International Conference on Condition Monitoring, Diagnosis and Maintenance -
CMDM 2011
177

Dynamic Thermal Line Rating in Slovenia

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SUMMARY

Due to the growth of consumption and difficulties with the erection of new overhead transmission lines, loading of majority of the power lines is gradually increasing and pushing some lines into violation of the current margin at which the line is designed to operate. This in turn means that the probability of high line loading, high temperature and low wind speeds which tailor the phase conductor temperature. As a result, power utilities and system operators are looking for solutions to increase ampacity of the existing OHL without increasing the risk of equipment or system failure due to higher loading. One approach to manage the reliable operation of these systems is to utilize modern monitoring techniques, which help to safely drive overhead line over the static thermal limit. The results obtained from a pilot project 110 kV OHL (Idrija – Ajdovščina) where several monitoring devices and systems were used are presented and discussed. The measurements were obtained from the following measuring devices and systems: OTLM – overhead transmission monitoring system for conductor temperature, DAMOS station – for outside temperature, wind speed and direction, and sun radiation, and ODIN – VIS –dynamic thermal rating module and Line load module). Measurements and events where transferred to the control centre (SCADA) via standard IEC protocols and presented in 3D (4D). The results show that with the utilization of conductor temperature measurements, ambient measurements and with the help of thermal rating algorithms increase in power loading is possible.

KEYWORDS

Over –head –line – temperature – measurement – energy – transmission – OTLM – ODIN - DLR

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1. Introduction

Due to the growth of consumption and difficulties with the erection of new overhead transmission lines (aesthetic and environmental grounds, or large capital investments in transmission systems), loading of the power lines is gradually increasing and pushing some lines into violation of the current margin at which the line is designed to operate. Additional uncertainty is also incentivising a higher percentage of energy production from renewable that causes unregulated and distributed generation. In the past, transmission lines were designed at assumption that the maximum current load was half of the thermal limits. This assumption was acceptable since the normal current load should be only about a quarter of a permanent allowed flow guides. Therefore, the likelihood that the high current load would occur simultaneously with high outside temperatures and low wind speed is extremely low. However, due to the persistent increase in electricity consumption and delay investment in new transmission capacity of network, the normal (average) current load significantly increased [1]. While designing new overhead line, line thermal ratings are normally calculated assuming conservative weather conditions and a maximum allowed conductor temperature, which allows adequate electrical clearance and avoids annealing to aluminium or copper wires. If we take into account time dimension at which the lines were suppose to operate in, we can also track changes in constructions under OHL [besides OHL aging] . Currently all transmission and distribution is in the need for uprating increasing capacity of many existing lines to be referred as the category of essentially problems of network companies. To facilitate high penetration levels of these new network participants it is crucial to adopt new control strategies in which the distribution systems are operated actively [4].

2. Dynamic Thermal Line Rating [DLR] in Slovenia

This article summarizes findings and suggests further steps in order to achieve maximum ampacity of 110 kV overhead line [OHL] Idrija – Ajdovščina (Slovenia) in the way that it doesn't influence safety and reliability of OHL operation. Selected transmission line was chosen because of its importance to Slovenian TSO and connection to PSP Avče. While considering the safety margins it is obvious that the key information is the conductor temperature. The conductor temperature can be measured or calculated. However the information about temperature, either measured or calculated and presented in control room, gives information only about present (real time) line temperature. With such information operator can monitor when specific line is approaching temperature limit. But we must take into account, that the same temperature of conductor in winter or in summer period reflects completely different current situation. The current conductor temperature alerts operator if it's approaching temperature limit, because it takes into account momentarily influences (current, wind, sun radiation) that reflect on the line temperature. However, the conductor temperature alone does not give to operator needed information such as: at what percentage of allowed load is the line at the moment; what is the allowed maximum load of the line; about the present capability of the conductor to cool. For this reason and future prediction someone needs to measure also the ambient conditions; temperature – with most impact on conductor heating, wind speed – with most impact on conductor cooling, wind direction and sun radiation. Based on this information and standard conductor thermal model it is possible to calculate the maximum thermal current. But for on line dynamic thermal rating (DLR), we must also consider set up changes of substation protection equipment that can process and act according to received data.

2.1 Line characteristics

Selected 110 kV transmission line 110 kV Ajdovščina - Idrija was build in 1987 and consists of 120 spans with total length of 28,321 m (figure 1 and 2). Installed conductor is 240/40 (ACSR) and was build according to JUS standard or now equivalent EN 50182 (243-AL1/39-ST1A) and for maximum temperature 40 °C. The lowest point is in Ajdovščina with on 85.9 m and the highest on 935.36 m. The standard deviation is 256 m, and indicates extremely rugged terrain. Maximum height difference between the two towers is 186.6 m.

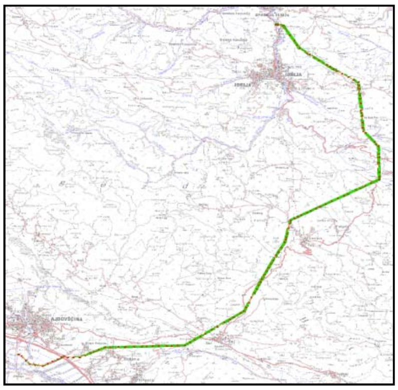

Figure 1: 110 kV transmission line Ajdovščina – Idrija

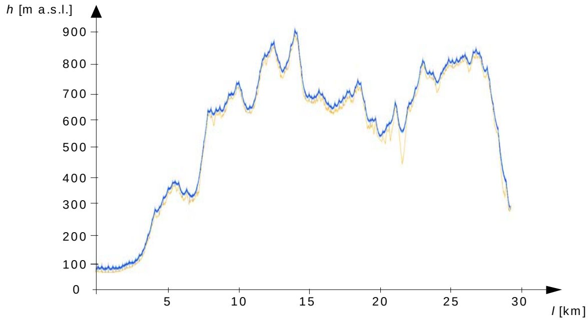

Figure 2: Longitudinal profile of 110 kV line route Ajdovščina (left) - Idrija (right). Data obtained by laser scanning (2003, air temperature 19 °C) (ground profile – orange, conductors – blue)

Before conducting a study, we have undergone short-term scenarios of increased ampacity for the mentioned OHL. Calculated results show that beside current, atmospheric conditions (particular ambient temperature and wind speed) have significant impact on the heating of the wire (figure 3).

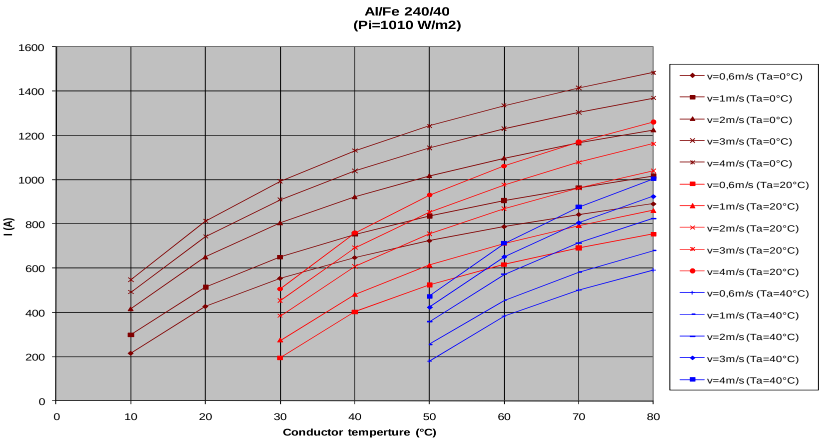

Figure 3: Values of thermal current for conductor ASCR 240/40 with various parameters

2.2 Equipment and software used for determination of maximum grid ampacity

Conductor temperature measurements improve the thermal rating as they offer the initial values for the calculation of the temperature response of the conductors in emergency situation eg. when the line loading exceeds the maximum thermal current.

Line temperature measurements were performed by the OTLM System (overhead transmission line monitoring – see figure 4). OTLM device enables measurements of temperature and current of power lines simultaneously. Measurements are transmitted to the control room via GSM channel. For this project we used additional current measurement from SCADA.

Figure 4: OTLM device

Ambient conditions measurements were performed by the DAMOS system. DAMOS units are implemented in all 400 kV substations in Slovenia and they measure weather conditions (air temperature, wind speed, wind direction and sun radiation).
Up to date accurate data about **conductor clearances to ground,** crossed objects were obtained with highly efficient airborne LIDAR survey technology widely used for this purposes. The LIDAR survey data were imported to specialized software used for 2D and 3D line modelling. OTLM System and DAMOS System together with obtained survey data about terrain and on ground objects after further analyses provide an accurate and up to date scheme about power line element status under various meteorological and operating conditions.
For determination of **maximum load – current capacity** we used software modules (dynamic thermal rating module and line load module) from ODIN – VIS (figure 5 and 6).
Measurements and high-resolution events were transferred to selected computers and the control centre (SCADA) via standard IEC protocols and presented in 3D (4D) format as percentage of momentary load versus available momentary maximum load (dynamic rating).

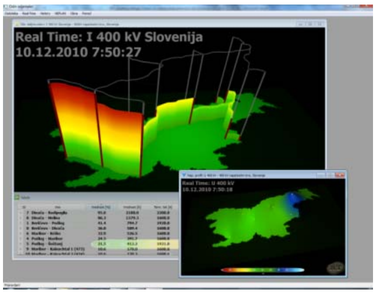

Figure 5: Line load module

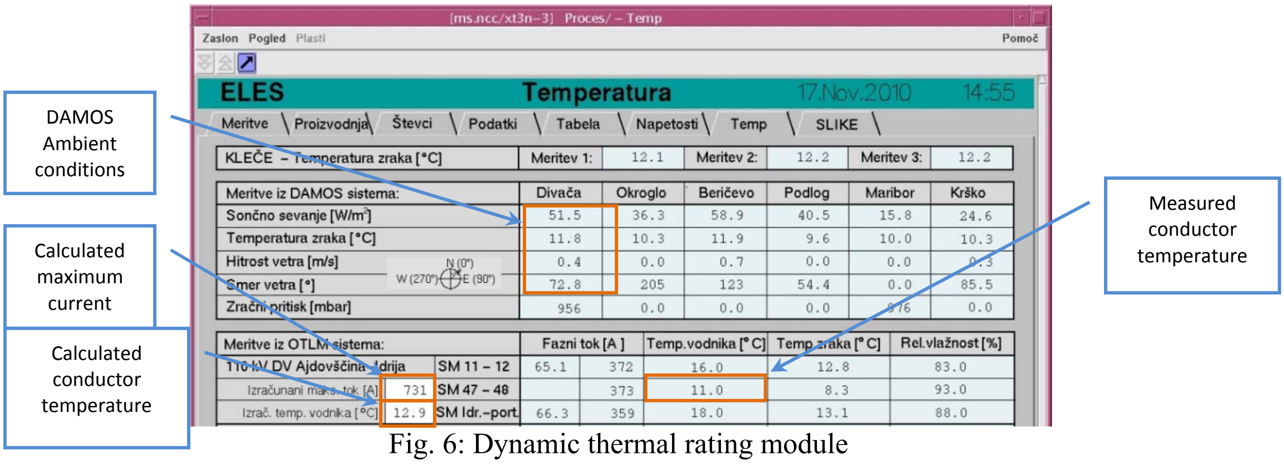

Fig. 6: Dynamic thermal rating module

The number and position of measuring points on the line was determined by the following factors: length of the line, geographical situation, climate (meteorological) conditions, geo-mechanical and hydrological conditions of the land, crossing of different supply lines and traffic routes, value and quality of the GSM signal, etc. [2].

2.3 Findings and analyses

For calulaction of maxmim current, we used on line and history data about: solar radiation, ambient temperature, wind speed with wind direction and LIDAR survey data. The figure 7 and 8 shows that the greatest impact on the ampacity increase are wind speed and ambient temperature. Smaller effect (but not negligible) is contributed by the intensity of solar radiation.

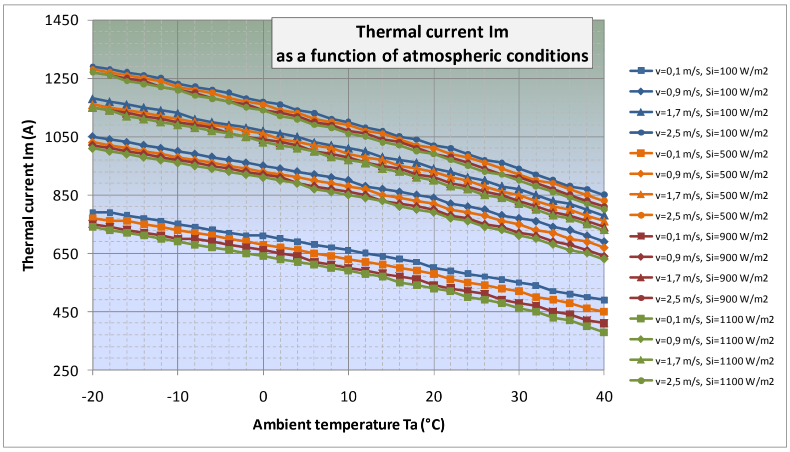

Figure 7: Maximum ampacity is interdependent with atmospheric parameters

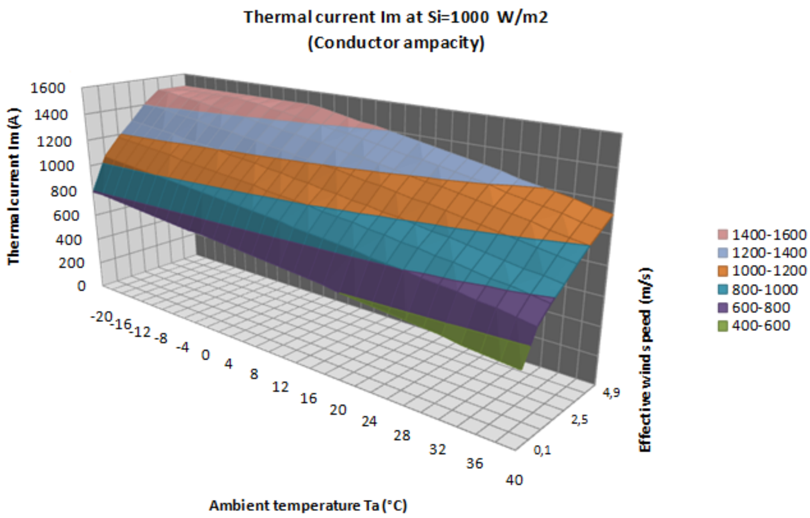

Figure 8: Current limit as a function of effective wind speed and ambient temperature. The value of solar radiation Si = 1000 W/m2

3. Conclusion

Power utilities and system operators are looking for solutions to control increased capacity of the existing OHL without increasing the risk of equipment or system failure due to higher loading. As we can see from the study "OHL thermal load monitoring in Slovenia" [3] , more than 90% of the time (according to environmental conditions) TSO is able to put additional load to transmission lines even if the majority of OHL projects waer build for maximum conductor temperature 40 ° C.
As for OHL 110 kV Ajdovščina – Idrija the study [1] demonstrates, that with one exception (critical span) , conductor sag and temperature are within required levels or they can be achieved with minor investments (clearing of vegetation on a few spans) . Because only one critical span can reduce energy flow between two substations, analyses show that specific critical span has violated safety distance at conductor temperature 40 °C. At the same time, in case of favourable weather conditions (moderate air temperatures and moderate wind speed) it is possible to increase phase current, without violating the safety limit or the maximum conductor temperature (80 °C) up to 731 A. Because of present protection relay settings, permanent maximum operation current is set to 645 A; if we would like to increase this line rating (from static to DLR) on OHL 110 kV Ajdovščina – Idrija, we suggest the following solutions:

- Replacement of protection relay with new one, that is adjustable in accordance to our data.
- **Conductor tension adjustment** that will ensure that temperature is the only line restrictions [thermal limits].

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