Applications of GIS in Electrical Power System

Abdulrahman M. AL-Sakkaf 201102310
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Dr. Baqer M. AL-Ramadan

Abstract **–** GIS has been widely used in various areas and disciplines. This paper shows the possible applications of GIS in electrical power system, how GIS helps to determine the optimal path for transmission lines, how it helps to forecast the growth of load and substation location, and how it is easier to manage disasters and locates fault using GIS. Brief review about GIS and GPS is given. A method to develop a GIS database for a power utility is proposed with how GIS can connect the information to that utility.

1. Introduction:

GIS has been very useful in the electrical power system. Problems of planning in distribution system can be solved by using new methods and specific techniques like GIS because of necessity of accurate up-to-date information of the network assets. GIS helps utilities discover new things about their investments and risks, and allows the simultaneous assessment of technical, financial, and environmental factors. GIS have been proven to be a workable system to connect database information such as billing, material account, distribution analysis and outage reporting in power utility. GISs are now being used widely for the mapping and modeling of utility network systems. With the help of GIS software changes in the network can be updated in less time and more accurate on a periodic basis. A wide range of solutions encompassing the entire business value chain in the power distribution sector has been provided by GIS[1]. GIS is built from a mapping foundation and thus creates a visual interface to the data. In addition to normal database queries, information can be examined through a variety of spatial attributes such as distance, proximity, and elevation[6]. GIS also helps with network routing which determines the optimal path that has the shortest and the fastest distance and minimum cost [2]. The applications of GIS play an important role in modern power system planning, analysis and control. They are improving power system visualization by associating spatial data with transmission and other assets of the electrical network [3].The objective of this paper is to show the possible applications of GIS in electrical power system.

2. Geographic Information System GIS:

GIS is an information system that is able to collect, store, retrieve, analyze and display geographical data. GIS system combines different layers of information about a place for better understanding and depending on the purpose. Different layers can be put together for better analysis. The power of a GIS over paper maps is its ability to select the information needed depending upon the intended application. Database which is the most important asset of an organization can be divided into two main various data types: spatial data that describe the location and the shape of geographic features and spatial relationship of map features. Attribute data known as descriptive information of the map features. GIS software and hardware are used in Electrical Power System as tools for storing, analyzing, interpreting, updating, displaying information, professional's designs and maintaining the system.

3. Global Positioning System GPS:

The Global Positioning System (GPS) is one of the main building blocks, helping in creation of any GIS system. It is a location system based on a constellation of about 24 satellites orbiting the earth at altitudes of approximately 11,000 miles. GPS satellites are orbited high enough to avoid the problems associated with land based systems, yet can provide accurate positioning 24 hours a day, anywhere in the world. The GPS is made up of three parts: satellites orbiting the Earth; control and monitoring stations on Earth; and the GPS receivers owned by users. GPS satellites broadcast signals from space that are picked up and identified by GPS receivers. Each GPS receiver then provides three-dimensional location (latitude, longitude, and altitude) plus the time. GPS can provide any point on earth with a unique address (its precise location). A GIS is basically a descriptive database of the earth (or a specific part of the earth). GPS tells you that you are at point X,Y,Z while GIS tells you what X,Y,Z is.

4. GIS Database Development:

To start developing a GIS map for power distribution network, a GPS survey becomes necessary for geo-referencing and mapping the relevant electrical assets on the digital base map. In some GIS applications, even the consumers are mapped to the corresponding electricity network. The purpose of such application is to index all the consumers and categorize the complete consumer database with respect to their unique electrical address. A successful GIS implementation seamlessly integrates the spatial data with various utility applications - Customer Information System, Assets Management, Outage Management and Utility Billing System and provides interfaces for cross-application data portability.

4.1. Digitization Process:

The digitization of electrical network assets, consumer indexing and network mapping involves the following steps:

1. GPS survey of electrical consumers and network assets: This involves the Identification of all consumers and their service connections, followed by the preparation of GIS base map.
2. Digitization of electrical network assets (Substations, Feeders, Transformers and Poles): Differential GPS is preferred to establish geo-coordinates with acceptable accuracy. Then the electrical connectivity with reference to the Pole, Transformer, Feeder and Substation is plotted on the base map.
3. GIS mapping, indexing and codification of electrical consumers and network assets with defined electrical relationships: This requires collection and updating of data of consumers along with their electrical connection attributes.

4.2. Data Collection:

Proper GPS survey and creation of an accurate digital base map for the distribution network is essential for a successful GIS implementation. The survey requires a GPS Base Station at a pre-determined location, aided by adequate number of GPS Rovers/ Receivers. Surveyors walk along the HT and LT feeders and capture the spatial position of the Pole, Transformer, Feeder and Sub-stations. The attribute data of the distribution network is also collected in the process. Differential correction is then performed on the spatial data thus captured. The digital base map must show the important landmarks like Roads, Rivers etc. which is necessary for easier identification of network assets and plan new distribution network. For better visualization, the vector map of the network can be overlaid on the digital base map or a satellite raster image.

5. Application of GIS in Electrical Power System:

5.1. GIS Integration:

The following utility applications are required to be integrated with the GIS application:

a. Customer Information System.

b. Asset Management System.

c. Trouble Call Management System.

d. Utility Billing and Energy Accounting System.

e. Load Flow and Load Growth studies.

The GIS must display now the network element and their attributes. The Customer Information System provides information of the consumer and the network map leading to the source from which the consumer is supplied electricity. This information can be used for Energy Audit, Load Management, Network Planning and analysis.

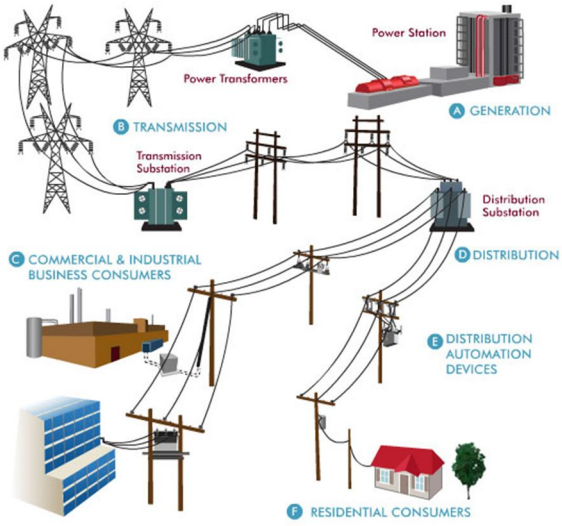

Fig.1. Electrical power network

5.2.Optimizing Electrical Lines Routing:

The transmission line routing is highly complex, and people are concerned about health issues due to the electric and magnetic fields, especially from high voltage transmission lines. GIS is used in transmission line routing as a technical tool. During the route selection for a transmission line, a straight route with minimum curves is desirable as it gives the best engineering and economic solution. In order to

Fig.2. Electrical transmission lines

achieve this route the line may have to pass through certain places which are already inhabited by people or areas that are unsuitable for locating the transmission towers. Environmental criteria are very important as well, soil type plays a significant part in the location of transmission lines. Soil stability is an important factor when locating transmission towers. The type and extent of geologic features also encountered along the proposed transmission corridor will impact decisions on siting. Geologic fault zones, seismic zones, rock type.

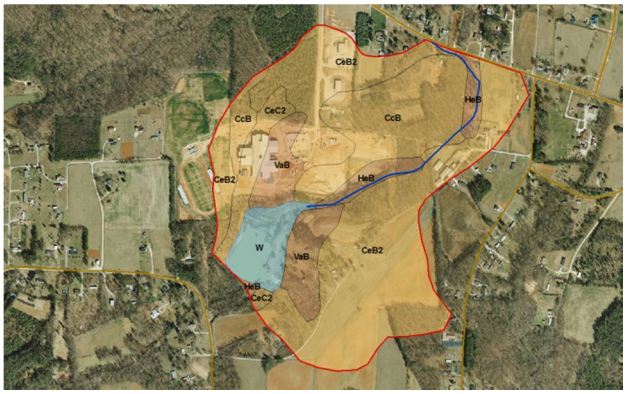

Fig.3. GIS map shows types of soils and trees in the area

GIS can be used to analyze the selection of suitable areas for transmission lines, so that there is minimal environmental disruption such

as minimizing the number of trees in a forest area, implement optimal routing algorithms based on electrical and material properties in addition to locational characteristics, visualize the network on a map helps make appropriate decision. Installing transmission lines is very expensive, so it's not an option to make errors about location. Buffer zone concept from spatial informatics can help in routing the High tension transmission line near to a populated area, where spatial buffer zone will protect the inhabitants from strong electric and magnetic field effects.

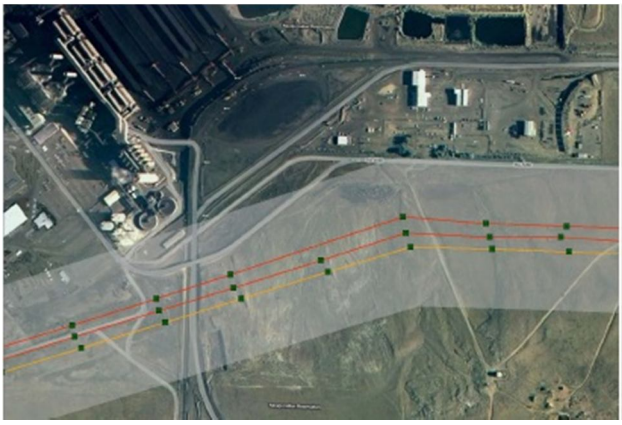

Fig.4. GIS map shows a rout for transmission lines

5.3. Load Forecasting:

Forecasting the amount of future load growth and predicts the location of load increment is called load forecasting. It is very important for power planning and the whole planning work depends on it. To perform spatial load forecasting techniques GIS technology provides an excellent platform which merge distribution system data with land-use and development data. Load forecasting is consisting of whole power, classified loads, load curve, and load distribution. To forecast the demand and the distribution of the load in power domain total power supply area should be divided into several sufficiently small areas based on the Geographic location which includes a number of demand points that indicate different customer loads. Each section gathers spatial data and forecasts the future load growth for every small area. Gathering spatial information can be performed on the geographic information system (GIS) Platform. To forecast load growth of the geographical area data such as current land use, transportation infrastructure, mountain slopes and urban centers and then location of new load additions which expected, are required. The future system can be planned from these load forecasts. Forecasting future load centers, prioritizing projects, identifying substation property requirements, control the demand growth with its rates and high load densities, are the results of load forecasting.

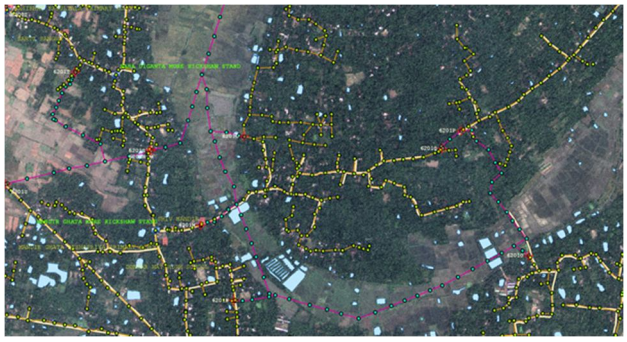

Fig.5. GIS map shows the growth of electrical demand

5.4. Disaster Management and Locating Faults:

GIS enhance visualization of power systems by associating spatial data with transmission assets, such as animation, making them attractive platforms for displaying geographically referenced real time power system data such as the voltage and line loading monitoring. GIS information is stored in geographical map layers making it easy to relate transmission network conditions with other relevant information such as weather, vegetation growth, and road networks. Real-time weather data integrated in GIS increases the operator's situational awareness. For example, with the help of such a system, the identification of a weather front moving towards a given area enables operators to quickly determine transmission facilities with increased risks of outage. In conjunction with

SCADA data, the operator can then initiate dispatching orders to protect the system against potential cascading failures.

Fig.6. Overhead lines fell down due to strong winds

Fig.7. A fire happened in transformer due to electrical fault

GIS maps can be combined with real time line loading information to identify lines with increased risk of flashovers and faults. Such lines can then be considered candidates in the contingency analysis. Conversely, if the mapping of voltage, load or generation profiles can be used to visualize the system-wide operating conditions, such as overloaded components, and help operators locate trouble spots in the grid with just a look at the screen. Based on a quick localization, more detailed numerical displays can be opened to further investigate the source and possible solution to an abnormal network situation. In a GIS map, the color indicates the severity of the threat and the locations in the maps correspond to the geographic location of the problem area. Once a trouble spot has been located on the map, an operator can take preventive action to ensure an abnormal situation does not progress into a system-wide outage.

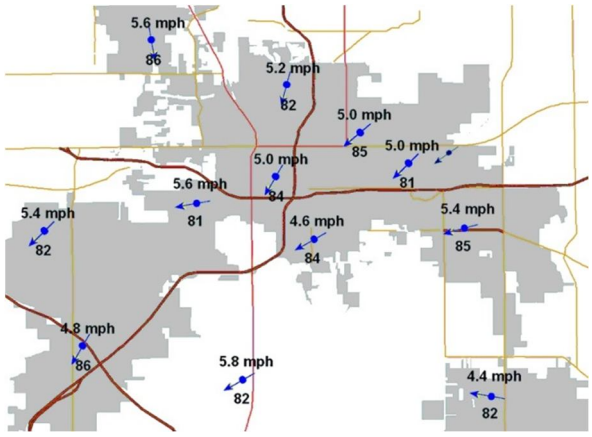

Fig.8. Weather monitoring to determine speed of winds

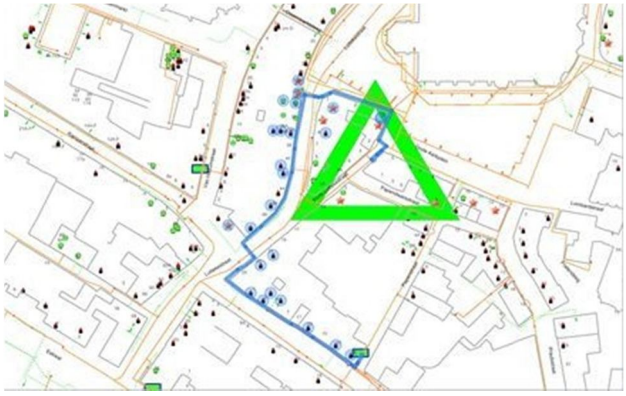

Fig.9. GIS map shows a location of fault

Fig.10. GIS map shows a location of fault

6. Findings:

(1) In order to utilize GIS in power system, power system data (load flow, network assets, customers' information, billing system, etc.) must be integrated with GIS system.
(2) Since planning transmission lines and disaster management are affected by residential and environmental conditions, GIS plays significant role in study and analyze these factors and then the right decision can be made upon these studies.
(3) The demand of electricity is increasing day after day due to the growth of population and residents. By using GIS this growth and its pattern can be observed to predict the future needs of energy.
(4) GIS can be very useful whenever there is a spatial data and attribute information linked together. This is why it's been very useful in electrical power system, when we connect the information that we have with the maps, we get better visualization.

7. Conclusion and Recommendations:

Applications of GIS in Electrical power system are stated in this paper, which are; Integrating between system data and GIS can be used for Energy Audit, Load Management, Network Planning and analysis; determining the optimum, shortest, and most economic path for transmission lines; forecasting and predicting the amount of power needed in the future which leads to prioritizing projects, identifying substation property requirements, control the demand growth. A method to create a GIS database for a power utility is proposed as well. For future, it's recommended to train some of the electrical engineers in the power utility on the use of GIS. Also GIS and GPS can get more involved in more application in electrical system like real-time wide area measurements using GPS as a trigger.

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