Journal of Geomatics Vol 9 No. 1 April 2015

Open source GIS and cloud computing technology for the power distribution system

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Abstract: The information keeping and managing in hard copies are very difficult to preserve and locate assets using traditional approaches, in case of emergencies. The GIS based techniques in combination with the remote sensing satellite images and GPS technology can be very helpful in the management and analysis of power distribution system infrastructure. This paper presents the utility of Open Source GIS with integration of QGIS Cloud Plugins (0.8.3) web based technology for management of electricity assets in the city of Bhopal. The electric poles, transformers, feeders, consumers and circuit information were collected from Madhya Pradesh Madhya Kshetra Vidyut Vitaran Company Ltd (MPMKVV) Bhopal for the development of Pole Information System (PIS). The GPS survey was carried out to confirm ground realities and digital intelligent map was prepared for electrical asset mapping. The details of consumers were linked with poles, transformers and feeders for spatial and non spatial analysis. The Road Graph and QGIS Cloud plug-ins were linked with PIS for establishment and encouragement of e-governance system in the city. The investigation results have shown that the Open Source GIS is capable, competent and effective system for managing electrical assets and networks in the city or state. In this context, conclusions and the recommendations have been suggested for the optimization of distribution system routes, preservation of data and transparency in existing system, interlinking of information etc. using Open Source GIS and web based QGIS Cloud Technology.

Keywords: e-governance system, Open Source GIS technology, QGIS cloud system

1. Introduction

In the power distribution system various type of information ranging from the distribution system infrastructure to consumers are required. The above information may be spatial or non spatial in nature depending on the situation. Availability of information regarding location, ratings, condition, service readiness and existing loading are important in the management of resources for providing electrical supply service, identification of redundancy, planning of expansion, maintenance and spares management. For asset management in a large power distribution system, various problems and issues related to handling of large amount of data are to be resolved. A more advanced but equally desirable result of an Asset Management System would be the reduction of transmission and distribution losses by efficient load dispatch.

For an efficient planning and management of power distribution system, the Geographic Information System (GIS) may prove an efficient tool due to fact that a large number of information is spatial in nature. The GIS based power distribution management can provide all the information in the digital form on the computers. The GIS based information can be assessed by different persons at different locations through web based GIS solutions. Various type statistics related to infrastructure status and consumer satisfaction etc. can be retrieved easily from the GIS based power distribution system database.

The recent GIS technologies have the capabilities to provide cost effective solutions in the maintenance, display, recording and analysis of electricity distribution system with the association of different aspects. The GIS utility mapping for electricity distribution helps in the identification of appropriate locations of consumers and information describing the attributes of each consumer such as location, consumption pattern, particular consumer connected at which transformers, feeders, substations, poles and circuit number etc. geographically (Chaurasia and Thakur, 2009).

The GIS visual products have become a powerful resource for infrastructure protection and emergency preparedness. The spatial analysis tool provides the planner with a means to compare costs of alternative routes produced as a result of terrain consideration, hence enables optimisation. These technologies can be utilized for e-Governance practices which are important component of the application of information and communication technologies to exchange information between government and the citizens, government and business organizations and between government organizations (Smitha et al., 2012).

The cloud computing offers a modern approach for storing the information and designing the software systems in order to manipulate the stored data. The advantage of cloud computing over local computer system is the ready and reliable availability of almost unlimited computer power, not restricted by local resources. Cloud computing has recently emerged as a new paradigm for hosting and delivering services over the internet (Zhang et al., 2010). GIS cloud has been a suggestive approach to upgrade the conventional GIS applications, in order to provide broad spectrum services to the users across the globe (Bhat et al., 2011).

The GIS cloud has capability for providing a common framework for all the data and geoprocesses available in the cloud. In GIS cloud, it is possible to combine the appropriate services in order to produce a solution for a specific need (Konstantinos et al., 2014). The GIS cloud offers such readymade resources, and algorithms which can be used as available, or after minor modifications to suit a particular requirement. The open source Google Earth imagery and other resources can be integrated in a cloud system to make the power distribution system data more meaningful.

In the literature, researchers have reported on the use of Open Source GIS technologies for resolving the issues of electrical asset maintenance. The developments of high speed internet access applications and virtualization techniques have made cloud computing a leading edge technology (Reddy et al., 2012). The cloud computing can be applied to solve and overcome the challenges in currently used GIS applications (Bhat et al., 2011). Cloud computing has emerged as a major technological breakthrough for small to medium scale enterprises and software users who are looking for dynamic scalability at a low or zero initial investment. GIS techniques can be more efficient in combination of cloud computing (Pandey, 2010). Technological advancements, easy access to the internet and the necessity for map publishing and information sharing have made WebGIS a mandatory tool for many organizations today (Elavazhagan and Vijayee, 2010). The open source GIS based cloud computing technology for the power distribution system purposes like consumer indexing, mapping of electrical utilities, unique Ids generation, geometric network creation, attribute attachment in each cable segment is very useful.

In this research paper, investigations have been carried out for the use of open source QGIS software and cloud computing approach. QGIS is the official software of the Open Source Geospatial Foundation (OSGeo). It runs on Linux, Unix, Mac OSX, Windows and Android. QGIS is user friendly Open Source GIS software licensed under the General Public License (GNU). QGIS has sufficient capabilities to visualize, manage, edit and analyze data geographically. It supports numerous vector and raster database formats. The QGIS resources are delivered over the internet in a quick and reliable manner for instant usage. The QGIS cloud works on the basis of Service-Oriented Architecture (SOA) design pattern, which are functionally as services to other applications via a protocol. The consumer interface, business process, services components and operational systems are main SOA layers.

2. Study area and data resources

The study area is situated in the Bhopal city in India. Bhopal is located by the side of Malwa Plateau in the Northern –Eastern part of Madhya Pradesh. The geographical location of AOI (Area of Interest) lies within central part of Bhopal city and bounded by Longitudes 77°23’24.00“ E to 77°24’36.00“ E and Latitudes 23°12’36.00“ N to 23°13’12.00“ N.

Quantum GIS – 1.8 Lisboa GIS software was used for the investigations of this research work. QGIS provides data visualisation, image enhancement, geometric network analysis, spatial and non-spatial query and analysis capabilities with data creation and editing environment. The Magellan Promark3 GPS receiver was used for the collection of latitude and longitude information of poles, consumer locations, transformers, important landmarks etc. The open sources Google Earth images were utilized to extract various layers of research area for creation of geometric network along with land based features for electric utility mapping.

3. Methodology

The methodology flowchart of this research work is shown in fig. 1. Various steps of the investigations are also given below:

3.1 GPS survey and assessment of ground truth

The GPS surveys was done for the determination of power distribution system infrastructure locations like poles, transformers, transmission line end points etc. The subset of images was extracted from Google satellite map service and stored separately. The collected data were stored into GPS device and prepared .csv files for creation of .shp files into QGIS software.

3.2 Geo-referencing of the satellite data

The well distributed control points were used for the geo-referencing of the study area images. In this process the coordinate system used was WGS-84 and map projection is UTM. The study area comes under UTM 43 zone.

Journal of Geomatics Vol 9 No. 1 April 2015

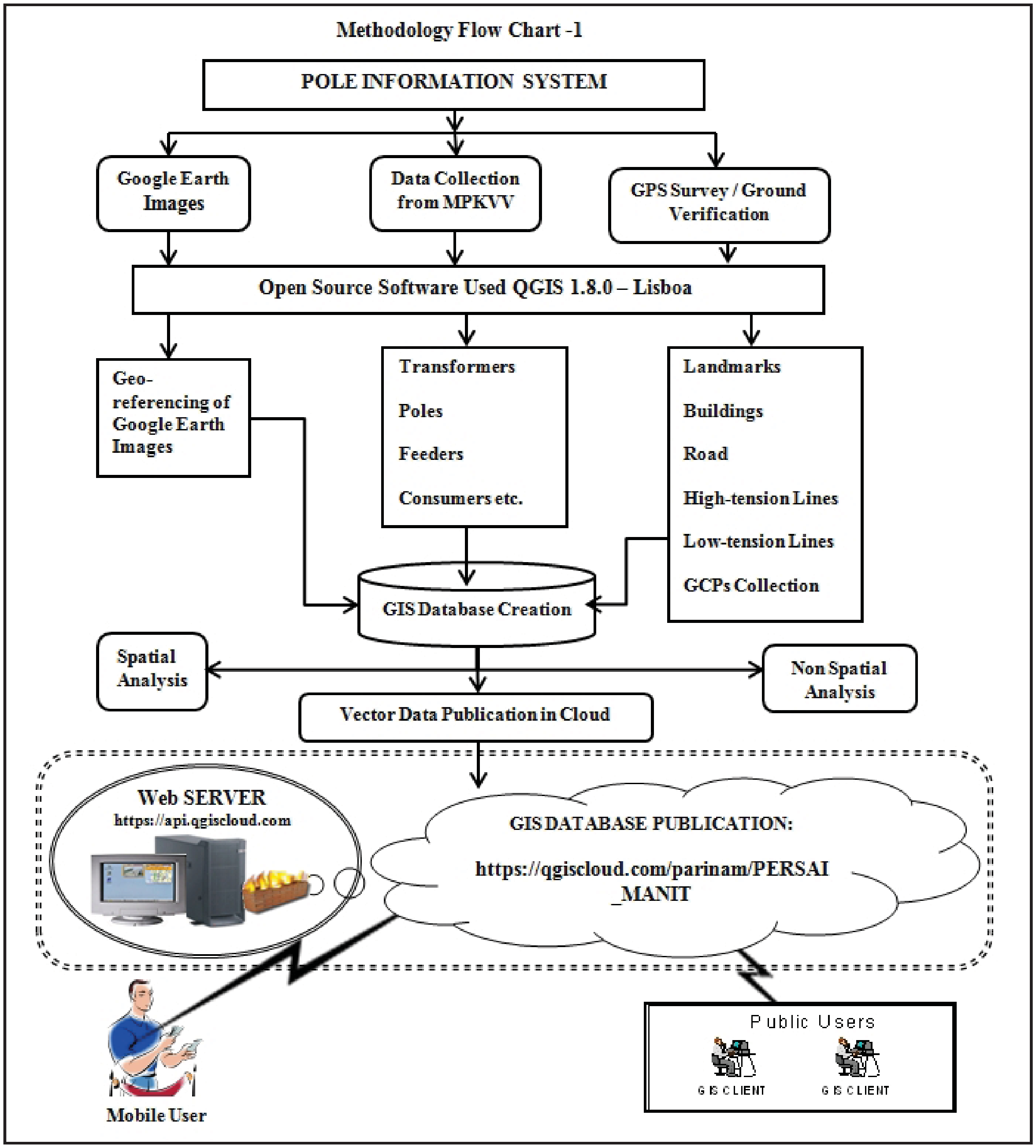

Figure 1: The flow chart of the methodology adopted

3.3 Thematic map generation, data acquisition and design of database

The high resolution remote sensing satellite images are an excellent source to understand the complex scenarios easily for electrical utilities. It provides integrated information of buildings, roads and important landmarks etc. which are directly or indirectly controlling the spatial relationship and helpful in the mapping of electrical utility. The consumers, transformers and pole related non spatial data were collected from MPKVV and finalized the layers. The various thematic maps like road networks, buildings and landmarks etc. were digitized in separate layers from Google satellite images. GIS database with corresponding feature types were also designed and mentioned below in the Tables 1, 2, 3, 4 and 5 respectively.

Table 1: Layers of GIS database, feature types and data type

S. No.	Name of Layer	Feature
1	Transformers	Point
2	Electric poles	Point
3	Transmission lines	Line
4	Roads	Line
5	Utilities	Point
6	Georeferenced Google	-

Journal of Geomatics Vol 9 No. 1 April 2015

Table 2: Electric pole attribute information

FIELD	DATA TYPE
Pole No.	Integer
Circuit No.	Integer
Transformer No.	Integer
Transformer location Name	Text
Pole category	Text
Pole material	Text
Pole condition	Text
Positional Status	Text
Pole label	Text
Numbering index	Integer
Remarks	Text

Table 3: Consumer attributes information

FIELD	DATA TYPE
Consumer No.	Integer
Consumer Name	Text
Consumer Address	Text
Email ID	Text
Telephone No.	Integer
Pole No.	Integer
Transformer No.	Integer
Transformer location	Text
Consumer category	Integer
Consumer	Integer
Phase	Text
Load Category	Integer
Meter Type:	Integer
Meter No.	Integer
Bill payment	Integer
Easting (X)	Integer
Northing (Y)	Integer
Cable Length (m)	Integer

Table 4: Transmission line attributes information

Field	Data Type
Circuit No.	Integer
Transformer No.	Integer
Transformer location	Text
Line category	Text
Line obstructions	Text
Connecting poles No.	Text
No. of faults	Integer
Any other remarks	Text

Table 5: Transformer attributes information

FIELD	DATA TYPE
Transformer	Text
Transformer No.	Integer
Capacity (in KW)	Integer
Make	Text
Serial no.	Integer
Year of manufacture	Integer
ID code	Integer
Design Life	Integer
Installation Year	Integer
No. of faults	Integer
HV Voltage (in KV)	Integer
LV Voltage (in KV)	Integer
HV Current (in	Integer
Any other remarks	Text

3.4 Creation of electrical network utility map

The extracted image covering an AOI was imported in QGIS Software along with shape files of roads and buildings. Various layers like, important landmarks, poles, transmission lines (HT and LT), transformers etc. were generated for creation of electrical network. Spatial data were generated using heads up digitization techniques. All necessary attribute data like pole number, transformer number, transmission lines number, circuit number, consumer details were attached with spatial data using unique ids. The developed data were found useful for analyzing the electric utility infrastructure in the study area.

3.5 Geometry validation and integration of GIS data

Cleaning and validation of geometry were perform to remove dangles, undershoots, overshoots, duplicate objects etc. All linear features were confirmed to meet the requirement, i.e., nodes created at intersection of linear features after validation of geometry. A seamless data covering the AOI was created and overlaid.

3.6 Creation of geometric network

A geometric network is a series of interconnected features form point 'A' to point 'B' or node to node connectivity or establishment of geographic relationship between set of points. A geometric network is composed of edges that are connected and specified the edges as junctions or intersection points. These edges can have weights or flow directions that are assigned to them and can be used to generate models for public utilities such as electric networks, pipeline networks etc.

3.7 Consumer indexing

The consumer indexing is a unique coding system for all types of customers. The unique code was created for all consumers while doing the survey. All consumers were connected from poles and stored into table as attributes.

3.8 Quality control and quality assurance

Quality Control and Quality Assurance (QC & QA) were undertaken in every step of the workflow to maintain the quality standard and achieve high accuracy of data. The measure of accuracy derived is based on the permissible limits that fall under physical and logical accuracy.

The following steps were carried out while creation of final outputs:

1. Verified features along symbology
2. Verified edges of features in between adjacent layers
3. Verified the appropriate attribute data entries
4. Verified the updated feature were having the attribute data in correct locations
5. Verified uniqueness of IDs and consumer numbers

3. 9 Data publication in QGIS cloud

At first QGIS Cloud Plugin and Open Layers Plugin was installed in appropriate location for displayed of background maps. Cost free QGIS Cloud account of authenticated user was created and got 50 MB space on server for data hosting.

The server “https://api.qgiscloud.com” was utilized for research purposes. Data published on server using “Publish Map” option from software. Database was uploaded and verified the connection in server for publication. The ‘Webmap’ link in plugin tab for viewing maps and layers geographically was utilized. Multiple users from mobile and computers could access the data geographically for spatial visualization of layers.

4. Results and discussions

The experiments described in this work, in particular, intends to do overlay operation, spatial query, non-spatial query, route identification, customer identification, shortest route identification, publication of data using QGIS Cloud technology for e-Governance of electrical asset maintenance and fault rectification or restoration with minimum time response.

4.1 Overlay of layers

The overlay operations were carried out to superimpose various layers like HT, LT, pole, transformers and landmarks etc. or more data layer that occupies the same location. The result of overlay operation is shown in fig. 2.

4.2 Spatial query

Spatial query was generated to get all information about electrical utilities like; pole, transformer, HT line, LT line, circuit number, consumer name etc. and queried for poles, where the feature intersects the HT_LINE_POINTS and software selected 28 out of 404 poles highlighted in query window. The result was displayed in QGIS as shown in fig. 3.

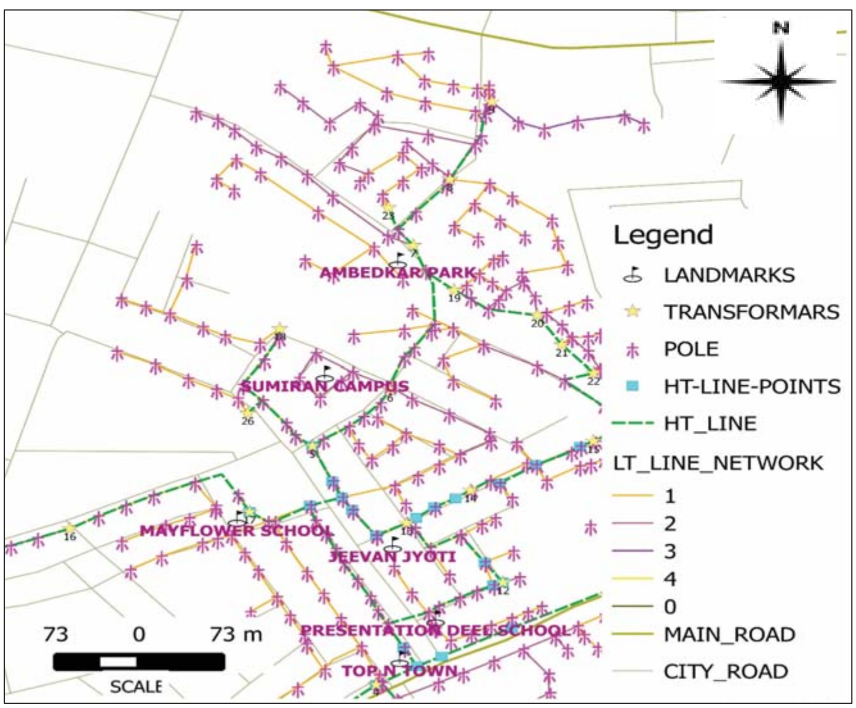

Figure 2: Overlay of layers

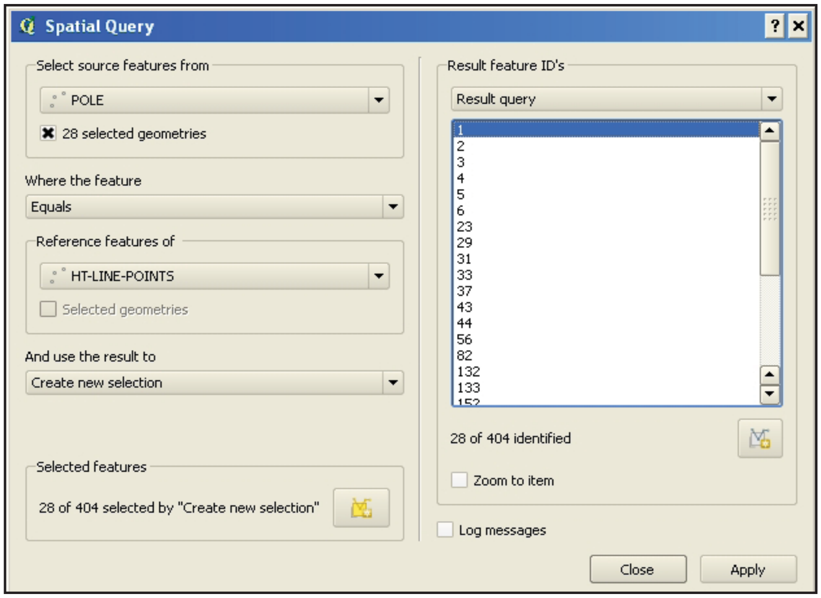

Figure 3: Spatial queries

4.3 Non-spatial query

Non-spatial query was carried out to identify the consumer details Like: feeder number, pole number, transformer number, circuit number, consumer number, consumer name and address etc. for identification of assigned electrical asset and consumer location on digital intelligent map. Hyperlinked and attached all the non-spatial data for poles and transformers. This data is dynamically editable and can be updated at any time. The result is shown in fig. 4.

4.4 Route identification and optimal path findings

The route identification and optimal path finding services are enough capable to restore the electric failure situations rapidly. The optimal route finding feature details that are stored spatially for continuos updateds in the database (Jayashree et al., 2010). If a fault occurs at any place and customer lodges a complaint, then repairmen can visualise the scenario. One can verify consumer details and confirm connectivity from transformers and feeders etc. The repairmen can identify optimal route based on different situations from its current position of failure sites.

The speed field was added in road layer and on an average speed limit "40 km/h" has assigned to all the city roads. Now, scenario has been created with presence of line repairman; if a customer lodged complaint for fault in Transformer Number "6" - 'Sudma Nagar' and another customer lodged the complaint for Transformar Number "13" – 'Chitragupt Nagar–II'. The repairman wants to know the connectivity and shortest path for restoration of fault urgently than he has to choose start and stop options in software. The statistics of point A (Sudama Nagar) and B (Chitragup Nagar-II) are as follows:

1. Point A: Transformer Number: 6 – Sudama Nagar, Longitude: 77.3973 and Latitude: 23.2208
2. Point B: Transformer Number: 13 – Citragupt Nagar-II, Longitude: 77.3974 and Latitude: 23.2194
3. The road network distance of Point A to Point B is: 0.204822km and Travel Time to reach at location would be: 0.00512056 h displayed in the software and shown in fig. 5.

4.5 Database publication on web and e-governance

The database was created and published with QGIS Cloud System displayed in fig. 6. QGIS Cloud link webpage was accessed and view all layers shown in fig. 7. This data is public and any one can use or access from any sources like mobile or internet. The published data is very useful for end users to view attribute data and planning route route for quick response. Government of India is also giving emphasize for better service delivery assurance in all aspects (The Times of India, 2013). The published data is for public and any one can view on internet to search "https://qgiscloud.com/parinam/PERSAI_MANIT" address. The published data is free from illegal manipulations and normal as well as authorized user can view the data geographically.

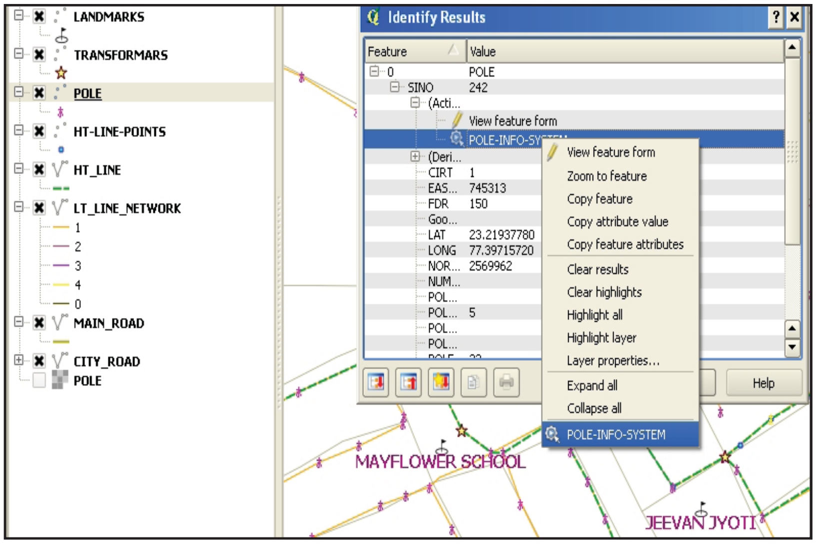

Figure 4: Result of non spatial queries

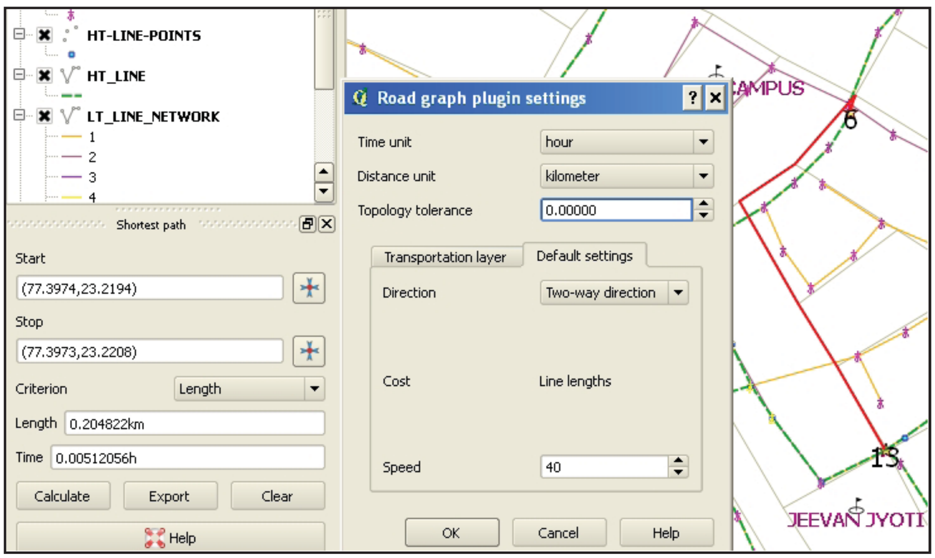

Figure 5: Result of optimal path findings

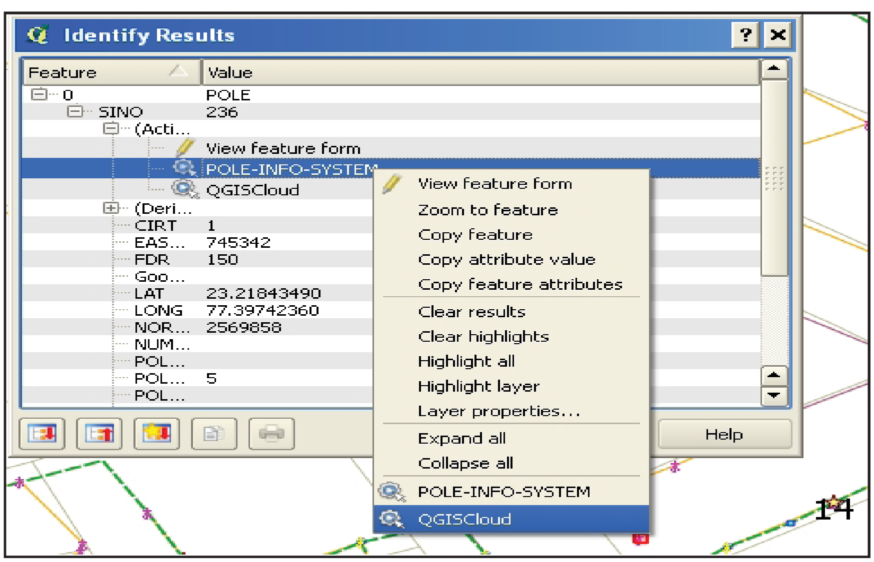

Figure 6: Hyperlinked attribute data with QGIS Cloud

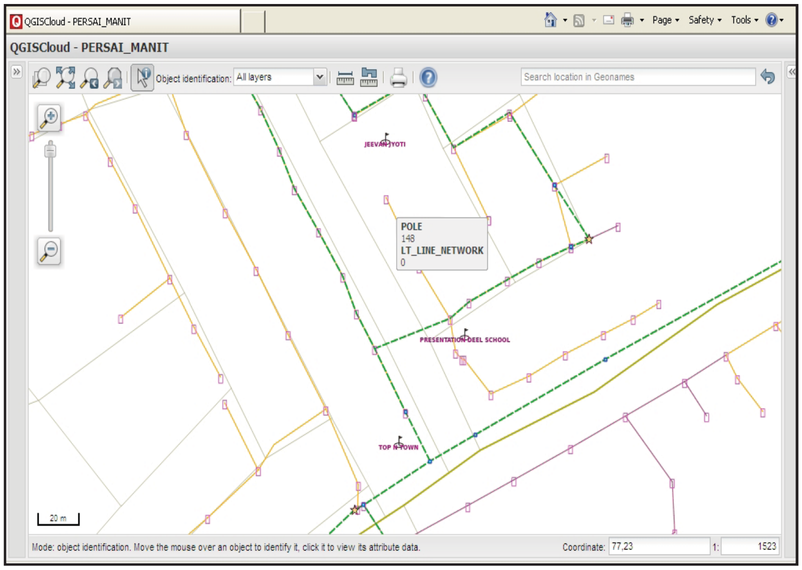

Figure 7: QGIS Cloud database and webpage

All the data visible in QGIS Cloud and some basic functions like: zoom in, zoom out, pan, distance measure scale, print, coordinate and details of layers property can be analyzed easily as shown in fig. 8. The layers panel shown all the published layers in panel with on and off functionality.

This is the process to bring out MPKVV closer to the consumers and mainly electrical department could achieve social objective to maintain, trust, and develop transparency in governance system.

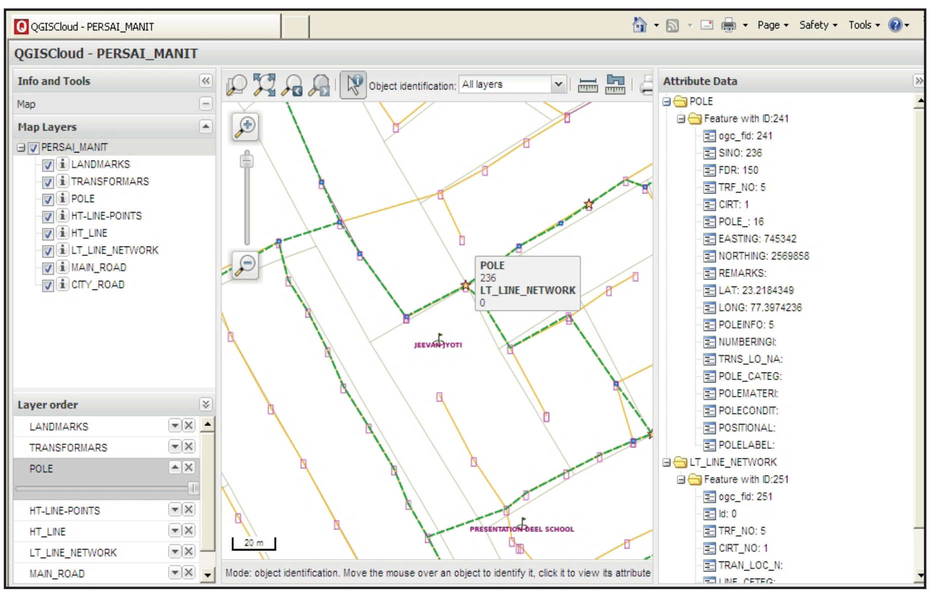

Figure 8: Attribute data and basic functions

5. Conclusions and recommendations

This paper has presented analysis on the use of Open source desktop QGIS and web based QGIS Cloud systems for incorporating various data geographically to facilitate planning and management of electrical assets. The GIS based data provides the facility to analyse attribute data, optimize and compare the routes, identification of transformers, poles, feeders information etc. for better services to the customers. The QGIS Cloud, which is becoming popular among community, was also discussed and implemented for establishment of e-Governance system for electrical utility. In this paper, an effective shortest path finding technique is presented which is useful in critical situations like electric power failures. In brief, the cost effective GIS based solutions were proposed for electric utility management.

This paper recommends that, there is need for greater awareness of Open source QGIS Cloud web and QGIS desktop system for establishment of GIS System in cities, specially of electricity utility. Various modules for specific purposes can be developed to improve the quality of life of the common citizens. These all applications should be linked with utility management financial transactions for revenue generation.

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