

The Comprehensive Evaluation Algorithm with Fault Location in HVDC Transmission Line

Zhenquan Sun¹, Qiyue Huang², Changjin Hu¹, Xiaoning Kang², Hao Wang², Xuze Zhang², Chong Zhao², Yali Ma³

¹Shaanxi Regional Electric Power Group Co., Ltd., Xi'an, China

²Shaanxi Key Laboratory of Smart Grid (Xi'an Jiaotong University), Xi'an Jiaotong University, Xi'an, China

³Tianjin Power Transmission and Transformation Engineering Company, Tianjin, China

Email: 839539199@qq.com

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Abstract

China has a vast territory with a great demand for electricity. However, the resources are in reverse distribution in the country. Therefore, high voltage direct current transmission has great practical significance and been widely used. However, traditional fault location methods have a lot of problems in engineering application for the length of transmission line and the complexity of the terrain. This paper proposes a comprehensive evaluation algorithm based on the travelling wave method and time domain method. It also proposes a concept of fault point reliability. This algorithm analyzes the fault point reliability in the whole transmission line to determine the specific location of the fault point. This paper proves that the algorithm has high reliability by PSCAD simulation software.

Keywords

Comprehensive Evaluation Algorithm, Travelling Wave Method, Time-Domain Method, Fault Location, Fault Point Reliability

1. Introduction

The development of power transmission technology has become faster than before since the 80s in the last century. Plenty of methods to improve the transmission capacity are also emerging. Comparing to the traditional AC transmission, HVDC technology has high economic, technical and performance of transmission. The direct current transmission line has the characteristics of low cost, lost power consumption and narrow line corridor. It also has advantages of high speed of adjustment and reliability operation. Therefore, high direct current transmission technology has been applied and popularized in our country.

These transmission systems have the advantages of high efficiency and high reliability, but they still have defects in practical application. At present, in addition to BTB project, the length of domestic DC transmission lines are more than 500 km. At the same time, long distance transmission lines cross the forest, mountains, rivers and other complex terrain. Bad work environment and high fault rate will greatly increase the difficult of the fault line when the fault occurs, which seriously affects the recovery time of the permanent fault. The fault has less damage to the line itself for the development of relay protection technology. Local defects with no obvious changes in appearance bring serious difficulties to the fault investigation. Therefore, it can be seen that HVDC transmission line fault location technology research has great practical significance and demands [1] [2].

2. Traditional Fault Location Method

The traditional fault location method of high voltage direction current transmission line is divided into two kinds, the travelling wave method and the time domain method. Travelling wave method is an algorithm using the theory of travelling wave to determine the location of the fault point, which is based on high sampling rate data. This algorithm has advantages of high accuracy and be little influenced by the system operation mode and fault resistance. It is popular in fault location technology. The time domain method is an algorithm using the system parameters and the double ended data of the line to determine the location of the fault point, which is based on low sampling rate data. Comparing to the travelling wave method, this algorithm has low accuracy, but it has good reliability in data resources [3].

From the above we can know that the HVDC fault location technology has been widely used in practical project, but there are still a lot of problems in it. It has a huge space for improvement. The principles of traditional fault location are introduced.

2.1. Travelling Wave Method in Fault Location

At present, travelling wave method is widely used in HVDC transmission system. This method is an algorithm using the theory of travelling wave to determine the location of the fault point. Travelling wave methods are divided into six types according to data source selection and source differences. Although the travelling wave method's reliability and accuracy is higher than other methods, it still has some difficulties in the practical engineering. The travelling wave phenomenon of the line's voltage and current must be measured by the transformer. It is a problem to measure the travelling wave signal in an economic and simple method. The uncertainty of the travelling wave signal generated by the fault also restricts the development of the fault location technology. Although there are various kinds of problem in fault location method, the research on the new technology has never been stopped.

2.2. Time-Domain Method in Fault Location

In addition to the travelling wave method, time domain method is used in fault location in HVDC system. HVDC transmission line has unstable power frequency which caused frequency domain method is replaced by time domain method in practical. This method is an algorithm to analysis and calculate the distance from the fault point, which is based on the system parameters and the value of current and voltage [4]. The criterion function is constructed as below:

$$f(x, t) = \sum_{t_1}^{t_2} |u_k(x, t) - u_m(l - x, t)| \quad (1)$$

Time domain method requires actual recorded data which is reliable. It can calculate the distance by the sampling point and becomes a new trend of modern transmission line fault location. In spite of this, there are still a lot of shortcomings in the practical application. Formula (3) shows that the parameters of line and velocity of wave are key factors which caused the accuracy of calculation. Comparing to AC lines, the parameters of DC lines are always not accurate. This phenomenon is more obvious with the increase length of DC transmission lines. At present, the application of time domain method in HVDC system is still in an initialstage [5] [6].

3. Comprehensive Evaluation Algorithm

It can be known that the traditional fault location method has been widely used in practical project. This paper proposes a new comprehensive assessment algorithm based on these methods. The comprehensive algorithm creatively combines travelling wave method with time domain method. It determines the fault point reliability by analyzing each point along the high voltage direct current transmission lines. Fault location is performed by selecting the highest reliability along the line. This comprehensive method combines the advantages of travelling wave method with time-domain method. It effectively avoids the disadvantages of traditional algorithm. It has high reliability and accuracy [7].

3.1. Fault Point Reliability

This paper proposes the conception of fault point reliability, aiming to analyze the possibility of each point along the line to be the point of fault, to measure the location of fault. Travelling wave location method calculates a result named L. The point at which the distance from the measuring point is L can be regarded as the fault point. This point's fault point reliability is 100% and other points' reliability is 0%. In practical project and PSCAD simulation, there are some errors in the traditional distance location methods. It can be seen that, in addition to ideal fault point has the possibility of being actual fault point, points near the ideal point also has possibility. The figure is presented to determine the fault point reliability which is in the vicinity of ideal fault point.

Point A is the ideal fault point in **Figure 1**. It can be concluded that the fault reliability is satisfied with the Gaussian distribution. Each point along the whole

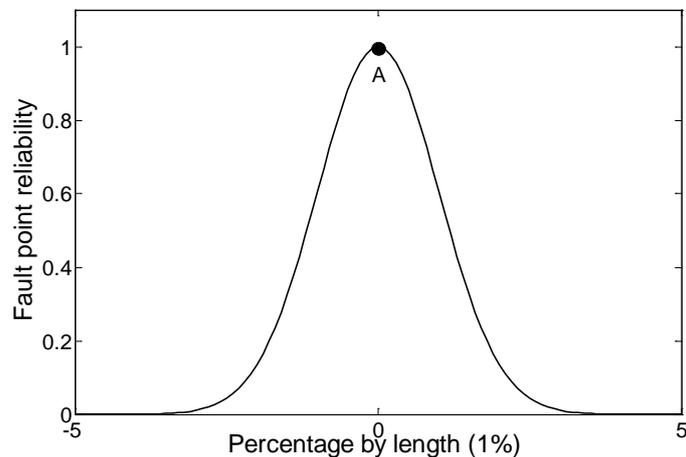


Figure 1. Gaussian distribution of fault point reliability.

line has corresponding fault point reliability. This plan satisfies actual model and reduces the defects of the measurement error in a certain extent.

3.2. The Principle of Comprehensive Evaluation Algorithm

This paper introduces the basic concept of the fault point reliability. The results of this method and traditional methods are the same when only one location method is used in comprehensive method. It still has traditional defects. The principle of comprehensive evaluation algorithm is combing traditional method and using fault point reliability to calculate fault location. This algorithm calculates the sum of the results measured by traditional methods in a certain weight. It calculates integrated fault point reliability and determines the location of fault point. The calculation formula is as below:

$$S_x = \frac{A \times S_A + B \times S_B}{2} \quad x \in (0, L) \quad (2)$$

$$A = A_1 + A_2 + A_3 + \dots \quad B = B_1 + B_2 + B_3 + \dots \quad (3)$$

In these formulas: S_A is the fault point reliability calculated by travelling wave method; S_B is the fault point reliability calculated by time-domain method; S_x is the integrated fault point reliability which is x meter away from measurement end; L is the length of line. A is the weight of travelling wave method; B is the weight of time-domain method; $A_1, A_2, A_3, B_1, B_2, B_3$ are weight factors; $A_1 = B_1 = 1$; A_1, A_2 are initial weight factors; the other weight factors' value depends on practical situation. This method determines the location of fault points by comparing the overall fault point reliability along the line.

Formula (2)-(3) shows that comprehensive evaluation algorithm is equivalent to the simple sum of traditional methods when they are normal. This algorithm can change traditional weights in it by changing the weight factors to reduce adverse effect when traditional methods in fault. It greatly increases the accuracy and reliability of fault location method. The block diagram of comprehensive evaluation algorithm is shown as below (**Figure 2**):

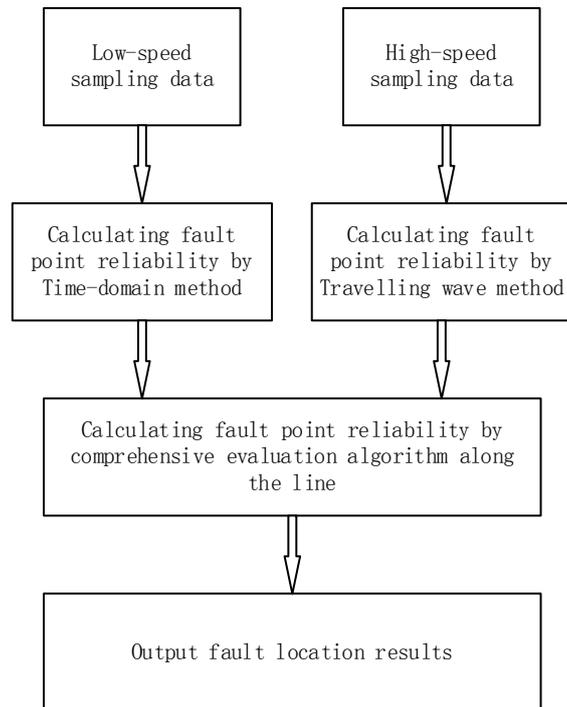


Figure 2. The block diagram of comprehensive evaluation algorithm.

4. Simulation and Experimental Results

The PSCAD/EMTDC simulation tool is used to construct a 500-kV HVDC transmission system model. The DC transmission line is built by Bergeron Model. The reliability of travelling wave method is low because of the high resistance grounding. The converter frequently turned on/off brought a large number of interference which affects the accurate identification of the reflected wave. There will be plenty of false results by using travelling wave method. The weight of travelling wave method in comprehensive algorithm is reduced. Assuming that $A_2 = -0.5$. The simulation's results are showed as below:

As can be seen from the above table, this algorithm has high reliability and accuracy. It proposes the conception of fault point reliability. It combines the travelling wave method with time-domain method and overcomes the shortcomings of traditional method. The system fault distance is calculated by measuring the highest fault point reliability along the line.

5. Conclusion

In this paper, the principle of HVDC transmission line fault location is introduced in detail. Traditional location methods' advantages and disadvantages are showed in practical project. Analyzing domestic and foreign well-known scholars' study on fault location, the existing fault location methods have plenty of problems: low accuracy, low reliability and high sampling rate. These shortcomings greatly influence the application of fault location in high voltage system. This paper creatively put forward a new concept of fault point reliability. It

Table 1. Results of simulation.

Ideal fault location	Travelling wave method location	Time-domain method location	Comprehensive evaluation method location
100 km	100 & 127 & 421 km	100 km	100 km
500 km	500 & 721 & 1107 km	494 km	500 km
900 km	462 & 900 km	885 km	896 km
1300 km	571 & 1300 & 1590 km	1278 km	1295 km
1700 km	910 & 1700 km	1669 km	1690 km

proposes a comprehensive evaluation algorithm, based on travelling wave method and time-domain method, to measure the fault location (**Table 1**). This algorithm combines the travelling wave method with time-domain method and overcomes the shortcomings of traditional method. The simulation of PSCAD software shows that the comprehensive evaluation method has high accuracy and reliability. It can measure fault location in any case. It has good economic performance because the system doesn't need to increase any device on the transmission line. It can be concluded that this algorithm has good application ability and research potential.

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