ICING FLASHOVER CHARACTERISTICS OF EHV TRANSMISSION LINE INSULATORS UNDER SEVER ICING

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***Abstract**:* To study the anti-icing performance of different insulator strings under severe icing condition, icing flashover test of full scale insulators of EHV transmission line were investigated in this paper. All tested insulator strings were equipped grading ring and conductor as the actual running state, icing flashover tests are conduced on porcelain insulators, composite insulator and insulator string of "3+1" arrangement method. The test results show that the flashover voltage of composite insulator (FXBW4-500/160) is higher than that of porcelain insulators (28 units of XWP_2-160) about 2% under serve icing condition, the flashover voltage of two type insulators are both lower than the phase voltage of 500kV power line, composite insulator is no obvious advantage to anti-icing under severe icing condition. Under light or moderate icing conditions, withstand voltage of "3+1" insulator string is higher than that of "I" string, the voltage is higher than the phase voltage about 20%.While under serve icing conditions, withstand voltage of "3+1" insulator string is lower than the phase voltage. The results may provide some reference value to anti-icing in serve icing domain.

Keywords: Icing, Flashover, EHV, Insulators

1. INTRODUCTION

A lot of experimental investigations were carried out on severe iced-covered insulator strings in the UHV AC laboratory of State Grid. The icing flashover performances of different type insulator strings were analysis. This is of great value for providing technical references to the external insulation design of EHV/UHV ac transmission lines in high cold in Western China.

2. RESULTS AND DISCUSSION

2.1 The flashover voltage of porcelain and composite insulators

Under sever icing condition (thickness of ice is 2 cm), the 50% icing flashover voltage $U_{50\%}$ of two kinds of insulators are shown in Table 1 and figure 1,their standard deviation σ are less than 7%.

From the Table 1, when the SDD is 0.10 mg/cm^2 and 0.05mg/cm^2,the icing flashover voltage of 28 units of XWP2-160 insulator is lower than the rated phase voltage of 500 kV transmission line (228.7kV) of 20.5% and 13.1%,the compile insulator $FXBW_4$-500/160 is lower than the rated phase voltage of 18.7% and 12.0%，that is to say, the flashover voltage of two type insulator are obviously lower than the rated phase voltage. When the SDD is 0.025 mg/cm^2, the flashover voltage of insulator XWP_2-160 and $FXBW_4$-500/160 is higher than the rated phase voltage 2.3% and 4.3%, but they are lower than the maximum value of phase voltage. This shows that flashover may happen on the surface of porcelain and composite insulators at light pollution level under sever icing condition.

Table 1. 50% icing flashover voltage of insulator string

Type	ρ_{SDD} / ρ_{NSDD} (mg/cm^2)		
	0.10/0.50	0.05/0.25	0.025/0.125
XWP_2-160	229.4	251.0	295.2
$FXBW_4$-500/160	234.6	254.2	301.0

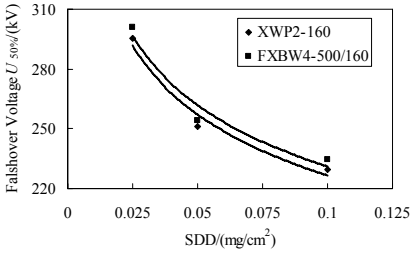

Figure1. Relationship between the icing flashover voltage and SDD

2.2 Withstand voltage of "3+1" string

The arrangement method of "3+1" insulator strings were selected in this paper and anti-icing performance of insulator strings were analysis under deferent icing condition. Under Light or moderate ice conditions (ice thickness 1cm), withstand voltage is 350 kV, the value higher than the rated phase voltage of 21.2%, higher than the maximum operating line phase voltage of 10.2%, the result show that "3 +1" string can significantly improved withstand voltage and effectively preventing flashover under moderate ice-covered insulator strings. While under serve ice conditions (ice thickness 2 cm), withstand voltage is 243.3 kV, the value higher than the "I" string about 6.1%, lower than the rated phase voltage, that is to say, "3 +1" string can significantly improved withstand voltage under moderate icing condition, but there no anti-ice advantage under serve icing condition.

3. CONCLUSIONS

1) Under sever icing condition, the 50% flashover voltages of porcelain and compile insulator are very close at same SDD, the compile insulator has no obviously anti-ice advantage in severe icing conditions.

2) "3 +1" string can significantly improved withstand voltage and effectively preventing flashover under light or moderate ice-covered insulator strings, but there no anti-ice advantage under serve icing condition.

Icing Flashover Characteristics of EHV Transmission Line Insulators under Sever Icing

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I. INTRODUCTION

Ice-covered insulators are serious nature disasters in transmission line. China is one of the most serious ice disaster country, over a thousand ice-coating accidents have happened in different voltage class of power line since 1950s [1-3].The harmfulness of icing has always been concerned in China, many observation and research have been done on ice-covered insulators, we have obtained many significance achievement on icing flashover characteristic and flashover mechanism [1-4]. However, icing is still threatening electrical network's security in China, such as, large scale icing disaster were happened in South of China in Feb.2008, 35968 transmission lines stopped the service by icing, 1731 transformer substations were out of work, 8868 tower collapsed in 110~500 kV power line , the direct economic loss was serious. It can be seen that the icing flashover characteristics, mechanism and methods to prevention of flashover on icing insulator need to in-depth system exploration.

With the implementation of development strategies of the West-to-East Power Transmission, and the forthcoming construction of UHV transmission lines, there will be more EHV/UHV ac transmission lines crossing micro terrain and microclimate regions, the icing phenomena of transmission lines will be unavoidable[5,6]. Current research and operational experience show that ice or snow accretion insulators may cause a drastic decrease such as power outages at normal service voltage [1-7].Therefore, icing phenomena is a key technology to select and design outdoor insulators in EHV/UHV ac transmission projects.

Thus, a lot of experimental investigations were carried out on severe iced-covered insulator strings in the UHV AC laboratory of State Grid. The icing flashover performances of different type insulator strings were analysis. This is of great value for providing technical references to the external insulation design of EHV/UHV ac transmission lines in high cold in Western China.

II. TEST SPECIMENS AND PROCEDURES

The icing tests have been carried out in large climate chamber with the diameter of 22 m and the height of 32 m in the 1000 kV UHV AC laboratory of State Grid. It mainly consists of a refrigeration system, a vacuum-pumping system, spraying system and a wind velocity system. The minimum temperature in the chamber can be adjusted to -19°C, which can meet the fundamental conditions of icing test study. The ac power was supplied from 3×500kV ac pollution test transformers. In this paper, the test power was supplied from lower test transformer, the major technical parameters are as follow: rated output voltage 500kV,rated current 10A, and short-circuit impedance less than 6%, the ac power meets the requirements of contamination tests commended by IEC publication [8,9].

The tested insulators are double shed porcelain insulators (XWP_2-160), the composite insulators (FXBW4-500/160) and aerodynamic type insulators (XMP-160).The configuration parameters are shown in Table 1.

Table.1 Configure of insulator

Type	H/mm	D/mm	L/mm
XWP_2-160	155	300	450
XMP-160	150	425	395
FXBW4-500/160	4450	180/150	13740

The suspension insulator strings of 28 units were used to simulate 500kV EHV ac transmission line in the artificial climate chamber. Before the test, the top and bottom surface of the insulators were contaminated by solid layer method, which used to simulate the pollution condition of

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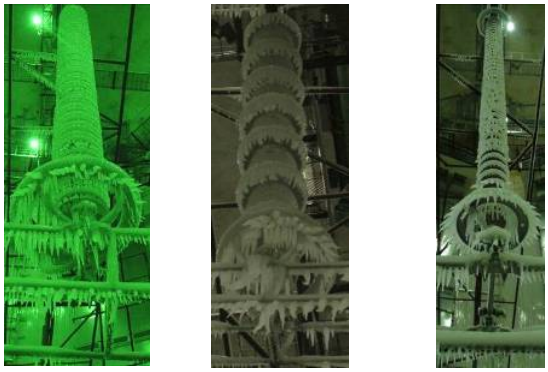
the insulator prior to ice deposit. The *SDD* (in mg/cm^2) were 0.025, 0.05 and 0.10 mg/cm^2 respectively, the ratio of the Non-Soluble Deposit Density *NSDD* (in mg/cm^2) and SDD is 5.The electrical conductivity of sprayed freezing water was 100 μs/cm. When the insulators were covering with ice accretions, the ambient temperature kept about -10^{o}C.

When the test power was supplied to the insulators, spraying system started and the insulators began to be covered with ice accretions. To simulate natural process of ice on the insulators, the test power should be adjusted to rated phase voltage of 500kV ac line. But experimental investigations show that under serve pollution level icing flashover would happen in the process of ice accretions on the surface of insulators in rated phase voltage. So the test power was adjusted to 80% of the rated phase voltage in the process of ice accretions.



(a)porcelain insulator (b) "3+1"string (c) composite insulator

Figure 1. Icing insulator string

In test, the large diameter shed insulators were aerodynamic type insulators (XMP-160) in the arrangement method of the string connected with alternately large and small diameter sheds, the string connected method was "3+1",that is to say, the insulator string connected with a aerodynamic type insulator per 3 unit porcelain insulators. Tested insulator strings were equipped grading ring and simulative conductor as the actual running state. The suspension insulator strings were 28 units, the "3+1" strings were tested under the thickness of ice accretions 1 cm and 2 cm, other insulator strings were tested under the thickness of 2 cm. The icing insulator strings were shown in figure 1.

III. RESULTS AND DISCUSSION

The flashover voltage of porcelain and composite insulators

The ac icing flashover performance of porcelain and composite insulators have been investigated based on the above mentioned test methods in this paper. Under sever icing condition (thickness of ice is 2 cm), the 50% icing flashover voltage $U_{50\%}$ of two kinds of insulators are shown in Table 2 and figure 2,their standard deviation σ are less than 7%.

From the Table 2, when the SDD is 0.10 mg/cm^2 and 0.05mg/cm^2,the icing flashover voltage of 28 units of XWP2-160 insulator is lower than the rated phase voltage of 500 kV transmission line (228.7kV) of 20.5% and 13.1%,the compile insulator FXBW$_4$-500/160 is lower than the rated phase voltage of 18.7% and 12.0%，that is to say, the flashover voltage of two type insulator are obviously lower than the rated phase voltage. When the SDD is 0.025 mg/cm^2, the flashover voltage of insulator XWP$_2$-160 and FXBW$_4$-500/160 is higher than the rated phase voltage 2.3% and 4.3%, but they are lower than the maximum value of phase voltage. This shows that flashover may happen on the surface of porcelain and composite insulators at light pollution level under sever icing condition.

Table 2. 50% icing flashover voltage of insulator string

Type	ρ_{SDD} / ρ_{NSDD} (mg/cm^2)		
	0.10/0.50	0.05/0.25	0.025/0.125
XWP$_2$-160	229.4	251.0	295.2
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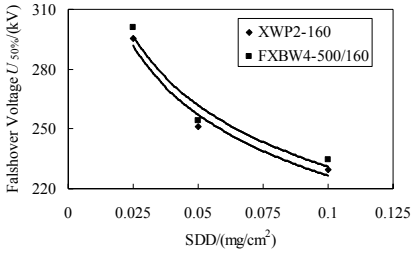

Figure 2. Relationship between the icing flashover voltage and SDD

Withstand voltage of "3+1" string

Research results in reference [1] show that "3+1" insulator string has a good effect to anti-icing. So arrangement method of "3+1" insulator strings were selected in this paper and anti-icing performance of insulator strings were analysis under deferent icing condition. Under Light or moderate ice conditions (ice thickness 1cm), withstand voltage is 350 kV, the value higher than the rated phase voltage of 21.2%, higher than the maximum operating line phase voltage of 10.2%, the result show that "3 +1" string can significantly improved withstand voltage and effectively preventing flashover under moderate ice-covered insulator strings. While under serve ice conditions (ice thickness 2 cm), withstand voltage is 243.3 kV, the value higher than the "I" string about 6.1%, lower than the rated phase voltage, that is to say, "3 +1" string can significantly improved withstand voltage under moderate icing condition, but there no anti-ice advantage under serve icing condition.

IV. CONCLUSIONS

1) Under sever icing condition, the 50% flashover voltage of insulators decrease with the increase of SDD, the relationship between the $U_{50\%}$ and SDD is power function, the 50% flashover voltages of porcelain and compile insulator are very close at same SDD, the compile insulator has no obviously anti-ice advantage in severe icing conditions.

2) “3 +1” string can significantly improved withstand voltage and effectively preventing flashover under light or moderate ice-covered insulator strings, but there no anti-ice advantage under serve icing condition.

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REFERENCES

[1] Jiang Xingliang,Shu Lichun,Suncaixin. Pollution and Icing Insulation in Power System. Beijing: Chinese Electric Power Press, 2009.

[2] ZHANG Zhi-jin,JIANG Xing-liang,HU Jian-lin,SUN Cai-xin and HUANG Hai-zhou. Natural Pollution Accumulating and Its DC Icing Flashover Performance of XZP-300 Insulator String [J]. High Voltage Engineering, 2010, 36 (8): 1900-1906.

[3] SHI Yan,JIANG Xing-liang,Yuan Jihe. Flashover Voltage Forecasting Mode of Iced Insulator Based on RBF Network [J]. High Voltage Engineering, 2009, 35 (3): 592-598.

[4] HU Yi. Analysis and Countermeasures Discussion for Large Area Icing Accident on Power Grid[J]. High Voltage Engineering, 2008, 34 (2):215-219.

[5] LI Peng,FAN Jian-bing,Su Zhi-yi. Out Insulator Design of insulators in icing zone for 750 kV ac transmissions line. Power Equipment, 2007,8(3):24-27.

[6] Xingliang Jiang,Shaohua Wang,Zhijing Zhang,Shujiao Xie and Yan Wang. Study on AC Flashover Performance and Discharge Process of Polluted and Iced IEC Standard Suspension Insulator String. IEEE Trans. On Power Delivery, Vol.22, No.1,Jan.2007:472-480.

[7] J.Hu,C.Sun,X.Jiang,Z.Zhang and L.Shu “Flashover performance of pre-contaminated and iced-covered insulators to be used in 1000 kV ac transmission lines ”, IEEE Transaction on Dielectrics and electrical and insulation,Vol.14,No.6,pp.1347-1353,Dec.2007.

[8] 2004.GB/T 4585-2004.Artificial pollution test method for AC 1000V and above[S].2004.

[9] “Artificial pollution tests on high-voltage insulators to be used on a.c. systems”, IEC 60507, 1991.