APPLICATION OF GIS IN ELECTRICAL DISTRIBUTION NETWORK SYSTEM

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APPLICATION OF GIS IN ELECTRICAL DISTRIBUTION NETWORK SYSTEM

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ABSTRACT

The distributions of electrical energy to end users in most urban area are faced with divers spatial problems particularly with the use of analogue system. Based on this, this study seeks to use geospatial technique for effective management of electricity distribution. The study assesses the spatial relationship between power holding company of Nigeria (PHCN) assets and their customer's connectivity in the study area and makes decision on how to improve and manage electricity distribution. The result shows that, the study area has only one transformer rated 500KVA with 4 upriser connected to numerous distribution lines serving 250 buildings with an average consumption rate of 2.1KW and total consumption of 525.6KW with an excess of 25.6KW, indicating that the transformer is overloaded. It is evident from the finding that asset management, load shedding technique, can easily be managed with the use of geospatial technique.

Key words: Electricity, Overloading, Geospatial, Distribution, Upriser, Load-shedding

1.0 INTRODUCTION

One of the primary contribution to the advancement and improvement in man's life style over the years has been the ability to use and control energy. The socio-economic and technological development of any nation and the society is largely dependent on the supply of electricity. It is one of the most important basic needs for the smooth, meaningful and productive economic life of any nation, as the growth of the economy of nations largely depend on the effective management and control of the available generated power, effective maintenance of the equipment and efficient generation of power to meet the growing demand for electricity supply. The use of electricity as a tool for socio-economic development of the nation cannot be overemphasized. Hence, there is a need to keep a comprehensive and accurate inventory of their physical assets, spatial location, both as part of normal service provision, extending the network and undertaking maintenance by the use of geospatial technique (Geographic Information System). GIS as an emerging technology is a software application, used to create and display cartographic information. In practice, however, GIS consists of five Components: software, data, procedures, hardware, and people. These five components work together to capture, store, retrieve, analyze, and display geographically referenced information. It has an added capability to analyze spatial data, through attribute and location analysis or spatial modeling.

Efficient functioning of the transmitted power cannot be achieved without proper record keeping and monitoring of the distribution network system. Any organizations that expect to run efficient day-to-day operation and to manage and develop its service effectively must know what asset it has, where they are, their condition and how they are performing (Pickering, 1993). The knowledge about physical assets of the electricity distribution network is necessary to make strategic and operational decision. Hence to make such informed decision regarding the distribution and management of electricity and its facilities, information must be collected and analyzed to its full extent through GIS technique.

GIS technique is used to create database and develop map which can show the spatial relationship between PHCN asset and their customers in the study area. The production of digital map and functional geo-database about the facilities will be able to show utility transformer and the rating of the transformer which can be used to determine the capacity of energy it can distribute and the current energy demanded on it. This will also show the numbers of customer attach to each transformer and the energy consumed by each customer. This will help to determine whether the transformer is overloaded or still operating within its installed capacity. At such, determine the upriser to put off from a transformer that is already overloaded for a period of time, make decision on how to carry out load shedding, how to detect illegal connection, due time for transformer replacement and when to stop new customer from connecting to a transformer.

The buffering analysis was carried out on the transformer and the principle of network ordering was also applied to validate the developed system.

The efficiency of distribution system can be affected by some of the identified problems below.

- Capacity of the distribution transformer.
- Lack of effective control of the available generated power.
- Distance of customers from the distribution transformer.
- Imbalanced allocation of the distribution lines.
- Metering inaccuracies and unmetered energy in other area

1.1 Objectives

- Create electricity distribution network map that shows the spatial location of the transformer, low tension poles and low tension lines of the study area.
- Create a map that will show the spatial relationship between transformer and consumer's connectivity to the transformer.

2.0 STUDY AREA

The study area selected for this project is Olonade community of Ife central local government, Ile-Ife. It lies between longitude $4^0$32'42E"- $4^0$33'4" E and Latitude $7^0$30'0N"- $7^0$30'26N".

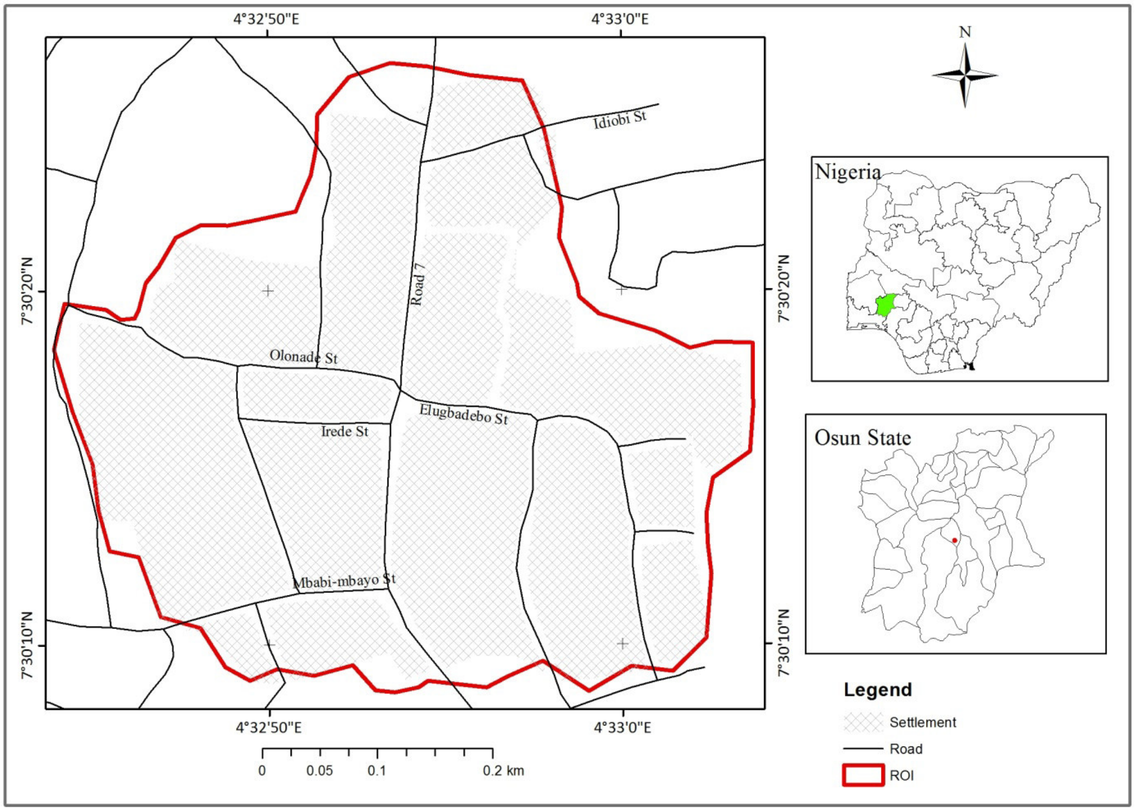


Figure 1.0 Map of the study area

3.0 MATERIALS AND METHOD

3.1 Data Requirement

- Satellite image
- GPS points
- Transformer detail
- The number of customers connected to the transformer
- Energy consumed by each customer

3.2 Software used

- ArcGIS 9.3
- Microsoft word

3.3 Hardware

- HP 4GB Ram, 500GB Hard Disc Computer
- GPS receiver

3.4 Data Analysis

High spatial resolution Satellite image was acquired and integrated into GIS environment whereby thematic layers such as buildings and road network were extracted and represented in form of polygons and lines, also service lines and customer connection point were digitized. A personal geodatabase was involved with dataset projected using coordinate system WGS 1984 UTM zone 31N. The personal geodatabase contain features named as building, roads, consumer points and service lines. The area of interest was delineated from the satellite image and subsequently used to subset others thematic layers. The coordinate point of the transformer and low tension poles acquired with the hand-held GPS, and customers records were linked together and captured into the geodatabase using add xy coordinate in Arc Map environment. Electricity Distribution network map and data was created which shows the spatial location of the transformer, low tension poles, as well as the spatial relationship between all PHCN asset and customer's connectivity to the transformer.

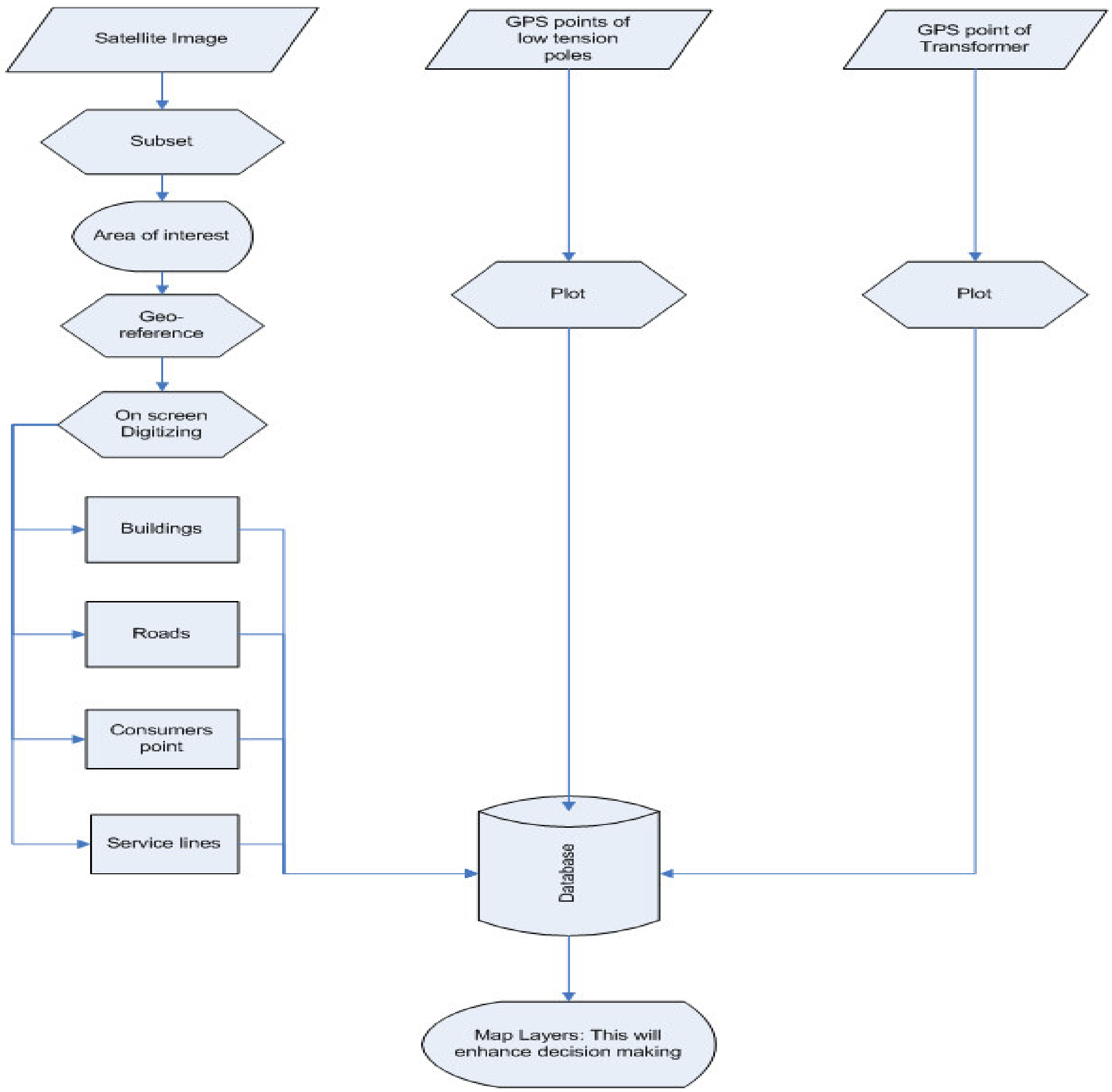


Figure 2.0: Flow chart diagram showing the method employed

4.0 RESULTS AND DISCUSSIONS

Figure 3 show the consumer point where customers are connected to the service lines, the spatial location of electric poles, and transformer with the four uprisers connecting the transformer to the service lines and also the road network of the study area. The thickness of the service line at any point is proportional to the level of energy on it at that very point, indicating the power flow level of the network system.

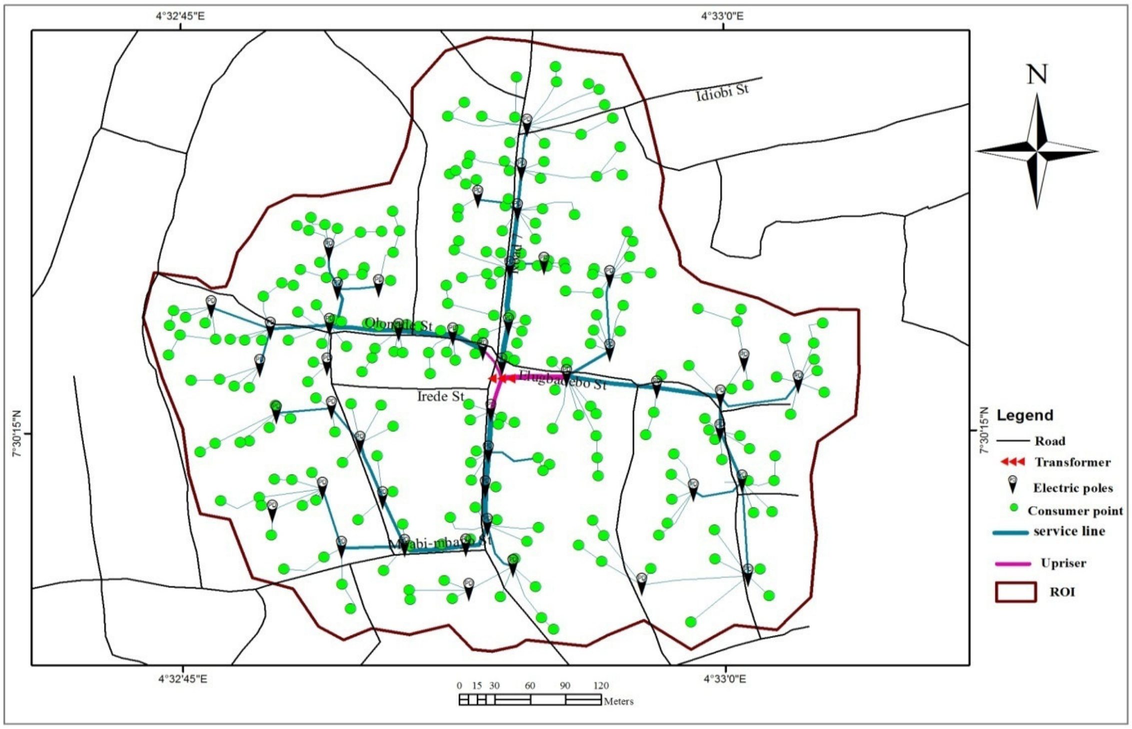


Figure 3.0: Electricity distribution network map

Figure 4 mapped the flow of electricity from the transformer to the poles and from the poles to the consumers (buildings). This shows the customer's connectivity to the distribution network. The total number of buildings served by the transformer can be determined from the attribute table of these building (table 1) in the database.

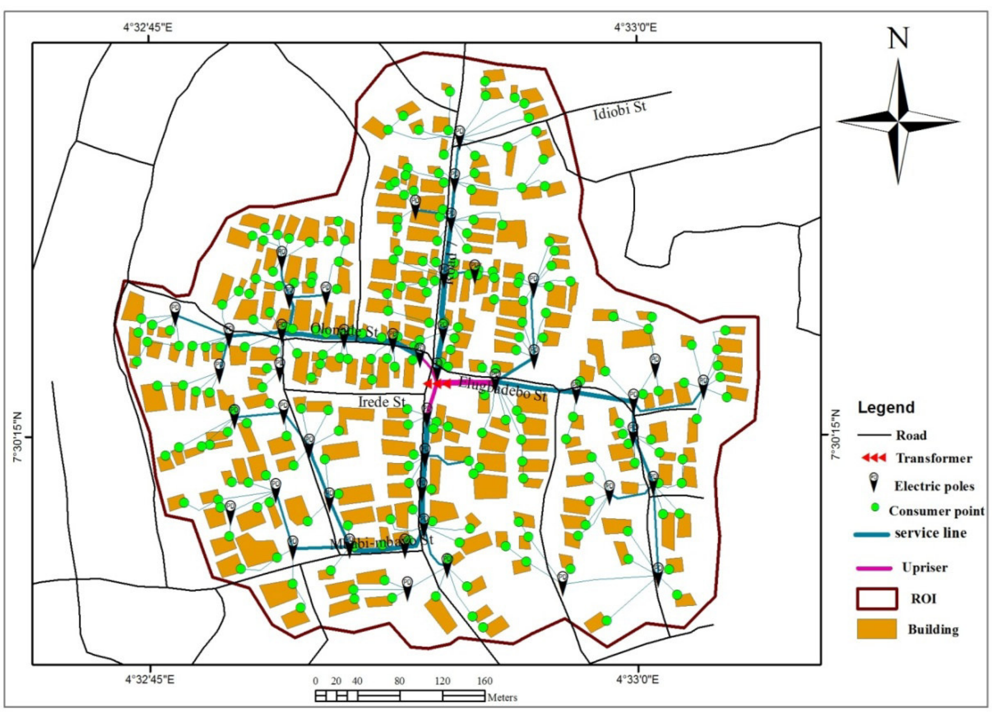


Figure 4.0: Map showing customer's connectivity to distribution network

Figure 5 shows the details of the energy consumed by each of the customers. This is indicated in the legend by the variation in color from dark to light colour, the darkest colour indicate the highest energy consumption level while the lightest colour shows the lowest in terms of energy consumption. The energy consumed by each customer as well as the total energy consumed by the entire area connected to the upriser can be visibly seen in the attribute table of the buildings in the area (table 1) and (figure 5). This will help the PHCN to know where they could extend or improve their services and equally area that need new installation.

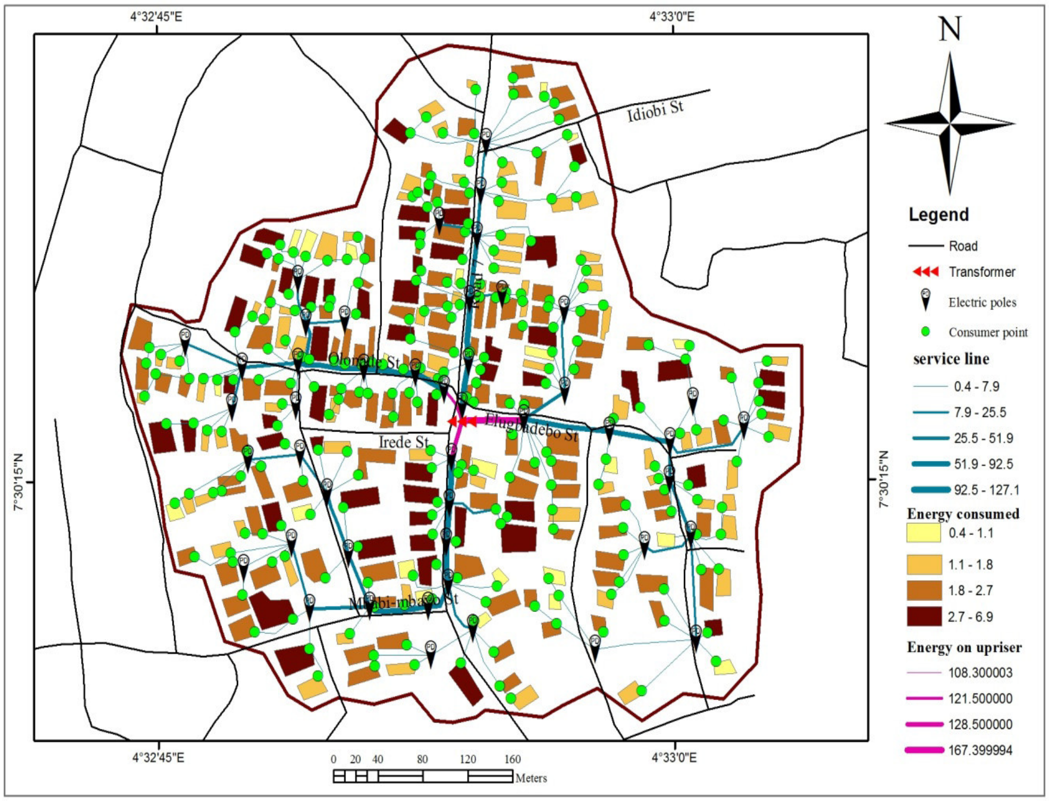


Figure 5.0: Map showing the power consumption level of each of the building

Table1.0: Attribute table of building

Attributes of Building

FID	Shape *	SHAPE_Leng	SHAPE_Area	Energy_con	Customer_N	Upriser_1	Meter	PresentReadi	PreviousRead	EnergyUsed	UnitChareg	TotalBill
24	Polygon	66.390141	234.475426	3.1	A26	B	PostPaid	19066	18975	93	12.3	1143.9
173	Polygon	42.645917	105.3543	1.6	A153	B	PrePaid	0	0	48	12.3	590.4
49	Polygon	67.034344	209.666105	3.5	A51	B	PrePaid	0	0	105	12.3	1291.5
29	Polygon	58.464846	121.509933	1.4	A31	B		0	0	42	12.3	516.6
183	Polygon	56.720677	194.661266	2.9	A162	B		0	0	87	12.3	1070.1
178	Polygon	63.160205	222.567434	2.1	A158	B	PostPaid	21730	21667	63	12.3	774.9
120	Polygon	71.774387	287.170955	3	A203	B	PrePaid	0	0	90	12.3	1107
58	Polygon	48.758372	125.612894	2.5	A60	B		0	0	75	12.3	922.5
224	Polygon	101.089665	558.175381	3.5	A226	B	PostPaid	16021	15916	105	12.3	1291.5
163	Polygon	36.748045	78.001119	1.5	A144	B	PrePaid	0	0	45	12.3	553.5
169	Polygon	79.966041	365.599631	1.8	A150	B	PostPaid	30016	29962	54	12.3	664.2
131	Polygon	37.464091	64.55478	1.4	A216	B		0	0	42	12.3	516.6
34	Polygon	64.660395	237.595453	2.1	A36	B	PostPaid	22450	22513	63	12.3	774.9
25	Polygon	55.043526	183.784457	1.8	A27	B		0	0	54	12.3	664.2
179	Polygon	59.040937	199.02033	2.5		B		0	0	75	12.3	922.5
174	Polygon	43.95866	94.538819	1.4	A154	B	PostPaid	20059	20017	42	12.3	516.6
59	Polygon	35.791092	70.256348	1.5	A61	B	PrePaid	0	0	45	12.3	553.5
50	Polygon	64.906392	178.649355	2.4	A52	B	PostPaid	9211	9139	72	12.3	885.6
247	Polygon	35.924767	79.452592	1.5	A253	B	PrePaid	0	0	45	12.3	553.5
184	Polygon	68.897496	196.622582	2.5	A163	B	PostPaid	22096	22021	75	12.3	922.5
168	Polygon	44.271145	110.393561	2.6	A149	B	PrePaid	0	0	78	12.3	959.4
121	Polygon	61.502193	197.676312	2.3	A204	B	PostPaid	200871	200802	69	12.3	848.7
140	Polygon	45.407219	119.482928	2.9	A112	B	PostPaid	14221	14134	87	12.3	1070.1
26	Polygon	38.252923	72.525653	1.5	A28	B		0	0	45	12.3	553.5
13	Polygon	59.062332	206.099165	1.5	A14	B	PrePaid	0	0	45	12.3	553.5
175	Polygon	55.614881	170.589613	2	A155	B		0	0	60	12.3	738
51	Polygon	59.966262	215.680935	2.2	A53	B	PostPaid	21121	21055	66	12.3	811.8
46	Polygon	56.621042	196.523727	2.5	A48	B		0	0	75	12.3	922.5
205	Polygon	74.576821	315.529885	3.1	A265	B	PrePaid	0	0	93	12.3	1143.9
180	Polygon	55.323614	183.67181	1.4	A159	B	PostPaid	29031	28989	42	12.3	516.6
122	Polygon	81.302219	406.497659	3.4	A205	B	PrePaid	0	0	102	12.3	1254.6
60	Polygon	37.196607	71.912464	1.5	A62	B		0	0	45	12.3	553.5
248	Polygon	81.659313	344.157696	4.1	A254	B	PostPaid	26001	25878	123	12.3	1512.9
136	Polygon	31.285017	55.762511	2.8		B	PostPaid	200871	200787	84	12.3	1033.2
167	Polygon	68.857955	274.432607	3	A148	B	PostPaid	21680	21590	90	12.3	1107
15	Polygon	62.427993	218.382656	2	A16	B		0	0	60	12.3	738
47	Polygon	40.944163	89.849089	2.3	A49	B	PostPaid	21354	21285	69	12.3	848.7
27	Polygon	63.811953	223.28011	1.5	A29	B		0	0	45	12.3	553.5

Record: 1 Show: All Selected Records (61 out of 250 Selected) Options

Figure 6 show the imbalance in the allocation of distribution line as the uprisers are not balanced in terms of the load. This in most cases result in the blowing off of fuse and tripping off of the transformer or low supply of voltage or voltage collapse and subsequently total blackout. The thickness of the upriser determines the level of energy it carries; the thicker it is the more energy it carries and the thinner it is the less energy it carries. Table1 validate it by showing the numerical value of the energy on the uprisers.

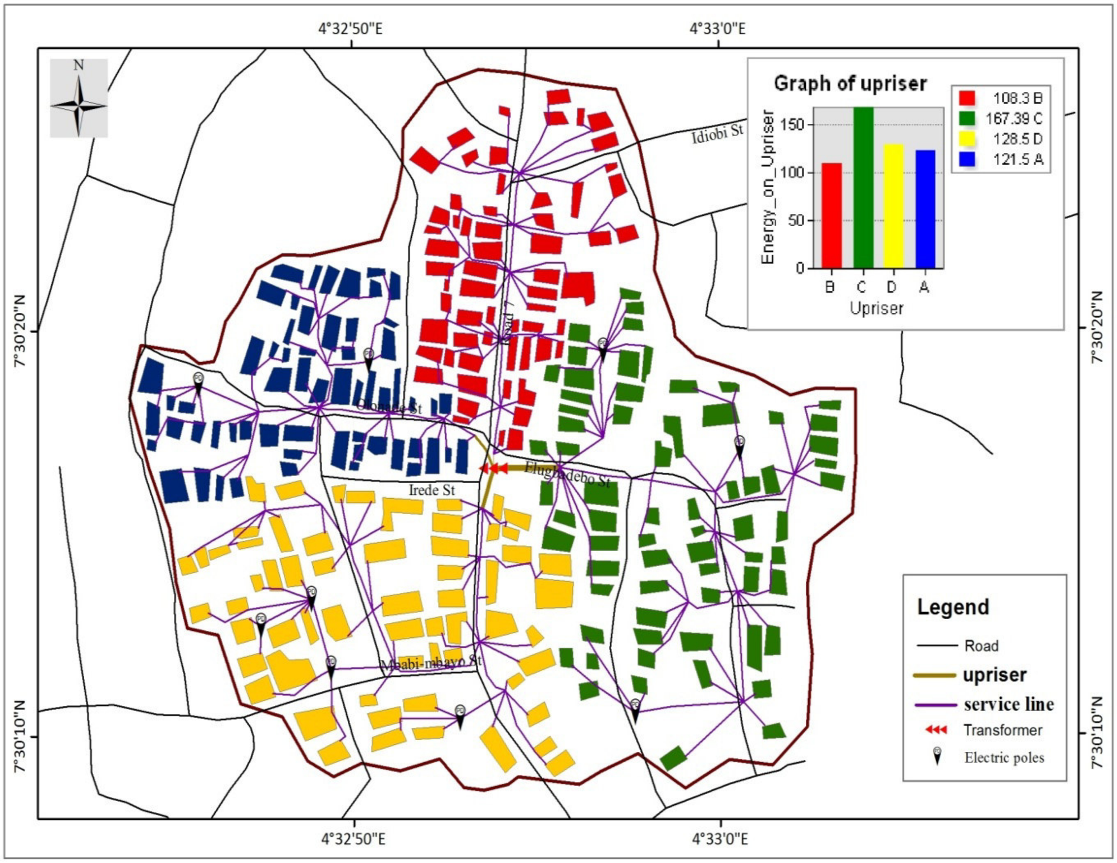


Figure 6.0: Map showing the unbalanced energy on the uprisers

Table 2.0: Attribute table of unbalanced upriser

Attributes of upriser

OBJECTID *	SHAPE *	SHAPE_Length	Energy_on_Upriser	Upriser_id	Upriser	Number	Number_of_pole
7	Polyline	12.193653	108.3	700032411	B	61	
8	Polyline	55.164019	167.39999	700032412	C	68	
9	Polyline	30.563286	128.5	700032413	D	61	
10	Polyline	30.842225	121.5	700032414	A	60	

Record: 1 Show: All Selected Records (0 out of 4 Selected) Options

Power can only be effectively distributed to the end user if all the phases are balanced, which is one of the area that GIS can effectively handle as is evident in figure 7 and table 2 below.

Figure 7.0: Map showing balanced stage of the uprisers

Table 2: Attribute table of balanced stage of uprisers

Attributes of upriser

OBJECTID *	SHAPE *	SHAPE_Length	Energy_on_Upriser	Upriser_id	Upriser	Number	Number_of_poles
7	Polyline	12.193653	130.10001	700032411	B	61	9
8	Polyline	55.164019	130.3	700032412	C	68	12
9	Polyline	30.563286	133.89999	700032413	D	61	15
10	Polyline	30.842225	131.10001	700032414	A	60	11

Record: 3 Show: All Selected Records (0 out of 4 Selected) Options

Figure 8 shows the buffer of the transformer with respect to the study area. This can be used to locate the load center for the installation of the transformer. The buffering analysis helps to determine the shortest possible length of connection as voltage drop may be permitted due to long distance covered in the distribution of power. This also help us to compute voltage drop and the power loss at a particular length as the exact distance of coverage can be determine from the buffering analysis. With the help of buffering analysis, the transformer can be centrally located with respect to the load area being served as this minimises the length of the distrbution lines connecting the transformer to the load and also reduce the numbers of electric polse. Cost of cable is reduced and also distribution losses will be minimised

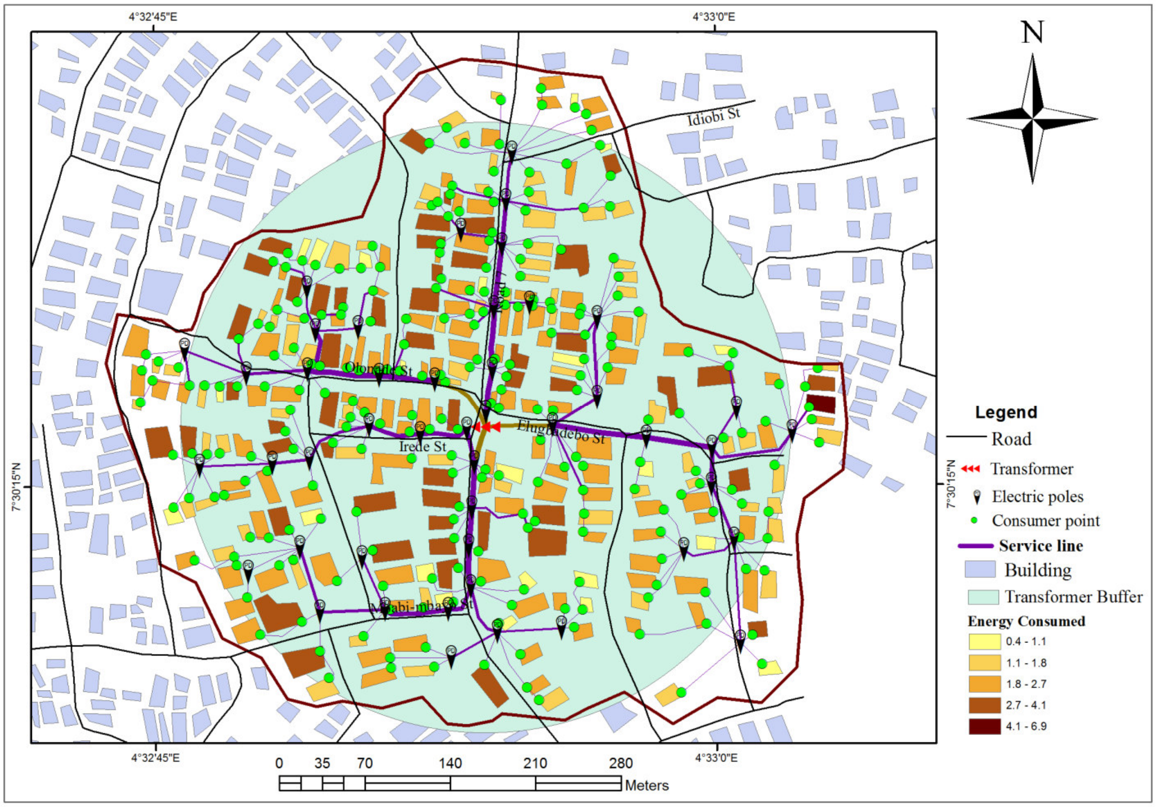
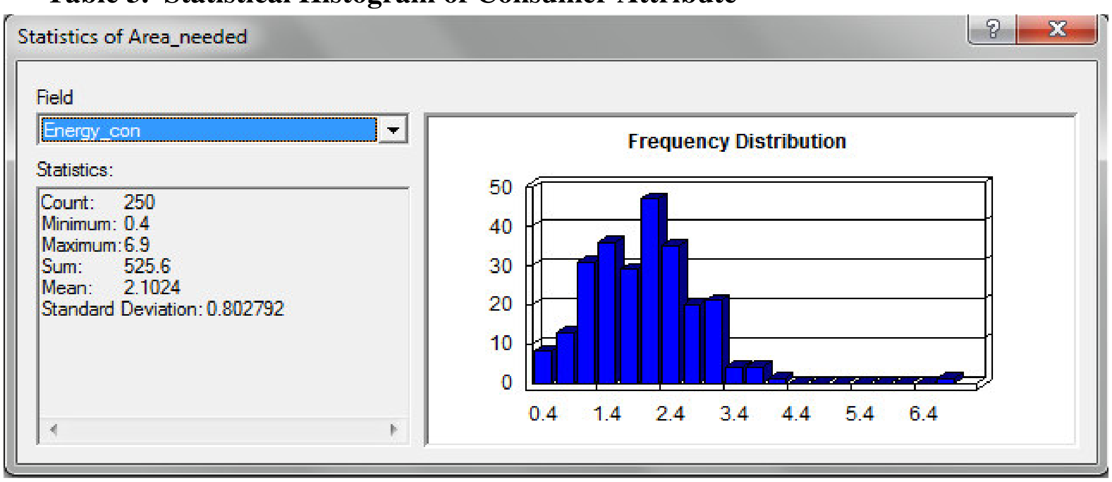


Figure 8.0: Map showing the buffer of transformer in relation with the study area

Table 3. Statistical Histogram of Consumer Attribute



This shows that 250 customers are attached to the transformer with a minimum consumption of 0.4KW and maximum of 6.9KW, average consumption rate of 2.1KW with a total consumption of 525.6KW. Comparing the total energy consumed by all the customers with the capacity of the transformer which is 500KVA as indicated on the attribute table of the transformer (Table 3 and 4), it can be observed that the transformer is overloaded by 25.6KW. With this result it will be easy to make decision on the number of customer to be disconnected from the transformer in order to reduce the load density; at such bringing the operation of the transformer to it installed capacity. Thus with GIS techniques, PHCN can ensure effective power distribution.

Table 4: Attribute table of transformer

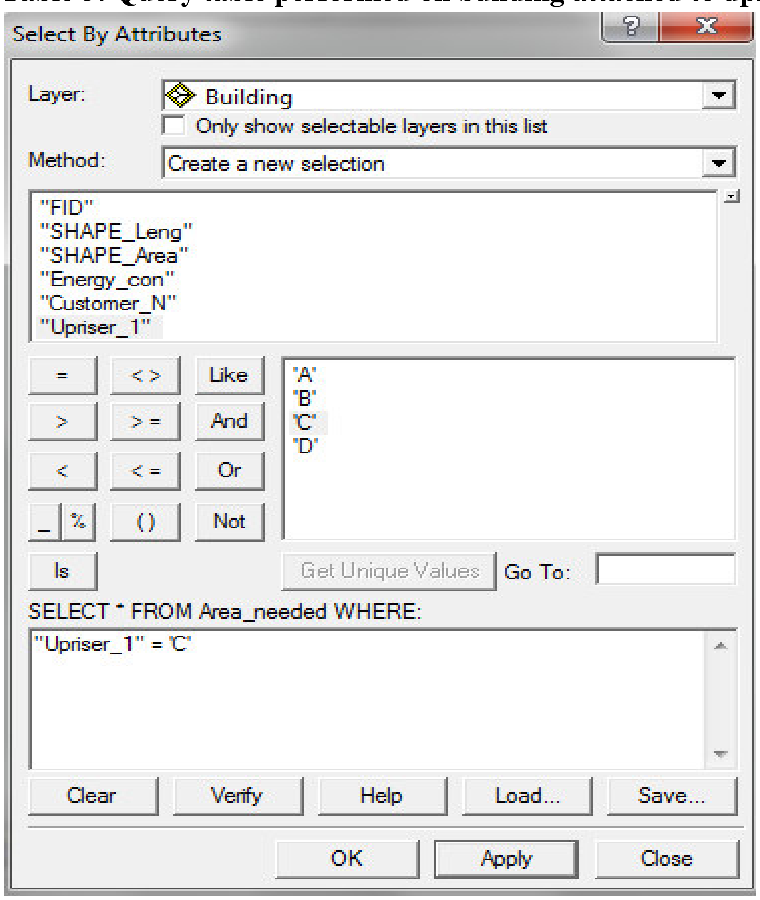
Attributes of Transformer

OBJECTID *	SHAPE *	Trx_Capacity	Make	CommunityName	LocalGovName	VoltRatio	X_Coordinate	Y_Coordinate
2	Point	500	NUWACO	Olonade	Ife Centra	11/0.415	7.504611	4.548278

Record: 1 Show: All Selected Records (0 out of 1 Selected) Options

GIS allows for creating, maintaining, and querying of electrical database to generate information, with an added capability to analyze spatial data, through attribute and location analysis or spatial modeling User can query any layer of the GIS map to get the attribute data for a particular feature of that layer. User has to click on any feature of a particular layer to get the attribute of that feature as indicated in table 5 and figure 9. GIS can be used to monitor power loss as a result of metering inaccuracy in the distribution sector by knowing the total number of customers using prepaid meter and those using postpaid meter as well as those that their energy are not metered at all by the use of query. This system provides timely, accurate and easier way of acquiring information, which is very vital in taking prompt and accurate decisions.

Table 5: Query table performed on building attached to upriser C



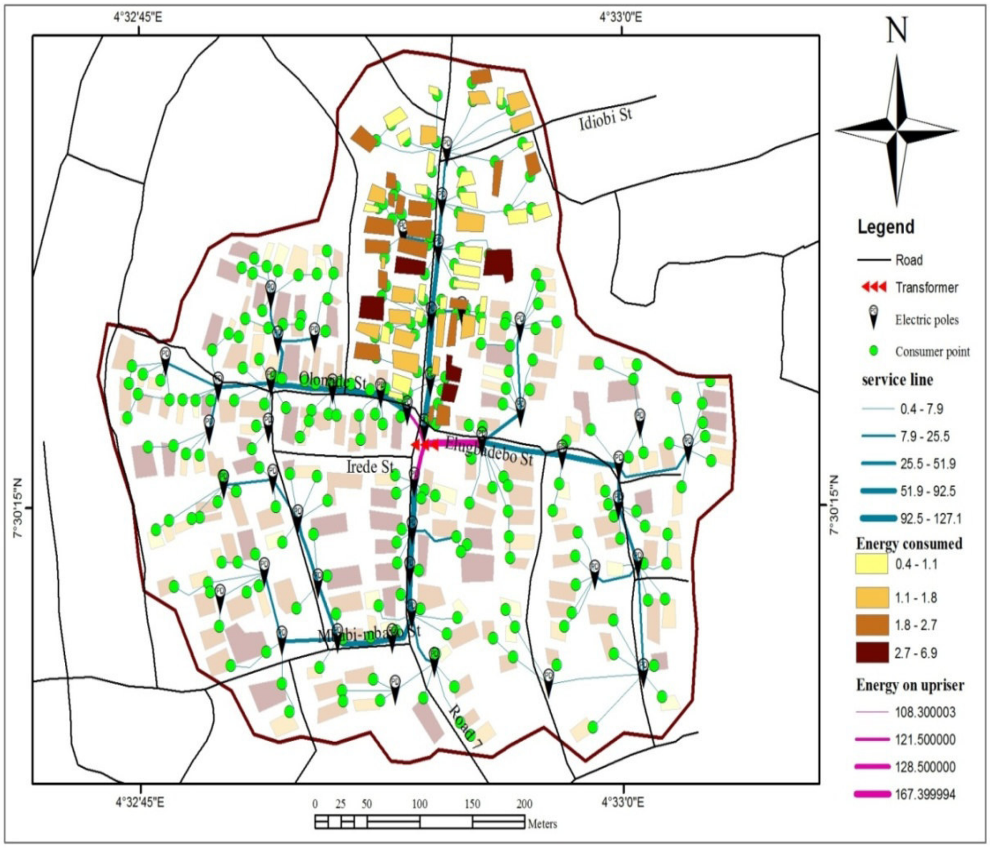


Figure 9.0: Result of query showing the number of customers on upriser C

The result of the query can also be used to determine how to carry out load shedding, which can be used to reduce the load on a transformer that is already overloaded. The table of the building was queried as shown in table 5 and the result of the query (as shown in fig 9) highlighted the attributes of the building connected to the upriser with id C. All customers connected to the highlighted upriser can be disconnected for a certain period of time while those connected to the other three uprisers are connected for that same period. This reduce the excess load on the transformer that is overloaded, at such effective services will be rendered.

Table 7: Attribute table of low tension poles.

Attributes of Low_tension_poles

OBJECTID *	Shape *	Name	StreetName	LocalGovName	PoleStatus	PoleMaterial	NoOfCables	CableMake
43	Point	4°34'20.4"E, 7°30'12.3"N	Olonade Street	Ife Central	Good	Concrete	4	Aluminium
44	Point	4°34'20.4"E, 7°30'12.3"N	Olonade Street	Ife Central	Good	Concrete	4	Aluminium
1	Point	4°32'50.9"E, 7°30'15.7"N	Olonade Street	Ife Central	Good	Concrete	4	Aluminium
2	Point	4°32'48.5"E, 7°30'15.6"N	Irede Street	Ife Central	Good	Concrete	4	Aluminium
3	Point	4°32'48.1"E, 7°30'15.6"N	Olonade Street	Ife Central	Bad	Wood	4	Aluminium
4	Point	4°32'50"E, 7°30'14"N	Olonade Street	Ife Central	Good	Concrete	4	Aluminium
5	Point	4°32'50.3"E, 7°30'13.1"N	Elugbadebo Street	Ife Central	Good	Concrete	3	Aluminium
6	Point	4°32'50.4"E, 7°30'12.3"N	Olonade Street	Ife Central	Good	Concrete	4	Aluminium
7	Point	4°32'51.1"E, 7°30'11.7"N	Mbabibayo Str	Ife Central	Bad	Concrete	4	Aluminium
8	Point	4°32'52.8"E, 7°30'11.7"N	Mbabibayo Str	Ife Central	Good	wood	3	Aluminium
9	Point	4°32'54.1"E, 7°30'11.1"N	Irede Street	Ife Central	Good	Concrete	3	Aluminium
10	Point	4°32'53.4"E, 7°30'12.3"N	Irede Street	Ife Central	Good	Concrete	4	Aluminium
11	Point	4°32'53.4"E, 7°30'13"N	Irede Street	Ife Central	Good	Concrete	4	Aluminium
12	Point	4°32'53.2"E, 7°30'14.1"N	Irede Street	Ife Central	Good	Concrete	3	Aluminium
13	Point	4°32'53.5"E, 7°30'15.6"N	Irede Street	Ife Central	Good	Concrete	4	Aluminium
14	Point	4°32'49.8"E, 7°30'13.7"N	Mbabibayo Str	Ife Central	Good	Concrete	3	Aluminium
15	Point	4°32'49.5"E, 7°30'14.6"N	Irede Street	Ife Central	Bad	Concrete	4	copper
16	Point	4°32'49.1"E, 7°30'15.7"N	Olonade Street	Ife Central	Good	Concrete	4	Aluminium
17	Point	4°32'48.9"E, 7°30'16.9"N	Irede Street	Ife Central	Good	Concrete	4	copper
18	Point	4°32'50.7"E, 7°30'16.6"N	Olonade Street	Ife Central	Good	Concrete	4	Aluminium
19	Point	4°32'52.1"E, 7°30'16.6"N	Olonade Street	Ife Central	Good	Concrete	4	Aluminium
20	Point	4°32'48.5"E, 7°30'13.3"N	Olonade Street	Ife Central	Good	Concrete	4	Aluminium
21	Point	4°32'54.3"E, 7°30'23.8"N	Idiobi Street	Ife Central	Good	Concrete	2	Aluminium
22	Point	4°32'54.3"E, 7°30'23.8"N	Idiobi Street	Ife Central	Good	Concrete	4	Aluminium
23	Point	4°32'54.3"E, 7°30'23.8"N	Idiobi Street	Ife Central	Good	Concrete	2	Aluminium
24	Point	4°32'54"E, 7°30'20.5"N	Idiobi Street	Ife Central	Good	Concrete	4	Aluminium
25	Point	4°32'53.9"E, 7°30'19.5"N	Idiobi Street	Ife Central	Good	Concrete	2	Aluminium
26	Point	4°32'54"E, 7°30'18.1"N	Idiobi Street	Ife Central	Good	Concrete	2	Aluminium
27	Point	4°32'55.6"E, 7°30'16.6"N	Elugbadebo Street	Ife Central	Good	wood	2	Aluminium
28	Point	4°32'56.5"E, 7°30'19.2"N	Elugbadebo Street	Ife Central	Good	Concrete	4	Aluminium
29	Point	4°33'2"E, 7°30'16.4"N	Elugbadebo Street	Ife Central	Good	Concrete	4	Aluminium
30	Point	4°33'1.5"E, 7°30'13.1"N	Idiobi Street	Ife Central	Good	Concrete	3	copper
31	Point	4°33'0.6"E, 7°30'10.8"N	Elugbadebo Street	Ife Central	Good	Concrete	4	Aluminium
32	Point	4°34'20.4"E, 7°30'12.3"N	Olonade Street	Ife Central	Good	Concrete	3	copper

Record: 5 Show: All Selected Records (0 out of 44 Selected) Options

This shows the detail of low tension poles, such as the geographic coordinate showing the spatial location, number of electric pole attached to the transformer, number of cables and the condition of the poles. Such updated information is required to improve planning, monitoring, maintenance and upgrading of the facilities when necessary. This shows that GIS technique can be used for proper asset management.

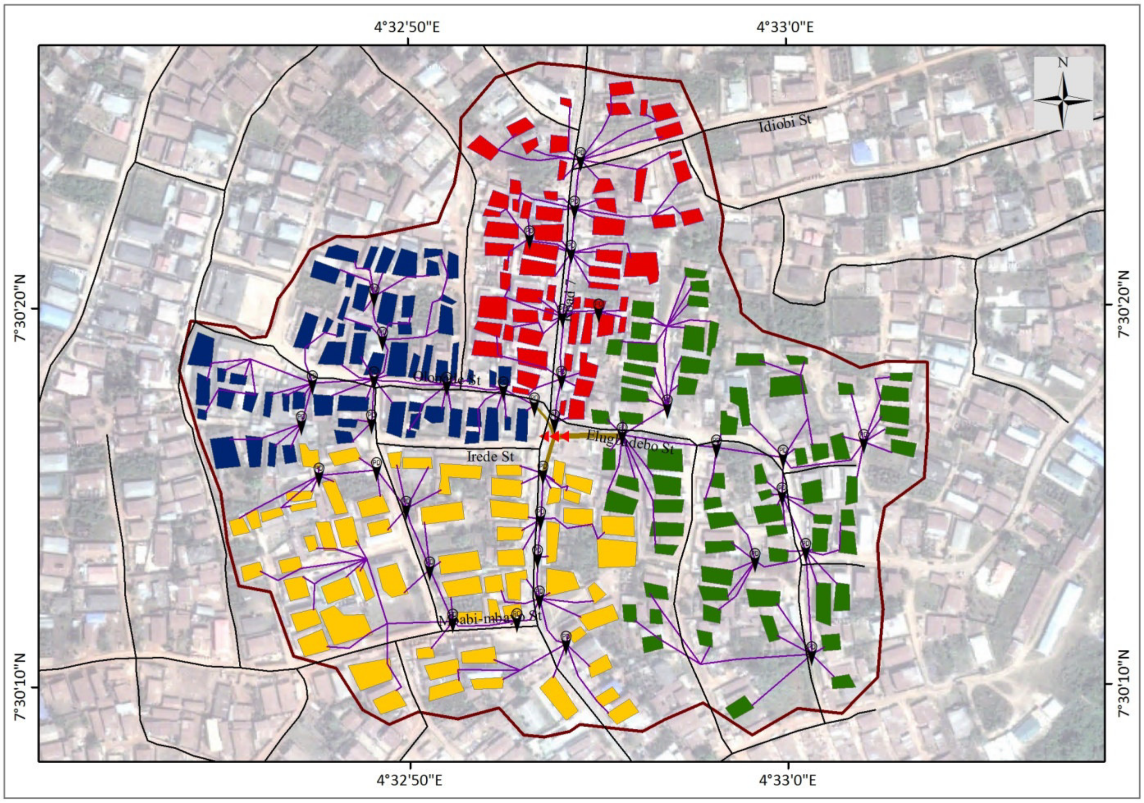


Figure 10: This is showing the study area superimposed on the satellite image.

5.0 CONCLUSION AND RECOMMENDATION

Improving the performance of distribution systems to meet the required target is a matter of selecting the most effective and appropriate technology with right operating practices. It is not sufficient to analyze how a particular portion of the network may be modified to improve its performance today, rather in determining the optimal solution based on future demand scenario.

Since the distribution network of a power utility have a geographical reference, it is beneficial to create the network on GIS map and constantly update the same as per field parameters. With periodic updating and monitoring, GIS mapping of the Electrical Network and Consumer database helps in improved planning, load management, loss reduction, better revenue realization, asset and management standard of the distribution network and possibly better consumer relationship.

GIS technology helps in fast, accurate and reliable data management, provides timely, accurate and easier way of acquiring information, which are very vital in taking prompt and accurate decisions necessary in electricity distribution network.

GIS principal task is to model "real world", perform spatial analyses and ensure high accuracy of optimization procedure. This help to carry out different analysis like, load analysis, location analysis, and problem identification analysis, also to find the average distributed power and utilized power. With this, the growing demand for electricity with growing rates and high densities can be satisfied in an optimum ways.

This study has demonstrated that geographic information system (GIS) can be used as a decision making tool to improve electricity distribution in Nigeria.

There is a need for greater awareness to be created at all level of government of the need and what is required to establish GIS. Briefing, training and re-training sessions among staff of PHCN and other municipal authorities in GIS is also needed.

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