Electricity Demand Pattern and Supply Availability on Nigeria Grid System

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Abstract

This paper presents the analysis of electricity transmitted and demand on Nigeria's electricity grid system from the year 2018 to 2020 to give the present progress of the electricity system in Nigeria. The daily electricity generated and transmitted data, daily distribution companies (DISCOs) electricity demand and consumption data, and data of transmission lines connected to other neighbouring countries (international lines) within the year 2018 and 2020 were used for the analysis. Also, the extrapolation of the monthly energy of each of the data obtained was computed. The analysis was done and graphs and results obtained showed that daily average electricity day-ahead demand by DISCOs varied majorly between 3.5GW to 4GW with a corresponding increase above 4GW and the total daily day-ahead electricity demand by DISCOs varied majorly between 80GW and 90GW from 2018 to 2020. But despite this demand, the study showed that distribution companies did not at any time pick up to their declared load demand despite being the major electricity stakeholder in electricity delivery to consumers. Also, some generating station units were not generating to their capacity due to fault and gas constraints and some generating stations were connected to the grid without using free governor mode (control required for the generating units to respond to the state of electricity demand on the grid in real-time). The study recommends that the government should ensure proper monitoring and impose necessary sanctions if needs be on any electricity stakeholders and participants who violate the Nigeria Electricity Supply Market Rules for effective and the Nigeria grid code created for efficient power delivery. The government should, as a matter of urgency, start the expansion of her generating stations as well as developing new ones considering other sources for power generation such as wind and solar which are predominately abundant in the northern part of the country.

Keywords: *Electricity, Generation, Transmission, Distribution.*

1. Introduction

Electricity remains the prime mover for any economic and most especially technological growth of every country and it is imperatively needed to enhance the standard of living and class of human life. There are huge challenges regarding access to a reliable and good electricity supply for urban and rural communities in Nigeria. Moreover, this issue is well known in rural areas where only about 10% of the populace has access to good and stable electricity [1].

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According to World Energy Council, Nigeria is ranked 106th in the retrogression world energy assessment index, and about 42 % of the Nigerians have no access to electricity [2]. The current electricity supply in Nigeria is unreliable and seems to be made available in what may be described from the consumer's point of view as an epileptic manner with electricity demand far greater than the available supply and is irregular and not reliable [3]. This has made Nigeria suffer seriously in her economic, industrial, social, and human development and due to all these challenges, Nigeria is viewed as one of the poorest countries in the world despite the huge resources from crude oil export and the availability of different natural resources required for electricity generation in the country [4].

These problems have caused the nation's industrial and commercial establishments to operate below their required production capacity. Many have resulted in the use of diesel generators as an alternative source of power for smooth production thereby resulting in an increment in the cost of production and leading to a high cost of goods and services across the country [5].

This study aims to compare and analyze the daily electricity transmitted to Nigeria's grid by all connected generating stations with electricity demand and consumption by all electricity distribution companies of Nigeria coupled with the lines feeding neighbouring countries between the years 2018 and 2020 for better analysis and understanding of the current trend and quality of electricity wheeled and distributed across Nigeria. This is to determine the pattern and extent of differentials in electricity consumption on the country grid system. The outcome of this study is capable of enhancing proper analysis, planning, and development of the electricity infrastructure of Nigeria.

2. Literature review

Before the year 1999, the Power Industry in Nigeria witnessed low investment development in infrastructural development which later caused a drastic drop in electricity generation in 2001 with only 19 out of the 79 installed electricity generating stations in operation [6]. The work analyzed the energy demand projections using the Model for the Analysis of Energy Demand MAED considering the demography, socio-economy, and technology effect. While modelling Nigeria's energy case, four economic scenarios (Reference Scenario with 7% GDP Growth, High Growth Scenario with 10% GDP Growth, Optimistic Scenario I with 11.5% GDP Growth, and Optimistic Scenario with 13% GDP Growth) were developed. The result obtained from the electricity demand using the developed scenarios study is shown in Table 1. The study reported that the demand for the year 2005 was a suppressed demand, due to insufficient generation, and limitations in transmission and distribution facilities. The work affirmed that the suppressed demand was likely to not be in existence by 2010.

Table 1: Economic scenarios for energy demand analysis [6]

Scenario	2005	2010	2015	2020	2025	2030
Reference (7%)	5,746	15,730	28,360	50,820	77,450	119,200
High Growth (10%)	5,746	15,920	30,210	58,180	107,220	192,000
Optimistic I (11.5%)	5,746	16,000	31,240	70,760	137,370	250,000
Optimistic II (13%)	5,746	33,250	64,200	107,600	172,900	297,900

Despite the electricity projection as shown in Table 1, [7] revealed that Nigeria has only recorded 5,801.60MW on the 25th of May 2022 as the maximum all-time electricity peak attained at a given time. Nigeria maintains a single National Integrated Power Grid system from integrated grid pool generation from both hydro and thermal stations, operated by the Transmission Company of

Nigeria through the National Control Centre (NCC). The hydro stations are Kainji, Jebba, and Shiroro Hydro Power Stations while the Privatized Thermal Stations are: Egbin, Sapele, Delta, Geregu, Afam (1V-V), Omotosho and Olorunsogo NIPP Thermal Stations are Sapele NIPP, Olorunsogo NIPP, Omotosho NIPP, Ihovbor NIPP, Geregu NIPP, Alaoji NIPP, Gbarain NIPP, and Odukpani NIPP; IPP Thermal Stations are Okpai, AfamVI, Ibom Power, Omoku, Paras Energy, Azura Edo, and Rivers IPP made significant contributions to Nigeria system generation.

According to [8], in major areas across Nigeria, the electricity distribution network configuration is observed to be bad with a substandard voltage profile and there is a need to ensure larger network coverage and provision of a quality power supply coupled with good marketing and customer service delivery. Some of the major problems of Distribution Companies (DISCOs) in Nigeria as identified by [9] are weak technical network coverage, overloading of transformers and associated equipment, poor distribution lines and billing system, poor and obsolete communication equipment, low staff morale, and lack of regular training, and insufficient funds for maintenance activities.

According to [10], the quality of the electricity distribution system must have the highest reliability of electricity supply to consumers, the minimum duration of the interruption, minimum operation and maintenance cost, and the voltage deviation at the consumers' side should be limited to about 5% of nominal value. Despite load demand expansion by consumers, technical grid network expansion, and an increase in the generating stations, many distribution substation equipment, and feeders are majorly overloaded. Hence, electricity cannot be effectively transferred to meet up with the load demand increase at the consumer end.

[11] researched the market organization of the Dutch and European markets on consistency between electricity markets for different time horizons and simultaneous alignment of energy provision and reserve capacity. The work identified some important policy options and therefore proposed them as measures for the improvement of the design of electricity markets which included; (1) shortening the time resolution of day-ahead products to 15 minutes, (2) marginal pricing of products in the intra-day market, and (3) implementing the same gate closure time for energy and reserve capacity markets to stimulate day-ahead and intra-day trading in a reserve capacity.

2.1 Load demand pattern in Nigeria

According to [12], daily load demand, weekly load demand, and annual load demand were explicatory defined as follows.

2.1.1 Daily load demand

In Nigeria, daily load demand is categorized into PEAK and OFF-PEAK periods. The period of minimum load demand of the day occurs around 0000hrs to 0500hrs in the morning when major commercial centres and industrial loads are shut down is referred to as the off-peak period. Also, the second off-peak period occurs around 0800hrs to 1800hrs whenever offices and industrial loads are at their peak with a drastic drop in domestic loads. From 0500hrs to 0800hrs (early in the morning) when people are awake in preparation for the day's activities, many home appliances are utilized during this period, the first peak period is experienced. The second peak period occurs between 1800hrs to 2400hrs during the period when electricity consumers return from their respective offices hence, many electrical appliances are put into use.

2.1.2 Weekly load demand

Weekly load demand in Nigeria follows a unique pattern. The demand increases during the weekdays when most commercial areas and factories are actively in operation and reduces during the weekends when the commercial areas and factories are not producing, hence, residential consumption predominates.

2.1.3 Annual load demand

Dry and rainy seasons determine the annual load demand. Annual peak demand happens around January to April when the weather is very hot (the use of air conditioning is at its peak during this time) while minimum annual load demand happens around June to December during the harmattan and rainy period of the year respectively. During this period, heavy electrical appliances like air conditioners are not in use.

2.1.4 Generation pattern of Nigeria

Grid generation availability remained grossly inadequate due to a reduction in water inflow to the lakes; inadequate gas supply, line limitations, and low machine availability profile. Consequently, the ever-increasing national load demand could not be met despite generation inadequacy as a result of load rejection by distribution companies [13].

Common identified generation problems in Nigeria are inadequacy of gas supply, unreliable black start the facility, poor generator spread, and fuel mix, impact of seasons on hydropower generation, difficulty in maintenance due to lack of spares, low machine availability, the inadequacy of units with free governor mode of operation, power evacuation difficulties at the transmission level, incessant tripping of distribution feeders during heavy rainfall, system security considerations, improper relay coordination, very wideband between peak and off-peak and the reluctance of some plants to keep their units on free governor control [7, 13, 14, 15]. Table 2 shows the different generating stations in Nigeria with their respective installed capacity and available factor.

2.2 Power distribution pattern in Nigeria

For smooth operation of the electricity market in Nigeria, the generating companies must be able to sell using transmission company facility to wheel power to distribution companies who then sell for the end consumers. Table 3 shows the different types of distribution companies in Nigeria, the number of feeders covered by each distribution company, the estimated population of the area covered by each distribution company and the percentage allocation of daily electricity generated per day by the National Electricity Regulation Commission (NERC).

In major areas across Nigeria, the distribution network configuration is observed to be bad, and the voltage profile is substandard. There is a need to ensure larger network coverage and provision of a quality power supply coupled with good marketing and customer service delivery. Some of the major problems of DISCOs in Nigeria as identified by [16] are weak technical network coverage, overloading of transformers and associated equipment, poor distribution lines and billing system, poor and obsolete communication equipment, low staff morale, and lack of regular training, and insufficient funds for maintenance activities. Also, [17] identifies some of the challenges of the power sector in Nigeria as policy somersault, improper or bad project execution, inadequate infrastructure, inadequate gas supply, financial challenges, and data inadequacy for estimation of consumers to plan.

Table 2: Generating station in Nigeria with an installed capacity [7].

Power Stations	Available Factor (MW)	Average Availability (MW)	Installed Capacity (Less DE-commissioned UNITS) MW
Privatised Companies - Hydro Stations			
Kainji hydro	0.52	393.94	760.00
Jebba hydro	0.72	417.13	578.40
Shiroro	0.82	492.03	600.00
Subtotal	0.67	1303.10	1938.40
Privatised Companies - Thermal Stations			
Egbin steam	0.41	543.37	1320.00
Afam (1-v) (gas)	0.12	42.97	351.00
Delta (gas)	0.44	395.80	900.00
Sapele st	0.06	41.26	720.00
Geregu (gas)	0.90	389.52	435.00
Olorunsogo i	0.66	221.59	335.00
Omotosho	0.43	144.86	335.00
Sub Total	**0.40**	**1779.37**	**4396.00**
Nipp - thermal stations			
Olorunsogo nipp	0.05	35.27	750.00
Alaoji nipp	0.14	70.31	500.00
Geregu nipp	0.49	0.49	450.00
Ihovbor nipp	0.24	117.53	500.00
Omotosho nipp	0.24	120.90	500.00
Sapele nipp	0.19	94.34	500.00
Odukpani	0.71	442.51	625.00
Gbarain	0.41	49.42	120.00
Sub Total	**0.29**	**1150.50**	**3945.00**
Ipp - Thermal Stations			
Rivers ipp	0.75	134.72	180.00
Omoku gt	0.43	64.56	150.00
Asco	0.00	0.00	110.00
Trans-amadi gt	0.44	43.81	100.00
Okpai gas	0.51	246.46	480.00
Ibom	0.56	86.63	155.00
Afam vi (gas)	0.67	434.23	650.00
Paras	0.65	61.90	95.00
Azura	0.98	449.73	461.00
A.e.s (gas)	0.00	0.00	294.00
Sub total	0.57	1522.03	2675.00
Grand Total	**0.44**	**5755.00**	**12954.40**

Table 3: Distribution companies' architecture in Nigeria

S/N	Name of DISCO	Areas of Operation	Number of Feeders	Area Population	Percentage Load Allocation (%)
1	Abuja Distribution Company	FCT, Kogi, and Niger Sate	92	13593863	11.5
2	Benin Distribution Company	Edo, Delta, Ekiti and Ondo State	69	17841450	9.0
3	Eko Distribution Company	Lagos (Lekki to Epe, Island and Victoria Island)	87	4800239	11.0
4	Enugu Distribution Company	Abia, Enugu Anambra, Ebonyi, and Imo State	75	21955414	9.0
5	Ibadan Distribution Company	Kwara, Oyo, Osun and Ogun State	119	20957062	13.0
6	Ikeja Distribution Company	Lagos (All of the mainland, Ikeja to Badagry)	86	7200359	15.0
7	Jos Distribution Company	Bauchi, Benue, Gombe, Nassarawa and Plateau	45	22259928	5.5
8	Kaduna Distribution Company	Kaduna, Kebbi, Sokoto and Zamfara	64	22205933	8.0
9	Kano Distribution Company	Jigawa, Kano and Kastina	63	28736374	8.0
10	PortHarcourt	Akwa Ibom, Bayelsa, Cross River, and Rivers	70	18930331	6.5
11	Yola Distribution Company	Adamawa, Borno, Taraba and Yobe	44	16469590	3.5

3. Methodology

3.1 Data collection and evaluation

The data required for this research was obtained from the Nigeria Electricity Regulation Commission and Transmission Company of Nigeria, National Control Centre, Osogbo Nigeria. The data included hourly day-ahead electricity demand by Nigeria distribution, daily peak electricity generated and transmitted to Nigeria's electricity grid and daily bulk electricity wheeled to Nigeria's electricity grid system by all electricity generating companies in Nigeria. All these data were from the year 2018 to 2020. The daily average ahead demand of the DISCOS was computed using Equation (1).

$$D_a = \frac{\sum P_h}{24} \quad (1)$$

Where P_h is the total electricity hourly day-ahead demand in a day by all the distribution companies in Nigeria and D_a is the average daily electricity day-ahead demand by all the distribution companies in Nigeria.

The total daily electricity day-ahead demand by all the electricity distribution companies in Nigeria was computed using equation (2).

$$D_{TE} = \sum P_T \times t \quad (2)$$

Where D_{TE} is the total electricity day-ahead by all the distribution companies in Nigeria, P_T is the total electricity demanded per day and t is the time of electricity demand.

The total monthly electricity generated and transmitted to the grid was obtained from the total daily electricity generated and was computed using Equation (3)

$$M_{TG} = \sum P_{TE} \times D \quad (3)$$

Where M_{TG} is the monthly electricity generated by all the electricity generating companies and transmitted to Nigeria's electricity grid, P_{TE} is the total daily electricity generated and transmitted to Nigeria's electricity grid and D is the total number of days in a month.

The monthly electricity demand by Nigeria's electricity distribution companies was computed using Equation (4)

$$M_{TD} = \sum P_h \times D \quad (4)$$

Where M_{TD} is the monthly electricity demand by all the distribution companies in Nigeria, P_h is the total electricity hourly day-ahead demand in a day by all the distribution companies in Nigeria and D is the total number of days in a month.

Electricity allocation data of all lines connecting to the neighbouring countries (international lines) based on the signed energy allocation was used in the evaluation process.

3.2 Comparison of electricity demand and consumption Pattern

In order to understand the pattern and identify the problem of electricity availability in Nigeria, the daily data of the electricity demand, generated and transmitted to the grid were extracted as mentioned in Section 3.1 which were computed and analyzed using the Microsoft Excel programme. The graph of the individual index and their comparison with other indices were done and the results are as shown in Section 4.

4. Results and discussion

4.1 Load demand by DISCOS

The pattern of daily average and total day-ahead demand by all the DISCOs are as shown in Figures 1 and 2 which varied between 3500MW and 4000MW with a corresponding increase above

4000MW toward the end of the year 2020 and 80GW and 90GW with a corresponding increase to about 100GW towards the end of the year 2020 respectively.

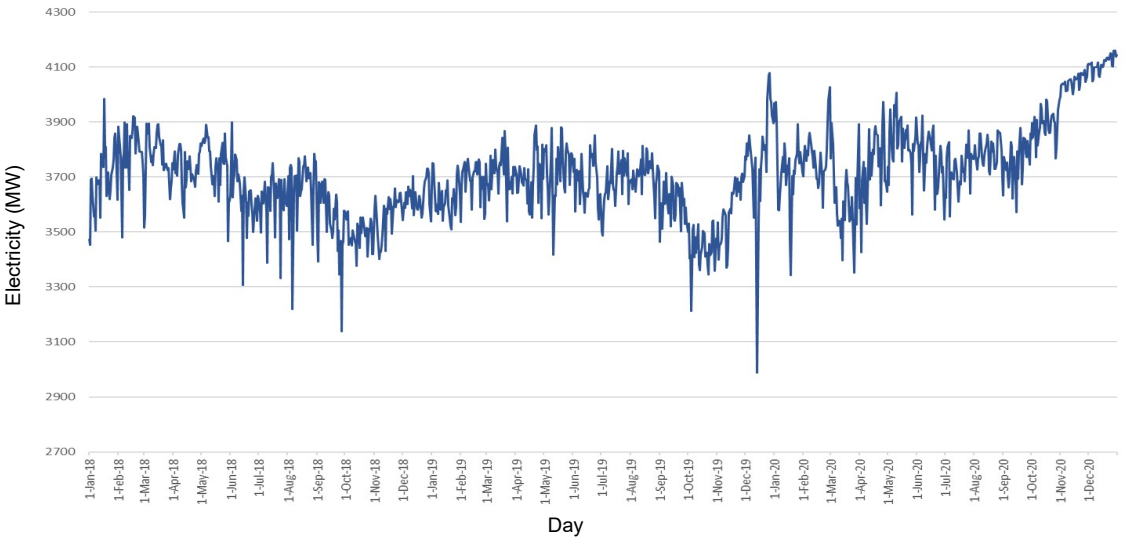

Figure 1: Daily Average Day-Ahead Demand by Discos in Nigeria.

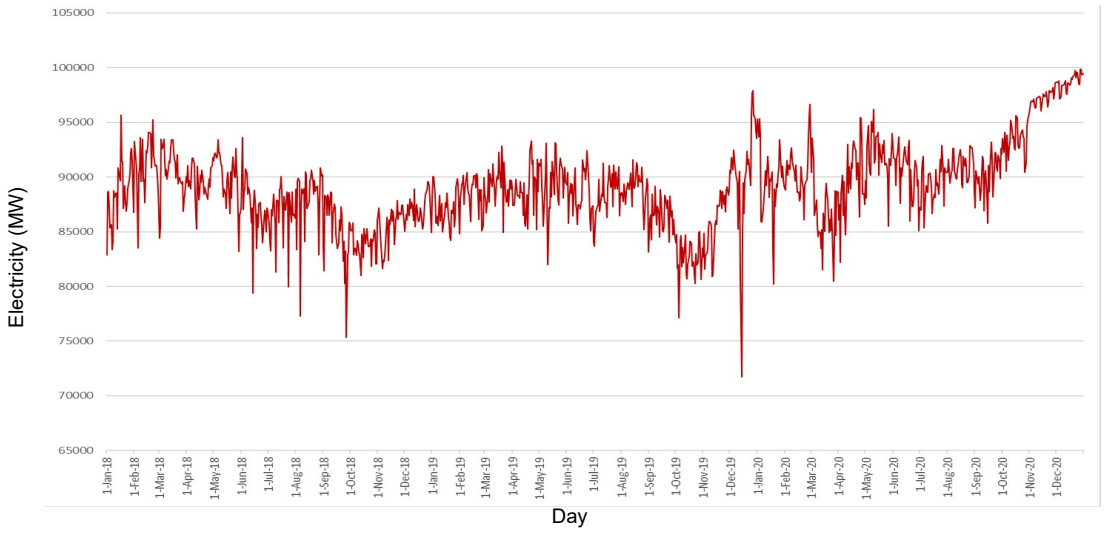

Figure 2: Total daily day-ahead demand by Discos in Nigeria.

4.2 Daily electricity peak generation pattern of Nigeria.

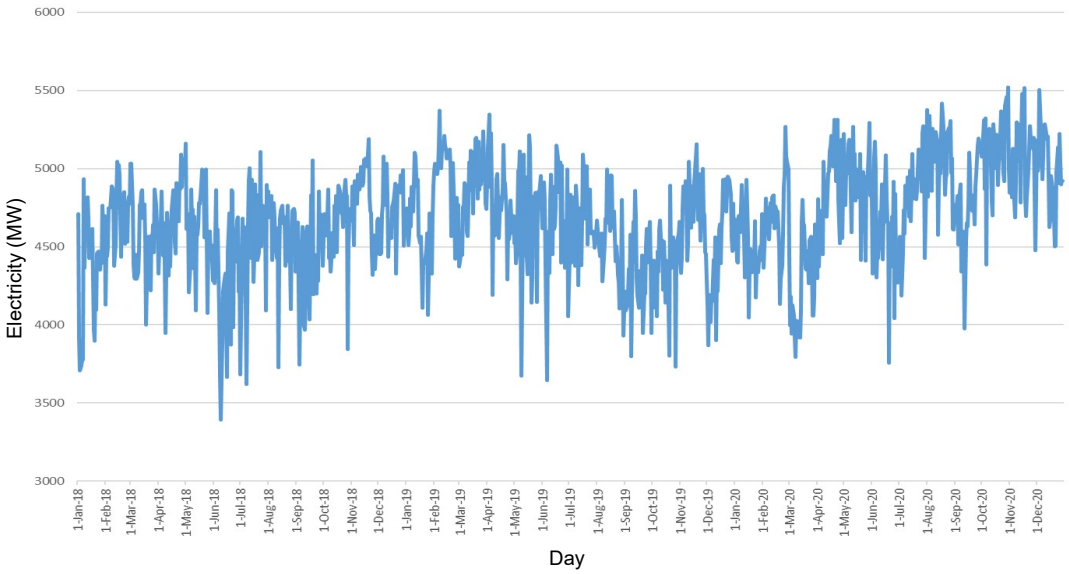

Figure 3: Maximum Daily Peak Generation Pattern (MW)

The daily peak electricity generation capacity of Nigeria as shown in Figure 3 varied majorly between 4000MW and 5400MW from 2018 to 2020. This confirmed the available capacity of each generating station as reported by [7]. A good peak period was experienced in 2019 as compared with 2018 and a better and marginally stable increase in the daily peak was experienced in 2020 as compared with the years 2018 and 2019.

4.3 Monthly energy transmitted to Nigeria Grid from January 2018 to November 2020

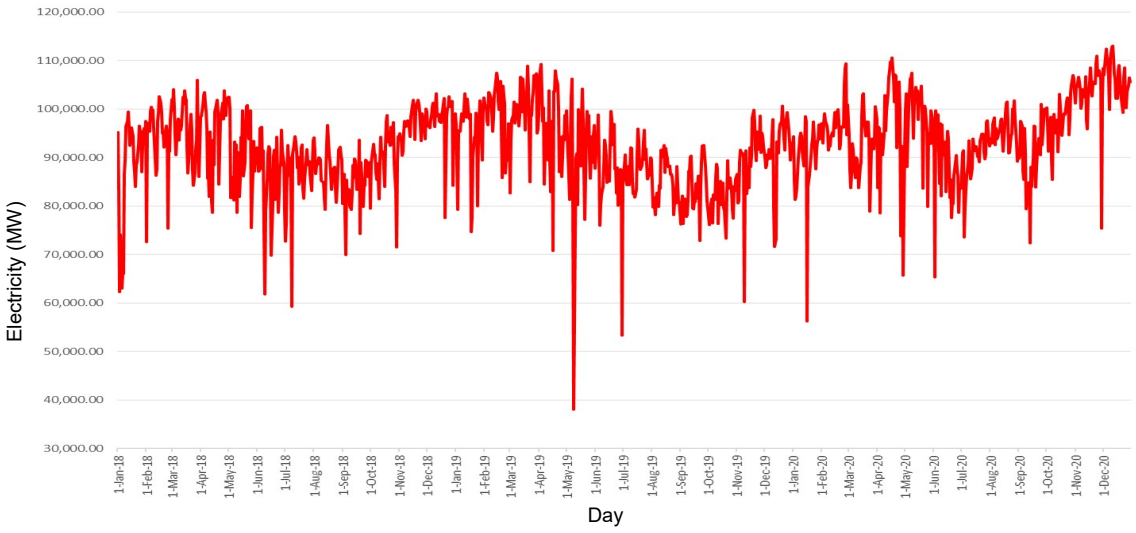

Figure 4: Monthly energy transmitted to the grid by generating stations

Figure 4 shows the monthly pattern of electricity transmitted to the Nigerian grid. The peak generation period occurs between January and April during the dry season while minimum generation occurs around May to November of the year. The sudden drop within specific periods in the graph shows the period when generating stations (especially the generating stations with high generating capacity) are not available due to technical reasons or unavailability of gas (for gas generating stations).

Also, a comparison between the total monthly demand with actual monthly energy consumed by DISCOs as shown in Figure 5 revealed that DISCOs daily electricity consumption is lesser than their declared daily electricity demand.

4.3 Energy demand, transmitted and consumed on the Nigeria Grid

The graph showing the comparison between total energy transmitted to the grid, total monthly demand by DISCOs, total monthly energy consumed by DISCOs, and total monthly energy consumed by both DISCOs and international Lines in Figure 5 revealed the following observations;

a) The corresponding difference between the graph of monthly total energy transmitted to the grid and the monthly energy consumed by DISCOs and lines connected to neighbouring countries (international lines) was equivalent to the summation of losses on the grid and unused/wasted energy. The wasted energy generated caused system frequency to drift beyond the nominal frequency of 50Hz.

b) Some generating station units were not connected to the free governor mode which was to regulate energy production and consumption balance on the grid.

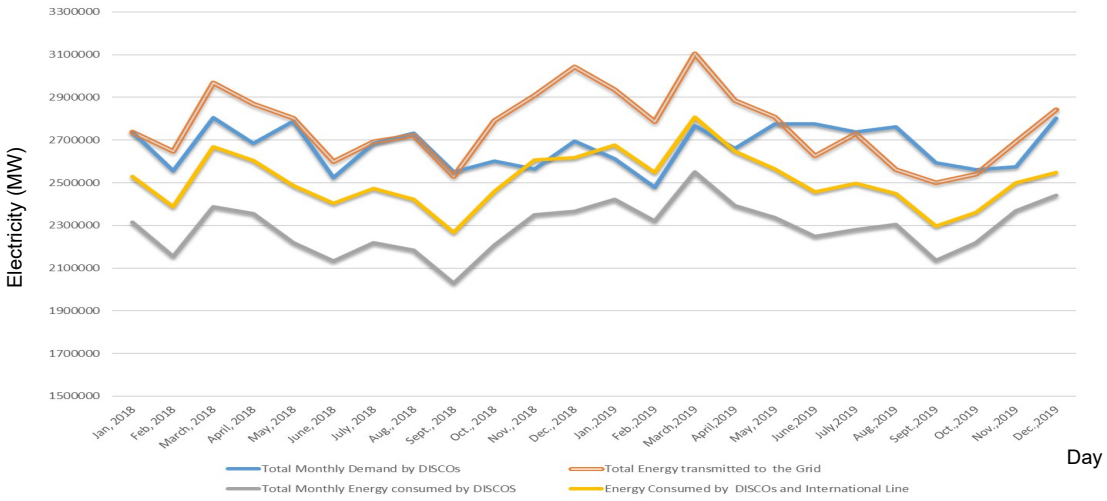

Figure 5: Comparison of Energy demand, transmitted and consumed on the Nigeria Grid.

c) The distribution companies were not picking up their maximum load despite being the major downstream stakeholder in energy delivery to electricity consumers as compared to international lines and eligible customers (registered participants with load consumption of at least 2MW connecting to transmission links)

d) Some gas generating stations experienced challenges of gas constraint thereby limiting the total generating power transmitted to the grid.

e) Many of the generating station units trip on fault. This limited the electricity-wheeling potential of the National grid sometimes leading to load shedding in order to achieve system stability.

5. Conclusions

This study investigated the electricity demand and generation pattern on the Nigeria Grid System by analyzing daily declared DISCOs electricity demand, DISCOs actual electricity consumption, and electricity demand by international lines being supplied by the Nigeria grid. The results of the analysis revealed the under-performance of the DISCOs in evacuating electricity to electricity consumers being the only link to Nigeria electricity consumers except for a few eligible customers connected directly to 132kV and 33kV after fulfilling the connection process as spelt out in Section 11 of the Nigeria Electricity Grid code. Daily average electricity day-ahead demand by DISCOs varied majorly between 3.5GW to 4GW with a corresponding increase above 4GW toward the end of the year 2020. The total daily electricity day-ahead Demand by DISCOs varied majorly between 80GW and 90GW from 2018 to 2020 with a corresponding increase to about 100GW towards the end of the year 2020. But despite this demand by DISCOs, the study revealed that distribution companies were not picking up on their electricity demand despite being the major downstream stakeholder in electricity delivery to consumers and this had led to undersupplying of electricity to final consumers and load rejection. Also, some generating station units were suspected to be not connected to the free governor mode which was to regulate the balance in electricity production and load demand on the Nigeria grid and some were facing challenges of gas constraint thereby limiting the total electricity generated and transmitted to the grid. Hence, there is a need for an adequate supply of electricity to meet the consumers' demand in the residential, commercial, and industrial sectors of Nigeria.

References

[1] Adaramola, M. S., Oyewola, O. M., & Paul, S. S. (2012). Technical and economic assessment of hybrid energy systems in South-West Nigeria. *Energy Exploration & Exploitation*, 30(4), 533-551. https://doi.org/10.1260%2F0144-5987.30.4.533

[2] World Energy Council, (2018). *World Energy Trilemma Index* 2018. p. 156.

[3] Ale T.O & Odesola A.O (2013). Effect of Distance on Transmission (Akure 33kV Transmission Line a Case Study). *International Journal of Research Findings in Engineering, Science & Technology*, 1(1), 27-32.

[4] Nwankwo, O. C., & Njogo, B. O. (2013). The effect of electricity supply on industrial production within the Nigerian economy (1970–2010). *Journal of Energy Technologies and Policy*, 3(4), 34-42.

[5] Adenikinju, A. F., 2003. Electric infrastructure failures in Nigeria: A survey-based analysis of the costs and adjustment responses. *Energy Policy*, 31(14), 1519 – 1530. doi.org/10.1016/S0301-4215(02)00208-2.

[6] Sambo, A. S. (2008). Matching electricity supply with demand in Nigeria. *International Association of Energy Economics*, *4*, 32-36.

[7] Transmission Company of Nigeria (TCN) (2019), Grid System Operations Annual Technical Report. Issued by: General Manager (NCC) National Control Centre, Osogbo. Unpublished.

[8] Monyei, C. G., Adewumi, A. O., Obolo, M. O., & Sajou, B. (2018). Nigeria's energy poverty: Insights and implications for smart policies and framework towards a smart Nigeria electricity network. *Renewable and Sustainable Energy Reviews,* 81, 1582-1601. https://doi.org/10.1016/j.rser.2017.05.237

[9] Sambo, AS; Garba, B; Zarma, IH; Gaji, MM (2012). Electricity generation and the present challenges in the Nigerian power sector. *Journal of Power and Energy Engineering,* 6, 1050–1059.**Error! Reference source not found.**

[10] Okereafor, F. C., Idoniboyeobu, D. C., & Bala, T. K. (2017). Analysis of 33/11kV RSU injection substation for improved performance with distributed generation (DG) units. *American Journal of Engineering Research (AJER)*, 6(9), 301-316. e-ISSN: 2320-0847

[11] Welle, and A.J van der (2016). Required adjustment of electricity market design for a more flexible within the Nigerian economy (1970 – 2010). *Journal of Energy Technologies and Policy*, 3 (4), 34-42. https://doi.org/10.7176/JETP

[12] Ezennaya, O. S., Isaac, O. E., Okolie, U. O., & Ezeanyim, O. I. C. (2014). Analysis of Nigeria's national electricity demand forecast (2013–2030). *International Journal of Science and Technology Research*, *3*(3), 333-340. ISSN 2277-8616.

[13] Anyadiegu C.I.C, Ohia N.P and Ukwujiagu C.M (2015). National Gas Transmission and Distribution in Nigeria. *Journal of Multidisciplinary Engineering Science and Technology (JMEST)*, 2(8), 2033-2039. ISSN: 3159-0040

[14] Nextier Power (2017). Nigeria's Power Sector: Experts Reviews Gas Supply Constraints. *Power Library hub.* www.nigeriaelectricity hub.com. Access date: 03/09/2020.

[15] Kingley Jeremiah (2020). How shortage of gas will cripple power generation in Nigeria. *The Guardian Newspaper* 01 April, 2020.

[16] Okibe, H. B., & Mokuye, C. S. (2018). An Appraisal of Power Sector Reforms and Delivery of Electric Services in Nigeria. *South East Journal of Political Science*, *3*(2).

[17] Okolobah, V., & Ismail, Z. (2013). On the issues, challenges and prospects of electrical power sector in Nigeria. *International Journal of Economy, Management and Social Sciences*, *2*(6), 410-418. ISSN 2306-7276.