Regional Protection Device of Reaction Ground Fault and Fault Determination Method

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Abstract. With the application of new technology and development of new energy, more and more distributed power sources are connected to the grid. A regional protection device and fault determination method are designed, as a result of failure to swiftly, efficiently and accurately identify, locate and cut off the fault in regard of ground fault reflection of distribution network, to solve the technique problems of variation of load distribution in distribution network, and the invalidation of segmental protection coordinated by time alone when massive distributed generation is input into operation. And designed a type of regional protection device.

1. Introduction
In recent years, with the rapid development of distributed generation technology, the cost of distributed generation technology has decreased, a large number of distributed generation have been injected into operation, resulting in the simultaneous existence of power source and load [1-3]. Therefore, the distribution network is no longer a single power network, which will break the radiation-type structure of the traditional distribution network and change the load distribution of the distribution network inevitably. In result, the current time coordinated segmental protection will be ineffective. Consequently, research on new protection scheme for intelligent distribution network has become a new subject we are facing with [4-6]. With the development and maturity of wide-area synchronous measurement systems and communication means, an opportunity to fundamentally improve and enhance the relay protection performance was provided. However, due to the constraints of application technology such as information synchronization and communication reliability, the wide-area relay protection is difficult to adapt to the rapidity and reliability requirements for relay protection actions of high-voltage transmission networks, for this reason it has not been widely used in the above networks.

In view of the above problems, from a relatively microscopic point of view, the distribution network has relatively lower requirements on the rapidity and reliability of the relay protection action, and the new digital devices and communication means make it possible for information integration and interaction. Therefore, the realization of limited wide-area relay protection in distribution network is attracting attention from experts and scholars increasingly.

Currently implemented distribution network fault location and isolation algorithm mainly has two kinds [7-10]: one kind is the basis of the knowledge of graph theory, combining with fault flow or pressure loss analysis, according to the topological structure of distribution network, through the
matrix to realize fault location matrix algorithm, such as the unity of the distribution network fault section judgement matrix algorithm, and is suitable for the complicated power distribution network fault location algorithm, SCADA information based fault location method; Another type of artificial intelligence fault location algorithm is represented by genetic algorithm, neural network algorithm and expert system method. Therefore, according to the research status at home and abroad, this paper designs a new type of regional protection device for reactive grounding fault, and proposes a fault determination method, which is based on the difference of fault line current waveform, and can identify the fault location more accurately.

2. Reaction grounding area protection device design
A regional protection device for reaction ground fault is designed, which includes CPU, with characteristics as follows: analog acquisition module is connected with filter module, the filter module is connected with AD conversion module, the AD conversion module is connected with CPU; the communication module is connected with CPU; and the opening and exiting module is connected with CPU. What’s more, CPU is also connected with the human-computer interaction unit. The mentioned communication module includes serial communication module, Ethernet communication module, GTAG communication module, and optical fiber communication module. The schematic diagram is shown in Fig.1.

![Regional protection device for reaction ground fault](image)

**Figure 1.** Regional protection device for reaction ground fault.

The analog data acquisition module is able to convert the analog voltage/current that cannot be directly collected by the input main control circuit through transformer step-down and low-pass filtering into the power-frequency weak current signal that can be converted within the range of A/D chip, and read by CPU through analog-to-digital conversion. At the same time, through the transformation of the transformer, it can isolate the high voltage signal in the secondary circuit and the weak current signal in the microcomputer protection device, reduce the interference of electromagnetic noise to the circuit board, and ensure the weak current circuit in the protection device can work stably.

This regional protection device for the reaction ground fault is designated to develop traditional distribution network towards diversified modes such as multi-source, grid and parallel grid, system loads distribution transforms from one-way fixed to two-way indefinite, and the invalidation of single time coordinated segmental protection. Each line combines IED to share current information, and discretely sampling the current waveform. When ground fault occurs in the line, locate in time, send signal, and cut off the fault.
3. Regional protection device fault location method

In a sound circuit, the waveforms have similarities with each other. While in the faulty line, the zero-mode current waveforms of the faulty line and the non-faulty line differ greatly. When single-phase ground fault occurs in the line, the ratio of the correlation coefficients at both ends of the non-fault line is approximately 1, and the ratio of the correlation coefficients at both ends of the faulty line is smaller (small figure by large number), so that the fault section can be screened. The waveform of the fault point is rather similar on the same side, and the ratio of the correlation coefficients is close to 1; the ratio of the correlation coefficients between the two points on the opposite sides of the fault point is smaller, which contributes to the swift location.

The faulty line selection steps are as follows:

1) Assuming \( x(t) \) and \( y(t) \) are the signals of two waveforms respectively, \( \rho_{xy} \) indicates the coefficient of similarity between the two waveforms, discretely sampling both waveforms by \( N \) points, then:

\[
\rho_{xy} = \frac{\sum_{n=0}^{N-1} x(n)y(n+m)}{\left[ \sum_{n=0}^{N-1} x^2(n) y^2(n+m) \right]^{1/2}}
\]  

Among them, \( \rho_{xy} \in [-1, 1] \).

2) Assuming that there are \( N \) number of lines in total, and the correlation coefficient matrix of the \( N \times N \) order can be obtained through calculation of the correlation coefficients between the lines:

\[
\rho = \begin{pmatrix}
\rho_{11} & \rho_{12} & \ldots & \rho_{14} \\
\rho_{21} & \rho_{22} & \ldots & \rho_{24} \\
\vdots & \vdots & \ddots & \vdots \\
\rho_{N1} & \rho_{N2} & \ldots & \rho_{NN}
\end{pmatrix}
\]  

The value on diagonal of the matrix is 1, and each row represents the correlation coefficient between this line and other lines.

3) Averaging each row of the above matrix, to obtain the comprehensive correlation coefficient \( \rho_i \) of the line, then \( N \) lines can form a new comprehensive correlation coefficients matrix:

\[
\rho_i = \frac{1}{N-1} \left( \sum_{j=1,j\neq i}^{N} \rho_{ij} \right)
\]  

\[
\rho' = [\rho_1, \rho_2, \ldots, \rho_N]
\]

4) The line corresponding to the minimum comprehensive correlation coefficient is the faulty line; if all correlation coefficients are greater than zero, and the difference between the maximum and minimum correlation coefficients is less than a threshold value of \( \rho_s \), that is:

\[
\rho_s > \max \{ \rho_i \} - \min \{ \rho_i \}, \min \{ \rho_i \} > 0
\]
It is identified as bus bar fault.

4. Conclusion

A regional protection device for reaction ground fault is designed in this article, which can solve the problem of invalidation of single time coordinated segment protection. Based on the large difference between the zero-mode current waveform of the faulty line and non-faulty line, a fault determination method is designed. Which uses the theory of the correlation coefficients ratio at the two ends of the non-faulty line is approximately 1, while the correlation coefficients ratio at the two ends of the faulty line is smaller when single-phase ground fault occurs to filter out the faulty segment.

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