NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Lesson Learned

Initiatives to Address and Reduce Misoperations

Primary Interest Groups
Transmission Owners (TOs)
Generator Owners (GOs)

Problem Statement
A registered entity experienced a high rate of Bulk Electric System (BES) misoperations over the last several years and desired to improve.

Details
The entity compiled their NERC and North American Transmission Forum (NATF) quarterly BES misoperation submittals over 15 quarters and studied the percentages and trends of the various cause codes. The most prominent categories of misoperations were the following:

- **24.5 percent:** relay failure or relay condition related
- **22 percent:** communication equipment or communication path related
- **18 percent:** relay setting or schematic design related

The entity then established several initiatives to address those top causes of misoperations. Those initiatives included the following:

1. **Target Worst Performing Communication Assisted Schemes**
   The registered entity studied the causes of reportable misoperations over a five-year period and found that a significant percentage were attributed to directional comparison blocking (DCB) line protection schemes.

   A team was formed to review and identify a mitigation strategy for reducing the number of misoperations attributed to communications equipment failures or path problems. This mitigation strategy centered on improving communication technologies and replacing equipment.

   The registered entity determined it needs to review the worst performing DCB circuits on a periodic basis, and may need to take action to improve their performance. These periodic reviews typically result in reliability improvement projects to upgrade the condition of equipment and enhance system performance.

2. **Identify Solutions for "Holes" in Carrier DCB Carrier Schemes and Misapplied Directional Settings**
   The registered entity experienced misoperations due to momentary "holes" in the blocking carrier signal for DCB line protection schemes. "Holes" in the carrier signal need to be investigated and mitigated, if possible. The registered entity determined that if microprocessor relays are involved,

they can be set to ride through momentary blocking carrier signal "holes" to avoid unnecessary trips for a fault on an adjacent line.

In addition, the registered entity experienced misoperations due to DCB scheme settings, timers, and misapplied directional element settings on microprocessor based relays. There have been optimization recommendations in recent years from manufacturers and industry regarding directional settings of microprocessor-based relays that the entity had not yet implemented.

The registered entity is adopting revised standard logic and timer settings for DCB schemes with microprocessor-based line relays and for directional element settings of microprocessor-based relays. This was due to discussions at a NATF peer review in which the registered entity participated as well as discussions during training sessions presented by a relay manufacturer.

3. **Identify Legacy Relay Settings that Are too Sensitive for Present Transmission System Short Circuit Conditions and Topology**
   The registered entity experienced misoperations due to incorrect legacy as-issued relay settings which did not account for changing system short circuit currents and nearby system topology. The legacy relay settings in question were issued several years ago but are no longer optimal and need to be reviewed and revised.

   Following a misoperation investigation, the original relay settings were reviewed with the aid of an EPRI macro called the Protective System Evaluation Tool (PSET). The inappropriate relay settings were detected by the running of the EPRI PSET macro in the registered entity's transmission system short circuit network and protection model of the transmission system. The transmission system short circuit network and protection model includes the system short circuit model as well as functioning protective relay models with present settings. The PSET macro is designed to detect and report on relay settings that are not optimal, which includes settings that are too sensitive, relays that do not coordinate with backup relays, or relays that do not clear faults on the protected power system element.

4. **Obtain Industry Peer Review and Assistance**
   Additionally, the entity sought industry peer review and assistance by hosting a week long on-site NATF peer review to discuss best practices for transmission protection and maintenance.

   The entity then requested a NATF challenge board review to analyze the entity's "Relay Misoperations Improvement Plan" to help reduce its high rate of misoperations and provide input on possible ways to improve the plan.

   The NATF challenge board took 13 weeks from initial request to final results. Approximately 20 documents were provided to the NATF subject matter expert team assembled from utility volunteers. A sub-team was formed to perform a detailed review of proposed settings practices for DCB schemes.

Corrective Actions

1. **Target Worst Performing Communication Assisted Schemes**
   The registered entity is targeting the replacement of obsolete transmission electromechanical and static relays used for primary and backup DCB line protection, breaker failure, reclosing, and sync check. The registered entity will manage this initiative by upgrading relays, line terminals, and installing fiber communication systems when feasible. When practical, the registered entity will reprioritize its fiber buildout plan to expedite the installation of fiber for its worst performing circuits. Additionally, the registered entity changed its preferred standard for new installations to include fiber for protection system communications.

2. **Identify Solutions for "Holes" in Carrier DCB Carrier Schemes and Misapplied Directional Settings**
   After discussion with industry peers and the relay manufacturer, the registered entity is adopting revised standard logic and timer settings for DCB schemes and directional element settings for microprocessor-based line protection relays. These revisions will be implemented in two phases.

   a. Phase 1 will change timer settings and/or logic settings to ride through holes in carrier signals on DCB line protection schemes that use microprocessor-based relays at one terminal end of a line when the same changes cannot be made at the other terminal end at the same time.

   b. Phase 2 will be accomplished during a five-year accelerated testing plan for transmission relays. The following setting changes will be made at both terminal ends of a line at the same time:

      i. Timer settings and/or logic settings to ride through carrier holes, if not already addressed

      ii. Carrier trip/carrier start margin check and adjustment

      iii. Non-directional ground start of carrier on DCB schemes

      iv. Directional settings for all microprocessor-based relays

Additionally, the entity will identify where manufacturer recommended optimizations regarding directional settings of microprocessor-based relay can be implemented.

3. **Identify Legacy Relay Settings that are too Sensitive for Present Transmission System Short Circuit Conditions and Topology**
   New relay settings based on present short-circuit conditions and system topology were calculated and applied to the relays that misoperated.

   To reduce future occurrence of misoperations of this type, the registered entity has been actively running the PSET macro throughout its entire transmission system model to flag other existing relay settings that may not be optimal and that may cause future misoperations.

   While engaged in this effort, the entity has also discovered deficiencies in its modeling of relays in the transmission system short circuit network and protection model and is working with a contractor to update the transmission system short circuit network and protection model.

The entity plans to periodically run the PSET macro throughout the transmission system model to identify any relay settings that may not be optimal and that may cause future Misoperations.

4. **Obtain Industry Peer Review and Assistance**
   As a result of the NATF on-site visits, transmission protection and maintenance documents were updated to reflect best practices.

   NATF challenge board meetings were conducted via webinar and no on-site visits were required. The NATF challenge board team made 27 recommendations of which 16 were accepted and related changes have been implemented, are in progress, or plans have been developed to do so. The other 11 recommendations were not implemented because present methods were deemed justified or the data did not support the need for the recommended change.

Lessons Learned

NERC has identified addressing misoperations as a key area of focus in reducing known risks to reliability. An unnecessary trip involves more protective devices operating than is necessary and is typically not previously studied in a day-ahead assessment while a failure to trip could lead to safety concerns for personnel and equipment.

Not every recommendation below would fit each registered entity. A risk assessment regarding the causes of misoperations plus a review of resources (staffing, technical expertise, third party assistance) is needed to determine which recommendation, or combination of these recommendations, may provide better entity-specific guidance for reducing misoperations.

1. Conduct an internal review of your company's practices to understand the nature and reasons behind misoperations.
2. Gain additional insight and overcome any internal biases and blindspots with an industry peer review of your company's practices to reduce misoperations, or a more general review of your company's transmission system protection practices. The peer review's requested output would be recommendations that, if implemented, would help reduce misoperations and other protection problems.
   a. Regional Entities can coordinate subject matter expert review and assistance from their various working groups and members.
   b. The NATF has several programs (peer review, assistance visit, etc.) for NATF members to request member SMEs to review company practices and make recommendations.
   c. EPRI has member assistance programs and processes as well.
   d. NERC reliability assurance assistance visits are an option for all registered entities.
   e. Many vendors and consultant organizations provide technical and organizational process & program review services.
3. Target replacement of obsolete transmission electromechanical and static relays used for primary and backup DCB line protection and consider upgrading to fiber for protection system

communications when feasible. Note: maintenance of obsolete equipment generally becomes more expensive over time.

4. Establish a company standard regarding settings for microprocessor-based relays used in DCB schemes that addresses:
   a. Timer and/or logic settings to ride through carrier holes. Microprocessor-based relays used in DCB line protection schemes can be set to mitigate unexpected tripping due to momentary blocking carrier "holes." This includes settings for new relay installations as well as for existing relays that may have been set before the latest setting standards. The use of such ride-through logic should be considered only as part of a mitigation strategy that also includes efforts to find and correct the causes of carrier holes to limit their occurrence.
   b. Carrier trip/carrier start margin check and adjustment
   c. Choice of directional versus non-directional carrier start
5. Review and change settings for microprocessor-based relays with directional elements to follow the latest manufacturer and industry recommendations.
6. Relay settings should be kept in a database and be accurate and optimal for present system short circuit conditions and system topology. Ensuring this requires periodic reviews of existing settings issued years ago that may have been optimal at that time, but are no longer optimal due to changing system short circuit conditions and nearby system topology. The need for a review can also be triggered by significant additions or retirements in the system–thresholds for triggering such a review could be determined by the entity's planning organization.
7. This effort can be assisted by use of automated tools that utilize a macro on a routine basis that are designed to run in the entity's short circuit and relay model application to identify errant or sub-optimal relay settings. Such automated tools simulate faults on the system and report relay settings that may over reach for faults beyond remote terminals or that do not coordinate with other relays.
8. Periodically analyze accumulated relay operations data to discover adverse trends. These analysis efforts should be customized to the entities size and the number of misoperations they have. Some large entities look at this data quarterly, others on an annual basis. Without analyzing operations, it is difficult to know the primary issues causing misoperations or where the "hot spots" are on a system. It is difficult to justify projects to comprehensively address issues without analysis. The more entities are aware of their issues, the more proactive they can be in addressing those issues. Entities without any type of review tend to waste time and money reacting to individual issues.

NERC's goal with publishing lessons learned is to provide industry with technical and understandable information that assists them with maintaining the reliability of the bulk power system. NERC requests that you provide input on this lesson learned by taking the short survey provided in the link below.

Click here for: Lesson Learned Comment Form

For more Information please contact:

NERC – Lessons Learned (via email)	RF – Event Analysis (via email)
Source of Lesson Learned:	Reliability*First*
Lesson Learned #:	20181201
Date Published:	December 17, 2018
Category:	Relaying and Protection Systems

This document is designed to convey lessons learned from NERC's various activities. It is not intended to establish new requirements under NERC's Reliability Standards or to modify the requirements in any existing Reliability Standards. Compliance will continue to be determined based on language in the NERC Reliability Standards as they may be amended from time to time. Implementation of this lesson learned is not a substitute for compliance with requirements in NERC's Reliability Standards.