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Review Article

Geographic Information System (GIS) for the Management of Electricity Distribution Assets and Infrastructure

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ABSTRACT

The distribution of electricity to end users in most urban areas are faced with diverse spatial problems particularly due to the use of analogue facility management system. Based on this, the study seeks to demonstrate the effectiveness of geospatial technique for the management and maintenance of electricity distribution assets and infrastructure of a section of the Enugu Metropolis, Enugu State, Nigeria. It also assesses the spatial relationship between Electricity Distribution Company (EDC) assets and their customer's connectivity in the study area. Data sourcing include collection of primary data where ground survey method was deployed through the use of handheld GPS for X, Y, positioning of these assets as well as direct interview of people within the study area and secondary data regarding feature attributes were collected from appropriate authorities, while a geo referenced satellite imagery was acquired, from which buildings and roads were extracted. GIS technique; ArcGIS v.10.1, was used for database creation and design from which series of spatial analysis such as queries and buffer were performed to solve a specific spatial problem relating to the electricity facilities within the study area. The study/analysis showed that buildings on particular phases can be disconnected during load shedding operation to minimize the load on transformer and also, buildings falling outside 300 m radius from the transformer may experience a drop in voltage compared to those within the buffered area. We recommended that the EDC's needs to employ GIS specialists to assist in the maintenance of their spatial data infrastructure in order to obtain a utility information system so as to proffer answers to some generic questions about fault detection and management of electricity facilities.

Keywords: Facility management; Utility management; GIS; Electricity distribution

INTRODUCTION

The ability to use, manage and control energy has contributed in no little way to the advancement and improvement of life on earth over the years. Electricity is the platform on which several technological advancements in every sector of human existence are based, be it medicine, engineering, commerce, etc. Power has proven to be the mother which gives birth to several discoveries. A popular automobile tyre manufacturer slogan has it that "power without control is nothing" and therefore it is very dangerous having so much energy without effective management, maintenance and control. Electricity whether at the generation, transmission or distribution stage needs to be properly maintained and managed [1]. To achieve this, there is therefore a need to keep a comprehensive, up-to-date and accurate inventory of the physical assets for all stages of electric power. Currently, a lot of the utility maps available in both the public and private's sectors in Nigeria are in analogue medium, characterized by fixed scale and forms. The worst affected are states and local government ministries and parastatals where over 80% of their inventories of maps are in paper form stored out in flat files. This makes the retrieval and updating of such products a herculean task and because Nigeria is a developing nation with constant improvements in

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utilities, most of these paper maps become outdated almost immediately after they are made available to the public. The situation is not different in the power sector which even though it has been privatized, most of the information about its utilities are still stored and managed using analogue method, making it cumbersome to manage and maintain with its attendant consequences of poor service delivery [2].

Having identified that the problems of electricity distribution can be reduced when there is up-to-date information for planning and quick response at time of need, there is a need to use a modern technology to manage information about electricity distribution facilities. In this paper, we demonstrate the effectiveness of Geographic Information System (GIS) in the management of electricity distribution facilities and assets in Ogui, Enugu North local government area, Enugu state, Nigeria. The advancement in technological development has made it very tedious to manage such utilities with a conventional utility map which features just a few attributes. Information about the components such as transformers, cables, meters etc. cannot always be stored on such and relevant analysis as well as queries is impossible in such a system. Therefore, there is need for a computerized system where analysis both spatial and otherwise can be carried, which supports several forms of queries and possesses the ability of seamless updating and retrieval of information. This is in-line with Zhang et al, who in their work titled Integrating BIM and GIS for large scale facilities asset management: A critical review, are of the opinion that "widely-dispersed assets such as buildings, equipment, roads and bridges present local governments as well as big organizations with a number of asset management challenges. Therefore, to manage them effectively, the management system must be that it is spatially based or referenced." The GIS therefore provides an effective platform for such operations [3].

A GIS, the definition of which is "a system designed to capture, store, manipulate, analyze, manage and present all types of spatial or geographical data," is a perfect fit for an asset registry because it allows you to visualize, question, analyze and interpret data to understand relationships, patterns and trends. Ayeni and Abiodun share the same opinion when they stated that "GIS are related to other database applications, but with an important difference information is linked to a spatial reference. Other databases may contain locational information (such as street addresses, codes etc.), but a GIS database uses geo-references as the primary means of storing and accessing information [4]."

Geographic Information System (GIS) tools which can be used to capture, store, retrieve, analyze and display geographically referenced information is an excellent tool for managing the inventory and properties for power generation, transmission and distribution companies. It has an added advantage of performing spatial analysis, location analysis and spatial modeling. GIS has been utilized for facility management in both electricity and other sectors, in the effective maintenance of physical assets. With the help of GIS, it is easier to update the system accurately in a timely fashion [5].

LITERATURE REVIEW

Problem and justification

The management of utility has become a major concern in most countries of the world. Just like the popular quote which says that "prevention is better than cure", therefore the need for effective management and maintenance of utilities and other infrastructures can never be over emphasized. There can be little or no improvement in a system if there is no proper maintenance to existing infrastructure. No wonder Igbokwe and Emengini in their paper titled GIS in management of electricity distribution network: A case study of Onitsha-North L.G.A., Anambra state, Nigeria are of the opinion that "the creation, updating, maintenance and general management of electricity distribution network in terms of spatial and non-spatial data is a herculean task. The voluminous nature of data involved for proper record keeping is indeed cumbersomeand cannot effectively be handled by traditional system of record keeping." We therefore demonstrate; in this study, the effectiveness of a GIS approach in the management of electricity facilities [6].

Study area

The study area is a section of the Enugu metropolis. electricity distribution in the study area is overseen by the Enugu Electricity Distribution Company (EEDC) which also is in-charge of electricity distribution in the entire south east of Nigeria comprising five states. Enugu state is in the south east geo-political zone of Nigeria. It is located at 6°30' North of Equator and 7°30' East of Latitude. It is plus one hour (+1 hr) GMT on the world time zone. It shares border with the following states: Abia and Imo to the South; Ebonyi to the East, Benue to the North-East, Kogi to the North West and Anambra State to the West. It covers an area of 7,161 km^2 (2,765 sq mi) and ranks 29th out of the 36 states of Nigeria in terms of land area (Figure 1).

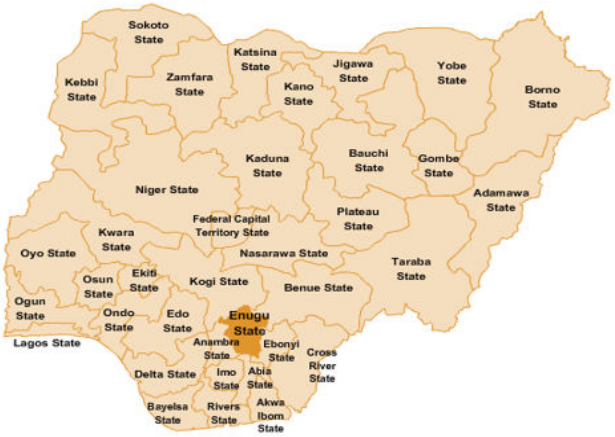

Figure 1: Diagram showing the study area.

Electricity in Nigeria

There are diverse opinions on the date that electricity was first introduced in Nigeria, though many authors believe that it was in the 19th Century. Awosope is of the view that electricity in Nigeria can be traced back to the installation of the first power generating plant at 1898 at Marina Lagos with a working capacity of 60 kW, while other towns in the country started developing electric power supply system on the individual scale after the Amalgamation of the northern and southern protectorates in 1914.

the electricity corporation of Nigeria (ecn) was established by the colonial government under the ordinance No.15 of 1950, though it was in April 1951 that the body (*i.e.,* ECN) officially took charge of all the electricity supply operations in the country by bringing together all the government owned as well as native owned generating plants and systems [7].

Geographic Information System (GIS)

GIS professionals have not presented any single definition that is generally accepted, therefore the general principles of which professionals agree will be examined. First, GIS requires a combination of hardware and software tools. Second, it requires data that must be spatially referenced. Third, a GIS requires knowledgeable individual to run it.

A GIS can be thought of as a database that provides a description of the earth (or a part of it). While the global positioning system and Global Navigation Satellite System (GNSS) gives one an idea of his or her position on earth, the GIS is used to organize and gives information of the location and details at that position. The combination of these two technologies is crucial because a pair of coordinates may not make a complete sense if there is no feature data.

A Geographic Information System (GIS) can be defined as a system of hardware, software, data and organizational structure for collecting, storing, manipulating and spatially analyzing "geo-referenced" data and displaying information resulting from those processes. GIS according to Heywood, et al., can be better understood by considering the generic types of questions that they have been designed to answer. Such questions according to them include questions about location, patterns, trends and conditions.

GIS therefore is a multi-disciplinary tool that can be used for solving problems that are related to land information system, soil information system, utility information system (as the case of this paper), cadastral information system, etc.

Challenges of electricity distribution

There are several challenges facing electricity distribution in Nigeria. It is important to mention at this point that this paper suggests solution to that of assets management and maintenance because the authors are aware of the fact that there are other challenges facing the distribution segment of the electricity network. Some of the challenges faced by electricity system in Nigeria especially as it concerns electricity distribution segment are given by Sambo, et al., to include:

- The poor utilization of existing assets and deferred maintenance
- Poor voltage profile to the tail end consumer
- Some sections of the national grid are outdated with equipment in a state of poor and inadequate maintenance
- There is a serious lack of required modern technologies or communication and monitoring of the generation, transmission and distribution infrastructure
- Low customer satisfaction (load shedding, poor voltage profile, inaccurate billing, difficulties in paying bills, no-notice disconnections, etc.)
- Overloaded transformers and bad feeder pillars

It is obvious that some of these problems can be tackled when there is a proper management and maintenance of these distribution utilities. In line with this, Pickering, et al., posits that any organization that expects to run an efficient day to day operation and to manage and develop its services effectively must know what asset it has, where they are, their condition, how they are performing and how much it costs to provide the service. Alamu and Ejiobih also believe that a well maintained infrastructure of utility information will enable an up to date feedback on what is where, its current state, its reactions to actions on it and how it can be deployed for optimal benefits [8].

Therefore, the challenges facing the management and planning of distribution of electricity can be solved using GIS. This can be achieved through the adoption of Utility Information System (UIS). Utility Information System deals with administration, planning, maintenance and mapping of infrastructure such as electricity, water, telephone etc. Utility mapping itself deals with the special inventory of these utilities and their representation in map form at an appropriate scale.

GIS in power utilities management

Due to the capabilities of a GIS, it has proven to be a wonderful tool for assets and utilities maintenance and management, especially where those assets are location bound and scattered across a large geographic area as in the case of the electricity sector. An electricity system possesses a lot of components which would be cumbersome to manage with analog systems. Olatoye points out that a fully operational power system incorporates a large number of constituents ranging from generating, transmitting, switching and distributions stations. He went ahead to assert that though the maintenance of each of these constituents has its own challenging peculiarity; they all operate together as a single unit [9].

Emengini noted that knowledge about physical assets of the enterprise is necessary to make strategic and operation decisions. Thus, to take wise decisions vital to the operations, growth and management of electricity distribution facilities, information must be collected and analyzed to its full extent, such information contributes not only to efficient services, but also to the operation and maintenance of assets and to the sensible planning of extensions and new works.

Meehan believes strongly that the challenges faced by power industries and utility operators are numerous and will continue to increase due to the recent advancements in technology in the

form of other alternative energy sources such as solar, wind, etc. He went further to state that the black out in the United States in 2003 has also given rise to the need of more effective ways of detecting faults in a timely fashion and proffering quick solutions. Though it was stated that the black out was caused by two trees coming in close contact with the transmission lines, the author however believes that it was not just the trees causing the blackout, but the lack of situational awareness, tools for collaboration and up to date data probably contributed as well [10].

Moore, et al., is of the opinion that electric utilities are rich in computer based information systems, which aids in facilities operation and management, provides customer support, control the substations and monitors the general performance of the distribution network. Diagnosing faults and repairs involve the combination of information gathered from these systems. Ayeni and Abiodun posit that GIS is a very efficient tool for the management and maintenance of a system of utilities whose information and decisions are land based.

This section deals with the general procedures, materials and methods deployed in the successful execution of this project. The processes involve acquiring relevant datasets after the planning has been completed. This is succeeded by data processing after which the database was designed and executed. Several queries and spatial analysis were then tried on the system and results are presented in the form of maps and tables.

These include the equipment and applications utilized for this operation. The following were notable among them.

- Garmin Etrex10 Handheld GPS receiver for position data acquisition
- Writing materials to record attribute data
- Dell latitude laptop computer with the following specifications: Windows 7 64bit operating system with Intel Core i5 processor and 4Gig installed memory
- HP LaserJet printer

Software include Microsoft office suites, notepad and ArcGIS 10.1.

Procedures and methods

Marking out of the area: The area to be covered was decided to be small enough that it can be effectively covered with our scarce resources and large enough that all the procedures were demonstrated.

Downloading of satellite image: The image was required to give an overview of the project area and that of the immediate surroundings. It was sourced through the google earth application program and utilized for visualization purposes during reconnaissance. The name of the area was keyed into the search panel in Google earth program and zoomed until the desired resolution and coverage was obtained.

Data acquisition

This consists of all the operations required to obtain both the geometric as well as attribute data required in the database and for other relevant analysis. The data acquisition is group into two major headings namely; primary and secondary data acquisition [11].

Primary data: These refer to those data directly captured on the field and they cover both spatial and attribute data. They include the satellite image acquired through the google earth platform, positions (X, Y coordinates) of relevant features (electric poles, transformers etc.) acquired with the GPS receiver and attribute data of features which were gotten from direct interactions (social survey) with the inhabitants of the area such as names of streets, meter types, etc., as well as by visual inspection (e.g. status of electric poles).

Secondary data: these are the data which were not directly acquired in the course of this project but were useful. They include a high resolution, geo-referenced aerial photograph covering the study area that was acquired from the Enugu state ministry of lands and survey which was used for digitizing the building footprints, roads, etc., existing base map of Enugu urban and information about the electric facilities gotten from the office of the Enugu Electricity Distribution Company (EEDC). Such information of electric facilities includes transformer capacity, number of transformer phases, transmission line voltage, meter type, etc.

Data processing

Data in its raw form will command very little value to the general public. Data processing is therefore a means of adding value to the acquired data and thereby generating information out of it. The data processing stages are discussed under the following headings

Data download and arrangement: The coordinate data obtained with the aid of the handheld GPS receiver was downloaded and arranged with the aid of microsoft excel.

Data conversion: The high resolution, geo-referenced aerial photograph acquired from the Enugu state ministry of lands was added into ArcGIS 10.1 application software and features of interest (buildings, roads etc.) were digitized into separate shapefiles/layers. Features digitized from the image are roads (linear feature), buildings (polygon feature) and boundary/ extents (polygon feature).

The coordinates of the electricity assets; downloaded and arranged in the microsoft excel sheet was imported into the ArcGIS environment. It is important to mention at this point that the coordinate system of the geo-referenced aerial photograph is the same with that of the GPS receiver utilized in capturing the coordinates of the electricity assets. The image therefore was used to ascertain visually, the coordinate positions of these features.

After the points were imported, separate layers were created for each individual feature namely transformers, electric poles and transmission line. The same digitizing procedures in ArcGIS were also used to get these features contained in their individual layers.

Database implementation

The ArcGIS application program also has database implementation ability and therefore this was adopted in the creation of the database for this project. The attribute tables for each layer were populated with the relevant information as obtained through direct field observations as well as from the electricity distribution company in charge of the area.

DISCUSSION

The results acquired at the end of the operation are maps and feature database of all electrical distribution facilities as well as the roads, river line, area extent and the buildings within the project area. The electrical distribution facilities include the electric poles, transformers and service lines. The Table 1 shows the features and the attributes of each feature as contained in the database.

Table 1: Feature attributes.

Electric poles	**Pole_ID, northings, easting, status, material**
Transformer	Trans_ID, northings, easting, capacity kv, rationed
Service line	Line_ID
Road	Road_ID, name, width
River	River_ID, name
Building	Building_ID, usage, No_of_meter, meter_type, phase, trans_ID

For the electrical poles, the material refers to what the pole is made of which could either be 'concrete' or 'wood' while the status refers to the condition of the pole and can either be 'good' or 'bad'. The transformers can be 'rationed' or not depending on if the areas connected to it has to enjoy power alternately. The building can either be in in commercial or private usage, either using single or multiple meter(s), the meter type can either be 'prepaid', 'postpaid' or 'no meter' and could be using any of the transformers contained in the area.

Therefore, the GIS present itself as a tool that could be very useful for management, as well as efficient maintenance of electricity infrastructure especially as it concerns the area of distribution. The database houses a rich source of information on all facilities under review with geographical locational ability making it easier to track location of faults and reduce the general downtime.

CONCLUSION

This research demonstrates that GIS can be effectively utilized in the management of facilities and assets as it was deployed as a powerful tool in mapping of EEDC facilities of independence layout service center, Ogui, Enugu. The aim and objectives of the project were attained. The result achieved can be used by the Enugu Electricity Distribution Company (EEDC) (Independent layout district) to locate and identify the spatial position of their facilities using GPS (navigation) or the developed maps. Also they can easily retrieve information instantaneously from their database for planning, maintenance operation and faults' detection as well as for the decision making. Changes in the facilities such as new addition of infrastructures or upgrade of existing ones can also be updated in the database seamlessly.The procedure adopted can also be applied in a much larger area like a whole state or region.

RECOMMENDATIONS

Companies whose assets are location based in operations need to employ GIS Specialists that will assist in acquiring, processing, managing, updating and presenting spatial data analysis of their assets.

EEDC should employ the use of GIS in mapping their facilities. Electric fault management is done when the transformer under fault is known. The distribution transformer under fault is selected and linked to the database with the help of GIS. From the database, the affected area is found and displayed on the map. This will help EEDC in the planning of maintenance routine.

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