Research on Single-phase Grounding Line Selection Method for Distribution Network Containing New Energy

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Abstract. With energy shortages and environmental pollution problems becoming more and more serious, new energy electric energy has been rapidly developed and applied in the power system. Since most new energy electric energy needs to be connected to the power distribution system through an inverter device, this type of new energy electric energy is called an inverter-type distributed power source. With the access of distributed power sources, the power distribution system has changed from a single power source to a multi-power source system, and the system structure has changed. This brings great challenges to relay protection and fault line selection in the distribution network. Therefore, this article discusses the problem of single-phase grounding fault line selection in distribution network with inverter-type distributed power generation.

1. Introduction
In recent years, the relevant policies of new energy have made relatively large adjustments in our country. The annual new photovoltaic power generation units nationwide have increased by 30% to 40% compared with previous years. This year, the latest new energy power generation policy has further improved the parity of its projects. Even projects that were not put into production last year have been launched this year. This phenomenon has focused the attention of all sectors of society on the growth of new energy units.

With the social and national energy policy support and the popularization of the use of new energy and the innovation of its power generation technology itself, in recent years, more and more inverter-type distributed renewable new energy (distributed generator, dg) has been connected to my country in the distribution network. While renewable energy is being used as much as possible, it also brings many new problems for the normal operation and development of the distribution network. Among them, the impact of distributed renewable power on the operation and fault characteristics of my country's distribution network is a hot technical problem that has been widely studied in the distribution network in recent years and affects the normal operation of the distribution network.

Since most of the current distribution networks in my country use single-phase grounded power supply methods with small currents, the influence of changes in the characteristics of power supply failures when single-phase grounding occurs before and after the power supply of dg is connected. Not big. Therefore, the current research on the ground fault protection characteristics of many active large-scale distribution networks is mainly concentrated on the three-phase short circuit of the cable and other phase-to-phase short circuits. However, with the increase in cable density and coverage of large-scale distribution networks in some urban areas, the structure of the grounding grid needs to be enhanced, and large-scale distribution networks in some cities and regions need to choose a neutral...
point grounding protection method with small resistance. After the neutral point of dg is connected, the difference between the neutral point of the single-phase transformer on the dg side and the single-phase grounding protection method will directly cause the neutral point and the single-phase grounding fault protection characteristics to have a greater impact and difference. This will also have a certain degree of interference and influence on its ground fault protection performance\textsuperscript{[4]}.

At present, China's renewable energy shortage, environmental pollution, global warming and other social problems are becoming more and more serious. To wind, solar and other new energy and wind power technology as the main representative of the research, development and application of renewable energy has entered a rapid development stage, and has developed into support and promote the contemporary Chinese renewable energy industry structure adjustment, support new energy and environment friendly and urbanization system the important technical foundation and development of strategic direction.

I have conducted in-depth research and analysis on the single-phase grounding fault and output characteristics of some distributed power distribution networks with a large amount of information and literature for a period of time, but its dg type single-phase grounding research mainly rotating type, and for the current market, we use more inverter-type distributed power sources (iidg), in which the output control strategy of the rotating inverter directly determines its fault and output characteristics. Compared with other inverters and dgs containing rotary inverters, there are big differences and differences, so it is necessary for us to deal with the single-phase grounding fault and output of the distribution network with inverter-type distributed power single-phase grounding. Characteristics to study.

2. Characteristic analysis and simulation of single-phase grounding fault in single-source radiant distribution network

Under normal circumstances:

The sum of the three-phase circuit and capacitor-to-earth current is zero, and the sum of the three-phase wire's voltage to the ground is equal. Fault analysis Normal situation: the voltage of the neutral point to the ground conductor of the system increases from zero to the phase voltage during normal line operation, and the voltage of the non-neutral point fault phase conductor to the ground increases to zero. The ground wire voltage drops to zero. Since the phase-to-phase capacitance does not have much influence on the entire system failure, it is not considered\textsuperscript{[5]}.

When a single-phase ground fault occurs in one phase of a distribution network system with a neutral point ungrounded system as the grounding method, the steady-state characteristics of the faulty electrical quantity in the network are:

(1) When a single-phase ground fault occurs in a network, the three-phase parallel ground loop voltage in the circuit is no longer symmetrical, and an output signal equal to the zero-sequence single-phase ground loop voltage is continuously generated in the system at the same time, and the value and the network generate circuit The output values before the fault are completely equal, but the output directions are still completely opposite.

(2) Since the faulty phase is connected to the earth, the voltage to ground on the faulty phase in the system becomes zero, and the voltage to ground of the non-faulty phase rises by 3 times.

(3) Since the problem of the zero-sequence-to-ground voltage of the sound line often occurs, and because there is a capacitance to the ground, each sound line will generate a zero-sequence current to the ground capacitance, and a sound line has three-phase zero-sequence current to the ground. The magnitude of is the sum of the zero-sequence current of the three-phase-to-ground capacitance of the sound line, and flows from the bus to the sound line; the zero-sequence current of the fault line is equal to the sum of the three-phase zero-sequence current of the sound line in the total power supply system, direction exactly the opposite\textsuperscript{[6]}. 
3. The impact of new energy integration on existing methods

The grounding system that we widely use in the power distribution network of developed countries is a system where the neutral point is not grounded by the arc suppression coil or the neutral point is grounded through the arc suppression coil, which is a small current grounding system. The single-phase grounding of the power grid has the highest low-current failure rate. However, due to the low current of the single-phase grounding point after the small-current fault, the basic characteristics of the single-phase grounding fault are less obvious[7]. Therefore, although the small current failure rate of the neutral point of the single-phase grounding of the small current grounding system and the reliability of the line selection have been studied for many years, they have not been found to be effectively solved, so this serious problem hinders. This has further improved the reliability of the power supply system and the technical level of power supply automation in my country's power distribution network.

3.1 Representation of knowledge

For the acquisition and analysis of the zero-sequence current signal of the normal faulty line, although the signal in the three-phase system of the normal faulty line and the normal line and the steady-state oscillation amplitude of the zero-sequence current signal of the faulty line may be very different, but In actual applications, due to the unbalanced factors in the three-phase line system, such as the zero sequence current signal source and the collected equipment (zero sequence current signal transformer), and the duration of the transient process of the zero sequence current signal It is very short, so when the zero-sequence current signal is collected on the normal line, a part of the steady-state zero-sequence current information may be superimposed in the transient zero-sequence current information at the same time, which makes us unable to determine the section where the
transient zero-sequence current information is collected. At the same time, it also leads to the inability to accurately determine the source of the steady-state zero-sequence current information of the normal line and the characteristics of the initial process duration. In the transient process, the steady-state oscillation amplitude and frequency of the fault current line may be significantly higher than the normal line, so we need to use these steady-state zero-sequence current information sections to select the fault zero-sequence signal line, reliability not tall[8]. Based on the above considerations, it is necessary to separate the normal line fault zero-sequence current information section collected in the line, separate the transient process of the zero-sequence current signal from the process of collecting steady-state zero-sequence information, and separate the transient process. The criterion of fault zero sequence signal line selection can be found in the fault information characteristics of.

4. Principle and simulation of fault line selection method based on EEMD

The method of empirical mode decomposition signal was first proposed by n.e.hilber in 1998. EMD does not need to set any basis function on the signal, but is a signal decomposed according to the basis function and the specific time scale and characteristic conditions of the signal itself, so that the EMD decomposition method is used to process nonlinear and non-stationary data. It has more technical advantages than Fourier decomposition and wavelet decomposition[9].

Arbitrarily complex signals can be directly calculated by decomposing the empirical mode to obtain several functional frequency components (IMF) of each order of eigenmodes, and each order of IMF must meet two basic conditions at the same time: In terms of length, the total number of local extremes of the signal passing through zero points is the same as the total number of signal passing through zero points or at most a difference of 1; at the zero point of any specific time period, the envelope formed by the maximum value point of the specific time period The envelope formed by the point of the local minimum in the specific time period, the average value tends to zero[10]. Each order of IMF reflects the time scale and local characteristics of each stage of the original signal, and the components containing different function frequencies can be linear or nonlinear, so when we deal with nonlinear and non-stationary signals, EMD can be very good It adapts to the frequency changes of the original signal and has a strong adaptive ability.

The components of each order of IMF and IMF accurately reflect the various local oscillation characteristics and frequency local oscillation characteristics of the original signal at different frequency bands and times. EMD accurately decomposes the complex continuous original signal into multiple IMFs and a remaining original signal. The component R(t), and the remaining component R(t) is a complex value that is close to the decomposition constant. The decomposition constant form is defined as follows:

\[
X_{(r)} = \sum_{i=1}^{N} c_{(r)} + R_{d}(t)
\]  

(1)

Where X(t) is the original data signal, c(t) is the IMF component, and R(t) is the remaining amount.

When a single-phase grounding short-circuit current input short-circuit location fault occurs in the monitoring circuit of the monitoring system, a short-circuit single-phase zero-sequence grounding current input location data obtained at the same time at a certain two monitoring points is the threshold i(t), and the input data is used to extract The short-circuit empirical mode data decomposition calculation method in the collection process can extract the basic characteristics of the positioning and the specific steps of the short-circuit zero sequence ground current input data set corresponding to the corresponding point and the design instructions are as follows:

Add the zero sequence total current signal w(t) in the Gaussian white sound noise to the signal with the overall step-down current of the Gaussian zero sequence value to make its signal value i0(t), then we can also directly obtain a signal with a Gaussian zero-sequence total current with white sound noise to make the total voltage signal value I0(t):

\[
I_0(t) = i_0(t) + \omega(t)
\]  

(2)

Perform empirical mode decomposition on the overall signal containing white noise, and obtain the
IMF components of each order of I0(t):

\[ I_0(t) = \sum_{j=1}^{n} c_j + R_n \]  \hspace{1cm} (3)

Eliminates the huge impact of blank noise on the time-domain high-frequency space of the independent voltage stabilized current coefficients of each test of the zero sequence and each step. After high-frequency testing of each independent voltage stabilized current coefficient, the average value of all independent current coefficients is obtained. The average component value of the independent regulated current coefficient IMF of each order is \( c_{m,n}(t) \):

\[ c_n(t) = \frac{1}{N} \sum_{m=1}^{n} c_{m,n}(t) \]  \hspace{1cm} (4)

The statistical law of the number of Gaussian white noise added to the original signal obeys:

\[ \mathcal{E}_n = \frac{\varepsilon}{\sqrt{N}} \]  \hspace{1cm} (5)

In the formula, \( \varepsilon \) is the true value error of the sum of the zero-sequence current component signal of the envelope and the IMF component signal of each order; \( \varepsilon \) is the amplitude of Gaussian white noise added; \( N \) is the total number of Gaussian white noise added to the decomposition result, and the noise The number of populations added to the decomposition results will directly affect the accuracy of the envelope decomposition results and the selection of the extreme points of the envelope, so the noise added to the decomposition results, the more the total decomposition results are added, the higher the accuracy will be. At the same time, the error between the result of envelope decomposition and the true value is smaller \[11\]. Since the number of Gaussian white noise added by the decomposition result will directly affect the selection of the extreme points of the envelope, the resolution and signal-to-noise ratio of Gaussian white noise should not be too high. In the process of noise decomposition, each overall noise test is independent. Although we will find some noise residues after each independent test, because the number of noise tests is relatively large, and we will all the noise The number of tests performed is reduced to an average value, so the residual influence on noise will be fundamentally minimized.

Among the calculated components of the IMF of each order function, the third order component IMF3 is selected, and the first order difference is 0.

After the zero sequence current analysis decomposes the EEMD algorithm, the fault signal adds Gaussian white noise during the signal decomposition process, and the transient process contains high frequency signals, so the residual high frequency in the process The noise is usually directly attached to the transient process, and these residual noises also change periodically with frequency, which will directly affect the residual transient and separation characteristics of the original fault signal. Since the frequency of the signal IMF component after the fault signal is decomposed is usually gradually reduced as the order of the fault signal increases, any high-frequency information will always stay in the component of the first three-order signal IMF3, taking into account the residual The periodic effect of high-frequency signal noise, the third-order signal IMF3 decomposed by the fault signal as the characteristic of signal separation. According to the above steps, using the zero-sequence current of each line as the decomposed signal, the algorithm is used to decompose the third-order signal of the EEMD signal, and the frequency in the third-order signal IMF3 component is first-ordered. The algorithm compares the polarity and the maximum modulus of the IMF3 first-order difference of each line to select the line where the fault occurs \[12\].

When the initial deflection angle of the ground resistance at the fault point is 0.01\( \omega \), the initial voltage deflection angle is 0°, and the operating speed at the time of the fault is 0.2s. When two single-phase grounding short-circuits (a-phase) short-circuit faults occur in the line respectively, the zero sequence current of each single-phase grounding line is decomposed by EEMD, and the zero sequence current DIFF (IMF3) of each fault grounding line is obtained as shown below Shown:
As shown in the figure above, after the zero sequence current of the fault line has been decomposed by wavelet EEMD, the transient characteristics of the fault line are very obvious. The polarity of the zero sequence current imDIFF (IMF3) of the fault line is the same as that of the normal fault line. It is completely opposite. At the same time, the largest value of the modulus is also the largest. According to this polarity and the largest value of the modulus, the faulty line can be accurately judged and found\cite{13}. Under the condition that the same line fails, the method of using wavelet EEMD algorithm to extract the transient characteristics of normal fault line has more obvious effect and higher reliability than wavelet, and the algorithm using EEMD does not require wavelet to set any screening basis functions. Avoiding the complicated problem of selecting basis function and setting decomposition scale for wavelet\cite{14}.

5. Conclusion
This article focuses on single-phase grounding fault line selection with inverter-type distributed power
sources[1]. First, on the basis of the existing theory, under the condition of single-phase grounding faults in the distribution network, for inverter-type distributed power sources it outputs the fault characteristics of the fault current for simulation and analysis, and provides a basis for analyzing the fault characteristics for the next step of fault line selection. Secondly, according to the output characteristics of the fault current of the inverter-type distributed power source, combined with the traditional distribution network fault line selection method, the EEMD algorithm is used to decompose the zero sequence current to determine the fault line.

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