Determination Method of Contact Ablation Degree of Circuit Breaker in Power System Based on Radiated Electromagnetic Wave Detection

Xiao Bing Zhao¹, Chao Wang¹, Xiao Ping Man¹, Bo Yu¹, Yong Xin Piao¹, Jie Yang¹ and Yu Ding¹*

¹ State Grid Tonghua Power Supply Company, Tonghua, Jilin, 134000, China
Corresponding author’s e-mail: stategridtonghua@163.com

Abstract. Power is the most important energy in the current society, so it is very important to ensure the stable operation of the power system. In order to determine the state of the circuit breaker in the power system effectively, the power supply is stable. This paper presents a method to determine the ablation degree of the contact of the circuit breaker based on the radiation electromagnetic wave detection. The method adopts the means of electrical measurement and waveform observation to realize the rapid diagnosis of the contact ablation degree of the circuit breaker. The antenna is used to receive the radiated electromagnetic wave generated in the opening process of the circuit breaker, and the common oscilloscope is used to monitor the waveform. The number of electromagnetic wave pulses per unit time is analyzed to determine the ablation degree of the circuit breaker contact. If the number of pulses found by oscilloscope is large, it can be judged that the contact ablation is serious. The method mentioned in this paper belongs to the field of electrical engineering, which is mainly used to determine the ablation degree of the contact of the circuit breaker by means of electrical detection. This method has the advantages of simplicity, rapidity and efficiency.

1. Introduction

Circuit breaker is widely used in power system. Its main function is to automatically cut off the circuit in case of serious overload, short circuit and undervoltage, so as to control the voltage stability of power system.[1-3] Under long-term working conditions, the contact of circuit breaker will be ablated due to the high temperature and high pressure environment or arc burning in the process of opening. [4-5]The ablated contact will affect the opening performance of circuit breaker, and the circuit breaker with serious ablation will produce some faults, such as inflexible operation and improper opening, which seriously threaten the safety and stable operation of power grid. Therefore, it is very important to find the characteristic variable which can reflect the ablation degree of circuit breaker contact for the performance evaluation of circuit breaker, and it is also one of the key parameters to reflect its performance.[6-7]

But at present, there is no effective method to determine the ablation degree of circuit breaker contact. Moreover, there are not many research results in this aspect, and the fault diagnosis methods and equipment of circuit breaker are not perfect. [8-10]Especially in the actual working conditions, due to the large number of circuit breakers running in the power system, and the rapid economic development, there are many practical problems, such as the lack of equipment outage opportunities or opportunities, which make this type of detection method difficult to use in practice. At present, most of them are based on preventive measures and empirical diagnosis, and there are few intuitive and
effective diagnostic methods. The existing detection and diagnosis methods can not meet the development requirements of security, stability and economy of power system no matter from the perspective of security and economy.[11-12]

Based on the above situation, this paper proposes a method to determine the degree of circuit breaker contact ablation by detecting the radiated electromagnetic wave generated by contact opening and analyzing the number of electromagnetic pulse per unit time.

2. Design ideas
For the contact defect of power circuit breaker, electrical measurement and waveform observation can be used to realize rapid diagnosis. The antenna is used to receive the radiated electromagnetic wave generated in the opening process of the circuit breaker, and the common oscilloscope is used to monitor the waveform.[13] The number of electromagnetic wave pulses per unit time is analyzed to determine the ablation degree of the circuit breaker contact. If more pulses are found, it can be judged that the contact is seriously ablated.

When the circuit breaker contacts are switched on or off, a variety of electromagnetic wave signals generated by discharge will occur in the insulation air gap. The radiated electromagnetic wave sensor is installed on the test bench, which is directly opposite to the moving and static contacts to collect the electromagnetic wave signals during the arc breaking process of the circuit breaker. The experimental environment will be subject to electrical interference, but according to the actual measurement, these electromagnetic interference signals are about several hundred megahertz, and the RF signal is GHz level, so in the field experiment, the sensor with the working frequency band of 0.5-2ghz is selected for electromagnetic signal acquisition. In this experiment, the RF signal after detection is used for sampling and analysis.[14-15]

When the switch is closed, the distance between the moving and static contacts decreases gradually. When the dielectric resistance between contacts is lower than the voltage between the contacts, the dynamic and static contacts will break down and then generate arc. At the moment of breakdown, the current between the dynamic and static contacts increases rapidly, and a sudden magnetic field is generated in space. The magnetic field then excites a sudden electric field, which then excites a sudden magnetic field, and circulates repeatedly, and then generates an electromagnetic wave signal in space. In the field test, the signal received by the radiated electromagnetic wave sensor is excited by its fast and frequent discharge signals. These discharge signals are very weak, so the received electromagnetic wave is also very weak. Therefore, a signal amplifier should be connected before the output is connected to the oscilloscope. In order to reduce the interference signal up to several hundred MHz in the field, the minimum frequency of the selected signal amplifier should be lower. The frequency is higher than the interference signal frequency, and the bandwidth is as high as possible to prevent the leakage of electromagnetic wave signal with arc extinguishing characteristics. Therefore, a signal amplifier with a gain of 20dB is adopted, and the characteristic curve is roughly as shown in Figure 1.

![Figure 1. Frequency gain curve of signal amplifier](image-url)
3. Simulation experiment

The method proposed in this paper belongs to an internal defect detection method of power circuit breaker, which is characterized by using the waveform characteristics of radiated electromagnetic wave to extract the number of electromagnetic pulse per unit time to determine the ablation degree of circuit breaker.

Three kinds of circuit breakers with different ablation degree are selected for simulation experiments. The experimental results show the relationship between radiation electromagnetic wave and contact ablation degree. The acquisition of electromagnetic wave is mainly accomplished by antenna receiving by using the built-up experimental platform. The signal source is amplified by signal amplifier, and the signal is transmitted to the oscilloscope, and then the number of pulses of the waveform is analyzed on the ordinary oscilloscope.

The experimental results are shown in Figure 2. The figure shows the schematic diagram of radiated electromagnetic wave under three ablation conditions of circuit breaker contact. Among them, (a) (b) (c) in the figure respectively show the schematic diagram of radiated electromagnetic wave when the contact is brand new, the contact is ablated, and the contact is seriously ablated when the circuit breaker is opened. The degree of contact ablation can be determined by analyzing the number of pulses of electromagnetic wave. From figure (a), we can see that the number of pulses is 1, so the contact is basically not ablated and the contact is well preserved; the number of pulses in figure (b) is about 3 ~ 6, so the contact is ablated, but it is not too serious; the number of pulses in figure (c) is more than 10, so the contact is seriously ablated. Therefore, there is a positive correlation between the ablation degree and the number of electromagnetic pulses. The more the number of pulses, the more serious the ablation.

4. Conclusion

The breaking performance of circuit breaker is closely related to the process of arcing and extinguishing. When the circuit breaker is working, the contact will be affected by arcing and other factors, resulting in varying degrees of ablation. In this paper, the method of radiated electromagnetic
wave is used to detect the contact ablation of circuit breaker. By monitoring the radiated electromagnetic wave of circuit breaker, the degree of contact ablation of circuit breaker is determined. Through the simulation experiment, it can be seen that the judgment method of contact ablation degree of circuit breaker proposed in this paper has obvious advantages such as intuitive, simple, fast and efficient. Different state characteristics of power equipment will produce different electromagnetic waves when it works. By monitoring the changes of electromagnetic waves, we can better find the defects in the equipment. The radiated electromagnetic wave method can also be applied to the detection of other kinds of power equipment in the future.

Acknowledgments
Here, I would like to express my thanks to the leaders of State Grid Tonghua Power Supply Company for their support to our scientific research work. At the same time, thanks to all the members of our team.

References
[1] Alan Meier, Tsuyoshi Ueno, Marco Pritoni. Using data from connected thermostats to track large power outages in the United States[J]. Applied Energy, 2019, 256.
[2] Dominanni Christine, Ahmed Munerah, Johnson Sarah, Blum Micheline, Ito Kazuhiro, Kathryn. Power Outage Preparedness and Concern among Vulnerable New York City Residents, [J]. Journal of urban health: bulletin of the New York Academy of Medicine, 2018, 95(5).
[3] Zhao Wenqiang, Zhang Haibo, Wu Shijing, et al. Optimization of Shaft Sleeve Slippage in High-Voltage Circuit Breaker Operation Mechanism[J]. Open Mechanical Engineering Journal, 2015, 9(1):1081-1091.
[4] Zhang Song, Wang Yang, Zhang Wei. The Effect of Measurement Instrument Input Impedance on the Opening and Closing Speed of the Circuit Breaker[J]. Febs Letters, 2014, 9(2):103-104.
[5] Huang J, Hu X, Yang F. Support vector machine with genetic algorithm for machinery fault diagnosis of high voltage circuit breaker[J]. Measurement, 2011, 44(6):1018-1027.
[6] Yoshizumi T, Ibi K, Hosomi M, et al. Hot gas flow analysis in SF6 gas circuit breaker during the short circuit interruption[J]. IEEE Transactions on Power Delivery, 1989, 4(3):1757-1764.
[7] Trepanier J Y, Reggio M, Lauze Y, et al. Analysis of the dielectric strength of an SF6 circuit breaker[J]. IEEE Transactions on Power Delivery, 1991, 6(2):809-815.
[8] Reggio M, Trepanier J, Camarero R, et al. Computer aided tools in gas circuit breaker design[J]. IEEE Transactions on Power Delivery, 1990, 5(1):163-169.
[9] Kim M H, Kim K H, Smajkic A, et al. Influence of contact erosion on the state of SF6 gas in interrupter chambers of HV SF6 circuit breakers[C]. 2014 IEEE International Power Modulator and High Voltage Conference (IPMHVC). IEEE, 2014.
[10] B. Bosovic, A. Smajkic, M. Muratovic, et al. Simulation and validation of pressure rise in a HV circuit breaker with SF6 and alternative interrupting media, 2017 4th International Conference on Electric Power Equipment - Switching Technology (ICEPE-ST), Xi’an, 2017, 76-79.
[11] Tominaga S, Kuwahara H, Hirooka K, et al. SF 6 Gas Analysis Technique and Its Application for Evaluation of Internal Conditions in SF 6 Gas Equipment[J]. IEEE Transactions on Power Apparatus and Systems, 1981, PER-1(9):4196-4206.
[12] Chu, F. Y. SF6 Decomposition in Gas-Insulated Equipment[J]. IEEE Transactions on Electrical Insulation, 1986, EI-21(5):693-725.
[13] Derdouri, A, Casanovas, J, Grob, R, et al. Spark decomposition of SF6/H2O mixtures[J]. IEEE Transactions on Electrical Insulation, 1989, 24(6):1147-1157.
[14] Belmadani B, Casanovas J, Casanovas A M. SF 6, decomposition under power arcs. II. Chemical aspects[J]. 1991, 26(6):1177-1182.

[15] Belarbi A, Pradayrol C, Casanovas J, et al. Influence of discharge production conditions, gas pressure, current intensity and voltage type, on SF6 dissociation under point–plane corona discharges[J]. Journal of Applied Physics, 1995, 77(4):1398.