Research on Safety Protection for Live Working on $\pm 500\text{kV}$ DC Transmission Line with AC and DC Multi-circuit Transmission Lines

Yan Xie^{1,a}, Mu Li² and Changzheng Zheng¹

¹School of Electrical and Electronic Engineering, Wuhan Polytechnic University, Wuhan, China

²Wuhan Nari Limited Liability Company of State Grid Electric Power Research Institute, Wuhan, China

^alimimimm@163.com

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Abstract. In recent years, in order to save line corridors and reduce the scope of demolition, some new transmission modes for high voltage AC and DC power transmission line are proposed. According to the characteristics of the parallel transmission line, this paper studies the distribution characteristics of the electric field intensity of multi circuit parallel transmission lines and the single circuit transmission line. Comparing and analyzing the simulation results of the electric field strength, the safety measures for live working of $\pm 500\text{kV}$ DC transmission line with multi circuit parallel transmission lines is put forward. That is the electric field protective equipment and measures used in the live line work of the $\pm 800\text{kV}$ HVDC single circuit line can meet the requirements of the live operation of the $\pm 500\text{kV}$ HVDC multi-circuit transmission line.

Introduction

With the rapid development of AC and DC transmission project construction, the transmission voltage level is higher. The number of extra high voltage and ultra-high voltage AC and DC transmission lines are increasing, and the transmission line corridor is becoming more and tenser. Meanwhile, the transmission line construction must also meet the requirements of the environment. ^[1-2] In recent years, in order to save line corridors and reduce the scope of demolition, some new transmission modes for high voltage AC and DC power transmission line are proposed, such as multi loop, parallel erection and so on. ^[3-4]

There are four parallel erection of high voltage transmission line in the province, including: two $\pm 800\text{kV}$ extra-HVDC transmission lines, $\pm 500\text{kV}$ double circuit ultra-HVDC transmission line, and 1000kV extra-high-voltage AC transmission lines.

According to the characteristics of the parallel transmission line, this paper studies the influence of the electric field on the human body, and verifies the safety and feasibility of the live line work on the multi circuit transmission line. And compared with $\pm 800\text{ kV}$ transmission line with the voltage level of live working methods, the safety measures for live working on $\pm 500\text{ kV}$ transmission line is put forward.

Calculation and analysis of electric field

Because of the low frequency electric field of operating transmission line, the electric field can be regarded as an electrostatic field when the finite element method is used to calculate the electric field. The field of each tower in typical operations is calculated based on multi circuit transmission lines running at the same time.

For the analysis of parallel multiple loop circuit of $\pm 500\text{ kV}$ HVDC transmission lines on the same tower space field intensity level, the simulation calculation model is considering the tower and the DC line operation mode of the electric field, and ignoring the effect of insulator effect on electric field distribution and ion current on DC electric field. The conductor is equivalent to single conductor to be calculated. The tower surface is considered as a conductor plane. The earth is considered as an infinite conductor plane. Finally, the calculated results are compared with the spatial field strength of single circuit.

Calculation parameters. When the electric field intensity is calculated, the related calculation conditions are as follows. The electric field of 1000kV transmission line is calculated by reverse order, and the maximum operating voltage of the system is 1100kV. The polarity of the DC transmission line is set to the left as the negative pole and the right as the positive pole, and its voltage is calculated in accordance with the rated operating voltage.

Figure 1 shows the tower section model of multi circuit transmission line with same corridor. Figure 2 shows the structure of transmission line tower.

Figure 1. Location map of the tower with transmission corridor.

Figure 2. Structure of AC and DC transmission lines tower.

Transmission line parameters are set as shown in table 1.

Table 1. Transmission lines parameters.

Line name	1000kV AC	±800kV DC(1)	±800kV DC(2)	±500kVDC
Wire type	8×ACSR-LG J630/45	6×ACSR-720/ 50	6×JL/G3A-900/ 40	4×ACSR-7 20/50
Split interval/mm	400	450	450	450
Sub wire radius /mm	16.8	15.14	16.93	15.14
Calculating radius/mm	441.21	344.66	351.14	258.2
Hanging point distance/m	13	11	11	7

Results of calculation. The electric field distribution on the vertical cross section of the tower and the conductor is shown in Figure 3(a). Figure 3(b) shows the contour map of the electric field strength on the plane.

Figure 3. Distribution map of space electric field and its contour

From Figure 3, it shows that the electric field distributions on the right side of ±800 kV DC (1) transmission line, on the left side of ±800 kV DC (2) transmission line and the double direct current transmission line are obviously distorted.

Safety protection for live working on ± 500 kV double circuit high voltage transmission line

Comparing the electric field intensity of ± 500 kV DC transmission line key points under multi circuit transmission line parallel erection condition with the electric field intensity of ± 800 kV DC single circuit transmission line, safety protection measures for live working of ± 500 kV DC transmission line with AC and DC multi-circuit transmission lines can be obtained.

Analysis of space electric field of ± 500 kV double circuit transmission line tower. Figure 4 shows the location of the point where the electric field intensity is calculated.

Figure 4. Position distribution diagram of calculation points of ± 500 kV DC transmission lines

The electric field distribution of the central section of the DC transmission line tower is shown in Figure 5(a). Figure 5(b) shows the contour map of the electric field strength.

Figure 5. Distribution map of space electric field and its contour

Table 2 shows the simulation results of the calculation of the electric field strength of the tower of ± 500 kV double circuit transmission lines.

Table 2. The effective value of the electric field strength of ± 500 kV double circuit transmission line

Calculation point	electric field intensity (kV/m)	Calculation point	electric field intensity (kV/m)
1	42.0	5	30.0
2	48.0	6	41.0
3	633.0	7	702.0
4	27.0	8	25.0

As can be seen from the table 2, the distribution of the electric field intensity has the following characteristics.

1) The electric field intensity on the surface of the conductor is maximum. Along with the increase of the distance of the conductor, the electric field intensity decays rapidly. 2) The electric field intensity of tower surface with the same height of the conductor, the insulator strings on the cross arm and the lower of the conductor is relatively large because they are close to the conductor.) The electric field intensity at the corner intersection with the tower of tower cross arm is relatively small.

Analysis of electric field of ± 800 kV DC high voltage transmission line tower. For the convenience of analysis and comparison, the single circuit tower with ± 800 kV DC transmission line is selected as the research object. Figure 6 shows distribution of space electric field and its contour. The electric field distribution of the central section of the line tower is shown in Figure 6(a). Figure 6(b) shows the contour map of the electric field strength.

Figure 6. Distribution map of space electric field and its contour

Table 3 shows the simulation results of the calculation of the electric field strength of ± 800 kV DC transmission line. From the results in Table 3, we can know that the maximum electric field strength of the wire surface. Along with the increase of the distance to the wire, the electric field intensity is quickly fading.

Table 3. Electric field intensity of ± 800 kV DC tower calculation point

Calculation point	electric field intensity (kV/m)	Calculation point	electric field intensity (kV/m)
1	12.0	3	852.0
2	38.0	4	12.0

Comparison and analysis of results. Comparing the electric field strength of the typical operation line tower working position of ± 500 kV DC transmission line with multi loop parallel charged transmission line and independent ± 800 kV DC single tower corridor, the calculation results show that electric field strength has the following characteristics and rules.

The electric field strength of the surface of the conductor is the largest for the two kinds of transmission lines, and the value of the field strength is basically equivalent. The maximum value of electric field strength on the surface of the conductor of ± 800 kV DC transmission line is slightly larger than that of the electric field strength on the surface of the conductor of ± 500 kV DC transmission line with multi loop parallel tower transmission lines.

Conclusion

By the above analysis, it can be known that the electric field protective equipment and measures used in the live line work of the ± 800 kV DC single circuit line can meet the requirements of the live working of the ± 500 kV DC double circuit transmission line with AC and DC multi-circuit transmission lines. That is live working personnel should be wearing a full set of ± 800 kV special shielding clothing. Special shielding clothing is made of shielding clothing cloth, the maximum electric field inside it is not more than 15 kV/m, and the current flowing through the human body is not more than 50 μ A.

References

- [1] HU Yi, LIU Kai, PENG Yong, SU Ziming, WU Tian: *Research Status and Development Trend of Live Working Key Technology*. High Voltage Engineering, 2014.07
- [2] HU Yi, LIU Kai, LIU Ting, XIAO Bin, PENG Yong, SU Zing: *Live Working on EHV/UHV Transmission Lines*, High Voltage Engineering, 2012.08
- [3] HU Tao, HU Yi, LI Jing lu, Long lihong: *Safety Protection for Live Working on Transmission Line*, High Voltage Engineering, 2006.05
- [4] Safety Hazard and its Prevention for Hot-line Work of 500 kV Transmission Line, XIE Yu-gan. Industrial Technology Innovation, 2016.05