

## ANTI-ICE SHEDDING TECHNOLOGY OF TRANSMISSION LINE

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**Abstract:** Ice-shedding from conductors is a familiar phenomenon on overhead transmission line in ice area. In heavy icing areas and long-span cases, the effects of ice-shedding are especially significant. This paper investigates the effect of the jumping induced by the ice-shedding and anti-ice shedding technology.

### 1. INTRODUCTION

The ice covered on transmission or ground line will be shedding from conductor unevenly or at different time when the temperature increases, or the force of wind and air humidity decreases, in this process coincided with the overhead transmission line's jumping or dancing and tower's sway. The ice-shedding of transmission line will cause a lot of damage to the conductors, insulators, towers and may finally cause power accidents. So it is important take corresponding measures and controls to prevent it from causing power accidents.

### 2. RESULTS AND DISCUSSION

The mechanism of ice-shedding jumping can be considered as a procedure that the elastic energy of the tensional wire translate into kinetic energy, then gravitational potential energy, so that it will cause conductor jumping. Along with the increase of ice load, the tension and sag of wire will increase gradually and obtain corresponding elastic energy and gravity potential energy. When the temperature get rising or affected by wind disturbing influence, the ice covered along the large or whole section of the line sheds and the potential energy translate into kinetic energy rapidly which causes the wire jumping up forming a few meters even several meters of large amplitude half wave.

The iced galloping also has negative effect on the safe operation of power system. Statistics show that bundle conductor is easier to gallop than single conductor. The large section conductor is easier to gallop than the small section conductor.

### 4. CONCLUSION

(1) Anti-ice shedding jumping and the galloping accident of tower-line system should be both considered, the key is to prevent or reduce the conductor icing.

(2) The line span in heavy icing zone should be not too long, the span should be as even as possible, we should reduce the number of the files of the continuous tangent towers in train sections or use strengthened tangent tower, to reduce the imbalance tension difference. The height difference of adjacent files should be as small as possible to avoid suspension insulator strings turning upward, damaging the insulators and the emergence of a permanent ground fault while ice shedding and uneven icing.

(3) In the medium and heavy icing zone, especially in the place spanning the gorges, tuye zone, passes, etc. We can partly take stronger steps to improve the power of the towers to withstand the longitudinal imbalance tensile strength. At the same time we can use Phase to Phase spacer, and we would use deicing ring (hammer) and air flow spoiler if the conductor is single conductor. At the same time interval by white bars, anti-icing can be a single wire loop (hammer), and spoiler control anti-galloping.

(4) For the ice zones which galloping is easy, according to operating experience, we all should take measures to prevent galloping. We can mainly adopt concentrated eccentric hammer, dual-swing damper, integral eccentric hammer, combined spacer and so on, they have high inhibition for galloping.

(5) The corner should no more than  $30^\circ$  when choosing the route, to increase the overload of the corner tower.

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# Anti-Ice Shedding Technology of Transmission Line

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**Abstract**—Ice-shedding from conductors is a familiar phenomenon on overhead transmission line in ice area. In heavy icing areas and long-span cases, the effects of ice-shedding are especially significant. This paper investigates the effect of the jumping induced by the ice-shedding and anti-ice shedding technology.

**Keywords**—overhead transmission line; conductor ice-shedding; jump; icing

## I. THE GENERATION AND DAMAGE OF ICE-SHEDDING OF TRANSMISSION LINE

### A. The Generation of Ice-Shedding of Transmission Line

The ice covered on transmission or ground line will be shedding from conductor unevenly or at different time when the temperature increases, or the force of wind and air humidity decreases, in this process coincided with the overhead transmission line's jumping or dancing and tower's sway. Therefore, for the transmission or ground line's jumping and dancing induced by the ice-shedding, it is important to take corresponding measures and controls to prevent it from causing power accidents.



Figure 1. The scene of Ice-shedding of transmission line

### B. The Damage of Ice-Shedding of Transmission Line

The jumping and dancing up and down induced by the ice-shedding may cause inter phase flashover or short circuit. With the ice cover increased, the sag of the transmission or ground line will descend. When the ice-shedding happened to the large or whole section of the line, it is elastic energy storage quickly transform into kinetic energy or potential energy which will cause the jumping up and down of the line. Then the tower may strongly vibrate, with seriously excursion of the trailer insulator string and then the breakdown of cross arm and insulator string. The ice-shedding may also cause difference in tension between wire ends which will cause wire-slide in overhang-line-folder or the breakage of outer aluminum of wire at the wire-clip-exit or twitch of the core. Meanwhile, because the ice shed from the adjacent wire at different periods, it will lead to break off or upward cock of the cross arm, stent damage of ground line and seriously tower collapse.

## II. THE ICE-SHEDDING JUMPING ANALYSIS OF TRANSMISSION LINE

### A. Dynamic Analysis of Conductor Ice-Shedding.

When the ice-shedding happens, the conductors and insulator string will vibrate at low frequency synchronously. At the straight tower pensile point, the lengthways imbalance tension also changes with the wires' jumping vibration synchronously. The mechanism of ice-shedding jumping can be considered as a procedure that the elastic energy of the tensional wire translate into kinetic energy, then gravitational potential energy, so that it will cause wire jumping.

Along with the increase of ice load, the tension and sag of wire will increase gradually and obtain corresponding elastic energy and gravity potential energy. When the temperature get rising or affected by wind disturbing influence, the ice covered along the large or whole section of the line sheds and the potential energy translate into kinetic energy rapidly which causes the wire jumping up forming a few meters even several meters of large amplitude half wave.

### B. The Influence Factors of Ice-Shedding Jumping

#### (1) The influence of insulator length

The insulator length will affect the jumping height of ice-shedding. When the ice-shedding happens, the longitudinal oscillation and migration of insulator string will increase jumping height of the wires under the longitudinal unbalanced amount of tension. The influence of insulator length to the jumping height of ice-shedding can be described as follows. For example, if the insulator length is short, closed to kind of rappel pensile, the coupling between adjacent wires will be smaller, so the jumping height of ice-shedding will be smaller, too. On the contrary, if the insulator length is long, when similar longitudinal migration happens, the vertical displacement of elevating is small, so that jumping height of ice-shedding will be small. So it can be inferred that jumping height of ice-shedding will reach maximum height when the insulator string length take a particular value.

#### (2) The influence of ice-shedding amount

More load of ice-shedding, more height the wire will jump. Only change the ice-shedding load (sign with the percentage of initial ice load), in the condition of uniform ice-shedding, the ice-shedding jumping height approximately satisfy the linear relationship with the percentage of the initial ice load.

#### (3) The influence of ice properties

It can be drawn from the field observation and simulation test data: the amount of ice-shedding is not only related to the size of the ice, but also depends on the properties of the ice. When the ice is Rain Song or mixed Song which has more strong adhesion, usually only shed a paragraph at a time, it is difficult to form great ice-shedding jumping. Conversely, if the ice is rime or wet snow which has weak adhesion, ice shedding at the same time is much easy to happen on the whole file wires, so it caused a strong ice-shedding jump.

(4) *The influence of the continuous span combination*

Research results show that the span combination has a salient effect for the ice-shedding jumping, the jumping height in the continuous file is much higher than it in an isolated case file. If there are more consecutive files, and the span is longer on both sides of ice-shedding file, the coupling between the files is stronger on the suspension point, so ice-shedding jumping height is higher. But with the distance of the ice-shedding files is increasing, the jumping heights under various combinations present a saturation trend.

(5) *The influence of conductor type*

Under the same section of aluminum, the stronger the rigidity of the wire, the smaller the ice-shedding jumping height.

(6) *The influence of uneven ice-shedding*

If the uneven ice-shedding place were closer to the middle of the span, the jumping height is higher, and it is significantly higher than the even ice-shedding situation. In the cable structure of overhead conductors, the wire rigidity is much larger near the suspension point and on the middle point of the span has minimum rigidity. Thus, when the ice-shedding happens along the different span locations, even if the ice-shedding load is exactly the same, the ice-shedding jump heights are different.

(7) *The influence of wind*

While conductor is jumping, there is a wind at the same time, then there is not only transverse fluctuation vertical movement but also lateral oscillation, the oscillation amplitude is determined by the wind. In the influence of the wind power and its self-gravity, the wire will produce shear breakdown, the shearing force is based on the wind speed, the angle of attack and the ice shape and so on. The maximum shear stress appears in the place the conductor close to the tower, and the largest twist angle appears in the middle of the conductor. Ice begins breaking and shedding from the end, it produces a concentrated stress at the ice-shedding place, and makes the surface adhesion strength become more and more weak, more vulnerable to the wind stress. Therefore, ice-shedding by the wind is a gradual process, it begins from the both ends of the conductor supporting place, then gradually develops to the middle of the file. Ice-shedding at different time or uneven shedding by wind would cause adjacent files of conductors shaking,

produce alternating stress vibration, and accelerate broken ice shedding.

C. *The Safe Operation Affected by Galloping of The Icing Single and Bundle Conductor*

(1) *Galloping of the icing conductor caused by single and bundle conductor*

Statistics show that bundle conductor is easier to gallop than single conductor. When the icing conductor is single conductor, the eccentric torque caused by the eccentric icing makes it rotate around its own axis, due to its torsional rigidity is small, the conductor is easy to happen large rotate under the eccentric icing, the conductor may have a relatively homogeneous symmetric icing, it's not easy to cause galloping. When the iced conductor is bundle conductor, after causing eccentric icing on conductor, due to the existence of the grip of clamp of separated bar, conductors are hard to cause rotating around its own axis, the relatively torsional rigidity of every conductor is much larger than single conductor, under the eccentric icing, the rotation of the conductor is very small, it can't prevent the uneven of the icing, conductor is easy to form fan-shaped, crescent-shaped, D-shaped and other forms of uneven icing, which inspires the formation of positive feedback on the wind, makes the system energy accumulating, and finally leads instability galloping, making bundle conductor easily gallop than single conductor.

(2) *Galloping of the icing conductor caused by conductor section*

The large section conductor is easier to gallop than the small section conductor. The relatively torsional rigidity of the large section conductor is smaller than the small section, because the twist angle is smaller under eccentric icing, the icing conductor is easier to form wing section, and the lift and torque are bigger under the wind excitation.

III. OVERSEAS AND DOMESTIC ANTI- ICE SHEDDING TECHNOLOGIES AND APPLICATIONS

A. *Lead Viscoelastic Dampers*

Regard lead viscoelastic dampers and tower as a whole, when it vibrates by the external force, due to the relative displacement between two points, make the damper reciprocating motion, use the viscoelastic material and lead core to cause shear deformation and energy dissipation. The structure is shown in Figure 2. Installing the lead viscoelastic dampers in parallel to the angle to the tower and it does not undermine the tower.

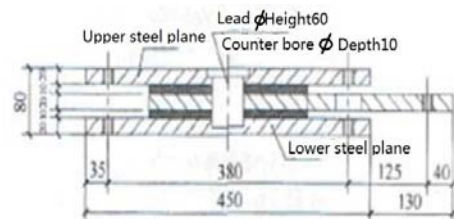


Figure 2. The structure of the lead viscoelastic dampers

This control had been applied to Guangdong Chuxiong  $\pm 800\text{kV}$  HVDC project (Using double lead viscoelastic damper), it is used to reduce the vibration caused by the anti-ice shedding jump of the transmission lines. Studies have shown that the maximum vertical vibration reduction rate of the lead viscoelastic dampers is 22.98% under the ice shedding, generally the effect of the vertical vibration reduction is better than the effect of the direction along the conductor. At the same time this damper has a highly effective wind vibration control for steel transmission towers.

### B. The New Cross Antiseismic Spacers

Hydro Quebec, Canada developed a new type of antiseismic spacer, this spacer has no latch.

Technical characteristics: ①it has abandoned fixture latch, but use prefabricated spiral pole to connect to the spacer and the conductor, the spiral pole grasps the line, and the open-style semi-circular seat snaps into the wire, the semicircle seat has elastic pad; ②The damping elastic cylinder is mainly worked in squeeze mode (rather than shear mode), so it has a longer service life and is more effective; ③The fatigue test of this fixture shows that its performance is perfect, its bending amplitude in the fatigue curve is twice more than the latch type.

So far, about 1 million these spacers were used on the double-bundle and four-bundle conductor in the Quebec power system, India, Britain, Argentina and Peru and other countries.

This spacer has been applied in Sichuan Xichang Electric Power Bureau 500kV Puhong three lines, two general three-wire, two general second, its anti-icing capability is better than the original spacer, which can effectively reduce the rotation and gallop amplitude of the uneven icing conductors. At the same time, the flexible structure of the spacer arm, the preformed armour rod attended mode of the spacer and the conductor can effectively reduce the jump of the uneven icing conductor, the damage for the spacer and the conductor when it is rotating, and had achieved good results.

### C. Deicing Ball

Increasing the torsional strength of the conductor, it can ensure that the conductor cannot rotate within certain icing thickness. The role of the deicing ball is to increase the torsional strength of the conductor, and to play the role of deicing and anti-ice shedding, so when we design the heavy twist and the number of the deicing balls, we should consider the whole load limit of the overhead lines.

### D. Deicing Ring

Using deicing rings on the conductors, its main purpose is to make the ice shed from the conductors and ground lines section by section, so it can avoid the ice on the conductors and ground lines shedding at the same time, lines jumping, causing touching lines accident.

The deicing balls and rings are useful for the conductors, especially for windy weather conditions, if there is no wind, the deicing balls and rings are failure, but the statistical laws show that (particular in the mountains) windy freezing weather conditions are dominant.

### E. Air Flow Spoiler

The air flow spoiler is made by winding plastic prefabricated interference line on the conductor, making the each body shape of the connection of the spoiler line and conductor is different, even in the case after icing, shown in Figure 3.

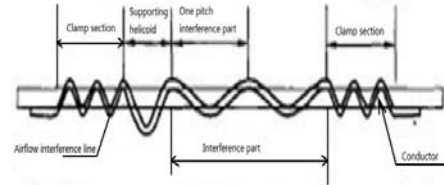


Figure 3. The air flow spoiler

This spoiler has light weight, is easily installed, and has small negative impact, is suitable for single wire.

In thinner icing, its anti-galloping effect is better; but in thicker icing region, its effect is general. As a polymer material, it has aging problem.

### F. Concentrated Damper

The anti-galloping principle of the concentrated damper (used for single conductor) is using heavy pressure to anti gallop, limiting the swing of the pressure focus, forming nodes, thus inhibiting the swing and vibration mode of the wire, and accomplishing the purpose of controlling conductor galloping. The advantage of the concentrated damper is easily derived, easily installed, and it can limit aeolian vibration. But something must be mentioned:

(1) They are installed on each sub wire, have large freedom degree, easy to cause disturbing, inducing high wave and sub-span oscillation. The countermeasure is that installing a spacer at about 5m's outer ends of the concentrated damper in crossing span to fix the damper, so it can improve its stability, we also can install spacer on the appropriate middle place of the crossing span, so it can narrow and stagger the sub-span, inhibit high wave and sub-span oscillation.

(2) Installing too many dampers will cause wire damage and increasing conductor tension at the wire clamp, and if the number of the installed dampers is small, they cannot inhibit galloping. Therefore, the application of the concentrated damper on single conductor transmission lines must be careful.

### G. Phase To Phase Spacer

Phase to Phase spacer (used for single conductor and bundle conductor) which is with high insulation properties and mechanical strength is used between phases, it mechanically connects each conductor, so that all wires exercise interact with each other, and it achieves the purpose of inhibiting galloping. Phase to Phase spacer has composite structure which is generally made of the bar with glass and steel core and silicone jacket. Phase to Phase spacer can not only inhibit galloping, but also prevent the accidents caused by ice shedding jump pendulous conductors, its function for

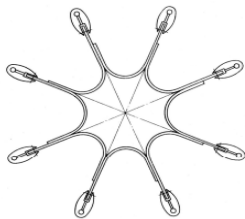
prevent galloping is best in all types of the existing spoilers. The disadvantage of the phase to phase spacer is its aging problem.

#### H. Dual-Swing Damper

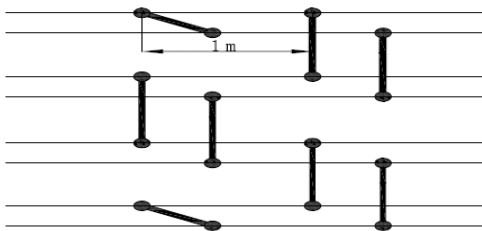
Dual-swing damper (suitable for bundle conductor) is a damper which is equipped with a double pendulum on spacer. This damper is developed by dynamic stability theory, and to improve the dynamic stability of the conductor system, also to use its heavy pressure to prevent galloping. Now it has been widely used in bundle conductors in China, and have achieved good results for anti galloping, accumulated rich experience, this damper is the most widely used in the overhead power distribution system of our country, shown in Figure 4.



Now the dampers used in Russian are star type spacer, combined type spacer and so on, they are available from the service conditions, shown in Figure 6.



Star type spacer



Combined type spacer

Figure 6. Russian anti-galloping measures

#### IV. CONCLUSION

Anti-ice shedding of transmission line, the following points should be noted:

1、Anti-ice shedding jumping and the galloping accident of tower-line system should be both considered, the key is to prevent or reduce the conductor icing.

2、The line span in heavy icing zone should be not too long, the span should be as even as possible, we

Figure 4. Dual-swing damper

#### I. Integral Eccentric Hammer

Integral eccentric hammer (suitable for bundle conductor) is a new type of damper which is developed on the design experience of Japanese distributed eccentric damper and the specific situation in China. This damper has comprehensive functions such as improving dynamic stability, providing reverse feedback control, disrupting the flow distribution along the file, and it has relatively low cost, it is an economic and effective damper. Integral eccentric hammer also builds the mathematical model of bundle conductors based on stability mechanism, and its modeling is similar to dual-swing damper, this damper has also been used in bundle conductors of our country, it also had made a good effect of anti-galloping, shown in Figure 5.

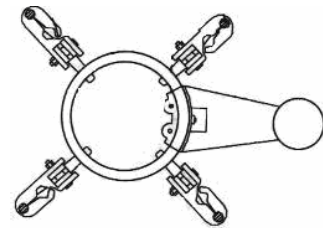


Figure 5. Integral eccentric hammer

#### J. Russian Anti-Galloping Measures

should reduce the number of the files of the continuous tangent towers in train sections or use strengthened tangent tower, to reduce the imbalance tension difference. The height difference of adjacent files should be as small as possible to avoid suspension insulator strings turning upward, damaging the insulators and the emergence of a permanent ground fault while ice shedding and uneven icing.

3、In the medium and heavy icing zone, especially in the place spanning the gorges, tuye zone, passes, etc. We can partly take stronger steps to improve the power of the towers to withstand the longitudinal imbalance tensile strength. At the same time we can use Phase to Phase spacer, and we would use deicing ring (hammer) and air flow spoiler if the conductor is single conductor. At the same time interval by white bars, anti-icing can be a single wire loop (hammer), and spoiler control anti-galloping.

4、For the ice zones which galloping is easy, according to operating experience, we all should take measures to prevent galloping. We can mainly adopt concentrated eccentric hammer, dual-swing damper, integral eccentric hammer, combined spacer and so on, they have high inhibition for galloping.

5、The corner should no more than  $30^\circ$  when choosing the route, to increase the overload of the corner tower.

6、For the important lines in the heavy icing zone, every few bases adding a base of tension tower.

7、For the tower has larger vertical span, we can use double-ended clamp to increase the bending strength of the conductor at the clamp exit. For the local sections which are easy to emerge uphill wind and causing

conductor jump by the micro-topography, we should adopt the double-lane clamp to avoid bending and breaking the insulator pins.

8、 In order to prevent or reduce the thread broke or strand breakage phenomenon when there is icing and ice-shedding jumping, the conductors in heavy icing zone should be high mechanical strength steel core aluminum wire or aluminum clad steel wire.

9、 In order to reduce or prevent damaging the conductors caused by uneven tension and ice-shedding jumping on heavily icing power transmission lines, we should adopt preformed rods.

10、 On the jumpers of the heavily iced power transmission lines' load-carrying towers, we should install insulator strings to prevent the jumpers' jumping

and then forming the flashover discharge on the lower plane of cross arm caused by ice-shedding jumping.

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