

REDUCTION OF DISTRIBUTION LOSSES, AN ESSENTIAL TO IMPROVE POWER SYSTEM OPERATIONS IN NIGERIA

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ABSTRACT

Power systems are extremely complex systems, comprising of generators, transformers, buses, lines, loads (motor) and the associated protection & control devices/circuitry. Power system engineering or operations in Nigeria deals with the business of generation, transmission and distribution of electric power (electricity). Each components of the power system of generation, transmission & distributions have losses inherent in them which affect the efficiency & reliability of the entire power system operations. Therefore, there is an urgent need to reduce these losses not just for operational and revenue gain but also for economic growth/infrastructure as a stable & affordable electricity is the backbone of industrialization. This study highlights the various components of Aggregate losses in Distribution Sector; the impact of these distribution losses on power delivered by grid; and offers the way forward to reduce these losses for optimal grid performance and accelerated socio-economic/infrastructural development.

Key words: DISCOs, Electricity, HVDS, Distribution Losses, Power Systems.

1.0. Introduction

The beginning of human civilization was marked using electricity. Electricity is the most widely used form of energy and the most basic component of modern civilization as it impacts every facet of a nation's economy, ranging from Manufacturing, Sport, Education, Military, Health, Agriculture, Entertainment, Aviation, Telecommunication, Mass Media etc. (Dugeri et al, 2019). It is apparent that the global electricity demand has more than doubled in the last two decade. This growth is accounted for by two factors namely, the drive for improved socio-economic lives of citizenry, and the increase of the world's population (Michaelides, 2012). As such, its availability and usage are an indicator of how well a nation is developed. Unfortunately, 1.6 billion people on this planet have no access to electricity (GENI, 2018). Of this number, 600 million people in Africa lack access to electricity (according to the World Bank data from 2016). The result has it that even on a very optimistic assumption the current trajectory of its universal electrification (7th item on Sustainable Development Goals), 240 million people will still lack electricity by 2030 (WEC, 2018). For instance, the average residential electricity consumption in sub-Saharan Africa (excluding South Africa) is the same as electricity consumption in New York State (IEA 2014). That is, the 19.5 million people in New York consume the same amount of electricity, approximately 40 terawatt-hours (TWh), as is shared between the 791 million people of sub-Saharan Africa. Universal access to electricity is thus widely believed to be the region's greatest energy challenge (Abaka et al, 2017). The rule of thumb has it that, for any industrialized nation (for which Nigeria aspired to be) requires minimum 1,000MW per million inhabitants. This would imply that Nigeria requires 180,000MW-200,000MW (going by the country's population estimate) of full power which is some distance away (Dugeri et al, 2019). This shows that Nigeria has a large electric power-hungry population and it then becomes imperative for maximum utilization of the available grid power. And one such effective way is to reduce losses associated with its power system operations.

Power systems are extremely complex network of generators, transformers, buses, lines, loads (motor) and the associated protection & control devices. Power system engineering or operation deals with the business of generation, transmission and distribution of electric power (Ducan, 5th edition). The key requirements in an optimized electricity system are supply security, improved system efficiency, high system reliability, low operational cost, improved system power quality, minimal environmental impact and the effective integration of available renewable energy resources (El-Saaday et al, 2017). Regrettably, Nigeria power grid is far from meeting these requirements as analysis of unutilized power recorded by the Independent System Operator, a section of Transmission Company of Nigeria (TCN) indicates an average 1000MW of power rejected daily by the Distribution Companies (TCN, 2013)

The three major component of power system in Nigeria are

- i. Generation system
- ii. Transmission system
- iii. Distribution system

This paper is focused on the distribution system and ways of reducing its losses which are summed up as the *Aggregate Technical, Commercial and Collection* (ATC & C) loss. This is due the critical role of distribution system in the electricity value chain as shown in figure 1.0.

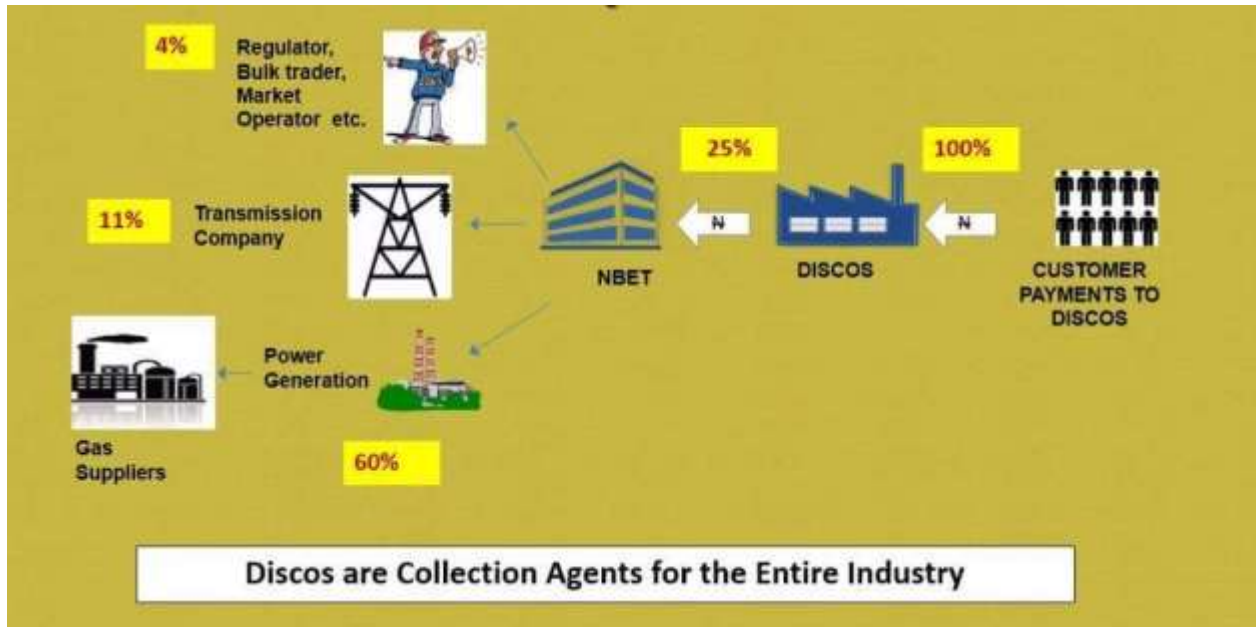


Fig 1.0: An image of electricity value chain in Nigeria, [Vigeo Power Training Institute]

2.0 Components of the Distribution Losses

- i. Technical losses
- ii. Commercial losses
- iii. Collection losses

These losses are usually expressed as Aggregate Technical Commercial & Collection (ATC & C) loss, which is mathematically represented as,

$$ATC \& C \text{ Loss (\%)} = \{1 - (1 - \text{technical losses}) \times (1 - \text{commercial losses}) \times (1 - \text{collection losses})\} \quad (1)$$

Or

$$ATC \& C \text{ Loss (\%)} = 1 - \{(tech. efficiency) \times (commercial efficiency) \times (collection efficiency)\} \quad (2)$$

Where

$$technical \text{ loss} = 1 - (\text{energy received at injection substation} / \text{energy delivered to customer}) \quad (3)$$

$$commercial \text{ loss} = 1 - (\text{energy delivered to customer} / \text{billed energy}) \quad (4)$$

$$collection \text{ loss} = 1 - (\text{collection in naira} / \text{billed energy in naira}) \quad (5)$$

2.1. Technical Losses

These are losses due the operations of distribution equipment such transformers, switches and distribution lines. They are more pronounced in distribution transformers and distribution lines.

2.1.1. Transformer Losses

Transformed voltage and current in transformer are always less than values predicted by its turn ratio as a result of losses. These losses are either

- i. No-load loss, also referred to as iron loss or core loss, because core losses do not require load currents but depends on the transformer core materials. This loss increases with transformer's aging and transformer of poor-quality materials.
- ii. Load loss or copper loss results only from load currents which is caused by poor transformer sizing (either under-sizing or over-sizing). The higher this load current, the higher the specific electric loading of the transformer (Ducan, 5th edition). i.e.

$$q = \left\{ \frac{3 \times I_{ph} \times Z_{ph}}{\pi D} \right\} \quad (6)$$

Where Z_{ph} = total no of conductor in transformer core

I_{ph} = phase current

D = diameter of transformer core

The large value of q means great amount of copper resulting in higher copper losses and temperature rise in the transformer. Thus, load losses limit the kVA capacity of transformer because the heat generated by the losses increase temperature.

2.1.2. Line Losses

This is due to the physical properties of distribution lines, principally resistance (Ducan, 5th edition)

$$\text{line losses} = I^2 R \quad (7)$$

Where

$$R = \frac{\rho l}{A} \quad (8)$$

I = current flowing in the line

R = effective line resistance

ρ = resistivity

l = Length of conductor

A = cross sectional area of conductor

Thus, distribution lines with multiple joints along its routes, tends to result in high technical losses. Also joints of two wires of different electrical properties (e.g. copper & aluminum) as seen in transformer cables contribute greatly to these losses.

3.2. Commercial Loss

This is primarily caused by poor metering infrastructure, wrong customers tariff classifications, illegal connections on lines (hooking/tapping) and power theft (meter infractions). The Association of Nigerian Electricity Distributors (ANED) reported that there are over 20 million buildings & facilities (consumers) connected to the grid with only 10.4 million in her members' books (customers). Unfortunately, of these 10.4 million customers only 8 million are currently being billed (as active customers), with nearly 4 million (representing 50%) having meters which are either obsolete or tempered/compromised. This has resulted in an average revenue collection deficit of 40 billion naira monthly (Kester, 2020). It's also reported that electricity theft accounts for up to 40% of the electricity distributed.

2.3. Collection Loss

This is a result of poor marketing strategies, in terms of difficulty in accessing payment channels and unwillingness of customers to pay fully for energy consumed. In the referenced ANED document, it was reported that the remaining 4 million un-metered customers are made to pay for the electricity consumed by them and the other 12 million consumers (those not on DISCOs books) & losses in the system (Kester, 2020). This anomaly has resulted in unwillingness of customers to pay for over blotted bills by DISCOs.

3.0. Impact of High ATC & C Losses

1. Load rejection by DISCOs which result in poor power supply to customers & grid disturbance. See tables 4.1, 4.2 respectively.

Table 4.1: Grid percentage load allocation to Discos October 2013 (TCN, 2013)

S/N	DISCO	Percentage Load Allocation (%)
1	Abuja	11.5
2	Benin	9
3	Eko	11
4	Enugu	9
5	Ibadan	13
6	Ikeja	15
7	Jos	5.5
8	Kaduna	8
9	Kano	8
10	Port-Harcourt	6.5
11	Yola	11.5

Tables 4.2: National grid performance TCN-DISCOs (TCN, 2017)

DAILY DISCOS LOAD SUMAARY FOR 13/08/2017						
DISCO	MAX Load Nominatio n (MW)	MYTO Allocatio n (MW)	Actual Consumptio n (MW)	Rejected /Unutiliz ed Load (MW)	Excess Load (MW)	Differenc e (%)
Abuja	399.89	453.01	303.78	149.23	0.00	-33
Benin	245.00	316.43	223.89	92.54	0.00	-29
Eko	350.31	460.78	356.07	104.71	0.00	-23
Enugu	252.17	295.18	233.45	61.73	0.00	-21
Ibadan	396.63	439.71	348.21	91.50	0.00	-21
Ikeja	411.78	701.97	441.04	260.93	0.00	-37
Jos	166.25	194.56	136.39	58.17	0.00	-30
Kaduna	280.00	218.46	158.47	59.99	0.00	-27
Kano	310.60	269.05	179.35	89.70	0.00	-33
Port-Harcourt	383.15	253.15	256.01	0.00	2.86	1
Yola	100.00	114.79	99.53	15.26	0.00	-13
DAILY DISCOS LOAD SUMAARY FOR 26/07/2020						
DISCO	Max Load Nominatio n (MW)	MYTO Allocatio n (MW)	Actual Consumptio n (MW)	Load Rejected (MW)	Excess Load (Mw)	Differenc e (%)
Abuja	396.4	544.08	388.16	155.92	0.00	-29
Benin	296.7	400.70	272.89	127.81	0.00	-32
Eko	400.0	589.74	351.00	238.74	0.00	-40
Enugu	367.3	425.70	255.25	170.45	0.00	-40

Ibadan	585.5	599.78	422.41	177.37	0.00	-30
Ikeja	620.9	767.83	513.75	254.08	0.00	-33
Jos	166.3	258.62	153.95	104.67	0.00	-40
Kaduna	273.8	356.17	263.11	93.06	0.00	-26
Kano	294.8	356.17	209.87	146.30	0.00	-41
Port-Harcourt	328.4	303.14	181.31	121.83	0.00	-40
Yola	137.1	169.58	114.19	55.39	0.00	-33

Note: $\text{difference \%} = \frac{((\text{actual cons} - \text{myto alloc}))}{(\text{myto alloc})} \times 100$

Max. Load Nomination: Daily Estimate of Power requested by Discos

2. Probable grid shutdown due to cash liquidity in the value chain, as customers have generated apathy toward payments of electricity occasioned by power poor supply and over blotted bills.
3. Discourage industrialization. In Nigeria the electricity consumption per capita is about 100kWh – which compares poorly with 4,500kWh, 1,934kWh and 1,379kWh in South Africa, Brazil & China respectively (Akuru & Okoro, 2014). This power deficit weight negatively on business operations in Nigeria and at this rate, the country’s quest for industrialization will become more difficult to attain.
4. Low per capita income of citizen due to high cost of alternative energy sources. The more affluent a society is the more energy it consumes per capita.
5. Discourages Investment. People and organizations would not invest in a system with high losses.

4.0. The Way Forward

1. Optimal sizing of transformers and conductors for new or reconstructed installations.
2. A practical and feasible solution to minimize losses associated with the current distribution system is by replacing the traditional low tension (LT) distribution system with High Voltage Distribution System (HVDS). [12] This system has been adopted world over and in developing country like India etc.

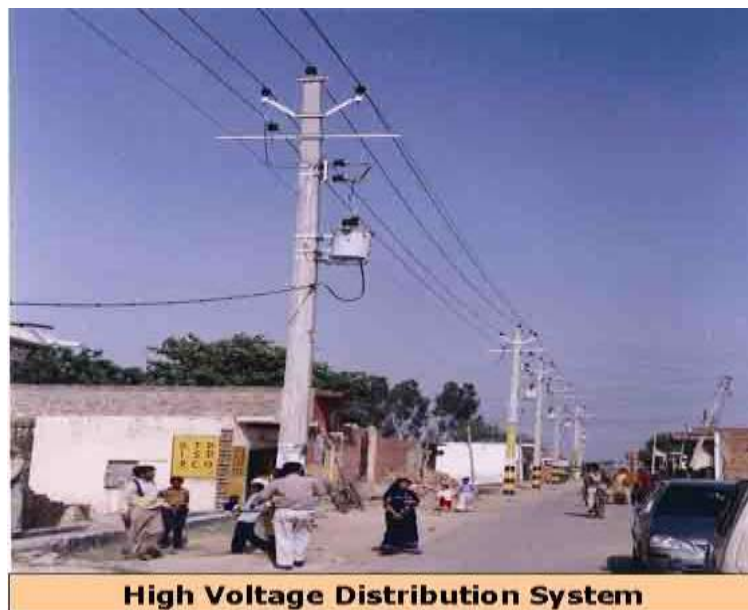


Fig 5.1: HVDS in High Loss Area, Andhra Pradesh India [source: Tata Power Company]

4.1. Technical superiority of HVDS over existing distribution systems.

- i. Reduced line losses.
- ii. Excellent voltage profile and grid stability.
- iii. Bringing un-authorized consumers into billing net as unauthorized hookings are avoided.
- iv. No frequent fuse blow outs due to transformer overloading.
- v. Lower instances of line faults due to reduction of LT line length.
- vi. This system helps to improve metering of customers.

4.1.1. Myths about HVDS

- i. High Capital Cost
 - ii. Safety
 - iii. Interference with telecommunication system
3. Deployment of Technology. The global energy industry faces fundamental changes in the way it generates, distributes and sells electricity today (WEF, 2018). Artificial intelligence (AI) could be a very useful and even powerful tool for meeting these needs. AI could offer the followings in reducing distribution losses [14].
- i. Load Forecasting: Short & Mid-term load forecasts are vital for Discos. AI could be used to forecast supply and demand in real time and optimize economic load dispatch.
 - ii. Predictive Maintenance: can be bolstered with drones for asset inspections, replacing time intensive and risky manual inspections. The drones are trained using deep learning algorithms to automatically identify defects and predict failures without interrupting operations.
 - iii. Energy Theft: AI can be used to detect usage patterns, payment history, and other customer data that may signal irregular behavior.
 - iv. Virtual agents: will revolutionize call centers, being able to respond to consumer queries and provide instant assistance. They will be able to automatically segment consumers based on service history and provide early warning of bad debts. This will eventually unlock the capacity to fully automate customer service.
4. Deployment of Distributed Generation (DG). Electrical networks recently in advance countries are in the epoch of key transition from steady passive distribution networks with uni-directional electricity delivery to active distribution networks with bi-directional electricity delivery which is offered by DG (Zareipour et al, 2004). CIGRE describe it as a concept of generation, which is characterized as follows; it is not centrally strategic or planned; it is not centrally dispatched at present; it is usually connected to the distribution networks (CIGRE, 1999).
5. Enforcement of enabling regulatory laws to help Discos collect their money and be compelled to offer quality services to their esteem customers. E.g. energy anti-theft law, quality service law, anti-estimated bill law, laws that will incriminate non-payment of electricity bill by users especially government MDAs etc.

5.0. Conclusion

From the study carried out, its obvious that reduction of distribution losses to its barest minimum will make available a daily average of 1500-1600MW un-utilized and stranded power on the grid. Its therefore, imperative for distribution companies to plan, design and re-design their distribution networks to ensure they are operating at optimal level leveraging on technologies such as HVDS, Smart Meters & Anti-Tamper Techniques, Distributed Generation, smart integrated payment channels, and a robot customer complaint resolution channel inter alia.

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