An SPP White Paper

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Incorrect Settings Misoperations

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Introduction

The fundamental objective of power system protection is to quickly provide isolation of a system problem while leaving the remainder of the system intact. There are times, however, that the protection system operates incorrectly, or "misoperates", due to failure, malfunction, or other reasons, which may result in tripping of unfaulted elements.

Purpose

In recent years, relay misoperations within the Southwest Power Pool (SPP) footprint have become a greater concern for the SPP, the System Protection and Control Working Group (SPCWG), and for the North American Reliability Corporation (NERC). Analysis, as shown in Figure 1, indicates that misoperations due to communication system failure and incorrect settings are leading causes. In 2015, The SPCWG issued a whitepaper regarding communications-related misoperations. To further that effort, this whitepaper discusses misoperations resulting from incorrect settings and analyzes data taken over thirteen (13) quarters. At the conclusion of this paper, some considerations are provided that, when translated into field application, may help to reduce the number of future misoperations.

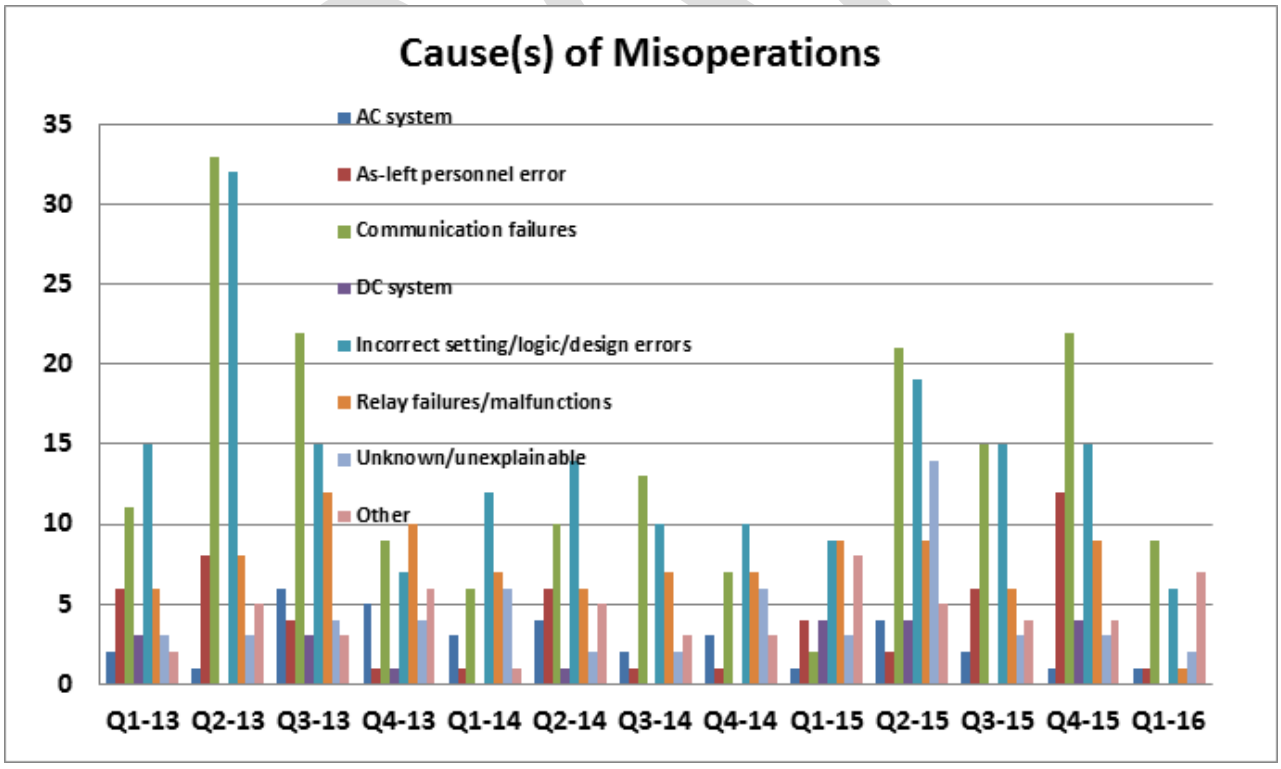

Figure 1: Misoperation Causes
1Q 2013 to 1Q 2016

Design Considerations

Protection schemes are applied to provide prompt removal from service of any element of a power system when it suffers a short circuit, or when it starts to operate in any abnormal manner that might cause damage or otherwise interfere with the effective operation of the rest of the system [1]. Although there are guidelines and standards for prescribing relay settings, there is also an art to protective relaying based upon a firm understanding of the power system. Relay settings and schemes must provide a reasonable balance between dependability and increased security. These terms are defined as:

Dependability – the assurance that any fault will be cleared.

Security – the assurance that a trip occurs only for faults in the protected zone.

Correctly applying the art of protective relaying involves years of experience built upon a basic understanding of power systems and relay schemes.

Analysis of Misoperations Resulting from Incorrect Settings

To assist in the analysis of misoperations resulting from incorrect settings, the SPCWG referred to an analysis by the NERC Protection System Misoperations Task Force (PSMTF) [2]. In its April 2013 Misoperations Report, the PSMTF introduced "sub-causes" for misoperations resulting from incorrect settings. For its analysis in this paper, the SPCWG chose to use the three (3) following sub-causes from the PSMTF report:

- Relay Settings – Logic (RSL)
  - Relay logic setting error, such as trip equations
  - Directionality related settings, including V, I and Q designations, and forward and reverse element designations
  - Carrier coordination timers not set properly
  - Winding compensation issues such as in transformer differential relays, and harmonics
  - Improper use of echo logic
  - Firmware issues

- Relay Settings – Protection Function (RSPF)
  - Improper relay coordination timing, such as zone timers and time overcurrent coordination
  - Overreaching instantaneous zone 1 distance and overcurrent elements
  - Improper coordination of Directional Comparison Blocking (DCB) scheme trip and block elements, such as reverse zone elements not seeing as far as remote forward zone elements
  - Modeling, such as line impedances and transformer connections in software programs
  - Protection element setting error, not including the above four sub-causes, such as impedance reaches, line current differential settings, overcurrent pickup values, and time dials

- Wiring/Design/Prints
  - Anything having to do with connections and wiring in the relay/case and associated connecting harnesses.

Figure 2 shows misoperations due to incorrect relay settings, broken down by sub-cause.

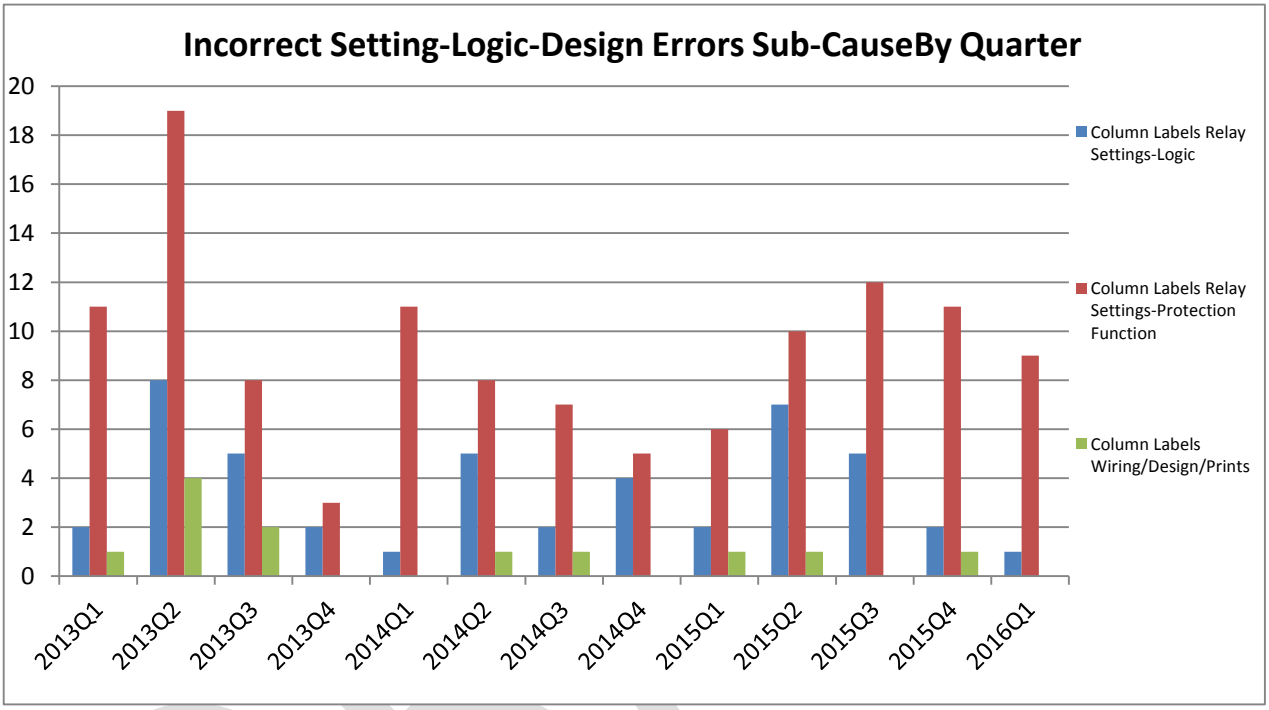

Figure 2: Misoperations Due to Incorrect Setting Sub-Causes
1Q 2013 to 1Q 2016

The data in Figure 2 indicates the greatest contributor to misoperations due to incorrect settings was the sub-cause category “Relay Settings – Protection Function”, followed second by “Relay Settings – Logic”.

Consistent with the PSMTF report, sub-causes were broken down further into the following third level sub-sub-causes, as shown in Figures 3 and 4 :

Note: Some misoperations contained insufficient details to determine the third level cause.

[RSPF] - Improper Coordination of DCB Scheme Trip and Block Element	Improper coordination of DCB scheme trip and block elements, such as reverse zone elements not seeing as far as remote

	forward zone elements
[RSPF] - Improper Relay Coordination Timing	Improper relay coordination timing, such as zone timers and time overcurrent coordination
[RSPF] - Modeling Error	Modeling, such as line impedances and transformer connections in software programs
[RSPF] - Overreaching Zone 1 or IOC Elements	Overreaching zone 1 and instantaneous overcurrent (IOC) elements
[RSPF] - Protection Element Setting Error	Protection element setting error such as impedance reaches, line current differential settings, and overcurrent pickup values and time dials

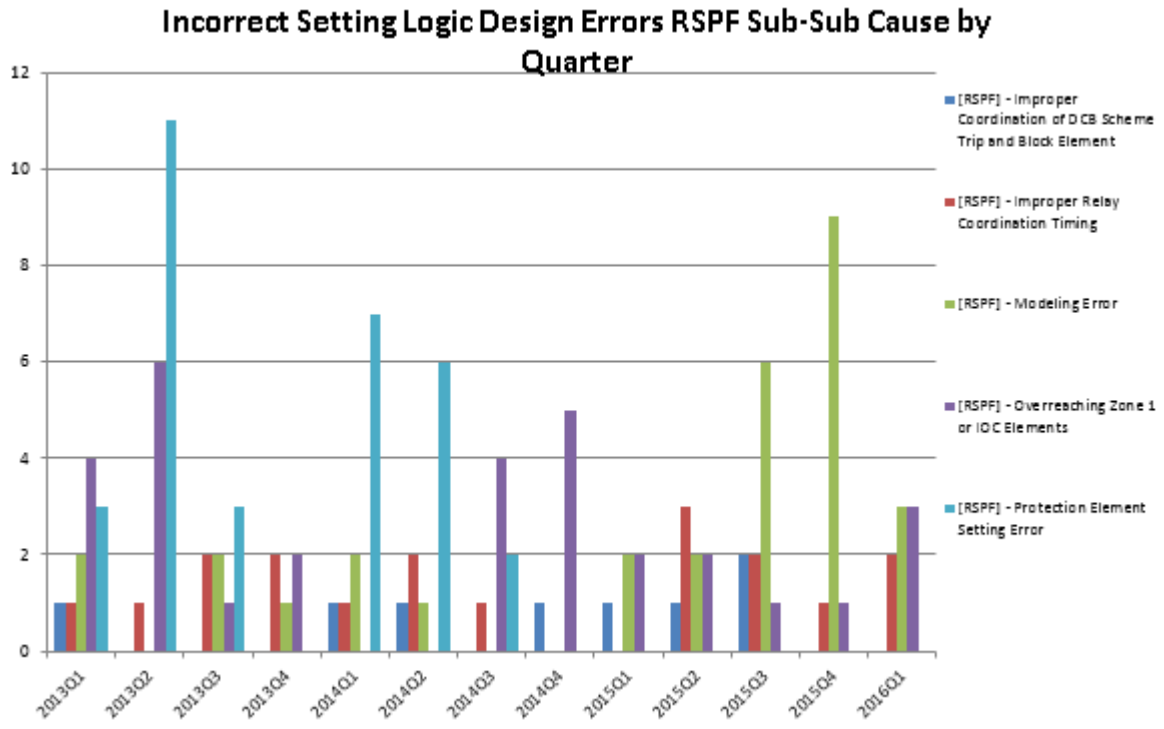

Figure 3: Misoperations Due to Incorrect Setting – RSPF Third Level Causes 1Q 2013 to 1Q 2016

[RSL] - Coordination Timers Set Improperly	Carrier coordination timers not set properly
[RSL] - Directional Settings Issues	Directionality related settings, including V, I and Q designations, and forward and reverse element designations
[RSL] - Firmware Issues	Firmware issues
[RSL] - General Setting Logic Error	Relay logic setting error, such as trip equations
[RSL] - Improper Use of Echo Logic	Improper use of echo logic
[RSL] - Winding Compensation Issues	Winding compensation issues such as in transformer differential relays, and harmonics

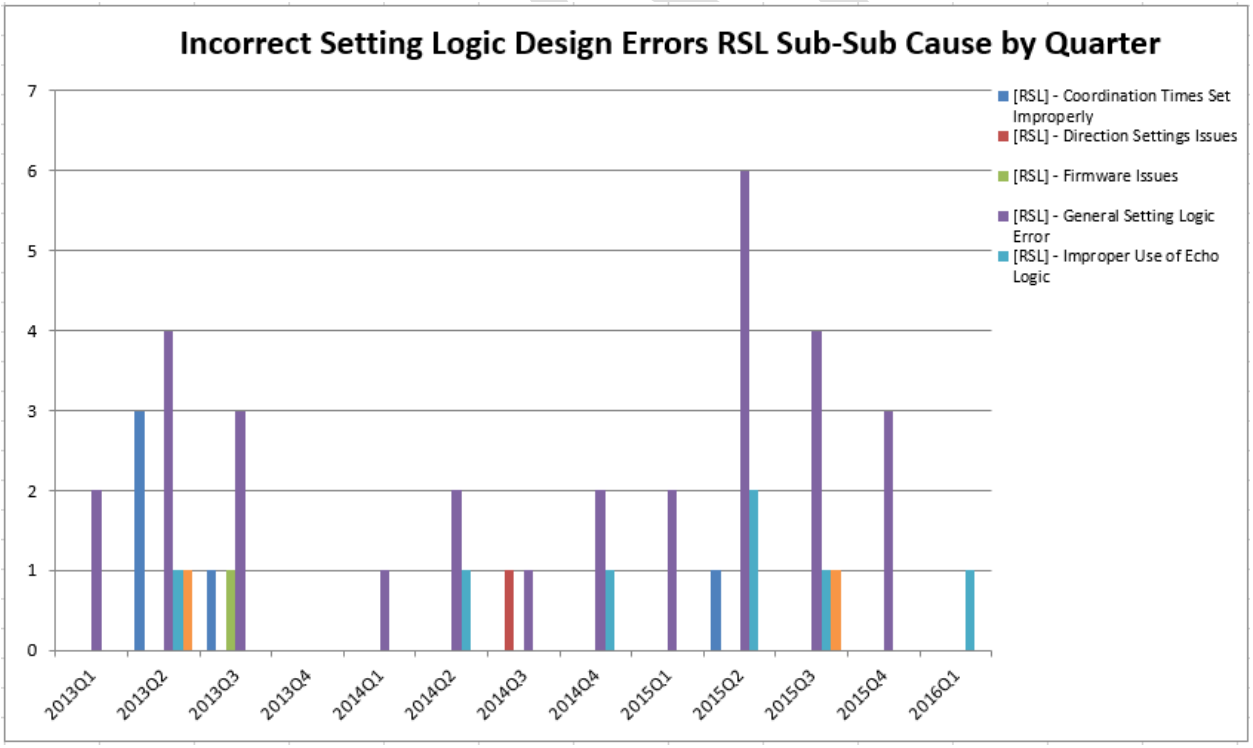

Figure 4: Misoperations Due to Incorrect Setting – RSL Third Level Cause
1Q 2013 to 1Q 2016

The data in this paper identifies Relay Settings – Protection Function (RSPF) and Relay Settings – Logic (RSL) as the most common Sub-Causes attributed to the misoperations analyzed during the study period. The most common sub-sub causes identified for each of these sub-cause categories is provided below. Sub-Cause percentages are based on misoperations of Cause category **Incorrect Settings**.

1. **Relay Settings – Protection Function: 120 (65%) of 186 Misoperations**
   - Protection Element Setting Error, such as impedance reaches, line current differential settings, and overcurrent pickup values and time dials (27% of this sub-cause)
   - Overreaching Zone 1 or IOC Elements (26% of this sub-cause)
   - Modeling Error such as line impedances and transformer connections in software programs (25% of this sub-cause)

2. **Relay Settings – Logic – 46 (25%) of 186 Misoperations**
   - General Setting Logic Error such as trip equations (67% of this sub-cause)
   - Improper Use of Echo Logic (16% of this sub-cause)
   - Coordination Timers Set Improperly (9% of this sub-cause)

Root Causes

Relay settings errors that occur in the above sub-cause categories may be attributed to human performance issues such as:

- Increasing complexity of microprocessor-based protection system relays. These relays require a high degree of knowledge and understanding of the multitude of settings options and their appropriate application.
- Experience level of engineers. Many utilities are experiencing high rates of retirement of their more-experienced protection engineers.
- Increased engineering workload. This may include compliance-related activities that can draw resources away from reliability-related activities.

Utilities may consider standardization of procedures and processes to potentially decrease the likelihood of human error.

Considerations

The following items provide actions that may help reduce the most common misoperations:

- Peer review of relay settings by an experienced protection engineer familiar with an entity's system and protection and control schemes.

- Ensure phase and ground IOC elements are set with consideration of the appropriate contingencies, and follow recommendations in NERC Reliability Standard PRC-027-1 [2].
- Review and confirm modeling data is correct when developing, reviewing and verifying relay settings.

The following items may also help entities reduce misoperations due to relay settings issues:

- Check coordination of new settings at least two buses away.
- Establish a written procedure to ensure changes in the field are reported back to the protection group for review – before the change occurs.
- Understand consultant capabilities – ask for credentials of PE signing off on relay settings and quality control process.
- Use standard approved logic schemes and setting templates. Changes to logic should go through peer review.
- Use actual relay fault data to check the system model.
- Monitor relay firmware versions. If the relay vendor has issued updated relay firmware, assess the new firmware's appropriateness for your relay application and proceed accordingly.
- Consider locking down relay firmware.
- Consider appropriate contingencies when setting relays.
- Applications requiring coordination of functionally-different relay elements should be avoided.
- Where mutual coupling exists, use negative sequence rather than zero sequence for polarization of ground protective relays.
- Ensure relays at both ends of the line employ the same polarization method.

Conclusions

This document provides background information for the misoperations that have occurred in the SPP region, and identifies common root causes. Knowing the root causes enables utilities to more accurately troubleshoot problems and take preventive measures to reduce the likelihood of future misoperations. The considerations above provide specific information that can be acted upon to help reduce the number of misoperations that occur due to relay settings errors.

Reference

[1] NERC Reliability Standard PRC-027-1 Coordination of Protection Systems for Performance During Faults

[2] *“Misoperations Report, Prepared by: Protection System Misoperations Task Force”*, by North American Electric Reliability Corporation (2013).
[3] C. R Mason, *Art and Science of Protective Relaying,* Wiley, 1956