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WHITE PAPER

SEL Recommendations on Periodic Maintenance Testing of Protective Relays

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Introduction

There continues to be high interest in testing practices for protective relaying systems. For example, in 2007, the U.S. Federal Energy Regulatory Commission (FERC) issued Order No. 693, which mandates that all users, owners, and operators of the bulk power system comply with electric reliability standards.

To address the FERC comments from this order, the North American Electric Reliability Corporation (NERC) developed Standard PRC-005-2, Protection System Maintenance, which merges the following previous standards:

- PRC-005-1 – Transmission and Generation Protection System Maintenance and Testing
- PRC-008-0 – Underfrequency Load Shedding Equipment Maintenance Programs
- PRC-011-0 – Underfrequency Load Shedding System Maintenance and Testing
- PRC-017-0 – Special Protection System Maintenance and Testing

NERC Standard PRC-005-2 defines what elements of a protection system should be tested and how often. The standard also includes requirements for developing and documenting the implementation of a test plan [1].

FERC issued the order approving PRC-005-2 on December 19, 2013. The enforcement date for PRC-005-2 will be April 1, 2015, which is the first date that entities must be compliant with the standard. The regulatory approval date in the United States is February 24, 2014.

The purpose of this paper is to provide recommendations for testing SEL relays and guidance for developing a test program. Utilities and other entities should use their own experience and expertise to develop and implement their test plans.

Background

The goal of testing relays is to maximize the availability of the protection and to minimize the risk of a misoperation. The paper “Philosophies for Testing Protective Relays” describes an approach to testing digital relays and the factors that affect a maintenance interval [2].

An important factor in analyzing test intervals is monitoring the self-test alarm of a relay. SEL relays continually monitor and control power protection systems in addition to continuously monitoring their internal self-test diagnostics. Relay self-test diagnostics are capable of detecting approximately 85% of component failures. The paper “Assessing the Effectiveness of Self-Tests and Other Monitoring Means in Protective Relays” shows a strategy for relay testing [3].

Using the best testing method is integral to a good testing philosophy. The paper “A Comparison of Line Relay System Testing Methods” provides guidance for selecting the best test method [4].

Finally, developing a plan for periodic testing assumes that a system is properly and comprehensively commissioned. The paper "Lessons Learned From Commissioning Protective Relaying Systems" describes best practices for commissioning protective relay systems [5].

Observed field return data show that SEL relays have a mean time between failures (MTBF) of about 500 years. This is a measurement of hardware failures and equates to about 0.2% (1/500) failures per year. Also, historical data show that self-tests detect about 85% of relay failures. Thus, about 15% of the 0.2% failures (about 0.03% per year) go undetected. The SEL maintenance indicator (MI), which tracks **all** maintenance performed on a particular relay, is approximately 130 years. Using the MI, the number of undetected failures per year is 0.12% (1 undetected failure in 870 relays).

Recommended Approach

The following describes the SEL recommended approach to relay testing and best practices:

1. **Perform comprehensive commissioning testing at the time of installation.** Use thorough checklists, simulations, laboratory testing, and/or field checks to verify the performance of the protection system, including inputs, outputs, and settings.
2. **Monitor the relay self-test alarm contact in real time via supervisory control and data acquisition (SCADA) or other monitoring system.** If an alarm contact asserts, take immediate steps to repair, replace, or take corrective action for the alarmed relay.
3. **Monitor potential relay failures not detected by self-tests.** Specifically, these are logic inputs, contact outputs, and analog (voltage and current) inputs. Use continuous check of inputs (e.g., loss-of-potential logic) when available. If a secondary relay system is in place, compare the metering values between the primary and secondary systems.
4. **Analyze event reports to root cause, and verify logic inputs and output contact operation.** Use event reports as documentation to validate correct operation of the protection system.
5. **Observe and act on all product service bulletins.** Not every service bulletin requires action, but each bulletin should be evaluated. Upon request, SEL can provide specific information or a secure website to track affected relays.

If Steps 1 through 5 are followed, periodic testing, if performed, will not identify any additional failures.

Many users follow Steps 1 and 2 but do not perform Steps 3 through 5 consistently. In this case, **perform periodic testing (e.g., once every ten years) on portions of the relay not tested by self-tests.** This includes injecting known current and voltage signals to verify relay measuring accuracy, asserting inputs, and pulsing output contacts. This need not include reverifying settings, plotting time-current curves or mho circles, and so on. These characteristics are verified at commissioning and do not change. This testing may identify the small number of failures not detected by self-tests (e.g., using the previous failure rates, testing every ten years would detect 0.12% • 10 = 1.2% failures, or 1 failed relay found in 83 relays tested).

This philosophy also applies to systems that do not operate frequently (e.g., bus or transformer differential protection).

Testing When Self-Test Alarm Is Not Monitored

In some rare applications (installations without SCADA or communications), the self-test alarm is not monitored. This is not recommended. For these applications, the relays should be tested every one to six years, including the following:

- Check that the self-test alarm is not asserted.
- Inject known current and voltage signals to verify proper metering.
- Assert inputs, and pulse outputs.

This need not include reverifying settings, plotting time-current curves or mho circles, and so on. These characteristics are verified at commissioning and do not change.

NERC PRC-005-2 Guidance

Table 1-1 and Table 3 of PRC-005-2 establish a specific maximum maintenance interval and required maintenance activities for components that possess the attributes stated in Table 1-1 as follows:

> Monitored microprocessor protective relay with the following:
> - Internal self-diagnosis and alarming…
> - Voltage and/or current waveform sampling three or more times per power cycle, and conversion of samples to numeric values for measurement calculations by microprocessor electronics.
>
> Alarming for power supply failure… [1]

SEL protective relay products include self-diagnostics, alarm functions, and sampling functions that are capable of fulfilling these requirements.

References

[1] NERC Standard PRC-005-2, *Protection System Maintenance*, February 2014. Available: http://www.nerc.com.

[2] J. J. Kumm, M. S. Weber, E. O. Schweitzer, III, and D. Hou, "Philosophies for Testing Protective Relays," proceedings of the 48th Annual Georgia Tech Protective Relaying Conference, Atlanta, GA, May 1994.

[3] J. J. Kumm, E. O. Schweitzer, III, and D. Hou, "Assessing the Effectiveness of Self-Tests and Other Monitoring Means in Protective Relays," proceedings of the PEA Relay Committee Spring Meeting, Matamoras, PA, May 1995.

[4] C. Araujo, F. Horvath, and J. Mack, "A Comparison of Line Relay System Testing Methods," proceedings of the 33rd Annual Western Protective Relay Conference, Spokane, WA, October 2006.

[5] K. Zimmerman and D. Costello, "Lessons Learned From Commissioning Protective Relaying Systems," proceedings of PowerTest 2009, San Antonio, TX, March 2009.

BIOGRAPHY

Karl Zimmerman is a regional technical manager with Schweitzer Engineering Laboratories, Inc. in Fairview Heights, Illinois. His work includes providing application and product support and technical training for protective relay users. He is an active member of the IEEE Power System Relaying Committee and vice chairman of the Line Protection Subcommittee.

Karl received his BSEE degree at the University of Illinois at Urbana-Champaign and has over 20 years of experience in the area of system protection. He is a registered Professional Engineer in the state of Wisconsin.

Karl was a recipient of the 2008 Walter A. Elmore Best Paper Award from the Georgia Institute of Technology Protective Relaying Conference, is a past speaker at many technical conferences, and has authored over 40 technical papers and application guides on protective relaying.

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