APPLICATION OF THE FINITE ELEMENTS METHOD FOR THE DESIGN OF NEW CLAMPS FOR GTACSR CONDUCTORS

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RESUMEN

El imparable crecimiento de la demanda eléctrica esta causando la saturación de las líneas de transmisión hasta un punto en donde hay problemas de abastecimiento en algunas áreas en donde las flechas de los conductores aéreos están sobrepasando los límites de seguridad.

Una de las propuestas para resolver este problema es reemplazar los actuales conductores por unos nuevos conductores de altas prestaciones térmicas. Este tipo de conductores es capaz de transportar mas potencia que los tradicionales ACSR así como trabajar a mayores temperaturas manteniendo la flecha dentro de los márgenes de seguridad.

Sin embargo, el aumento de temperatura en los conductores puede afectar al correcto funcionamiento de los sistemas de amarre tradicionales. Para analizar el problema se han empleado herramientas informáticas de CAD para el diseño y modelización, así como programas informáticos basados en el método de los elementos finitos para realizar las simulaciones. Este artículo expone los resultados del estudio describiendo las características típicas del proceso de simulación.

ABSTRACT

The unstoppable rise in electricity demand is causing the saturation of the power transmission network to a point that problems of supply are arising in some areas due to overheated conductors sagging above security distance limits.

Several approaches are being studied to solve this problem. One of them is the replacement of actual conductors by new conductors with high temperature and low sag (HTLS) capabilities. This type of conductors is able to transmit more power than traditional ACSR conductors, as they can work at high temperatures while keeping their sag under actual security margins.

However, the higher temperature in the conductors can affect the correct performance of the traditional clamps. To develop an analysis on this subject software tools have been used, consisting of CAD programs for the design and modelling of the clamps and FEM programs for the simulation of the models. This paper shows the results of the study describing the typical characteristics of the simulation process.

1. INTRODUCTION

The technological growth and the increase in the quality-of-life experienced in recent decades by the most industrialized countries in the world have led to a growing demand for electrical power. In order to be able to meet this increase in demand, existing electrical transmission lines are being forced to transmit increasingly higher power loads. As a result, the ampacity of some transmission lines is close to its critical limit. In addition, the higher power transmission automatically results in a higher temperature in the conductor; and the ensuing dilatation has the effect of augmenting the total length of the conductor and, as a result, the increasing sag may eventually overcome the safety limits.

One of the most accessible solutions to be considered appears to be the use of high-temperature low sag conductors. For instance, the so called GTACSR type conductors allow continuous working temperatures as high as 150 ºC, whereas conventional conductors currently installed in electrical lines can stand only 80 ºC. These high-temperature low sag conductors can replace the current ones without neither modifying the original design of the supporting structures, nor requiring new rights-of-way that could alter the present use of the lands involved.

However, the higher temperature in the conductors can affect the correct performance of the traditional clamps. So, as a previous step to the installation of the new conductors, there is a need to study how traditional clamps performance can be affected by the temperature increase in the conductors. In fact, the temperature increase could jeopardize the correct performance of the insulator, which is the most delicate element in the clamp system. That is why, in addition to the study of traditional clamp systems, new ones providing higher security levels are proposed. This study has been carried out by the authors and is presented in this paper. The study allows updating the design of traditional clamps to take into account the new stresses.

2. GENERAL CHARACTERISTICS OF GTACSR CONDUCTORS

The so called GTACSR “gap” type construction conductors are really modified traditional ACSR conductors capable to operate at 150 ºC while maintaining sags similar to ACSR conductors, and thus capable of driving an approximately 1,6 times higher current. These conductors, made up with several layers of aluminium wires of 60% conductivity surrounding a steel core, are characterized by the fact that the aluminium wires of the innermost layer are trapezoidal in section, so that a gap is cleared between the steel core and the aluminium layers. This gap is usually filled with a grease resistant to high temperatures. This construction method allows reducing the friction between the core and the aluminium layers.

GTACSR conductors show a transition temperature (between 10 and 20 ºC) above which all the mechanical resistance of the conductor is provided by the steel core. Hence, GTACSR conductors can be strung by tightening only the steel core, leaving the aluminium layers untightened.

The fact that the mechanical stress of the core is at any time independent of the aluminium stress implies that the sag increase in these conductors is smaller than in the ACSR type, because the sag depends almost exclusively on linear expansion coefficient, and on elongation characteristics of the steel core. Since only the steel core supports the mechanical stresses, the steel used in GTACSR type conductors has a high breaking strength (180 kgf/mm2 compared to 130 kgf/mm2 of an ACSR).

GTACSR conductors exhibit external dimensions similar to ACSR conductors, although the presence of the aluminium layer of trapezoidal section enables to adopt new dimensions more adequate to the conditions of the line where they are to be installed. Also, it is worth commenting that the stringing procedure for these conductors is more cumbersome than the one for conventional conductors, as the mechanical stress has to be applied only to the core of the conductor.

3. TRADITIONAL CLAMPS

The conductors in overhead electrical lines are always used without any insulation so they ought to be insulated in the corresponding towers. Hence, there is a need for an intermediate element with good insulating properties, required to completely insulate conductors under voltage from the towers supporting the line. The most common type of insulator used in overhead lines is the “cap and pin” insulator, in such a way that different number of elements, depending on the voltage level, is connected together to form an insulator string. The union of the conductors to the insulators is done by means of metallic elements called clamps.

The primary purpose of the insulator string is to avoid the circulation of electrical current from the conductor to the tower, but this property of the insulator depends strongly on the temperature it reaches. Consequently, it is of the utmost importance to know the temperature distribution along the clamp system and, particularly, the temperature reached by the insulator taking into account that GTACSR conductors operate at temperatures of nearly 150º C by contrast with the temperature of 80º C reached by ACSR conductors. An often utilized clamp system is represented in Figure 1.

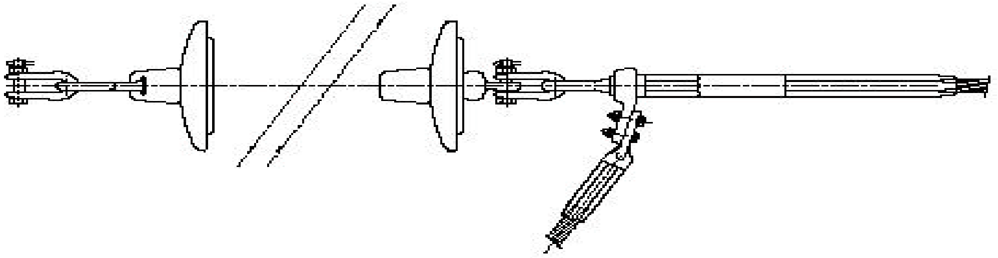

Figure 1: Simple compression system for simple conductor

Depending on the technical and structural needs, there are at our disposal many combinations to erect the clamp systems: single chains for double conductors, double chains for single conductors, double chains for double conductors, “V” shaped double chains for double and triple conductors, etc. However, the configuration showed in Figure 1 is the one with the lowest distance from the first insulator to the conductor so consequently this is the configuration that will bring about the highest temperature increase in the insulator string. That is why we have analysed this configuration more thoroughly. In the other arrangements the temperature reached by the first insulator unit will be lower as there is more distance to the conductor.

4. SIMULATION OF THE CLAMP SYSTEM

The modelling of the clamp systems has been performed using the Solid Edge application, a software tool with high graphic power in 3D. Likewise, this software allows depicting the set of assembled pieces, as represented in Figure 2.

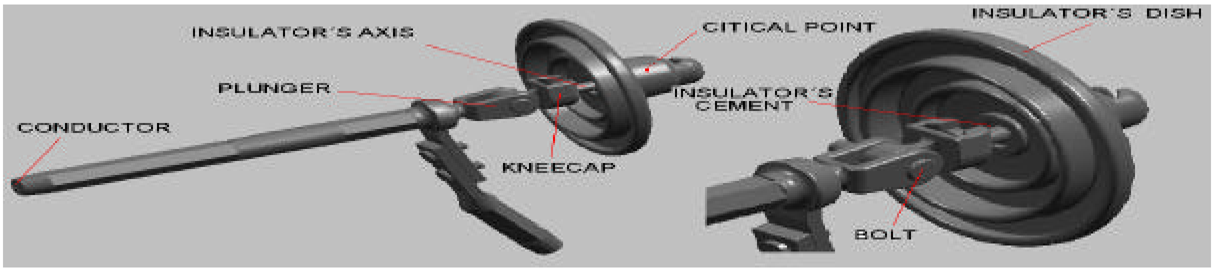

Figure 2: Clamp system’s elements

Once the pieces have been modelled, the analysis of the temperature distribution in the aforementioned compression systems is accomplished by means of a software tool relying upon the Finite Element Method (FEM).

4.1. The finite element method

The general idea behind the Finite Element Method consists in dividing a continuous system into a denumerable set of small, discrete elements interconnected at points called nodes. The equations ruling the behaviour of the continuum are discretised at each element so that the basic variables to be solved for are nodal variables.

For that reason, we are able to transform a continuous system with infinitely many degrees of freedom, obeying a differential equation, or a system of coupled differential equations, into an “equivalent” system with a finite number of freedom degrees whose behaviour is described by a system of algebraic equations, linear or not. We have carried out the FEM simulations of the clamp chains by means of the COSMOS/DesignStar software application.

4.2. Conditions of the simulation.

As regards the material corresponding to each element of the ensemble, Figure 2, the pieces in close contact with the conductor are made of an aluminium alloy, whereas the insulator is made of glass and the remaining elements are made of steel. In addition, the cement joining the different parts of the insulator has been considered as an independent piece. The values of the different parameters entering the simulation are selected according to the material of each element.

The worst case simulation occurs when GTACSR conductor reaches a temperature of 150 ºC with natural convection (a “film coefficient” around 5-15 N/m^2K) and an ambient temperature of 40 ºC. It has been considered the power loss as a result of the Joule effect. In addition, the clamp system is simulated taking into account the conditions under which it would work with traditional ACSR conductors. These conditions are identical to the previous ones except for the temperature of the conductor that in this case is 80ºC. In connection with the type of union, it has been considered that the different surfaces in contact in the clamp system are stiffly bound.

The meshing of the system is certainly the most critical step of the FEM analysis, requiring a great deal of experience and a thoughtful insight into the problem. The total number of elements used to mesh the model bears a strong command upon the precision of the solution. Indeed, the use of very fine meshes provides us with solutions as close as we like to the true solution of the problem, although the burden of computational effort may well be exceeding. In contrast, a coarser mesh takes less computer time to solve, but the results are much worse.

Clearly, we should balance the total number of elements used in the simulation and the precision required. Nevertheless, the number of elements is not the only factor that affects precision, as we have also to determine the type of elements to be used. In this particular case we have used throughout second order tetrahedral.

4.3. Results

Once the FEM model is solved, the typical temperature distribution obtained for the aforementioned conditions is shown in Figure 3.

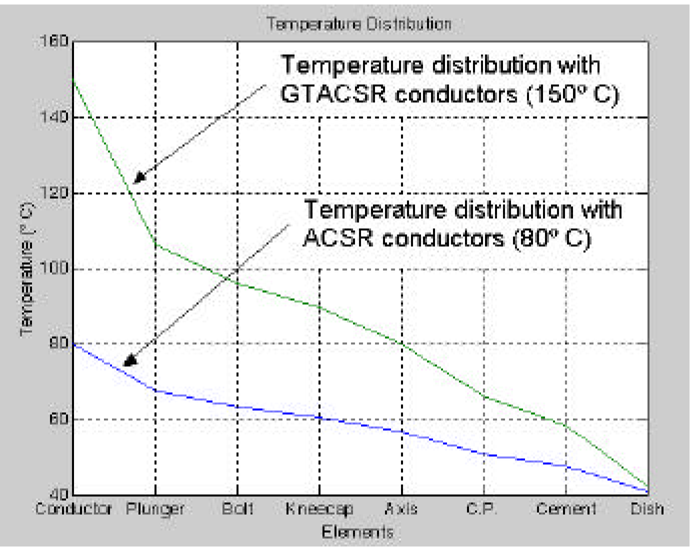

Figure 3: Temperature distribution (º C) in the clamp system

The most sensitive element in the compression chain is the first insulator of the string. For this reason, the study has been focused on calculating the temperature distribution in the compression system in general, and in the first insulator unit in particular. The insulator unit reaches its maximum temperature at the contact point between the insulating glass and the insulator's axis so this point has been called critical point (C.P.). It is readily deduced that in the worst case the replacement of the conductor introduces a temperature increase at the critical point of approximately 20ºC by comparison with the ACSR conductor. Thus, the highest temperatures attained anywhere in the insulator do not preclude it from working correctly.

5. NEW DESIGNS OF COMPRESSION SYSTEMS

It can be deduced from the simulation that although the temperature reached at critical zones of the clamp system does not imply a potential risk, it is advisable to propose some modifications in order to obtain a higher security level, ensuring also a better and more lasting operation of the clamp system. In this paper, as an alternative, identical systems are proposed but with longer compression clamps, as it is shown in Figure 4.

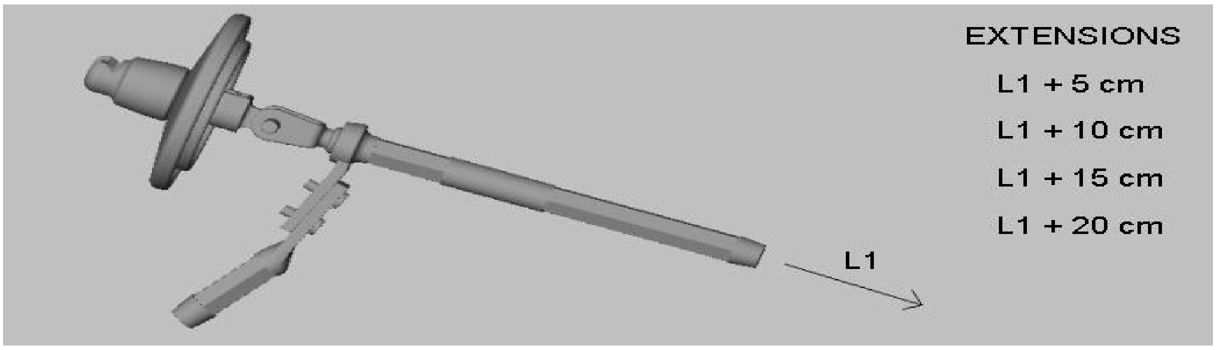

Figure 4: Extensions in the clamp system

The same simulation described in the previous section is developed with the proposed clamp systems and the GTACSR conductor (150ºC) using the Finite Elements Method. Taking into account that the most delicate component of the clamp system is the insulator, the temperature at the critical point of the insulator has been determined for each one of the proposed systems, and it has been compared with the original system. The results of this analysis are shown in Figure 5.

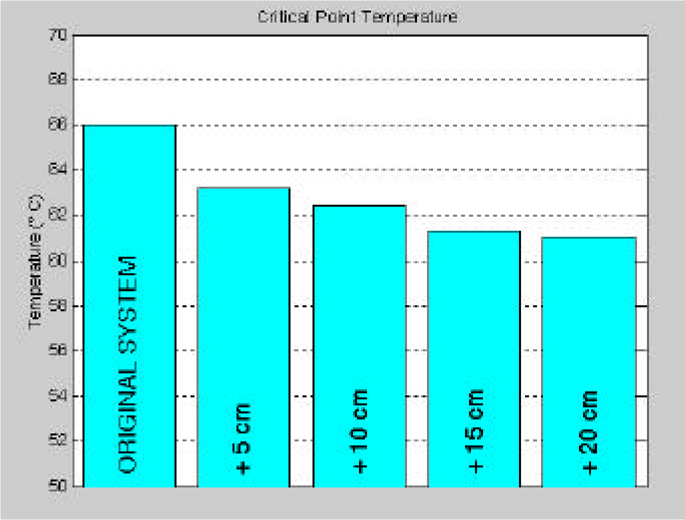

Figure 5: Critical Point Temperature (º C)

6. CONCLUSION

Traditional compression systems are valid for GTACSR conductors. Nevertheless, new arrangements with longer compression clamps are proposed in order to provide a greater safety margin.

The simulation of these new clamp systems by means of the Finite Elements Method has shown a temperature decrease of about 5ºC at the insulator's critical point in the worst case.

7. ACKNOWLEDGEMENTS

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