

The Implications of the Nigeria Power Systems Losses on the Electricity Market and Consumers

ABSTRACT:

Different types of energy exist but so far electrical energy is the most important form of energy. The electrical power grid operated in most parts of the world today is made up of three sections which are generation, transmission, and distribution, where the Nigerian electrical power sector holds a lot of unfulfilled potential for economic development with electric energy generated not up to 30% of the national demand and 50% of it recorded as losses.

This paper will examine the losses involved in power systems starting from the generation station to the transmission line, then the distribution sector and the practical ways these losses affect both consumers and businesses.

These losses could be technical or non-technical losses affecting the efficiency of power supply, its revenue in the economy, sustainability, reliance on the people and the effective operation of the power system due to poor grid structure, low financial investment, and lack of policy in the country.

KEYWORDS: Consumer, Energy, Losses, Power System network, Reliability

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1.0

INTRODUCTION

Energy has been and is still an important factor for socioeconomic and economic development in the world, its use cannot be over-emphasized in key areas of the economy such as industries, agriculture, transportation and service sectors. According to the World Bank 2013, only 48% of Nigeria's 174 million people have access to electricity compared to other African countries. Hence, an inadequate supply of energy restricts socioeconomic activities such as manufacturing, mining, transportation, telecommunication, and worker productivity which are essential factors for economic growth due to its dependency on electricity. Electric energy losses are broadly divided into two sections: technical losses which occur because the electrical equipment used in the power system has losses which cannot be eliminated naturally and non-technical losses which occur due to energy theft, poorly estimated billing, defective metering equipment, unpaid bills etc. Loss minimization is crucial to ensure that electricity systems can deliver a clean, secure and affordable energy supply to society.

1.1 BACKGROUND STUDY:

Electricity is one of the greatest technological innovations of mankind which have become a part of our life and one cannot think of a world without it. Almost all devices at home and industries run on electricity and electrical energy is generally produced by conversion from other forms of energy. This often takes place at a remote location without human habitation and the electricity generated is sent through transmission lines to distribution networks from where it is delivered to the consumers through various means of electrical equipment. The equipment and apparatus required for the generation, transmission and distribution of electrical energy from the electric power system. Losses in power systems are inevitable, and there are two types of losses namely non-technical (due to human errors and social issues) and technical losses (the result of heat dissipation resulting from current utilization in the power lines. It is therefore necessary to evaluate and minimize power system losses to enhance network efficiency and high-quality supply of electricity to end-users with reliability and economy.

Figure 1 shows the block diagram describing the different power sector in the Nigeria power grid.

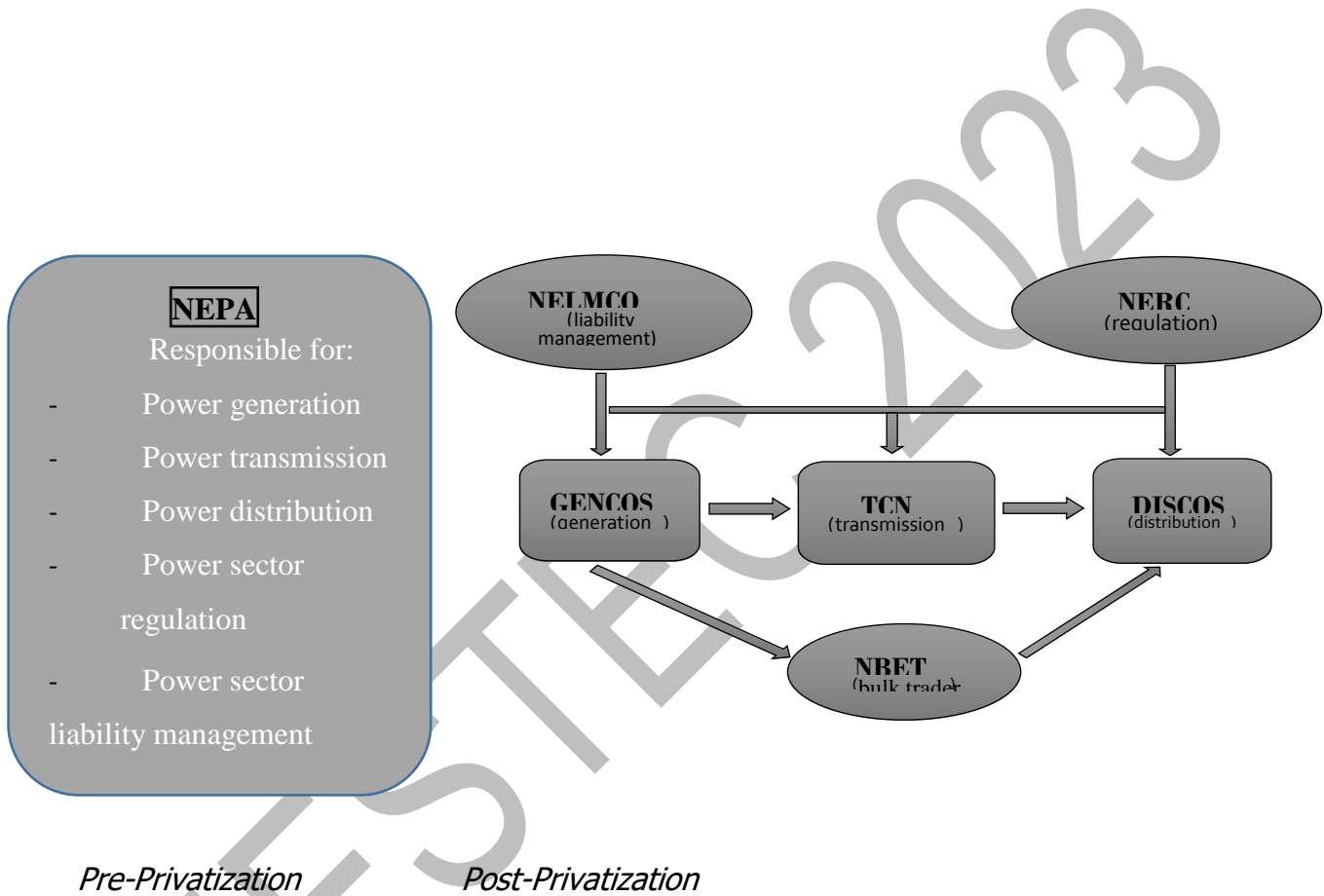


Fig1: Structure of the Nigerian Power Sector (before and after privatization).

1.2 AIMS AND OBJECTIVES

The study aims to focus on the losses in the Nigeria Power System and look at the practical ways in which the losses affect consumers and businesses.

Objectives of this work include:

1. To understand the need for power supply (electricity) in our daily life, and how it affects society at large.
2. To understand the magnitude and causes of losses involved in the Nigeria Power System.
3. To analyze how the losses occur in GENCOS to TCN and DISCOS, with its effects on consumers.
4. To understand the losses in Power Distribution Systems and ways of minimizing them.

1.5 SIGNIFICANCE OF STUDY

This study looks at the losses encountered in the Nigerian power system and the ways they affect consumers and businesses. It would provide an understanding of how to minimize those losses that can be controlled by employing rules and regulations for offenders (theft), providing various ways electricity can be transported to final consumers at its minimal loss and exploring renewable means of power generation thus guiding the power sector. With the losses minimized, the energy can be used effectively in the areas of agriculture, education, transportation, technological advancements and others for the growth and progress of the country, thus providing revenue for the country and meeting the electricity demand needed in the country.

2. DISCUSSION

2.1 Nigeria Electrical Power Sector:

The Electricity Corporation of Nigeria (ECN) managed the electricity supply in Nigeria way back as from 1950 when it was first established until 1972 when the National Electric Power Authority (NEPA) came into existence. NEPA continued to grow until its unbundling after the enactment of the Electric Power Sector Reform Act (EPSRA) in 2005. With the power sector unbundled and generation/distribution sectors privatized, it now leads to a renewed focus on achieving profitability. The sectors of the Nigeria Electricity Supply Industry (NESI) operating today are as follows:

1. GENERATION COMPANIES (GENCOS):

GENCOs are privately owned power plants located all over the country which produce the electricity used using commercially viable approved means and inject it into the grid. About 28 power plants exist in Nigeria today with installed capacity ranging from 22 MW to 1074 MW. Particularly, ensuring the availability, reliability, sustainability, and affordability of energy sources is critical to higher and sustained power generation in the country, where the bulk of Nigeria's power supply is derived from fossil fuels, although Nigeria can generate up to 6.5 kWh/m² of solar energy per day yet it is not being exploited sufficiently.

Currently, the NESI (Nigeria Energy Systems Integrator) has undiversified energy sources, with GENCOs heavily dependent on thermal energy consisting of 80% of the electric source and hydro being 20%. The generators/transformers have losses in their windings (due to the winding resistance) as well as their core (due to eddy current and hysteresis), there is a large (and widening) gap between the national demand and the available generation capacity.

2. TRANSMISSION COMPANY OF NIGERIA (TCN):

TCN is responsible for the transmission of high voltage electricity, management, operation and expansion of 330 kV and 132 kV transmission system. Whereas, the transmission loss is computed from the difference between the power metered at the GENCO and the power metered at the distribution end; the regulatory target is 8.05% (although this is above the emerging countries benchmark of 2% to 6%).

The challenges in the transmission segment of the electricity value chain lie in financial constraints, lack of modern transmission lines and equipment, gross mismanagement, poor maintenance of available infrastructure as well and inefficient grid design and operation.

3. DISTRIBUTION COMPANIES (DISCOs):

There are eleven DISCOs in operation which handles the billing/collection of tariff and remit to the Market Operator for disbursement to eligible stakeholders in the NESI. However, they are faced with the challenges of huge Aggregate Technical, Commercial, and Collection (ATC&C) losses and lack of access to funding. Firstly, DISCOs are experiencing subsequently ATC&C losses daily due to their poor distribution infrastructure, poor billing system, electricity theft, and non-payment of electricity bills, where a lot of electricity consumers are either not metered or use obsolete meters leading to inaccurate billing; thus culminates in commercial losses for DISCOS. In this regard, NERC mandated all DISCOS to meter their customers and avoid estimated billing.

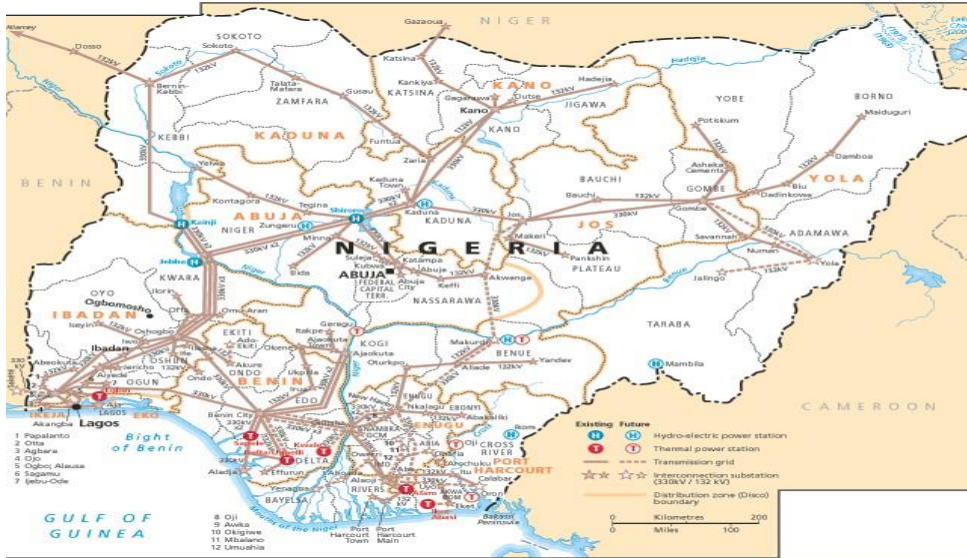


Figure 2: The Nigeria Electricity Grid Network.

2.2 THEORETICAL ANALYSIS:

Electricity losses in Nigeria are on the increase with a series of glaring losses ranging from economic losses, Social losses, Health sector and Political losses which have led to the collapse of Nigeria's economy. With the power generating stations situated far from the consumer's premises, it is essential to step up the generated voltage during transmission to higher levels, where electrical distribution is the last stage in the delivery of electricity to consumers.

Distribution network losses occur between the electrical energy entering the distribution line from the embedded generators or upstream to downstream and leaving it to the consumers for consumption purposes. The losses are detailed into (2) broad categories:

1. TECHNICAL LOSSES:

This type of loss in the power system occurs naturally consisting of energy dissipation in electrical system components such as transformers, connections, measurement systems and other electrical components used in transmitting electrical energy to consumers. It depends on the power grid, transformational and voltage level likewise

the length of the power lines. The technical losses can be further divided into Variable losses (load-related), Fixed losses and Network services.

- A. **Variable Losses:** These are losses occurring when current flows through resistive materials, power system components and their parts such as transformer coils, aluminium or copper wires in transmission and distribution lines or cables and other components having internal resistances, which generate heat when current flows through them. However, distribution networks operate at lower voltages and are subjected to a higher level of losses.
- B. **Fixed Losses:** These types of losses do not change with current, they occur in the form of noise and heat, alongside electrical network components and equipment such as transformers when energized. Fixed losses are commonly caused by no-load losses of a transformer, corona losses, as well as losses caused by the continuous load of measuring elements. These losses occur in the transformers' core and are called 'core losses' or 'iron losses'. The two types of core losses existing are Hysteresis losses and Eddy current losses.
- C. **Network Services:** These losses are related to uncontracted consumption which is the power consumed by the measuring devices such as meters, and information systems which are installed within the system. They can be electromechanical, electronics or general ICT equipment. Generally, technical losses depend on the network characteristics and mode of operation of electricity. These losses cannot be eliminated but can be reduced by using efficient and proper planning and maintenance schemes.

2. NON-TECHNICAL LOSSES:

These losses are also known as commercial and collection losses which are associated with the amount of non-billed electricity and billed electricity that is not paid for or even paid but not properly remitted [5]. The non-billed electricity occurs due to errors in the metering or billing systems as a result of illegitimate behaviour of customers. The costs of losses associated with NTL are covered by the participation of utilities and/or legitimate consumers paying bills through meters etc. Non-technical losses can be divided into the following categories:

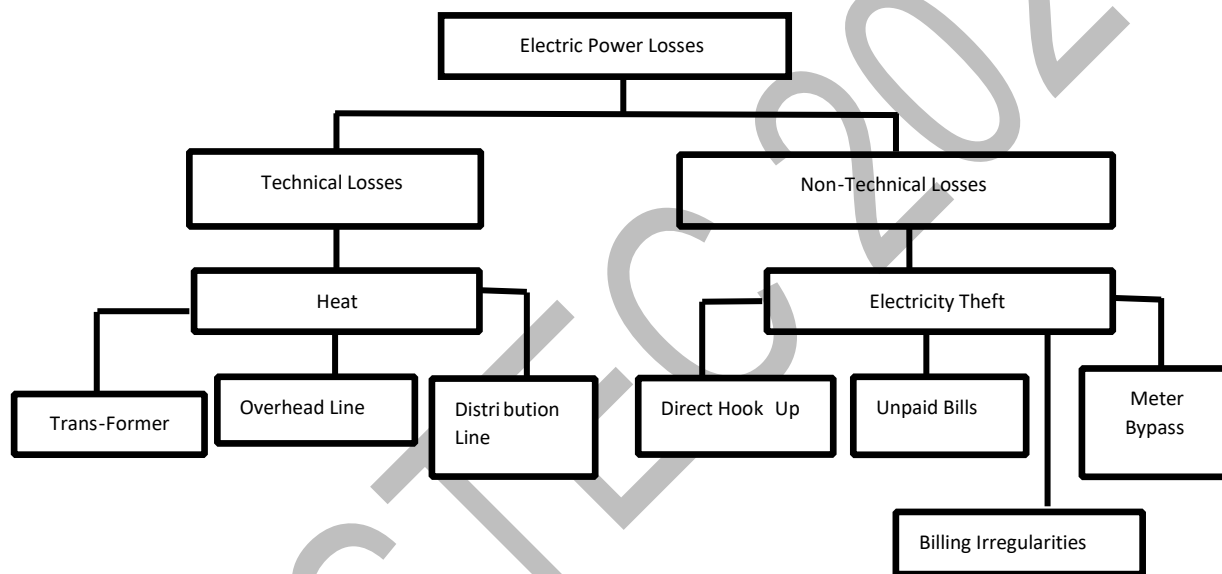


FIG 3: Classifications of electric power losses

A. Network Equipment Issues: These are associated with theft, fraud, and measurement errors. Theft can be referred to as any illogical connection to the use of electricity aside from the points where metering systems are positioned by the supplier, while fraud can take many shapes, ranging from manipulation of the customer's meter so that the meter would read slowly or it can also come in the form of meter bypass, where some of the customer's loads are connected directly without being recorded by the meter.

- B. **Challenges of measuring systems:** Errors from measuring devices, such as the metering system, are also categorized under NTLs. These losses are the difference between the amount of electricity delivered via the meter and the amount registered by the meter. The causes of these losses are as follows; uncertainty associated with the measuring system, errors in the meter reading, defective measuring system, inappropriate configuration or installation of measurement equipment.
- C. **Network Information Challenges:** In this situation, electricity is delivered and consumed but the energy is not accurately measured due to errors occurring in the distribution network, which are as a result of the following, unregistered or missing connection points, inappropriate location of connection points, and incorrect information from the measuring equipment.
- D. **Problems Associated with Data Processing:** The inaccuracies occurring here are associated with the error in the evaluation of energy produced or consumed. These errors are also incorporated in NTL and are as a result of the following: estimation of the consumption that is not metered, estimation of the calculated consumption and the readings from the meter, Technical Loss estimation, and other energy data processing.

Therefore, Aggregate Technical, Commercial and Collection losses comprise technical losses, commercial losses and shortages resulting from failure to collect the total amount of money billed to the consumers. No matter how carefully the power system is designed, technical losses are bound to happen as a result of heat dissipation, resulting from current utilization in the power lines causing power to unbalance between generation, distribution and major load centres.

The more power flows through the power lines, the more current flow will be and eventually, the power quality will decline. It is therefore necessary to evaluate and minimize power system losses to enhance network efficiency and high-quality supply of electricity to end-users with reliability and economy.

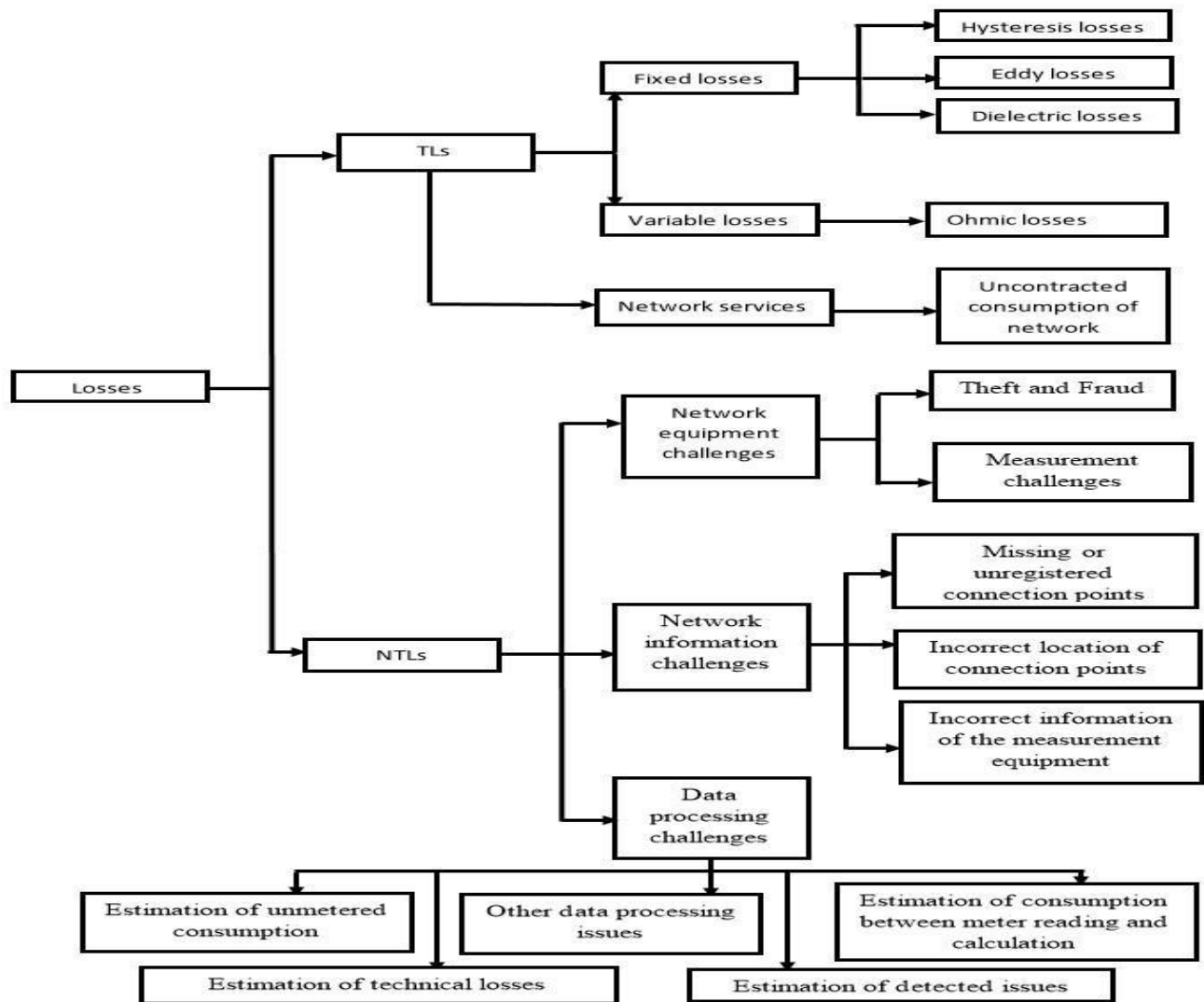


FIG 4: THE ENTIRE SOURCES OF LOSSES IN THE DISTRIBUTION SYSTEM OF NIGERIA.

3. MATHEMATICAL ANALYSIS OF LOSSES IN A POWER TRANSFORMER:

1. The load factor and load loss factor technique was employed in calculating the technical power losses and energy losses of the distribution transformer.

A. Loss Factor (L_f) is defined as the ratio of average power consumed over a designated period to maximum demand occurring within the same period.

B. Load Loss Factor (L_{1f}) is defined as the average electrical energy losses for electricity distributed during a given period, where $LLF = \text{Average Power Loss} / \text{Power loss at peak}$.

The approximate value of the load loss factor (LLF) can be calculated from the load factor (LF) using equation (2):

$$LLF = (k \times LF) + (1 - k) \times (LF)^2 \quad (2)$$

Where $LF = \text{Average Demand} / \text{Maximum Demand} = kVA_{AVG} / KVA_{MD}$

$$(3)$$

And k is the coefficient of loading given by

$$k = \text{Minimum } kVA / \text{Maximum } kVA \quad (4)$$

The value of k can be 0.1, 0.2 or 0.3 depending on the subsystem of the power system network.

$$W_L = W_c \left(\frac{KVA_{max}}{KVA_{rating}} \right)^2 \times L_{1f} \quad (5)$$

Where, $W_c = \text{Full load copper}$

$KVA_{MAX} = \text{Maximum KVA demand in a period}$

$KVA_{RATING} = \text{KVA rating of the transformer.}$

For medium-voltage feeders and distribution substations, $k = 0.2$ is used whereas for the sub-transmission station, $k = 0.3$ is used. To evaluate the total losses in a distribution system network, the power losses in the power transformers, the distribution lines or cables as well as the power losses in the low voltage transformers must be known.

2. TOTAL LOSSES IN THE POWER TRANSFORMER:

A transformer has two major components of power losses occurring and there are losses in the laminated iron (core) and the copper (windings). The core loss is a no-load loss and occurs when the core is magnetized or energized whereas the copper loss

is a non-load loss which occurs when current flows through the resistance of the primary and secondary windings of the transformer.

The total power loss in the power transformer P_{TFLoss} in kilowatt (kW) is given by

$$P_{TFLoss} = (P_{LLoss} + P_{NLLoss}) \times 10^{-3} \quad (6).$$

Where P_{LLoss} is the on-load power loss and P_{NLLoss} is the no-load power loss also known as iron loss (P_i). The load power loss P_{LLoss} is related to the copper loss P_C and the load loss factor LLF as follows:

$$P_{LLoss} = P_C \times (kV_{AMD} / kV_{ARating})^2 \times LLF \quad (7).$$

Where P_C is the full load copper loss, kV_{AMD} is the maximum demand in a period, $kV_{ARating}$ is the kVA rating of the transformer. Substituting equation (7) into Equation (6), the total power losses P_{TFLoss} in the transformer becomes:

$$P_{TFLoss} = P_C \times (kV_{AMD} / kV_{ARating})^2 \times LLF + P_{NLLoss}.$$

$$\text{Where, } P_{TFLoss} = P_C \times (kV_{AMD} / kV_{ARating})^2 \times LLF + P_i \quad (8)$$

The values for P_C and P_i can be obtained from the transformer technical specifications.

3. TOTAL LOSSES ON THE DISTRIBUTION LINES OR FEEDER:

The total power losses of three-phase distribution lines or feeders are given by

$$P_{LLoss} = 3(I_m)^2 \times R \quad (9)$$

Considering the Load Loss Factor (LLF), equation (9) becomes;

$$P_{LLoss} = 3(I_m)^2 \times R \times LLF \quad (10)$$

where, I_m is the maximum current in amperes (A) flowing through the distribution lines and R is the total resistance of the conductor of the lines in ohms (Ω). When the resistance per unit length in kilometer is known, the total resistance R is also the product of the unit resistance r (Ω km) and the length of the conductor of the lines in the feeder.

4. **NON-TECHNICAL LOSSES:**

These losses are caused by external factors to the power system and can neither be calculated nor computed but can be regulated and reduced through ensuring law enforcement of electricity regulatory, impromptu checks on consumers, punishable acts to lawbreakers, use of prepaid meters and others.

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CONCLUSION AND RECOMMENDATION:

The Nigeria Electrical Power Sector has proved to be incapable of meeting the demand of the Nigeria power supply due to the losses occurring in the different sectors of the electricity grid hence crippling the growth of the country.

Through understanding the losses and diversifying into other forms of energy, electricity can be distributed at its optimal level.

I hereby recommend the Federal Government and the electrical power sector to implement laws guiding the distribution of electricity thus ensuring growth and revenue to the country.

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