Modeling and Technology application for Transmission Line Fault

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***Abstract*—Due to its wide geographical distribution, many points and long lines, the transmission line is affected by humanities, environment, geology and climate. Faults in the operation of transmission lines have both ontologies and external aspects. It mainly includes ice coating, dancing, lightning, tree damage, theft, bird damage, pollution flash and external damage. The data analysis of the internal and external causes of the failure of the integrated transmission line summarizes the fault law. In this paper, based on the time distribution of transmission line faults in different seasons, combined with the statistical application of design modeling technology, the fault analysis model of transmission line is established. The model can effectively guide the anti-accident struggle, strengthen the fault prevention and reduce the trip rate of the transmission line.**

Keywords—Transmission line, Fault model, Technical application

I INTRODUCTION

The transmission line is a basic component of the power grid, with a wide distribution range and long line characteristics. Transmission line operation is affected by many factors such as geographical environment, climate and human environment. Different types of accidents occur every year, causing many types of failures in the line.

Fault statistics of zibo power supply company displays the probability of the line suffering from human factors and external forces is the highest, in In the fault of the entire power transmission line, during the period from 2016 to 2017. Secondly, it is caused by lightning, mountain fire, bird damage, external force and other reasons. They all have a distinct seasonal character in the various faults of the line. There is a seasonal and monthly “time domain” relationship in the occurrence of faults and there is a performance time domain “protection zone relaxation spectrum” relationship in one year. This paper analyzes the human factors and the influencing factors and data of the transmission line, and establishes the fault model of the transmission line with different "time domain" fault characteristics and types. Therefore, it is of great significance to formulate a more targeted fault prevention and control measures, enhance the ability of the power grid to defend against external forces and various disasters, and improve the safe operation level of the power grid lines.

II STATISTICS OF TRANSMISSION LINE FAULTS

A. Annual Fault Trip Statistics of Transmission Lines

251 lines of 35-220KV transmission line directly under the State Grid Zibo Power Supply Company and total length is 2633 kilometers. Line trip statistics and Trip ratio statistics of transmission lines from 2016 to 2017 are as follows:

1) Transmission line trip statistics :

The number of trips in the year is 21 and 19 times respectively [1-2]. Biennial total data displays external force damage 19 times, lightning strike 11 times, pollution flash 3 times The reason is not clear flashover 3 times, construction once, equipment failure, wind deviation and bird damage are all 3 times. Among them, the external force was destroyed 19 times (the tower crane in the protection zone 5 times, the large freight dump truck 10 times, the homemade crane 4 times)

2) Trip ratio statistics of transmission lines:

A total of 40 unscheduled outages or coincidences occurred successfully. The trip ratio of the transmission line is as follows. External force damage 19 times accounted for 47.5%; Lightning strike 11 times, accounting for 27.5%; Scattered flash, unknown cause flashover 3 times, accounting for 15%; Construction, equipment failure, wind deviation, and bird damage are all 3 times, each accounting for 2.5%.

3) Transmission line voltage level fault statistics

The 220KV transmission line has failed 7 times, accounting for 25%; The 110KV transmission line has failed 23 times, accounting for 57.5%; The 35KV transmission line has failed 10 times, accounting for 17.5%.

B. Seasonal Fault Trip Statistics of Transmission Lines

According to the season classification, 14 fault trips of Zibo City transmission lines from 2016 to 2017 are shown in the following table.：

TABLE 1 STATISTICAL TABLE OF SEASONAL FAULT TRIPS OF TRANSMISSION LINES IN ZIBO CITY IN 2016

Quarter	I quarter	II quarter	III quarter	IV quarter	annual
Number of failures	0	4	7	5	14

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Table 2 Statistical Table of Seasonal Fault Trips of Transmission Lines in Zibo City in 2017

Quarter	I quarter	II quarter	III quarter	IV quarter	annual
Number of failures	2	2	5	2	11

III CONSTRUCTION OF SEASONAL FAULT MODEL FOR TRANSMISSION LINES

A Establishment Of A Coordinate System

The coordinate system of the seasonal fault model of the transmission line is established as follows:

1) Seasonal transmission line fault data statistical method : According to the principle of Cartesian coordinate system [3], draw the parallel lines of the vertical and horizontal groups, and equalize the distances between adjacent parallel lines to form the intersection of two sets of parallel lines, namely the grid points.

2) Select the beginning of the year as the coordinate origin. The horizontal and vertical lines of the grid point are the horizontal axis ox and the vertical axis oy of the coordinate axes, respectively. Select the length of the square to do the statistical unit length. The point on the coordinate plane is the fault of the transmission line. External force damage, lightning strikes, mountain fires, and bird damages are represented by fault points.

3) Establish a seasonal fault coordinate system, the X-axis represents 2016 data, and the Y-axis represents 2017 data. Forming the coverage area of fault four seasons as an annual statistical analysis of transmission line faults [4].

B Establishment Of The Fourth Quarter Failure Model

Make a four-season coordinate chart as shown in Fig 1. the X-axis represents 2016 data, and the Y-axis represents 2017 data. The coordinates of the fourth quarter are as follows:

I quarter:(0,2) (X,Y); II quarter:(4,0) (X,Y)

III quarter:(7,5) (X,Y); IV quarter:(4,3) (X,Y)

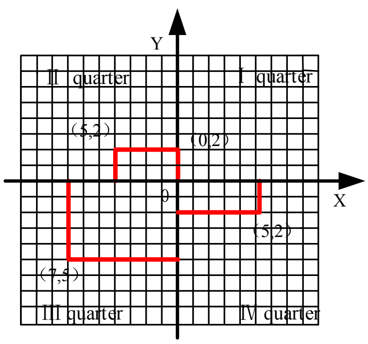

Fig. 1. 2016~2017 Fault statistics four seasons chart

The four-season coordinate map is established, and the seasonal fault statistics distributed in the four regions are obtained, whereby the intersection point where the fault is located can be found, and the area is calculated by the vertical and horizontal coordinate points and the number of grids (the setting is 1S per grid). From this, the area law of the faults throughout the year can be counted.

The calculation formula of the area is: $S = X * Y$, X represents the horizontal coordinate value, and Y represents the vertical coordinate value. The four quarters represent four quadrants and the areas of the four quadrants are calculated separately.

$$S = X * Y \tag{1}$$

This results in the fault area in the 2016 and 2017 season four-year chart: 2S for the I quarter, 8S for the second quarter, 35S for the Ⅲ quarter, and 10S for the Ⅳ quarter.

Let S denote the area of the polygon, N denote the number of grid points in the polygon, and L denote the number of grid points on the polygon side.

Then, the fault coordinate graphs of I quarter, II quarter, III quarter, and IV quarter are respectively established, and then the calculation formula of the model solution is found. The data of the solution is statistically analyzed through the table, and the relationship between them is explored [5].

The four-quarter transmission line fault exploded views are as follows:

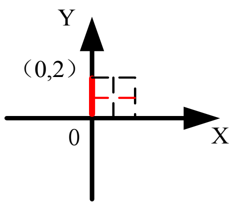

Fig. 2. 2016~2017 Fault I quarter exploded view

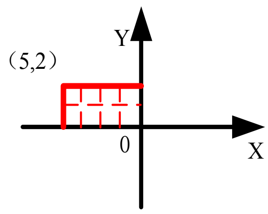

Fig. 3. 2016~2017 Fault II quarter exploded view

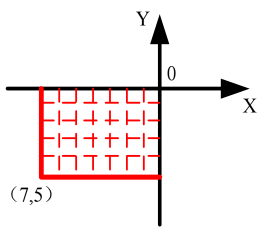

Fig. 4. 2016~2017 Fault III quarter exploded view

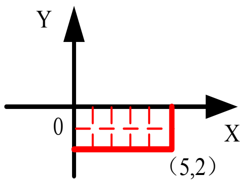

Fig. 5. 2016~2017 Fault Ⅳ quarter exploded view

C Establish Fault Correlation System

TABLE 3 S, N AND L ASSOCIATED DATA TABLE

Graphics	S	N	L	S-N	L/2
Ⅰ Quarter	0	0	1	0	0.5
Ⅱ Quarter	8	8	3	0	1.5
Ⅲ Quarter	35	22	24	13	12
Ⅳ Quarter	10	12	5	2	2.5

In the table: S - area; N - grid number; L - the number of grid points.

In the fault tables of the above quarters, the fault data can be seen from the fault data between S, N and L [6]. It can be seen from the more prominent data in the table that as the value of S increases, the value of the fault area increases, and the difference between the surface and the point (compared to it) also increases. In other columns, including the S-N column, the values vary with increasing L. Divide by L to get the last column of data.

Statistics on the fault model data can be used to obtain the relationship of the Pick theorem.

$$S=N+L/2-1 \tag{2}$$

It can be seen from the graph that the edges of the polygons are often not at the grid points. This needs to be turned into a lattice polygon of similar area by the method of clipping, and then calculated by using the Pick formula.

In the coordinate system, the polygon area S can be calculated in two ways: one is solved directly by S=X*Y, indicating that no fault occurs in X*Y; another way to calculate the area S is to solve it by the X and Y clipping methods.

If the failure of the year is calculated and analyzed on a quarterly basis, the data between the area, point and line of the polygon is visible, and the number of grid points in which the fault data occurs is regularly ruled.

IV MODEL APPLICATION CASES

A Transmission Lline Fault Statistics

1) quarterly statistics

Transmission line fault in 2016 and 2017 are shown in the above chart, which shows the number of major failures in 2016 and 2017, with the highest number in the third quarter, followed by the second, fourth and first quarters.

The third quarter results were (7, 5) (X, Y), indicating that there were seven failures in the third quarter of 2016 and five in the third quarter of 2017.The area occupied by the third quarter was 35S.The third quarter is the season of increasing investment in line protection. Facing various factors, such as crane, lightning strike, tree damage, bird damage and so on, the number of fault spots is the highest.

It can be seen from the analysis of the third quarter that the third quarter is the peak season of the thunderstorm season and external damage in summer. The peak of the line is in summer, and various operating parameters such as wire current carrying capacity and temperature are in the maximum running sag, and within the minimum distance between the wire and the ground and various crossovers. Considering the running stress, sag, offset, wind deflection and other factors of the wire and ground wire, it is concluded that the fault in the third quarter is mainly a lightning accident.

From the time analysis, the third quarter is the time zone of the summer and autumn, the longest white line, and the longest line, the line is most associated with humanities, environment, geology and climate.

2) Monthly statistics

According to the results of the seasonal analysis, it can be similarly subdivided into months. It can be seen from the monthly statistics table that in the points, grids and polygons of 2016 and 2017: external force destruction (11,10), lightning strike (6,3), pollution flash (1,2), user failure reason (2,2), bird damage and wind bias (1, 2).The statistics from January to December of 2016 and 2017 and the coordinates of points, grids and polygons are made separately.

According to the transmission line monthly fault statistics during in the period 2016 to 2017 are as follows

TABLE 4 TRANSMISSION LINE MONTHLY FAULT STATISTICS IN 2016

Month / accident	*Month statistics*	1	2	3	4	5	6	7	8	9	10
Cause and classification of accidents	*Lightning strike*				1		1		4		
	Pollution flash										
	Bird damage (Gale)										
	User failure (unknown reason)							1	1		
	External force damage (construction, mobile vehicles, tower cranes)			1	1	1	2	2		2	1
Total of months				1	1	1	3	3	5	2	1

TABLE 5 TRANSMISSION LINE MONTHLY FAULT STATISTICS IN 2017

Month / accident	*Month statistics*	1	2	3	4	5	6	7	8	9	10
	Lightning strike						1	1	1		
	Pollution flash		2								

Cause and classification of accidents	***Bird damage (Gale)***							1	1		
	User failure (unknown reason)										1
	External force damage (construction, mobile vehicles, tower cranes)	1				1	1	2	2	2	1
Total of months		1	2			1	2	4	4	2	2

3) Accident classification statistics

According to the line trip statistics for 2016 and 2017, the annual number of trips is 21 and 19 respectively. The total data of the two years showed that the external force was destroyed 19 times, the lightning strike was 11 times, the pollution flashed 3 times, the cause was unknown for 3 times, and the construction was performed once. The equipment failure, wind deviation and bird damage were 3 times each.

Among them, the external force was destroyed 19 times (the tower crane in the protection zone was 5 times, the large freight dump truck 10 times, and the homemade crane 4 times).

Draw the accident classification coordinate system, that is, the classification coordinate map and use X to represent 2016 data and Y to represent 2017 data.

The coordinates are displayed as follows: external force damage (11,10), lightning strike (6,3), user failure (2,2), pollution flashover (1,2), bird damage and wind deviation (1,2).

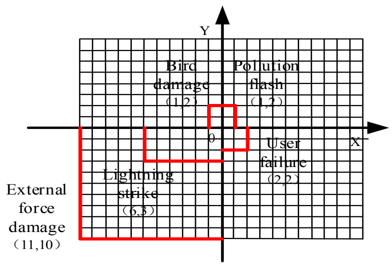

Fig. 6. 2016~2017 fault classification statistical graph

B Establishment of S, N, and L Data Associated With Transmission Line Faults

The establishment of the associated S, N, and L data tables for accident classification is shown in the following table.

TABLE 5 S, N, L ASSOCIATED DATA TABLE

Graphics	S	N	L	S-N	L/2
Pollution flash	2	0.5	0	1.5	0
User failure	4	2	1	2	0.5
Bird damage (Gale)	2	0.5	0	1.5	0
Lightning strike	18	18	10	0	5
External force damage	110	109	90	2	45

In the table: S - area; N - grid number; L - grid points.

It can be seen from the classification fault tables that S, N, and L are not necessarily related to the fault data; however, the more prominent data in the table can be found: S increases greatly, and the number of areas, the difference between face and point (compared to say) is very small. Other columns, including S-N, change as L increases. The last column of data can be obtained by using 2 to remove L.

The relationship of classification faults is searchable. According to the Pick theorem S-N = L/2, that is, S = N+ L/2, the type and nature of the fault can be found simply and clearly. In the graph, the external force damage S is 110, N is 80, L is 40; S is 18 when lightning strikes, N is 18, L is 10. Surprisingly from the chart, no matter the area and the number of grids, the number of grid points has a difference. Using model mathematical classification to analyze faults, it is convenient for us to develop measures to provide data reference for classification prevention.

V PREVENTION MEASURES

A Measures To Prevent External Damage

Visible from the coordinates of the points, grids and polygons of the 2016 and 2017 data charts. From July to September, the season with the highest failure rate, the correlation data between the classifications S, N, and L is the most.

Mobile cranes, building tower cranes, and various self-made earth cranes in the data association are the main causes of accidents. Another factor that occurs in the above season is that the various application meteorological conditions and parameters of the line are in the upper limit "time domain" period. Due to the longest alternating white day and the thunderstorm season, the transmission line includes various distances and safety distances such as wire-to-ground, such as thunderstorm season, wire current carrying capacity, and discharge parameters. These factors and parameters are also in the maximum "relaxation spectrum", that is, the minimum distance "domain segment".

The following is an example analysis based on the subject and object constituting the fault, such as a fault caused by a mobile vehicle, the main body of the fault is the driver, and the object is the line. From July to September, the human body clock is in the summer and autumn seasons, and the time difference between white and white is large, people's energy and physical fitness are in the maximum consumption period and adjustment period, and people are prone to sleep. In addition to external mosquitoes, bites and high temperatures, drivers are prone to excessive consumption, fatigue and central nervous system numbness, mental retardation and so on. The parameters such as current carrying capacity, wet flash discharge, and various distances and safety distances such as line-to-ground are in the minimum operating period.

For the characteristics of wide line coverage, many points, and long lines, therefore, we must clarify our responsibilities and actively collect and analyze information, and do a good job in the promotion of crane drivers and the installation of various safety warnings, and actively use information interaction tips. Taking measures such as inspection, supervision, limit, height limit, safety notice, and responsibility book. And carry out the "external committee" three-level line of protection activities, add visual video management to the dangerous points of individual protection areas, illegal buildings, private pulls, etc. Taking measures such as the government, police and enterprises [7].

B Measures To Prevent Lightning Strike

July to September is the most frequent season for lightning strikes. Most of the lightning strikes of type S, N, and L are second only to the incidence of external damage. The main reason is that Zibo Power Supply Company is located in the Luzhong Mountain Area. The terrain is mainly plains and hills, and it is a gentle slope from north to south. According to the analysis of the “region” of lightning strikes, the “thunder” in the southern and southeastern mountainous areas accounts for more than 80%; according to the voltage level analysis [8], the number of lightning strikes of 35 kV and 110 kV lines is far greater than the number of lightning strikes of 220kV.

To prevent lightning strikes, it is necessary to carry out data statistics according to the classification of accidents, and then carry out targeted lightning protection to improve the grounding resistance of the tower; and according to the "four lines of defense", based on two technical measures: guidance, blockage and prevention. Line arrester, negative angle protection, grounding conductive resistance reduction module; finally, lightning monitoring and drawing lightning distribution map.

1) Use the ground wire of the line and the natural grounding of the OPGW.

2) External grounding device.

3) Vertical deep buried epitaxial grounding.

4) Appropriately increase and increase the cross section of the grounding electrode material.

5) Use modules and new materials that increase the grounding resistivity.

C Measures To Prevent Pollution Flash

The geographical location of Zibo Power Supply Company is a heavy industrial area integrating metallurgy, chemical industry, building materials and thermal power generation, and also a serious environmental treatment area; 90% of the transmission lines in its jurisdiction are located in E-class sewage areas.

In accordance with the requirements of the new division standard of the State Grid Corporation, in accordance with the principle of “margin” for insulation, the “soil flash” prevention and control is carried out.

1) Establish an anti-pollution flash account.

2) Update the dynamic pollution map in time.

3) Actively promote the application of composite insulators and RTV long-lasting coatings.

4) Conduct online and offline monitoring.

5) Conducting insulation tracking and rotation system for key pollution sections.

VI CONCLUSION

The construction and application of the fault data model of the transmission line is of great significance for guiding the transmission line to have a purposeful and targeted anti-accident struggle. Through the data of seasons and accident types, a mathematical model is established to implement the tracking management and data analysis of the previous transmission line faults, thus forming a fault-data modeling-analysis-prevention-solving fault handling scheme. This is conducive to scientifically guiding the anti-accident struggle, carrying out failure analysis, and formulating accident prevention and control measures; it can eliminate the weak links and the lack of pertinence in the anti-accident struggle. Through the establishment of the fault data model, using its method analysis and formulating countermeasures, it has realized the "precautionary medicine" for fault prevention and control; it can solve various fault problems with less effort, reduce the trip rate, and lay a solid foundation for the safe operation of the power grid. To achieve "controllable, controlled, and controllable" power grid.

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