



2024 Misoperations Report
Protection and Control Subcommittee
October 2025

Executive Summary

Protection System Misoperations are a critical reliability concern for the Bulk Electric System (BES), due to their potential to escalate the severity of system events. Through several efforts supported by the WECC Protection and Control Subcommittee (PCS) and initiatives implemented by entities, the misoperation rate for the Western Interconnection for 2024 was the lowest in last 5 years, 4.55%. To continue this favorable rate PCS urges all entities to maintain momentum by routinely evaluating and improving their internal protection system practices.

The leading causes for misoperations in 2024 were Incorrect Settings, responsible for 41% of incidents, followed by Relay Failures/Malfunctions with 14%. While these two categories have been the highest contributing causes in the Western Interconnection for the past five years, a notable observation is the 48.6% for the incorrect settings category between 2023 and 2024.

To better assess root causes, PCS classified misoperations into two primary groups: Human Error and Protection System Component Failures. Human Error contributed to 57% of incidents, highlighting areas where approaches, procedural enhancements and training may help reduce risk. Component Failures comprised 32%, with some issues deemed unavoidable due to equipment limitations. The unknown category is excluded from either group. The PCS urges entities to focus on the misoperations with human error involved since these are more controllable.

The report includes several recommended practices that can establish solid approaches and practices that can help limit the number of misoperations in the Western interconnection. A few noteworthy practices include:

- Standardize protection system documentation and settings verification procedures.
- Strengthen peer review and training programs for protection engineers.
- Adoption of satellite-synchronized testing for communications-assisted schemes.
- Expand use of synchrophasor data and digital fault recorders to support post-event analysis.
- Comprehensive in-service and primary injection checks
- Deployment of commissioning checklists and quality assurance practices
- Implementation of time delays to mitigate communication noise
- Firmware management processes to ensure compatibility and test validity

By addressing misoperations through rigorous enhanced commissioning and maintenance approaches, improving engineering practices and using data-driven diagnostics, the Western Interconnection can continue to see favorable misoperations rates and severity impact.

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Introduction

Background

The North American Electric Reliability Corporation (NERC) has identified Protection System Misoperations as a critical reliability concern for the Bulk Electric System (BES), due to their potential to escalate the severity of system events. To assess protection system performance, NERC monitors annual misoperation rates across regions using a standard metric: the ratio of Protection System Misoperations to Composite Protection System operations.

Figure 1 presents a five-year trend of these rates for the Western Interconnection, offering a consistent benchmark to evaluate misoperation patterns while normalizing variables such as weather and other external influences.

The primary purpose of this metric is to measure and interpret the relative effectiveness of protection system operations within the Western Interconnection. This allows both NERC and the Western Electricity Coordinating Council (WECC) to track performance trends—whether concerning or improving—and focus efforts on enhancing system reliability.

This report was developed by the WECC Protection and Control Subcommittee (PCS), formerly known as the Relay work Group, a component of the WECC committee structure. This 2024 edition offers a comprehensive review of misoperations within the Western Interconnection, including a detailed evaluation of cause categories outlined in the NERC Misoperation Information Data Analysis System (MIDAS).

The analysis aims to share key findings and actionable insights that can drive improvements in protection system effectiveness and reinforce the resilience of the BES throughout the Western Interconnection.

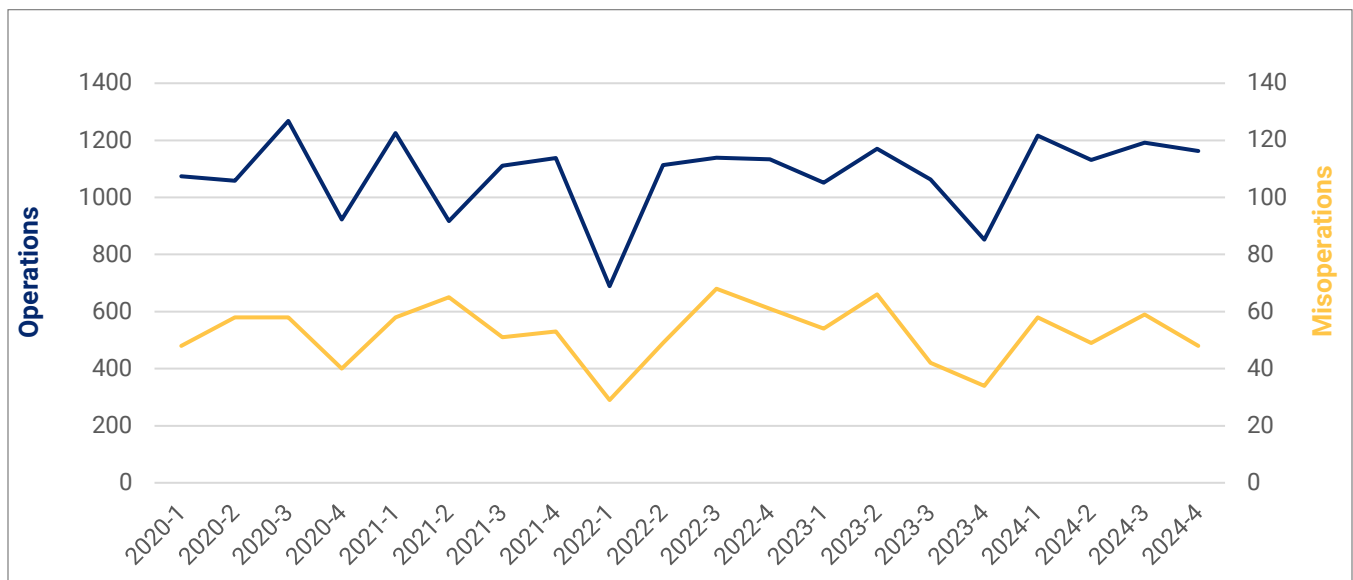


Figure 1: Total Operations/Misoperations Trend, 2020–2024

The annual Protection System Misoperation rate within the Western Interconnection has shown a continued downward trend, as illustrated in **Figure 2**. In 2024, the rate reached 4.55%—the lowest rate in the past five years. The PCS views this trend as encouraging and urges entities across the interconnection to regularly examine and enhance their internal protection system practices to sustain this progress.

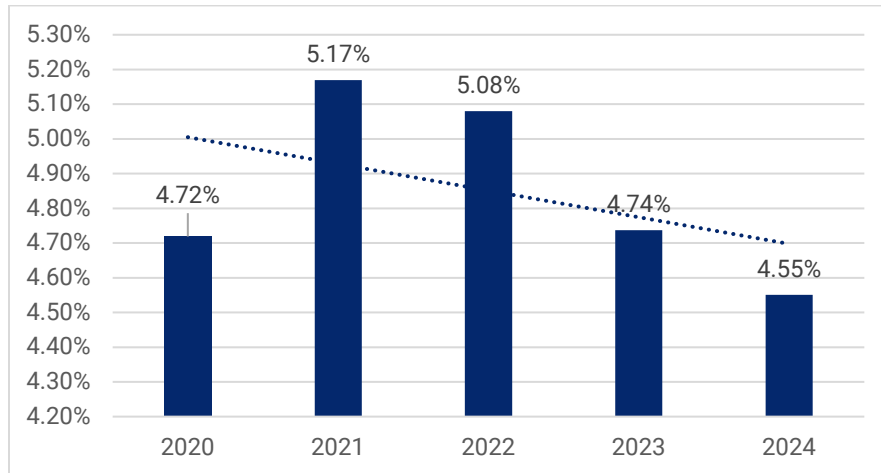


Figure 2: Western Interconnection Misoperation Rate, 2020–2024

Incremental improvements at the entity level play a vital role in strengthening the overall performance of protection systems, thereby supporting the reliability of the BES. While a declining misoperation rate is a promising sign, it does not fully capture the severity or operational consequences of each misoperation event.

To address this limitation, NERC introduced the Misoperations Impact Score in 2024. This metric provides a standardized framework for evaluating the potential impact of misoperations—at the individual event level, across entities, regions, or even at the national level.

The score ranges from 0.3034, indicating minimal impact, to 1.0, denoting the most severe consequences to the BES. Though the scoring system relies on certain assumptions—such as considering the loss of a 500 kV element to be more severe than that of a 230 kV element—these generalizations are necessary to establish this metric.

The Misoperation Impact Score is calculated using:

- Voltage class,
- Equipment type,
- Cause of misoperation, and
- Misoperation category.

A detailed explanation of the scoring method and weighting criteria is available in the [Misoperations Impact Score](#) document on the NERC website.

Figure 3 shows the distribution of this impact score for each quarter since 2020. The average impact score in the Western Interconnection for this period is 0.61. In the five-year window there were six misoperations with a score of 0.80 or higher with the highest score being 0.87. This was a slow-to-trip

during a fault on a 345 kV transformer breaker due to an Incorrect Setting. Each facet of this misoperation contributed to the higher score. The lowest score for this period was 0.44. This was an AC System misoperation on a 115 kV shunt capacitor that was a slow trip without a fault on the system. WECC's desire is to maintain a low misoperations rate for the interconnection and maintain a relatively low impact from the misoperations that do occur. Both desires can be realized as entities incorporate the recommendations in this report.

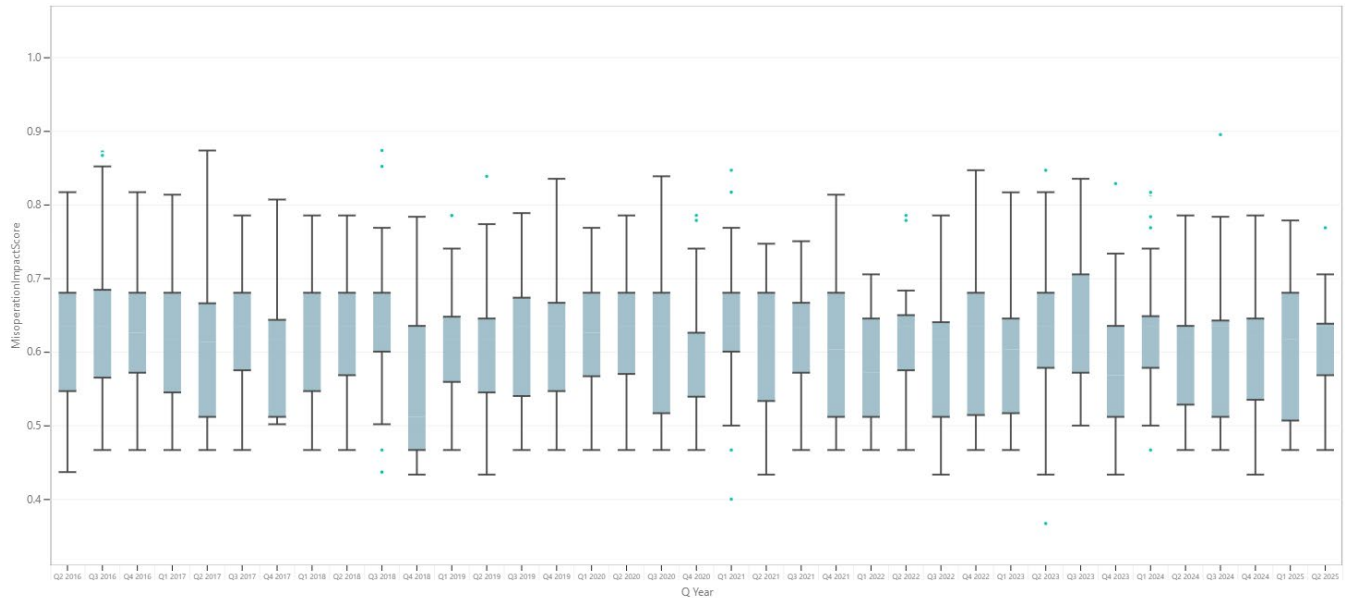


Figure 3: Western Interconnection Misoperation Impact Score by Quarter, 2020–2024

Purpose of PCS Misoperation Analysis

The PCS conducts quarterly reviews of misoperation data reported to NERC under Section 1600 by registered entities in the Western Interconnection. This process culminates in this annual analysis and multi-year trending study designed to:

- Identify misoperation trends and root causes.
- Develop recommendations to minimize future misoperations.
- Share industry guidance via technical documents and webinars.
- Present findings to WECC's Reliability Risk Committee (RRC) and WECC stakeholders.

The PCS places a strong emphasis on understanding misoperation causes and using these insights to guide prevention strategies across the interconnection. The following assisted the PCS in this objective:

- The dataset was compiled using NERC's MIDAS 1600 reporting template, which organizes misoperations into defined categories and causes.
- The PCS used event descriptions, reported corrective actions, and identified causes to assist with root cause analysis.
- The PCS conducted quarterly reviews of the data, incorporating resubmittals to clarify and correct entries.

2024 Misoperation Analysis

This report presents an in-depth analysis of misoperations within the Western Interconnection based on 2024 data, alongside a trend comparison spanning the 2020 to 2024 datasets. It includes detailed findings, conclusions, and targeted recommendations categorized by cause.

Misoperations by Cause Category

Misoperations are submitted under one of ten causes defined by NERC and industry. **Figure 4** illustrates the 2024 distribution of misoperations by cause.

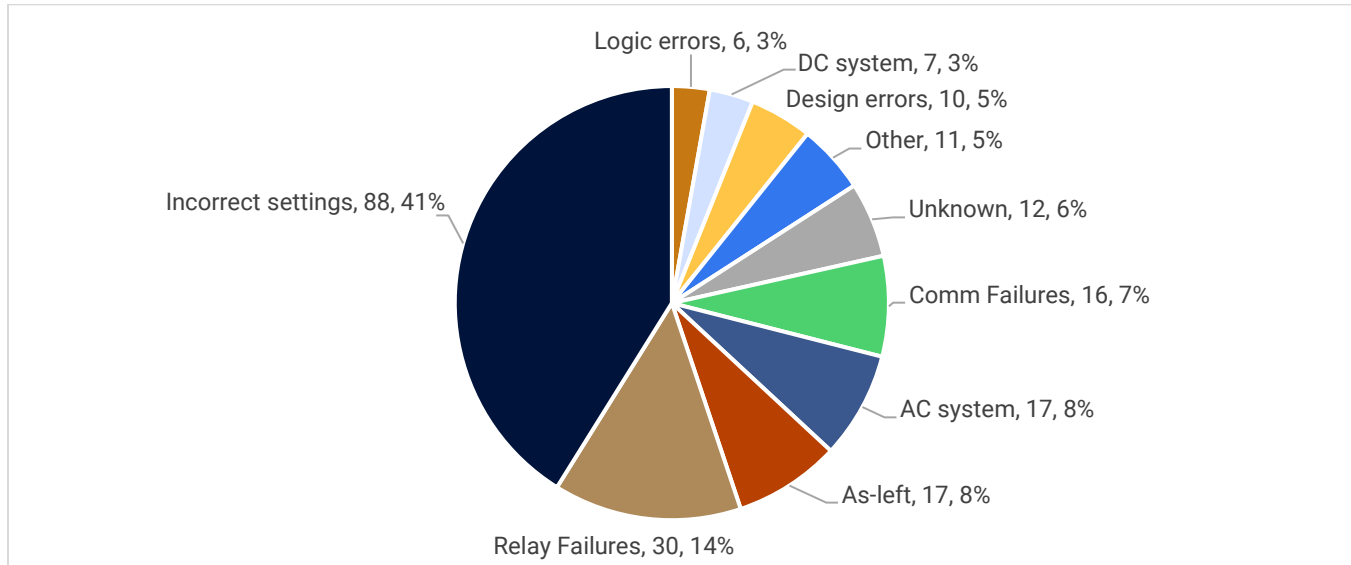


Figure 4: 2024 Misoperations by Cause

In 2024, the leading contributor to misoperations across the Western Interconnection was Incorrect Settings, accounting for 41% of all reportable incidents. Relay Failures/Malfunctions followed with 14%, while As-left Personnel Errors, AC System issues, and Communication Failures collectively constitute 23%. Together, nearly 80% of all misoperations were attributed to these five causes.

To better understand the nature of these events, the PCS categorized misoperations into two overarching groups: Human Error and Protection System Component Failures.

- **Human Error:**
 - Incorrect Settings
 - Logic Errors
 - Design Errors
 - As-left Personnel Errors
- **Protection System Component Failures:**
 - Relay Failures/Malfunctions
 - Communication Failures
 - AC System issues
 - DC System issues

Note: “Unknown/Unexplainable” and “Other/Explainable” categories were excluded from this analysis.

This breakdown underscores that 57% of misoperations reported in 2024 were attributed to human error. While not all human-related misoperations are entirely preventable, the PCS recognizes opportunities for improvement—particularly within categories where interventions and process enhancements are feasible.

In contrast, 32% of misoperations stemmed from protection system component failures. Although diligent maintenance and monitoring can mitigate many of these failures, the PCS acknowledges that certain equipment-related issues may be inherently unavoidable due to material limitations or unpredictable behavior.

Trends and Observations

Figure 5 illustrates the persistence of Incorrect Settings and Relay Failures/Malfunctions as the top contributors over the past five years. However, there were differing patterns seen in 2024. Incorrect Settings experienced a 60% increase in 2024. Relay Failures/Malfunctions saw a notable 28% reduction compared to the previous year.

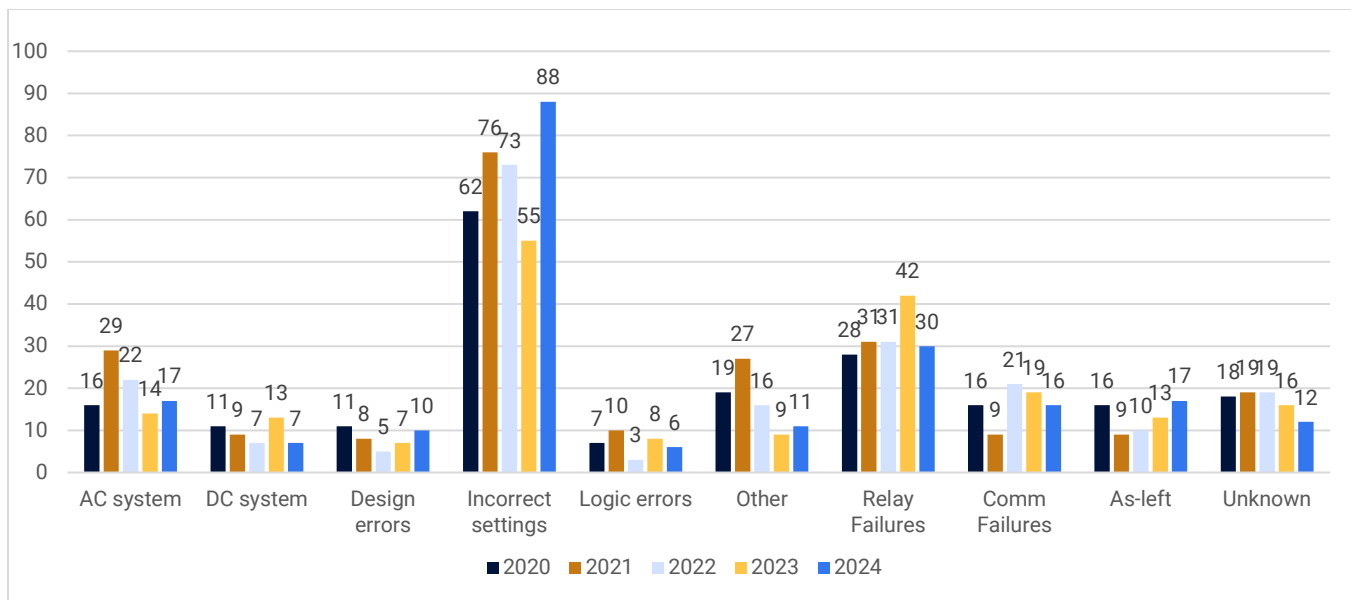


Figure 5: Trending Misoperation by Cause, 2020–2024

Of note is the decline in Unknown/Unexplainable misoperations over the analyzed period. These types of incidents are particularly concerning, as developing an effective Corrective Action Plan is difficult when the root cause is unidentified. Without clear causation, misoperations may recur under similar system conditions. The reduction in this category suggests improvements in diagnostic capabilities and event analysis procedures across the interconnection.

Figure 6 illustrates the distribution of misoperation causes by quarter for 2024, alongside a comparison to the quarterly averages since 2020. In 2024, Q1 recorded the highest number of misoperations. This pattern differs from prior years, as Q3 had the most misoperations in 2022, while Q3 had the highest count in 2023.

This variability indicates that no single quarter consistently experiences the highest frequency of misoperation, highlighting the importance of sustained monitoring and preparedness across all seasons.

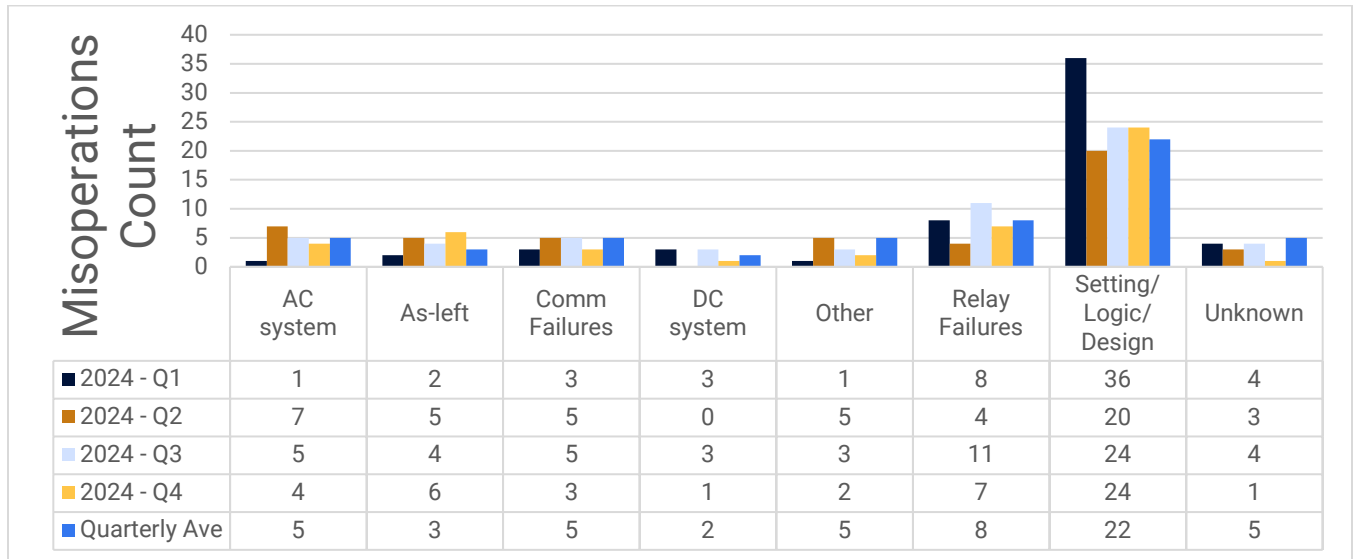


Figure 6: 2024 Misoperation by Cause per Quarter

Figure 7 depicts the average number of misoperations per year across each cause category over the past five years. This long-term perspective supports the identification of persistent contributors and emerging trends, which are vital for targeted mitigation strategies.

Comparing these averages to the yearly totals in **Figure 5** shows that most categories have seen a reduction over this five-year period aligning with the downward trend of total misoperations for the interconnection.

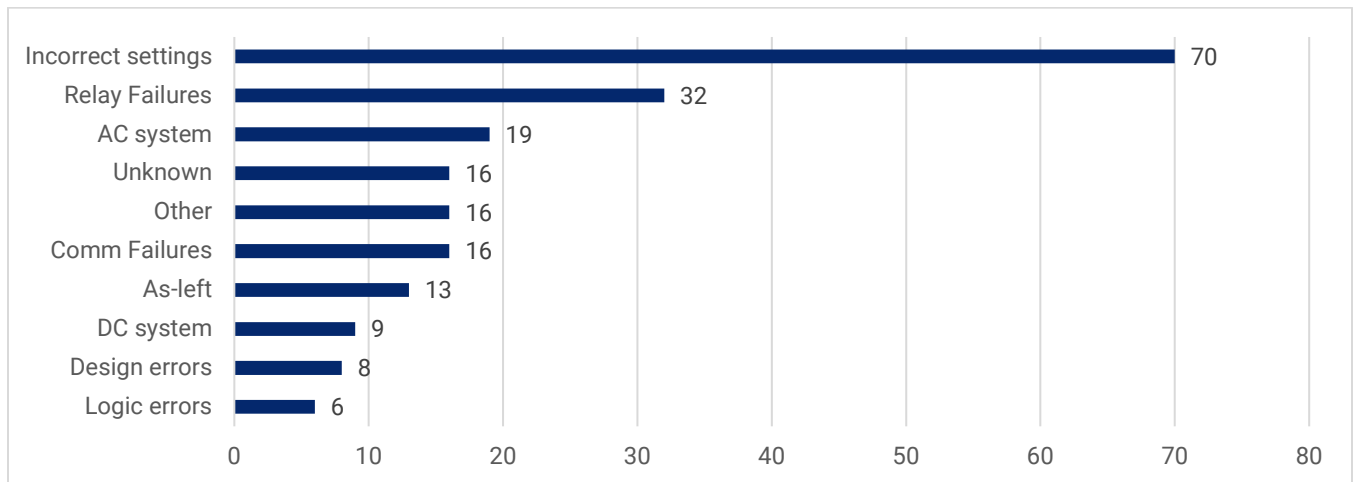


Figure 7: Misoperation by Cause, Average Annual Count, 2020–2024

Analyzing misoperations from multiple angles continues to provide valuable insights. One particularly useful finding is that 57% of all misoperations in 2024 involved some level of human influence. This data empowers entities to pinpoint areas where process improvements, personnel training, and

procedural refinements could meaningfully reduce future occurrences. By focusing on controllable, human error misoperations such as Incorrect Settings, design oversights, and Logic Errors—organizations can implement strategies aimed at enhancing Protection System reliability.

Misoperations by Voltage Class

For MIDAS reporting, voltage class refers to the operating voltage level of the equipment protected by the Protection System. In cases where misoperations involve equipment spanning multiple voltage levels—such as transformers—the voltage class reported corresponds to the highest voltage level involved.

Figure 8 presents a breakdown of 2024 misoperations by voltage class, offering insight into the distribution across different system voltages. This is followed by **Figure 9**, which provides a five-year trending analysis, enabling an evaluation of long-term shifts and patterns in misoperations across voltage classes.

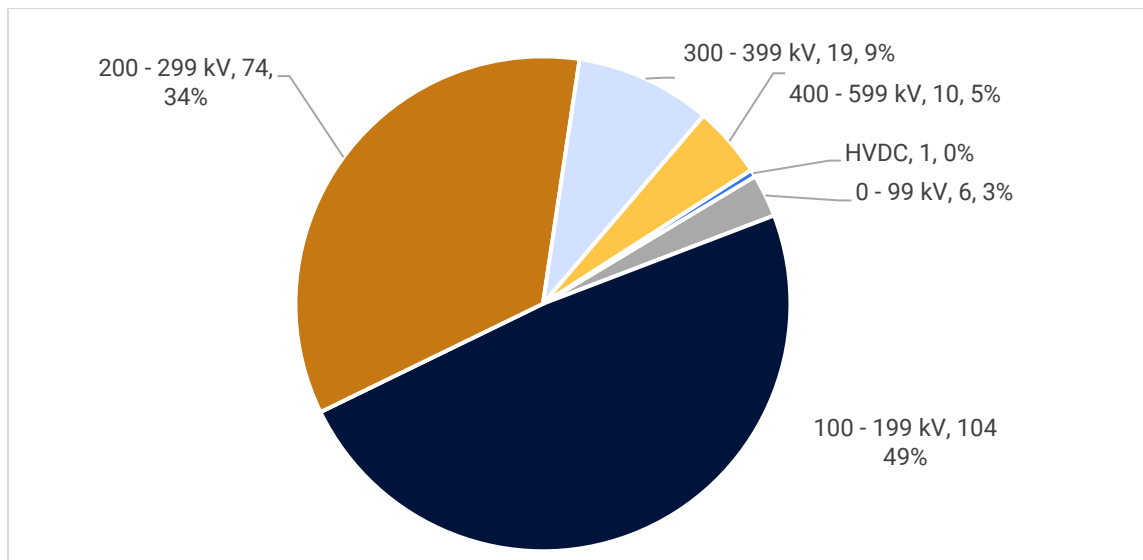


Figure 8: 2024 Misoperation by Voltage Class

Figure 8 shows that in 2024, 86% of all misoperations occurred on systems operating below 300 kV, continuing the trend seen in previous years shown in **Figure 9**. This is expected, since these voltage classes represent the highest count of BES circuits in the Western Interconnection (see **Table 1**). While these voltage classes generally have less impact on system stability, there are still reliability implications related to misoperations at these voltage levels, and all reasonable efforts should be taken to ensure protection operates as intended.

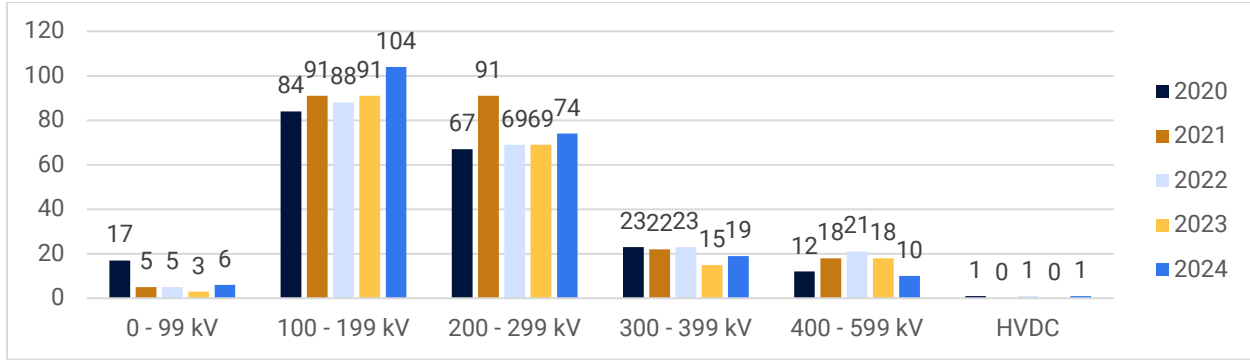


Figure 9: Misoperation Count by Voltage Class, 2020–2024

A meaningful reliability indicator can be derived by knowing the number of elements within each voltage class. By calculating the ratio of misoperations to the total number of elements in each class, we gain deeper insight into where misoperations are concentrated across the Western Interconnection. The element counts per voltage class were taken from the Transmission Availability Data System (TADS) database. These ratios are expressed as percentages and presented in **Table 1**. This table offers a normalized view that accounts for changes in infrastructure, such as the addition or retirement of facilities within the system.

Table 1: 2024 Fraction of Misoperations per TADS Element by Voltage Class

Voltage Class	AC Circuit	Converter	DC Circuit	Transformer	Total Elements	# Misops	Fraction of Misops by Elements
0-99 kV BES	505	0	0	42	547	6	1.11%
100-199 kV	3515	0	0	196	3711	104	2.80%
200-299 kV	2048	5	3	741	2797	74	2.65%
300-399 kV	207	2	0	181	390	19	4.87%
400-599 kV	310	0	6	261	577	11	1.91%

The table shows that the highest number of circuits within the Western Interconnection is in the 100–199 kV and 200–299 kV ranges. It also shows that the fraction of misoperations per TADS element by voltage class is highest for the 300–399 kV elements in the Western Interconnection. This is the voltage class with the fewest elements. In 2024, nine of the 19 misoperations in this voltage class were caused by either Incorrect Settings(6) or As-left Personnel Errors(3). An additional six were categorized as Unknown/Unexplainable(3) or Other Explainable(3). Thirteen of these misoperations were categorized as Unnecessary Faults—Other than Fault.

Figure 9 shows that misoperation rates by voltage class have remained relatively stable for the 100–299 kV systems, which account for approximately 85% of Bulk Electric System (BES) elements within the Western Interconnection over the past five years. In contrast, other voltage classes have exhibited greater variability. Notably, the 0–99 kV BES and 300–399 kV systems experienced an uptick in misoperation rates, while the 400–599 kV class saw a decline compared to the previous year.

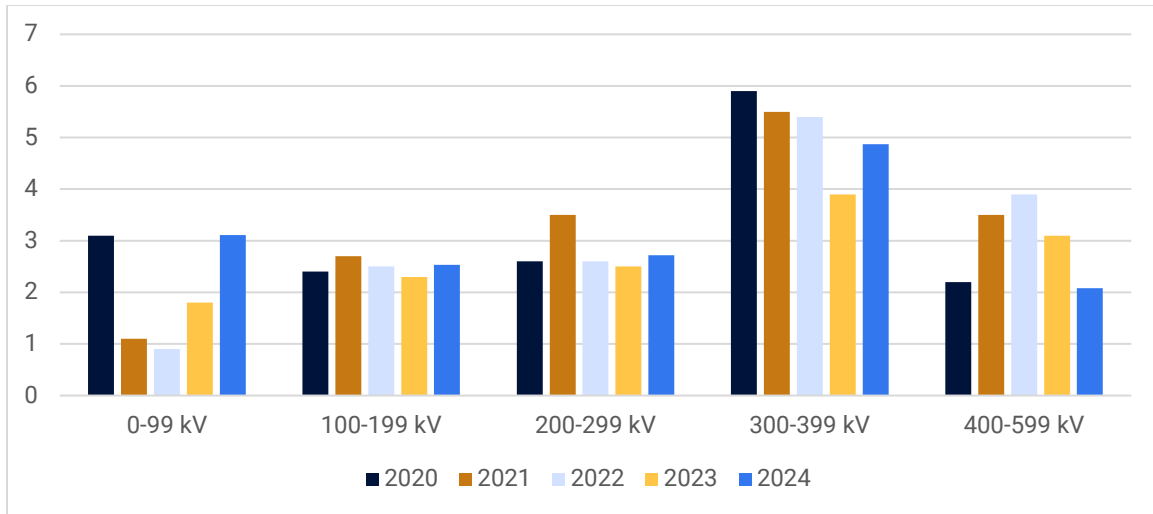


Figure 9: Fraction of Misoperations per TADS Element by Voltage Class, 2020–2024

Despite a modest decline in misoperations, equipment owners and operators should continue to assess the broader impact of such events. Entities should implement more rigorous in-service testing and commissioning protocols during initial deployment for assets deemed critical to their system or to the Western Interconnection. Additionally, these assets may warrant a more stringent and proactive maintenance schedule to mitigate risk. 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 of Incorrect Settings, Logic Errors, and Design Errors

For analysis in this report, these three cause categories are combined. There were 104 misoperations attributed to Incorrect Settings, Logic Errors, and Design Errors, which is an increase of 48.6% from the previous year. This continues to be the largest of all cause categories in 2024. In 2024, 100% of the misoperations caused by Incorrect Settings, Logic Errors, and Design Errors were on microprocessor relays.

While microprocessors relays were the technology associated with all the misoperations for these causes, this is likely due to their widespread use, and the retirement of legacy relay technology. Additionally, misoperations related to Incorrect Settings, Logic Errors, etc. are more likely to occur in new protection schemes or relay upgrades, of which nearly all will involve microprocessor relays.

Figure 10 shows the distribution of the three cause categories. The chart shows that Incorrect Settings make up 84% of the misoperations, with Logic Errors, and Design Errors contributing smaller numbers.

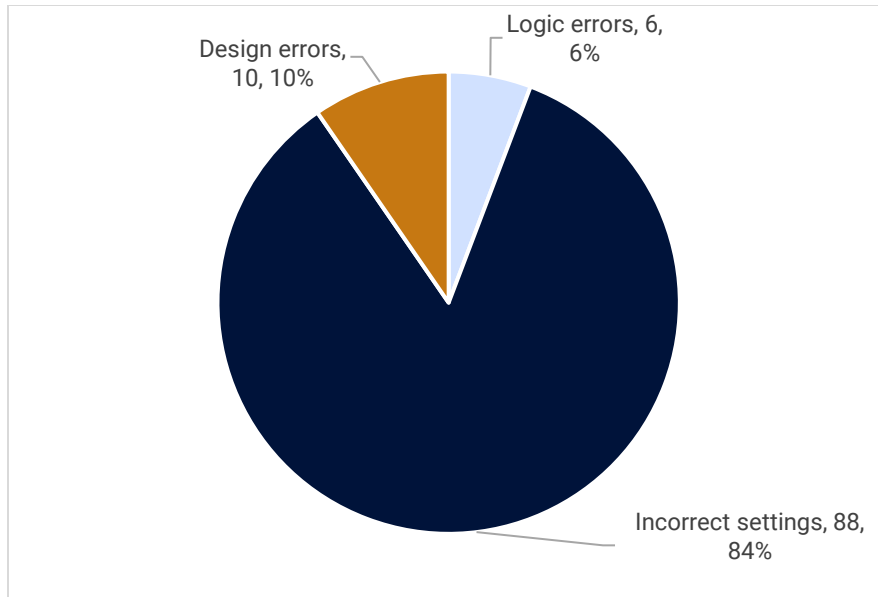


Figure 10: 2024 Misoperations by Subgroup

The five-year trend shown in **Figure 11** indicates Incorrect Settings continue to be the significant cause of misoperations in the Western Interconnection.

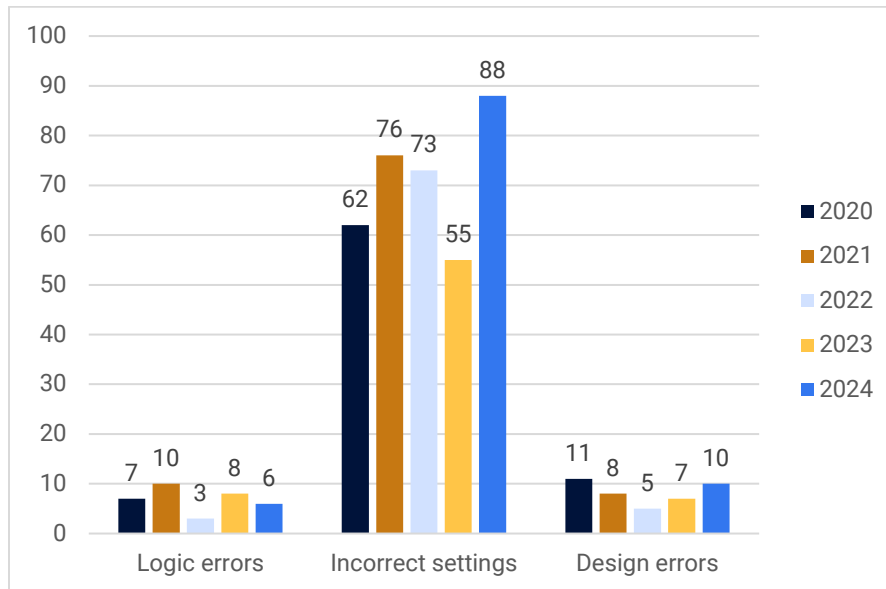


Figure 11: Misoperations Subdivided into Setting and Logic/Design Errors, 2020–2024

The trend for Logic Errors and Design Errors has remained static over the last five years. However, the Incorrect Settings, which constitutes the largest category, increased by 60% compared to 2023 and is the highest in the previous five years. This may correlate with the deployment of new microprocessor-based relays, which introduces unfamiliar configuration protocols. Another contributing factor to these misoperations may be the loss of experienced employees due to natural attrition, and a reliance on a less experienced workforce.

Figure 12 analyzes the Incorrect Settings, Logic Errors, and Design Errors misoperation cause categories as they relate to whether a fault occurs at the same time.

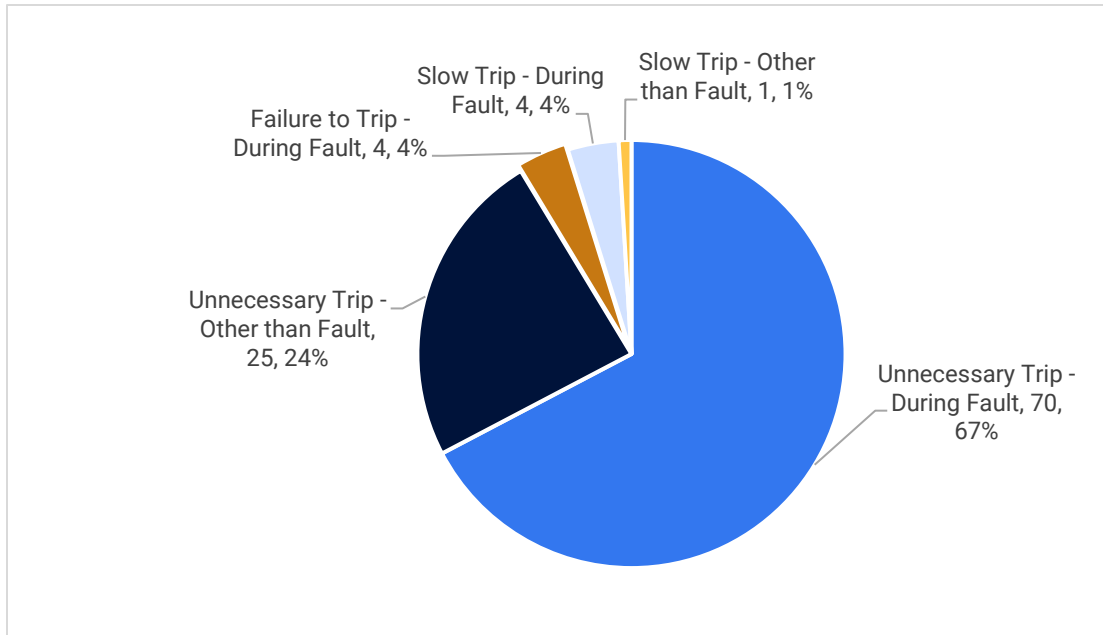


Figure 12: 2024 Incorrect Settings, Logic Errors, and Design Errors by Misoperation Category

Figure 12 shows 67% of Incorrect Settings, Logic Errors, and Design Errors resulted in an “unnecessary trip—during fault” pointing towards overtripping during fault conditions. While it is not ideal to have more elements removed during a fault, it is generally preferable to a failure to trip or slow trip during a fault. There is a balance between dependability and security when developing relay settings. Dependability is the certainty that the relays will operate correctly for all faults for which they are designed to operate. Security is the certainty that the relays will correctly not operate for all faults for which they are designed not to operate. The observation that relay settings lean more toward unnecessarily tripping than failing to trip points to the general practice to elect dependability over security when trying to achieve this balance.

For major bulk power paths and EHV lines, both maximum security and dependability are crucial to meet the reliability and stability requirements of these paths. For these paths, additional effort and testing methods are often required to verify modeling and relay settings such as hardware-in-the-loop testing and satellite-synchronized end-to-end testing. These methods, among others, are listed among the recommendations described at the end of this section.

Figure 13 shows a five-year trend of misoperations relating to system faults and demonstrates that the trend continues to favor dependability over the past five years.

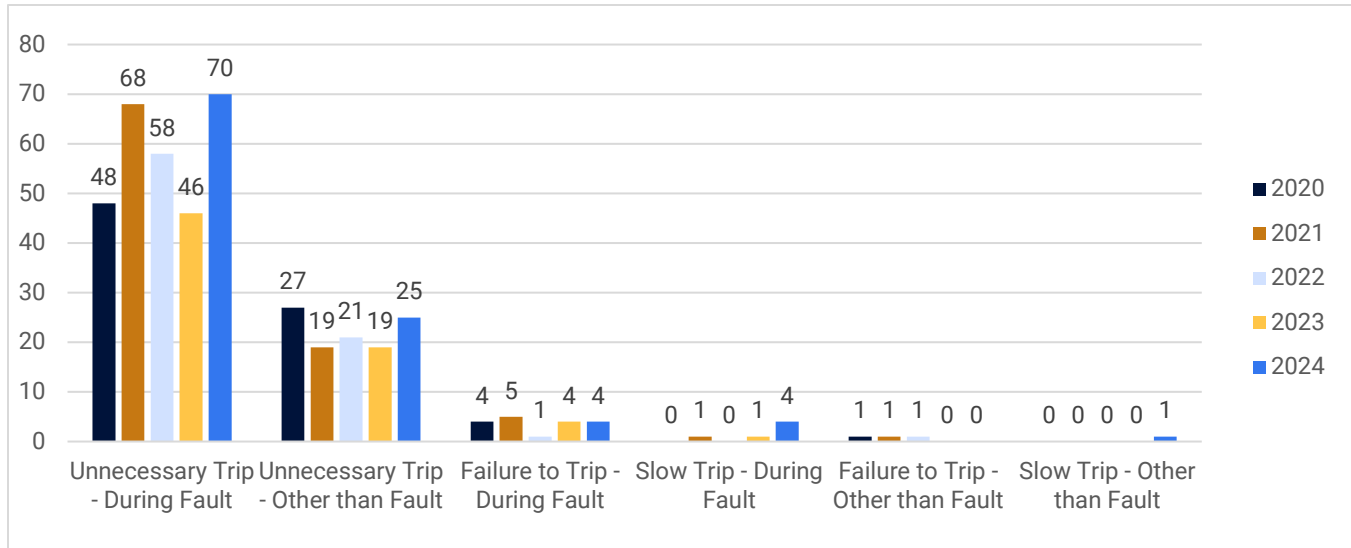


Figure 13: Incorrect Settings, Logic Errors, and Design Errors by Misoperation Category, 2020–2024

The Failure to Trip and Slow to Trip categories of misoperations generally represent more harmful misoperations. Fault conditions remain on the system for longer periods, exposing expensive, long-lead-time equipment to high current while also requiring remote equipment to operate to clear the fault. All efforts to prevent these misoperations should be made.

In **Figure 14**, the PCS further investigated the 2024 misoperations in the category Incorrect Settings, Logic Errors, and Design Errors to identify the applications of these settings involved in misoperations.

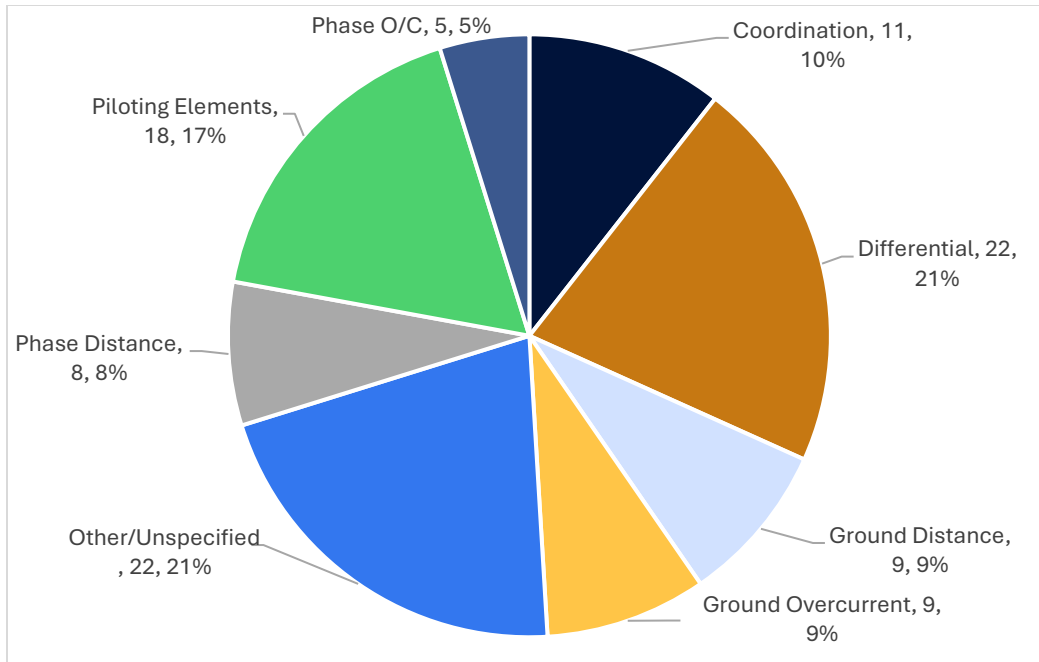


Figure 14: 2024 Incorrect Settings, Logic Errors, and Design Errors by Protection Elements

The significant causes of misoperations identified were differential protection, piloting elements, and other/unspecified errors. There were 18 misoperations included in the other section which included generator protection, breaker failure logic, directional element settings, and broken conductor logic. The broken conductor logic protection represent relatively new schemes and misoperations are more likely when adopting new relay technology. There were four misoperations with “unspecified” schemes or protection elements.

Misoperations using differential schemes increased compared to 2023 values. These include differential schemes on transmission lines, transformers, and buses. While misoperations on transmission line differential schemes are expected to increase as this application becomes more widely used, a notable increase in transformer differential misoperations were reported. These misoperations included settings errors involving CT and winding compensation, harmonic blocking threshold levels which resulted in tripping on inrush, and Design Errors involving incorrect CT polarities.

Incorrect Setting, Logic Errors, and Design Errors Misoperation Recommendations:

Entities should consider the following recommended practices:

- Develop written standards and guides explaining the expectations for their protection engineers about verifying that the fault system model is correct including mutual coupling, the settings have been properly coordinated, the contingencies considered for coordination are consistently addressed, proper setting values of the elements are applied, and the elements for the application are enabled to ensure consistent performance.
- Develop a process for reviewing new and existing settings to ensure changes to the system do not result in misoperations. Have a formal training process for employees who are new to the Protection Department.

- Use experienced personnel as mentors.
- Establish a strategy on what and when skills should be introduced as experience is developed; for instance, non-directional overcurrent followed by transformer, differential followed by step distance, etc. during the first year to guide the mentor in developing the new engineer.
- Establish familiarity with company standards and practices for protection systems.
- Involve new employees in the setting testing process.
- Review the process for developing and updating short-circuit models and testing programs.
- Consider impedance testing of transmission lines to verify parameters used in models
- Use satellite-synchronized testing technologies when commissioning communications-assisted schemes to ensure all components of the protection system work as designed.
- Use standardized settings templates to reduce the opportunity for human errors when developing settings.
- Develop a process to regularly review existing ground overcurrent settings to ensure changing system conditions do not result in a misoperation.
- Review, from a process perspective, misoperations that occur. Determine changes that can be made in the process to prevent misoperations from recurring.
- Develop an applications-based testing approach as a quality assurance measure for new and modified relay applications.
- Recommend hardware-in-the-loop testing on critical transmission circuits and series compensated lines.
- Additionally, entities can review the IEEE Power System Relaying Subcommittee report, "[Processes, Issues, Trends and Quality Control of Relay Settings](#)," for technical guidance for quality control of protective relay settings.

Analysis of Relay Failures and Malfunctions

As shown in **Figure 15**, there were 30 misoperations attributed to relay failures or malfunctions in 2024. This number has remained fairly consistent over recent years. It could be said that given the large number of protective relays deployed within WECC, the complex circuitry and electronics of these devices, and the harsh environment of the substations where they are deployed, the relatively low number of relay failures or malfunctions is a testament to the successful engineering and construction of the modern protective relay. Still, these 30 misoperations make up 14% of the total number of misoperations in 2024, so they are a significant part of the total, and there is room for improvement.

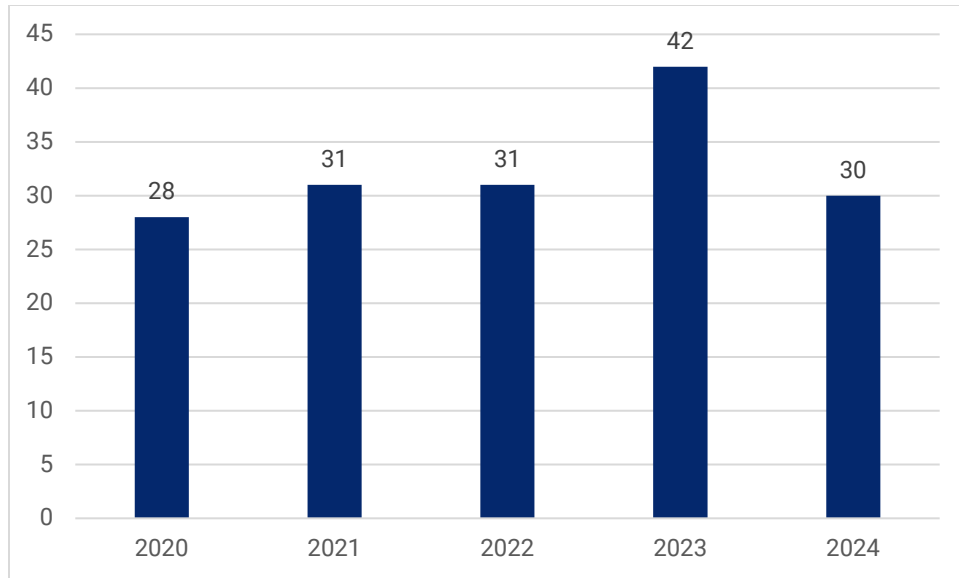


Figure 15: Relay Failure/Malfunction, 2020–2024

Figure 16 shows the relative share of the total relay failures or malfunctions from electromechanical, solid state, and microprocessor relays. The share of solid-state relay failures appear to be trending upward, even while the percentage of these relays in service is trending downward (since, by and large, they are no longer being installed). This could indicate a higher rate of failure of this relay technology as these devices continue to age. Similarly, the share of electromechanical relay failures appears to be holding steady although the percentage of these relays within WECC is also trending downward (since they are rarely being installed now and continue to be replaced with microprocessor relays). This too could indicate a higher rate of failure of these devices as they continue to age.

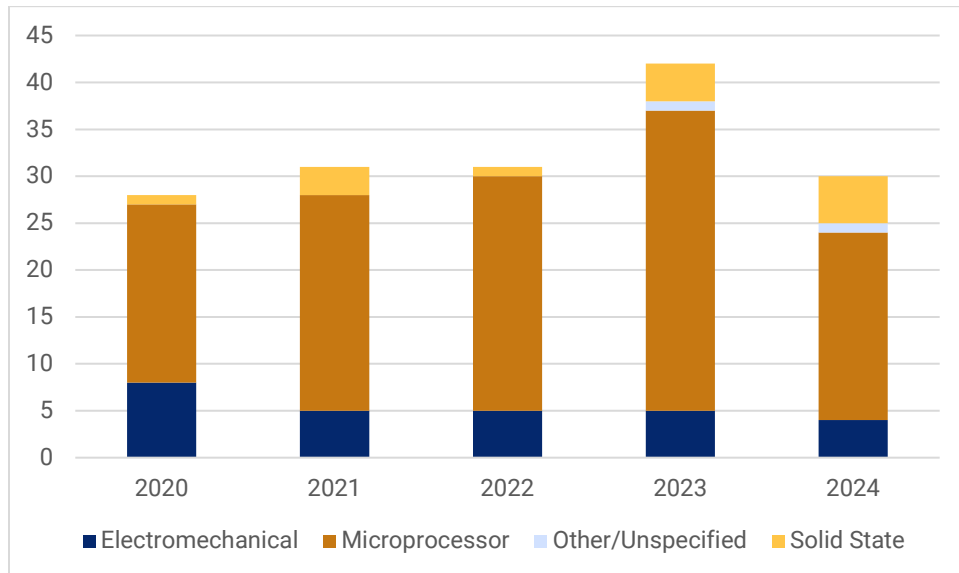


Figure 16: Relay Failure/Malfunction by Relay Technology 2020–2024

Many of the 2024 Relay Failure/Malfunction submissions did not provide enough detail in the event description to identify the cause of failure. 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 their systems that are prone to the same type of failure. This can also help the manufacturer identify and correct issues with their products and prevent other utilities from experiencing similar misoperations.

The Relay Failure/Malfunction sub-cause column and information provided some insights into the types of relay failures in 2024. A failed component within the relay was the most indicated cause. In 2024, I/O module failures resulted in the greatest number of misoperations at five followed by CPU self-diagnostic failures at two and power supply failures at one. In the past, there have been several malfunctions of electromechanical relays due to calibration drift. In 2024 there was one misoperation reported due to this issue.

There were 25 relay failures in 2024 categorized as unnecessary trips other than fault, meaning these events occurred while there was not condition on the system that needed to be cleared. The remaining five were categorized as unnecessary trip during a fault, which means additional facilities other than those necessary to clear the fault were tripped. Unnecessary trips, whether during a fault or other than a fault, generally have a lower impact to the BES than a failure of a relay to detect and clear a fault from the system. In 2024, there were no failures to trip or slow trips during a fault due to relay failures or malfunctions, which is a desirable outcome. **Figure 17** shows the trend of misoperation category for the years 2020 through 2024.

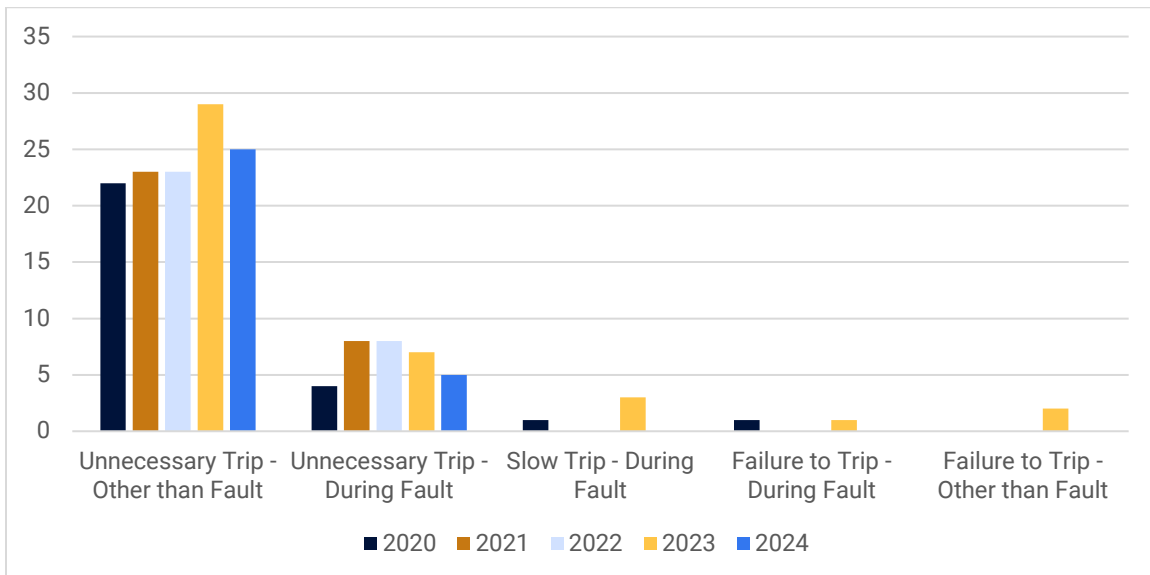


Figure 17: Relay Failures/Malfunctions Misoperations by Category, 2020–2024

Relay Failures/Malfunctions Cause Category Recommendations:

Entities should consider the following recommended practices:

- Don't conclude that the relay failed or malfunctioned without a thorough investigation into the settings, logic, and coordination of the relay. This could include contacting the relay manufacturer and getting assistance in analyzing the failure.

- Determine the root causes of misoperations. This is critical to determining the proper corrective action to apply. It can show whether the event is a singular occurrence or whether corrective actions are needed for all similar installations in the system. Some helpful questions when investigating Relay Failures/Malfunctions are:
 - Are there maintenance practices that could help in the reduction of Relay Failures/Malfunctions?
 - Are there known makes and models of relays with a higher rate of failure?
 - Stay up to date on lessons learned from NERC/WECC or Relay Manufacturers regarding known issues with certain relay models or firmware versions.
- Establish a process to document and manage the firmware in place for each device to avoid incompatibility issues. For hardware-in-the-loop testing, ensure the same firmware version originally installed is used so the testing results remain valid.
- 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 or other cause. An undetected component failure, or one left uncorrected, may cause a later misoperation under different conditions.

Analysis of Communications Failures

Figure 18 shows there were 16 misoperations attributed to Communication Failure during 2024 within this cause category grouping. This is essentially the five-year average for Communication Failures, though the last three years indicate a possible downward trend.

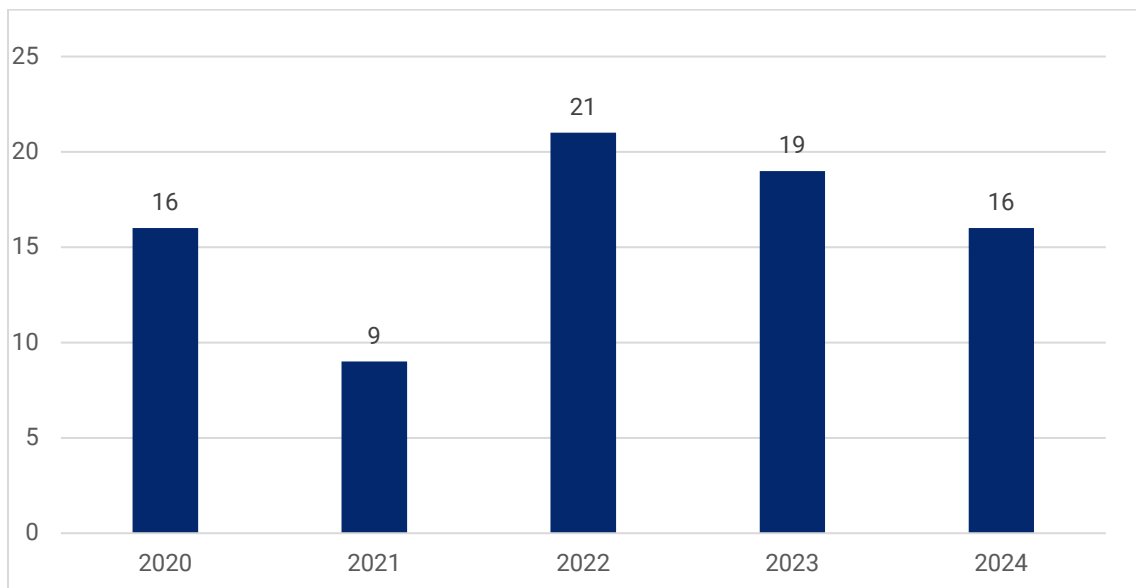


Figure 18: Communication Failure Misoperations 2020-2024

Twelve of the 16 misoperations resulted in unnecessary trips without a fault on the system while four involved system faults. The 2024 events did not include any failures to trip or slow trips during faults, which generally are considered higher severity misoperations.

Figure 19 shows failure to trip and slow trip during fault for communication failure misoperations have been a small fraction, usually zero during the 2020 – 2024 period, and never more than two in a single year.

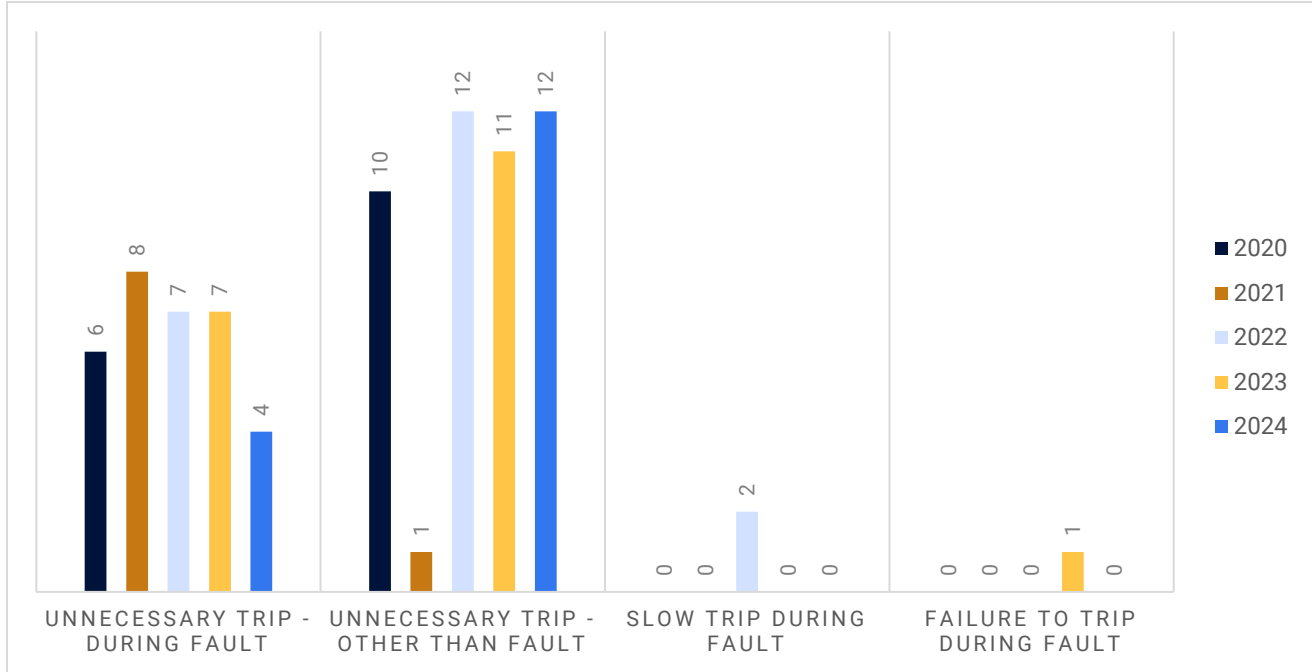


Figure 19: Communication Failure Misoperations by Category 2020–2024

Figure 20 shows the distribution of communication-related misoperations by communication system media type. The initial issue observed when looking at this data is that less than half of the submissions included this detail. The Communication System Type is an optional field in MIDAS, and this information was often not provided. However, the more detailed event descriptions for these events generally indicated that some other component of the communication system caused the misoperation, so that the system media type didn't factor into those events.

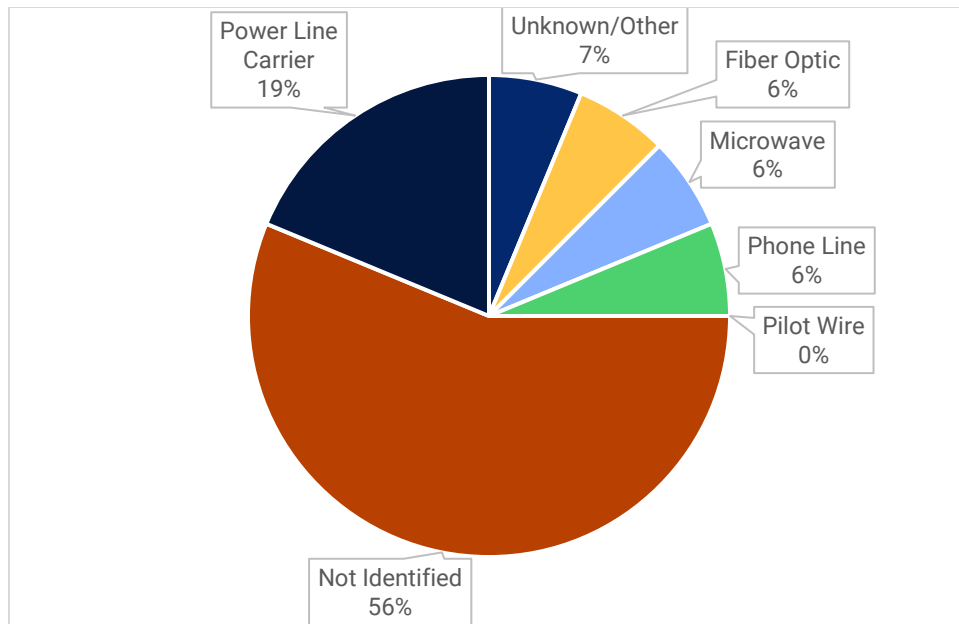


Figure 20: 2024 Communication-Related Protection Misoperations by Communication System Media Type

Communication Failures Misoperation Recommendations:

Entities should consider the following recommended practices:

- Protection engineers should understand the technology being employed in the protection scheme, including the risks of channel asymmetry, and the mitigation methods available to reduce the risk of misoperation.
- A possible solution for noise on a communication channel is to insert a small-time delay to help ride-through noise. Entities must ensure that maximum safe clearing times allow for this delay.
- Entities should complete all fields in the MIDAS 1600 request, allowing the PCS to enhance its analysis. The PCS will encourage NERC to make the Communication System Type field be required, as well as adding fields to capture the protocols and technology used in the communications network (e.g., switched, MPLS, IP, Ethernet, TDM).

Analysis of As-left Personnel Errors

As-left Personnel Errors occur after construction, operations, and maintenance activities once personnel have completed their work, returned equipment to service, and left the job site. Incorrect operations that occur with personnel on site during the work procedures are not counted as misoperations for reporting in the MIDAS system.

Figure 21 shows the five-year trend of misoperations for all As-left Personnel Errors. The overall numbers have been relatively flat, between 9 and 17, with an annual average of 13. These misoperations are a small fraction of the overall system misoperations.

As-left Personnel Errors do not include incorrect relay settings provided to field personnel, wiring Design Errors, and similar causes, which have their own separate cause codes within the MIDAS system.

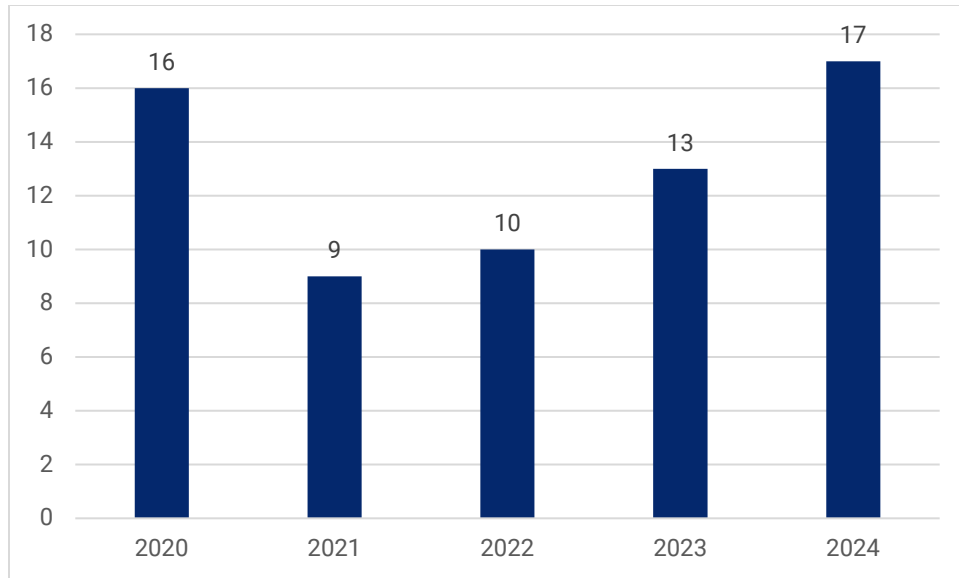


Figure 21: Western Interconnection As-Left Personnel Error Misoperations, 2020–2024

Figure 22 shows the trend for As-left Personnel Errors by voltage class. As with the overall misoperations, events for 100–299 kV facilities tend to dominate the numbers. Low voltage BES (<100 kV) and EHV (300+ kV) mostly include either a single misoperation or none. This correlates with the lower number of these facilities on the system.

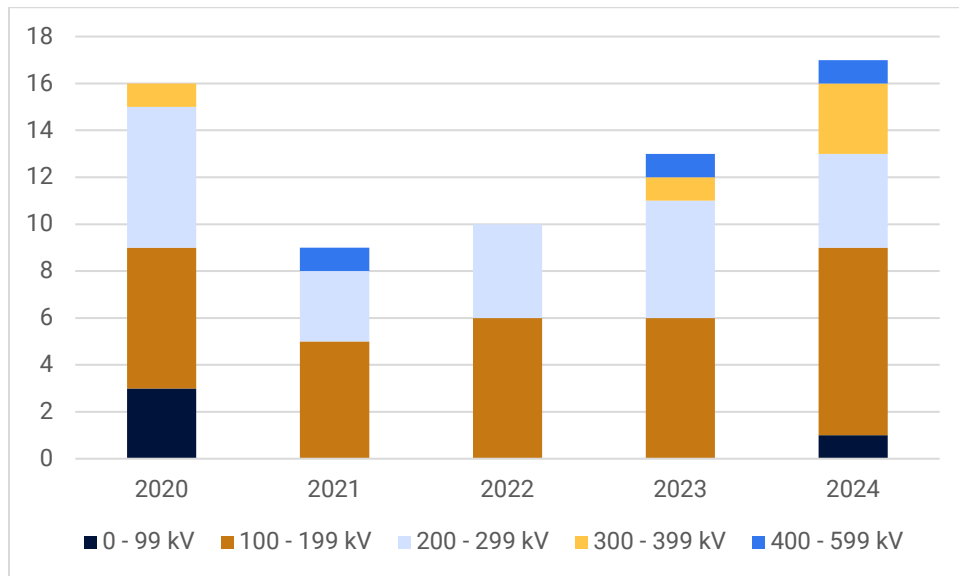


Figure 22: As-Left Personnel Error Misoperations by Voltage Class, 2020–2024

Figure 23 shows the trend for As-left Personnel Errors by tripping category. The 2020–2024 events did not include any Slow Trip during Fault misoperations, so that category does not appear in the figure. Nearly all these misoperations are unnecessary trips, either during or without a fault. Only one failure to trip during fault event occurred during this five-year period.

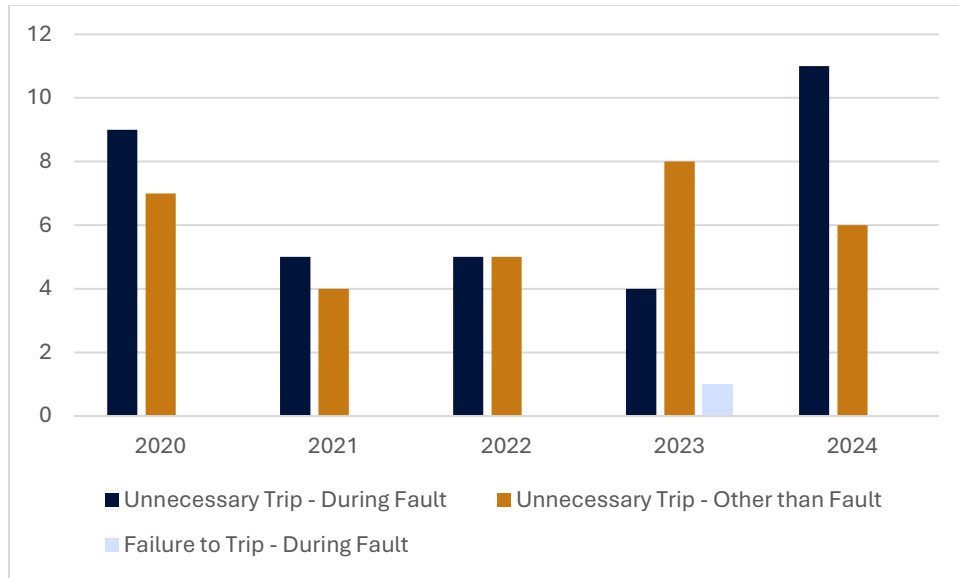


Figure 23: As-Left Personnel Error Misoperations by Tripping Category, 2020–2024

Figure 24 shows the trend for As-left Personnel Errors by cause. These categories, with some common examples, include:

- Left open switches or wiring—test switches incorrectly left open or loose wiring.
- Testing errors—“test” settings left on the relay after test rather than the correct “issued” settings, as-left relay testing calibration.
- Wiring errors—CT ratios, shorted CTs, rolled phases, inverted polarity.
- Switching errors—selector switch left in wrong position.
- Incorrect Settings—error in installing intended “field” settings to the relay.

Wiring errors are the biggest root cause in the As-Left Personnel Errors category every year from 2020 through 2024, always substantially more than the next-largest cause and usually at least half of all events in this category. Several common wiring issues include wrong CT ratios wired, shorted CTs, and rolled phases among CTs. Inverted polarity has occurred with both CT and PT circuits. Testing errors are less common, consistently at two each year until zero in 2024. Leaving the wrong settings on a relay, like testing errors, average two per year.

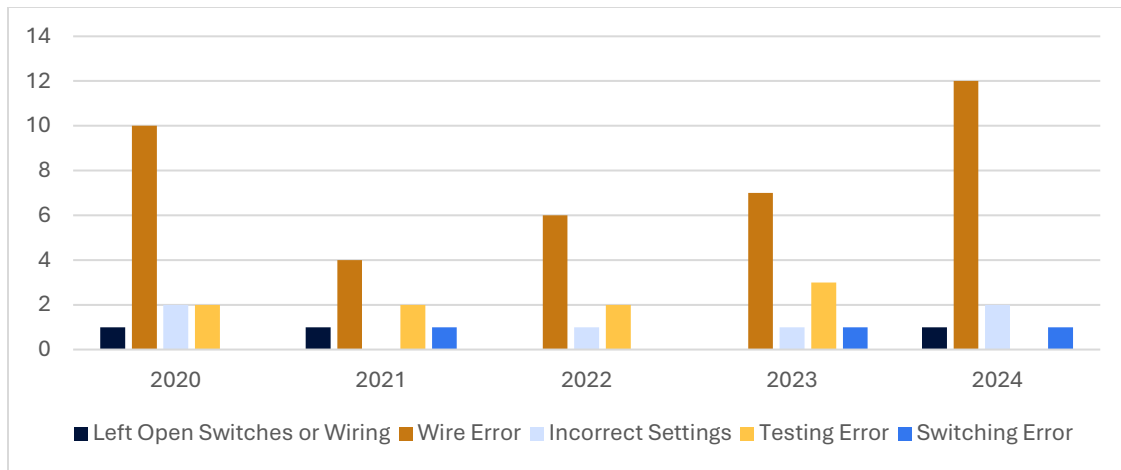


Figure 24: As-Left Personnel Error Misoperations by Cause, 2020–2024

As-left Personnel Errors represent a small fraction of overall misoperations, between 4% and 8% from 2020 to 2024. Nevertheless, wiring errors with CT circuits are the largest contributor to these misoperations, with other causes generally involving only two or fewer events per year. These types of misoperations are preventable and efforts to reduce these types of misoperations should be taken.

As-Left Personnel Error Recommendations

Entities should consider the following recommended practices:

- Perform peer reviews of the CT connections. Two common errors are: wrong CT ratios, and shorting screws improperly left in place. These should be easy to identify because the proper configuration can be confirmed visually even before in-service (load) checks are performed.
 - One form of peer review will use a different person to perform wiring checks than the person who did the original wiring.
- Perform in-service checks to confirm correct CT and PT phasing and polarity. If system conditions make in-service (load) checks difficult or inconclusive, primary injection tests can be helpful. Using the differential command to verify no operating current can be helpful as well.
- Use commissioning checklists. Most of these issues can be successfully addressed using appropriate commissioning checklists, including in-service and primary injection checks, checking for tight connections, tugging on connections, and leaving quality assurance marking at the terminal block.
- Relay technicians should compare as-found and as-left settings after relay maintenance testing to reduce the chances of leaving wrong settings on a relay.
- Settings engineers should review as-left settings from the field and verify that any changes from the issued settings are acceptable.
- Perform test procedures designed to use engineer-issued settings (not requiring temporary “test” settings) to reduce testing and Incorrect Settings errors. When this is not practical or possible, to minimize the chance that “test” settings could be left in place when “issued” settings should be restored, system design could include SCADA, annunciator, or HMI alarms when a “test” setting group is active or a selector switch is in the “test” position. Use design or

operations practices that result in all test switches being closed during normal operation, making it easy to identify improperly open test switches.

- Point-to-point continuity checks can be documented to be completed with acknowledgement on the wiring diagram using a known marking color that represents completion of the task.

Analysis of AC/DC System Misoperations

NERC defines AC system misoperations as “misoperations due to problems in the AC inputs to the Composite Protection System,” including issues such as CT saturation, loss of potential, or damaged wiring in voltage or current circuits. In 2024, there were 17 misoperations attributed to AC System issues—below the five-year average recorded from 2020 to 2024. Overall, the trend in AC-related failures during this period has remained relatively flat, as seen in **Figure 25**.

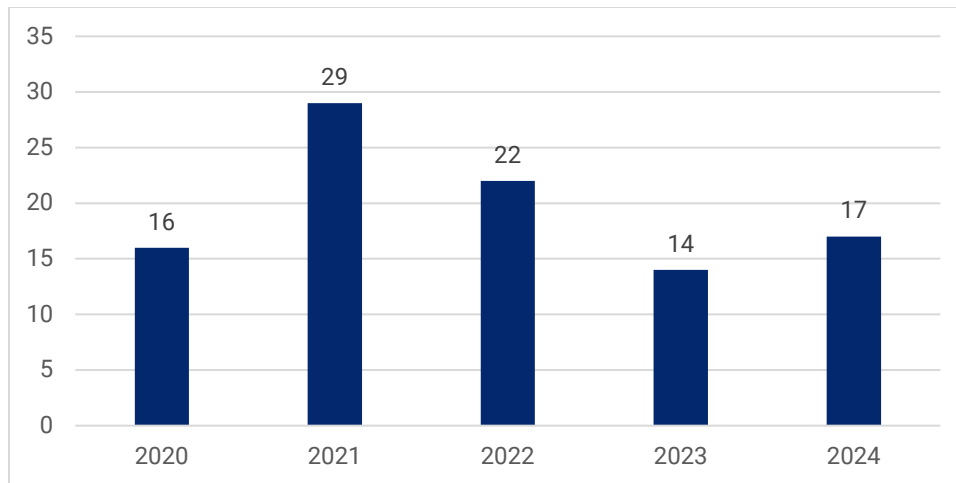


Figure 25: AC Systems Misoperation Totals, 2020–2024

ERC defines DC System misoperations as “misoperations due to problems in the DC control circuits,” which may involve issues with battery or charging systems, trip wiring to breakers, or loss of DC power to relays or communication devices. In 2024, there were seven misoperations attributed to DC System issues—a decrease compared to previous years. The overall trend from 2020 to 2024 has remained relatively flat, with 2024 showing a modest decline in DC-related failures as seen in **Figure 26**.

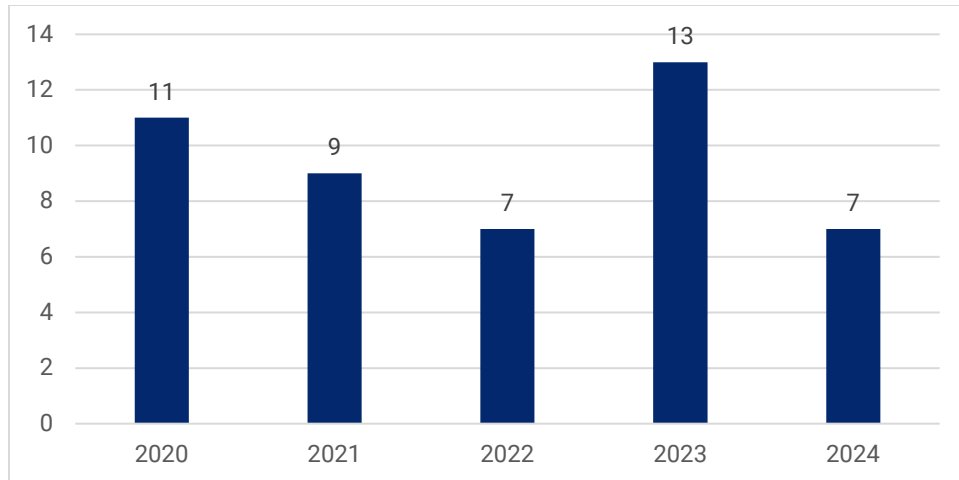


Figure 26: DC Systems Misoperation Totals, 2020–2024

Using the entity’s reported descriptions of the misoperations and the Corrective Action Plans, the PCS broke AC/DC systems into various categories. Like the previous years, the largest source of misoperations in 2024 was wiring/connection issues at 42%, followed by equipment failure at 29%, as seen in **Figure 27**.

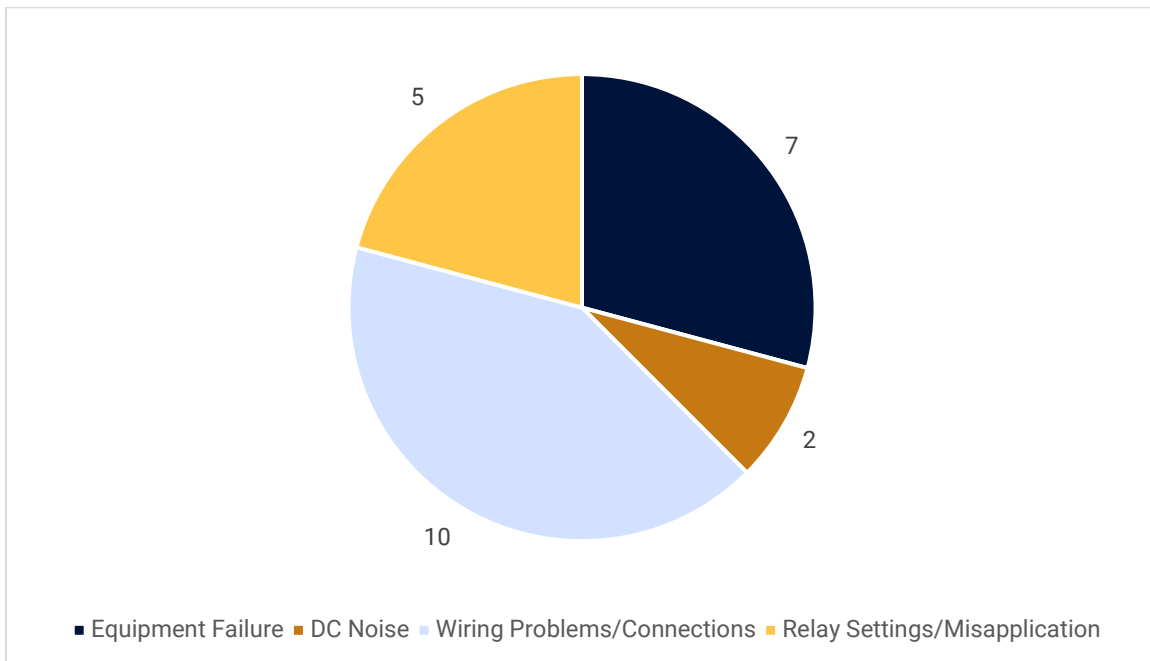


Figure 27: 2024 AC/DC System Misoperations by Failure Mode

These two issues have consistently been the highest contributing failure modes in the 2020–2024 period, as shown in **Figure 28**.

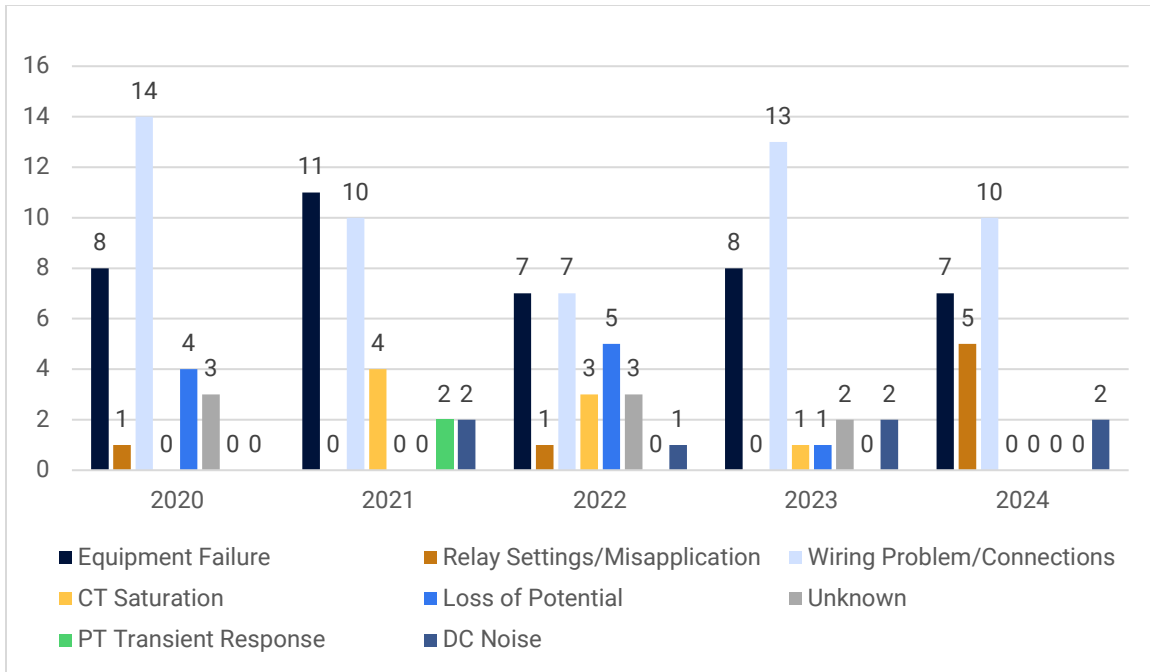


Figure 28: AC/DC Misoperation by Cause, 2020–2024

Many of the wiring and CT/PT connection issues could have been detected during initial commissioning or routine maintenance activities. These types of preventable misoperations highlight clear opportunities for improvement in installation practices, testing protocols, and ongoing system upkeep. Strengthening these processes can help reduce misoperations in the Western Interconnection

AC/DC System Misoperation Recommendations:

To enhance reliability and minimize preventable misoperations, entities should consider implementing the following best practices:

- Ensure maintenance and commissioning practices include burden and continuity checks of wiring, along with thorough visual inspections of equipment.
- Perform proper insulation tests during commissioning to proactively identify potential issues that may compromise system integrity.
- Integrate redundancy into AC and DC system designs to mitigate single points of failure and reduce the likelihood of failure-to-trip misoperations.
- Require in-service checks as part of the commissioning process to confirm current and voltage signals are as expected at the relay.
- Use industry guidance such as the IEEE PSRC Working Group I-25 document, [Commissioning Testing of Protection Systems](#), to inform and improve commissioning practices.

Analysis of Other/Explainable Misoperations

Figure 29 below demonstrates a rise in the number of Other/Explainable misoperations from 2023 to 2024. However, overall, there has been a decreasing trend since 2021, from 27 events to nine events, roughly a 67% decrease in three years.

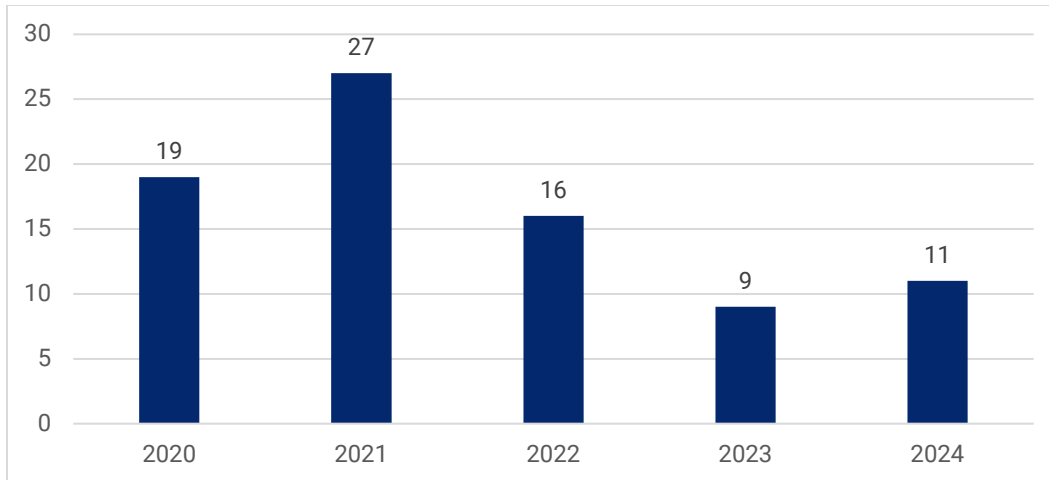


Figure 29: Other/Explainable Misoperations, 2020–2024

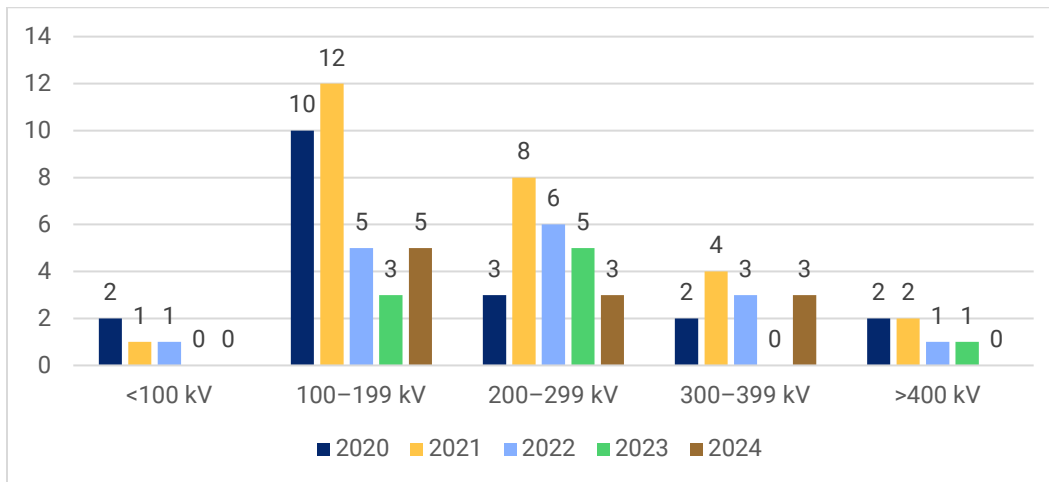


Figure 30: Other/Explainable Misoperations by Voltage Class, 2020–2024

Figure 30 shows the breakdown of the 2020-2024 Other/Explainable misoperations by voltage class. All 2024 Other/Explainable misoperations occurred on systems greater than 100 kV and less than 400 kV, with the 11 events for 2024, seen mainly in the 100 kv–199 kV system. This is a unique category, as the 11 misoperations reported for this cause vary greatly. These are uncommon types of misoperations for which the cause has been identified, but the types do not fit the criteria of the other misoperation categories. Two of these events were on the same equipment for the same cause within a few days. Since the causes of these misoperations tend to be unique, there are no conclusions or recommendations made for this section.

Analysis of Unknown/Unexplainable Misoperations

In 2024 there were 12 events reported with the Unknown/Unexplainable cause category. The Unknown/Unexplainable cause category is used when no clear cause can be determined. After extensive investigation, the submitting entity may select this cause when no other option is suitable or the operation is still under investigation. If reporting Unknown/Unexplainable as the cause due to an

ongoing investigation, the category should be updated in MIDAS at the conclusion of the investigation if a cause is found.

In 2024, Unknown/Unexplainable misoperations represented 5.61% of all reported misoperations. In comparison, the 2020, 2021, 2022, and 2023 data represented 8.8%, 8.4%, 9.1%, and 8.16% respectively, of all reported misoperations.

When the reason for a Misoperation is unknown, effective corrective actions cannot be taken to prevent another Misoperation from occurring at that terminal, nor can knowledge be gained that would allow the prevention of a similar Misoperation from occurring at other locations. Therefore, it is desirable to reduce the number of misoperations that cannot be explained and are categorized as Unknown/Unexplainable.

Figure 31 shows the total number of misoperations reported as Unknown/Unexplainable for each year from 2020 through 2024. The bar chart below shows that misoperations reported under this cause are trending downward overall.

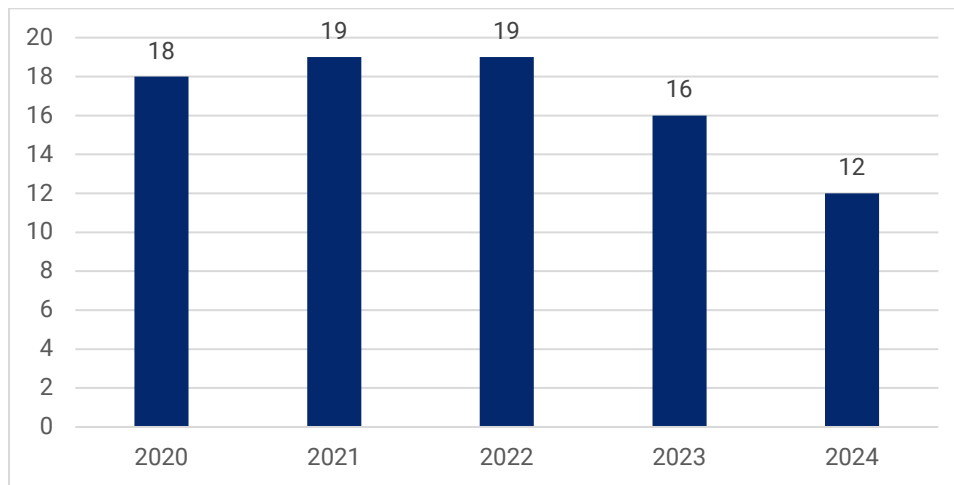


Figure 31: Misoperations for Unknown/Unexplainable, 2020–2024

Misoperations reported as Unknown/Unexplainable were further categorized by relay type, voltage class and Misoperation category to understand the effect on the Western Interconnection.

While the PCS does not have access to a complete inventory of BES relays in service in the Western Interconnection, it is expected that electromechanical and solid-state relays represent a small fraction of the installed fleet. Due to no event recording capability of electromechanical and limited event records for solid state relays, there is a higher probability of an unknown Misoperation occurring with these technologies. We recommend that entities install digital fault recorders (DFR) in locations with a high number of electromechanical relays to assist in event investigations.

In 2024, the percentage of Unknown/Unexplainable misoperations associated with each of the relay types continued toward a higher percentage of microprocessor technology, as shown in **Figure 32**. The higher percentage could suggest the larger installed fleet of microprocessor relays naturally results in a higher percentage of overall misoperations; or, as entities upgrade or replace older technologies, microprocessor relays may be sensitive to issues that older relays were not.

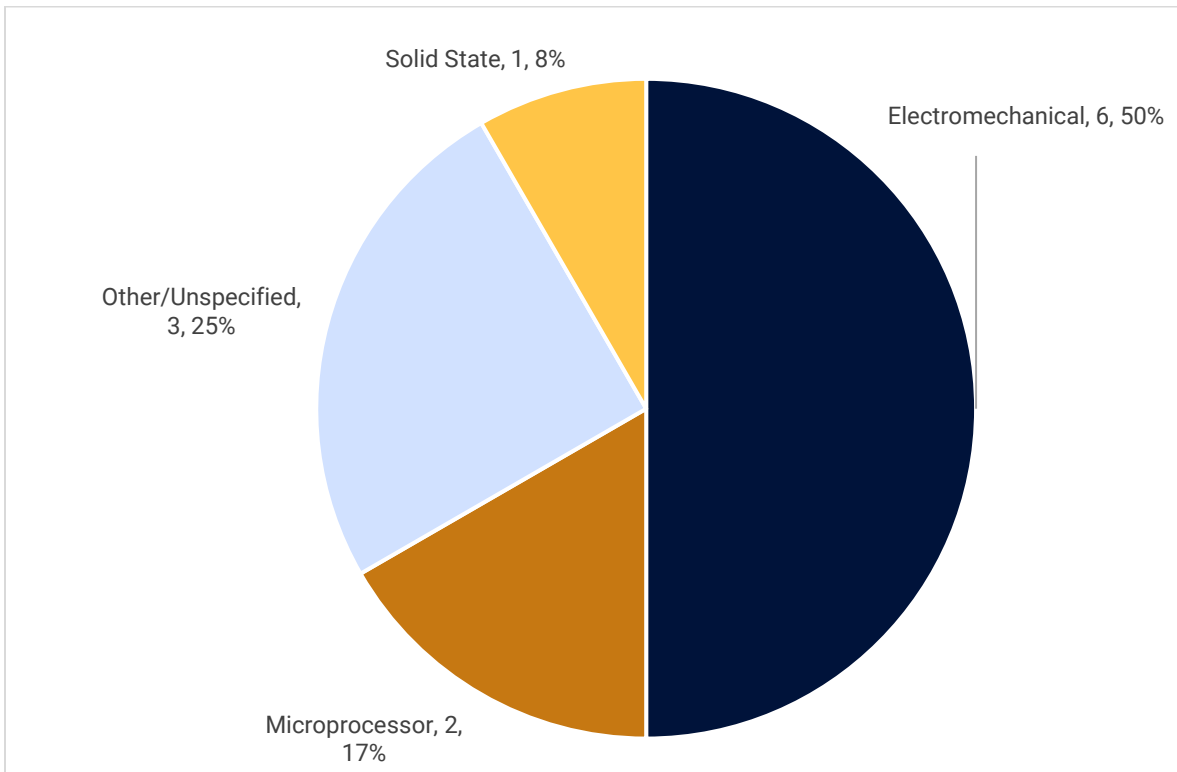


Figure 32: 2024 Misoperations for Unknown/Unexplainable by Relay Type

When voltage class is considered, there are fewer Unknown/Unexplainable misoperations on the 300 kV and higher voltage levels, as shown in **Figure 33**. This is most likely due to the higher number of microprocessor-based schemes that provide more diagnostic and event capture data.

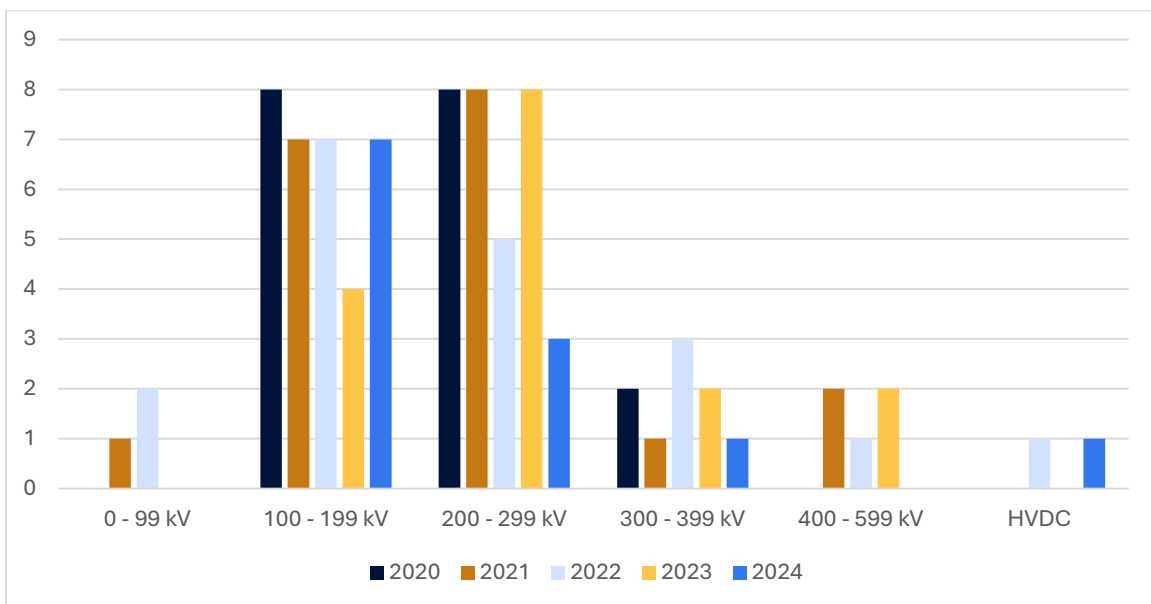


Figure 33: Misoperations for Unknown/Unexplainable by Voltage Class, 2020–2024

Most misoperations reported as Unknown/Unexplainable fell within the “Unnecessary trip—other than fault” category, as **Figure 34** shows. An “Unnecessary trip—other than fault” can be more difficult to diagnose. The difficulty is such that during conditions of no fault, relay events may not be triggered and are not available to assist in the analysis. Adding triggering on breaker operations for DFRs, relay events, and SER may help to better identify non-fault-based misoperations.

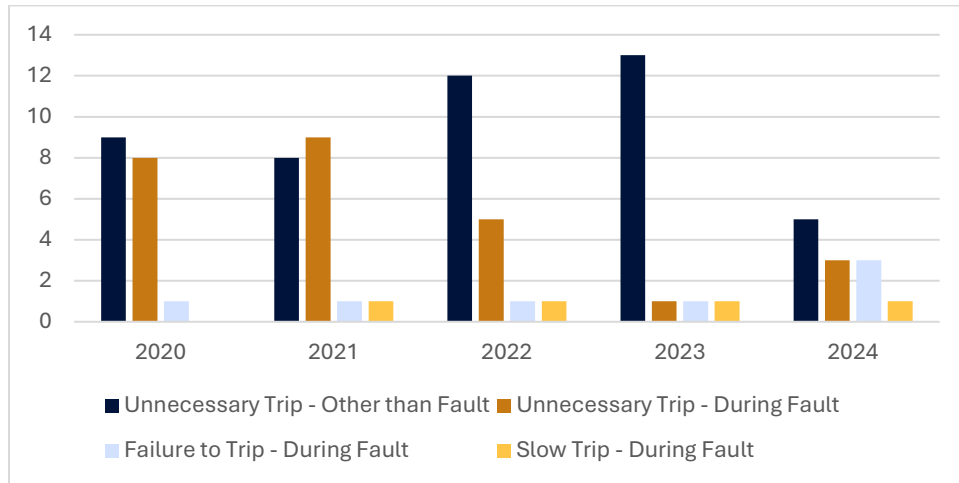


Figure 34: 2020-2024 Unknown/Unexplainable Misoperations by Category

The number of misoperations reported as Unknown/Unexplainable remains low and gradually decreasing for the five-year trend and is now no longer one of the top three leading Misoperation causes in the Western Interconnection.

Many of the unknown causes continue to have Corrective Action Plans that involve testing the system, monitoring, working with the manufacturer, or replacing with microprocessor relays. The analysis in progress shows that entities are committed to finding root causes. Reporting to the NERC Section 1600 has improved, as entities now update the progress of investigations and include investigation actions being taken to determine misoperations.

Misoperation Unknown/Unexplainable Recommendations

Entities should consider the following recommended practices:

- Install DFRs at locations with elements protected by electromechanical relays. These recorders can provide valuable data for future operations for relays that do not give event records.
- Provide a time source to microprocessor relays to facilitate alignment of event reports from relays and DFRs.
- Ensure MIDAS submissions that are reported as Unknown/Unexplainable are updated if the cause of the misoperation is identified after the original submission.
- Make all reasonable efforts to identify the cause of a misoperation. This allows a Corrective Action Plan to be developed to prevent future occurrences.

As an Unknown/Unexplainable instance is resolved, and a cause is determined, the entity should resubmit to update the correct cause category of the Misoperation in MIDAS.

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