LCE-04-2017

Innovation Action

flexitranstore

An Integrated Platform for Increased FLEXIbility in smart TRANSmission grids with STORage Entities and large penetration of Renewable Energy Sources

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774407

D7.3 First version of demonstrator operational in one country (Slovenia)

Report Identifier:	D7.3		
Work-package, Task:	WP7	**Status – Version:**	1.0
Distribution Security:	CO	**Deliverable Type:**	***Publishable summary***
Editor:	BME		
Contributors:	C&G, ELJ		
Reviewers:	KIOS CoE , R&D NESTER		
Quality Reviewer:	ED		
Keywords	d7.3, demonstrator, wp7, icing, dynamic line rating		
Project website: www.FLEXITRANSTORE.eu			

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Executive summary

1.1 Scope of the demonstration

The icing of the power lines poses serious challenges for the transmission and distribution system operators all over the world. The main problem of transmission line icing is that a distributed additional mechanical load appears on the phase conductors due to the accretion of ice layer, which affects the mechanical behavior of the power line structures. This mechanism can lead to increased sag in some cases, or it can cause even serious damage due to collapsing high voltage towers. The damage of the infrastructure is not only dangerous for the environment, but also can cause safety and reliability issues of the power grid which means that several consumer could lose the electricity supply temporarily.

The Republic of Slovenia is in Central Europe and, due to its very diverse geography, different climatic zones characterize the different parts of the country that leads to snow and ice storms, sleet, and freezing rain every year. The most recent transmission line icing event in Slovenia occurred in 2014, affecting both the distribution and the transmission grid. Due to the damage in the power system around 10% of Slovenia's population (almost 200.000 citizens) were left without energy supply that posed a serious challenge to the system operator.

In February 2014, almost all of Slovenia was affected by severe weather conditions, and due to this some parts of the electricity system were damaged seriously. 110 kV distribution and transmission lines, and 220 kV and 400 kV transmission line towers collapsed, which causing serious energy outage problems countrywide. The results were extremely disastrous on the line between the transformers in the vicinity of Ljubljana and Divača, where 220 kV and 400 kV transmission lines were destroyed. An additional load of ice also broke the towers and ruptured the conductors. [1]

These natural disasters were the motivation behind the Slovenian demonstration, in which sensors are installed on the power line and a complete DLR-based line management system was implemented.

1.2 Concept and methodology

The project aims to demonstrate sensor technology for power system operators (both at DSO and TSO levels) to effectively handle and prevent sudden, and often fatal failures, especially during icing events. Another aim of the demonstration is to increase the security of the system and network reliability by reducing icing phenomena on the OHL structures. [2]-[6] For this purpose, a complex hardware and software infrastructure has been implemented on the Kleče – Logatec (KLLO) 110 kV distribution line, from which video is available. Within the framework of the demonstration, two weather stations were installed on the towers of the line to collect weather parameter data in real-time. Four pieces of line monitoring sensors provided by OTLM d.o.o. were also installed in the western end part of the line. These sensors are for measuring the conductor temperature and line load with high resolution. To achieve accurate ice prediction, forecast data for the environmental parameters are available by ARSO (national weather agency) in this area. To collect the data of weather stations, line monitoring sensors, and weather forecasts, a physical server was established at Elektro Ljubljana (ELJ). This server also performs the calculations, visualize, and store the results.

For the demonstration on the Kleče – Logatec line two different software environments were implemented, the OTLM software system and the BME's complex grid management model. [3] The OTLM Smart Center offers a visualization platform to display the measurement result of OTLM equipment installed on the demo line. The model also contains an ice detection system developed by C&G d.o.o. and OTLM d.o.o. The core of this system is that the inclination measured by the sensor is completely different whether an ice layer is formed on the conductor or not. By monitoring the inclination, normal operating conditions and icing events can be distinguished. Moreover, the OTLM device is equipped with a camera that provides images about the actual state of the conductor.

BME's complex grid management system is based on a dynamic line rating method which is a promising and cost-efficient way to set the transfer capacity of the line to the changing environment conditions. [2]-[4] This technology, however, can be completed by other features such as predetermined line rating, conductor temperature tracking subsystem, ice prediction subsystem, and sag – clearance simulation subsystem [6]. BME's extended white box model calculates the real-time line rating every 5 minutes, as the weather stations' data are available. Predetermined line rating is simulated hourly since the weather forecast is also refreshed in every hour. For the conductor temperature tracking the extended model is also suitable, on the other hand, a novel, neural network-based black box model was also implemented by BME [8]. The ice prediction subsystem uses a 24 h weather forecast to determine the expected ice type and its physical properties such as its diameter and its additional mechanical load [9]-[11]. The algorithm calculates based on every forecast grid-point data. The sag-clearance simulation subsystem is an essential component of the newly developed dynamic ampacity prediction algorithm. This MATLAB-based software applies the most accurate formulas to determine the position of the conductor with the prescribed accuracy in the whole tension span.

All in all, a complex and far-reaching software background has been implemented to achieve a proper power line management system on the KLLO line.

1.3 Key activities

The first step in the demonstration was the installation of the devices onto the KLLO power line in October 2018. Since the installation, the data collection was continuous, and reliable. During the demonstration period there was an opportunity to install a new device with a completely new camera system including IR function for night imaging on the conductor.

Figure 1 – ELJ experts are installing OTLM devices on Kleče – Logatec line

Besides the installation, a physical server was established at Elektro Ljubljana (ELJ). The server procurement was accomplished according to the preliminary specification.

When the hardware background was implemented, the software design of the DLR system has been established. On the central DLR server, Microsoft Windows, MS SQL, and MATLAB with the required toolboxes were installed. Furthermore, there were initial requirements also regarding the management and functions of the servers' software, such as remote desktop and VPN access.

After it, the central database was established to collect field measurements' data provided by weather stations and line monitoring sensors, to gather weather forecasts provided by the national weather agency and to store the actual load of the line measured by the SCADA system. Moreover, the calculation results of BME's expert system are also accumulated in this database. The data collection process was established in 3 steps. In the first step the data collection of the field equipment – namely the two weather stations and four OTLM devices – was established immediately after the installation of this equipment. Accordingly, these data are continuously collected and stored since October 2018. In the second stage the implementation of BME's system was started. The calculated real-time and predetermined ampacity with BME's extended white box model is available in the central database since the first half of December 2018. Other subsystems of the expert system have been working constantly since that, while the last subsystem, namely the sag – clearance modelling is functioning since the middle of September 2019. In the last step, the need for the most accurate calculation indicated the requirement regarding SCADA measurement implementation in the existing system. Based on SCADA's real-time load measurement, the conductor temperature tracking is fine-tuned. Thus, SCADA measurement was integrated into the system in the middle of April 2019, while the archive SCADA measurements are also inserted into the database retroactively since the beginning of the demo.

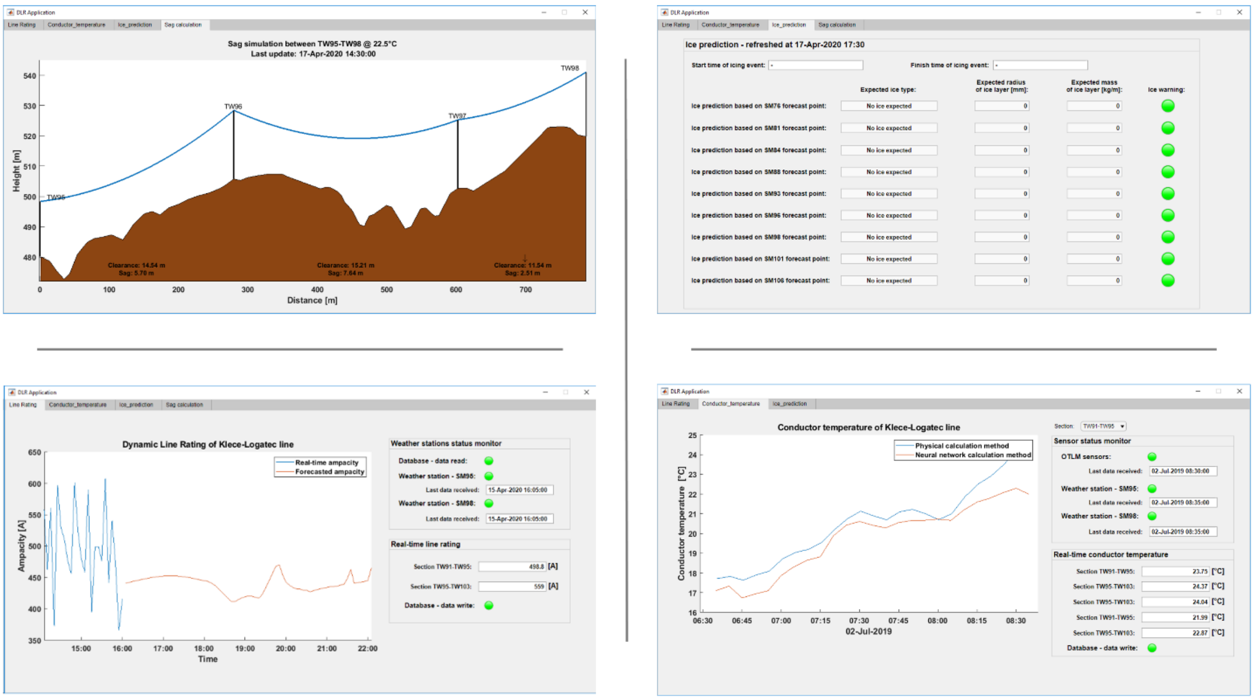

Figure 2 – BME's expert system in operation on ELJ server

Another important step in the demonstration is the validation of the models could be achieved by catenary measurements that could provide data about the inclination value. To validate the applied models and to get information about the lower phase conductors, two catenary measurements were performed on Kleče-Logatec OHL.

1.4 Key results/Main findings

To supervise the utilization of the implemented system data analysis was performed by BME and catenary measurement was performed twice for the selected spans of the line by the University of Maribor.

BME performs data analysis about the reliability and accuracy of the implemented system every month. In general, it can be stated that the two weather stations and four OTLM sensor are also work reliably. There was also an analysis for the OTLM sensors' measurement that focuses on the difference between the minimum and maximum measured current by the three OTLM sensors at the same time. The difference between the average of the measured current by the online OTLM devices and the SCADA current was also compared. The results show that the average deviation is within the acceptance rate for the entire duration of the data collecting period. In this presented period, the accuracy of the sensor was over 95% regarding the SCADA measurements. The temperature difference between the 4 spans was also compared according to OTLM measurements, based on the results some consequences can be deducted regarding the longitudinal conductor temperature distribution, which has been varying between 1.5-3 °C [12].

To find out the accuracy of conductor temperature tracking models the calculated results were compared with the measured values. Both for the BME's white box model and BME's black box model the deviation was in the same range, and the shape of the distributions also fulfils the preliminary expectations.

Catenary measurements were performed to validate the result of the applied models. The first measurement was performed in November 2018 by the Faculty of Mechanical Engineering of the University of Maribor. According to the results of the catenary measurement, the boundary conditions were available to set up the sag determination of OTLM devices through real-time inclination measurements. The second measurement was performed in June 2019. With the second measurement the sag model of the OTLM system was fine-tuned.

During the demonstration Elektro Ljubljana (ELJ) was deeply involved in all the different phases of DLR system implementation since the procurement of the required infrastructure to the use of the continuously evolving system. After the catenary measurements in collaboration with the University of Maribor Faculty of Mechanical Engineering, ELJ also involved their in-house experts, who subsequently repeated the measurement of the catenary together with the University of Maribor. Measurement methods and results were compared, while this cooperation proved very beneficial to both sides. During the implementation of the demo, in cooperation with C&G, ELJ monitors the results of individual functions provided by the OTLM Smart Center. The temperature of the conductor is particularly interesting for ELJ because it gives direct feedback regarding the load of the conductor. Weather station data and OTLM devices provide ELJ sag, ice alarm, and DLR information. The photos from the cameras installed in OTLM devices are very useful especially for ELJ dispatchers who can see the real state of this hilly and forested section of the OHL that was collapsed by ice in February 2014.

1.5 Conclusions

Flexitranstore Demonstration D7.3 presents the implementation of the complex grid management system on the Slovenian Kleče – Logatec (KLLO) 110 kV distribution line. Within the framework of the project, two weather stations and four OTLM sensors were installed on the line providing real-time data for the load and weather parameters in the vicinity of the line. For the monitored territory weather forecast from the national weather agency (ARSO) was also available. One aim of the demonstration was to present the reliability and measurement accuracy of the applied sensors.

Another aim was to gain operational experience for the application of the OTLM ice detection system and BME's complex grid management model. The results of the demonstration verified the positive preliminary expectations, the accuracy, and the reliability of the implemented system meet the requirements of the system operators. During the demonstration, Elektro Ljubljana (ELJ) was also involved in the subtasks and in this way gained insight into the real-time operation of the models and valuable experience from the operational phase. The positive results of the demonstration can further deepen collaborations between the partners and can provide a good basis for further improvements.

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