Experimental icing monitoring system in the Slovenian transmission network

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Abstract— **Territory of the Slovenian transmission network is rather small (covering some 20.000 km^2) but impacted by three different climatic zones (Mediterranean, Alpine, and Continental) and frequently exposed to different level of ice storms. The varieties of ice, which occur on transmission overhead lines, vary with regard to the topography and climatic situation. Based to the statistical methods and data collection the national ice loading map have been prepared for upgrading version of standard for construction of electric power lines. National ice loading map contain three zones with the most tangible zone close to Italian border.**

Transmission and distribution network providers every year report on expenditures due to icing or heavy snow damages in electrical network, which is over 1 M Euro per winter. This is without cost of non-delivered energy.

With the aim of increasing the reliability of the existing network and preparing better observability models for new overhead lines, (designed for a higher degree of resistance against adverse weather conditions) the transmission company has ordered several studies and analyses for the improvement of the existing situation. Objective of those studies were development of better understanding of icing (precipitation and in-cloud icing), distribution over Slovenian territory and improvement of monitor as well as forecast of them. With regard to the selected criteria, the studies proposed the needs for the construction of 17 weather stations, covering complete territory. First 6 stations with software packages for monitoring are already in trial operation.

The function of this new monitoring system, which operates completely in the GIS platform, could include besides of control of high accuracy weather data also online observation of icing, thermal ratings of lines, or/and control of vegetation under the lines.

The ice monitoring system is part of this observation system and the first station is installed in one of the most ice sensitive zones (Tatre) at an altitude of 740 m above sea level at the junction of the Mediterranean and Continental climate zones. It is intended for the surveillance of glaze icing, which already demolished 400 kV line at same location, some years ago. System uses ice sensor Meteo made by Czech producer.

The monitoring weather station is part of the integral monitoring system for overhead lines (DAMOS) connecting six other stations with data transmitting by optical network to the central computer located in S/S Bericevo and by intranet to the users inside transmission company.

I. Introduction

THIS paper dealing with implementation of the first icing monitoring system in the Slovenian transmission network. Atmospherics impacts play paramount role in the reliability of the overhead ground electric power networks. Targeting to improve observability of the Slovenian transmission network (400 kV, 220 kV, and 110 kV) a couple of years ago transmission company developed concept of meteorological stations [3], which assumed to cover measuring of ambient temperature, wind speed and direction, solar radiation, and also icing monitoring and predicting as possible. The concept proposed to build 17 stations covering all the territory of Slovenia (about 20.000 km^2). Last four years many obstacles have been solved and six weather stations constructed and are in on-line operation.

Fig. 1: Slovenia is exposed by three climatic zones

From Fig. 1 it is evident that Slovenian territory in Europe is on the way between Alps on north, Adriatic Sea on western side and continental clime conditions at the Eastern side. This mix of climate zones lead to typical icing conditions impacting electrical overhead networks. The configuration of transmission network is shown at Fig. 2 presenting about 3000 km of corridors of existing network.

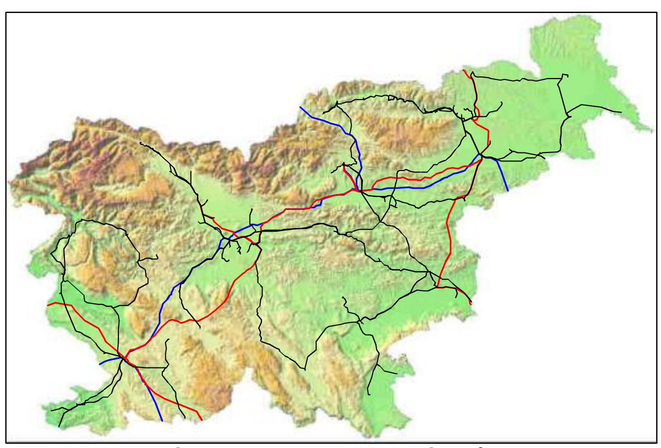

Fig. 2: Slovenian transmission network configuration

Is same time as new observability concept was established a new model for overhead lines monitoring called DAMOS, which was designed in Geographical Information System (GIS) platform, connecting weather stations and sensors over optical communication network installed in the transmission network. All data are transmitted to information center located in central substation Bericevo, where software package enables data handling for different functions in main computer.

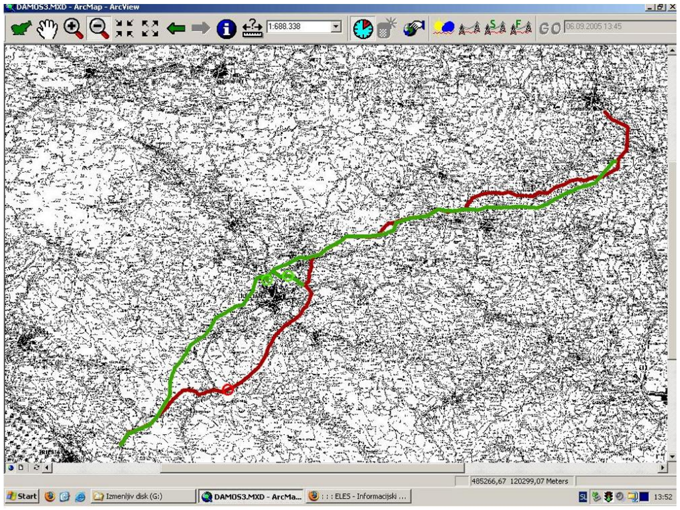

Fig. 3: DAMOS monitoring system for over head lines including ice monitoring

Figure 3 shows front form of program DAMOS indicating corridors of two most important OHL (400 kV and 220 kV) from Nord-East border with Austria to South-West border with Italy. Its enables to monitor different applications as weather conditions (ambient temperature, wind speed and direction, solar radiation, air pressure, and in one location icing), thermal ratings, sag checking, every 5 minutes re-calculating data. With changing the scale it is possible to monitor trac e profiles and technical data details. Presently all data are transmitted over intranet every 5 minutes updated and it is possible to use inside transmission utility. The system is in trial operation with ongoing extensions with new weather stations and up grading applications.
In 2006 a new study [4] was ordered with intentions to develop better understanding of icing (precipitation and in-cloud), their distribution over Slovenian territory, selection of ice detectors, and establishing of ice monitoring as well as forecast models. This study was important support for make decisions on ice monitoring system.
The technical aspects of ice detectors have been analyzed with particular stressing on energy supply and communication issues between sensors and main computer of the DAMOS system, which is located in substation 400/220/110 kV Bericevo near Ljubljana, capital of Slovenia.

In the past Slovenian transmission network had suffered a couple of ice storms which caused a lot of damages. This was the reason that Transmission Company for many years has planned an ice monitoring observatory to collect data for support operation and development activities.

From operational aspects, icing data is important information for operators to be ready for possible critical states in system, but also it is very important information for network designers for construction of new lines. Regulators are very interested for implementation of new technology with aim to increase system reliability and security.

Climate changes and the new Europe Union standardization for construction of new OHL and refurbishment old ones [9] dictate to better knowledge on icing in certain electrical overhead networks.
Researches have focused their analyze to three possible location for ice monitoring observatories, all in corridors of important 400 kV lines, in the zones where glaze ice already damaged transmission lines (Brkini, Unec).

Icing in the air is quite complex meteorological phenomenon, impacted by couple of physical procedures, which are subjected of very different situations in time and space. Particularly it depends of topography of line corridors.
The physical background of icing is basically good covered, but knowledge of frequency and intensity at the particular location is very limited.

II DATA OF ICING STORMS IN SLOVENIA

Presently from meteorological literature it is not evident that any holistic analyses of icing in Slovenia exist. Perhaps, the reason is that certain type of ice doesn't have a large damage effects. But, a couple of contributions analyzed glaze ice particularly due to freezing rain, which causes the most damages. Stated references [1, 2] dealt with these issues in Slovenia and helped to develop icing maps for electric overhead lines. In Fig. 4, it is shown the map of glaze ice threatening in Slovenia based on statistical model. Dark blue means every year high possibility for damages by glaze ice; medium blue means glaze ice every few years and periodically causes the damages; and light blue means possibility for glaze ice but without damages.
The green-blue color means very high altitude above sea and very low probability for glaze icing.

So, in Slovenia the most possible appearance of glaze ice and heavy snowing are at the altitudes between 500 m and 1000 m over sea level, particularly in **South Alpine region** and in the **region of Sneznik (Dinaric mountains)**. Hence, additional collecting data of icing is reasonable in these regions.

Study [4] dedicated three locations for future ice monitoring observatory in Slovenia; two on the 400 kV line Meline-Divaca (in region Brkini) at altitude 740 m above sea level, and one on 400 kV line Bericevo-Divaca (Unec). Fig. 5 shows Slovenian zones for icing based on statistical model and three investigated locations for ice monitoring observation. Those zones are also the zones defined in new Standard for construction of overhead lines in Slovenia [9].

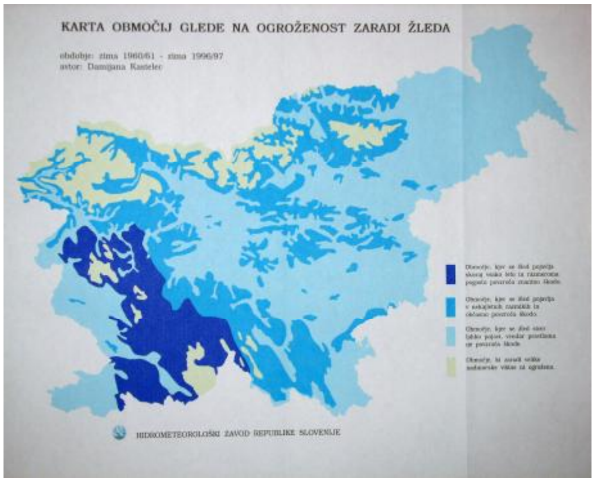

Fig. 4: Map with regions jeopardized by glaze ice (Re: [1])

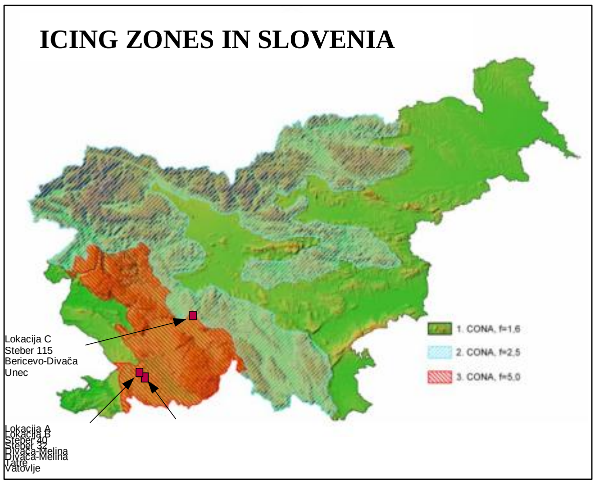

Fig. 5: Three icing Zones based to Standards [9] in Slovenia and locations for experimental ice monitoring in the transmission network

One of the largest damages in Slovenian transmission network was in 1999 when ice storm demolished 400 kV and 220 kV lines in close tracing corridors at the location Unec. Figure 6 shows 400 kV tower demolished at the location Unec in 1999 after storm. This location is considered for potential location for experimental ice monitoring observatory.

Fig. 6: Damages caused by ice storm on 220 kV and 400 kV towers in the same corridor Ljubljana - Divaca

III. SELECTION OF ICE SENSORS FOR OHL

Nowadays many different sensors are in use in different transmission company. In study [4] different ice detectors have been analyzed as Ice detector IM101, Rosemont model 0872, PIM (Pasive Ice Meter), Holooptics and IceMonitor from Sweden, IRM Icing-Rate Meter from HydroQuebec, LID from Finland, Meteo from Czech Republic, etc. Very interesting and wide applied systems are CAT-1 monitoring systems with M-ICE detectors (Germany, Poland, USA). All those ice detectors and developed monitoring systems have different the pros and cons in different environments.

Based on defined criteria

- Commercial attainable,
- Principles of ice sensors operation and data transmission methods,
- Reasonable price for sensors,
- Possibility to integrate with existing Damos system, and
- Possibility for easy movement.

Study have proposed ice detector from Brno (Czech R) with commercial name METEO. This ice sensor gives as output data the mass of ice. Construction of weather station with this sensor doesn't require any switching off overhead line during construction works. Movement of sensor is easy.

A good experience with this sensor as reported in literature [8] was also positive argument.

IV. MODEL OF PROPOSED ICE MONITORING SYSTEM

As stated before three possible locations have been evaluated (Fig. 5):

- **A**, at 400 kV OHL Divaca-Meline (CRO), tower 40, location Tatre, region Brkini, altitude 740 m above sea level, area is very sensitive to glaze ice storms,
- **B,** at same line , tower 32, location Vatovlje, altitude 640 m above sea level; area is sensitive to glaze ice storms; possibility for low voltage electricity supply of weather station, and
- **C,** at 400 kv OHL Bericevo-Divaca, tower 115, location Unec, region Notranjska, altitude 660 m above sea level, area is sensitive to glaze ice and wet snow storms.

The following criteria have been used:

- Importance of OHL corridor,,
- Climate conditions in the corridor and sensitivity of region to icing,
- Possibility for communications at the short listed locations,
- Possibility for energy supply for weather station, and
- Experiences of maintenance staff.

Based on selected criteria for the first icing monitoring station has chosen location A - Tatre in Region Brkini (Sneznik-Dinaric Mountain) at altitude 740 m.

Selected sensor METEO is quite compact device with low maintenance cost, low energy consumption. Energy supplying system was applied by solar cells.

As presented in Figure 7, communication between weather station and system DAMOS is applied by optical network installed at overhead line. As backup system it uses GSM/GPRS mobile communication. The sensor is also equipped with an Ethernet communication port. For the practical use of this communication, a connection within the ELES optical network has been created. The sensor is connected to the optics or the clamp on the OHL tower with the aid of a converter, where it is connected to the optical cable, which is terminated in the substation Divaca. At this substation, it is with the aid of another converter connected into the Ethernet network of ELES. Within the Ethernet network of ELES all data are collected in the data collection centre DAMOS at Beričevo Substation.

The output data of the sensor is the mass of the ice on the measuring rod, the sensor is also measuring the air temperature as well as the speed and direction of the wind. It is capable of collecting measurement data from additional external sensors (solar radiation, ultrasonic sensor for the measurement of wind speed and direction).

The device consists of the body (length: 240 mm, height: 820 mm, width: 240 mm), and the measuring rod, which is pointing in the vertical downward direction. The body of the sensor contains temperature sensors (measurements with a resolution of 0,1 °C), ice masses (up to 20 kg with an accuracy of 0,01 kg), the speed and direction of wind and electronic parts for the processing of measured data, and for the communication with the supervising system.

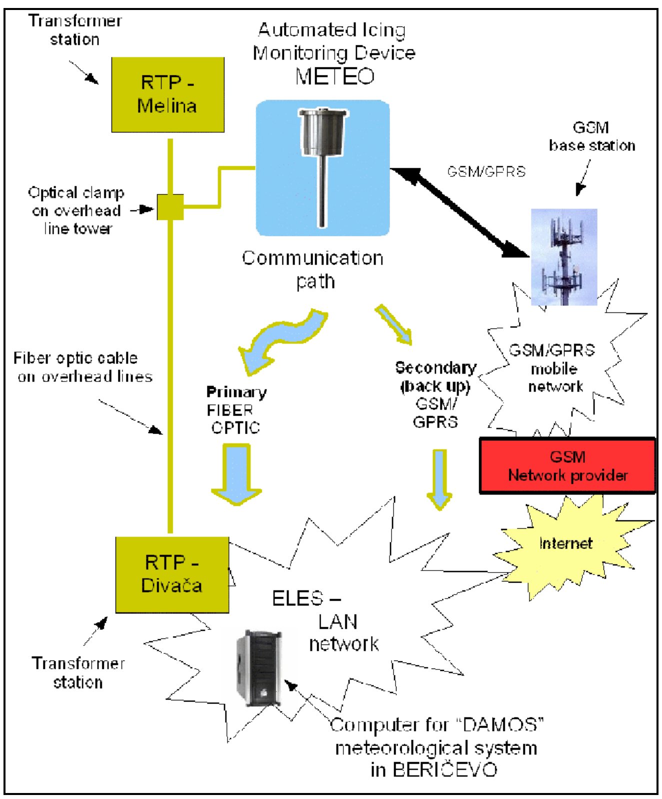

Fig 7: Data communications between sensors and monitoring centre

V. Conclusions

Climate changes more and more impacting to electrical overhead lines. Particularly, high speed winds and ice storms as well as wet snow storms in short time period cause huge damages in the overhead power lines. Slovenian electric power OHL have experienced with huge damages by glaze and wet snow, too. From those reasons existing overhead lines have to be better observed and also construction of new lines must be considered with better resistance to climatic impacts.

On other side new requirements to achieve better reliability of transmission networks and new ICT and sensors technologies enables to improve observability and utilisation of existing overhead transmission lines.

Analyse of different ice detectors and already operated transmission monitoring systems world wide have shown a suitable solution for Slovenian environment with Meteo sensor, which was selected as the first experimental ice monitoring system.

New experimental icing system in Slovenian network en able to monitor and recording ice intensity as well as all other weather parameters for integral OHL monitoring system DAMOS.

Based on selected criteria for the first icing monitoring station has chosen location Tatre in Region Brkini (Sneznik-Dinaric mountain) at altitude 740 m, in the tower no. 40 on the interconnection 400 kV line Meline (Croatia) – Divaca (Slovenia). Station is connected in intranet transmitting data every 5 minutes to all eligible users.

VI. Acknowledgment

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