Distributed vs spot temperature measurements in dynamic rating of overhead power lines

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Abstract

The increase of global energy demand and new ways of electricity production are two of the main challenges for the power sector. The electric market has to address the addition of new and renewable sources of energy to the energy mix and to be able to integrate them into the grid, while maintaining the principles of robustness, security and reliability [1]. All of these changes point to the creation of smart grids, in which advanced generation, information and communication technologies are needed.

An accurate knowledge of the electric grid state is crucial for operating the line as efficiently as possible and one of the most important grid parameters to be measured and controlled is the temperature of the overhead conductors due to their relation with the maximum allowable sag of the line and its thermal limit (annealing).

This paper presents the results of real-time monitoring of an overhead power line using a distributed temperature sensing system (DTS) and compares these results with spot temperature measurements in order to estimate the loss of accuracy of having less thermal information. This comparison has been carried out in a 30 km long distributed temperature sensing system with fiber optic inside a LA-455 conductor and 6 weather stations placed along the line. An area of influence is defined for each weather station corresponding to the orography of the surroundings. The spot temperatures are obtained from the DTS in the nearest point from the weather stations assuming these six locations to be the ones where the spot temperature measurement equipment would be located.

The main conclusion is that, in the case of study, spot measurements are enough to obtain a good approximation of the average temperature of the line conductor.

Keywords: distributed temperature sensing system (DTS), power line, dynamic rating, spot temperature

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1. Introduction

The increase of global energy demand and new ways of electricity production are two of the main challenges for the power sector. The electric market has to address the addition of

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new and renewable sources of energy to the energy mix and to be able to include them into the grid, while maintaining the principles of robustness, security and reliability. All of these changes point to the creation of smart grids, in which advanced generation, information and communication technologies are needed [2, 3].

An accurate knowledge of the electric grid state is crucial for operating the line as efficiently as possible and one of the most important grid parameters to be measured and controlled is the temperature of the overhead conductors due to their relation with the maximum allowable sag of the line and its thermal limit[4].

This paper presents the results of real-time monitoring of an overhead power line using a distributed temperature sensing system (DTS) [5, 6] and compares these results with spot temperature measurements in order to estimate the loss of accuracy of having less thermal information.

2. Materials and methods

The system of the study is a 220 kV line placed in the north-east of Spain with a LA-455 conductor and seasonal static rates (790 A spring, 730 A summer, 760 A autumn and 870 A winter) with a length of approximately 30 km. The line has 6 weather stations distributed uniformly along the line as can be seen in Figure 1. Ambient temperature, humidity, wind and solar ration data are provided every 5 minutes for all the positions.

Additionally, this line has a Distributed Temperature Sensor (DTS) that monitors approximately 10,200 points along the line with a resolution of 2 meters. The values of conductor temperature are provided approximately every 10 minutes. For the operation, the line has been divided into 23 sections. A section is understood as the set of consecutive spans with the same direction. Furthermore, 6 areas of influence are selected for each weather station corresponding to the orography of the surroundings.

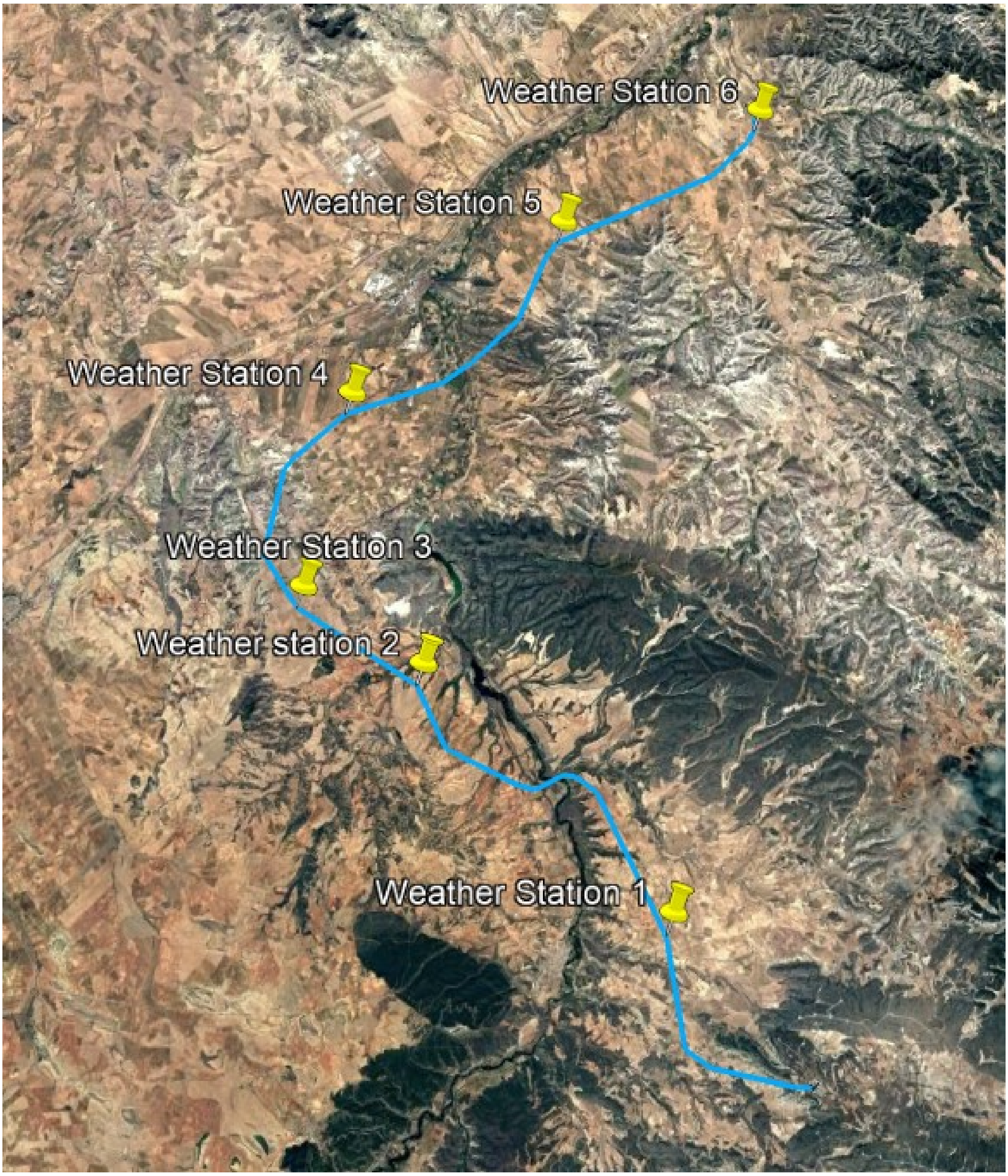

Figure 1: Weather stations placed in the line

From 10 September 2013 to 31 March 2014 environmental conditions and conductor temperature measurements were recorded and all the information was then analyzed in several ways in order to obtain a better knowledge of the accuracy of the measurements. The idea was to estimate the loss of accuracy when just spot temperature measurements can be recorded, in this case one measurement close to each weather station, instead of having all the distributed thermal information.

To do so, the average, maximum and minimum temperatures obtained in each area of influence by the DTS were stored with 10 minutes resolution. At the same time, the closest DTS measurement to the weather stations were also stored.

3. Results

Once the type of monitoring system used in this study was explained, the main results are presented. This section is divided in the results of the spot temperature measurements and the distributed ones and then a comparison between both is made.

3.1. Spot temperature measurements, Tc

The spot temperatures are obtained from the DTS in the nearest point from the weather stations assuming these six locations to be the ones where the spot temperature measurement equipment would be located.

3.2. Distribution temperature measurements, Tmax, Tmin, Tav

The distributed temperature measurements are divided in the areas of influence of the 6 weather stations and the average, Tav, the minimum, Tmin, and the maximum, Tmax, temperatures recorded in every area are presented.

The maximum temperature difference detected between the maximum and the minimum temperature measurements in an area of influence was 24.8°C.

If this data is split in the different areas of influence, the maximum and minimum differences are summarized in Table 1.

Table 1: Maximum and minimum temperature differences

Area	Max. diff.	Tmax	Tmin	Tav	Min. diff.	Tmax	Tmin	Tav
1	24.8	30.6	5.8	15.5	5.3	23	17.7	20.2
2	16.7	24.6	7.9	15.9	4.4	27.7	23.3	25.6
3	17.8	22.6	4.8	12.4	4.2	11.4	7.2	9.3
4	20.1	21.4	1.3	8.9	4.1	18	13.9	15.7
5	19.3	34.4	15.1	24.3	4.8	9	4.2	6.6
6	19.5	19.5	0	14.6	4.4	8.1	3.7	5.8

It can be noticed that the minimum difference is between 4 and 5°C and the maximum between 17 and 25°C. Another interesting result is that this difference increases as the ambient temperature decreases as can be seen in Figure 2. This is an important aspect in the study of the critical values as the differences are reduced when the ambient temperature increases.

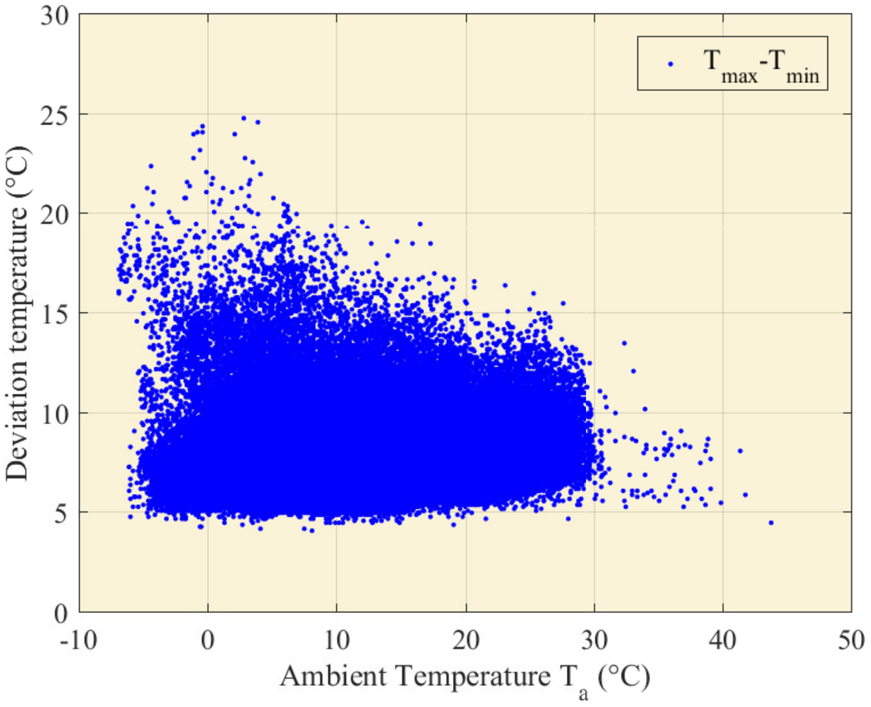

Figure 2: Temperature difference vs ambient temperature

However, the most critical parameter in the decrease of the difference between the maximum and minimum temperature measured in an area of influence is the wind speed. As it increases, the distributed temperature tends to be more homogeneous as can be seen in Figure 3 and it is predicted in the literature [7, 8].

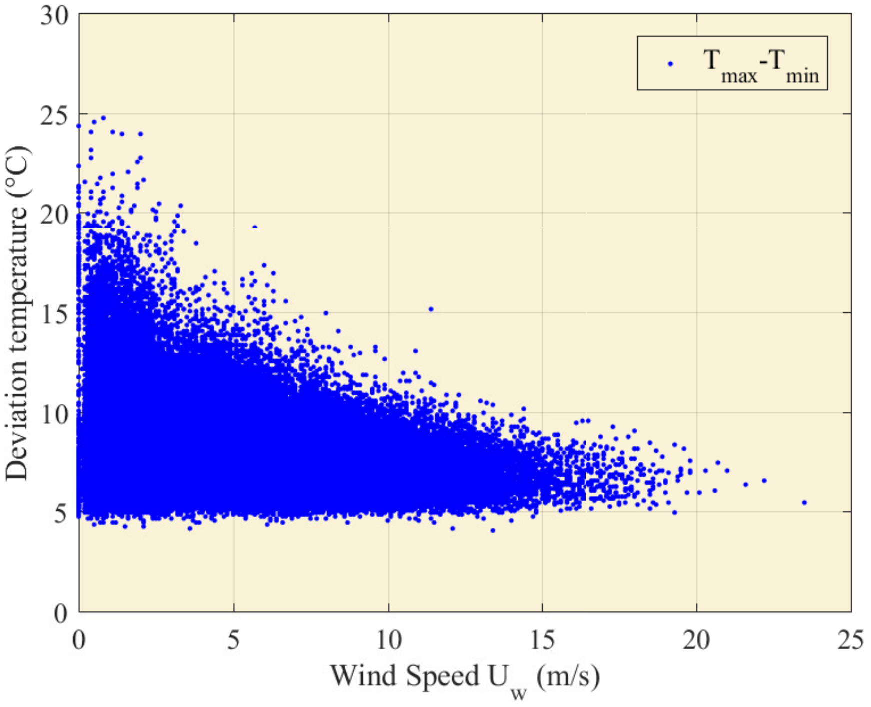

Figure 3: Temperature difference vs wind speed

3.3. Distributed vs spot temperature measurements

The first thing to be noted is that the average of the distributed temperature and the spot temperature measured nearby the weather station are very similar, with the main difference in the smoothness of the temperature profile and with variations lower than +-5°C in more than 99 of the cases as can be seen in figures 4 and 5.

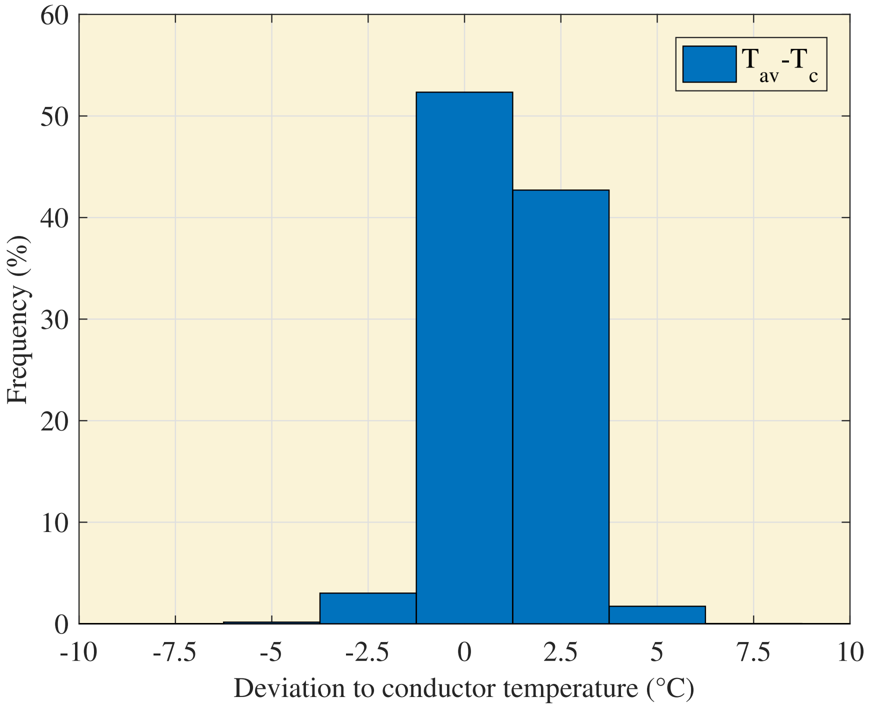

Figure 4: Temperature difference frequency ($T_{av} - T_c$)

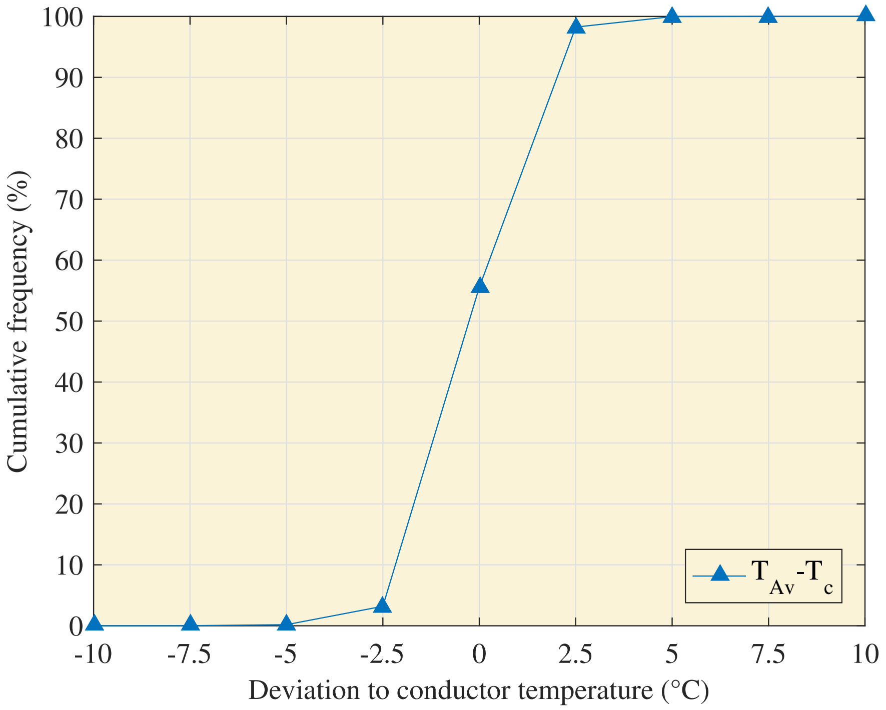

Figure 5: Temperature difference accumulated frequency $(T_{av} - T_c)$

As a matter of example a specific day is represented in figure 6 with the values of the spot temperature, the average, minimum and maximum distributed temperatures for the corresponding area of influence. Furthermore, solar radiation, ambient temperature and current are also represented.

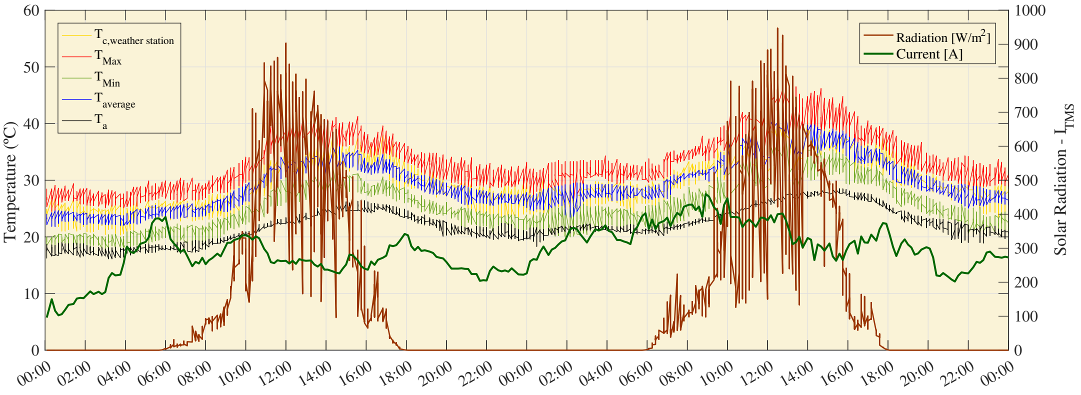

Figure 6: Main line and weather parameters for a specific day

Even in the cases with the highest conductor temperatures the differences between the spot and average temperature are inside +-5°C. This is an important conclusion in favor of the discrete temperature measurements to be extrapolated as the average vane temperature to calculate sag elongations.

Table 2 shows the average of the standard deviation of Tc, Tav, Tmax and Tmin for the 6 areas of influence, i .e, in every recorded sample the standard deviation between the values of the measures of the six areas of influence is calculated and then the average of the standard deviation for all the recorded samples is summarized.

Table 2: Average of the standard deviation between areas of influence

Temperature measurement	Standard deviation
Tc (spot temperature)	1.6
Tav (average temperature of the area of influence)	1.2
Tmax (average temperature of the area of influence)	1.7
Tmin (average temperature of the area of influence)	1.2

In order to continue evaluating the effect of measuring the distributed temperature and the spot temperature, the average of the distributed temperature measured for the total length of the line is compared with the average of the temperature measured in the 6 spot zones, close to the weather stations. The result is that for the more than 17.000 measurements, the difference between making the average of all the distributed temperatures and the average just for the 6 spot measurements is less than 3°C, with a difference average of 0.1 and a standard deviation of 0.5. Figures 7 and 8 represent the frequency and accumulated frequency of the difference between the two averages.

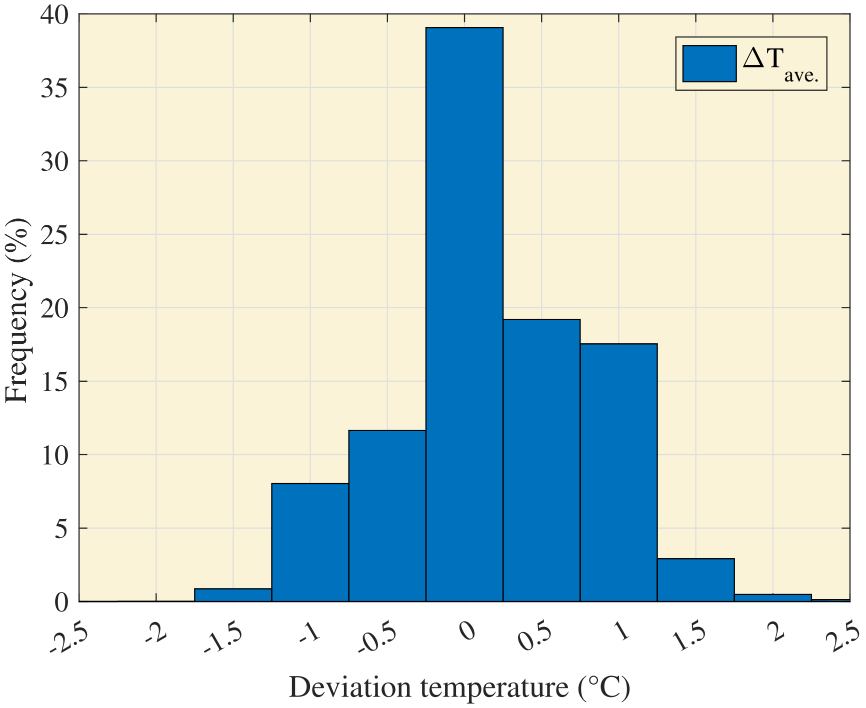

Figure 7: Temperature difference frequency ($\overline{T_{av}} - \overline{T_c}$)

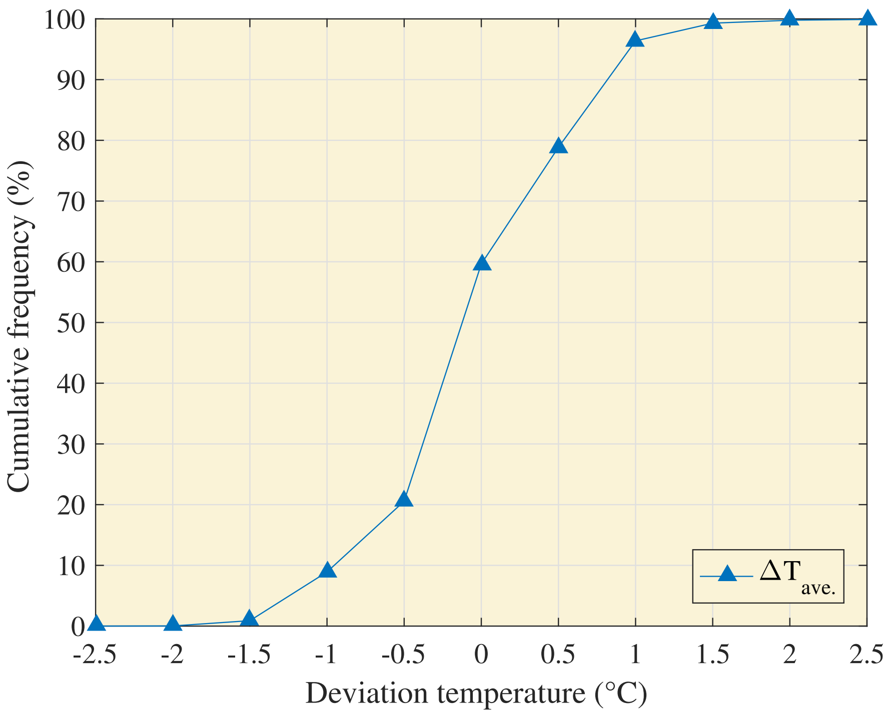

Figure 8: Temperature difference accumulated frequency ($\overline{T_{av}} - \overline{T_c}$)

4. Conclusions

30 km of a high voltage power line were monitorized with a distributed temperature sensing system (DTS) and six weather stations placed along the line from 10 September 2013 to 31 March 2014. These data were recorded every 10 minutes and the conductor temperature measured every 2 meters.

The data analysis was focused on the differences between using spot or distributed temperature measurements in dynamic rating operation of overhead power lines. Distributed temperature sensors are very expensive to implement and needs to stop the line operation for a considerable period of time. Spot temperature sensors are cheaper and faster to implement but with the uncertainty of where to place them to have a representative value of the temperature of the conductor.

This paper shows that, in the case studied, spot measurements are enough to obtain a good approximation of the temperature of the line conductor. The line was not heavily loaded during the time of the study and no temperatures above 50°C were reached. Further analysis should be done to check a broader range of load and weather conditions in order to be used in dynamic rating operation.

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