Analysis of Lightning Protection Status of 35~110kV Transmission Lines and Countermeasures

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Abstract. According to relevant investigations, 50%-60% of transmission line faults are caused by lightning strikes, especially in mountainous areas or plateau areas with relatively special geographical conditions and high incidence of lightning damage. The faults of transmission lines laid in relevant areas are mainly lightning trips or disconnection, which seriously affects the stability and safety of transmission line operation. Based on the influence of lightning on 35~110kV transmission lines, this paper explores the current lightning protection status of such transmission lines, and puts forward countermeasures to solve the lightning protection problems of 35~110kV transmission lines according to the relevant lightning protection principles, providing reference for power enterprises and related technical personnel, so as to minimize the lightning damage of transmission lines.

Keywords: 35~110kV transmission lines; Lightning protection status; Solution countermeasures.

1. Introduction
During the period of power transmission, transmission lines will face various dangerous factors, which affect the safety and quality of power transmission. Lightning is one of the important factors that threaten the safe and reliable operation of transmission lines, and it is easy for transmission lines to trip and break during operation due to lightning. In order to further improve the operational reliability of 35~110kV transmission lines, it is necessary for relevant departments to fully understand the law of lightning strikes, face up to the current lightning protection status of 35~110kV transmission lines, and put forward a series of countermeasures to solve lightning protection problems according to relevant lightning protection principles, so as to ensure that the implemented lightning protection technology has high effectiveness, maintain the stability, reliability and safety of power transmission, and promote power enterprises to continuously improve economic benefits.

2. Influence of lightning on 35~110kV transmission lines
During the operation of 35~110kV transmission line, once lightning strikes the pole tower, transmission line or nearby ground, electromagnetic induction will appear, which will cause voltage in the conductor. At the same time, the current in the conductor will increase rapidly in a short time, which will turn the transmission line into high-voltage line and seriously threaten the safety of surrounding personnel.
Affected by factors such as wire properties, there will be induced overvoltage waves on both sides of the wire after lightning strike, which makes the transmission line quickly become a high-voltage line. However, if the transmission line is directly struck by lightning, a large number of lightning in the conductor will be grounded under the impedance, and the voltage will drop rapidly at this time, and the potential will rise at the part hit by lightning in the line. In addition, direct lightning overvoltage will cause electrical effects, thermal effects, etc., thus causing serious damage to transmission lines and even causing casualties. Lightning fault in line operation may also lead to lightning counterattack and lightning shielding failure. If lightning shielding failure occurs, that is, lightning bypasses the lightning conductor and the lightning rod hits the conductor, it will cause flashover of porcelain bottle string. When lightning strikes back, the problem of tripping will be caused when the poles or lightning protection facilities are directly hit by lightning. The lightning trip can be caused by counterattack or shielding failure, and the sum of the two is the total lightning trip rate of the line. The trip rate of counterattack is: 

$$\eta_1 = 0.6 H_d \times \delta \times \eta \times p_1 \text{ (40 lightning days.time/100km)}$$

The trip rate of shielding failure is: 

$$\eta_2 = 0.6 H_d \times p_o \times \eta \times p_2 \text{ (40 lightning days.time/100km)}$$

At this time, under the condition that the neutral point is directly grounded and the lightning wire is laid, the total trip rate of the line is: 

$$\eta = \eta_1 + \eta_2 = 0.6 H_d \times (\delta \times p_1 + p_o \times p_2) \text{ (40 lightning days.time/100km)}$$ \[1\]

$$\eta$$ in the above formula represents arc building rate; $$H_d$$ represents the average height of the upper conductor, and the unit is m; $$\delta$$ stands for stroke rate; $$p_o$$ represents the line shielding failure rate; $$p_1$$ represent that specific probability that the amplitude of lightning stroke current exceeds the lightning withstand level at the top of lightning stroke; $$p_2$$ represent that specific probability that the lightning current is higher than the lightning strike level.

3. Lightning protection status of 35~110kV transmission lines

50% of power system faults are transmission line faults, and lightning strike is the key cause of transmission line faults, which accounts for 70%~80% of the faults. Therefore, in order to ensure the normal and reliable operation of transmission lines, it is necessary to pay great attention to improving the lightning protection performance of transmission lines. 35~110kV transmission lines are easily disturbed by many factors in the actual operation process because of the relatively low voltage level of the lines. At present, lightning protection measures for 35~110kV transmission lines mainly include the following.

3.1. Install lightning rod

For 35~110kV transmission lines, lightning rod is the most frequently used lightning protection measure at present, which can improve the lightning protection effect of transmission lines. However, many experts at home and abroad have studied that in transmission lines, lightning rod can not provide complete lightning protection in protected areas. In addition, because lightning rod has certain lightning inducing effect, installing lightning rod may cause more lightning strikes on the line, which will make the lightning strikes on the line more serious and even cause counterattack hazards [2]. Therefore, it is necessary to improve and optimize the lightning protection status of transmission lines.

3.2. Erection of lightning arrester

At present, erecting lightning conductor is also a commonly used lightning protection strategy for transmission lines in power system, which has outstanding effect and simple application. After a large number of practical applications, it is proved that the lightning protection effect can be better if the lightning conductor is erected reasonably in the 35kV transmission line, especially to prevent the conductor from being struck by lightning directly. In addition, by erecting the lightning conductor, it can play a certain shunt role, and promote the voltage of the line insulator to be reduced, thus reducing the induced overvoltage in the conductor.
3.3. Neutral ungrounded mode
At present, the lightning protection effect of transmission lines is often achieved in 35 kV power systems by means of ungrounded neutral points. By applying this lightning protection measure, it is helpful to automatically eliminate single-line grounding faults caused by lightning strikes and avoid line tripping or short circuit. Therefore, during the erection of 35kV line, a series of grounding measures should be taken for the iron tower and reinforced concrete pole. However, if this method is applied in some areas with relatively high soil resistivity, especially in mountainous areas, because the local soil resistivity often exceeds 5000Ω·m, it is difficult to implement measures to reduce grounding resistance. If this method is blindly applied, it will consume a lot of material and financial resources, and the lightning protection effect is not ideal.

3.4. Strengthen line insulation
During the erection of 35~110kV transmission lines in some areas, some special requirements will be put forward, such as the erection of towers with large span and high height, which will increase the probability of tower lightning to a certain extent. To solve this problem, the line insulation can be further strengthened to effectively prevent lightning strikes. In actual operation, the number of insulators can be reasonably increased or the distance between conductor and ground wire of large span can be increased, so as to keep higher insulation performance of transmission line and comprehensively improve the lightning resistance level of the whole line. However, this measure also has some shortcomings. Compared with this method, it can only reduce the lightning trip rate of some lines, and the tower erected in some areas with relatively high soil resistivity will not have a good lightning protection effect. Under normal circumstances, if the insulator string needs to bear half of the impulse discharge voltage than usual, an insulator can be added, which can obviously improve the lightning resistance level of the line and reduce the probability of lightning trip failure. However, if composite insulators are used in many minefields, there will be some disadvantages. For example, the general size composite insulators keep a low lightning protection level, and the full-wave impact voltage of composite insulators in 110kV transmission lines can only withstand 500kV. Under the condition that the transmission lines keep the same voltage level, their porcelain insulators can withstand 600 kV voltage, which should be applied reasonably according to local conditions in practical application [3].

4. Lightning protection principle of 35~110kV transmission line
During the formulation of lightning protection strategy for 35~110kV transmission lines, the following principles are mainly followed: (1) During the application of lightning protection measures for transmission lines, the phenomenon of insulator flashover should be minimized to avoid stable arc caused by flashover turning into short circuit; (2) During the implementation of line lightning protection measures, attention should be paid to the fact that lightning will not hit the conductor after installing the lightning conductor, and there will be no counterattack after lightning strikes the lightning conductor or the tower top. In addition, the grounding device should be optimized reasonably in the construction to prevent counterattack. During construction, arc suppression coil can be reasonably installed to ensure that flashover will not turn into stable arc. Finally, an automatic reclosing device can be reasonably added to avoid power supply interruption.

5. Countermeasures for Lightning Protection of 35~110kV Transmission Lines

5.1. Do a good job in transmission line management
In order to effectively improve the lightning protection effect of 35~110kV transmission lines, it is necessary to dynamically monitor various environmental factors in the operation of the lines, take certain countermeasures in combination with relevant interference factors, strengthen dynamic maintenance of transmission lines and optimize management means. The line manager timely and dynamically monitors the natural factors and social factors in the area where the line is located, and strengthens the control of various factors that may have an impact on the operation of the transmission line. For example, it is
necessary to pay attention to the overall inspection of the growth of plants near the line. Once the plants have an impact on the operation of the transmission line, they should be reported in time and take effective measures to deal with them. The line manager should also conduct comprehensive investigation and in-depth analysis of the line operation, and reasonably design lightning protection measures. If the existing lightning protection technologies or devices are relatively lagging behind, it is necessary to update and maintain the lightning protection technology and equipment in time to ensure the overall lightning protection performance of the line is excellent.

5.2. Reasonable setting of lightning protection clearance

There are two main protection gap situations in 35~110kV transmission lines, i.e. rod-shaped and ring-shaped. Rod electrodes are mainly made of round steel (with a diameter of 28mm), and the number of rod electrodes is generally 2, which are opposite to each other and keep a certain distance to build a discharge gap. In the case of gap discharge, in order to prevent the end of the rod electrode from burning, two metal balls (with a diameter of 38mm) can be installed at the rod end to construct a spherical gap. However, if the voltage level is too high, the rod gap may still be burned, so the line applicable to this gap is usually lower than 220kV level. The annular protective gap is mainly made of round steel (28mm in diameter) by bending, so as to keep the two rings in a relative state to build a discharge gap. The annular protective gap can play a good role in equalizing voltage of insulator strings, and the applicable lines are generally 330 kV voltage class or 220kV voltage class. Galvanized steel is generally selected as the protective gap material, and both ends of the round steel need to be opened by about 712mm. The distance between two arc starting ends is determined according to the insulation performance of insulator string and the design of protective gap. For 35kV transmission lines, the protection gap usually keeps a U-shaped curve relationship with the operating shock breakdown voltage and wavefront time. If the gap is less than 7m, the wavefront time is usually in the range of 50~200s, so the protection gap of such lines is generally selected as 250/2500I [4]. For 110 kV transmission lines, the maximum operating overvoltage of the system is 309kV.

5.3. Improve lightning guiding device for transmission line

In order to strengthen lightning protection in 35~110 kV transmission lines, it is necessary to base on several lightning protection links to minimize the probability of lightning strikes and keep the transmission lines in stable and safe operation. Because lightning strikes can cause indirect or direct damage to transmission lines, in order to effectively prevent and control lightning strikes, it is necessary to actively apply advanced technologies to improve lightning-induced devices of transmission lines to avoid the negative impact of lightning strikes on line operation. For example, during the actual operation of 35kV transmission lines, appropriate lightning protection devices can be installed in the lines, and the other end of the devices is connected to the ground. Through the application of this protection measure, once lightning strikes the lines directly, lightning can be led to the ground under the action of lightning protection devices, so as to reduce the lightning damage of the lines [5].

6. Summary

35~110 kV transmission lines operate reliably and stably, which can provide high-quality power transmission services for people's daily life and production, and promote power enterprises to continuously improve economic benefits. Lightning strike is an important factor affecting the normal operation of transmission lines, which requires power enterprises and related technical personnel to pay close attention to the current lightning protection situation of transmission lines, correctly understand the existing problems in lightning protection work, and actively take effective measures to continuously improve the lightning protection performance of transmission lines, reduce the risk of power transmission, and maintain the stability and safety of transmission lines.
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