ASPECTS OF IMPLEMENTING GIS AS A CENTRALISED SYSTEM IN AN ENTERPRISE IT/OT ENVIRONMENT

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ABSTRACT

Everyday tasks, process workflows and legislation issues force utility companies to ground their business model on information technologies, the components of which are the fastest developing products nowadays. An enterprise information system is a group of interleaved individual systems (IT&OT) which share a significant amount of common data, yet they typically exist as a separate system and on a separate platform. Data exchange between those systems is inevitable and among them the geographic information system (GIS) with its geodatabase, represents a key integration component. GIS also provides tools and methods for spatial data analyses which serve as a guide in business and development decision. Nonetheless, the GIS aim is also to offer tools and to serve accurate and reliable data to the end users.

This paper presents an ongoing project (December, 2018) of enterprise GIS platform implementation at the electricity distribution company Elektro Primorska, Slovenia. The main stress is placed on data modelling and system integration. Besides this, the advantages in reports building as well as the end user Web-based GIS application are discussed.

INTRODUCTION

Electricity is very important for society as it supports the economy as well as the well-being of individuals. Delivering power from the transmission network to the end-use customers is in the domain of distribution companies. In theory, the minimum requirements of electricity distribution are supplying continuous power to end user customers with minimised momentary outages and little or no variation in voltage. This should be done keeping power losses as low as possible [1].

Alongside this, the distribution company has to run an efficient day-to-day operation and efficiently manage and develop its services, due to strong competition introduced by market deregulation. This could only be done by knowing what assets it has, where and in what condition they are, how they are performing and how much it costs to provide the service [2]. On the other hand, companies are facing challenges like increased electricity usage, distributed power generation, infrastructure ageing, retiring work force with undocumented knowledge of network behaviour, customer demands of better and better services (smart grids), security (physical and cyber) issues and, nonetheless, lack of money. With all the abovementioned in mind, it is practically unfeasible to take crucial decisions vital to the operation, growth and management of the electricity distribution facility, without the support of a “state of the art” information system. The latter consists of a number of components – sub-systems, which are related to the distribution network, its monitoring and various analyses/reports on its day-to-day operations. Such sub-systems no longer act as isolated tools with their own datasets limited to a particular department; however, the dynamic changes of network configuration demand better collaboration and information sharing among these components. Therefore the systems in a contemporary data driven company have to integrate in a complex information system, of which Geographic Information System - GIS plays a central role [3].

GIS is the system that provides mechanisms for collecting, storing, visualising and manipulating spatial-related data. It enables fast, unique and accurate presentation of the utility network. Moreover, GIS allows the connecting of various type of non-spatial information in the spatial context, which increase operational efficiency. All this information is being integrated into both critical operational processes and into tactical and strategic decision-making.

GIS represents a main repository for assets and their technical data which are linked to many processes and applications across the business/departments (Fig. 1). The latter requires network information – to some extent – on a daily basis. If an early stage of GIS technology development was oriented to end-user functionalities (mapping, analysis, proximity relationships), nowadays more and more effort is made towards system integrations i.e. system users [4].

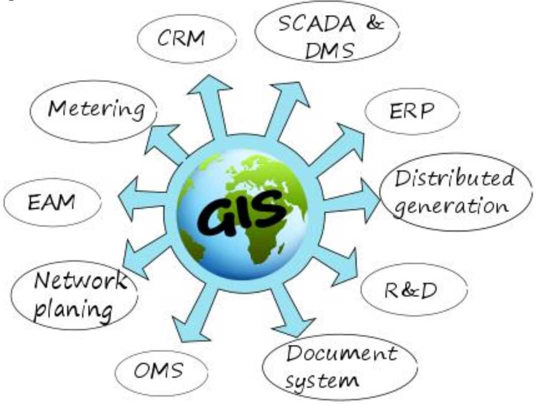

Figure 1: GIS-centric enterprise information system

BACKGROUND

Elektro Primorska d.d. (EP) is one of five electricity distribution companies in Slovenia, covering roughly 22% of territory. It is in charge of the operation, maintenance and development of the distribution network infrastructure which spreads on the west side of the state alongside the Italian border. EP operates 9000km of lines (HV, MV and LV), 18 stations (HV/MV) and nearly 2400 sub-stations (MV/LV).

In EP, a geographic system (GS) was introduced in the 1990s with an intention to replace old paper-based maps with their digital successors. The word "Information" is deliberately omitted from the above nomenclature "GS", as the information held in separate CAD drawings was limited to spatial data only. Later on, the GS was upgraded – connected and paired with the independent non-geo databases BTP and eIS, where assets with their technical data and customer's information were stored, respectively. However, this still wasn't quite an "information" system as at least two data sets from independent data sources were needed to represent network data.

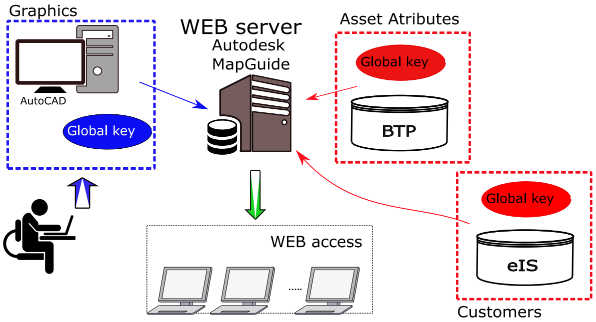

Figure 2: Configuration of the GS at Elektro Primorska

GS in such configuration had no ability to integrate with other enterprise IT/OT systems and was exclusively designed for end users only. Yet, as data were entered to at least two data sources with insufficient editing rules and limited data visualisation, a lot of faulty information had accumulated in databases through the years. As a consequence, data presented by GS were unreliable resulting in distrust of the employees. Due to the abovementioned, it is clear that the GS in EP was extremely outdated. Fortunately, that was also recognised by the company management which defined IT/OT strategy for the next few years, in which a contemporary enterprise GIS system is recognised as one of the core systems.

ENTERPRISE GIS

Enterprise GIS will serve as the main tool to manage and analyse electrical grid assets data at Elektro Primorska. Both customised mapping and schematics tools will be used to meet user demands. Enterprise GIS is a complex system build of several diverse components, as seen in Fig. 3. Only a few of them can be purchased, therefore implementing GIS refers to building the GIS rather than buying it.

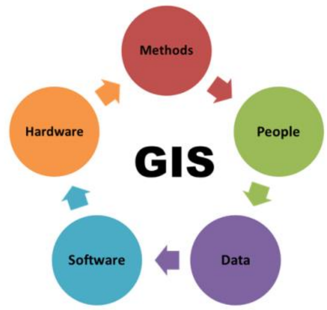

Figure 3: GIS components

Requirements

The software is a key element for establishing a GIS platform and as such, a component that defines GIS functionalities and on the other side fulfils our expectations. One of them is a unified geo-database as the main asset repository where assets and their technical data (attributes) are stored. Each record must be inspected by predefined entering rules in order to avoid data errors and to assure data consistency.

Electricity distribution depends on infrastructure which consists of many elements (station, feeder, pole, bus, wire…). In order to catalogue all of them, the GIS platform has to offer a data model adapted to distribution needs, yet the model has to be configurable and further extensible.

In the electricity distribution business many IT/OT systems like GIS, Automatic Meter Reading System (AMR), Distribution Management System (DMS), SCADA, Enterprise Asset Management (EAM)… are involved in processing common information, therefore integrations between them are of great importance. Our ultimate goal is that any data has its unique entry point and each data insertion or modification in the particular system automatically, without human intervention, reflects in all other systems this data concerns. As the Enterprise GIS is intended to supply a majority of asset data to other systems, the GIS platform has to be compatible with various types of system integration.

Web GIS is another feature expected from Enterprise GIS since it offers global insight (organisation or public) into the network assets data. It has to be easy to use and available to a large number of users. The possibility of including custom-made applications and tools is also important.

Infrastructure maintenance and repair activities are carried out by specialised crews. In the field, they have often encountered difficulties in performing tasks, as they are faced with a lack of data, wrong data, missing data... In such cases, a mobile GIS with the ability not only to visualise assets but also to edit their data, turns out to be of great help.

Due to the new technology evolutions like distributed generation, smart metering and smart grids distribution, business becomes more and more data intensive. Asset repository no longer seems to be the number one GIS functionality, namely GIS development is moving more and more in the direction of providing network topology and network model building in order to support managing dynamic changes in network configuration.

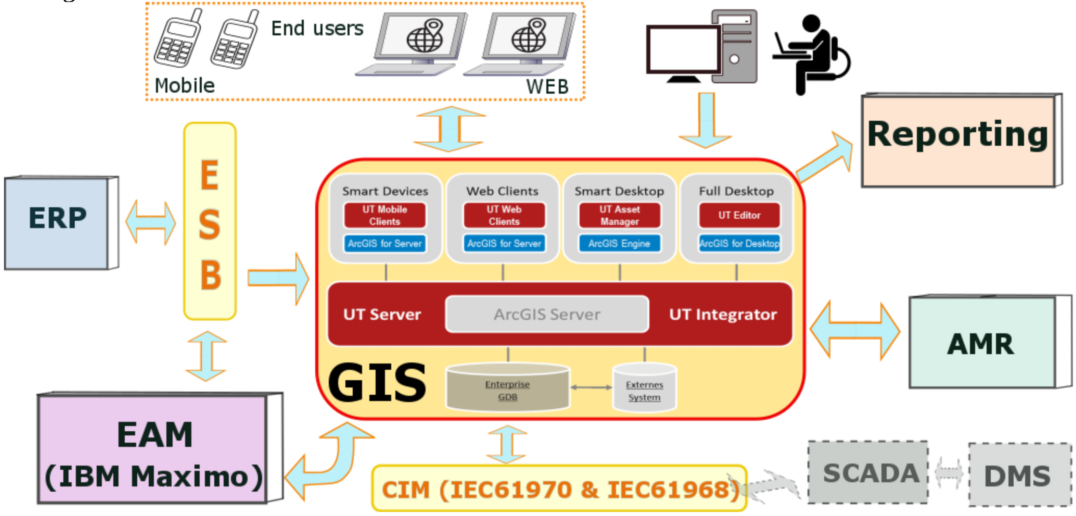

Figure 4: Configuration of enterprise information system after the GIS implementation

Implementation

At Elektro Primorska, a project of "Enterprise GIS implementation" has been in progress for two years. As requested in the public tender, an open, flexible and interoperable platform was offered by the Slovenian company GDi, a local AED-SICAD partner and Esri's ArcGIS distributor. The latter form a framework for a GIS platform on top of which the SICAD extension, deliberately developed for network infrastructure inventory, is mounted. GDi was also chosen to be our GIS implementation contractor which turned out to be a good decision, as they have proven to be a highly professional and trustworthy company, offering one of the best GIS products. The configuration of implemented GIS and its placement in the enterprise information system environment is seen from Fig. 4.

Data model and data migration

The useful GIS value is determined by its content or data. The user will use the system only if it provides them with access to the desired information. The key factor is the data model or its architectural design, which must contain all the key data of the infrastructure assets. In regard to this, the model must not be limited to the requirements of end users only, but it also must contain information which is crucial to system users. However, the data model is also the basis for the GIS system configuration and for determining the processes of data capture and processing, and therefore it must be carefully planned.

When designing the data model, we used the general preset and object-based SICAD template that was specially developed for the purpose of making an inventory of the distribution network assets. Figure 5 shows the structure of an object-based data model, whereby each data model object represents an individual network asset. Each object in the database has a corresponding table containing attribute data. The data model also indicates the structural connections between objects which are the basis for the design of the relational database.

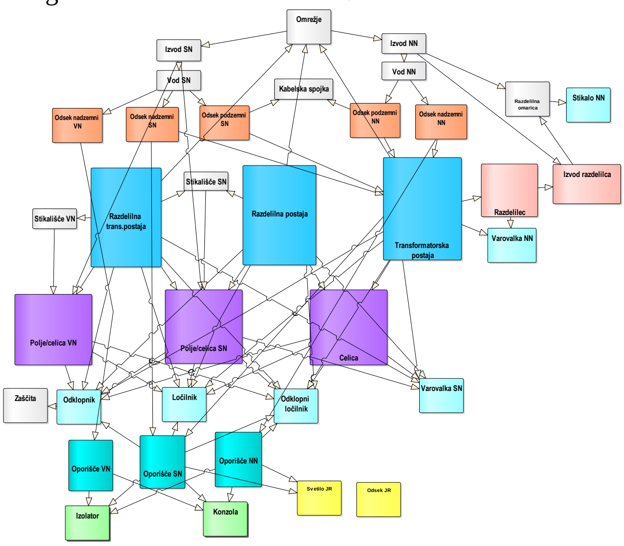

Figure 5: Part of the GIS data model

The general data model template did not contain the complete set of assets that we wanted to monitor using GIS, therefore we defined additional objects and integrated them into the model. We considered the system requirements and requirements of each individual process. Thus, the data model was upgraded to meet demands of:

- asset maintenance process,
- exporting into the standardised CIM format,
- planning and operating systems,
- monitoring of measuring points,

- reporting.

On the basis of the final data model, we configured the relational databases and corresponding tables. Before we populated them with the data from the legacy geographic system, we thoroughly examined all data resources, thoroughly analysed the available data and performed a rough data cleaning. In this regard, we encountered the problem of data integrity and sparsity – geographic data were contained in CAD files, while the attribute data were in table form. Therefore, when compiling and transferring data into a single database, we were forced to apply different migration approaches:

1. For the assets (sections, stations, etc.), for which the database included both the graphical (CAD files) and attribute data, we created the appropriate objects with graphics in the new GIS system using a unique identifier (ID).
2. For the assets without graphics (switches, switching substations, cells) we created objects containing graphics solely on the basis of attribute data.
3. For assets containing graphics but no attribute data (NN network), we created objects containing graphics using advanced tools for spatial analysis.
4. For the migration of transformer stations, we created a dedicated tool which enabled us to generate internal single-pole station schemes during the migration on the basis of structural connections between the assets. The result of this migration is shown in Figure 6.

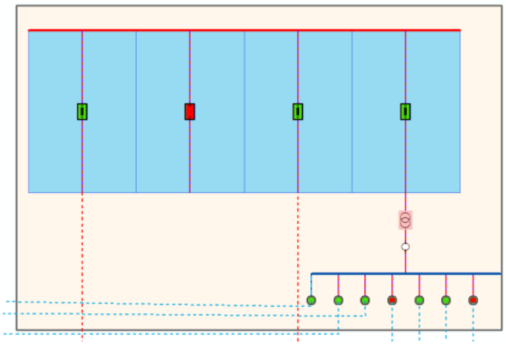

Figure 6: Substation single line diagram

Integration with other IT/OT systems

Within the context of the IT environment of the company, the GIS system plays a significant role since it is functionally located at the point of intersection of IT and OT systems which are integrated into a complex IT system via GIS. Due to this strategic and interconnecting role, the GIS system is extremely suitable for storing a great volume of information that are usually processed and used in the IT/OT systems for purposes of process implementation. Therefore, the GIS system must enable a smooth transmission and exchange of data with these subsystems – i.e. integration, which was one of the GIS system implementation objectives.

During the first phase of implementation, we envisaged and implemented a bidirectional system integration between GIS and the IBM Maximo (MX) software, in which processes related to asset management are executed. The integration ensures that asset information in the MX is synchronised with assets in the GIS system and vice versa. Data synchronisation is automatically performed using a global identifier (asset ID) whenever the data in the GIS system is changed. MX assigns the ID to the newly created asset.

Figure 7 shows the basic principle of data exchange between systems based on rules defined within integration modules ("GIS Integrator" and "MX Integrator"). The data exchange between both systems is triggered when "GIS Integrator" detects that a certain object has been changed in the GIS system. If the change relates only to the asset attribute data with ID (the existing asset), the asset data of this asset is updated accordingly in the MX system and the data exchange is completed.

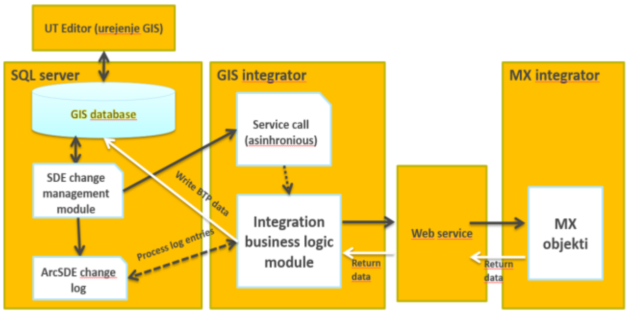

Figure 7: Principal integration dataflow

In the event that a new maintenance asset is created in the GIS system, it is transferred to the MX system together with the attribute data. The MX system recognises that the asset was newly created, and therefore assigns a unique ID to that asset. At the same time, the MX system resubmits the ID of the asset to the GIS system, which adds it to the newly created asset, thus the data exchange between both systems is completed.

During the implementation of the GIS system, we noticed the need for additional integration, therefore we connected the GIS system with the AMR system (measurements database), ERP (purchasing and warehouse activity) and the eIS (service point database).

The GIS system allows data visualisation that can be linked in any way to the location itself or with assets in the environment space. For this reason, we can expect that the rate of integration will increase in the future. In order to facilitate the management of connections, it will therefore make sense in the future to consider a dedicated integration platform through which data exchange between systems is standardised. A step in this direction has already been made since due to the needs of future integration using the SCADA system we developed a tool that prepares and exports the network model in CIM format on the basis of topology.

Reporting

With a properly designed data model, its underlying relational table structure and in conjunction with contemporary GIS platform, we have gained a powerful environment to build an advanced analytics and reporting framework. Namely, as a relational database more complex questions can be answered such as "*How many wooden poles older than 20 years support a certain feeder?*"

The reports of any kind are the first step in taking decisions essential for operations, management, planning and above all for distribution facility growth. Since all the data are stored in a central geo-database, the reports are easily equipped with a spatial component enriching reports with the map-based visualisation experience.

In Slovenia, the regulatory authorities (GURS, SODO) periodically require certain inventory reports. These were implemented as custom ArcMap add-in tools which cover reporting needs such as e.g. infrastructure age, LV and MV line lengths etc.

Above all, users from different departments have the opportunity to make their own query/reports and since the same data source is used (single truth), the discrepancy between data is excluded.

Web GIS

Besides sharing spatial and network data among various IT/OT systems, the aim of the GIS platform is also and above all to provide spatial-related insight into the network data to the daily users – employees – in the office and on the field. This was done through the web client (UT JavaScript), which enables users to perform simple attributes as well as spatial-related queries. Moreover, certain web users have the ability to participate in data collecting and data cleaning (spatial and non-spatial) in order to further improve the data quality. This is accomplished by custom-made web applications, which were tailored within the web extension tool (WebGEN). Its advantage is a configuration-based approach making it possible to implement very powerful web apps without any code programming knowledge. To name a few realised tools: exporting parcel list based on a line or polygon drawn, updating switch SCADA IDs arrangement, advanced search of service points and transformers… Web GIS is not restricted to the visualisation of network assets but is also intended to expose data from other enterprise systems – metering data, quality index, contract documents, photos… as well as from public and commercial map services. An example of web tool for AMR data presentation – loading diagram at a given time interval - for a certain service point is shown on Fig 8.

From day to day, the amount of data to be accessible through the web GIS is growing steadily due to the newly emerging technologies. It makes no sense therefore, that all datasets would be at the disposal of a single map to each and every employee as the system performance and data transparency would deteriorate. To avoid this situation, we prepared thematic dataset-limited web GIS applications addressed to the individual department needs.

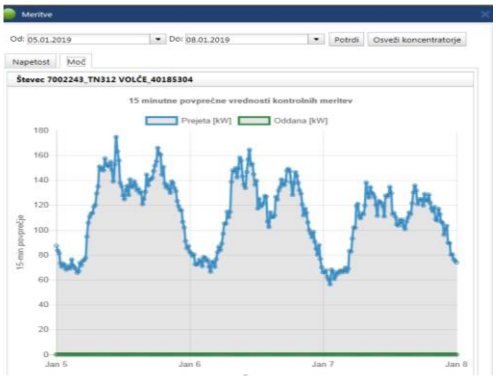

Figure 8: Diagram of power delivered

CONCLUSION

In the past few years, conventional GIS systems have transformed into sophisticated platforms and nowadays, spatial visualisation with the ability of spatial analyses and reports has become only part of the GIS functionality. Terms like network topology, connectivity, system integration, IoT and nonetheless smart grid have come more and more into the foreground, when GIS functionality is to be exposed. With all that in mind we have approached the renovation of the Geographic Information System (GIS). Implementation was undertaken in several phases, of which the data modelling and migration, system integrations, reporting and web functionality are highlighted in the paper. Thanks to the management support, the experienced implementation team and the contribution of experts from various departments, the project of implementation run smoothly, and the implemented GIS was well accepted by the users.

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