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CIGRE 2016

B2-105

Operational aspects of dynamic line rating. Application to a real case of grid integration of wind farms

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SUMMARY

Dynamic line rating is a technique that is becoming more and more important in order to increase the capacity of existing overhead lines without upgrading the infrastructure in a significant way. This paper summarizes the methodology and the most important results related to the project DYNELEC. In this project VIESGO Distribution has developed this technology from scratch, not only including the technical design but also the legal approval for this kind of operation by government agencies. One of the novelties of this research project is related to the fact that since January 2015 the Dynamic Thermal Rating (DTR) is computed using the new CIGRE TB601 "Guide for Thermal Rating Calculations of Overhead Lines" that was published in December 2014. Currently, there has been a successful pilot project running since 2012. In 2015 this project obtained the final approval from the government.

KEYWORDS

thermal rating; ampacity; overhead line temperature; weather parameters; real-time monitoring; OHL (Overhead Line), ACSR (Aluminium Conductors Steel Reinforced),

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1. INTRODUCTION

The installation of new wind farm facilities in remote areas that are far away from the transmission networks is motivating the use of the existing distribution networks as elements for their grid integration. In addition, as the demand for electricity is continuously growing in some coastal areas the available capacity of the existing infrastructures is becoming more and more reduced. The construction of new lines is limited by a number of constrains, such as economic, environmental, regulatory and even social.

A way to overcome this problem is by improving the capacity of the existing infrastructures. The most obvious approach is to operate the lines by using Dynamic Thermal Ratings (DTR). The optimization of the line thermal limit is a methodology that has been widely analysed for the last two decades. Organizations like CIGRE and IEEE have proposed standards that face this problem by means of step-by-step methodologies. The basic approach of both CIGRE TB601 [1] and IEEE 736.2012 [2] is to define the heat balance equation in the conductor. In [3] it can be found a comparison of the application of both methodologies to a real case.

$$m \cdot c \cdot \frac{dT}{dt} = P_J + P_S + P_M + P_i - P_c - P_r - P_w \quad (1)$$

where m is the mass per unit length of the conductor $(kg \cdot m^{-1})$, c is the specific heat capacity of the conductor $(J \cdot kg^{-1} \cdot K^{-1})$, P_J is the Joule heating, P_S is the solar heating, P_M is the magnetic heating, P_i is the corona heating, P_c is the convective cooling, P_r is the radiative cooling and P_w is the evaporative cooling. All the values of P are computed in $(W \cdot m^{-1})$.

In steady-state it is assumed a thermal equilibrium condition $(\frac{dT}{dt} = 0)$ in which the maximum conductor temperature is established as a constrain in order to computed the conductor thermal rating I_{CTR} for a specific maximum conductor temperature $T_{c,max}$:

$$I_{CTR} = \sqrt{\frac{P_S + P_M + P_i - P_c - P_r - P_W}{R_{AC}}} \cong \sqrt{\frac{P_S - P_c - P_r}{R_{AC}}} \quad (2)$$

From a general point of view, corona and evaporative cooling can be neglected. As the cable used in this project is a two-layer LA-280 HAWK, the magnetic heating can be omitted as well. The computation of P_S, P_C, P_r and even the value of R_{AC} depend on weather conditions surrounding the cable.

2. AMPACITY PROJECT “DYNELEC”

The dynamic operation of transmission and distribution networks is a non-trivial task that goes beyond the scientific thermal model proposed by both IEEE and CIGRE. It must consider technical and legal aspects that have to be solved before the move from static to dynamic limits.

Figure 1 summarizes the protocol followed by VIESGO in project “DYNELEC”. From a practical point of view, the DTR was computed using CIGRE WG22.12 [4] from the beginning of this pilot project in August 2012 to December 2014. Since January 2015 the DTR has been evaluated using CIGRE TB601 [1]. This methodology can be considered a novelty considering other research projects put to the test before the approval of CIGRE TB601.

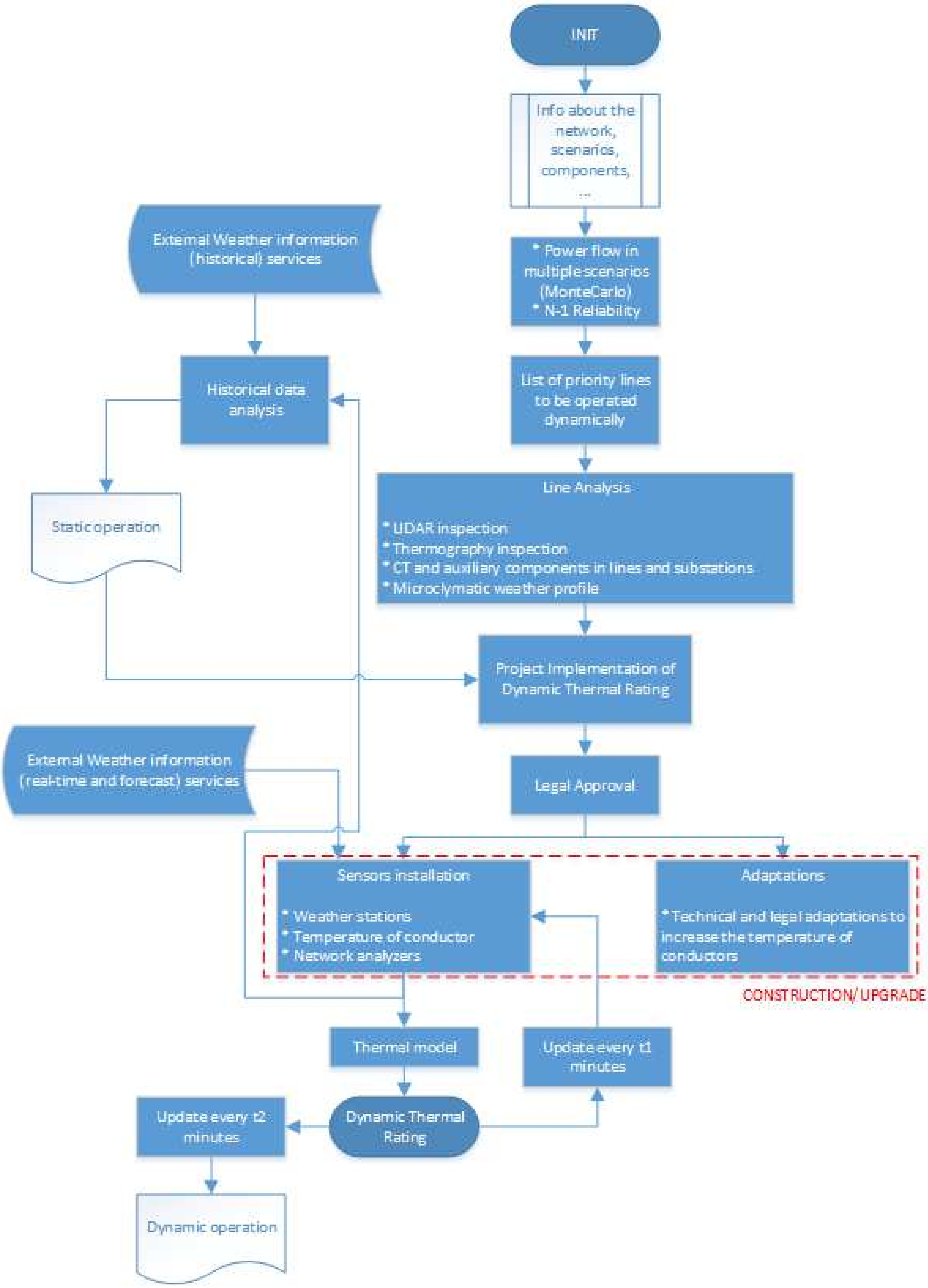

Figure 1. Flow diagram of the methodology to operate the lines in dynamic mode.

Tasks like selecting the optimal location for the weather stations have been carefully analysed. An extensive measurement of weather conditions has been carried out for the last three years in several weather stations installed in places considered hot points in a previous climatological study from the point of view of cable cooling.

The climatological study was developed using real data from available weather stations and also weather prediction from forecasting models like HIRLAM. Figure 2 shows the quantile 75% in the area surrounding the line (represented by small circles). Yellow circles show the sections of the overhead line where it is expected to have the highest ambient temperatures and solar irradiation and also the worst wind cooling conditions.

In addition, there are several aspects to take into account when the cable is operated at high temperature: line sag, cable joins, current transformers, breakers, etc. Once the location of weather stations was obtained, it was necessary to analyse all the aspects related to both communication and security. In the full paper, the problems related to the real-time operation using DTR are explained.

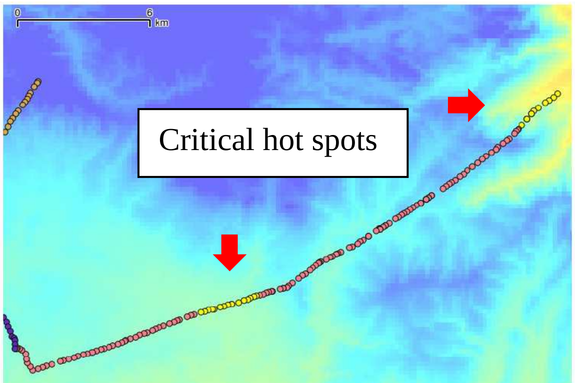

Figure 2. Example of the graphical summary of the climatological study in the area surrounding the line.

Once the analysis of critical hot spots was performed, several weather stations and conductor surface temperature meters (STM) were installed in order to measure the physical parameters that have to be supplied to the DTR. Figure 3 shows pictures with the installed STM.

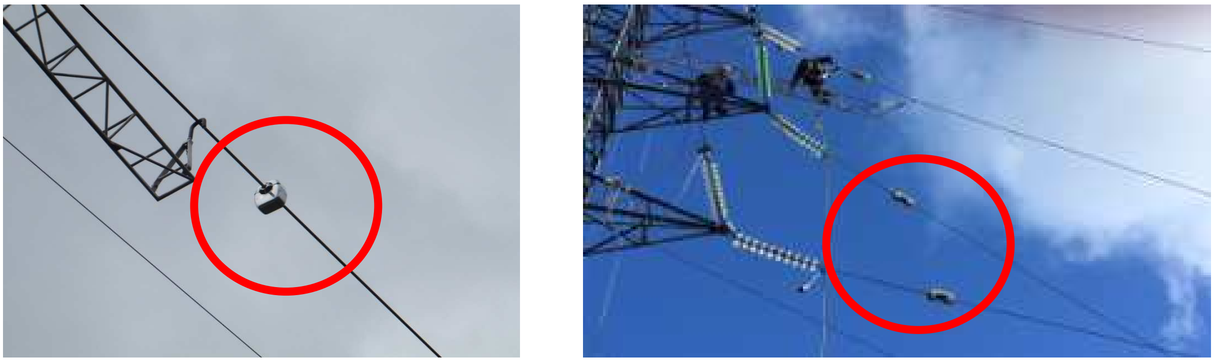

Figure 3. Conductor surface temperature meters.

3. RESULTS

There are several sets of results than can be provided using extensive data mining techniques:

- Information about weather conditions.
- Information about dynamic thermal operation of the network.

Figure 4 summarizes the values of the DTR as a function of the weather conditions. The grid of panels show how important wind speed, ambient temperature and solar irradiation is in order to compute the ampacity.

The results have been obtained from a pilot study that has been dynamically operated since June of 2012. The operation is supported by several weather stations that are located at both ends and also at an intermediate point defined by the microclimatic study. During this preliminary study supported by a research project INNPACTO and RETOS partially funded by the Spanish Government. The line current has been above the static rating for more than 880 hours.

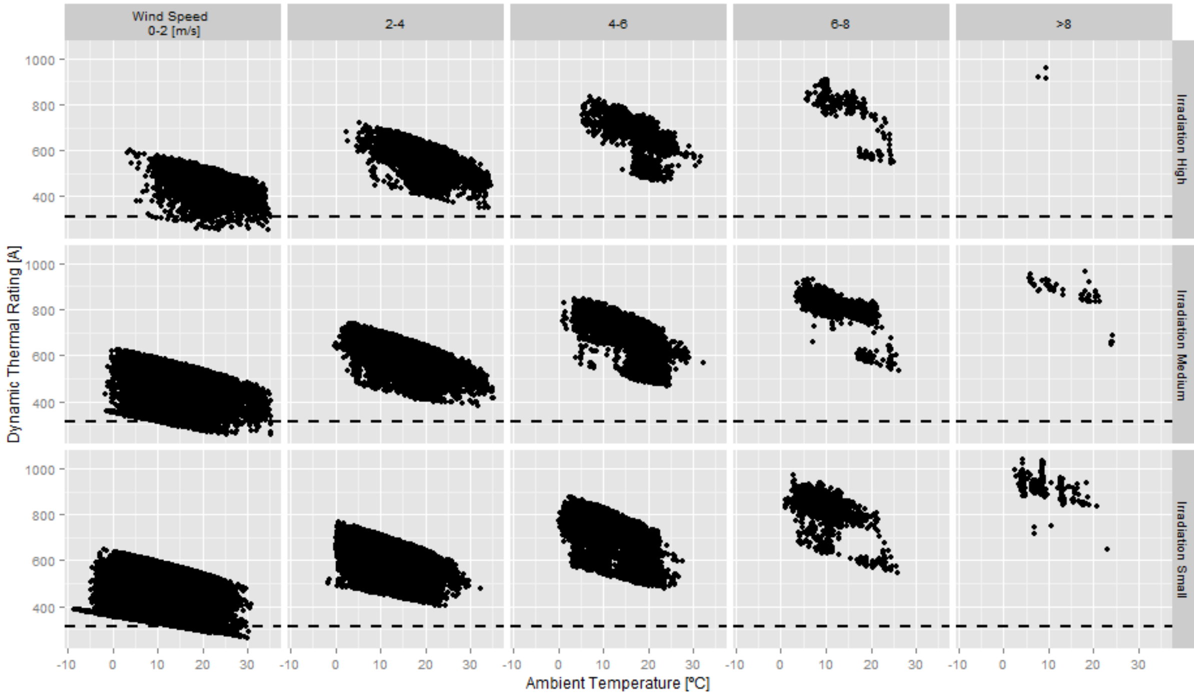

Figure 4. Dynamic Thermal Rating vs weather conditions (Static rating = 314 A).

Figure 5 shows the histogram of values of current during the operation of the line above the static rating (314 A).

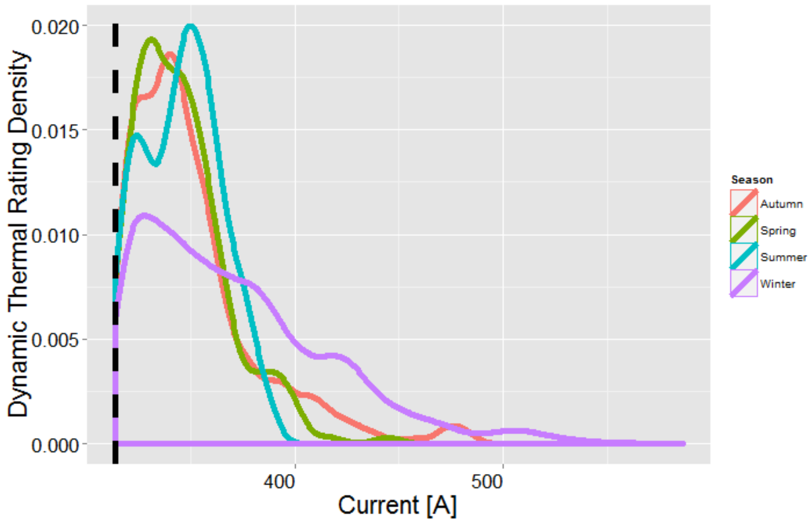

Figure 5. Density values of current above the static rating grouped by season.

Figure 6 shows an overhead line that has been dynamically operated. It is important to underline that line current was operated at values that were up to 79.8% greater than the static rate.

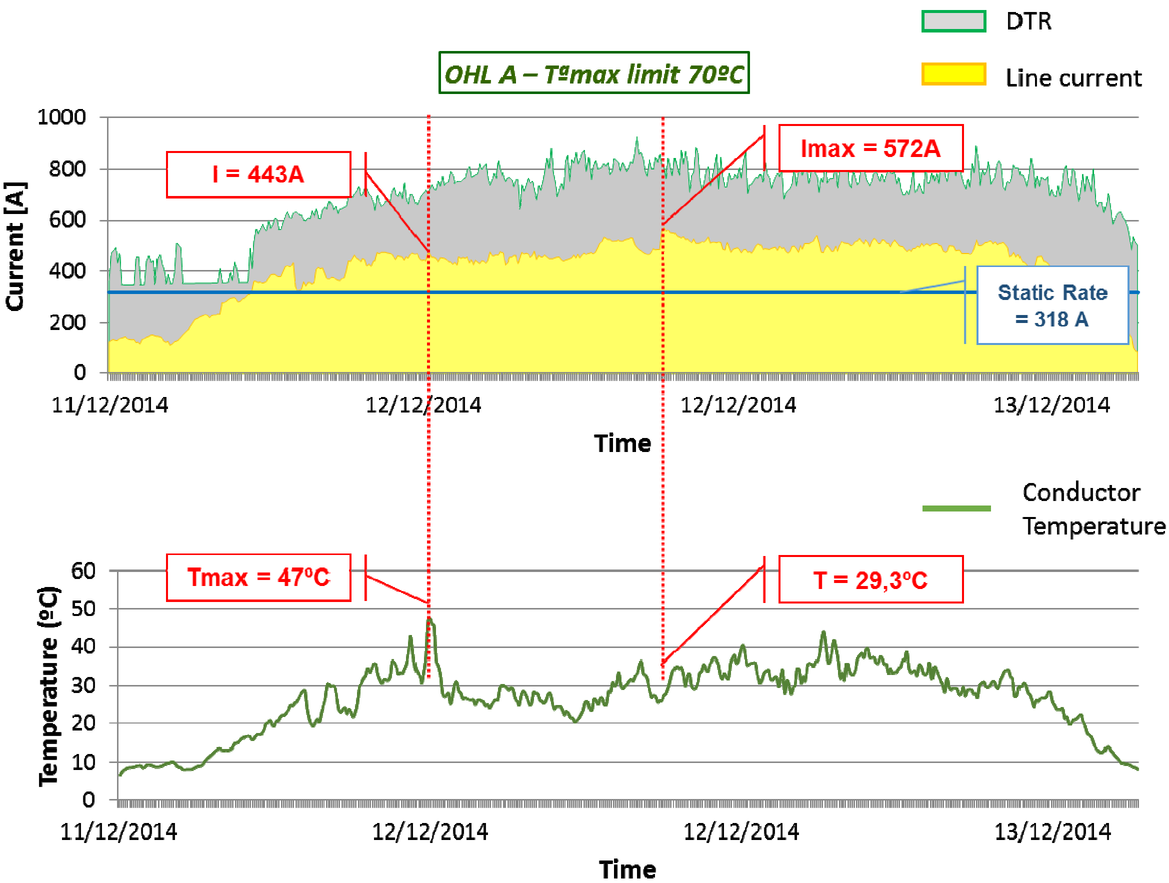

Figure 6. Example of a real DTR operation.

4. CONCLUSIONS

The dynamic operation of distribution networks can be considered a suitable solution in applications like wind farm integration in which overhead lines have to operate near their operational limits when wind speeds have high values. However, the industrial operation using dynamic thermal rating involves a complex methodology that includes not only the thermal model but also legal and technical aspects that have to be solved in advance in order to guarantee that operation is safe and reliable.
This paper summarizes the methodology and the most interesting results related to a pilot project that puts this technology to the test. The paper also describes the methodology followed by the DSO in order to obtain the legal approval from the government to operate the line using DTR.

ACKNOWLEDGEMENTS

The authors would like to thank all their colleagues from VIESGO Distribution Spain and Arteche SmartGrid who contributed to this paper as well as the Spanish Ministry of Economics and Technology which partially supported the pilot project in Galicia under the grants IPT-2011-1447-920000, ENE2013-42720-R and RTC-2015-3795-3.

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