Research and Application of New AC/DC De-Icing Devices in Hunan Power Grid

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***Abstract*—The icing disasters influence Hunan power grid every winter. To solve the limitations of traditional AC de-icing way, new series capacitor compensation AC de-icing method and DC de-icing method are proposed. At the same time, regulative capacitor compensation AC de-icing device (ice melting distance: 0-40km), controllable DC de-icing device (ice melting distance: 0-40km) and uncontrollable DC de-icing device (ice melting distance: 0-150km) are manufactured. The devices have been done the field test on the corresponding transmission lines.**

1 INTRODUCTION

Ice disaster is one of the most serious problems causing damage of power system. The traditional AC de-icing technology has the following disadvantages: (1) It needs large de-icing power capacity; (2) It needs to tandem many transmission lines in order to melt the ice covering upon them in most condition, which involving more substations, more excessively complex brake operation and more load transfer during de-icing. For many shortcomings of the traditional short-circuit AC de-icing method, this article presents a new series capacitor compensation AC de-icing method and a new DC de-icing method, and manufactures regulative capacitor compensation AC de-icing device, controllable DC de-icing device and uncontrollable DC de-icing device.

2 STUDY OF NEW AC/DC DE-ICING METHOD

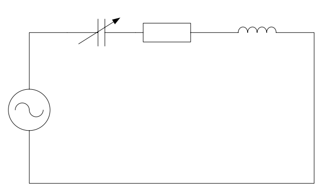

Figure 1. Principle of new series capacitor compensation AC de-icing method

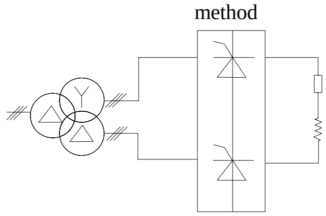

Figure 2. Principle of Controllable DC de-icing method

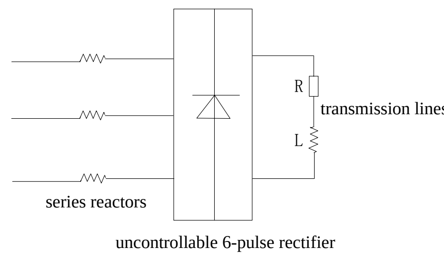

Figure 3. Principle of Uncontrollable 6-pulse DC de-icing method

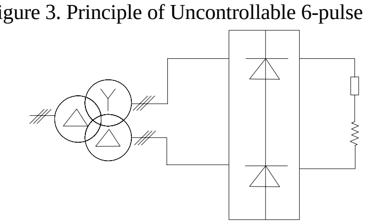

Figure 4. Principle of Uncontrollable 12-pulse DC de-icing method

3 CONCLUSION

In order to overcome the shortcomings of the traditional AC de-icing technique, this article presents a new series AC de-icing method and a new DC de-icing method, and the regulative capacitor compensation AC de-icing device, controllable DC de-icing device and uncontrollable DC de-icing device are manufactured. The devices can satisfy ice—melting demand of 97 percent of 220kV transmission lines and important 500kV lines in Hunan power grid.

These devices have been successfully used in the field test on the corresponding transmission lines. They can achieve favorable ice-melting effect, and provide important technical approach for Hunan network protection from ice—storm to ensure the safe and stable operation of the power grid in Hunan.

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***Abstract*—The icing disasters influence Hunan power grid every winter, which cause the phenomenon such as tower collapses and breaking of lines etc, and seriously affect the normal operation of the transmission lines and the safe and stable operation of the power grid. At the same time, it brings huge economic losses to Hunan power grid. To reduce the influence on transmission lines by ice cladding, Hunan power grid mainly adopted the traditional AC de-icing technique to melt ice in the past. However, this method has deficiencies such as larger de-icing power capacity requirement, more load transfer, and excessive brake operation etc. To solve the above limitations of AC de-icing way, new series capacitor compensation AC de-icing method and DC de-icing method are proposed. New series capacitor compensation AC de-icing method connects different sizes of capacitor in series lines to compensate inductive components of different types and length of lines. And then the inductive component of lines is zero in DC de-icing method. Therefore, the two methods of melting ice greatly reduce the required capacity. At the same time, they can achieve ice melting demand of various transmission lines. According to the statistical analysis of the type and length of transmission lines in Hunan power grid, and minimum and maximum ice-melting current of various kinds of lines, and according to the calculation of melting ice voltage etc, regulative capacitor compensation AC de-icing device (ice melting distance: 0-40km), controllable DC de-icing device (ice melting distance: 0-40km) and uncontrollable DC de-icing device (ice melting distance: 0-150km) are manufactured. The devices can satisfy ice melting demand of 97 percent of 220kV transmission lines and important 500kV lines in Hunan power grid, and has been done the field test on the corresponding transmission lines. They can achieve favorable ice-melting effect, and provide important technical approach for Hunan network protection from ice storm to ensure the safe and stable operation of the grid in Hunan.**

Keywords-Transmission lines; De-icing device; DC de-icing; AC de-icing; Capacitor compensation; Regulative capacitor

1 INTRODUCTION

Ice disaster is one of the most serious problems causing damage of power system. Ice disaster in 2008 made transmission lines ice seriously in every province of the South, the Centre and the East of China , causing massive power outages and up to￥111.1 billion in direct economic losses. It seriously affected the development of the national economy and the improvement of the quality of people's life[1-2]. Thermal de-icing is the most effective, quick and economical way of solving the problem of transmission lines covered with ice, and it becomes the focus of current research about de-icing of transmission lines[3-7]. Thermal de-icing method commonly used is short-circuit AC de-icing method, which played good results in the process of transmission lines' de-icing in Hunan electric power system[8], but the traditional AC de-icing technology has the following disadvantages: (1) It needs large de-icing power capacity; (2) It needs to tandem many transmission lines in order to melt the ice covering upon them in most condition, which involving more substations, more excessively complex brake operation and more load transfer during de-icing. As the power grid scale expands, the limitation of the short-circuit AC de-icing method becomes more and more increasingly clear. In addition, it is hard to work quickly and efficiently when the ice is more seriously covering the transmission lines.

For many shortcomings of the traditional short-circuit AC de-icing method, it urgently need to study new de-icing technology and equipment, which should meet the need of transmission lines' de-icing and provide a newly practical and effective solution to overcome the frozen disaster of power grid[9-12]. This article presents a new series capacitor compensation AC de-icing method and a new DC de-icing method, which solves many questions, such as larger de-icing power capacity requirement, more load transfer, and excessive brake operation etc. According to the statistical analysis of the type and length of transmission lines in Hunan power grid, and minimum and maximum of ice-melting current of various kinds of lines, and according to the calculation of ice—melting voltage etc, regulative capacitor compensation AC de-icing device, controllable DC de-icing device and uncontrollable DC de-icing device are manufactured. The devices can satisfy ice—melting demand of 97 percent of 220kV transmission lines and many important 500kV lines in Hunan power grid.

2 STUDY OF NEW AC/DC DE-ICING METHOD

2.1 New series capacitor compensation AC de-icing method

New series capacitor compensation AC de-icing method connects different sizes of capacitor in series lines, which compensate inductive components of different types and length of lines by regulating the regulative sizes of capacitor. Therefore this guarantees that de-icing current is in the appropriate range. Its principle is depicted as Figure 1.

The impedance of each phase of transmission lines before capacitor-compensating is

$$Z_0 = R + jX_0$$

R is the line resistance, X_0 is the inductive reactance before capacitor-compensating.

The impedance of each phase of transmission lines after capacitor-compensating is

$$Z_1 = R + jX_1 = R + j(X_0 - X_c)$$

X_1 is the inductive reactance after capacitor-compensating, X_c is capacity reactance which is regulated from the sizes of capacitor to the lines.

The relationship of impedance between uncompensation and compensation is depicted as Figure 2.

It can be seen clearly from Figure 2. The total impedance of icing transmission line is decreasing greatly after compensating capacitor appropriately.

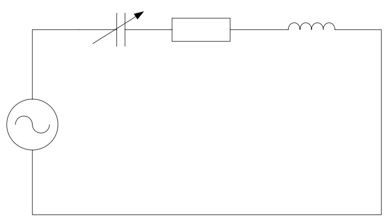

Figure 1. Principle of new series capacitor compensation AC de-icing method

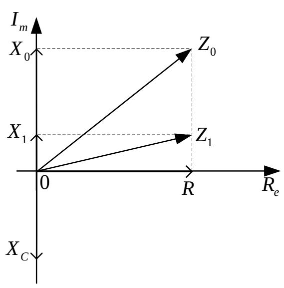

Figure 2. Relationship of impedance between uncompensation and compensation

I is de-icing current when ice-melting. And the de-icing power capacity required uncompensatingly is

$$S_0 = 3I^2|Z_0|$$

The de-icing power capacity required compensatingly is

$$S_1 = 3I^2|Z_1|$$

The impedance of icing transmission line is decreasing greatly when compensating appropriately ($Z_1 \ll Z_0$), so the de-icing power capacity required is less when adopting new series capacitor compensation AC de-icing method than traditional AC de-icing method.

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2.2 New DC de-icing method

2.2.1 Controllable DC de-icing method

Principle of controllable DC de-icing method is depicted as Figure 3. The phase difference between the two groups of the outputting-voltage is 30° after the inputting-voltage goes through the rectifier-transformer. Then the DC which is formed by outputting-voltage going through controlled 12-pulse rectifier could melt the ice covering upon the transmission lines. The DC outputting-voltage of this method can smoothly adjust.

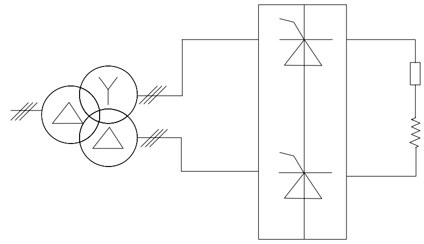

Figure 3. Principle of Controllable DC de-icing method

2.2.2 Uncontrollable DC de-icing method

(1)Uncontrollable 6-pulse DC de-icing method

Principle of uncontrollable 6-pulse DC de-icing method is depicted as Figure 4. The DC which is formed by inputting-voltage going through uncontrollable 6-pulse rectifier could melt the ice covering upon the transmission lines directly. There will greatly reduce the grid harmonics when the AC inputting side of the rectifier is in tandem with series reactors.

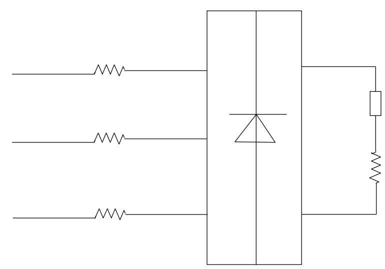

Figure 4. Principle of Uncontrollable 6-pulse DC de-icing method

(2)Uncontrollable 12-pulse DC de-icing method

Principle of uncontrollable 12-pulse DC de-icing method is depicted as Figure 5. The phase difference between the two groups of the outputting-voltage is 30° after the inputting-voltage goes through the rectifier-transformer. Then the DC which is formed by outputting-voltage going through uncontrollable 12-pulse rectifier could melt the ice covering upon the transmission lines.

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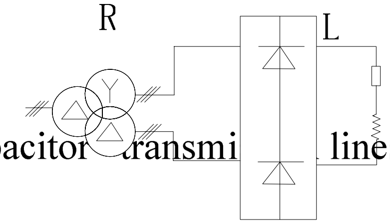

Figure 5. Principle of Uncontrollable 12-pulse DC de-icing method

3 DE-ICING DEVICE BASED ON NEW AC/DC DE-ICING METHOD

3.1 Regulative capacitor compensation AC de-icing device

Regulative capacitor compensation AC de-icing device consists mainly of the capacitor bank. Capacitor bank is divided into three-phase structure, each consisting of three sets of capacitors. And each set of capacitor consists of 10 capacitors in parallel. When the ice covering upon the transmission lines need to be melted, it is able to regulate capacity reactance of the bank flexibly by adjusting three sets of capacitors and selecting the number of each set of capacitors. Finally, it successfully compensates the inductive components of type-different and length-different lines. In a word, this de-icing device can satisfy the length of 0～40km during ice-melting of transmission lines. Principle of regulative capacitor compensate AC de-icing equipment is depicted as Figure 6.

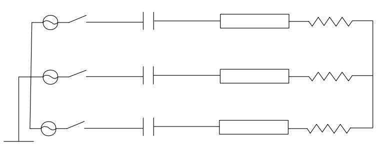

Figure 6. Principle of regulative capacitor compensate AC de-icing equipment

3.2 Controllable DC de-icing device

Controllable DC de-icing device mainly consists of a rectifier-transformer and a 12-pulse controllable rectifier. The outputting voltage of the device is regulative. Its nominal power capacity is 4.2MW and nominal outputting voltage is 3000V, which can satisfy the length of 0～40km during ice-melting of transmission lines. Principle of controllable DC de-icing device is depicted as Figure 7.

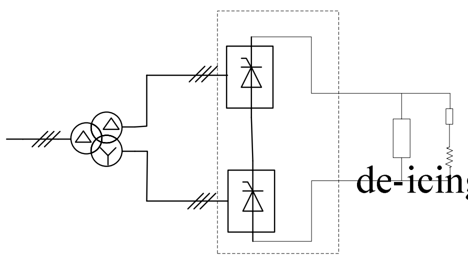

Figure 7. Principle of controllable DC de-icing device

3.3 Uncontrollable DC de-icing device

In order to satisfy the de-icing requirement of different types and different length of transmission lines, uncontrollable DC de-icing device consists of long distance de-icing unit and short distance de-icing unit , which can satisfy the length of 150km during ice-melting of transmission lines.

3.3.1 Long distance de-icing unit

Long distance de-icing unit consists of three-phase series reactors, a 6-pulse uncontrollable DC rectifier, combined switches and a reactive voltage suppression component. Principle of Long distance de-icing unit is depicted as Figure 8.

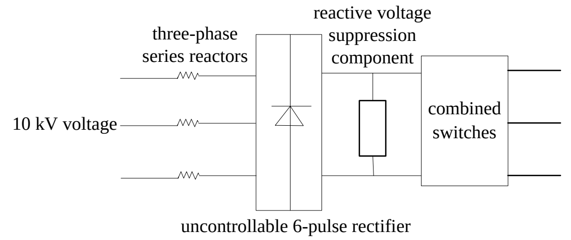

Figure 8. Principle of long distance de-icing unit

Long distance de-icing unit mainly melts the ice covering upon transmission lines about 50～150km in length. The unit directly uses the power of 10 kV and transforms it to DC by an uncontrollable 6-pulse DC rectifier. In order to suppress the harmonics which will go into the power system, the AC input-side should connect equipment consisting of reactance chips. At the same time, in order to eliminate the influence to 6-pulse rectifier, which the reactive voltage of transmission lines causes, the DC output-side should connects a reactive voltage suppression component. Combined switches make the change of the de-icing method easily, such as the method of one line plus one line or the method of two lines connection in parallel plus the third one. The nominal power capacity of long distance de-icing unit is 25MW, and the nominal outputting voltage is 12.5kV.

3.3.2 Short distance de-icing unit

Short distance de-icing unit mainly consists of a rectifier-transformer, a 12-pulse uncontrollable rectifier, combined switches and a reactive voltage suppression component. Principle of short distance de-icing unit is depicted as Figure 9.

Short distance de-icing unit mainly melts the ice covering upon transmission lines below 50km in length. It uses a rectifier-transformer to step the power voltage of 10kV down and transforms it to DC by using a 12-pulse uncontrollable rectifier. It is able to regulate the outputting DC voltage by changing the connection of the two arms of the rectifier and adjusting the voltage-grade of the rectifier-transformer. This could expand the range of de-icing. The nominal power capacity of short distance de-icing unit is 8.1MW, and the nominal outputting voltage is 6kV.

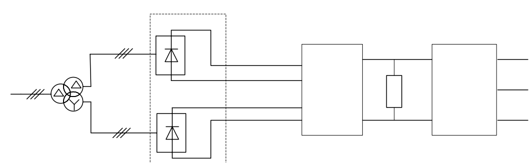

Figure 9. Principle of short distance de-icing unit

4 FIELD TEST OF NEW AC/DC DE-ICING DEVICE

4.1 Field test of regulative capacitor compensation AC de-icing device

Regulative capacitor compensation AC de-icing device was tested in 220kV Jili-Substation in Changsha city, Hunan province on November 2, 2008. This used the 220kV transmission line of Cong-Ji as the testing object. The type and the length of the transmission line are LGJ-400 and

37km respectively. The de-icing current went readily up to 810A and the temperature of the conductor raise from 17℃ to 35℃ after 15 min. Then it successfully de-iced the ice covering upon the transmission line.

4.2 Field test of Controllable DC de-icing device

The icing thickness of 220 kV transmission line (Cheng-Yong) was about 21mm in Chenzhou city, Hunan province on January 6, 2011. Its type is LGJ-400 and the length is 38.04km. Controllable DC de-icing device produced steady de-icing current of 860A. After 182 min, such a high current made the ice covering upon the Cheng-Yong line dropped successfully and the temperature of the conductor raise from 1.2℃ to 6.8℃.

4.3 Field test of uncontrollable DC de-icing device

Tian-Shang transmission line which connects 220kV Tianjia substation of Huaihua city and 220kV Shangdu substation of Loudi city is 126km in length and its type is 2×LGJ-300. Part of the icing thickness was 10mm in Huaihua city, Hunan province on February 28, 2009. Uncontrollable DC de-icing device produced steady de-icing current of 1400A. After 2 hours, such a high current made the ice covering upon the Tian-Shang line dropped successfully and the temperature of the conductor raise from 0℃ to 15℃.

5 CONCLUSION

In order to overcome the shortcomings of the traditional AC de-icing technique, such as larger de-icing power capacity requirement, more load transfer, and excessive brake operation etc, this article presents a new series capacitor compensation AC de-icing method and a new DC de-icing method. According to the statistical analysis of the type and length of transmission lines in Hunan power grid, regulative capacitor compensation AC de-icing device, controllable DC de-icing device and uncontrollable DC de-icing device are manufactured. The devices can satisfy ice—melting demand of 97 percent of 220kV transmission lines and important 500kV lines in Hunan power grid.

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