Development of Simulated Disturbing Source for Isolation Switch

Lin Cheng[1], Xiang Liu[2], Xiaoping Deng[2], Zhezhe Pan[3], Hang Zhou[4], Yong Zhu[4,*]

[1]Electric Power Research Institute of Shaanxi Electric Power Company, Shaanxi, China
[2]China Electric Power Research Institute Limited Company, Beijing, China
[3]Wuhan Nanrui Limited Liability Company of State Grid Electric Power Research Institute, Wuhan, China
[4]School of Wuhan University, Wuhan, China

*Corresponding author e-mail: zhuyong-whu@qq.com

Abstract. In order to simulate the substation in the actual scene of the harsh electromagnetic environment, and then research on electromagnetic compatibility testing of electronic instrument transformer, On the basis of the original isolation switch as a harassment source of the electronic instrument transformer electromagnetic compatibility test system, an isolated switch simulation source system was developed, to promote the standardization of the original test. In this paper, the circuit breaker is used to control the opening and closing of the gap arc to simulate the operating of isolating switch, and the isolation switch simulation harassment source system is designed accordingly. Comparison with the actual test results of the isolating switch, it is proved that the system can meet the test requirements, and the simulation harassment source system has good stability and high reliability.

1. Introduction

With the rapid construction and development of intelligent substations, electronic transformers are widely used because of their unique advantages such as high measurement accuracy, wide transient response range, simple insulation structure, small size, light weight, no saturation and other unique advantages. But with the increase in the number of applications, electronic transformer in the operation of the number of failures increased significantly, one of the most prominent is the field of electromagnetic environment on the impact of electronic transformer operation. Therefore, how to improve the electromagnetic compatibility of electronic transformers, as well as improve the long-term stability of electronic transformers has become the focus of the current power system concerns [1-6].

At present, proposed "anti-immunity test of electronic transformer under isolation switch separating with capacitive small current" test has been included in the electronic transformer network must be carried out test, this experiment is the most stringent electromagnetic disturbance test of the electromagnetic compatibility test method of electronic transformer. Although the experimental operation seems simple, but the test experiment in the actual operation of the following aspects of the problems and deficiencies:

(1)The actual time of the resignations and extinguishment of the gap arc between the contacts due to the isolation switch operation is uncertain and randomized, resulting in the experiment being not reproducible.

(2)Although the test is a system-level test, but in the course of the process found a lot of problems, such as transient electromagnetic pulse intensity cannot control, transient electromagnetic process the overall time is not control, ground potential of tested equipment is not controllable.

On the whole, these problems set a great obstacle to the standardization of the test. In order to promote the standardization of the original experiment, this paper studies the isolated harrowing source system, and laid a solid foundation for the standardization implementation of the electronic transformer immunity test based on the isolating switch simulation harassment source, and thus provides a solid foundation for the stable operation of the power system.

2. Theoretical analysis and design principle of isolating switch simulation harassment source

In order to advance the standardization of the test and solve the problems in the test process, this paper designs an isolated switch simulation source system based on the original isolation switch as the disturbance source of the electronic transformer immunity test system.

2.1. Design of isolation switch simulation harassment source system

Isolated switch simulation harassment source system design mainly considers the following aspects:

(1) Equivalence: In order to produce a similar arc, a suitable discharge medium must be selected. Group after a large number of tests, the final choice of discharge ball gap as the generator of the arc.

(2)Standardization: In order to solve the problem, this paper chooses the method of setting the vacuum switch before the discharge gap, and uses the switching of the control circuit breaker to solve the problem of the discharge time control of the discharge gap because the isolation switch is highly dispersible as the disturbance source, so the overall time of each test transient electromagnetic process is uncontrollable, so that the electromagnetic field effect of each test is less reproducible.

(3) Controlled: This paper proposes to control the separation of the vacuum circuit breaker by using the circuit breaker operation control instrument to control the on- Which includes the gap discharge conduction and turn off, which can be better to achieve the transient electromagnetic pulse control of the time. In addition, by adjusting the gap spacing and power side and load side capacitance, can be more precise control of the intensity of transient electromagnetic pulse.

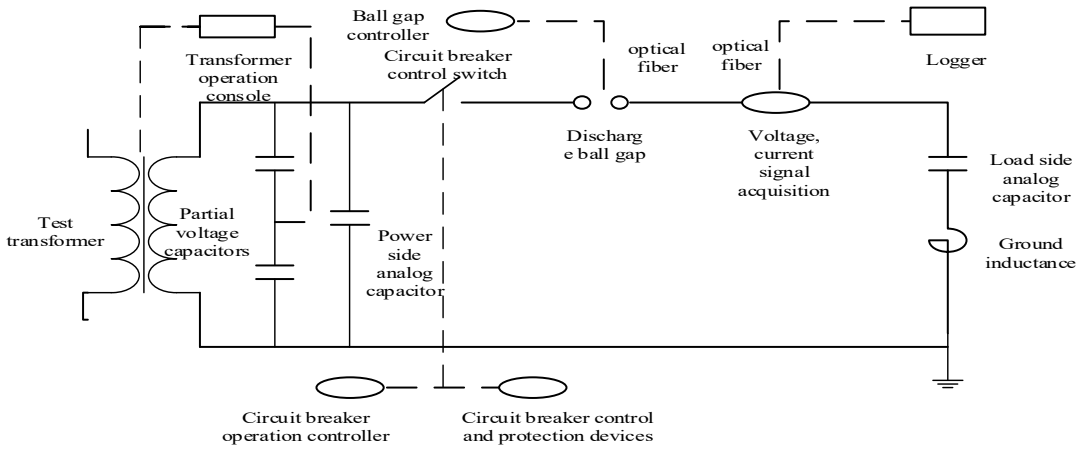


Figure 1 Isolating switch simulation harassment source system

2.2. Analysis of quarantine switch simulation source system

Based on the above basis, this paper presents an isolated switch simulation source system, which consists of a high-voltage primary device that generates a disturbance of electromagnetic pulse and a

secondary device that plays a role in controlling and detecting [7], as shown in Figure 1. The design principle is that the simulated harassment source test is achieved by repeatedly charging a capacitor and discharging it to the capacitive load by the gap. The overvoltage applied to the load, such as an operational shock with an exponentially attenuated sinusoidal waveform.

The primary device of isolation switch simulation harassment source includes test transformer, capacitive voltage divider, adjustable ground inductance, power side analog capacitor, vacuum circuit breaker switch, discharge ball gap and load side analog capacitor.

The formation of pulse oscillation on the load voltage waveform is achieved by the discharge of the charging capacitor, this discharge produces a steeper than the lightning impulse, and be similar to the transient impact signal of the isolation switch operation [8]. Set the initial charging voltage of the charging capacitor as U_{C0}, the total branch of the load branch is set to X ,so $X = \frac{1}{\omega^2 C_2} + L$,

When the circuit is oscillating, Loop current i , Charging capacitor U_{C1} and the voltage across the load U_{C2} can be expressed as:

$$i = -\frac{1}{\omega X} U_{C0} e^{-\delta t} \sin(\omega t) \tag{1}$$

$$U_{C1} = \frac{\omega_0}{\omega} U_{C0} e^{-\delta t} \sin(\omega t + \beta) \tag{2}$$

$$U_{c2} = \frac{\omega_0}{\omega} U_{C0} e^{-\delta t} \sin(\omega t - \beta) \tag{3}$$

In (1) - (3), $\omega_0 = 1/\sqrt{XC_1}$ is the oscillation angle frequency. $\delta = R/(2X)$ is the attenuation factor. $\omega = \sqrt{\omega_0^2 - \delta^2}$ is the actual oscillation angle frequency. $\beta = \arctan(\omega/\delta)$ is the initial phase.

When δ is small enough, $\omega_0 = \omega$, at this point the voltage on the load can be approximated as equation (4), the oscillation frequency can be approximated by (5):

$$U_{c2} = U_{C0} e^{-\delta t} \sin(\omega t - \pi/2) \tag{4}$$

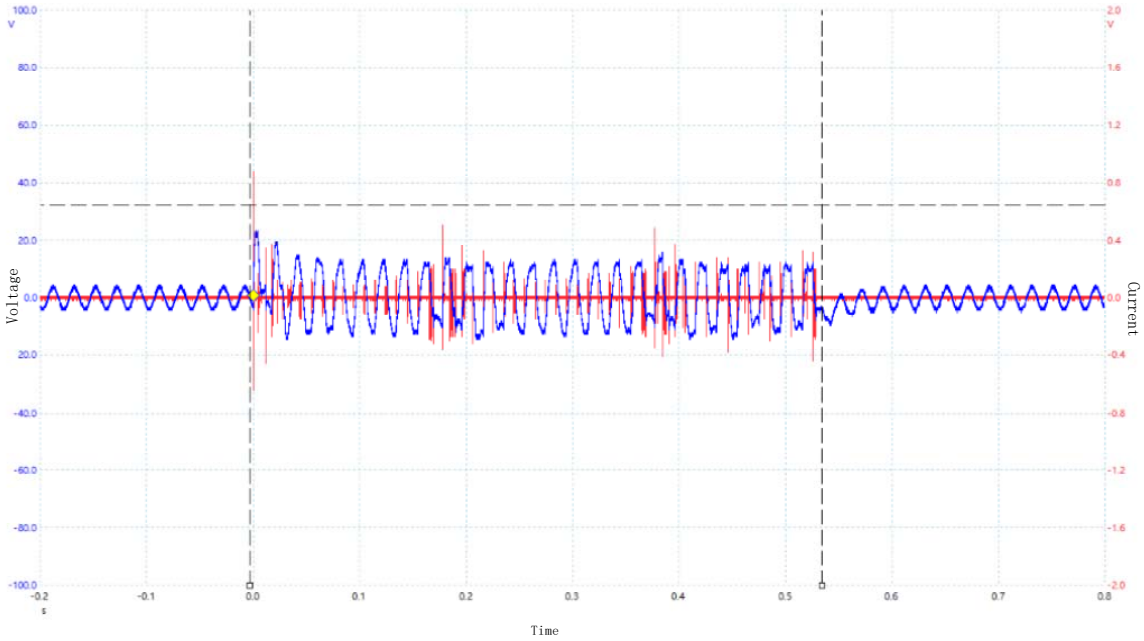
$$f = \frac{1}{2\pi\sqrt{XC_1}} \tag{5}$$

From the specific experimental data from the back, it can be seen that the simulated disturbance source is indeed a transient signal similar to that of the isolated switch operation.

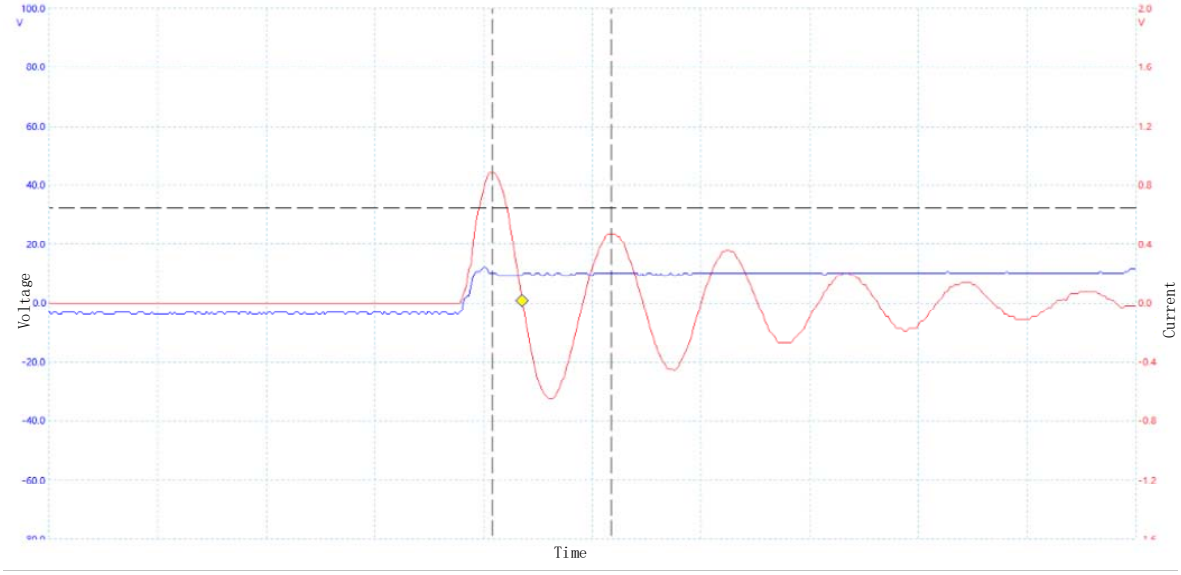
3. Experimental verification of simulated disturbance source of isolated switch

3.1. Simulated harassment source experiment

Simulation of disturbance source circuit parameters are as follows: the power side of the capacitor is 1000pF, load side capacitance of 1000pF case, the gap distance of 20mm, the primary voltage is 50kV. The experimental data are as follows:



(a)Full waveform



(b)Current pulse magnification

Figure 2 Simulation harrow source circuit experimental data

When the ball gap distance is adjusted to 20 mm and the primary voltage is set to 50 kV and operating, set the circuit breaker operating controller to "close-delay-open", and the delay is set to 500ms, it will get the maximum transient pulse current waveform as figure 2. Where Figure 2 (a) shows the full current of the voltage and current, the red waveform in the figure is the current waveform, and the blue waveform is the voltage waveform. Figure 2(b) is an enlarged view of the current pulse. The average overvoltage of this experiment is1.67p.u., the maximum overvoltage is 1.86p.u., the average pulse current is 507A. From Figure 2 (a) shows that the maximum pulse current in the experiment is 578A. As can be seen from Figure 2 (b), the rise in voltage and current is about 211ns, the equivalent frequency is 1.18MHz.

3.2. Isolation switch splicing transient test

In order to verify the effectiveness of the isolated switch simulation source system, a 500kV isolating switch test was carried out, and the test results were compared with the simulated disturbance source system test in this project. Isolation switch split transient test principle wiring as shown in Figure 3[9].

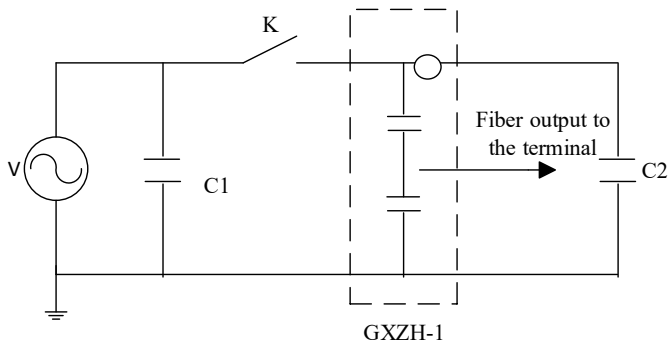
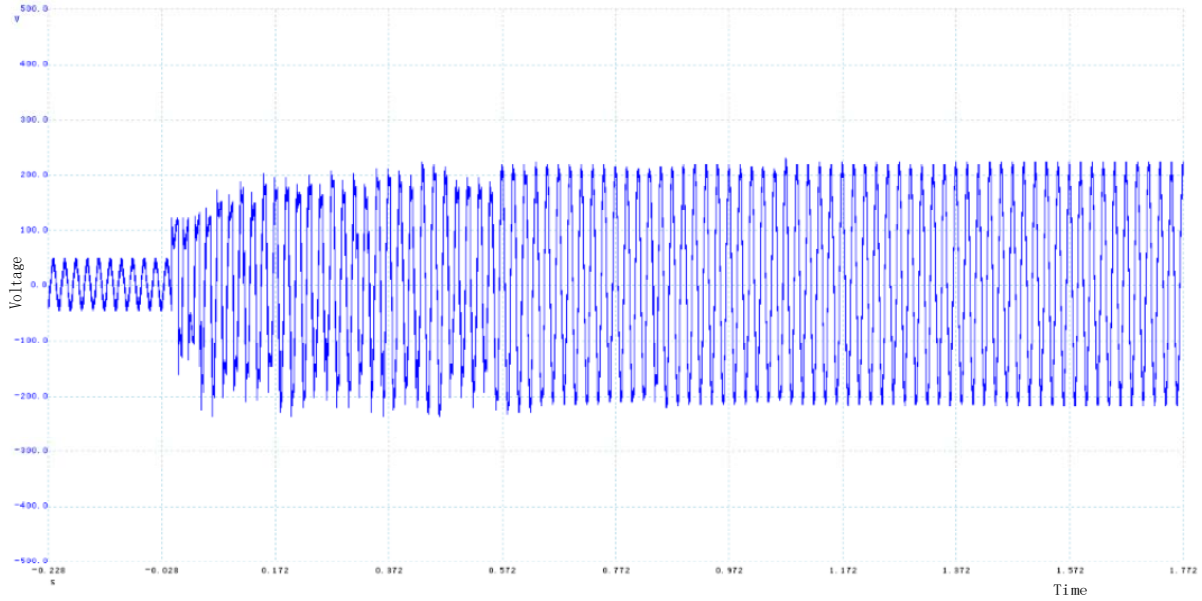
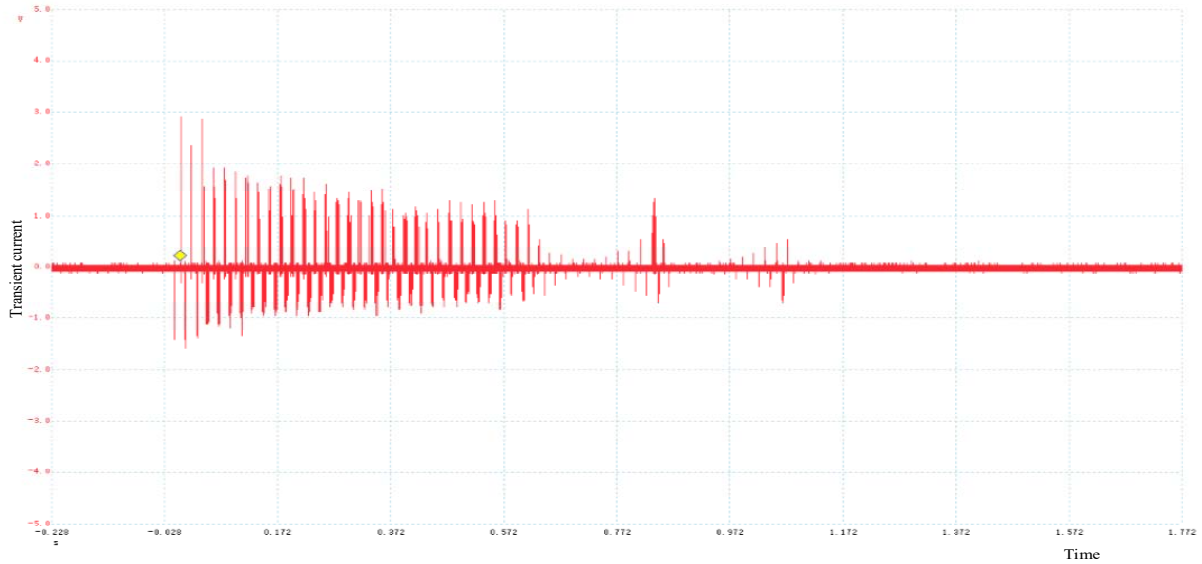


Figure3 Schematic diagram of isolation switch split transient test

This experiment is for single-phase isolation switch test, in Figure 3, V is the AC high voltage test power supply, C1 is the capacitor of 5000PF, C2 is the capacitor of 5000PF, GXZH-1 is a combination of fiber-optic voltage and current measurement system, K is 500kV isolation switch. The average overvoltage measured by experiment is 1.1p.u., maximum overvoltage is 1.3p.u., When the power supply voltage is 250kV, the maximum pulse current is 2180A.



(a)isolation switch closing voltage



(b) Isolation switch closing current

Figure 4 500kV isolation switch closing test

In Figure 4, (a) shows the transient overvoltage, and (b) shows the transient overcurrent when the 500kV Isolated Switch is closed. It can be seen from Figure 4 that the closing process of the isolation switch is a typical transient process waveform of the switch breakage gap because gap arc continues to reignite. Comparing the voltage waveform produced by the simulated disturbance source shown in Figure2 (a), since the isolation switch test is only a single "minute" or "combined" test, so after the process of the isolation switch "together", it is a continuous power frequency voltage waveform. But the simulated harassment source can precisely control the operating time for "minute" and "combined", so the transient process of the disturbance source on both sides is only interference waveform. The above two kinds of voltage waveforms are transient over-voltage and arc reigniting, indicating that the two principles of the process are consistent. In addition, the transient overvoltage in Figure 2 (a) is the average overvoltage, and it is 1.67p.u., the maximum overvoltage is 1. 86p.u, which are significantly greater than the maximum overvoltage of the isolation switches of 1.3p.u., indicating that simulated harassment sources can produce more severe overvoltage. Therefore, from the transient voltage and current waveform point of view, the simulation of the source of interference for the electronic transformer immunity test is valid.

4. Conclusion

In this paper, the principle of isolation switch operation is simulated by ball gap discharge, and the isolating switch is designed. And carried out theoretical analysis, comparison test of transient splitting process of 500kV isolated switch and simulated disturbance source of isolating switch, reach the following conclusions:

(1) The isolating switch simulates the disturbing source circuit to produce a transient voltage current signal similar to the attenuation signal generated by the isolate switch operation;

(2) The performance of the isolating switch simulates the disturbance source arrive at the original design requirements. The transient characteristic data measured in the splitting process of isolating switch by the disturbance source system is normal, and it can be effectively applied to the detection of the immunity performance of the electronic transformer.

(3) The design advantage of simulated harassing source circuit lies in that transient electromagnetic pulse intensity and the role of time is controllable, it can be very good to promote the test of electronic transformer electromagnetic compatibility test performance standardization.

Acknowledgments
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