

Study on Method for Field Secondary Signal Simulation of Optical Current Transformer

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Abstract. The optical current transformer play an important role on the security and stability of the power system especially HVDC. The HVDC control and protection system cannot be field verified without field simulation for the optical current transformer secondary signal. But the existing method for field simulation of optical current transformer is lacking for easy to implement and meeting requirement. This paper proposed a novel method for field secondary signal simulation of optical current transformer. The advantage of the method are that not need to explain the photoelectric conversion protocol, easy to implement and meeting requirement, low security risk, and low cost. The field test device has been developed with secondary signal simulation quantity of optical current transformer. Its validity was verified by field testing of secondary signal simulation of optical current transformer in echeng convert station of jiang-cheng $\pm 500\text{kV}$ HVDC transmission project.

Introduction

The optical current transformer[1,2] is widely used in the power system, especially the HVDC project[3,4], and plays an important role on the security and stability of the power system. As a core measuring equipment of HVDC, the optical current transformer is used to measure current including DC line current, pole bus current, valve high-side current, high-side current and imbalance current between the capacitor of AC or DC filter [5] and provide accurate and reliable measurement data for DC control and protection system[6]. It could have significant impact on performance of the DC control and protection system[7]. The HVDC control and protection system[8] cannot be field verified without field simulation for the optical current transformer secondary signal.

The measuring principle and transmission mode of the optical current transformer in HVDC are different with electromagnetic current transformer in AC power system[9,10]. The photoelectric conversion protocol of the optical current transformer which is used to transmit data even is proprietary protocol. The existing method for field simulation of optical current transformer is lacking for easy to implement and meeting requirement. Therefore, the field test for DC control and protection system of HVDC has not been carried out after put into operation. These HVDC projects even have put into operation more than ten years. That is serious problem for security and stability of the power grid.

This paper proposed a novel method for field secondary signal simulation of optical current transformer. The advantage of the method are that not need to explain the photoelectric conversion protocol, easy to implement and meeting requirement, low security risk, and low cost.

This paper is organized as follows. Section 2 describes the principle of optical current transformer and introduces the existing method for field simulation of optical current transformer. The method for field secondary signal simulation of optical current transformer is proposed in Section 3. According to the proposed method, the field test device has been developed with secondary signal simulation ability of optical current transformer, as shown in section 4. Subsequently, in section 5, the field testing of secondary signal simulation of optical current transformer has been carried out in Echeng

convert station of Jiangling-Echeng $\pm 500\text{kV}$ HVDC project which in operation for more than ten years. Test results are presented to verify the feasibility and effectiveness of the proposed method with simulation range from 0 to 5p.u. rated current. Finally, the conclusion is obtained in Section 6.

Optical Current Transformer

Principle

The optical current transformer used in HVDC is composed of measuring unit, photoelectric sensor unit and optical digital conversion unit, shown in Fig.1.

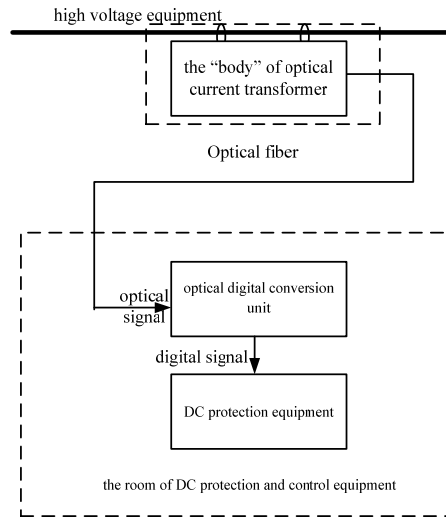


Figure 1. The block diagram of optical current transformer

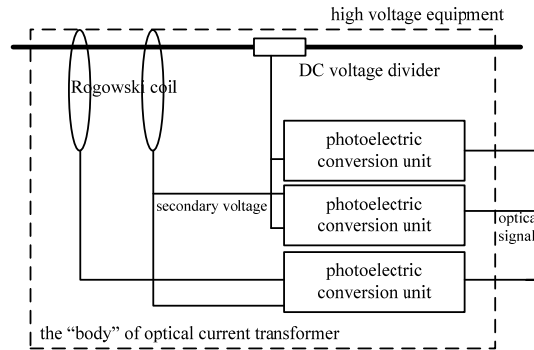


Figure 2. The "body" of optical current transformer

The measuring unit includes the Rogowski coil[11,12], and the DC voltage divider, which measures primary current to secondary voltage by the following equation[13]:

$$I_{\text{OCT}} = k_{\text{OCT}} u_{\text{OCT}} \quad (1)$$

Where I_{OCT} is the primary current measured by optical current transformer. u_{OCT} is the secondary voltage of measuring unit output. k_{OCT} is the measuring unit ratio, and its unit is kA/mV .

The photoelectric sensor unit[14] is used to convert u_{OCT} to optical signal according to proprietary photoelectric sensor protocol [15]. The measuring unit and photoelectric sensor unit constitute the "body" of optical current transformer, shown in Fig.2. The "body" is installed on the high voltage equipment.

The optical digital conversion unit is used to receive and analysis the optical signal from the "body". The optical digital conversion unit is installed in the room of DC protection and control equipment, in some projects even directly inside DC control and protection system.

Existing Method for Field Simulation

At present, there are two existing methods for field simulation of optical current transformer. One is field simulation by primary current. The other is field simulation by optical signal with explanation of photoelectric conversion protocol.

The former simulates the signal by applying the primary current directly in measured high voltage equipment. The main problem of this method is need the device with large current output capacity, hard work, long time for preparation, high security risk, and high cost, especially not meeting requirement of protection system testing with simulation range from 0 to 5p.u. rated current.

The latter simulates the signal by applying the optical signal with explanation of photoelectric conversion protocol to the optical digital conversion unit. The main problem of this method is that the photoelectric conversion protocol is almost all proprietary protocol and is very hard to explain unless authorized. It is impossible to obtain authorization for each proprietary protocol.

These two existing methods both would not been suitable for field simulating signal of the optical current transformer to test the DC protection and control equipment of HVDC.

The Proposed Field Simulation Method

The method for field secondary signal simulation of optical current transformer is proposed without explanation of the photoelectric conversion protocol, shown in Fig.3. The DC voltage source and photoelectric sensor unit are used to simulate the “body” of optical current transformer. The adjustable DC voltage source would simulate the measuring unit and provide the secondary voltage. The photoelectric sensor unit is spare parts of the simulated optical current transformer. It could be purchased directly and convert the secondary voltage to optical signal without additional authorization.

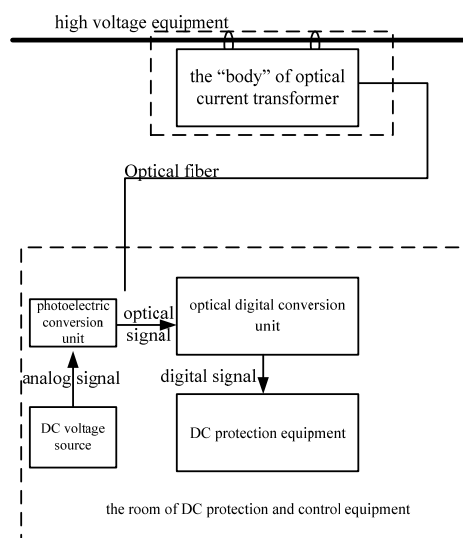


Figure 3. The proposed method for filed simulation



Figure 4. The field test device

Compared with the two existing methods, the obvious advantage of the proposed method is easy to implement and meet requirement of protection system testing without device with large current output capacity and explanation of photoelectric conversion protocol. In addition, it has other advantages such as low security risk, wide application, and low cost. Therefore, the proposed method could be very suitable for field simulating signal of the optical current transformer to test the DC protection and control equipment of HVDC.

The Field Test Device

For facilitating field testing, the field test device has been developed according to the proposed method, shown in Fig.4. It is named DCPTE -001 with secondary signal simulation ability of various the optical current transformers.

The device has two signal simulation channels with independent, adjustable and variable scale. Each channel could simulate secondary signal of all types of optical current transformer used in HVDC. Their accuracy both are 0.05%, and their control step lengths are 0.002%. There is a variety of output interfaces in the developed device, which could connect flexibly with the photoelectric sensor unit of various optical current transformers. The stability of its crystal frequency is ± 0.2 ppm. And it could be externally timed with B code. There is communication interface by RS45 in the device.

Field Testing

The Jiangling-Echeng ± 500 kV HVDC project has put into operation during 2004. And the Echeng convert station is inverter convert station. During examination reparation in power cut, the field testing for simulating secondary signal of optical current transformer in the Echeng convert station has been carried out by the proposed method and the developed device. The feasibility and effectiveness of the proposed method and the developed device was verified by the test results. In this paper, the test results of optical current transformer named P2.U.T1 are presented as an example.

The P2.U.T1 is used to measure the valve high-side current named I_{DP} in pole II. The type of the P2.U.T1 is ABB DOCT3000. And the measuring unit ratio of P2.U.T1 is 3kA/20mV. The rated dc current of the valve is 3000A. The requirement for I_{DP} measurement accuracy is 0.5% with measuring range from 0 to 5p.u. rated current.

According to the proposed method, the secondary signal of P2.U.T1 was simulated by the developed device. The field results of simulating P2.U.T1 is presented, as shown in Table 1.

Table 1. The field results of simulating P2.U.T1

u_1	simulated I_{DP}	displayed I_{DP}	σ_1
0.000mV	0 A	0 A	0%
0.858 mV	128.7 A	134 A	0.18%
1.298 mV	194.7 A	199 A	0.14%
4.980 mV	747 A	757 A	0.33%
9.987 mV	1498.1 A	1506 A	0.26%
14.99 mV	2248.5 A	2255 A	0.18%
19.99 mV	2998.5 A	3004 A	0.18%
39.99 mV	5998.5 A	6005 A	0.22%
99.98 mV	14997 A	15006 A	0.30%

In Table 1, u_1 is the output value of the developed device with simulated P2.U.T1. The simulated $I_{DP} = u_1 \times$ the measuring unit ratio of P2.U.T1. The displayed I_{DP} is displayed values from the monitoring system of the Echeng convert station. σ_1 is the percentage error of simulating P2.U.T1.

$\sigma_1 \leq 0.5\%$ with simulating range from 0 to 5p.u. rated current, as demonstrate in Table 1. Therefore, The field results of simulating P2.U.T1 indicate that it is feasible to simulate optical current transformer signal by the proposed method and the developed device.

Conclusion

This paper proposes the method for field secondary signal simulation of optical current transformer with not device with large current output capacity and explanation of the photoelectric conversion protocol, low security risk, wide application, and low cost. The proposed method could be very suitable for field simulating signal of the optical current transformer to test the DC protection and control equipment of HVDC. According to the proposed method, the field test device has been developed with secondary signal simulation ability of various the optical current transformers. In Echeng convert station of Jiangling-Echeng $\pm 500\text{kV}$ HVDC project which in operation for more than ten years, the field testing for simulating secondary signal of optical current transformer has been carried out by the proposed method and the developed device. The feasibility and effectiveness of the proposed method and the developed device was verified by the test results.

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