# ICING FLASHOVER CHARACTERISTICS OF INSULATORS STRINGS WITH DIFFERENT ALTERNATING SHEDS

Su Huafeng[1], Li Zhining[1], Jia Zhidong[1], Guan Zhicheng[1], Li Licheng[1], Zhou Jun[2], Gao Haifeng[2]
1Department of Electrical Engineering, Tsinghua University, Beijing, China
2Electric Power Research Institute, Beijing, China
*Email: shf03@126.com

***Abstract:*** In winter and early spring the insulator strings of the transmission lines may be coated with ice and bridged by icicles, which significantly reduce the insulation strength and lead to flashovers. The icing flashover characteristics of iced insulator strings with different alternating sheds and different suspension types will provide important references to the construction and maintenance of the high voltage level transmission lines.

## 1. INTRODUCTION

In winter and early spring the insulator strings of the transmission lines may be coated with ice and bridged by icicles, which significantly reduce the insulation strength and lead to flashovers. The icing flashover characteristics of iced insulator strings with different alternating sheds and different suspension types will provide important references to the construction and maintenance of the high voltage level transmission lines. The icing flashover Characteristics of icing insulator strings has been investigated in the past, but the comparative results of icing insulator strings with different sheds and different suspension types has seldom been published. Insulator strings with different sheds and the V-shape suspension help to stop the freezing rain forming icicles which bridge the space between the insulator sheds, thus leading to an increase in the anti-icing flashover ability. It is a measure to decrease the icing flashover of insulator strings in icing areas.

This paper conducted a series of icing flashover tests on insulators with different alternating sheds and with different suspension shapes. The flashover process is recorded by the high speed camera and the comparative icing flashover results are given.

## 2. RESULTS AND DISCUSSION

When the icing regime finished, the icing insulator strings are kept for hardening for 2 hours. The insulator strings was applied with the operating stress 63.5 kV. The door of the icing climatic chamber was open and the temperature rose gradually. When the temperature is about 2~3°C, the ice on the insulator strings melted. There was water flowing and dripping down the insulator strings. At that time when the melting is substantial, voltage was increase to flashover. 5 to 6 tests were conducted on every type of insulator strings, and the average icing flashover voltages were calculated. The icing flashover voltage of normal insulator strings was used as the reference.

From Figure 1, it can be concluded that the V-shaped suspension strings has the highest icing flashover voltage, and the “3+1” and “4+1” insulator strings are in the middle, while the normal strings has the lowest icing flashover voltage.

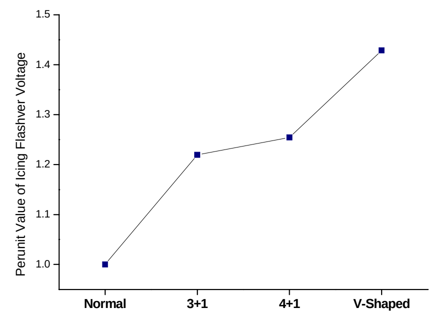


**Figure 1:** The perunit value of icing flashover voltage of the insulator strings with different alternating sheds and different suspension type. The icing flashover voltage of normal insulator strings was used as the reference.

## 3. CONCLUSION

As to the I-string transmission lines which has been built, it is difficult to change the suspension type. Using insulators of big diameter to add in the normal strings is a good solution to increase the anti-icing flashover ability.

## 4. REFERENCES

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# Icing Flashover Characteristics of Insulators Strings with Different Alternating Sheds

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1Department of Electrical Engineering, Tsinghua University, Beijing, China
2Electric Power Research Institute, Beijing, China

***Abstract*—In winter and early spring the insulator strings of the transmission lines may be coated with ice and bridged by icicles, which significantly reduce the insulation strength and lead to flashovers. The icing flashover characteristics of iced insulator strings with different alternating sheds and different suspension types will provide important references to the construction and maintenance of the high voltage level transmission lines.**

***Keywords-alternating sheds; flashover; ice; insulator***

## I. INTRODUCTION

In winter and early spring the insulator strings of the transmission lines may be coated with ice and bridged by icicles, which significantly reduce the insulation strength and lead to flashovers. The icing flashover characteristics of iced insulator strings with different alternating sheds and different suspension types will provide important references to the construction and maintenance of the high voltage level transmission lines. The icing flashover Characteristics of icing insulator strings has been investigated in the past, but the comparative results of icing insulator strings with different sheds and different suspension types has seldom been published. Insulator strings with different sheds and the V-shape suspension help to stop the freezing rain forming icicles which bridge the space between the insulator sheds, thus leading to an increase in the anti-icing flashover ability. It is a measure to decrease the icing flashover of insulator strings in icing areas.

This paper conducted a series of icing flashover tests on insulators with different alternating sheds and with different suspension shapes. The flashover process is recorded by the high speed camera and the comparative icing flashover results are given.

## II. EXPERIMENT

### A. Insulators

In the test, the glass insulators which are widely used in the icing areas of south China are showed in TABLE I. TU160P/155/CG is the insulator with large diameter used to stop the freezing rain bridging the insulator strings TU160/155/CG. Due to the limit of the icing climate chamber, 8 insulators as a string were used in the icing and flashover tests. The icing flashover characteristics of insulators with different alternating sheds and V-shape suspension were analyzed. The ice thickness on the rotating cylinder under the insulator string was 6-8 mm when the insulator strings were nearly bridged by the icicles.

The insulator strings were contaminated with NaCl and Kaolin before the ice accretion tests. The ESDD was 0.1 mg/cm$^2$ and the NSDD was 0.5 mg/cm$^2$. The test was carried out 24 hours later, during which the hydrophobicity of the anti-icing coating had seldom transferred to the contamination layer.

TABLE I. THE PARAMETERS OF INSULATOR

| Type | Structural height (mm) | Diameter (mm) | Creepage distance (mm) |
|---|---|---|---|
| TU160/155/CG | 155 | 280 | 400 |
| TU160P/155/CG | 155 | 350 | 550 |

### B. The HV Power Source and the Icing Climatic Chamber

A 750 kV, 4 A experimental transformer intended for AC pollution flashover test was used in this study.

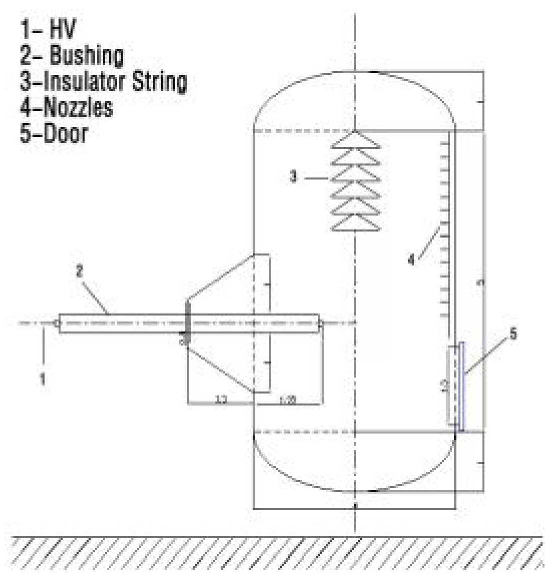


Figure 1. Diagram of the climatic chamber for artificial icing of HV insulators

The structural diagram of the artificial icing test chamber is presented in Figure 1. The climate room is a cylinder tank with the interior height of 7m and the diameter of 4m. The support system has refrigeration, vacuum, spray and other functions. Refrigeration system is able to adjust the temperature from zero to ~ -19°C. Two insulator strings can be hung for icing test at the same time in the center of the climatic room. On the wall opposite to each other are two lines of sprayers from top to bottom. Each line has 10 sprayers with 30 mm between each other. The angle between the spray direction and the insulator string is 45°.

The icing parameters are in TABLE II to simulate the most dangerous types of icing.

TABLE II. ICE ACCUMULATION TEST PARAMETERS

| Parameters | Value |
|---|---|
| Ice accumulation type | Wet-Grown |
| Temperature | -7°C |
| Rainfall | 70 l/h/m$^2$ |
| Average water drop diameter | 100-200 μm |
| Freezing water conductivity | 100 μs/cm @ 20°C |
| Spraying angle | 45° |
| Wind speed | 3 m/s |
| Applied voltage | 63.5 kV |

## III. RESULTS

### A. The Insulators after Icing Regime

The ice thickness on the rotating cylinder under the insulator string was 6-8 mm when the insulator strings were nearly bridged by the icicles.

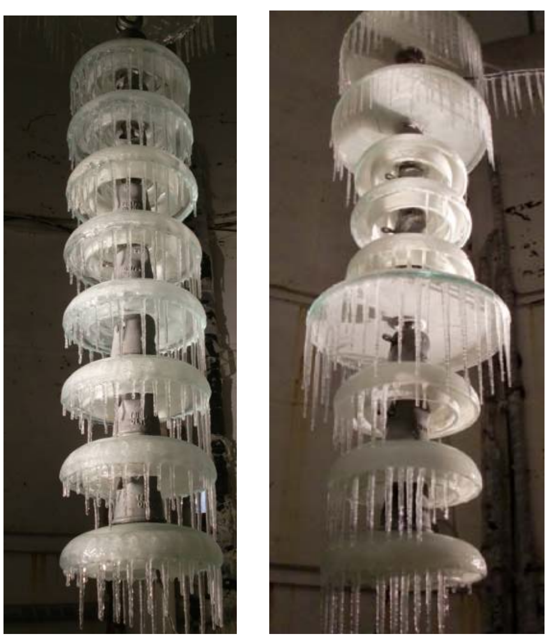

Figure 2. The icing insulators of normal strings and “3+1” insulator strings with alternating diameter sheds

Figure 3. The icing insulators of “4+1” insulator strings with alternating diameter sheds

Figure 4. The icing insulators of V-shape suspension strings

### B. The Icing Flashover of Normal Insulator Strings

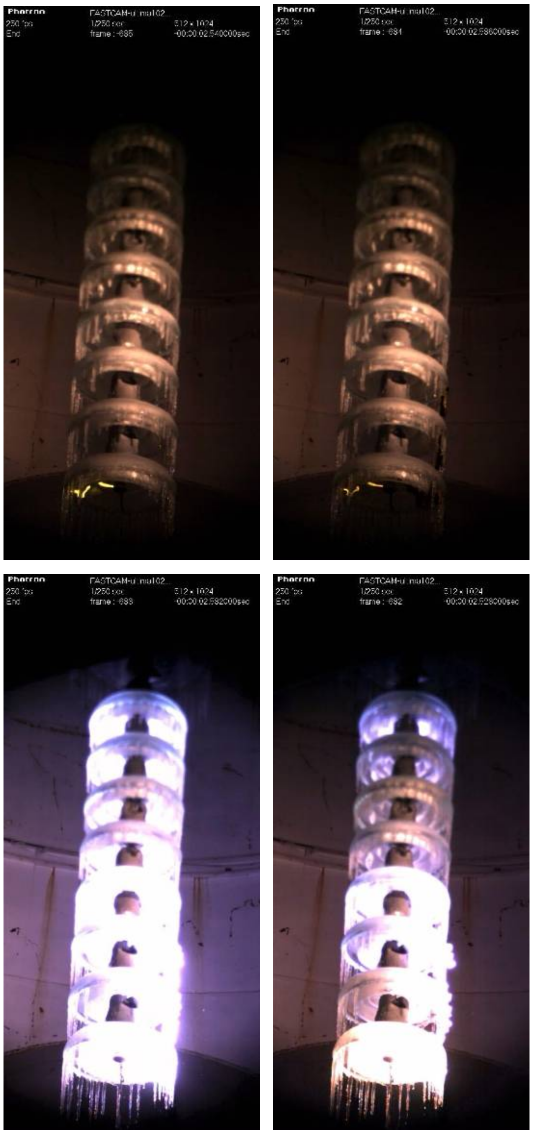

Figure 5. The Icing Flashover of Normal Insulator Strings without insulators of big diameter

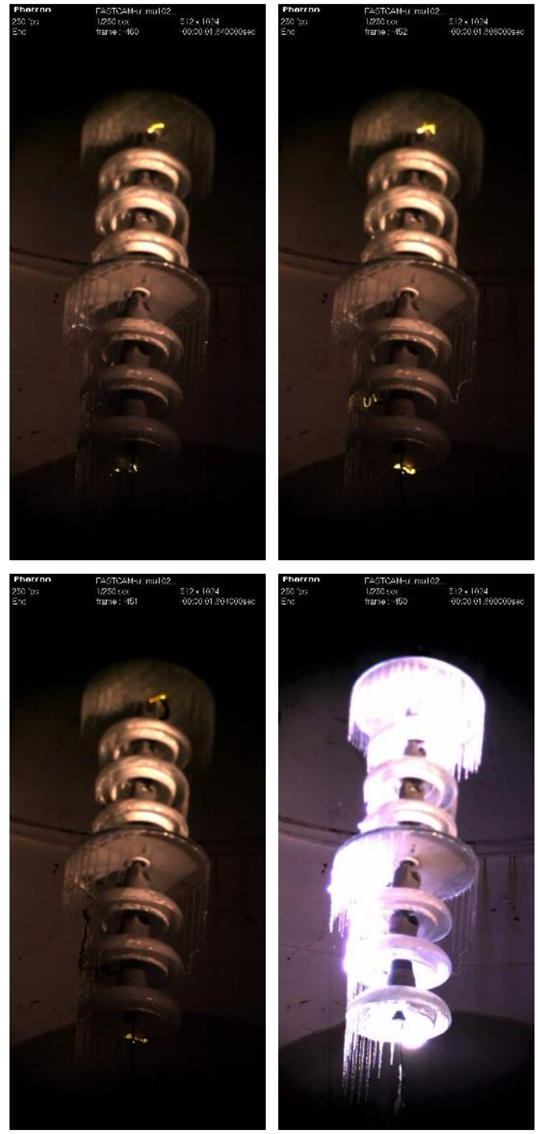

Figure 6. The Icing Flashover of "3+1" Insulator Strings with one insulator of big diameter every 3 normal insulators

### *C. The Icing Flashover of "3+1" Insulator Strings*

### *D. The Icing Flashover of "4+1" Insulator Strings*

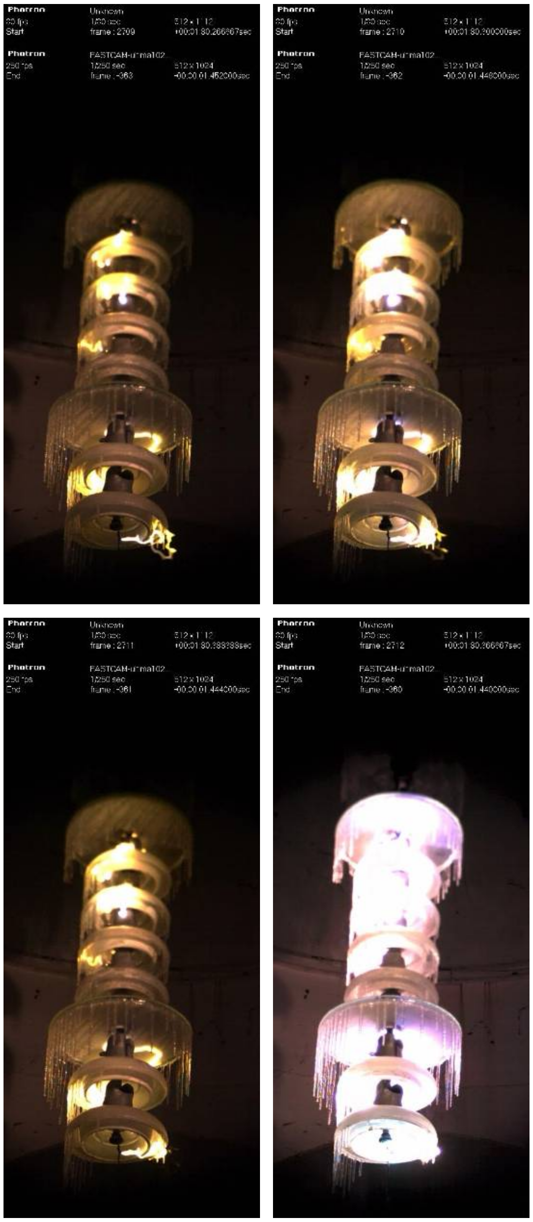

Figure 7. The Icing Flashover of “4+1” Insulator Strings with one insulator of big diameter every 4 normal insulators

## E. *The Icing Flashover of V-shaped Suspension Strings*

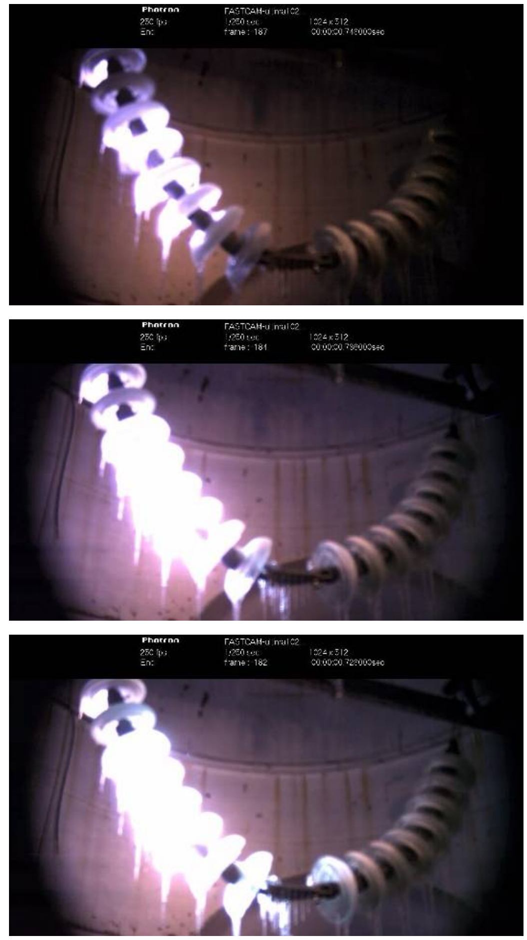

Figure 8. The Icing Flashover of V-shaped (45°) suspension strings

## F. *Flashover Voltage of the Four Insulator Strings*

When the icing regime finished, the icing insulator strings are kept for hardening for 2 hours. The insulator strings was applied with the operating stress 63.5 kV. The door of the icing climatic chamber was open and the temperature rose gradually. When the temperature is about 2~3°C, the ice on the insulator strings melted. There was water flowing and dripping down the insulator strings. At that time when the melting is substantial, voltage was increase to flashover. 5 to 6 tests were conducted on every type of insulator strings, and the average icing flashover voltages were calculated. The icing flashover voltage of normal insulator strings was used as the reference.

From Figure 9, it can be concluded that the V-shaped suspension strings has the highest icing flashover voltage, and the “3+1” and “4+1” insulator strings are in the middle, while the normal strings has the lowest icing flashover voltage.

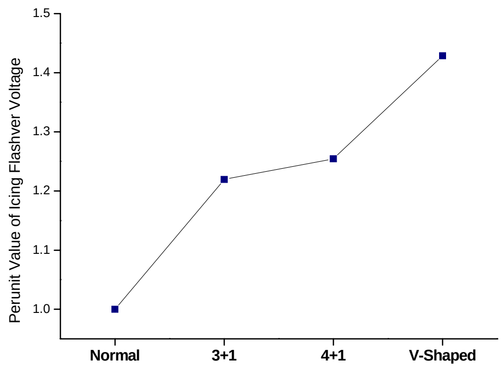


Figure 9. The perunit value of icing flashover voltage of the insulator strings with different alternating sheds and different suspension type. The icing flashover voltage of normal insulator strings was used as the reference.

## IV. Conclusions

As to the I-string transmission lines which has been built, it is difficult to change the suspension type. Using insulators of big diameter to add in the normal strings is a good solution to increase the anti-icing flashover ability.

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