Relay Communication Misoperations

Southwest Power Pool

System Protection and Control Working Group
Relay Misoperations

• The fundamental objective of power system protection schemes 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”.

• A misoperation occurs when a protective relaying scheme trips for a disturbance or fault outside of its zone of protection, which can result in unintended outages.
Misoperations in SPP

![Graph showing misoperations in SPP across different quarters, with categories for AC system, as-left personnel error, communication failures, DC system, incorrect setting/logic/design errors, relay failures/malfunctions, unknown/unexplainable, and other categories.](image)
Misoperations Analysis

• SPP had the highest percentage of misops of any region in the U.S. in 2013.
• Communications related misops are a leading cause.
• Analysis was performed on misops over a 1 year period from Q4 2012 through Q3 2013.
• Purpose is to determine the root causes associated with communication system failures.
• Also provide lessons learned that can be applied to reduce the number of future misops.
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.
Design Considerations

• 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.
Design Considerations
Three common types of communications assisted schemes

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.
Design Considerations
Three common types of communications assisted schemes

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.
Design Considerations

Three common types of communications assisted schemes

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

- 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.
- Blocking schemes are the most commonly used type of design because they allow relay engineers to take a more conservative approach toward protection.
- The relays have a directional characteristic – to differentiate forward faults from reverse faults.
Blocking Schemes

• These schemes are 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 Approach

• Same as 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 five sub-causes.
Analysis Approach
PSMTF 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.
Components of a Typical Power Line Carrier Scheme
Analysis of SPP Misops

• The SPCWG added two additional categories of sub-causes:
  – Limited Investigation Due to Equipment Upgrade
  – Other

• The SPCWG reviewed 101 misoperations that occurred in SPP for the one year period. The two sub-causes with the most misoperations were
  – 1.) Communication Interface Failure, and
  – 2.) Station Signal Path Failure.
Results of Sub-cause Analysis

Total Failures By Subcause Code (4th QTR 2012 - 3rd QTR 2013)

- Communication Interface Failure: 30
- Communication Medium: 2
- Human Error: 2
- Incorrect Logic Settings Issued: 1
- Limited Investigation due to equipment upgrade: 15
- No Data: 10
- Other: 1
- Station Signal Path Failure: 35

[Bar chart showing the number of failures for each category]
## Comparison to PSMTF Analysis

<table>
<thead>
<tr>
<th>Sub-cause</th>
<th>SPCWG Analysis</th>
<th>NERC Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication Interface Failure (Modulator)</td>
<td>29%</td>
<td>32%</td>
</tr>
<tr>
<td>Communication Medium</td>
<td>3%</td>
<td>16%</td>
</tr>
<tr>
<td>Station Signal Path Failure</td>
<td>35%</td>
<td>17%</td>
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<tr>
<td>Incorrect Logic Settings Issued</td>
<td>1%</td>
<td>6%</td>
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<tr>
<td>Human Error</td>
<td>1%</td>
<td>3%</td>
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<tr>
<td>Insufficient/No Data</td>
<td>11%</td>
<td>27%</td>
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<tr>
<td>Limited Investigation Due To Equipment Upgrade</td>
<td>18%</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>2%</td>
<td>---</td>
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</table>
Root Causes for each Sub-cause

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

2. **Communication Medium** (red area – high voltage)
   - 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** (green area – signal coupling)
   - Protective Gap calibration
   - Deteriorated spark gaps in the line tuner
   - Failed component in the line tuner

4. **Incorrect Logic Settings** (yellow box or green box)
   - Incorrect communication settings in the carrier or relay

5. **Human Error** (green area)
   - Carrier cutoff left off at one terminal and on at the other terminal.
   - Ground switch on CCVT left in “ground” position
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 a misoperation.
Conclusions

• Communications assisted schemes add sophistication to line protection schemes:
  – provide the advantage of high speed clearing of faults to improve power quality and reduce damage to power equipment.
  – The increased complexity of these schemes also means there are more components that require maintenance and possible replacement when they become deteriorated.

• Knowing the root causes enables utilities to more accurately troubleshoot 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.
Questions

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