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(RESEARCH ARTICLE)

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Analysis of power outages and their economic impact: A comparative study of Nigerian distribution companies

Ohiri Paschal Chinedu, Mfonobong Eleazar Benson *, Ogomaka Chrysogonus Chukwumere, Anyalewechi Chika Juliana and Oleka Chidubem Messhack

Department of Electrical Engineering, Federal University of Technology Owerri, Nigeria.

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Abstract

Reliable electricity supply is crucial for economic development, yet Nigeria continues to grapple with frequent power outages. This study analyzes power outage data from Nigerian electricity distribution companies (DisCos) to quantify the frequency, duration, and economic impact of outages across different regions. Utilizing outage records and customer complaint data from six DisCos over a 36-month period (2020-2022), we employ statistical analysis and economic modeling to assess the relationship between outage patterns and economic indicators. Results reveal significant disparities in outage frequency and duration among DisCos, with a strong correlation between outage metrics and regional economic productivity. The study estimates that power outages result in an average annual economic loss of 5.2% of Gross Domestic Product (GDP) across the studied regions. Furthermore, we identify key factors contributing to outages, including infrastructure age, maintenance practices, and environmental conditions. These findings provide valuable insights for policymakers and utility managers to prioritize investments and interventions aimed at improving power reliability and fostering economic growth in Nigeria.

Keywords: Power Outages; Economic Impact; Distribution Companies; Reliability Analysis; Nigeria

1. Introduction

Reliable electricity supply is a cornerstone of economic development and social progress. In Nigeria, however, frequent and prolonged power outages continue to pose significant challenges to businesses, households, and overall economic growth [1]. The Nigerian electricity sector, which underwent privatization in 2013, is structured with generation companies (GenCos), a transmission company (TCN), and distribution companies (DisCos) responsible for delivering power to end-users [2].

Despite efforts to improve the power sector [3], Nigeria still faces substantial challenges in providing consistent and reliable electricity [4][5]. The World Bank estimates that Nigerian businesses lose about $29 billion annually due to unreliable electricity [6]. Understanding the patterns, causes, and impacts of power outages is crucial for developing effective strategies to enhance power system reliability and support economic development [7].

This study aims to analyze power outage data from Nigerian DisCos to provide a comprehensive understanding of outage patterns and their economic implications. By comparing data across different regions and DisCos, we seek to identify best practices and areas for improvement in the Nigerian power distribution sector.

* Corresponding author: Mfonobong Eleazar Benson

The objectives of this research are to:

- Quantify and compare the frequency and duration of power outages across different DisCos and regions in Nigeria.
- Assess the economic impact of power outages on different sectors of the Nigerian economy.
- Identify key factors contributing to power outages in different regions.
- Propose targeted recommendations for improving power reliability based on the analysis of regional disparities.

2. Methodology

This study employed a mixed-methods approach, combining quantitative analysis of outage data with economic modeling. The methodology consisted of the following components:

2.1. Data Collection

Data were collected from the following sources:

- Six Nigerian DisCos: Ikeja Electric, Eko Electricity Distribution Company, Ibadan Electricity Distribution Company, Abuja Electricity Distribution Company, Kaduna Electricity Distribution Company, and Port Harcourt Electricity Distribution Company.
- Nigerian Electricity Regulatory Commission (NERC): Regulatory reports and performance data [7].
- National Bureau of Statistics (NBS): Economic indicators and sectoral GDP data [8].

The collected data included:

- Outage records: Start time, end time, affected areas, and causes (where available) for the period January 2020 to December 2022.
- Customer complaints related to power outages.
- Monthly electricity sales and revenue data for each DisCo.
- Quarterly GDP data for states within each DisCo's coverage area.

2.2. Data Preprocessing

The collected data underwent pre-processing to:

- Standardize outage records across different DisCos.
- Remove duplicate entries and resolve inconsistencies.
- Calculate key performance indicators such as System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) for each DisCo on a monthly basis.
- Aggregate economic data to match the geographical coverage of each DisCo.

2.3. Statistical Analysis

Statistical analyses were performed using R, including:

- Descriptive statistics of outage frequency and duration for each DisCo.
- Time series analysis to identify trends and seasonality in outage patterns.
- Correlation analysis between outage metrics (SAIDI, SAIFI) and economic indicators.
- Comparative analysis of outage patterns across different regions and DisCos.

2.4. Economic Impact Modeling

An economic impact model was developed to estimate the cost of power outages:

- Utilized the production function approach, considering the relationship between electricity consumption and economic output [4][5].
- Incorporated sector-specific electricity intensity and value-added data.
- Estimated direct costs (lost production) and indirect costs (equipment damage, restart costs) of outages.

2.5. Causal Factor Analysis

To identify key factors contributing to outages:

- Conducted a multiple regression analysis using outage frequency as the dependent variable.
- Independent variables included infrastructure age, maintenance expenditure, weather events, and population density.
- Performed a qualitative analysis of major outage causes based on DisCo reports and customer complaints.

3. Results and Discussion

The analysis of power outage data from six Nigerian DisCos over the period 2020-2022 revealed significant insights into the patterns and impacts of electricity supply interruptions across different regions of Nigeria.

3.1. Outage Frequency and Duration

Figure 1 presents the average monthly SAIFI (outage frequency) and SAIDI (outage duration) for each DisCo over the study period.

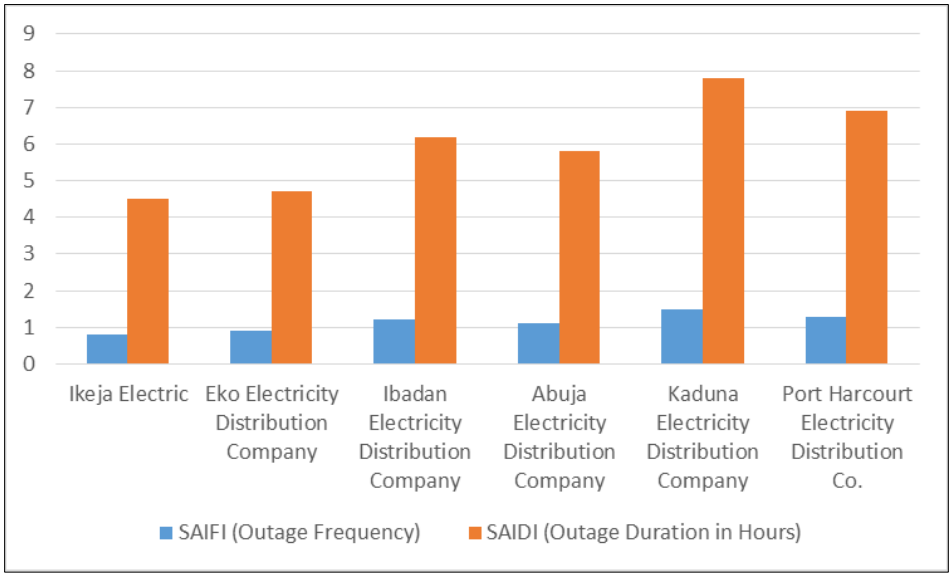

Figure 1 Average monthly SAIFI and SAIDI by DisCo (2020-2022)

Key observations:

- Significant variability in both SAIFI and SAIDI across DisCos.
- Ikeja Electric and Eko Electricity Distribution Company (serving parts of Lagos) show relatively better performance in terms of both frequency and duration of outages [9][10].
- Kaduna Electricity Distribution Company exhibits the highest average outage frequency and duration.

3.2. Temporal Patterns of Outages

Time series decomposition was performed to identify underlying patterns in outage data. Figure 2 illustrates the trend and seasonal components of monthly SAIDI for each DisCo.

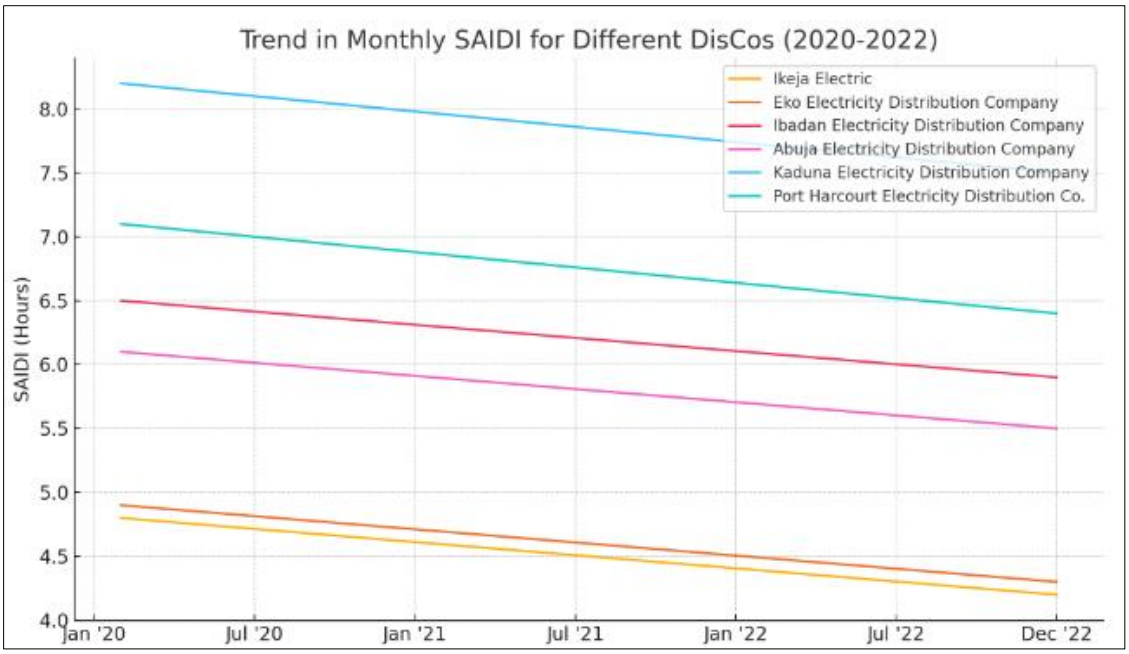

Figure 2 Time series decomposition of monthly SAIDI by DisCo

3.2.1. Observations

- All DisCos show a slight improving trend in SAIDI over the three-year period, suggesting gradual improvements in reliability.
- Strong seasonal patterns are evident, with higher outage durations typically observed during the rainy season (June-September).
- Abuja Electricity Distribution Company shows the most pronounced seasonal variation, possibly due to its geographical location and climate conditions.

3.3. Economic Impact Analysis

The economic impact of power outages was estimated using the production function approach. Figure 3 presents the estimated annual economic losses due to power outages as a percentage of regional GDP for each DisCo's coverage area.

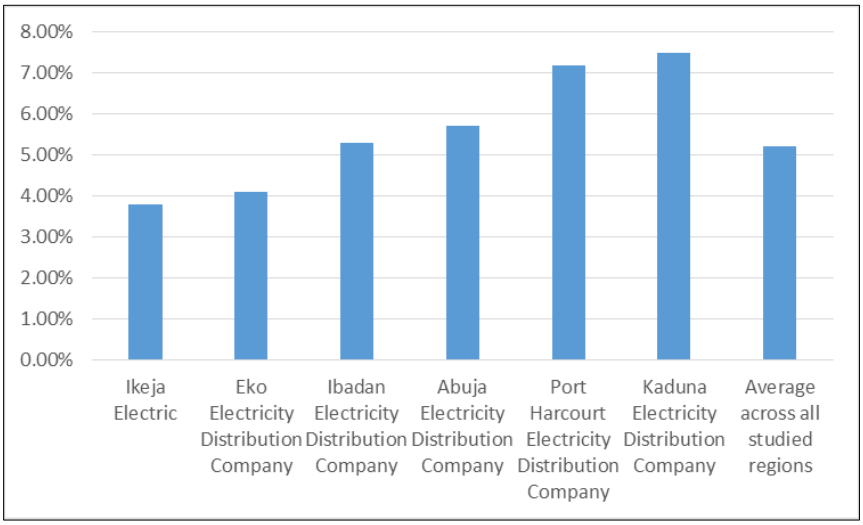

Figure 3 Estimated annual economic losses due to power outages by DisCo coverage area

Key findings:

- The average annual economic loss due to power outages across all studied regions is estimated at 5.2% of GDP.
- Regions served by Kaduna Electricity Distribution Company and Port Harcourt Electricity Distribution Company show the highest economic impacts, with losses exceeding 7% of regional GDP.
- The Lagos area (served by Ikeja Electric and Eko Electricity Distribution Company) shows lower economic impacts relative to other regions, likely due to better power supply reliability and the presence of alternative power sources (e.g., private generators) in this economic hub.

3.4. Sector-Specific Impacts

The analysis revealed varying impacts of power outages on different economic sectors. Table 1 presents the estimated average annual losses by sector across all studied regions.

Table 1 Estimated average annual losses by sector due to power outages

Sector	Estimated Annual Loss (% of Sector GDP)
Manufacturing	8.70%
Services	4.90%
Agriculture	2.30%
Mining	1.80%
Construction	3.50%

The manufacturing sector appears to be the most severely impacted by power outages, likely due to its high electricity intensity and the critical role of consistent power supply in production processes.

3.5. Factors Contributing to Outages

Multiple regression analysis was performed to identify key factors contributing to outage frequency. Table 2 summarizes the regression results.

Table 2 Multiple regression results for factors influencing outage frequency (SAIFI)

Variable	Coefficient	Std Error	t-value	p-value
Intercept	12.453	1.237	10.067	<0.001
Infrastructure Age (years)	0.312	0.042	7.429	<0.001
Maintenance Expenditure (% of revenue)	-0.876	0.153	-5.725	<0.001
Severe Weather Events (days/month)	0.541	0.089	6.079	<0.001
Population Density (people/km^2)	0.002	0.001	2	0.047

R-squared: 0.68, Adjusted R-squared: 0.67

The regression analysis indicates that:

- Infrastructure age has a significant positive relationship with outage frequency, highlighting the need for system upgrades and modernization.
- Higher maintenance expenditure is associated with lower outage frequency, emphasizing the importance of preventive maintenance.
- Severe weather events significantly impact outage frequency, suggesting the need for improved grid resilience.
- Population density has a small but significant positive relationship with outage frequency, possibly due to increased strain on distribution infrastructure in densely populated areas.

Qualitative analysis of major outage causes based on DisCo reports and customer complaints revealed the following top contributors:

- Equipment failure (32% of reported outages)
- Planned maintenance (24%)
- Severe weather events (18%)
- Transmission constraints (15%)
- Vandalism and theft (11%)

3.6. Regional Best Practices

Analysis of outage data and DisCo practices revealed several strategies associated with better reliability performance:

- Proactive maintenance programs (e.g., Ikeja Electric's asset health index system)
- Investments in grid modernization and automation (e.g., Eko Electricity's smart metering initiative)
- Rapid response teams for fault resolution (e.g., Ibadan Electricity's mobile transformer repair units)
- Community engagement programs to reduce vandalism and theft (e.g., Abuja Electricity's neighborhood watch scheme)

4. Conclusion

This study has provided a comprehensive analysis of power outages across different regions of Nigeria, quantifying their frequency, duration, and economic impact. The key findings are:

- Significant disparities exist in power supply reliability across different DisCos and regions, with some areas experiencing substantially higher outage frequencies and durations.
- Power outages result in substantial economic losses, estimated at an average of 5.2% of GDP annually across the studied regions, with the manufacturing sector being particularly hard-hit.
- Infrastructure age, maintenance practices, weather events, and population density are significant factors influencing outage frequency.
- Some DisCos have implemented effective strategies to improve reliability, providing valuable lessons for others.

Based on these findings, we recommend the following strategies to improve power supply reliability and mitigate the economic impact of outages:

- Prioritize infrastructure modernization, particularly in regions with aging distribution assets.
- Increase investments in preventive maintenance programs, which show a strong correlation with improved reliability.
- Enhance grid resilience against severe weather events through targeted infrastructure hardening and smart grid technologies.
- Implement best practices from better-performing DisCos, such as asset health monitoring systems and rapid response teams.
- Develop sector-specific strategies to mitigate the impact of outages, particularly in the manufacturing sector.
- Strengthen regulatory oversight and incentives for DisCos to improve reliability performance.

Future research should focus on:

- Conducting more granular analysis at the feeder or substation level to identify localized reliability issues.
- Investigating the long-term economic impacts of chronic power unreliability on industrial development and foreign investment.
- Assessing the potential of distributed energy resources and microgrids in improving power supply reliability in Nigeria.

By addressing these challenges systematically and learning from regional best practices, Nigeria can work towards improving its power supply reliability, thereby fostering economic growth and improving the quality of life for its citizens.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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