Ikeja Distribution Company | 15% |
| 7 | Jos Distribution Company | 5.5% |
| 8 | Kaduna Distribution Company | 8% |
| 9 | Kano Distribution Company | 8% |
| 10 | Port Harcourt Distribution Company | 6.5% |
| 11 | Yola Distribution Company | 11.5% |

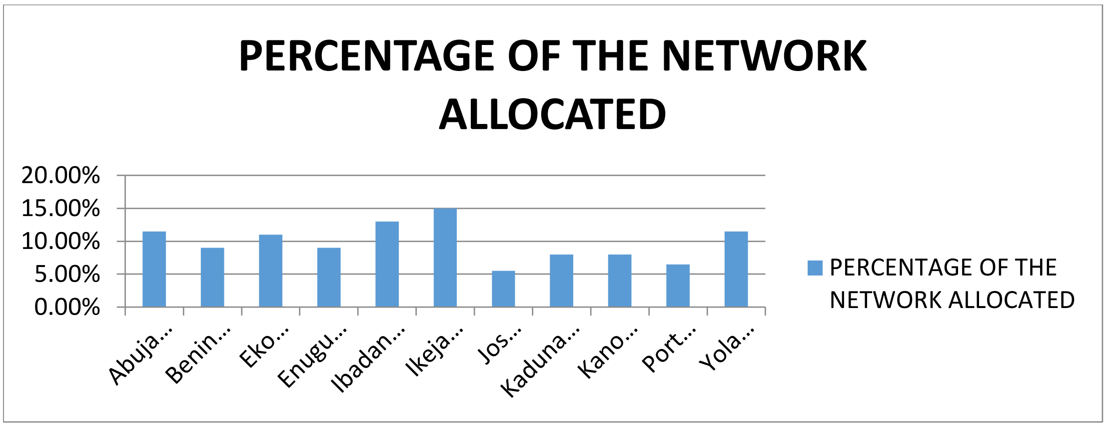



Figure 1: Electricity Distribution Company in Nigeria with the percentage of network allocated

## POWER GENERATING CAPACITY PRIOR TO IPP AND NIPP SCHEMES

Table 3 (Labo, 2010) and Figure 2 show the installed capacity of the generating plants and their operational capacity in Nigeria before the inception of the IPP and NIPP projects. The major means of electricity generation is the use of gas and the Egbin power plant has the highest generating capacity of 1,320 MW which is slightly lower than the combined generating capacity of the Kainji and Jebba hydro plants.

Table 3: Generation Companies in Nigeria (Labo, 2010)

| S/N | GENERATION COMPANY | TYPE OF PLANT | CAPACITY(MW) |
|---|---|---|---|
| 1 | Afam power plc (1-V) | Thermal | 987.2 |
| 2 | Egbin Power Plc | Thermal | 1,320 |
| 3 | Kainji/ Jebba Hydro Electric Plc | Hydro | 1330 |
| 4 | Sapele Power Plc | Thermal | 1,020 |
| 5 | Shiroro Hydro Electric Plc | Hydro | 600 |
| 6 | Ughelli Power Plc | Thermal | 942 |

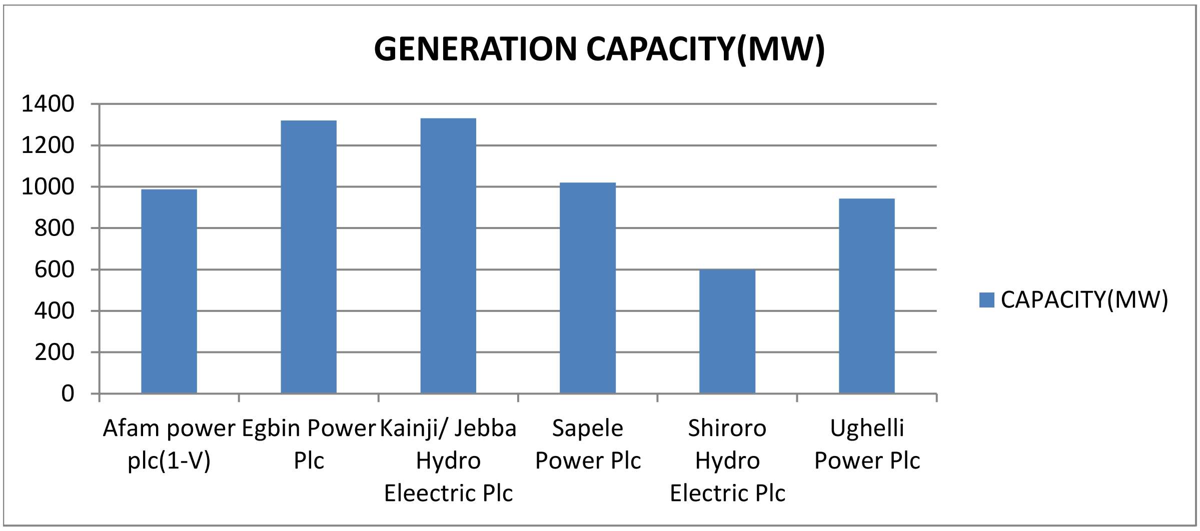



Figure 2: Installed capacity of generating plants before IPP and NIPP Projects

## MATHEMATICAL CORRELATION MODEL OF PAST AND FUTURE ENERGY DEMAND IN NIGERIA

Linear correlation model could be used to relate the past and future electricity demand in Nigeria based on the growing population. Considering the statistical model for correlation with assumption that both x and y are normally distributed (x been electricity generated and y the growing population), the standard method for ascertaining correlation can be computed by using the Pearson correlation coefficient. This method assumes a linear correlation between x and y. In the Pearson's method, the key quantity that is computed is the correlation coefficient described by equation (1) as (Banfielder, 2010):

$$r = \frac{1}{N}\sum\left[\frac{(x_i - \bar{x})}{SD_x} \cdot \frac{(y_i - \bar{y})}{SD_y}\right] \qquad (1)$$

Normally, the range of the correlation coefficient is from -1 to 1. A zero value represents no correlation between the two data x and y under investigation. A value of 1 indicates perfect correlation between the variables, while a value of -1 is a perfect anti-correlation. Unfortunately, the Nigerian electricity system is the anti-correlation based on past and future estimated data of electricity generation, whereby when x (electricity generated) goes down, y (growing population) goes up due to lack of sustainable development plans in the country regarding electricity generation. Based on equation (1), whenever both variables are above or below their means, a positive contribution to *r* would be achieved. On the other hand, when one variable is above and the other variable is below, a negative contribution is obtained. If the data are uncorrelated, these effects will tend to cancel each other out and the overall correlation *r* will tend toward zero.

**THE IPP AND NIPP SCHEMES IN NIGERIA**

The IPPs are power stations owned and managed by investors and were licenced to generate electricity for the purpose of encouraging sustainable development and improving the electricity situation in the country. Table 4 (Ajumigobia, and Okeke, 2015) and Figure 3 show the existing IPPs installed and available capacities in the Nigerian electricity sector. From Table 4 and Figure 3, the IPPs would help boost electricity supply as it could be observed that there is almost a close match between the installed and available capacities. The good performance of the IPPs is basically because they are owned and managed by the oil producing and servicing companies in the country.

The NIPPs was the first step in the implementation of the EPSRA, which provided a platform for private investors to build, own and operate power plants by generating and selling electricity to the national grid through a bulk buyer. In 1999, the total installed generation capacity was about 1,500MW in Nigeria, consequently, there was a plan to increase this capacity to about 10,000MW within eight years (2008), while hoping that another 10,000MW would be added by subsequent government administrations coming into power before 2015. This was the premise upon which the NIPP was established. The NDPHC was therefore created as a special purpose vehicle to manage this project [30, 31] (TCN, 2015 and Titus et al, 2013).

Table 4: Independent Power Plants in Nigeria (Ajumigobia and Okeke 2015)

| S/N | Generation Company | Location | Installed Capacity (MW) | Available Capacity(MW) |
|---|---|---|---|---|
| 1 | AES Power station | Egbin, Lagos State | 224 | 224 |
| 2 | Shell-Afam VI power station | Afam, Rivers State | 650 | 650 |
| 3 | AGIP-OKPAI Power Station | Okpai, Delta State | 480 | 480 |
| 4 | ASG-IBIOM Power Station | Akwa Ibom State | 155 | 76 |
| 5 | RSG-TRANS Amadi power station | Port Harcourt Rivers State | 100 | 24 |
| 6 | RSG-Omoku Power Station | Omoku Rivers State | 150 | 30 |
| | | **Total** | **1,759** | **1,484** |

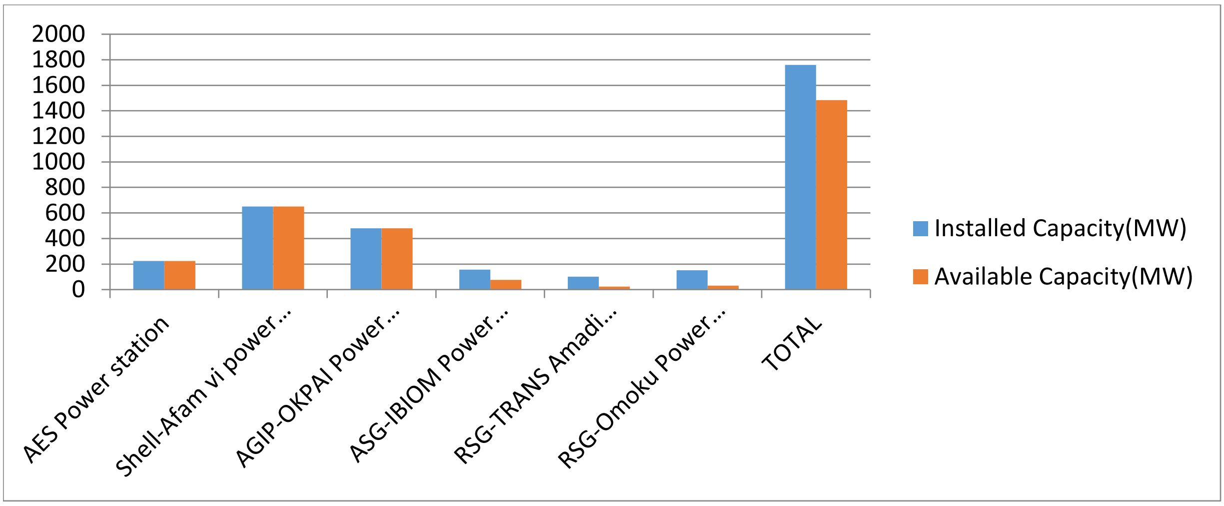



Figure 3: Independent Power Plants in Nigeria

## DELAYS AND SOCIO-ECONOMIC FACTORS IN THE IMPLEMENTATION OF THE NIPPS AND IPPS

The funding plan for the NIPP was to source a foreign loan and afterward sell 80% stake of the completed power plants to private investors who will operate them efficiently and profitably, in order to recover the investment. About 2.5 Billion USD was approved in 2005 to fund the projects from the excess crude account, and by 2007, about 2.8 billion USD had been spent on advance payments. Following a change in government in 2008, funding for the project was interrupted for a period of two years, as the new administration subjected the project to rigorous legal, financial and political review. The power plants were originally estimated to cost about 200 million USD each (that is, 2 Billion USD for all the ten projects) and were planned to be completed by 2008. However, due to the various delays suffered by the projects, coupled with other socio-economic effects, the projects ended up costing over 8 Billion USD (NIPP, 2015); with only 4,774MW out of the planned 10,000MW being built.

The location of these power plants was originally planned to be strategically chosen in order to address the growing environmental impact of gas flaring in the Niger Delta region, which was fast becoming an urgent issue before the FGN due to climate change. Hence, the NIPPs were planned to be sited at various gas flaring points across the Niger Delta states, so that the flared gas would be re-directed to feed the new thermal power plants, thus reducing gas flaring in the region and promoting sustainable development. However, a close look at the location of the NIPPs today reveals that this plan got derailed because of the oil facilities and pipeline vandalization by indigenous militants seeking for amnesty, jobs and development of the rich oil Niger Delta region by the government. Thus, putting investors at risk with huge loss of capital. Another salient reason for the poor performance of the power project is that most of the plants were not sited in the gas flaring region as technically planned due to corruption, tribal and political sentiments in the government, where influential politicians would want to favour their regions. Thus, expensive gas pipelines have to be constructed in order to channel the flared gas from the rich oil Niger Delta region to a non-oil producing region where most of the NIPP plants are sited. In such case, the destruction of the gas pipeline would mean a total collapse of power in the network.

Another aspect of the NIPP plan includes the construction of extensive distribution and transmission facilities in order to provide robust evacuation channels for the anticipated power generation. Consequently, a 330kV switching station, 330/132kV and 132/33kV transmission stations and several 33/11kV injection substations, with associated transmission and distribution infrastructure have been built and commissioned, while others in this category are at various stages of completion.

The NIPPs were established in the same vein as the IPPs to curtail the electricity problems in the country. Table 5 (Independent system operator, 2016) and Figure 4 show the various NIPPs and their capacities, including the completed and yet to commission stations. The ten NIPPs have a total contribution of 5,455MW generation capacity to the grid as at 2015, and this value has dropped considerably in recent times below the expected electricity generation from the projects considering the amount of money that has been invested. This is due to the low crude oil production as a result of oil theft, vandalized infrastructures and global oil price drop. From Table 5, two NIPP stations are under construction while one station is yet to be commissioned. The Alaoji NIPP station has the highest capacity of 1,131 MW as shown in Figure 4.

Table 5: NIPPs in Nigeria (Independent system operator, 2016)

| S/N | NIPPs | CAPACITY (MW) | COMPLETION DATE |
|---|---|---|---|
| 1 | Alaoji Generation Company Nigeria Limited. | 1,131 | 504 MW Simple Gas Cycle Power Plant out of 1074 MW Commissioned in March 2013 |
| 2 | Benin Generation Company Nigeria Limited. | 508 | March 2013 |
| 3 | Calabar Generation Company Nigeria Limited. | 634 | March 2015 |
| 4 | Egbema Generation Company Nigeria Limited. | 381 | Under Construction |
| 5 | Gbarain Generation Company Nigeria Limited. | 254 | Commissioning |
| 6 | Geregu Generation Company Nigeria Limited. | 506 | May 2013 |
| 7 | Ogorode Generation Company Nigeria Limited. | 508 | August 2013 |
| 8 | Olorunsogo Generation Company Nigeria Limited. | 754 | February 2015 |
| 9 | Omoku Generation Company Nigeria Limited. | 265 | Under Construction |
| 10 | Omotosho Generation Company Nigeria Limited. | 513 | October 2013 |

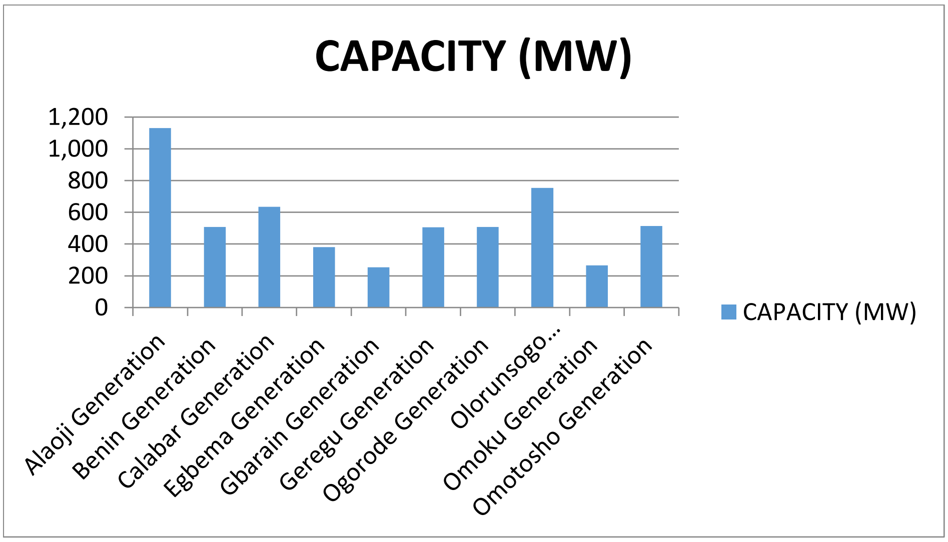



Figure 4: National Integrated Power Plants in Nigeria

## DESCRIPTION AND SITE LOCATION OF THE VARIOUS NIPP PLANTS IN NIGERIA

A brief description of the various NIPPs and their location based on sustainable development plans by the government of Nigeria is as follows (Momoh, 2013 and Income Electrix, 2015):

***Alaoji Power Station, Abia State***

The Alaoji Power Station was originally designed to be a 504MW simple cycle gas turbine power plant located in Alaoji, Abia state, Nigeria. It is composed of 4 Nos. 112.5MW gas turbines, and in order to increase its capacity, 2 Nos 255MW steam turbines were added under a combined cycle arrangement, bringing the total capacity to 1074MW (ISO). The simple cycle gas turbines were commissioned in March 2013 by President Goodluck Jonathan, but the steam turbines are still being installed. This power station is being fuelled by Total Nigeria, from the Obigbo gas plant via the Norten Option Gas Pipeline.

***Ihovbor Power Station, Edo State***

This NIPP power plant is located at Ihovbor near Benin City, Nigeria and it boosts 4 Nos. 112.5MW GE Frame 9E, simple cycle gas turbines which can be converted to combined-cycle gas turbines in the future. Out of the four power plants, only two of the gas turbines have been commissioned since May 2013 till date, producing 225MW of power to the grid when they are not faced with gas supply shortages from the Escravos-Lagos gas supply system.

***Calabar Power Station, Odukpani, Cross River State***

The Calabar power station NIPP is located at Odukpani in Cross River state, Nigeria. It is also a simple cycle gas turbine system of 5 Nos. 112.5MW GE Frame 9E gas turbines totalling 634.5MW, with provision for conversion into a combined cycle power plant at a later time. Only 112.5MW power generation was technically commissioned in March 2015 out of the total installed generation and the plant has been supplying electricity to the grid since that time. The other units are yet to come on stream. This power plant is being fed by Seven Energy International Limited from their Uquo gas processing facility in Akwa-Ibom State. The Contractor for this project was Marubeni Corporation.

***Egbema Power Station, Imo State***

This NIPP power plant is located at the Mmahu community of the Ohaji-Egbema local government area of Imo state, Nigeria. The Egbema power plant is a 380.7MW simple cycle gas turbine plant made up of 3 Nos. 112.5 MW GE Frame 9E turbines. This project is yet to come on stream as it is only 60% completed. Gas supply to this power plant is planned to come from the Gbarain-Ubie gas plant in Bayelsa State.

***Gbarain Power Station, Yenagoa, Bayelsa State***

The Gbarain-Ubie NIPP power plant is located in Yenagoa, Bayelsa state, Nigeria and has 2 Nos. GE Frame 9E turbines with a capacity of 112.5MW (126MW ISO) each. It is a simple cycle gas turbine power plant which can be expanded into a combined cycle power plant in the future. One of the turbines in this power plant was technically commissioned in May 2016 and is delivering 112.5MW to the national grid. Gas is being supplied to this power plant by Shell Petroleum Gbarain-

Ubie Integrated Gas Project. It is expected that this power plant will have no gas shortages while in operation due to its unique proximity to the source of gas in the oil-rich Niger Delta region of the country.

***Geregu II Power Station, Kogi State***

The Geregu II NIPP power station was built by Siemens AG of Germany. It is a 506.1MW power plant comprising 3 Nos. Siemens SGT5-2000E gas turbines operated in simple cycle mode. This power plant is located in Geregu community of Ajaokuta local government area of Kogi state, Nigeria. This is the only NIPP project that was completed on schedule. This project is located within the same area as the Geregu I power plant, which was also built by Siemens AG and has a similar configuration. Both Geregu I and Geregu II gas turbines are being fed from the Oben-Geregu pipeline which comes from Seplat Petroleum Oben gas processing plant in Orhionmwon local government area of Edo State. The Geregu power plant is currently generating an average of 289.4MW to the national grid when it is not being constrained by gas shortages. It was commissioned in May 2013 by President Goodluck Jonathan.

***Sapele Power Station, Delta State***

This NIPP power station is located at Ogorode in Sapele, Delta State, Nigeria. It is a simple cycle gas turbine system of 4 Nos. 112.5MW GE Frame 9E gas turbines totaling 507.6MW (ISO), with provision for a later conversion into a combined cycle power plant. About 112.5MW of electricity generation was built out of the total installed capacity by the Marubeni Corporation and commissioned in August 2013 by President Goodluck Jonathan. The power plant has been supplying electricity to the grid since that time, though the other units are yet to come on stream. This power plant is being fed by the Escravos-Lagos pipeline system operated by Chevron. The gas pipeline takes gas from the Escravos gas processing plant in Escravos, Delta State, which has a capacity of 680MMcf/day. The Escravos-Lagos pipeline system feeds the NIPP Ihovbor power plant, the NIPP Sapele power plant, the NIPP Omotosho II power plant, the NIPP Olorunshogo II power plant, the Warri refining and petrochemical company in Warri, the Delta power plant at Ughelli, the West African Portland Cement (WAPCO) plants in Shagamu and Ewekoro, among others. This pipeline accounts for 72% of the gas shortages being experienced by the NIPP power plants.

***Olorunshogo II Power Station, Ogun State***

The Olorunshogo Phase II power plant built by the NIPP is an extension of the Olorunshogo power plant at Papalanto in Ogun state, Nigeria. It is a 754MW combined cycle power plant comprised of 4 Nos. 112.5MW GE Frame 9E gas turbines, two GE steam turbines, two heat recovery steam generators and associated control system equipment. It was commissioned in February 2015 by President Goodluck Jonathan and currently contributes 506 MW to the national grid, when not constrained by gas shortages or high frequency. The gas supply for this station comes from the Escravos-Lagos pipeline system.

***Omoku II Power Station, Rivers State***

The Omoku II power station is also an extension of the Omoku power station built by the Rivers state government in Nigeria. This power plant site selection by NIPP was based on the expansion of its capacity by the installation of additional 2 Nos. GE Frame 9E gas turbines operated in simple cycle mode, with provision for the addition of a steam turbine when there is a need to convert the power plant to a combined cycle mode for increased electricity generation. Due to a number of factors, this power plant is still under construction and is yet to come on stream. Gas supply to the site is already available from the Agip (Obiafu-Obrikom (Ob-Ob) gas plant, which already powers the Omoku I gas turbines.

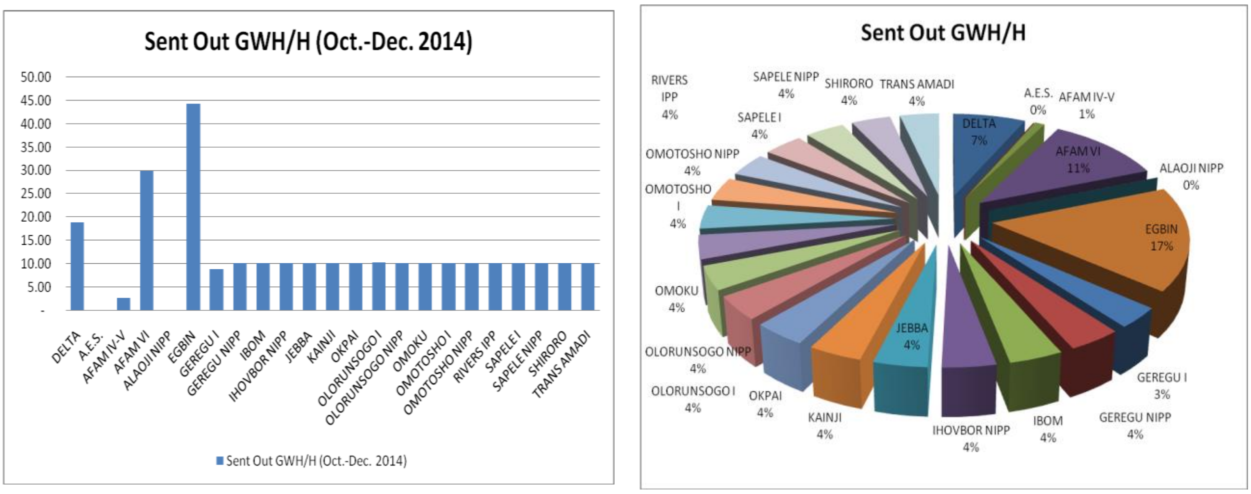
***Omotosho II Power Station, Okitipupa, Ondo State***

The Omotosho II power station is also an extension of the original Omotosho power station situated in Okitipupa local government area of Ondo state, Nigeria. This power plant is a 512.8MW power plant comprising 4 Nos GE Frame 9E gas turbines operated in simple cycle mode with the option of conversion into a combined cycle power plant by the addition of steam turbines. It was commissioned in October 2013 by President Goodluck Jonathan and currently delivers 335MW to the national grid when there are no gas supply shortages.

## PERFORMANCE EVALUATION OF THE IPP AND NIPP SCHEMES IN THE NIGERIAN GRID NETWORK

One of the benefits of the deregulation of the Nigerian ESI is the creation of an opportunity to share important information about the performance of the industry freely to the general public on a daily basis. One of such platforms is the Nigerian Electricity Supply Industry Statistics (NESIS, 2016), a website wholly devoted to providing detailed information on the status and performance of the power industry on a daily basis. This includes daily details on generation profile for every power plant connected to the national grid, the detailed load allocation of the generated power, number of partial system collapse and total system collapse, frequency and voltage profile of the system, available spinning reserve and frequency, as well as other briefings from October 2014 till date. This website provided most of the data on the performance of the NIPP power plants and these data were analyzed in this paper to ascertain whether the project objectives of the IPPs and NIPPs have been met or not.

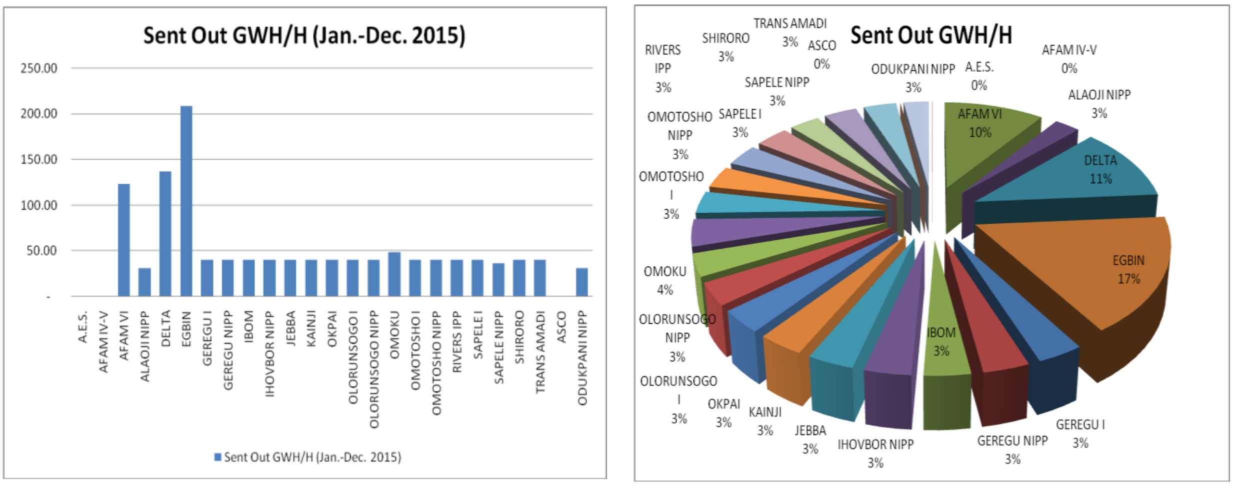
From Table 5, it could be observed that there was little or no impact of the NIPPs on electricity generation in the country until after March 2013, when the first power plant under the NIPP scheme was commissioned. Another constraint is that most of the commissioned plants are not working till date due to some political and economic reasons as earlier stated, hence, hindering the sustainable development of the nation. The analysis of this work is done for electricity generation from October 2014, when most of the plants came on stream to February 2017. Figure 5 shows the overall performance of all power stations in Nigeria from October to December 2014. The total power sent out within this period was 6,413.28 GWH




(a) (b)

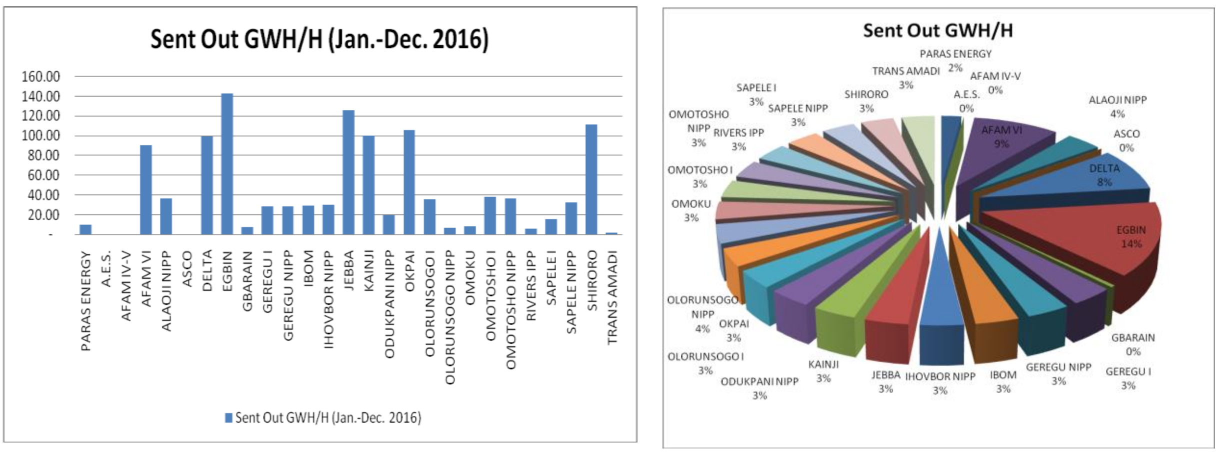
Figure 5: Performance of all power stations in Nigeria from October to December 2014

Figure 6 shows the overall performance of all power stations in Nigeria from January to December 2015. The total power sent out within this period was 28,639.20 GWH. Figure 7 shows the overall performance of all power stations in Nigeria from January to December 2016. The total power sent out within this period was 18,808.10 GWH. The performance of the power system for January to February 2017 is shown in Figure 8. It could be observed from these figures that the generated power drastically increased by 22,225.92 GWH between 2014 and 2015 due to the penetrations of the NIPP power plants when they were at their operational peak periods, however, due to gas shortages as a result of pipeline vandalization in the restive Niger Delta region, the power supply drastically dropped by 9,831.1 GWH. There were considerable improvements in the electricity generation of the country from 2014 through 2015, however, from 2015 through 2016, most of the IPP and NIPP plants fell short of supply due to militant activities in the oil rich region of the country and change in administration of the government. In order to investigate the effects of the penetration of the NIPP projects on the Nigerian electricity sector, Figures 9 to 12 give the percentage contribution of these projects to the entire electricity network system from October 2014 to February 2017.




(a) (b)

Figure 6: Performance of all power stations in Nigeria from January to December 2015




(a) (b)

Figure 7: Performance of all power stations in Nigeria from January to December 2016

In Figure 9, 19% of total electricity generated within the period was contributed by the 6 NIPP stations when they came on stream. The Egbin, Afam IV, and Delta power plants contributed 17%, 11% and 7% of the total electricity generated in this period respectively. The contribution of the NIPPs gradually grew from 19% to 21% with the addition of one NIPP station between January and December 2015 as shown in Figure 10. In this period, the Egbin power plant output remained the same, while there was a slight drop in power output from Afam IV and a considerable increase in power output from 7% to 11% for Delta power plant. Similar changes could be observed for other power plants within this period. The eight NIPP stations that were running in 2016 contributed 25% of total electricity within this period as shown in Figure 11, with a drop in electricity generation from Egbin, Afam IV, and Delta power stations which were the major thermal stations on the grid network. Figure 12 shows the contribution of the power plants for January and February, 2017, where it could be observed that the electricity production in the country has gone below expectation with a drastic fall in electricity supply compared to 2014 and 2015, when the power projects were at their peak operation. The drop in electricity output is mainly due to the destruction of gas pipeline, hence, leading to the shutdown of the new plants. The output of these NIPP stations would have been much better than the observed values if there were adequate gas supply to the areas where they are sited, as would be described in the subsequent figures on gas constraints.

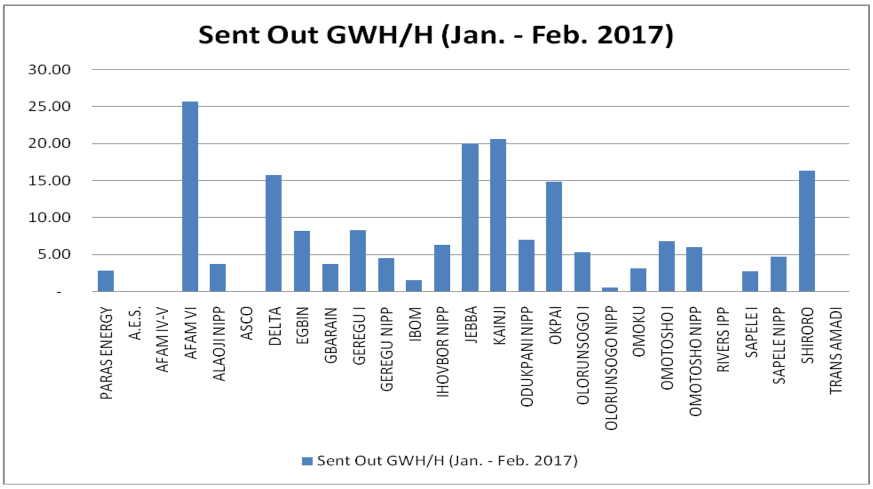
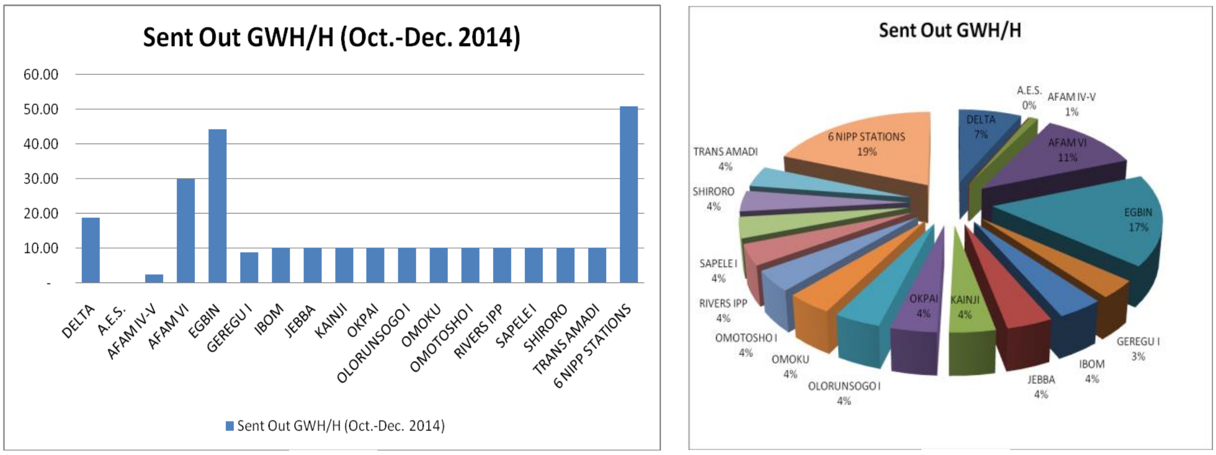
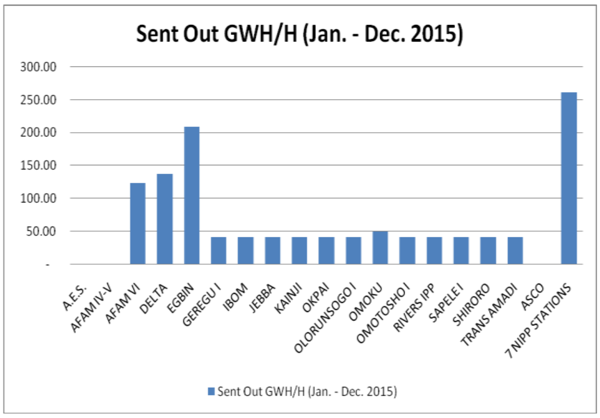



Figure 8: Performance of all power stations in Nigeria from January to February 2017




(a) (b)

Figure 9: Contribution of NIPP Stations to total Power Generated from October to December 2014




(a)

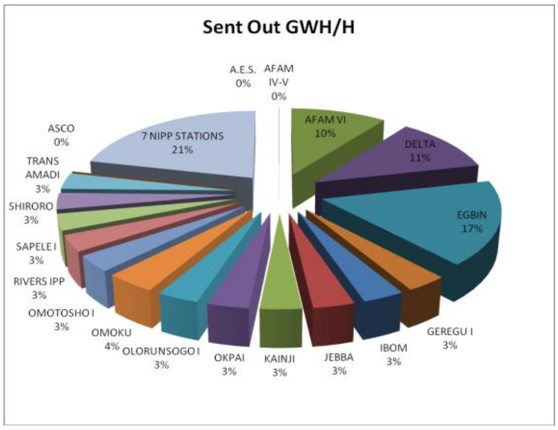



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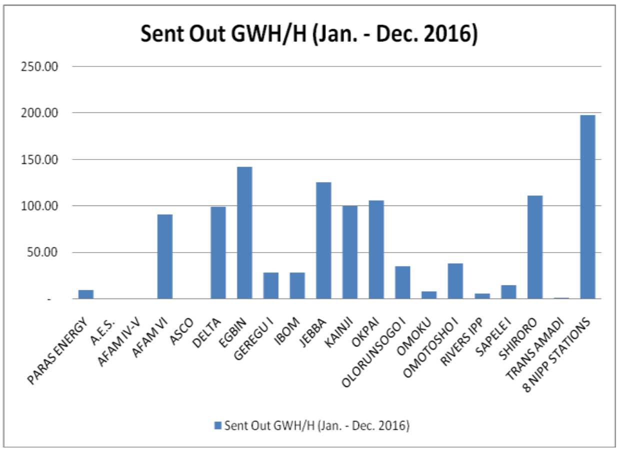
Figure 10: Contribution of NIPP Stations to total Power Generated from January to December 2015




(a)

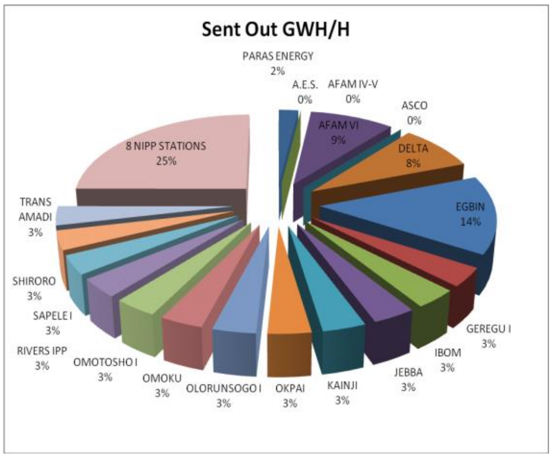



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Figure 11: Contribution of NIPP Stations to total Power Generated from January to December 2016

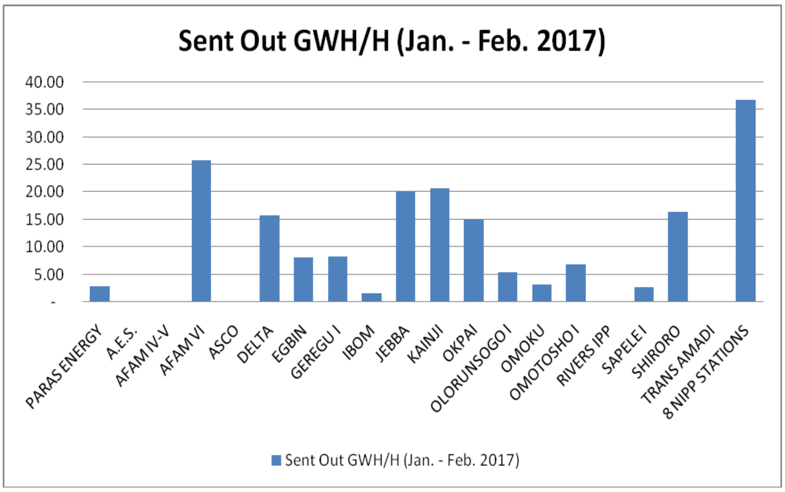
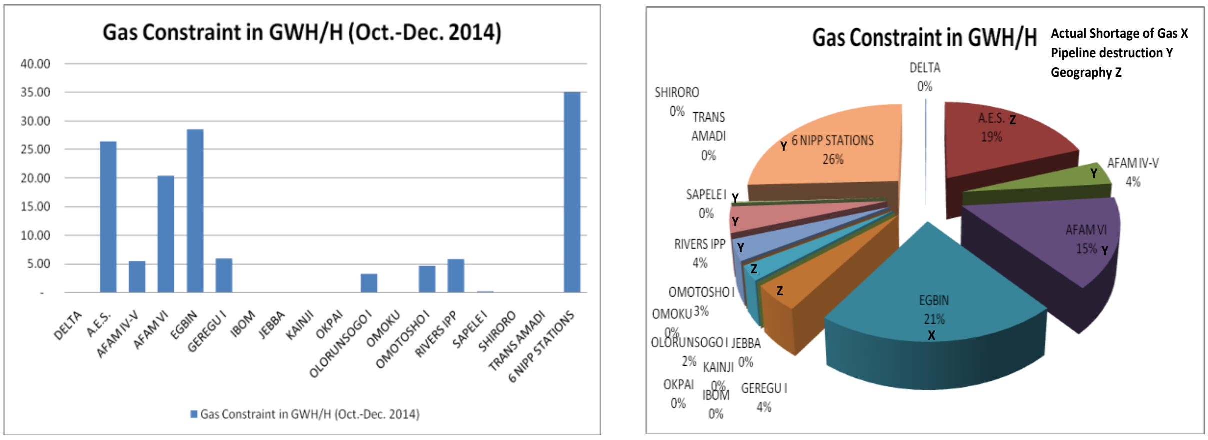



Figure 12: Contribution of NIPP Stations to total Power Generated from January to February 2017

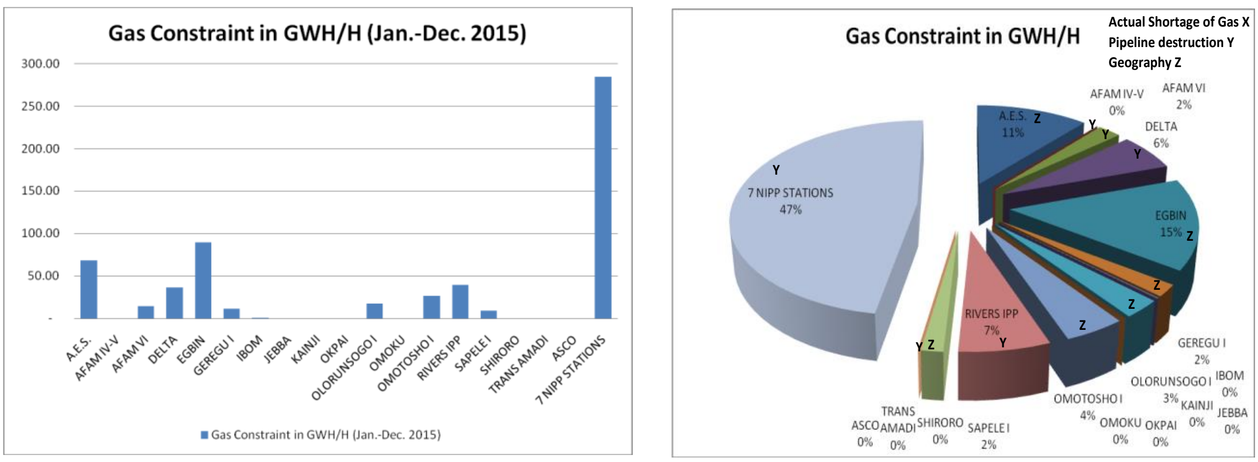
## REASONS FOR GAS CONSTRAINTS IN THE VARIOUS GENERATING PLANTS

Figures 13 to 16 show the major constraints of gas supply in implementing the NIPP projects for the period under consideration. The reasons for the gas constraints were either actual gas shortage (marked x) or pipeline destruction (marked y) and geography (marked z). The major reason for the gas constrained energy generation is pipeline destruction by militants in the oil rich Niger Delta region, where the gas flaring occurs, due to the FGN negligence in the development of the region. Consequently, this led to the shortage of gas in other plants that were not technically sited as planned in the gas flaring region, rather located far, thus, require pipelines to channel the flared gas to these plants. Also, the geographical location of some of these plants require some time and difficulties for the plants to have supply of the flared gas. From Figure 13, the 6 NIPP stations on stream from October to December 2014 accounted for 26% of the total constrained energy generation due to gas supply limitations. This resulted in a loss of 3,277.68 GWH. The Egbin plant suffered a gas constrained energy generation of 21%, while AES and Afam IV were 19% and 15% respectively. The 7 NIPP stations on the network from January to December 2015 as shown in Figure 14 accounted for 47% of the total constrained energy generation because of gas supply limitations. This accounted for a total constrained energy generation of 14,299.9 GWH within this period. The Egbin and AES power plants reduced to 15% and 11% respectively, while the Rivers IPP plant increased to 7%. In Figure 15, the 8 NIPP stations in the network from January to December 2016 had a combined constrained energy generation of 54% of the total constrained energy generation for that period because of gas supply shortages. The effect resulted in 17,815.40 GWH of the total constrained energy generation within this period. The Egbin power plant increased to 16%, while Afam VI and Omotosho were 6% each respectively. Figure 16 shows the generation gas constraint for January and February, 2017. The values in this figure are almost same for the previous year, showing no improvement in the system to curtail the problem of continuous gas constraints to the power plants.



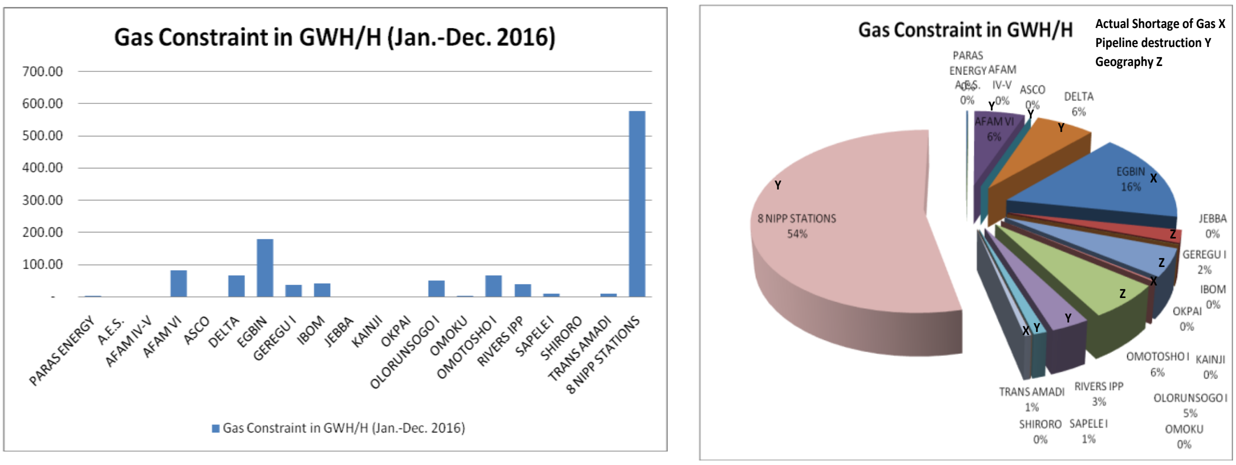

(a) (b)

Figure 13: Gas Constraints suffered by NIPP Stations Compared to the Other Generating Stations from October to December 2014.




(a) (b)

Figure 14: Gas Constraints suffered by NIPP Stations Compared to the Other Generating Stations from January to December 2015




(a) (b)

Figure 15: Gas Constraints suffered by NIPP Stations Compared to the Other Generating Stations from January to December 2016

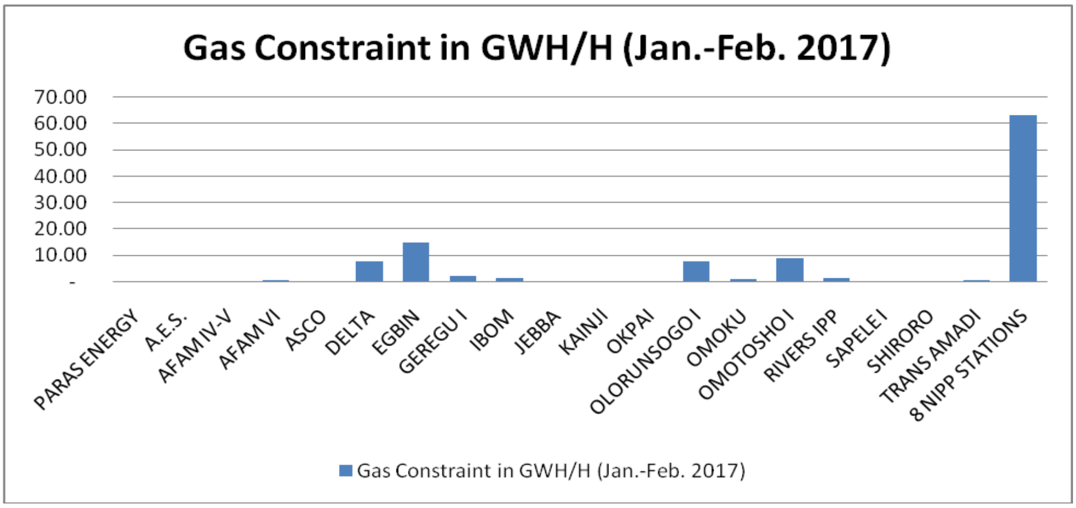



Figure 16: Gas Constraints suffered by NIPP Stations Compared to the Other Generating Stations from January to February 2017

The other constraints that affected the performance of the IPPs and NIPPs were line constraints and high-frequency constraints (NNIPP, 2016). Line constraints occur due to collapsed or faulty transmission lines linking the power plants and distribution stations. Frequency constraints is as a result of very high or low frequency in the grid network, leading to the shutdown or running on stream some of the power stations based on load schedules. However, gas supply shortage is the major factor hindering the sustainable development and realization of the main NIPP objective of increased electricity supply to the national grid for transmission and distribution to consumers.

**OPTIMAL UTILIZATION OF THE SUPPLY GAS TO IPP AND NIPP PROJECTS**

The deregularization of electricity sector in any country is expected to boost sustainable development, electricity supply and improve reliability of the system (Walid et al, 2017 and Kishomoto, 2017). The occurrence of gas supply shortage for the IPP and NIPP power plants was not anticipated by the FGN or the NDPHC at the conceptual stage of the power projects. As previously noted, a close examination of the current sites of all the power plants show that the original plan of building them close to gas flare points in order to utilize the abundant gas reserves was not followed. From section 10 and Table 5 of this work, it can be seen that none of the NIPP is utilizing gas that is harnessed from a known flare point and only a few were sited along existing gas pipeline routes. Therefore, the international issue of climate change, to reduce gas flaring has not been addressed properly. Also, a close look at the table and based on the site location of the various plants discussed in section 10, reveals that four of the NIPP plants (Ihovbor power station, Olorunshogo II power station, Omotosho II power station, and Sapele power station) all depend on the Escravos- Lagos gas pipeline system. This pipeline system alone accounts for 72% of total gas shortage experienced by the eight active NIPP stations. News reports (Nigerian Vanguard, 2015) indicate that this pipeline has been vandalized repeatedly and is a direct cause of the gas shortages being experienced by the other power plants. This indicates that the ultimate choice of location of the NIPP plants was not motivated by technical considerations, as should have been the case if the original intentions of the NIPP were maintained.

## EFFECTS OF DEREGULATION OF NIGERIAN ELECTRICITY SECTOR

Unfortunately, the Nigerian electricity sector has been deregulated for over three years, however, the positive impact of the reform for sustainable development has not be felt. Some of the opportunities and challenges are discussed below.

### Opportunities

#### *Enhanced generation capacity to the grid*

Since the NERC was licensed more power in the range of over 20,000 MW is expected to be fed into the grid. Though this has not been achieved, however, there are considerable improvements in the power generated capacity under the deregulation reform. The Egbin thermal station, under the watch of the Sahara Power Group, has been contributing over 20% of the national grid power. The deregulation reform has also led to individual generations by investors and not considering political decisions.

#### *Easy access to information*

Another benefit of the deregulation reform is the easy access to information pertaining to the Nigerian grid system. The NERC recently launched a weekly energy watch that reports up to date operation of the Nigerian grid network.

Some of the other pros of the deregulation reform are:

- Efficient and reliable electricity supply
- Investment opportunities for both locals and foreigners
- Employment opportunities
- Technical skills improvement of the citizens by foreign experts
- Low electricity tariff due to strong market force
- Accountability of the performance of the various private firms.

## Challenges

### *Competition*

The deregulation program was expected to bring competition in the Nigerian electricity sector, unfortunately, this is not happening as seen from earlier data presented. This may be as a result of monopoly in each region, where the distribution companies are located. If new policies are established, it may help in encouraging competition in the electricity market.

### *Service Delivery*

The oil and gas industries still play a major role in the electricity industry, even though it has been deregulated. This is because most of the new power plants are thermal based. It was reported that gas supply shortage since December 2015 till date, has led to suppressed power generation of over 2,000MW capacity. Other major constraints in this vein are the lack of electricity bills that have been paid by consumers, vandalization of infrastructure (pipeline destruction). If the new management of the distribution companies could invest more in providing damaged infrastructures and installing pre-paid metering meters, then more revenues may be collected from consumers.

### *Increased rate of employment*

One of the major cons affecting the Nigerian society as a result of the deregulation program is the laying off of former PHCN government staff without appropriate settlements and benefits. This has increased the unemployment rate of the country because the private investors are interested in only a few staff in order to maximize profit.

### *High tariffs*

It was forecasted that competitive electricity market would be one of the aftermaths of the deregulation process, however, NERC is in charge of the multi-year tariffs order till date, thus discouraging competition among the distribution companies.

### *Weak support by unions to consumers*

Due to the deregulation of the Nigerian electricity sector, the private investors can easily increase tariffs without the intervention of the national labour unions to fight for them. This would leave the consumers at no choice since it is not a government body.

## CONCLUSION AND RECOMMENDATIONS

One of the salient reasons for the establishment of the Independent Power Producers (IPPs) and the National Integrated Power Projects (NIPPs) in Nigeria was to contribute about 4,700MW of daily electricity generation to the national grid network using natural gas as fuel, in order to reduce gas flaring in the Niger Delta region. Recent energy reports show that these power projects have only added an average of about 612MW of daily generation to the electricity grid, as against the 5,000MW originally conceived. About 1,362MW power is constrained daily because of gas supply shortages, while the delay in completion and commissioning of some of the generating units has led to another 1,469MW of constrained power capacity.

It is recommended that the Federal Government of Nigeria set up committees to address the incessant oil and gas facilities vandalization by militants in the oil-rich Niger Delta region which host the gas pipelines, in order to improve gas availability to these IPP and NIPP power stations as well as other grid-connected existing power stations. Besides, the management and caretakers of the IPPs and NIPPs should take measures to fast track the completion and commissioning of the Egbema and Omoku power stations as well as the second phase of the Alaoji power station, so that the huge financial investment made will be justified. It is further recommended that the Federal Government of Nigeria should adopt industry best practices for the siting of future power plants in order to guarantee the optimal and profitable performance of the facilities.

Also, the following recommendations could help address some of these problems in a bid to achieve sustainable development, improve the electricity supply situation in the country and justify reasons for the deregulation reform:

- Providing a conducive and safe environment for private investors willing to go into the electricity business in the country.
- Eliminate corruption from the Nigerian Electricity Regulatory Commission body so that it could carry out its functions independently.
- Educating consumers on how to effectively manage produced electricity in the national grid network, by for instance, the use of energy saving bulbs and other measures.
- Design and implementation of new pricing strategies to support load management and minimize energy consumption.
- Encouraging demand side management by an appropriate billing system.
- Improving the technical know-how of local engineers by actively participating in planning and implementation of projects in the network.
- Providing security to avoid vandalization of the network facilities.

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