Electricity Generation and Distribution in Nigeria: Technical Issues and Solutions

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ABSTRACT

This paper attempts to address the problem of extreme electricity shortage in Nigeria. This deficiency is multidimensional which are attributed to inadequate infrastructure, inadequate funding of this sector, and energy losses from generation to billing. Some technical issues were raised and solutions proffered taking the Awka business unit of Power Holding Company of Nigeria, (PHCN) as a case. It was suggested that the actual load demand of the PHCN Awka business unit which at present is 135.12MVA be increased to 150MVA by building new substations to accommodate this proposed new load demand. This new distribution system should be able to handle the present need of the Awka Business Unit of 135.12MVA with a margin capacity of 14.88MVA for future expansion. This when fully implemented will ensure constant and adequate power supply in Awka and its environs.

Keywords: **Electricity, Sub Stations, Power, Distribution, Generation, Load Demand.**

1.0 INTRODUCTION

The Electric Power Sector is one of the most important sectors to national development. The power sector is critical to the developmental reform of any country. To discuss the electric power sector in Nigeria in a realistic way, an appraisal of its development since independence is necessary in this study.

Electricity supply in Nigeria dates back to 1886 when two small generating sets were installed to serve the then Colony of Lagos. By an Act of Parliament in 1951, the Electricity Corporation of Nigeria (ECN) was established, and in 1962, the Niger Dams Authority (NDA) was also established for the development of Hydro Electric Power. However, a merger of the two was made in 1972 to form the National Electric power Authority (NEPA), which as a result of unbundling and the power reform process, was renamed Power holding Company of Nigeria (PHCN) in 2005 [1], [2].

The Nigerian power sector is controlled by state-owned Power Holding Company of Nigeria (PHCN), formerly known as the National Electric Power Authority (NEPA). In March 2005, President Olusegun Obasanjo signed the Power Sector Reform Bill into law, enabling private companies to participate in electricity generation, transmission, and distribution.

The government has separated PHCN into eleven distribution firms, six generating companies, and a transmission company, all of which will be privatized soon.

For many years in Nigeria, the sector has been plagued by a plethora of problems. These problems included low generation capacity, poor distribution, decaying facilities and many others [3].

Many countries prior to reform have largely one state owned utility carrying out all the activities in that sector.

Considering all the efforts towards sustainability of power in Nigeria, from ECN to NEPA down to PHCN, many problems persisted against realizing the goal. Problems such as uncompleted target of power generation, insufficient equipment, substandard methods of transmission, poor zoning of distribution, low voltage supply, unauthorized connection and disconnection, corruption in the management, equipment vandalization and inefficient distribution planning remain the menace in accomplishing the aim of adequate power supply in Nigeria.

1.1 Distribution System

In the early days of electricity distribution, direct current (DC) generators were connected at loads at the same voltage. The generation, transmission and loads had to be of the same voltage because there was no way of changing DC voltage levels. Low DC voltages were used since that was a practical voltage for incandescent lamps, which were the primary electrical loads then.

The adoption of alternating current (AC) for electricity generation dramatically changed the situation. Power transformers, installed at power stations, could be used to raise the voltage from the generators, and transformers at local substations reduced it to supply loads. Increasing the voltage reduced the current in the transmission and distribution lines and hence the size of conductors and distribution losses. This made it more economical to distribute power over long distances.

Distribution network are typically of two types: radial network and interconnected network. A radial network leaves the station and passes through the network area with no normal connection to any other supply. This is a typical of long rural lines with isolated load areas. An interconnected network has multiple connections to other points of supply. These points of connection are normally open but allow various configurations by the operating utility by closing and opening switches. Operation of these switches may be by remote control from a control centre or by a lineman. The benefit of the interconnected model is that in the event of a fault or required maintenance, a small area of network can be isolated and the remainder kept on supply.

Generated power cannot all be utilized at the generating stations and its immediate environ. Therefore, it must be distributed at suitable voltage to points and consumers. Distribution involves primary and secondary transformation of high voltage to the standard medium and low voltage by the appropriate transforming equipment.

1.1.1 Primary Distribution System

These consist of high voltage (11 and 33KV) networks from primary and sub-primary substations. These substations are interconnected with high voltage transmission lines. In most cases, large industries consumers like cement factories, refineries, breweries, flour mills, steel rolling mills and so on take supply at primary distribution system with associated transformers, switchgears and breakers.

1.1.2 Secondary Distribution Systems

These consist of low voltage feeder networks from the secondary transformers that are constructed along main roads and streets. Service connections are made to individual consumers by service cables from these networks feeder lines. The various system of alternating current distribution for domestic consumers includes:

Single-phase 2-wire system
Single-phase 3-wire system
Three-phase 3-wire system
Three-phase 4-wire system

Of these, the single phase 2-wire and the three phase 4-wire system are the most widely used in Nigeria. The discussion so far, refers to alternating current distribution system. The direct current distribution, which is rarely used, has areas of application. Alternating current is usually converted into direct current by rotary converters. Direct current (DC) is supplied to substation bus bars and distributed locally by feeders, distributors and service lines. Usually DC is distributed by single phase 2-wire system at 230 volts and three-phase 3-wire at 460/230 volts.

2.0 METHODOLOGY

2.1 Solution Technique

The distribution system is an important part of the total electric supply system and provides the final link between a utility's bulk transmission system and its ultimate customers (consumers). It has been reported in many technical publications that over eighty percent of all customer interruptions occur due to failures in the distribution systems. The problem of distribution system planning consists of determining the optimum numbers and locations of the distribution substations and the optimum way of connecting the load nodes to these substations through the interconnection of feeders. Solving the exact problem by using classical optimization technique is not possible because of the combinatorial nature of the problem. The solution technique prescribed is clearly shown in an earlier article by the authors in [3].

3.0 RESULTS

3.1 Load Demand Curve

It is first necessary to find out the load requirement of the area where electricity is to be distributed. This depends on the nature of the area, the population of the town or village under consideration, the density of the population of the town or village the population, the standard of living of the people in the locality industrial development in the area and the cost of electric power [4]. Load curve is a plot showing the variation of load with respect to time. Load curve of a locality indicates cyclic variation. Load curves are useful for both generation and distribution planning and enable station engineers to study the pattern of variation of demand. Load curves help to select size and number of distribution units and to create operating schedule of the distribution network.

Yearly load curve shows load variation during the year which is derived from monthly load curves of a particular year. For our study, load curve for 2008, 2009 and 2010 were considered. Table 1 shows the value of average monthly load demand for Awka Business units for 2008, 2009 and some part of 2010.

Table 1: Average Monthly Load Demand

Month	Average monthly load Mw)		
	2008	2009	2010
January	7.00	14. 15	14.34
February	8.20	10.80	11.98
March	8.30	12.00	8.99
April	8.30	11.80	12.09
May	7.88	11.6	13. 03
June	7.73	12.30	13.90
July	7.33	12.50	12.56
August	14.60	13.60	9.08
September	14.17	13.13	12.40
October	8.90	13.80	11.99
November	8.90	14.10	-
December	13.50	14. 98	

Source: *PHCN Awka Business Unit*

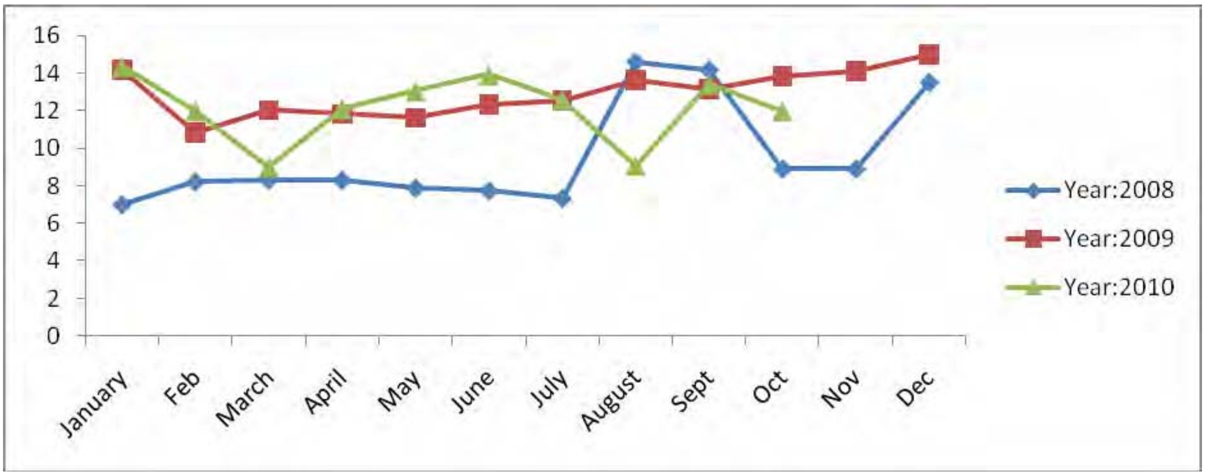

Figure 1: Load Demand Curve for the years 2008 to 2010.

3.2 Load Factor

Load factor is an indicator of how steady an electrical load is over time. The load can be seen as the ratio of the energy consumed during a given period to the energy which would have been raised if the maximum demand had been maintained throughout that period [4].

$$Load\ factor = \frac{Average\ load}{Maximum\ load} \qquad (1)$$

In the electricity industry, load factor is a measure of the output a power system compared to the maximum out put it could produce. A power system may be less efficient at low load factors. A high load factor means fixed costs are spread over more megawatts hour of output. A high load factor means greater total output. Therefore, a higher load factor usually means more output and a lower cost per unit.

The load factor is a per unit value which is considered to be that point on a feeder having distributed loading where the total feeder load can be assumed to be concentrated for the purpose of I^2R loss calculations. The loss factor is the ratio of the average power loss over a year period to the peak loss occurring in that period. This can also be defined as the ratio of the actual total megawatts hour losses to what the megawatts hour losses would have been if the peak losses had continued throughout the 8760 hours in the year. The loss factor is the annual power loss divided by the annual peak which is approximated by the following relationship [5].

$$L_{sf} = 0.3l_f + 0.7l_f^2 \quad (2)$$

Where l_f is the load factor

Tables 2- 4 represents the average monthly load demands, maximum load demands and load factors for a period of three years for Awka Business Unit (Power Holding Company of Nigerian)

Table 2: Load factor for 2008

Month	Average Monthly Load (MW)	Maximum Load Demand (MW)	Load Factor
January	7.00	31.00	0.23
February	8.20	32.00	0.26
March	8.30	39.00	0.21
April	8.30	30.00	0.28
May	7.88	32.00	0.25
June	7.73	37.00	0.21
July	7.33	30.00	0.24
August	14.60	32.00	0.46
September	14.17	35.00	0.14
November	8.90	38.00	0.23
December	13.50	36.00	0.38

Source: *PHCN AWKA BUSINESS UNIT*

Table 3: Load factor for 2009

Month	Average monthly load (Mw)	Maximum factor Demand (Mw)	Load factor
January	14.15	39.50	0.36
February	10.8	42.30	0.26
March	12	43.20	0.28
April	11.8	43.00	0.27
May	11.6	45.00	0.26
June	12.3	47.00	0.26
July	12.5	46.00	0.27
Aug	13.6	46.00	0.27
September	13.13	45.00	0.29
October	13.8	45.00	0.31
November	14.1	46.00	0.31
December	14.98	47.00	0.32

Source: *PHCN AWKA BUSINESS UNIT*

Table 4: Load Factor For 2010

Month	Average monthly load (Mw)	Maximum factor Demand (Mw)	Load factor
January	14.34	48.oo	0.30
February	11.98	48.00	0.25
March	8.99	47.00	0.19
April	12.09	50.00	0.24
May	13.03	50.00	0.26
June	13.09	80.00	0.16
July	12.56	50.00	0.25
Aug	9.08	49.00	0.19
September	13.40	50.00	0.27
October	11.99	60.00	0.20
November	-	-	-
December	-	-	-

Source: *PHCN AWKA BUSINESS UNIT*

4.0 DISCUSSIONS

Existing Substation and Load Demand Data

In Awka business unit, there is a transmission substation located at Nibo. The substation has two 30 MVA 132/33/KV transformer and two 15 MVA 33/11KV transformers. Fig.5 shows the station diagram for Nibo transmission substation.

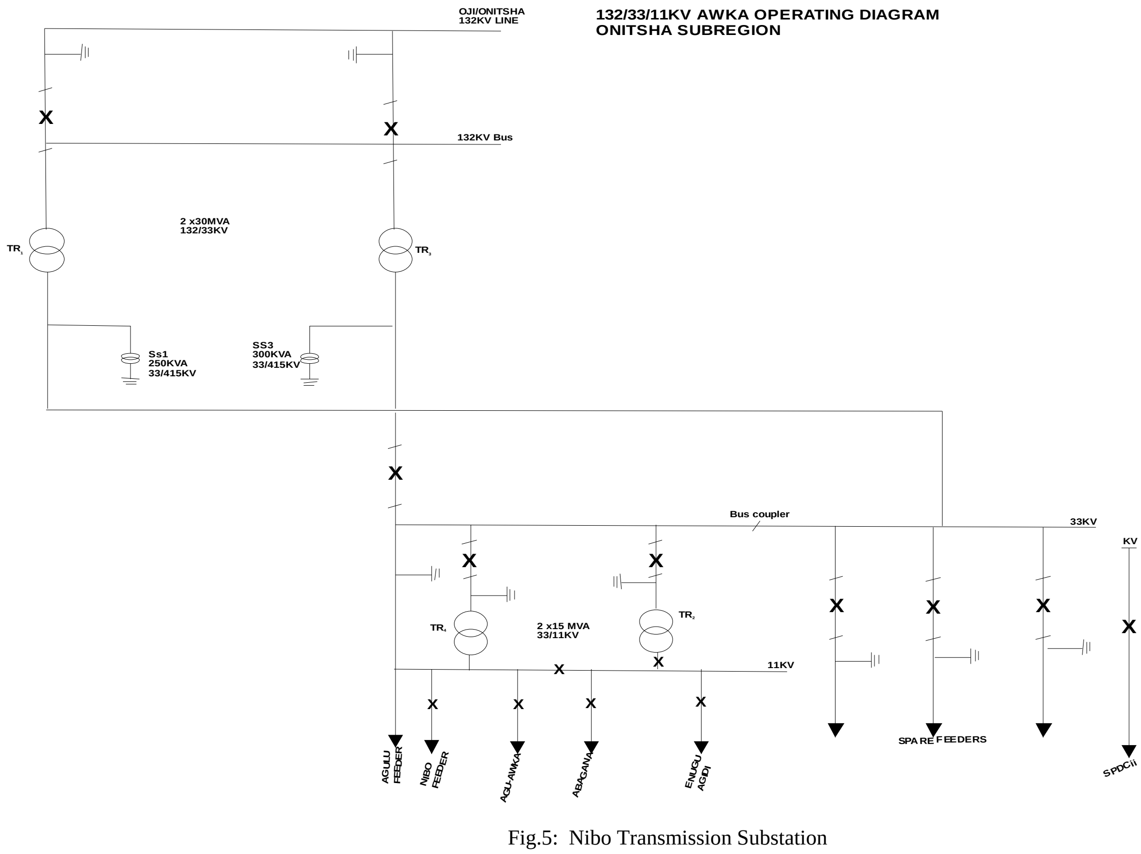

Fig.5: Nibo Transmission Substation

Source: *Nibo transmission substation, Awka.*

From the diagram, it can be seen that one 15 MVA 33/11KV transformer (TR4) supplies power to Nibo feeder and Agu Awka feeder and the other transformer (TR2) supplies power to Abagana and Enugu Agidi. The local demand at the various feeders and the route length of the feeders are presented in table 5.

Table 5: Existing load demand data

Feeder	**Route length (km)**	**Load capacity (MVA)**
Agu Awka	70.55	57.75
Abagana	65.75	29.17
Enugu Agidi	52.93	30.75
Nibo	36.44	14.48

Source: *PHCN Business Unit, Awka*

At full load capacity, each of the feeders carries about above 6MW of power. This power is not sufficient to get to the entire consumer on the feeder. In order to maintain safety and satisfy the consumers, the utility is forced to load shedding. This load shedding is not only disadvantageous to consumers as it put them off power supply but it causes the utility to incur outage cost. This outage cost results because consumers are not billed during the outage period, but the utility facilities run at full capacity.

Electricity distribution capacity has value, and there is a cost associated with the rental of space on the grid. In the event of peak demand for power, it contributes to congestion over the distribution grid. Congestion is an insufficient distribution capacity to supply all the demand on a grid. This condition could lead to grid failures such as blackouts.

The actual load demand of Awka Business Unit of PHCN is summarized in Table 7.

A proposed load distribution scheme is presented in Table 8

Table 7: Actual load demand data

Load Location	**Load Demand (MVA)**
Nibo Feeder	14.85
Agu Awka Feeder	57.75
Abagana Feeder	29.17
Enugu Agidi Feeder	30.75
Total	**135.12**

Table 8: Proposed load demand data

Load Location	**Load Demand (MVA)**
Nibo	30
Abagana	30
Enugu Agidi	30
Agu Awka	60
Total	**150**

Table 9: Proposed substation Data

Load Location	Maximum Capacity MVA
*Nibo	30
Agu Awka	120
Enugu Agidi	60
Abagana	60

* Nibo transmission substation is existing already.

5.0 CONCLUSIONS

To ensure sustainability and reliability of power supply, a new distribution network for Awka business unit is proposed. The new proposed network has four transmission substations including the existing substation at Nibo. The proposed Power distribution system is supposed to have a capacity of 150MVA (this means that a 120MVA 33/11 KV be built at Agu Awka, with distribution substations of 30MVA 11/.415 KV sited at both Enugwu Agidi and Abagana). This new distribution system should be able to handle the present need of the Awka Business Unit of 135.12MVA with a margin capacity of 14.88MVA for future expansion. This will ensure constant and adequate power supply in Awka and its environs. It will equally reduced power outages and thereby reduce the cost incurred by the utility as a result of outages. Therefore making power supply a profitable venture as the Federal Government concludes plans for the privatization of the power sector.

6.0 REFERENCES

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