Utility of GIS on improving energy utility distribution network

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Abstract

Transporting comfort in life through series of inventions and discoveries is an act humans have always executed since emerge. Process of bringing further luxury in life is still continue and will go on until human exist. Sophistication in life is directly proportional to energy consumption rate. Thus with each passing of the day, demand of energy is increasing and will increase further. Rise of demand naturally increase complexity of demand management. Thus exiting approaches of management will become insufficient to bear load of anticipated demands. This is something similar to what we can realize in road traffic management. Traffic management process is continually enhancing to cope with increasing number of vehicles on road. As traffic management particularly in big cities is not possible without utilization of ICT, similarly management of energy supply chain will become unmanageable. Energy supply service providers must need real-time information system which could assist them in visualizing real-time ground information. Entrenching such systems for the management and monitoring of energy utility distribution network will enable organization on making better strategic and operational decision on mitigating load distribution & quality level issues. GIS technology embeds all sorts of features that are needed for efficient distribution network management.

Keyword: GIS, Electricity, Distribution network, GPS, Simulation, Mapping

INTRODUCTION

GIS technology is getting wider acceptances these days on the field of simulations of real world fact into digital world. Simulations of real field assets of energy utility distribution network not only provide benefit the electric utilities in the management of demand for engineering, construction operations, and maintenance and services purposes but also help in management of the spatial data. At present problem for service providers is just not only the day to day service management and expansion of the network but also with the management of loss. Features of GIS equally applies well on solving all such sorts of problems related to planning, monitoring and maintenances.

Deriving way-out for resolving necessities of increasing intricacies of electrical distribution system along with necessity of accurate up-to-date information of the network assets is the sole purpose of this research. This research utilizes features of GIS on top of data collected using GPS enabled mobile device. GIS technology utilizing GPS enabled data can analyze spatial data, through attribute and location analysis or spatial modeling. Spatial modelling of data empower service provider capability to simulate real field information on computer desk of operators. Capability of visualizing ground level data from computer desk aid enormous support on

satisfying needs of maintaining large power infrastructure. System operators will require assistance from the technology that could support them on making optimal strategic & operational decisions laid on real field facts. In this connection, GIS can be a sophisticated tool to simulate and organize real field data to a computer system linking the database to map. GIS tool enable operators on visualizing real-time distribution network from their desk for efficient day-to-day operation.

METHODOLOGY

Significances of Geographical Information System, Global Positioning System, Global Navigation Satellite system and Remote Sensing technologies as the three most important spatial database technologies for developmental planning and decision support have rigorously increased since last two decades. Increase in usages of these technologies have also amplified the usages of GPS satellite which act as reference points from which receivers on the ground resects, their position, and a precise orbit. In the same way utilization of basemaps also increasing. Basemaps are another essential component needed for these technologies. Different service providers such as OSM, Bing, and Google Maps provides updated real-time basemaps of earth crust. These maps can be accessed under different view options such as street view, satellite view, hybrid view etc.

Generation of map from the analyzed data is another critical requirement for this research. Several technologies have emerged to support the utilization of GIS capabilities over the internet as web services. These technologies allow sharing maps and accessing spatial data over internet from different sources. These tool even allow performing spatial analysis on local machines. Evolution of these capabilities have laid new arena for researchers of the kind current research aiming.

Different commercial and open source tools exists to generate maps. Some popular GIS mapping commercial tools are ArcGIS, Geomedia, MapInfo, Blue Marble, Manifold, Smallworld , Bentley Map, MapViewer and Surfer, Maptitude, SuperGIS, IDRISI, AutoCAD Map 3D, Tatuk GIS, TNTgis, MapMaker, XMap, MapRite etc. But commercial tools closed source software which can only be modified from the vendor of the software while open source software possess flexibility of modifications based on requirement of an individual. Different open source GIS mapping tools also exists. Some of them are QGIS server, Geoserver, MapServer, Mapnik, MapGuide, OpenMap etc.

This research renders support of Geoserver opensource mapping tool for generation of the map. Geoserver is developed in 2001 and support geospatial data such as shapefiles, special database like posgresql with post GIS extension to publish web based map. Focus of this system is to enable citizens, researchers to be involved in building tools that could support in planning the decisions based on reality. Geoserver supports Web Feature Service, Web Map Service, Web Coverage Service, Web Processing Service, and Web Map Tile Service. These services are open standards services for GIS.   Among these services Web Processing Service, and Web Map Tile Service are supported through the extensions.

- Web Map Service is a protocol to obtain spatial data as images. Requested map is served to user as maps and map layers from a server. This maps and map layers is displayed on a map viewer.

- Web Coverage Service protocol serves geospatial data as coverage. User can request specific coverage data from a server and implement subsetting, re-projection, and resampling operations on the data.

- Web Processing Service protocol for executes algorithms or models on geospatial. User can request the execution of needed processes on a server and receive the results of the process as output.
- Web Feature Service open standard protocol to acquire geospatial data as points, lines, and polygons vector data through the web. User can request specific feature data from a server and execute querying, inserting, updating, and deleting operations on the data. This research uses WFS for data mining and analysis.

Combining capabilities of GIS, GPS, base-maps and mapping servers to address challenges of electric distribution network utilized by this research to simulate distribution network in terms of what asset it has, where they are, their condition and how they are performing. Simulation of physical assets deduced by the research following the approaches shown on methodology section will replicate cloned environment of physical distribution network on computer of operator's desk. Cloned environment of ground assets enable operators on visualizing fault location, haphazard installation of meters/poles/transformers, installation of renewable power resources, utility asset management, optimizing electrical lines routing, power monitoring, and forecasting load directly from working desk of operators.

This research usage sql functions of mysql & postgressql and spatial functions of Postgis (an extension of PostgreSQL database) on the field asset data (such as consumer, pole, transformer, feeder and substraction) of energy utility distribution network for data manipulation and analysis. Postgis include several functions such as

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ST_MakePoint, ST_MakeLine, ST_Polygon, ST_Length, ST_Distance, ST_Area, ST_difference, ST_Buffer, ST_X, ST_XMax, ST_XMin, ST_Scale, ST_Rotate, ST_Line_Substring, ST_LineToCurve, ST_LineFromMultiPoint, ST_Boundary, ST_MakeBox, ST_Touches, ST_SRID, ST_NumPoints, ST_Intersection, ST_Envelope, ST_Equals, ST_Centroid, ST_Extent.

These functions support on executing different types of spatial data manipulations and analysis [1]. Functional details of some of these functions is as follows,

Function Name	Functional details
ST_MakePoint	ST_MakePoint function builds a spatial point object from the longitude and latitude data.
ST_MakeLine	ST_MakeLine command generates spatial line object linking different input point objects.
ST_Polygon	This geospatial function construct spatial polygon object from line segments.
ST_Length	This function measures geodesic or Euclidean length of the spatial Line string object.
ST_Distance	This function returns minimum geodesic/Euclidean distance between two spatial objects.
ST_Area	This function is used for getting area of polygon.
ST_CONTAINS	Used for determining spatial objects falling within area.
ST_Centroid	Determines spatial central location of an area.

ST_NumPoints	This functions gives the number of points in a geographical area.
ST_Boundary	Used for determining boundary of a geographical area.
ST_SRID	This function is used for identifying spatial reference system identifier.
ST_Scale	This function is used for scaling the spatial object to a new size.
ST_Touches	Used for determining whether two points intersects
ST_Extent	This is an aggregate function which determines a box2d bounding box that bounds a set of spatial objects.
ST_Equals	Used for comparing two spatial objects. Returns true if objects are equal.

Query result of sql functions is applied to articulate level of criticality based on calculation of impact. Sql functions also allow querying degree of impact due to outage. This is used for setting priority order. Amount of energy loss, number of consumers affected, transformer overload, phase imbalance, nature of fault etc. are the parameters taken into consideration for querying the level of impact from PostgeSQL with postgis extension database. PostgreSQL include different logical, comparison, mathematical, string, pattern matching, datetime, search and geometric functions for such purposes [2].

This research utilizes WebGIS technology and Geoserver mapping server to display results. PostgreSQL/Postgis database serves as store for Geoserver. Geoserver encompass feature of creating sqlview based on type of display and filter criteria applied utilizing the store. These sqlviews is the foundation for generating map layers [3]. Geoserver include interfaces as Web Mapping (WMS), Web Features (WFS), Web Coverage (WCS) and Web Map Tile (WMTS) services to publish & export data [4]. These services are open standards services for GIS. Among these services Web Processing Service, and Web Map Tile Service are supported through the extensions.

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Combining capabilities of GIS, GPS, base-maps and mapping servers to address challenges of electric distribution network utilized by this research to simulate distribution network in terms of what asset it has, where they are, their condition and how they are performing. Easy grasping of simulated environment of physical assets also require decent presentation. Geoserver uses an XML-based markup language called Styled Layer Descriptor (SLD) to symbolize distinct elements of map in different style [5]. This is one of the essential feature needed by the users for better visualization and understanding of the simulated environment. Similarly to customize map elements information output, Geoserver uses freemaker template. By means of three files header.ftl, content.ftl and footer.ftl map

information output can be customized in Geoserver [6].   But just map of surveyed data is not enough to simulate real field environment. Creating exact simulation require superimposing of survey map on top of basemap. This research utilizes concept of WebGIS to generate simulated environment of distributed network. API from Openlayer and leaflet has been used by this research to develop WebGIS [7, 8]. Derived approach will allow representation of information in pictorial format. Pictorial representation of information can quickly be grasped.

I.   MODELING AND ANALYSIS

Study area selected for carrying out this research is electricity utility office which fall on latitude range varies from 27.7256437 to 27.7278388 while longitude ranges from 85.3625784 to 85.3782068. Following table shows electrification factsheet of study area.

Heading	Value	Remarks		
Total population	109430			
Total municipality	03	Shankharapur, Kageshwori Manahara and Gokarneshwor		
Total household	27357			
Total household electrified	22906			
Total Feeders	4	Mulpani	Length : 10.85286 km	Load : 285/202
		Sankhu	Length : 70.25 km	Load : 187/157
		Gothatar	Length : 9.8764 km	Load : 228/173
		Danchi	Length : 20.1556 km	Load : 268/223
Data source: NEA regional office website [https://www.nea.org.np/regional/4/dcs]				

Table 1: Electrification factsheet of sample area

This research to ascertain its hypothesis of improving electricity distribution network through utilization of GIS follows set steps as follows

a. Collect field inventory of distribution network along with their GPS. This include data of consumer, pole, distribution transformer, feeder and substation data along with their GPS. Mobile application is used for collecting the data. Mysql database is used for collecting the data.

b. Collect data from the field to send to central data module. Central data module is developed on web technology. This module is utilized for data consolidation process.

c. Validate correctness and completeness of data using different database queries. MySql database queries are used for cross checking the data correctness and completeness. Data correctness checks linkage issues among linked data objects such as consumer to pole linkage, pole to transformer linkage etc. Similarly data completeness check completeness of all the attributes value as per the designed schema of database objects (Consumer, pole, transformer, feeder and substation).

d. Mysql database is to be migrated to spatial database to render features of spatial analysis of data. Postgresql with postgis extension is used as spatial database. "FromMySqlToPostgreSql" tool is used for the migration.

e. Postgresql with postgis extension allow creating sql and spatial views needed for

- checking data integrity

- Calculating mean, count, spatial distances, postions

   These are needed for data mining and analysis.

f. Geoserver is utilized as mapping server for generating maps from the data. Postgresql database can be linked to Geoserver as store. Geoserver uses this store to generate layers, styles and views.

g. Finally webgis tool is prepared using openlayer and leaflets. Webgis imports map layers from geoserver and topup the map with different user friendly elements such as legends, Map navigators, search functions etc.
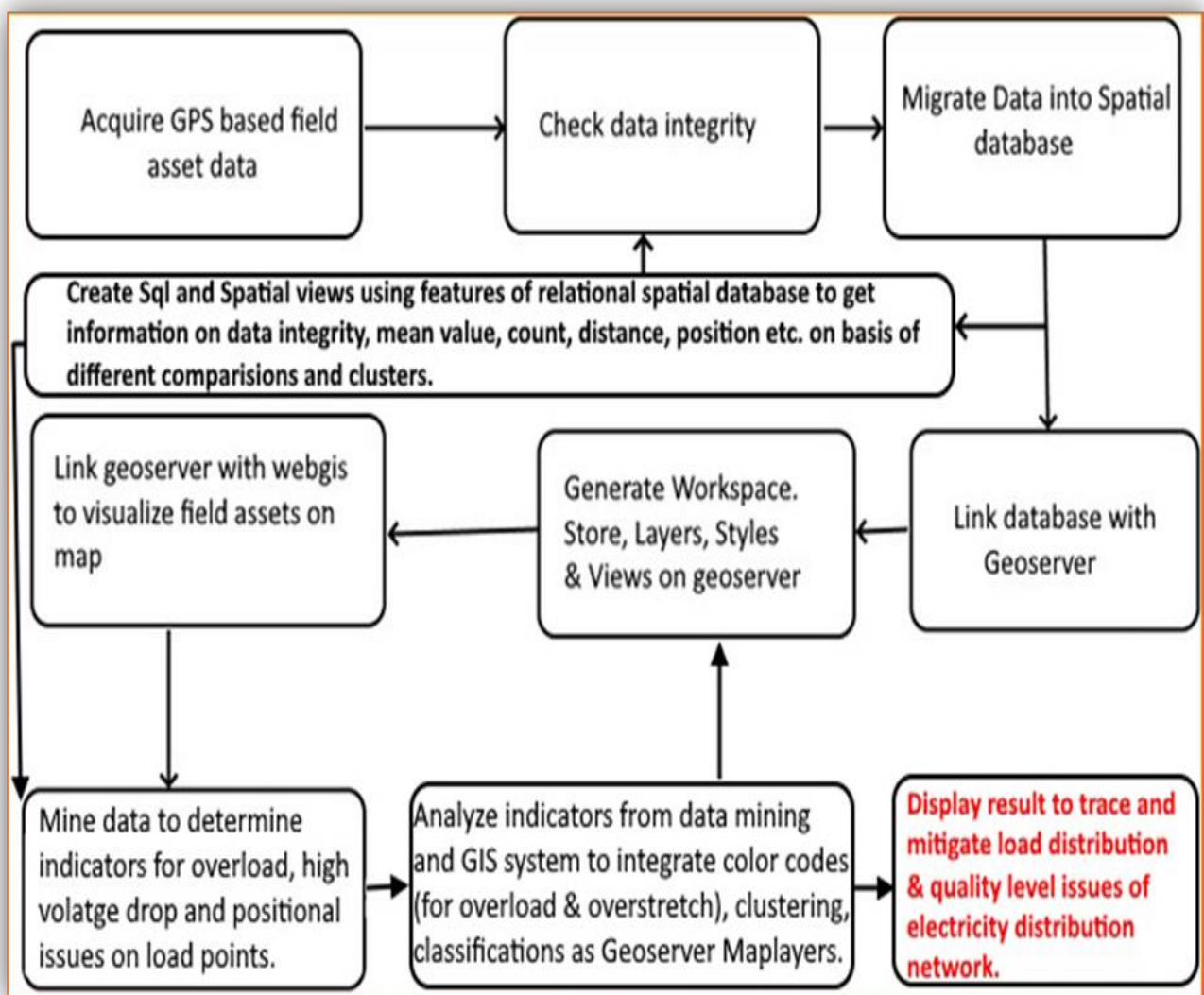
Following figure details portrays the steps described above.

Figure 1: Roadmap of Implementation

Technical platform used for this research is as follows

Data Capture Module	
Technology Platform	**Technical utilization**
Android Studio	Integrated development environment (IDE) for mobile application development.
Java	Programming language used for mobile application
SqlLite	Database for mobile platform
GNSS enabled GPS Mobile device	To receive more accurate latitude and longitude coordinate from satellite.
Javascript Object Notation (JSON)	This is utilized for uploading data collected on mobile device to central server.
Data Consolidation Module	
PHP	PHP is utilized for server side scripting of web application
MySQL	Database for web application
Sqlyog	IDE for MySql data management
Ajax	Ajax is used as client side scripting for web application
Xampp	IDE used for deployment of apache and mysql server
PostgreSQL	Database used for GIS.
Pgadmin	IDE for PostgreSQL data management
FromMySqlToPostgreSql	This tool is used for migrating data from MySql to PostgreSQL.
Postgis	This an extension of PostgreSQL for performing spatial analysis of data.
Data Presentation Module	
Geoserver	Geoserver generates map from PostgreSQL data store.
Style Layer Descriptor	SLD is utilized for styling map.
Freemarker Temaplate	FTL is used for preparing customized popup window.
Open Layer	Used for WebGIS
Leaflet	Used for WebGIS (parameterized query)
BaseMap APIs	Used for rendering basemap from google and openstreetmap.

Table 2: Technical Platform

Implementation for the research objectives composed of five main processes as follow

- Data Collection Process.
- Data Consolidation Process.
- GIS Simulation Process.
- Tracing Distribution Network Degrading Factor and Location of Fault Process. &
- Generate Alert & Notification Process.

Data collection process

Data collection process under this research gather attributes of distribution transformers, poles and consumers associating location information of these inventories. Data of 217 Transformers, 7809 poles and 14960 consumers is collected for this research.

Data consolidation process

Data consolidation processes verifies integrity of data in terms spatial accuracy, connectivity from transformer to consumer and completeness of captured attributes of transformers/poles/consumers. This research employs tool for data verification both at field and central repository levels.

GIS simulation process

GIS simulation is central core process of this research. Under this process collected data in MySQL after verification is migrated to spatial database (PostgreSQL with Postgis extension). On this spatial database tables for Transformer, Pole and Consumer are altered to add spatial/geometry point/line fields under Spatial Reference System ID (SRID) 4326. This is a WGS84 standards to show latitude and longitude spatial data. Geoserver, an open source spatial data mapping server, uses this spatial data to create GIS map. Finally Open Layers & Leaflets platform is utilized for embedding GIS map along with Base map and other operator assistance tools to produce simulated distribution environment as WebGIS.

Tracing Distribution Network Degrading Factor Process

Simulate GIS environment assist in visualizing distribution network load distribution point elements in terms of overload (no of load points), voltage drop (overstretched distance), positional accuracy and loss measurement due to outage. This research uses color codes as green, dark blue, maroon and red to indicate load distribution point elements as normal, overloaded, high voltage drop and both overloaded & high voltage drop respectively. Similarly current research utilizes this GIS tool to locate nearest distribution point (such as pole and transformer) from point of electricity defect.

Generate Alert & Notification Process.

This research recommends and utilizes process of SMS gateway integration with Webgis system to deliver generated alert for the notification to consumer and technician. Alerts are generated during situations of outage, acknowledgement of nolight complaint and maintenance activities to inform affected consumers.

RESULTS AND DISCUSSION

This research realizes its objectives of resolving the improving distributed network through series of processes shown above. This knowledge of explorations are realized utilizing technology of GIS to reap following information:

- Line segments identification.
- Associating location with other attribute of consumer meter, pole & transformer.
- Establishing link among consumer meter, pole & transformer
- Map preparation.
- Calculation of load at each pole, transformer, transformer each phase.
- Classification of consumer meter, pole & transformer based on parameters
- Identification of overloaded & overstretched load points and segments through point and line diagrams &
- Alarming zone identification

Finally services of WebGIS is rendered to present results on.

- Detection of faulty load points & segments
- Identify requirements of Maintenances & upgrading.
- Area to isolate for maintenance
- Estimation of loss due to outage
- Recommendations of best path and load points for expansions.
- Estimation and recommendation of best load pole for new connection.
- Recognize positional realignments needed for the load points
- Locating nearest field technician from point of fault &
- Many more

Following figure illustrates snapshot of webgis used for tracing feeder line diagram (on the basis of connected nearest and farthest transformer)
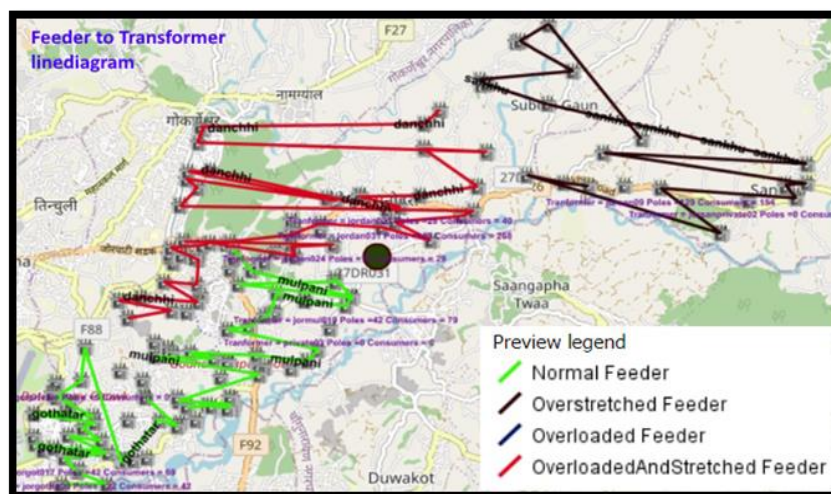

Figure 2: Webgis Snapshot

Conclusion

Outcome of the result of this research has visibly demonstrated approach, technology and tool to trace load distribution & quality level issues of electrical distribution network but still mitigating actions for all such identified situations is not possible. Particularly the case

- When System has traced nearest isolation point from fault but nonexistence of circuit breakers on that isolation point prohibits operators to disconnect from that point.
- Load calculation is based on assumptions of max approved load of consumers not on actual load consumed on a particular time. Load calculation on actual basis require smart meters connected with billing system.
- Approach of fault detection and mitigation in case of underground cabling
- Implementation of time sequential sectionalizing system that auto diagnose and cut the power from nearest load point

Handling such cases requires integration of these missing elements on distribution network along with improvements on system proposed by this research. This study may help as a guide for the future researchers to use this research as a reference to overcome limitations existed and utilize this on different other energy utility distribution sectors. Researchers can get literature review from this and formulate a new research, based on the findings of this study.

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