An SPP White Paper

201 Worthen Drive
Little Rock, AR 72223
www.spp.org

Relay Communication Misoperations

By:
System Protection and Control Working Group
July 16, 2014

Contents

Introduction	3
Purpose	3
Design Considerations	4
Risk Assessment and Operating Considerations	5
Analysis of Communication Related Misoperations	5
Root Causes	8
Lessons Learned	9
Conclusions	9
Reference	9

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 various other reasons which may result in tripping of unfaulted elements.

Purpose

In recent years, relay misoperations within the SPP footprint have become a higher concern for SPP, the SPCWG, and for NERC. Analysis, as shown in Figure 1, indicates that misoperations due to communication system failure are a leading cause. This whitepaper discusses these communication misoperations and analyzes data taken over one year to determine their root cause. Lessons learned are then provided that can be translated into field application, thus reducing the number of future misoperations.

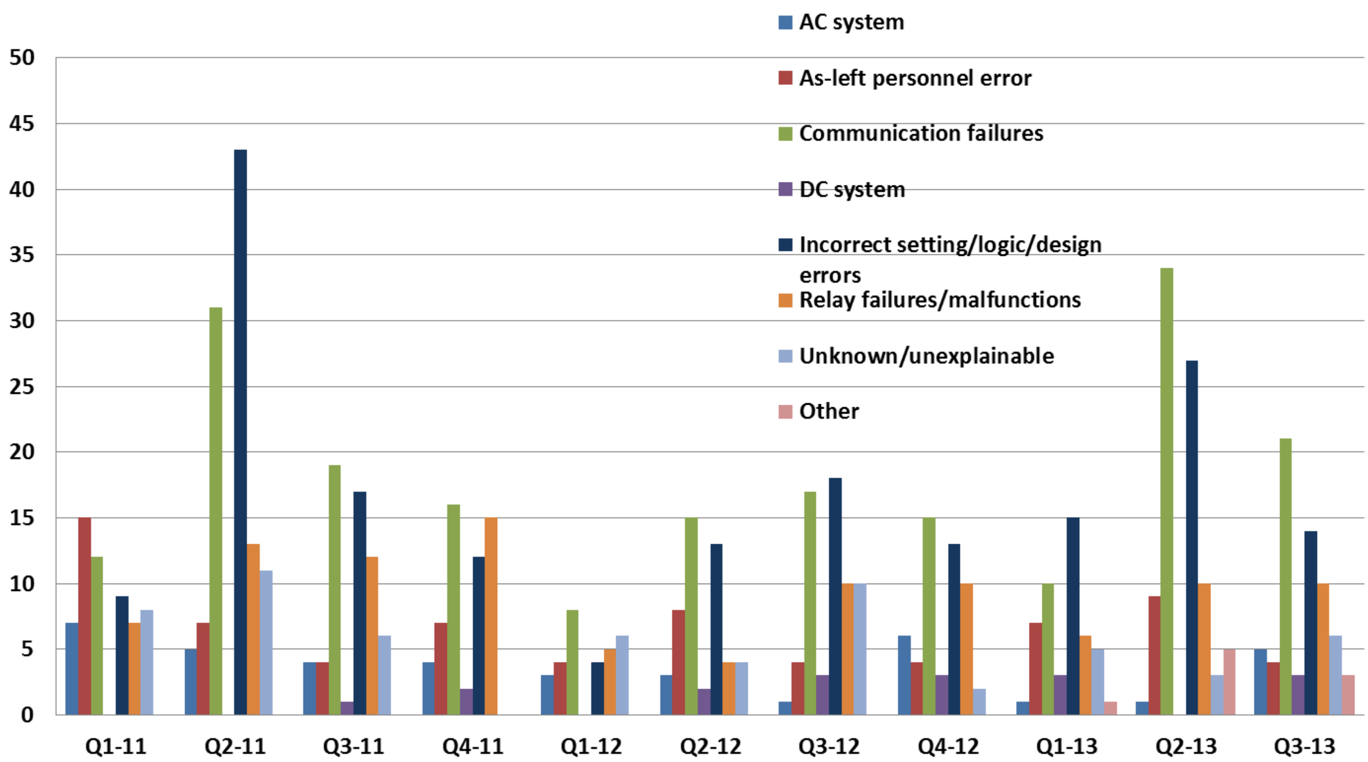

Figure 1: Misoperation Causes 1Q 2011 to 3Q 2013

Design Considerations

Communication assisted protection schemes are applied to provide high speed tripping for faults over 100% of the transmission line length. These schemes are not mandatory from a regulatory perspective unless driven by a transmission planning (TPL) compliance concern such as critical clearing time to maintain stability. These schemes are typically installed to improve power quality and reduce equipment damage due to fault duration.

These communication assisted schemes are designed to provide either increased dependability or increased security. These are defined as:

Dependability – the assurance that any fault will be cleared.

Security – the assurance that a trip occurs only for faults on the protected line.

The three (3) common types of communication assisted protection schemes are:

1. Differential – Operates on the principle that the relays at all ends of a line measure the current and communicate to ensure that the amount of current going into the line equals the current going out, or else a fault is assumed.

   This scheme is biased more toward security than dependability.

2. Permissive – Operates on the principle that the relays at all ends of a line detect a fault and communicate to agree that the fault appears in the forward looking direction (on the protected line) for which a trip with no intentional time delay will occur. Otherwise, a trip occurs only after a time delay.

   This scheme is biased more toward security than dependability.

3. Blocking – Operates on the principle that the relays at all ends of a line each individually detect a fault and that the fault appears in the forward looking direction, for which they trip with no intentional time delay, unless a remote end relay communicates that the fault is in the reverse direction. Only then will they trip after a time delay.

   This scheme is biased more toward dependability than security.

Blocking schemes (also referred to as Directional Comparison Blocking or DCB) are typically chosen when a failure to trip will be more detrimental to the system than over-tripping. This scheme is immune to failing to trip for a fault on the protected line if communication is lost in conjunction with that fault, since tripping will occur when no signal (Block) is received. These schemes are designed to reach (to detect faults) past the end of the line and trip with no intentional delay unless a signal is received from the remote end to block the local breaker from tripping. This provides dependability but increases the chance of over-tripping if the block signal is not received for faults beyond the remote end breaker, making the scheme less secure

Risk Assessment and Operating Considerations

Occasionally a deteriorated communication scheme will need to be temporarily left in service due to customer considerations (avoiding prolonged voltage dip). Should this decision be made, there remains a possibility of misoperations until corrective actions can be completed. Stability related issues and risk of equipment damage can also be reasons to keep a deteriorated scheme in service.

Analysis of Communication Related Misoperations

To assist in the analysis of the communication related misoperations, the System Protection & Control Working Group (SPCWG) referred to a recently completed (April 2013) analysis by the NERC Protection System Misoperations Task Force (PSMTF). The PSMTF came up with “sub-causes” for misoperations related to communications failures. The SPCWG chose to use these same sub-causes for its analysis, to provide consistency with the PSMTF’s analysis. The PSMTF determined that these misoperations could be broken down into one of the following five sub-causes:

1. Communication Interface Failure (Modulator): Power-line carrier radios, fiber optic interfaces, microwave radios, audio-tone/telecommunications, and pilot wire components.
2. Communication Medium: The external signal path, leased phone circuits, cables, transmission lines, etc.
3. Station Signal Path Failure: All signal carrying components within the substation fence including cables, frequency filters, connectors, etc.
4. Incorrect Logic Settings Issued: Channel timing, dip switches, etc. Protective relay settings were considered as a settings problem and not counted as a logic issue. (This is difficult to determine when digital relays contain both logic and settings).
5. Human Error (Misapplication in field): Incorrect settings both logic and relay reach, as left conditions, etc.

In addition there were some events for which there was insufficient information.

Figure 2 identifies the communication components for a typical power line carrier scheme and related misoperation sub-causes[1].

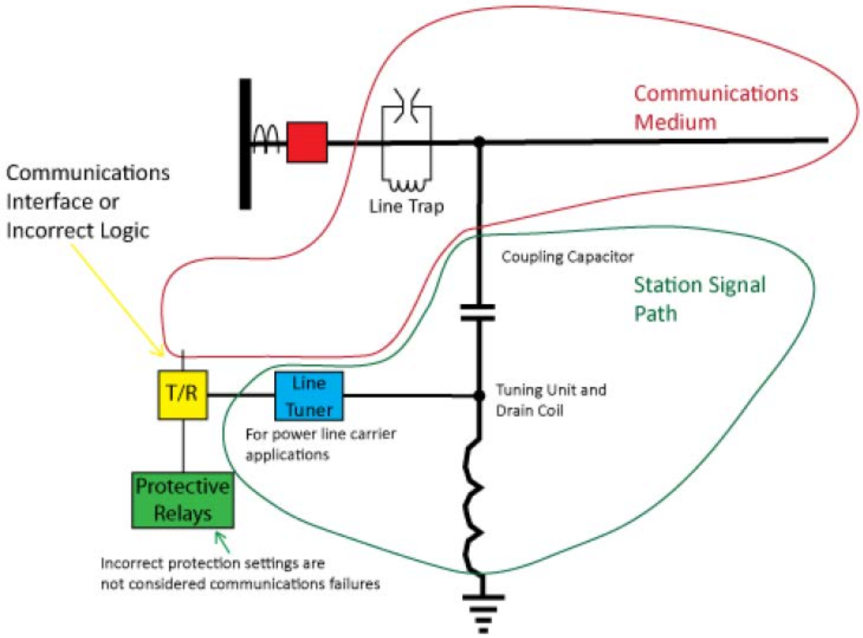

Figure 2: Communication Failure Misoperations

The SPCWG added two additional categories for misoperations for events that did not fit within the five PSMTF sub-causes. These are: Limited Investigation Due to Equipment Upgrade, and Other.

The SPCWG reviewed 101 misoperations that occurred in SPP for a one year period, from the fourth quarter of 2012 through the third quarter of 2013. The graph shown in Figure 3 shows the results of the analysis. The two sub-causes with the most misoperations were 1.) Communication Interface Failure, and 2.) Station Signal Path Failure.

The misoperations data shows that a majority of line protection schemes are designed to use Blocking systems. As described above, Blocking systems are more susceptible to misoperating when the communications system becomes deteriorated; however, blocking schemes are also more secure for clearing of faults when the communications system becomes deteriorated.

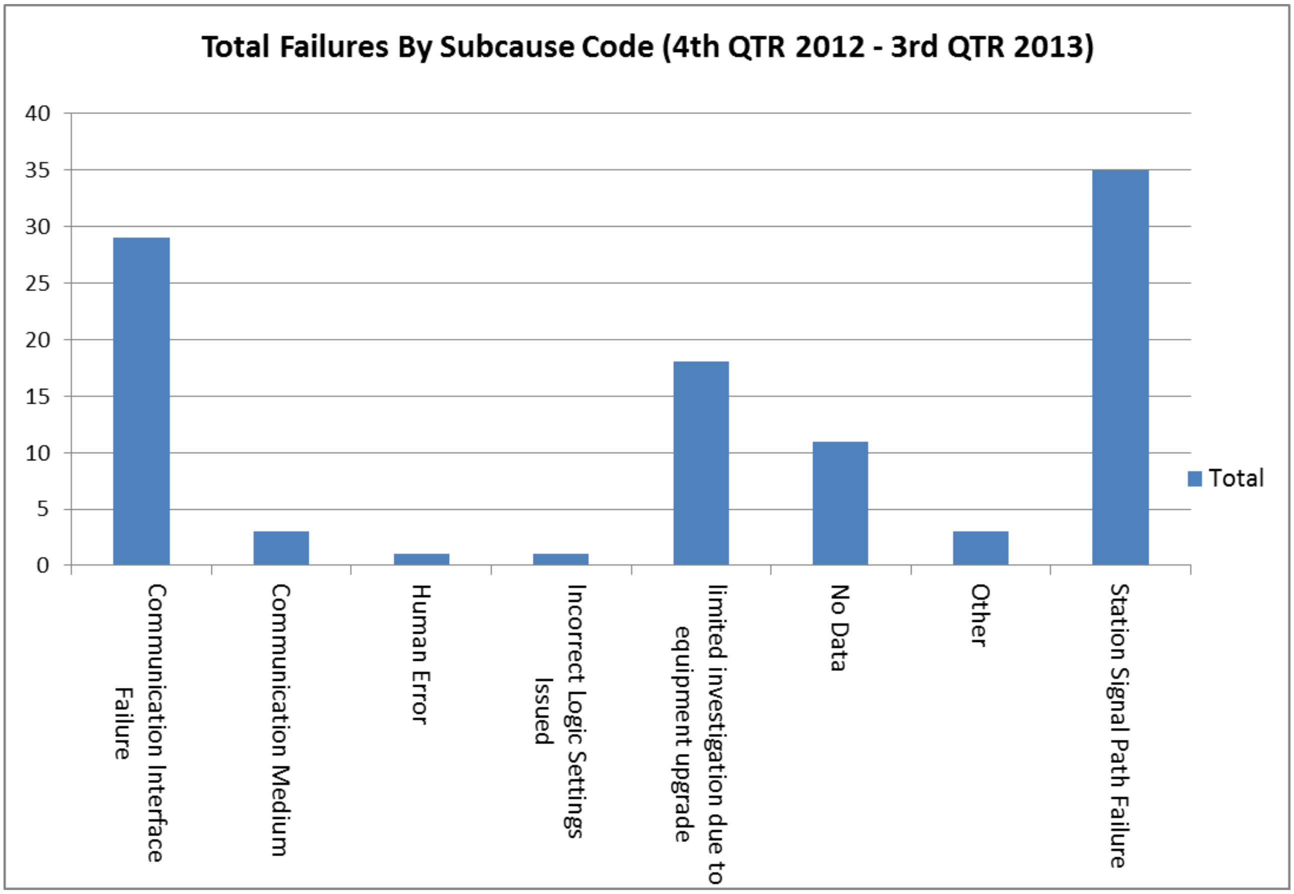

Figure 3: Total Failures By Sub-cause

Comparing the SPP analysis with the NERC PSMTF analysis, there were a few differences. The table below shows the percentage of misperations by sub-cause for both SPP and NERC.

Sub-cause	SPCWG Analysis	NERC Analysis
Communication Interface Failure (Modulator)	29%	32%
Communication Medium	3%	16%
Station Signal Path Failure	35%	17%
Incorrect Logic Settings Issued	1%	6%
Human Error	1%	3%
Insufficient/No Data	11%	27%
Limited Investigation Due To Equipment Upgrade	18%	
Other	2%	---

Table 1: SPP/NERC Communication Misoperation Sub-cause Comparison

Root Causes

The following are examples or possible root causes for each of the sub-cause categories.

1. **Communication Interface Failure**
   - Shorted surge protection (Transient Voltage Suppressor)
   - Failed Transceiver

2. **Communication Medium**
   - Failed wave trap (tuning out of adjustment or malfunction)
   - Loss or degradation of signal (microwave or tone signals)
   - Lack of wave traps at tapped load locations (results in loss of signal)

3. **Station Signal Path Failure**
   - Protective Gap calibration
   - Deteriorated spark gaps in the line tuner
   - Failed component in the line tuner

4. **Incorrect Logic Settings**
   - Incorrect communication settings in the carrier or relay

5. **Human Error**
   - Carrier cutoff left off at one terminal and on at the other terminal.
   - Ground switch on CCVT left in “ground” position

Lessons Learned

Lessons Learned:

- Equipment spark gaps, insulators, and surge arresters are known to cause carrier holes if not maintained properly
- Fiber optic communications provide increased reliability and security over microwave or power line carrier systems
    - Power Line Carrier systems are subject to “carrier holes”
    - Microwave systems have issues with signal fading
- End-to-end testing is advantageous during commissioning to find timing errors and to confirm signal quality
- Deteriorated, older equipment requires increased maintenance activity and is more likely to fail than newer equipment. Diagnostic capabilities are lacking as well.
- Mismatched equipment or differing setting philosophies at opposite ends of the line can create timing issues resulting in misoperation.

Conclusions

Communications assisted schemes add sophistication to line protection schemes and provide the advantage of high speed clearing of faults, which improves power quality for our customers. The increased complexity of these schemes also means there are more components that require maintenance and possible replacement when they become deteriorated.

Historically, the most prevalent design used by utilities has been Blocking schemes which err on the side dependability, resulting in a tendency to trip unnecessarily rather than failing to trip. As a result, when the communications systems do not work properly, misoperations occur.

This document provides information on the background of the misoperations that have occurred in SPP and identifies root causes. Knowing the root causes enables utilities to more accurately trouble shoot problems and take preventive measures to reduce the likelihood of misoperations in the future. The lessons learned provide specific information that can be acted on to help prevent misoperations.

Reference

[1] *“Misoperations Report, Prepared by: Protection System Misoperations Task Force”*, by North American Electric Reliability Corporation (2013).