Neutral Grounding Fault Line Selection Algorithms for Low Voltage Side of Distribution Transformers in Civil Buildings

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Abstract. The neutral grounding fault line selection of low-voltage side of distribution transformer in civil buildings is of great significance in the field of power system. It is necessary to analyze the grounding fault of distribution transformer in civil buildings, calculate the current energy of distribution transformer by using the frequency coefficient of wavelet packet decomposition, and analyze the current fault components of grounding fault phase and sound phase, get the energy ratio of grounding fault current component, and complete the grounding fault of distribution transformer. Experiments show that the proposed algorithm can reasonably judge the fault line of distribution transformer nodes, and has a high accuracy in the selection of grounding faults.

Keywords: Civil Building, Distribution Transformer, Ground Fault, Line Selection Algorithm

1. Introduction
As we all know, large generators are the most important main equipment in the whole power system. Naturally, their price should not be underestimated. If it fails, it will bring great harm, which will not only lead to the unstable operation of power system, but also destroy the generator equipment, then the major losses will be incalculable. Therefore, it is very necessary to greatly improve the reliability, rapidity, sensitivity and selectivity of the relay protection of large generator units in the whole power system and play a very good preventive role. At present, the structure of power system is relatively weak, but with the rapid development of science and technology, it is necessary to increase the capacity of generator to adapt to it. Therefore, there is a high requirement for the quality of generator. On the one hand, the cost of equipment for a single generator is enormous; on the other hand, damage to the generator is inevitable. Due to damage to the generator, a series of chain reactions caused by bow | are quite troublesome. Generator damage, the first cause of blackouts, the serious consequences of large-area blackouts are self-evident. In addition, repairing the generator unit is a huge expense. The most serious is the fatal consequence of generator Burnout - generator scrap, which is unbearable to the power plant. Therefore, the protection of generator is urgently needed.

Grounding faults easily occur in distribution transformers of civil buildings, so the grounding protection of distribution transformers has attracted wide attention [1]. When grounding fault occurs in distribution transformer in civil buildings, the signal of grounding fault includes transient component.
In the initial stage of grounding fault at neutral point of low-voltage side of distribution transformer, larger grounding resistance will appear at the grounding fault point of transformer, smaller current component will be obtained, and sensitivity to grounding fault line selection will also be obtained. Affect [2-3]. Distribution transformer low voltage side neutral grounding fault line selection needs to determine the line length, resistance size and fault location, etc. These conditions are combined to make reasonable line selection when distribution transformer grounding fault occurs. Grounding fault line selection algorithm is widely used in many fields, and for civil construction. The identification of grounding fault of distribution transformer is of guiding significance [4-6].

2. Wavelet Packet Analysis for Distribution Transformer Grounding Fault Line Selection

According to the actual and specific data of generator operation in China given in the literature, the fault of generator stator ground has become the most common kind of fault in the generator itself. Although the single-phase ground fault of stator winding does not cause much damage to the generator, there are many factors that cause its failure. The most important thing is that frequent single-phase ground fault of stator winding will lead to more serious internal phase-to-phase or turn-to-turn short circuit fault. Therefore, if the probability of more serious internal short circuit fault is to be reduced, the reliability and sensitivity of generator must be greatly improved. If the fault current of stator single-phase ground is not large, the damage to generator stator core can be avoided and the economic loss caused by the fault can be reduced. Therefore, single-phase grounding protection of stator winding is a very important content in large-scale generator relay protection system.

Wavelet transform is a method of signal analysis to overcome the defects of other signal processing techniques. Wavelet is composed of a group of wavelet basis functions, which can describe the local characteristics of signal in time (space) and frequency (scale) domain. The biggest advantage of wavelet analysis is that it can carry out local analysis on the signal and analyze the signal in any time or space domain. Wavelet analysis has the information which can not be recognized by other signal analysis methods and hidden in the data to show the structural characteristics, which are particularly important for the identification of mechanical faults and material damage.

Based on the analysis of grounding fault of distribution transformer in civil buildings, the energy of current of distribution transformer is calculated by using the frequency coefficient of wavelet packet decomposition [7-9]. When the neutral point of low voltage side of distribution transformer is grounded, whether the feeder of distribution transformer is grounded fault line is judged, and the fault component of current is calculated [10-12]. The current fault components of the grounding fault phase and the sound phase are analyzed, and the energy ratio of the grounding fault current component is obtained to complete the grounding fault line selection of distribution transformer.

For the current components of the fault phase and non-fault phase of distribution transformer lines, the wavelet packet is used to decompose them. The sampling frequency is 5 kHz. The energy of the frequency band is calculated by the width of the frequency band of the wavelet packet. The calculation formula is as follows:

\[ E = \sum_{j,k} (\omega_j^k(n))^2 \]  

Among them, \( \omega_j^k(n) \) represents the coefficients of wavelet packet decomposition in band \( (j,k) \). In the characteristic frequency band, the fault of distribution transformer line is judged according to the transient fault components of fault phase and non-fault phase of distribution transformer line in civil buildings [13-15]. After decomposing the original signal of transformer by wavelet packet, less data can be obtained, which is not conducive to the option of grounding fault. It is necessary to reconstruct the fault current of neutral point on low voltage side of distribution transformer, so as to improve the reliability of fault line selection of distribution transformer [16-17].

When the neutral point of low-voltage side of distribution transformer in civil buildings undergoes grounding fault, the steps to determine whether the feeder of distribution transformer is grounding fault line are as follows:
Data acquisition of three-phase voltage and current in distribution transformer, the sampling rate is 5 kHz.

According to the reduction and perfection of the phase voltage of the grounding fault, the distribution transformer is distinguished according to the voltage reduction of the grounding fault phase and the sound phase of the grounding fault.

The current fault components of the neutral point on the low-voltage side of distribution transformer are extracted.

\[ \Delta i(k) = i(k) - i(k - N) \] (2)

Among them, \( N \) represents the data sampling points of voltage and current of distribution transformer.

In each feeder of distribution transformer, the current fault components of grounding fault phase and sound phase are analyzed, and the effective ratio is calculated.

\[ K_1 = \frac{\sqrt{\sum_{k}^{N} \Delta i_{\alpha}^2(k)}}{\sqrt{\sum_{k}^{N} \Delta i_{\beta}^2(k)}} \] (3)

Among them, \( \alpha \) and \( \beta \) respectively represent the grounding fault phase and the sound phase of distribution transformer in civil buildings.

According to the size of \( K_1 \), the fault phase is initially judged. \( \lambda \) is set as the threshold to judge the line, and \( \lambda_0 = 1.2, \lambda_1 = 3 \), when \( K_1 < \lambda_0 \), the line of distribution transformer in civil buildings is sound, when \( K_1 < \lambda_1 \), the line of distribution transformer is fault, and when \( \lambda_0 < K_1 < \lambda_1 \), the line of distribution transformer in civil buildings may be fault.

Wavelet packet decomposition [18-20] is used to decompose the lines that may be faulty in distribution transformers of civil buildings, and the characteristic frequency band of current distribution is selected according to the maximum energy of frequency band.

In the characteristic frequency band of the current distribution, the reconstructed current component may be the sound phase and the fault phase of the fault line, and the energy ratio of the current component is calculated according to formula (1):

\[ K_2 = \frac{E_{\alpha}}{E_{\beta}} \] (4)

Among them, \( E_{\alpha} \) and \( E_{\beta} \) represent the band energy of fault phase and sound phase respectively.

According to formula (4), the grounding fault line can be judged. When \( K_2 > \lambda_2 \), the fault line can be judged.

To sum up, the line selection of neutral grounding fault on low voltage side of distribution transformer in civil buildings is completed, and the expression is as follows:

\[ Q = K_1 / K_2 + \Delta i(k) \] (5)

3. Experimental Results and Data Analysis

In order to select the neutral grounding fault line of low-voltage side of distribution transformer in civil buildings, experiments are carried out in four line models of software ATP/EMTP grounding distribution transformer. Four lines include cable line, branch overhead line, overhead line and cable hybrid line.
Five grounding faults of distribution transformers in civil buildings are selected randomly in the experiment, and the correct rate of grounding faults is tested. The experiment is shown in Table 1.

Table 1. Correct rate of ground fault line selection results.

| Ground fault point | Proposed algorithm | Literature [8] algorithm | Literature [9] algorithm |
|--------------------|--------------------|--------------------------|--------------------------|
| 1                  | 95                 | 75                       | 52                       |
| 2                  | 98                 | 78                       | 58                       |
| 3                  | 97                 | 76                       | 53                       |
| 4                  | 96                 | 77                       | 51                       |
| 5                  | 99                 | 79                       | 56                       |

By comparison, the proposed algorithm can correctly select the neutral grounding fault of low-voltage side of distribution transformer in civil buildings.

4. Conclusion
By analyzing the neutral grounding fault of low voltage side of distribution transformer in civil buildings, the grounding fault and non-fault current of distribution transformer can be obtained. The experimental results show that the proposed algorithm is applied to civil buildings. The neutral grounding fault line selection of low voltage side of transformer has a high accuracy.

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