

## GEOGRAPHICAL STRUCTURE OF THE NIGERIAN POWER SECTOR

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Article Information	ABSTRACT
<p>Received: 10<sup>th</sup> February, 2024</p> <p>Accepted: 22<sup>th</sup> February, 2024</p> <p>Published: 8<sup>th</sup> March, 2024</p> <p><b>KEYWORDS:</b> Geographical Structure, Power Sector, and Nigeria</p> <p><b>Publisher:</b> Empirical Studies and Communication - (A Research Center)</p> <p><b>Website:</b> <a href="http://www.cescd.com.ng">www.cescd.com.ng</a></p>	<p><i>The research main objective was to investigate the imbalance in the system due to increasing load demand surpassing supply. The research result is as follows; Table 4.1 shows that the south-south zone consist of total plant installed capacity of 5,879MW, total available capacity of 3,234MW and total grid load of 1,786.92MW. Table 4.2 shows that the south-east zone consist of total plant installed capacity of 504.4MW, total available capacity of 240MW and total grid load of 113.8MW. Table 4.3 shows that the south-west zone consist of total plant installed capacity of 2,724MW, total available capacity of 1,894MW and total grid load of 708.1MW. Table 4.4 shows that the north-west zone consist off total plant installed capacity of 1,938.4MW, total available capacity of 1,332MW and total grid load of 957MW. Table 4.5 shows that the north-central zone consist of; total plant installed capacity of 858MW, total available capacity of 858MW and total grid load of 414MW. Table 4.6 shows that the north-east zone consist of total plant installed capacity of 0MW, total available capacity of 0MW and total grid load of 0MW.</i></p>

### 1.1 INTRODUCTION

It is worth knowing that only 12 states, at of the 36 states in Nigeria and Federal Capital Territory, Abuja, generate the entire power utilized in the country. The geographical spread of Nigeria electricity generation sources is basically located in the South with the exception of Niger and Kogi states, which host three hydro power Gencos. Having the country's energy concentrated in one region consequently increases transmission and distribution cost with addition of lower supply to the required demand to serve the entire country. It is worth knowing that every region in Nigeria possess sources of electricity that could be exploited, but these potentials are not being maximized.

This research is to basically to expose our laxity in exploiting the available energy sources across every region in Nigeria that would be of immense benefit to Nigeria to expand its

energy supply mix. It is imperative to eminently initiate regulations that would facilitate investment in the various energy sources in the country across all region.

Also, utilizing the different clean and reliable renewable energy sources will be a great value in enhancing and increasing generation in the country thereby decentralizing its energy generation and supplies to meet up demand. The abundant sun energy in the North is wasting without being exploited. There are hydro potentials in both the North and South of Nigeria; there is also potentials for wind. Generating electricity through all the various energy sources across the country will Significantly decentralize electricity generation and distribution across Nigeria to boost and complement the grid power supply. If utilized, our clean energy resources and potentials are enough to meet and surpass our power demand and reach even more of the most remote communities in states and regions across Nigeria.

## 2.1 Review of Related Works

Numerous research studies of geographical structure of the Nigerian power sector have been carried out by different scholars in past years but because of the continued increase in demand surpassing supply by miles has open more research on the power sector in order to mitigate and narrow down the demand and supply.

Olakunle A., & Kehinde A. (2018). They worked on an overview of the Nigerian power sector, the challenges of its National Grid and Off-Grid development as a proposed solution. They found out that Nigeria can increase its electrification rate through the provision of off-grid energy services to rural households and businesses using the country's abundant renewable energy resource potential. This paper analyses the current electrification rates in the different geopolitical zones of Nigeria and proposes the application of off-grid solar PV in the North of Nigeria as the quickest way to increase electricity access in the country. Likewise, this paper then examines relative successes of rural electrification programs in Kenya, Peru and Chile and applies the lessons learnt from these countries to provide recommendations to accelerate the pace of rural electrification through off-grid development.

Oladimeji A., al et. (2019). They worked on Nigeria electricity power supply system: The Past, Present and the Future. They found out that electric power system in Nigeria has undergone a lot of transformation both in its physical structure and organization. From a small generating station, it has metamorphosed into its present form of 16 generating stations, a transmission company and 11 distributed companies. Considering its present state and the need to harness the abundant renewable energy resources in the country, it is envisioned that the transformation will continue into the future to meet the ever increasing load demand of Nigerians. The survey revealed that with the right policies in place private sector participation will be encouraged, leading to the rapid development of the Power Sector.

## 2.2 Overview of Nigerian Power System

Nigeria electricity supply started in 1896 during the erstwhile Colony era in Lagos when two small (60KW) generating sets were installed for their use. In 1978, an imbalanced between electricity generation capacity and load demand emerged, thereby causing power outage occurrence frequently. In view of this, the establishment of the Niger Dams Authority (NDA) was set up through its scheme, the construction of three hydro and three thermal generating plants was done. Nigeria population grew to 73.7 million in 1980 but was lacking available power growth pegged at 783MW. Available power was later increase to 1273MW in the year 1988 and subsequently, total available increase to 3,000MW in year 1992 with her population rose to 80 million. In 2001, because of poor maintenance culture, the existing generating plants were already depreciating and this dropped the available generated power. In order to

combat the depreciating available generated power and power shortage challenges, the Independent power producers (IPPs) and National Integrated Power Projects (NIPP) were established. Nigeria was only able to account for approximately 6,861MW of installed electric generating capacitor as at 2005. (Oladimeji, *et al.*, 2019)

The unbundling resulted in 6 generating companies and IPP which are jointly referred to as Gencos. With average available capacity of 3736.55MW in 2005 and a total PHCN installed capacities of 6656.40MW having a percentage availability of 56.13%. The total PHCN installed generating capacities was increased in 2009 to 9,914.4MW while IPPs ( Okpai, Afam and Omoku power plants) contributed 1,115MW. The total generating power installed capacities was still at 8,876MW in 2014 while the available capacity at 3,795MW. Thus, load shedding resulted due to the increasing power generation deficit. (Oladimeji, *et al.*, 2019)

In 2016, there were available seventeen functional grid connected generating plant in Nigeria, eight (8) owned by federal government with a total installed generating capacity of 6,256MW with 2,484MW available capacity, while NIPP and IPP jointly owned nine (9) with a total generating installed capacity of 2,809MW with an available capacity of 1,336.5MW. The Nigerian thermal generating plant contributes up to 83% (4116MW) of the total available generation capacity. But then, as at that 2016, the total generating installed capacity was 10,396MW while total available power was 4,959. (Oladimeji, *et al.*, 2019)

Table 2.1 shows the high difference between the load demand and actual electricity supply. Using 2014 and 2016 as a reference point where the difference between the load demand and load supply were 21,639MW and 23,401MW respectively, courtesy of population growth without corresponding load supply growth representing about 15% and 17% of power availability. (Oladimeji, *et al.*, 2019)

**Table 2.1: Nigeria Power Demand and Generated Power** (Source: Oladimeji, *et al.*, 2019)

Year	Population (Million)	Estimated Demand (MW)	Generated Power (MW0)	Available Power (MW)
1896	2.0	0.050	0.060	0.060
1980	73.7	5,085	2,240	783
1985	83.9	6,863	4,574	1,273
1990	95.6	8,291	4,960	2,400
2010	159.7	21,624	6,904	3,358
2014	165.0	25,434	8,876	3,795
2016	190.0	28,360	10,396	4,959

Presently, in 20 August 2020, there was a press release by the Transmission Company of Nigeria that the power sector recorded a new improved all time peak available load of 5,420.30MW which was effectively transmitted through the national grid at a frequency of 50.10Hz.(source: Transmission Company of Nigeria) while according to Nigeria energy sector released in 2020, Nigeria has a total installed generating capacity of 22 grid-connected generating plants in Nigeria is approximately 12,500MW, being largely dependent on both hydro power plant which account for about 15.7% with a total installed generating capacity of 1,967MW (3 Hydro plants) and fossil (gas) thermal power plants account for about 69.5% with a total installed generating capacity of 8,685MW (22 Gas Plants). Lack of maintenance and repairs reduced the installed capacity to 7,141MW available capacity while other issues such as gas constraint, water constraint, high frequency, line constraint and other constraint

reduced the available capacity to the peak available load of 5,420.30MW. (Source: Nigeria Energy Sector).

Base on updated and latest information gotten from generating companies and Transmission Company of Nigeria is presented below:

- (i) installed gross capacity of existing power plants is now about 13,000MW
  - (ii) About 1967MW giving 15.7% from Hydroelectric power plant (HYDRO)
  - (iii) About 8685MW giving 69.5% from gas-fires Gas Turbine Power plants
    - (a) 6749MW (77.7%) in Open Cycle Gas Turbine Plants (GT OC)
    - (b) 1936MW (22.3%) in Combined Cycle Gas Turbine Plants (GT CC)
  - (iv) About 1848MW giving 14.8% from conventional Steam Power Plants (STEAM)
- (Source: Nigeria Energy Sector)

Table 2.2 below depicts the existing Nigerian generation plants and status of availability.

**Table 2.2: Existing Nigerian Generation Plants and Status of Availability**

(Source: Transmission Company of Nigeria)

NCC No	Name of Station	Primary Energy Resource	Power Plant Type	Commercial Operation Date	No. of Units	Units Capacity (MW)	Units Capacity (MW)	Available Capacity (MW)	Infeed to Grid (MW)	Outage due to Gas Constraints (MW)	Outage due to Repair/Maintenance (MW)
1	Kainji-G7-10	Hydro	Hydro	1978	4	80	320	160	160		160
1	Kainji-G5-6	Hydro	Hydro	1968	2	120	240	240	154		
1	Kainji-G11-12	Hydro	Hydro	1976	2	100	200	100	100		100
2	Jebba	Hydro	Hydro	1983-88	6	96.4	578.4	482	336		96.4
3	Shiroro	Hydro	Hydro	1990	4	150	600	450	207		150
4	Egbin	Gas	Steam	1985-1987	6	220	1320	880	437	220	220
5	Sapele	Gas	Steam GT OC	1978 1981	6 4	120 75	1020	120	50	300	600
6	Delta GT3-8	Gas	GT OC	1975	6	25	150	100	60	25	25
6	Delta GT9-14	Gas	GT OC	1978	6	25	150	120	80		25
6	Delta GT5-20	Gas	GT OC	1990	6	100	600	400	357	100	100
7	Afam GT13-18	Gas	GT OC	1982	6	75	450	150	80		300
7	Afam GT19-20	Gas	GT OC	2002	2	138	276				276
7	Afam ST1 GT13-E2	Steam Gas	GT OC	2005 2008	1 3	200 150	650	650	215		
8	Geregu FGN 1	Gas	GT OC	2007	3	138	414	414	300		
8	Geregu NIPP 1	Gas	GT OC	2013	3	148	444	148	96		
9	Omotosho 1	Gas	GT OC	2007	8	42	335				335

9	Omotosho 11	Gas	GT OC	2012	4	125	500	480	100.1		
10	Alaoji-NIPP	Gas	GT OC	2013-14	4	126.1	504.4	240	113.80	120	120
11	Olorunsogo 1	Gas	GT OC	2007	8	42	335	126	90		210
11	Olorunsogo 11	Gas Steam	GT CC	2011 20012	4 2	125	750			750	
12	Calabar/Odukpani	Gas	GT OC	2015	5	113	565	226	116		339
13	IHOVBOR (Eyaen)	Gas	GT OC	2013-14	4	113	452	225	8	225	113
14	Okpai IPP	Gas Steam	GT CC	2005	2 1	150	450	300	294		150
15	Ibom 1	Gas	GT OC	2009	1	42	42				42
15	Ibom 1	Gas	GT OC	2016	1	40	40	40	4.42		
15	Ibom 1	Gas	GT OC	2010	1	114	114	114			
16	Ebute Barge	Gas	GT OC	2002	9	30	270				270
17	Omoku IPP	Gas	GT OC	2006	6	25	150	75	51		75
18	Trans-Amadi IPP	Gas	GT OC	2002 2009	3 4	12 25	136	75	42.5		62
19	Rivers IPP	Gas	GT OC	2012	1	180	180	180	153		
20	Gbarain GT2 NIPP	Gas	GT OC	2016	1	113	113	113			
21	Paras Energy	Gas	GT OC		6	9	54	45	45	9	
22	Azura-Edo IPP	Gas	GT OC	2018	3	153	459	459	284		
<b>TOTAL</b>						<b>12,861.8</b>	<b>7,037</b>	<b>3,937.82</b>	<b>1,505</b>	<b>4397.8</b>	

Table 2.2 reveals a detailed existing Nigerian generation plants and status of availability inclusive of unplanned/planned outages for maintenance or others reasons. From the information given in table 2.2, it shows that:

- (i) 7953MW giving 63.6% of the total installed capacity is shown as being available
- (ii) About 3850MW giving 30.8% of the total installed capacitor or 48.4% of the available could be utilized for the purpose of power evacuation
- (iii) About 3674MW giving 29.4% of the total installed capacity was out for maintenance/repair (long term as well as short term)
- (iv) About 3708MW giving 29.7% of the total installed capacity was not available due to gas constraints/vandalism.
- (v) About 1267MW giving 1267 MW giving 10.1% of the total installed capacity were out or reduced infeed capacity for other reasons.

(Source: Transmission Company of Nigeria)

### 3.1 Materials and Method

Method applied in carrying out the research is investigation of the Nigerian electricity generation sector and energy sources available across the geographical regions in Nigeria. The geographical impact of every region was utmost importance to ascertain the utilization of all available energy sources across the country.

The materials used include:

- (i) Generating station data sought from the following generating stations via transmission company of Nigeria:  
Shiroro G/S, Afam G/S, Egbin G/S, Sapele G/S, Delta G/S, Alaoji G/S, Kainji G/S, Omotosho G/S, Odukpani G/S (Calabar), Jebba G/S, Okpai G/S, Olorunsogo G/S, Ihovbor G/S and Geregu G/S.
- (ii) Nigerian 330kV grid network diagram.
- (iii) Microsoft Excel

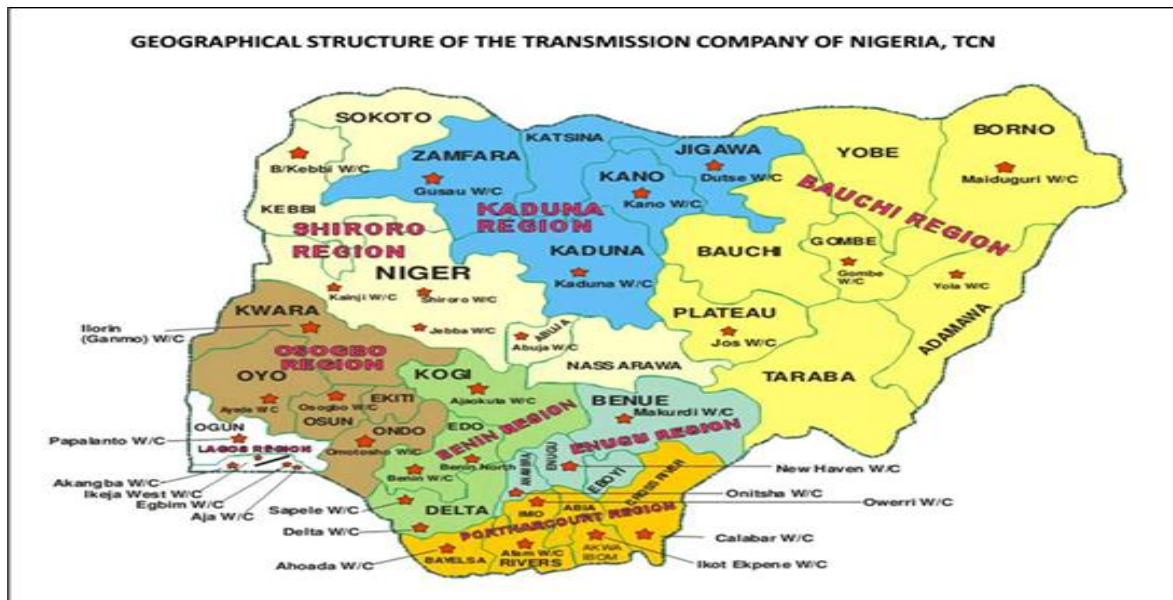
### 3.2 Data Collection

The data utilized in this research were collected from Transmission Company of Nigerian (TCN). Also, oral interaction and site visitation with senior engineers from Transmission Company of Nigerian (TCN). The data comprises of existing Nigerian generation plants and status of availability.

### 3.3 Geographical Structure of the Nigerian Power Sector

There is an imbalance in the system due to generation mainly concentrated in the southern part of the country (Thermal stations in Port Harcourt, Delta, Enugu, Benin and Lagos) and Central west (hydro stations of Jebba, Kainji and Shiroro region). While there is a total absence of generating stations in the Central North, North East, though the load demand is mainly in South and South West. Long 330KV transmission lines are built (radial system) for the sole purpose of supplying load to little or no generating zones such as North East thereby leading to voltage regulation problems with excessive reactive power flowing through these lines which requires large reactive power compensation equipment (reactors) at the corresponding stations (Kano, Gombe, Maiduguri). Also additional compensation equipment at Yola, Jalingo, and other substations necessitated because of aggravated overvoltage issues resulting from additional 330KV lines running in parallel. (Source: Transmission Company of Nigeria, 2017).

Figure 2.1 depicts the Geographical structure of the transmission company of Nigeria



**Figure 2.1: Geographical structure of the transmission company of Nigeria**  
(Source: Transmission Company of Nigeria)

Nigeria is divided into 6 geopolitical zones as shown in Figure 2.1 comprising of; South-South, South-East, South-West, North-West, North-East and North-Central. The tables below depict the total plant capacity, total available capacity, total grid load and voltage magnitudes of each zone.

#### 4.0 Result and Discussions

##### 4.1 Result

The geographical structure of the Nigerian generating company is listed in tables below.

**Table 4.1: Generating Stations in South-South and Voltage Magnitude**

(Source: Transmission Company of Nigeria)

S/N	Name of Station	Primary Energy Resources	Plant Capacity (MW)	Available Capacity (MW)	Infeed to Grid (MW)	Voltage Magnitude (KV)
1	Sapele G/S	Gas	1020	120	50	330
2	Delta G/S	Gas	900	620	497	330
3	Afam G/S	Gas	1376	800	295	330
4	Odukpani G/S	Gas	565	226	116	330
5	Ibom G/S	Gas	191	40	4.42	330
6	Ikot Ekpene Bus	-	-	-	-	324.72
7	Omoku IPP G/S	Gas	150	75	51	330
8	Transamadi IPP G/S	Gas	136	75	42.5	330

S/N	Name of Station	Primary Energy Resources	Plant Capacity (MW)	Available Capacity (MW)	Infeed to Grid (MW)	Voltage Magnitude (KV)
9	Azura-Edo G/S	Gas	459	459	284	330
10	Benin Bus	-	-	-	-	330
11	Okpai IPP G/S	Gas	450	300	294	330
		Steam				
12	Ihovbor	Gas	452	339		330
13	Rivers IPP G/S	Gas	180	180	153	330
14	Adiabor Bus	-	-	-	-	324.786
15	Aladja Bus	-	-	-	-	329.934
16	Asaba Bus	-	-	-	-	329.538
17	Benin Bus	-	-	-	-	329.868
18	Sakete Bus	-	-	-	-	327.69
<b>Total</b>			<b>5,879</b>	<b>3,234</b>	<b>1,786.92</b>	

Table 4.1 shows that the south-south zone consist of; total plant installed capacity of 5,879MW, total available capacity of 3,234MW and total grid load of 1,786.92MW with all the voltage buses within the statutory voltage stability limit of 313.5kV – 326.5kV.

**Table 4.2: Generating Station in South – East and Voltage Magnitude**

(Source: Transmission Company of Nigeria)

S/N	Name of Station	Primary Energy Resources	Plant Capacity (MW)	Available Capacity (MW)	Infeed to Grid (MW)	Voltage Magnitude (KV)
1	Alaoji G/S	Gas	504.4	240	113.8	325.116
2	Alaoji T/S Bus	-	-	-	-	325.116
3	New Heaven Bus	-	-	-	-	323.697
4	Onitsha Bus	-	-	-	-	329.505
5	Ugwaji Bus	-	-	-	-	323.697
<b>Total</b>			<b>504.4</b>	<b>240</b>	<b>113.8</b>	

Table 4.2 shows that the south-east zone consist of; total plant installed capacity of 504.4MW, total available capacity of 240MW and total grid load of 113.8MW with all the voltage buses within the statutory voltage stability limit of 313.5kV – 326.5kV.



**Table 2****4.3: Generating Stations in South – West and Voltage Magnitude**

(Source: Transmission Company of Nigeria)

S/N	Name of Station	Primary Energy Resources	Plant Capacity (MW)	Available Capacity (MW)	Infeed to Grid (MW)	Voltage Magnitude (KV)
1	Omotosho G/S	Gas	835	784	100.1	330
4	Ebute Barge G/S	Gas	270	-	-	-
5	Paras Energy G/S	Gas	132	45	45	300
6	Ayede Bus	-	-	-	-	328.812
7	Ikeja West Bus	-	-	-	-	328.977
8	Aja Bus	-	-	-	-	329.967
9	Akangba Bus	-	-	-	-	328.944
10	Alagbon Bus	-	-	-	-	329.868
11	Lekki Bus	-	-	-	-	329.967
12	Okearo Bus	-	-	-	-	329.142
13	Oshogbo Bus	-	-	-	-	328.845
<b>Total</b>			<b>2,724</b>	<b>1,894</b>	<b>708.1</b>	

Table 4.3 shows that the south-west zone consist of; total plant installed capacity of 2,724MW, total available capacity of 1,894MW and total grid load of 708.1MW with all the voltage buses within the statutory voltage stability limit of 313.5kV – 326.5kV.

**Table 4.4: Generating Stations in North – West and Voltage Magnitude**

(Source: Transmission Company of Nigeria)

S/N	Name of Station	Primary Energy Resources	Plant Capacity (MW)	Available Capacity (MW)	Infeed to Grid (MW)	Voltage Magnitude (KV)
1	Kainji G/S	Hydro	760	400	414	330
3	Shiroro G/S	Hydro	600	450	207	330
4	Birnin Kebbi	-	-	-	-	320.463
5	Jebba TS Bus	-	-	-	-	330
6	Kumbotso	-	-	-	-	323.07
7	Mando	-	-	-	-	327.591
<b>Total</b>			<b>1,938.4</b>	<b>1,332</b>	<b>957</b>	

Table 4.4 shows that the north-west zone consist of; total plant installed capacity of 1,938.4MW, total available capacity of 1,332MW and total grid load of 957MW with all the voltage buses within the statutory voltage stability limit of 313.5kV – 326.5kV.

**Table 4.5: Generating Stations in North – Central and Voltage Magnitude**

(Source: Transmission Company of Nigeria)

S/N	Name of Station	Primary Energy Resources	Plant Capacity (MW)	Available Capacity (MW)	Infeed to Grid (MW)	Voltage Magnitude (KV)
1	Geregu G/S	Gas	858	858	414	330
2	Ajakuta Bus	-	-	-	-	328.317
3	Gwagalada Bus	-	-	-	-	328.383
4	Jos Bus	-	-	-	-	313.566
5	Katampe Bus	-	-	-	-	328.383
6	Lokoja Bus	-	-	-	-	328.218
7	Markudi Bus	-	-	-	-	321.057
<b>Total</b>			<b>858</b>	<b>858</b>	<b>414</b>	

Table 4.5 shows that the north-central zone consist of; total plant installed capacity of 858MW, total available capacity of 858MW and total grid load of 414MW with Jos bus violating the statutory voltage stability limit of 313.5kV – 326.5kV.

**Table 4.6: Generating Stations in North – East and Voltage Magnitude**

(Source: Transmission Company of Nigeria)

S/N	Name of Station	Primary Energy Resources	Plant Capacity (MW)	Available Capacity (MW)	Infeed to Grid (MW)	Voltage Magnitude (KV)
1	Damaturu Bus	-	-	-	-	292.149
2	Ganmo Bus	-	-	-	-	328.977
3	Gombe Bus	-	-	-	-	327.36
4	Jalingo Bus	-	-	-	-	292.314
5	Maiduguri Bus	-	-	-	-	287.562
6	Yola Bus	-	-	-	-	293.568
<b>Total</b>			<b>0</b>	<b>0</b>	<b>0</b>	

Table 4.6 shows that the north-east zone consist of; total plant installed capacity of 0MW, total available capacity of 0MW and total grid load of 0MW with Damaturu bus, Jalingo bus, Maiduguri bus and Yola bus violating the statutory voltage stability limit of 313.5kV – 326.5kV.

## 5.1 Conclusion

The research main objective was to investigate the imbalance in the system due to generation mainly concentrated in the southern part of the country (Thermal stations in Port Harcourt, Delta, Enugu, Benin and Lagos) and Central west (hydro stations of Jebba, Kainji and Shiroro region). While there is a total absence of generating stations in the Central North, North East, though the load demand is mainly in South and South West. The conclusion of the research is listed below;

- (i) Table 4.1 shows that the south-south zone consist of; total plant installed capacity of 5,879MW, total available capacity of 3,234MW and total grid load of 1,786.92MW.
- (ii) Table 4.2 shows that the south-east zone consist of; total plant installed capacity of 504.4MW, total available capacity of 240MW and total grid load of 113.8MW.
- (iii) Table 4.3 shows that the south-west zone consist of; total plant installed capacity of 2,724MW, total available capacity of 1,894MW and total grid load of 708.1MW.
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- (v) Table 4.5 shows that the north-central zone consist of; total plant installed capacity of 858MW, total available capacity of 858MW and total grid load of 414MW.
- (vi) Table 4.6 shows that the north-east zone consist of; total plant installed capacity of 0MW, total available capacity of 0MW and total grid load of 0MW.

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