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Analysis of the Design and Application of a Novel CT Secondary Cable Line Calibrator

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Abstract: With the rapid development of electrical power systems, ensuring the accuracy and reliability of power transmission has become particularly crucial. The secondary cable line calibrator for current transformers (CT) plays an essential role in calibrating electrical power systems. It is not only related to the safe operation of the system but also directly impacts the accuracy of energy metering. This study aims to design and analyze an efficient CT secondary cable line calibrator to explore its application effects in the power system. By thoroughly analyzing the characteristics of CT secondary cable lines and the design requirements of the calibrator, this paper proposes an innovative design scheme for the calibrator. This device demonstrates significant effects in enhancing the accuracy and stability of power system calibration, providing robust technical support for the optimization and upgrade of the power system. This research not only offers a theoretical basis and practical guidance for the design and application of CT secondary cable line calibrators but also contributes new ideas and methods for the precise calibration and efficient management of the power system.

Keywords: CT secondary cable line; Calibrator; Power system; Design; Application

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1. Introduction

In recent years, the continuous growth in regional power demand has led to the expansion of substation capacities [1]. This expansion has not only made the debugging and maintenance of secondary systems in substations more laborious but has also intensified the manpower shortages and task burdens in the field of relay protection. Although multicore cables used in substations are equipped with digital or color identifications for recognition, these markers can wear off or detach over time, complicating the identification and calibration of cables. To address this issue [2-6], this study developed a novel cable calibration instrument aimed at enhancing the efficiency and accuracy of secondary cable calibration in substations.

The instrument has been applied and validated in real-world scenarios. This innovation not only optimizes the calibration process of secondary cables but also provides robust support for the operation and maintenance tasks in substations, further ensuring the stability and safety of the power system.

2. Problems associated with existing line methods

In the inspection of secondary circuits in substations, the calibration process of cable core wires has always been a time-consuming and labor-intensive task. The calibration of multicore cables typically requires the cooperation of at least two technicians, who use walkie-talkies and multimeters to perform the calibration tasks at both ends of the cable. The specific operations include stripping the outer protective layer at both ends of the cable to expose the internal core wires, then short-circuiting the core wire with a grounding point at one end, and subsequently using a multimeter to test whether each core wire at the other end is connected to the grounding point. When the multimeter emits a continuous beep, it indicates that the corresponding core wire has been correctly identified, and the next step is to mark it. This method requires the sequential verification of each core wire; if there are m core wires to be tested, then the traditional method needs to conduct m(m-1)/2 measurements.

This mode of operation requires multiple communications and collaborations between two operators at both ends of the cable, which is not only inefficient but also susceptible to the influence of the on-site environment, increasing the risk of errors.

In current substations, secondary cables typically utilize 14-core or 10-core cables. To ensure system reliability and future scalability, some spare cores are usually reserved. The on-site calibration process includes preparation work at both ends of the cable (such as stripping and short-circuiting), continuity testing of each core, and final marking confirmation. See the process in **Figure 1** for the on-site calibration steps.

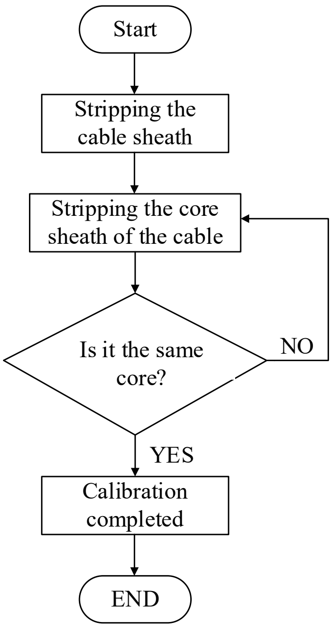

Figure 1. Calibration process of CT secondary cable lines

3. Design of the novel CT secondary cable calibrator

Considering the limitations of traditional line detection methods and inspired by network patrol robots, a portable and easy-to-operate calibration device has been developed. This device is designed for single-person operation, featuring a compact size, lightweight, and low energy consumption to meet daily usage needs. The overall design of the device is presented in **Figure 2**.

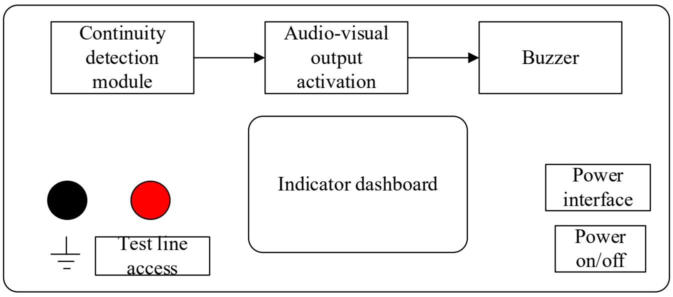

Figure 2. Overall scheme of the CT secondary cable line calibrator

During use, the device's grounding port is first connected to the ground, and the test interface is connected to the secondary wire of the current loop to be tested in the terminal box or to the terminal (the current terminal connector is lifted and slid open) to ensure good contact between the test wire and the terminal. On the CT body wiring box side, the grounding wire is connected to the terminal to be tested, forming a circuit through the ground and the secondary wire to be tested. If the resistance being tested only includes the resistance of the secondary wire (which is minimal since the wire is copper-core), the detection module activates the audio-visual output module, triggering the buzzer. If the circuit passes through the CT's secondary winding, the resistance increases, the circuit is interrupted, and the buzzer does not sound. By testing in sequence and changing wires one by one, the calibration of the secondary wires can be completed quickly.

The device uses a rechargeable lithium battery to ensure environmental friendliness and cost-effectiveness. This lithium battery is equipped with triple safety protection measures, including a pressure relief safety valve, a thermistor, and a polymer membrane, to enhance safety. Specifically, when the internal pressure is too high, the pressure relief valve can automatically activate to release pressure and prevent explosions; the thermistor increases its resistance value when an overcurrent or short circuit causes a rapid temperature rise, thereby cutting off the current to prevent further energy output; and when the temperature of the polymer membrane exceeds 160 °C, its microporous structure closes to physically block and cut off the current, ensuring the safe operation of the device.

The device's signal indication system is designed in two forms: one is a high-decibel alarm focusing on auditory signals, and the other is an LED bead focusing on visual signals. Considering that the high-decibel alarm may vary in sound or fail due to various interferences, especially in noisy calibration environments, its reliability and accuracy may be insufficient. Therefore, the device uses 24V LED beads as the primary signal indication method. LED beads are more reliable and effective in providing visual signals, clearly conveying warning information in noisy environments.

The test terminal includes calibration ports for connecting the main and auxiliary devices and a common port. To effectively test without damaging the cable cores, the calibration ports use a probe design, allowing direct contact with the tested circuit without damage. The common port uses a banana socket, simplifying the plugging and unplugging process and making field wiring more convenient. By grounding the common ports of both the main and auxiliary devices, this configuration is superior to using external leads in terms of component use, enhancing the test's stability and reliability. The device's casing is designed to meet multiple requirements, including excellent insulation, mechanical strength, and corrosion resistance, and also being lightweight, easy to process, and easy to observe. The physical design of the calibrator is shown in **Figure 3**.

Figure 3. CT secondary cable line calibrator

4. Working principle of the CT secondary cable line calibrator

The secondary terminals of the CT do not need to be disassembled. They are accessed by opening the current terminal connection strips of the switchgear or protection screen. The wiring is shown in **Figure 4**.

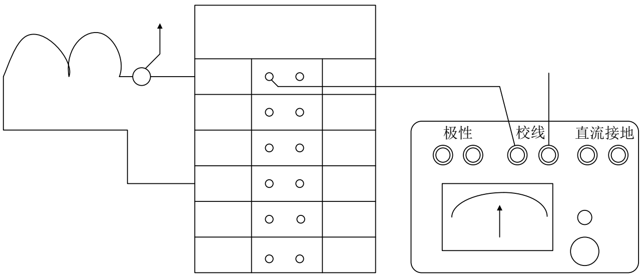

Figure 4. Wiring for CT secondary cable line calibration

The power switch of the calibrator and ground terminal 1S1 are turned on. The calibration terminal of the instrument is connected to the ground terminal (black) for grounding, and the calibration and wiring terminals (red) overlap with the terminal strip on the transformer side. If the continuity light illuminates and the buzzer sounds, it indicates 1S1; if not, the aforementioned phenomenon will not occur.

5. Conclusion

The novel CT secondary line calibrator, with its module control, features a highly sensitive switch variable acquisition function, rapid response, and low energy consumption. Its testing wiring module achieves an integrated design, considering the development difficulty while ensuring the reliability of the device's use. This design allows the device to be operated single-handedly, adapting to various complex working environments.

The novel CT secondary line calibrator can improve efficiency in troubleshooting and new station acceptance, effectively reducing the time for power outage maintenance. This provides strong support for overhaul, technical transformation, acceptance, and equipment defect rectification work, also demonstrating its efficiency and reliability in practical applications. References.

Disclosure statement

The author declares no conflict of interest.

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