The Development of an Intelligent Zinc Oxide Lighting Arrester Tester

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Abstract. Zinc oxide arrester is often used as lightning protection device in 10KV distribution network. In order to check the reliable operation of the zinc oxide arrester, preventive tests are often carried out. In this project, the intelligent tester adopts high-precision clamp current mutual inductance technology as the front-end acquisition mode of current signals; Magnetic isolation technology is used to ensure the accuracy of current and voltage sampling and the anti-interference ability and testing accuracy of the instrument are improved by using fast Fourier transform for data processing. The integrated application of several technologies provides a basis for judging the operating state of the 10kV zinc oxide arrester. The charged measurement of operating parameters of 10kV zinc oxide arrester is realized and the measurement efficiency is improved.

1. Introduction
10KV distribution grid is the most complex link of the use environment in the power network. In order to ensure safety, lightning arrester must be installed on a large number of distribution transformers and cable lines as lightning protection. Due to the remarkable advantages of the zinc oxide lightning arrester, it has been widely used. But, a large number of applications means increased failure rates. In order to make the operation of zinc oxide arrester safe and reliable in the power system, the power industry standard clearly stipulates the preventive test of zinc oxide arrester [1-2]. Standard preventive test includes DC leakage current test under power failure conditions and live test under operating voltage. But when the operating voltage of the power system is high and the number of power plant (or substation) is large, it is difficult for DC leakage current test when the power failure. Therefore, the live test of zinc oxide arrester under operating voltage is paying more and more attention [3-4]. This paper is to solve the intelligent detection problem of 10KV zinc oxide lightning arresters without affecting the operation, namely the charged working state.

2. The overall design of the zinc oxide lightning arrester intelligent tester system
2.1. Lightning arrester tester measuring principle
When measuring, the arrester tester will input the PT secondary voltage and the arrester current signal as a reference signal. In electrician, the current and voltage signals are generally expressed as:

\[ f(t) = \sum_{n=1}^{\infty} A_n \sin(n\omega t + \phi_n) \]  

(1)
or

\[ f(t) = \sum_{n=1}^{\infty} B_n \cos(n\omega t + \phi_n) \]  

(2)

Where the \( A_n, B_n, \phi_n(n=1,2,3...) \) is constant; Through the digital filtering of fast Fourier transform, the fundamental wave of current, voltage and peak current \( I_x \) can be obtained, and the phase angle \( \Phi \) between current and voltage can be obtained by comparing. “\( \delta = 90^\circ - \Phi \)” is regarded as the dielectric loss angle of lightning arrester, and it is very simple to evaluate the performance of lightning arrester directly by \( \Phi \). When there is no interphase interference, most \( \Phi \) is between 81° ~ 86°. According to the requirement of "the resistive current should not exceed 25% of the total current"; and the \( \Phi \) should not be less than 75.5°, the performance of the arrester can be evaluated in sections by referring to Table 1.1 below. In the field measurement, due to the existence of phase interference, the instrument needs to be intelligent correction, through programming, automatic compensation by the tester.

| Table 1. Lightning arrester evaluation |
|----------------------------------------|
| \( \Phi \)                  | <75° | 75°-77° | 78°-80° | 81°-83° | 84°-86° | >86° |
| performance                     | Poor | Bad    | Middle  | Excellent | Perfect|
| interference                   |      |        |         |          |        |

2.2. The system block diagram

The structural block diagram of the whole system is shown in Figure 1, which mainly includes modules such as signal acquisition, signal conversion, signal processing and result output. In addition, the system also includes a power supply, a power electrolyser and a magnetic isolation module. The workflow of the whole system is as follows: firstly, the current and voltage signals are collected, and then the signals are adjusted and then the analog signals are transformed into A/D signals. Then, the data after A/D conversion is read to the internal dual-port RAM in time-sharing, which is preprocessed by CPU for fast Fourier transform and information analysis and processing, and the processing results are cached by RAM. After all the sampled data are processed, the LCD display and the printer outputs the results for the user to judge the results. The whole process can be controlled by the keyboard.

![Figure 1. Overall structure block diagram of the system](image_url)

3. System key function module selection and function implementation

3.1. Acquisition of the current signal and the voltage signal

The acquisition of the voltage signal is relatively simple, The voltage signal input terminal receives a secondary measurement located in the same phase PT as the measured lightning arrester, and the voltage input signal is obtained through the voltage transformer. For the current signal, because the
counter is generally not installed below the 10KV arrester, it is impossible to use direct current collection if adopt online connection, so the clamp current transformer is adopted. The ETCR clamp current sensor was used here. ETCR clamp current sensor High-precision clamp leakage current sensor adopts the latest CT technology, almost unaffected by the external magnetic field, ensuring the high accuracy, high stability and high reliability of continuous uninterrupted collection and measurement.

3.2. Operational Amplifier(OPAMP) and A/D conversion module
Processing of the signal includes not only the A/D converter, but usually also the OPAMP, which is used to separate the signal source from the A/D converter to provide a low resistance drive to the A/D, while providing a certain gain to match the input signal to the input voltage range of the A/D. Here we use the TI's TLV2372, functions to convert both the input voltage and the collected current signal to a voltage AC signal of 0-2V. For A/D conversion chips, ADI's AD 7686 was used.

3.3. Magnetic isolation module
Since the voltage signal and the current signal are collected respectively, the converted voltage of the signal is different from the operating voltage of the CPU. In order to avoid mutual interference, the magnetic isolation module is introduced. To ensure the effects of magnetic isolation, an AD U M1420 four-channel isolation gate drive from ADI iCoupler® technology is used here.

3.4. Selection and main characteristics of CPU CHIP
The CPU is the core module of the entire lightning arrester. It is responsible for receiving current and voltage signals from the arrester, and analyzing both, and showing the resulting liquid crystal display output or printer printing under keyboard-driven conditions. So it requires that it has multiple features, and that it be powered by enough memory space. The PHILIPS single-chip 32-bit Microcontroller LPC2138 does this very well.

3.5. Analysis and processing of the signals
The current and voltage signal from the A/D converter needs to be analyzed and processed by the CPU of the entire arrester system. One of the most important is to determine the phase difference with the fast Fourier transform to separate the voltage and the current base wave difference. The Discrete Fourier Transform (DFT) is an important mathematical tool for describing the discrete-signal time-domain and frequency-domain relations, and with the advent of many fast Fourier algorithms (FFT), it is widely used in digital signal processing and image signal processing, and is the core operation of many systems. Since FFT has a special operational structure and data access structure, designing special processors according to its algorithm characteristics is one of the effective methods to improve the operation speed. Due to the high rate of signal sampling, the FFT processor directly performs 1024-point FFT operations on the two parallel data after the front end passes A/D, and compile the operation program.

3.6. Other modules
Other parts of the tester include printers, LCD displays, memory, and keyboards. These modules are common modules commonly used in the power industry. For these parts, the development of its program is its main core work.

4. The structure of the instrument and laboratory tests
Here in the form of pictures form to illustrate the main structure of the instrument and its applications in the laboratory test.

Figure 2 is the overall picture of the instrument.
Figure 2. Overall picture of the instrument

Table 2 is the partial measurement data.

| Item | Capacitance | Resistance | Capacitor resistance mixing |
|------|-------------|------------|----------------------------|
| Ux(V) | 22.63       | 22.55      | 22.63                      |
| U1    | 22.63       | 22.55      | 22.62                      |
| U3    | 0.288       | 0.293      | 0.284                      |
| U5    | 0.360       | 0.336      | 0.350                      |
| U7    | 0.186       | 0.186      | 0.187                      |
| Ix(mA)| 0.233       | 0.894      | 0.239                      |
| Ixp   | 0.342       | 1.248      | 1.341                      |
| Ix1   | 0.237       | 0.894      | 0.237                      |
| Ix3   | 0.008       | 0.011      | 0.009                      |
| Ix5   | 0.018       | 0.013      | 0.018                      |
| Ix7   | 0.013       | 0.007      | 0.014                      |
| Ir(mA)| 0.000       | 0.894      | 0.019                      |
| Irp   | 0.001       | 1.265      | 0.031                      |
| Ir1   | 0.000       | 1.265      | 0.026                      |
| Ir3   | 0.000       | 0.000      | 0.001                      |
| Ir5   | 0.000       | 0.000      | 0.003                      |
| Ir7   | 0.000       | 0.000      | 0.004                      |
| Icp   | 0.336       | 0.004      | 0.335                      |
| Φ     | 90°         | 0.1°       | 85.4°                      |
| F(HZ) | 50          | 50         | 50                         |

The data from laboratory measurements are fully qualified and the tester is accurate.
5. Conclusion
In order to check the reliable operation of the zinc oxide arrester, preventive tests are often carried out. In this project, the charged measurement of operating parameters of 10kV zinc oxide arrester is realized and the measurement efficiency is improved.

1) The Project can realize the online measuring of the 10kv zinc oxide lightning arrester, improve the efficiency of the measurement and can save the time.

2) Using pliers type current transformer technology has high precision, and increasing the anti-jamming performance of magnetic isolation of product digital transmission to ensure the accuracy of the instrument to measure.

In the future, Zinc oxide lightning arrester tester can be combined with statistics to realize automatic prediction of arrester life based on a period of detection. This is the direction of future research of the Zinc oxide lighting arrester tester.

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