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Field validation of a new model for uprating transmission lines

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ABSTRACT

A new model for uprating transmission lines using a technique termed "mixed conductor tensioning section" was introduced in the paper "A Model for Uprating Transmission Lines by Using HTSL Conductors". The present paper continues the work of the previous and presents the use of small diameter conductors including a series of specific mechanical characteristics alongside conventional conductors in order to uprate the loading capacity of electrical power transmission lines. The methodology, which was successfully tested, avoids the assembly of any additional large-scale structures, since it corrects any safety breaches of the clearance distances, which jeopardize the operational limits of the transmission lines, and at a much lower cost.

1. Introduction

Increasing the capacity of transporting electricity is restricted by the high costs involved in constructing new lines and the difficulties in obtaining new rights-of-way from licensing and community organizations. Numerous solutions have been put forward in order to increase the capacity of current conduction on Transmission Lines (TLs). One of these solutions has been the use of conductors capable of operating at high temperatures with reduced sags, also known as High-Temperature Low-Sag (HTLS) conductors.

Conductors placed at incorrect clearance distances, due to inaccuracies within the project and/or construction stages, or indeed any change of activity under the TLs, may also impose further limits on the ability of the line to transmit electrical power. It is within this context that we propose a technique aimed at correcting clearance distances by applying HTLS conductors or different gauges only to those spans that present inaccuracies, whilst retaining the remaining original conductors on the tensioning sections. Such techniques are also very useful when applied to increase the ampacity of a line that presents restrictions along short sections, thus freeing capacity on the rest of the installation [1].

Fig. 1 illustrates a tensioning section of a TL on which breaches have occurred on four consecutive spans. The dotted line represents the safety clearance distance from the conductor to the ground. If the conductor is below this line the regulatory limits have been breached, otherwise restrictions are being complied with. By only replacing conductors on the spans where breaches have occurred through different conductors, as in Fig. 2, the assembly of additional large-scale structures is avoided, since any safety breaches of the clearance distances, which jeopardize the operational limits of the transmission lines, are corrected at a much lower cost.

In order to apply the above-mentioned technique, a model was developed to calculate the tensions and the sags of a tensioning section with different conductors on level and non-level spans at any temperature. This also included situations where the conductor temperature varies along the tensioning section. Traditional methods function with only one temperature for all spans, which would not be consistent with different conductors, since there are unequal temperatures for the same current. Some methods take this difference into consideration, although the conductor on the tensioning section is the same. Initially, we present the methodology employed, followed by the analyzed cases, the identified restrictions and, finally an analysis of the results.

2. Material and methods

2.1. Calculating tensions and sags on transmission lines

Over the past 80 years, the ruling span method has traditionally been widely used to calculate tensions and sags on tensioning sections [2]. The basic premise is that during tensioning, conductors may slide freely over the intermediary supports transmitting

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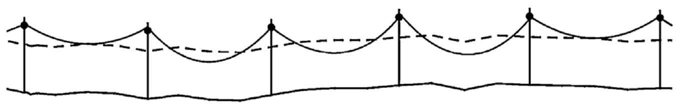

Fig. 1. Tensioning section of a transmission line with safety breaches of clearance distances in consecutive spans.

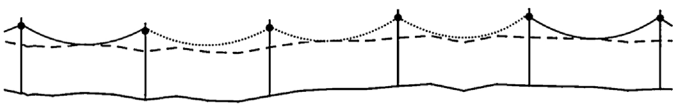

Fig. 2. Tensioning section of a transmission line using HTLS conductors or different gauges to correct any safety breaches of clearance distances.

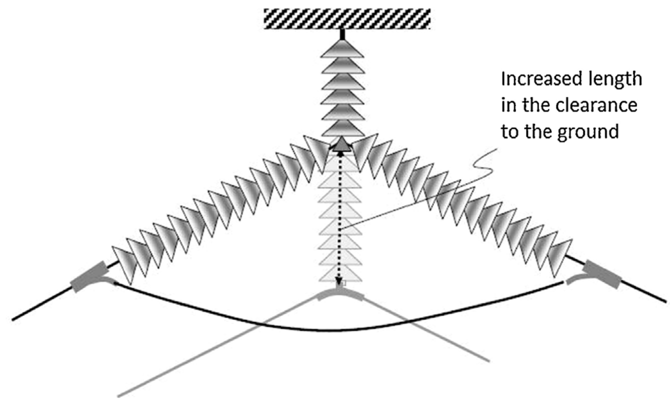

Fig. 3. Conversion of a suspension string into a floating dead-end string [7].

tension evenly along all the spans. Satisfactory results have been obtained for level spans of the same length at any temperature or for non-level spans with approximate lengths at low temperatures. However, unacceptable errors may occur when calculating the sag with conductors that operate at a temperature above 100 °C if the tension differences have not been taken into consideration in a tension section with spans of different lengths [3].

The Modified Ruling Span Method, published in 2000, is used to determine the tensions and sags on tension sections with only level spans of different sizes at high temperatures by including the inclination effect of the suspension strings in the calculations [4]. Three years later, the Centro de Pesquisas de Energia Elétrica known as CEPEL, in Brazil (the Research Center for Electrical Energy) presented a further method for calculating the cited parameters on level or non-level multi-span tension sections [5]. This methodology also made it possible to analyze situations in which the temperature of a conductor varies along the tensioning section, which is not possible with the ruling span method, where the temperature remains the same for all spans.

With the simultaneous application of more than one type of conductor on the same tensioning section, a set of different elastic behaviors comes into existence if the conductors possess distinct physical, electrical or chemical properties. It is essential to take all these factors into consideration when calculating tensions and sags. Therefore, a method was developed, based on the description in [6], to determine the change of state equation on tensioning sections composed of level or non-level, equal or unequal spans, which not only allows for different temperatures on each span, but also for the presence of different conductors along the tensioning section.

In order to guarantee the placement of a HTLS conductor on a span with restrictions, floating dead-end strings were used, as presented in Fig. 3 [7]. The vertical element of this unit may be an insulator string of either the same length or shorter than the original insulator string or a stem measuring 0.5 m. With some restrictions, it is also possible to use a floating dead-end string without a vertical element.

Defining the reduced length of the insulator string very much depends on the desired gain in order to guarantee a safe clearance distance. In the case of an insulator string with a partially reduced length, the whole unit will become dislocated when a change occurs in the status of the line. Therefore the weight of the floating dead-end string should be included in the calculations. This technique may be applied to specific situations, ensuring that the mechanical forces of the altered tensioning section will not be overpowered should one of its towers fall. It is worth noting that this contingency situation is attenuated by the suspension structures through the movement of the insulator string. When a floating dead-end string without a vertical element is used then no further displacement will occur and the structure will have to support the resulting vertical forces.

Correcting the clearance distance to the ground using HTLS conductors on spans with restrictions may require that the adjacent spans possess some excess clearance distance to the ground, depending on the manner in which the floating dead-end strings are arranged. With the use of a vertical element on the floating dead-end string a gain in ground clearance is achieved on the spans with a HTLS conductor. However, these distances are reduced on the adjacent spans because the HTLS conductor weighs less than traditionally-used cables. Without a vertical element, the mechanical behavior of the HTLS conductor is restricted to its span, and the variation in the clearance distance of the adjacent spans is due to the elevated suspension point of the conductors. The mathematical model for determining the tensions and the sags with the mixed conductor tensioning sections technique is detailed in [1,10] and is summarized in Appendix.

2.2. Case study

The mixed conductor tensioning section technique was applied to the EDAL – Eletrobras Distribuição Alagoas (an electrical distribution company in the state of Alagoas, Northeast Brazil) through the research and development project "Research into New Technologies for Uprating Sub-Transmission Lines." As previously mentioned, this technique may be used to increase current conduction on a TL or only to correct safety breaches of clearance distances.

After undertaking various analyzes with the technical team at EDAL, studies were conducted on the 69 kV Rio Largo – Pilar TL, which extends for 18.5 km and uses CAA 4/0 AWG cable.

This line can basically be divided into three sections, each with its own typical characteristics. The first 8 km of the line cross through a region formed by several ravines. Since the intention of the study was to correct breaches in the distances between the conductor and the ground, it was unnecessary to collect topographic data along this stretch of the line. As demonstrated by Fig. 4(a) there was no breach of regulatory limits under these circumstances. Between structures 10/1 and 16/3 the line stretches across dense sugarcane fields, as recorded in Fig. 4(b). Under the final stretch of the line there is an illegal land occupation, clearly breaching the rules set out in NBR 5422 [11]. Such occupations deserve special treatment by the company, since they are beyond the scope of the analysis.

It was impossible to undertake a complete topographical survey along the line due to budget constraints. Therefore, as an alternative, we performed a simplified survey, which provided a strong