RESEARCH OF DE-ICING METHOD AND DEVICE BASED ON 12-PULSE RECTIFICATION FOR 500KV TRANSMISSION LINES

Zhang Yun, Lu Jiazheng, Tan Yanjun , Li Bo
Hunan Electric Power Test and Research Institute
Power transmission and Distribution equipment anti-icing & Reducing-disaster technology key Laboratory of State Grid
Hunan, Changsha, China
*Email: zfst01@163.com

Abstract: Because of the multi-splitting of the 500kV lines, the large de-icing current is required. This paper presents the DC de-icing method based on 12-pulse rectification by the regulation of the multilevel voltage and the parallel or series DC out voltage. Through the analysis of the mathematical theory and the system simulation, this method can satisfy the ice-melting demands of different lengths of 500kV line. The device has been used to conduct the field test on the 500kV transmission lines. The experiment results show that the temperature-rise is obvious. It can solve the problem of ice-melting of 500kV transmission lines.

1. INTRODUCTION

The AC de-icing method is in practice, there are many disadvantages such as the difficulty of the load transfer, the excessive change-brake operation and the large power to melt ice etc. In recent years, with the breakthrough of the extra-high voltage and DC technology, and with the rapid development of power electronics technology and high voltage DC transmission technology, it is possible to product the high voltage and high-capacity DC power supply by the power electronics technology.

2. RESULTS AND DISCUSSION

At the end of 2010, DC de-icing test on 500kV transmission line is carried on in transformer substation. DC de-icing device the paper referred is shown in figure1.

Figure 1: 500kV DC De-icing Device Field

The connection way of the transmission line is Two Parallel and One Series, and illustrated as figure 2. To complete the three-phase line of melting ice needs 2 operation of changing brake.

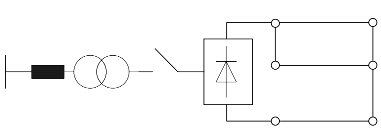

Figure 2: Two Parallel and One Series

The connection ways of the line is used as the two parallel and one series, the waveform of DC voltage in the process of the de-icing test is shown in figure 3. A current of the de-icing power supply is shown in figure 4; other current spectrum is shown in figure 5.

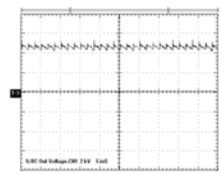

Figure 3: DC Voltage Waveform of Test

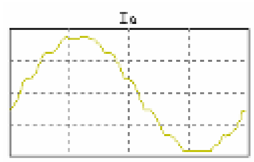

Figure 4: AC Current of Test

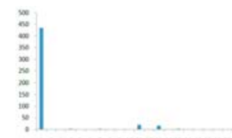

Figure 5: Spectrum of Current

The infrared imaging of the change of wire temperature lasting 10 minutes is shown in figure 6. Wire temperature rose to 42.9°C from 31.3°, and the effect is obvious.

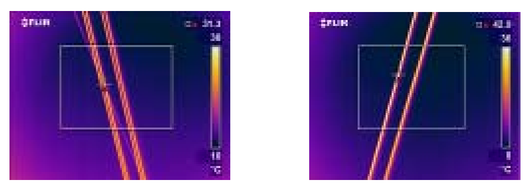

Figure 11: Infrared Imaging Pictures of the Rise of Wire Temperature

3. CONCLUSION

The results of the field test indicate that 500kV DC de-icing device is effectively used and has good function. With the rise of wire temperature, the DC de-icing device needs of 500kV and 220kV transmission line in 500kV transformer substation are met.

4. REFERENCES

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Research of De-icing Method and Device Based on 12-Pulse Rectification for 500kV Transmission Lines

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Hunan Electric Power Test and Research Institute
Power transmission and Distribution equipment anti-icing & Reducing-disaster technology key Laboratory of State Grid
Changsha, China

***Abstract*—The cut accident of power in big area will appear, if 500kV transmission lines are influenced by the ice disasters, such as the tower collapse and the breakage of lines etc. Because of the multi-splitting of the 500kV lines, the large de-icing current is required. If the traditional AC de-icing way is used to melt ice, the power source cannot provide the adequate power to satisfy the demand of the ice-melting. In DC system, the inductance of transmission lines is zero. Therefore, the required power will be greatly reduced. Considering the diversity of 500kV transmission line length, this paper presents the DC de-icing method based on 12-pulse rectification by the regulation of the multilevel voltage and the parallel or series DC out voltage. Through the analysis of the mathematical theory and the system simulation, this method can satisfy the ice-melting demands of different lengths of 500kV line. According to the parameters of 500kV lines of 500kV Transformer Substation in Hunan Power Grid, the DC de-icing device based on the proposed method is also developed, which can fulfill the ice-melting of 15-50km of 500kV line. The device has been used to conduct the field test on the 500kV transmission lines. The experiment results show that the temperature rising is obvious. It can solve the problem of ice-melting of 500kV transmission lines.**

Keywords-500 kV transmission lines；De-icing device；DC de-icing；Multi-grade voltage regulation；Parallel 12-pulse rectification

I. INTRODUCTION

The icing of the transmission line is one of electrical power system's significant natural disasters. Because Hunan is situated at the center of the southeast China, Hunan's northwest part and the south area are extremely easy to present the large-area icing of the transmission line [1]. In order to prevent that the ice disaster influences the transmission line, various countries spent the massive energy researching the anti-ice and de-icing technology under the ice disaster [2]. According to the recent technology, the AC and DC de-icing methods are the mature and flexible ways to melt the ice. However, the AC de-icing method is in practice, there are many disadvantages such as the difficulty of the load transfer, the excessive change-brake operation and the large power to melt ice etc [3]. In recent years, with the breakthrough of the extra-high voltage and DC technology, and with the rapid development of power electronics technology and high voltage DC transmission technology, it is possible to product the high voltage and high-capacity DC power supply by the power electronics technology.

According to the parameters of 500kV lines of 500kV transformer substation in Hunan, this paper explores the theory of DC de-icing method, and designs the DC de-icing project and do some research on de-icing device based on 12-pulse rectification for 500kV transmission lines. DC de-icing project is simulated by MATLAB, the field test of 500kV lines indicates that the rise of wire temperature is obvious, which can satisfy the 500kV transmission line to melt the ice

II. DC DE-ICING TECHNOLOGY OF 500KV TRANSMISSON LINE

A. *500kV Transmisson Line Summary*

Because the 500kV line is made up of the fission wire, and the distributed capacity of line is large, but the DC resistance is probable 16% of AC resistance, when AC short circuit melts the ice, the de-icing power supply must provide the massive reactive power and gives off the heat in the resistance which is relatively very small. Therefore, in order to get the same de-icing power, DC de-icing power source will reduce a lot, DC de-icing technology of 500kV transmission line is only feasible option at present.

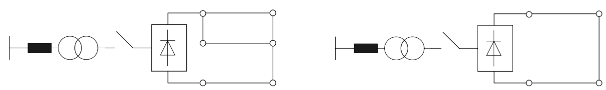
B. *DC De-icing Current Selection*

Heat produced by the direct current of transmission line must be greater than the heat dissipation of the line and the heat melting ice, the ice of the line will melt. This requires the de-icing current meets the thermal equilibrium equation (thermal balance equation) (to: Reference 2 /Appendix 1). Moreover, according to the stipulation of DL/T5092-1999 <Technical Code for Designing 110~500kV Overhead Transmission Line>, the typical meteorological condition including the wind and the ice and the temperature is: air temperature - 5℃, wind speed 10m/s, ice thickness 1cm. If melting ice is for 2 hours, then the de-icing current of 3 kinds of wire such as LGJ-300、LGJ-400 and LG-500 is less than 1kA.

At present the 500kV transmission line uses 4×LGJ-300, 4×LGJ-400 and 4×LG-500 these 3 kinds of models, which results in the outputting current of DC de-icing device of 500kV transmission line is less than 4kA.

III. Parameter Selection of Rectifier

The de-icing power source is from the main transformer low voltage side, after through the rectification transformer and rectifier the outputting DC voltage with the line melts ice, the connection ways of the line to melt ice are illustrated as figure 1. To complete the three-phase line of melting ice needs 2-3 times operation of changing brake.



(a)Two Parallel and One Series (b) Two series

Figure 1: The connection ways of line

Taking into account the de-icing needs of 500kV transmission lines and 220kV transmission line of 500kV transformer substation, comprehensively considering the line impedance, the de-icing current and the de-icing time etc., ultimately the technical parameters of the 500kV DC de-icing device are determined as follows: capacity 17.6MW, rated inputting voltage 20kV, rated outputting current 4000A. Rectification transformer through the multilevel output voltage, which meets the de-icing needs of all kinds of transmission lines in the substation.

A. *Design of Rectification Transformer*

In order to reduce the impact of the current harmonics of the rectifier on the grid and DC Voltage pulse, 12-pulse rectification is used in the design of this device; the transformer is designed as the double-coils output. By optimizing the design, the turn ratio difference between the two coils is within 0.2% in order to ensure that the difference of voltage is within 0.2%. The coils of the transformer are connected with Dd0y11, the primary coil with a "△"; two secondary coils are connected by a "△" and "Y", respectively, for the three-phase rectifier power supply.

The primary coil current i_A of 12-pulse rectifier transformer is equivalent to the sum of two equivalent transformer [4]. With Dd0 connection, the voltage and current shape and phase of the primary and secondary are the same, the value meets the ratio "n"; with Dy11 connection, the secondary voltage is ahead of the 30 ° compared with the primary voltage, then the primary current fundamental components and the phase sequence of the positive sequence harmonic is the same, while the phase sequence of the negative sequence harmonics is that the primary voltage is ahead of the 30 ° compared with the secondary voltage . Through the analysis, the primary current is as follows:

$$i_A = \frac{4\sqrt{3}}{\pi} I_d (\sin \omega t + \frac{1}{11}\sin(11\omega t) + \frac{1}{13}\sin(13\omega t) + \cdots) \quad (1)$$

In formula (1), *Id* is the output DC current of the rectifier, the primary input current of the transformer , in theory, contains only 12k ± 1 (k is a positive integer) harmonics. That is to say, with the use of 12-pulse rectification technology of DC de-icing device, the current harmonics of power supply are effectively suppressed and the power factor is also greatly improved, which is also very beneficial to the stability of the grid.

B. *The Design of Pulse Recifier*

A rectification transformer uses the multi-gear adjusting way of the voltage output in order to reduce the maintenance and the use of preparation time. It uses the way of the diode uncontrolled rectification to save the cost and size of the whole device.

The main circuit of 12-pulse rectifier consists of two there-phase full-bridge rectifier, and shown in figure 2; it is in the way of the series and parallel according to the situation of the field de-icing line.

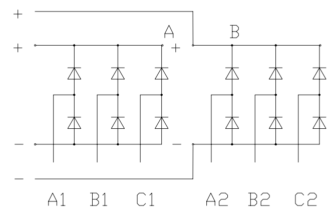


Figure 2: Rectifier Main Circuit Topology

The DC voltage U_d of 12-pulse rectifier has 12 pulse in a period, and each pulse waveform is same. As in the calculation of the average, it is enough that only a pulse (ie 1 / 12period) is calculated [5].

$$U_d = \frac{12}{2\pi}\int_{-\frac{\pi}{12}}^{\frac{\pi}{12}} \sqrt{2} \cdot u_{AB} \cdot \cos \omega t d(\omega t) = 1.398 u_{AB} \quad (2)$$

In formula (2), u_{AB} is the phase-to-phase voltage of the rectification transformer output. The rated output current of every rectifier bridge is 2000A, by the parallel connection of two bridges, the output of DC current I_d is 4000A, then the average of the bridge arm current I_{AV} is

$$I_{AV} = \frac{1}{3} \times \frac{1}{2} \times I_d = 667A \quad (3)$$

Considering treble safety factor, 2300A diode is chosen according to the component manual.

The output highest voltage of rectification transformer u_2 is 3525V, the highest repeat peak voltage of the diode V_{RP} is:

$$V_{RP} = \sqrt{2} \times u_2 = 4985V \quad (4)$$

Considering treble safety factor, 3 diodes are used in the series mode, and of every diode is V_{RP}=5200V.

IV. Analysis of Simulation

According to the relevant parameters of 500kV lines of 500kV Transformer Substation, DC de-icing device is carried on the systematic simulation, and the simulation tool is the "Simpowersystems" toolbox in MATLAB [6]. The length of line is 35.7km, the type of line is 4 × LGJ-300, line impedance is(0.858 + j5.397) Ω, transformer output is at the grade of 3520V, 12-pulse rectifier bridge is in parallel, the connection ways of the line to melt ice is used as the two parallel and one series , the simulation model is shown in figure 3.

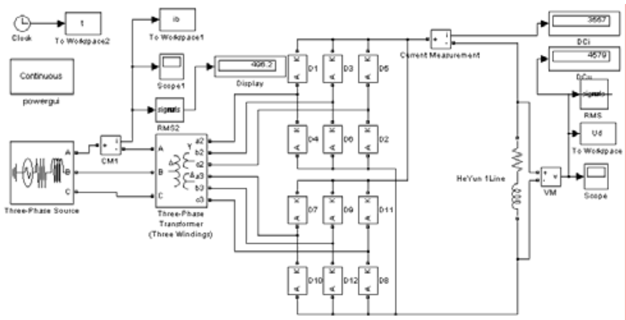


Figure 3: DC de-icing simulation of 500kV transmission line

Through the simulation, the de-icing current is 3557A, which meets the demand of the de-icing current of lines. The output voltage of the rectifier is 4579V; the waveform is illustrated as figure 4. It is obvious that DC voltage pushes 12 times in a period.

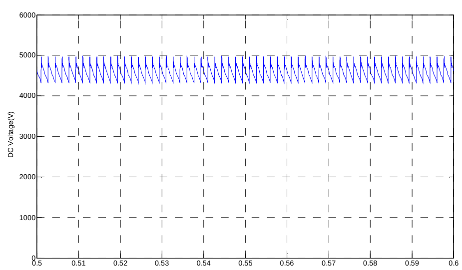
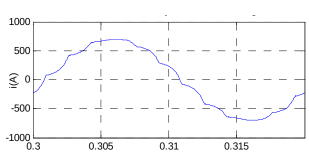


Figure 4: Waveform of the output voltage of the recifier

AC de-icing current that 20kV side provides is 496.2A, the waveform is shown in figure 5, the spectrum is shown in figure 6.



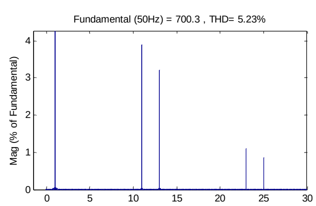


Figure 5: AC Current Figure 6: Spectrum of AC Current

Figure 6 is the analysis of AC current spectrum. It is clear that AC current contains only 12k ± 1 (k is a positive integer) harmonics, and the fundamental content of less share, not including the low-order harmonic, the quality of the current waveform is good.

V. FIELD TEST

At the end of 2010, DC de-icing test on 500kV transmission line is carried on in 500kV Transformer Substation. DC de-icing device the paper referred is shown in figure 7.

Figure 7: 500kV DC De-icing Device Field

The wiring ways of the line to melt ice is used as the two parallel and one series, the waveform of DC voltage in the process of the de-icing test is shown in figure 8. A current of the de-icing power supply is shown in figure 9; other current spectrum is shown in figure 10.

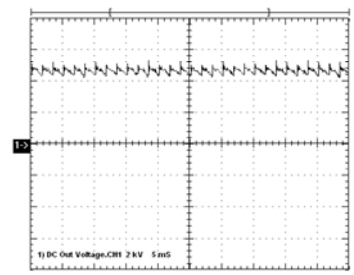
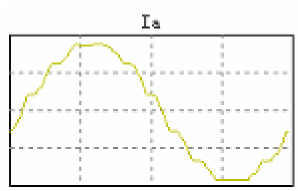


Figure 8: DC Voltage Waveform of Test



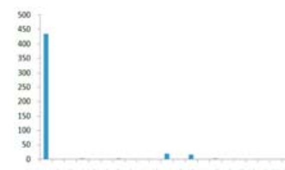
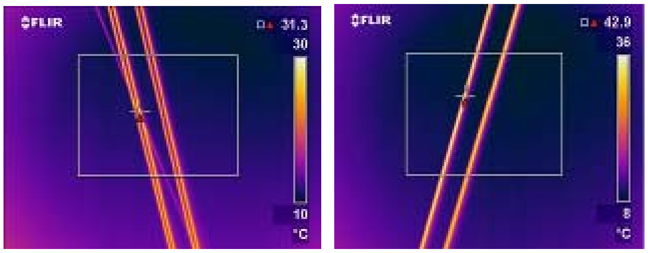


Figure 9: AC Current of Test Figure 10: Spectrum of Current

The waveform of the test voltage in figure 8 is same as the simulation waveform in figure 4. The actual voltage is 4700V, which is consistent with the simulation voltage. At the current of the two rectifier bridges are respectively 1691A and 1685A, the total de-icing current is 3376A. With the rise of temperature, DC current decreases.

The test waveforms in figure 9 and figure 10 are same as the simulation waveforms in figure 5 and figure 6. Experiment validates the validity of the system simulation and theoretical analysis.

In the process of melting ice, the infrared imaging of the change of wire temperature lasting 10 minutes is shown in figure 11. Wire temperature rose to 42.9°C from 31.3°, the rise of temperature reaches 11.6°C, and the effect is obvious and the DC de-icing device worked normally in this process.



(a) Initial Temperature 31.3°C (b) Last Temperature 42.9°C

Figure 11: Infrared Imaging Pictures of the Rise of Wire Temperature

VI. CONCLUSION

The results of the field test indicate that 500kV DC de-icing device is effectively used and has good function. With the rise of wire temperature, the DC de-icing device needs of 500kV and 220kV transmission line in 500kV Transformer Substation are met. Moreover, rectification transformer of the multi-grade and 12-pulse rectifier are used so as to keep the maintenance easy, the operation simple, the reliability high and the long life, which can ensure the transmission lines to have the safe and stable operation under the freezing cold weather. Through the economic accounting, 500kV DC de-icing device can saves the cost of nearly ￥30 hundred million Yuan.

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