CS154

Analysis of the Impact Response to Backup Clamp from Broken Transmission Line Tension Clamp

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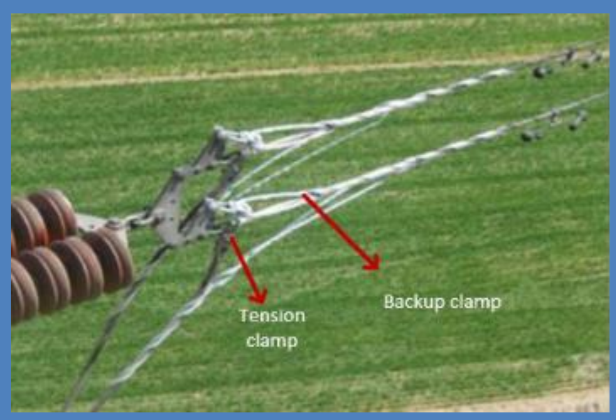
Introduction

Background:

The use of backup clamps, the original purpose is to prevent the combined effect of adverse factors such as ice, dance and sub-grade distance oscillation, resulting in damage to the fixture or the conductor from the tension clamps. With the rapid extension of high-speed railroads, highways and other transportation networks across the country, some transmission lines in the suburbs originally did not belong to the important cross section, gradually transformed into cross-over lines. In order to improve the safety of these lines, the power grid company on these lines for centralized transformation, one of the important measures is the installation of backup line clamp. The installation of backup clamps can play a three-fold role: share the mechanical load of the wire tension clamp, increase the security margin of the tension clamp; additional diversion lines can play a role in shunting, reducing the failure rate of the tension clamp diversion plate heat; in extreme cases, once the tension clamp fracture failure, can prevent the wire from falling and continue to guide the flow.

The most common type of back-up clamps are pre-twisted back-up clamps. Figure 1 shows a pre-twisted backup clamp installed on a transmission line. The backup clamps consist of two main components. The system that provides mechanical tension consists of a set of safety backup clamps, a set of reinforcement splice strips, a section of strand filler strip, a set of thimbles and a set of shackles. The system providing electrical diversion consists of a set of shunt strips. The principle of operation of the backup clamps is that the pre-twisted wire legs are twisted together to form a hollow tube with a pre-formed ring at the rear, which is fixed to the connection fixture. The tubular structure formed by the legs of the pre-twisted wire is naturally wrapped around the conductor after installation to create an extremely strong grip.



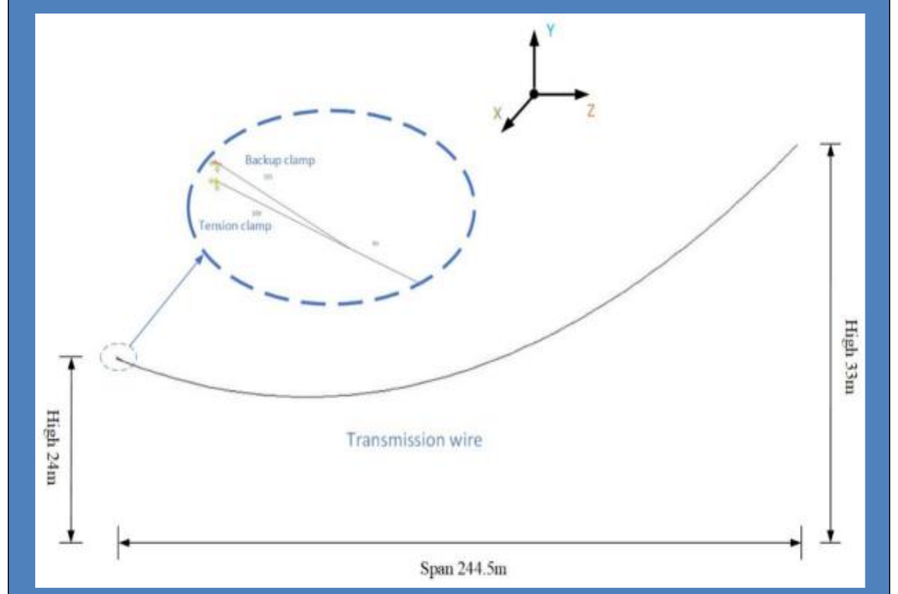
Finite Element Model Building

Finite Element Model:

In order to simplify the analysis and save calculation costs, the insulator strings and towers were not considered in the modelling. ANSYS finite element software was used to create a simplified finite element model of a sub-conductor of the right-phase conductor, its tensor clamps and backup clamps, with fixed end constraints at the ends of the conductor and at the hook points of the backup clamps. The tensor clamps, conductor and backup clamps are modelled using LINK180 rod units.

Conductor for Shape:

As a highly flexible structure, the conductor can only withstand tensile forces and is prone to large displacement deformations when subjected to vertical loads, with a very high degree of non-linearity. As a typical suspension structure, the cables need to be shaped in order to determine the stresses and displacements of the cables in their initial state (under self-weight). After deformation, the cable structure has stresses and, due to the stress stiffening, has vertical stiffness, which allows various hydrostatic calculations to be carried out, therefore, deformation is an important step in the various calculations of the cable structure and is related to the accuracy of the calculations. The process of finding the shape of the conductor is based on the creation of a geometric model at the location of the chord of the transmission conductor and the setting of the real constants and actual parameters of the transmission conductor. Although the conductor tension is generated under load, a very small initial strain is defined at the moment 0 in order to obtain stability in the solution. Then, using the discharge horizontal stress of the transmission conductor in the actual project as the iterative target, a self-weight load is applied to obtain the horizontal stress in the finite element model. If the error with the discharge stress is greater than 1/100, the deformation factor is defined to update the finite element model and the next iteration is performed. When the stress error is less than 1/100, the iteration is stopped and the static equilibrium state at this point is the initial configuration of the transmission conductor.



Model Validation:

In order to verify the correctness of the model built and to ensure the accuracy of the later analytical calculations, the arc sag values in the model are compared with the analytical solution of the wire arc sag for the purpose of verification. The approximate formula for calculating the central arc sag at unequal suspension point stall distances on overhead transmission lines is：

$$f_{\frac{1}{2}}=\sqrt{1+\left(\frac{h}{L_{h=0}}\right)^2}\,\frac{\dot{\sigma}_0}{\gamma}\left(ch\frac{\gamma l}{2\sigma_0}-1\right)$$

$$L_{h=0}=\frac{2\sigma_0}{\gamma}sh\frac{\gamma l}{2\sigma_0}$$

Through the formula (1), (2) calculation to get the conductor stall distance central arc dip analytical solution is 3.713m, and the model stall distance central arc dip is 3.800m, the error is 2.3%. Compared with the analytical solution, the error of the model is smaller, which can indicate that the model meets the accuracy requirements.

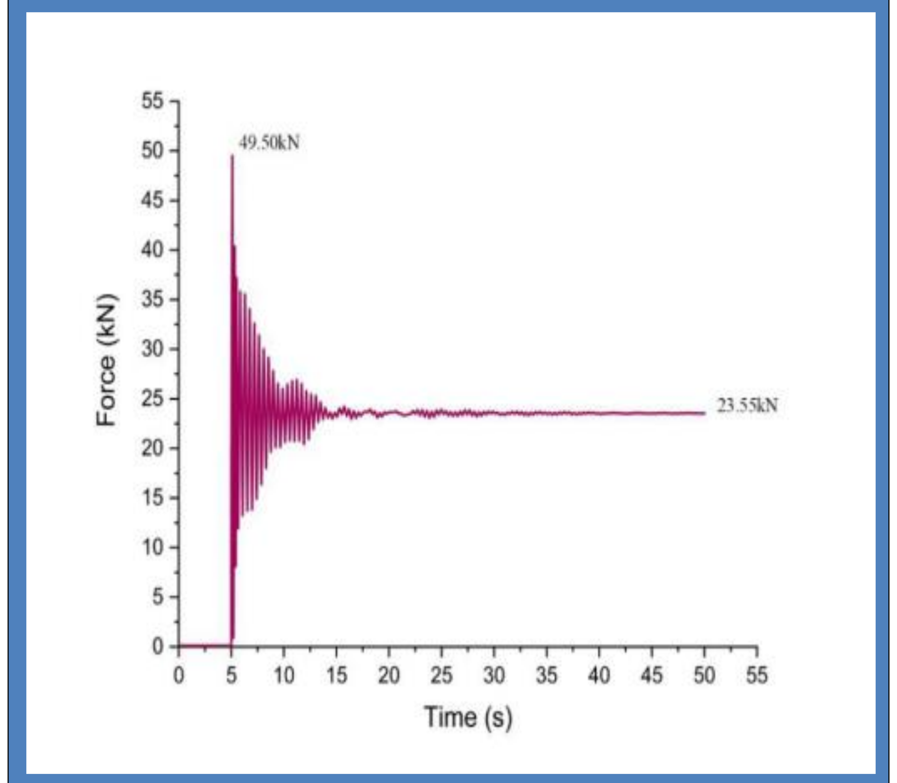
Backup Clamp Shock Response Analysis

Tension Clamp Fracture Simulation:

The impact effects of backup wire clamps are analysed using non-linear complete transient analysis. Tensioning clamp fracture is simulated using the following approach: firstly the whole system is allowed to equilibrate under the influence of gravity and the individual cells are made to generate internal forces. The sudden fracture of the tension binder is simulated using the raw and dead cell method in finite elements. The fracture of the tension binder is sudden and occurs within a very short period of time, so that the break time can be determined as 10-2 s. In the whole time analysis, an automatic time step is used, with a time duration of 50 s.

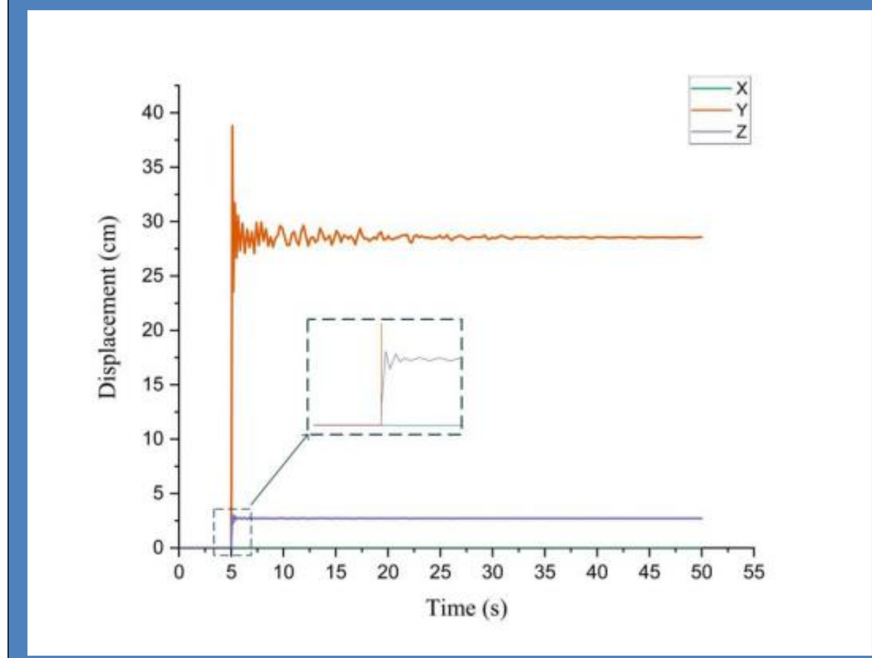
Axial force response analysis:

Using the above finite element model and the tension-resistant clamp fracture simulation method, the impact effect on the backup clamp after the tension-resistant clamp fracture is analysed. The extracted axial force time curve of the backup clamp is shown in Figure 4. It can be seen that at the beginning of the equilibrium phase, the backup clamp is almost force-free, and at the moment of the sudden fracture of the tensioning clamp at 5 s, the axial force of the backup clamp instantaneously reaches 49501.1 N. After that, the wire and the backup clamp enter the non-linear free vibration phase under the action of damping. The tension on the original tensor clamps is transferred to the backup clamps. Eventually the whole system reaches a new equilibrium state.



Displacement response analysis:

One end of the backup clamp is fixed to the upper end of the wire hook-up point and the other end is connected to the wire. The X, Y and Z displacement curves for the X, Y and Z directions were extracted from the end of the backup clamp connected to the wire as shown in Figure 5. Backup wire clamp in the moment of the break occurs, under the action of the wire tension, its Y direction and Z direction have produced a large displacement, the extreme value of the displacement of 38.77cm and 3.05cm, respectively, when the wire and backup wire clamp to re-equilibrium, backup wire clamp equilibrium position than before the break equilibrium position has changed, the Y direction and Z direction displacement change amount of 28.56cm and 2.72cm, while the backup clamp in the entire analysis process in the X direction basically did not produce displacement, because the X direction is perpendicular to the direction of the wire, the backup clamp in the entire process basically will not produce displacement in the X direction, which is also in line with the actual situation.

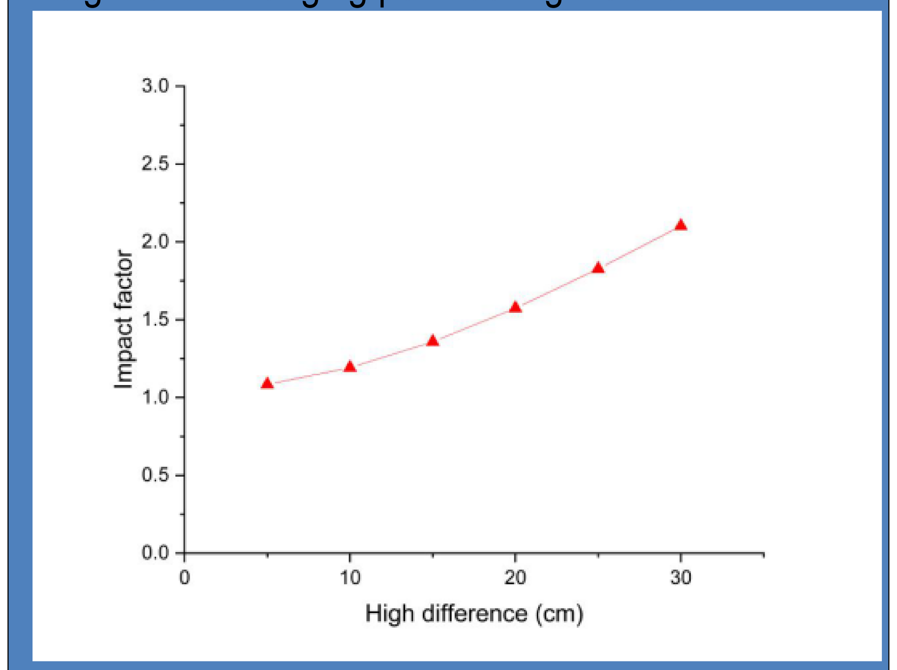


Influence of the height of the backup wire clamp hanging point on the impact factor:

The impact factor is the ratio of the response under dynamic impact loading to the static response. Also known as：

$$\mu=R_{\max}/R_{stc}$$

The above analysis shows the dynamic response of the backup clamp when the difference in height between the backup clamp hanging point and the tension-resistant clamp hanging point is 30cm.The impact factor can be calculated as 2.102 according to equation 3. In order to study the effect of the height of the backup clamp on this impact response, the difference in height between the backup clamp hanging point and the tensioner clamp hanging point is set to 5cm, 10cm, 15cm, 20cm, 25cm and 30cm respectively, and the impact response of the model is analysed by the previous method and the impact coefficient is calculated for different hanging point heights. It can be seen that as the backup clamp hanging point gradually rises, the impact factor of the wire on the backup clamp impact when the tension-resistant clamp breaks is also gradually increasing. Therefore, in order to improve the effectiveness of the backup clamps, appropriate measures can be taken to reduce the height of the hanging point during installation.



Results and Conclusions

- This paper uses an actual transmission line as the engineering background and establishes a finite element model of the conductor-tensioner clamp with a backup clamp, and verifies the accuracy of the model by comparing it with the analytical solution.
- The use of life and death of the unit method to simulate the fracture of the tension-resistant clamps, the backup clamps at the time of fracture transient analysis, the results show that at the moment of fracture the backup clamp axial force instantly reached 49501.1N, the backup clamp and the wire connection Y direction and Z direction displacement reached 38.77cm and 3.05cm, while the X direction did not occur larger displacement.
- Analysis of the impact coefficient of the backup clamp hanging point height, the results show that in a certain range with the backup clamp installation height increase the impact coefficient is also greater. This conclusion also provides a reference basis for the installation height of the backup clamps in the project.
- This analysis does not consider the influence of transmission towers and insulator strings, so there may be some errors.

Future Work

In the future, the influence of tower and insulator will be considered, and the model of the whole tower line system will be established to analyze the impact effect of the backup line clip when the tension clamp breaks. Study the validity and security of backup clamp.

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