Research Status and Development Trend of Photoelectric Transformer Technology

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Abstract: For the photoelectric transformer technology, this paper analyzes the principle of passive transformer and active transformer. We discuss the current research status and main technical difficulties of photocurrent transformers in this field. With the gradual and in-depth theoretical research on the photoelectric transformer technology in China and the achievements in practice, it is necessary to study the development trend of the photocurrent transformer technology.

Introduction

Transformers are one of the main protection and monitoring devices in the power system. With the continuous development of the power industry, the measurement requirements for electric energy are also constantly improving. Traditional electromagnetic transformers have gradually shown disadvantages that the manufacturing process is complicated, the reliability is poor and cost is high [1]. Because of the shortcomings faced by traditional transformers, power systems urgently need to replace the traditional electromagnetic transformers with new transformers that can overcome the above shortcomings. After the 1950s, with the development of fiber optic technology, sensing technology and electronic technology, photoelectric transformers went from principle research to prototype production of laboratory prototypes. Until the 21st century network trial operation, research and exploration lasted for about half century [2]. At present, optoelectronic transformers based on optical and electronic principles have gradually matured, which effectively solves the problems in traditional transformers, while there are still some technical problems [3].

Principle of Photoelectric Transformer

(1) Principle of passive photocurrent transformer

This type of transformer can be divided into two types according to the principle of the high voltage part of the sensor: one is active and the other is passive. The passive sensor head does not require a power supply compared to the active type. In general, it is based on the principle of Faraday magneto-optical effect. If the direction of the magnetic field remains parallel to the direction of propagation of the linearly polarized beam in the Faraday rotating material, the plane of polarization of the light will rotate. That is to say, the magnetic field generated by the current signal modulates the polarized light wave [4].
As shown in Figure 1, the light from the low voltage light source is transmitted through the optical fiber to the sampler in the high voltage side magnetic field, and the polarized light wave returned by the sensing head is transmitted to the low potential side via the optical fiber, and is photoelectrically transformed, amplified and shaped. Processing such as A/D conversion, logic control and CPU calculation is converted into a signal required by the power user [6].

(2) Principle of active photoelectric current transformer

The active photocurrent transformer measures the current through a high voltage. The electrical signal can be transmitted through the sampling coil and then converted into an optical signal. The signal can be transmitted through the light to the low voltage side where it reverses into an external electrical signal that can be output [7].

The high voltage side signal acquisition and processing part mainly include data acquisition and signal processing systems, which analog to digital A/D conversion systems, electro optical conversion LED systems, optical fiber transmission systems and insulation parts. Its main function
is to convert the high voltage side analog signal obtained by the sensor head into a clock and digital signal through acquisition processing. Then, it analog to digital converter and convert the clock and digital signals into optical fiber transmittable optical pulse signals through the electro optical converter LED. Finally, it is transmitted to the low voltage side via the optical fiber.

The low voltage side signal receiving processing section mainly includes a photodiode conversion PIN system and a microprocessor PC system (amplifying shaping circuit, logic control circuit, digital to analog conversion circuit). Its function is to receive the optical pulse signal transmitted from the high voltage side of the optical fiber, and then re-revert it into a clock and digital signal through the photodiode conversion PIN system. Under the action of the logic control circuit, the amplification shaping, D/A conversion and CPU operation are performed, which convert to the signal the user needs [5].

The active photoelectric transformer has the advantages of simple structure, good stability and high reliability. However, the structure of the sensor head and the high voltage side working power supply is complicated. However with the development of laser technology, these problems have been basically solved.

**Domestic and Foreign Research Status of Photoelectric Transformer**

(1) Current status of foreign research on photoelectric transformers

Photoelectric transformers are a collection of theories and applications of many disciplines, such as fiber optic sensing technology, nonlinear optics and optoelectronics. In the early 1960s, many developed countries have studied this topic. In 1963, the device successfully transmitted signals using a glass waveguide and was installed at 230kV, which is the original form of this new interaction. In 1977, the British Research Center began to study the principle of fiber-optic current sensors based on the principle and successfully produced experimental devices in the laboratory. In 1979, the commissioning of the power station was successful. In 1991, T&D Ltd. released an OCT system for a 345kV power station that enables measurement and relay protection. After four months of running tests, they announced a difference of only 0.4% between their standard current transformers. A few years later, the voltage level of the AC digital OCT was successfully increased from 72.5kV to 800kV [8-10].

(2) Domestic research status of photoelectric transformers

At the same time, domestic research in the field of OCT has been developed back to 1980. The earliest optoelectronic transformer in China was the 110kV OCT jointly developed by Shenyang Transformer Factory and Siping Electric Power Bureau in the 1980s, and was commissioned by Siping Electric Power Bureau. In the early 1990s, the 110kV OCT jointly developed by Tsinghua University and the China Electric Power Research Institute passed the national appraisal and conducted a network test run. In 1993, Huazhong University of Science and Technology and Guangdong Xinhui Power Supply Bureau cooperated to develop 110kV OCT in the Daze Substation of Guangdong Xinhui Power Supply Bureau. In 1994, it passed the identification of the former Ministry of Electric Power. The rated current is 100A~300A with an accuracy of 0.3% [11-12].

Although domestic research on this aspect is getting deeper and deeper, there is still a gap compared with developed countries due to the fact that the commercialization of products has not yet been achieved.

**Development Trend of Photoelectric Transformer Research**

In the 21st century, the research of photoelectric transformers is more comprehensive. It not only continues to conduct in depth research on the production of photoelectric transformers, but also extends to the verification and interface of photoelectric transformers, in order to standardize photoelectric transformers. In 2002, the 38th Technical Committee of the International Electrotechnical Commission (IECTC38) was responsible for the development of the electronic voltage and current transformer manufacturing standard IEC60044-7/8. At the same time, since
2004, IECTC57 has successively introduced the substation communication system and structure IEC61850 international standard protocol, which is future oriented and covers all interfaces of substation. The purpose is to effectively solve the interoperability and interchangeability of automation systems produced by different manufacturers.

During the “Twelfth Five-Year Plan” period, the construction of smart grid, UHV and new energy will become the troika for the development of the power equipment industry. The total investment of UHV grids and smart grids is expected to be 1 trillion yuan in the next decade, and the production and technical improvement of related power transformers will be fully rolled out. With the construction of UHV power grids and the rapid expansion of digital substations, the demand for photoelectric transformers will increase significantly. As the basic equipment of digital substation process layer, photoelectric transformer will gradually replace traditional transformers. Photoelectric transformers will also lead a technological innovation and market restructuring of power equipment manufacturing.

**Technical Difficulties in the Research of Photoelectric Transformer**

1. The passive photoelectric transformer is based on the principle of magneto-optical effect, which also leads to the measurement of the interference of the surrounding magnetic field, so that the measurement deviation comes.

2. There is only one electromagnetic connection called a conductive fiber between the high and low potential sides of the active photoelectric transformer. Of course, the power supply mode of the high potential side circuit has become one of the main technical researches at present.

3. Almost all single-mode fibers have linear birefringence due to the incomplete symmetry of the refractive index or diameter of the fiber core structure. Since it will affect the accuracy of the measured values more or less, study the birefringence effect and find the corresponding solution. It is especially important to improve measurement accuracy and obtain more sensitive transformers.

4. In the measurement process, when the optical system is disturbed, an error in the measurement result may occur. But the inevitable factors such as circuit switches, the surrounding environment and human interference are crucial.

**Conclusion**

Photoelectric current transformer technology is a combination of many discipline theories and applications. There are still many difficulties in the research of photoelectric transformers in China. In recent years, China's power transformer industry has made great progress in technology introduction and innovation. And the overall quality of the industry has been substantially improved. However, the development gap at home and abroad still exists, and some technical problems are faced in the research process. Therefore, it is necessary to continuously strengthen its research, in order to meet the needs of society, and the development of China's electric transformers has reached the international advanced level.

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