Design of electromagnetic compatibility test platform for transformer fire-fighting nitrogen injection extinguishing system

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Abstract. The transformer fire-fighting nitrogen injection extinguishing system plays an important role in preventing transformer fires in the field of power transformation. However, the fire-fighting system operating on site is often misoperation or non-operation caused by electromagnetic interference and other factors, which affects the reliability of transformer fire extinguishing. This paper builds an electromagnetic compatibility platform for the fire control cabinet of the transformer oil discharge and nitrogen injection system to develop the simulation system of the oil discharge and nitrogen injection fire extinguishing device, and study the factors affecting the reliability of the oil discharge and nitrogen injection fire extinguishing device. Electromagnetic compatibility test refers to a test that uses electromagnetic interference detection equipment and electromagnetic interference generation equipment to assess the electromagnetic compatibility of systems and equipment under laboratory or external environmental conditions. The electromagnetic compatibility test is mainly divided into electrostatic test, electric fast pulse EFT, surge impact and so on.

1. Introduction
In the process of power conversion and transmission, oil-immersed power transformers play a very important role. Transformer oil with insulating properties is stored inside the transformer oil tank. The transformer oil itself is a flammable substance, and there is a danger of fire. Compared with the water spray fire extinguishing system, the transformer oil discharge and nitrogen injection fire extinguishing device has the advantages of adapting to the complex working environment, low device cost, convenient installation, and small maintenance. It has been widely used in the power system [1-3]. Based on the on-site electromagnetic environment, the electromagnetic compatibility platform of the transformer oil discharge and nitrogen injection system designed in this paper. The electromagnetic compatibility platform includes the system power supply and signal Inject electromagnetic interference signals into weak parts such as the interface, human-machine interface display and chassis, and other internal components, and obtains the current operating status of the test product through the detection platform, and locates the part caused by the interference in the system that cannot operate normally.

The electromagnetic compatibility platform of the transformer oil discharge and nitrogen injection system is shown in Figure 1.
Research on electromagnetic interference of fire control cabinet

This paper studies the generation of electromagnetic interference on site, simulates typical electromagnetic interference signals, and designs the input channels of electromagnetic interference: electromagnetic interference sources, coupling channels and sensitive devices. The specific model is shown in Figure 2. The signal generated by the electromagnetic interference source is coupled to the sensitive equipment through some unconventional way, which damages its working state.

Electromagnetic interference sources mainly simulate space and signal interference, electromagnetic radiation and static electricity in space, signal surges and electrical fast pulses. The coupling path is the intermediate medium through which electromagnetic interference acts on the sensitive equipment. It is generally divided into two types: conduction coupling and radiation coupling. There is a power line of a certain device or system in a noise environment. When the noise in the environment acts on the power line and is transmitted to the device or system by it; and the electromagnetic wave generated by the change of current or voltage in the circuit of the device Acting on other equipment or systems and interfering with other signals is also one of the coupling propagation paths. Generally, any electronic device or circuit is a sensitive device, especially the critical signal in a digital circuit is easily affected by electromagnetic interference.

The substation is in a strong magnetic field environment, and the electromagnetic field near the main transformer is stronger. In the event of lightning strikes, switching operations, reactor switching, and equipment short-circuit failures, they may cause greater electromagnetic interference, and the oil discharge and nitrogen injection system loop There are a large number of low-voltage electrical modules. The electrical circuit cables and electrical modules need to pass through or be arranged in strong magnetic fields such as the main transformer or 220kV power distribution device site. Once an interference signal is generated, it is very easy to cause false alarms or start-up oil discharge in the nitrogen system works.

Electromagnetic interference simulation of fire control cabinet

3.1 Static simulation generation test

The electrostatic test can be divided into two modes: direct discharge Contact discharge gun and indirect discharge Air discharge gun. In the electrostatic test, 20 fixed-point discharges are used, and the discharge time is 1 time/second. At the same time, in order to ensure the repeatability and comparability
of the results, the discharge electrode is perpendicular to the surface of the device under test. The electrostatic test standard is GB/T17626.2 (IEC61000-4-2). The discharge points adopted in the electrostatic test are the four vertices of the display screen and the transformer fire control cabinet. Through the analysis of the experimental data, it is concluded under what conditions can the display screen reflect the actual operation of the transformer and the transformer oil and nitrogen injection system will not malfunction [5].

![Schematic diagram of electrostatic test configuration](image)

Table 1. Verification discharge test data table during static tester

| Voltage/KV | Rise Time/ns | The Current of 30ns/A | The Current of 60ns/A |
|-----------|--------------|-----------------------|-----------------------|
|           | allowance (1±15%) Check value | allowance (1±25%) Check value | allowance (1±30%) Check value | allowance (1±30%) Check value |
| 2         | 7.5          | 7.06                  | 0.8                   | 0.860                  | 4                      | 4.00                  | 2                      | 1.90                  |
| 4         | 1.5          | 13.72                 | 0.8                   | 0.849                  | 8                      | 7.38                  | 4                      | 3.69                  |
| 6         | 22.5         | 21.01                 | 0.8                   | 0.886                  | 12                     | 12.01                 | 6                      | 5.72                  |
| 8         | 30           | 28.11                 | 0.8                   | 0.882                  | 16                     | 16.07                 | 8                      | 7.51                  |
| -2        | 7.5          | -7.08                 | 0.8                   | 0.863                  | -4                     | -4.02                 | -2                     | -1.92                 |
| -4        | 15           | -13.69                | 0.8                   | 0.852                  | 8                      | -7.41                 | -4                     | -3.71                 |
| -6        | 22.5         | -21.15                | 0.8                   | 0.883                  | -12                    | -12.11                | -6                     | -5.82                 |
| -8        | 30           | -28.32                | 0.8                   | 0.814                  | -16                    | -16.46                | -8                     | -7.50                 |

3.2 Surge simulation test

The cause of the surge is related to the start and stop of the equipment inside the power supply system and the failure of the power supply network. The surge signal generator required for the surge test is applied to the signal line through the probe. During the verification, the parameters are the wavefront time and half-peak time of the generator output signal open circuit voltage/short circuit current, and the amplitude of the output voltage should be verified value. The surge test needs to meet GB/T17626.5 (IEC61000-4-5). The surge test needs to connect the surge generator to the signal line of the transformer fire control cabinet to detect the degree of interference of different intensity surge signals to the fire control cabinet.
Figure 4. Schematic diagram of surge test configuration

Surge occurs in two polarities, with a maximum voltage of 4KV, imitating lightning impact and operating overvoltage impact, impacting the power and signal lines of the transformer fire-fighting nitrogen injection device, and detecting the power supply, signal module, display module, and fire protection inside the device. Whether the system works reliably, the test data is shown in Table 2.

Table 2. Test data of open circuit voltage and short circuit current of surge generator port

| mode          | polarity | Nominal value/KV | Check value KV | Front time μS | Half-peak time μS | Nominal value/KV | Check value KV | Front time μS | Half-peak time μS |
|---------------|----------|------------------|----------------|---------------|------------------|------------------|----------------|---------------|------------------|
| Surge generator side | +        | 0.5              | 0.49           | 1.09          | 50.4             | 0.25             | 0.25           | 8.63          | 19.3             |
|               |          | 1                | 0.96           | 0.96          | 51.7             | 0.5              | 0.51           | 7.75          | 18.2             |
|               |          | 2                | 1.99           | 1.24          | 49.8             | 1                | 1.02           | 7.63          | 19.9             |
|               |          | 4                | 3.98           | 1.10          | 49.4             | 2                | 2.04           | 7.63          | 19.7             |
|               | -        | 0.5              | 0.48           | 1.30          | 45.4             | 0.25             | 0.50           | 8.52          | 79.3             |
|               |          | 1                | 0.96           | 1.32          | 45.0             | 0.5              | 1.04           | 7.75          | 19.8             |
|               |          | 2                | 1.95           | 1.39          | 47.0             | 1                | 2.04           | 7.62          | 19.7             |
|               |          | 4                | 3.86           | 1.27          | 46.4             | 2                | 4.08           | 7.66          | 19.9             |

3.3 Electrical fast transient pulse group immunity test

Electrical fast transient pulse group EFT/B refers to a limited number and clearly distinguishable pulse sequence or a limited duration of oscillation. A single pulse in a pulse group has a specific repetition period, voltage amplitude, rise time, and pulse width. Group pulse generally occurs in the interference caused by many mechanical switches in the power grid during the switching process. Its interference characteristics are: the pulse group interval is 300ms, the single pulse width is 50ns, the pulse amplitude is 2KV, the rising edge of the pulse is 5ns, the pulse repetition frequency is 2.5KHz, and the positive and negative pulse group interference time is 1 minute. The EFT test needs to meet GB/T17626.4 (IEC61000-4-4) Level requirements. During the test, the pulse group generator should be connected to the power line of the transformer oil discharge and nitrogen injection system.
Figure 5. Schematic diagram of EFT test configuration

Electric fast pulse is a source of interference in the substation site, mainly because the power sine wave contains a certain intensity of high-order harmonics, which generally appear in regular groups, which greatly affects the reliability of equipment power supply and signal. The fire-fighting nitrogen injection device needs special electromagnetic protection to ensure that it is not interfered by EFT [7].

The electric fast pulse group generator designed in this paper can be injected into the power line and signal line, and can use the coupling plate to simulate interference to the device cable from space. The test data is shown in Table 3.

Table 3. Verification data of burst generator port

| load          | polarity | Nominal value KV | Peak voltage KV | Rise Time ns | Pulse duration/ns | Repea t frequency/ ns | Burst duration/m s | Burst period ms |
|---------------|----------|-----------------|----------------|--------------|------------------|----------------------|-------------------|-----------------|
| Transformer fire control cabinet | +        | 0.5             | 0.25           | 0.24         | 4.6              | 51.4                 | 5                 | 14.8            | 300.4           |
|               |          | 1               | 0.5            | 0.48         | 4.6              | 48.9                 | 5                 | 14.8            | 300.4           |
|               |          | 2               | 1              | 0.95         | 5.8              | 48.3                 | 5                 | 14.8            | 300.2           |
|               |          | 4               | 2              | 1.9          | 4.7              | 47.6                 | 5                 | 14.8            | 300.4           |
|               | -        | 0.5             | 0.25           | 0.24         | 4.6              | 51.2                 | 5                 | 14.8            | 300.4           |
|               |          | 1               | 0.5            | 0.48         | 5.2              | 47.6                 | 5                 | 14.8            | 300.2           |
|               |          | 2               | 1              | 0.94         | 5.0              | 47.4                 | 5                 | 14.8            | 300.2           |
|               |          | 4               | 2              | 1.94         | 5.5              | 47.4                 | 5                 | 14.8            | 300.2           |

4. Conclusion

With the gradual increase of transformer capacity and voltage level, the power grid puts forward higher requirements for power supply reliability. The power system requires that transformers of 35kV and above must be equipped with fire-fighting nitrogen injection fire-extinguishing devices. At present, the malfunction or non-operation of the control system of the power transformer drain and nitrogen injection fire extinguishing device is the main problem, and electromagnetic compatibility is one of the main factors affecting the reliability of the fire extinguishing device. The EMC platform designed in this paper mainly uses interference signals such as applied surge, EFT electric fast pulse, static electricity and other interference signals to test the reliability of the transformer oil discharge and nitrogen injection system, locate the weak part, and develop the technical plan for the improvement of the oil discharge and nitrogen injection fire extinguishing device. The EMC platform designed in this paper provides an effective technical means to improve the reliability of the oil discharge.

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