Why Test Switches Still Matter

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***Abstract*--The test switch was originally developed for the electromechanical (EM) relays relay case design well over 60 years ago. Electromechanical relays are still used in virtually every power plant and utility substation in the US. The EM relays are well known for being robust and their ease of testing when using a separate source, in-service, or an individual current test plug.**

An EM relay can be tested either in or out of its associated case by opening individual knife blade switches on the test switch. Therefore, by design, test switches are opened to securely isolate trip circuits and safely short current transformer (CT) secondary circuits.

A technology shift toward more intelligent microprocessor based relays, along with new relay test standards have perpetuated the necessity of the stand alone, test switch. Consequently, test switch designs were developed which incorporated the same classic benefits and flexibility of the EM relay case design. With the test switch, microprocessor based relays gain the same benefits in testing that the older EM relays enjoyed.

I. Introduction

All measurements and tests can be performed at the front of the switchboard, without taking any relays out of service, and without the need to access wired connections at the rear of the relay. Test switches and test plugs have all the features for applications requiring the safe measurement and isolation of individual currents, voltages, and digital I/O signals to facilitate testing of substation instrumentation and protection relays. The proper sequence must be followed in order to prevent relay misoperation. For example, the relay trip circuit must be opened first, which in the electromechanical world is typically terminals 10 (DC+) and 1 (DC-). Then the current and potential test switch blades can be opened. Conversely, after the relay tests have been completed, the trip circuit is closed last. Also, if the right test tools are not used an open CT condition can occur which can be detrimental to both the operator and the power system. The individual current test plug, sometimes referred to as a stab because it stabs into the current test jack, provides a safe, simple, fast and reliable method to isolate, test, and service installed equipment without disturbing the power system. The 10 position separate source test plug is used for testing the relay with external test equipment. This test plug is used to insert into the test switch with all test switch blades in the open position. The test plug has an insulating barrier designed to interrupt current test jacks. It is very important that this barrier be fully intact and inserted into the current test jacks to isolate the test equipment from the CT's. If the test switch current test jacks are not fully open circuited, damage to equipment or a relay misoperation can occur. The 10 position single source test plug is used primarily for monitoring voltage and current when the test switch blades are in the closed position.

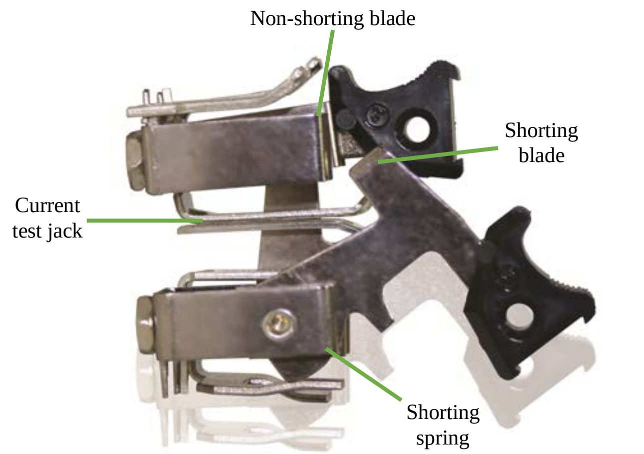

Figure 1: Current switch depicting Make-Before-Break Actuation. Before shorting blade disengages from jaw, bottom cam on blade make contact with shorting spring.

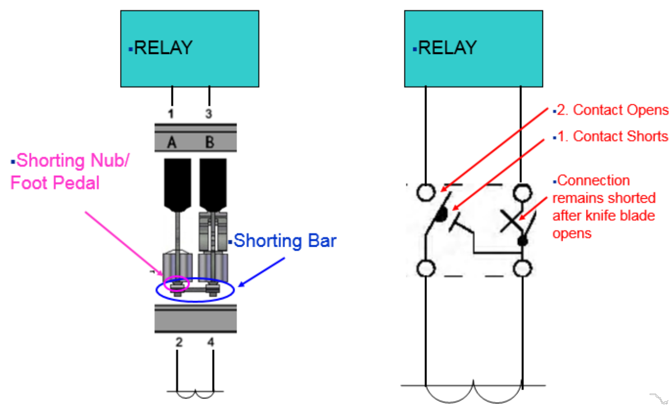

Figure 2: Current switch circuit configuration

Voltage measurements can be made directly without disturbing existing connections. There is a test clip located on the top of each pole that allows connection with standard spring clip test leads. The make-before-break current shorting feature allows test personnel to quickly and safely isolate equipment from current transformer (CT) circuits. The make-before-break feature can easily be seen when the FT switch knife blade cam connects with the (foot pedal) shorting spring before the knife blade disconnects from the switch jaw. Figure 1A and 1B depict the make-before-break mechanism.

II. Effects of an Open CT Condition

If a CT is open circuited without the current being shorted, voltage spikes are developed which can be extremely high in amplitude. The voltage magnitude is dependent upon the short circuit impedance, CT type, cable type, contact gap and time lapse. The voltage spikes are only limited to the saturation of the CT secondary and contact spark distance.

A primary concern with respect to overvoltage is the integrity of the current transformer itself. Some CT manufacturers warn against overvoltage of any kind. Typically CT's are insulated to temporarily withstand peak secondary voltages up to 3.5kV during emergencies. Smaller CT's with relay accuracy class under T200 fall into this category, however larger CT's can develop higher voltages in the order of 9kV which can potentially cause internal insulation damage.

If the duration of an open CT circuit condition is short but is repeated, this overvoltage will age and can permanently damage the CT insulating characteristics. Therefore the lifespan of the CT can be significantly diminished.

A. Protective Relay Equipment

Both IEC and ANSI relay standards require protective relay equipment to meet Impulse withstand up to 5kV. Voltage surges greater than 5kV can cause damage to power supplies, digital, analog, input/ output and other circuits. Lesser levels may not be catastrophic, however, impulse can stress equipment and affect equipment lifespan. Another concern is waveform distortion which is a hidden problem that can cause the relay to meter incorrectly and misoperate. CT magnetization can remain hidden long after an open CT condition is corrected which has been known to cause relay misoperations (often referred to a false trip) and can be very costly. This type of failure mode is difficult to pinpoint and correct since the entire system can be affected. A great deal of time and effort is spent trying to demagnetize CT circuits and bring equipment back on line.

B. Other Devices Connected to the Secondary of CT's

In some instances Hall Effect sensors are connected to the CT secondary. The sensors enhance circuits where control and monitoring need to be performed. However these additional components are not designed to meet impulse withstand requirements and are therefore more susceptible to catastrophic failure.

C. Safety During Make-Before-Break Operation

Just to reiterate, when the secondary of a CT is open-circuited, a very high voltage develops across the secondary current transformer terminals. The current will cyclically pass through reference zero (120 times per second for American and 100 times per second for European power systems). The rate of change of flux at zero current is not limited by saturation. This effect induces extremely high voltage peaks. Personnel safety must always be the main focus of concern. The potential exposure to thousands of volts at exactly the same moment in time that a user is interacting with the test switch can be a recipe for disaster. Significant mitigating factors come into play. Most of the mitigating factors are inside the test switches, but the technician must be well trained for the potential danger. Since technicians extend the circuit under test with current and voltage meters using leads, the shock risk is no longer contained. One relay technician shared his experience removing an EM relay live not knowing there was a missing shorting spring inside the case. He clarified "there were a lot of sparks spitting from the relay case." Fortunately, due to knowledge of the dangers of an open CT condition, and some very quick reflexes; he reinserted the EM relay back into the case, then immediately closed the test switch blades without causing an incident to himself or the power system. By inserting the relay back into the case and closing the associated test switch blades, the relay current terminals were reconnected to the CT secondary circuit, thereby squelching the potentially high voltage output. See Figures 3 and 4.

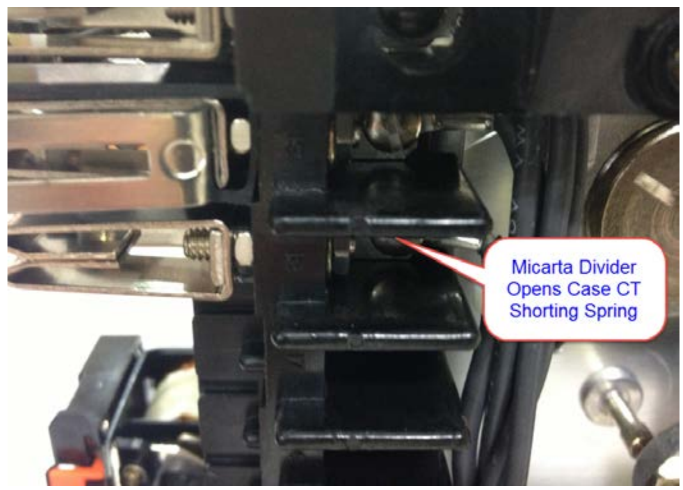

Figure 3: Electromechanical relay Micarta divider

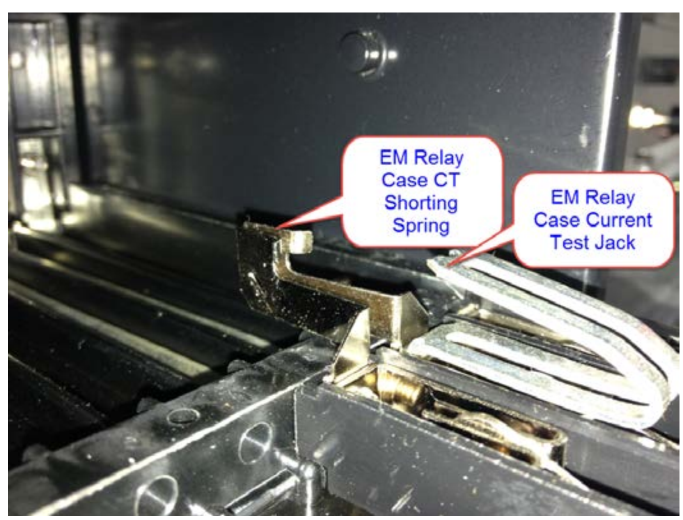

Figure 4: Electromechanical relay CT shorting spring

D. Safety while measuring current

Test switches provide convenient points of contact for current and voltage measurements in the power system. During current measurements, an ammeter is inserted in series with the CT secondary circuit using an individual current test plug inserted into the test switch current test jack. If for any reason, the ammeter opens, including broken or disconnected leads or blown fuse, the overvoltage condition will occur. A smart test plug which offers overvoltage protection can sense voltage and clamp the voltage to safer levels for this type of occurrence. The resulting voltage waveform is shown in Figure 5.

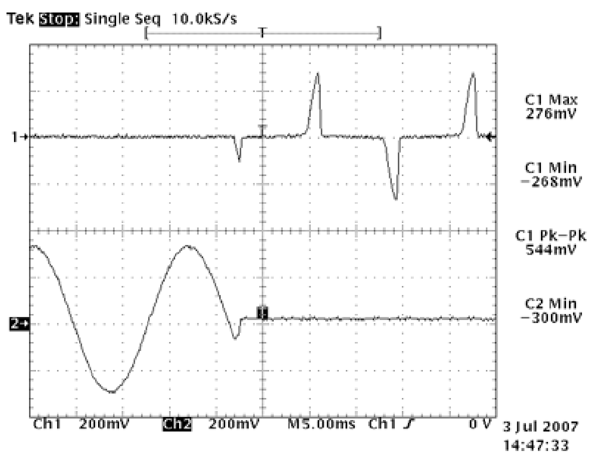

Figure 5: Effect of using an individual current test plug with open CT protection

As the voltage reaches a predetermined level, the test plug restores the current path, extinguishing the voltage. As the voltage drops to zero, the electronic circuit in the test plug reverts to its initial condition. As the current tries to continue to flow in the once-again open circuit, another instance of the overvoltage in the opposite polarity develops and the cycle repeats. The primary goal of safety is achieved.

III. Conclusion

Test switches used in the power system successfully perform the make-before-break action consistently every time. Using test switches as a standard practice can be the best remedy for:

- Power System misoperations (blackouts)
- Damage to the current transformer (avoid magnetization and erroneous readings)
- Damage to protective relays, test switches and other devices (overvoltage)
- Personnel safety (shock hazard)

A single instance where a misoperation occurs can cause power system issues unseen long after the occurrence. However, with due diligence, proper use of FT switches and associated test tools, risk can be mitigated.

IV. References

[1] *FT Switch Descriptive Bulletin* – DB 41-077 Rev D March 2011

[2] A. Elmore, *Protective Relaying: Theory and Application,* Marcel Decker, Inc., 1994.

[3] *IEEE Standard for Relays and Relays Systems Associated with Electric Power Apparatus*. IEEE Std. C37-90, 2005

[4] *IEEE Standard Requirements for instrument transformers*, IEEE Std. C57.13

V. Biography

Glenn Goldfarb holds an A.S. in Electronics Technology from Broward College and has been best known as “the Answer Man” during most of his career at ABB. Currently, Senior Marketing Engineer at ABB’s Coral Springs, Florida, plant, he has been the go-to person for questions about electromechanical relays and FT switches. He has also been responsible for high-voltage microprocessor-based relays in ABB Allentown, Pennsylvania, and for recloser control products at ABB Lake Mary, Florida. He has a total of 38 years of experience with Westinghouse and ABB relay products and is the primary instructor for Electromechanical Hands-On Relay Training. In fact, it’s his job to answer application and other technical relay questions.