

GEOSPATIAL MODELING OF ELECTRICITY DISTRIBUTION NETWORK IN IFE CENTRAL LOCAL GOVERNMENT AREA, OSUN STATE, NIGERIA

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ABSTRACT

Electric utilities have a need to keep a comprehensive and accurate inventory of their physical assets, both as a part of normal service provision (extending the network, undertaking maintenance, etc.) and as a part of their obligation to inform third parties about their facilities. Complexity of electrical distribution power system is a good reason for introducing new information technology - GIS (Geographic Information System) that carries out complex power system analyses (e.g., fault analysis, optimization of networks, load forecasting) in acceptable amount of time. In pursuance of an understanding of the electricity distribution network, the Geographic Information Technology approach was adopted. GIS provides a better scenario in the management and monitoring of electricity distribution facilities so as to provide adequate power supply for the resident sector of the economy. The aim of the project is to generate a geospatial model for electricity consumers and facilities to provide a better understanding towards effective distribution and conservation of electricity. This involves locating and mapping all the facilities involved in distributing energy to the end-users. This modeling involves the collection of both the geometric and attributes data of all the entities identified including that of the consumers. The GIS technology adopted involves the use of computer based wares. A Hand-Held GPS was used in acquiring positional data. These data were formally integrated into computer based software for several analyses. The database generated contained information on the facilities and residential consumers. Series of spatial query operation was carried out to provide answer questions that lead to effective management and monitoring of the distribution facilities. Further analyses such as determining the trend/pattern of the rate in consumption of energy by the households within the study area were carried out. Areas of short-comings were identified and proposed locations/sites were generated in the service areas that needed new facilities. The end products are maps, tables and project report. It was however ascertained from the results that GIS is a competent and effective tool for managing/monitoring electricity distribution network. It also provides a better understanding towards effective distribution and conservation of electricity. In this context, the wrapping up shows that GIS makes map revision and digital mapping easier and some useful recommendations were proffered.

KEYWORDS: GIS - Geographic Information Science, DSS - Distribution Substation, PHCN - Power Holding Company Nigeria

INTRODUCTION

Background to Electricity Network

In the last few decades, electric power industries have been developing transmission systems to follow up with the rapid growth of the power demand. On the other hand, the suitable site for new transmission lines has been getting restricted, because of development of rural areas and the growing concern over environmental issues. Generally, Electric network can be described as a set of devices used to transport electric power from the power plants to the consumers. These various devices include Overhead transmission lines, underground cables (found mostly in developed countries), switching equipments (circuit breakers and disconnectors), substations (i.e. subsystems equipped with transformers that allow power transfer between systems operating at different voltage levels) and reactive power compensation devices (such as capacitors and reactors). GIS can effectively be 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 electricity use.

Aims and Objectives

The aim of the project is to generate a geospatial model for electricity consumers and facilities to provide a better understanding towards effective distribution and conservation of electricity. The objectives of the study are to:

1. Carry out an appraisal of the existing electrical distribution network in the study area
2. Map the existing electricity distribution facilities in the study area
3. Estimate the trend in electricity consumption pattern in the study area
4. Conduct gap analysis of electricity requirement in the study area

METHODOLOGY

Data Acquisition

The Data acquisition began with the physical phenomenon to be measured. The first step in the methodology of this work was the collection of the required data from the study area. In this case, there were two types of GIS data involved which included: spatial and non-spatial data.

Spatial Data

The spatial data used for the research study include the following;

- (i) Base Map: The base map consists of roads, buildings and facilities digitized from a High-Resolution Image data
- (ii) GPS Data: GPS Collection points on the available PHCN (Power Holding Company Nigeria) facilities (Poles, Transformers, etc) are acquired from the field of study using a Hand Held GPS.

Non-Spatial Data

The non-spatial data includes the following information which was acquired from the PHCN (Power Holding Company Nigeria), Ife District Office and consumers;

- (i) Consumer Details: Meter Account Number, Address of the consumer, the Line Transmission Pole/Pillar to which a consumer is connected
- (ii) Electrical Network Details: 11kV line diagrams with cable sizes, lengths, distribution substation (DSS) transformers, parameters of the equipments, pillars, poles and low voltage networks
- (iii) Transformer Details: The details about transformers and other related facilities For this study, PHCN (Power Holding Company Nigeria) bills were acquired so as to acquire information on the average amount of energy consumption.

Database Design, Creation, Processing and Analysis

Database design is the process of producing a detailed data model of a database. This data model contains all the needed logical and physical design choices and physical storage

parameters needed to generate a design in a Data Definition Language, which can then be used to create a database. A fully attributed data model contains detailed attributes for each entity ([www.en.wikipedia.org/wiki/Database design](http://www.en.wikipedia.org/wiki/Database_design)).

The database in the cause of this study supports an object-oriented vector data model. In this model, real world entities were represented as objects with their various properties, behavior and relationships. In GIS, a database is often referred to as a spatial database or geodatabase and it is the heart of GIS. This process involved the analysis and modeling of real world entities and their interrelationships in such a way that benefits were derived while utilizing minimum amount of data.

Data were formally entered into their respective tables, created in Arc Catalog, in the Arc Map environment. After the data entry process, the personal geo database was saved in Arc Map in a folder for easy recovery, geo spatial analysis and queries carried out on them. The data stored in the database forms the information base. Once the layers were digitized, the non-spatial data were then added as attributes to the digitized features. This attribute table was linked to the spatial themes containing geographic information. The database created included location and descriptive information for all the different components of the system.

To estimate the areas in the study area that were of short comings in terms of the distribution and develop an estimation trend in the consumption of electricity, the following were operations carried out during the course of this study; overlay operations, spatial queries, proximity analysis and measurement of electricity consumption trend pattern.

RESEARCH FINDINGS

Nature of Electricity Distribution Network in the Study Area

Figure 1 below shows the map of electricity distribution network in the area of study. The map displays the geographic location of all the facilities in the selected area of interest. The entities identified included the Low Tension Electric Poles, High Tension Electric Poles; high and low tension cables, Distribution substation transformer, power transformers, feeders and Injection Substation.

Figure 2 shows a more detailed map of the electricity distribution facilities connected to the end consumers.

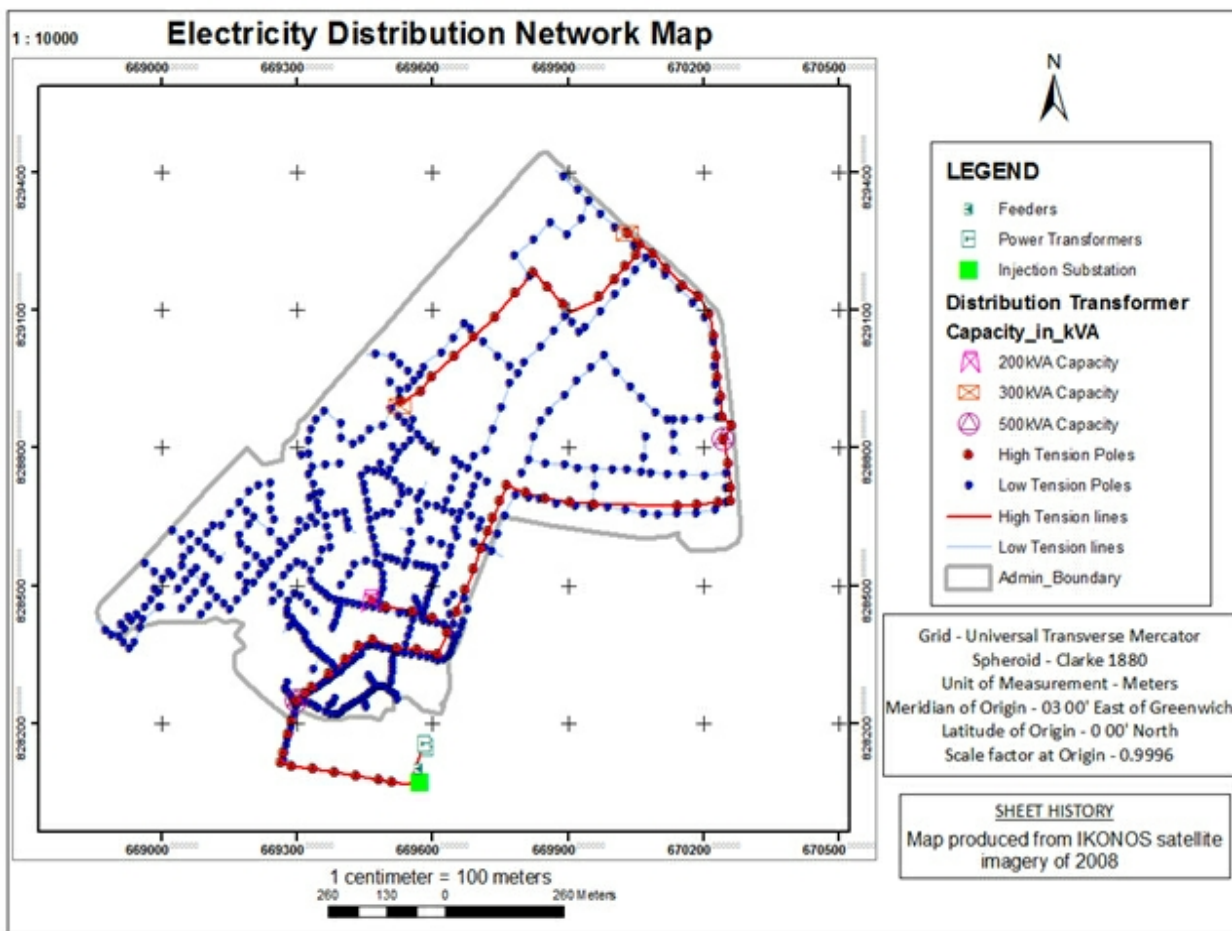


Fig 1: Electricity Distribution Network Map

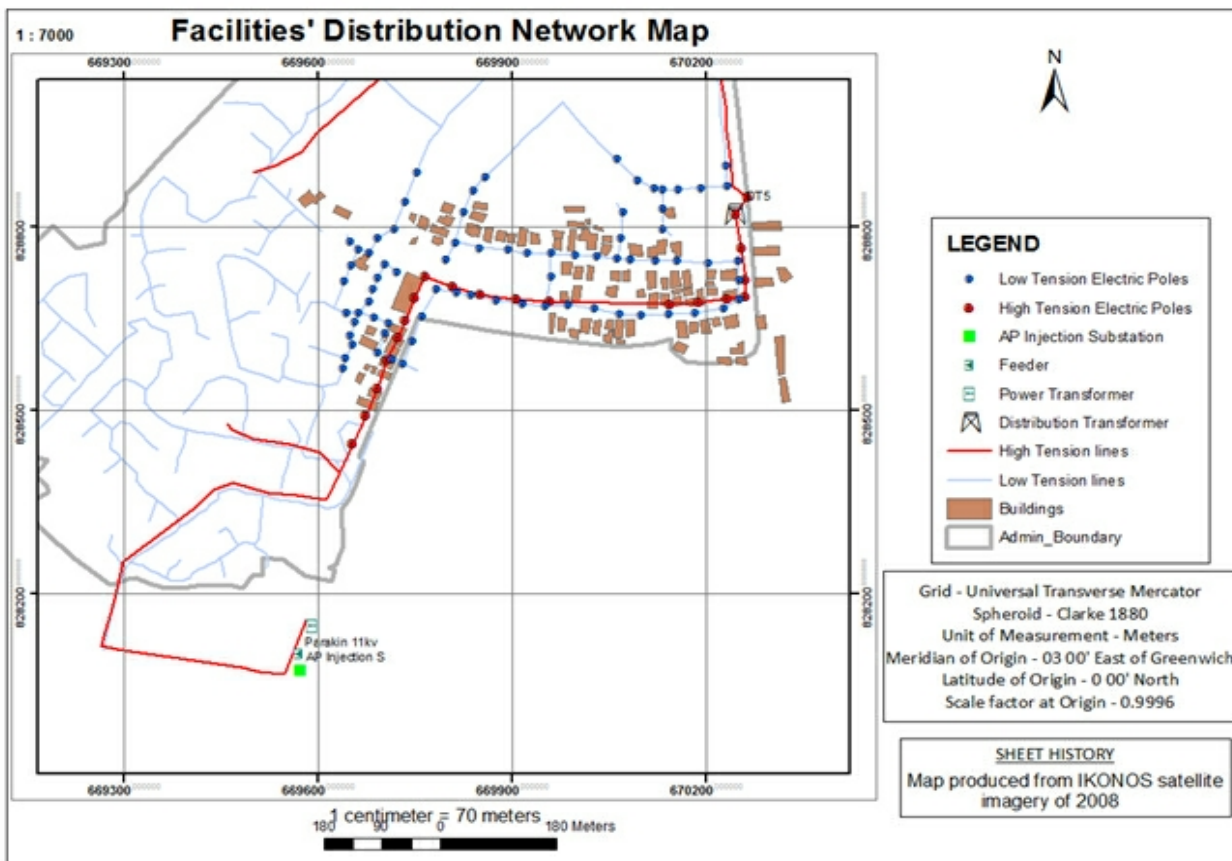


Fig. 2: Map showing the facilities involved in the distribution of electricity to consumers

Information showing all the facilities involved in the service of electricity to the consumers in a selected part of the area of interest is shown in Figure 2 above provide a better understanding of the electricity distribution network pattern.

Spatial Queries Generation

In GIS, a spatial operation tool is essential for processing or manipulating of data to suit user's need. Geographical Information Systems have a distinctive disparity from other Information Systems which is in the area of spatial analyses. In this project, the spatial search operation was carried out through query generation to retrieve the information stored in the database pertaining to certain systematically defined attributes within the database to answer spatially related questions. This operation involved the link between the database and the map of the selected area of interest. Spatial queries were generated to provide answers to the application use of GIS in developing a model (representation of reality) for the PHCN facilities.

Database query can be referred to as the selection of various combinations of various tables for examination; it involves the retrieval of information stored in the database using structured query language (SQL). However, the queries generated are basically through database extraction in

ArcMap 9.3. Some other queries can also be generated based on the user's need. In the course of the project, the results obtained have assisted in the several areas;

- i. Monitoring the status of the facilities in the Feeder so as to know the status of the facilities.
- ii. Retrieval of Geographical Information of the facilities. The spatial information would include coordinates (X and Y), and symbol representation, capacity and location.
- iii. Prioritization of facility replacement based on the available information. In this study, of all the existing facilities on ground, none was due for immediate replacement.
- iv. Update the information system in the case whereby new facilities are to be installed. In the near future, when new buildings are connected to the existing facilities, the information system can be updated.

Figure 3 suggests proposed location for the installments of new Distribution Substation Transformers within the study area. This was generated based on the average consumption rate by the existing households and the amount of Power generated by each distribution substation transformers connected to them.

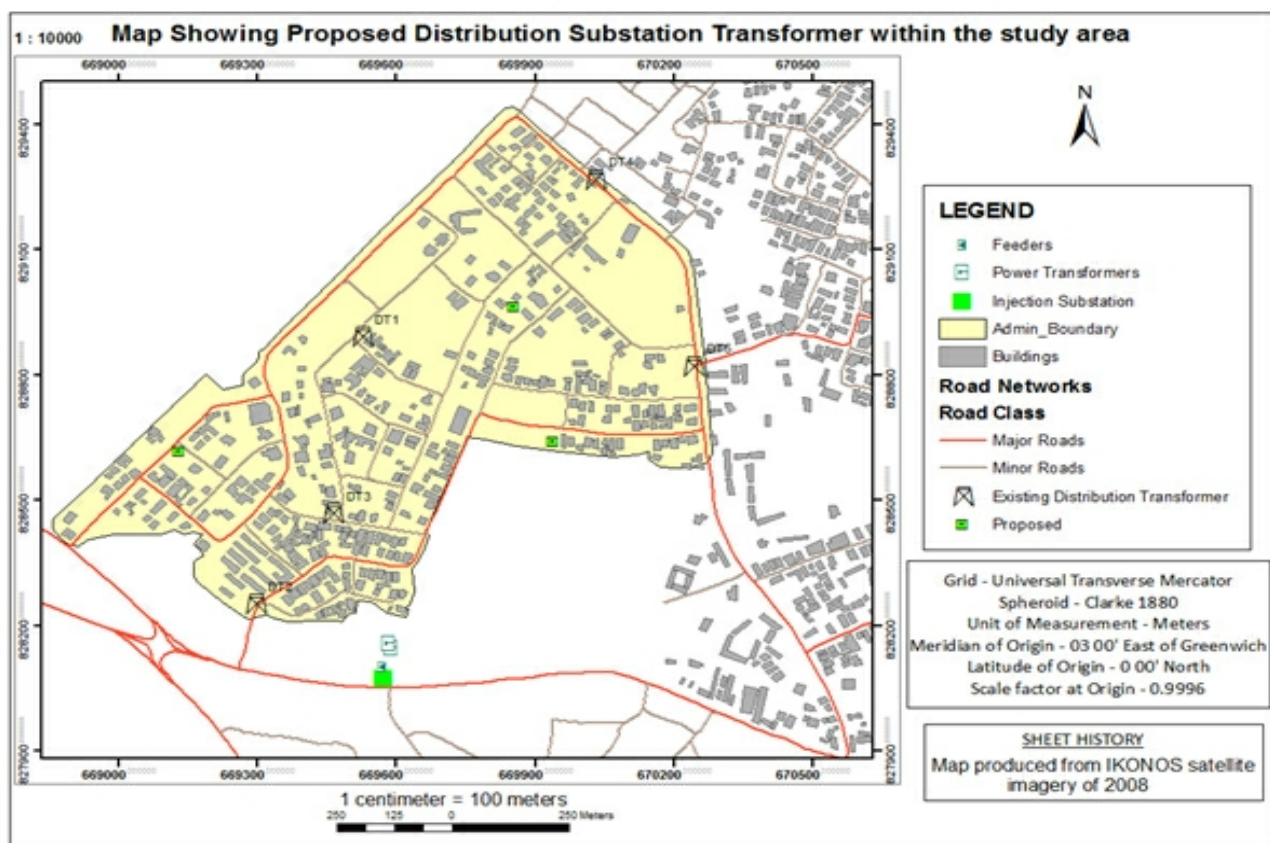


Fig 3: Map showing existing and proposed location of DSS

The above results are expected to equally provide good information for other professionals, which may include Urban Planners, Construction Managers, Engineers, etc. the knowledge of the locations (spatial locations) of the facilities will help to avoid or reduce damages done to these facilities during construction works especially in newly developed areas (such as, Parakin).

Proximity Analysis and Estimation of Consumption Trends

Other analyses were carried out during the course of this work. Proximity Analysis such as Buffering analysis was carried out to identify the areas for the requested availability and quality of energy supply. As shown in Figure 4 below,

the buildings connected to a particular transformer (DT5 in this case) that fall outside a 300m radius experience a drop in voltage compared to those within the buffered area. The

buffering analysis performed helped in identifying the pattern of the supply and distribution of power in terms of voltage within the study area.

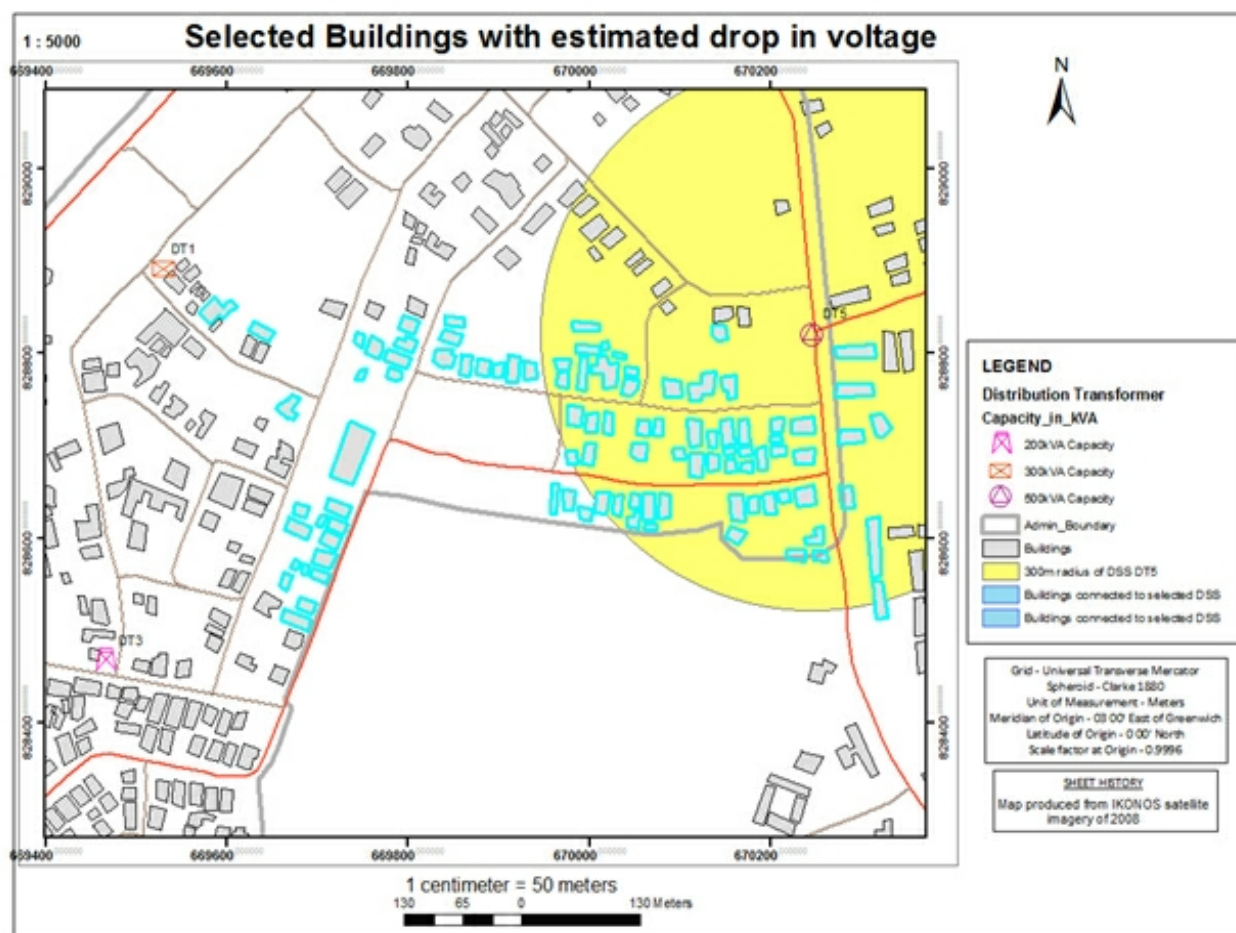


Fig 4: Selected Buildings with estimated drop in voltage

In the case of Figure 5, the result displayed was based on the average consumption rate of the house-holds within the study area. Based on the level of consumption, it clearly shows that most of the households within the area of interest were classed as residential houses. The results displayed show the variation in the energy consumption rate within the area. This is because of the various types of electrical appliances used by different households within the area. As represented in the map displayed, the Buildings with darker colors consume higher consumption rate than those with brighter colors.

In order to estimate the consumption trend during the course of this work, other analyses were performed. The relevance and importance of mapping utilities in GIS environment is to provide spatial solutions in a real time manner. The common problems that have been identified in the Power Utility Sector include the following;

1. Unequal distribution/transmission of load
2. Bad conditions of the equipments due to improper monitoring and maintenance
3. Frequent power surge due to natural incidences It was been observed that in the study area electrical facilities are either obsolete or too old for efficient performance. Therefore, routine maintenance and

replacement are necessary for efficient performance the electrical equipment in the study area. The threshold of each electrical facility should however be noted at installation and strictly adhered to during operational period. In advanced GIS, locating the facility and finding the exact fault wherein it has occurred could be substantiated by hand held palmtops. The notified location on the spatial network wherein the fault has occurred could be easily identified and trained engineers could be alerted to go to the exact area and rectify the problem immediately.

This showed that the major advantage of GIS in Electricity distribution network is the location component. The electricity distribution network map of the study area revealed the spatial distribution and locations of the electrical facilities within 11kV feeder in the area of interest. In the course of this work, it was observed that electricity consumers within a 300meter radius to a distribution substation transformer, experience higher voltage of power compared to the households outside the radius. It was however noted that about 55% - 60% of households connected to the distribution substation transformers experience average voltage of power supply while about 40% - 45% experience drop in voltage of power supply. The gap analysis showed that, voltage drop in power supply is experienced the farther the households are connected to a distribution transformer. As shown in figure 5, the system shows descriptive information about the households and

their average rate of consumption. This clearly reveals the consumption rate pattern within the households connected to all the facilities within the area. Within the network, 37% of households consume high amount of electricity, 36% consume average and 27% consume less amount of electricity. The spatial analysis and the resulting maps provided a better knowledge and understanding on spatial

relationships among electricity facilities and consumer demands. Such knowledge is expected to help them know the sections of the service area that lack inadequate services. It is also expected to serve as a guide to them in order to know where they could extend or improve their services and areas that need new installation based on the distribution of power.

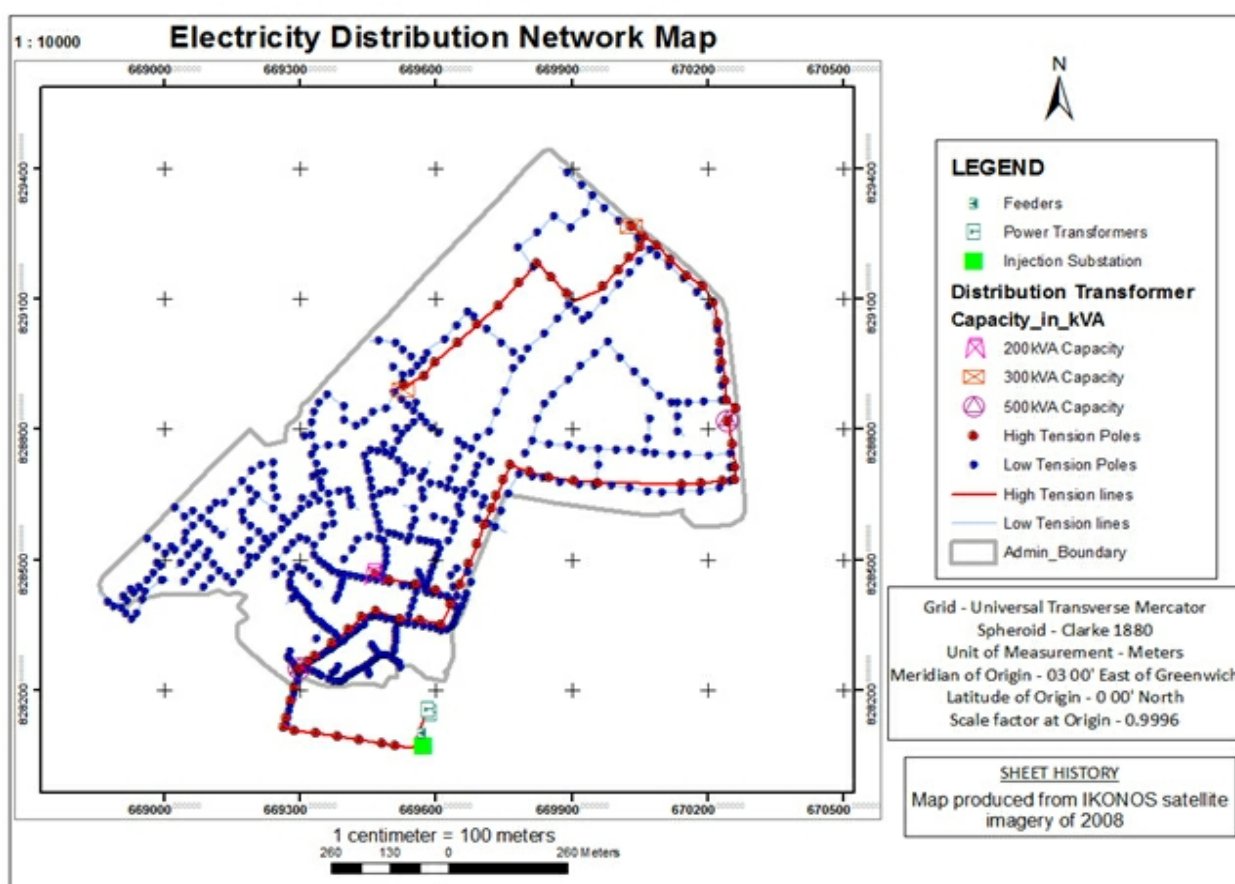


Fig 5: Rate of consumption of residential households

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CONCLUSION AND RECOMMENDATION

The study clearly indicates the capability of spatially enabled information system in the management of electricity distribution network. Spatial and attribute data of power distribution network of any part of the selected areas of interest of this study, which are presently acquired, processed, managed, stored and presented in analogue form, can be digitalized. Ayeni et al., (2003) noted that Geospatial Information (GI) is very essential to economic planning and national development. This is buttressed further by Alamu and Ejiobih (2002), when they concluded that a well maintained utility information infrastructure gives up-to-date information on what is where, the state of it, the reaction other actions on it would cause, how it can be harnessed for optimum use of the people and economy. It has been shown that GIS has been employed as one of the technologies for better and improved delivery of networked services. This further enlightens that regardless of cost, GIS has prominently improved the manner of service delivery with respect to time period.

Conclusively, it has been observed that GIS applications have not reached the optimum exploration and there is still room for further exploration and extension in the field as far as utility service delivery like in the case of electricity distribution is concerned. The following recommendations are advanced for efficient electricity distribution networks;

1. More efforts must be made to bring in refined and scientific approaches such as Geographic Information Systems into the management of electricity distribution network.
2. Training programs should be organized for technical online staff of electricity distribution on the integration of GIS in the management/monitoring of electricity distribution.
3. The user requirement and survey analysis conducted before implementation of electricity projects should include spatial information system from the onset so as to forestall drop in voltage within the distribution network.
4. Establishment of more distribution substation transformers in low voltage area within the study area.

REFERENCES

1. Alamu, E. O. and Ejiobih, H. C. (2002). Utility Information Infrastructure Needs in Utility Organisations in Nigeria: A Case Study of Niger State Water Board. Proceedings of the Technical Session of the 37th Annual General Conference and Meeting of Nigerian Institution of Surveyors, Owerri, Imo State, Nigeria, pp. 85-88.
 2. Ayeni, O. O., Kufoniya, O. and Akinyede, J. O. (2003). Towards a National Geospatial Information Policy for Nigeria", Proceeding of the Technical Session of the 38th Annual General Conference and Meeting of Nigeria Institution of Surveyors, Lokoja, Kogi State, Nigeria, pp. 21.
 3. Douglas, D. H., (1994), Least Cost Path in GIS Using an Accumulated Cost Surface and Slope Lines. *Cartographica* 31 (3): 37-51.
 4. Emengini, E. J. (2004). Application of Geographic Information System (GIS) to Utility Information Management: A Case Study of Onitsha-North L.G.A., Anambra State, Nigeria. Unpublished M.Sc. Thesis Submitted to the Department of Surveying and Geoinformatics, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.
 5. Ezeigbo, C. U. (1998). Application of Geographic Information Systems (GIS) to Utility Mapping, in C. U. Ezeigbo (ed.), Principles and Applications of Geographic Information Systems, Lagos, Panef Press, pp. 124-131.
 6. Korte, G (2001). The GIS book: how to implement, manage and assess the value of Geography
 7. Kufoniya, Olajide (1998). Database Design and Creation in C. U. Ezeigbo (ed.). Principles and Applications of Geographic Information Systems, Lagos, Panef Press, pp. 1-15.
 8. Sipes, J. L. (2007). Spatial Tech- GIS for the utilities Industry. Cadalyst Publications
- www.usgs.com
- www.gis.rgs.org