GEOGRAPHIC INFORMATION SYSTEM (GIS) – AN INTEGRATED TECHNOLOGY FOR DISTRIBUTION SYSTEMS ANALYSIS

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Utility companies and system operators perform power system analysis for planning and operation of their systems. The evolution of the computer and Internet technology have created a flood of information, and the amount of information about power system analysis models and results seems to outrun the ability of people to utilize it.

In this paper it is presented a tool for power system analysis that interfaces with geographic information system (GIS).

Keywords: GIS, distribution systems, power analysis.

1. Introduction

The creation, updating, and analysis of electrical distribution networks in terms of spatial and non-spatial data are a herculean task. The voluminous nature of data involved for proper record keeping is indeed cumbersome, and cannot effectively be handled by traditional system of record keeping. An alternative approach of maintaining a coherent database in an efficient manner by use of advanced information technology is therefore, required.

Electric companies have a need to keep a comprehensive and accurate inventory of their physical assets, both as a part of normal service provision (extending the network, undertaking maintenance, etc) and as a part of their obligation to inform third parties about their facilities. Therefore, Geographic Information System (GIS) was developed for electric power studies, especially in electrical distribution systems analysis and design. Thus, GIS is used in the problem of designing the electrical supply system for new residential development, investing on process automation in order to provide their customers with high quality attendance, to rebuild the design of the whole work procedures in electric utilities etc. GIS and GPS (Global Positioning System) are also integrated for mapping and analysis of electric distribution circuits [1, 3, 4].

The distribution system is particularly important to an electrical company for two reasons: its proximity to the ultimate customer and its high investment

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cost. The objective of distribution system planning is to ensure that the growing demand for electricity, with growing rates and high load densities, can be satisfied in an optimum way, mainly to achieve minimum of total cost of the distribution system expansion.

Database plays a central role in the operation of planning, where analysis programs form a part of the system supported by a database management system, which stores, retrieves, and modifies various data on the distribution systems. The thing that distinguishes an electrical utility information system from other information system - such as those used in banking, stock control, or payroll systems - is needed to record geographical information in the database. Electrical utility companies need two types of geographical information: details on the location of facilities, and information on the spatial interrelations between them. The integration of geographically referenced database, analytical tools and in-house developed software tools will allow the system to be designed more economically and to be operated much closer to its limits resulting in more efficient, low-cost power distribution systems [1, 3, 5].

Technical information system is designed to cover the requirements of power supply utilities considering network expansion and operation planning, maintenance management and system documentation.

2. Using of GIS in Distribution Systems

Distribution is the weakest link in the chain of power supply. GIS can help reduce losses and improve energy efficiency through its contribution in the following areas [3, 6, 8]:

- 100 % consumer metering;
- Feeders and Distribution Transformers metering;
- Total energy accounting;
- Installation of capacitor banks&network reconfiguration, etc.

The applications of GIS in above areas can be [8]:

- Creation of consumer database: The consumers are mapped using GIS technology and identified based on their unique address;
- Mapping Electrical Distribution Networks: All stations, substations, feeders are digitally mapped and geo-referenced;
- Load Flow Study: Load and Consumer profile can be studied for load analysis in various segments of networks.

- Load Forecasting: GIS becomes an effective tool in optimal design and choice of substation location, demand-side management, future load assessment and load planning;
- Management Information System: Based on inputs from GIS, which is regulary updated and monitored, a robust Management Information System can be built for analyzing and reducing losses, collection and load demand /supply analysis.

The best know capabilities of GIS are to store, manipulate and visualize geographical data and related attributes. For to resume the GIS capabilities we will present a list of general functionalities [6]:

- Data maintenance and manipulation: editing, cleaning, updating, coordinate adjustment and transformation, create topology, conversions between data structures, selecting, counting, calculate distances and areas.
- Data output: zooming, scaling, graphic formatting, map edition, charts and reports edition.
- Spatial data analysis: topology and proprieties operations, overlay operation etc.

In conclusion, the GIS can be used in analysis and planning of distribution systems as a tool for to show geographically the network, to interact with the user by friendly graphics and show on network database.

3. Fuzzy modeling of the loads in distribution systems

In distribution systems, except the usual measurements from substations, there are few information about the network state. The feeders and the loads are not usually monitored. As a result, there is a high degree of uncertainty about the power demand and, consequently, about the network loading, voltage level and power losses. Therefore, the fuzzy approach may reflect better the real behavior of a distribution network under various loading conditions [4].

The fuzzy set theory was introduced to various system engineering problems in which uncertainties were represented as intrinsic ambiguities. In this paper, trapezoidal fuzzy numbers, Fig.1, associated to a membership function are used to represent a vague knowledge about the load behavior.

The expert is supposed to declare an interval $[x_2, x_3]$ integrating a set of values having high credibility, being considered as good representations of load characteristics. Besides, values x_1 and x_4, under and above which the load is considered not possible to occur, are also be specified. Then, values in the intervals $[x_1, x_2]$ and $[x_3, x_4]$ are taken as possible representations of the load, but not with the same strength as values in [x_2, x_3]. This representation can be considered as the translation of the following linguistic declaration: ”load may occur between x_1 and x_4 but it is likely to occur in [x_2, x_3].

For modeling of the loads, two primary fuzzy variables are considered: the loading factor kI (%) and power factor cosφ, so that the fuzzy representation of the active and reactive powers result from relations [4]:

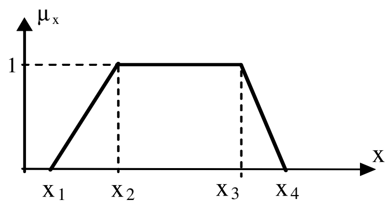

Fig.1. Trapezoidal fuzzy load

$$P = \frac{kI}{100} \cdot S_n \cdot \cos\varphi, \quad Q = P \cdot \tan\varphi \qquad (1)$$

where S_n (kVA) is the nominal power of the distribution transformer from the distribution substations.

The fuzzy variables, kI and cosφ, are associated to trapezoidal membership function. The two fuzzy variables must be correlated, just like that fuzzy variables P and cosφ.

Because the most electric utilities have not historical records of the loads, in the distribution substations, linguistic terms are used. Therefore, the loading factor kI and the power factor cosφ are divided into five linguistic levels [4]. For example, in the case of the studied distribution networks these linguistic levels are given in Table 1, but the values can be modified as function of the load types.

Table 1

Chosen values of the primary variables

Linguistic levels		kI (%)	cosφ	Linguistic levels		kI (%)	cosφ
VS	x_1	10	0.75	M	x_3	31	0.87
	x_2	10	0.77		x_4	33	0.89
	x_3	13	0.79	H	x_1	31	0.87
	x_4	15	0.81		x_2	33	0.89
S	x_1	13	0.79		x_3	39	0.91
	x_2	15	0.81		x_4	41	0.93
	x_3	22	0.83	VH	x_1	39	0.91
	x_4	24	0.85		x_2	41	0.93
M	x_1	22	0.83		x_3	60	0.95
	x_2	24	0.85		x_4	60	0.97

4. GIS-FPF Integrated System

The integrated system is based on software that uses GIS for the implementation of the power tool including a Fuzzy Power Flow algorithm. The software is developed in MATLAB.

The power and flexibility of GIS comes from two characteristics: it is a computer-based system that operates with geographically referenced data and it allows the user to perform complex analyses, making it a powerful tool for data query and management.

GIS is an important tool where the value of visual feedback is used to supplement the detailed result tables coming from circuit analysis tools. Moreover, GIS and analysis tools such as Fuzzy Power Flow, permits to the user to test various network configurations in various loading levels and view the results on a color-coded graphical display, and other graphical representations such as graphs. Having a visual display of the electric network the analysis process is quicker, easier, and more accurate.

The integrated system consists of four components:

- **GIS software package.** GIS is considered as highly efficient software in terms of user interface, graphical output, and data analysis and query.
- **Power analysis package.** This is based on a Fuzzy Power Flow algorithm. In the algorithm, the load models used in the analysis are fuzzy models. The program is accessible and changes can be easily introduced, if this is found necessary. The results of the runs are stored in special data files and transferred to and from GIS software package, supported in MATLAB.
- **Database.** The data needed for Fuzzy Power Flow is initially fed by the user through GIS digitizing or data entry facilities. The data consists of both coverages, representing the electric network components and the geographic regions, and attribute and coordinate tables. These tables are naturally related to the coverages they present. Other data, necessary for the power algorithms are fed by simple tabular data entry forming text files supported by MATLAB.

The components of the integrated system are shown in Fig. 2. In the figure the user is considered as an evident and indispensable "component" of the overall system.

The database can be created by inputting the relevant spatial and attribute data into the system. The tables will be populated with the attribute data. The spatial data can be captured by scanning the paper maps. The images are separated and digitized under the following layers:

- Layer 1: buildings, roads, streets;
- Layer 2: electric distribution networks;
- Layer 3: other public utilities (water networks, sewage networks, gas networks etc).

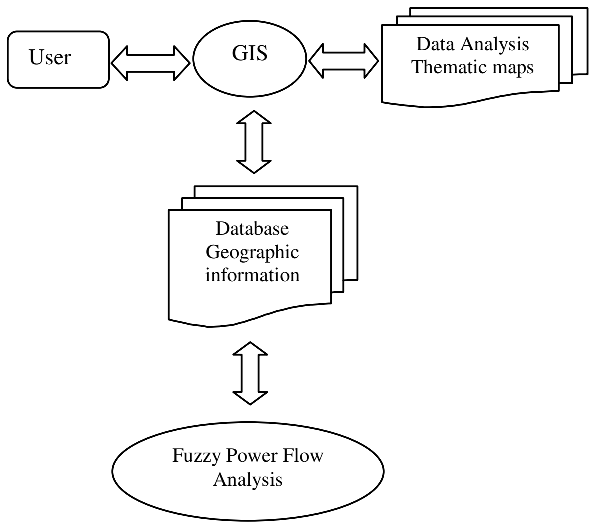

Fig. 2. GIS-RPC Integrated System

5. Application

The software performs a large number of scenarios in order to get the solution sets. Moreover, these runs are accompanied by a set of power flow calculations needed to update the distribution system data in use. The load models used in the analysis are fuzzy models.

In the program, GIS package allows the user to perform complex analyses, making it a powerful tool for data query and management. Moreover, the interaction between the geographic and network information gives access to more usable information.

For example, for a study region the layer corresponding to the electric networks (110 kV lines, 20 kV lines, 110/20 kV stations and 20/0.4 kV distribution substations) is presented in Fig. 3.

Using information from the database, a fuzzy power flow analysis of the electrical distribution network (20 kV) was made. The network has 24 nodes, the node 1 being the supply node which represented the 20 kV bus of the 110/20 kV distribution station. A number by 13 nodes represents the medium voltage buss of the distribution substations equipped with the power transformers by 100, 160, 250 and 1000 kVA.

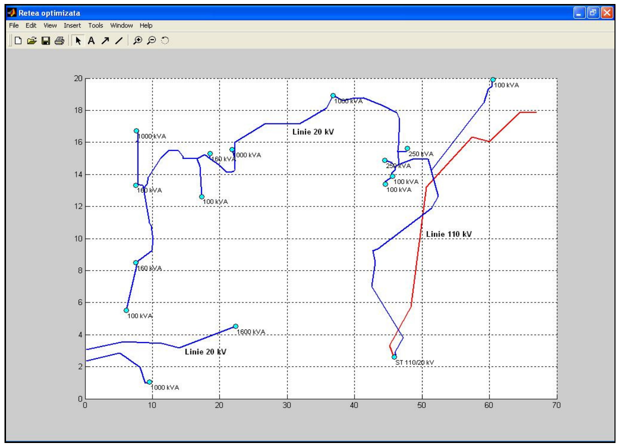

Fig. 3. The layer corresponding to electric networks

The network analysis was made for all loading levels, (VS, S, M, H and VH), using fuzzy load models based on the fuzzy variables from the Paragraph 3. Among the important quantities from a fuzzy power flow analysis are the power losses from distribution network. Thus, for example, the power losses in the transformers from electric substations, it used a representation through five linguistic categories: Very Small (VS_ΔP_T), Small (S_ΔP_T), Medium (M_ΔP_T), High (H_ΔP_T) and Very High (VH_ΔP_T).

In Fig. 4 the linguistic categories of the power losses from electric transformers are presented in GIS document for the Loading level Medium (yellow – VS, green – S, turcoise – M, blue – H, red – VH).

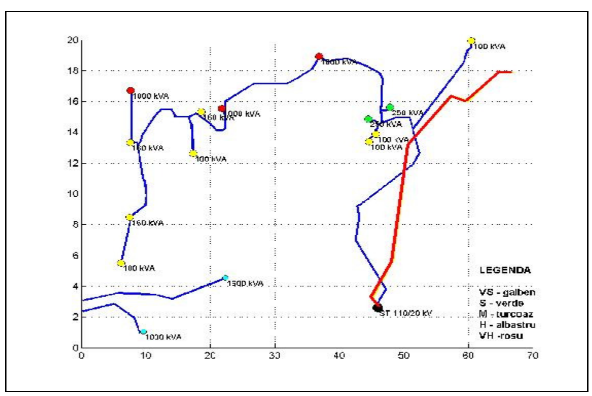

Fig. 4. Linguistic categories of the power losses from electric transformers in GIS document (Loading level – M)

6. Conclusions

Integration of GIS with fuzzy power flow analysis tools is tremendously improving decision -making process in the distribution systems. This software package has many capabilities to assist the makers and operators in the planning and operation of the distribution networks. Application of this to a test distribution network is presented where different scenarios for loading level are provided and it is up to the decision maker to set the priorities and choose the appropriate solution.

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