Study on Characteristics of Radiated Electromagnetic Waves of Circuit Breakers

Yao Chen, Xiaobing Zhao, Baojian Wang and Xinming Hou

Tonghua Power Supply Company, State Grid Jilin Electric Power Co., Ltd, 676 Xinhua St., Tonghua, Jilin Province, China.
Email: thchenyao@jl.sgcc.com.cn

Abstract. In order to study the new method of onsite detection of circuit breaker based on electromagnetic method, the characteristics of electromagnetic signal in the process of circuit breaker opening and closing were studied. The research results show that the electromagnetic wave will be radiated during opening and closing of the circuit breaker, and its frequency can reach 2GHz. The signal excited when the circuit breaker is closed is greater than the signal when the switch is opened, and the signal excited when the load is activated is greater than the signal when the switch is not loaded.

1. Introduction

The number of circuit breakers in the power grid is huge, which plays a role of control and protection. When a fault occurs, it will directly cause grid accidents, or lead to the further expansion of existing accidents, causing considerable economic and social losses [1-4]. How to effectively detect the working state of the circuit breaker, find defects in time, deal with the defective parts in advance, and prevent the occurrence of malignant accidents such as explosion of the circuit breaker is of great significance for ensuring the safe and reliable operation of the power grid. Statistics show that 70% of the main faults of circuit breakers and 86% of the secondary faults are mechanical in nature, mainly involving operating mechanisms, monitoring devices and auxiliary devices. The electromagnetic waves radiated during the opening and closing of circuit breakers are affected by their performance and may be used for the detection and analysis of circuit breaker performance.

2. Test System

The test system is a temporary system. The sensor is a 300MHz-2GHz isometric helical antenna, the amplifier gain is 40dB, and notch processing is performed near 900MHz, in order to eliminate the interference of the mobile phone signal to the measurement. The signal acquisition and recording are collected by Tektronix Tek 2024. The sampling frequency is 2GHz and the coupling bandwidth is 1GHz. The test system is shown in figure 1.

Figure 1. Test system.
3. Amplitude Characteristics of Electromagnetic Wave Signals

3.1. Closed Signal Amplitude Characteristics
In the test, the electromagnetic wave signal radiated during the load closing and closing of the LW10B-252 circuit breaker with load and the closing line (without load closing) was measured. The electromagnetic wave signal waveform is shown in figure 2. The waveform image in figure 2a) shows that there is a load, while there is no load in figure 2b). It can be seen that when the circuit breaker is closed with load and without load, the amplitude of the electromagnetic wave signal is not much different, both are above 1V. The positive signal of the load closing signal exceeds the range, and the negative signal amplitude is about 1.3V. However, the duration of the signal when the load is closed is longer, close to 1us, and the duration of the signal when the load is not closed is about 600ns.

![Figure 2](image)

3.2. Opening Signal Amplitude Characteristics
In the test, the electromagnetic wave signal radiated in the process of opening with load and without load of the LW10B-252 circuit breaker was measured. The waveform of the electromagnetic wave signal is shown in figure 3. The waveform image in figure 3a) shows that there is a load, while there is no load in figure 3b). It can be seen that when the circuit breaker is opened with load and without load, the amplitude of the electromagnetic wave signal is greatly different. When the load is closed, the signal is close to 0.8v, and when the load is not opened, the signal is only about 80mv, only 10% of the signal when the load is opened. The duration of the two is not much different, both are around 300ns.
3.3. **Comparative Analysis of the Amplitude of Opening and Closing**

During the closing process, the moving contact moves toward the static contact, and during the opening process, the moving contact moves away from the static contact. During the closing and opening process, the voltage between the moving and static contacts is the line voltage, but the breakdown distance between the moving and static contacts during the closing process is greater than the breakdown distance during the opening process. This makes the amplitude of the electromagnetic wave signal emitted when closing is greater than when opening.

The electromagnetic signal generated during the process of opening and closing with load is stronger than that without load, which is most obvious in the process of opening. The amplitude of the signal when opening with load is 10 times the amplitude of the signal without opening.

4. **Spectrum Characteristics of Electromagnetic Wave Signals**

4.1. **Closed Signal Spectrum Characteristic**

In the test, the electromagnetic wave signal radiated during the closing of the LW10B-252 circuit breaker with load and the closing line (closing without load) was measured. Since the sampling frequency of the oscilloscope is 2 GHz, the original data is interpolated in order to analyze signals in a wider frequency band. The interpolated sampling frequency is 4 GHz, and the upper limit of the spectrum analysis is 2 GHz. The spectrum distribution is shown in figure 4. The waveform image in figure 4a) shows that there is a load, while there is no load in figure 4b). It can be seen that when the circuit breaker is closed with load and without load, the electromagnetic wave signal is distributed below 2GHz, and the energy is higher in the low frequency range. The energy of the signal in each frequency band when closing with load is higher than the signal when closing without load.
Figure 4. The amplitude of the electromagnetic wave signal generated during the circuit breaker closing process.

4.2. Opening Signal Spectrum Characteristics
In the test, the electromagnetic wave signal radiated during the process of opening with load and without load of the LW10B-252 circuit breaker was measured, and its frequency spectrum distribution is shown in figure 5. The waveform image in figure 5a) shows that there is a load, while there is no load in figure 5b). It can be seen that when the circuit breaker is closed with load and without load, the electromagnetic wave signals are distributed below 2GHz, and the energy in the low frequency range is higher. The energy of the signal in each frequency band when opening with load is significantly higher than the signal when opening without load.

Figure 5. The amplitude of the electromagnetic wave signal generated during the circuit breaker opening process.

4.3. Comparative Analysis of Frequency Spectrum Characteristics of Open and Closed Signals
In the process of opening and closing, the energy of the electromagnetic wave signal is widely distributed within 0-2GHz, and the energy of the low-frequency signal is relatively strong, there is no significant difference, and the energy during load operation is higher than that without load. Therefore, in the development of the detection system prototype, a wide frequency band can be used to couple more energy. At the same time, in order to avoid electromagnetic interference on the site of the substation, the lower limit frequency band can be 300MHz.
5. Conclusions
We have got some conclusions.
- The electromagnetic waves emitted by the circuit breaker opening and closing have different amplitude and frequency characteristics.
- The electromagnetic wave will be radiated during the opening and closing of the circuit breaker, and its frequency can reach 2GHz.
- The signal excited when the circuit breaker is closed is greater than the signal when the switch is opened, and the signal excited when the load is activated is greater than the signal when the switch is not loaded.

6. References
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