Discussion on Differential Lightning Protection of Transmission Line

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Abstract: By analyzing the harmfulness of lightning to transmission lines, two representative lightning protection methods are expounded, Generalized Lightning Protection method and differential Lightning Protection method, and the advantages and disadvantages of differential lightning protection for power transmission lines are emphatically demonstrated. Examples Counter lightning and circle lightning is given to prove the correctness and scientific nature of the differentiated lightning protection method. Combined with practice, the paper discusses that the method of differential lightning protection is the development direction of lightning protection for transmission lines, such as installation of lightning protection lines and grounding devices, installation of line arresters, strengthening of insulation configuration, improvement of grounding resistance and installation of various forms of lightning arresters. Through the comparison, statistics and analysis of lightning protection effect of transmission lines in recent years, it is feasible to adopt differential lightning protection on transmission lines.

1. Introduction

Lightning protection adopted in engineering practice is mainly divided into installation of lightning protection lines and grounding devices, installation of line arresters, strengthening of insulation configuration, improvement of grounding resistance, installation of various forms of lightning arresters and so on. In the academic circles, there are many lightning protection methods, such as adding tower when the distance is too large, reducing the protection angle of lightning protection line, erecting coupling ground wire and so on, but these methods are rarely used in engineering practice due to cost performance and other reasons. In these lightning protection methods,the three methods of lightning protection, such as installing ground wire, installing grounding device and improving grounding resistance, are commonly used in the erection of lines, so they are called a universal lightning protection method. However, other methods are not widely used in the erection of lines. They are generally chosen according to the actual needs, and are called differentiated lightning protection methods[3].

2. The Summary of Lightning

Lightning accident has always been an important factor affecting the reliability of power supply line. Due to the randomness and complexity of atmospheric lightning activities, there are still many unknown components in the research on lightning damage of transmission lines in the world. Lightning accidents in overhead power transmission lines are always a difficult problem for the safety of power supply. Lightning accidents account for almost half or more of all accidents on the lines[2]. Therefore, more and more attention has been paid to how to prevent lightning damage and reduce the damage to transmission lines.

At present, the lightning protection measures of power transmission line itself mainly depend on the overhead ground wire installed at the top of the tower. Because of the singularity of lightning protection measures, it cannot meet the requirements of lightning protection. The main work of its operation and maintenance is to detect and reform the grounding resistance of the tower. The

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lightning protection measures to install coupled ground wires and enhance the insulation level of the lines are restricted by certain conditions and cannot be effectively implemented. The method of increasing the number of insulators or replacing composite insulators with large creeping distance is usually used to improve the insulation of the line, and it is better to prevent the Counterattack overvoltage by lightning stroke. But the effect is not good for preventing the circle lightning, and increasing the number of insulators is limited by the insulation gap at the head of the tower and the safety distance of the conductor to the ground, so the line insulation is limited. The installation of coupled ground wire is generally applicable to the hilly or mountainous areas across large distances, which can effectively shield and protect conductors. According to the principle of equal-distance breakdown, the exposed arc section of conductors is reduced[2].However, it is affected by the strength of tower, the safety distance to the ground, the cross crossing and the transportation under the line, so it is difficult to set up the coupling ground wire for the old line. Therefore, it is very important to study the lightning protection measures which are not restricted by the conditions. The installation of line arresters lightning arresters and the reduction of tower grounding resistance are analyzed and applied synthetically. From their pertinence to prevent the form of lightning strike, we can achieve the practical and practical effect.

3. The Harm of Lightning

Power transmission line is the main frame (skeleton) of the power network, and its operation safety is the guarantee of the whole power grid safe operation. At present, the lightning damage of power transmission lines is mainly manifested by lightning tripping, breakage and so on， more forms of expression are lightning tripping. In this way, the substation with single power supply will be blackout, which will directly affect the power supply of the whole area. At the same time, the higher the voltage level, the more serious the contradiction between the safe operation of the line and the lightning hazard. If the 500kV line running at full load, when subjected to a lightning stroke, the load of the line belt cannot be transferred instantaneously, the power failure of a plurality of 220KV and the following substations can be caused, and the power failure in the whole area can be directly caused. Even lead to the breakdown of the power network accidents, expand the impact of lightning damage, resulting in greater losses. Therefore, the current design of ultra-high voltage lines first takes the lightning protection design as the top priority[4].

The main reason for line breakage caused by lightning strike is that the insulator of transmission line is broken down and the insulation degree of transmission line is reduced instantly, which results in the wire discharging the connecting hardware of ground potential and the transverse tower, or flashovering along the electrical insulator until the line is broken. In general, the lightning break occurs on the 10kV line, but there is little or no lightning break on the 66kV or above line. Therefore, the lightning protection of transmission lines should be focused on preventing lightning tripping accidents.

4. The lightning Stroke Accidents

There are four main factors related to the lightning accident of transmission line: 50% discharge voltage of line insulator, the presence of overhead ground wire, the lightning current intensity and the grounding resistance of tower. All kinds of lightning protection measures of transmission line have their pertinence. Therefore, when we design the transmission line, we should first make clear the reason of lightning tripping when we choose the lightning protection method.

4.1 The circle lightning accidents on power transmission line

The operation experience, field measurement and simulation test of the transmission line can prove that rate of circle lightning is related to The failure rate is related to the protection angle of the lightning arrester and the outer conductor, the height of the tower and the topography, geomorphology and geological conditions of the high voltage power transmission line. The rate of circle lightning of power transmission line in mountainous area is about three times as high as that

in flat ground transmission line. In the design of power transmission lines in the mountainous area, large-span and large-height difference is inevitable, which is the weak link of the lightning protection level of the line, and the lightning activity in some areas is relatively strong, so that the line of a certain section is more susceptible to a lightning stroke than other lines.

On August 7, 2016, at 22:39:06.897, the phase A of 220 kV Fuqian second line No.19 tower was struck by lightning. The relay protection of both substations took place, the switch tripped, and the fault current was cut off. 22:39:07.360 (463 milliseconds later), Stroke Line A again by Lightning. The phase A of 220 kV Fuqian second line is again struck by Lightning, the total reflection of the lightning traveling wave occurs at the switch break of Fuqian second line at Wutun substation, which results in switch break restriking of Fuqian second line at Wutun substation and Load side internal string insulator breakdown in phase A of No.18 tower .

The total length of 220kV Fuqian second line is 30.872 km. Three general methods of lightning protection are adopted: installation of ground wire, installation of grounding device and improvement of grounding resistance. After the accident, it was found that porcelain part of the Load side inner string insulator in A phase had all fallen off from the fourth piece of insulator in No.18 tower.

Fig. 1 The flashover situation of insulator in No.18 tower

The phase A external series insulators of the phase A power supply side are completely detached from the third and fourth pieces of porcelain at the beginning of the crossarm on 220 kV Fuqian second line No.19 tower.

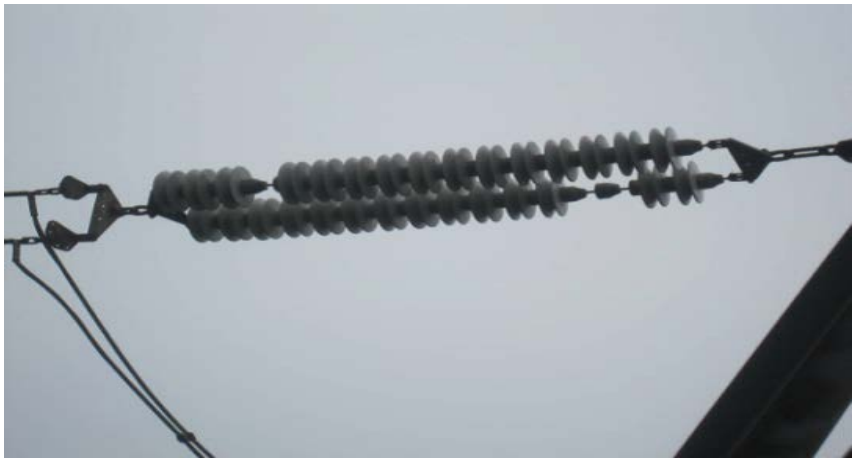

Fig. 2 The flashover situation of insulator in No.19 tower

The design resistance of Np.19 tower is 15Ω, and the measured grounding resistance is 7.86Ω and 8.19Ω respectively. The flashover analysis of insulators is caused by circle lightning. Lightning location system monitoring information is shown in Table 1.

Tab. 1 Lightning location system monitoring information on Fuqian Second line

Object range	Line: Liaoning , Fushun 220kV Fuqian second Line buffer radius (m): 3000							
Time tange	Lightning:2016-08-07 22:29:00 ～ 2016-08-07 22:49:00							
Number	Longitude	latitude	Current (kA)	Counterattack	Station number	Probe station involved in positioning	minimum distance (m)	The nearest tower
1	121.8145	39.1391	-23.8	1	3	Fushun, Xinbin, Zhuanghe, Shenyang	2,176	27～28
2	121.7761	39.1240	-29.2	1	8	Chaoyang Yingkou Fushun Dandong Nanfen Shenyang	281	18～19

4.2 The example of Power Transmission Line counterattack accident

The lightning current flows through the tower body and the earthing body when in lightning strike rod, tower top or lightning conductor, which increases the potential of the tower and generates the inductive overvoltage on the phase conductor. If the potential difference between tower body potential and phase conductor inductive overvoltage is higher than the voltage of insulation flashover of high voltage transmission line, that is, Uj > U50%, there will be flashover between conductor and tower. This kind of flashover is called counter flashover.

On June 4, 2012, there was thunderstorm in Fushun area, 17:16:12 220kV Beilin second line tripping (successful reclosing) and 17:16:18 220kV Beilin second line tripping again (successful reclosing).The location of the lightning discharge is quickly found through the lightning location system ..The top of the No.23 tower on 220kV Beilin second line is thundered, which results in the lightning overvoltage of phase C, lightning struck the top of the No.36 tower the on 220kV Beilin second line, causing a counterattack lightning overvoltage in phase B.

Fig. 3 line corridor thunderbolt displayed by Lightning Positioning system

Fig. 4 The porcelain bottle discharge of phase C on No. 23 tower by Counter lightning

Fig. 5 The discharge trace of phase B on No.36 tower by Counter lightning

5. Differential Lightning Protection Measures

It is clear from the above two examples that the lightning tripping rate is very high with the universal lightning protection method used in the transmission line. We should take corresponding lightning protection measures for different sections and different geographical position of tower, that is to say, adopt differential lightning protection. At present, the line in Fushun area adopts differentiated lightning protection measures as follows.

5.1 Strengthening the Insulation level of Transmission Lines

The insulation level of transmission line is directly proportional to the lightning resistance level. It is an important factor to improve the lightning resistance level to strengthen the detection of zero value insulator and ensure the sufficient insulation strength of transmission line. For example, the method of increasing the number of insulators or replacing composite insulators with large creeping distance is usually used to improve the insulation of the line. It is better to prevent the overvoltage at the top of the lightning stroke tower, but it is less effective to prevent the circle lightning, and increasing the number of insulators is limited by the insulation gap at the head of the tower and the safety distance of the conductor to the ground, so the enhancement of the line insulation is also limited.

5.2 Installation of controllable discharge lightning rod

Controllable discharge lightning arrester is the latest research result obtained by Wuhan High Voltage Research Institute of China Power Grid after long term lightning protection research and a large number of high voltage tests. It is designed on the basis of slowly changing small current upward to the form of lightning flashover discharge to release the thundercloud charge and to avoid the strong downlink lightning flashover hazard. Through thousands of high voltage discharge tests, it is proved that it is an upward lightning, which has the characteristics of high reliability, wide

range and no influence of the protection height. It is considered by experts that the principle is correct, the design idea is novel, and the protection performance is good. It is a kind of direct lightning protection device with wide application prospect. In recent years, 35 sets of controllable discharge lightning rods have been installed on the 220kV Zhongyong Line (a total of 103 base towers) of Fushun Power supply Company. Judging from the number of lightning accidents in the past five years, there has been an obvious downward trend. In the past five years, there were 2 accidents caused by lightning (It used to be an average of 4 cases per year.). The lightning protection effect is very obvious and can be popularized in the future. The lightning rod installed on the tower is as shown in Figure 6.

Fig. 6 Controlled discharge Lightning Rod installed on Tower

5.3 Reducing grounding resistance of tower

The grounding resistance of the transmission line is inversely proportional to the lightning resistance level. According to the soil resistivity of each base tower, the grounding resistance of the tower is reduced as far as possible, which is the basis of improving the lightning resistance level of the high-voltage transmission line and is the most economical and effective means. It is important to note that reducing the grounding resistance is not effective in preventing circle lightning.

5.4 Additional coupled ground wire

According to the regulation, coupling ground wire can be added in the area where lightning activity is strong and the tower and section where lightning strike failure occurs frequently. The coupled ground wire can increase the coupling coefficient between the lightning arrester and the conductor, and make the lightning flowing through the tower flow to both sides, thus improving the lightning resistance level of the transmission line. The installation of coupled ground wire is generally applicable to the hilly or mountainous areas across large distances, which can effectively shield and protect conductors. According to the principle of constant distance breakdown, this reduces the exposed arc segment of the conductor. However, it is affected by the strength of tower, safety distance to ground, cross crossing and transportation under the line, so it is not easy to put up coupling ground wire for the old line.

5.5 Proper use of lightning arrester for power transmission line

Because of the installation of the arrester, once the potential difference between the tower and the conductor exceeds the action voltage of the arrester, the arrester will be added to the shunt to ensure that the insulator does not flashover. According to the actual operating experience, the lightning arrester can be selectively installed on the high-voltage power transmission line which is more frequent in the lightning tripping, and the lightning protection effect can be achieved. At present, a certain number of power transmission line lightning arresters have been used throughout the country, the operation is better, and the lightning arrester on the line is shown in Figure 7.

Fig. 7 The lightning arrester on the line

In 2014, 21 groups and 19 groups of line arresters (with series gap) were separately installed on the middle line of 220kV Liuzhong line (a total of 78 base towers) and Liaogong line (a total of 85 base towers) in Fushun Power supply Company. According to the number of lightning accidents in the past three years, there has been an obvious downward trend. In the past three years, there were 2 lightning accidents (It used to be an average of 4 cases per year.), and the effect of lightning protection was very remarkable.

6. Conclusion

To sum up, Fushun Power supply Company adopts the method of differential lightning protection to power transmission line, which effectively reduces the accident rate of lightning damage. For some special geology such as rock, it is difficult to reduce the grounding resistance of tower. The most effective measure to reduce trip-out rate by counter lightning is to install lightning arrester. It is difficult to reduce the protection angle of lightning protection for the running lines, and the most effective way to reduce trip-out rate by circle lightning is to install the controllable discharge lightning arrester.

In a word, in order to prevent and reduce the incidence of lightning damage, In view of the power transmission lines in operation, we should consider the intensity of lightning activity, the characteristics of topography and geomorphology and the soil resistivity in the area passing through power transmission line, and then combines the operation experience of the transmission line and the operation mode of the system, etc. It is effective to adopt differential lightning protection measures on power transmission lines.

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