WECC

2022 Protection Systems Performance Report

Protection and Controls Subcommittee

October 18, 2023

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Introduction

Background

NERC has identified Protection System Misoperations as a major area of concern to the reliability of the Bulk Electric System (BES) since Protection System Misoperations can significantly increase the severity of an event. NERC tracks the number of Protection System operations and Protection System Misoperations that occur in each region to evaluate the performance of the Protection Systems applied on the BES. This data is combined into a metric defined as the ratio of Protection System Misoperations to the total number of Protection System operations. This metric is known as the Misoperations rate. The Misoperations rate provides a consistent way to normalize performance for weather and other factors that can influence the raw number of Protection System Misoperations that occur from year to year. This allows the Misoperation rate to be used to identify trends and compare the relative performance of Protection Systems on the BES.

Each year, the Protection and Control Subcommittee (PCS), formerly the Relay Work Group (RWG), calculates the Misoperation rate for the Western Interconnection. Additionally, it reviews all the Protection System Misoperations that occurred the prior year, analyzing the causes of the Misoperations and looking for any trends that could help in reducing the frequency of Protection System Misoperations. As part of that effort, the findings of the PCS are provided in this Protection Systems Performance Report so entities in the Western Interconnection can learn about these trends and act on them, as appropriate. The 2022 report includes a yearly review of Misoperation cause categories and an in-depth assessment of the top three cause categories within the Western Interconnection. The intent of the analysis is to identify important findings and items the can be acted upon within the Western Interconnection to improve the reliability of the BES.

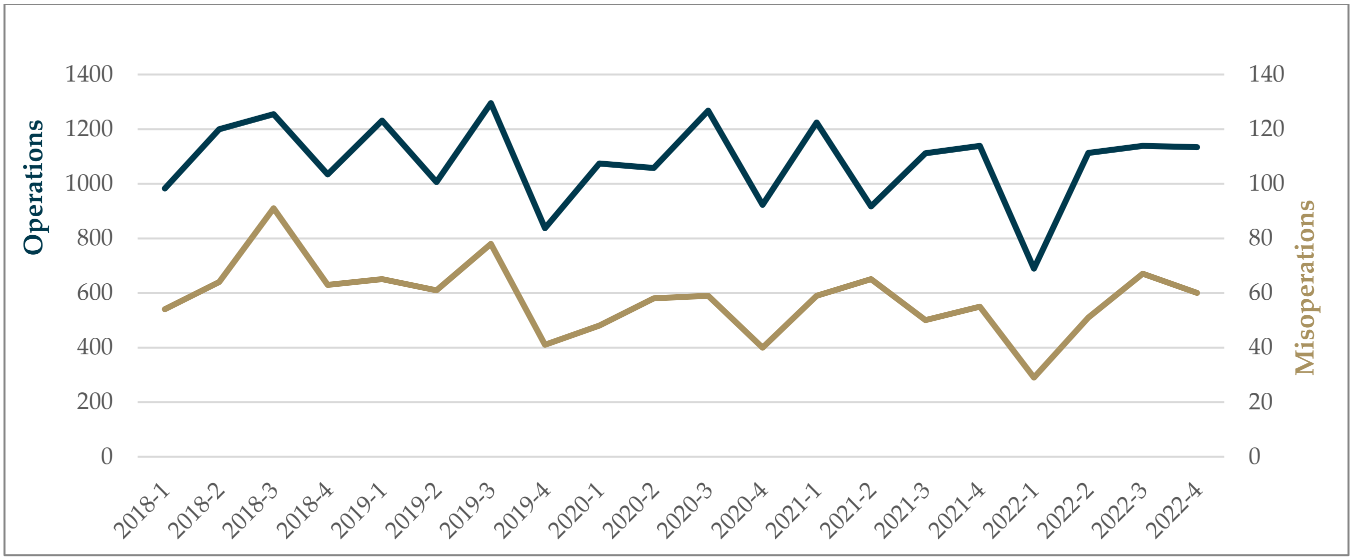


Figure 1: Total Operations/Misoperations trend from 2018 through 2022

Figure 1 shows the total number of Protection System operations (left axis) and the total number of Protection System Misoperations (right axis) per quarter from 2018 through 2022. Figure 2 shows the annual Misoperation rate for the Western Interconnection from 2018 through 2022. Over this time, the annual Misoperation rate has continued to trend downward, with the 2022 rate equal to 5.08%. While the trend in the Misoperation rate is positive, the PCS encourages entities within the interconnection to continue to look at their internal Protection System practices and identify where they can make improvements. Incremental improvements will enhance the performance of the Protection Systems within the Western Interconnection. Also, one limitation of the Misoperation rate is it does not account for the impact or severity of a Misoperation on the system. The PCS is looking at ways these aspects can be included in future analysis.

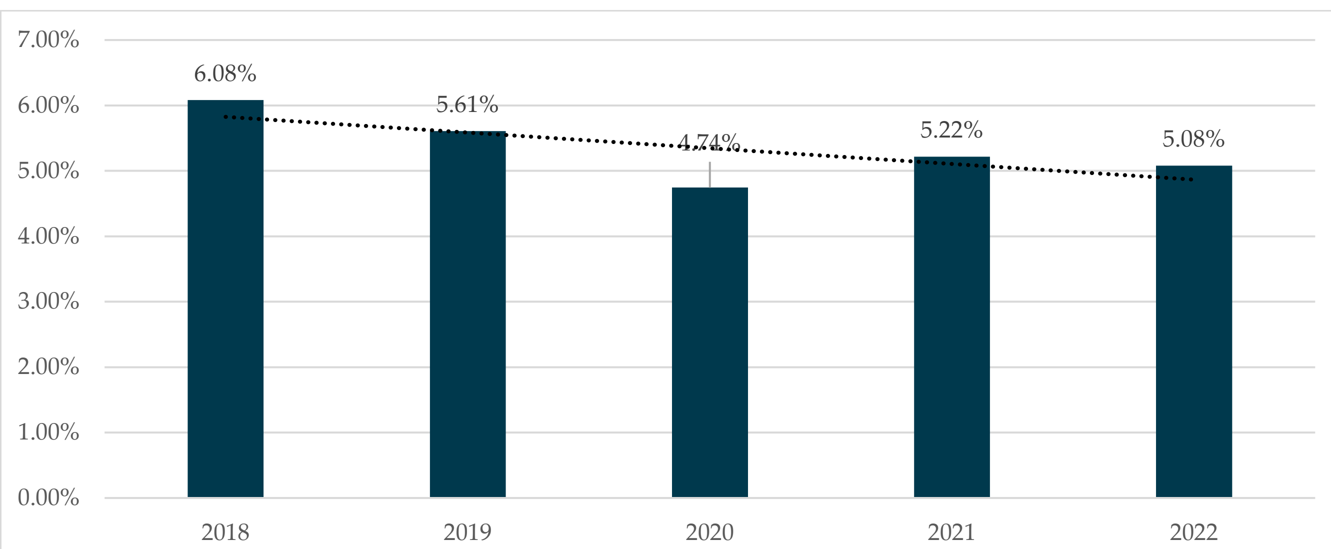


Figure 2: Western Interconnection Misoperation rate from 2018 through 2022

Purpose

The PCS reviews the quarterly Misoperation data reported to NERC under Section 1600 for registered entities in the Western Interconnection. The PCS performs a yearly analysis and multiyear trending to:

- Provide trend analysis of Protection System Misoperation data and possible root cause identification.
- Form conclusions and recommendations from the analysis to reduce the likelihood of future Misoperations.
- Develop guidance and best practices for the industry through technical documents and webinars pertaining to Protection System Misoperation trends, conclusions, and recommendations.
- Publish the analysis results to WECC's Reliability Risk Committee (RRC) and the WECC membership.

The PCS focus is on Misoperations by cause to identify ways to reduce future Misoperations. The impact of a Misoperation on the BES was not considered in the evaluation.

Data

The Misoperation data used for the one-year analysis is from January 1 through December 31, 2022. Trending data was from January 1, 2018, to December 31, 2022.

- WECC obtained the dataset was from the NERC Misoperation Information Data Analysis System (MIDAS) 1600 reporting template with defined categories and causes.
- Western Interconnection entities reported 206 Misoperations during 2022.
- The reported corrective actions, event description, and cause of the Misoperation were used to assist in root cause identification.
- The 2022 Misoperation data was reviewed quarterly by the PCS with resubmittals for clarification and correction.

2022 Misoperation Analysis

In this section, an analysis of data reported for the Western Interconnection 2022 is provided along with a trending analysis of the 2018 through 2022 data reported for the Western Interconnection. The analyses, conclusions, and recommendations for Misoperations by the top causes are also included.

Misoperation by Cause Category

Evaluation of Misoperations by cause category shows key indicators of Misoperations attributed to human performance or a Protection System component. Figure 3 shows the distribution of Misoperations as reported by cause category for 2022. For this analysis, the "Incorrect setting/logic/design errors" categories are combined into one category. This combined category is the largest contributor to Misoperations in the Western Interconnection. In 2022 this category represented 38% of all Misoperations, followed by "Relay failures/malfunction" with 15%, and AC Systems and Communications Failures with 11% each. Two-thirds of all Misoperations for 2022 fall into these cause categories.

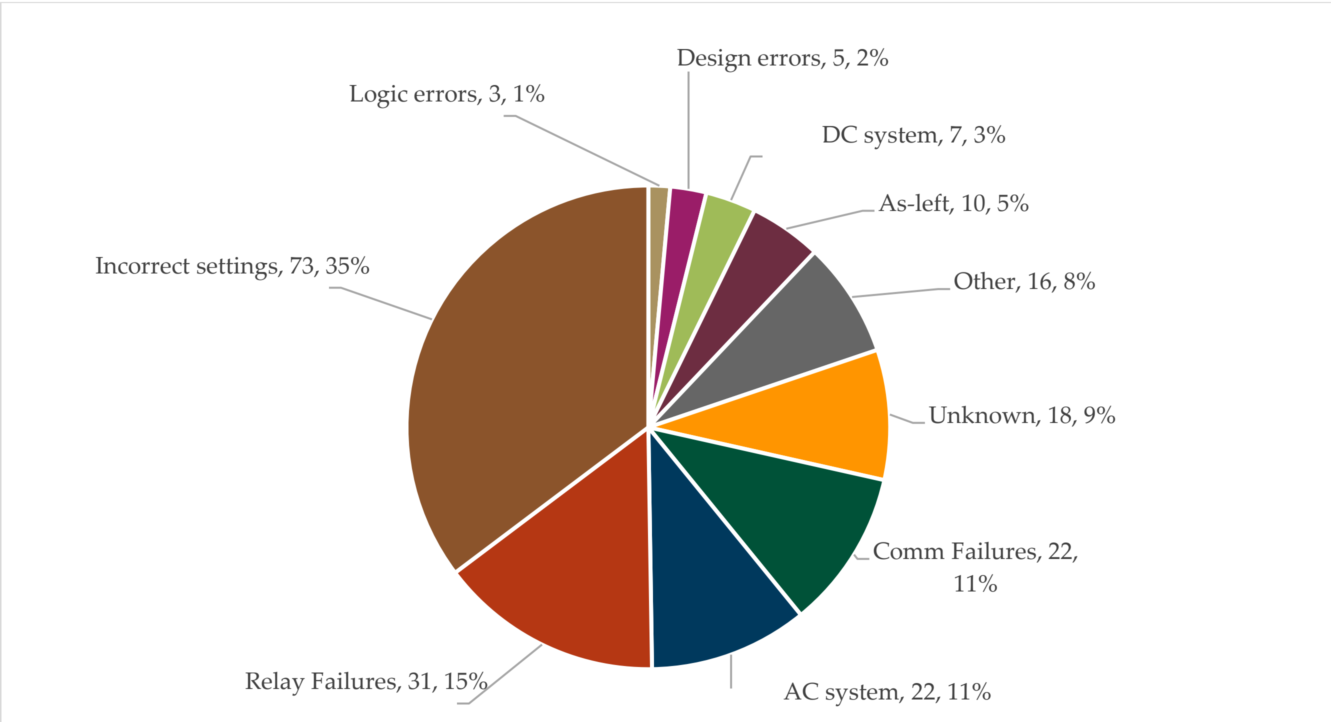


Figure 3: 2022 Misoperations by cause

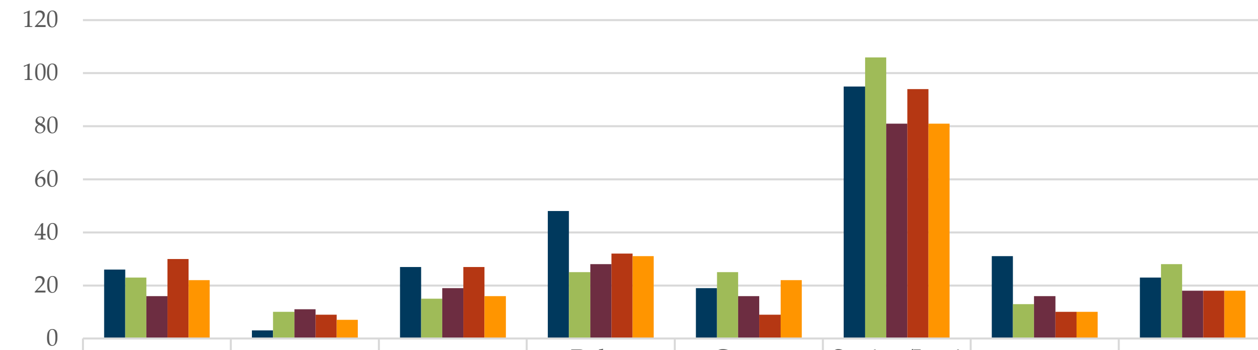
The PCS has separated the Misoperations of 2022 into two general categories: human influenced and equipment/material influenced. The "Incorrect setting/logic/design errors" cause category, and "As-left personnel error" category make up the human influenced group, while Relay failure/Malfunction, Communication Failures, AC and DC Systems make up the equipment influenced group. The "Unknown/unexplainable" and "Other/explainable" categories were excluded from this analysis.

Evaluating the two groupings shows—

1. 44% of all Misoperations can be attributed to one of the cause categories related to human performance:
   a. Incorrect setting/logic/design errors,
   b. As-left personnel error.
2. 40% of all Misoperations can be attributed to a Protection System component type category:
   a. AC system,
   b. Communication failure,
   c. DC system,
   d. Relay failures/malfunctions.

An observation from this breakdown is the significant contribution of human related Misoperations. The PCS recognizes that not all of the Misoperations in these two categories are preventable, however, it also shows there are opportunities for improvement within these controllable categories.

Figure 4 shows that the Incorrect Settings/Logic/Design Errors and Relay Failure/Malfunctions categories have consistently been the highest contributors to Misoperations over the past five years. A positive observation is the reduction in the number of Misoperations with an unknown cause over this period. Misoperations for which a cause is not identified are concerning because it becomes difficult to create an effective Corrective Action Plan when the root cause is unknown, and the Protection Systems involved are prone to repeated Misoperations when similar system conditions are present.

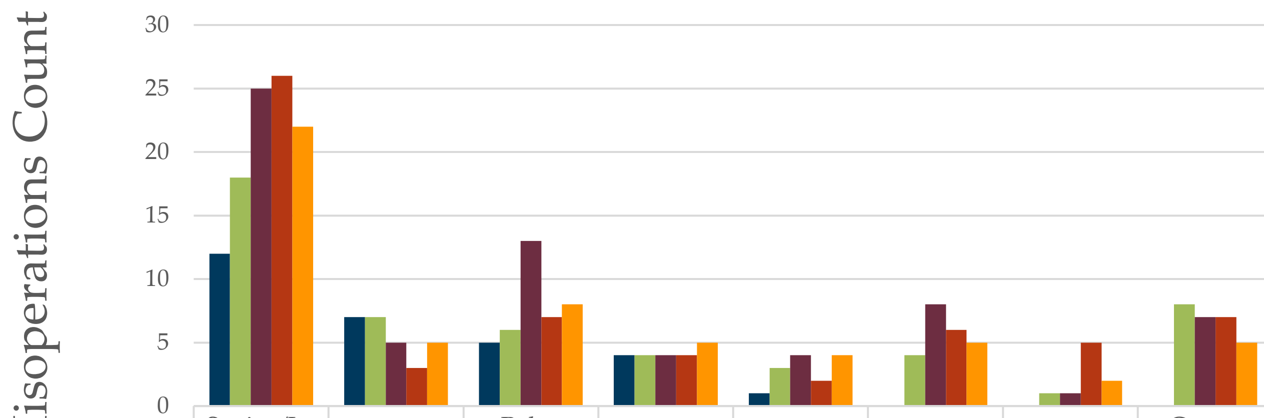


	AC system	DC system	Other	Relay Failures	Comm Failures	Setting/Logic/Design	As-left	Unknown
2018	26	3	27	48	19	95	31	23
2019	23	10	15	25	25	106	13	28
2020	16	11	19	28	16	81	16	18
2021	30	9	27	32	9	94	10	18
2022	22	7	16	31	22	81	10	18

Figure 4: Trending Misoperation by cause from 2018 through 2022

Of interest is a higher contribution from the Communication Failures category. There was an increase in this cause category in 2022, and the group elected to include a closer look as part of this report to identify what led to the increase and find ways to mitigate these issues.

Figure 5 shows the distribution of Misoperation causes by quarter for 2022, with a comparison to the quarterly average since 2018. We are able to see Q3 of 2022 had the most Misoperations for the year. This aligns with four of the past five years where Q3 experienced the most operations and Misoperations for the year. This is a quarter where Protection Systems are challenged by high demand, wildfires, thunderstorms, and severe weather.



	Setting/Logic/Design	AC system	Relay Failures	Other	As-left	Unknown	DC system	Comm Failures
2022 - Q1	12	7	5	4	1	0	0	0
2022 - Q2	18	7	6	4	3	4	1	8
2022 - Q3	25	5	13	4	4	8	1	7
2022 - Q4	26	3	7	4	2	6	5	7
Quarterly Ave	22	5	8	5	4	5	2	5

Figure 5: 2022 Misoperation by cause per quarter

Figure 6 is another view of the breakdown of Misoperation causes. This chart shows the average number of Misoperations per year over the last five years. Most categories have seen a reduction over this five-year period aligning with the downward trend of total Misoperations for the interconnection.

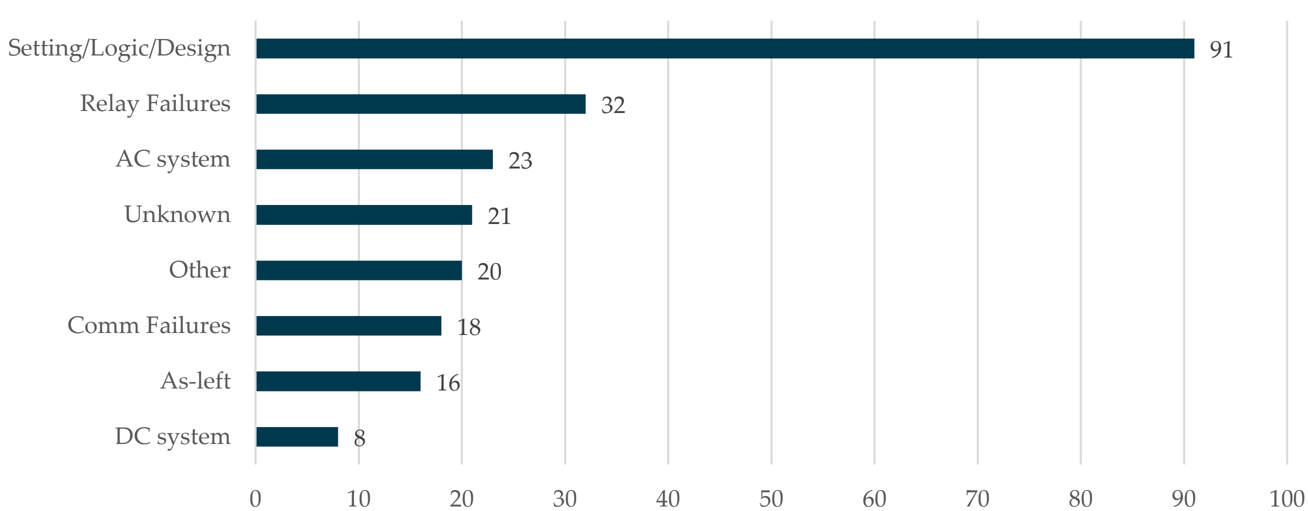


Figure 6: Misoperation by cause, average annual count from 2018 through 2022

Looking at the causes of Misoperations through these various methods reveals some helpful information. Though the Western Interconnection has a low Misoperations rate, 44% of Misoperations in 2022 had some level of human performance leading to the Misoperation. This information allows entities to look inwardly to find areas to improve.

Misoperation by Voltage Class

Voltage class is the operating voltage level of the equipment where the Protection System is applied. For Misoperations involving equipment at multiple voltages (i.e., transformers) or Misoperations affecting equipment at different voltage levels (e.g., breaker failure), the highest voltage class involved is reported. Figure 7 shows the breakdown of 2022 Misoperations by voltage class, followed by the five-year trend in Figure 8.

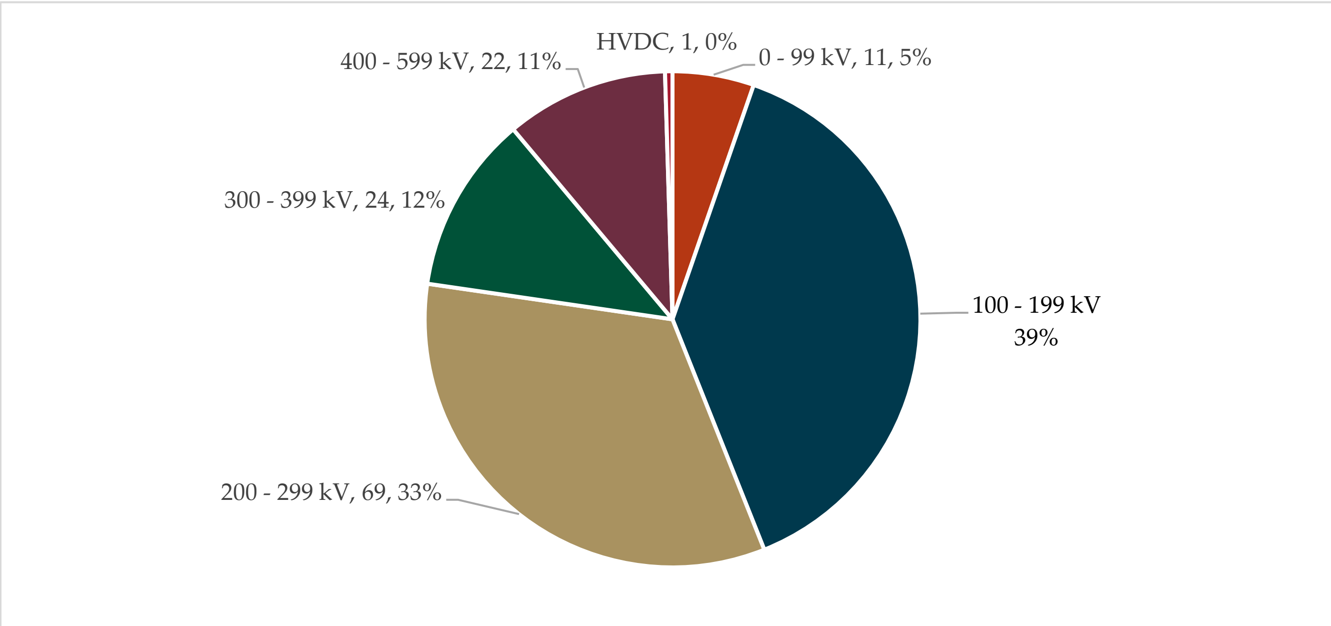


Figure 7: 2022 Misoperation by voltage class

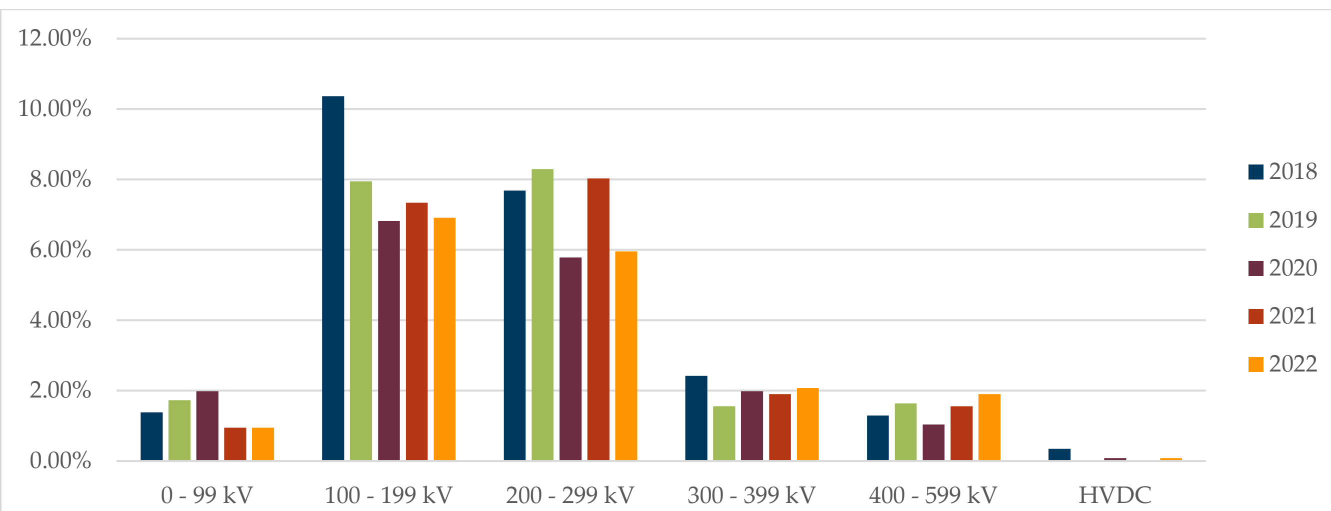


Figure 8: Misoperation ratio by voltage class from 2018 through 2022 trending

More than three-quarters of the Misoperations for the year occurred on systems under 299 kV. As shown in Figure 8, this has been the case over the past five years. While these voltage classes generally have less influence on system stability, there are reliability implications related to Misoperations at these voltage levels, and all reasonable efforts should be taken to ensure they operate as desired.

An indicator of reliability can be had by knowing the number of Elements in each voltage class. The number of Misoperations per number of Elements in a voltage class gives a more accurate trend of what is happening in the Western Interconnection. The number of Western Interconnection Transmission Availability Data System (TADS) Elements active in 2022 was used to determine the number of Elements in a voltage class. The results are the Misoperation ratios in percentage shown in Table 1. The ratio will normalize the numbers as facilities are added or removed from the Western Interconnection.

The table shows highest number of circuits within the Western Interconnection are in the 100-199 kV and 200-299 kV range. It also shows the fraction of Misoperations per TADS element by voltage class is highest for the 345 kV elements in the Western Interconnection, followed by the 500 kV elements.

Protection Systems installed on these two voltage classes can be quite challenging to set. Typically they are highly redundant, with three or even more separate relay sets. The use of series compensation can cause traditional impedance-based elements to operate incorrectly and an Real-Time Digital Simulator (RTDS) study may be required to correctly set the relays. Single pole breaker tripping is more commonly used at these two voltage classes to maintain power flow and system stability during single phase faults. It is more challenging for the Protection Systems to correctly identify and trip a single pole than to open all three poles. Also, because there are fewer of these elements, many protection engineers may not develop the same level of experience setting these protection schemes as they will for the more common protection schemes used at low voltage classes. This may explain why these voltage classes have a higher number of Misoperations per TADS element.

Table 1: 2022 Misoperations per 100 TADS Elements in voltage class

Voltage Class	AC Circuit	Converter	DC Circuit	Transformer	Total Elements per voltage class	# Misops	Misops per 100 elements in voltage class
0–99 kV	505	0	0	42	547	5	0.9
100–199 kV	3319	0	0	186	3505	86	2.5
200–299 kV	1964	5	3	716	2688	69	2.6
300–399 kV	203	2	0	181	386	25	6.5
400–599 kV	305	0	6	247	558	22	3.9

The four-year trend in Figure 9 shows that Misoperation ratios by voltage class have stayed fairly constant. However, there is a decrease in the 0–99 kV voltage class. Data is only available since 2019 when the PCS adopted the voltage class reporting levels used by NERC MIDAS criteria.

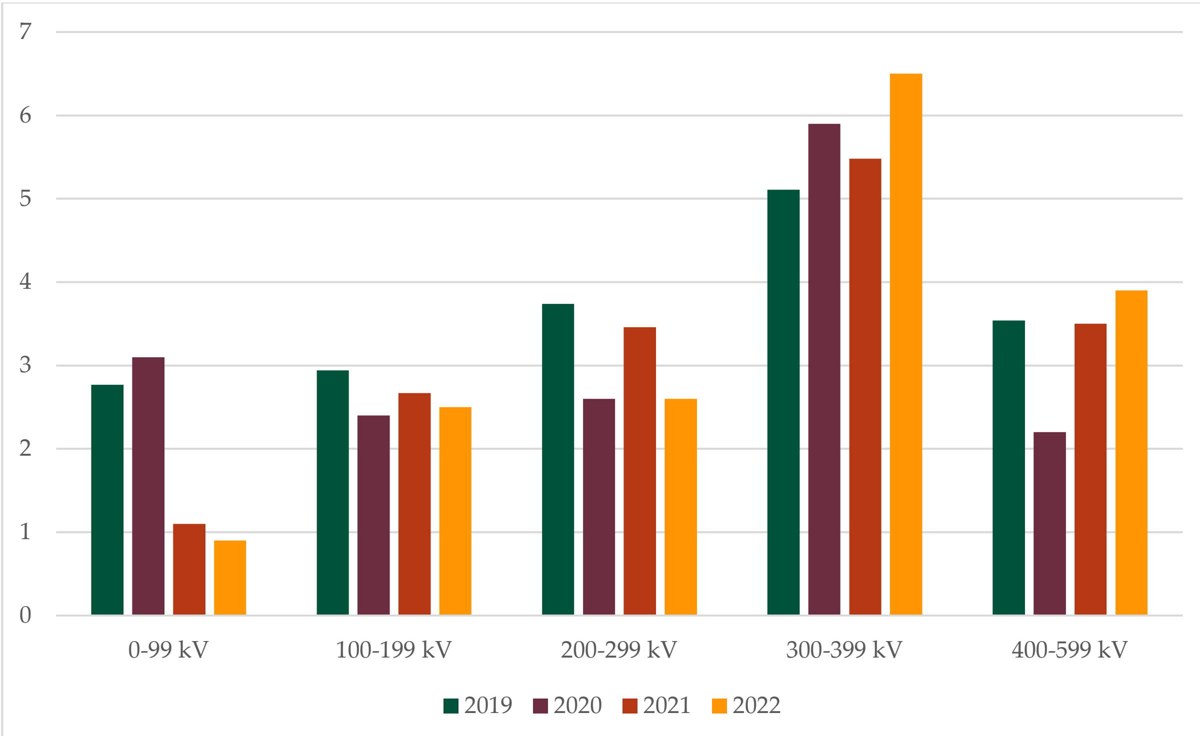


Figure 9: Misoperations per 100 TADS Elements in voltage class, 2019–2022 trending

While the counts of the Misoperations have remained relatively constant, overall impact should be considered by the owner/operator of the equipment. Equipment that is considered critical by an entity should have more rigid in-service testing and commissioning performed on it when initially brought into service, and possibly be maintained on a more stringent maintenance cycle. When a Misoperation occurs on a more critical piece of equipment, a thorough investigation, Corrective Action Plan, and extent of condition should be completed.

Analysis for Incorrect Setting/Logic/Design Errors

There were 81 Misoperations attributed to "Incorrect setting/logic/design errors," which is a decrease from 2021. However, this is still by far the largest of all cause categories in 2022. Figure 10 shows that 96% of the Misoperations caused by incorrect settings, logic, design errors were on microprocessor relays.

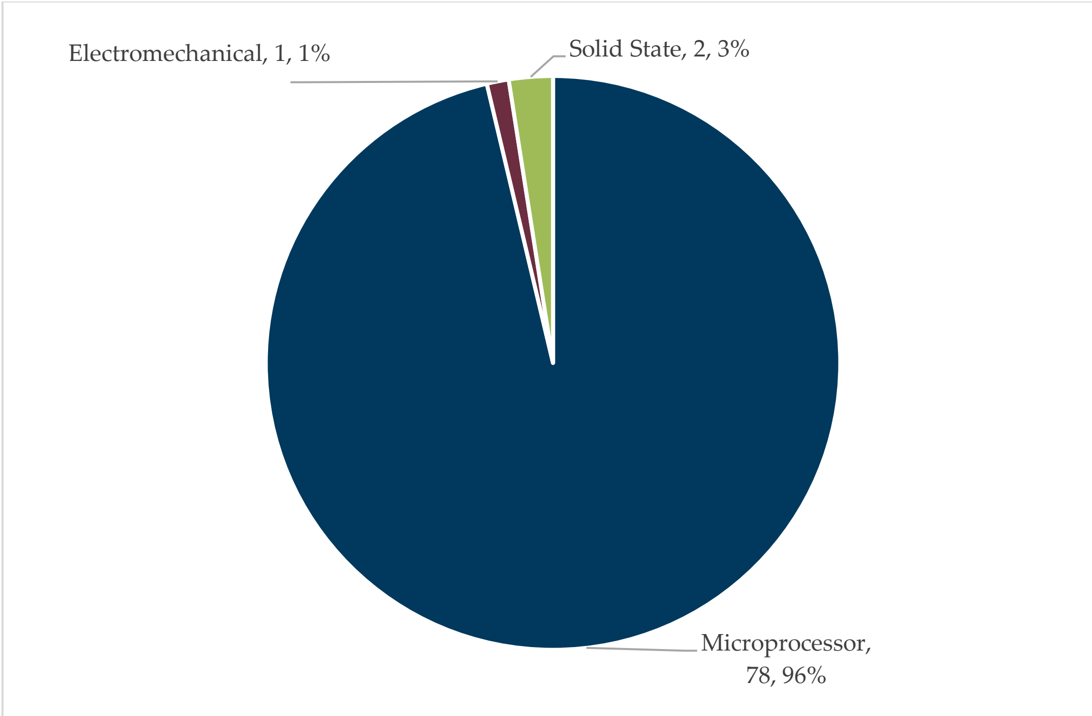


Figure 10: 2022 Misoperations by relay technology

The large number of Misoperations suggests the widely adopted use of microprocessor technology. While microprocessor relays provide enhanced event analysis capabilities that assist in Misoperation diagnosis, there is additional complexity that contributes to the number of Misoperations associated with this relay technology. Eventually all of the Misoperations may be caused by microprocessor-based relays when older technologies have been entirely replaced.

Figure 11 further subdivides the "Incorrect setting/logic/design errors" cause into setting, logic, and design errors. The chart shows setting errors make up 90% of the Misoperations, while logic and design errors only account for 10%, which is about half of the percentage reported in 2021. The trend from the last five years is shown in Figure 12. Knowing most Misoperations are attributed to setting errors, and when considered in conjunction with statistics on relay type, may be indicative of the complexity of microprocessor relays and their applications. The relatively small percentages of logic and design errors suggests these subgroups have become more standardized for common applications.

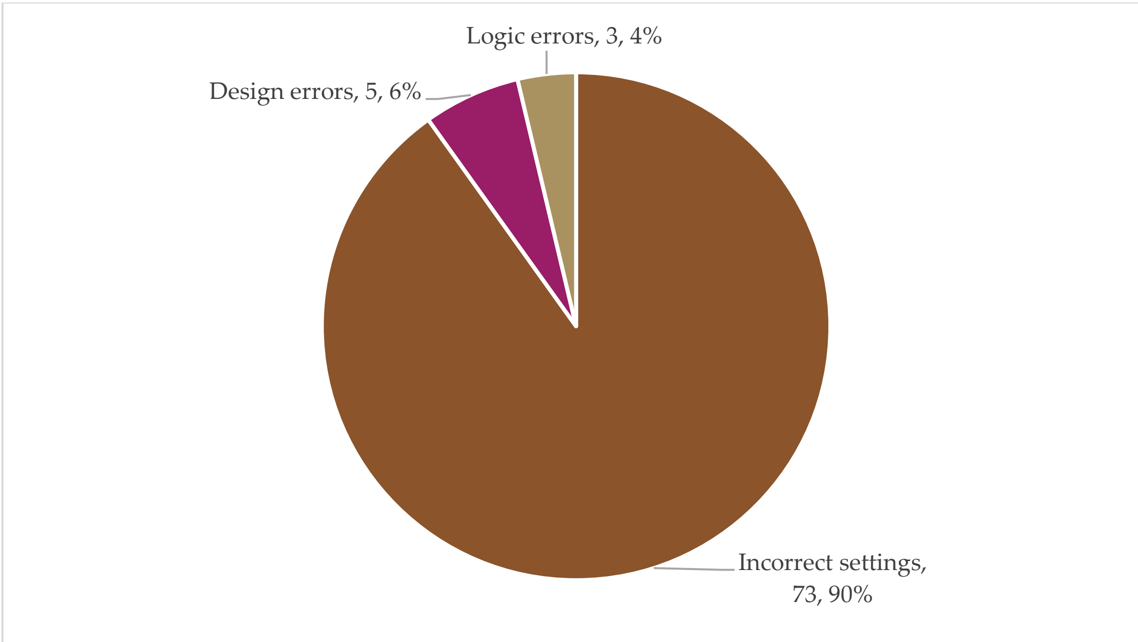


Figure 11: 2022 Misoperations by subgroup

The trend in Figure 12 shows setting errors continue to be the primary cause of Misoperations. However, the trend shows a gradual decrease in the Misoperations attributed to settings errors, with a corresponding decrease in Misoperations due to logic and design errors as well.

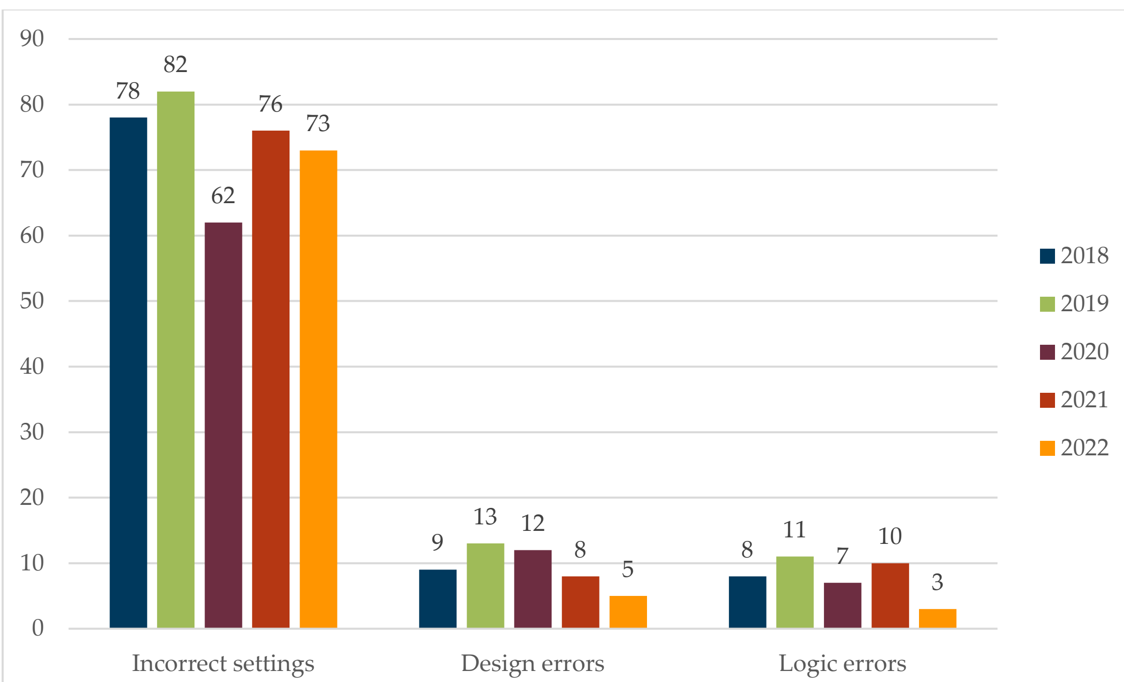


Figure 12: Misoperations subdivided into incorrect settings/logic/design errors, 2018–2022 trending

Figure 13 shows over 70% of settings, logic, and design errors resulted in an "Unnecessary Trip—during fault." This points to overtripping during fault conditions. While it is not ideal to have more elements removed during a fault, it is generally preferred over a failure to trip or slow trip during a fault. There is a balance of dependability and security when developing relay settings. Dependability is defined as the measure of the certainty that the relays will operate correctly for all faults for which they are designed to operate. Security is the measure of the certainty that the relays will not operate incorrectly. This observation that relay settings lean more toward unnecessarily tripping than failing to trip points to the generally accepted practice to favor dependability when attempting to achieve this balance.

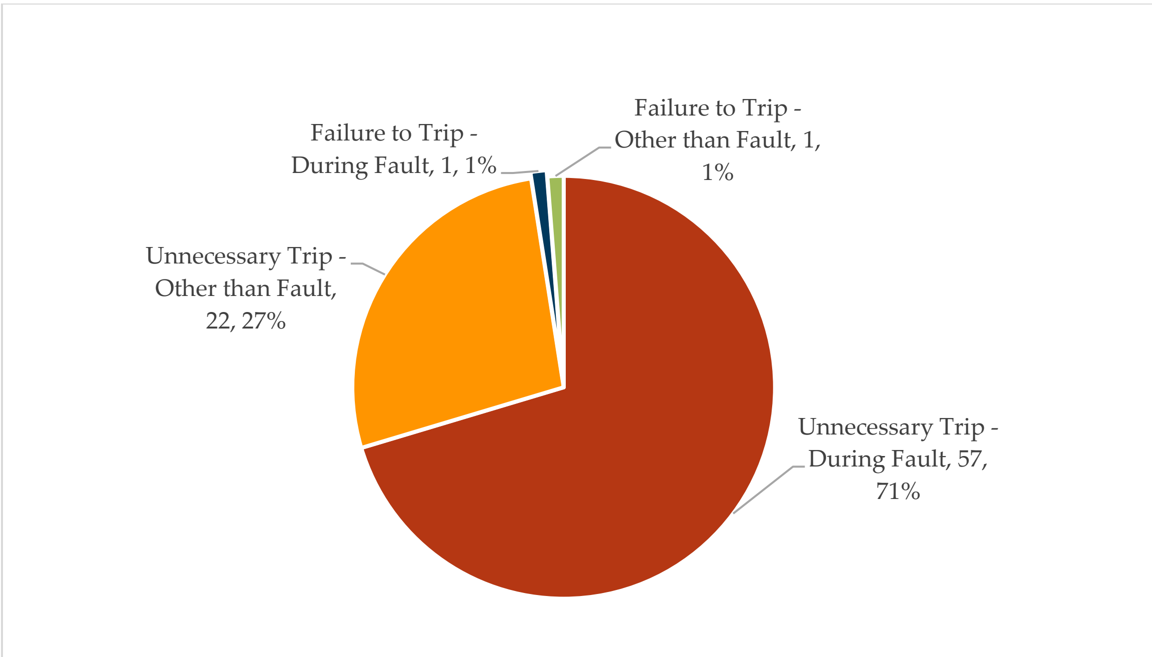


Figure 13: 2022 incorrect settings/logic/design errors by Misoperation category

Figure 14 shows the trend of leaning towards dependability has been observed over the past five years. The failure to trip and slow to trip categories of Misoperations generally represent more influential Misoperations. Fault conditions remain on the system for longer periods, exposing expensive, long-lead equipment to high current while also requiring remote equipment to operate to clear the fault. All efforts to prevent these categories of Misoperations should be taken.

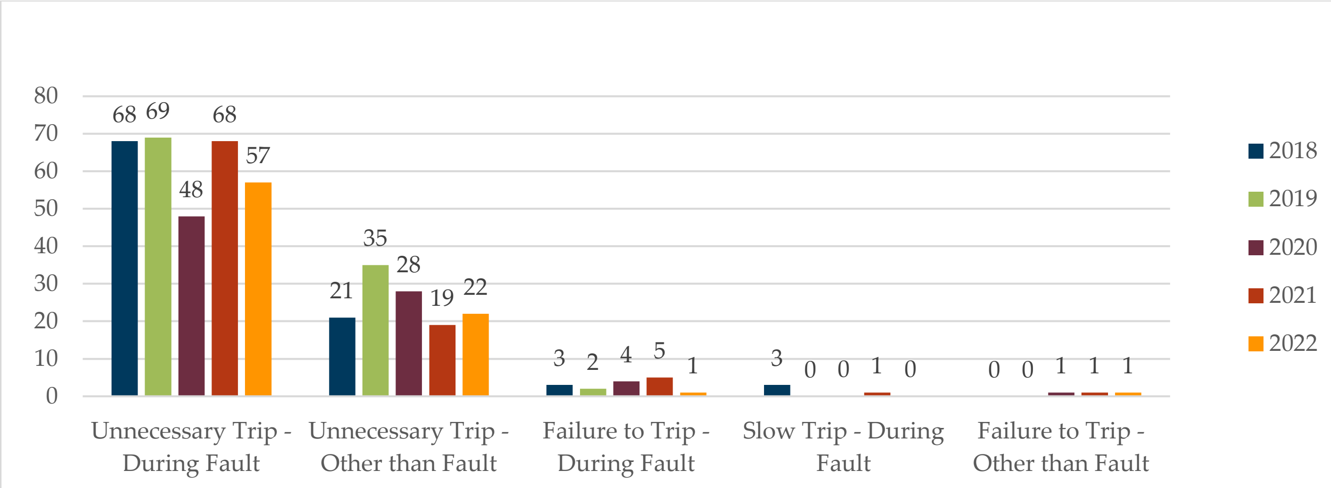


Figure 14: Incorrect settings/logic/design errors by Misoperation category, 2018–2022 trending

The PCS further investigated the 2022 Misoperations in the category "Incorrect settings/logic/design errors," shown in Figure 15, and three significant causes of Misoperations were identified. These were incorrect ground overcurrent/distance settings, setting coordination issues, and errors with differential schemes. Three Misoperations involved transfer trip application, and 11 submissions could not be determined from the details provided in the MIDAS database. We encourage entities to implement the recommendations below to help reduce the Misoperations caused by incorrect settings, logic, and design.

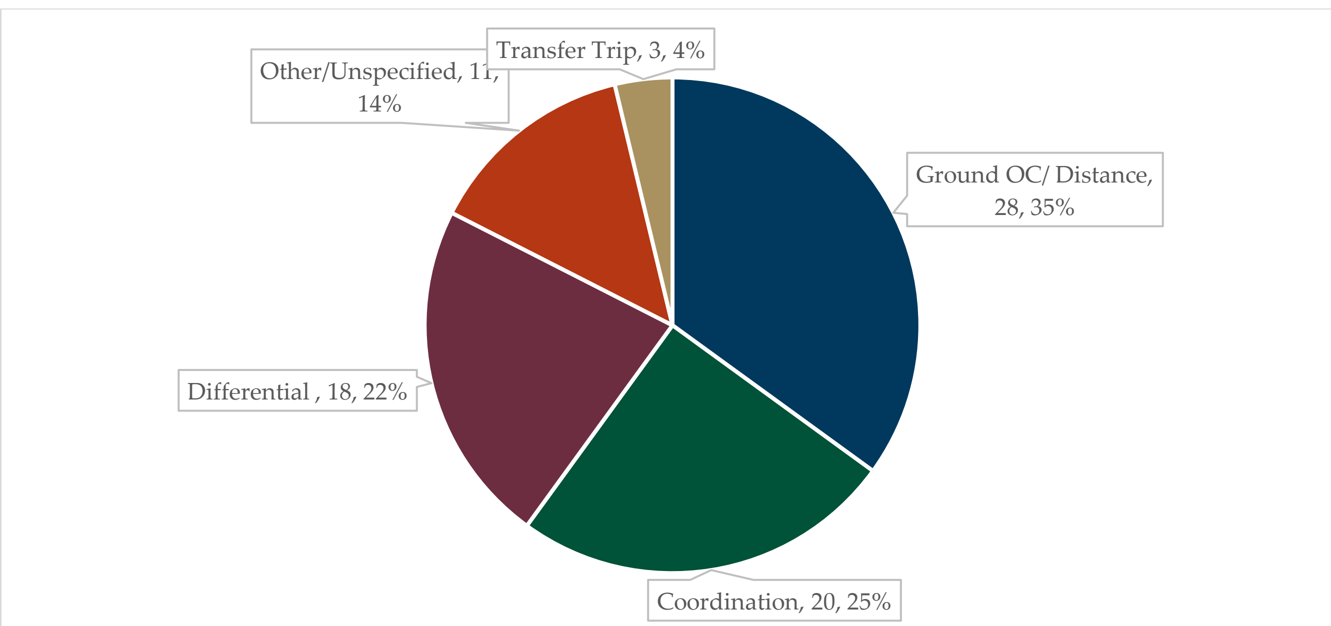


Figure 15: 2022 settings and logic/design errors by root cause

Incorrect Setting/Logic/Design Errors Misoperation Conclusions and Recommendations:

Entities should:

- Perform peer review including verifying that the fault system model is correct, the coordination study is complete, the contingencies within the study are correct, proper setting values of the elements are applied, and the elements for the application are enabled.
- Develop Standards and guides for fault studies and a process for reviewing new and existing settings to ensure changes to the system do not result in Misoperations. The recently implemented Standard PRC-027 addresses the periodic review of Protection Systems.
- Have a formal training process for new employees to the Protection Department
  - Use experienced personnel as a mentors
  - Ensure familiarity with company standards and practices for Protection Systems
  - Start with simple models and escalate to more complex applications as skills develop
  - Involve new employees in the relay testing process
- Ensure the tools used to develop the settings—such as the modeling and testing programs—are regularly updated
- Use satellite-synchronized testing technologies when commissioning communications-assisted schemes to ensure all components of the Protection System work as designed
- Use setting templates where available.
- Develop an applications-based testing method and apply as a quality assurance measure to new and modified relay applications.
- Recommend RTDS testing on EHV circuits and series compensated lines.

Additionally, entities should review the IEEE Power System Relaying Subcommittee report, which provides technical guidance for quality control of protective relay settings: "Processes, Issues, Trends and Quality Control of Relay Settings" (Working Group C3 of Power System Relaying Committee of IEEE Power Engineering Society, March 2007).

Relay Failures and Malfunctions

Figure 16 shows there were 31 Misoperations attributed to "Relay failures/malfunctions" in 2022. The number of Misoperations for this cause is significantly lower than in 2018 and has stabilized around 30 Misoperations per year for the past three years.

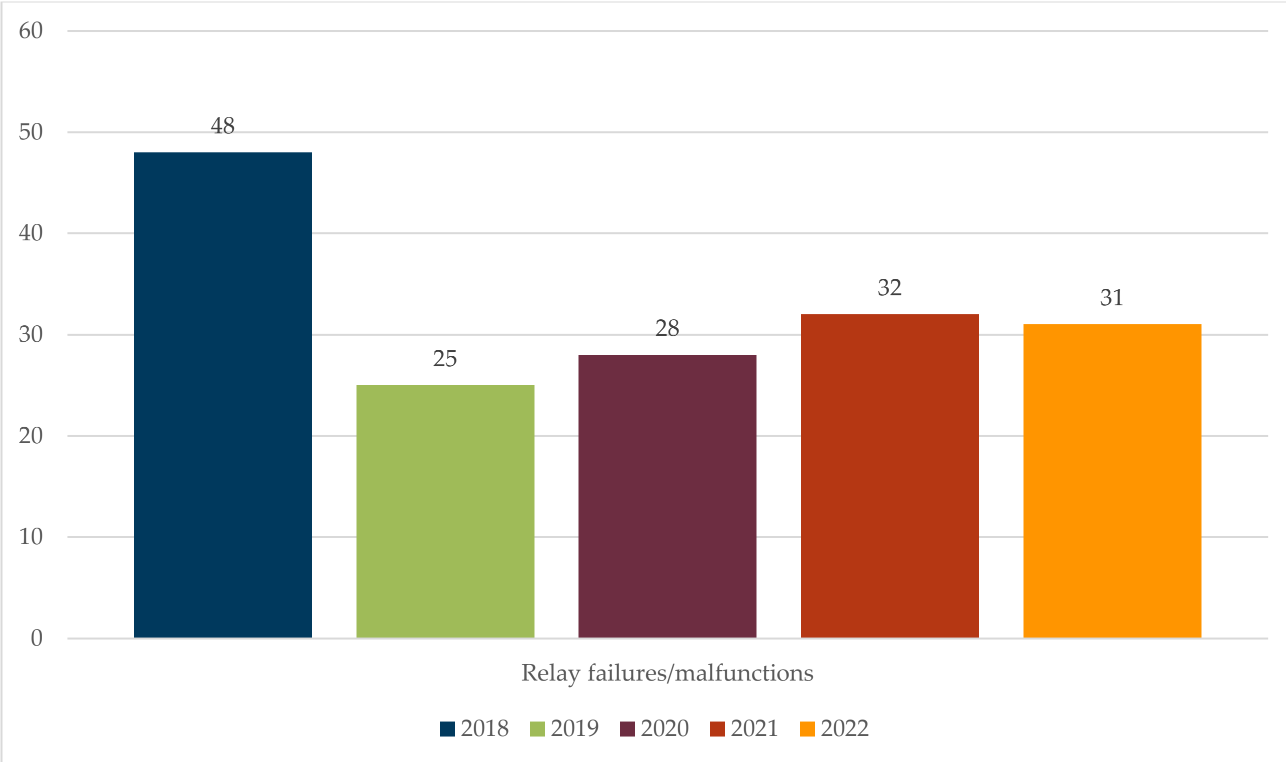


Figure 16: Relay failures and malfunctions, 2018–2022 trending

Microprocessor relays continue to be the most common relay type associated with relay failures. Figure 17 shows the distribution of failures by relay technology for 2022, with over 80 percent of relay failures for the year occurring in microprocessor relays. Interestingly, there has not been a significant change in the percentage of failures attributed to microprocessor relay type during the last three years. Since all new installations employ this relay type, it is believed that they will continue to represent a greater percentage of the total relay inventory, which may result in representing a greater percentage of the relay failures as well. Since a complete inventory of relays is unavailable, we cannot say whether these relays have a higher failure rate than other relay technologies.

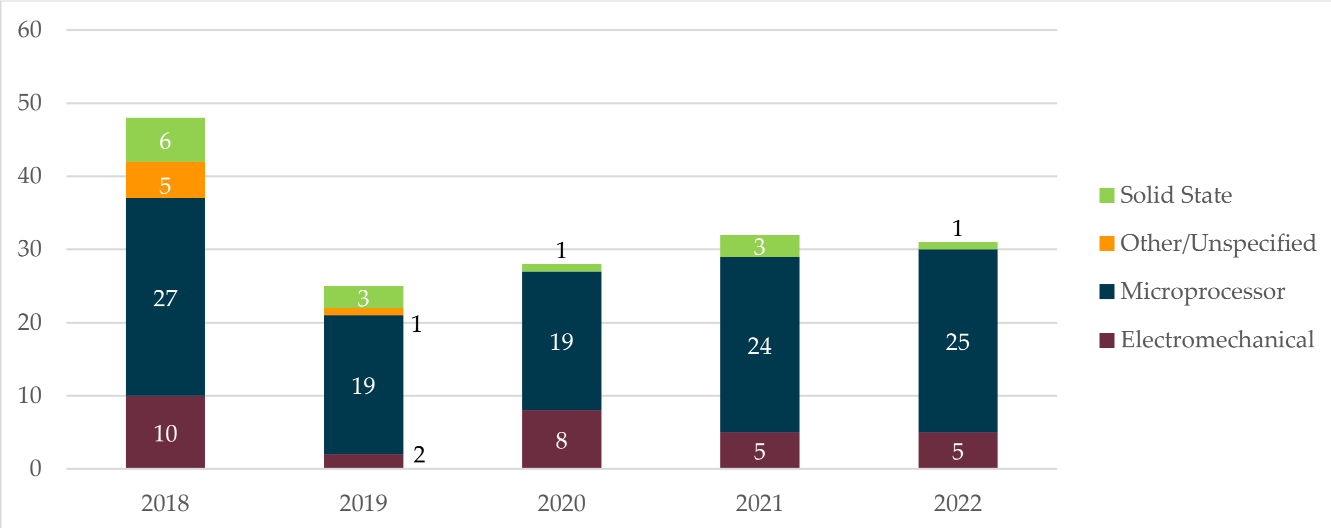


Figure 17: Relay failures and malfunctions by relay technology

Over half of the 2022 Relay failure/malfunction submissions did not provide enough detail in the description to identify what failed within the relay, or the entity did not know. Many of the corrective actions for these submissions were to replace the relay without finding the cause of failure. We encourage entities to work with the relay manufacturer to identify the cause of failure. This can help identify whether there are other relays on an entity's system that are prone to the same type of failure. This can also help the manufacturer identify and correct issues with its products.

For the 2022 Relay failures/malfunction the sub-cause column and information provided in free form cells gave insights into some common types of relay failure. Of known causes, failed components within the relay was the most common. Some of the components leading to these Misoperations were power supply failures, AC I/O module failures, and CPU process failures. In 2022, power supply failures resulted in the highest number of Misoperations with five. Several of these power supply failures occurred in the same type of relay. The manufacturer of this common relay has issued a service bulletin for this known power supply issue.

In past years the PCS has seen several failures/malfunctions of electromechanical relays due to calibration drift, however, in 2022 there were no Misoperations reported for this cause. Possible causes for this change could be the improved PRC-005 maintenance programs, which address the calibration of electromechanical relays. It could also be due the shrinking number of electromechanical relays in service, as most failed relays are replaced with microprocessor relays. If an entity has had an issue with relays drifting out of calibration, some practices that may help are tracking makes and models with this problem. With this known information, entities can decrease the interval between maintenance cycles for these relays to catch potential drift before a Misoperation occurs. These units can also be put on a replacement list to eliminate the potential for a Misoperation from this cause.

Reported relay failures for 2022 were categorized by the type of misoperation that they caused, and the results are shown in Figure 18. Most relay failures caused an "Unnecessary trip—other than fault," indicating these failures are prone to cause a trip without a fault present. This cause often has a lower impact than a failure of a relay to detect and clear a fault from the system. We were pleased to see no failure or slow trip Misoperations in 2022 for the relay failure cause.

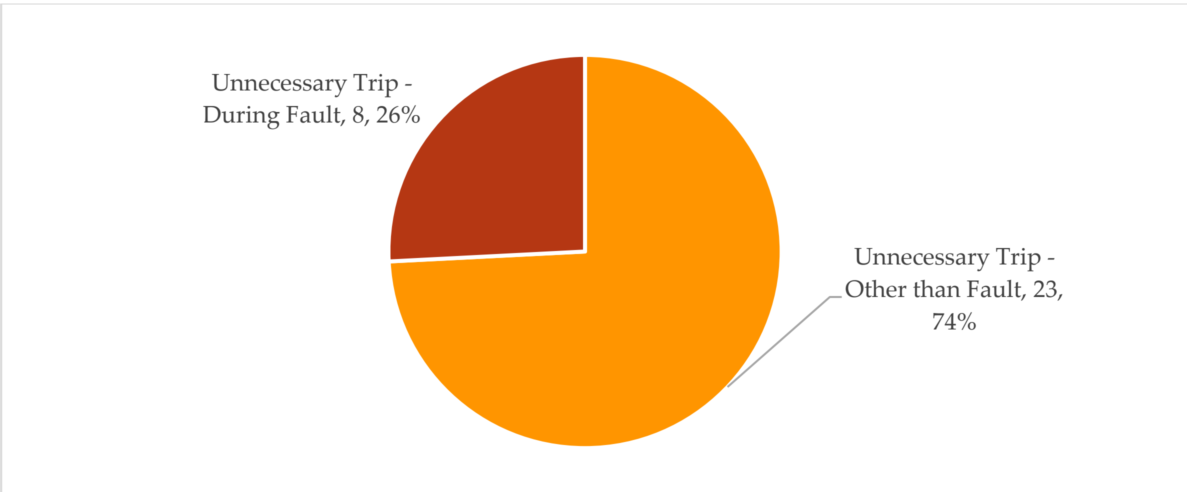


Figure 18: 2021 relay failures/malfunctions misoperations by cause category

Figure 19 shows previous years are similar to 2022, in that most relay failures result in an "Unnecessary trip—other than fault." Failure to trip and slow trips remain minimal through the trending time frame.

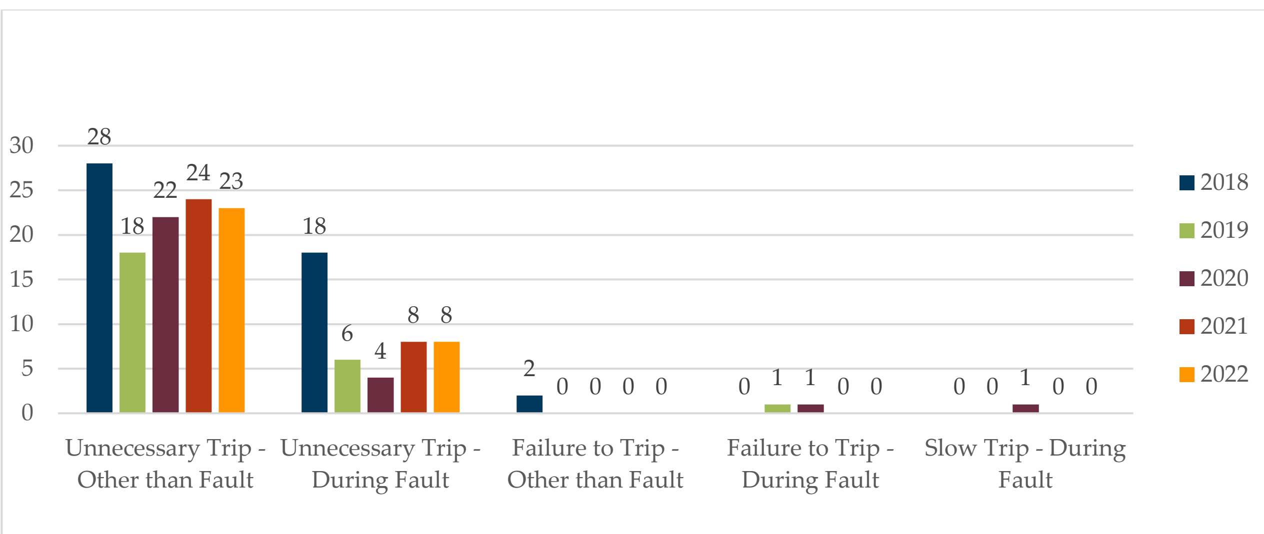


Figure 19: Relay failures/malfunctions misoperations by category, 2018-2022 trending

Relay Failures/Malfunctions Cause Category Conclusions and Recommendations:

Recommended practices include:

- Determining the actual causes of Misoperations is critical to identifying root causes, which then determines the proper corrective action to apply. This can help determine whether you are dealing with a singular occurrence, or whether corrective actions need to be taken across all similar installations in the system. Some helpful questions when investigating relay failures/malfunctions are:
  - Are there maintenance practices that could help reduce relay failures/malfunctions?
  - Are there known makes and models of relays with a higher rate of failure? If so, is this information available to all entities?

  Many entities replaced the relay as the planned corrective action, with no further investigation. As root causes are found, the fixes should be applied on similar Protection Systems throughout the entity's system.

- Manage firmware versions to avoid incompatibility issues through a designed process to document and manage the firmware in place for each device. For RTDS, ensure you are using the same firmware version during testing that was installed originally.
- When a failure cause is known, look throughout the system to see if there are other applications where the same failure may happen, then take action to address before a Misoperation occurs at these locations as well.
- Verify the operation of the entire composite Protection System (e.g., both A and B schemes) following all relay operations. Even though the composite Protection System may have operated successfully, components of the system may not have responded adequately due to a component failure. The component failure may cause a Misoperation later under different conditions. Thorough analysis of the entire composite Protection System can help avoid a related future Misoperation.
- Develop a process to ensure that entities review and address service advisories from relay manufacturers. This allows an entity to address known issues with a relay make or model before a Misoperation occurs on their system.

Communications Failures

Figure 20 shows there were 22 Misoperations attributed to Communication Failure during 2022 within this cause category grouping. This is more than double the number of Misoperations reported in 2021, and is the second highest over the past five years. This noticeable increase is why the PCS decided to perform additional analysis on this category.

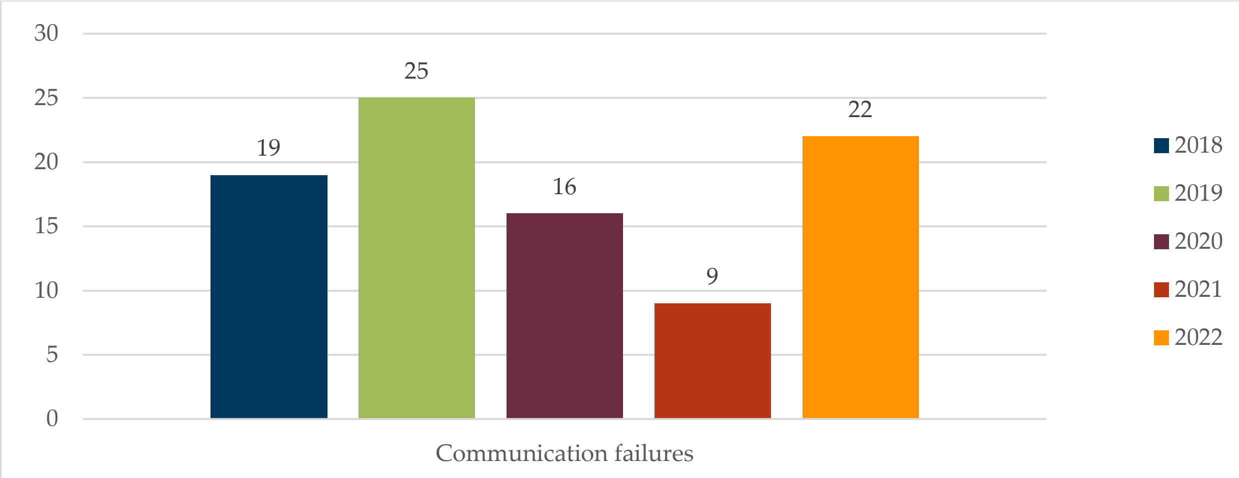


Figure 20: 2022 communication failure Misoperations, 2018–2022

Figure 21 shows the 2022 communication failure related Misoperations by category. Over half of the Misoperations resulted in unnecessary trips without a fault on the system. Of concern is the two slow trips during faults. These are generally considered higher severity Misoperations.

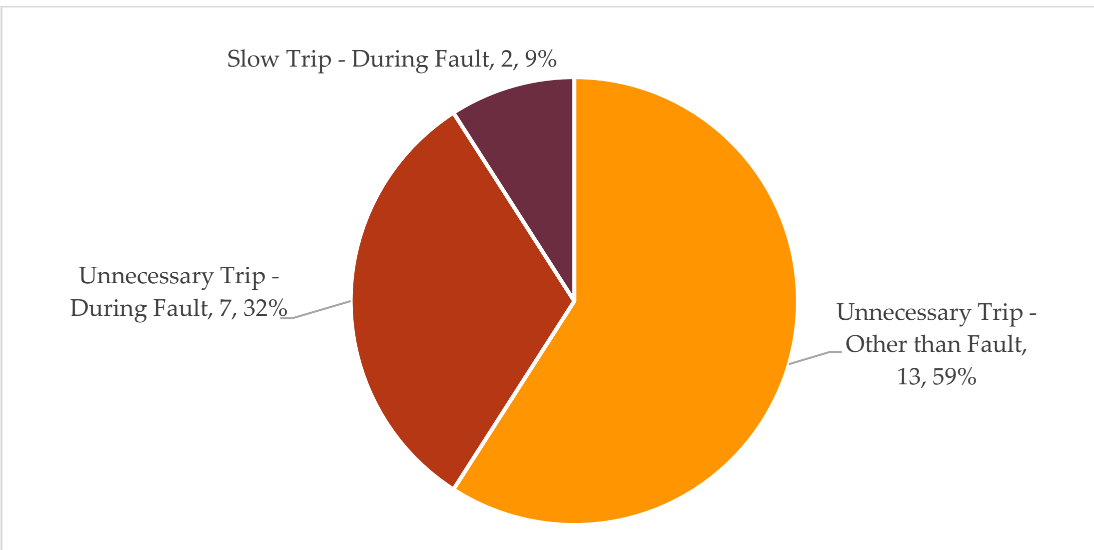


Figure 21: 2022 communication failure Misoperations by category

Figure 22 shows these are the only two slow trip during fault Misoperations involved in communication failure Misoperations over the past five years. One of these involved a three-terminal POTT scheme on a 230 kV system that did not operate correctly during a single-line-to-ground fault, requiring remote protection to clear the fault from the system. The other took place on a 115 kV system where the transfer trip signal was not received during a single-line-to-ground fault.

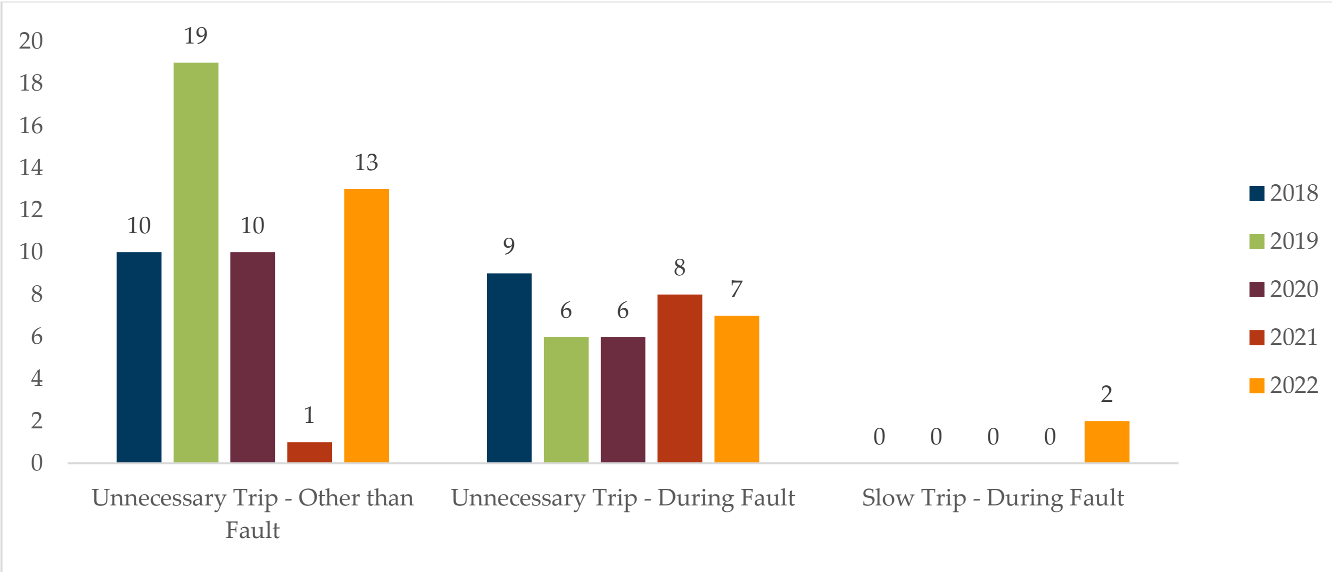


Figure 22: Communication failure Misoperations by category, 2018–2022

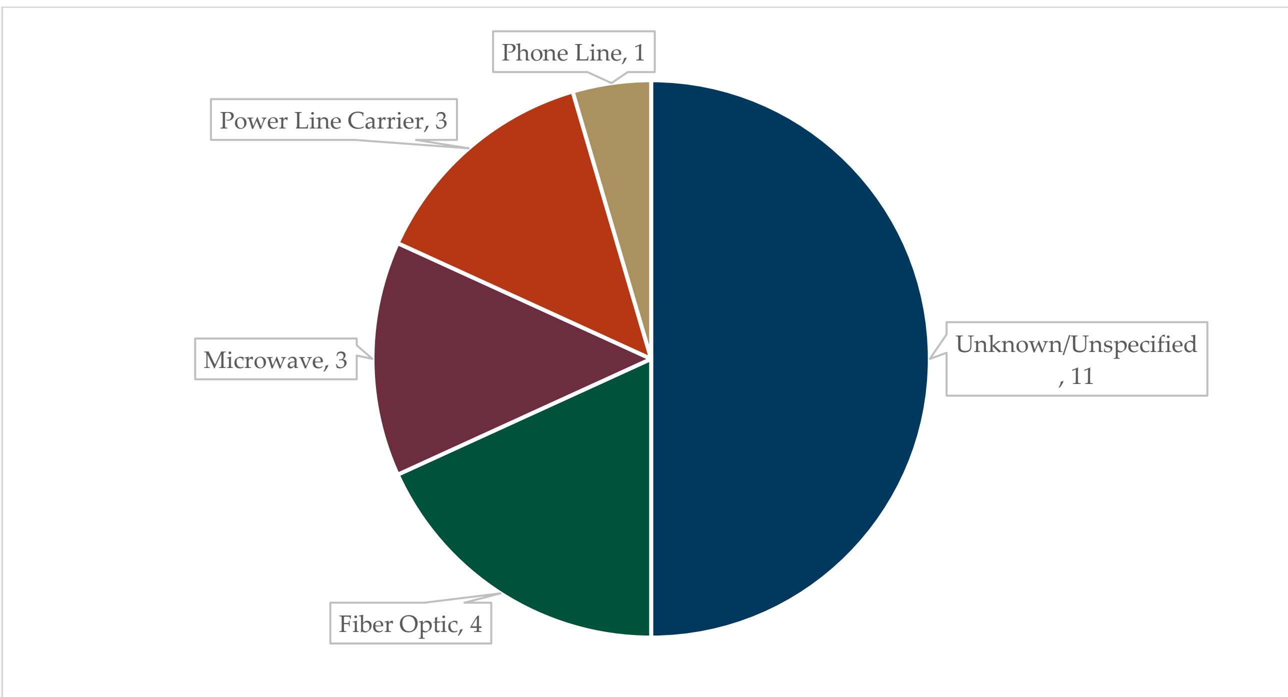


Figure 23: 2022 communication-related protection Misoperations by communication system type

Figure 23 shows the breakdown of communication-related Misoperations by communication system type. The data shows that half of the submissions did not include this detail. The Communication System Type is an optional field in MIDAS, and this information was not provided in this field, or in the event descriptions for half the submissions for 2022.

Communication Failure Misoperation Conclusions and Recommendations:

There were more Misoperations due to communication failures in 2022 than in all but one year over the past five years. The high number of unspecified communication system types makes it difficult to determine what communication method led to the increase. Communication Misoperation causes may increase as entities move to new technology and packet-based communication systems for use in Protection Systems. Migration to new technology, in particular packet-based, has not widely occurred. The impact of implementation of new communication system technology on Misoperations is not well understood. It may be that current installations are not causing Misoperations, or there is not enough detail in the Misoperation submission data fields to show the type of technology used. When employing new technology, thorough testing and verification should be performed to ensure Protection System reliability.

Conclusions

The trending of 2018 through 2022 indicates that the total Misoperations has had a slight downward trend over the past five years—267, 244, 200, 226, and 206. “Incorrect setting/logic/design errors” is still the leading cause of Misoperations within the Western Interconnection. The PCS believes the majority of Misoperations due to setting errors are preventable.

Best practices to avoid settings errors include peer reviews, appropriate training, and standardized protection scheme setting/design/logic templates.

A periodic review of the existing settings in the installed relay fleet (for example, wide-area coordination studies) can also reduce Misoperations caused by a change in system topography. NERC PRC-027 has requirements for periodic reviews and is intended to reduce the number of Misoperations in the future.

A thorough investigation of a Misoperation can help improve reliability. Entities should investigate Misoperations in a manner to fully understand the cause and develop a Corrective Action Plan to address the issues at that location, as well as addressing the extent of that condition across the system.

The NERC 1600 reporting template added sub-cause categories in 2018 to the “Incorrect setting/logic/design errors” and “Relay failures/malfunctions” at the request of NPCC and SERC. Although the sub-cause entry is not required, entities who provide this data will allow the industry to better perform trend analysis on Misoperation causes and allow targeted use of resources to address potential Misoperation causes.

The NERC MIDAS User Group has drafted a Data Reporting Instructions manual that has improved the quality of Misoperation reporting by providing examples to the entities’ main compliance contacts and the engineering staff performing the analysis. The PCS found that, while event descriptions continue to improve, they are still lacking in establishing the root cause. A root cause is necessary to determine the proper corrective action to apply either to the Protection System, entity processes, or across all similar installations in the entity's system.

Recommendations

The PCS has a new recommendation to entities in the Western Interconnection based on the latest review of Misoperation data.

1. Complete optional fields in the "incorrect setting/logic/design errors" and "relay failures/malfunctions" sub-cause categories in the Misoperation Reporting Template.

Previous recommendations made to entities in the Western interconnection by the PCS that it now believes should be considered best practices are listed below:

1. Update maintenance and commissioning practices to include burden and continuity checks of wiring plus visual inspection of equipment. Better practices will find most problems before an AC Misoperation can occur.
2. Perform peer review including verifying that the fault system model is correct, the coordination study is complete, the contingencies within the study are correct, proper setting values of the elements are applied, and the elements for the application are enabled.
3. Develop standards and guides for fault studies and a process for reviewing new and existing settings to ensure changes to the system do not result in Misoperations. The recently implemented Standard NERC PRC-027 addresses the periodic review of Protection Systems. This standard also established a peer review requirement, as well as performing evaluations on fault system models. Strong approaches to these topics can help prevent Misoperations.
4. Establish a training program for personnel who work on protection schemes and applications.
5. Develop an applications-based testing method and apply as a quality assurance measure to new and modified relay applications.
6. As root causes are found for "relay failures," the corrective action should be applied on similar Protection Systems throughout the entity's system.
7. To avoid leaving incorrect settings on a relay, the technicians performing the work should compare the "as-left" settings on the relay to the desired settings given by the setting engineer. Setting engineers should perform a second check once they receive the settings back from the field.