Influence Analysis of Transmission Lines Insulator on the Conductor Ice-shedding

Xin-bo HUANG[1], Guan-hua XU[2],Yong-can ZHU[3], Ming-jin LIAO[1],Xin-xin ZHENG[1]

[1]College of Electronics and Information, Xi'an Polytechnic University, Xi'an 710048, China;

[2]College of Mechanical and Electrical Engineering, Xi'an Polytechnic University, Xi'an 710048,China;

[3]College of Mechanical and Electrical Engineering, Xidian University, Xi'an 710071,China)

(hxb1998@163.com)

Abstract: **Conductor strenuous exercise will be caused by the ice-shedding. It is easy to cause the occurrence of electrical or mechanical accident of transmission line. Therefore, Conductor-insulator finite element model has been established through the ANSYS, and it is the analysis of the dynamic characteristics for the wire type, material properties and the length of the insulator string under different ice shedding. The influence of insulator has been separately analyzed from the jump height, unbalanced tension etc. for the conductor ice-shedding. The results showed that: It I type insulator on ice-shedding unbalanced tension impact is about 0.9 times smaller than the V type insulator. It is not significant for ice-shedding unbalanced tension effects about the composite and ceramics materials. The ice-shedding jump height will be unchanged for the V type or I type insulator with the length increase of insulator string, but ice-shedding unbalanced tension will be decreased. The related results provide a reference for the subsequent study on conductor ice-shedding and lines structure design.**

Keywords: icing; ice-shedding; FEM; insulator; ice-shedding jump height; unbalanced tension

INTRODUCTION

Ice-shedding recently caused mechanical or electrical accidents by a serious threat to the safe and stable operation of power system. Overhead transmission lines in our country is affected by the terrain, line structure and natural disasters, part of the line will inevitably through the heavy ice areas, there is an urgent need for ice-shedding problem in-depth analysis[1].

The some research of domestic and foreign scholars on the conductor ice-shedding. Foreign, Jamaledding et al [2] to simulate the conductor length of 3.22 m in a variety of ice-shedding in the artificial climate chamber. Kalman T et al [3] by establishing the finite element model, considering the dynamic response under various conditions of icing conductor. In China, under the tower-line system dynamic response simulation of ice-shedding of ABAQUS for different numerical Yan Bo et al [4] use, and gives the influence of wind load on the ice-shedding the maximum transverse swing. Yao Chen-guo et al [5] by using the finite element analysis method, analysis of different wind speed for dynamic response characteristics of ice-shedding. Yang Feng-li et al [6] of ice shedding model, study of different factors on the dynamic response of the tower. Jiang Xing-liang et al [7] in the icing experiment station of DC ice melting, recording and observation of ice-shedding process. The above research is mainly concentrated in the ice-shedding of transverse swing, lead stress, study of tower line system of unbalanced tension and the jump amplitude less.

ANSYS to establish the finite element model of ice-shedding in this paper, the additional force simulation of icing simulation method, a sudden withdrawal load simulation method for dynamic characteristics of ice-shedding, insulation substring type, material properties and the length of ice-shedding, in-depth study the ice jump height and ice-shedding from the unbalanced tension of conductors, the research results have been completed.

Ⅰ. CALCULATION CONDITION

A. Finite element modal

Ice-shedding model includes two parts: transmission line, insulator string. ANSYS establishes the conductor insulator coupled finite element model used in this article, as shown in figure 1. According to the conduct and grounding line in accordance with Hooke Law, only by the properties of tension can not be compressed, the bar element Link10 simulation, the unit can only bear the axial tension or compression, with geometric nonlinearity, in order to simulate the cable or clearance. The bar element Link8 simulation of insulator string, the unit has the stress stiffness, large deformation characteristics. Between conductor and ground and insulator string is connected by hinge. Figure A, B, C, D were the conductor suspension point.

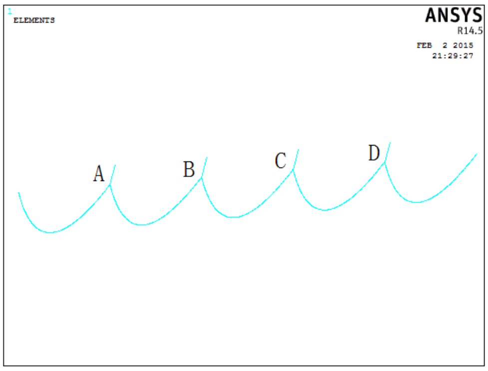


Figure 1 Finite element model of conductor-insulator

B. Analysis method

Nonlinear dynamic process of conductor ice-shedding of large displacement and small deformation, to solve the problem, literature [8] by using the central difference explicit direct integral algorithm to solve the problem, but this method is too complicated and the accuracy is not high. In this paper using the finite element method is solve.

By using the finite element transient dynamics method of ice-shedding are numerical simulation. It is used to determine the dynamic response analysis method of structure change with time under arbitrary load. It can analyze the structure change with time under static load, transient load, harmonic load under the action of the random combination of the displacement, strain, stress, etc.

C. Meteorological condition

The temperature of -5oC, does not consider the effect of the wind speed. The jumping height is increase with the increasing ice thickness. So the paper consider is 15mm of the ice thickness.

D. Material parameters

In this paper, the conductor type is LGJ-630/45, and its mechanical parameters are shown in Table1. Insulator adopts composite insulator. Ice-shedding analysis is simplified of insulator. It main consideration is insulator core, the other components as the added mass of core. The ice load of the insulator string is equivalent to the vertical load of the insulator string. It is applied on the insulator.

Table1 Mechanical parameters of conductor LGJ-630/45

Parameters	LGJ-630/45
Aluminum / steel root number	45/7
The total cross section /mm^2	666.55
Outer diameter /mm	33.60
Linear density /（kg/km）	2060
Pull off force /kN	48.7
EX/MPa	63000
The coefficient of linear expansion /10^{-6}	20.9

E. Icing load simulation

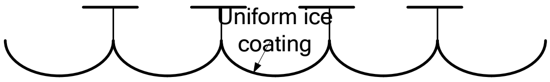
Assuming that the conductor is uniformly coated with circular cross-section, the load is simulated by the additional force simulation method, and the ice load is simulated by the method of abrupt withdrawal. It assuming that the quality of each spacing concentrated load is M of simulation icing load, see (2) [9]

$$\begin{cases} m=\rho\pi b(D+b) \\ M=mL/n \end{cases} \qquad (2)$$

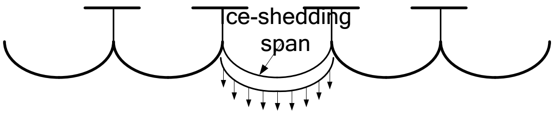
Type: *m*: conductor icing quality on per unit length, kg/m; ρ: ice density, 900 kg/m^3; D: conductor outside diameter, mm; *b*: ice thickness, mm; *L*: conductor length, m; *n*: divide the number of elements.

F. De-ice simulation

In order to facilitate the calculation, the ice-shedding analysis usually abbreviated to along the span direction uniform coating of ice, as shows in figure 2(a). This paper analyzes the method of uniform ice-shedding in middle span, as shows in figure 2(b).



(a) Initial ice



(b) Middle Span Uniform Ice-shedding

Figure 2 Ice-shedding Span Location of Conductors

Ⅱ. CALCULATION RESULT AND ANALYSIS

A Conductor ice-shedding dynamic characteristics

Ice-shedding is easy to cause the mechanical or electrical accident. Due to the change of the load will vibrate of de-icing span conductors. It is adjacent span the insulator strings and conductors will change. This section will analyze the dynamic response of ice-shedding in conductors. Analysis of ice-shedding is a strain section within the period of continuous span of calculation model. It is L-L-L-L-L and L is 400m. It is ice thickness 15mm and ice-shedding rate is 50%. Middle span happens to ice-shedding. The length of the insulator string is 5m. Conductor type is LGJ-630/45. It is not considering the influence of altitude difference and wind speed. Figure 3 for conductor vertical displacement of the middle span nodes time-history curve. From figure 3 shows that the jumping height of middle span nodes is 5.471m. Since the middle span of ice-shedding, left and right sides of the symmetrical reverse, so only take one side, as shows in Figure 4. Figure 4 for the longitudinal unbalanced tension time-history curve.

From figure 3 and figure 4 shows that when conductors is ice-shedding, its a low frequency motion. The longitudinal unbalanced tension is also low frequency synchronization, and not the instantaneous generation of the conductors icing.

B Impact analysis insulator material properties on ice-shedding of iced conductor

Conductors ice-shedding analysis is consider insulator composite and ceramics materials of unbalance tension influence. It is other calculation the conditions of the 2.1 sections, the results are shown in Table 2.

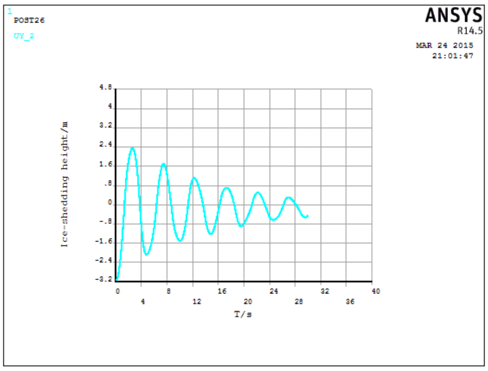


Figure 3 The jumping height of ice-shedding time-history curve

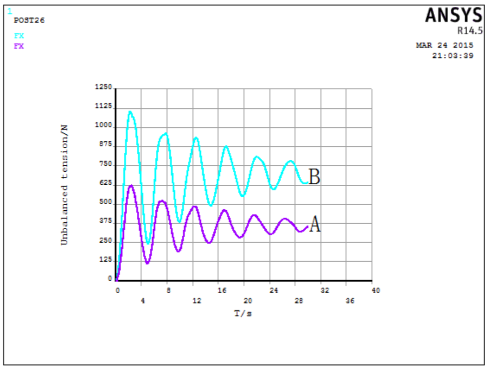


Figure 4 The longitudinal unbalanced tension time-history curve

Table 2 The longitudinal unbalanced tension of ice-shedding with different materials of insulator

Span/m	materials	
	composite	ceramics
200	169.169	166.505
300	589.036	581.477
400	1508.88	1485.264
500	2915.520	2878.105
600	5019.826	4940.774

From table 2 shows that composite and ceramics materials to de-ice longitudinal unbalanced tension had no significant influence, its error within the allowable range. In the following chapters selected composite as the research object.

C Impact analysis insulator on the jumping height of ice-shedding of iced conductor

Analysis of consider insulator string type and length of the jumping height of ice-shedding the influence for ice-shedding. The insulator string type consists of I and V. The length is respectively 3m, 5m, 8m, 10m, 15, 20m. It is the other calculation the conditions of the 2.1 sections, the results are shown in Figure 5 and Figure 6.

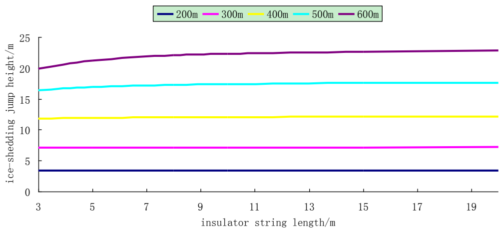


Figure 5 The jumping height of ice-shedding under the length of I different insulator

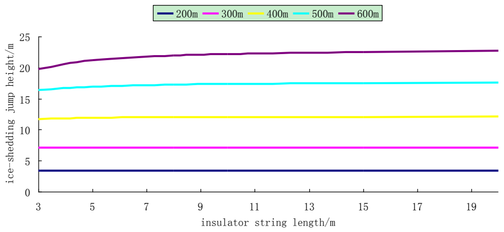


Figure 6 The jumping height of ice-shedding under the length of V different insulator

From figure 5 and figure 6 shows that the influence of the V insulator string on the jumping height of the conductors is slightly lower than the I insulator string. Whether it is V type insulator or I type insulator, with the increase of insulator string length, the jumping height of ice-shedding has no influence. When insulator string length must be, the jumping height of ice-shedding is probably linear increase with increasing the ice-shedding span.

D Impact analysis insulator on ice-shedding unbalanced tension of iced conductor

Conductors ice-shedding analysis are consider insulator string type and length of the influence unbalance tension, and calculate the conditions of the 2.2 sections, the results are shown in Figure 7 and Figure 8.

From Figure 7 and figure 8 shows that V type and I type insulator string on conductors ice-shedding unbalanced tension effect trend of approximately same, but I type insulator the influence of conductors ice-shedding unbalanced tension than the V type insulator on small about 0.9 times. Whether it is V type insulator or I type insulator, with the increase of insulator string length, conductors ice-shedding unbalanced tension decreases. When insulator string length must be, conductors ice-shedding unbalanced tension is increase with increasing the span.

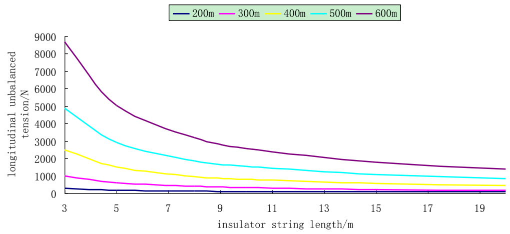


Figure 7 I type insulator longitudinal unbalanced tension

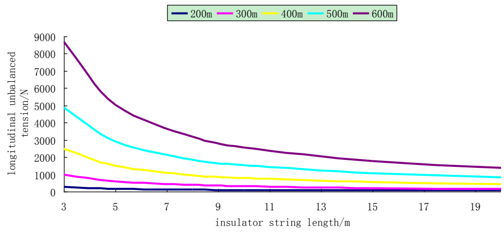


Figure 8 V type unilateral longitudinal unbalanced tension

III. CONCLUSION

(1)Composite and ceramics materials to de-ice longitudinal unbalanced tension had no significant influence, its error within the allowable range.

(2)The influence of the V insulator string on the jumping height of the conductors is slightly lower than the I insulator string, but I type insulator the influence of conductors ice-shedding unbalanced tension than the V type insulator on small about 0.9 times.

(3)Whether it is V type insulator or I type insulator, with the increase of insulator string length, the jumping height of ice-shedding has no influence, but the unbalanced tension of ice-shedding decreases.

(4)When the length of insulator string must be, whether it is V type insulator or I type insulator, ice-shedding unbalanced tension and jumping height are increase with increasing the ice-shedding span.

REFERENCES

[1] HUANG Xinbo, MA Longtao, XIAO Yuan, et al, “Form-finding analysis based on finite element method for line with uniform ice-coating”, Electric Power Automation Equipment, 2014, pp. 72-76.

[2] A.Jamaleddine, G.McClure, J.Rousselet, et al, “Simulation of ice shedding on electrical transmission

lines using ADINA", Computers & Structures, 1993, pp. 523-536.

[3] Kalman T, Farzaneh M, McClure G, "Numerical analysis of the dynamic effects of shock-load-induced ice shedding on overhead ground Wires", Computers & Structures, 2007, pp. 375-384.

[4] Yan Bo, Chen Kequan, Xiao Hongwei, et al, "Horizontal amplitude of iced conductor after ice-shedding under wind load", Chinese Journal of Applied Mechanics, 2013, pp. 913-919.

[5] YAO Chenguo, ZHANG Rufang, ZHANG Lei,et al, "Influence of Wind Vibration of Overhead Transmission Tower-line System on Ice Shedding", High Voltage Engineering, 2014, pp. 381-387.

[6] Yang Fengli, Yang Jingbo, "Analysis on Loads Form Ice Shedding Conductors in Heavy Icing Areas", Journal of Vibration and Shock, 2013, pp. 10-15.

[7] Jiang Xingliang, Bi Maoqiang, Li Zhenyu, et al, "Study on DC Ice Melting and Ice Shedding Process Under Natural Condition", Power System Technology, 2013, pp. 2626-2631.

[8] HUAG Xinbo, CHEN Ronggui, WANG Xiaojing, et al, "Online Monitoring System and Fault Diagnosis of Overhead Transmission Line", Beijing: China Electric Power Press, 2008, pp.157-196.

[9] WANG Zhangqi, QI Lizhong, YANG Wen-gang, et al, "Research on the applicability of Lumped Mass Method for Cable's Dynamic Tension in the Ice Shedding Experiment", Proceedings of the CSEE, 2014, pp. 1982-1988.

[10] A. Jamaledding, et al, "Weigh-dropping Simulation of ice-shedding effects on an overhead transmission line model", Proeeedings of 7th IWAIS (International Workshop on atmosphereic Icing of Struetures), Canada, 1996, pp.44-48.

[11] Laszlo E. Kollar and Masoud Farzaneh, "Vibration of Bundled Conductors Following Ice Shedding", IEEE Transactions On Power Delivery, 2008, pp.1097-1104.

[12] CHEN Yong, HU Wei, WANG Liming, HOU Lei, "Research on Ice-shedding Characteristic of Icing Conductor", Proceedings of the CSEE, 2009, pp. 115-120.

[13] ZHAO Yuzhe, LI Li, DENG Wei, "Numerical Simulation of Dynamic Response of Ice-shedding on Transmission Line", Resources and Power, 2013, pp. 205-209.

[14] YANG Fengli, YANG Jingbo, "Analysis on loads form ice shedding conductors in heavy icing areas",Journal of Vibration and Shock, 2013,pp. 10-15.

[15] HOU Lei, WANG Liming, ZHU Puxuan, et al, "Dynamic Behavior Computation of Ice Shedding of UHV Overhead Transmission Lines", Proceedings of the CSEE[J], 2008, pp. 1-6.

[16] MENG Xiaobo, WANG Liming, HOU Lei, et al, "Dynamic characteristics of ice-shedding on UHV overhead transmission lines", J Tsinghua Univ (Sci & Tech), 2010, pp. 1631-1636.

[17] HE Qing, LV Xifeng, ZHAO Xiaotong, "Research on Application of De-icing Technology on High Voltage Transmission Line Under the Condition of Incentive", Proceedings of the CSEE. 2014, pp. 2997-3003.