

Geospatial Assessment of Distribution Patterns of Electricity Transformers in Rigasa, Igabi Local Government Area, Kaduna State

Habiba Ibrahim Mohammed ^a

^aDepartment of Geography and Sustainability Studies, Kaduna State University, Kaduna, Nigeria.

ABSTRACT

This paper analyzed the spatial distribution of electricity transformers in Taro-Taro, Makera, and Hayin Dangaladima Rigasa, Igabi L.G.A. QGIS 3.18 software was used for data processing and analysis. The geographic locations of transformers were acquired using GPS and displayed in the QGIS environment, appearing as a point layer on the map, with the transformer attribute tables displayed. In view of this study, nineteen electric transformers in Taro-Taro and Makera/Hayin Dangaladima were examined. The pattern of distribution of electric transformers in the Taro-Taro and Makera/Hayin Dangaladima is dispersed. The facilities in the electric transformers were also examined, where the 500KVA transformer has the highest number, while the 200KVA, which is only one, has the least number in terms of capacity. Five electric transformers with ten years of service have the highest with 26.32%, and four electric transformers each with one year, two years, eight years, and 12 years of service have the lowest with 5.26%. This study reveals the ability of GIS and remote sensing techniques to capture and acquire spatiotemporal data for analyzing the distribution of electricity transformers. Kaduna Electricity Distribution Company should, as a matter of urgency, come to the aid of this community to improve and increase the number of transformers that require replacement and those that require upgrading.

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1 Introduction

The electrical power sector plays an important role in the economic growth and development of every country around the world (Strielkowski et al., 2021). Fortunately, demand analyses and load forecasts for this sector have a better foundation than those of other energy sources because of the availability of accurate consumption data from individually metered customers, although such data may not always be available in a convenient format, for analytical purposes (Mir et al., 2020). The Power Holding Company of Nigeria (PHCN), formerly known as the National Electric Power Authority (NEPA), is an organization involved in the supply of electricity in Nigeria. Presently, due to the privatization of the power sector, Kaduna, Zamfara, Kebbi, and Sokoto states now have an electricity distribution power body called Kaduna Electricity Distribution Company (Kaduna Electric). The power sector plays a very important role in the economic development of a nation; therefore, the growth of industries, agriculture, infrastructure, and the private sector is dependent on the state of the power sector (Abana, 2018; Ota, 2021).

Electric power is the engine that drives industrialization, which improves communication, helps innovation in science and technology, provides a sound healthcare delivery system, and improves citizens' standard of living (Oluwatoyin et al., 2015). Since electric power is the engine that drives industrialization, a stable

supply is the key for Nigeria to become one of the 20 developed economies in the world (Baba et al., 2020). However, it is unfortunate that the biggest problem in Nigeria is the electricity crisis, a crisis without end, as the electricity supply in Nigeria is characterized by frequent power failures and load shedding (Aliyu et al., 2013).

Generally, electricity could be accepted as an electric current. This involves the generation, transmission, and distribution of the electric current to consumers. Electricity is an aspect of the utility sector that is essential to the smooth and meaningful development of a society. It supports the economy and promotes the well-being of individuals. The efficient functioning of this utility is of paramount importance for the sustenance of its growth and the consequential realization of its planning and managerial objectives (Shabalov et al., 2021). According to Arunagiri and Agarwal (2005), distributing transformers can also be fitted with meters so that loading of the transformers can be monitored in real-time and the need for new transformers can be decided (Usman et al., 2022). This can be made visual by assigning a different colour on the map for a transformer once it is overloaded, hence giving a proper warning. Any aberration can be easily detected (Chatta 2011).

Transformers are not evenly distributed in Nigeria, and as a result of that, the rate of utilization of each one may be high (Amadi & Izuegbunam, 2016). Because a lot of houses use just one transformer, which will in turn cause

the transformers to develop problems and at the end, even pack up. An example is the case where there is one transformer serving many houses beyond its capacity; that transformer may pack up due to the excess load it is carrying. Energy demand in developing countries will rise enormously as per capita incomes and population grow. No country has been able to raise per capita income from low levels to high levels without increasing its use of commercial energy. Sule (2015) also reported that the distribution areas in Kaduna, Kebbi, and Sokoto have been completed but are yet to be commissioned, and once commissioned, they will add to what the states are receiving from the distribution company, and that will boost power supply in the zone.

Due to the above-highlighted challenges facing power sectors as well as the current reforms aimed at mitigating the challenges, this study can therefore be considered timely and relevant as it is meant to improve the understanding of effective power supply in electricity distribution. Most importantly, it will help the power industry to keep track of the electrical facilities (transformers) involved in the delivery of energy to the end-users. This was made possible with the aid of a geodatabase management system, as a variety of information can be better organized on a computer system linking the database to an output map, and is effectively used to manage and monitor information on the distribution of electricity to end-users, including information describing their spatial and non-spatial attributes such as geographical location and transformer capacity in KVA.

2 Materials and Methods

2.1 Study Area

The study area is situated between Latitudes $10^{\circ} 31' 30.14$, $10^{\circ} 32' 53.62$ N of the equator, and Longitudes $7^{\circ} 22' 33.88$, $7^{\circ} 23' 45.02$ E, of the Greenwich meridian (Figure 1). The study area is located in Kaduna Metropolis, which is the capital city of Kaduna State in Northern Nigeria (Abdullahi, 2020). It covers mainly some localities within the Igabi Local Government Area. The study is restricted to Taro-taro and Makera/Hayin Dangeladima Rigasa, Igaba LGA.

Igabi LGA is situated in a tropical wet and dry climate, with the wet season running for about six to seven months, mostly between April and October, with an average rainfall of 1400mm, and the dry season, denoted Harmattan, has severe dust haze, with northerly winds blowing from the desert (Abubakar et al., 2024). The maximum temperature in Kaduna metropolis can be over 30°C , with the hottest months being March, April, and May. Relative humidity typically ranges 25% and 90%, depending on the month of the year, with the lowest humidity between December and February (Nigerian

Meteorological Agency [NIMET], 2018).

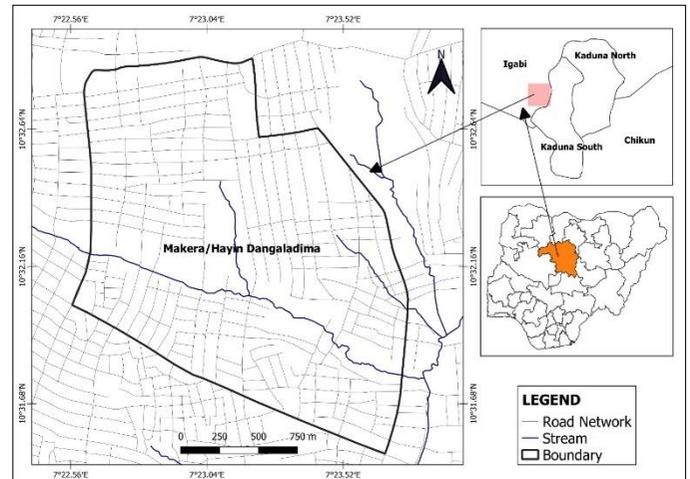


Figure 1: Map of The Study Area

Source: Modified from GRID3 Nigeria

2.2 Reconnaissance Survey

A reconnaissance survey was conducted to familiarize oneself with the study area. This gave the researchers an in-depth knowledge of the electricity distribution and the condition of the transformer in the study area.

2.3 Data Sources

The administrative map of Taro-Taro and Makera/Hayin Dangeladima was obtained from GRID3 Nigeria. The geographical coordinates of the electricity transformers were obtained using a Garmin 60CSx handheld GPS receiver; these geographic locations were used to create a map showing the various locations of the electricity transformers with the aid of technical staff from Kaduna Electricity Distribution Company. Lastly, the names of substations, capacity, condition, ownership, and year of service of the electricity transformers.

2.4 Data Analysis

The data obtained were processed and analyzed as follows, based on the research objectives. This study used QGIS 3.18 software for data processing and analysis. Thus, all datasets were transformed into ESRI format (shape files). The administrative map of Taro-Taro and Makera/Hayin Dangeladima was projected to UTM Zone 32 N using a shape file that was created for all features of interest, such as the location of electricity transformers is represented as points, and roads were represented with lines and administrative boundaries with polygons.

The geographical location of transformers was acquired using GPS and transformed into a plain text file format in Microsoft Excel, and was imported into the QGIS environment as waypoints, which appeared as a points layer on the map showing the attributes tables of the transformers. The pattern of distribution of

transformers was determined using the Average Nearest Neighbour (NN) statistical tool. The tool measures the distance between each feature and its nearest Neighbour's location. It then averaged all these nearest Neighbour distances.

Based on the attributes derived from the administration of the questionnaire, a database was created using Microsoft Access and QGIS software. The data for each transformer was entered into its attribute table. The table created in Microsoft Access was exported as a CSV file format, which was compatible with QGIS. The tables were imported into the QGIS environment for analysis.

3 Results and Discussion

3.1 Spatial Distribution of Electric Transformer

Figure 2 illustrates the geographical location of electric transformers in some of the neighborhoods and localities such as Ado Gwaran, Millennium, Satellite, Hayin Amina (split into 1 and 2), Taro-Taro (1 and 2), Rimi, Bayan Wuya (1, 2, and 3), Dogara Ga Allah (1 and 2), Maker(a), Kwanar Gurgu, Lokoja 1, Signboard, and Kachia 1. The transformers are located along or close to roads. This is a common layout in low-voltage distribution in Nigerian residential and semi-formal areas, where the transformers are located in a manner that supplies localized groups of consumers to reduce voltage drop

and line losses (Ogunbiyi et al., 2019). The map indicates the coverage of infrastructure in densely developed areas (for instance, around Satellite, Hayin Amina, and Bayan Wuya) and the periphery (for instance, around Lokoja 1 and Kachia 1), which indicates the attempt to map and possibly optimize electricity access in a region that is known to have irregular power supply, overload, and extension requests due to population growth.

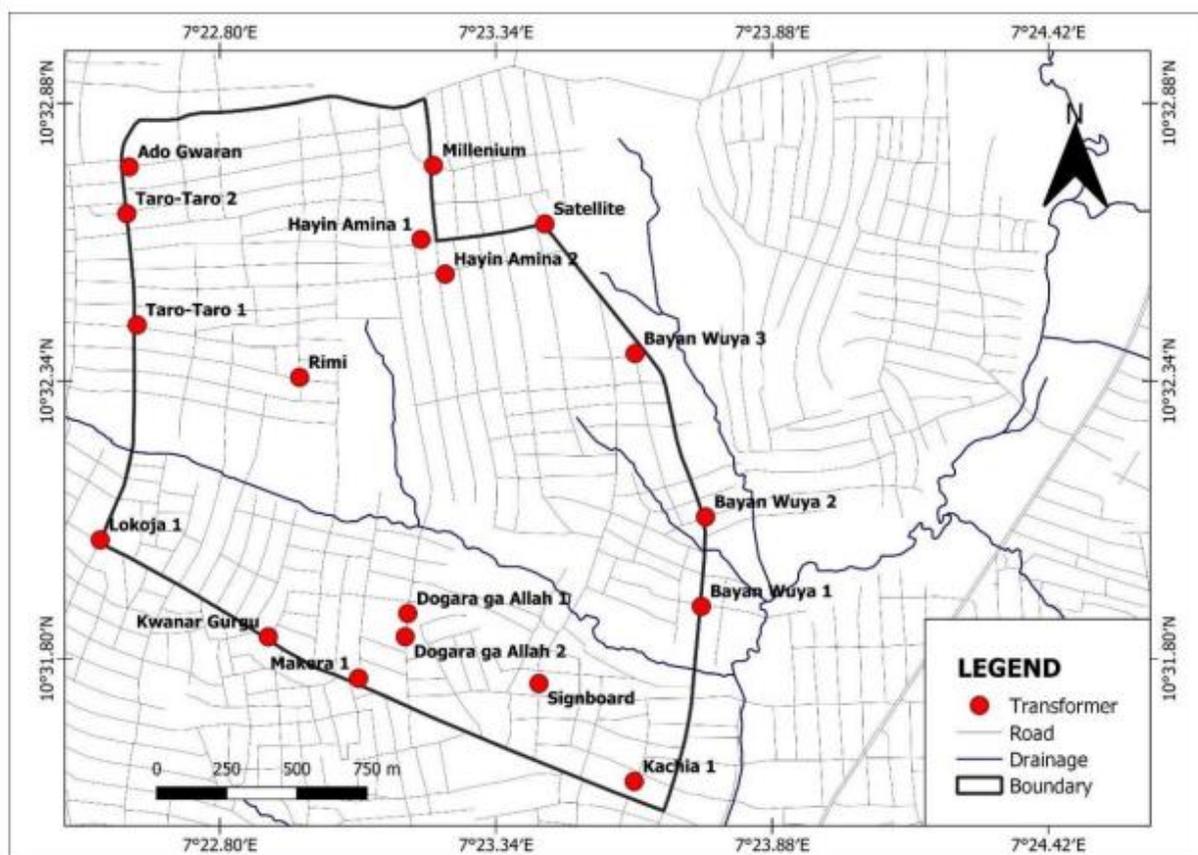


Figure 2: Spatial Distribution of Electric Transformers

3.2 Spatial Pattern of Distribution of Electric Transformer

Table 1 revealed the spatial pattern of distribution of electric transformers using the Average Nearest Neighbour on ArcGIS 10.3 software. The NNA calculates the nearest neighbour index, which is a measure of the distance between each facility centroid and its nearest neighbour's centroid location; it then averages all these nearest neighbour distances. According to Getis and Ord (1998), the z-score usually returns a range of values between -2.58 and 2.58; therefore, a negative z-score less than -2.58 indicates a significant clustering at the 0.01 probability level. A range of scores between both 2.58 to -1.96 at a 0.05 significance level and -1.96 and -1.65 at a 0.10 probability level shows that there is a tendency towards a clustered pattern. A range of z-scores between -1.65 and 1.65 indicates a random distribution. Again, if the z-score lies between 1.65 and 1.95 at the 0.10 significance level

and 1.96 to 2.58 at the 0.05 probability level, then it is obvious that there is a tendency towards a regular pattern.

Table 1: Average Nearest Neighbor Summary

Observed Mean Distance	329.8690 m
Expected Mean Distance	248.9263 m
Nearest Neighbor Ratio:	1.325168
Z-score	2.639213
p-value	0.008310

Looking at the Nearest Neighbor Ratio of 1.325168 with a critical value (z-score) of 2.639213 at 0.008310 level of significance (p-value), it can be concluded that the pattern of distribution of electric transformers in the Taro-Taro and Makera/Hayin Dangaladima is that the public electric transformers are dispersed around each other and around those areas where services are available. This result is illustrated in Figure 3.

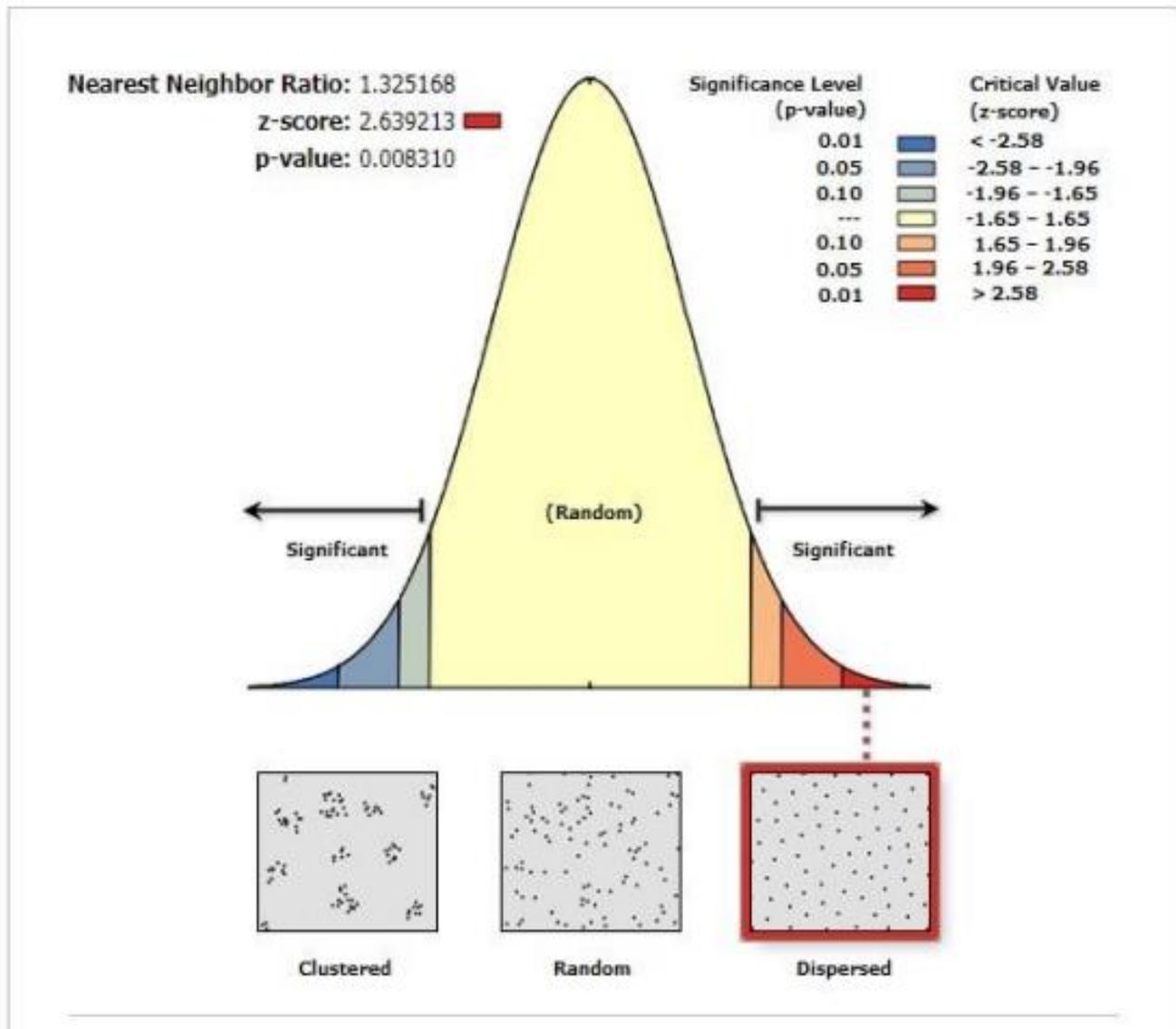


Figure 3: Spatial pattern of electric transformers

3.3 Distribution of Electric Transformers by their Capacities

Table 2 revealed Igabi had only one 200KVA transformer, which amounted to 5.26%, while 300KVA transformers were five in number and accounted for 26.32% of the study area. While 500KVA transformers were thirteen in number and accounted for 68.42% of the study area. In summary, the 500KVA transformer has the highest number, while the 200KVA transformer, which is only one, has the lowest number. Figure 4 shows how the spatial distribution of the capacity of the transformers is distributed. 200KVA, which is identified in red, is located in the northern part of the study area. While the 300KVA, which is in yellow, is located in the northern and southern parts of the study area. The third, which is the 500KVA, is green in color and is located in the northwest, southern part, and southeast of the study area.

Table 2: Capacity of transformer in percentage

S/No	Capacity	Number	%
1	200kva	1	5.26
2	300kva	5	26.32
3	500kva	13	68.42
4	Total	19	100

Figure 4 shows the distribution and capacity variation of electricity transformers in a part of Rigasa, Igabi L.G.A. The map uses a graduated symbol technique to show the capacity of the transformers, with red, yellow, and green symbols representing 200 KVA, 300 KVA, and 500 KVA capacity, respectively. This allows for the determination of capacity distribution in the landscape. Line features show the road network and drainage channels, which are essential in the analysis of the placement of infrastructure in relation to accessibility and environmental considerations. The boundary line is a dashed line that shows the study area and is labeled with toponyms such as Hayin Amina, Millennium, Satellite, and Bayan Wuya, which help to locate the study area in particular localities.

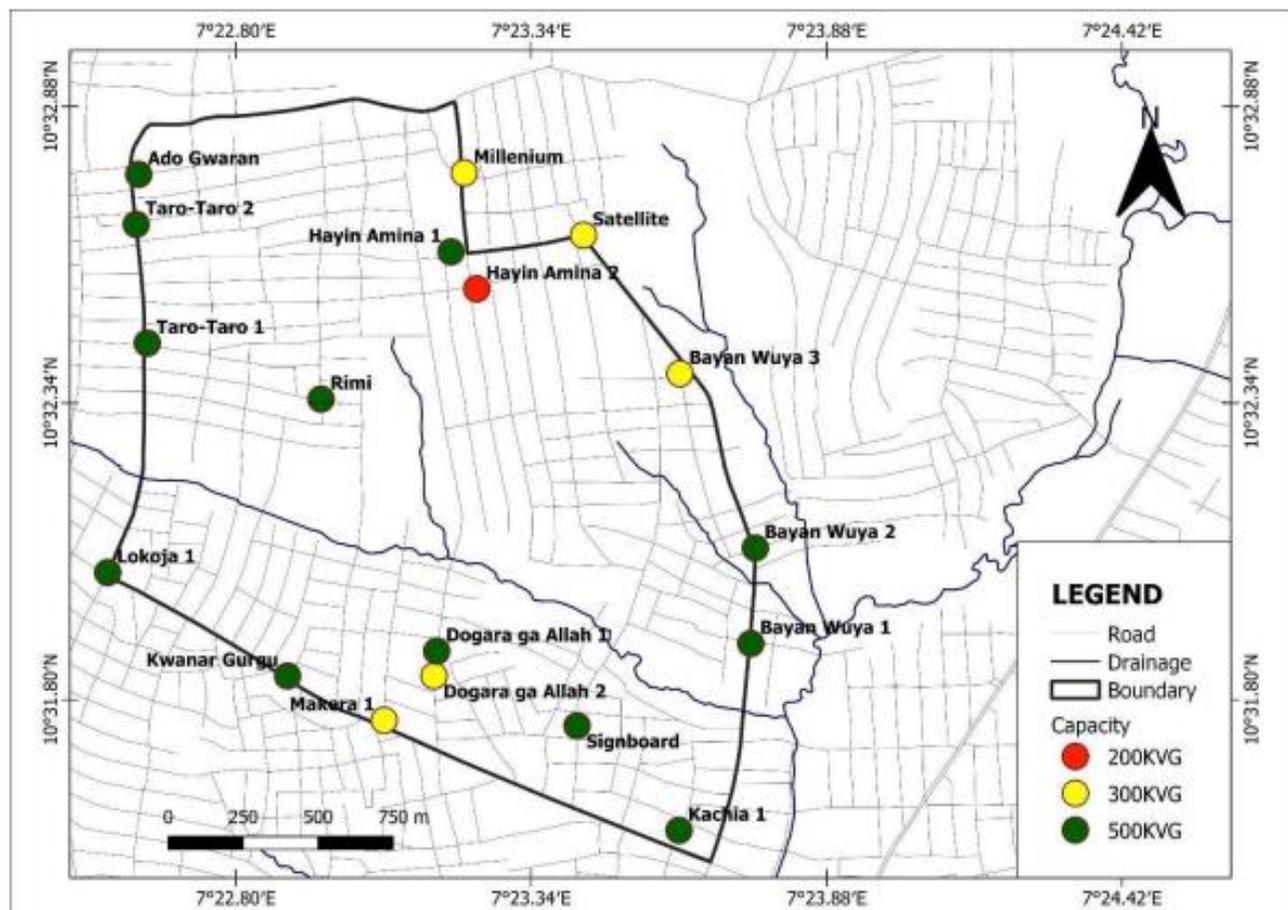


Figure 4: Capacity of Transformer

4 Conclusion

The research work reveals the ability of GIS and remote sensing techniques to capture and acquire spatial data for analyzing the distribution of electricity transformers, their locations, the average transformers requiring upgrading, those requiring total replacement, and the ones required to be a relief to enable safeguarding the networks and prevent the occurrence of electrical facilities damage, life, and property. More so, to improve the living conditions of the society through socio-

economic activities. Furthermore, based on the acknowledged analysis and the degree of various data acquired, in reference to the area of the research, the study has identified that the Kaduna Electricity Distribution Company (Kaduna Electric) should act as a matter of urgency to come to the aid of this community to improve and increase the level of their income to the company.

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