

Utilizing SCALAR lightning location system for power systems applications

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SUMMARY

The SCALAR system is a lightning location system, which has been in the operation since 1997. From the beginning, the system has been developed taking into account the needs of transmission and distribution system operators, especially in field of power system operation, planning and maintenance. The users of the system have specified requirements that have dictated high level of efficiency and availability of delivering lightning data and related services. Nowadays the system serves also users from other domains, such as transportation (railway, aviation), communications (broadcasting radio and television and telecommunication companies) and supports the insurance business.

During 18 years of operation, many applications have been developed and put into the operation to fulfil the requirements of the power system operators, such as:

- Reliable delivery of real-time lightning data and visualization of the data in a modern way,
- Real-time correlator of power line outages caused by lightning,
- Real-time selective alarm notification of the lightning presence in the vicinity of overhead power lines and substations,
- Advanced analytics:
 - utilizing of high resolution flash density data for analysis of lightning threat and influences on electric power facilities,
 - utilizing of lightning data archive for statistical analyses such as amplitude distribution and propagation in coordination of basic insulation level in power facilities.

The paper presents the SCALAR system's advanced technology solutions, which support power system operation, planning and maintenance processes and help protect the power system infrastructure. Some use cases and examples of a good practice will also be presented.

KEYWORDS

ScalarFlashClient, SCALAR Lightning Location System, Web Services, Custom GIS, real-time Correlator, Selective Alarming

INTRODUCTION

Electric power research institute Milan Vidmar (EIMV) is a Slovenian engineering and scientific research organization active in the area of electric power system engineering and general energy. Since 1997, EIMV owns, runs and develops SCALAR lightning localization system. At the beginning, the lightning information system was developed primarily to fulfil the needs of the electric power utilities. The SCALAR system is mostly used by Slovenian transmission system operator utility and distribution utilities.

The 18 years of operation, new technologies, especially JavaFX and Web Services, have emerged and become standardized. They are nowadays widely available and are, together with much more powerful computers and easy Internet access, becoming a platform of choice for new development. Therefore, we decided to improve our old user interfaces based on years of experience with much more advanced mapping capabilities and functionalities. The user can now access the lightning data much easier and is able to perform data analysis and monitor weather data in real time. Custom GIS, alarming and correlation services can now be integrated in a whole new way.

After 2 years of development and integration of the above-mentioned technologies, the lightning mapping software ScalarFlashClient (SFC) becomes our new lightning information system.

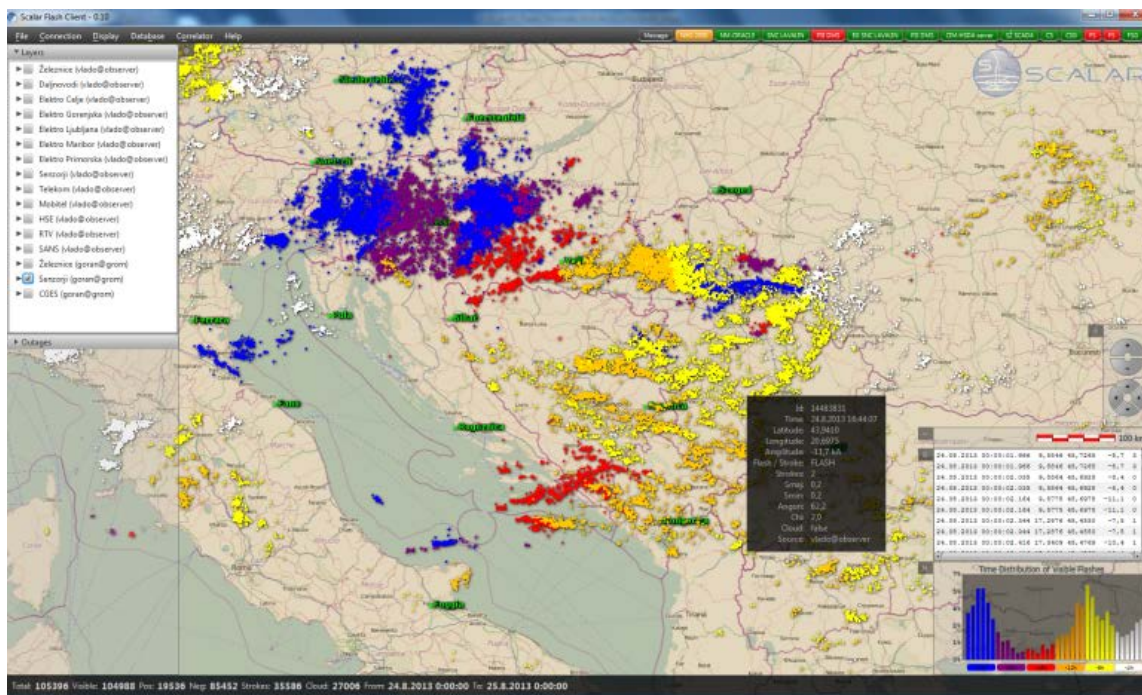


Figure 1 : ScalarFlashClient user interface

1. NEW SCALAR INFORMATION TECHNOLOGY

Definition of requirements

At the beginning of the development of SCALAR's new system platform, we defined the general requirements that are needed by our users and operators of the SCALAR system. Several specific requirements define which technology and solutions meet the criteria. The basic criteria are:

- All SCALAR services have to be accessible from single entry point, for example an integration bus like SCALAR interface – web service (see Figure 2).

- The lightning domain server platform has to contain a set of common services like the discovery, authentication and authorization of the user. The discovery service helps the client to discover the domain server capabilities and therefore simplifies user's access to the lightning server.
- Administrator must be able to create user profiles to which several SCALAR services can be attached. This simplifies procedures of creating and setting up user's permissions.
- The life cycle of software solutions should be at least 10 years long.
- The lightning mapping has to use advanced techniques and maps.
- All displayed lightning and weather service data have to be in vector format.
- User interfaces on the client side must offer high performance of data and maps displaying.
- The SFC has to be capable of using other services from several server domains. Different Web Map Service can offer different geographical information to the end users.

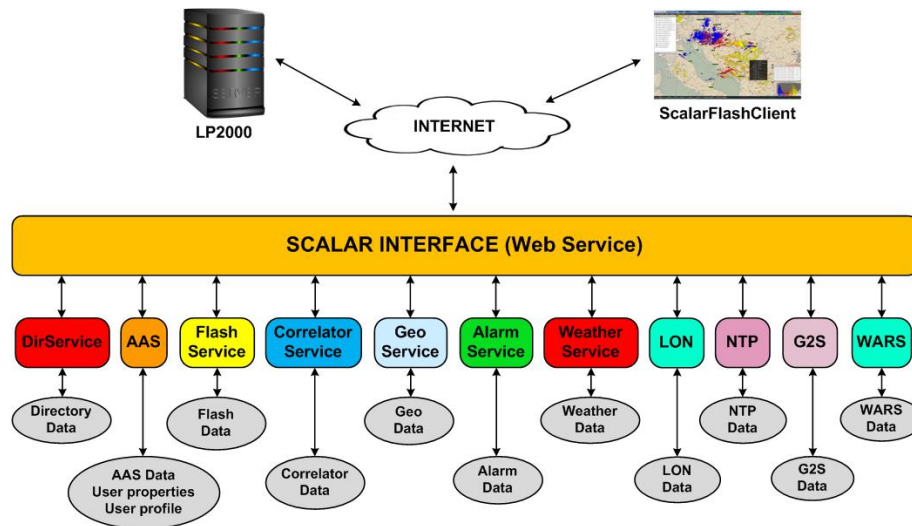


Figure 2: SCALAR information architecture

Selected technology

In general, we can divide the selected technologies into server and client sites. The server side is service-oriented and is basically hidden from the user.

Server site:

- Uses a standard communication protocol SOAP/WSDL over HTTP/HTTPS protocol. Business logic is implemented in Java EE.

- Enterprise Java BeansEJB is used as builder.
- Persistence / Database access:
 - Java Persistence API JPA 2.0 and
 - Java Transaction API 2.0.
- Java message service JMS 1.0 as message builder.
- Java application server GlassFish as Web Service server.
- Administration module on server site is implemented in Spring Web technology.
- Databases:
 - PostgreSQL database
 - MySQL database.

The client side is more focused on the user interface and display performance, as this are the first things the user experiences. While selecting the technologies, modern graphical user interface was also taken into account. Client side SFC is based on JavaFX technology which offers OS independent solution and uses OpenGL standards to boost the user's graphics experience.

GIS implementation:

- SFC supports Open Geospatial Consortium (OGC) specifications. It is implemented with Geotools Java libraries, which support almost all standard data formats, Shapefiles, WMS and WFS, etc.
- It supports raster maps of OpenStreetMaps tile – Slippy Map protocol, rendering of map tiles is optimized and customized from the user side with JavaFX technology.
- Weather data (rainfall radar reflectivity and satellite imagery) is supported and stored in PostgreSQL database.
- Calculated statistic data (high-resolution flash density map) is supported and stored in PostgreSQL database.

All displayed geographical information is organized in layers, which means that only certain information is displayed at a predefined zoom level. This results in clear, readable maps which are easy to use and offer good orientation to the end user.

The users can also apply their own geographical data which are compatible with the OGC specifications. In this case, a multi-GIS connection is established and all GIS data is merged into one at the user site (Figure 3).

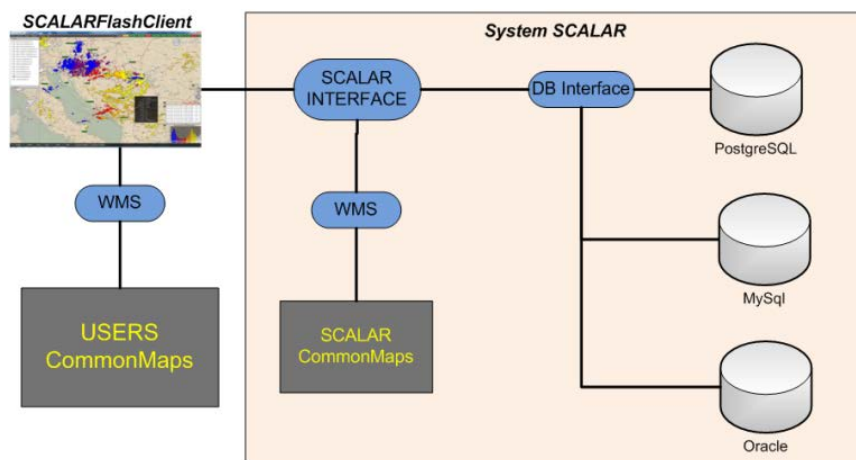


Figure 3 : Multi-GIS connections

2. EVOLUTION OF USER INTERFACE

Most of our users utilize SFC to access to the lightning data. Therefore, we devoted a lot of attention to the final appearance of the new interface, particularly the functionality that will provide operational reliability for the user, the ease of use and simplified procedures for data analysis processing. The basic idea was to serve the user with the desired results and views as fast as possible. Layout optimization of user interfaces and procedure to reach the desired functionality were based on years of experience.

Features of ScalarFlashClient

There are several new features in the SFC that need to be addressed. A completely new one in lightning localization world is displaying lightning data in a vector format with the visual connection lines between all the strokes related to a single flash (Figure 4). This gives the user a quick overview of the stroke multiplicity and spatial dispersion over the area. The first return stroke is coloured differently and is clearly marked.

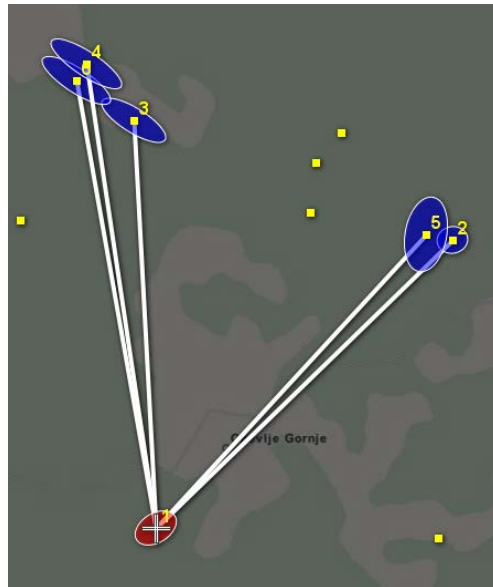


Figure 4 Flash and strokes relations

A time lapse lightning and weather data animation is another new feature added to the SFC. So called 'Animation mode' (Figure 5) allows to setup speed, duration and time span of animation which offers an easy way to browse through the stroke list from historian data.

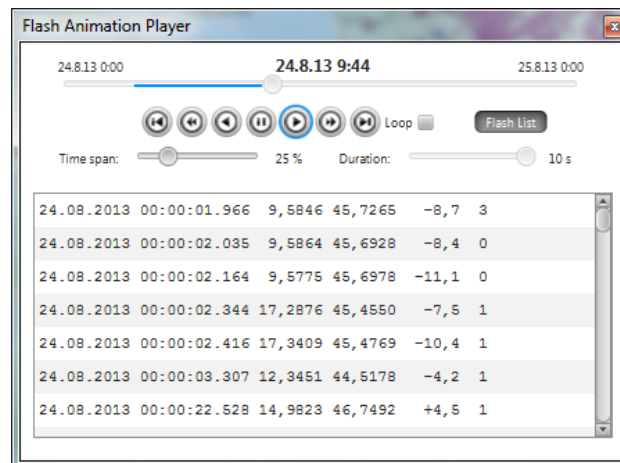


Figure 5 Lightning animation mode

The upgraded features of SFC are a multi-layered organization of geographical information. Nowadays, the GIS system is very complex and is usually organized in several layers. SFC uses two main groups of layers to represent the desired result. The general layers are those which are basically geographical nature:

- Basic maps,
- Borders: state borders, sea borders, islands...
- Towns; major towns, towns, villages...
- Roads, railways...

- Transmission (400 kV, 220 kV, 110 kV) and distribution power lines
- Substations and other legal entities
- Custom maps

The second group of layers is more focused on the lightning, weather and other LLS services:

- LLS sensors
- Lightning data
- Radar reflectivity
- Satellite weather data
- Power line outage correlation
- Alarming
- Statistic

Several layers are object-oriented, which means that the user can get additional visual information and other properties of the object (Figure 6).

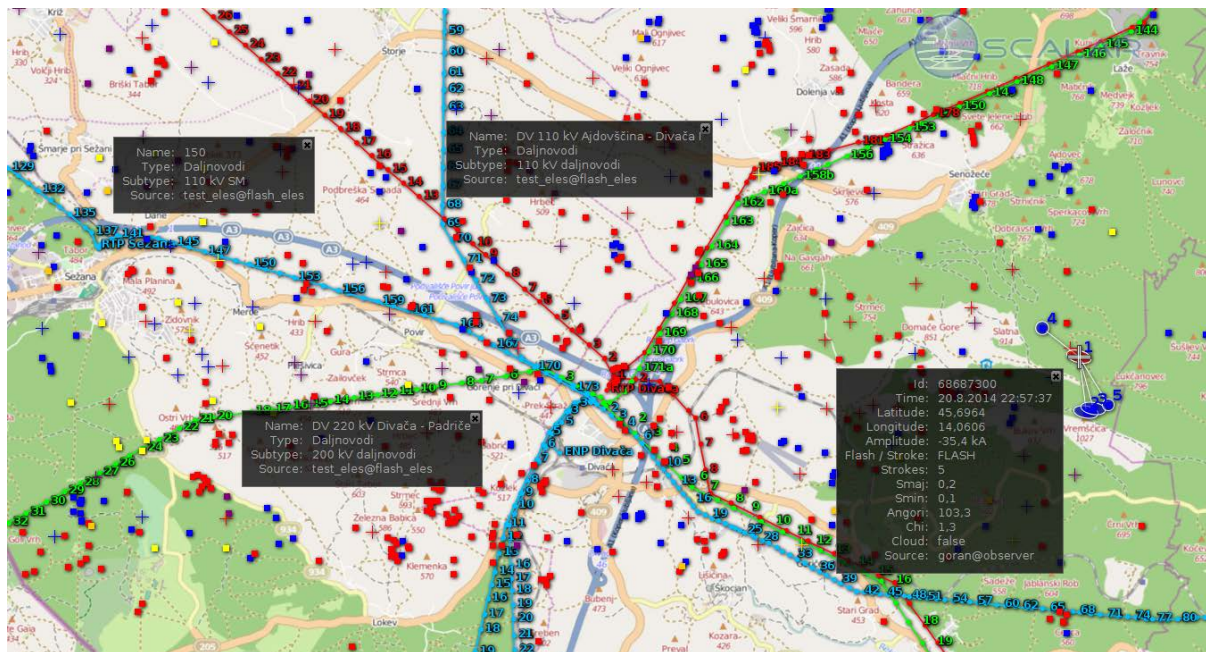


Figure 6 Geographical information in vector format with properties displayed

SFC also offers sound notifications for incoming thunderstorms. For each of the first 20 lightnings, SFC produces sound notification and then turns off until the end of the thunderstorm. If a new thunderstorm occurs, SFC produces the sound notification once again.

The lack of lightning data sharing was one of the drawbacks of the old interface. In the new SFC, this functionality was upgraded with the export function, which exports all the lightning events listed upon user's request in a numerical fashion (time, location, polarity and amplitude, as well as number of return strokes). Lightning analysis and damage report generation are therefore much easier.

Displaying statistic lightning data and weather data layers

The new solution allows the different data layers to be displayed as:

- High resolution flash density maps (Figure 7).
- Weather data (radar reflectivity rainfall and cloud satellite images), see Figure 8 and Figure 9.

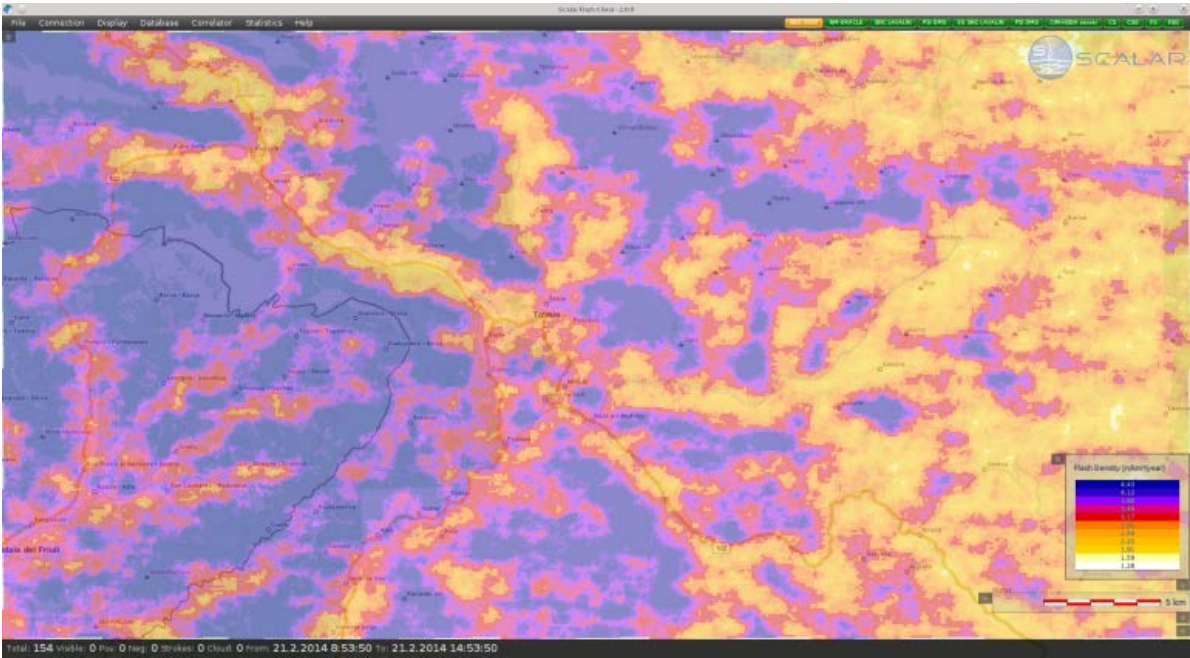


Figure 7 : High resolution flash density map of 100m x 100m resolution

SFC displays composite pictures of lightning, rainfall radar reflectivity and (or) cloud satellite data on the same view in real time.

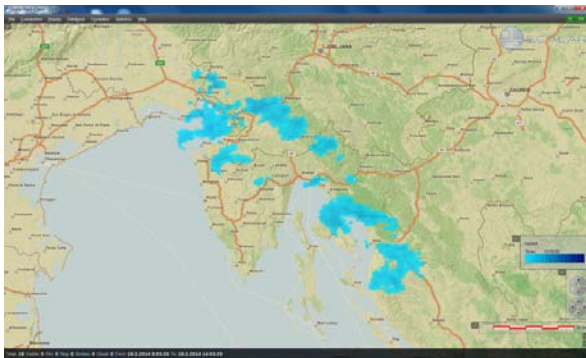


Figure 8 : Rainfall radar data layer

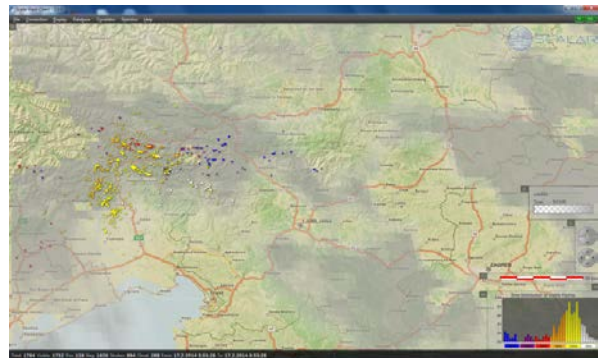


Figure 9 : Cloud satellite data layer and lightning locations

All statistical and weather data layers with custom view are configurable through the GUI on the client site. Settings are subsequently stored on the server site and are available for the next use. The user can therefore use many instances of the application on the different machines and have the same settings setup.

Service of added value

During the several years of operation, the SCALAR system developed some additional lightning data services, which have added value to the user's experience:

- Real-Time Alarm services and monitoring alarm service on SFC display (see Figure 10 and Figure 11) and
- Real-Time power line outage correlation for transmission and distribution power lines (see Figure 12 and Figure 13).

Real time Alarm service enables end user notifications alerts of lightning activity over the desired area. The end user can select the desired zones that are under alarm and monitor their

alert levels and post actions. An upgraded functionality of alarm service supports so called “selective” alarming. Selective alarming has been developed primarily for maintainers in power transmission companies. It works in a manner that when a thunderstorm is approaching or is above the powerline of interests an alarm is triggered. Alarm service further checks if maintenance works is undergoing at the moment of alarm triggering. If so, the coordinator of works gets alarm notification over SMS.

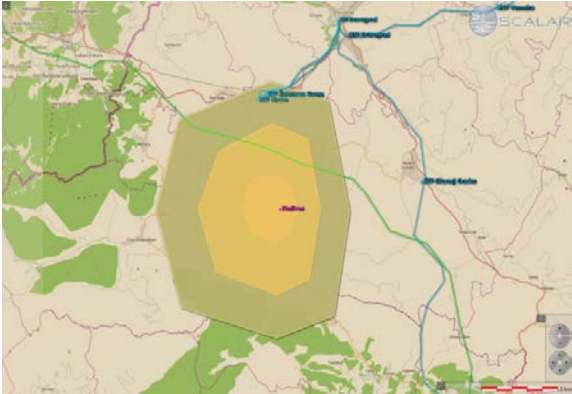


Figure 10 : Alarm zones visualization with different alarm levels in SFC

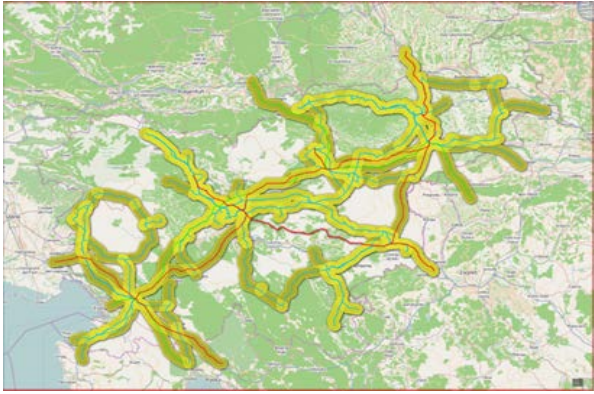


Figure 11 : Alarm zones visualization around TSO powerlines

Real time power line outage correlation service is one of the most complex services of the SCALAR system. The service has been presented in many academic papers in the past 15 years and is too extensive for this topic. A new feature is the integration into SFC to allow users to monitor the desired powerlines outages in the new GUI. The user can select different views and search events in real time or just browse through the archive.



Figure 12 : Power line outage correlation on a distribution level

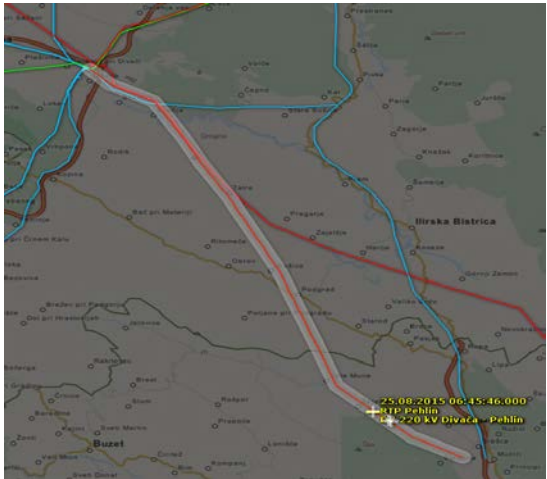


Figure 13 : Power line outage correlation on a transmission level

CONCLUSION

A new information platform of the SCALAR system and a new ScalarFlashClient has been developed during the last two years. The main result of the development is a modern approach to deliver services to the end users. Lightning data, value added services, weather data and visualization of different maps are combined in the same application. Despite the

development being an ongoing process, the new information system is already running in production and the selected technology has proven to be the right one.

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