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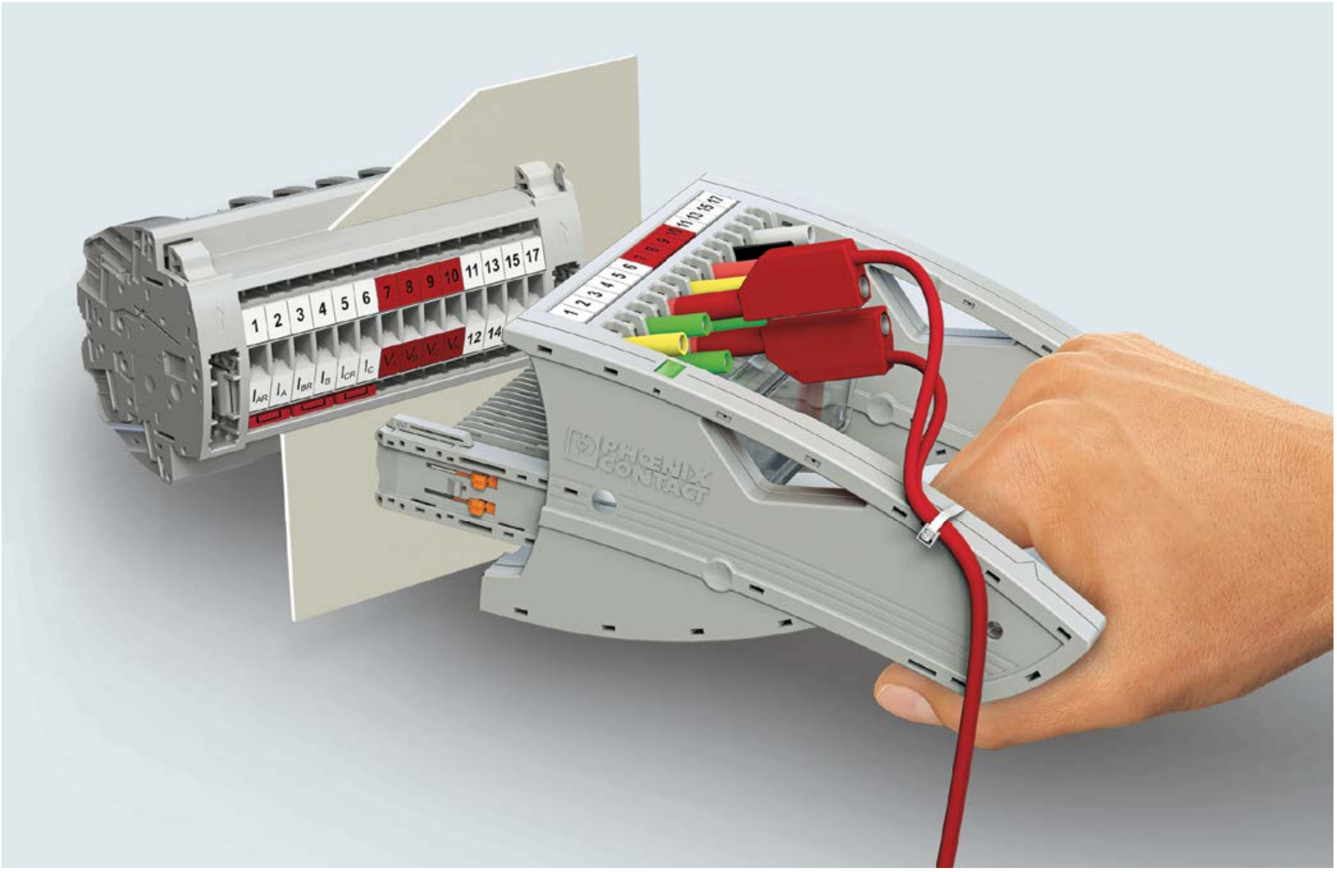

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Safe methods for relay field device testing

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Introduction

Electric power systems must operate at the highest level of reliability and safety, and protection systems are an important part of these systems. According to Care Labs, a company that provides electrical installation and equipment services, "Properly working protection devices help to maintain the safety of the system and to safeguard assets from damage. To ensure reliable operation, protective relays must be tested throughout their lifecycle, from initial development through production and commissioning to periodical maintenance during operation."[1]

This paper will describe testing methods using an innovative switch for protective relay and protection systems. Whether you are in the commissioning, maintaining or recommissioning phase, this new technology can ensure safe, effective, and reliable testing.

INSIDE:

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Background

When commissioning or retrofitting a substation, engineers need to meet tight schedules. To meet these deadlines, the engineers cannot afford to have equipment down. Automating the standard test procedures is another valuable way to save time.

Omicron, a manufacturer serving the electric power industry, states, “In addition to typical protection tests, commissioning engineers verify the correct operation of all the statuses and interlocking elements in a substation. Other typical tasks include SCADA annunciations checks, burden measurement, polarity checks for current transformers (CT) or voltage transformers (VT), wiring checks, logic scheme tests, and plausibility checks for CT/VT with primary injection. Recording transformer inrush currents can also be an important task for verifying whether or not the protection has been set correctly.” [2]

A utility defines the duration of routine test cycles or system maintenance and recommissioning. This cycle depends on the type of relays installed. For instance, microprocessor-based relays are not tested as frequently as early-version electromechanical relays. However, most utilities still perform tests due to firmware upgrades or other changes that could influence the reliability of the protection system.

Based on various phases of protection system design and deployment, testing is a crucial aspect for successful commissioning and operation. Industry practice recommends that protective and auxiliary relays be given a complete calibration test and inspection at least once a year. However, existing workloads and available manpower may impact the schedule, so that many relays wait longer than a year for routine calibration testing.

In the rugged, day-to-day world of a relay technician, safety is one of the most concerning aspects of the job. The current transformer, commonly referred to as a CT, is a necessary component used in virtually all substation environments. A CT is used to reduce or multiply an alternating current (AC). It produces a current in its secondary winding that is proportional to the current in its primary.

Electronics Tutorials explains that CTs “reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter… The primary current of a CT is not dependent of the secondary load current but instead is controlled by an external load. The secondary current is usually rated at 1 Ampere or 5 Amperes for larger primary current ratings.” [3]

When CT circuits are modified, such as by the addition of relays, meters, or auxiliary CTs, measurements are recorded to determine the burden of the overall CT secondary circuit. Measurements are made at three current levels while recording voltage, amperage, and phase angle.

The ABCs of CTs

The hazard of a CT lies in the basic physics of its operation. In a simplified definition, transformers operate under the principle of “Power In equals Power Out,” or:

$P_{in} = P_{out}$

Again, in a simple understanding, power is voltage times current:

$P = V \times I$

Using mathematical substitution:

$V_{in} \times I_{in} = V_{out} \times I_{out}$

The “in” wiring is physically incapable of being disconnected in most cases because the CT is wrapped around the conductor being monitored. The CT wiring that is connected to a safety relay is represented in the above equations as I_{out}. If one of the wires is disconnected, or “lifted,” I_{out} goes to zero, and V_{out} theoretically goes to infinity. It is precisely this infinite voltage that presents the safety concern for the technicians. Just like static electricity and lightning, it is seeking a path to ground.

WARNING: Secondary circuits of CTs must not be open while primary current flows. It is imperative that safety precautions be taken while working on or around CTs. CTs rely on the current from the primary load through the principle of electromagnetic induction. In the event of an open circuit on the secondary side, the core flux will exceed the desired level due to the lack of Magneto Motive Force (MMF). This in turn raises the voltage to unsafe levels on the secondary side, leading to personnel injury, equipment damage, or possible death. To prevent this, vendors and suppliers often handle, ship, and install CTs with the secondary circuits shorted. Only after the circuit is installed and inspected should the shorted contact be removed.

The hazard must be recognized as an ongoing risk, even after the CT has been safely installed in the system. For operators to perform required testing and calibration of hardware, they must have a means to periodically interrupt a CT's normal operation in protective relay and high-current metering applications. Test switches can accomplish this.

The prevalent design of relay test switches is based on decades-old knife-switch technology. Knife switches are effective in safely shorting CTs and isolating field devices (CTs, PTs, etc.) from monitoring systems and devices such as a protective relay. The downside of the knife switch is that the blades are always energized, exposing technicians to live currents and voltages.

Current practice

Many relay technicians carry a wide roll of tape that they use to cover open knife blades on an FT-style test switch. This is important because even though the relay is safely isolated, the open knife blades are still live conductors. The technicians use the wide tape to cover these open knives to protect themselves from incidental, potentially dangerous, contact with the exposed conductors.

WARNING: Secondary circuits of CTs must not be open while primary current flows. To troubleshoot or take in-process readings, the technicians must first open a knife switch to expose a test point.

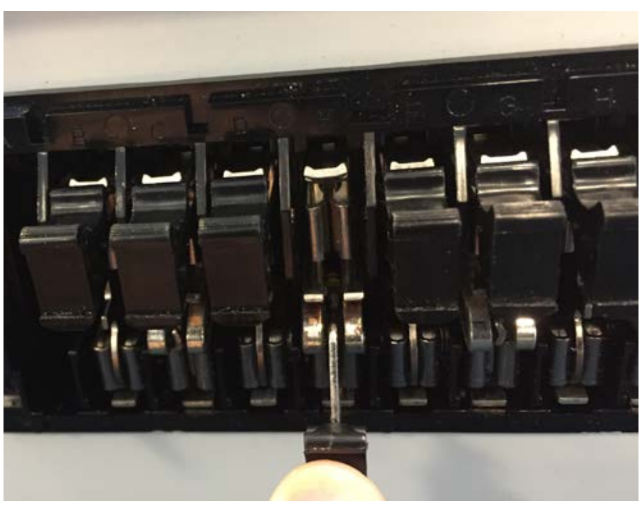

Figure 1: Opening knife switch to expose test point.

The next step is to insert a special probe with test leads attached (sometimes referred to as a "duck bill"). If making a current measurement, the test leads must be attached to an ammeter prior to the insertion of the duck bill into the test point.

Figure 2: Duck bill.

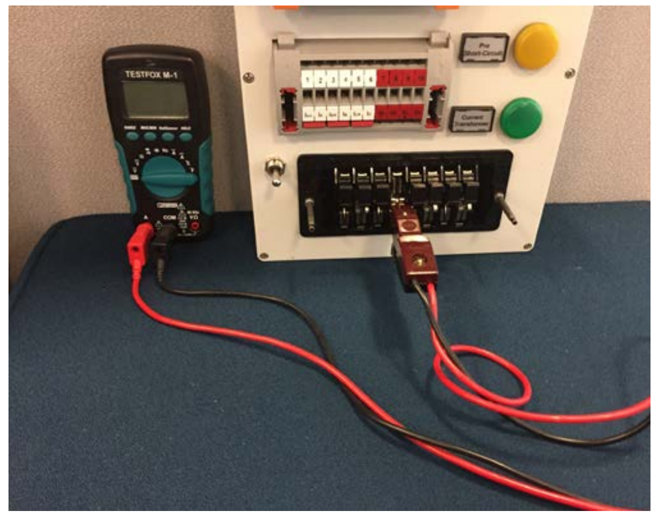

Figure 3: Duck bill attached to ammeter prior to inserting into test point.

To measure the voltage, the technicians typically use electrical test clips commonly known as "alligator clips." When attaching an alligator clip, the technician must wear appropriate protective apparel because the alligator clip will be attached to an exposed live conductor.

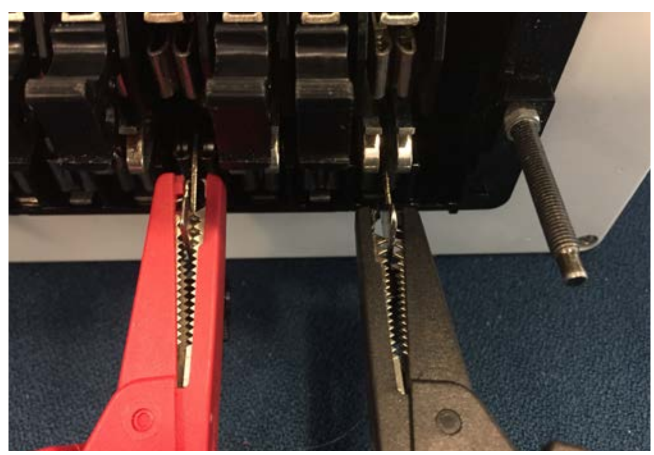

Figure 4: Voltage measurement using alligator clips.

To isolate a CT, two switches must be opened and an insulated "popsicle stick" must be inserted into the test point. (Note: CT shorting takes place with the make-before-break connection in the FT-style switches).

FAME 3 blends safety with innovation

A new plug-in test switch design from Phoenix Contact, branded FAME 3, is UL Recognized for 600 V and 30 A (20-8 AWG) with modular actuation features and service plugs for touch-safe operation. With FAME 3, every pole is a touch-safe test point. Technicians use a special test probe, properly configured for either voltage or current measurement. The probe is the same for both; however, the voltage probe has a bridge to prevent inadvertent opening of the circuit.

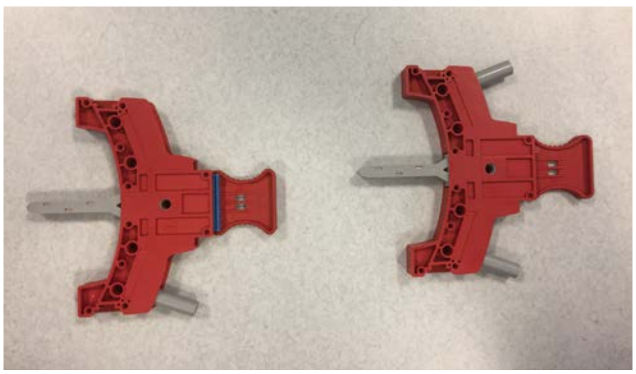

Figure 5: FAME test probes used for voltage with a bridge (left) and used for current (right).

If CT shorting is required, the technician will need a two-pole test probe, which will safely short and then isolate a CT when inserted.

Figure 6: Two-pole test probe safely shorts CT and isolates it from the circuit.

To measure CT saturation, or de-magnetize a CT, the current procedure using FT-style switches is to open circuit the primary of the CT and apply AC voltage to the secondary.

The FAME 3 method for this same testing is to open circuit the primary of the CT and apply AC voltage to the secondary using the two-pole test probe.

To pass relay tests mandated by the North American Electric Reliability Corporation (NERC), a tester is prewired to a test paddle (handle), the knife switches are all "opened," and then the test paddle is inserted. The tester has software to simulate many different scenarios (tree falling on line, transformer struck by lightning, etc.) with field devices isolated from the safety relays. This tests the relay response to known inputs without actually tripping breakers. The test equipment can capture and measure the trip signal, if needed.

For the FAME 3 performance of this same testing, the handle is prewired to the tester, and then inserted into the test switch. The remainder of the test procedure is identical to the present method.

Comparison of basic testing

Figure 7: Alligator clips used to take voltage readings.

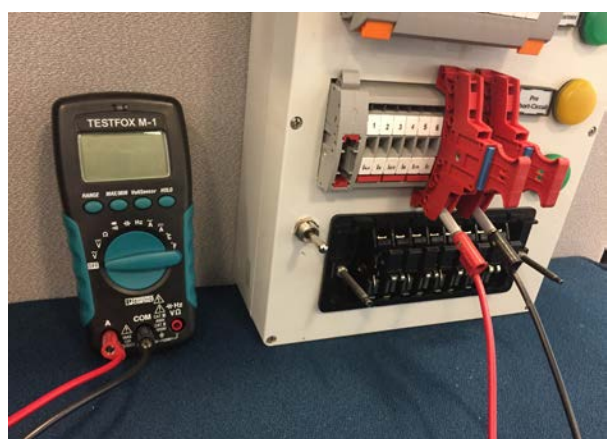

Figure 8: FAME test probes used for voltage readings.

Current reading:
For the FT-style switch, the ammeter is attached to the duck bill, as shown in Figure 3. A test point is exposed by opening a knife switch, and then the "duck bill" is inserted to put the ammeter in series and obtain a reading.

For the FAME test switch, the current test plug shown on the right in Figure 5 is attached to the ammeter, and the test plug is inserted into the desired pole on the switch to put the ammeter in series and obtain a reading.

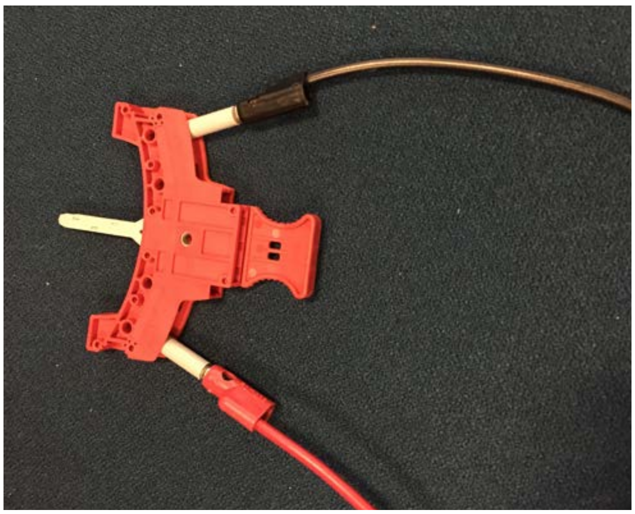

Figure 9: Test plug connected to ammeter.

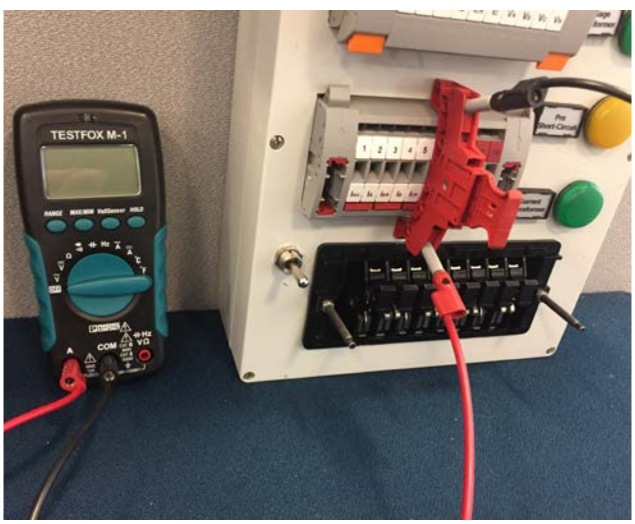

Figure 10: Test plug inserted, and current reading obtained.

Conclusion

Although substation technicians have used the old knife-switch technology for decades, it comes with many risks. Technicians can perform all required tests with the touch-safe FAME 3 test switch. This newly designed switch has the added benefits of modularity and plug-in capability.

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