INVESTIGATING POINTS-OF-GENERATION POWER LOSSES ON THE NIGERIAN NATIONAL GRID FOLLOWING UNBUNDLING OF THE ELECTRIC UTILITY INDUSTRY

AJEWOLE TITUS OLUWASUJI[*1], OLABODE OLAKUNLE ELIJAH[2], OKAKWU IGNATIUS KEMA[3], EGBEDINNI OLAKUNLE FEMI[4]

[1]*Department of Electrical and Electronic Engineering, Osun State University, Osogbo, Osun State, Nigeria*

[2]*Department of Electrical, Electronic and Computer Engineering, Bells University of Technology, Ota, Ogun State, Nigeria*

[3] *Department of Electrical and Electronic Engineering, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria*

[4]*Systems Operation Department, Transmission Company of Nigeria, Regional Control Centre, Osogbo, Osun State, Nigeria*

Abstract: Aside from the domino effects of being radial in structure, the Nigerian national electric grid is currently suffering from deteriorated infrastructures and unpredictable fuel supply for power generation. Massive introduction of green energy-based microgrid alternatives has been proposed as a major means of resolving the challenges. Such paradigm shift needs to be substantiated within the context of the present situation of the grid, for the consumption of policy makers and implementers, hence; the performance of the generation sub-system of the grid in the post-deregulation era is evaluated in this study. Two-year numerical data on the operational capacities of the twenty-nine power plants that are currently connected to the grid are employed to profile the behaviours of the plants over the period. Yearly averages of the three operational capacities of each plant are estimated, and by comparing the respective capacities, generation losses are computed for each of the plants. With 5,063.8 MW yearly average generation capacity in the year 2018, a loss of 61.02 % was experienced on the sub-system; while the generation loss was 61.55 % in the year 2019 that has yearly average generation capacity of 5,062.5 MW. For the two years combined, the average generation capacity is 5,063.2 MW at 61.36 % power loss. These estimations reveal that the pre-deregulation loss profile of the generation sub-system has not been curtailed despite the unbundling of the electric power industry. Generation loss has rather persisted and keeps taking a heavy toll on the electric utility market of the country. Significant deployment of renewable electricity microgrid is therefore required to provide enduring solution.

Keywords: power plants; generation loss; loss profile, green energy, renewable electricity

1. INTRODUCTION

Reformation of the Nigerian electric power industry commenced in 1999 and as part of the process, the electric power sector was in 2013 deregulated. This was with a hope of better functionality of the industry as each of the

[*] Corresponding author, email: titus.ajewole@uniosun.edu.ng
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players in the unbundled power market was expected to run effectively and efficiently. Implementation of the privatization has since been backed up with huge financial supports by the Federal Government and other private investors, but despite the unbundling and several other interventions, the industry has continued miring in crisis that is not only multidimensional and propagative, but also worsened by the incessant blame shifting among the major participants in the deregulated market. At over two decades of the reformative exercise, all that can be shown for the huge expenditures, technicalities and logistics provided by the government and the investors, is increasing indebtedness and erratic power supply that has degenerated to frequent occurrences of grid collapse.

Efficient power supply plays critical roles in national development, while inadequate provision of electricity is a cog in the wheel of the progress of any nation. The potential that Nigeria has, to become one of the world's largest economies, will remain illusionary without secured electricity supply that is required to pursue aggressive industrialization and modernization. There have been a number of studies into the persistent ill-performance of the Nigerian electric utility sub-sector and reports have been made by authors who have not only identified causes, but also suggested probable solutions to the challenge.

The banes of the Nigerian power industry, as obtained from the literatures, include infrastructural deficiency, regulatory inconsistency, inadequate technical and financial capability, political interference, and operational inefficiency. Most of the post-privatization challenges facing the industry have been re-traced to the process of the privatization, in which entities lacking in sufficient technical and financial capabilities for such a huge electric power businesses are somehow licensed into taking over generation and distribution assets. In addition, it is noted by [1] that during the process, the National Electricity Regulatory Commission (NERC), the investors and the Bureau of Private Enterprises (BPE) that superintended over the privatization process did not have critical data on the extent of technical and collection losses, as well as infrastructural depreciation of the power supply network facilities that have been erstwhile monopolistically owned by the government.

So far, a lump sum of ₦5 trillion ($31.45 billion) has been expended on the industry since 1999 hitherto [2], yet the industry is currently in indebtedness to the tune of ₦400 billion ($2.48 billion) and still increasing [3]. The huge investments so far made by the Federal Government, over the last two decades, has only yielded recurring debts that can soon bankrupt the industry if not properly handled. The more fund expended on the power system, the poorer the industry is performing. Within the first half of 2019, eight cases of grid collapse were reported [4, 5] and a total of seventy-five of such occurrences between May 29, 2015 and June 6, 2019 [6].

Though massive adoption of renewable energy alternatives was part of the deregulation policy, yet as at present the proportion of green energy option in the energy mix for electricity generation in Nigeria remains insignificant. It therefore appears that the paradigm shifting from fissile-based to green energy option, or complementing the former with the latter, needs to be more firmly substantiated, particularly within the context of the current situation of the national grid, for the consumption of policy makers and implementers.

Most of the recent researches have employed the inefficiencies inherent in the operations of the Nigerian grid in the post-deregulation era, to advocate further the cause of renewable electricity adoption in the country [7, 8]. Using the seven major distribution zones of the grid, [7] presents a study on the reliability of electric power supply in Nigeria during the pre-privatization era, in the effort to provide a standard for comparison in the assessment of the post-privatization performances of the industry. In [8], the authors used 81 injection feeders of a distribution network as a case study in a post-privatization evaluation of the power industry from the viewpoint of whether or not the downstream consequences of some operational lapses of the upstream operators, particularly the Transmission Company of Nigeria (TCN), are the main causes of setbacks in the operations of the Distribution Companies (DisCos). These authors, focusing mainly on transmission and distribution sub-systems and operators, examines the performances of the grid in order to enhance improvement in the operations of the power industry. They, however, do not place attention on the performance of the generation sub-system in the post-deregulation.

There are some assessments of the generation facilities over certain periods within the era preceding the unbundling. From a study by [9], power loss of over 50 % used to be experienced on the entire grid, from the points of generation to the points of utilization of the supplied power. It is also placed on record that during the era, the available capacities of most of the generating stations were between 60 % and 80 % of their respective installation capacity [10]. While [9] attributes the losses mostly to inefficient operations of the transmission and distribution facilities, a study of the three power plants sited at Delta area of the country, during the same period revealed that the average power generation from the plants was 30.5 % of their total installation capacity [11]. This indicates that 69.5 % of the power that would have added to the grid from the studied plants, was lost at the point of generation. From this it could be deduced that generation sub-system, like other segments of the then monopolistic power system, was also culpable of performance inefficiency.

The whole essence of the unbundling, and the reformation in general, was to enhance the efficiency of the entire power sector, so that end users would begin to have good electricity supply experience. Based on an estimation that developing economies would need about 1,000 MW per million people to meet their electricity demands, it was submitted that for a steady growth, Nigeria with population of over 160 million needs a generation of over 160,000 MW [12]. In the post-deregulation, this can be achieved through proper and effective synergy among all the participators within the value-chain of the electricity supply industry, from generation to utilization. Advantages offered by massive deployment of renewable energy based microgrid alternatives needs to be leveraged on to enhance the efficiency of the entire system, and thus the huge investments that Federal Government has hitherto made on the sector as a whole would turn beneficial.

In addition to the initial capitalizations, generation sub-system together with other sub-systems of the grid, has receive a number of palliative interventions of the Federal Government, aimed at improving the efficiency of the privatized power market. Sums of ₦701 billion ($4.35 billion) [1, 13] and ₦600 billion ($3.73 billion) [13] were disbursed to the privatized market in 2017 and 2019 respectively. The earlier fund was meant for the Generation Companies (GenCos) in particular to offset their gas bills since the sub-system has been recording huge power loss. But in spite of these and other palliations, generation sub-system remains operationally inefficient and this the GenCos ascribe to:

(i) Limitation in the wheeling capacities of the downstream operators (TCN and DisCos) due to weakness of facilities [14, 15, 16];
(ii) Non-optimal operation of power plants as a result of shortage of fuel supply [15, 16];
(iii) Inefficient operation due to depreciated plant equipment [6].

As at present, twenty-nine power plants are connected to the grid as shown in Figure 1, two of which are currently not operational [17]. Despite the prevailing devastation, however, a study has shown that Nigerian power sector still has potential to serve the entire nation effectively [17]. The repeated investments and bail-outs by the Federal Government are expected to strengthen the industry [18], but the funds need to be properly and productively directed.

One of the ways to achieve this is reduction of power losses at generation plants to the barest minimum, which can be achieved through massive deployment electric microgrid technology with green energy options. Therefore, this present study assesses the performance of the Nigerian national grid in the post-deregulation era, with attention on the generation sub-system. This is to determine how much the reformation in general and the privatization in particular has enabled curtailment of generation losses. outcome of the study will also be employed to advocate further on renewable energy based power generation, being a major way out of the huge losses currently experienced at the points of generation. In essence, policy makers and implementers would be guided the more. Operational capacities of each of the power generating plants currently connected to the grid are compared and, from which the generation losses incurred by each plant are computed. This paper is structured as follows: the second section details the materials and method of the study, while the results of the study is presented and discussed in the third section, and the work is concluded in the fourth section.

2. MATERIALS AND METHOD

Information on the generation sub-system of the grid is obtained from the Regional Control Centre (RCC), Osogbo, Nigeria. Records on the installation capacity (IC), as well as the performance of each plant in terms of available capacity (AC) and generation capacity (GC) for each day of the years 2018 and 2019, are contained in the obtained data. While Figure 1 is a description of the structure of the grid, Table 1 presents the ICs of the plants as at 2018. The table also shows that for the year 2018, the aggregate IC of all the twenty-nine plants contained in the grid is 12,9914 MW.

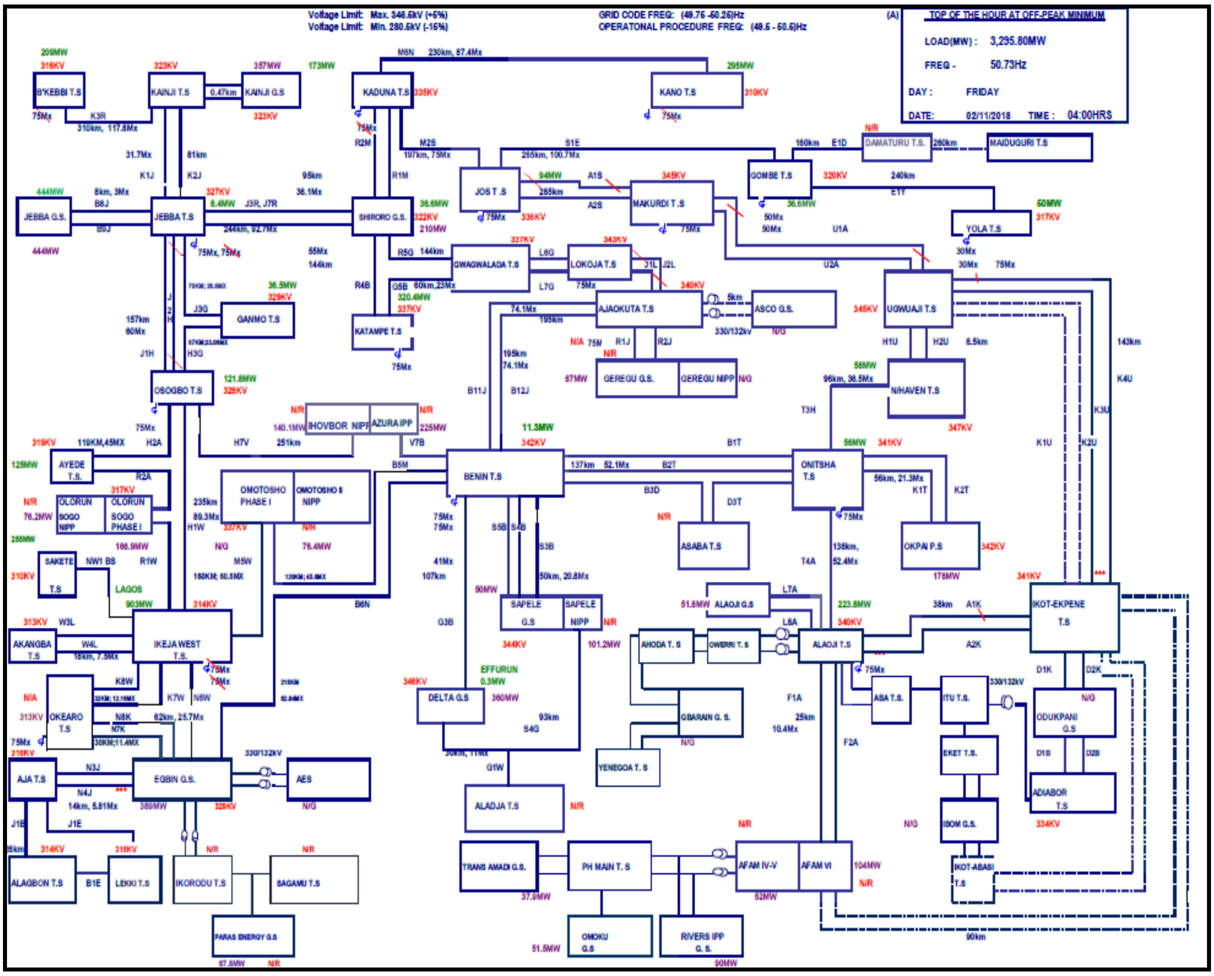

Fig. 1. Nigerian National Power Grid [Courtesy: National Control Centre (NCC)].

Table 1. Installation capacities of the power plants in 2018.

S/N	Power Plant	Installation Capacity [MW]
1.	Kainji	760.0
2.	Jebba	578.4
3.	Shiroro	600.0
4.	Sapele	720.0
5.	Sapele NIPP	500.0
6.	Afam IV	351.0
7.	Afam VI	650.0
8.	Egbin	1,320.0
9.	Egbin ST6	220.0
10.	Delta	900.0
11.	Rivers IPP	180.0
12.	Alaoji	500.0
13.	AES	294.0
14.	Okpai	480.0
15.	Ihovbor NIPP	450.0
16.	Omoku	150.0
17.	Geregu	450.0
18.	Geregu NIPP	450.0
19.	Omotosho	335.0
20.	Omotosho NIPP	500.0

21.	Olorunsogo	335.0
22.	Olorunsogo NIPP	750.0
23.	Ibom	155.0
24.	Trans Amadi	100.0
25.	Odukpani	500.0
26.	Paras Energy	72.0
27.	Gbarain	120.0
28.	ASCO	110.0
29.	Azura	461.0
Total		12,991.4

By definition, IC is the maximum capacity of a plant as at the time of the installation based on manufacturer's designed, while AC is the capacity the plant can discharge putting in mind the possibility of losses when subjected to real time stress, and GC is what the plant is permitted to discharge at a particular time having in mind that other units are also running at that particular time. While IC is fixed, AC depends mostly on age of the plant and availability of fuel (or water for hydropower plants), and GC is a function of parameters like load demand, state of the grid, state of the machine, and availability of fuel (or water for hydropower plants).

Performances of the plants over the two years under study are profiled, then yearly averages of the three capacities of each plant are estimated. The actual losses incurred at each plant are computed by comparing their respective yearly average available capacity (YAAC) and yearly average generation capacity (YAGC) with the yearly average installation capacity (YAIC). While Loss A expresses the deviation of the YAAC from the YAIC, Loss B describes the variation of YAGC from YAAC, and Loss C is the difference between YAGC and YAIC.

$$Loss\ A = \frac{YAIC - YAAC}{YAIC} \times 100\% \tag{1}$$

$$Loss\ B = \frac{YAAC - YAGC}{YAIC} \times 100\% \tag{2}$$

$$Loss\ C = \frac{YAIC - YAGC}{YAIC} \times 100\% = Loss\ A + Loss\ B \tag{3}$$

3. RESULTS AND DISCUSSION

Presented in Figure 2 is a general profile of the performances of the generation sub-system across the 730 days of the years 2018 and 2019. It could be observed from the profile that throughout the two-year period, none of the plants operated at its full IC. Many of them even generated far less. In the same vein, asides Paras Energy, they all operated below their respective AC. In particular, Sapele, Afam IV, Egbin, Alaoji and Olorunsogo NIPP had their respective ACs far below ICs and consequentially their GCs were too low throughout the period. This same condition applies to Sapele NIPP also during 2019. The profile also reflects that many of the plants were intermittently down, with each downtime covering a considerable number of days, even as Egbin ST6 experienced a complete lockdown throughout the year 2019.

Whereas Paras Energy was remarkably generating at very close to its full IC all through the two years, both AES and ASCO were found to be completely down for the entire period. For AES, this might have resulted from the plant's loss of bid for renewal of operation license at a period coinciding with the dawn of the privatization. In the case of ASCO, the plant has not been functioning as the Ajaokuta Steel Company that the plant was meant to serve has been experiencing years of operational redundancy.

There were upgrades in the ICs of two plants commencing from 1st January 2019, as Ihovibor NIPP and Odukpani were upgraded from 450 MW to 500 MW and from 500 MW to 625 MW respectively. However, while the upgrading did not yield any incremental effect on either the AC or the GC of Ihovibor NIPP plant, the reverse is the case on Odukpani as the plant experienced significant increment in both the AC and the GC following the upgrading.

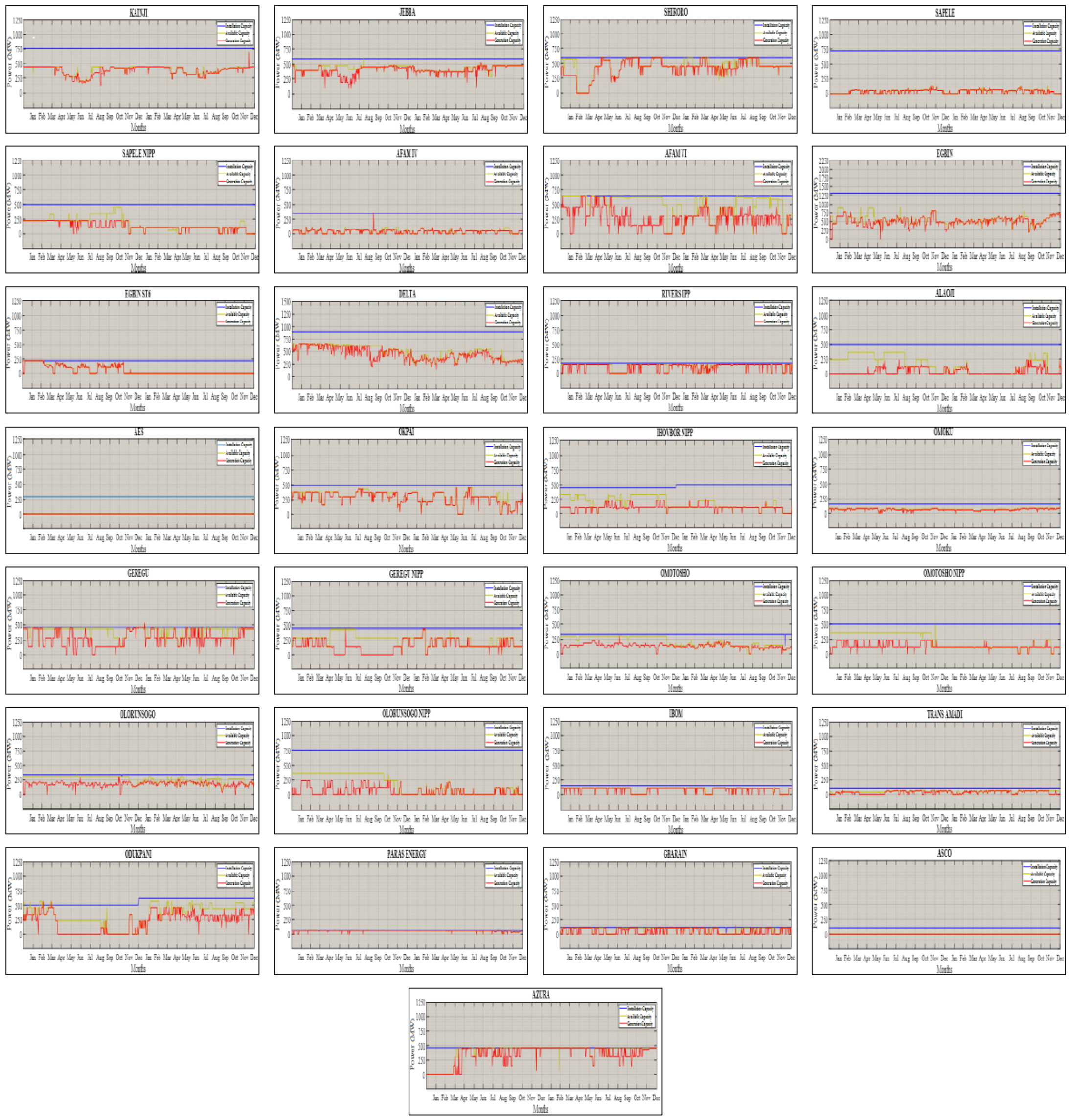

Fig. 2. Two-year general profile of the generation sub-system.

In Table 2, the yearly averages of the operational capacities of all the plants are presented. The table also shows the losses incurred at each power plant as depend on the comparison of the averages and, expressed in the percentages of the YAIC. YAAC and YAGC for the year 2018 are 7,369.7 MW and 5,063.8 MW respectively. Comparing the YAGC with the YAIC of 12,991.4 MW shows that 61.02 % loss was experienced in that year. Similarly, in the year 2019 with YAIC, YAAC and YAGC of 13,166.4 MW, 5,808.1 MW and 5,062.5 MW respectively, there was 61.55 % power loss.

Among other reasons for the slight increase in the percentage loss experienced in 2019, as compared to the preceding year, is that instead of having appreciable increase in the GC of Ihovbor for the upgrade, further reduction was experienced. This is in addition to the fact that Egbin ST6 that was functional all through 2018 was completely down throughout the following year.

Figure 3 describes the generation sub-system across the entire period of study. While the average installation capacity (AIC) was 13,103.9 MW, the average available capacity (AAC) was 6,589.5 MW and the average generation capacity (AGC) was 5,063.2 MW. The loss incurred at the generation for the two years combined was 61.36 %.

Table 2. Yearly capacities and power losses.

S/N	Power Plant	2018 Performance						2019 Performance					
		Yearly Average I.C. (MW)	Yearly Average A.C. (MW)	Yearly Average G.C. (MW)	Loss A (%)	Loss B (%)	Loss C (%)	Yearly Average I.C. (MW)	Yearly Average A.C. (MW)	Yearly Average G.C. (MW)	Loss A (%)	Loss B (%)	Loss C (%)
1.	Kainji	760.0	381.345	366.225	49.82	01.99	51.81	760.0	393.005	387.167	48.29	00.77	49.06
2.	Jebba	578.4	436.036	379.444	24.61	09.78	34.40	578.4	414.847	405.077	28.28	01.69	29.97
3.	Shiroro	600.0	446.723	390.967	25.55	09.29	34.84	600.0	486.381	456.619	18.94	04.96	23.90
4.	Sapele	720.0	037.970	034.753	94.73	00.45	95.17	720.0	042.625	038.942	94.08	00.51	94.59
5.	Sapele NIPP	500.0	257.932	186.339	48.41	14.31	62.73	500.0	092.366	092.256	81.53	00.02	81.55
6.	Afam IV	351.0	049.197	040.736	85.98	02.41	88.39	351.0	042.641	037.356	87.85	01.51	89.36
7.	Afam VI	650.0	585.290	288.900	09.96	45.60	55.55	650.0	439.380	263.100	32.40	27.12	59.52
8.	Egbin	1320.0	586.885	508.134	55.54	05.97	61.51	1320.0	536.132	520.233	59.38	01.21	60.59
9.	Egbin ST6	220.0	118.626	113.059	46.08	02.53	48.61	220.0	000.000	000.000	100.0	00.00	100.0
10.	Delta	900.0	594.986	533.625	33.89	06.82	40.71	900.0	394.364	361.756	56.18	03.62	59.80
11.	Rivers IPP	180.0	134.638	110.484	25.20	13.42	38.62	180.0	139.123	128.934	22.71	05.66	28.37
12.	Alaoji	500.0	251.034	039.656	49.79	42.28	92.07	500.0	070.881	038.576	85.82	06.46	92.28
13.	AES	294.0	000.000	000.000	100.0	00.00	100.0	294.0	000.000	000.000	100.0	00.00	100.0
14.	Okpai	480.0	339.715	320.762	29.23	03.95	33.17	480.0	257.940	236.026	46.26	04.57	50.83
15.	Ihovbor NIPP	450.0	257.705	111.489	42.73	32.50	75.22	500.0	120.955	100.240	75.81	04.14	79.95
16.	Omoku	150.0	069.031	063.515	53.98	03.68	57.66	150.0	064.699	061.841	56.86	01.91	58.77
17.	Geregu	450.0	405.882	260.490	09.80	32.31	42.11	450.0	388.775	315.267	13.61	16.34	29.95
18.	Geregu NIPP	450.0	308.674	112.951	31.41	43.49	74.90	450.0	221.693	205.553	50.73	03.57	54.30
19.	Omotosho	335.0	288.626	152.570	13.84	40.61	54.45	335.0	144.510	127.430	56.86	05.10	61.96
20.	Omotosho NIPP	500.0	335.518	149.019	32.90	37.30	70.20	500.0	119.500	114.502	76.10	01.00	77.10
21.	Olorunsogo	335.0	293.013	165.598	12.53	38.03	50.57	335.0	222.732	176.904	33.51	13.68	47.19
22.	Olorunsogo NIPP	750.0	319.262	087.463	57.43	30.91	88.34	750.0	043.436	033.221	94.21	01.36	95.57
23.	Ibom	155.0	094.849	090.891	38.81	02.55	41.36	155.0	092.041	085.354	40.62	04.31	44.93
24.	Trans Amadi	100.0	049.172	032.334	50.83	16.84	67.67	100.0	050.616	042.246	49.38	08.37	57.75
25.	Odukpani	500.0	230.830	119.643	53.83	22.24	76.07	625.0	442.478	318.730	29.20	19.80	49.00
26.	Paras Energy	072.0	068.304	066.493	05.13	02.52	07.65	072.0	061.572	060.089	14.48	02.06	16.54
27.	Gbarain	120.0	091.945	063.064	23.38	24.07	47.45	120.0	076.685	047.965	36.10	23.93	60.03
28.	ASCO	110.0	000.000	000.000	100.0	00.00	100.0	110.0	000.000	000.000	100.0	00.00	100.0
29.	Azura	461.0	336.579	275.209	26.99	13.31	40.30	461.0	448.721	407.096	02.66	09.03	11.69
Generation Sub-System [All the Plants Combined]		12991.4	7369.77	5063.81	43.27	17,75	61.02	13166.4	5808.10	5062.48	55.89	05.66	61.55

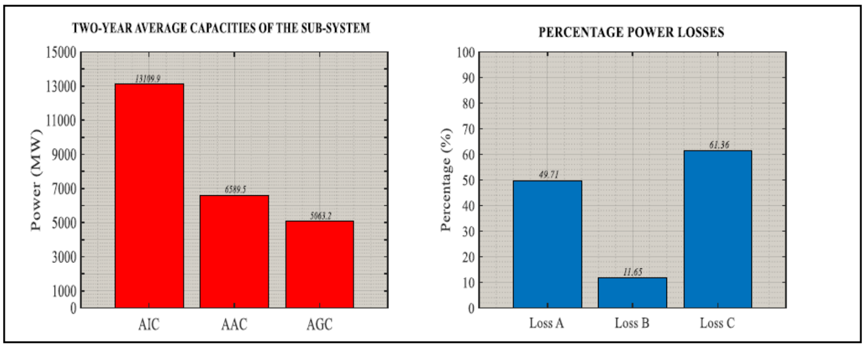

Fig. 3. Two years combined average capacities and power losses.

It is identified that the generation sub-system is persistently plagued in three major ways. As a result of their infrastructural weaknesses, the downstream sub-systems (transmission and distribution) are having their capacities for wheeling generated power, dwindling. There is also the problem of protracted shortage in gas supply for the generation of power. Likewise, the inherent challenge of depreciation in the equipment of the generating plants due to aging and poor maintenance. These are parts of the long-time problems of the electric utility subsector that engendered the reformation of the industry, yet at over two decade of the reformative agenda the operators are still grappling with the old problems. One way by which the listed challenges can be surmounted is massive investment on renewable energy alternatives. Through application of green energy based electric microgrid technology:

(i) The problem of inadequate wheeling capacities by the transmission and the distribution is resolved as these networks are either not required or required at reduced complexities in microgrid operations. The huge costs involved in securing, upgrading and expanding the facilities of these downstream sub-systems are also eliminated or reduced;

(ii) In microgrid operations, generation plants are sited at close proximity to the load centers and so the need to transport energy resources is eliminated based on ready accessibility of the resources. Rather than endlessly struggling with unpredictable availability, persistent shortage supply and price fluctuations of fossil fuels; green energy resources are characterized by abundant availability, free supply and replenishable nature that can propel optimal performance in microgrid systems;

(iii) Depreciations of generation plants equipment are minimized with less dependence on the conventional power plants.

4. CONCLUSIONS

Situation of the electric utility industry in Nigeria continues to deteriorate over the years despite substantial investments in the sector. A major among others factor that are responsible for this is the huge power losses that occur at the generation points. This study has shown that over 61 % power was lost at the generation sub-system of the national grid in each of the years 2018 and 2019. Showing that years after unbundling the power market, there has not been improvement to the pre-deregulation loss profile of the generation sub-system. In essence, the study has ascertained that the generation sub-system, like every other segment of the Nigerian electricity value-chain, is also in crisis mode as the operators are still grappling with the old problems of the sub-system.

Points-of-generation loss has been a continuous phenomenon on the Nigerian grid and has been taking a heavy toll on the performances of the power industry. The effects include limiting the amounts of power wheeled to end users and causing repeated instabilities across the grid network. This is worrisome, as the economic growth of a nation that is keenly looking forward to become, in no distant time, a leading economy on the global scale is being grievously jeopardized. For sustainable development, therefore, synergic attention is required of relevant stakeholders to provide enduring curtailment of the huge power loss.

Electric microgrid technology based on green energy option has an all-encompassing potential to override causes and effects of generation losses. On-going revamping of the existing power plants into their maximum functionalities, together with soonest completion of the fossil-based plants that have been additionally licensed for operation, could make an immediate palliation to the devastating effects of the acute deficit of electric power supply that is at present pervading every aspect of the country’s national existence. However, among the measures earmarked to possibly provide lasting solution to the crisis, massive deployment of green energy option is further advocated.

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