WECC

Misoperations Reduction Strategies

Event Analysis and Situation Awareness

2018

Executive Summary

Protection systems are critical to the reliable operation of the electric grid. Protection systems detect certain conditions and react in a predetermined way to protect sensitive equipment. This allows the system to return to normal operations once the condition has passed. A protection system consists of protective relays, associated communication systems, voltage- and current-sensing devices, station batteries, and DC control circuitry. There are tens of thousands of protection system devices in the Western Interconnection.

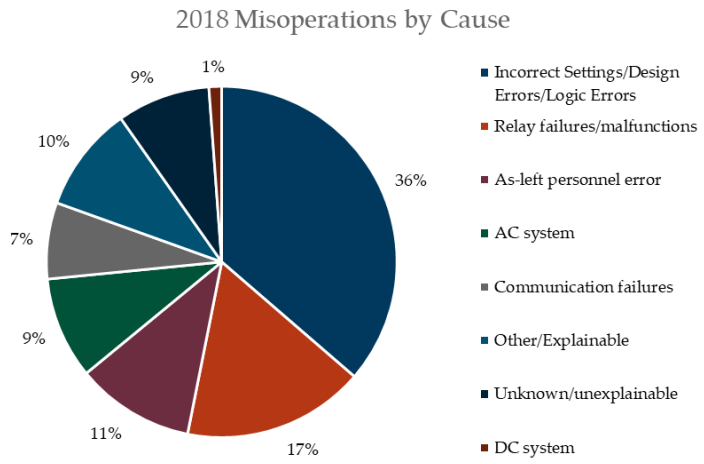
When a protection system malfunctions or "misoperates," the system runs in a less reliable state. A protection system element misoperates when it does not operate as designed or operates outside its zone of protection. In addition to interfering with the protection of system equipment, protection system misoperations contribute to transmission outages and negatively affect system reliability.

WECC is part of a national effort to reduce misoperations. In 2018, a group of WECC staff, stakeholders, and industry subject matter experts developed voluntary Misoperations Reduction Strategies to help entities throughout the Western Interconnection to reduce their misoperations. These strategies suggest several actions entities can use in their own approaches to reduce misoperations. Together with its Relay Work Group (RWG), WECC analyzes all misoperations reported through the NERC MIDAS system and tracks the progress of the Western Interconnection collectively and on the individual-entity level.

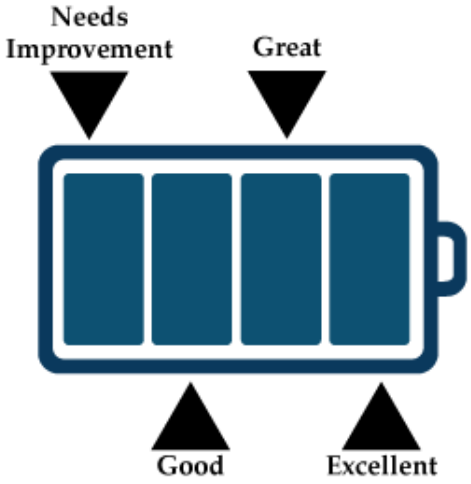
The Misoperations Reduction Strategies focus on the top three causes of misoperations in the Western Interconnection, as well as misoperations involving human factors. The following "cause categories" make up about 75% of all reported misoperations.

- Incorrect setting/logic/design errors
- Relay failures/malfunctions
- Unknown/unexplainable
- As-left personnel error

By targeting these causes, entities in the West can take actions that will effectively reduce the rate of misoperations.



To track the Western Interconnection's progress implementing the Misoperations Reduction Strategies, WECC and the RWG have assigned battery status indicators to each section of the strategies. These indicators are meant to reflect a qualitative assessment of that section's progress rather than a quantified measurement. These indicators will be updated periodically to show areas of continued improvement and to highlight areas that need heightened attention.



Background

The Misoperations Reduction Strategies are divided into seven subject matter sections:

- Ground Overcurrent Protection
- Human Performance During Commissioning
- Knowledge Transfer
- Limited Information for Investigations
- Root Cause Analysis
- Settings Validation

- Short-Circuit Model Quality

For each of these sections, the strategies provide an analysis and suggested actions that entities can take to help reduce misoperations in that category. WECC will track progress in each of these categories as entities take action.

Setting the Goal

The misoperation rate is the percentage of all protection system operations that are misoperations, including failed operations. The rate varies over time. The Misoperations Reduction Goal uses a statistical model to tell whether a rate decrease is due to normal variability or a decreasing trend in misoperations across the Interconnection.

The number of misoperations and correct operations are assumed to be independent, random variables that follow known distributions. Although we do not know what the numbers will be in the future, based on our assumptions, we expect they will fall within certain ranges with known probabilities. If the rates are much lower than the rates we predicted in the model, we will infer the rate is decreasing.

The misoperation rate seen in 2017 was 5.74%. The model predicts that, if the frequency of misoperations is not decreasing, future rates will be above 5.09%, 90%of the time. In other words, accounting for normal variation in rates, after one year, we would expect the misoperation rate to be no more than 11% lower than the rate in 2017. This is the Misoperations Reduction Goal.

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Strategies to Reduce Misoperations—Ground Overcurrent Protection

Suggested Action

The actions below are recommended based on the data related to this category and the experience of the Reduction Strategies team. Consider the existing practices of your entity to decide which actions will bring the greatest improvement.

Examine

WECC and the RWG analyze the extent of the condition in the Western Interconnection.

Evaluate

Entities assess ground fault protection practices.

Educate

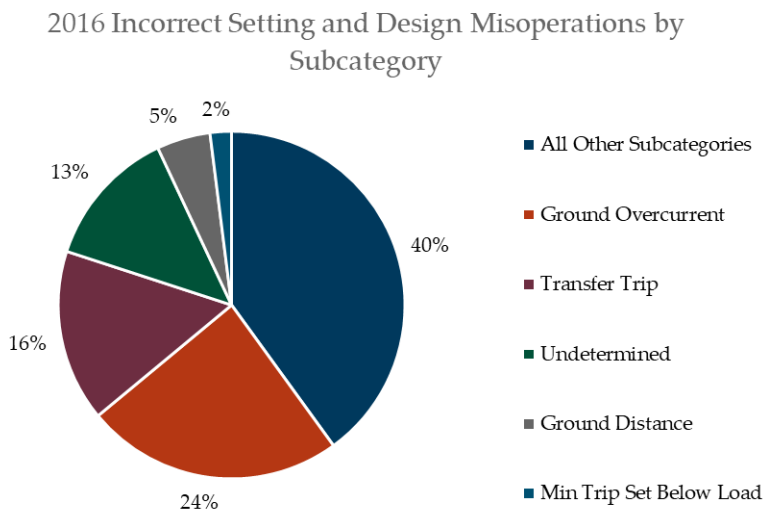
WECC hosts educational webinars or workshops with industry subject matter experts addressing Ground Fault Protection challenges.

Develop Guide

WECC and the RWG develop a guide with examples of effective coordination of ground overcurrent fault settings.

Summary of the Issue

Many incorrect setting misoperations in the Western Interconnection are caused by ground overcurrent settings. This shows that most protection schemes favor dependability (relay will not fail to trip) over security (relay will not trip unnecessarily). Generally, this approach ensures relays trip when necessary to protect the system. However, when a ground overcurrent setting misoperation occurs, more facilities than necessary are removed from service, reducing system reliability. In some cases, this can affect load covered by removed facilities.



Analysis

In 2016, incorrect ground overcurrent settings accounted for 9% of total misoperations, and 24% of misoperations in the "Incorrect Settings, Logic or Design" cause code.

Ground Overcurrent Protection Continued

Exemplary Practices

Ground overcurrent protection consistently represents many misoperations reported each year. WECC encourages entities to review their approach and be open to potential changes. Here are a few things to consider when developing protection settings:

- Mutual coupling can have a significant effect on how ground fault conditions are perceived by protective relays. System modeling of mutual coupling and post-operation fault analysis are essential to verify that relay settings match model assumptions.
- Ground instantaneous overcurrent (50G) is a common and well-understood protection scheme, but it must be reviewed to be sure it coordinates with system changes and contingencies. The 50G element should be set greater than the maximum external fault current plus some margin.
- Ground time-overcurrent (GTO) (51G) is a proven and effective method for system protection. GTO provides good sensitivity; non-directionality; simplicity of testing; and, when used non-directionally, an independence from the requirement for PT signals. Like its ground-instantaneous counterpart, coordination studies are required due to fault-level variability, and the effects of mutual coupling must be considered.
- Misoperations due to ground overcurrent protection are common to power systems. Entities can leverage industry publications on the topic to ensure their approach includes recommended practices. IEEE published "Transmission Line Applications of Directional Ground Overcurrent Relays" to address this topic.

Strategies to Reduce Misoperations—Human Performance During Commissioning

Suggested Action

The actions below are recommended based on the data related to this category and the experience of the Reduction Strategies team. Consider the existing practices of your entity to decide which actions will bring the greatest improvement.

Share Data

WECC shares data with each entity about misoperations related to human performance during commissioning (e.g., as-left personnel errors, AC/DC systems).

Develop Guide

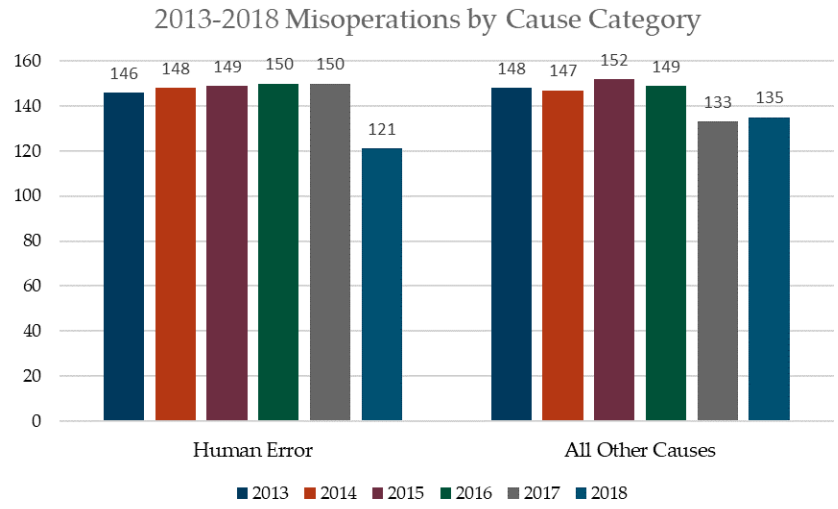
WECC, the RWG, and the Human Performance Work Group (HPWG) develop a guide to address human performance in commission testing based on field experience and documents such as the IEEE commissioning document "Commissioning Testing of Protection Systems."

Discuss

Entities bring commission testing issues and questions to the RWG for discussion.

Summary of the Issue

Commissioning is crucial to making sure new equipment is installed correctly and functions properly. Crossover and shared responsibilities among contractors and entity personnel complicate this process and increase the chances of error. Processes that account for potential complications can reduce the number of errors and misoperations.



Analysis

Misoperations involving human factors account for half of the misoperations reported in the Western Interconnection. This category includes misoperations due to errors in relay scheme logic and design, application of designed settings to equipment, and as-left personnel errors.

Human Performance During Commissioning Continued

Exemplary Practices

Whether an error is made developing settings or implementing those settings in the field, commissioning is one of the last barriers that can catch the error. Having a thorough commissioning process can help give confidence when new equipment and settings are put in service. The following are practices that may help catch errors before new equipment is energized:

- Make sure intended protection schematic is consistent with company design standards.
- Confirm that actual wiring matches schematic design standard. Resolve differences.
- Verify relay panel wiring at panel shop or site before installation.
- Load production relay settings and test to make sure desired setting is installed.
- Test and evaluate first-time installation of new "Standard" settings.
- Use methods to identify wiring that will be involved in isolation and removal if this is an upgrade to an existing installation. Color code prints to mark which circuits to remove and retain, as well as new circuits.
- Verify point-to-point wiring of all protection system wiring. Check against intended design.
- Compare all CT/PT ratios against setting sheets and document that they are set properly.
- Do secondary tests on CTs. Remove shorting wires on connected CT circuits.
- Follow IEEE c57.13.3 “IEEE Guide for Grounding of Instrument Transformer Secondary Circuits and Cases” to ensure proper grounding. Single point of grounding is required to prevent ground loops.
- Test new PTs using established PT testing procedures. If existing, or when initial testing is complete, the load test should be used to validate PT phasing and polarity against a known source, like an adjacent circuit.
- Use current as a secondary way to make sure all CT wiring has been verified. For instance, to verify that the neutral leg of the circuit has not been accidentally left open, push from the CT for each phase to neutral.
- Verify that proper settings have been loaded into the relay.
- Verify all telecommunication equipment is operational and programmed as desired.
- Generate dynamic test routines using state-simulated events based on relay system fault parameters for systems with telecommunications-aided protection schemes. Satellite synchronized test equipment is needed to test at remote facilities.
- Trip-check each relay for all phases and verify each expected output. Use schematic drawing as a reference to make sure all inputs and outputs are verified.
- Make sure alarms communicate as expected from the field to System Operations or monitored location.
- Perform load test with system load to verify overall relay performance.

- Evaluate load test results against expected values. Flag any discrepancies and follow up.
- Submit complete test result package to supervisor or Operations and Maintenance (O&M) team for use as baseline information for future testing and PRC-005 compliance.

Strategies to Reduce Misoperations—Knowledge Transfer

Suggested Action

The actions below are recommended based on the data related to this category and the experience of the Reduction Strategies team. Consider the existing practices of your entity to decide which actions will bring the greatest improvement.

Educate

The HPWG hosts educational webinars on knowledge transfer techniques and addresses challenges in the electric industry.

Evaluate

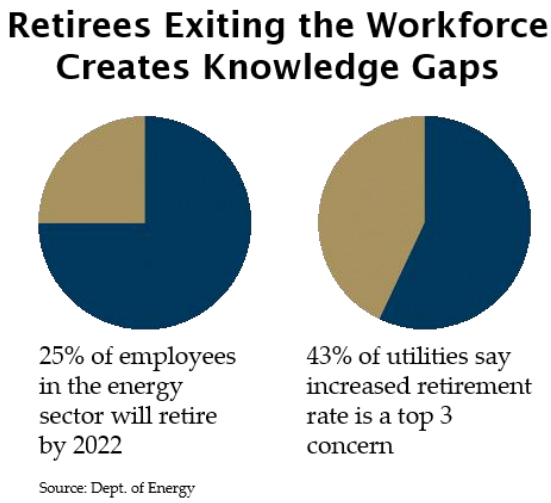
WECC, the HPWG, and stakeholders develop a guide to help entities evaluate strengths and weaknesses in their knowledge transfer practices.

Develop Guide

WECC, in partnership with stakeholders, drafts a guide for knowledge transfer, including real-world examples and points of contact from across the industry.

Summary of the Issue

Workforce turnover is an issue for the entire industry. As skilled technicians and engineers retire, the loss of system-specific experience and expertise increases. Without a process to capture and transfer this knowledge, valuable information is lost.



Analysis

By 2024, nearly 1 in 4 people in the labor force are projected to be age 55 or over. Additionally, 10,000 baby boomers retire each day.

Knowledge Transfer Continued

Exemplary Practices

System knowledge and experience is one of the most difficult things to replace as seasoned employees retire. Having a well-documented plan to transfer this knowledge can help make this transition less shocking to the remaining workforce. This succession plan should—

- Ensure department has enough experience and system knowledge;
- Transfer nuances associated with system and protection schemes already in place;
- Create routine training for the department with a focus on transferring key concepts; and
- Create and update department process documents.

Strategies to Reduce Misoperations—Limited Information for Investigations

Suggested Action

The actions below are recommended based on the data related to this category and the experience of the Reduction Strategies team. Consider the existing practices of your entity to decide which actions will bring the greatest improvement.

Examine

Entities evaluate the nature of this issue in their company using unknown misoperations data provided by WECC.

Evaluate

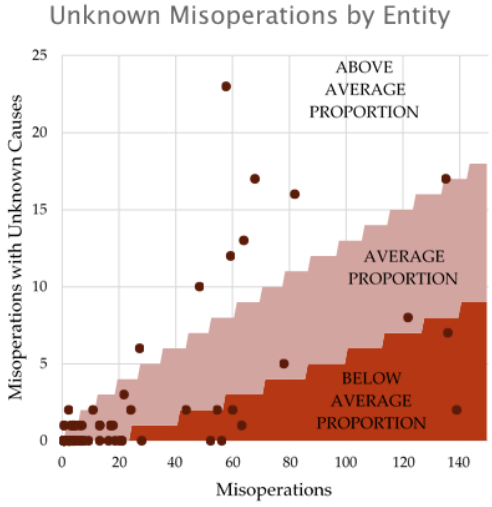
Entities determine the extent of the condition by breaking down relay inventory by type, identifying the percentage of unknown misoperations by relay type, and performing internal evaluations of non-microprocessor systems to find areas for improvement.

Execute

Entities create replacement plans for non-microprocessor systems with performance issues and use reinforcement strategies to find areas in which monitoring equipment may capture useful information.

Summary of the Issue

Nearly 60% of misoperations with unknown causes are associated with electromechanical or solid-state relays. Compared to microprocessor-type relays, the data available from these two types of relays is limited, which makes it more difficult to find the cause of a misoperation. Since many of these relays are still in service and replacement would be costly, resource intensive, and time consuming, developing investigation approaches for these relay types may reduce the tendency to assign "unknown cause" by default.



Analysis

"Unknown" remains one of the top causes of misoperations in the Western Interconnection. When the cause cannot be found, the same misoperation will probably recur. Initial analysis suggests that at least one-fifth of misoperations are repeats.

Limited Information for Investigations Continued

Exemplary Practices

WECC has more recorded unknown misoperations than any other region. These misoperations are a concern because corrective actions are seldom taken, and many times the misoperation is repeated when similar system conditions are present. Some approaches that can help reduce the number of unknown misoperations are—

- Create an investigation checklist to ensure system events are analyzed thoroughly and consistently;
- Augment information available by installing Digital Fault Recorders (DFR) in areas with high concentrations of Electromagnetic relays; and

Work with neighboring entities if event occurred on joint-owned line or tie-line.

- Check for fault records on microprocessor relays near, but not expected to provide primary protection of the faulted element (either forward or reverse from the fault) that may provide useful data.

Strategies to Reduce Misoperations—Root Cause Analysis

Suggested Action

The actions below are recommended based on the data related to this category and the experience of the Reduction Strategies team. Consider the existing practices of your entity to decide which actions will bring the greatest improvement.

Examine

NERC and the ERO Enterprise develop root cause analysis training and guidelines specific to misoperations

Share Data

WECC shares information with entities about their incorrect setting misoperations relative to other entities and the WECC average.

Develop Guide

WECC and subject matter experts draft a guide with examples of effective misoperations root cause analyses.

Educate

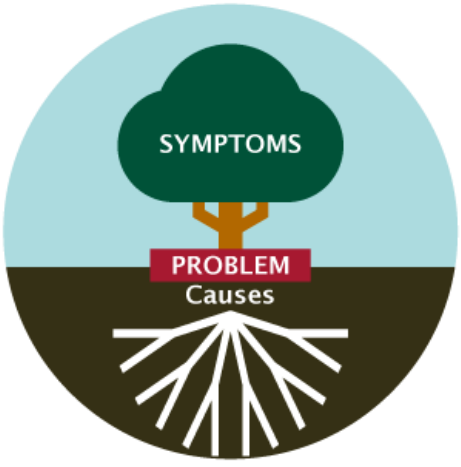
NERC and ERO Enterprise conduct webinar or in-person training to address root cause analysis in misoperation investigation.

Evaluate

WECC and subject matter experts create an evaluation guide to facilitate entity self-assessment of misoperation root cause analysis practices.

Summary of the Issue

Some misoperation investigations end once the initiating cause is determined. Ending an investigation at this stage may provide enough information to resolve a single instance of the issue but can miss the extent of condition on the system. Thorough root cause analyses can reveal latent errors and may prevent more misoperations stemming from the same issue.



Analysis

Misoperation reports do not always give enough detail to show common and trending causes. This may indicate that misoperation investigations focus solely on initiating causes.

Root Cause Analysis Continued

Exemplary Practices

Having staff members who are trained in root cause analysis perform event investigations can help those investigations look beyond the apparent cause and identify latent errors elsewhere on the system. Root cause analysis can also help when developing Corrective Action Plans. There are many approaches to root cause analysis. Most will provide the following benefits:

- Looking beyond apparent causes;
- Determining extent of condition across system;
- Identifying most impactful issues to system; and
- Developing thorough corrective action plans.

Some ideas for developing successful Corrective Action Plans are—

- Hold periodic meetings with affected staff to review and discuss the misoperation and status of the Corrective Action Plan. These meetings keep misoperations at the forefront of staff's minds, ensure that progress is being made, divide accountability among departments and establish deadlines, and receive input from multiple departments;
- Create short-term and long-term Corrective Action Plan goals; and
- Engage multiple departments in the entire process to take ownership from investigation through to the completion of the Corrective Action Plan.

Strategies to Reduce Misoperations—Setting Validation

Suggested Actions

The actions below are recommended based on the data related to this category and the experience of the Reduction Strategies team. Consider the existing practices of your entity to decide which actions will bring the greatest improvement.

Develop Guide

WECC and the RWG create a guideline for testing application of settings and includes an evaluation checklist. This includes tests performed before settings issued to the field and tests performed in the field.

Evaluate

Entities evaluate their practices regarding application testing before field use and identify areas for improvement

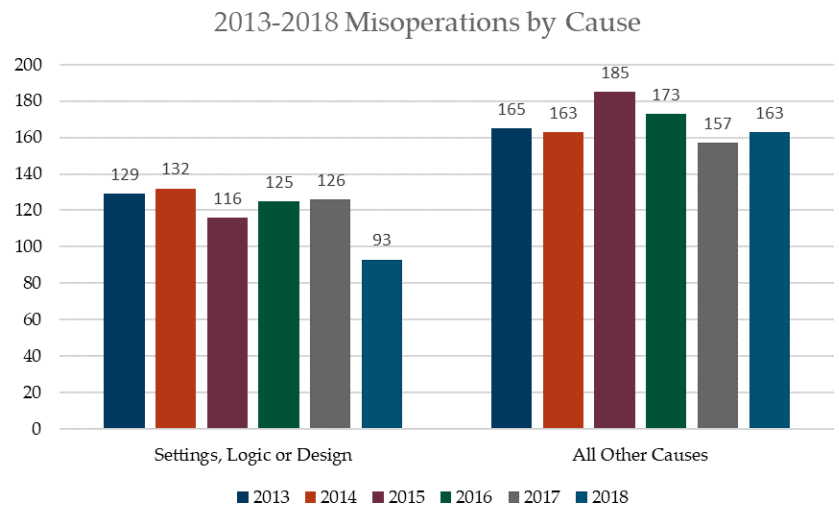
Discuss

The RWG remains a point of contact for entities interested in refining their processes.

Summary of the Issue

During the setting creation process, entities have many chances to make sure relay settings are accurate for the intended application. Common approaches include comprehensive quality control reviews and power system simulator testing. Proactively validating settings before applying and testing them in the field creates opportunities to catch errors and prevent misoperations. Simulations can show whether settings will operate as intended and help to identify potential adjustments.

Entities should also have controls to prevent errors when the settings are applied in the field. These controls can ensure setting application processes are followed and can help reduce misoperations. Processes should include guidance from the IEEE paper "Processes, Issues, Trends, and Quality Control of Relay Settings."



Analysis

Preventing misoperations caused by "Incorrect settings, logic or design" can reduce the number of misoperations in the Western Interconnection. This cause code accounts for 43% of all misoperations in the Western Interconnection and is the leading cause of misoperations nationally.

Setting Validation Continued

Exemplary Practices

Settings validation refers to steps taken to ensure settings are correct before releasing them to the field. These validation techniques can save time and money when investigating, correcting, and reporting misoperations caused by settings errors. Some recommended techniques are—

- Preparing relay test plans using an applications-based philosophy:
- Having a documented peer review in place before settings being issued to the field;
- Using templates for consistent approach;
- Running fault simulations to check settings; and
- Ensuring appropriate short-circuit model is used during setting development.

Strategies to Reduce Misoperations—Circuit Model Quality

Suggested Actions

The actions below are recommended based on the data related to this category and the experience of the Reduction Strategies team. Consider the existing practices of your entity to decide which actions will bring the greatest improvement.

Examine

WECC and the RWG host a webinar to discuss top issues and inconsistencies in short-circuit models with the WECC Short-Circuit Modeling Work Group (SCMWG).

Evaluate

WECC and RWG create an evaluation checklist for short-circuit models and related practices, including communication and information sharing practices.

Share Data

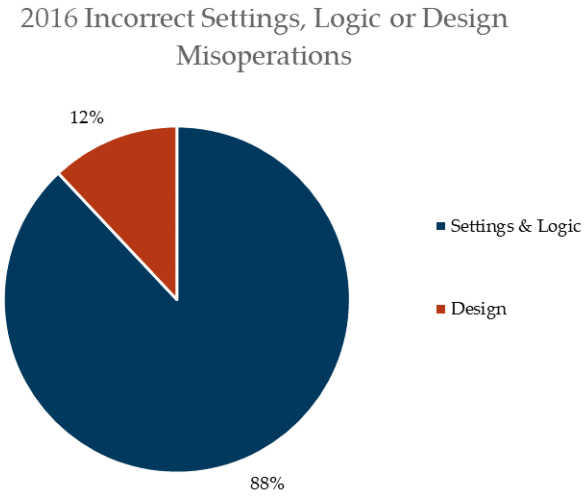
Entities participate in regional model initiatives or share short-circuit information with neighboring entities.

Discuss

Entities participate in the WECC SCMWG.

Summary of Issue

Short-circuit models are critical to develop settings and study effects of elements on the system. Flawed or outdated short-circuit models may result in creating or applying inaccurate settings. Established processes for updating and sharing short-circuit model information may improve setting consistency and accuracy by ensuring that settings are based on timely, accurate models.



Analysis

"Incorrect settings, logic, or design errors "—the largest subcategory of misoperations involving "Human Factors"—cause 40% of misoperations reported in the Western Interconnection.

Most of these misoperations concern protection system setting errors, which can be reduced by improving short-circuit model quality.

Short-Circuit Model Quality Continued

Exemplary Practices

Short-circuit model quality can affect the relay settings. Entities can take steps to ensure short circuit models, and the settings based on those models, are as accurate as possible:

- Have a process to update short circuit models. This process should include sharing results with neighbors who may be affected by this information; and
- If applicable, participate in a regional model effort.

Resources

Acknowledgements

WECC would like to thank the members of the RWG who participated in the Misoperations Reduction Strategies focus group review.

Sources

The Misoperations Reduction Strategies presents the historical data available at the time of publication. All data are subject to revision without notice in future updates to the report and in other WECC documents. The following is a comprehensive list of sources used in preparing this report:

Source	Publisher
Misoperation Information Data Analysis System (MIDAS)	North American Electric Reliability Corporation
"The Electricity Workforce: Changing Needs, New Opportunities"	U.S. Department of Energy
U.S. Department of Labor blog	U.S. Department of Labor
"Processes, Issues, Trends and Quality Control of Relay Settings" and "Commissioning Testing of Protection Systems"	IEEE Power System Relaying and Control Committee
Various	WECC RWG

Feedback

If you have questions or comments about the Misoperations Reduction Strategies, please contact **WECC Support**.