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2.5 MECHANICAL LOADS ON OVERHEAD LINES BUNDLE CONDUCTORS

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1. Abstract :

So far, a lot of work has been devoted to experimental tests and numerical computations of short-circuit electrodynamic effect on overhead lines with single conductor or bundle conductors but limited to two subconductors per phase.

This paper exposes the short-circuit behaviour of multiconductors bundle in overhead lines.

The approach or methodology, based on crossing of subconductors, for determining the impact of conductors is detailed.

Influence of unequal span length, for reduction of subspans oscillations, is summary presented. The effect of unequal subspans, on the peak of the tension, caused by the impact of subconductors under high short-circuit currents is also presented.

Some recommendations for design, taking into account the mechanical loads will be suggested.

2. Introduction :

In bundled conductors of overhead transmission lines, spacers are used to maintain the distance between the individual conductor cables. These spacers are often subject from conductors to different type of loads.

The spacers should be perform properly under all the different conditions. However, numerous spacers have been destroyed during short-circuit. Consequently, computations and tests will be reinforced in the object to take the mechanical loads into account in the design.

In fact, during short-circuit current, the electrodynamic forces acting on the conductors, caused by the current flowing in bundle conductors, causes a fast acceleration of the subconductors towards each other until they clash together.

A wave propagate towards the spacers causes an increase of the subconductors stresses. So that, tower, insulating hardware fitting and spacers must support this increase of tension.

3. Pinch effect in multiconductors:

The physic of the bundle conductor behaviour under high short-circuit current, has already been described and analysed in the literature [1,2,3,4]. But only for twin bundled.

The problem of pinch effect phenomenon has also been approached by different simplified models [5,6]. But these approaches are limited, because they can't take into account all the structure (droppers, busbars with droppers, non parallel horizontal configuration, insulating hardware,...).

In object to point up some important parameters which influence bundle dynamic behaviour, we will study many structure configurations.

Our final aim is to generalise the model developed in SAMCEF [7] for multiconductors bundle in any spatial configuration.

The dynamic study of the pinch effect phenomenon on the multiconductors is too complex:

In fact, the impact of subconductors must be modelized to take into account the fact that the corresponding nodes will be burst in impact together.

To avoid the numerical instability, the constraints characterising the impact of subconductors must be advisedly established.

The separation of subconductors must take into account, moreover, the position of elements which have tendency to separate, of the manner to avoid that one of elements in the middle of structure separate firstly. Otherwise, the separation of nodes in impact, must propagate to spacers towards the middle of subspans.

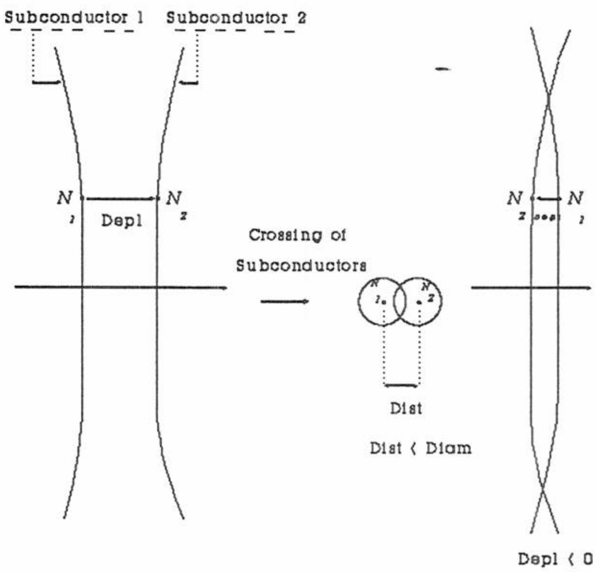
To ensure perfect impact and reduce computation time, we have preferred, for determining the impact of subconductors an approach based on crossing of subconductors.

This approach consist to choice a constant integration time step constant until the crossing of subconductors. Then, we adopt a methodology based on the automatic evaluation of integration step.

This approach is based on geometrical methodology who permit to follow temporal evolution of subconductors trajectory and the change of direction of forces between subconductors.

To judge if the crossing occurs or not, we observe the vector displacement projection value. The crossing is effective if this value change the sign or become lower than diameter (Figure.1).

After that the impact of subconductors is detected, we imposes the constraints of impact, which consist to place an element of non linear constraints between the different nodes. These elements of non linear constraint permit to maintain the distance between the nodes constant (Figure 2).



Depl: Displacement of the corresponding nodes.
Dist : Distance between the nodes candidate for an eventual impact.
Diam: Diameter of subconductor.
N1, N2: Nodes candidate for an eventual impact.

Figure 1: Determining of conductors crossing.

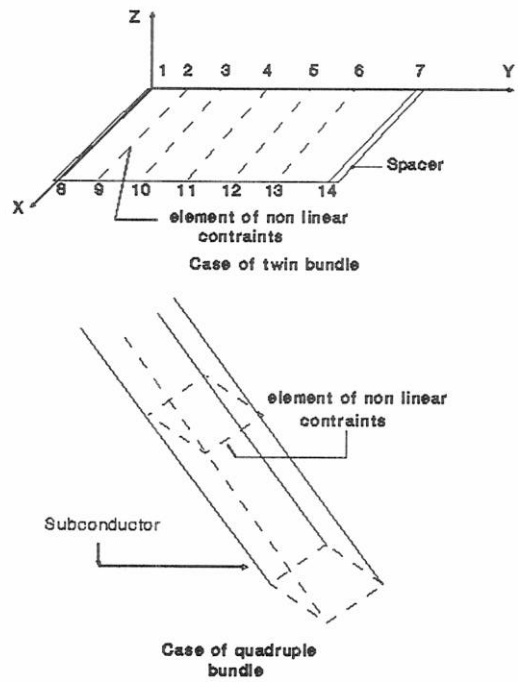


Figure 2: Disposition of non linear constraints elements.

To illustrate the dynamic behaviour of multiconductors bundle under short-circuit currents, we have addressed, on the following figures, some results, displaying the tension force, the electrodynamic force and the time evolution of the structure.

Figure. 3 shows the structure studied, as base to test the approach of impact of subconductors, at different time of the structure evolution.

The short-circuit intensity was 40 KA per phase, with a time constant of 100ms (maximum asymmetry).

It was a two phase short-circuit. Conductor size was ACSR 806mm^2 three bundle with 33 cm separation. the span length was 6x17m. The distance between subconductors was 40 cm.

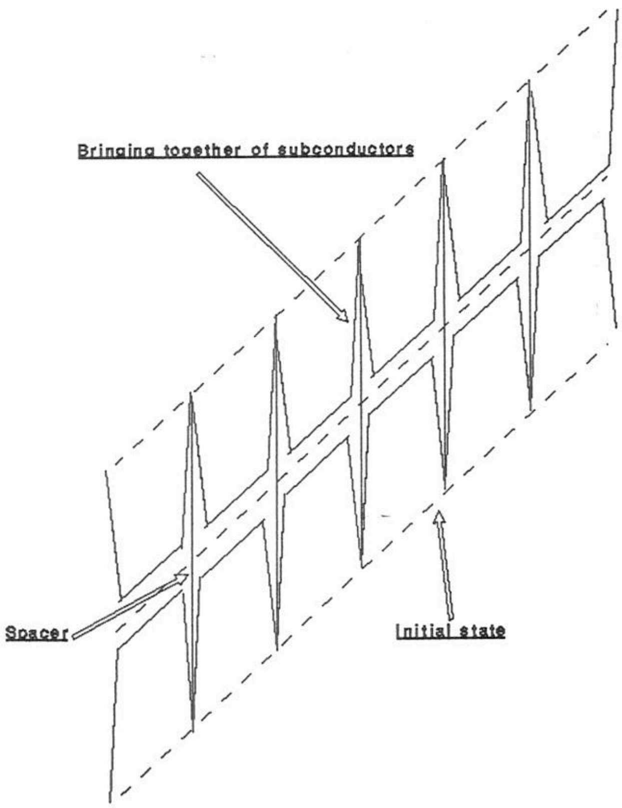


Figure 3: Time evolution of subconductors position.

Figure 3 shows the structure configuration, after subconductors discretisation (initial state), by using finite element model. It, also, shows the bringing together of subconductors. This corresponding to the impact of maximum nodes and provoke the peak of subconductors stresses.

The tension oscillation is presented in Figure. 4 with a big increase corresponding to the impact of the maximum nodes.

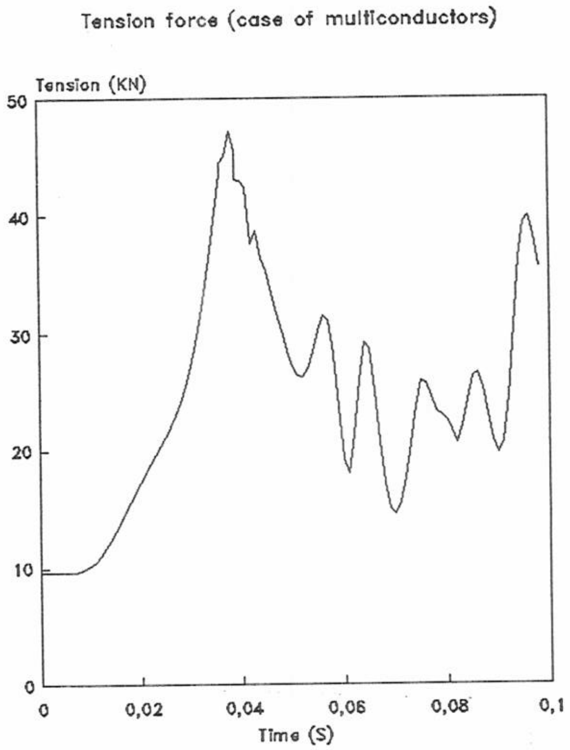


Figure 4: Traction time evolution.

The first peak of mechanical tension is Fpi = 50 kN; for consequence the relative increase of the mechanical tension is Fpi/Fst = 5.

We establish that the increase of tension is so high. The problem is what exactly do with Fpi : If the design must take into account that value, and if we suppose that Fpi is statically applied, the design would be largely overestimated.

We have also, in figure 5, addressed the electrodynamic force between subconductors in the middle of subspan.

The maximum intensity of this force is corresponding, in the case of the pinch effect phenomenon, to the impact of subconductors and the fact that the distance between the corresponding nodes is reduced to the diameter.

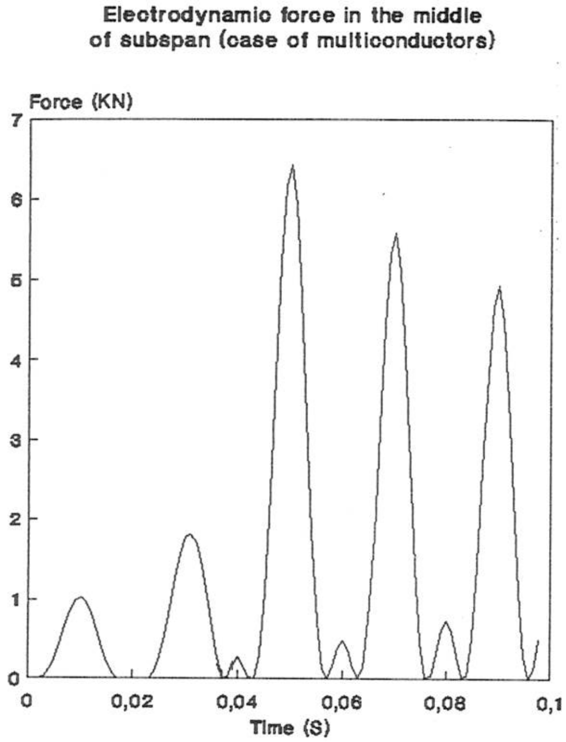


Figure 5: Electrodynamic force between subconductors.

4. Influence of unequal span length :

One of objects of tests and computations is to focus the designer on appropriate parameters which influence the behaviour of bundle conductors in overhead lines taking into account different loads (short-circuit, subspan oscillation, aeolian vibration, corona effect,...).

Structures of unequal spans are generally used to reduce the instability of subconductors caused by the oscillation of subspan under wind effect.

It has been established that the influence of unequal span length on the stabilisation of subconductors is only for twin bundle [8].

In the case of bundled of more than two subconductors per phase (triple or quadruple bundle), the various of position of spacers in the subspans (unequal subspan length) don't presents most effect on the stabilisation of bundle under oscillation of subspans.

In the object to show if the unequal subspans presents some effect on the peak of tension provoked by the pinch effect phenomenon under short-circuit current, we have studied many cases of multiconductors structures.

The results are presented in the following graphics.

These results are relating to the structure tested by EDF [9] and represented in figure 6.

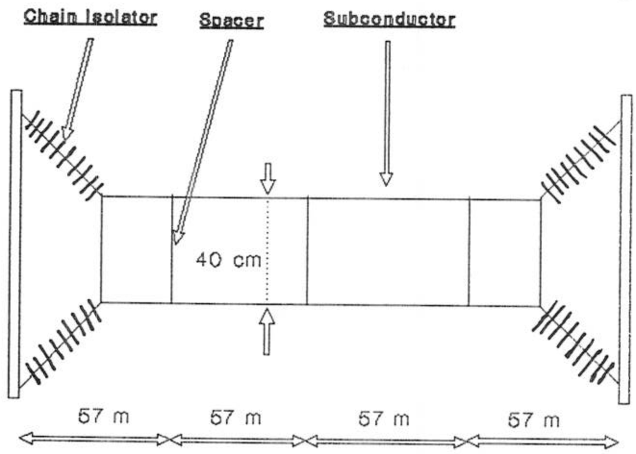


Figure 6: Structure tested by EDF.

The short-circuit intensity was 60 kA (163 kA peak), with a 120 ms time constant. Conductor size was ASTER 2x570 mm^2, with 40 cm separation, 4 subspans of 57m. Insulator chain mass of 327 kg, length 4.64m.

The fact that the structure is symmetrical, we have studied the only two subspans.

We have compared two configurations of disposition of subspans:

The case that the subspans are equal (2x57m) and the case that the length of subspans are respectively 38m and 76m.

The results, representing the comparison of the tension force and the spacer compression are presented in figures 7 and 8.

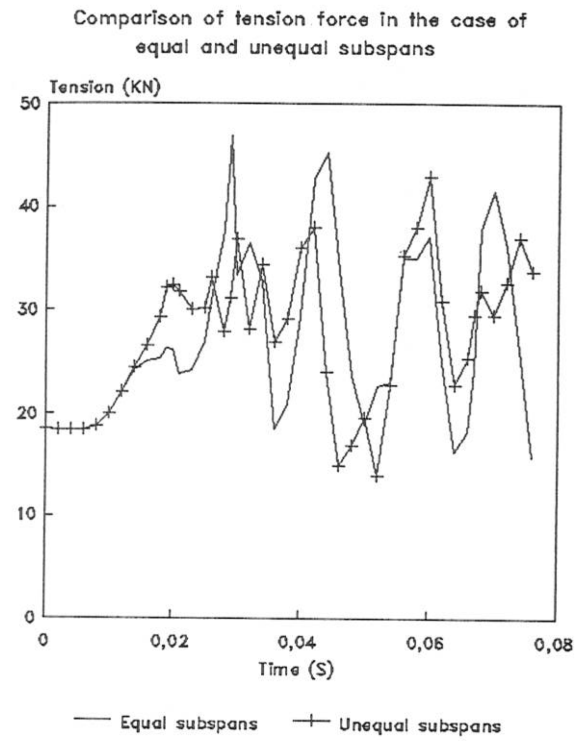


Figure 7: Traction time evolution.

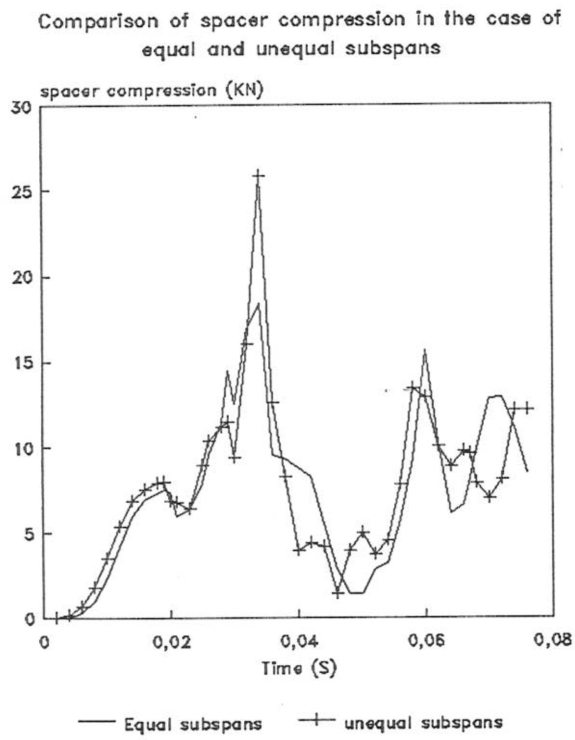


Figure 8: The compression of spacer

The comparison of tension force, in these two cases, shows that the frequency contents is practically respected. We note that one of the difference between these two cases, is the lower value of tension peak in the case of unequal subspans, and that the peak of the tension is produced at 30 ms. However, this is corresponding to 60 ms in the case of equal subspans.

The spacers compression presents, practically, similar aspect. The maximum value of spacer compression is most higher in the case of unequal subspans.

Finally, we established that the influence of unequal subspans is more important on the peak of spacer compression than the peak of tension force. Parametrical study of many structures, must be developed, to evaluate the real effect of choice of unequal subspans in the design of structures.

5. Conclusion and Recommendations :

In object to develop a general program for design of bundled conductors, taken into account the principal mechanical loads, we have opted, in the first time, for study of bundle conductors behaviour under short-circuit currents.

In this paper, we have presented a methodology used for simulate the pinch effect phenomenon in the case of multiconductors per phase (more than two subconductors per phase) and in any spatial configuration (horizontal, vertical and oblique bundle).

We have resolved this complex phenomenon by adopting an approach based on crossing of subconductors.

The results obtained are fundamentally good and respect the physic of phenomenon. Tests of multiconductors bundled under short-circuit current must be realised in the object to permit a confrontation between numerical calculations and tests and to valid the models developed.

Specific recommendations to focus the designer on the parameters which influence the behaviour of all structure under different loads, will be deduced to the dynamic model in comparison with experimental tests. Other investigations are requested in this field.

In the future, tests are necessary and must be coupled with computations to quantify what is the actual effect of different loads on the behaviour of the structure.

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