Research on Single Grounding Location Technology of Power Grid Based on Wavelet Analysis

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Abstract. The research of single grounding location technology based on wavelet analysis aims at the current situation of complex distribution network structure, high failure rate, many branches of lines, large transition resistance, difficult to detect fault signals. This method analyzes the characteristics of fault traveling wave signal generated by single effective grounding, and filters the collected traveling wave signal by wavelet analysis, so as to improve the credibility of traveling wave signal characteristics. Through calculating the traveling wave line mode and zero mode component at the time of fault occurrence, the singular point of traveling wave waveform is obtained, and the fault point is determined by accurate traveling wave velocity. For the tree distribution system, the zero mode waveform of the reflected traveling wave is recorded by injecting the voltage ranging traveling wave into the system during normal operation, and the reflected traveling wave is injected into the fault phase during fault, and the zero mode voltage waveform of the reflected wave is recorded. The two waveforms are subtracted to eliminate the reflected wave head of the grid node, and the fault distance is calculated by wavelet analysis. The method needs to measure the current and voltage of each terminal of the line synchronously when the parameters of the line are known. Through the experiment of fault location for single-phase ground fault of multi branch distribution lines, the results show that this method is effective.

1. Introduction
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. the fault location of distribution network automation is slow due to huge investment; the past research is to calculate the steady-state component of the system, because the signal amplitude of the steady-state component is relatively small, coupled with the complexity of the power grid, which makes it difficult to distinguish the signal and noise, resulting in misjudgement and missed judgment [1, 2]. With the emergence of wavelet theory, not only the transient components of voltage and current can be analyzed, but also the singular points of line mode can be obtained by calculating the line mode and zero mode components of travel wave, and then the distance between the fault point and the detection point can be calculated according to the arrival time of the singular point and the travel wave speed. For complex distribution system, voltage can be injected into the system to measure the zero mode voltage waveform of the reflection wave is recorded and injected into the fault phase when the fault occurs. The two waveforms are subtracted from the reflection wave head of the grid node, and the fault distance is calculated by wavelet analysis.
2. Wavelet Transform and Singular Value Decomposition of Line Modulus

Definition of wavelet function: \( \psi(t) \in L^2(R), L^2(R) \) represents the square integrable real number space, that is, the signal space with limited energy. Its Fourier transform is \( \psi(\omega) \). When the allowable condition formula (1) is met, \( \psi(t) \) is mother wavelet.

\[
C_\psi = \int_{-\infty}^{+\infty} \frac{|\psi(\omega)|^2}{|\omega|} d\omega < +\infty
\]  

(1)

A series of sub functions generated by the expansion and translation of the parent wavelet are called wavelet basis functions. In the formula, \( \alpha \) is called scaling factor or scaling factor. Its function is to scale the basic wavelet. The larger and wider the \( \alpha \) is, the longer the duration of the \( \psi(t/a) \) is. It reflects the scale (or width) of the function. It is a translation factor, and the variable detects the translation position of the wavelet function on the number axis.

\[
\psi_{a,b}(t) = |a|^{-1/2} \psi \left( \frac{t - b}{a} \right) \quad a, b \in R, a \neq 0
\]  

(2)

From the above definition of wavelet, the characteristics of wavelet function are as follows:

(1) Wavelets have compact or approximately compact support in time domain. Generally, compact or nearly compact support sets are selected (with local property in time domain, i.e. rapidly decaying to 0 in a finite area) and regular (with local property in frequency domain. In order to make the mother wavelet have better locality in time domain and frequency domain.

(2) Volatility. It is known from the allowable conditions that the DC component must be zero, so the wavelets have positive and negative alternating waves.

In the calculation process, the scaling factor of continuous wavelet transform needs to be discretized, and the following discrete wavelet transform is obtained. The corresponding wavelets are as follows:

\[
\psi_{2^j,k2^j}(t) = |a|^{-1/2} \psi \left( t2^{-j} - k \right)
\]  

(3)

Discrete wavelet transform is to use the power of 2 to divide the frequency axis into binary, adjacent frequency bands.

When wavelet decomposition is carried out, the high-frequency signal and low-frequency signal occupy half of the frequency band in this frequency domain respectively. Again, when using wavelet decomposition, the low frequency part is divided into two frequency bands of the same width, and so on [3, 4]. Wavelet packet decomposition is to re decompose the high-frequency signals which are not decomposed in the process of wavelet decomposition according to the need. Its purpose is to select the appropriate basic wave function according to the cost function, and then carry out time-frequency analysis on the decomposed signals under the optimal wavelet packet basis function. It not only has the advantages of wavelet analysis, but also extends the advantages of wavelet analysis. The wavelet packet used in this paper is dB (Daubechies) orthogonal wavelet packet. The energy lossless and power complementary of the conjugate orthogonal filter are used. Energy lossless refers to that the signal energy is not lost and remains unchanged after passing through the filter; power complementarity refers to that although the frequency characteristics of each channel are not all-pass or ideal band-pass, all channels together have all-pass characteristics. At the same time, orthogonal wavelet transform belongs to linear transform, so we can use the frequency of wavelet packet decomposition to analyze the frequency distribution of the original signal and extract the characteristics of the zero-sequence current transient signal.
Singular value decomposition (SVD) is an effective method to extract signal features. The singular value obtained by SVD represents the inherent properties of data, and its stability and invariance are good. The research shows that the noise in the signal can be effectively removed and useful information can be left by signal reconstruction after SVD. By constructing the trajectories of attractors and SVD and selecting the appropriate singular value to reconstruct the signal, the random part of the signal can be eliminated, and the useful part of the signal can be retained to the greatest extent to achieve signal denoising.

3. Neutral Grounding Mode and Characteristics
The internal over-voltage problem of 35 kV distribution network is closely related to the neutral point grounding mode, and the selection of neutral point grounding mode is a comprehensive technical problem, which is directly related to the insulation level, over-voltage level, power supply reliability, communication interference, grounding protection mode, personal and equipment safety of power equipment, and is the technical basis for the safe and economic operation of power system. Due to the development of historical technology, there are two representative solutions, one is the neutral point grounding system led by Germany through arc suppression coil, which can reduce the interference to communication lines and ensure the correct operation of railway signals. The other is to use the neutral point directly grounded or through low resistance, low reactance and other grounding methods led by the United States, together with fast relay protection and switching devices and other equipment, to instantly cut off the fault line. In China, the non-effective grounding mode of distribution network, which is represented by the non-grounded neutral point and grounded through arc suppression coil, has advantages in power supply reliability, personal equipment safety and electromagnetic compatibility, but there are problems such as high over-voltage level and difficult to realize ground fault detection. The neutral point direct grounding or resistance grounding is conducive to limit the over-voltage level, and the grounding fault is easy to detect. However, the fault current is large under this grounding mode, so the safety of personal equipment and electromagnetic compatibility should be paid attention to. The neutral point grounded by parallel resistance of arc suppression coil makes up for the shortage of single operation mode grounded by arc suppression coil or grounded by resistance, which is not only conducive to instantaneous fault arc extinguishing, limiting or even eliminating the possibility of intermittent arc grounding and other resonant overvoltage, but also convenient for the detection of permanent ground fault.

4. System Composition
Based on the above analysis and calculation, aiming at the actual situation of 35kV in Weizhou substation, the neutral point ungrounded mode is currently adopted in the substation, and the measured maximum capacitance current is 26.23a. After analysis and calculation, the capacity of arc suppression coil in the substation is determined to be replaced by 800kVA. The main equipment consists of turn regulating arc suppression coil, 35kV neutral point, controller, grounding resistor and control panel. The auxiliary equipment includes single-phase disconnector, arrester, neutral point zero sequence current transformer. The neutral grounding resistor adopts the wire braided high-voltage non inductive resistor. A support insulator is arranged on the base of the resistor, which is connected with a frame support frame through the support insulator. On the frame support frame, a plurality of sheet resistance units composed of a resistance sheet frame, a glass wire and a resistance wire are fixed. It can work normally in the strong magnetic field environment, with low temperature rise and stable and reliable performance in various complex environments. Both indoor installation and outdoor installation can be adopted. In this project, the resistor is installed near the original installation place of outdoor arc suppression coil of Weizhou station.

It is mainly composed of the main controller, AD acquisition module, DIO acquisition module, DIO output control module, etc. the main controller, AD acquisition module and DIO acquisition module constitute the measurement and control part of the system controller, which mainly completes
all measurement and control tasks, i.e. measuring the electric capacity current of the system and adjusting and controlling the gear of arc suppression coil.

Based on the mechanism of single-phase ground fault in distribution network, considering the large error of zero sequence current transformer in 35kV outgoing line and the difficulty of installing zero sequence current transformer, considering the universality of transition resistance in grounding point, this paper studies the error characteristics of zero sequence current filter composed of each phase current transformer, and makes use of the advantages and characteristics of wavelet analysis in transient analysis. The 35kV ground fault monitoring and diagnosis device developed in this paper can quickly and accurately select the name of the ground line when the single-phase ground fault occurs in the distribution network, shorten the abnormal operation time of the power grid, cut off the ground fault line according to the site operation requirements, ensure the safe operation of the non-fault line, and fundamentally improve the power supply reliability, safety, economy and continuity of the distribution network [5, 6].

5. Actual Operation Effect
The following data in table 1 are obtained through experiments.

Table 1. Primary and secondary values of reactive residual current at the c-phase single-phase ground fault point of Mianwei line.

| Number | Gear | Power meter | Secondary power value | voltmeter | Secondary voltage value | Secondary value of reactive residual current | Primary value of reactive residual current |
|--------|------|-------------|-----------------------|----------|-------------------------|---------------------------------------------|--------------------------------------------|
| 1      | 3    | 15          | 30                    | 51       | 102                     | 0.294118                                    | 1.176471                                  |
| 2      | 3    | 15          | 30                    | 51       | 102                     | 0.294118                                    | 1.176471                                  |
| 3      | 5    | 67          | 134                   | 51       | 102                     | 1.313725                                    | 5.254902                                  |
| 4      | 5    | 67          | 134                   | 51       | 102                     | 1.313725                                    | 5.254902                                  |
| 5      | 1    | -36.5       | -73                   | 51       | 102                     | -0.71569                                    | -2.86275                                  |
| 6      | 1    | -36.5       | -73                   | 51       | 102                     | -0.71569                                    | -2.86275                                  |

As can be seen from table 1, the minimum value of the absolute value of reactive residual current (i.e., full compensation) occurs between gear 2 and gear 3. Before the test, the controller follows the real-time working condition of 35kV Power Grid and the change of capacitance current in real time and calculates that the system capacitance current is 13.88a. The compensation gear of voltage suppression complete set of devices is controlled at gear 3. At the moment of grounding, the gear closest to full compensation is used to compensate the system capacitance current to the ground in 0s. The measured reactive residual current is only It is 1.2 amperes; the complete set of device has accurate calculation of the capacitance current of the system, ideal compensation effect of the grid capacitance current, and effectively suppresses the arc grounding over-voltage of the single-phase grounding fault; meanwhile, the control gear 3 of the system is very close to the full compensation gear, so the system does not have series resonance and virtual grounding phenomenon, indicating that the complete set of device for overvoltage suppression has over-voltage for series resonance Voltage suppression is very effective.

6. Conclusion
Through the actual experiment, it can be concluded that this system can effectively detect the grounding term, and through the automatic control system, effectively suppress the series resonance of overvoltage. Through the continuous operation for more than half a year, three times of ground fault are detected in total, and the ground fault line is selected accurately. It can be concluded that the system is more accurate and practical.
Reference

[1] Nthontho M P, Chowdhury S P, Winberg S, et al. 2012 Protection of domestic solar photovoltaic based microgrid 11th International Conference on Developments in Power Systems Protection DPSP 2012 (IET).

[2] Fan C, Cai H and Yu W 2005 Application of six-sequence fault components in fault location for joint parallel transmission line Tsinghua Science & Technology 10 (2) 247-253.

[3] Jin T and Chu F L 2015 Grounding Selection of new distribution network with DG based on transient non power frequency zero sequence current Journal of Electrical Technology 30 (17) 96-105.

[4] Li G, Zhang X K, Li Q, et al. 2014 A review of the principle of line selection and section location in small current grounding system Shandong Electric Power Technology 41 (4) 43-48.

[5] Jiang J and Bao G H 2015 Summary of single phase to ground fault line selection methods for small current grounding system Electrical Technology (12) 1-5.

[6] Tang J R, Yin X G, Zhang Z, et al. 2013 Overview of research on automatic fault location technology of distribution network Power Automation Equipment 33 (5) 7-13.