Electrical Power and Energy Systems 105 (2019) 602–611

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Field validation of gap-type overhead conductor creep

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ARTICLE INFO

Keywords:
Transmission line
Gap-type overhead conductor
Creep
Sag-tension calculation
Power system operation
Power system expansion planning

ABSTRACT

Gap-type overhead conductor sag-tension calculations based on experimental conductor creep tests are based on stress-strain and metallurgical creep tests. Although for bi-metallic conductors, these tests are carried out for both the core and the full conductor, for gap-type overhead conductors the aluminum metallurgical creep is usually neglected and the full conductor metallurgical creep is not carried out. The purpose of the presented study is the validation of these calculation methods. For this purpose, field measurements have been obtained in a pilot line in operation. The gap-type conductor installation process has been measured and the conductor creep has been monitored during three years of line operation. In order to model relevant events such as the pre-sagging and sagging steps during the installation, and ice and wind events during the operation, a flexible sag-tension calculation method has been used. Besides, the widely used graphical sag-tension method has also been evaluated, obtaining similar results as the flexible method. The tension-decrease is used as the indicator of the creep. The calculated and measured tension-decrease values are close. Therefore, it is concluded that the sag-tension calculations based on experimental conductor creep tests are valid to represent the actual creep of the conductor in operation.

1. Introduction

Power system operation and planning are constrained by the rating of system components. In the case of the overhead lines, there is a limitation in the maximum sag so that the distance between the conductor and ground is secure. The sag increases with the conductor thermal expansion and for this reason, the maximum allowable temperature is limited. Besides, the sag also grows due to the permanent deformation experienced by the conductor because of creep. Sag-tension calculation methods calculate the change on the conductor sag as a function of the conductor temperature and time [1–6].

Creep can be defined as the permanent deformation of conductors due to the metallurgical creep of the conductor material and the geometrical settlement of the conductor wires [7–10]. Metallurgical creep is a function of stress, temperature and time, and it is cumulative. Creep development rate decreases over time and accumulated creep. On the other hand, geometrical settlement depends only on stress. As the historical maximum stress of the conductor increases, a geometrical settlement of the conductor wires occurs and an increase of the conductor length is developed. Initially, the historical maximum stress value is the experienced in the installation process. In operation, if the stress in the event is higher than the historical maximum stress, the permanent deformation due to geometrical settlement increases its value due to events of wind or ice loads.

High Temperature Low Sag (HTLS) conductors are used for the uprating of overhead lines due to their lower coefficient of thermal expansion CTE and higher maximum allowable temperature values [11–13]. Among the different types of HTLS conductors, one of the most widely used is the gap-type conductor. The gap-type conductors are composed of steel core and aluminum outer strands [14–17]. The gap between the steel and the aluminum ensures aluminum layers remain slack during the conductor installation process.

The installation process is a key influence on the creep developed by the conductors. As the creep is cumulative, it is beneficial if some creep is permitted to occur during the installation process [10]. Pre-tensioning and over-tensioning in the installation are used to mitigate the creep developed during operation. Pre-tensioning means tensioning the conductor for a short period before the conductor is clamped. Over-tensioning means increasing the installation tension to compensate for the creep during operation.

Due to the limitations of the existing sag-tension methods to model the installation process of the gap-type conductors, the authors developed a method for the gap-type conductors and the conductor performance was analyzed from simulated results [18–20]. In order to

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https://doi.org/10.1016/j.ijepes.2018.09.006
Received 28 November 2017; Received in revised form 19 August 2018; Accepted 8 September 2018
0142-0615/

validate the simulated results with actual measurements, this paper demonstrates the results obtained in a pilot line. A 119 mm^2 ACSR LA-145 conductor has been replaced by a 131 mm^2 GTACSR-150 gap-type conductor in a 30 kV distribution line. A 282.5 m length span has been monitored with conductor tension and temperature measuring systems. The conductor installation process has been measured and the operation of the line has been monitored during three years. Three years is a long period for the creep evaluation because most of the creep develops at the beginning of the installed conductors' lifetime.

The paper starts describing the installation process of gap-type conductors because it is important to understand the creep performance of the conductor. Then, creep calculation methods are discussed, and the need for a flexible calculation method is justified. In the next section, the steps for the creep calculation are defined from the measured tension and temperature values. These steps are applied with the flexible creep calculation method developed by the authors and creep results are obtained. Besides, the calculations are carried out with the widely used graphical method. The creep that an ACSR conductor would develop has also been calculated for comparative purposes. Next, the measured creep is quantified and the difference with the calculated values is analyzed. Finally, some conclusions are described.

2. Installation process of gap-type conductors

The installation process of gap-type conductors is particular. The objective is to leave slack the aluminum layer when the installation is completed [17]. As a result, the knee-point temperature of the conductor is the installation temperature and the conductor shows low sag performance above this temperature.

The first step in the installation is the stringing. Fig. 1 shows the stringing process in the pilot line. The original ACSR conductor is removed and the new conductor is strung in the pulley blocks. The stringing tension should be low, below 70% of the installation tension.

The first end-point of the conductor was clamped in a conventional way and a load cell that measures the tension was installed between the tower and the insulating string (Fig. 2). A temperature and current measurement sensor for high voltage lines (Arteche SMT) is used for measuring the conductor temperature (Fig. 3). The conductor surface temperature is measured.

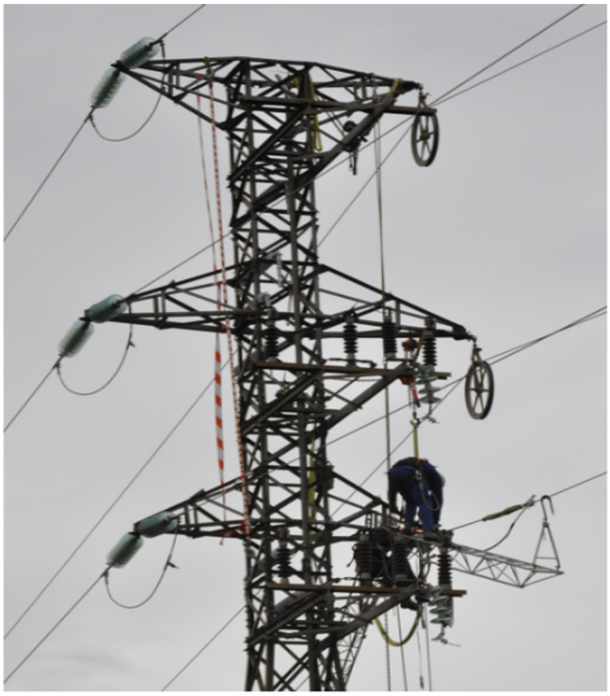

Fig. 1. Stringing the gap-type conductor.

Fig. 2. Load cell for measuring the conductor tension.

The installation process of the second end-point is special, so that the aluminum is slack at the end of the installation process. The next step in the second end-point is the pre-sagging. Fig. 4 shows the process of pulling the gap-type conductor by means of the aluminum gripping clamp. The pre-sagging tension value is 70% of the installation tension. The conductor is cut and a portion of the aluminum layer is removed in the looser part of the conductor. In a conventional ACSR conductor, in the pre-sagging step, both the steel and aluminum share the tension, as there is no possibility of relative displacement. However, in the gap-type conductor, due to the gap between the steel and aluminum, the steel is slack and the tension is in the aluminum. This is relevant, as the geometrical settlement experienced by the aluminum in this step will reduce the geometrical settlement in wind or ice events.

The conductor sagging is the final step. The steel core is tensioned by the steel gripping clamp, after inserting the steel clamp (Fig. 5). Then, the aluminum gripping clamp is loosened. The aim of the sagging process is to obtain a certain tension or sag at ambient temperature as indicated by the sagging tables. For the gap-type conductors, a period of time where the conductor is at rest over the steel core with the aluminum loose is needed. This is to guarantee that the aluminum is slack when the clamp is compressed. While in a conventional bi-metallic ACSR conductor both the steel and aluminum share the tension in the sagging step, in the gap-type conductor all the tension is in the steel core. The creep experienced by the steel in this step is removed from the creep experienced during operation.

3. Creep calculation method for gap-type overhead conductors

The sag-tension calculation methods are classified according to the conductor elongation models: Linear Elongation (LE), Simplified Plastic Elongation (SPE), or Experimental Plastic Elongation (EPE) models [4]. The EPE models are based on experimental conductor tests. Two types of standard tests are carried out in order to characterize the creep performance of overhead conductors: the stress-strain test and the creep test. In the stress-strain test, the conductor stress is increased, maintained constant for one hour, and decreased, in several cycles. The stress-strain characterizes the geometrical settlement as a function of the conductor stress. In the creep test, the conductor is under a constant stress for 1000 h at a constant temperature. In this test, the metallurgical creep development rate is characterized. The whole conductor and the conductor core are tested separately. The aim of the whole conductor test is to measure the aluminum performance. Removing the performance of the core from the whole conductor performance, the aluminum performance is calculated. This is carried out both for the stress-strain and the metallurgical creep test.

The creep does not depend on the conductor size. It depends on the stranding of the conductor and the material type of the wires. In [21], initial stress-strain curves and final stress-strain curves (including 10 year metallurgical creep) are given for different conductor stranding types: 6/1 ACSR, 24/7 ACSR, 26/7 ACSR, etc. Regarding the material type of the wires, for example, metallurgical creep tests for Aluminum Clad Steel (ACS) cores result in higher strain values than tests carried out for galvanized steel core. This is due to the contribution of the