The influence of load type on electromagnetic wave radiation during the opening of circuit breaker

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Abstract. Radiated electromagnetic waves during the opening of the circuit breaker can be used to evaluate the arc extinguishing performance of the circuit breaker. Current research shows that the duration of electromagnetic waves is the main feature. However, the current research does not consider the influence of the type of load on the electromagnetic wave radiation during the opening process. In this paper, an experimental research platform is established, and the influence of the load type on the electromagnetic wave radiation during the opening process is studied by testing the resistance, inductance and capacitance loads. The research results show that the arcing time and visible arcing times of breaking capacitive loads are significantly greater than resistive and inductive loads.

Keywords: Circuit breaker, load type, radiated electromagnetic waves.

1. Introduction

Because of the large number, and the role of protection and control, circuit breakers are one of the most important power equipment in the power system. Their safe and reliable operation greatly affects the reliability of the entire power system [1-3]. The research of circuit breaker defect detection has been paid close attention to by people [4, 5]. The arc extinguishing performance of the circuit breaker make it one of the most important properties [6].

2. Test Platform and Method

2.1. Test platform

To verify the effectiveness of the method, a simulation circuit breaker platform was built in the laboratory. The test circuit is shown in Fig.2. The moving contact is grounded through the load, and the dynamic contact is controlled to complete the analog opening process. The test condition is limited. The breaking is done in the air and is not filled with SF6. The simulation platform consists of stepper motor (maximum speed 3m/s), motor control box, tie rod (epoxy resin), simulated arc extinguishing chamber (metal cavity, epoxy glass plate, real dynamic and static contact system) and insulation bracket. The appearance is shown in Fig.3.
The simulated circuit breaker has a transparent housing, and the process of the arc can be recorded using a high-speed camera. The speed of the high-speed camera is 1000 frames/s.

2.2. Test method
First, the test first disconnected the 23kΩ pure resistance load, measured the radiated electromagnetic wave signal and the voltage and current signal, and the high-speed camera took pictures of the arcing process. Then disconnect the 0.2μF capacitor and 3.6H inductive load respectively, and repeat three sets of test data for each test. Through comparative analysis, we can find the influence of different types of loads on arc combustion and radiated electromagnetic waves.

3. Test Results

3.1. Resistive load
When the circuit breaker breaks the 23kΩ resistance load, the measured electrical signal of the typical breaking process is shown in Figure 3. The typical arcing process captured by the high-speed camera at the time of opening is shown in Figure 4.
Figure 3. Electromagnetic wave signal when breaking resistive load

Figure 4. Arcing when breaking resistive load
It can be seen from the images captured by the high-speed camera that the arc can be captured at -21ms, and electromagnetic wave signals are radiated to the outside at the same time, and then the arc reignites or intensifies combustion at the current zero crossing point, and radiates electromagnetic wave signals to the outside. At 18ms, there is no obvious arc and the voltage and current become zero, and the arc is completely extinguished. It can be seen that the arc burning time is longer when the resistance load is interrupted, which lasts about 39ms, and the number of arc burning is 4 times.

3.2. Inductive load
When the circuit breaker breaks the 3.6H inductive load, the measured electrical signal of the typical breaking process is shown in Figure 5. The typical arcing process captured by the high-speed camera at the time of opening is shown in Figure 6.

![Figure 5. Electromagnetic wave signal when breaking inductive load](image-url)
From the images captured by high-speed cameras, it can be seen that the arc can be captured at -10ms, and electromagnetic wave signals are radiated to the outside at the same time, and then the arc reignites or intensifies combustion at the current zero crossing point, and radiates electromagnetic wave signals to the outside. At 29ms, there is no obvious arc and the voltage and current become zero, the arc is completely extinguished. It can be seen that the arc burning time is longer when the resistance load is interrupted, which lasts about 39ms, and the number of arc burning is 4 times.

3.3. Capacitive load
When the circuit breaker breaks the 0.2μF capacitive load, the measured electrical signal of the typical breaking process is shown in Figure 7. The typical arcing process captured by the high-speed camera at the time of opening is shown in Figure 8.
Figure 8. Arcing when breaking capacitive load
It can be seen from the images captured by the high-speed camera that the arc can be captured at 12ms, and electromagnetic wave signals are radiated to the outside at the same time, and then the arc reignites or intensifies combustion at the current zero crossing point and radiates electromagnetic wave signals to the outside. The arc is completely extinguished at 70ms. It can be seen that the arc burning time is longer when breaking the resistance load, which lasts about 58ms, and the number of arc burning is 6 times.

4. Comparison and Analysis
Compare the arcing time and visible arcing times under different types of loads, as shown in Table 1. It can be found from the table that the arcing time and visible arcing times of breaking the capacitive load are obviously greater than that of the resistive and inductive loads, and there is a phase difference between the voltage and current signals in the capacitive load and the inductive load. It can be clearly seen that the arc is in the current it goes out at zero crossing.

**Table 1.** Arcing time and visible arcing times under different types of loads.

| Type of load | Arcing duration | Visible arcing times |
|--------------|-----------------|----------------------|
| Resistive    | 39ms            | 4                    |
| Inductive    | 39ms            | 4                    |
| Capacitive   | 58ms            | 6                    |

5. Conclusion
The test results show that the arcing time and visible arcing times of breaking capacitive loads are significantly greater than resistive and inductive loads. Therefore, when using radiated electromagnetic waves to evaluate the arc extinguishing performance of circuit breakers, the impact of load types on the test results must be considered.

References
[1] CHEN Lijuan, LI Xia. Statistic analysis on reliability of power transmission and transformation facilities in China in 2011 [J]. Electric Power, 2012, 45 (7): 89 - 93.
[2] CHEN Lijuan, HU Xiaozheng. Statistic analysis on reliability of power transmission and transformation facilities in China in 2010 [J]. Electric Power, 2011, 44 (6): 71 -77.
[3] Heising C R, Colombo E, Janssen ALJ, Maaskola JE, Dialynas E. Final report on high voltage circuit breaker reliability data for use in substation and system studies (Report on behalf of WG 13. 06). CIGRE Seession 1994, 13 – 201.
[4] H UANG Xingquan, WANG Wei, ZHANG Yuxiao, XIE Wei, LI Qi, FAN Fei, LI Chengroung. Mechanical properties detection of circuit breaker by high speed digital camera method [J]. Journal of North China Electric Power University, 2011, 38 (05): 43 - 47.
[5] MA Hongming, WANG Wei, CHENG Zhiwan, LI Zhenciao. Non-contact Charged Detection for Circuit Breaker Three-Phase Un-Synchronization Time Based on UHF Method [J]. Southern Power Grid Technology, 2018, 12 (01): 27 - 32.
[6] WANG Chao. Research on Arc Fault Circuit Breaker [D]. Shenyang: Shenyang University of Technology, 2009.