Development and Application of Live Replacement of Insulator Suspension Tool Components for Transmission Lines

Ma Jun¹, Yu Liang², Shi Yonggang¹, Dong Gang¹, Gong Fuxing¹, Wei Kegang¹, Su Xin¹, Ren Yushuai¹

¹ State Grid Tonghua Power Supply Company, Tonghua, Jilin, 134000, China

² University of Edinburgh, Architecture, Minto House, 20 Chambers Street, Edinburgh

Abstract. Transmission line insulators will reduce the insulation level and become low-value insulators because of lightning flashover. Toughened glass insulators are used in 500kV Tongfeng 1 and 2 lines in Tonghua area. Most umbrella skirts will break and fall off after lightning flashover, which greatly reduces the insulation performance. It needs to be replaced in time, but frequent blackouts will bring great losses and reduce the reliability of power supply. Aiming at the frequent lightning hazards and lightning strikes on transmission lines in Tonghua area, a tool assembly for live replacement of insulators for transmission lines is developed. Through the application of this tool, the live operation mode is adopted to eliminate such defects. The operation time can be arranged and implemented in a very timely manner, which avoids the threat of long-term defects, effectively reduces the outage time of equipment, enhances the stability of power grid, and greatly improves the reliability of power supply of lines. Finally, taking the live line insulator suspension tool as an example, the economic benefit analysis is given, and the feasibility and correctness of the tool are verified.

1 Introduction

At present, there are many 500kV transmission lines in China, but because of the high voltage level, large volume and heavy weight of the supporting insulators, before the development of this tool, there was no special tool to replace such insulators. For this reason, we carried out research on 500kV Tongfeng 1 and 2 lines in Tonghua area. This line adopted a variety of tower shapes. The design includes SZ1, SZ2, SZ3 and SZ4 double-loop straight-line towers and ZBV1, ZB2 and ZB3 single-loop straight-line towers[1-3]. The crossbar and insulator hanging points of these towers are improved design. There is no place to install the lifting clamp of the original 500kV line fixed conductor. In addition, the insulator hanging point of the crossbar of the straight tower is the closed design. There is no insulator hanging point when replacing the straight insulator string, the fixture can not be used, and the 500kV straight tempered glass insulator can not be used. The weight of the string is 300 kg, so it can not be disassembled and assembled by manpower. Tonghua area is a mountainous area with frequent lightning hazards. Every year, lightning strikes occur frequently on all voltage level lines. After flashover, insulators will reduce the insulation level and become low-value insulators. Toughened glass insulators are used in 500kV Tongfeng Line 1 and Line 2. After lightning flashover, most umbrella skirts will break down and fall off, which greatly reduces the insulation performance. It needs to be replaced in time, but frequent blackouts will bring great

losses and reduce the reliability of power supply. This tool can realize the purpose of live replacement of insulators [4-6].

2 Design scheme

According to the design idea of the tool, two principles need to be determined, that is, the operating principle of live replacement of insulators for 500kV lines and the design principle of live replacement of insulators for 500kV lines. Principle of live replacement of insulators for 500kV transmission lines: When equipotential operators enter a strong electric field, the combined clearance of each part shall not be less than 4.0 meters. The minimum safe distance between the ground potential operator and the charged body shall not be less than 3.4 meters. The minimum effective insulation length of the insulating load-bearing tool shall not be less than 3.4 meters when lifting the conductor. The minimum effective insulation length of the insulated operating rod shall not be less than 3.7 meters. When replacing insulators, the number of good insulators shall not be less than 23[7-10].

The design principle of live replacement of insulators for 500kV transmission lines is that the lifting and hanging points of conductors should be located on or near a longitudinal line to avoid excessive deviation of conductors during lifting. The insulator lifting and hanging point should be in a longitudinal line with the original hanging point to prevent the insulator from being able to restore its original position after breaking

away. All parts of load-bearing tools should meet the maximum force requirements of Tonghua 500kV transmission line. The material used for metal tools should be high strength and light weight aluminium alloy. The material selected for the insulating load-bearing tool should be composed of soft suspension belts with high insulation performance, high tensile strength and low elongation coefficient, such as Dinima and other materials. The lifting screw should adopt torsion-proof and labor-saving screw, and the lifting tonnage should meet the maximum force requirement of ordinary 500kV transmission line. For the newly designed live working tools for Tonghua 500kV transmission line, after a comprehensive technical comparison of all tower structures and stress conditions, the design should be carried out to make the new tools universal and universal, so as to avoid a set of tools only applicable to one tower or one structure[11-13].

After confirming the two principles, the design scheme is formulated according to the specific situation. Design scheme of live replacement of insulators for 500kV transmission lines: Aiming at the tower form and characteristics of Tonghua 500kV transmission lines, the method of entering strong electric field is first determined. Because the tower shape of 500kV transmission lines in Tonghua area is "drum" double-circuit tower, so the climbing soft ladder and umbrella lifting method can not be used to enter the strong electric field on the middle and upper lines. Compared with the arc entry of the short suspension ladder, the arc entry of the suspension basket uses more tools than the arc entry of the short suspension ladder, and the safety is the same. So the short suspension ladder arc is used to enter the strong electric field. The comparison of lead screw pull rod suspension wire and lead screw soft belt suspension wire adopts lead screw lifting wire. Compared with lead rod and soft belt suspension, soft belt suspension has the characteristics of light weight and easy to carry, but the disadvantage of its inability to adjust the length flexibly seriously limits its practicability. Insulating pull rod can process multiple installation holes, which can be based on the above analysis. It is necessary to adjust its effective length, and sectional design can be adopted to overcome its large size and inconvenience to carry, so the insulated tie rod is adopted. Insertion method and bottle holder method can be selected according to the actual situation, and the tools of both methods should be fully equipped.

Technical Basis (1) Implementation Standards: GB/18037-2000 Basic Technical Requirements and Design Guidelines for Live Work Tools, DL/T877-2004 Insulation Tools, Devices and Equipment Requirements for Live Work, DL409-1991 Safety Work Regulations for Electric Industry (Power Line Part), GB13398-2003 Hollow Insulation for Live Work Tube, foam filled insulating tube and solid insulation rod ", live working management regulation (National Power Grid Corp), live working operation guideline (National Power Grid Corp).

(2) Technical requirements

Work load: $G = 4000\text{kg}$ K (> 2.5)

Applicable spacing: 450 x 450

Effective insulation: $> 3.7\text{m}$

The length of insulating pull rod and bottle carrier should meet the requirements of tower equipment.

Tool composition: 500kV straight line to pull type horizontal stretcher card 2 pay; tension rod and small tightener 1 set for pull type horizontal stretcher card, adjusting range: 1.2 m-2 m; 500kV straight line screw 2 pay ($L > 800$); 500kV straight line four hook card 2 pay; 500kV straight line pull rod 2 pay; 500kV straight line bottle carrier 1 pay.

Fig.1 Assembly Drawing

Fig.2 Physical map of fixtures

Tool assembly steps (fixtures and pull rods)

- (1) pairs of pulling cross-barrel clamps on the main materials on both sides of the end of the cross-barrel;
- (2) is used to tighten the tension rod and the tightener, and to pull the cross bar clamp on both sides.
- (3) The 500kV linear tightener is placed in the crossbar card.
- (4) onnect tightener and four Hook Clip with pull rod.

Fig.3 Assembly Schematic

Fig.4 Field-application Test

3 Scope of Use

Within the scope of the above design conditions, the above tools and operation methods can be safely used on the straight tower of 500kV transmission lines with all horizontal crossbars. The successful completion of this project has made it possible for the first time to replace linear insulators for live operation of 500kV double circuit transmission lines on the same tower with the fourth generation tower design in Henan Province, filling in the blank of replacing linear insulators for live operation of 500kV double circuit transmission lines on the same tower with the fourth generation tower design in China, and providing safe and reliable operation of power system. It provides a powerful guarantee to avoid the great economic losses caused by the replacement of linear insulators in such tower lines due to power outage. In design, he avoids the cross-bearing hanging point of the tower and uses the main material of the cross-bearing to hang the clamp. This can be used on the cross-bearing of any hanging point. It has the greatest scope of use and can be applied on all 500kV transmission line straight-line towers without considering the form of the hanging point. It has very high popularization value.

4 Economic Benefit Analysis

At present, there are 96 bad insulators in Tonghua 500kV Tongfeng Line 1 and Line 2, and they have been increasing year by year with about 2 pieces per year. If they are replaced by blackouts, according to the current overhaul strength of the unit, they can be replaced up to

10 pieces per day, which requires 10 days of blackouts. According to statistics, the load of the line is 100,000 kW. At present, the load of the line is 100,000 kW.

References

1. Kelly J J . Transformer Fault Diagnosis by Dissolved-Gas Analysis[J]. IEEE Transactions on Industry Applications, 1980, 6(6): 777~782.
2. Lin C E, Ling J M, Huang C L. An expert system for transformer fault diagnosis using dissolved gas analysis[J]. IEEE Transactions on Power Delivery (Institute of Electrical and Electronics Engineers); (United States), 1993, 8: 1(1): 231~238.
3. Duval M. Dissolved gas analysis: It can save your transformer[J] . IEEE Electrical Insulation Magazine, 1989, 5(6): 22~27.
4. Singh S, Bandyopadhyay M N. Dissolved gas analysis technique for incipient fault diagnosis in power transformers : A bibliographic survey[J]. IEEE Electrical Insulation Magazine, 2010, 26(6): 41~46.
5. Bhalla D, Bansal R K, Gupta H O. Function analysis based rule extraction from artificial neural networks for transformer incipient fault diagnosis[J] . International Journal of Electrical Power & Energy Systems , 2012 , 43(1) : 1196~1203.
6. Seifeddine S, Khmais B, Abdelkader C. Power transformer fault diagnosis based on dissolved gas analysis by artificial neural network[C]// First International Conference on Renewable Energies and Vehicular Technology . IEEE , 2012 : 230~236.
7. Hu W P, Yin X G, Zhang Z, et al. Fault diagnosis of transformer insulation based on compensated fuzzy neural network[C]// Electrical Insulation and Dielectric Phenomena , 2003 Report. Conference on. IEEE Xplore, 2012 : 273~276.
8. Zheng R, Zhao J, Zhao T, et al. Power transformer fault diagnosis based on genetic support vector machine and gray artificial immune algorithm[J]. Proceedings of the Csee, 2011, 31(7): 56~63.
9. Fei S W, Zhang X B. Fault diagnosis of power transformer based on support vector machine with genetic algorithm[J] . Expert Systems with Applications, 2009, 36(8): 11352~11357.
10. Bacha K, Souahlia S, Gossa M. Power transformer fault diagnosis based on dissolved gas analysis by support vector machine[J]. Electric Power Systems Research, 2012, 83(1): 73~79.

11. Muhamad N A, Phung B T, Blackburn T R, et al . Comparative Study and Analysis of DGA Methods for Transformer Mineral Oil[C]// Power Tech, 2007 IEEE Lausanne. IEEE, 2007: 45~50.
12. Kan H , Miyamoto T . Proposals for an improvement in transformer diagnosis using dissolved gas analysis (DGA)[J]. IEEE Electrical Insulation Magazine, 1995, 11(6): 15~21.
13. Ward S A. Evaluating transformer condition using DGA oil analysis[C]// Electrical Insulation and Dielectric Phenomena, 2003 Report. Conference on. IEEE Xplore, 2003: 463~468.