

Post-Reform Evaluation of the Transmission Sub-System of the Nigerian Electricity Value-Chain

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Abstract: This paper provides a post-deregulation performance assessment of the transmission infrastructure of the Nigerian electric power grid using nine years performance profile of eight primary lines of the transmission sub-system. Performances of the lines for the six earliest post-deregulation years are evaluated on a three-year basis, taking their performances for the three-year period that immediately preceded the deregulation as a baseline for comparison. Failure counts and outage durations per each line, in the two three-year post-reform periods, are compared to what was obtained in the baseline period. The results obtained show that the deregulation has not yielded significant improvement in the reliability of the transmission network. This indicates that better attention is needed to be given to the transmission assets being at the heart of the power system. Like the privatized assets of the industry, the state-owned Transmission Company of Nigeria must also be properly attended to in order to achieve sustainable development in the Nigerian electric power sector.

Keywords: Trippings, networks, Primary transmission, Sub-system, Post-deregulation, Relays, Outage durations

I. Introduction

Energy has been a major driving force for social development and economic growth of nations across the world. Thus the development of sub-Sahara Africa depends substantially on the energy potential of the region and the sufficiency of the energy sectors of the constituent countries. Access to a reliable, affordable and sustainable supply of electrical energy has been the mainstay of national advancement because electricity is the pivotal energy source for industrial, commercial, and domestic activities [1]. With its over 170 million inhabitants, Nigeria is the sub-Saharan nation with the highest economic advantage of population [2], but more than half of the population is currently living without electric power [3]. This has been a persistent threat to the advancement of the

country and its people [4] as every aspect of the national economy: rural livelihoods, services provision, manufacturing and imports and exports; is adversely affected by the nation's deficient generation, transmission and distribution capacities.

For more than a decade now, the Nigerian electric utility industry has been under a comprehensive transformation process [5] that is purposed at ending the acute shortage of electric power supply that is confronting the country. The reform process came into a remarkable stage in 2013 with the unbundling of the erstwhile monopoly of the electric power market. Generation and distribution sub-systems of the national grid were ceded to a number of private investors, while the monopolistic and the state-ownership identities were retained for the transmission sub-system.

There have been huge investments in the industry since 1999 hitherto, as a lump sum of \$31.45 billion (₦5 trillion) has been expended [6] in the form of initial capitalizations, as well as palliative interventions that have been directed at improving the efficiency of the

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deregulated market. In 2014, 2017 and 2019, sums of \$1.05 billion (₦213 billion) [7], \$4.35 billion (₦701 billion) [7, 8] and \$3.73 billion (₦600 billion) [7] respectively, were disbursed to the privatized segments of the value chain. While the 2014 grant was for the privatized entities generally, the 2017 disbursement was meant for the Generation Companies, in particular, to offset their gas bills since the generation sub-system has been recording power loss due to the inability of the Distribution Companies to distribute all the power wheeled to the latter by the former [9], and the fund released in 2019 was directed at the Distribution Companies with the goal of paying for revenue deficit that accrued as a result of the end users' tariffs not being cost reflective [8]. In a very recent development, the Federal Government in the year 2020 funded the power sector by \$6.15 billion (₦2.37 trillion), out of which only \$1.6 billion (₦617 billion) was earmarked for the Transmission Rehabilitation and Expansion Programme [10].

The post-reform performance of the deregulated industry has been evaluated in a number of researches. Most of the works provide information on the general challenges that bother mainly on regulatory, financial, incentive and infrastructural issues in the power market [2, 5], while the focuses of certain authors have been on the effectiveness of the reform in terms of the reliability of power supply [11, 12, 13]. The author in [5] isolates the major challenges facing the industry and then analyzes the political economy developments that influence institutional, legislative, and fiscal regulations of the reformed industry. Presented in [11] is an analysis that classifies power supply outages on generation and transmission sub-systems as forced, planned, urgent or emergency, and state the rate of occurrence of each category. In [12], the reliability of the

power industry in the post-deregulation era is discussed in terms of infrastructural improvement in the privatized generation and distribution sub-systems without reference made to the state-owned transmission sub-system. In an assessment carried out on the transmission sub-system by [13], the focus is on secondary (sub-transmission) transmission level together with primary (main) distribution level comprising of a number of 132kV and 33kV circuits respectively.

Transmission is at the heart of the power system. Electrical energy is generated at the power stations that are often far away from the load centres where consumers are located and delivered to the ultimate end users through transmission and distribution sub-systems. Generally, transmission is divided into primary and secondary networks. As regard to Nigerian grid, the primary transmission network comprises of 330kV lines, while the secondary networks are operated at 132kV voltage level. Hence, to provide a holistic evaluation of the power market reform in the context of performance improvement, it is imperative that the transmission sub-system is wholly assessed. Most of the transmission assets are between half-century and a century in age [14] at the time of the unbundling, yet there has been a continual increase in transmission congestion with the ever increasing demand for electricity. Despite this stress, it could be noticed that in the actual implementation of the deregulation, transmission more than any other sub-system of the power industry, has been suffering from deferred investments [7, 8, 9, 10]. This might be due to underestimation of the depreciation that has taken place on the infrastructural asset of the sub-system over the pre-deregulation years, thus holistic performance evaluation of the sub-system is imperative. Improved transmission asset reinforces the grid for

better performance, hence; this study assesses the primary network of the transmission, to complement the assessment of the secondary section that is already available in the literature. More so, the renewable portfolio standard that is an integral part of the reform plan, may soon increase the burden on the transmission facilities as there is a possibility of having renewable generation sites located far from load centres.

The evaluation carried out in this study, therefore, emphasizes the post-deregulation performance of the primary networks of the transmission assets of the national grid, as compared to the pre-deregulation performance of the sub-system

II. Materials and Methods

This study involves data collection and analysis, with the primary transmission network within Osogbo Region of the Nigerian national grid employed as a case study. The network under study is made up of 10 lines of 330kV with an aggregate length of 1,496.02 km as presented in Table 1, until two of the lines (CCT M5W and CCT B5M) were seceded to the neighbouring Benin Region starting from January 2018. This study thus focuses on 8 lines of 1,206.02 km aggregate length.

Table 1: Primary (330kV) Transmission Lines within Osogbo Region

S/N	Line	Code	Length (km)
1	Osogbo – Ihovbor	CCT H7V	222.35
2	Osogbo – Ikeja West	CCT H1W	247.65
3	Olorunsogo – Ayede	CCT R2A	159.00
4	Omotosho – Ikeja West	CCT M5W	183.00
5	Osogbo – Ayede	CCT H2A	104.62
6	Benin – Omotosho	CCT B5M	107.00
7	Jebba – Ganmo	CCT J3G	105.00
8	Osogbo – Ganmo	CCT H3G	53.40
9	Jebba – Osogbo 1	CCT J1H	157.00
10	Jebba – Osogbo 2	CCT J2H	157.00

Note: CCT M5W and CCT B5M were seceded to the neighbouring (Benin) region as from January 2018

Data relating to the performances of the lines for a period spanning nine years (2011–2019)

was obtained from the Osogbo Regional Control Center (RCC) of the Transmission Company of Nigeria (TCN), which is situated in the city of Osogbo in the South-Western part of the country. Contained in the data are records of tripping occurrences on the lines, together with the locality of each of the trippings whether it was within or outside the region. Dates, times and durations of the failures, as well as information on the remedial responses given to each failure also form parts of the record.

Deregulation of the Nigerian power industry was signed into law in November 2013 [15]. This study is, therefore, based on three distinct three-year periods designated in the study as: Pre-Deregulation (2011–2013), Deregulation-Dawn (2014–2016), and Late-Deregulation (2017–2019). The pre-deregulation period is considered as the baseline, to which the other two periods are compared to show if there has been improvement in the power supply reliability of the lines due to the power sector reform. Failure counts and total outage duration per line, in the two three-year periods, are compared to what is obtained during the baseline period.

III. Results and Discussions

Failures recorded on the transmission network were due to tripping of relays occasioned by fault occurrences. The type of faults experienced on the network includes burnt relay leg, burnt gear switch, over-voltage, short/open circuit, earth fault and transmission tower collapse. The faults in the post-deregulation are classified by their locations of occurrence as figure 1 shows, though there was no record of fault locations for the pre-deregulation period. From the figure, it could be found that during the deregulation-dawn period, 74% of the faults was within the facility of the network, while

23% occurred outside the facility of the network, and the locations of 3% was not recorded. Similarly, in the late-deregulation period, 66%, 29% and 5% of the faults did occur within the network, outside the network and un-recorded locations, respectfully. The high frequency of fault occurrences within the network, in the two post-deregulation periods, indicates degradation of the infrastructural assets of the network as well as lack of adequate attention.

On each tripping, either a power outage on a certain portion of the network or a total collapse of the entire network is experienced. For outages involving a portion of the network, load on the concerned line is transferred to another line, pending the clearance of the fault, with a number of lines linked together when it is so required to accommodate a large load. Cases of network collapse were as presented in Figure 2 that shows a significant reductions in the number of collapses from 58 in the pre-deregulation period to 25 in the deregulation-dawn period and 23 in the late-deregulation period. Following each collapse, the network used to be re-energized after identifying type and location of the causative fault and, the fault is rectified.

The actual performance of the network, in terms of tripping cases along the lengths of the lines, were as presented in Table 2. It could be deduced from the table that except CCT R2A, CCT H2A and CCT J3G, there were more trippings on the lines during the deregulation-dawn period than was experienced during the pre-deregulation period. On the whole, the incidents of tripping on the entire network were more during the deregulation-dawn than what obtained during the pre-deregulation. In a similar vein, tripping counts on CCT H7V, CCT H1W, CCT H3G and CCT J1H were

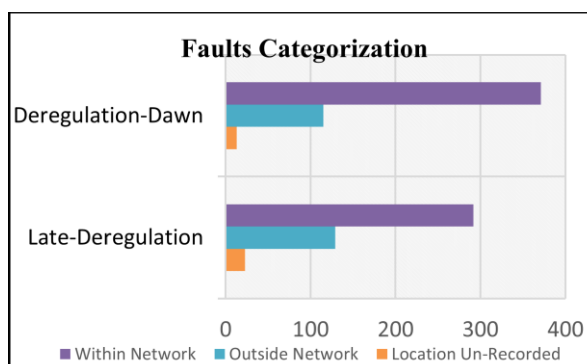


Figure 1: Categorization Faults by their Locations of Occurrence

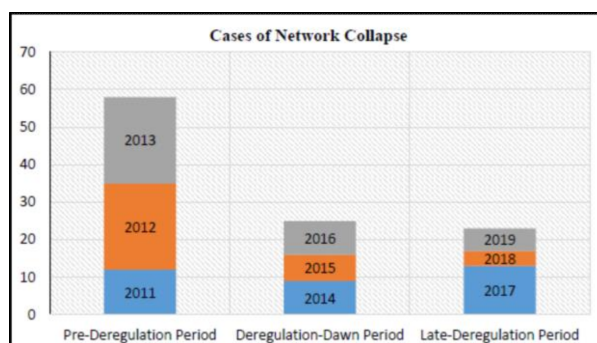


Figure 2: Rate of Network Collapse per Period

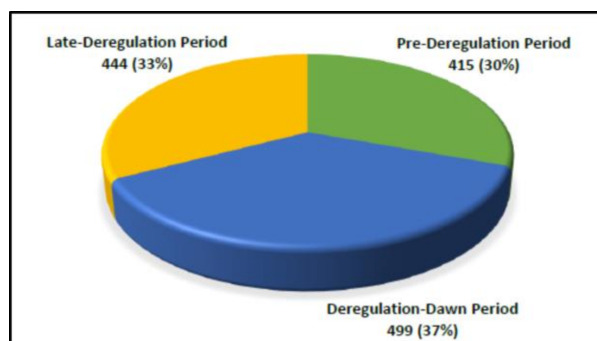


Figure 3: Comparison of Tripping Counts per Period

higher during the late-deregulation period than what were obtained during the pre-deregulation period, while the reverse is the case on CCT R2A, CCT H2A and CCT J3G, and the counts on CCT J2H were equal for both periods. Across the entire network, nevertheless, there were more trippings during the late-deregulation period as compared to the pre-deregulation period.

Table 2: Yearly Counts of Trippings on Circuits

PERIOD	YEAR	CCT H7V	CCT H1W	CCT R2A	CCT H2A	CCT J3G	CCT H3G	CCT J1H	CCT J2H
Pre- Deregulation	2011	38	48	20	21	04	10	01	04
	2012	29	38	29	25	08	05	02	02
	2013	25	35	40	19	07	03	02	00
	Total	92	121	89	65	19	18	05	06
Deregulation- Dawn	2014	52	45	29	18	05	21	16	10
	2015	41	35	27	13	03	06	10	04
	2016	61	57	28	14	00	04	00	00
	Total	154	137	84	45	08	31	26	14
Late- Deregulation	2017	54	57	23	17	03	10	05	03
	2018	15	34	26	05	04	05	05	01
	2019	36	50	25	21	10	20	13	02
	Total	105	141	74	43	17	35	23	06

From Figure 3, it is obtained that there was a total of 1,358 cases of trippings across the entire network for the nine years under study; with 415 (30%), 499 (37%) and 444 (33%) of the cases experienced during pre-deregulation, deregulation-dawn and late-deregulation periods respectively.

Separately comparing each of the two post-reform periods with the baseline pre-deregulation period reflects a general lack of improvement in the operation and, invariably, the infrastructural facilities of the network. Increase in the tripping counts of the deregulation-dawn over the pre-deregulation might have been due to lack of adequate attention on the transmission assets during the early season of the deregulation, possibly resulting from underrating or underestimating the depreciation that has occurred on the assets over decades preceding the reform

However, a reduction is noticed in the tripping counts of the late-deregulation period compared to that of the deregulation-dawn period. This could be due to the assets receiving some attention, though not much significant yet.

Presented in Table 3 are the details of power outage durations on the lines. Outage on the entire network was generally longer during the deregulation-dawn than what was obtained during the pre-deregulation. This is because except on CCT J3G, longer outages were

experienced on all other lines during the deregulation-dawn period than the pre-deregulation period. Likewise, the period of power outages were longer on CCT R2A, CCT J3G, CCT H3G, CCT J1H and CCT J2H during the late-deregulation period than what were obtained during the pre-deregulation period, with the reverse being the case on CCT H7V, CCT H1W and CCT H2A. Nevertheless, when the two periods are compared, the network as a whole had a longer outage duration during the late-deregulation period than what obtained in the pre-deregulation period.

Throughout the nine years under study, there were outages of power for a total duration of five thousand one hundred and sixty-six hours, and thirty-five minutes (5,166h:35m) on the network as Figure 4 reveals. Distribution of the duration for pre-deregulation, deregulation-dawn and late-deregulation periods are 1,376h:50m (26.6%), 2,394h:02m (27.1%) and 1,395h:43m (46.3%) respectively. As it is obtained in the tripping counts, there are increases in the outage durations during the deregulation-dawn period and the late-deregulation period as separately compared to the pre-deregulation period, as well as a reduction in the outage duration of the late-deregulation period compared to that of the deregulation-dawn period.

Table 3: Cumulative Durations of Line Outages

PERIOD	YEAR	CCT H7V (h:m)	CCT H1W (h:m)	CCT R2A (h:m)	CCT H2A (h:m)	CCT J3G (h:m)	CCT H3G (h:m)	CCT J1H (h:m)	CCT J2H (h:m)
Pre-Deregulation	2011	15:33	134:22	03:15	53:25	15:53	82:03	01:14	03:00
	2012	37:29	237:14	81:49	38:48	08:38	16:27	08:44	06:18
	2013	216:54	152:23	174:42	60:14	23:24	02:49	02:12	00:00
	Total	269:56	523:59	259:46	152:27	47:55	101:19	12:10	09:18
Deregulation-Dawn	2014	116:45	130:29	130:23	92:38	08:46	298:12	92:37	50:56
	2015	43:34	75:08	140:23	48:50	30:24	35:17	47:13	00:17
	2016	420:17	373:14	104:03	52:57	00:00	59:22	00:00	42:17
	Total	580:36	578:51	374:49	194:25	39:10	392:51	139:50	93:30
Late-Deregulation	2017	44:44	104:22	27:51	40:46	01:14	45:37	21:50	00:58
	2018	17:55	64:31	160:19	01:48	03:53	02:36	00:49	240:48
	2019	45:13	136:10	93:19	103:12	92:29	102:59	42:04	00:16
	Total	107:52	305:03	281:29	145:46	97:36	151:12	64:43	242:02

h:m = hour:minute

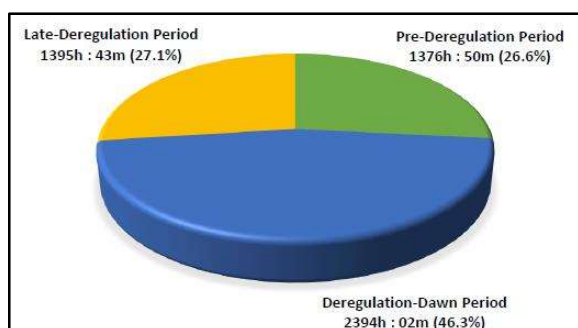


Figure 4: Comparison of Outage Durations per Period

The similarity in the trends of failure counts and outage durations reinforces the assertion that there was lack of adequate attention on the transmission assets during the early season of the deregulation, followed by minimal attention as time passed by.

IV. Conclusion

The latest reform in the Nigerian electric power sub-sector commenced in 1999 and has lasted a decade. The year 2013 deregulation of the power industry and the huge investments on same in terms of initial capitals and subsequent palliative funding have been prominent features of the reform, all in the effort to ensure improvement of electricity supply experience in the country. However, this study by comparing the post-deregulation dispensation with the pre-deregulation era, reveals that the transmission

sub-system in particular has not been faring well in the post-deregulation. Unlike the privatized firms of the electricity value-chain that have been heavily funded, the state-owned transmission asset of the industry has not been accorded much attention.

As Nigeria continues striving towards achieving the target of having a steady power supply to end-users. It is important that the transmission infrastructures be accorded better management than it is presently experienced. By expediting action on overhauling, upgrading and expansion of the transmission assets, this segment of the power system would become fully functional. With the transmission sub-system having a robust energy wheeling capacity, the downstream distribution facilities would be enabled to tap into a rich energy mix. This would make achievement of sustainable development in the Nigerian electric power sub-sector possible.

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