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THE ICE-COVERED INSULATION CONFIGURATION OF 1000KV AC TRANSMISSION LINE

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Abstract: Based on the flashover test of composite insulator, anti-icing insulator and 300kN double-shed porcelain insulator as length of 9m and 9.75 m, and ice-covered insulation configuration of 500kV AC Transmission Line, the Ice-covered insulation configuration of 1000kV AC Transmission Line is given in this paper.

1. INTRODUCTION

The insulation configuration of 1000kV experimental demonstrated AC transmission line project adopts the composite insulator which is 9.75m in length. Through the deeply research on the key technology of extra-high voltage, the length of the insulator not to cause pollution flashover in extra-high voltage AC transmission line project is 9m when the 1000kV composite insulator is below the III grade pollution areas. Based on the experimental demonstrated AC transmission line project has been built, the follow-up results of the deeply research on the extra-high voltage and the flashover test of composite insulator, anti-icing insulator and 300kN double-shed porcelain insulator as length of 9m and 9.75m, and Ice-covered insulation configuration of 500kV AC Transmission Line, the Ice-covered insulation configuration of 1000kV AC transmission line is given in this paper.

2. RESULTS AND DISCUSSION

The flashover test of composite insulator, anti-icing insulator and 300kN double-shed porcelain insulator as length of 9 m and 9.75 m has been carried out in the climate laboratory.

Table 1: Test results of 9m anti-icing composite insulator.

No.	SDD/NSDD mg/cm^2	Water conductivity μS/cm	Amount of ice		Voltage kV	Result
			Time h	Thickness mm		
1	0.05/0.3	100	3.5	15	698.8	Withstand
2	0.05/0.3	100	3	15	700	Withstand
3	0.05/0.3	100	3	15	698	Withstand

Table 2: Test results of 9m porcelain insulator.

No.	SDD/NSDD mg/cm^2	Water conductivity μS/cm	Amount of ice		Voltage kV	Result
			Time h	Thickness mm		
1	0.03/0.18	100	3	15	628.5	Withstand
2			3	15	636.6	Withstand
3			3	15	690	Withstand
4			4	20	628.5	Withstand
5	0.05/0.3	100	3	20	625	Flashover
6			4	20	644	Flashover

Table 3: Test results of 9.75m composite insulator.

No.	SDD/ NSDD mg/cm^2	Water conductivity μS/cm	Amount of ice		Voltage kV	Result
			Time h	Thickness mm		
1	0.05/0.3	100	3.5	15	665	Flashover
2	0.05/0.3	100	3.5	15	697	Flashover
3	0.05/0.3	100	3.5	15	636	Withstand

Table 4: The parameters of insulators and the estimate of $U_{50\%}$.

Insulator model/type	Length /mm	Net length of insulation/mm	U50%（kV） 0.025 mg/cm2
FXBW4-500/160	4450	4000	301
FXBW-1000/300	9750	9353	704
FXBW-1000/300	9000	8603	647

3. CONCLUSION

In lightly-polluted areas or lightly ice-covered areas, composite insulators of 9m can be of engineering satisfaction; In lightly-polluted areas or moderately ice-covered areas, anti-icing insulators can be adopted to increase it's performance of external insulation of ice coating; In severely ice-covered areas (20mm and above), complete bridges occur to various-styled insulators of the same length, and their flashover voltages are close to one another. As a result, severely ice-covered microclimate areas should be avoided in design phase of transmission lines.

4. REFERENCES

[1] Xingliang Jiang, Bo Wang, Zhijin Zhagn, Jianlin Hu and Caixin Sun. Influence of Length and Arrangement of Iced Insulator Strings on DC Flashover Voltage at High Altitude Districts. Proceedings of the CSEE, 2008, Vol.28(No.3): 1-5.

[2] Qing Yang, Wenxia Sima, Caixin Sun, Kun Wu and Tao Yuan. Reasearch on DC and AC Flashover Field-circuit Model of Ice-covered HV Insulator. Proceedings of the CSEE, 2008, Vol.28(No.6): 13-19.

[3] Yan Wang, Lichun Shu, Jihe Yuan and Xingliang Jiang. AC Flashover Performance and Discharge Process of Iced Insulator Strings. High Voltage Engineering, 2007, Vol.33(No.9): 24-27.

The Ice-covered Insulation Configuration of 1000 kV AC Transmission Line

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***Abstract*—Based on the flashover test of composite insulator, anti-icing insulator and 300kN double-shed porcelain insulator as length of 9 m and 9.75 m, and ice-covered insulation configuration of 500kV AC Transmission Line, the Ice-covered insulation configuration of 1000kV AC Transmission Line is given in this paper.**

Keywords-1000kV AC Transmission Line;Flashover of Ice-covered Insulators;Insulation Configuration

I. INTRODUCTION

The insulation configuration of 1000kV experimental demonstrated AC transmission line project adopts the composite insulator which is 9.75m in length. Through the deeply research on the key technology of extra-high voltage, the length of the insulator not to cause pollution flashover in extra-high voltage AC transmission line project is 9m when the 1000kV composite insulator is below the III grade pollution areas. Based on the experimental demonstrated AC transmission line project has been built, the follow-up results of the deeply research on the extra-high voltage and the flashover test of composite insulator, anti-icing insulator and 300kN double-shed porcelain insulator as length of 9m and 9.75m, and Ice-covered insulation configuration of 500kV AC Transmission Line, the Ice-covered insulation configuration of 1000kV AC transmission line is given in this paper.

II. THE FLASHOVER PERFORMANCE TEST OF 1000KV INSULATORS

The flashover voltage of iced-insulator will be impacted by the characteristic parameters of the ice above the insulator, the type of the insulator and the environmental condition [3]. Base to meet the demands of the engineering and command the flashover characteristics of the iced-insulator, the icing experimental research of extra-high voltage composite insulators in different dirtiness and amount of ice covered was carried out in the climate laboratory of extra-high voltage AC test.

A. Test Conditions

The climate laboratory is a cylindrical structure, concrete placement, hot insulation inside. The diameter of the hall is 22m, the height is 32m, the diameter inside is 20m and the height inside is 25m, as the Fig.1. The laboratory can simulate the special natural condition such as icing, defiling and high elevation in one time, the lowest temperature in the laboratory can reach -20°C. The elevation of the laboratory is 36m, the laboratory was expected to simulate a elevation of 5500m (from the normal elevation to 0.05Mpa in 25min), actually, the laboratory can simulate a elevation of 5800m.

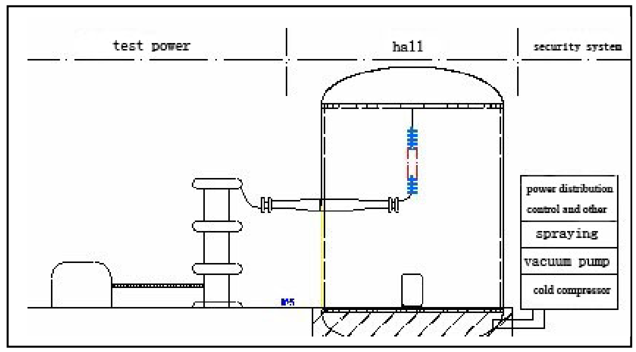

Figure 1. The elements diagram of the climate laboratory

Figure 2. Hall of the climate laboratory and the experimental electrical source of power frequency

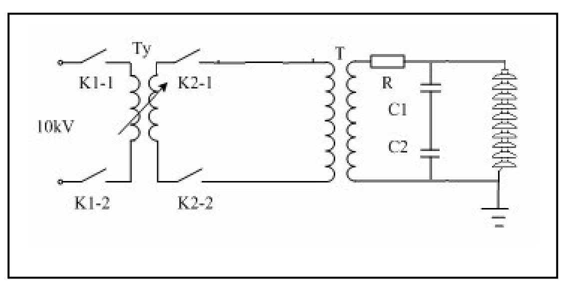

Figure 3. The test circuit schematic of the flashover test of the ice-covered insulators

K1,K2:the former and latter switch Ty: columniform pressure regulator
T: experimental transformer R:protecting resistance
C1/C2: capacitive divider

B. A Simulation Test on 9-meter Common Composite Insulator

The flashover voltage of icing composite insulator is related to many factors such as the type of ice, the weight of ice, ice conductivity and Contamination [2]. The transmission lines in icing area usually locate in the light polluted area, so two of the SDD were decided in the icing test of the insulator, one was 0.03mg/ cm^2(b grade range), and the other was 0.05mg/cm^2(lower limit of c grade). Their salt to ash ratio were both 1:6. In this test, the water conductivity was 100μS/cm（20℃）, which is consistent with the requirement of rainwater conductivity in the standard wet test in GB/T 16927.1.

The test used the withstand voltage law, and Table 1. shows the test results.

TABLE 1. TEST RESULTS OF 9-METER COMMON COMPOSITE INSULATOR

No.	SDD/NSDD mg/cm^2	Water conductivity μS/cm	Amount of ice		Voltage kV	Result
			Time h	*Thickness mm*		
1	0.03/0.18	100	3	10	700	Withstand
2			3.5	15	698.6	Withstand
3			3.5	15	700	Withstand
4			3.5	15	700	Withstand
5			4.5	20	670	Flashover
6			4.4	20	640.2	Withstand
7			4.5	20	659.3	Withstand
8			4.5	20	634.6	Withstand
9	0.05/0.3	100	2.7	10	636.2	Withstand
10			2.7	10	670	Withstand
11			2.8	10	699.2	Withstand
12			2.8	10	698.5	Withstand
13			3	15	692.5	Flashover
14			4	15	671.6	Flashover
15			4	15	636	Withstand
16			4	20	579.2	Flashover
17			5	20	580.1	Flashover

According to the withstand testing principle, the withstand characteristics of 9 m porcelain insulator string can be concluded as follows:

1) the SDD, salt-ash ratio and icing water conductivity are adjusted at 0.03 mg/cm^2, 1:6 and 100μS/cm（20℃）respectively. when the ice accumulation thickness is 15mm, the maximum withstand voltage of 9 m porcelain insulator string is 1.1 times of the maximum rated operating phase voltage of 1000 kV transmission line; when the ice accumulation thickness is 20mm, the maximum withstand voltage of 9 m porcelain insulator string is equal to the maximum rated operating phase voltage of 1000 kV transmission line;

2) the SDD, salt-ash ratio and icing water conductivity are adjusted at 0.05 mg/cm^2, 1:6 and 100μS/cm（20℃）respectively. when the ice accumulation thickness is 10mm, the maximum withstand voltage of 9 m porcelain insulator string is 1.1 times of the maximum rated operating phase voltage of 1000 kV transmission line; and the insulator string would be flashover when the ice accumulation thickness increased up to 15mm.

C. Experimental Study on Simulation Icing Performance of 9m Anti-icing Composite Insulators

To reflect the performance of anti-icing composite insulators， test on the withstand performance in condition of SDD=0.05mg/cm2 and ice thickness is 15mm， the results shown in Table 2.

TABLE 2. TEST RESULTS OF 9M ANTI-ICING COMPOSITE INSULATOR

No.	SDD/NSDD mg/cm^2	Water conductivity μS/cm	Amount of ice		Voltage kV	Result
			Time h	*Thickness mm*		
1	0.05/0.3	100	3.5	15	698.8	Withstand
2	0.05/0.3	100	3	15	700	Withstand
3	0.05/0.3	100	3	15	698	Withstand

D. Performance test of the 9 m porcelain insulator string under artificial icing condition

Table 3 shows the withstand characteristics of 9 m porcelain insulator string when the SDD is 0.03 and 0.05 mg/cm^2 , the ice accumulation thickness is 15mm and 20mm.

TABLE 3. TEST RESULTS OF 9M PORCELAIN INSULATOR

No.	SDD/NSDD mg/cm^2	Water conductivity μS/cm	Amount of ice		Voltage kV	Result
			Time h	*Thickness mm*		
1	0.03/0.18	100	3	15	628.5	Withstand
2			3	15	636.6	Withstand
3			3	15	690	Withstand
4			4	20	628.5	Withstand
5	0.05/0.3	100	3	20	625	Flashover
6			4	20	644	Flashover

E. Characteristics test of the 9.75 m composite insulator string under artificial icing condition

Table 4 shows the withstand characteristics of 9.75 m composite insulator string when the SDD is 0.05 mg/cm^2 and the ice accumulation thickness is 15mm.

TABLE 4. TEST RESULTS OF 9.75M COMPOSITE INSULATOR

No.	SDD/NSDD mg/cm^2	Water conductivity μS/cm	Amount of ice		Voltage kV	Result
			Time h	*Thickness mm*		
1	0.05/0.3	100	3.5	15	665	Flashover
2	0.05/0.3	100	3.5	15	697	Flashover
3	0.05/0.3	100	3.5	15	636	Withstand

III. CONFIGURATION DERIVATION OF EXTERNAL INSULATION OF ICE-COATED 1000KV TRANSMISSION LINES

The configuration of insulators is determined by external insulation of pollution in existing technical regulations for design of transmission line, in which the configuration methods and basis of external insulation of ice coating are unavailable. External insulation of ice coating resembles external insulation of pollution, and however, due to the complexity of external insulation of ice coating and the limited appreciation for it, the configuration and process of it falls short of perfection of that of external insulation of pollution. The configuration results of external insulation of ice-coated 1000kV transmission lines can be derived from that of 500kV transmission lines.

In accordance with $U_{50\%}$=75.3kV/m, standard deviation=8.4%, the data generated by *State Grid Electric Power Research Institute* on ice-coated test of 500kV insulator chains under severe icing condition of 0.025 mg/cm2, 100μS/cm, the authors simply deduce that $U_{50\%}$ of composite insulators of 9m and 9.75m approximately coincides with test data of insulators of 9m and 9.75m above mentioned.

Derived from the $U_{50\%}$ of ice-coated 500kV composite insulators, the $U_{50\%}$ of ice-coated 1000kV composite insulators are as follows:

TABLE 5. THE PARAMETERS OF INSULATORS AND THE ESTIMATE OF $U_{50\%}$

Insulator model/type	Length/mm	Net length of insulation/mm	*U*50%(kV) 0.025 mg/cm2
FXBW4-500/160	4450	4000	301
FXBW-1000/300	9750	9353	704
FXBW-1000/300	9000	8603	647

According to Table of curve calculations, the composite insulators of 9m can be adopted in light-polluted areas (0.025mg/cm^2). Furthermore, with the consideration of nonlinear relations between the $U_{50\%}$ of ice-coated insulator strings and the strings length [1], anti-icing composite insulator can be adopted to increase its performance of external insulation of ice coating in moderately and severely ice-covered areas.

IV. PROPOSALS FOR THE LENGTH OF 1000KV INSULATOR

Due to the complexity of external insulation of ice coating and the limited appreciation for it, the configuration and process of it falls short of perfection of that of external insulation of pollution nowadays. In accordance with the test results and the comparative analysis of configuration of the external insulation of ice-coated 500kV transmission lines, the test results are for reference purposes in engineering designs. The proposals are as follows.

1) In lightly-polluted areas or lightly ice-covered areas, composite insulators of 9m can be of engineering satisfaction;

2) In lightly-polluted areas or moderately ice-covered areas, anti-icing insulators can be adopted to increase it's performance of external insulation of ice coating;

3) In severely ice-covered areas (20mm and above), complete bridges occur to various-styled insulators of the same length, and their flashover voltages are close to one another. As a result, severely ice-covered microclimate areas should be avoided in design phase of transmission lines.

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