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AN APPROACH FOR CALCULATION OF DISTRIBUTION NETWORK LOSSES BASED ON THE USAGE OF SPECIALIZED GI SYSTEM

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Abstract: *This paper presents our research in the field of usage of Geo-Information Systems (GIS) for calculation of distribution network losses. Paper contains a description of solutions and corresponding sofware for the calculation of losses in the distribution network. This software was developed using GinisED GIS system.*

Key Words: ***GIS, integration, distribution network losses***

1. INTRODUCTION

Efficient energy utilization problems and energy crisis have motivated development of effective mechanisms for the optimal use of available energy. From the electric power supply companies' point of view, efficient energy utilization is coupled with the losses in distribution of electric power. For this reason, great attention has been devoted to the issue of energy losses and their reduction in the expert debates and analysis. This is particularly significant in situations when the distribution losses are not at the satisfactory level [1].

Electric power supply companies use distribution network losses as one of the key elements that indicate the degree of quality of performing their business activities [2]. Therefore, the reduction of energy losses in the distribution network has become one of the priority business goals in companies engaged in distribution of electricity. The low voltage (LV) network losses can prove to be the significant part in distribution network losses.

The first step in LV network reduction process could be the calculation of losses based on available information concerning network infrastructure, customers and their consumption. The procedures used for calculation of LV losses are known and defined. The problem that needs to be solved is the problem of availability of data required for the calculation. Data needed for the calculation of LV losses are often located in isolated information systems. Therefore, in order to make the calculation of losses as precise as possible, information integration and access to all necessary information sources from single access point needs to be ensured [3].

This paper presents out researches in the area of development of specialized Geo-Information Systems (GIS) used for calculation of losses in the distribution network. 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 presents a prototype solution, realized as a part of the GinisED system, for the calculation of losses in the distribution network.

2. CALCULATION OF ELECTRIC ENERGY LOSSES

The difference between amount of transmitted energy and the amount of energy delivered to customers corresponds to the losses of electric power in the electric power supply network. Due to a large number of parameters, the analysis of electricity losses is very complex. 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 the electric power supply network.

Electric power supply systems often use several IT systems: 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]. These systems provide electric power supply companies with support for business processes such as recording, maintaining and planning of electric power supply network. Therefore, they contain information necessary for the calculation of LV distribution network losses.

Calculation of losses in the LV network is quite complex due to the existence of large number of elements in LV distribution network. In particular case,

if input power and electric current that flows through each section of LV network are known in advance, the methodology based on the calculation of radial network can be applied (Fig. 1).

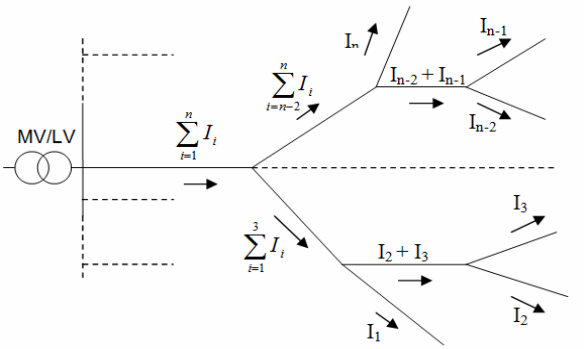

Fig. 1. *Distribution of current values through sections of LV lead*

As previously mentioned, the calculation of electric energy losses requires information that can be found in different information systems belonging to a single electric power supply company. Being completely isolated, these systems generate data available only to users of a single system. Therefore, the problem of ensuring that different users in different locations have access to all necessary information arises. In order to overcome this problem and support the exchange of information between isolated systems, IT systems integration techniques should be applied.

3. LV NETWORK LOSSES CALCULATION SOLUTION

The existence of appropriate electric power supply network geodata is closely coupled to the functioning of companies engaged in the transmission and distribution of electricity [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, in recent years, many electric energy distribution companies have made significant investments in the development of specialized geo-information system that should provide mechanisms for collecting, storing and manipulating spatial data.

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 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.

The development of GinisED system has been based on the usage of 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 (Fig. 3) [3, 9]. This platform can also be applied for information integration purposes on a single company level. It enables intelligent integration of information from a number of heterogeneous GIS (geographical and spatial) and non-spatial data sources.

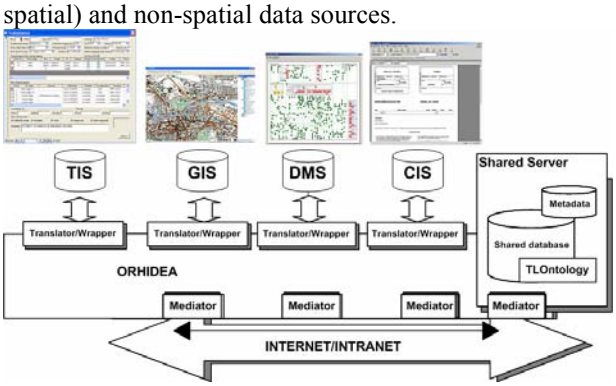

Fig. 2. *GeoNis platform for the interoperability of GIS applications*

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.

Based on development of GinisED system, which allows the integration of information from different IT systems in the PD Jugoistok Niš, an application for calculation of losses in the LV network is currently being developed. The overall architecture of this system consists of several separate modules as shown in the Fig. 3.

Solution for calculation of network power losses is derived from GinisED system. Central part of solution is based on GIS module that integrates all other data necessary for calculation. 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.

Data that could be obtained from GIS system provides all vital data related to LV network topology and technical description of LV electric power line sections (section lengths, type and diameter of the conductors, number of consumers attached, their location etc.). LV network spatial data was recorded in the field and is being regularly updated. Based on this data other data needed for calculus could be integrated from other systems like CIS and AMR.

Information considering customers, contained inside CIS system [10], is integrated with LV network GIS data. Integration of GIS and CIS allows determination of consumer's exact position on the LV electric power line. It also permits the determination of geographical location of connection that the consumer is related to. GIS and CIS data integration performed in this manner enables easy identification of all customers related to the particular LV electric power line.

When all consumers related to the particular LV electric power line are identified, their unique consumer codes are used as the input data to obtain their daily load characteristic diagrams from AMR system. AMR system uses modern electronic consumption meters. These meters allow storing of the load characteristic diagrams

for some 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 the LV electric power line losses [11].

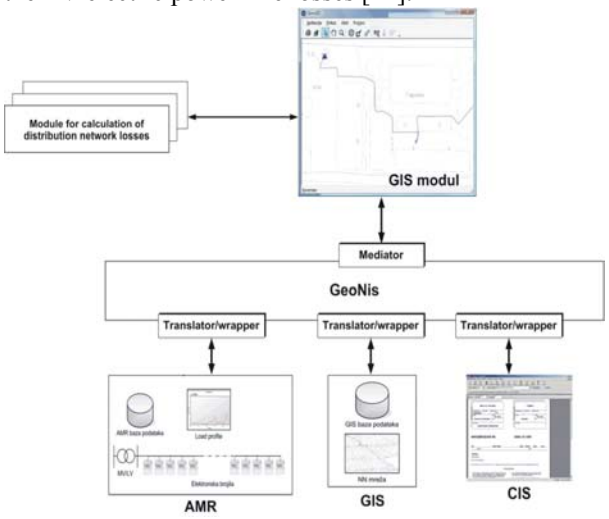

Fig. 3. *LV network losses calculation application architecture*

Based on the technical information related to the LV electric power line (section length, type and diameter of the conductors) and the consumer load characteristic diagram, the calculation module determines losses on a particular LV electric power line. This 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.

4. GINISED APPLICATION FOR LV NETWORK LOSSES CALCULATION

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.

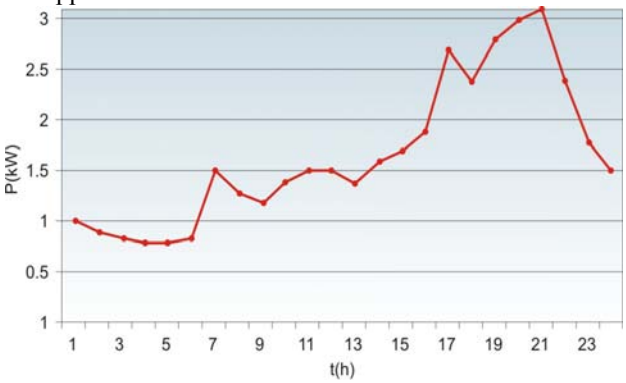

Fig. 4. *Load characteristic diagram*

AMR system uses modern electronic consumption meters for reading load characteristics remotely. Based on these readings, consumer's daily load characteristic diagrams for period of time can be derived. Not all consumers have AMR system installed so their load characteristic diagrams can not be obtained from AMR. Based on identified key factors [1] for level of electric power consumption such as day of week, part of year, type of heating etc. different profiles of consumers can be defined. Based on the behavior of consumers who belong to the same profile, with installed AMR system, it is possible to define a standard load diagram for all consumers who belong to the same profile and don't have AMR (Fig. 4). These diagrams are stored in database and could be modified and updated regularly.

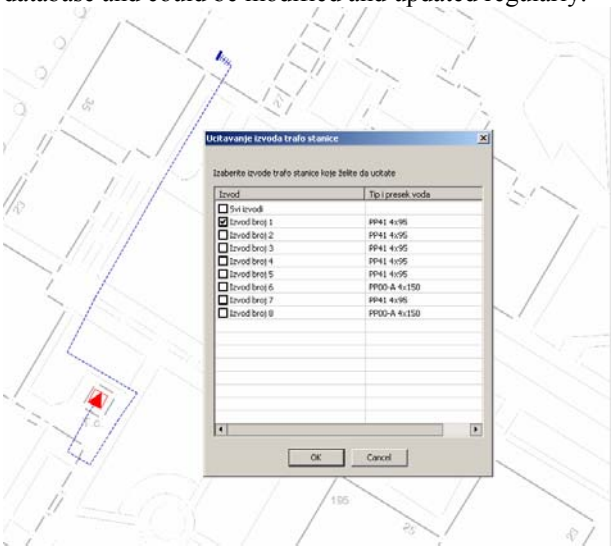

Fig. 5. *Partial data loading for LV power supply network.*

The calculation of losses for LV power supply network is based on data acquired for transformer station and consumers connected to adequate power line. This means that data for only part of network, from transformer station to all consumers, should be loaded into memory. Following this characteristic an optimization that reduces data flow between other integrated systems and main application (GIS module) is introduced. Main user interface is based on choosing only desired transformer station for which the calculation should be performed and loading desired power line or all lines connected to it (Fig. 5). This concept speeds up data acquiring and provides the possibility of performing calculation right after a part of graph that simulates network topology is loaded. The possibility of loading the whole data graph for entire network is retained for usage, for example when losses should be paired between different consumers connected to different transformer station. This option is time consuming because of the amount of data needed for calculation and calculation itself and should be used only in extreme situations.

Data obtained from GIS system is used in order to assemble data graph. Graph is consisted of edges and nodes where each edge represents power line segment and nodes represent connection of line segments or all other objects connected to power line like consumers, power network poles, line splitters etc. Having data graph based on the topology of network it is possible to acquire data from CIS for each consumer connected to it, its location, its type of consumption meter, its assigned profile [10]. Next, for each consumer load characteristic diagram is obtained either dynamically from AMR based on remote readings or from database based on his assigned profile depending on the type of consumption meter he uses.

Process of calculating starts with loading of selected part of power network for which the energy losses should be obtained. This data is used to assemble data graph. Given period of time for which the calculation should be performed is divided into 15 minutes slices. For each time slice 15 minutes power consumption is extracted from daily load characteristic diagrams for each consumer connected (Fig. 6). These time slices depend on the time for which AMR system acquires data and could be changed in future use. Fifteen minute power consumption is summed making total power consumption for given period of time. These are fed into the leaves of graph representing consumers and recursively calculated for each node towards the root node representing transformer station. Having data about power in each node, it is possible to calculate technical energy losses and voltage drop according to [1].

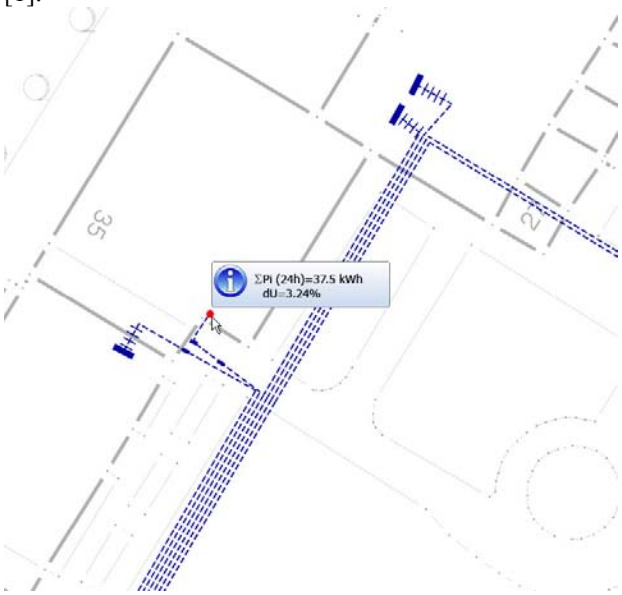

Fig. 6. *Electrical node info*

Module for calculation of losses is developed using plug-in architecture. According to this it is possible to expand application with different algorithms for calculation of losses in LV network. Each algorithm is implemented as a separate plug-in that can be loaded on demand and used for calculation of losses.

For the purposes of this plug-in architecture IGraph interface has been designed which all plug-ins must implement. IGraph interface defines the methods necessary for creating electric graph, calculation of losses and displaying of information about losses in each node, or edge of the graph. This interface provides the possibility to dynamically change the data graph implementation. This way it is possible to use custom or third party implementation of graph and to compare calculations from different algorithms.

Data structures used for holding data about load characteristic diagrams are organized like shown on Fig. 7. PowerDiagramGroups holds PowerDiagramGroup in hash table. Each PowerDiagramGroup holds all instances of PowerDiagram class for that profile in Dictionary structure. Different PowerDiagrams are used for working days, weekends and major holidays.

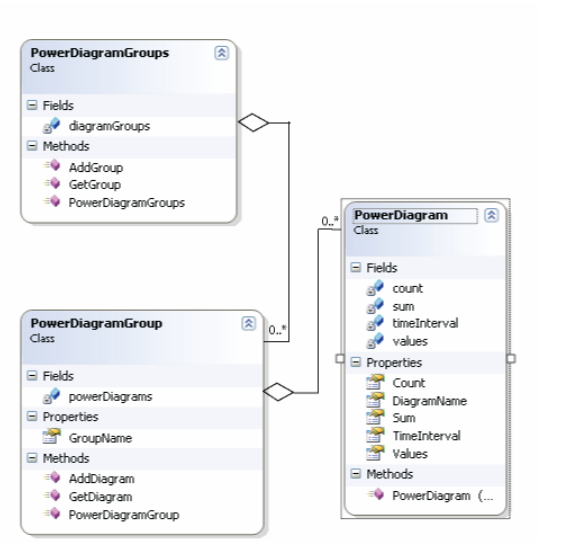

Fig. 7. *Power diagram data structures.*

All dialogs needed for data representation are module dependable. This enables the possibility of changing user data representation depending on the methodology used for calculation.

5. CONCLUSION

Every company that deals with the distribution of electricity pays 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.

As a starting point for the development of losses calculation prototype application, GinisED system was used. This application is developed for the purpose of recording spatial electric power supply network information. The system is based on calculation of electricity losses, using a recursive method for calculating the electric current that flows through each LV electric power line section. The goal of 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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