Specialized Geo-Information System for Calculation of Distribution Network Losses

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Abstract –**This paper presents out researches in the area of geodata integration and Geo-Information Systems (GIS). As a result of this research we have developed GinisED geo-information system for public electric power supply company PD Jugoistok Niš. Main purpose of GinisED is documentation, maintenance and analysis of electric power supply networks. This paper contains a description of solutions for the calculation of losses in the distribution network. Also, we present a prototype application for the calculation of losses in the distribution network. This application was developed using GinisED system as a base.**

Keywords – **GIS, integration, distribution network losses**

I. INTRODUCTION

In recent years integration of information from heterogeneous sources is one of the most popular research directions in the field of information systems [1]. Information integration involves the usage of data from two or more databases (e.g. information sources) for the development of a new database. New database can be physically implemented, or developed as a virtual database. This database enables unified querying of integrated information. Integrated information sources may be conventional databases, Web pages, text files, mail etc. The need for such integration is present in the process of calculation of low voltage distribution network losses.

Energy crisis and current problems of efficient energy utilization demand introduction of effective mechanisms for the optimal use of available energy. From the aspect of electric power supply companies, energy efficiency is closely related to losses in distribution of electric power. Therefore, expert debates and analysis devotes a great attention to the issue of energy losses and their reduction, especially when losses are not at a satisfactory level [2].

Energy losses are one of the key elements that indicate the degree of quality of performing the business activities in electric power supply companies. Therefore, the reduction of energy losses in the distribution network has become one of the priority business goals [3] in companies engaged in distribution of electricity, such as PD Jugoistok Niš company. A significant part of losses in the distribution of electricity refers to the low voltage (LV) network losses.

The first step in the process of reducing the LV network losses is the calculation of losses based on available information concerning network infrastructure, customers and their consumption. Procedures used for calculation of LV losses are known and defined, but the problem of availability of data, required for the calculation, still remains. The data needed for the calculation of LV losses are often located in isolated information systems. Therefore, for successful calculation of LV losses, it is necessary to ensure the integration of information and access to all necessary information sources from single access point.

This rest of the paper is organized in the following way: next chapter presents the problem of LV losses calculation. In Chapter 3 GinisED system is presented along with information integration platform it uses. Chapter 4 gives an overview of the application for calculation of LV network losses. At the end of the paper, a conclusion and review of literature are given.

II. CALCULATION OF ELECTRIC ENERGY LOSSES

Losses of electric power in electric power supply network correspond to difference between amount of transmitted energy and the amount of energy sold to customers. Analysis of electricity losses is very complex due to a large number of parameters that affect them. In order to perform this kind of analysis, it is necessary for the data used to estimate losses to be as specific as possible and to reflect the real state of electric power supply network [2].

The basic structure of electricity transfer/distribution system consists of a large number of different plants, electric power lines and devices. For the purposes of managing this complex network, several IT systems that cover different areas of network functioning are used. Electric power supply systems often use: Geo-Information System (GIS), Supervisory Control and Data Acquisition (SCADA), Distribution Management System (DMS), Automatic Meter Reading (AMR), Computerized Maintenance Management System (CMMS), Consumer Information System (CIS) and other [4, 5, 6].

The basic purpose of all the above mentioned systems is to provide electric power supply companies with support for business processes such as recording, maintaining and planning of electric power supply network. From the standpoint of reducing the losses in LV network, these systems contain information necessary for the calculation of losses. GIS allows recording and georeferencing of all electric

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power supply network elements. Spatial database contains details about the length and diameter of network electric power lines. This data can be successfully used for the calculation of a part of LV network losses. On the other hand, measured data from SCADA, electric power supply network state from DMS, current consumption data acquired by AMR and charged electricity consumption data from CIS can significantly contribute to increase the accuracy of calculation of losses and possibly locate a potentially critical location [2].

Calculation of losses in the LV network is quite complex due to existence of a large number of elements in LV distribution network. In this case, if we know input power and electric current that flows through each section of LV network in advance, we can apply methodology based on the calculation of radial network [2]. Electricity losses calculation requires information that can be found in different information systems that operate within the electric power supply company. These systems are usually completely isolated which makes data they generate available only to users of a single system. Therefore, there is a problem of ensuring that different users in different locations have access to all necessary information. If the data processing is done manually, the probability of harming or losing data consistency is increased. In order to support the exchange of information, IT systems integration techniques should be applied.

III. GINISED SYSTEM AND INFORMATION INTEGRATION PROCESS

The functioning of companies engaged in the transmission and distribution of electricity depends on the existence of appropriate electric power supply network geodata [7, 8]. It is estimated that more than 80% of data used in a variety of processes (network design process, data input and update, maintenance and various analysis) posses geographic (spatial) component. Therefore, almost any electric power supply company has a need for the existence of specialized geo-information system that should provide mechanisms for collecting, storing and manipulating spatial data.

GIS applications enable connecting various types of information in the spatial context and generating new information and conclusions on the basis of these connections. GIS allows the integration of information in a manner that is impossible to achieve using any other type of tool. This significantly increases the value of GIS in everyday usage and maintenance of electric power supply network. In addition, integration with other systems reduces costs and simplifies the maintenance of GIS systems. There is no need for special hardware, software platforms or special trained GIS users. Because of its openness, GIS system is very easy to integrate with other IT systems within a single electric power supply company (Fig. 1).

For the needs of PD Jugoistok Niš, CG&GIS Lab, Faculty of Electronic Engineering in Niš, with the support Ministry of Science of Republic of Serbia, developed a geo-information system GinisED [7, 8]. GinisED is a specialized geo-information system which, in addition to standard alphanumeric data concerning electrical parameters of electric power supply network, allows recording, processing, analysis and graphic presentation of specialized information about the electric power supply network, such as spatial data, temporal data, image and multimedia.

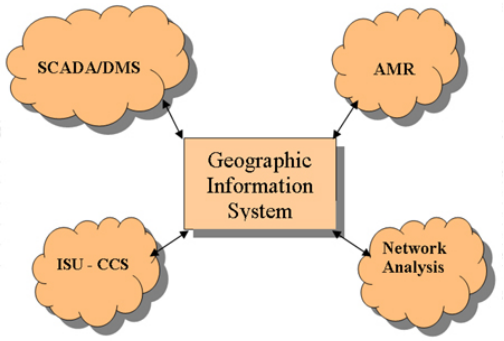

Fig. 1. GIS as a basis for IT systems integration in electric power supply company environment

GinisED system was developed using GeoNis platform for the interoperability of GIS applications. GeoNis platform provides the mechanisms and infrastructure for the exchange of information in the environment of local government [1, 9], but can be applied for integration of information on a single company level. This platform is developed for purpose of intelligent integration of information from a number of heterogeneous GIS (geographical and spatial) and non-spatial data sources. Companies, institutions or their parts that have some information of interest are considered to be data sources.

GeoNis platform is located between GinisED system, which operates as a C3 (Command Control and Communication) module, and relevant data sources (GeoInformation Community - GIC) (Fig. 2). GeoNis environment nodes can be existing applications. For each of applications, it is necessary to develop translators and domain (local) ontologies. Nodes may also be new applications developed in accordance with the OpenGIS standards and component software development methodology [10].

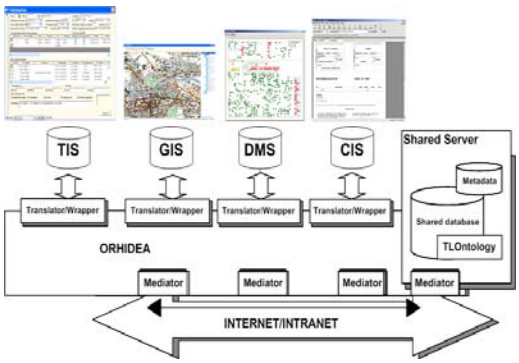

Fig. 2. GeoNis platform for the interoperability of GIS applications

Integration of information from all relevant sources provides data necessary for calculation of losses in electric power supply network. Thus, it is possible for users to receive real-time information about all parameters that are relevant to the functioning of electric power supply network.

IV. APPLICATION FOR LV NETWORK LOSSES CALCULATION

On the basis of developed GinisED system, which allows the integration of information from different IT systems in the PD Jugoistok Niš, a prototype application for calculation of losses in the LV network was developed. The architecture of this application is shown in the Fig. 3.

GIS module holds the central part in the application for the calculation of electricity losses. It is a downscaled GIS application that has retained only the minimum of required GIS functionalities. This application visualizes spatial data of electric power supply network and provides users with a simple interface to GinisED information integration system.

For the purposes of analysis and calculation of losses, data from three different information systems is currently being used. Other systems as information sources will be added with the further development and improvement of the application.

GIS system is used as a source of data related to LV network topology and technical description of LV electric power line sections (section length, section resistance, electric power line type, type of conductor, conductor diameter etc). LV network spatial data was recorded in the field and is being regularly updated.

LV network GIS data is related to information about consumers. CIS system contains consumer information [11]. Integration of GIS and CIS allow determination of consumer's exact position on LV electric power line. It also allows determination of geographical location of connection that the consumer is related to. This enables easy identification of all customers related to particular LV electric power line.

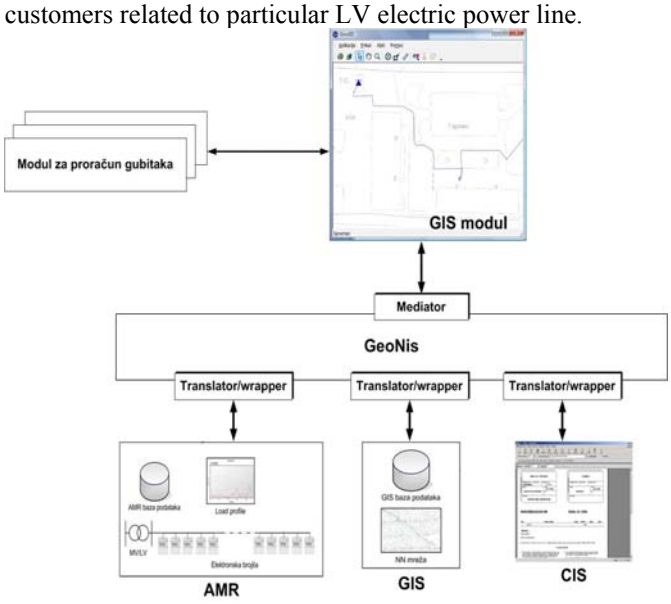

Fig. 3. LV network losses calculation application architecture

When all consumers related to a particular LV electric power line are identified, their unique consumer codes are used as input data to obtain their daily load characteristic diagrams from AMR system. AMR system uses modern electronic consumption meters. These meters allow storing of load characteristic diagrams for a period of time (load profile). Hence, load characteristic diagram is imposed as one of the basic analytical data for the calculation of energy balance and LV electric power line losses [12]. Fig. 4. shows typical load characteristic diagram.

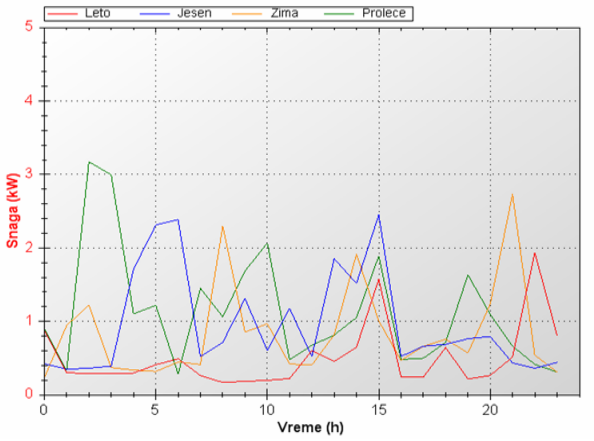

Fig. 4. Typical load characteristic diagram

Based on technical information related to LV electric power line (section length, type and diameter of the conductors) and consumer load characteristic diagram, losses calculation module determines losses on a particular LV electric power line. Losses calculation module is not based on approximative methods. Instead, it uses recursive method for calculating the electric current that flows through each LV electric power line section [2]. This module uses LV electric power line data topology as graph (from the transformer station to the end consumer). This graph consists of transmission facilities, sub facilities and consumption meters related to company clients. Based on unique customer codes, daily load characteristic diagrams are obtained from AMR system. If daily load characteristic can not be obtained, particular consumer is related to one of standard load characteristic diagrams.

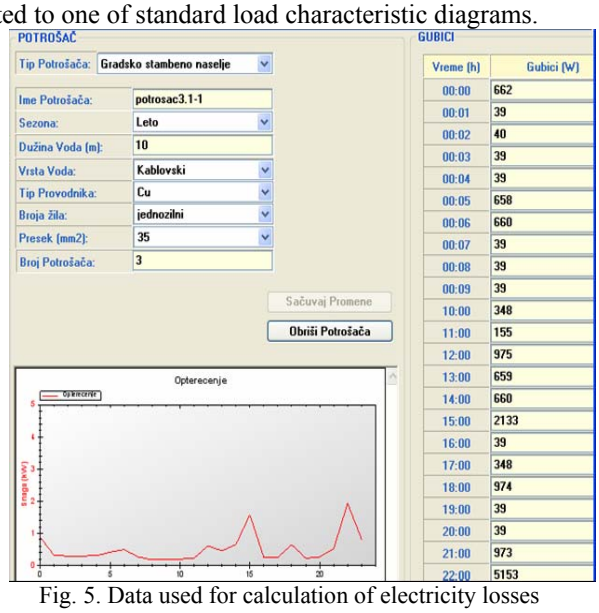

Fig. 5. Data used for calculation of electricity losses

Fig. 5. presents data related to a particular LV electric power line and consumer load characteristic diagram used for calculation of electricity losses. It is possible to alternate LV electric power line section parameters (electric power line

length, electric power line type, conductor type, number of cores and conductor diameter) and analyze how these changes affect the percentage of technical losses. It is also possible to define standard load characteristic diagrams for all four seasons.

Part of the application that is responsible for the calculation of losses has a modular architecture so it can be easily expanded with modules using a different methodology for calculation of losses. This allows recalculation of losses for LV electric power line using different methodologies and comparison and analysis of obtained results.

V. CONCLUSION

Every company that deals with the distribution of electricity paid great attention to the problem of energy losses, especially in a situation where the losses are not at a satisfactory level. Electricity losses are one of the key factors that indicate the degree of economy and quality of business in the area of electricity distribution. Due to these reasons, the problem of reducing energy losses has become one of the priority business objectives in PD Jugoistok Niš.

Calculation of electricity losses requires usage of information from various IT systems that operate in the PD Jugoistok Niš. As a starting point for the development of losses calculation prototype application, GinisED system was used. This system is developed for the purpose of recording spatial electric power supply network information. For integration with other systems within PD Jugoistok Niš, GinisED system uses GeoNis platform for interoperability. This provides transparent access to data regardless of their original format and storage location within the organization, which is of extreme importance in the application for calculation of electricity losses.

A prototype application for the calculation of electricity losses, using a recursive method for calculating the electric current that flows through each LV electric power line section, was developed. This application will enhance the detection and reduction of electricity losses.

Analysis of the results of electricity losses calculation opened the possibility for better work in the following fields:

- planning development and reconstruction of LV network where, in addition to other parameters for the financial justification of investments, technical losses reduction parameter is added
- possibility of simulating consumption increase in order to locate the parts of the network exposed to a large degree of losses
- selection of optimal LV network topology
- planning the introduction of remote reading meters

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