Study on Lightning Overvotage of 35kV Transmission Line in Daqing Oilfield

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Abstract

The lightning overvoltage has seriously affected the safe operation of daqing oilfield. In this paper, using ATP electromagnetic transient calculation program, simulated 35kV power transmission line being struck by lightning, build a model of the line in lightning condition. Through the simulation analysis revealed the influencing factors of lightning withstand level and lightning trip-out rate. At the same time, the transmission line lightning performance measures were studied.

Keywords

Daqing oilfield; 35kV transmission Line; Lightning overvoltage; Lightning protection.

1. Introduction

Daqing is located on Songliao basin, in this area, thunderstorm day for an average year is about 30 days, it belongs to medium lightning area, the power company of Daqing oil field taking the responsibility of maintaining the 35-110kV transmission line, its total length is 3289.04 km, whether the transmission line is running safely is related to the production of all the oil field directly, besed on the statistic of accident in the past years, the accident which caused by lightning strike to grid occupies the main position. Lighting overvoltage have seriously impacted the safe operation of Daqing oil field and caused a great loss to the crude production of Daqing oil field. It is important for the oil field and chemical production to improve the protection of lightning overvoltage of grid.

As far as circumstance allow, the lightning protection of transmission line should build fourfold line of defence[1-2], namely let the transmission line do not hit by lightning directly, line insulation flashover do not occurre after lightning, do not establish stable power frequency arc after flashing over and do not cut the power supply after building power frequency arc. When the lightning protection measures of transmission line is making, some aspect of the transmission line should be considered, such as the importance degree, the system operation mode, the intensity of lightning activity of the area which pass by the transmission line, the feature of landfall and the degree level of soil resistance rate. Adopting suitable protection measures rely on the operating experience of local transmission line and the comparison result of technology and economic.

According to the current situation of the lightning strike accident of Daqing oil field 35kV transmission line, This paper obtain the lightning withstand level of transmission line, the lightning trip-out rate and the relationship between the related parameters and them, and it guides the making and implementation of the lightning overvoltage protection measures of Daqing oil field.

2. The Lightning and Tripping Accident Situation of Daqing Oil Field 35kV Power Transmission Lines

Statistics shows that, the average value of the lightning trip-out rate of Daqing oil field 35kV power transmission lines was 0.8295 times/(100km•40Thunder day) higher than the theoretical value 0.352 times /(100km•40Thunder day) while the average value of the coincidence success rate of reclosure was 38% much less than the normal range of the coincidence success rate of reclosure of 35kV power transmission lines(about 50%~80%). Lightning stroke have caused wire breakage and insulator damage for many times. High lightning trip-out rate, low the coincidence success rate of reclosure

and the phenomenon of line breakage frequently and insulator damage caused by lightning absolutely affect the reliability of Daqing grid.

3. Fault Analysis and Lightning Protection Measures

3.1 The establishment of simulation model

The widely used lightning current waveform is 2.6/50μs obligue wave to make simulation at present, the channel waves Impedance Z0 was 300W. Use single-wave impedance model because of the tower of Daqing oil field 35kV power transmission lines was not very high, using voltage controlled switch to simulate insulator string.

ATP contains many standard components, including the model of transmission line namely LCC model [3]. The simulation is completed by using the basic form of BERGERON model, the software Generated related circuit parameters directly after inputing corresponding parameters such as span distance between poles, soil resistivity, Wire Properties and wire distribution. The typical model of 35kV line in this area is shown in figure 1.

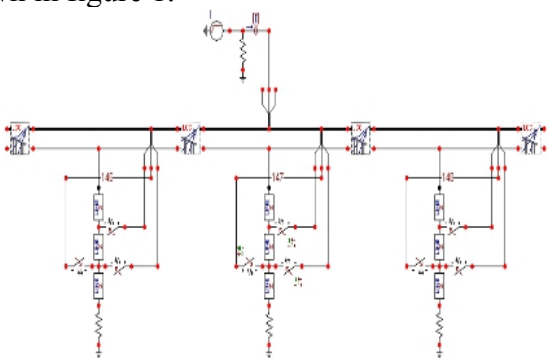

Figure 1. Typical simulation model of 35kV line.

3.2 Discrimination for lightning accidents of Daqing 35kV line

When the distance between Lightning Strike Point and transmission line S>65, the max value of inductive thunder overvoltage Ug can calculate according to the following formula:

$$U_g = 25\frac{I_L \times h_d}{S} \tag{1}$$

Then the lightning Withstand Level of inductive thunder accident IL (lightning current amplitude kA) is derived:

$$I_L \approx \frac{U_g \times S}{25h_d} \tag{2}$$

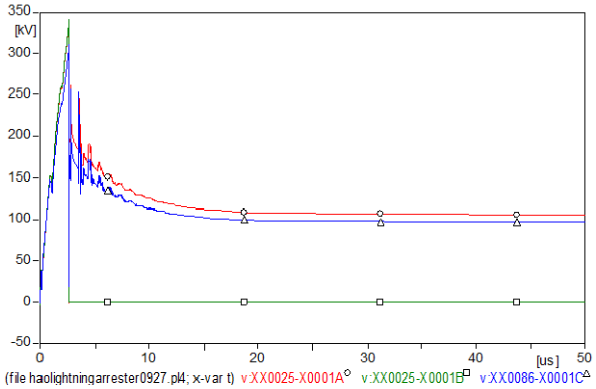

Figure 2. The voltage waveform of composite insulator.

In which Ug is inductive strike overvoltage (kV), hd is the average hanging height of wire(m) and S is the distance between Lightning Strike Point and transmission line(m).

The value of XP-7 porcelain insulator is 384.5 kV and the value of composite insulator is 341.65kV. When the lightning Withstand Level which is got by simulated analysis lower than the level which is got by inductive strike calculate, it is direct lightning strike accident, otherwise it is induction strike accident[4].

3.3 Cause analysis and lightning protection measures of lightning trip of Daqing 35kV line

1). The influence of impulse grounding resistance on lightning withstand level

Take 35kV Longgu line 147# tower for example, the lightning withstand level changes by changing the value of mpulse grounding resistance of the tower are shown in Table 1. As a result, the smaller the value of impulse grounding resistance of the tower, the higher lightning withstand level. When the value blew 15Ω, the lightning withstand level significantly increases with the impulse grounding resistance decreases and when the value above 15Ω, the lightning withstand level slowly decreases with the impulse grounding resistance increases.

Base on the rules, the lightning withstand level of 35kv transmission line which has lightning shield wire should not less than 20~30kA by this time, the value of the corresponding ground resistance below 15Ω [5]. Therefore, as for Daqing 35kV transmission line, power frequency ground resistance should keep the value below 15Ω to meet the rules.

Table 1 The impact of ground lightning withstand level of resistance

impulse grounding resistance	7	10	15	20	25	30
Lightning withstand level(KA)	48.4	42.2	33.1	26	24.2	22.4

2). The influence of installing lightning arrester on lightning withstand level

Take 35kV Longgu line 56#,57# and 58# tower, for example, the total length of transmission line is 0.442km, condoctor type is LGJ-120, power frequency ground resistance is 23.74Ω. 35kV Longgu line tripped, instantaneous trip protection acted and automatic reclosing succeed on 15:03 10 August 2013. At the moment, the weather was thunderstorm, the A and C phase insulator of 57#tower broke down. Use ATP to simulate, when lightning current is 24.5kA, the waveform of current and the voltage of composite insulator are shown in Figure 2. Based on simulation, we have found the lightning withstand level is 24kA when the three phase of 57# tower do not install lightning arrester.

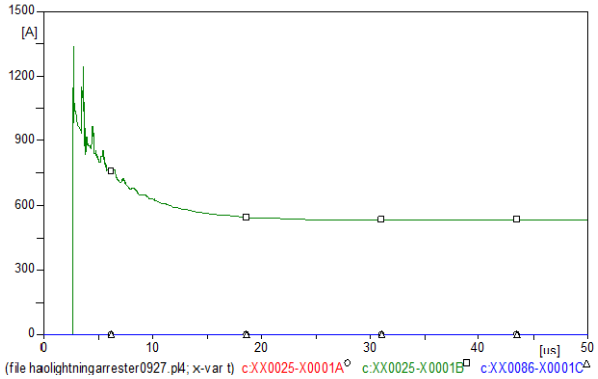

Figure 3. The current waveform of composite insultor

If we install line arrester on the B phase of insulator string which occur flashover firstly, change the altitude of lightning current frequently, when the current is 33kA, the A phase flashover, therefore the lightning withstand level increase from 24kA to 32.5kA after installing the lightning shield wire on the B phase of insulator string.

If we install line arrester on the A and B phase at the same time, the lightning withstand level of 57# tower is 45.5kA, however, the B phase of insulator string of 56# tower and 58# tower both flashover and the flashover of the B phase of insulator string of 56# tower and 58# tower had occurred when the lightning current reached 40kA.

If we install line arrester on the upper-phase, the bottom phase of B phase flashover when the current is 32.5kA, therefore we should install line arrester on the bottom phase of single line side.

3). The influence of number and type of insulator

Table 2. The lightning trip-out rate of different number and type of insulator

The number and type of insulator	The trip-out rate caused by lightning strike to tower[time/(100km-year)]	Shielding failure trip-out rate [time/(100km-year)]	lightning trip-out rate of line [time/(100km-year)]
3 X XP-7	0.52103	0.16987	0.69987
4 X XP-7	0.35214	0.13568	0.47996
FXB-35/70	0.51276	0.17351	0.69021

each phase hung 3 XP-7 insulators and hung 4 XP-7 insulators after reinforcing insulation. Take Songzhao line 96# tower, for example, the value of impulse grounding resistance of the tower is 9.17, the hanging height of single lightning shield wire is 17.95m, the sag of lightning shield wire is 0.73m, so the average height of lightning shield wire is 17.46m. Use LGJ-120 wire, the radii of wire is 7.6mm, the size of pole head is the size of single pole in electricity-4610. Caculate the lightning trip-out rate of thunderstorm day (take 30.5) of Daqing are shown in table 2.

Therefore, when the thunderstorm day of Daqing oil field is 30.5, after reinforcing insulation, the trip-out rate caused by lightning strike to tower decreased 33.43%, shielding failure trip-out rate decreased 24.12% and the lightning trip-out rate of transmission line decreased 31.10%. Consequently, the lightning trip-out rate decrease significantly after reinforcing insulation.

According to Daqing oil field to use two types of insulator and they are XP-7 porcelain insulator and FXB-35/70 composite insulator, when the thunderstorm day of Daqing oil field is 30.5, take lightning Songzhao line 96# Tower, for example, the result got by simulating and calculating is that the lightning withstand level of composite insulator string is 9% lower than porcelain insulator string, the trip-out rate caused by lightning strike to tower of 4 porcelain insulator strings is 31.7% lower than composite insulator string, this value of the shieding failure trip-out rate and the lightning trip-out rate of transmission line are 22.19% and 29.34%.

4). The influence of different tower model on the lightning overvoltages of 35kV transmission line

Take long V-2 line, for example, compare the changing 32 Tower model as shown in table 3.

According to table 3, we known that the lightning withstand level which has adopt different transmission line of Tower under the same fault and the same type of wire arrangement mode can improve obviously, the lightning withstand level from highest to lowest are A model upward-formed double pole, upward-formed straight iron Tower and upward-formed straight ferroconcrete single pole. In addition, when the nominal height of the same Tower model changes, as the nominal height increases, the lightning withstand level of transmission line decreases accordingly.

When the 35kV transmission line adopt the 110kV Tower and the number of insulator slice don't change, the strike-back lightning withstand level of transmission line would decrease, but the degree of level lost not large. Therefore 35kV transmission line which adopt 110kV Tower is not generally recommended.

Table 2. The insulation level comparison of different long v-2 line tower model

The model of Tower	35S2318	35S2321	60NA3018	60NA3021	35ZS1	35ZS1
Nominal height （m）	11.6	14.5	10.6	13.7	15.2	18.3
Lightning withstand level （kA）	82.3	74.2	151.8	142	96.1	86.7

4. Conclusion

According to the simulation model of Daqing oil field 35kV transmission line, calculate the lightning withstand level and lightning trip-out rate of typical transmission line which adopt lightning protection measures before and after and through comparative analysis, we obtain the adaptive lightning protection measure of Daqing oil field 35kV transmission line:

1).Span lightning conductor for whole line;

2).Reinforce insulation of transmission line, increase the number of insulator from 3 to 4

3).Adopt adaptive tower model: Upward-formed straight iron Tower is recommended and 35kV transmission line which adopt 110kV Tower is not generally recommended.

4).Decrease soil resistivity and tower grounding resistance: The soil resistivity of Daqing oil field is less than 100Ω•m basicly, but the soil resistivity of some areas is between 100Ω•m and 500Ω•m, it is best to control the impulse grounding resistance in lightning protection less than 15Ω.

5). Install line arrester

The lightning protection scheme which has install line arrester should be applied in the transmission line section which has small line span, relatively concentrated lightning accident areas and is difficult to adopt other lightning protection measures. For the transmission line which has important production load, require high demand for power quality and do not occur lightning strike accident, in order to prevention, installing line arrester is recommended. For the Tower which is easy to be stroke, installing line arrester under the side of single line should be considered primarily. The line arrester should adopt external air gap transmission line MOA primarily then some Tower which have hard installation conditions should adopt external insulation gap transmission line MOA to reduce the per unit maintenance workload of running transmission line.

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