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Monitoring and analysis of electronic current transformer's field operating errors

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ABSTRACT

The energy metering accuracy and relay protection reliability in power grid systems critically depends on the phase current measurement accuracy. Commonly manufactured electronic current transformers (ECT) may exhibit unacceptable errors during field operation. Our research platform targets to remotely monitor ECT's errors caused by ambient temperature variation, load current, and adjacent phase interference. A 0.2% accuracy, 110 kV, Rogowski coil-based ECT prototype was selected for field operation in over 2 years of monitoring tests. Correlated field and laboratory tests showed ambient temperature-related errors of less than 0.1% in current ratio and 2′ in phase, findings consistent with the type tests. The load current and adjacent phase interference introduce negligible errors for load currents larger than 0.2*In* (where *In* represents the phase rated current). However, the phase error exceeds 20′ for load currents less than 0.2*In*, possibly leading to false conclusions. Based on the above influencing factors, standardize the 0.2% accuracy ECT's error less than half of the error limit ensures acceptable field error levels.

1. Introduction

In recent years, the research on the electronic current transformer (ECT) topic has become a hot spot in the industry [1–6], thus this device is being now widely accepted and used in grid applications. Compared to the standard current transformer (CT), the ECT has significant advantages like wide bandwidth, wide range of linearity, light weight, no hysteresis, etc. [7,8]. The ECT is one of the key devices in energy metering applications, current measurements, and relay protection in power grid applications, its error being the most important index of performance. In actual operation, however, an ECT achieving the expected level of accuracy in type tests shows often higher-than-allowed field errors, mostly in metering applications. This issue seriously affects its trustworthiness and reliability, negatively impacting its evaluated performance and application usage.

In order to improve the accuracy and reliability of the ECT, it is first necessary to study the field operating error characteristics. Currently, the ongoing research [9–13] is mostly oriented toward theoretical analysis and laboratory verification, but is lacking the most critical element—the field operation validation. This paper describes the research platform used to monitor the ECT field operating characteristics and analyzes the obtained results. A Rogowski coil-based 110 kV ECT was selected as tested device for monitoring its error over long-term field operation. Correlated laboratory and field test results are used to analyze and discuss the causes of higher-than-allowed errors.

2. Error test principle and ECT calibrator

The direct-digital measurement method is commonly used for ECT's error test [14,15]. Fig. 1 presents the error test schematic diagram for the digital ECT, where the standard transformer is an electromagnetic current transformer. The standard CT and the ECT are connected in a series loop. The secondary output of the standard CT is converted to a voltage signal through a standard resistance, and connected to the standard A/D input port of the ECT calibrator. The digital signal from the secondary output of the tested ECT is transmitted to the digital input port of the ECT calibrator through fiber optic Ethernet. The standard A/D and the tested ECT are sampled synchronously. The processing unit calculates the current ratio and phase error of the output digital signal from the standard A/D and of the merging unit, using the appropriate algorithm. The laboratory, offline, and type tests all use a 0.05% accuracy class ECT calibrator, which meets the error test requirements for the 0.2% accuracy class ECT.

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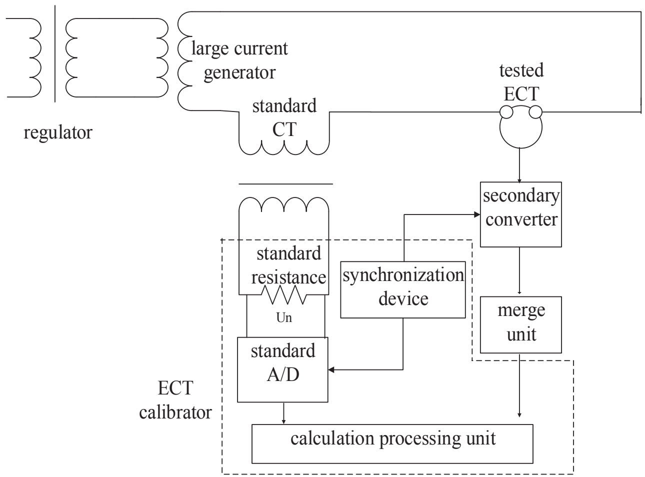

Fig. 1. ECT error test setup schematic diagram.

3. Research platform for ECT operating characteristics measurement

The research platform for measuring the ECT operating characteristics was established in the Hegang Dongshan substation, in Heilongjiang. As shown in Fig. 2, the platform was designed to perform the measurements and remotely transmit the ECT error and transformer substation's outdoor temperature data, as well as other parameters. The platform consists of a process layer, an interface layer, and a station-control layer. The process layer includes the tested ECT and the standard CT, the interface layer includes the synchronization device and the online test device. The local workstation forms the station-control layer, the data being transmitted to the remote workstation through the local workstation to achieve remote data downloading, reading, and analysis.

The tested ECT, the standard CT, the station synchronization device, the online test device, and the local workstation constitute the field operating error test system. As shown in Fig. 3, the tested ECT and the standard CT are the outdoor devices of the test system. As shown in Fig. 4, the station synchronization device, the online test device (ECT calibrator, 0.05% accuracy class), and the local workstation are the indoor devices of the test system. Fig. 5 shows the Wuhan remote terminal, located 2700 km away from Hegang, by which we could continuously monitor the ECT operating status and error variation.

The field operating error test system uses the direct-digital measurement method. Digital signals are transmitted and processed by local and remote workstations, which will not affect the overall system's test error.

In order to study the operating error characteristics of electronic transformers, three sets of 110 kV, Rogowski coil-based ECT devices undergone type tests for extracting the error parameters. First, the ECT is tested in the laboratory, then single-phase offline tests are conducted

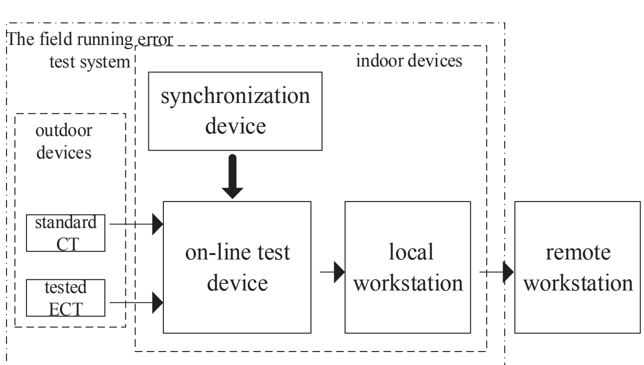

Fig. 2. ECT operating characteristics measurement research platform.

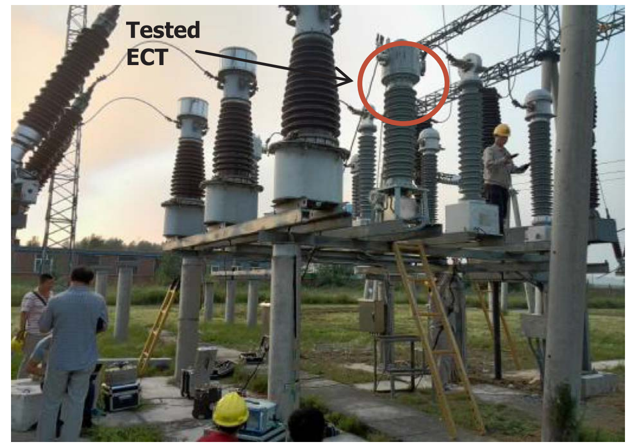

Fig. 3. 110 kV outdoor devices in Dongshan, Hegang, Heilongjiang.

Fig. 4. Indoor field operating error test system devices.

after substation's field installation, and finally three-phase online operation and monitoring is performed under normal operating grid conditions. In the laboratory and field offline conditions, the single-phase ECT is tested using the ECT calibrator shown in Fig. 1. During the three-phase online operation, the research platform shown in Fig. 2 is used to monitor the operating state of phase-A.

The difference between field operating error test system and ECT calibrator laboratory test setup is the standard CT's working environment. The laboratory's standard CT is placed indoors, while the test system is placed outdoors, which requires better temperature stability and higher interference rejection.

In order to ensure the system's consistency, the ECT calibrator and field operating error test system were compared. The results for the same ECT test on the selected network using two sets of test equipment are shown in Table 1.

Measurements were performed at an ambient temperature of 21 °C and the resulting error is calculated as the mean of 3 measurements. The measurement uncertainty is 0.05% for current ratio and 0.1′ for phase. The test results show that the two test equipment sets have good consistency and meet the requirements for the 0.2% accuracy class ECT.

4. Field operating error monitoring

Considering the difference between the field and the laboratory conditions, the changes in ECT error caused by the load current, ambient temperature, and adjacent phase interference are monitored.