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The Method and Implementation of Icing and De-icing at Xuefeng Mountain Natural Icing Station

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***Abstract*—This paper introduces the basic situations of the natural icing station on Xufeng Mountain built by the state key laboratory of power transmission equipment & system security and new technology of Chongqing University, and explains the implementation methods of icing/de-icing at this station in a detail way. It is proved that this icing/de-icing method is feasible after over 3 years operation. The icing type and shape under natural environment is related to ambient parameters, conductor types, and distance between conductors and ground; the ice melting time under natural environment is determined by de-icing current, conductor types and environment factors. The research achievements can provide the power system with technology supply for keeping from icing disasters and lowering loss.**

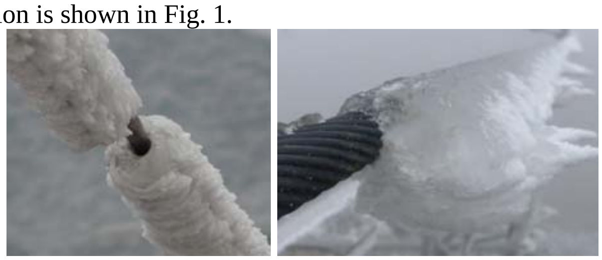
1 Introduction

The ice covered on transmission lines has a serious threat on the safe operation of power system. Many icing accidents have occured all over the world. Since the 50 years of the 20th century, domestic and foreign research institutions have established some artificial climate chambers to explore the mechanism, conditions for the formation of transmission lines icing and the calculation method of the wind load of transmission lines covered ice, and to study the electrical characteristics of icing insulator strings and the method of anti-icing and de-icing . Canada, Russia, China and other countries with serious icing on transmission lines have put into technology research on ice, and achieved remarkable results.

2 Result and discussion

In order to understand the real situation of icing and de-icing on transmission lines, Chongqing University has set up a natural icing station at Xuefeng Mountain in Hunan in 2008.

The icing shape on typical conductors of natural icing station is shown in Fig. 1.



(a) Snow (b) glaze icing

(c) Mixed snow and glaze icing (d) three bundled-conductors

Figure 1. Icing photo of conductors

To make the research results guide the practical engineering application directly, de-icing tests were conducted at the natural icing station on Xuefeng Mountain and typical results can be seen in Tab. I.

TABLE I. TYPICAL RESULTS OF DE-ICING TESTS

Types of Conductor	I(A)	Current type	Wind Velocity (m/s)	Temperature (℃)	De-icing time (min)
2×JTMH120	693	DC	4	-2.2	12
2×JTMH120	693	AC	4	-2.2	12
LGJ-300	700	DC	0.8	-4.2	19
LGJ-240	700	DC	0.8	-4.2	13
4×LGJ-240	2100	DC	12	-2.9	40
3×LGJ-185	1200	DC	3	-4.5	48

3 Conclusion

Icing forms are affected by ambient temperature, humidity, droplet water size and wind velocity. Under the natural environment, ice shapes are irregular, similar to elliptic in most cases. And the thickest parts of ice layer exist on the windward side of the conductor; on the other hand, the thinnest parts are on the leeward side. Under the natural environment, the de-icing stages include: the rotation of warming ice layer, the de-icing of ice layer and the shedding of ice layer. In addition, there exists ice unsynchronized shedding phenomenon in the third stage.

4 References

[1] Jiang Xingliang, Shu Lichun, Sun Caixin, Insulation under pollution or icing environment in power system[M]. Beijing: China Electric Power Press, 2009.

[2] P. Personne,J. F. Gayet. Ice accretion on wires and anti-icing induced by the Joule effect [J]. Journal of Applied Meteorology, 1988, 27(2): 101-110.

[3] Jiang Xingliang, Wang Daxing, Fan Songhai, Zhang Zhijin, Hu Jianlin. Experimental research on maximum temperature of ice-covered conductors during DC ice-melting[J]. High Voltage Engineering, 2009, 35(11): 2796-2799.

[4] Jiang Xingliang , Shen Qiang , Experimental research on influence of environmental parameters on the conductor icing thickness[J], High Voltage Engineering, 2010, 36(5) : 1096～1100.

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***Abstract*—Because of the difference between icing under artificial and natural environment, effective icing test technology and methods must be established to implement the research of icing on transmission lines, de-icing mechanisms and new technology of ant-icing/de-icing. This paper introduces the basic situations of the natural icing station on Xufeng Mountain built by the state key laboratory of power transmission equipment & system security and new technology of Chongqing University, and explains the implementation methods of icing/de-icing at this station in a detail way. It is proved that this icing/de-icing method is feasible after over 3 years operation. The icing type and shape under natural environment is related to ambient parameters, conductor types, and distance between conductors and ground; the ice melting time under natural environment is determined by de-icing current, conductor types and environment factors. The research achievements can provide the power system with technology supply for keeping from icing disasters and lowering loss.**

Introduction

The ice covered on transmission lines has a serious threat on the safe operation of power system. Many icing accidents have occured all over the world in the last ten years[1~3], especially, during the end of 2007 to February 2008, most parts of Southern China include Hunan, Anhui, Guizhou, Jiangxi encountered the most serious ice and snow disaster in the meteorological record history. This ice disaster not only damaged the grid structure and caused widespread interruption of power supply in serious iced area, but also influence other industries such as communication, transportation, tourism and so on. It caused huge losses to the national economy.

Since the 50 years of the 20th century, domestic and foreign research institutions have established some artificial climate chambers to explore the mechanism, conditions for the formation of transmission lines icing and the calculation method of the wind load of transmission lines covered ice, and to study the electrical characteristics of icing insulator strings and the method of anti-icing and de-icing [4-8]. Canada, Russia, China and other countries with serious icing on transmission lines have put into technology research on ice [9-21], and achieved remarkable results.

It is the focus of great concern to us that whether the results of artificial icing tests could guide the external insulation design of transmission lines. The experts who studies on the ice on transmission lines all over the world agree that there is a big error between the icing form under artificial environment and the real form of nature ice [22]. The research results in reference [23] indicate that, in spite of the diameter of droplets come from nozzles in artificial climate chamber can very closed to the nature icing droplets size, the composition and subcooling of droplets in artificial climate chamber are different with that of droplets in nature. In order to understand the real situation of icing and de-icing on transmission lines, Chongqing University has set up a natural icing station at Xuefeng Mountain in Huaihua City, Hunan Province in 2008. The Method and Implementation of Icing and De-icing at Xuefeng Mountain Natural Icing Station is introduced in this paper and then the results such as icing process, de-icing process is discussed. The research results have important reference value and significance to carry out anti-icing and disaster mitigation technology in power system.

SUMMARY OF XUEFENG MOUNTAIN NATURAL ICING STATION

In order to understand the real situation of icing and de-icing on transmission lines, Chongqing University has set up a natural icing station, as shown in Fig. 1, at Xuefeng Mountain in Hunan in 2008.

Figure 1. Xuefeng Mountain natural icing station

Xuefeng Mountain, between east longitude 109º39' to 110º55', northern latitudes 26º58' to 28º19', locates in the southwest of Hunan Province. This region has the humid subtropical monsoon climate. The annual average temperature and the annual average rainfall at the mountain is 12.7 ℃ and 1810mm, respectively. The natural icing station locates at Ping Shan Tang at Xuefeng Mountain. This area with an altitude of 1400m is a typical micro-topography and micro-weather icing zone. The natural icing station covers with ice over 60 days a year. The maximum thickness of glaze ice and maximum wind speed over 500mm and 25m/s, respectively. Early 2008, when most parts of Southern China encountered the serious ice and snow disaster, the weight of glaze ice on 400mm^2 conductors is up to 68kg/m at this place. And it is up to 48kg/m in February 2009 and 50kg/m in early 2010. So the Xuefeng Mountain natural icing station is the best place to study the icing of power grid.

There are two steel shelves for glaze icing (as shown in Fig. 1) at the test station. Different types of conductors and bondled-conductors with the length of 80 meters can be installed between the steel two shelves (as shown in Fig. 2, the conductors from up to down at left side are LGJ-120, LGJ-300 and 4×LGJ-240 separately, the conductors from up to down at right side are 2×LGJ-150, LGJ-400, 3×LGJ-185 and 2×JTMH-120 separately).

Figure 2. The arrangement of conductors

To conduct icing/de-icing field test at the natural icing station on Xuefeng Mountain, 10kV test power supply has been constructed, 5000A/800kVA high current generator and bridge rectifier were also assembled (as shown in Fig. 3 and 4).

Figure 3. 5000A/800kVA current generator

Figure 4. Bridge rectifier

Conductor constructions at the natural icing station on Xuefeng Mountain

To conduct icing/de-icing field test at the natural icing station on Xuefeng Mountain, the constructions of conductors were shown in Fig. 5.

For the purpose of leading current in test conductors or the simulation of energized icing on actual wires, it is necessary to set insulation between conductors and glaze shelves. In station, insulators were used to solve this problem.

To monitor the load evolution of conductors during the icing growth, de-icing and shedding process online, tension sensors have been fixed between glaze shelves and insulators and data lines were also used to send data to computers for saving automatically.

PTU multifunction meteorological device has been installed on glaze shelves to collect environment data to reveal the relationship between the icing growth of conductors and meteorological parameters like temperature, velocity and humidity.

For the convenience of connecting de-icing test circuit, conductor ends on one of the glaze shelves were connected with each other; meanwhile, conductor ends on the other glaze shelve were suspended near the ground.

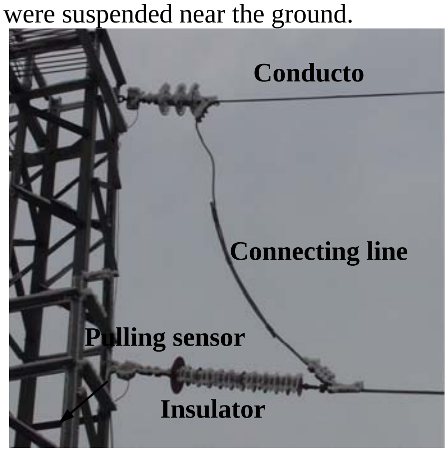


Figure 5. Installing method of conductor

Icing methods and implementation at the natural icing station on Xuefeng Mountain

Launching monitor devices to monitor the meteorological information around the field (as shown in Fig. 6) and the tension variation of conductors (as shown in Fig. 7)

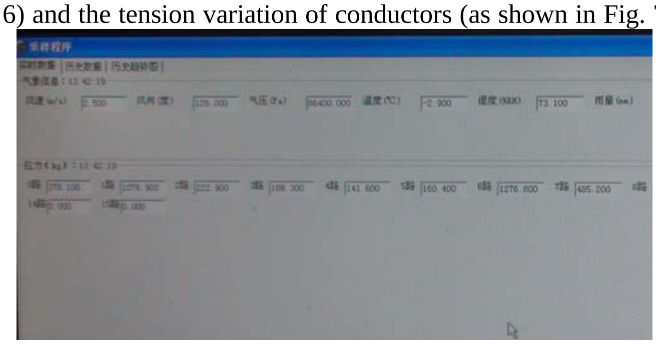


Figure 6. Measurement results from monitor devices

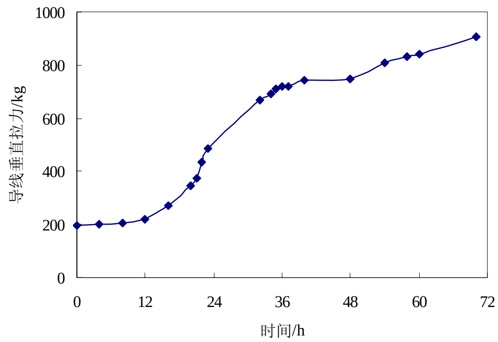
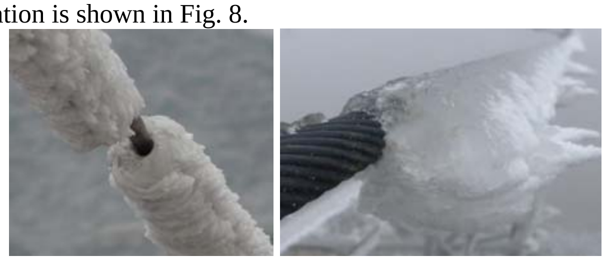


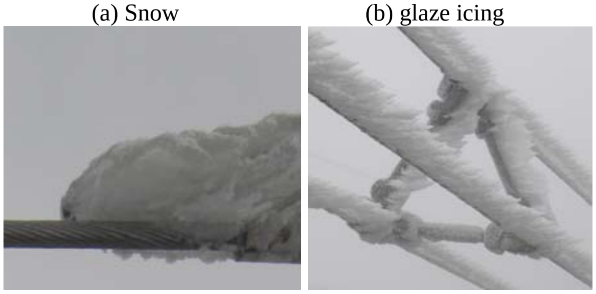
Figure 7. Relationship between the vertical tension variations of conductor icing growth and time

From monitoring results and field observations at the station, we can find that: Meteorological parameters in natural environment can't be controlled and may change at any time and there is no rule to follow. The ice accretion on structures is a comprehensive physical phenomenon depended on temperature, humidity, Warm and cold air convection, circulation, wind and so on. The relationship between ice accretion and time is nonlinear and relate to environmental parameters.

The icing shape on typical conductors of natural icing station is shown in Fig. 8.



(a) Snow (b) glaze icing



(c) Mixed snow and glaze icing (d) three bundled-conductors

Figure 8. Icing photo of conductors

From Fig. 8 and field observations at the station in the last three years, we can get such conclusions: The type of ice on structure relate to temperature, particle size of water drops, wind speed and other environmental parameters. Under natural icing environment, the shape of glaze on conductors is in-regular and similar to the oval-shaped in most cases. And the ice is generally thickest on the windward side, while the thinnest on the leeward side. Under the same natural icing environment, the weight and thickness of ice on conductors are relate to the height of conductors above ground and the type of conductors. And the higher the wires above ground the more serious the icing on conductors.

De-icing methods and implementation at the natural icing station on Xuefeng Mountain

To make the research results guide the practical engineering application directly, de-icing tests were conducted at the natural icing station on Xuefeng Mountain. Fig. 9 shows the sketch map of the DC de-icing field test circuit. Bridge rectifier should be removed before AC de-icing test is carried out.

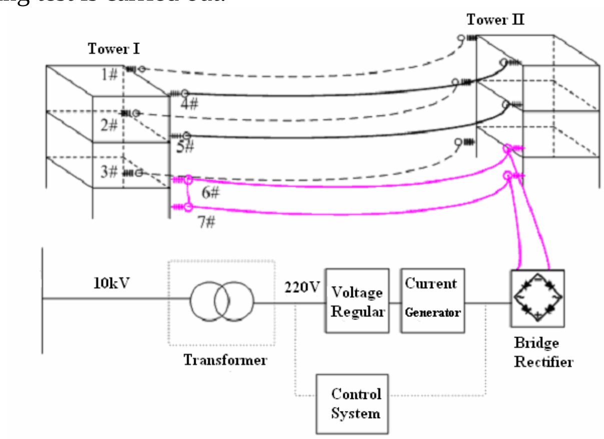


Figure 9. The sketch map of the DC de-icing field test circuit

The program of de-icing in natural icing station as following: (1) Make the ice accretion on conductors in natural icing station reach to the book value. (2) Connect the test line as test require. (3) Apply the initial setting short-circuit current and record the meteorological parameters, the variation of temperature and tension on conductors and the corresponding time. Meanwhile, take photos on the de-icing conductors. (4) Removal off the power at the end of de-icing test.

According to the field observations at the station, the de-icing process includes three stages: (1) Temperature of conductor rising and ice rotating stage. When the current flow through the conductor, the temperature of conductor and ice begin to rise. When the inner surface temperature of ice reaches 0 °C, the cohesive force between the conductor and the ice is weakening gradually and then the ice sleeve will rotate with gravity torque. (2) Ice-melting stage. It is that the time when the ice shed from conductor after rotation of ice. In this stage, the temperature of conductor is rising continue and the ice melting gradually. (3) The ice shed from conductors stage. This stage starts from the ice begin shed from conductors to all the ice on conductors shed off.

It was found that the wind velocity around tower I was greater than that around tower II due to the effect of topography, leading to the ice close to tower II dropped earlier compared with that near tower I, which is so-called ice unsynchronized shedding phenomenon. Fig. 10 indicates that the corresponding relationship between the conductor shedding length and time at the natural icing station (test conditions: LGJ-400, T=-5°C, DC=800A, the wind velocity at tower I and tower II equals 8m/s and 6m/s respectively).

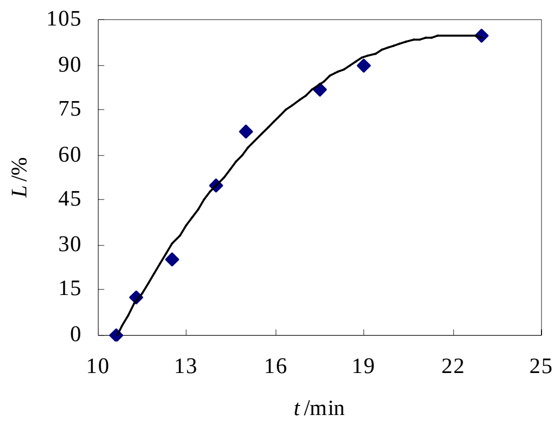


Figure 10. The relationship between the conductor shedding length and time

According to Fig. 10, during the time from the ice layer on the conductor began to drop to falling completely, the shedding speed related to the ice layer is nonlinear and decreasing gradually. The reason is that the difference of heat dissipation resulted from the high wind velocity makes the temperature of the bareness conductor lower than that of the ice covered one; therefore, heat flows from the icing part to naked part, bringing about the decrement of shedding speed gradually.

Based on this method, de-icing tests have been conducted at the natural icing station on Xuefeng Mountain; typical results can be seen in Tab. I.

TABLE I. TYPICAL RESULTS OF DE-ICING TESTS

Types of Conductor	I(A)	Current type	Wind Velocity (m/s)	Temperature (℃)	De-icing time (min)
2×JTMH120	693	DC	4	-2.2	12
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4×LGJ-240	2100	DC	12	-2.9	40
3×LGJ-185	1200	DC	3	-4.5	48

According to the field results in Tab. I, it can be known that:

De-icing time has nothing to do with the current type when implementing de-icing tests with large current. For example, the de-icing time corresponding to AC and DC were both 12min under the conditions that ice-melting current was 600A, wind velocity was 4m/s, environment temperature equaled -2.2℃ and conductor type was 2×JTMH120.

Ice melting time is related to conductor types when carrying out de-icing tests with the same current, and the de-icing time becomes shorter with the smaller diameter of conductors. For instance, the de-icing time of LGJ-240 and LGJ-300 were 19min and 13min respectively under the conditions that ice-melting current was 7000A, wind velocity was 0.8m/s, environment temperature equaled -4.2℃.

De-icing time involves ice melting current, wind velocity and temperature when conducting de-icing test with large current. And with the decrement of current and temperature, the increment of wind velocity, ice-melting time is on the rise.

Conclusion

The appropriate configuration and installation of conductors at the natural icing station on Xuefeng Mountain enables the station to implement the energized and non-energized icing test on transmission lines, the icing growth process of conductors and the dynamic process of de-icing/shedding.

Icing forms are affected by ambient temperature, humidity, droplet size and wind velocity. Under the natural environment, ice shapes are irregular, similar to elliptic in most cases. And the thickest parts of ice layer exist on the windward side of the conductor; on the other hand, the thinnest parts are on the leeward side.

Under the natural environment, the de-icing stages include: the rotation of warming ice layer, the de-icing of ice layer and the shedding of ice layer. In addition, there exists ice unsynchronized shedding phenomenon in the third stage.

With the decrement of de-icing current and temperature, the increment of wind velocity, ice-melting time is on the rise

REFERENCES

[1] Jiang Xingliang, Shu Lichun, Sun Caixin, Insulation under pollution or icing environment in power system[M]. Beijing: China Electric Power Press, 2009.

[2] Jiang Xingliang, Yi Hui. Ice accretion on transmission lines and protection[M]. Beijing: China Electric Power Press, 2001.

[3] Sun Caixin, Sima Wenxia, Shu Lichun. Atmosphere Environment and Electric outdoor insulation[M]. Beijing: China Electric Power Press, 2002.

[4] Meghnefi F., Volat C., Farzanech M. Temporal and frequency analysis of the leakage current of a station post insulator during ice accretion[J]. IEEE Transactions on Dielectrics and Electrical Insulation, 2007, 14(6) : 1381～1389.

[5] Berlijn S.M., Gutman I., Halsan K.A., et al. Laboratory tests and web based surveillance to determine the ice and snow performance of insulators[J]. IEEE Transactions on Dielectrics and Electrical Insulation, 2007, 14(6) : 1373～1380.

[6] Hu Jianlin, Sun Caixin, Jiang Xingliang, *et al*. Flashover performance of pre-contaminated and ice-covered composite insulators to be used in 1000kV UHV AC transmission lines [J]. IEEE Transactions on Electrical Insulation, 2007, 14(6) : 1347-1356.

[7] Yao Tao, Hu Yi, Wu Xiong, Cai Wei, Wu Guangya, Chen Yong, Liu Yunpeng, Xu Zuoming, Huang Daochun. Icing test techniques of EHV and UHV transmission and transformation equipment[J]. High Voltage Engineering, 2009, 35(3) : 574-578.

[8] Yu Yongqing, Li Guangfan, Su Zhiyi, Lu Jiayu, Sun Lin, Fan Jianbin. Construction of UHV DC test base station[J]. Electric Power, 2006, 39(10) : 10-14.

[9] Zhang Zhijin, Jiang Xingliang, Hu Jianlin, Sun Caixin. AC electric characteristics of 110kV post insulators covered with ice of snow [J]. High Voltage Engineering, 2009, 35(10) : 2528-2534.

[10] Zhang Zhijin, Jiang Xingliang, Hu Jianlin, Sun Caixin. Influence of icing degree on DC icing flashover performance of composite insulator[J]. High Voltage Engineering, 2009, 35(10) : 2545-2550.

[11] Zhang Zhijin, Jiang Xingliang, Hu Jianlin, Shen Qiang, Chen Ling, Liu Guifu. Influence of Environment parameters on icing accretion on the surface of insulator[J]. High Voltage Engineering, 2010, 36(10) : 2418-2423.

[12] Wen Xishan , Gong Yuqing , Yao Gang , Jiang Rikun , Lan Lei. Experimental study on growth law of conductor's icing[J], High Voltage Engineering. 2009, 35(7) : 1724-1729.

[13] Farzaneh M , Baker T , et al . Insulator icing test methods and procedures : a position paper prepared by the IEEE task force on insulator icing test methods[J]. IEEE Trans. on Power Delivery, 2002, 18(4) : 1503-1515.

[14] Jiang Xinliang , Wen Zuoming , Numerical simulation of supercooled water droplet impingement on composite insulator surface[J] , High Voltage Engineering, 2008, 38(5) : 888～892.

[15] C. Volat, F. Meghnefi, M. Farzaneh. Monitoring Leakage current of iced-covered station post insulators using artificial neural networks[J]. IEEE Transactions on Dielectrics and Electrical Insulation, 2010, 17(2): 443-450.

[16] Jiang Xingliang, Wang Daxing, Fan Songhai, Zhang Zhijin, Hu Jianlin. Experimental research on maximum temperature of ice-covered conductors during DC ice-melting[J]. High Voltage Engineering, 2009, 35(11): 2796-2799.

[17] H. Wieck, I. Gutman and T. Ohnstad. Investigation of flashover performance of snow-covered breakers[J].IEEE Transactions on Dielectrics and Electrical Insulation, 2007, 14(6): 1339-1345.

[18] Jiang Xingliang , Shen Qiang , Experimental research on influence of environmental parameters on the conductor icing thickness[J] , High Voltage Engineering, 2010, 36(5) : 1096～1100.

[19] Jiang Xingliang, Chen Ling, Zhang Zhijin, Sun Caixin, and Hu Jianlin, Equivalence of Influence of Pollution Simulating Methods on DC Flashover Stress of Ice-Covered Insulators [J].IEEE Transactions on Power Delivery, 2010, 25(4): 2113-2120.

[20] Jiang Xingliang, Wang Dayou, Factors of the cohesive force between RTV coating and ice[J], High Voltage Engineering, 2010, 36(6): 1359 ~ 1364.

[21] Jiang Xingliang, Ma Jun, Zhang Zhijin and Hu Jianlin, Effect of Hydrophobicity Coating on Insulator Icing and DC Flashover Performance of Iced Insulators[J]. IEEE Transactions on Dielectrics and Electrical Insulation, 2010, 17(2): 351-359.

[22] S. Fikke. Modern meteorology and atmospheric icing[C]. Proc 11th International Workshop on Atmospheric Icing of Structures(IWAIS 2005), Montreal, Canada,2005.

[23] P. Personne,J. F. Gayet. Ice accretion on wires and anti-icing induced by the Joule effect [J]. Journal of Applied Meteorology, 1988, 27(2): 101-110.