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OPTIMISATION OF POWER TRANSMISSION TO REDUCE ENERGY LOSSES IN NIGERIA

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ABSTRACT

Growing up in Nigeria in the early '90s meant living with unreliable and irregular electricity supply. As a child, I experienced a well-known distribution company - NEPA pattern of one day of power supply followed by two days of blackout, so common that even newborns recognised the phrases "Up NEPA" when electricity returned and "Shamed NEPA" when it was taken away. More than three decades later, many Nigerians, especially those living in rural communities, can still go up to a month without electricity. This persistent outage made academic life difficult; many students in the rural areas often relied on candles and kerosene lanterns to study and prepare for exams while those in urban centres used rechargeable lamps nowadays. Sadly, as of December 2025, TCN still struggles to supply steady electricity despite having enough capacity to generate over 12,000 MW rather less than 5,000 MW reaches consumers of over 220 million population because about 40% of generated power is lost on the transmission and distribution corridors. These losses happen due to old infrastructure, aging conductors, overloaded transmission lines and distances, substation transformers inefficiencies, poor reactive power and voltage control, corona effects, inefficient management systems, poor maintenance culture, town planning and grid design, vandalism as a result of communal crises, banditry, militancy, terrorism and electricity theft, inadequate funding, corruption at both management and employee levels, as well as government regulatory failures.

This research examines the primary causes of transmission losses in Nigeria and evaluates practical optimisation strategies to enhance transmission efficiency. A mixed methodology was adopted, including descriptive analysis, analytical modelling of resistive (I^2R) losses, voltage-drop assessment, thermal loading evaluation, and comparative scenario analysis. Primary data was collected through a survey, which include custom-designed questionnaire created with a laptop notepad, a Google Form, internet Wi-Fi, and communication via WhatsApp calls and messages, while Secondary data were sourced from TCN operational reports, journals, regulatory documents, and peer-reviewed literature.

The analysis of the data aims to extract valuable insights from electrical and mechanical engineers, technicians, regulatory officers, consultants, academic and researchers within the Nigerian power

sector, identifying demographic patterns, trends, correlations, and provides information that supports decision-making with the following specific questions: (i) What are the main causes of energy losses in Nigeria's power transmission network? (ii) How efficient is the current transmission system in terms of technical performance? (iii) Which optimisation method can most effectively reduce power losses? (iv) What are the expected economic and operational benefits of implementing these strategies?

Findings reveal that technical losses average 12-18% and non-technical losses 10-15%, far exceeding global benchmarks. Key loss drivers include overloaded corridors operating above rated thermal limits, obsolete ACSR conductors, poor power factor (often <0.85), and limited SCADA telemetry coverage. The most serious weaknesses identified include aging and inadequate infrastructure, weak and overloaded transmission lines, system bottlenecks, bribery and corruption, low-quality conductors, lack of monitoring, poor data and grid control, vandalism, and a shortage of well-trained manpower.

Four major optimisation approaches were assessed: conductor upgrades (e.g., replace ACSR with ACCC), reactive power compensation, smart monitoring systems (e.g. SCADA, PMUs), and network reconfiguration with substation automation. Additional suggested strategies include advanced manpower training, dynamic parameter optimisation, integration of advanced technologies such as UPFC and TCSC, leveraging decentralised energy sources, hybrid optimisation algorithms, infrastructure upgrades, deployment of more efficient transformers, improved policing to protect transmission lines, procurement of high-quality conductors and cables, smart grid implementation, decentralisation of the national grid, and adequate funding. The main barriers to implementing these optimisation techniques include funding limitations, poor maintenance culture, lack of skilled manpower, bureaucratic and policy challenges, vandalism, security issues, and inadequate data availability.

Results show that conductor upgrades yield the highest technical loss reduction (10-15%) but require substantial capital investment. Reactive power compensation and smart monitoring offer medium-cost, high-impact improvements (5-10% loss reduction). When combined, these

techniques can reduce total transmission losses by 15-20%, improving voltage stability, increasing available power to DisCos, and aligning Nigeria's grid performance more closely with global standards.

The recommendations provide a realistic pathway for reducing losses, enhancing reliability, and supporting long-term economic development. Economic benefits include lower operational costs, increased power delivery to DisCos, reduced fuel consumption, increased investor confidence, and improved tariff stability. Operational improvements expected from smart monitoring systems include faster fault detection, reduced downtime, better load forecasting, improved energy accounting, and reduced non-technical losses.

The suggestions emphasise the need for aggressive investment, infrastructure modernisation, increased transmission budget allocation, zero tolerance for corruption and vandalism, continuous manpower training, protection of transmission infrastructure, adoption of modern metaheuristics and AI tools, and the development of a reliable planning system.

The study concludes that modernising Nigeria's transmission infrastructure through a balanced mix of technical upgrades, digital monitoring, and improved operational practices is essential for sustainable power delivery because improving the transmission system is essential for energy efficiency, lower costs, and reliable service as Nigeria strives toward industrial and economic growth.

KEYWORDS

Nigeria, Electric Power Transmission, Transmission Losses, High-Voltage Lines, Technical Losses, Non-Technical Losses, Aging Infrastructure, Conductor Upgrades, Reactive Power Compensation, Network Reconfiguration, Smart Grid Technology, Substation Automation, Voltage Stability, Energy Efficiency, Grid Reliability, Optimisation Strategies, Power-Flow Modelling, Cost-Benefit Analysis, Thermal Loading.

Aluminium Conductor Steel Reinforced (ACSR), Aluminium Conductor Composite Core (ACCC), Supervisory Control and Data Acquisition (SCADA), Phasor Measurement Unit (PMU), Unified Power Flow Controller (UPFC), Thyristor Controlled Series Capacitor (TCSC), Static Synchronous Compensator (STATCOM), Static Var Compensator (SVC), High-Temperature Low-Sag (HTLS), Dynamic Line Rating (DLR), Remote Terminal Unit (RTU), Internet of Things (IoT), Energy Management System (EMS).

Distribution Companies (DisCos), Transmission Company of Nigeria (TCN), Nigerian Electricity Power Authority (NEPA), Ikeja Electric Distribution Company (IKEDC), Nigeria National Grid (NNG), National Grid Code (NGC), Nigerian Electricity Regulatory Commission (NERC), Institute of Electrical and Electronics Engineers (IEEE).

DEDICATION

This dissertation is dedicated to my family and to all engineers working tirelessly to build a stable and reliable power systems in Nigeria.

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CHAPTER 1

1.0 Introduction

1.1 Background of the Study

Electric power transmission plays a vital role in delivering generated electricity to distribution networks and consumers. In Nigeria, the TCN operates a vast network of 330 kV and 132 kV lines designed to wheel power from generating stations to DisCos. However, despite having an installed generation capacity exceeding 12,000 MW, only 4,500-5,700 MW typically reaches consumers of over 220 million population. This means approximately 40% of generated power is lost on the transmission and distribution corridors.

Key causes include:

- Aging and weak transmission lines
- Use of outdated conductor materials
- Overloaded circuits due to population and industrial growth
- Absence of smart-grid components for real-time monitoring
- Insufficient reactive power compensation
- Poor maintenance culture and weak grid planning

These losses lead to high operational costs, increased tariffs, unreliable electricity supply, and slow socio-economic development to Nigerians. Therefore, optimising transmission efficiency is crucial to achieving Nigeria's medium and long-time development goals.

1.2 Statement of the Problem

Nigeria's central grid loses much of its energy due to outdated, overloaded, and poorly maintained infrastructure. Many components of the grid are over 30 years old and have exceeded their designed lifespan. Without modern technology such as smart grids, network

optimisation, and power factor correction, the outdated transmission system will continue to slow national development.

1.3 Research Objectives

The main objective is to investigate and propose effective optimisation strategies for reducing transmission losses in Nigeria.

The specific aim of this research is to:

- i. Identify major sources of power losses in Nigeria's transmission network.
- ii. Evaluate current transmission system performance.
- iii. Propose practical optimisation techniques such as smart monitoring systems.
- iv. Evaluate impact of proposed methods on transmission efficiency and energy delivery.

1.4 Research Questions

- i. What are the main causes of energy losses in Nigeria's power transmission network?
- ii. How efficient is the current transmission system in terms of technical performance?
- iii. Which optimisation method can most effectively reduce power losses?
- iv. What are the expected economic and operational benefits of implementing these strategies?

1.5 Scope of the Study

The study focuses on Nigeria's 330 kV and 132 kV high-voltage transmission network, examining:

- Technical line losses
- Transformer losses

- Reactive power issues
- Network design inefficiencies
- Maintenance challenges

1.6 Significance of the Study

This study is important because it tackles Nigeria's inefficient and epileptic power delivery, a major barrier to economic growth. By creating practical optimisation strategies, it aims to improve reliability, cut costs, and promote energy sustainability, offering valuable guidance to:

- Government and policymakers - for better grid planning and investment decisions
- TCN and engineers - for selecting effective technical solutions
- Investors and power sector developers - by providing practical frameworks for modernisation
- Consumers and industries - by enhancing supply reliability and lowering costs

CHAPTER 2

2.0 Literature Review

2.1 Overview of Power Transmission Systems

Power transmission refers to moving electricity from generating stations to load-centres (cities, industries, homes) using high-voltage lines. Raising voltage reduces the current for a given power, which then lowers I^2R (resistive) losses - a key reason high-voltage transmission is used ^[1]. Typical voltages are 110 kV and above; in many countries (especially developing ones) major transmission occurs at ~132 kV, 330 kV and sometimes higher ^[2].

2.2 Types of Transmission Losses

Electricity doesn't simply flow from generation facilities to consumers without some portion being lost along the way. These losses occur in two primary categories: technical and non-technical (commercial) ^[1].

2.2.1 **Technical Losses:** These result from the physical properties of electricity transmission and are largely unavoidable, though they can be minimised. These include:

- i. **Resistive (I^2R) Losses:** Lines due to conductor resistance. As current flows, some energy is dissipated as heat.
- ii. **Transformer Losses:** When voltage is stepped up or down, there are transformer core (hysteresis, eddy-current) losses and copper winding losses.
- iii. **Dielectric Losses:** Losses in insulating materials (in cables, equipment) when subjected to high voltages.

- iv. **High-Voltage “Corona” Losses:** At high voltages, surrounding air can become partially conductive, causing energy leakage into the atmosphere - especially on very long or poorly maintained lines.

Thus, the classical resistive loss formula remains relevant:

$$\text{Formula: } P_{\text{loss}} = I^2R$$

2.2.2 **Non-Technical Losses:** These losses due to human, managerial, or infrastructural issues. These may include:

- i. **Electricity Theft:** Unauthorized connections to the grid, meter tampering, and bypassing meters represent significant losses in many regions.
- ii. **Billing Inefficiencies:** Errors in meter reading, billing, and collection processes contribute to commercial losses.
- iii. **Unmetered Supply:** Some consumers receive unmetered electricity, making accurate billing impossible.
- iv. **Accounting Errors:** Mistakes in energy accounting and record-keeping can result in apparent losses.

In poorly maintained or managed systems (common in many developing countries like Nigeria), non-technical losses may sometimes rival or exceed technical losses.

2.3 Causes of Transmission Losses in Developing Countries

Several papers show recurring themes across countries such as in Asia (India), Africa (Kenya, South Africa), Latin America (Brazil), and others ^[3]. Common contributing factors include:

- i. **Overloaded Substations / Lines:** When demand outpaces design capacity, components operate beyond optimal load → higher losses, increased fault risk.

- ii. **Old or Ageing Infrastructure:** Conductors, transformers, insulation and switchgear degrade, increasing losses and risks of failure.
- iii. **Lack of Network Automation / Real-Time Monitoring:** Making it difficult to detect overloads, reactive-power imbalances, or fault conditions quickly.
- iv. **Poor Reactive Power Management:** Reactive power flows waste energy if unmanaged; reactive flow causes higher currents than necessary.
- v. **Weak Funding:** Weak institutional capacity to maintain or upgrade the grid; maintenance is often irregular or postponed.

These factors interplay and amplify total losses (technical + non-technical), reducing reliability and increasing cost. Several case studies from developing countries document these issues; the patterns are similar across regions ^[3].

2.4 The Nigerian Transmission Grid

For the case of TCN and NNG:

- i. The transmission network uses 330 kV (primary) and 132 kV (secondary) high-voltage lines, then steps down further for distribution ^[4].
- ii. As of recent surveys, there are approximately 5,523.8 km of 330 kV lines and 6,801.49 km of 132 kV lines in active operation ^[5].
- iii. The grid also involves 330/132 kV and 132/33 or 132/11 kV substations, providing the voltage transformation needed for distribution ^[5].
- iv. The system is largely radial (single-circuit lines, minimal redundancy), which means a fault or line overload can cause widespread disruption ^[4].
- v. Actual “wheeling capacity” (the maximum power the grid can reliably carry) is often well below theoretical potential. For instance, while theoretical capacity may be 7,500 MW (or higher in older studies) ^[5] in practice the grid frequently transmits much less (because of line loading limits, maintenance deficits, instability, etc.) ^[4]

- vi. Losses in the Nigerian transmission grid have been estimated around 7.4% (on transmission lines), which is high compared to typical benchmarks of ~2-6% for efficient systems ^[4].
- vii. The network suffers frequent disturbances, blackouts, and collapses - due to combined factors: aging infrastructure, overloads, poor reactive-power and voltage control, lack of redundancy, and weak maintenance culture ^[6].

Overall, the Nigerian grid suffers from both structural limitations (radial design, inadequate redundancy) and operational challenges (maintenance, overloading, poor control/monitoring), making it vulnerable to high losses and instability.

2.5 Optimisation Techniques from Literature

To address transmission losses and instability, researchers and practitioners have proposed and studied various optimisation and modernisation strategies. Key among them:

- i. **Reactive Power Compensation:** Installing devices such as shunt capacitor banks, STATCOM, or SVC to manage reactive power flow, stabilise voltage, reduce over-current, and hence reduce losses ^[3].
- ii. **Network Reconfiguration:** Adjusting the configuration/ topology of the network (e.g., switching circuits, re-routing flows, changing loop / radial structure) to balance load across lines, avoid overloading, and reduce line losses. This can be done manually or via optimisation techniques (e.g., genetic algorithms for distribution networks) ^[7].
- iii. **Use of High-Efficiency Conductors:** Upgrading from older conductors (e.g., ACSR to higher-efficiency ones (e.g. HTLS conductors or newer materials) to reduce resistive losses and allow higher load capacity ^[3].
- iv. **Dynamic Line Rating (DLR):** Instead of using fixed conservative ratings for all lines, using real-time monitoring (weather, conductor temperature, environmental conditions) to adjust line capacity dynamically - allowing more efficient utilisation

without exceeding safe thermal limits. This is a technique increasingly cited in power systems loss-mitigation literature [3].

- v. **Smart Grid Technologies & Monitoring** (SCADA/ EMS, real-time monitoring, automated switches, sensors): Deployment of modern control systems to continuously monitor voltages, reactive power, line loading; detect faults early; perform automatic reconfiguration; thereby improving reliability, reducing outages and loss [3].
- vi. **Upgrading Grid Structure** (From Radial → Ring / Mesh / Higher-Voltage grid): Some studies propose combining existing 330 kV grids with upgraded higher-voltage buses (e.g. 750 kV) to create a “super-grid” with more redundancy, improved voltage stability, and significantly lower losses. Simulation results show that such redesigns can reduce line losses by 30% or more and drastically improve voltage profile under contingency conditions [8]. These optimisation and modernisation strategies - though often costly and requiring institutional commitment - show strong potential to reduce both technical losses and improve grid resilience and reliability.

2.6 Synthesis- Why Nigerian Grid Matches Global Patterns

Initial review noted that causes in Nigeria are similar to those in India, Brazil, Kenya, and South Africa - and literature confirms this. The combination of ageing infrastructure, lack of automation/monitoring, reactive-power issues, old conductors, overloaded lines, weak maintenance culture, and poor funding is a common pattern in many developing-country grids [3]. Hence, the problems observed in Nigeria - high transmission losses, frequent collapses, low wheeling capacity, voltage instability, overloaded lines - are not unique but part of a broader “transmission challenges in developing economies” phenomenon.

At the same time, the literature offers a roadmap for improvement: reactive-power management, better conductors, dynamic line rating, grid modernisation, smart-grid

deployment, network reconfiguration, and structural upgrade to more robust topologies (ring/mesh, higher voltage backbone).

If TCN or other stakeholders were to implement a combination of these measures (with adequate funding and governance commitment), significant reductions in losses and better grid stability are attainable - a conclusion supported by simulation-based studies ^[8].

2.7 Gaps - Considerations in Nigerian Context

Based on review of recent studies:

- i. Many analyses highlight that Nigeria's network remains largely radial, with minimal redundancy. This structure is more vulnerable to faults and disturbances compared to ring/mesh networks ^[4].
- ii. There is limited up-to-date documentation on comprehensive grid modernisation (e.g., upgrading all 330 kV lines, redeploying SVC/STATCOM, full smart-grid rollout). Budget constraints, vandalism, and funding shortfalls remain a big obstacle.
- iii. Even when studies propose high-end solutions (e.g., 750 kV super-grid backbone), the practical challenges - funding, right-of-way, regulatory, execution capacity - may pose serious barriers to implementation ^[8].
- iv. Non-technical losses (theft, tampering, poor metering) are under-studied compared to technical losses; though globally recognized as significant, local research quantifying them in Nigeria is limited or dated. More empirical, field-level study is needed to capture the current magnitude accurately.

Therefore, while literature provides several robust technical prescriptions, the real-world applicability in Nigeria depends critically on policy commitment, funding, governance, maintenance culture and anti-vandalism measures.

CHAPTER 3

3.0 Research Methodology

3.1 Research Design

This study adopts:

- i. Descriptive Design: To characterise the current state of transmission losses in the Nigeria grid, magnitude, distribution, line-by-line loss rates, and relevant system parameters (line loading levels, voltage profiles, etc.).
- ii. Analytical Modelling: To mathematically model technical losses (resistive/ohmic, voltage drop, thermal loading) on transmission lines under different operating conditions.
- iii. Case-Study Review: To examine specific transmission corridors/elements (for example 330 kV lines) within Nigeria (or particular zones) using historical data from TCN, regional grid studies, or published loss studies.
- iv. Comparative Analysis: To compare “baseline” (current practice) vs “optimised” scenarios (e.g. changing conductor parameters, voltage levels, load balancing, use of compensation devices) to estimate potential improvements.

By combining these methods ^[10], the study both describes present losses and forecasts potential gains under optimisation - a pragmatic way to inform policy or technical recommendations.

3.2 Data Sources

Data for this study was sourced from both primary and secondary sources.

3.2.1 **Primary Data:** Primary data was collected through the survey, which include custom-designed questionnaire created with a laptop notepad, Microsoft word, a Google Form survey, internet Wi-Fi, and communication via WhatsApp calls and messages.

3.2.2 **Secondary Data:** Secondary data from TCN reports, NERC publications, journals, textbooks, articles and existing regional grid studies were used.

S/Nr.	Data Source	Purpose / Use	Notes
1	TCN operational statistics and reports ^[11]	Real data online loading, line lengths, types of conductors, voltage levels, outages to calibrate analytical model and validate loss estimates.	Ensure access permission, data completeness, and recency.
2	Published academic journals / IEEE publications [3][12]	For theoretical foundations, existing studies on transmission losses, modelling methods (e.g. resistive losses, power flow analysis), and examples of similar studies.	Peer-reviewed sources add credibility; helps frame methodology in the context of global research.

3	National Grid Code (NGC) or relevant regulatory/ technical documents ^[13]	For design standards, permissible operating limits (voltage tolerances, thermal limits), and regulatory baseline.	Useful to compare actual vs standard practice, and for recommendations.
4	International / global reports (e.g. from World Bank) on power sector and transmission performance ^[14]	For benchmarking Nigeria's transmission losses versus international standards; to support broader system-level recommendations.	Helps put findings in context and may provide data on system losses, typical loss percentages, etc.

3.3 Analytical Methods

3.3.1 Line-loss (Ohmic / Resistive) Modelling:

- i. Use the well-known formula for Joule (resistive) losses -

$$P_{loss} = 3I^2R$$

(for three-phase systems, summing over the three conductors) ^[15]

- ii. This captures the bulk of line losses under normal conditions, especially for high-voltage transmission ^[16].
- iii. Use actual conductor resistance (from TCN data or standard conductor specs) and current load data to compute losses per line, then aggregate for the network.

3.3.2 Voltage Drop Analysis:

- i. Use a formula such as:

$$V_{drop} = \frac{IR\cos\phi + IX\sin\phi}{V_{line}}$$

to assess voltage deviation along lines under load (where R is resistance, X is reactance, ϕ the power factor) helpful in understanding under-/over-voltage issues. This supports diagnosing quality and stability issues in addition to power losses.

- ii. Such voltage drop/voltage-profile analysis helps identify “weak” busbars or segments where voltage regulation or reactive compensation may be required (per findings from similar Nigerian transmission studies).^[17]

3.3.3 **Thermal Loading Assessment:**

1. Evaluate conductor/line loading vs rated thermal limits (ampacity), to identify lines routinely operating above safe loading - this is critical, because overloading increases losses, risk of overheating, sagging, and failure. Literature on thermal constraints and line optimisation often pairs resistive models with thermal-limit checks^[18].
2. This assessment provides a basis for recommending upgrades (e.g. higher-capacity conductors, re-routing loads, or using parallel circuits) to reduce losses and enhance reliability.

3.3.4 **Cost-Benefit Evaluation (Economic Analysis):**

- i. Based on the loss reduction (in MW or MWh) from optimised scenarios, estimate economic savings (e.g. fuel savings at generating side, increased revenue, decreased waste) over a defined period.
- ii. Compare cost of interventions (e.g. upgrading conductors, installing reactive-power compensation, re-engineering transmission routes) with projected savings - this helps articulate pragmatic recommendations.
- iii. This economic framing is often essential when presenting recommendations to regulators, utilities or policymakers.

3.3.5 Power-Flow / Network Simulation:

- i. Use simulation tools (e.g. load-flow analysis software such as DIgSILENT PowerFactory, MATLAB with power-flow modules, or similar) to model network behaviour under different load conditions, and to simulate optimised scenarios (e.g. altered conductor parameters, reactive compensation, re-routing, distributed generation). Similar approaches have been successfully used in Nigeria studies ^[17].
- ii. This approach gives more realistic results than purely analytical (closed form) formulas, especially when network is large and complex (multiple buses, load centres, variable loading).

3.3.6 Comparative Analysis & Scenario Modelling:

- i. Define baseline (current network conditions) and multiple alternative “optimisation” scenarios (e.g. higher voltage transmission, upgraded conductors, reactive-power compensation, load balancing, distributed generation, etc.).
- ii. For each scenario, compute losses, voltage profiles, thermal load, and economic impact. Then compare - quantify percentage reduction in losses, percentage improvement in voltage stability, payback periods, etc ^[19].
- iii. This structure allows robust recommendations: what works best under what conditions. In fact, studies using optimisation techniques - classical optimisation, evolutionary/computational methods - have been used to minimize transmission losses ^[15].

CHAPTER 4

4.0 Data Analysis and Discussion

4.1 Data Analysis - Survey

4.1.1 **Collection of Data:** A Google Form was used to collect data for this research. The data analysis aims to extract valuable insights from electrical and mechanical technicians, engineers, regulatory officers, consultants, academics, and researchers within the Nigerian power sector. The analysis identifies demographic patterns, trends, and correlations that help transform raw data into useful information for decision-making. This supports the evaluation of power transmission optimisation strategies to reduce energy losses in Nigeria.

The analysis seeks to answer key questions, test hypotheses, and support decision-making by addressing the following:

- (i) What are the main causes of energy losses in Nigeria's power transmission network?
- (ii) How efficient is the current transmission system in terms of technical performance?
- (iii) Which optimisation methods can most effectively reduce power losses?
- (iv) What economic and operational benefits are expected from implementing these strategies?

4.1.2 **Survey Responses:** A sample of the Google Forms questionnaire and valid responses were analysed and summarised below. Thirty (30) completed responses were received from 200 professionals contacted within the Nigerian power sector, resulting in a response rate of 15% and a non-response rate of 85%.

The questionnaire consisted of 40 multiple-choice questions and was designed to prevent respondents from skipping any questions, ensuring complete data for evaluating power transmission optimisation to reduce energy losses in Nigeria.

All respondents who completed the questionnaire consented to participate.

<i>Table 4.1</i>	
Survey	<i>Optimisation of Power Transmission to Reduce Energy Losses in Nigeria</i>
No of Professionals Contacted	200
No of Respondents	30
No of Multiple-Choice Questions	40
Professionals Targeted	Electrical Technicians / Engineers / Consultants
Sector	Power / Electricity
Survey Tool for Data Collection	Google Form
<i>Please see survey questions and responses on page 48-73 pages.</i>	
<i>A sample of the questionnaire, the Google Form link, the demographic and detailed responses are presented in Appendix C on pages 48-73.</i>	

4.1.3 **Survey Responses Analysis:** This section is divided into A, B, C, D and E.

Section A: Respondent Information

Seventy percent (70%) of the respondents were male, while 30% were female. Forty percent (40%) of the respondents were engineers with professional experience ranging from 6 to 20 years. Most respondents work closely with the TCN and are familiar with Nigeria’s 330 kV and 132 kV transmission networks. They demonstrated a strong understanding of transmission losses in Nigeria and agreed that reducing transmission losses is extremely important to Nigeria’s power sector.

Section B: Sources of Transmission Losses

Seventy percent (70%) of respondents believed that Nigeria currently experiences technical and non-technical transmission losses above 30%. Factors contributing to technical losses include aging conductors, overloaded transmission lines, substation transformer inefficiencies, poor reactive power management, long transmission distances, and poor voltage control. Aging conductors were identified as a very critical cause of power losses, while transmission lines were reported to be frequently overloaded. Vandalism was identified as having a very high impact on transmission losses. Other major contributors include cable joint inefficiencies, communal crises, corona effects, corruption at both management and employee levels, harmonics distortion, inadequate conductor sizing, old infrastructure, poor maintenance culture, poor town planning, electricity theft, overloading, inadequate funding, and regulatory failures.

Section C: Current Transmission System Performance

Respondents rated the overall performance of Nigeria's transmission grid as poor. Voltage instability occurs frequently, and the network suffers from insufficient redundancy, such as a lack of parallel lines and ring topology. Current monitoring and SCADA systems were described as ineffective, resulting in very slow fault detection. Respondents also reported inadequate reactive power support across substations and frequent outages in operational areas. The most serious weaknesses identified include aging and inadequate infrastructure, overloaded lines, system bottlenecks, bribery and corruption, low-quality conductors, lack of monitoring, poor data and grid control, vandalism, weak transmission lines, and a shortage of well-trained manpower.

Section D: Optimisation Techniques

Respondents identified the most effective optimization methods as conductor upgrades, substation automation, reactive power compensation, network reconfiguration, SCADA expansion, and DLR. Conductor upgrades and reactive power compensation were rated as very effective in reducing transmission losses. SCADA expansion was considered very useful, while substation automation was viewed as very important for improving grid reliability. Dynamic line rating was regarded as highly relevant for Nigeria's transmission

grid. The main barriers to implementing these optimisation techniques include funding limitations, poor maintenance culture, lack of skilled manpower, bureaucratic and policy challenges, vandalism, security issues, and inadequate data availability. Additional suggested strategies include advanced manpower training, dynamic parameter optimization, integration of advanced technologies such as UPFC and TCSC, leveraging decentralized energy sources, hybrid optimization algorithms, infrastructure upgrades, deployment of more efficient transformers, improved policing to protect transmission lines, procurement of high-quality conductors and cables, smart grid implementation, decentralization of the national grid, and adequate funding.

Section E: Expected Benefits and Impact

Respondents expect an improvement of 11% to 30% in transmission efficiency from the proposed strategies. Economic benefits include lower operational costs, increased power delivery to DISCOs, reduced fuel consumption, increased investor confidence, and improved tariff stability. The majority of respondents strongly believe that these measures will significantly improve system reliability and are very likely to reduce nationwide power outages. Improved reactive power management was considered extremely beneficial. Operational improvements expected from smart monitoring systems include faster fault detection, reduced downtime, better load forecasting, improved energy accounting, and reduced non-technical losses. Loss reduction was identified as extremely important for Nigeria's long-term economic growth.

Final comments and suggestions emphasize the need for aggressive investment, infrastructure modernisation, increased transmission budget allocation, zero tolerance for corruption and vandalism, continuous manpower training, protection of transmission infrastructure, adoption of modern metaheuristics and AI tools, and the development of a reliable planning system. Optimising Nigeria's transmission network will improve power supply reliability, stimulate economic growth, create jobs, and enhance the quality of life for Nigerians.

4.2 Current System Efficiency

Losses in Nigeria's transmission grid stem from both technical and non-technical factors. Technical losses arise naturally from electrical and thermal effects in transmission lines, transformers, and network components. Non-technical losses originate from human, procedural, and operational inefficiencies. Data from system performance reports and comparative studies show the following:

4.2.1 Technical Losses

Technical losses in the TCN network typically range from 12% to 18%, significantly higher than the global average of 6%-8% for developing countries and 3%-5% for advanced power networks ^{[20][21]}.

Nigeria: Showed losses around 16.1% in 2014, but studies point to much higher rates (over 50%) due to overloading and vandalism ^[20].

Sub-Saharan Africa: Lost roughly 18% of generated electricity annually, costing billions, according to a World Bank report ^[20].

Global Average (2011): Around 8.1% of total electricity output, per a World Bank report in 2011 cited in a research paper ^[20].

These elevated losses indicate systemic stress due to overloaded transmission lines, aging conductors, and insufficient reactive power support.

4.2.2 Non-Technical Losses

Non-technical losses are estimated at 10%-15%, largely driven by weak monitoring systems, manual substation operation, metering gaps, and operational inefficiencies. Although less common at the transmission level globally, such losses persist in Nigeria due to poor telemetry, delayed fault detection, and insufficient energy accounting systems ^[22].

4.2.3 **Combined Loss Levels**

The cumulative loss level of 30%-40% far exceeds international benchmarks and negatively impacts available power for DisCos. This underperformance directly contributes to low supply reliability, revenue shortfalls, and the need for continuous grid support interventions by the regulator.

4.3 Identification of Loss Sources

A detailed assessment reveals several key technical contributors to high losses within the Nigerian transmission grid.

4.3.1 **Overloaded Transmission Lines**

Several 132 kV corridors operate between 110% and 150% of their rated thermal limits, especially around Lagos, Abuja, and Kano. Overloaded lines result in elevated current flow, which increases I²R losses exponentially and accelerates conductor heating [23]. Such overloading also increases the risk of voltage collapse and line trips during peak loading.

4.3.2 **Aging and Obsolete Conductors**

Many ACSR lines were installed over 30-40 years ago and have experienced mechanical fatigue, corrosion, and increased resistance. As conductor resistance rises with age, thermal losses increase, reducing the effective power-transfer capability [24]

4.3.3 **Reactive Power Deficiency**

Power-factor levels below 0.85 are common in many substations due to inadequate reactive power compensation. Low power factor results in increased reactive current flow, higher line loading, and greater losses. According to IEEE Std 141-1993, poor power factor can increase system losses by up to 20% depending on network topology.

4.3.4 **Weak Monitoring and Manual Operation**

A significant number of TCN substations still rely on manual switching, limited SCADA coverage, and inadequate telemetry. This restricts real-time monitoring of line loading, voltage conditions, and outage response time. Studies show that weak grid visibility significantly increases operational losses and duration of network disturbances [25].

4.4 Proposed Optimisation Techniques

To reduce system losses and enhance transmission efficiency, four main strategies are proposed: conductor upgrades, reactive power compensation, smart monitoring systems, and substation automation.

4.4.1 Conductor Upgrades

Replacing aging ACSR conductors with modern ACCC can reduce resistance by 30-40% while allowing higher current capacity and lower sag. ACCC lines also enhance thermal stability and reduce I²R losses substantially under high load conditions [26]. This upgrade is highly effective but capital-intensive due to material and installation costs.

4.4.2 Reactive Power Compensation

Installing shunt capacitor banks, STATCOMs, or synchronous condensers helps maintain acceptable voltage levels, reduce reactive current flow, and improve power factor. This leads to a 6-10% reduction in line losses across typical 132 kV corridors. Reactive compensation is moderately priced relative to conductor upgrades and delivers immediate system-wide improvements.

4.4.3 Smart Monitoring Systems

Deployment of SCADA/EMS systems, PMUs, and IoT-based line sensors enables real-time visibility of voltage, current, frequency, and line health. These digital tools support early fault detection, predictive maintenance, accurate energy accounting, and rapid post-fault restoration. Studies show 5-8% loss reduction when SCADA/PMUs are widely implemented in similar developing-country grids [27].

4.4.4 Substation Automation

Automating substations with RTUs, digital relays, and automated switching devices reduces outage duration, improves fault isolation, and enhances network reliability. Substation automation also supports more accurate load-flow control and reduces non-technical losses from manual operation delays.

4.5 Impact Assessment of Optimisation Techniques

The estimated impact of the proposed optimisation methods is summarized in Table 4.5.

Optimisation Method	Expected Loss Reduction	Cost Level
Conductor Upgrade	10-15%	High
Reactive Compensation	6-10%	Medium
Smart Monitoring	5-8%	Medium
Network Reconfiguration	5-8%	Low

4.5.1 Combined Impact

When deployed in an integrated manner, these optimisation techniques can yield a cumulative loss reduction of 15-20%, depending on installation scale, system loading, and automation penetration. This would significantly reduce overall national grid losses from the current 30-40% range to approximately 15-25%, moving Nigeria closer to global performance standards for emerging economies.

4.5.2 Discussion

The results highlight that high-quality conductor upgrades provide the highest technical loss reduction potential, but at the greatest cost.

Reactive power compensation and smart monitoring provide balanced, medium-cost, high-impact improvements that can be implemented rapidly.

Network reconfiguration, though low-cost, delivers modest but meaningful improvements in corridors suffering from poor power flow distribution.

Overall, a combined technical, operational, and digital approach offers the most sustainable path toward optimising Nigeria's transmission system.

CHAPTER 5

5.0 Summary, Conclusion & Recommendations

5.1 Summary

This study investigated why Nigeria loses a large portion of the electricity it generates before it reaches consumers, and how the transmission system can be optimised to reduce these losses. Although Nigeria has over 12,000 MW of installed generation capacity, only about 4,500-5,000 MW is delivered. This means roughly 40% of generated energy is lost - far higher than global standards.

The research identified technical losses (such as I²R line losses, transformer losses, aging conductors, overloaded lines, poor power factor, and weak voltage control) and non-technical losses (manual operation, poor monitoring, energy accounting gaps). Technical losses in Nigeria typically range from 12-18%, while non-technical losses add another 10-15%, creating a combined loss level of about 30-40%.

The Nigerian transmission grid suffers from aging infrastructure, obsolete ACSR conductors, reactive-power shortages, poor maintenance, limited SCADA / telemetry coverage and skilled manpower.

Many 132 kV lines operate above their thermal limits, causing overheating and additional I²R losses. Voltage instability, outages, and grid collapses are frequent due to manual substation operations and insufficient network redundancy.

To address these problems, the study proposed four main optimisation strategies:

- i. Conductor upgrades: Replacing ACSR with ACCC to reduce resistance and increase capacity.
- ii. Reactive power compensation using capacitor banks, STATCOMs, or synchronous condensers to reduce reactive current flow and stabilise voltage.
- iii. Smart monitoring systems such as SCADA, PMUs, and IoT sensors for real-time grid visibility and predictive maintenance.
- iv. Network reconfiguration and substation automation to balance loads, improve reliability, and minimize operational losses.

Impact assessment showed that these measures can reduce losses by 15-20% when combined, bringing Nigeria closer to international benchmarks and significantly improving power delivery, reliability, and economic performance.

5.2 Conclusion

This research concludes that the high level of transmission losses in Nigeria results primarily from outdated infrastructure, overloaded transmission corridors, weak reactive power support, and inadequate monitoring and control systems. The current grid is heavily strained and operates below modern technical standards, leading to excessive energy losses, voltage instability, poor reliability, and reduced power availability to consumers.

Analytical modelling and literature evidence show that Nigeria's loss levels (30-40%) are far above global norms, which typically range from 5-10% for similar developing economies. Without system modernisation, Nigeria will continue to face persistent blackouts, high tariffs, and poor economic growth.

The optimisation strategies evaluated in this study- conductor upgrades, reactive power compensation, smart-grid integration, and network reconfiguration- can significantly reduce technical losses and improve system stability. Among these, conductor upgrades offer the highest loss reduction but are capital-intensive, while reactive compensation and smart monitoring offer high impact at moderate cost.

Overall, the study demonstrates that modernising the transmission network is both technically feasible and economically beneficial. Implementing these strategies will substantially enhance transmission efficiency, improve power delivery to DisCos and consumers, and support Nigeria's broader socio-economic development goals.

5.3 Recommendations

Based on the findings, the following recommendations are proposed:

5.3.1 Upgrade Aging Transmission Lines and Conductors

- i. Replace old ACSR conductors with ACCC or other high-performance conductors.
- ii. Prioritise heavily loaded corridors (e.g., Lagos, Abuja, Kano).
- iii. This will reduce I²R losses by 10-15% and improve thermal stability.

5.3.2 Strengthen Reactive Power Compensation

- i. Install shunt capacitor banks, STATCOMs, and synchronous condensers at key substations.
- ii. Maintain a power factor above 0.9 to reduce unnecessary reactive current.
- iii. This can reduce losses by 6-10% and improve voltage quality.

5.3.3 Deploy Smart Grid Monitoring Technologies

- i. Expand full SCADA / EMS coverage across all transmission company of TCN substations.
- ii. Install PMUs, line sensors, and IoT monitoring for real-time data.
- iii. This improves loss tracking, speeds up fault response, and reduces non-technical losses.

5.3.4 Automate Substations and Improve Remote Operations

- i. Implement digital relays, RTUs, and automated switches.
- ii. Reduce reliance on manual switching, which increases operational errors and delays.
- iii. Automation enhances reliability and reduces outage duration.

5.3.5 Reconfigure Network Topology Where Feasible

- i. Balance loads across parallel circuits and optimise power routing.
- ii. Introduce ring/mesh topology gradually to improve redundancy.
- iii. This offers low-cost, immediate improvements in flow distribution.

5.3.6. Improve Maintenance and Asset Management Culture

- i. Adopt predictive maintenance strategies using sensors and condition monitoring.
- ii. Increase maintenance frequency for aging conductors and transformers.
- iii. Maintain proper vegetation control and anti-vandalism measures.

5.3.7. Increase Investment and Policy Support

- i. Government and regulators should allocate funding for modern grid technology.
- ii. Encourage private-sector or PPP investment in transmission upgrades.
- iii. Implement transparent energy accounting to reduce non-technical losses.

5.3.8. Conduct Continuous Loss Audits

- i. Perform periodic technical and commercial loss assessments.
- ii. Update national grid performance metrics to track improvements over time.

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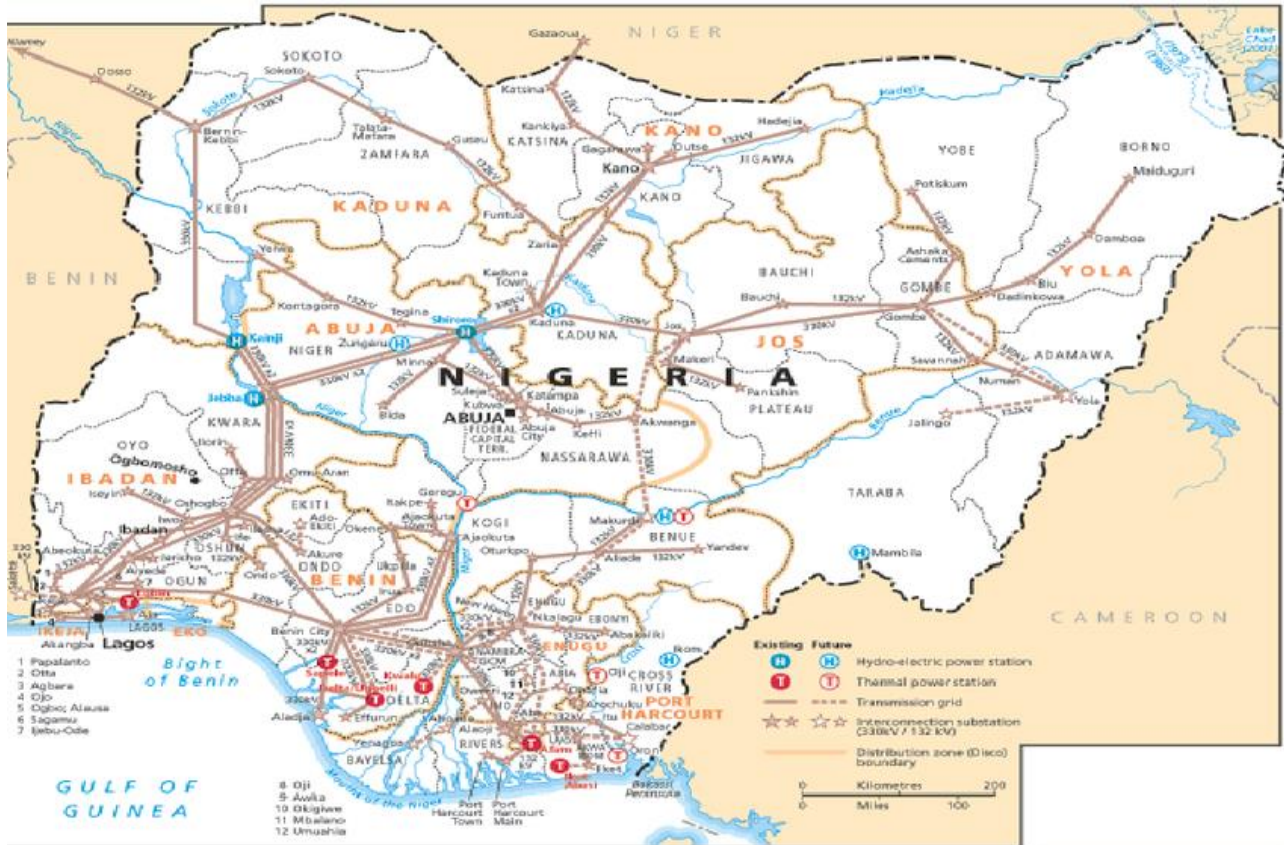
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APPENDICES

APPENDIX A

Nigerian Grid Map



Nigerian Grid Map

APPENDIX B

Sample Line Loss Calculation

This appendix provides an example of how to calculate electrical line losses for a distribution feeder segment. The calculation includes current, resistance, real power loss, and percent loss.

1.0 Given Data

Parameter	Symbol	Value
Line-to-line system voltage	VLL	13.8 kV
Three-phase load	P_{load}	2.0 MW
Power factor	PF	0.92 lagging
Conductor type	--	1/0 ACSR
Conductor resistance (per phase)	R	0.321 Ω per mile
Line length	L	3 miles

2.0 Step 1: Calculate Phase Current

Three-phase current:

$$\% \text{ Loss} = \frac{P_{loss}}{P_{load}} \times 100\%$$
$$\% \text{ Loss} = \frac{23.8 \text{ kW}}{2000 \text{ kW}} \times 100\% = 1.19\%$$

3.0 Step 2: Determine Total Resistance

$$R_{total} = R \times L = 0.321 \Omega/\text{mile} \times 3 = 0.963 \Omega$$

(Per phase; line losses calculated per phase and scaled by 3.)

4.0 Step 3: Calculate Real Power Loss

Per-phase copper loss:

$$P_{loss, per phase} = I^2 R_{total}$$
$$P_{loss, per phase} = (90.7)^2 \times 0.963 = 7,926 \text{ W}$$

Three-phase copper loss:

$$P_{loss, 3\phi} = 3 \times P_{loss, per phase} = 23,778 \text{ W} \approx 23.8 \text{ kW}$$

5.0 Step 4: Percent Line Loss

$$\% \text{ Loss} = \frac{P_{loss}}{P_{load}} \times 100\%$$
$$\% \text{ Loss} = \frac{23.8 \text{ kW}}{2000 \text{ kW}} \times 100\% = 1.19\%$$

6.0 Summary of Results

Quantity	Result
Line current	90.7 A
Total resistance (per phase)	0.963 Ω
Real line losses (3-phase)	23.8 Kw
Percent line loss	1.19%

APPENDIX C

Survey

1.0 Cover Letter

Hello Professional,

I hope you are doing well.

I am currently conducting a survey to evaluate the optimisation of power transmission to reduce energy losses in Nigeria. I would greatly appreciate it if you could take a few minutes to complete the attached form and share it with any relevant professionals (Electrical / Mechanical Technicians, Engineers, Researchers, Academics, Regulatory Officers, Consultants) within the Nigerian power sector.

https://docs.google.com/forms/d/e/1FAIpQLSdFgjQGV1s_uxcrZjtRFhClk79Ld52ltS801VhDg2xtz2OOQ/viewform?usp=publish-editor

The survey consists of 40 multiple-choice questions and should take approximately 10 minutes to complete.

Please be assured that all responses will remain anonymous and will be used solely for research purposes. Your participation would be an invaluable contribution to this study.

Thank you very much for your time and support.

Best regards,

Azeez Anjuwon,

Lagos, Nigeria.

2.0 Questionnaire & Responses

OPTIMISATION OF POWER TRANSMISSION TO REDUCE ENERGY LOSSES IN NIGERIA

Dear Respondent,

I am currently conducting a survey to evaluate the optimisation of power transmission in order to reduce energy losses in Nigeria. The primary aim of this study is to assess strategies for improving the efficiency of the power transmission network.

This research seeks to address the following specific questions:

- i. What are the main causes of energy losses in Nigeria's power transmission network?
- ii. How efficient is the current transmission system in terms of technical performance?
- iii. Which optimisation method can most effectively reduce power losses?
- iv. What are the expected economic and operational benefits of implementing these strategies?

Please be assured that all information provided will be used exclusively for this research and will be treated with the highest level of confidentiality.

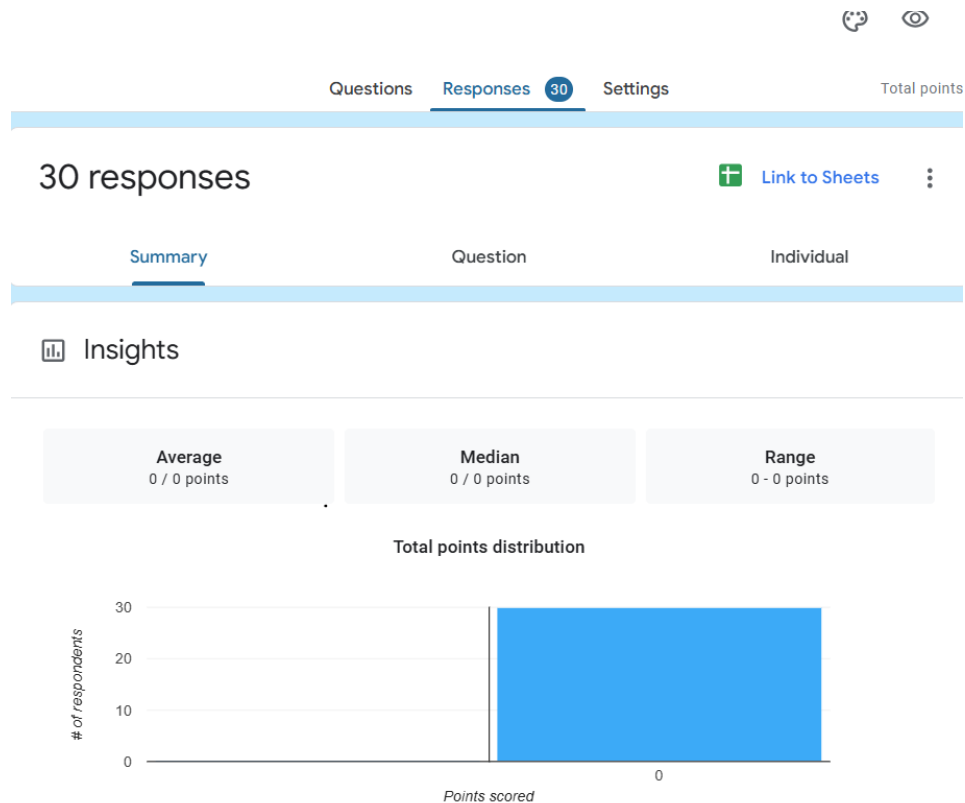
Should you have any questions, please feel free to contact me at am.anjuwon@gmail.com

Thank you for your participation and valuable contribution to this study.

Yours sincerely,

Azeez Anjuwon,

Lagos, Nigeria.



Consent to Participate in the Research Study:

I confirm that I have been adequately informed about the purpose and nature of this research study.

I understand that my participation is entirely voluntary, and I may decline to answer any specific question or withdraw from the study at any time without any consequences.

Please indicate your agreement with the statement above:

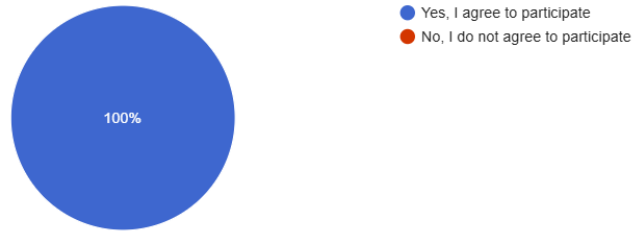
- i. Yes, I agree to participate
- ii. No, I do not agree to participate

Consent to Participate in the Research Study

Please indicate your agreement with the statement above:

 Copy chart

30 responses



SECTION A: RESPONDENT INFORMATION (8 Questions)

1. What is your gender?

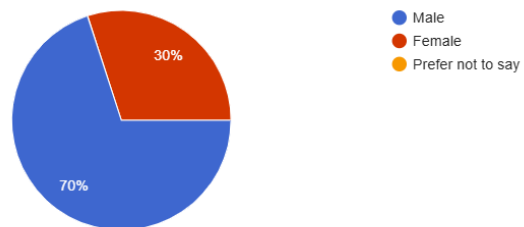
- Male
- Female
- Prefer not to say

SECTION A: RESPONDENT INFORMATION (8 Questions)

1. What is your gender?

 Copy chart

30 responses



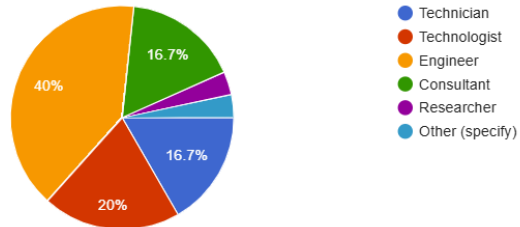
2. What is your current role in the Nigerian power sector?

- Technician
- Technologist
- Engineer
- Consultant
- Researcher
- Other (specify)

2. What is your current role in the Nigerian power sector?

30 responses

 [Copy chart](#)

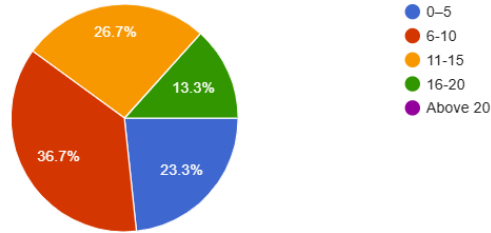


3. How many years of professional experience do you have in the Nigerian power sector?

- 0–5
- 6–10
- 11–15
- 16–20
- Above 20

3. How many years of professional experience do you have in the Nigerian power sector? [Copy chart](#)

30 responses

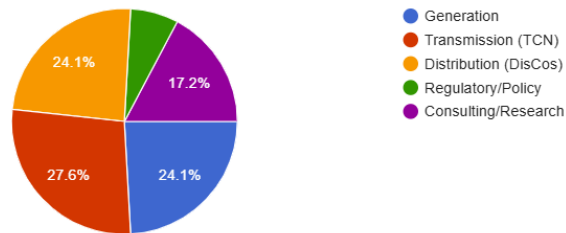


4. Which section of the grid do you work closely with?

- Generation
- Transmission (TCN)
- Distribution (DisCos)
- Regulatory/Policy
- Consulting/Research

4. Which section of the grid do you work closely with? [Copy chart](#)

29 responses



5. Are you familiar with Nigeria's 330 kV and 132 kV transmission network?

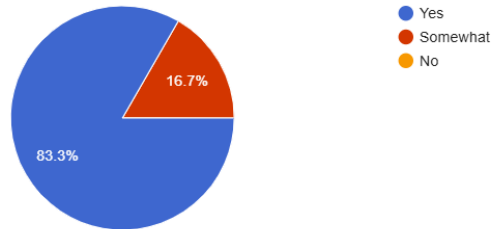
- Yes
- Somewhat

- No

5. Are you familiar with Nigeria's 330 kV and 132 kV transmission network?

[Copy chart](#)

30 responses



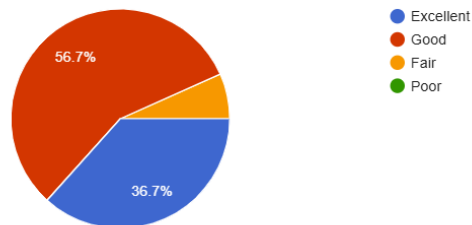
6. Rate your understanding of transmission losses in Nigeria.

- Excellent
- Good
- Fair
- Poor

6. Rate your understanding of transmission losses in Nigeria

[Copy chart](#)

30 responses



7. How important is transmission loss reduction to Nigeria's power sector?

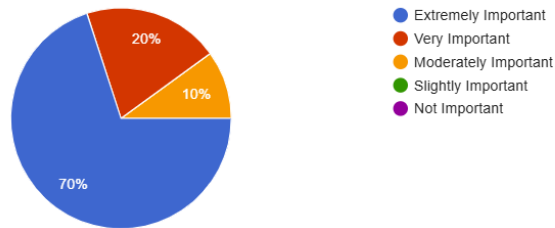
- Extremely important
- Very important
- Moderately important

- Slightly important
- Not important

7. How important is transmission loss reduction to Nigeria's power sector?

[Copy chart](#)

30 responses



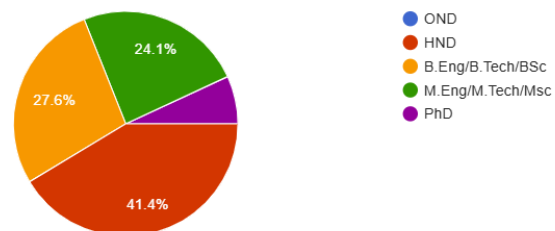
8. Which professional qualification do you hold?

- OND
- HND
- B.Eng/B.Tech
- M.Eng/M.Tech
- PhD
- Other professional certification (specify)

8. Which professional qualification do you hold?

[Copy chart](#)

29 responses



SECTION B: SOURCES OF TRANSMISSION LOSSES (8 Questions)

9. In your opinion, how serious are transmission losses in Nigeria?

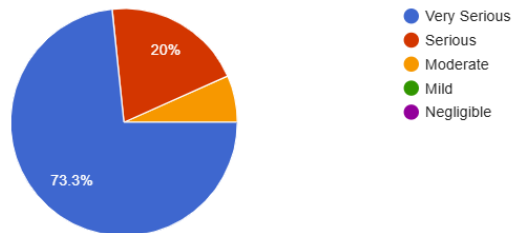
- Very serious
- Serious
- Moderate
- Mild
- Negligible

SECTION B: SOURCES OF TRANSMISSION LOSSES (8 Questions)

9. In your opinion, how serious are transmission losses in Nigeria?

[Copy chart](#)

30 responses



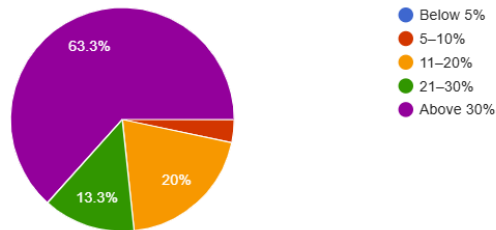
10. What level of technical losses do you believe Nigeria currently experiences?

- Below 5%
- 5–10%
- 11–20%
- 21–30%
- Above 30%

10. What level of technical losses do you believe Nigeria currently experiences?

[Copy chart](#)

30 responses



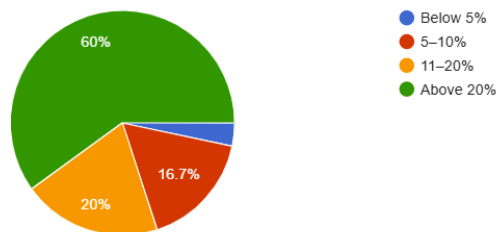
11. What level of non-technical losses do you believe Nigeria currently experiences?

- Below 5%
- 5-10%
- 11-20%
- Above 20%

11. What level of non-technical losses do you believe Nigeria currently experiences?

[Copy chart](#)

30 responses



12. Which factors contribute most to technical losses? (Select all that apply)

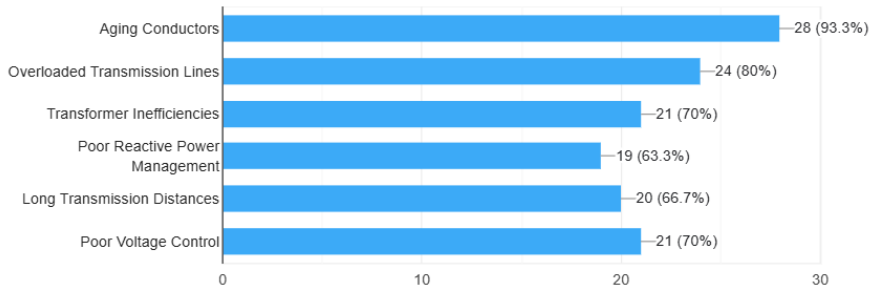
- Aging conductors
- Overloaded transmission lines
- Transformer inefficiencies

- Poor reactive power management
- Long transmission distances
- Poor voltage control

12. Which factors contribute most to technical losses? (Select all that apply)

[Copy chart](#)

30 responses



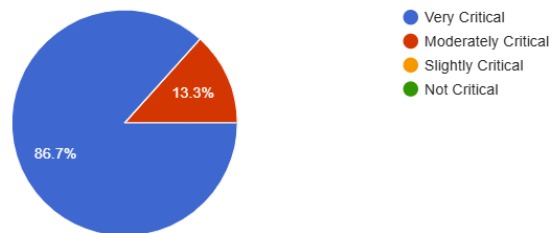
13. How critical is conductor aging as a cause of power losses?

- Very critical
- Moderately critical
- Slightly critical
- Not critical

13. How critical is conductor aging as a cause of power losses?

[Copy chart](#)

30 responses



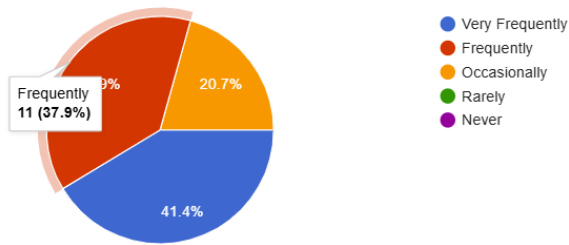
14. How often do transmission lines become overloaded in your area?

- Very frequently
- Frequently
- Occasionally
- Rarely
- Never

14. How often do transmission lines become overloaded in your area?

[Copy chart](#)

29 responses



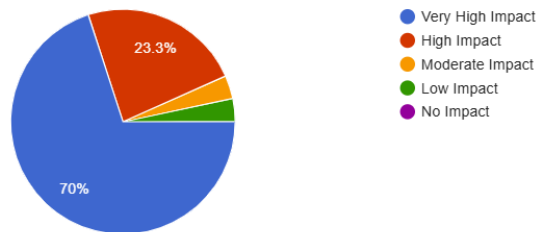
15. To what extent does vandalism contribute to transmission losses?

- Very high impact
- High impact
- Moderate impact
- Low impact
- No impact

15. To what extent does vandalism contribute to transmission losses?

[Copy chart](#)

30 responses



16. In your experience, what other major loss contributors exist?

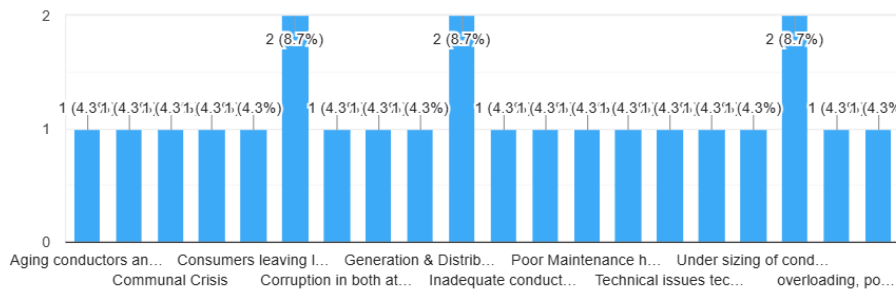
- Open-ended response

16. In your experience, what other major loss contributors exist?

[Copy chart](#)

• Open-ended response

23 responses



SECTION C: CURRENT TRANSMISSION SYSTEM PERFORMANCE (8 Questions)

17. How would you rate the overall performance of Nigeria’s transmission grid?

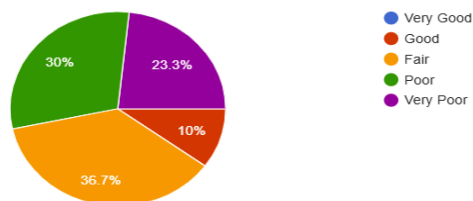
- Very good
- Good
- Fair
- Poor
- Very poor

SECTION C: CURRENT TRANSMISSION SYSTEM PERFORMANCE (8 Questions)

17. How would you rate the overall performance of Nigeria’s transmission grid?

[Copy chart](#)

30 responses



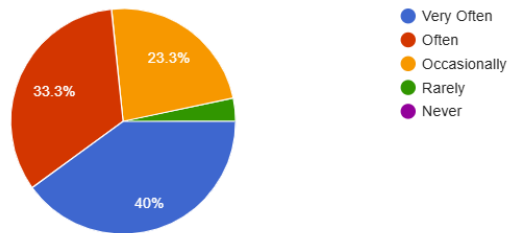
18. How often do voltage instability issues occur?

- Very often
- Often
- Occasionally
- Rarely
- Never

18. How often do voltage instability issues occur?

30 responses

[Copy chart](#)



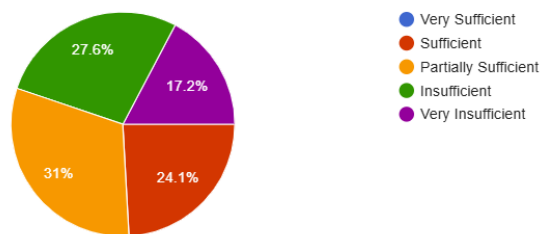
19. How sufficient is network redundancy (parallel lines, ring topology)?

- Very sufficient
- Sufficient
- Partially sufficient
- Insufficient
- Very insufficient

19. How sufficient is network redundancy (parallel lines, ring topology)?

29 responses

[Copy chart](#)



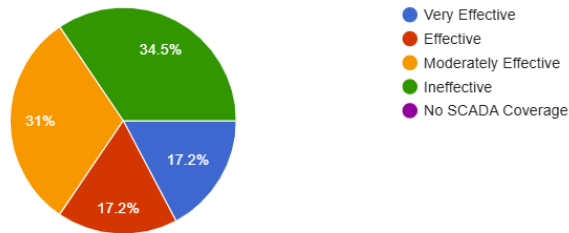
20. Rate the effectiveness of current monitoring and SCADA systems.

- Very effective
- Effective
- Moderately effective
- Ineffective
- No SCADA Coverage

20. Rate the effectiveness of current monitoring and SCADA systems.

[Copy chart](#)

29 responses



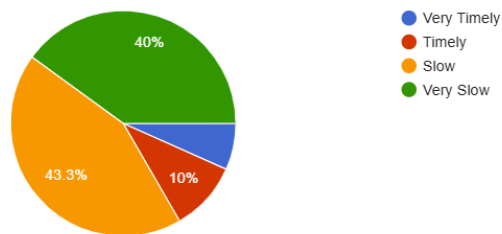
21. How timely is fault detection on the transmission network?

- Very timely
- Timely
- Slow
- Very slow

21. How timely is fault detection on the transmission network?

[Copy chart](#)

30 responses



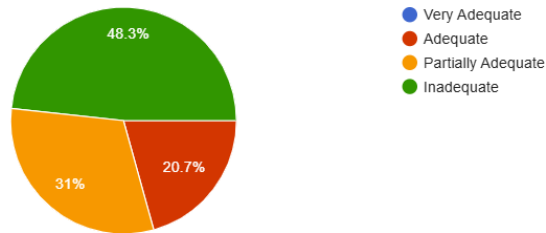
22. How adequate is reactive power support across substations?

- Very adequate
- Adequate
- Partially adequate
- Inadequate
- Very inadequate

22. How adequate is reactive power support across substations?

[Copy chart](#)

29 responses



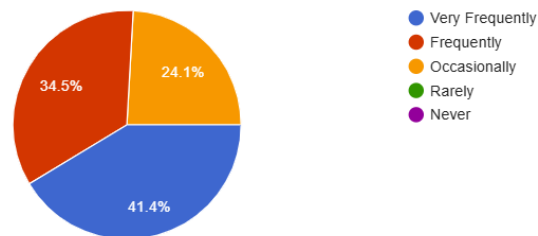
23. How frequently do line trips or outages occur in your operational area?

- Very frequently
- Frequently
- Occasionally
- Rarely
- Never

23. How frequently do line trips or outages occur in your operational area?

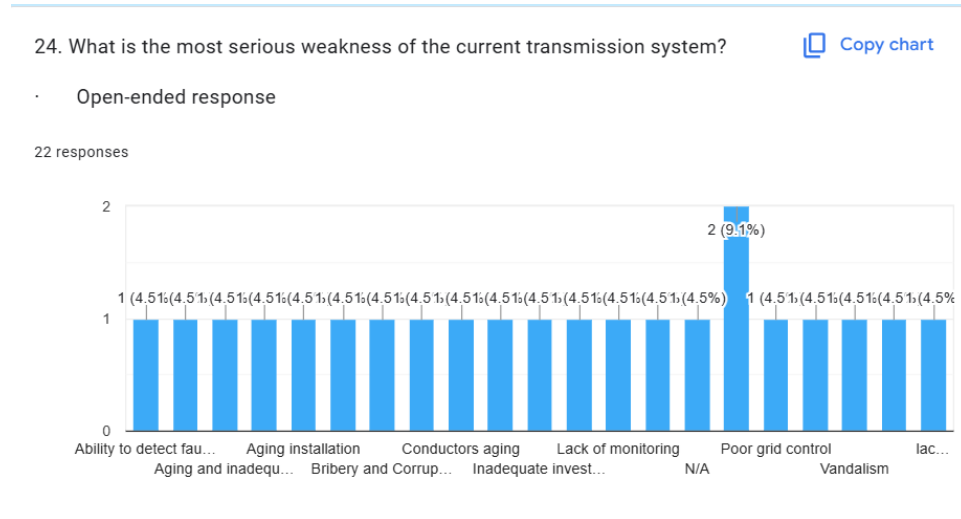
[Copy chart](#)

29 responses



24. What is the most serious weakness of the current transmission system?

- Open-ended response



SECTION D: OPTIMISATION TECHNIQUES (8 Questions)

25. Which optimisation methods are most effective? (Select all that apply)

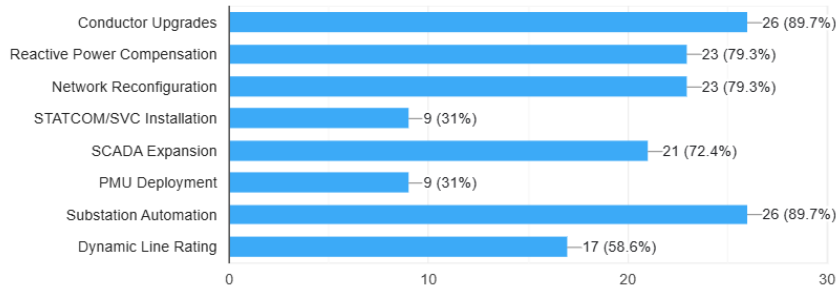
- Conductor upgrades
- Reactive power compensation
- Network reconfiguration
- STATCOM/SVC installation
- SCADA expansion
- PMU deployment
- Substation automation
- Dynamic line rating

SECTION D: OPTIMIZATION TECHNIQUES (8 Questions)

25. Which optimization methods are most effective? (Select all that apply)

[Copy chart](#)

29 responses



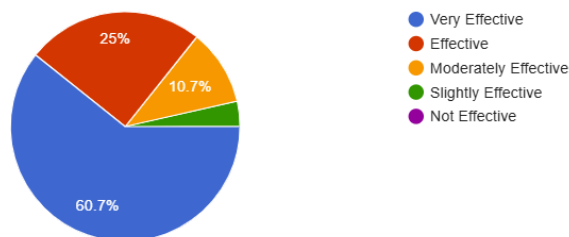
26. Rate the potential effectiveness of conductor upgrades in reducing losses.

- Very effective
- Effective
- Moderately effective
- Slightly effective
- Not effective

26. Rate the potential effectiveness of conductor upgrades in reducing losses.

[Copy chart](#)

28 responses



27. Rate the potential effectiveness of reactive power compensation.

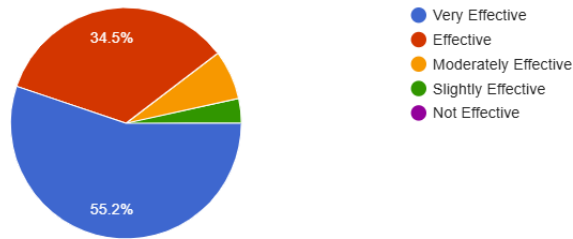
- Very effective
- Effective
- Moderately effective

- Slightly effective
- Not effective

27. Rate the potential effectiveness of reactive power compensation.

[Copy chart](#)

29 responses



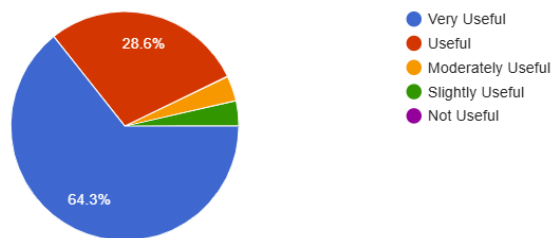
28. How useful is SCADA expansion for reducing losses?

- Very useful
- Useful
- Moderately useful
- Slightly useful
- Not useful

28. How useful is SCADA expansion for reducing losses?

[Copy chart](#)

28 responses



29. How important is substation automation for improving grid reliability?

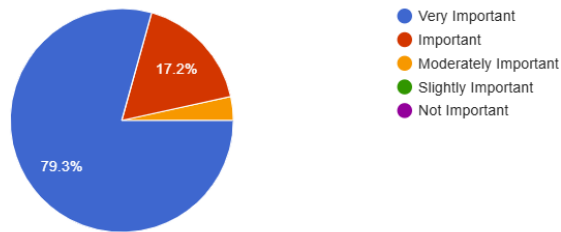
- Very important
- Important
- Moderately important

- Slightly important
- Not important

29. How important is substation automation for improving grid reliability?

[Copy chart](#)

29 responses



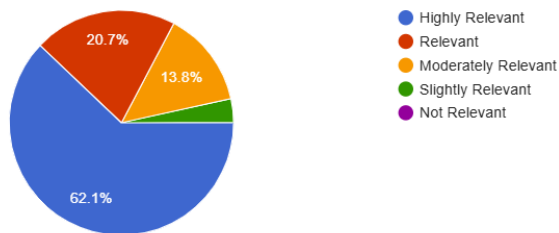
30. How relevant is dynamic line rating (DLR) for Nigeria's grid?

- Highly relevant
- Relevant
- Moderately relevant
- Slightly relevant
- Not relevant

30. How relevant is dynamic line rating (DLR) for Nigeria's grid?

[Copy chart](#)

29 responses



31. What are the main barriers to implementing optimization techniques? (Select all that apply)

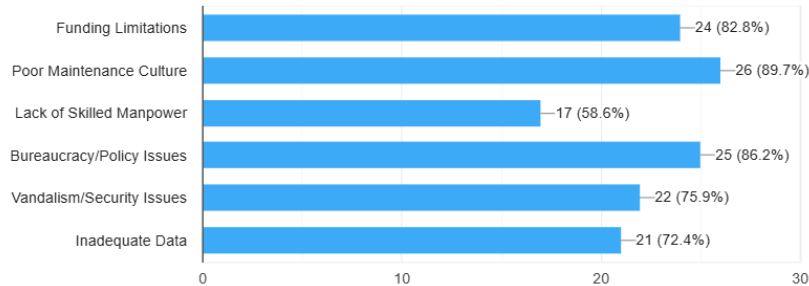
- Funding limitations
- Poor maintenance culture
- Lack of skilled manpower

- Bureaucracy/policy issues
- Vandalism/security issues
- Inadequate data

31. What are the main barriers to implementing optimization techniques?
(Select all that apply)

[Copy chart](#)

29 responses



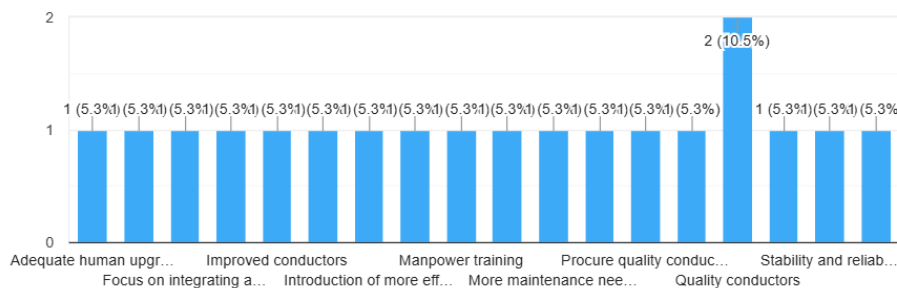
32. Suggest additional optimization strategies for Nigeria's transmission network.

- Open-ended response

32. Suggest additional optimization strategies for Nigeria's transmission network.

[Copy chart](#)

19 responses



SECTION E: EXPECTED BENEFITS AND IMPACT (8 Questions)

33. How much improvement in transmission efficiency is expected from these strategies?

- 0–5%

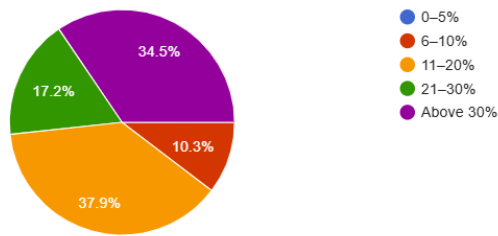
- 6–10%
- 11–20%
- 21–30%
- Above 30%

SECTION E: EXPECTED BENEFITS AND IMPACT (8 Questions)

33. How much improvement in transmission efficiency is expected from these strategies?

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29 responses

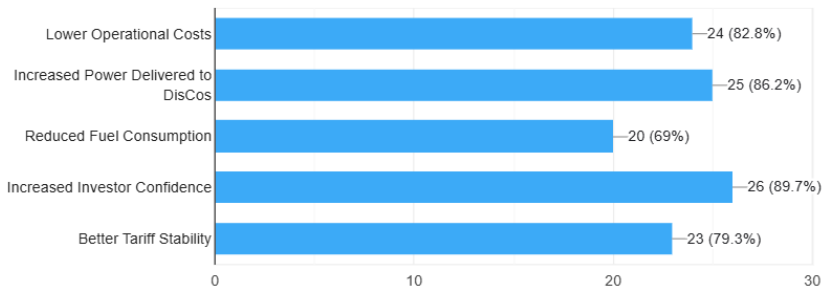


34. What economic benefits will improve transmission efficiency bring? (Select all that apply)

- Lower operational costs
- Increased power delivered to DisCos
- Reduced fuel consumption
- Increased investor confidence
- Better tariff stability

34. What economic benefits will improve transmission efficiency bring? (Select all that apply) [Copy chart](#)

29 responses



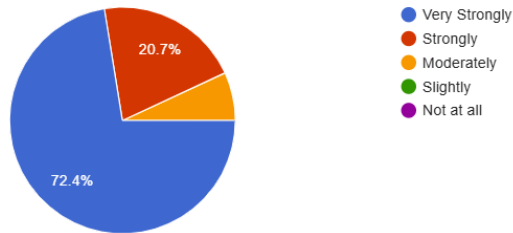
35. How strongly will these measures improve system reliability?

- Very strongly
- Strongly
- Moderately
- Slightly
- Not at all

35. How strongly will these measures improve system reliability?

[Copy chart](#)

29 responses



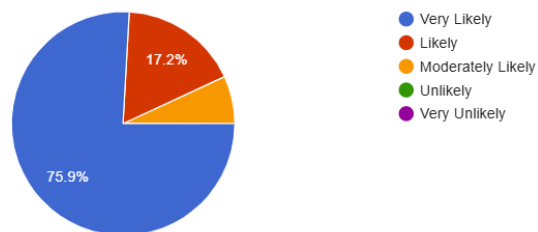
36. How likely are these strategies to reduce nationwide outages?

- Very likely
- Likely
- Moderately likely
- Unlikely
- Very unlikely

36. How likely are these strategies to reduce nationwide outages?

[Copy chart](#)

29 responses



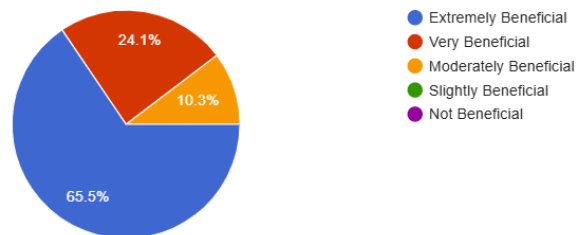
37. How beneficial is improved reactive power management?

- Extremely beneficial
- Very beneficial
- Moderately beneficial
- Slightly beneficial
- Not beneficial

37. How beneficial is improved reactive power management?

29 responses

 [Copy chart](#)



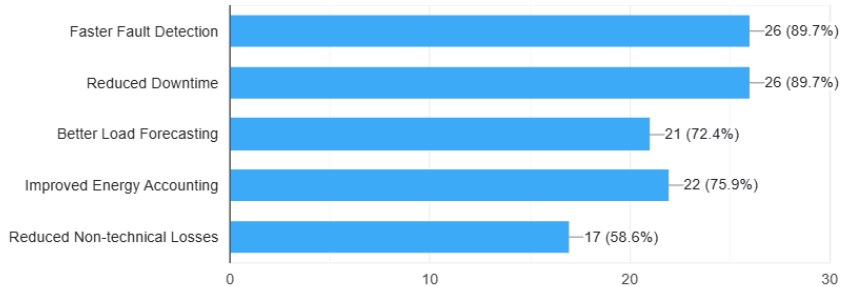
38. What operational improvements are expected from smart monitoring systems? (Select all that apply)

- Faster fault detection
- Reduced downtime
- Better load forecasting
- Improved energy accounting
- Reduced non-technical losses

38. What operational improvements are expected from smart monitoring systems? (Select all that apply)

[Copy chart](#)

29 responses



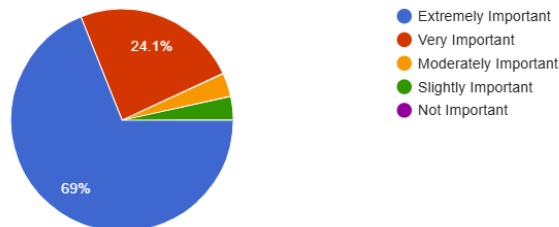
39. How important is loss reduction for Nigeria's long-term economic growth?

- Extremely important
- Very important
- Moderately important
- Slightly important
- Not important

39. How important is loss reduction for Nigeria's long-term economic growth?

[Copy chart](#)

29 responses



40. Please share any final comments or suggestions on optimising Nigeria's transmission network.

- Open-ended response

40. Please share any final comments or suggestions on optimizing Nigeria's transmission network.

· Open-ended Response

17 responses

Capital punishment for corruption and vandalism

Requires a multi pronged approach: aggressive investment and infrastructure modernization

More budget for the transmission

Optimizing Nigeria transmission network will increase the energy supply to the discos and so in turn make power available for both companies and households and so bring more investments into the economy and create jobs

Training, Employment,

Infrastructure update and protection of transmission lines from vandalism and theft

Optimizing Nigeria transmission network, will improve Nigeria transmission efficiency and add to the stability of Nigeria economy. Development will also improve and life will become more easy for Nigerians

Zero corruption and lines protection

Cont'd..

40. Please share any final comments or suggestions on optimizing Nigeria's transmission network.

· Open-ended Response

17 responses

Adequate investment

A reliable planing system

This approach will generally improve power supply and ensure reliability

No to Bribery and Corruption

Modern metaheuristics and AI offer powerful tools for planning and managing

Zero tolerance for corruption

Zero tolerance for bribery, corruption and vandalism

Continuous Manpower training

Continuous training of transmission personnel