Research on the Technology of Ground Fault Location Based on Two Terminal Measuring Points

Hongwen Chen
China Aerodynamics Research and Development Center, No.6, South Section, Second Ring Road, Mianyang 621000, Sichuan, P. R. China

Abstract. At present, the power grid is particularly prone to small current grounding, it is difficult to detect the fault signal due to the large transition resistance, and it is very difficult to locate the fault accurately. Sometimes the fault is very difficult to find, because the line is longer and the wiring is more complex. At this time, we can only rely on the experience of on-site workers for line finding and investigation, and find out the problem in time. Ground fault line, find fault point, Sometimes, obvious fault is easy to find, but hidden fault is difficult to find, and the fault is not continuous, so accurate fault finding is very useful for the State Grid. Therefore, this paper through advanced computer technology, the latest sensor technology, through the installation of appropriate detectors at both ends of the power grid, can real-time monitor the changes of the power grid and find fault points. Through theoretical derivation and practical verification, this method is proved to be very effective.

1. Introduction
With the development of China’s urbanization, more and more areas of the power grid, the load of the power grid is also growing, and the power grid is through a variety of environments, so sometimes the branches will cause grid failure. and sometimes the user's irregular power consumption will also bring grid failure, even causing personal injury. Therefore, when the fault occurs, quickly find the fault point and conduct the phase Solutions. 10kV power grid in our country belongs to the small current grounding system (that is, the neutral point is not effectively grounded system). In case of single-phase grounding fault, although the regulations allow operation with fault for 2 hours, it may still cause accidents due to over-voltage damage to insulation. Especially, it is difficult to implement the location technology of earth point, and the existing fault indicator after the earth fault occurs The operation accuracy is poor, while the maintenance workload is heavy; the fault location of distribution network automation is slow due to the huge investment; at present, most of them recover to the way of blind line patrol from manual to fault lines, which takes a long time, human and material resources to determine the location of the section where the grounding point is located [1,2]. The first way is to greatly delay the troubleshooting time and power supply recovery time of grounding fault, increase the induced serious short-circuit fault and Pt explosion fault, which threaten the safe and stable operation of distribution network; the second way is that during the long troubleshooting period, due to the step-by-step voltage and contact voltage around the grounding point, the nearby personnel include grounding fault troubleshooting personnel and farming personnel The possibility of electric shock to livestock has greatly increased, threatening the safety of people's life and property. Based on the advanced microelectronics and computer technology, the current and voltage monitoring device is installed at the terminal of multi dominating wire. Through the real-time detection of the data characteristics when the fault occurs, the distribution network is monitored in real time. When the fault...
is detected, all terminals summarize the data to the server, and calculate the data through the server to get the fault point, which greatly reduces the power consumption. The scope of manual inspection is reduced, the stability of power grid is improved, and the economic loss caused by grounding is reduced.

2. The Main Problems in the Current Power Grid

(1) In the distribution network, there are often high amplitude and long duration temporary overvoltage, which is easy to cause equipment failure with weak insulation. The operation experience shows that the over-voltage accidents of the distribution network account for about 70% – 80% of the over-voltage accidents of the whole power system, among which the internal over-voltage accidents account for a considerable proportion [3, 4].

(2) Most of the distribution network lines are arranged in the form of overhead conductors, and the single-phase or phase to phase short-circuit fault rate is high, resulting in frequent equipment failures. There are often both overhead lines and cables in the distribution network in the city, and the cable insulation accidents caused by the overhead line grounding fault occur from time to time [5].

(3) It takes a long time to locate and eliminate the fault point. After the fault occurs, in order to reduce the outage time, it is necessary to find the fault point as soon as possible to eliminate the fault [6].

3. Steady State Analysis of Non-full Phase Break Fault in Arc Suppression Coil Compensation System

The neutral point of the arc suppression coil in normal operation is grounded through the zero sequence circuit of the arc suppression coil, $L_g$, $L_c$ are the inductance and equivalent conductance of arc suppression coil; $C_g$, $C$ is the capacitance and leakage conductance of each phase to ground of the grid; $U_{un}$ is asymmetric voltage.

The displacement voltage of neutral point is:

$$U_0 = -\frac{K_c}{\nu -jd} U_\phi$$

D is the damping rate of the grid,

$$\dot{U}_{un} = -\frac{K_c}{1 - j \frac{3g}{3\omega C}} U_\phi$$

Asymmetric voltage:

$$K_c = \frac{C_A + \alpha^2 C_B + \alpha C_C}{C_A + C_B + C_C}$$

Among which, $\nu$ is the detuning degree of power grid before disconnection.

$$\nu = \frac{\omega^3 C - \frac{1}{\omega L}}{\omega^3 C} = 1 - \frac{1}{3\omega^2 LC} = 1 - K$$

In case of disconnection or asymmetric disconnection, the three-phase symmetry degree will be greatly damaged, and the asymmetry degree and displacement voltage will be greatly increased. The following is an example of single-phase disconnection to analyze the asymmetry degree and displacement voltage under disconnection fault. Compared with the disconnection fault, the asymmetry value of the compensation grid is very small in normal operation, so it can be considered that the capacitance of the first three phases of disconnection is equal to each other, $C_A = C_B = C_C = C$. When a single-phase disconnection occurs, the fault phase capacitance to
ground decreases, and the ratio of its value to the sound capacitance to ground \( m < 1 \) is used to express.

When single-phase disconnection occurs:

The capacitance current is:

\[
I_{c1} = \alpha (m + 2) C U_{\varphi} = \frac{m + 2}{3} I_{c} 
\]  
(4)

The degree of grid asymmetry is:

\[
K_{c1} = \frac{m - 1}{m + 2} < 1
\]  
(5)

The tuning degree is:

\[
K_{1} = \frac{I_{c}}{I_{c1}} = \frac{3K}{m + 2}
\]  
(6)

The degree of detuning is:

\[
\nu_{1} = 1 - K_{1} = 1 - K(1 - K_{c1}) = (1 - K) + KK_{c1} = \nu + KK_{c1}
\]  
(7)

The displacement voltage is:

\[
\dot{U}_{01} = - \frac{K_{c1}}{\nu_{1} - jd} U_{\varphi}
\]  
(8)

It can be seen from the expression \( \nu_{1} \), because \( K_{c1} < 1 \), So \( \nu_{1} \) changes in the direction of over compensation. Therefore, when the under compensation power grid breaks, It will change from under compensation to over compensation, and the neutral point voltage will reach the maximum value at a certain disconnection position.

4. Principle of Fault Location System

Each terminal sends the collected voltage data and current data to the server in real time, and sorts the data through GPS time service. If the synchronous sampling frequency is 100kHz, the data collected per second is 200K, and the time mark of each data is 0.000005 seconds. At the same time, all terminals are synchronized by GPS second synchronization, so the data of the server is based on the clock Row sorted. Through the analysis of all the data, the server can find the fault line by comparison method and fault feature search method. After finding the fault line, the server calculates the data according to the formula shown above and calculates the parameters in the above formula. The fault point can be located by analysis the characteristics of the parameters.

According to the voltage and current detection value reported by each terminal node, the fault location can be calculated by using matrix algorithm. Firstly, according to the network topology diagram given by the substation management department, the total number of detection terminals is calculated, and the voltage and current values detected by each terminal are sorted according to the time to form the corresponding determinant. When a fault is detected, the determinants of these data can be packaged and analysis.

If there are \( n \) nodes on the power grid topology, the row column matrix of \( N \) can be obtained according to the collected data. If the two nearest nodes of the faulty line are \( I \) and \( j \), the fault information can be detected between \( I \) and \( j \), then the fault can be located between \( I \) and \( J \). Assuming that the distance between the fault point and point \( I \) is \( s \) and the distance from point \( J \) is \( t \), then the distance between point \( I \) and point \( J \) is \( s + T \). according to the matrix of fault information, the time when point \( I \) receives fault information and point \( J \) receives fault information can be obtained. If the
propagation speed of fault information is \( V \), the position of fault point can be calculated by determinant.

5. Field Test and Conclusion of Fault Location System

In order to verify the accuracy of single-phase ground fault location technology of multi branch distribution lines based on double terminal measurement points under different transition resistances, ground fault location function and ground residual current, the field test of artificial single-phase ground of 10kV distribution lines in 35kV substation was jointly organized and implemented from September 26 to 29, 2019.

The 10kV line of substation has two sections of buses running in parallel with a total of 6 outgoing lines. The outgoing line of 911 incredibly home is selected as the grounding test line, and the grounding point is determined at the No.3 pole of Malian branch of 911 incredibly line.

This artificial single-phase grounding test has been carried out for 15 times in total. All the grounding lines are selected as 911 line, and the selection is correct. Except for the twelfth test, the error between the positioning tower and the actual grounding tower is less than 700 meters, including the results of ranging and positioning, of which 7 positioning error is less than 100 meters; the maximum residual current of the grounding point is less than 2 amperes.

This test tests the accuracy of single-phase ground fault location of multi branch distribution lines based on the principle of double terminal measuring points. The test results show that the device has a high accuracy of ground fault location action even under the condition of high transition resistance. In the field multiple grounding tests, all the correct actions are taken to roughly locate the range of ground fault points, which basically reaches (some exceed) Technical project contract and task specification requirements (when the transition resistance is less than 500 ohms, the positioning error is less than 1600 meters; the grounding residual current is less than 5 amps).

From the test results, it can be seen that the single-phase ground fault location technology of multi branch distribution lines based on double terminal test points can quickly and accurately select the ground line when the single-phase ground fault occurs in the distribution network, roughly locate the area where the ground fault point is located, and solve the problem of long-term troubleshooting of single-phase ground fault in the system.

6. Conclusion

In this paper, a single-phase ground fault location system for multi branch distribution lines based on double terminal test points is designed. Through the determinant calculation of the collected voltage and current value, and through the synchronization information, all monitoring points are synchronized. Through the calculation method in this paper, it is easy to find the location of the fault, reduce the workload of line finding and improve the stability of the power grid.

Reference
[1] Fang W M, Cheng H X, Li Y, et al. 2016 A kind of fault location method for multi-terminal power distribution network not affected by wave speed Guangdong Electric Power 29 79-83.
[2] Zhou G, Zhang G, Ma L, et al. 2015 A fault Location method in distribution networks based on impedance analysis and traveling wave analysis Power System & Clean Energy 31 21-26.
[3] Liao X, Zhao X and Liang H 2017 A power cable fault location method based on Hilbert-Huang transform Power System Protection & Control 45 20-25.
[4] Yang L and Shu Q 2016 A new multiterminal detecting location method of single-phase grounding to the overhead-line for distribution network based on travelling-wave mutation of line-mode Power System Protection & Control 44 22-28.
[5] Shen Y W, Cui M J, Wang Q, et al. 2017 Comprehensive reactive power support of DFIG adapted to different depth of voltage sags Energies 10 808-827.
[6] Zhang J, Cui M J, Fang H L, et al. 2016 Smart charging of electric vehicles penetrating into residential distribution systems based on the extended iterative method Energies 9 985-999.