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Analysis of a Real Case of Ampacity Management in a 132 kV Network Integrating High Rates of Wind Energy.

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Abstract.

The grid integration of renewable energy, and particularly in Spain, supposes an important problem to deal with for Distributor System Operators (DSO). Most of the times Wind Energy Farms are located in places that are far away from the transmission networks so they have to be integrated into distribution networks that are frequently next to their static rate. Current regulations make almost impossible to build new overhead lines so the increase of the capacity of the existing lines is a new target for the DSO. One of the developed options to solve this issue is the dynamic management of the network. This paper is devoted to the analysis of a real case of ampacity management in a 132 kV overhead line placed in a high-wind generation area. The obtained results show that this approach can increase the lines capacity in a significant percentage.

Key words

Wind Energy, Ampacity, Grid Integration, Dynamic Management.

1. Introduction

The increasing number of renewable generation facilities, especially those based on wind energy, greatly affects the operation of the distribution networks, making them more complex to operate. In this scenario, the need to increase the capacity of the overhead lines is an important issue in order to avoid contingencies and to achieve good grid integration avoiding generation restrictions.

In recent years it has been observed an increase in renewable energy spills, mainly from wind power generation, motivated by the stagnation of electricity consumption and high level of hydraulicity. Red Eléctrica de España (REE) which is the Transport System Operator (TSO) has raised different scenarios to predict the level of renewables energies spills for 2015 and 2020 [1], obtained an increasing trend (see Fig. 1 and Fig. 2).

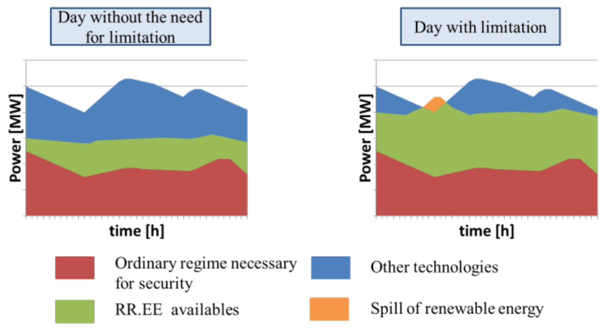

Fig. 1. Renewable energy spills representation

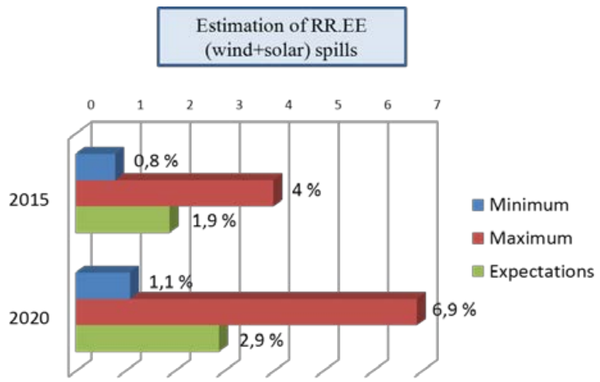

Fig. 2. Trend scenario raised by REE [1]

As it is not possible to build new lines due to both environmental and governmental restrictions and even in the case in which this option is available it has high cost so it is compulsory to define new suitable methods to increase the capacity of the existing infrastructure. In [2, 3] it was defined a methodology to obtain the level of ampacity and the estimated conductor temperature of an overhead line at real time. Following the approach proposed by [4-6], several variables have been obtained to know the degree of effectiveness of the system.

2. Methodology

The methodology proposed in this paper is to show the results of ampacity and conductor temperature calculations and define the different results of dynamic management.

The features of the studied overhead line are shown in table 1.

Table 1. Features of the studied line

VOLTAGE	132 kV	
CAPACITY	72 MW	
LENGTH	30 km	
SETTING	Simplex	
CONDUCTOR	Type	LA-110
	Diameter	14.3 mm
	Composition	30/7
	Resistance	23.77 x10^{-2} Ω/km
	Static rate	314 A
	Maximum temperature	80 ºC

Firstly, ampacity data are obtained following the methodology described in [2,3]. In the same way, conductor temperature is estimated and can be compared with the measured conductor temperature. This temperature is collected by the SMT (temperature measuring sensor) and, together with estimated values, the ampacity/conductor temperature algorithm computes the estimation error. This error has been reduced through an algorithm that corrects the estimated temperature based on historical data. Correction of estimation error has been implemented using a linear regression approach. First of all, a study about the relationship between the error in estimation of conductor temperature and different variables has been carried out in several scenarios. These include, among others, wind speed, ambient temperature, current and ampacity calculation. The chosen scenarios are the optimal, wind speeds (v<0.5 m/s), medium wind speeds (0.5 m/s ≤v<1 m/s) and ampacity calculation below 100 and wind speed greater than 1 m/s.

The second step is to identify the necessary indicators to show the impact of the implementation of the ampacity management system during the study period. These indicators are:

- Capacity increase (maximum, minimum and average).
- Additional dispatched energy.
- Savings in atmospheric emissions of CO_2.
- % occurrence of ampacity below the defined static rate.

3. Results

The results have been obtained through the study of the overhead line during 29 months.

Ampacity results during the period under study are shown in Figure 3.

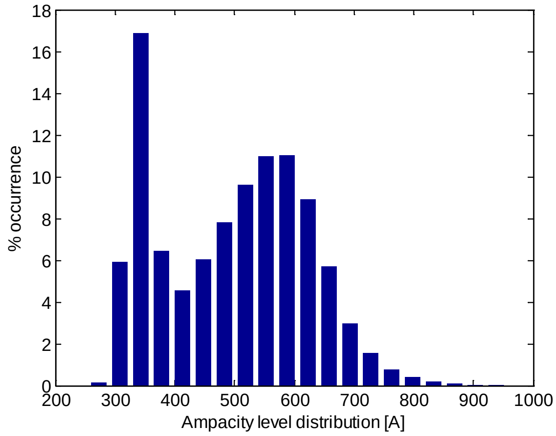

Fig. 3. Histogram of Dynamic ampacity distribution

It can be observed that the level of ampacity with greater occurrence is around 350 A. These values are close to the static rate defined, so the conclusion is that static rate has been chosen with a suitable approach.

It can be observed that approximately in a 90% of the cases the ampacity is above the static rate.

To analyze the accuracy of the estimates, ampacity cannot be compared with a physical value since ampacity is not a measurable magnitude. By contrast, conductor temperature is a measurable magnitude and its calculation is made with the same algorithm, consequently it is possible to acquaint the level of accuracy by comparing measured and calculated temperature.

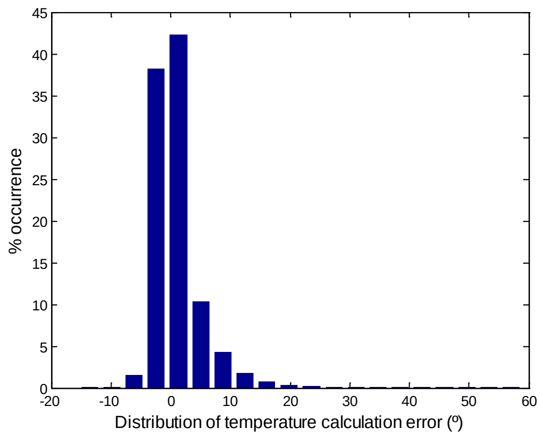

Fig. 4. Histogram of conductor temperature calculation error

Figure 4 shows that the error in calculation of conductor temperature is bounded between -10 y 10 ºC in most cases with a mean squared error of 4.12 ºC and a correlation coefficient of 0.84. About 80% of the cases error is between -5 and 5 ºC.

In view of the results of the estimation, correction of the error is needed to improve the calculation.

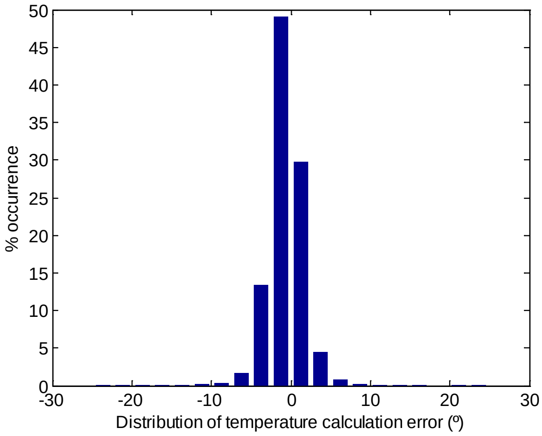

Fig. 5. Histogram of recalculated conductor temperature error

Figure 5 shows that the error in the correction of conductor temperature is bounded between -5 y 5 ºC in most cases with a mean squared error of 2.42 ºC and a correlation coefficient of 0.94. About 95% of the cases error is between -5 and 5 ºC.

On the other hand, ampacity management indicators are calculated and displayed in Table 2.

Table 2. Ampacity management indicators

	Absolute	Relative
DYNAMIC MEAN CAPACITY	113.4 MW	--
CAPACITY INCREASE	41.6 MW	58.00%
MAXIMUM INSTANTANEOUS INCREASE	146.8 MW	204.60%
MINIMUM INSTANTANEOUS INCREASE	-13.5 MW	-18.80%
ADITIONAL ENERGY	2188 MWh	0.40%

Table 2 shows that, by operating with dynamic ampacity, the energy dispatched has been 0.40% greater than in the static operation.

Figure 6 shows an example of a high capacity day. In this day dynamic ampacity reaches a maximum level of 141% above static rate. Therefore, as this figure implies, there is a strong correlation between dynamic ampacity and wind speed.

Another significant indicator is the statistic of the number of times that ampacity is below static rate. This implies that in these conditions if DSO operates based on static rate, the conductor may suffers major damages as conductor temperature would be over the maximum permissible temperature.

During the reference period, 2% of the times ampacity has been below the static rate, that is, if this line had been operated in static conditions, conductor would have been in critic levels of temperature for approximately 380 hours during the period of study.

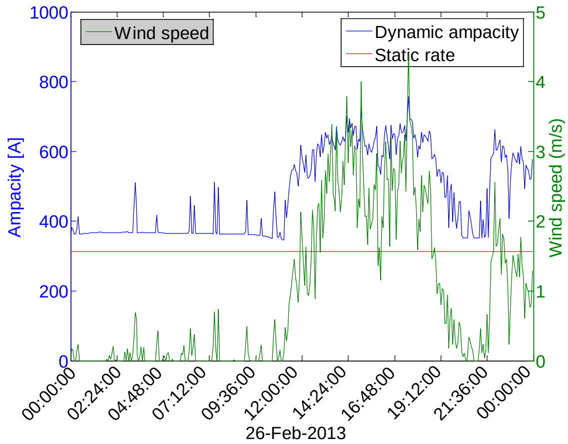

Fig. 6. Comparison between ampacity, static rate and wind speed in a day with a high ampacity level

This situation over the time could reduce considerably the life time of the conductor.

4. Conclusions

The ampacity monitoring system, as the same time as permitting to operate in higher levels than the static rate, contributes to the security of the system since it identifies moments with very unfavourable conditions when ampacity is below to the static rate.

In terms of ampacity management, an average increase of 58% in capacity has been achieved by the implementation of the system so this line can evacuate more energy from wind farms without restrictions or contingencies. From this point of view, renewable energy spills that are produced by capacity constraints can be reduced.

Concerning about the additional energy, the system has been able to dispatch 3,692 MWh more than operating with static rate. This means an increase of 0.40%. This figure is not a huge increase but it must be taken into account that dynamic management has covered short periods with high necessity of capacity in the line that it has avoided the request to stop wind energy generation.

Initially, errors in calculation of conductor temperature, even though small, could be improved in particular in low wind cases in which conductor temperature estimation gives the highest values of error. With the correction error, it has gone down from 4.12 ºC to 2.42 ºC.

In the near future, the introduction in the algorithm of the thermal inertia of the conductor will greatly improve the results providing more accurate estimations of temperature and ampacity.

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