MIDWEST RELIABILITY ORGANIZATION

PROTECTION SYSTEM COMMISSIONING WEBINAR

MRO PROTECTIVE RELAY SUBGROUP

July 14, 2022

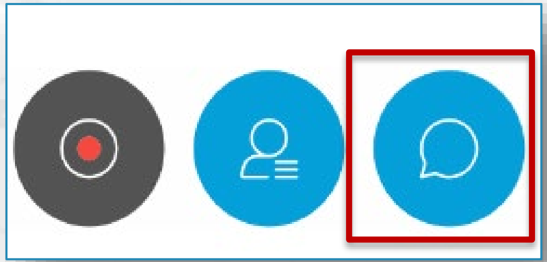
10:00 a.m. – 11:30 a.m. Central

Max Desruisseaux

Senior Power Systems Engineer
Reliability Analysis
Midwest Reliability Organization

WebEx Chat Feature

Open the Chat Feature:



The chat feature will appear to the right of the WebEx window.

Attendees should chat their questions to: “MRO Host”.

Select MRO Host by using the drop down arrow in the “To” field.

Purpose

- Misoperations Due to Errors Occurring During Commissioning is a Medium Risk in the MRO reliability risk matrix.
- Provide information on and raise awareness of the Joint Review of Protection System Commissioning Programs report.
- Highlight some of the work being done by entities and the PRS.
- Discuss Performance Data

Discussion Topics

- Overview of Protection System Commissioning Report
- Best Practices
- Case Studies
- PRS Misoperations Phase II Report
- Event Analysis Data
- MIDAS Data

Gilbert Lowe III, P.E.

Electrical Engineer

Office of Electric Reliability
Federal Energy Regulatory Commission

Protection System Commissioning Program Review Project

Efforts to Reduce Misops From Inadequate PSC

- 2015-2021 NERC Issued Lessons Learned
- 2017 IEEE WG I-25 guide Commissioning Testing of Protection Systems
- 2019 Analysis of MIDAS finding 18-36% of Misops could have been prevented better PSC

PSC Review Project Process

- Eight registered entities and one PSC contractor.
- Selected based on geographical locations and performance data such as events and Misop rates.
- Surveys and Interviews on participants' PSC programs and Procedures.
- Used the IEEE WG I-25 guide as a benchmark.
- Team discussed and agreed upon the best practices, opportunities for improvement, and related recommendations.

PSC Programs Key Elements

- Stated goals and objectives
- Well-defined plans to perform commissioning
- Clearly identified lines of responsibility
- Authority given to responsible parties
- Feedback methods for improvements

PSC Program Recommendations

- All entities should document a formal PSC program. Having a formal, documented program in a central location (e.g., a single document) allows easy reference to all 5 elements of the PSC program.
- Have well-documented training requirements of classroom and on-the-job training coupled with some type of proficiency assessment to ensure well-qualified commission testing personnel.
- Entities should use internal controls to find, track and correct issues in their PSC programs. Entities should implement controls to ensure that lessons learned are documented and fed back into future project design and commissioning processes.
- Entities should separate the commissioning agent from the design and installation processes.

PSC Program Best Practices

- Designated senior management from different departments to share responsibility for program approval. Senior management involvement is likely to draw attention to and support commission testing programs.
- Multi-layer contractor selection process that vetted the contractor's firm then its employees assigned to project followed by frequent meetings with the contractor to review work performance
- Intranet access to lessons learned in standardized form that is reviewed during scoping of new projects and shared with industry groups

PSC Procedure Core Elements

- Planning and sequencing
- Print and technical review
- Preparing installed equipment for modification
- Equipment and device acceptance testing
- Equipment isolation
- Functional testing
- Operational (or in-service load) checks
- Documentation

PSC Procedure Recommendation

- Ensure PSC team (including contractors) performs independent design review prior to the start of construction
- Maintain a documented isolation log in a standardized format that includes the repositioning of test switches, temporary jumpers, and shorting blocks; who made the changes; time and date of the change; and when the equipment was returned to normal.
- CT circuit errors represent a significant portion of misops primarily due to incorrect CT ratios, polarity, and left in shorted position.
- All Entities should perform current testing on all phases to ground, phase-to-phase, and 3-phase faults. This will ensure that CT ratios, CT and polarity, and polarization of ground elements is correct for all fault scenarios.

PSC Procedure Best Practices

- PSC procedures included back-to-back testing on tie lines, unfamiliar relay models, configurations, and/or firmware editions.
- Engineering package identified all equipment that needed isolated or shorted ensuring adequate in-service protection
- Peer review process to assess test results and avoid possible bias.
- Maintain an isolation log and tagged the circuits at the point of isolation for equipment isolation.

Sarah Marshall

Team Lead

System Protection

Alliant Energy

Alliant Energy’s Commissioning Best Practices

How to Keep Bugs Out of the Ointment

Sarah Marshall – Team Lead System Protection, Alliant Energy

Alliant Energy®

Pillars for Success

STANDARDS

COMMISSIONING CHECKLISTS

HUMAN PERFORMANCE TOOLS

System Protection Standards Committee

All template changes reviewed quarterly for approval.

Review team: engineers, operations, management.

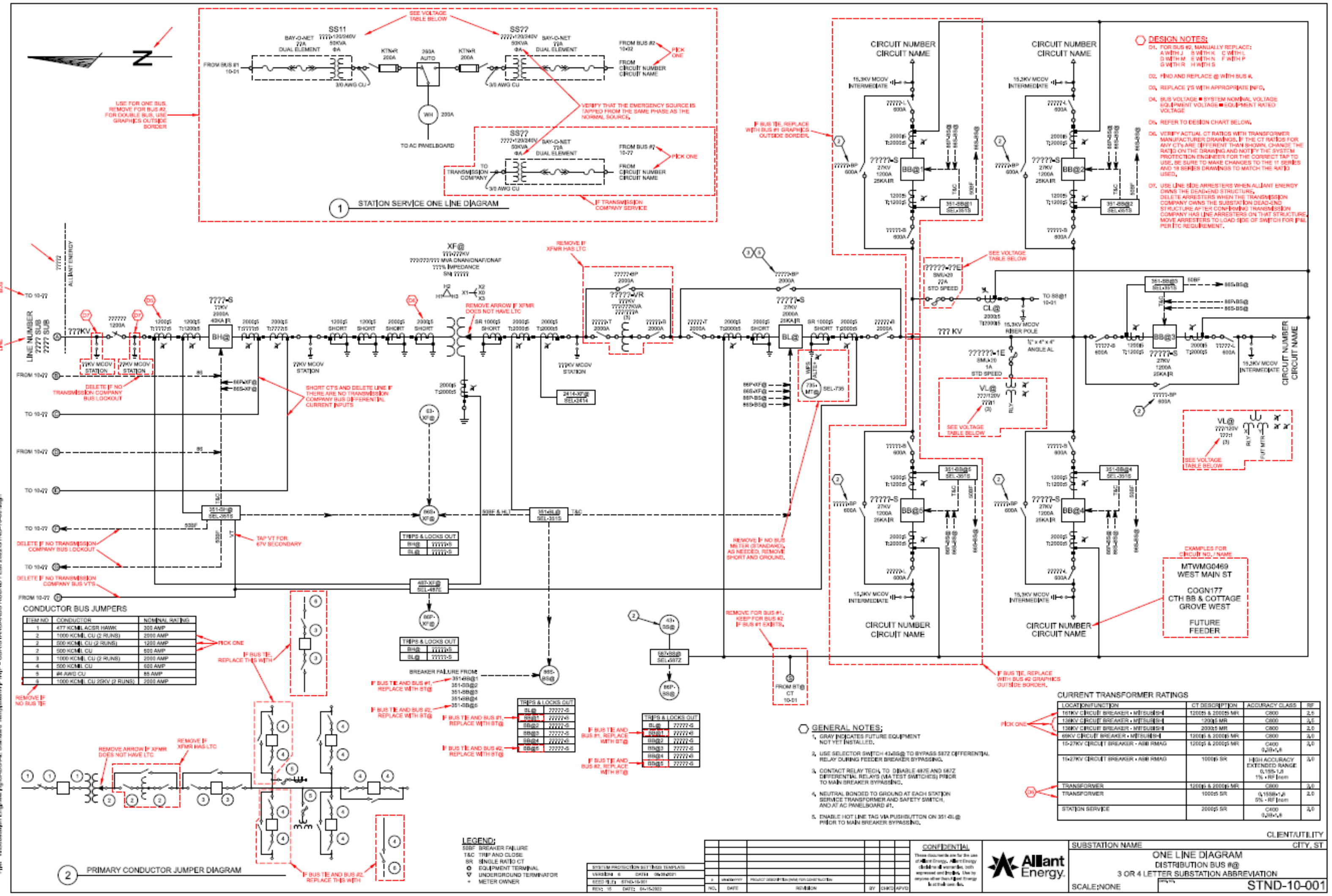
Limits the frequency of major design changes to 1-2 times per year.

- Hardware changes
- New protection schemes
- Operational changes impacting the design

Minor changes are permitted as needed at any time.

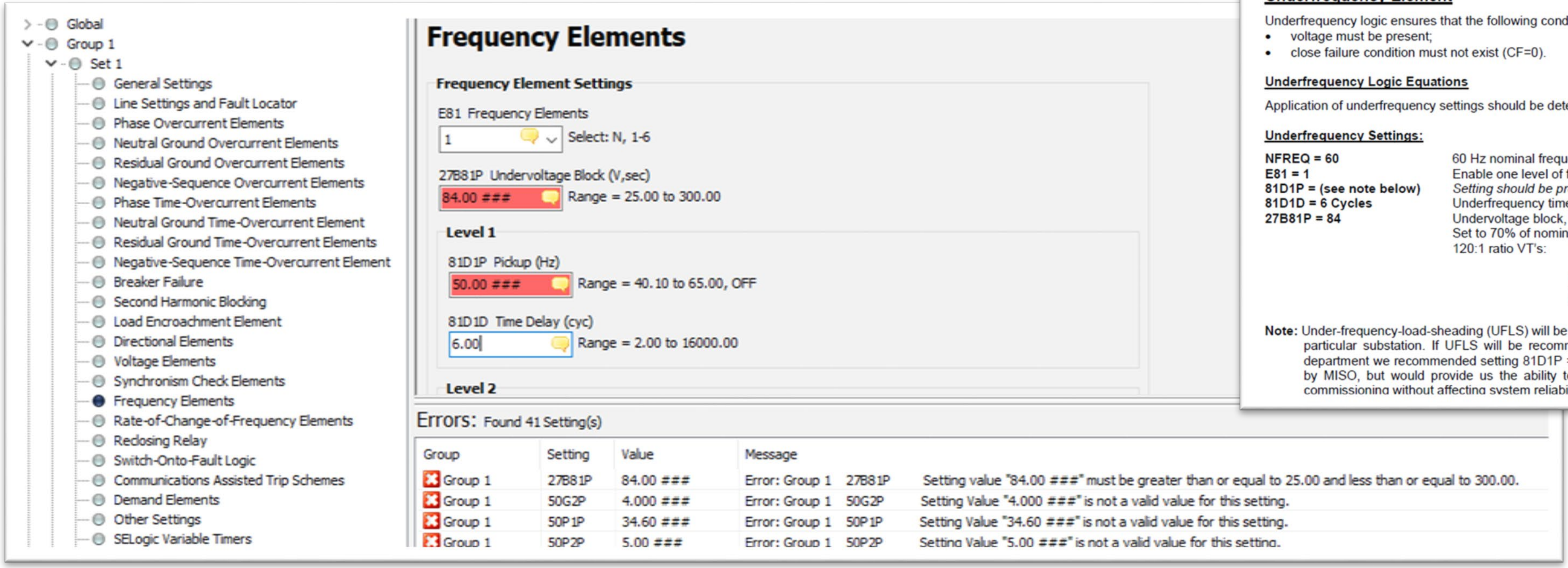
- Firmware version changes
- Correcting design errors

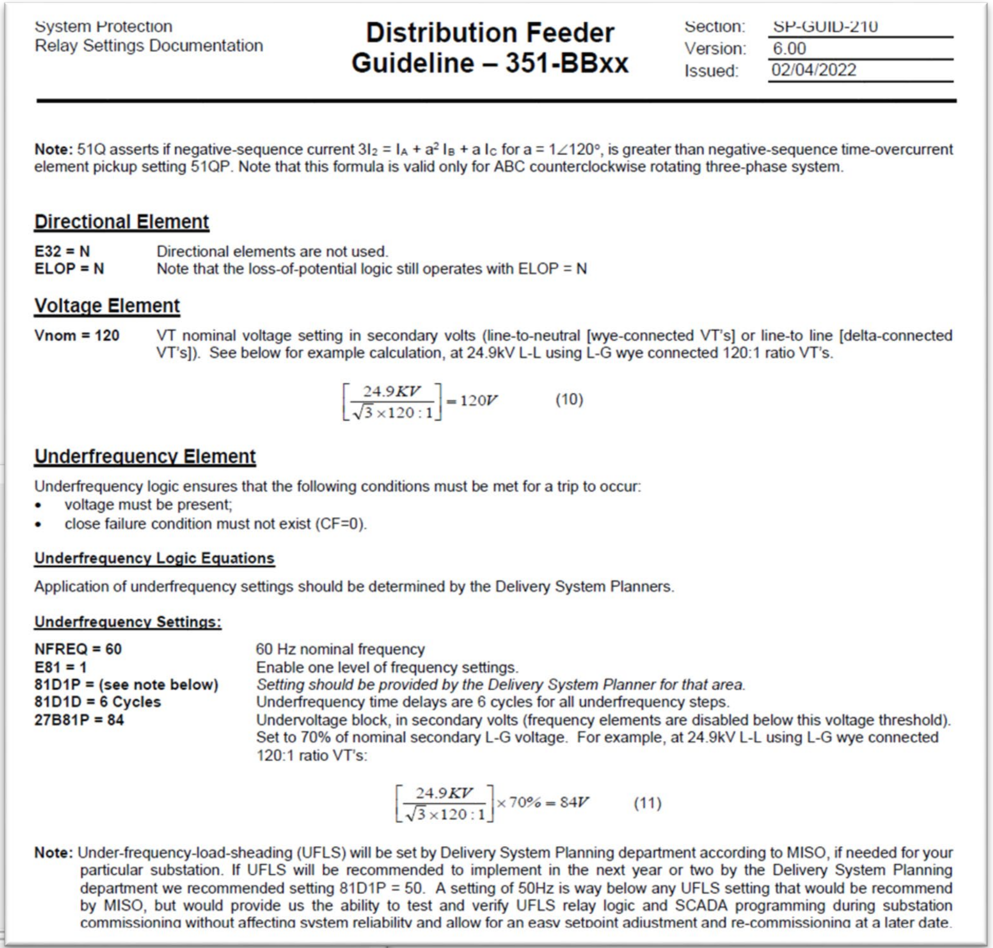
Substation Drawing Template



Relay Settings Template

Relay Setpoints File





System Protection
Relay Settings Documentation

Distribution Feeder Guideline – 351-BBxx

Section: SP-GUID-210
Version: 6.00
Issued: 02/04/2022

Note: 51Q asserts if negative-sequence current $3I_2 = I_A + a^2 I_B + a I_C$ for $a = 1\angle 120°$, is greater than negative-sequence time-overcurrent element pickup setting 51QP. Note that this formula is valid only for ABC counterclockwise rotating three-phase system.

Directional Element

E32 = N Directional elements are not used.
ELOP = N Note that the loss-of-potential logic still operates with ELOP = N

Voltage Element

Vnom = 120 VT nominal voltage setting in secondary volts (line-to-neutral [wye-connected VT's] or line-to line [delta-connected VT's]). See below for example calculation, at 24.9kV L-L using L-G wye connected 120:1 ratio VT's.

$$\left[\frac{24.9KV}{\sqrt{3}\times 120:1}\right] = 120V \qquad (10)$$

Underfrequency Element

Underfrequency logic ensures that the following conditions must be met for a trip to occur:
- voltage must be present;
- close failure condition must not exist (CF=0).

Underfrequency Logic Equations

Application of underfrequency settings should be determined by the Delivery System Planners.

Underfrequency Settings:

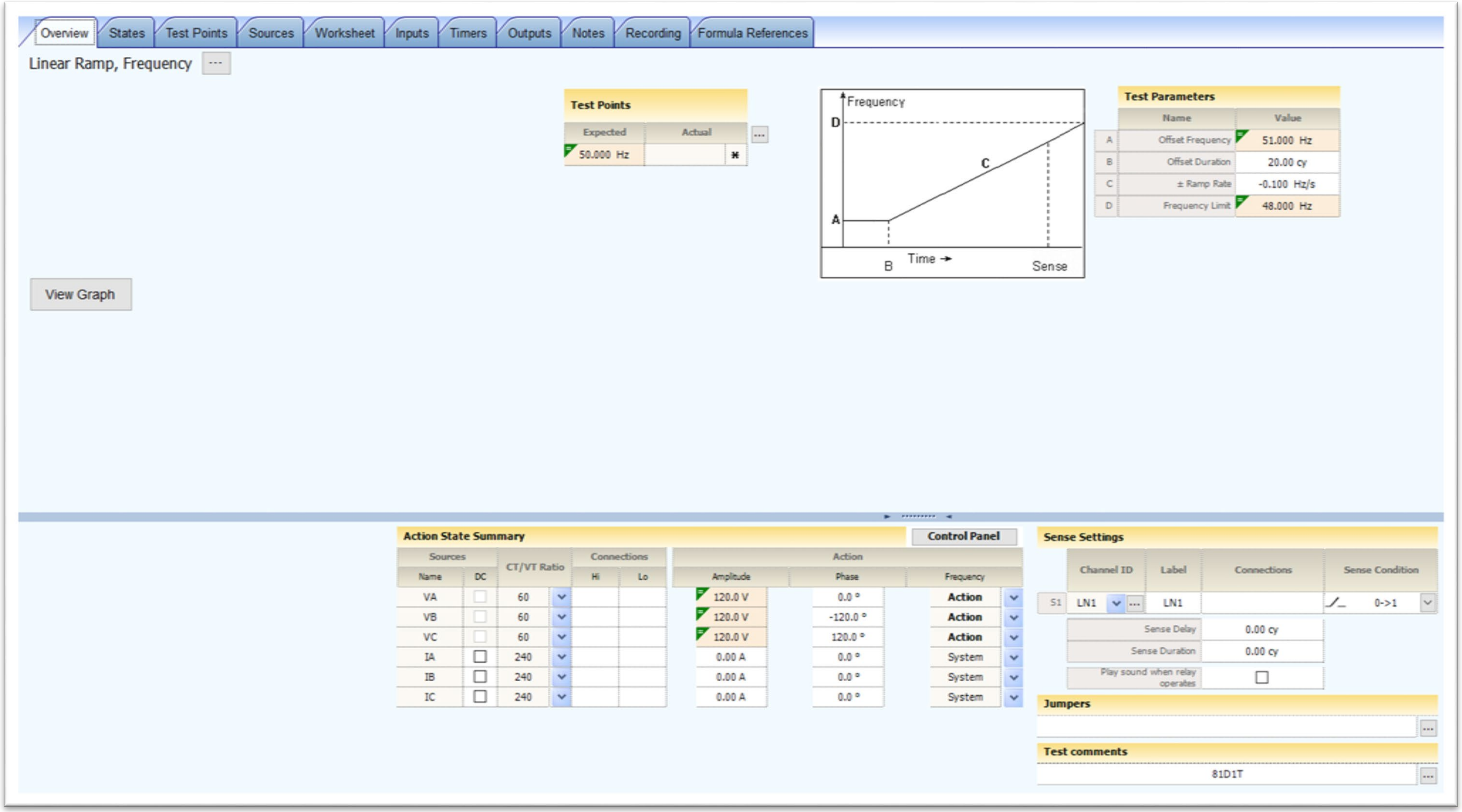
NFREQ = 60 60 Hz nominal frequency
E81 = 1 Enable one level of frequency settings.
81D1P = (see note below) *Setting should be provided by the Delivery System Planner for that area.*
81D1D = 6 Cycles Underfrequency time delays are 6 cycles for all underfrequency steps.
27B81P = 84 Undervoltage block, in secondary volts (frequency elements are disabled below this voltage threshold). Set to 70% of nominal secondary L-G voltage. For example, at 24.9kV L-L using L-G wye connected 120:1 ratio VT's:

$$\left[\frac{24.9KV}{\sqrt{3}\times 120:1}\right]\times 70\% = 84V \qquad (11)$$

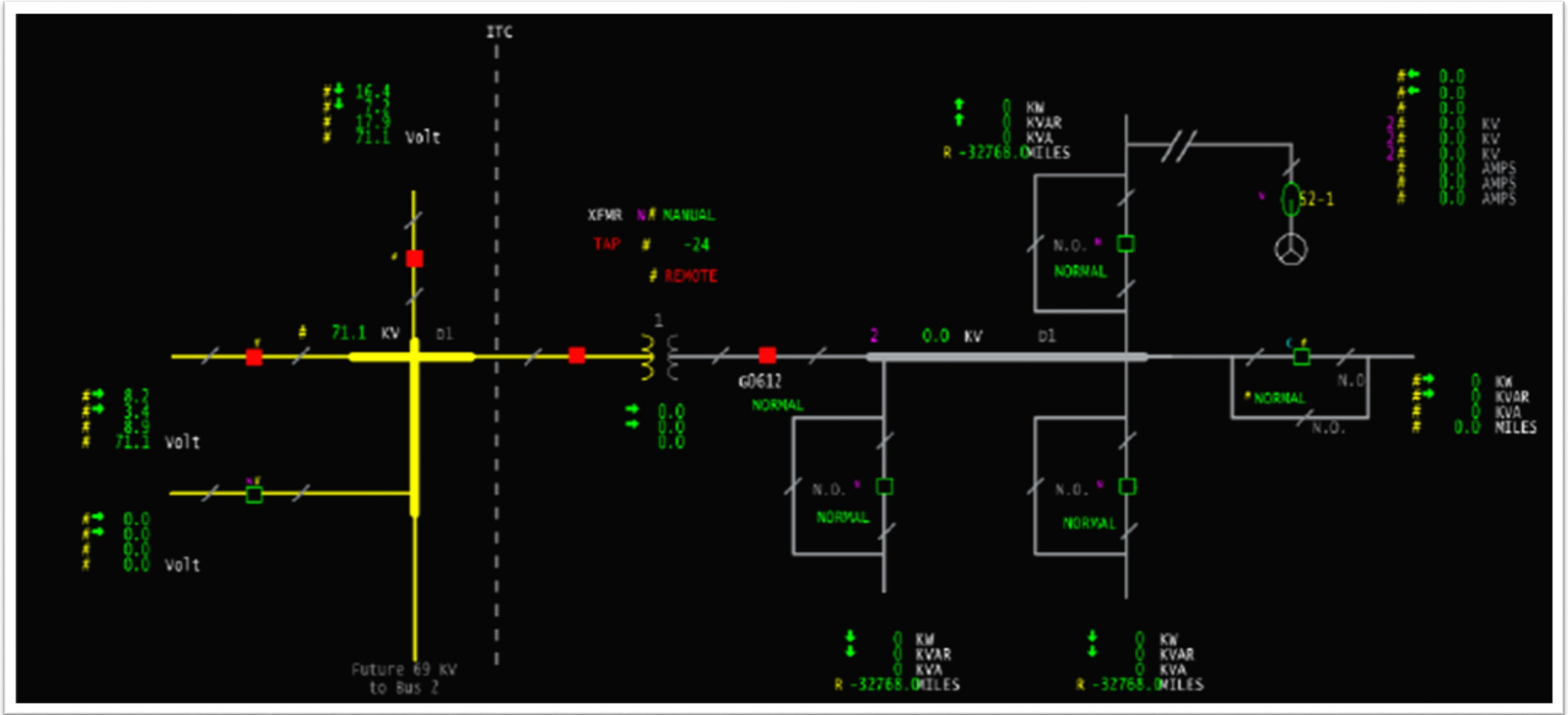
Note: Under-frequency-load-sheading (UFLS) will be set by Delivery System Planning department according to MISO, if needed for your particular substation. If UFLS will be recommended to implement in the next year or two by the Delivery System Planning department we recommended setting 81D1P = 50. A setting of 50Hz is way below any UFLS setting that would be recommend by MISO, but would provide us the ability to test and verify UFLS relay logic and SCADA programming during substation commissioning without affecting system reliability and allow for an easy setpoint adjustment and re-commissioning at a later date.

Relay Settings Guide

Commissioning Template



Trip at Substation



Commissioning Checklist

Substation Commissioning Review Checklist V3

Conduct Review 1 to 4 weeks after Checkout is Complete

Project:

Project Checkout Date:

Review Completion Date:

Review Completed With (Personnel):

		Comment
☐	**Is Corporate Project Folder Set Up Correctly (Use Template)**	
☐	**Commissioning Checklist**	
	Completed and saved to corporate project folder	
☐	**Protective Relays**	
	As-Left settings - System Protection Engineering notified to remotely access relays and save settings to corporate database	
	Protection Suite commissioning file saved to corporate project folder	
	Protection Suite maintenance test plan complete	
	For UFLS implemented relays confirm UF pickup and time delay were tested and Cascade has correct values entered	
☐	**Instrument Transformers**	
	Test results saved to corporate project folder?	

Commissioning Task List

Group	Task	Task	Task	Task	Task	Task	Task	Task	Task	Task	Task	Task	Task	Task	Task
System Tech			As checkout date gets closer touch base with DSOW SCADA team to confirm checkout time/date		Ensure all pre-checkout Commissioning Checklist tasks are completed and perform 'local' checkout with OSI verification	Perform Checkout	Energize Transformer and verify LTC operation(typically completed day following checkout)	Notify DSOW SCADA Team, assigned Substation Protection Engineer and Sub Tech Support Manager/Foreman that transformer has been energized		Verify differential relaying values, relay metering and metering values in OSI are correct when sufficient load is added	Contact System Protection Engineer to have them remotely access and save the 'final' relay settings to Alliant's corporate drive	Complete field markups of as-built electrical/communications drawings, sign first page and submit to Substation Engineer	Complete Project Commissioning Checklist	Perform Project Review - Complete Substation Commissioning Review Checklist	Receive final As-Built drawings from drafting, review for accuracy against field marked up copy and replace field marked up copy in substation
Telecom Tech					Ensure all pre-checkout Commissioning Checklist tasks are completed and perform 'local' checkout with OSI verification	Perform Checkout						Complete field markups of as-built electrical/communications drawings, sign first page and submit to Substation Engineer	Complete Project Commissioning Checklist	Perform Project Review - Complete Substation Commissioning Review Checklist	For communications only projects - Receive final As-Built drawings from drafting, review for accuracy against field marked up copy and replace field marked up copy in substation
System Protection Engineering		Provide relay and SCADA programming information to technicians 2 weeks prior to System Technician	Minimum 2 weeks prior to scheduled checkout date submit SCADA information to DSOW SCADA Team. Build				Verify voltages and check relays and remote access to relays			Review site in OSI to ensure one line, metering, alarming, etc. are accurate	Save final relay/SCADA files to corporate drive(relay settings files, LTC Controller, 2414s, RTU, etc)				
DSOW SCADA Team(Bev & Martin)				Refer to Sub Tech Support work schedule for site checkout dates		Perform Checkout		Move site in OSI from Under Construction to Actively Monitor. Change site font color to white unless site has special consideration(2nd phase to complete, etc.). Ensure all alarm inhibits							
Sub Tech Support Foreman or Manager	Set date in work schedule for checkout								Send email to DSOW manager and supervisor, Substation Maintenance manager, DSOW SCADA team, System Protection Engineer and Substation Engineer notifying them that site is in service and DSOW has monitoring/control responsibility.					Lead Project Review - Complete Substation Commissioning Review Checklist	

Alliant Energy

Human Performance Tools

Pre-Job Briefing	Self-Check	3-Way Communication
Barriers	Flagging	Equipment Isolation List

Rely on the process.

Find a framework, then use it.

Ryan Einer, PE

Manager

Operations Support

Oklahoma Gas And Electric Co.

Case Studies: The Impact of Commissioning on Recent Misoperations

Ryan Einer, PE – Manager Operations Support

OG+E®

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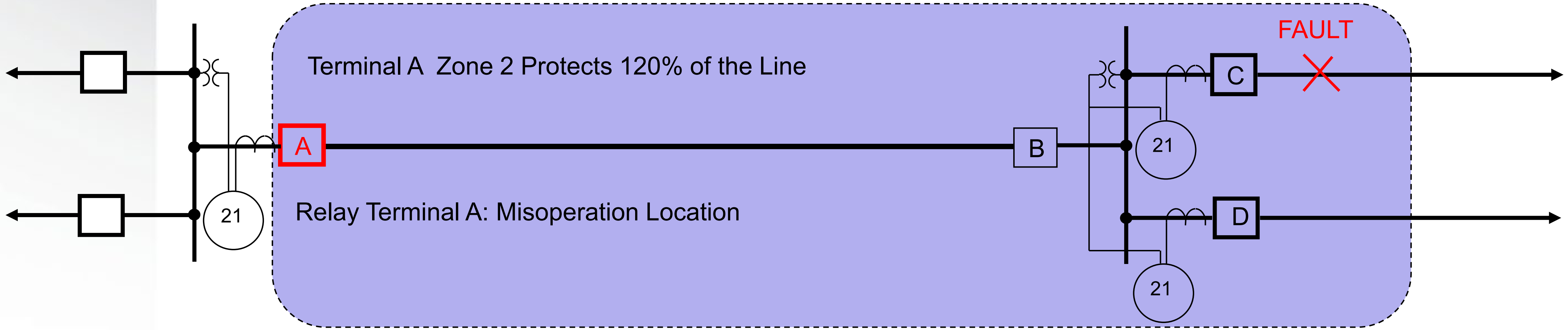
Protection System Commissioning

We Energize Life

DCB Carrier Misoperation



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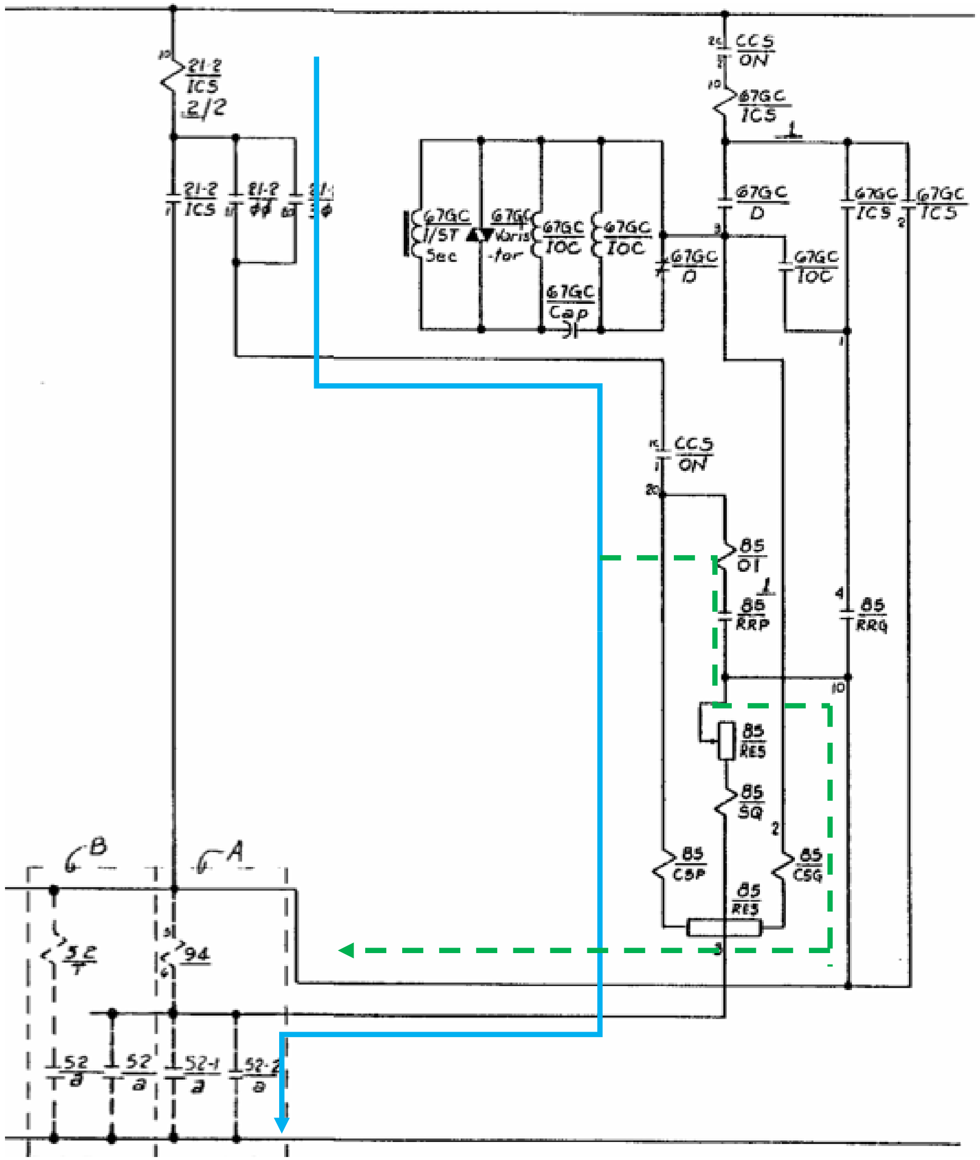
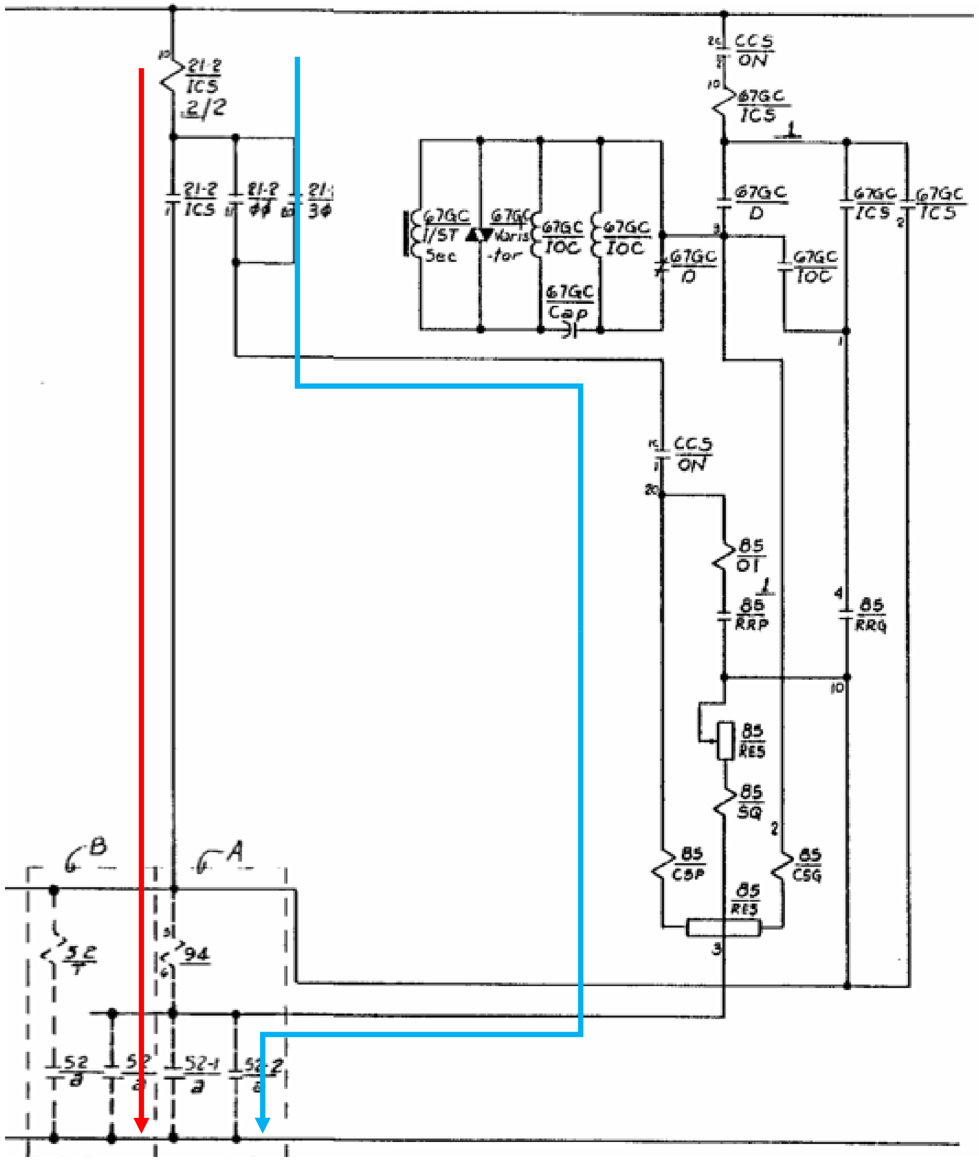
DCB Carrier Misoperation



We Energize Life

DCB Carrier Misoperation



Protection System Commissioning Program

- No job is too small to establish well-defined plans to perform commissioning
- Establish a feedback method for improvements

Protection System Commissioning Process

- Functional testing of the protection system with effective component testing.
- Utilize a consistent and complete PSC test checklist that identifies specific tasks in the commissioning procedure

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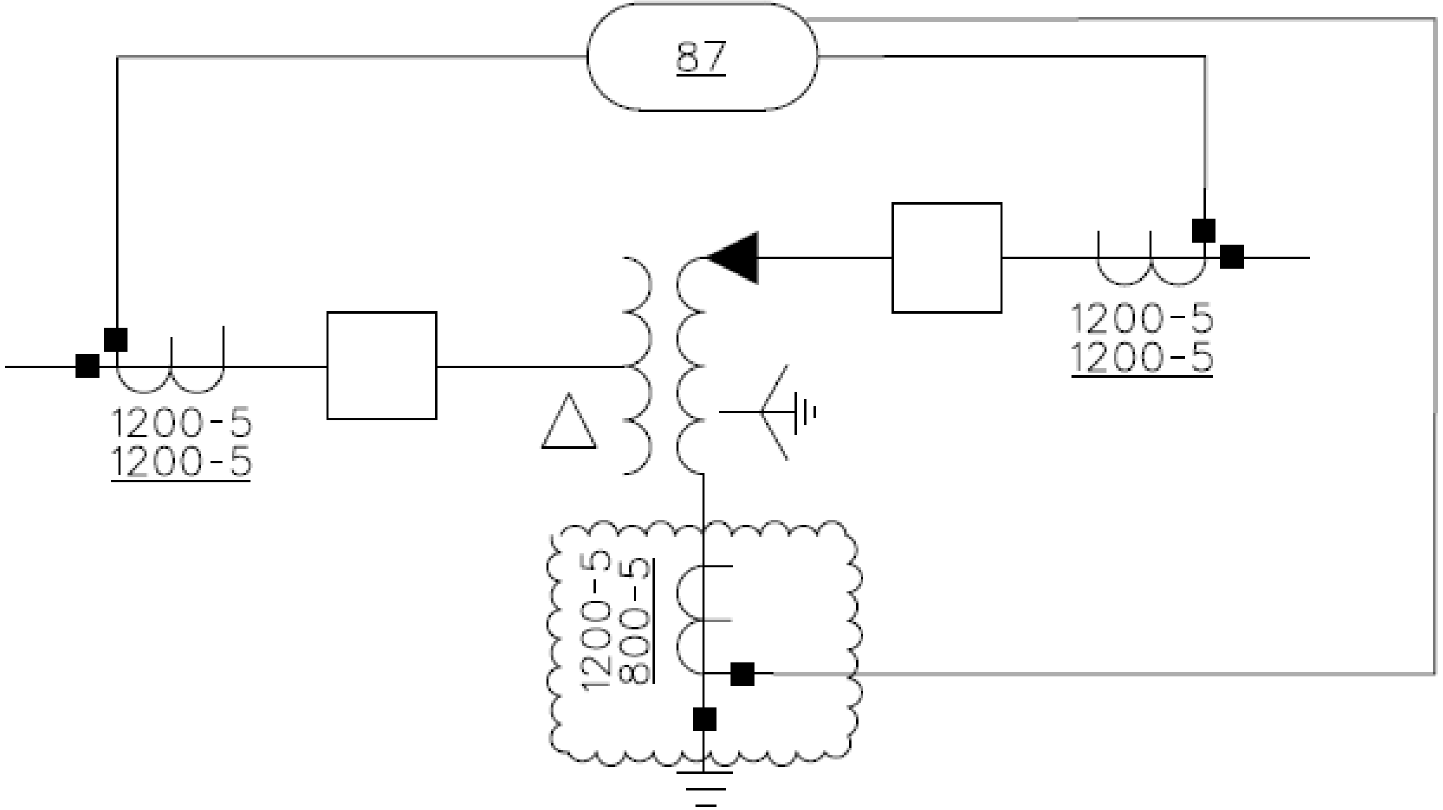
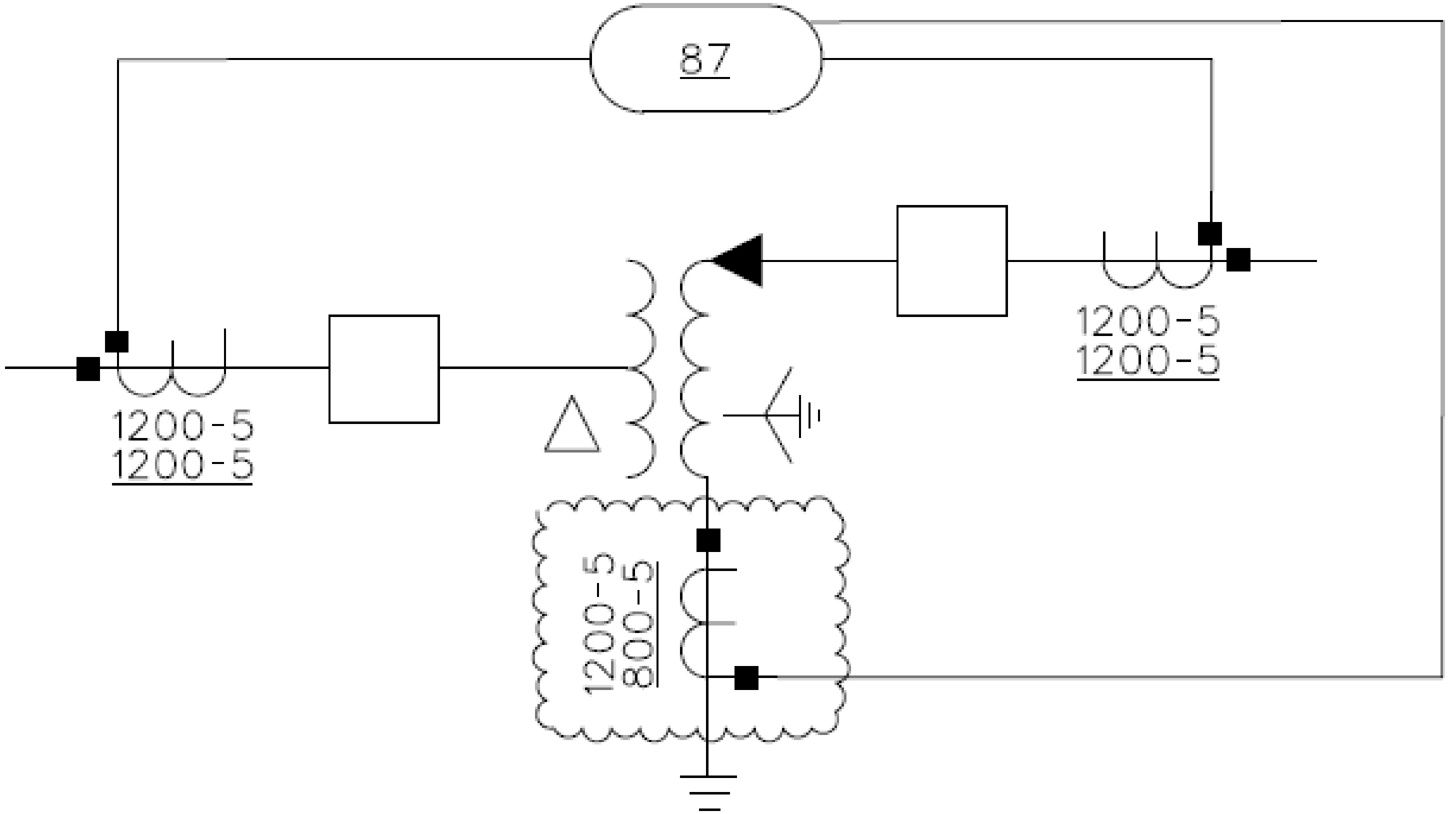
As Designed CT Polarity



As Built CT Polarity



Protection System Commissioning Program

- All construction projects are unique, and a one-size fits all approach to a commissioning plan will have gaps
- Clearly identified lines of responsibility

Protection System Commissioning Process

- In-service tests to verify AC voltage and current circuits to verify proper magnitude and phase relationships
- Entities should perform a final walkdown upon completion of in-service testing using a checklist to document the results
- Utilize a consistent and complete PSC test checklist that identifies specific tasks in the commissioning procedure

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John Grimm, PE

Principal Systems Protection Engineer

Reliability Analysis

Midwest Reliability Organization

MRO Protective Relay Subcommittee Misoperations Phase II Report

By John Grimm, P.E. – Principal Systems Protection Engineer

PRS Whitepapers

Protection System Misoperations

https://www.mro.net/wp-content/uploads/document-library/Protection-System-Misoperation-White-Paper.pdf

PRS Phase II Misoperations White Paper

https://www.mro.net/wp-content/uploads/document-library/Protective-Relay-Subcommittee-Misoperations-Phase-II-Whitepaper.docx.pdf

Misoperations Phase II Report

- The PRS identified high impact schemes that when they misoperate or fail to operate, they can lead to more severe events.
- The areas of focus for this Phase II report are:
    - *Breaker Failure Schemes*
    - *Differential Schemes*
    - *Differential Commissioning Practices*
- The PRS reviewed the misoperation submissions for 2010 to first quarter of 2016 and identified submissions related to breaker failure and differential misoperations.

Commissioning Practices to Reduce Misoperations

- **As the PRS was analyzing the misoperation submittals within the MRO, it was evident that a significant portion of the errors involved with differential misoperations could have been caught during commissioning.**
- **Many could have been prevented with detailed commissioning and testing practices by on-site personnel.**
- **The third chapter of the whitepaper addresses commissioning practices:**
  - Commissioning AC circuitry
  - Commissioning DC circuitry
  - Thorough load checks during commissioning
- **For effective commissioning, *make sure that the construction schedule is not compressed to the point such that insufficient time is given to properly commission the protection schemes*.**

Commissioning Practices and Checks

- **Verify orientation of components installed matches design documents.**
- **CT ratio field checks to verify the ratio in the relay settings match the CT tap settings and the CT wiring matches the drawings.**
- **Verify relay winding compensation settings are appropriate for the transformer winding being protected.**
- **Electrical test should be performed to validate CT saturation curves, CT dielectric strength, and integrity of the secondary circuits.**
- **Verify the lockout relay properly trips and blocks closing of all devices within the zone of protection.**
- **Verify CT secondary has proper grounding.**
- **Use primary current injection to verify secondary CT to relay wiring.**
- **Verify CT polarity also matches the drawings and relay settings.**
- **Other checks:**
  - Compare as-left Settings to as-received settings and report any differences to Engineering
  - Review the schematics and settings to ensure all outputs that are used are properly programmed.
  - Ensure all windings being used in differential protection are enabled.

Load Checks During Commissioning

- **Load checks will help identify errors such as a mismatch between wiring and the relay settings.**
- **It is very important to ensure that system conditions will provide sufficient load current on the day of commissioning.**
- **Each of the following should be evaluated with the relay's measured values when applicable:**
  - Phasor currents – Closely balanced and near 120 degree between phases
  - Power factor - Acceptable level
  - Differential current - A near zero operate current should be observed, $< I_{op}$
- **All relay current inputs being used need to be load checked.**

Examples of Load Checking Typical Schemes

- **The whitepaper provides detailed discussion of loading checking the following typical schemes:**
  - Low Impedance Bus Differential Example
  - High Impedance Bus Differential Example
  - Transformer Differential Example
  - Generator Differential Example

Rich Bauer

Associate Principal Engineer
RAPA/Event Analysis
North American Electric Reliability Corporation

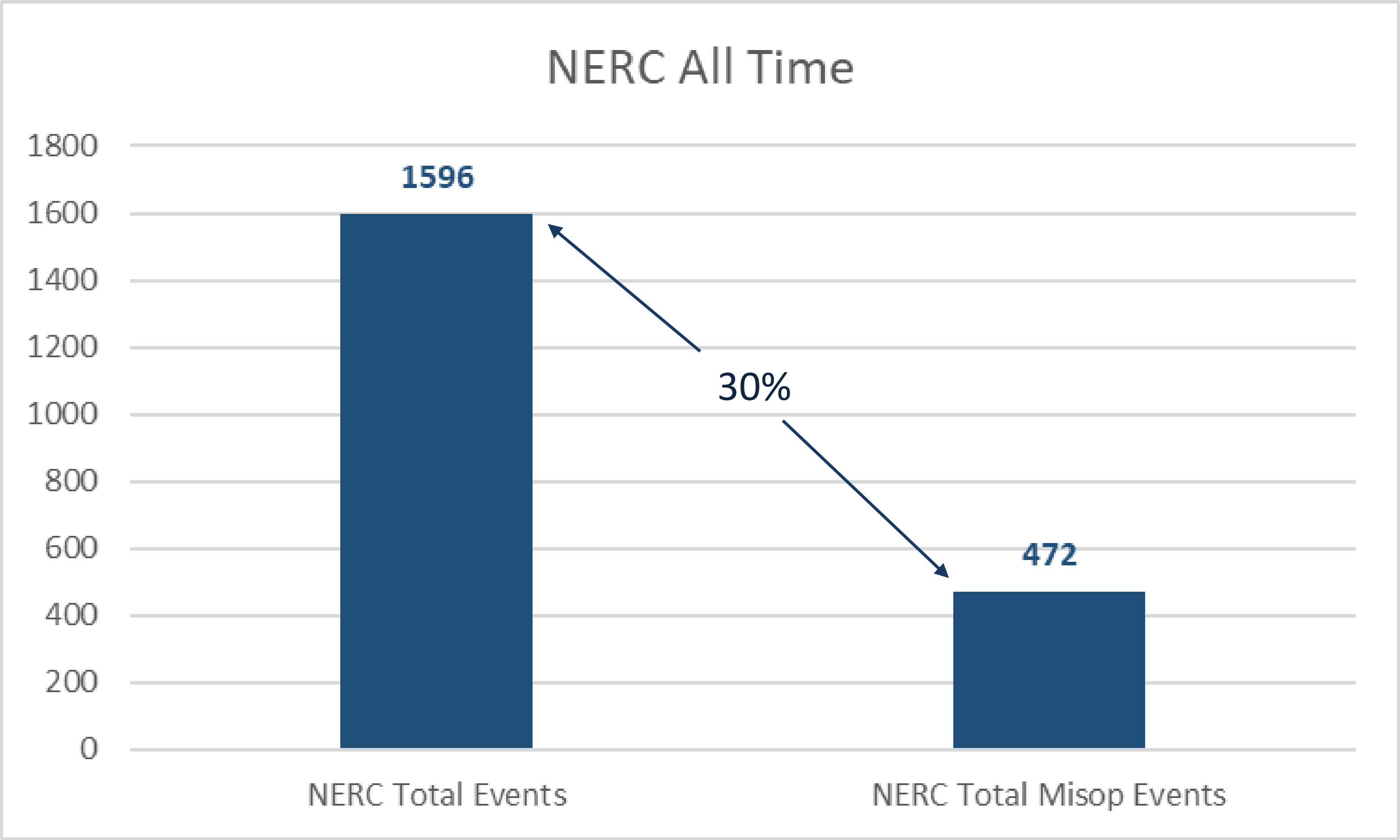
NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

MRO PRS Webinar on Protection System Commissioning

Rich Bauer
NERC RAPA/Event Analysis
July 14, 2022

RELIABILITY | ACCOUNTABILITY

Event Analysis data



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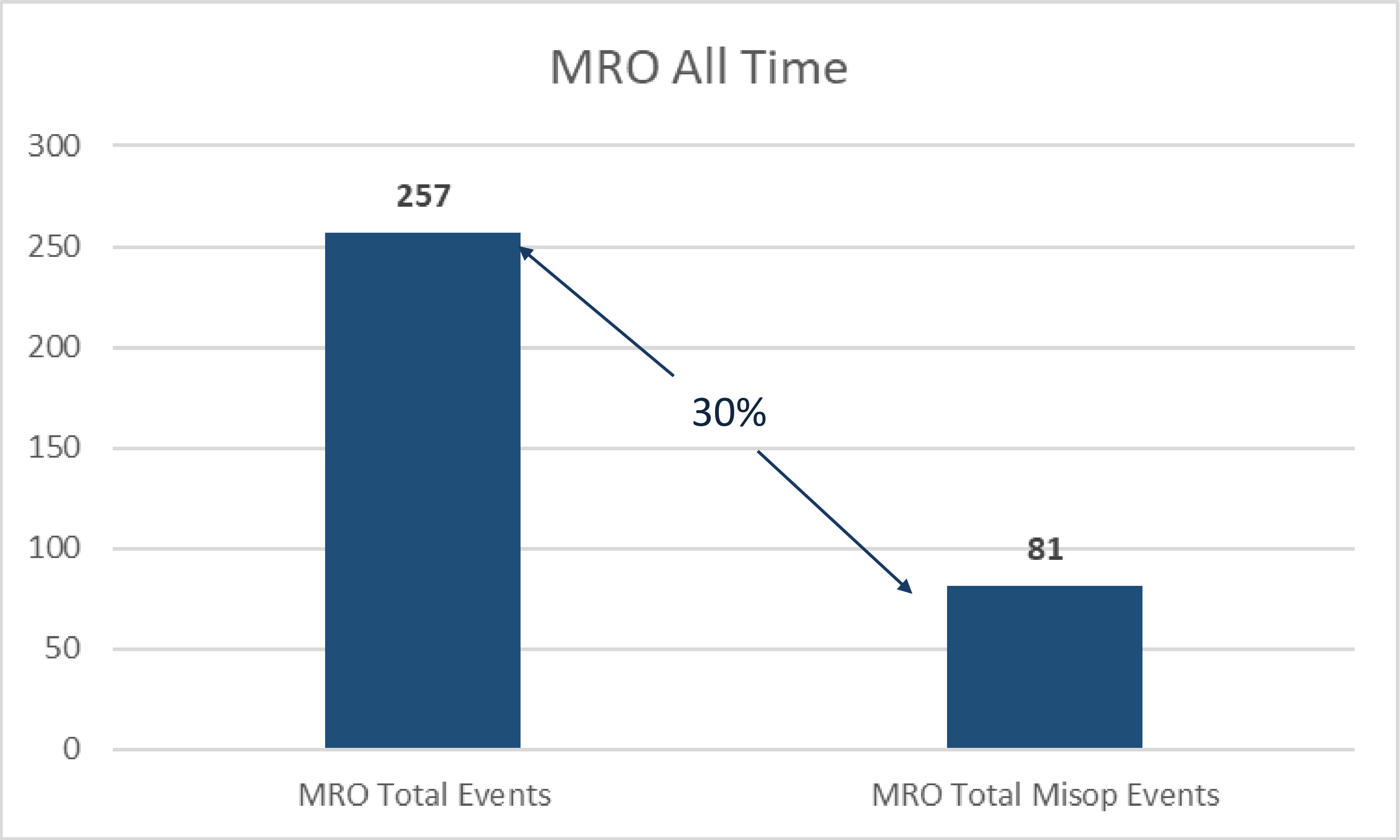

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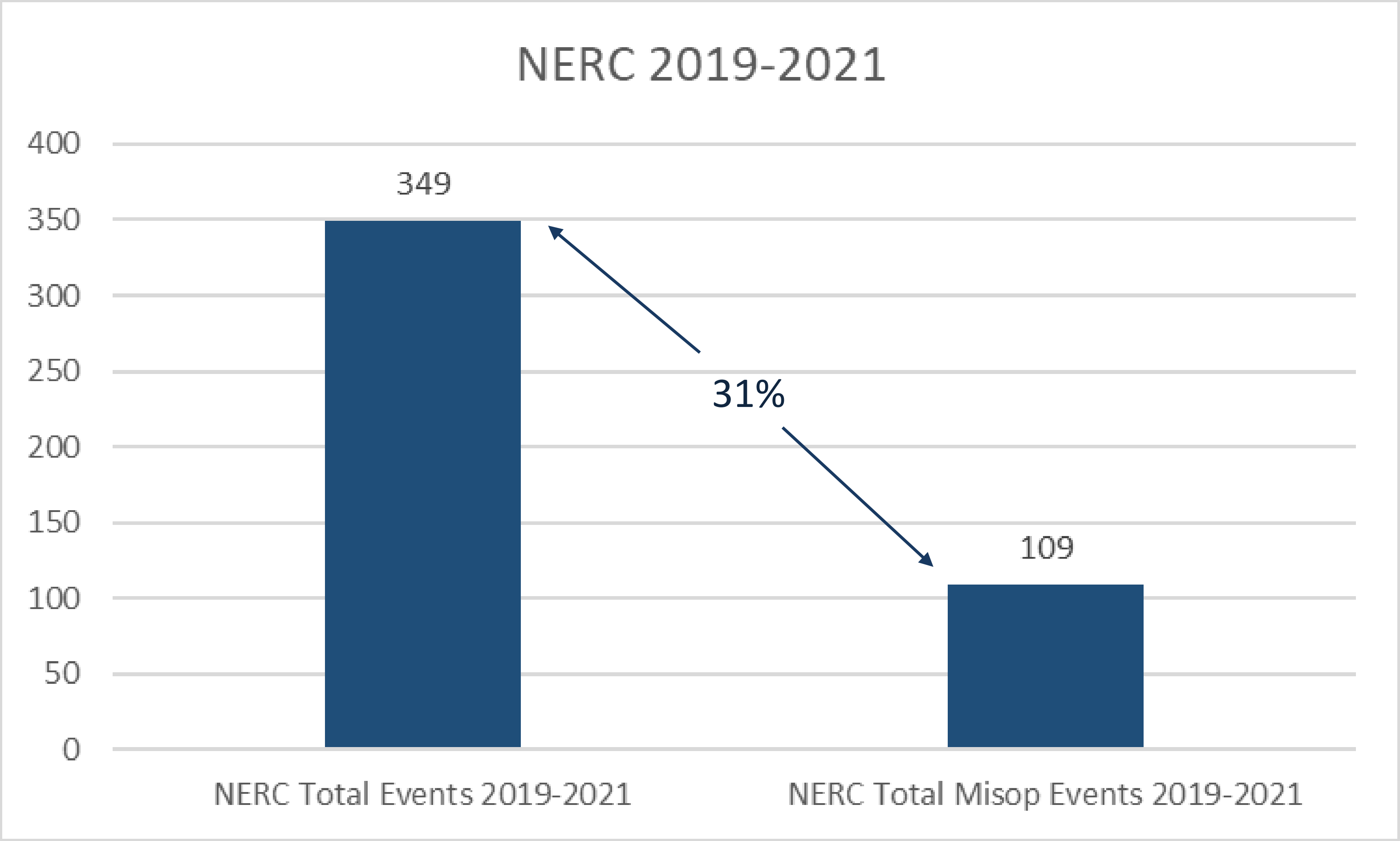

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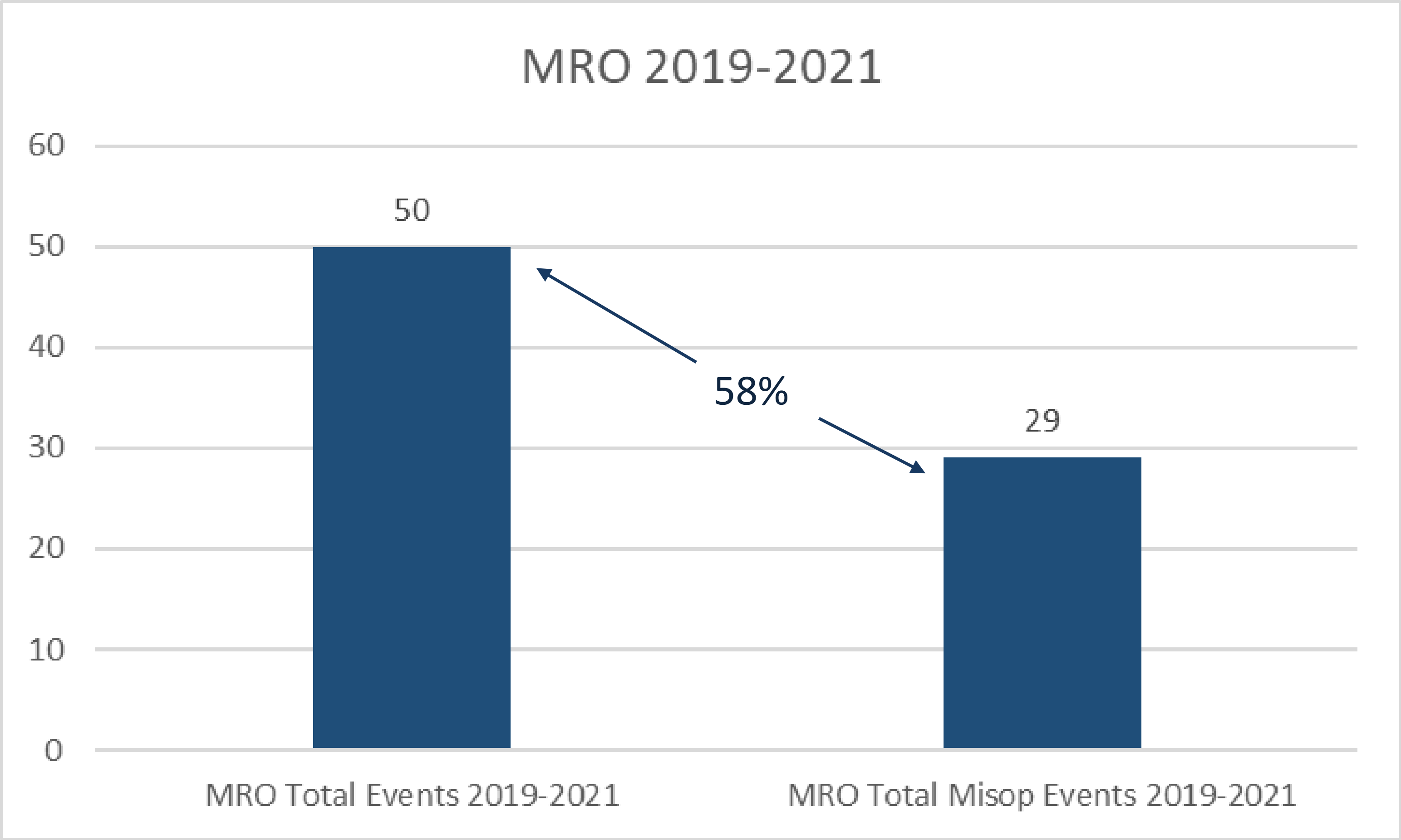

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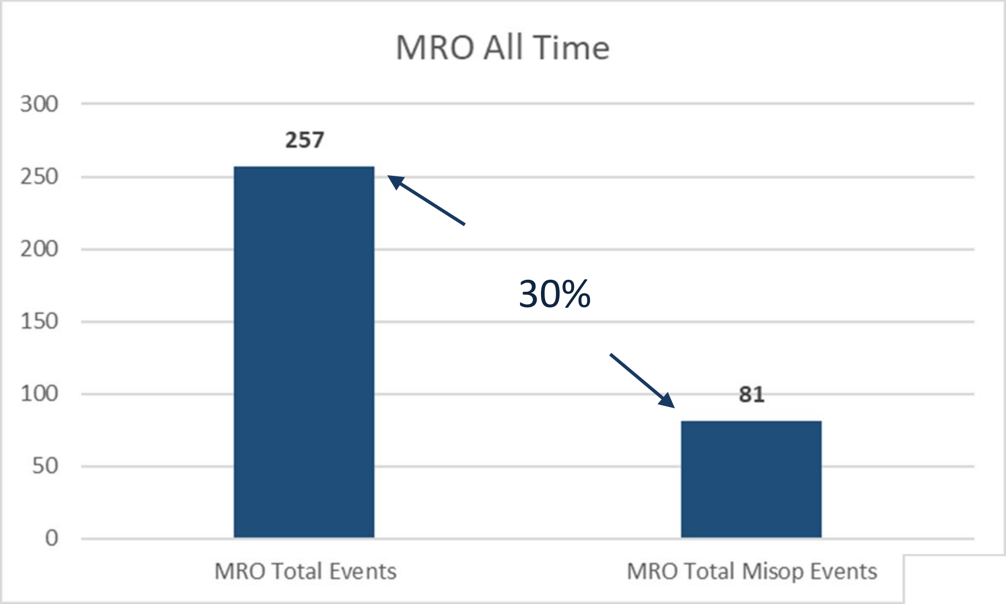

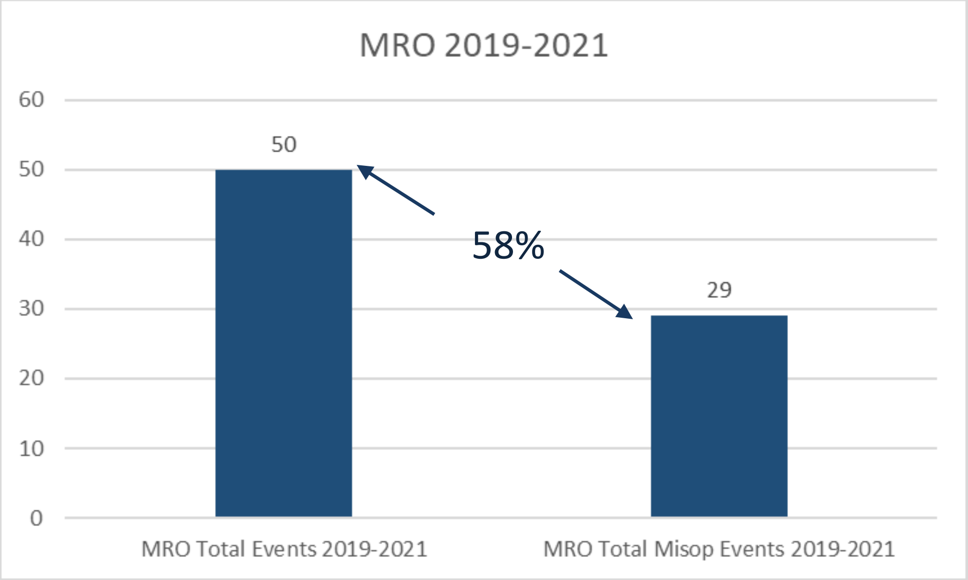

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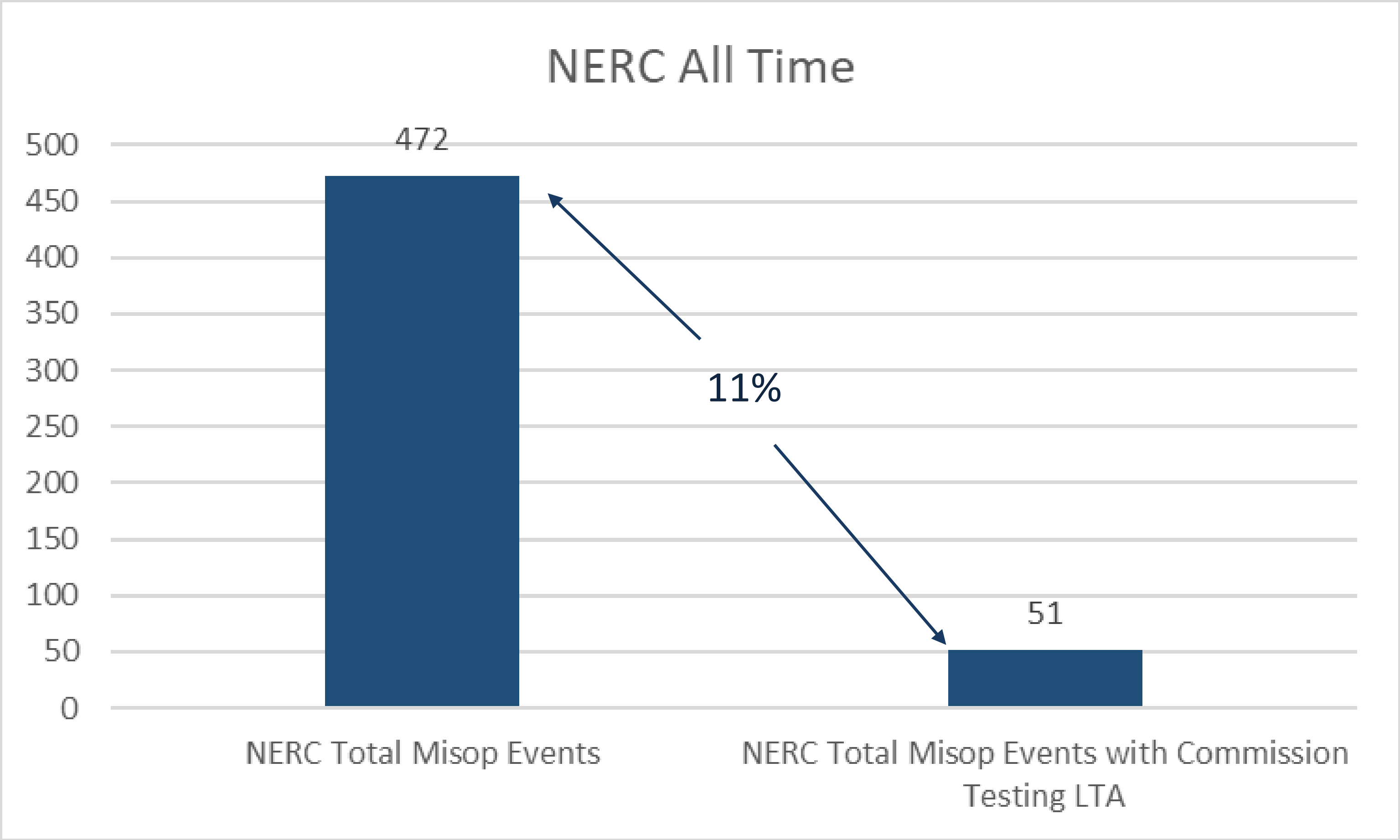

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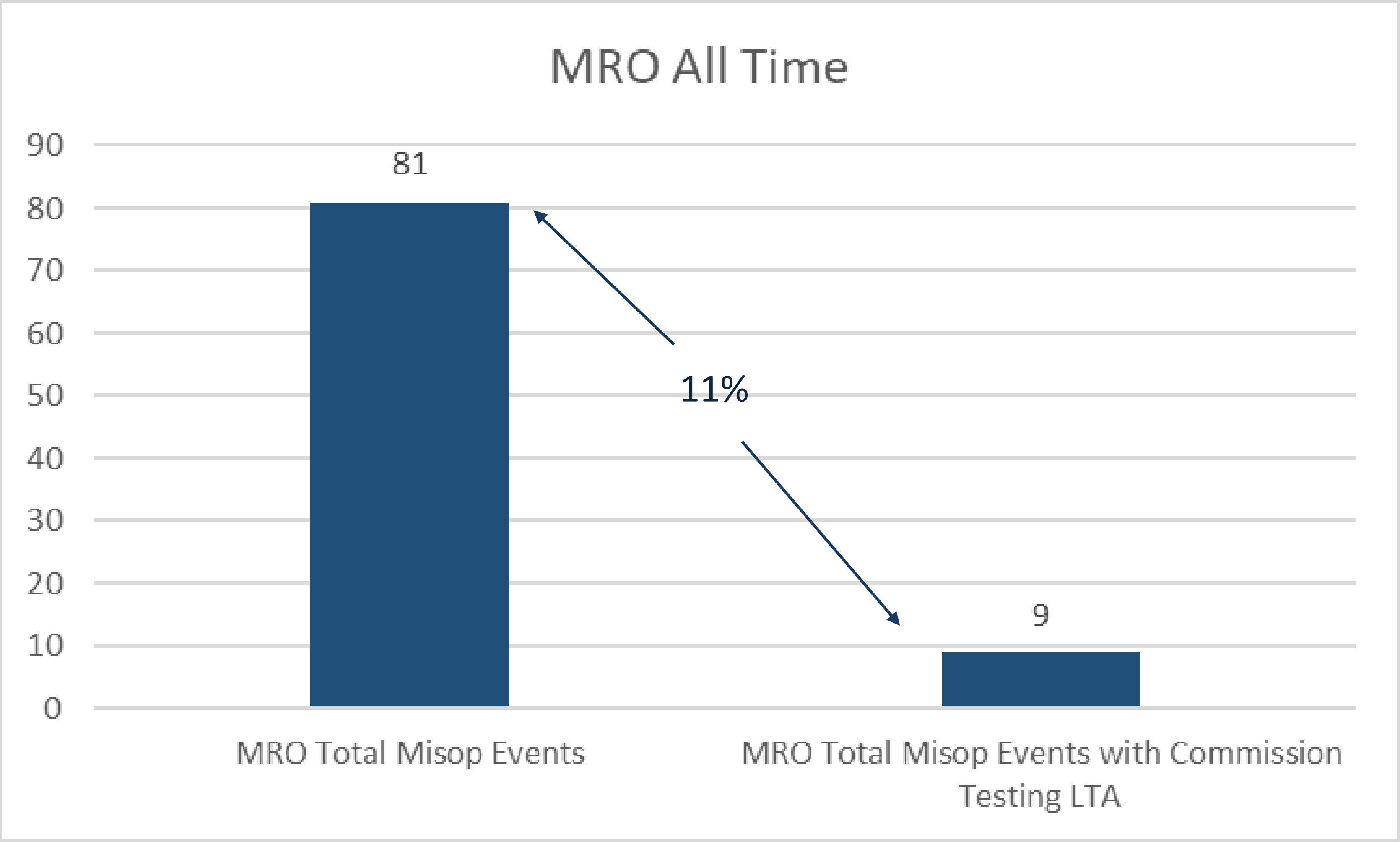

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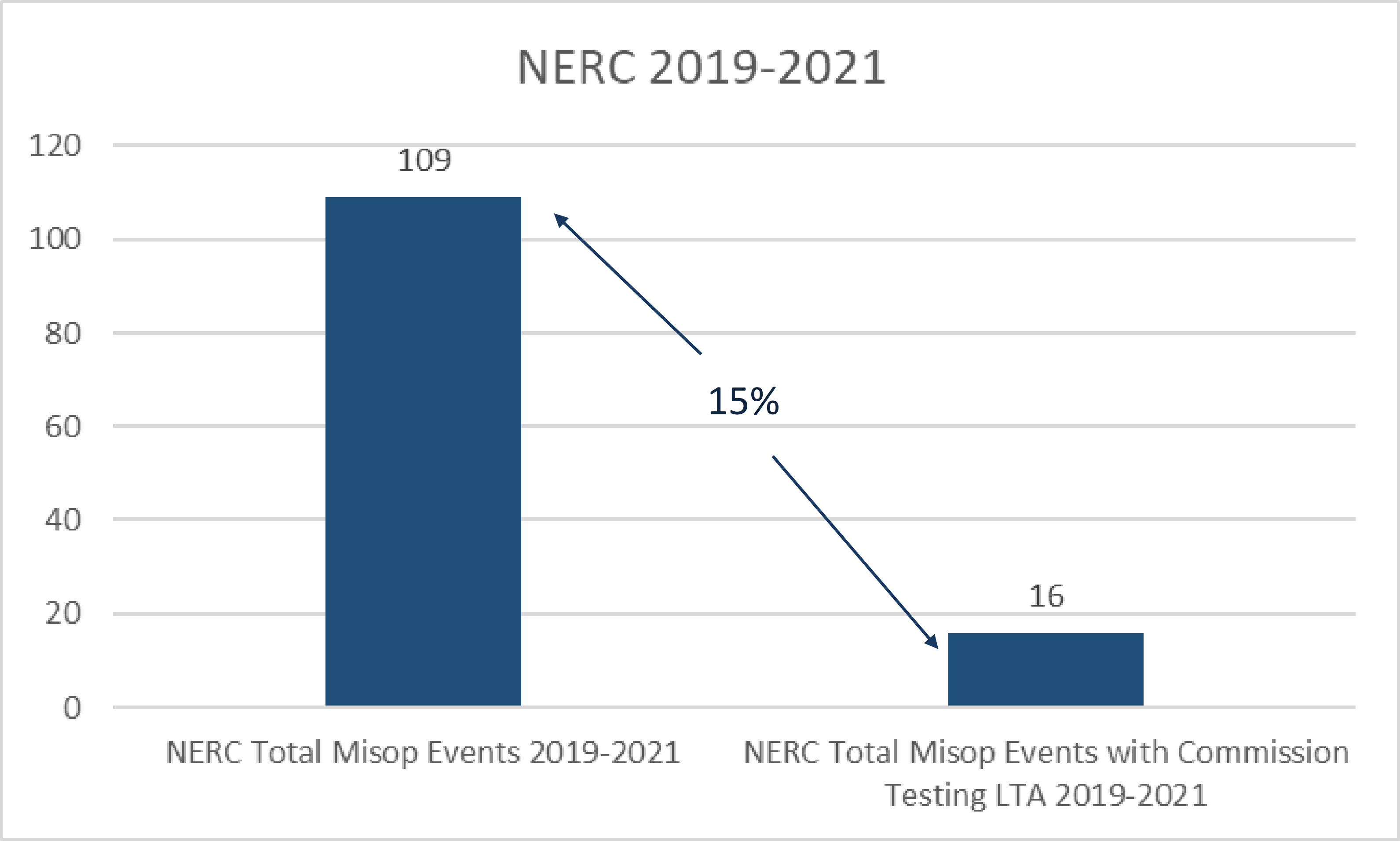

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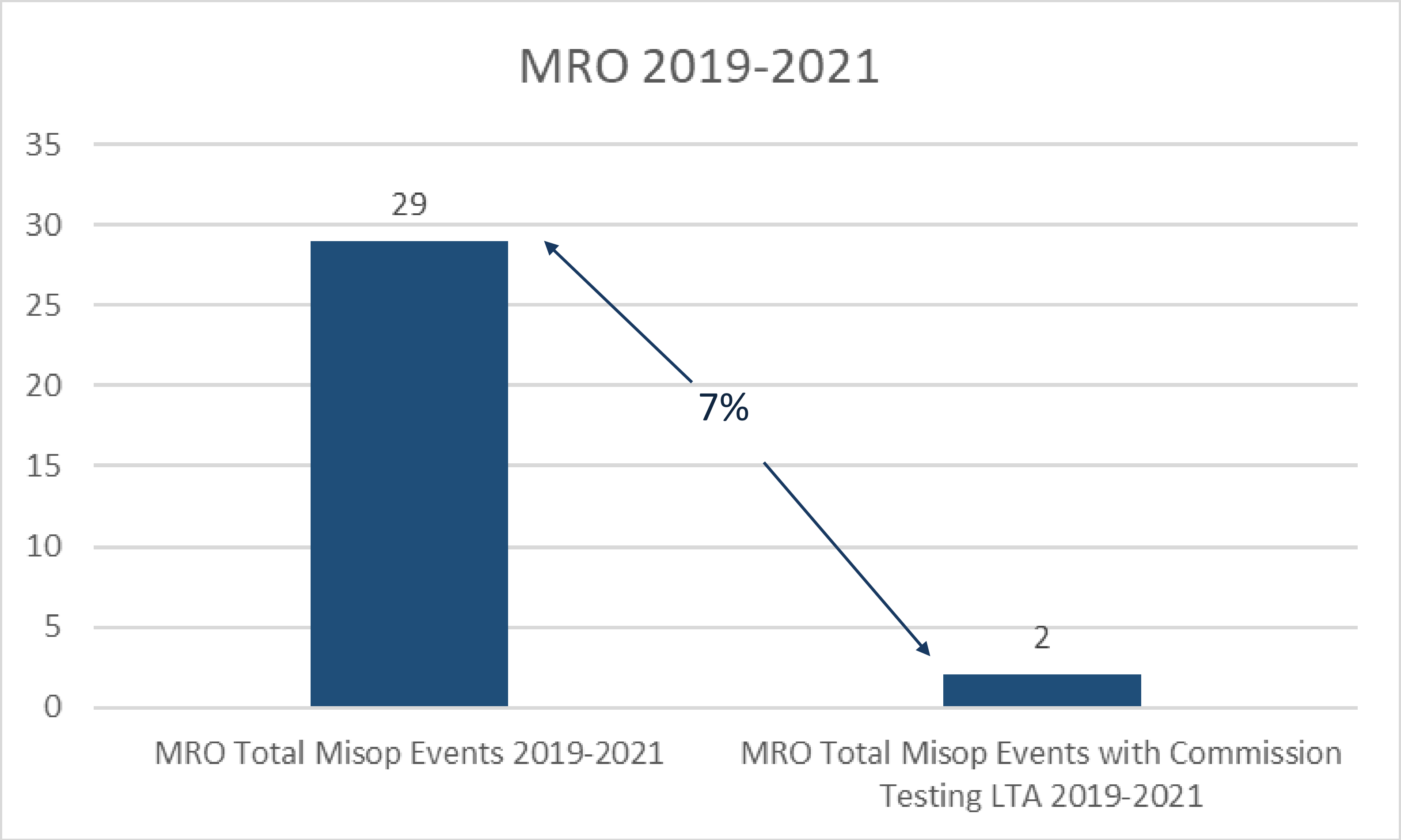

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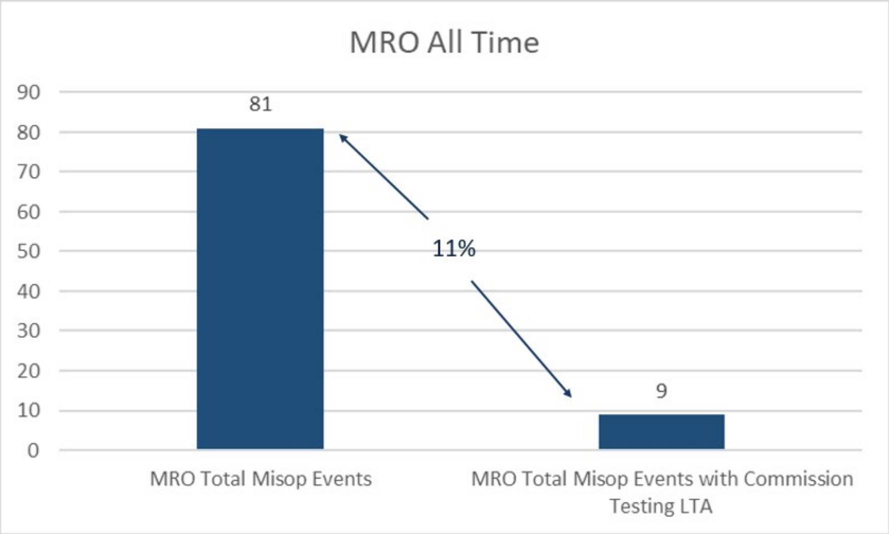
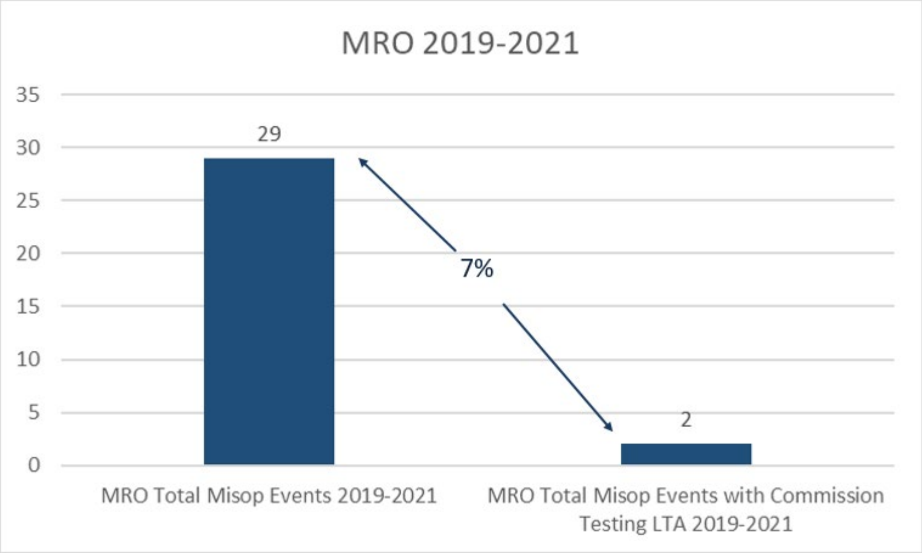




Jake Bernhagen, PE

Senior Systems Protection Engineer

Reliability Analysis

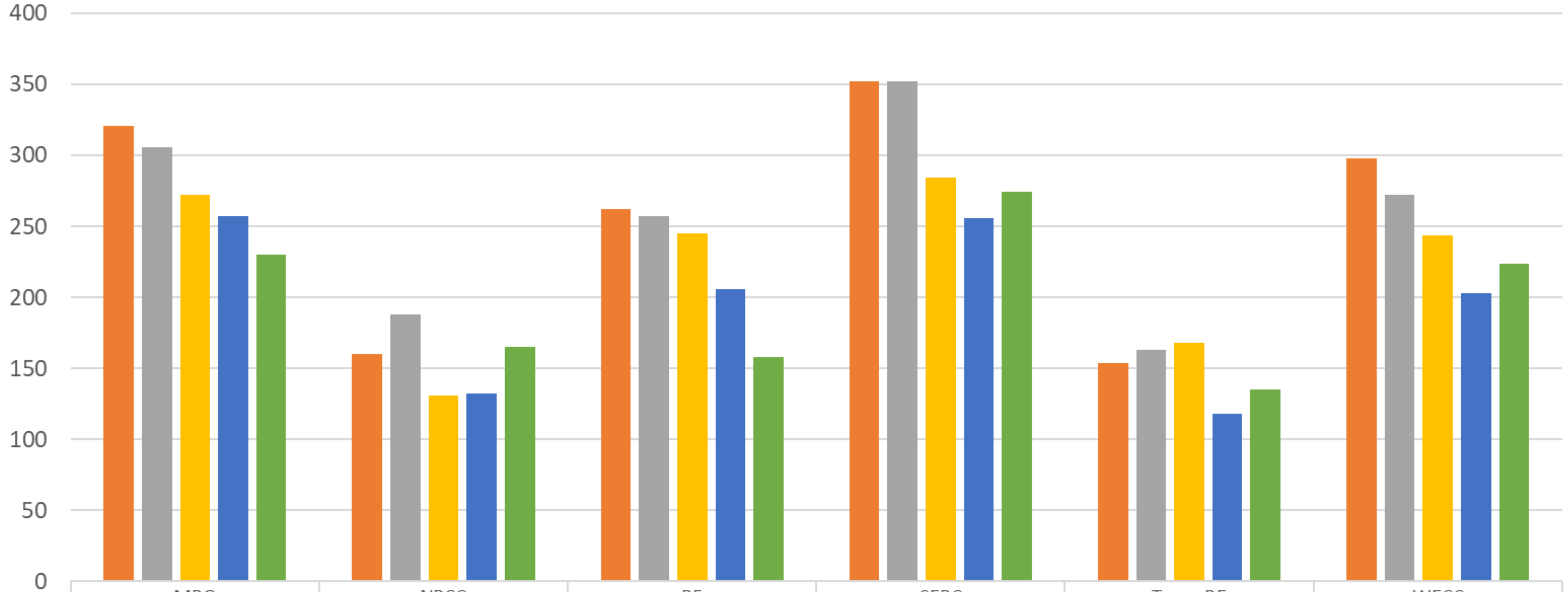
Midwest Reliability Organization

MIDWEST RELIABILITY ORGANIZATION

MRO Misoperations and Commissioning

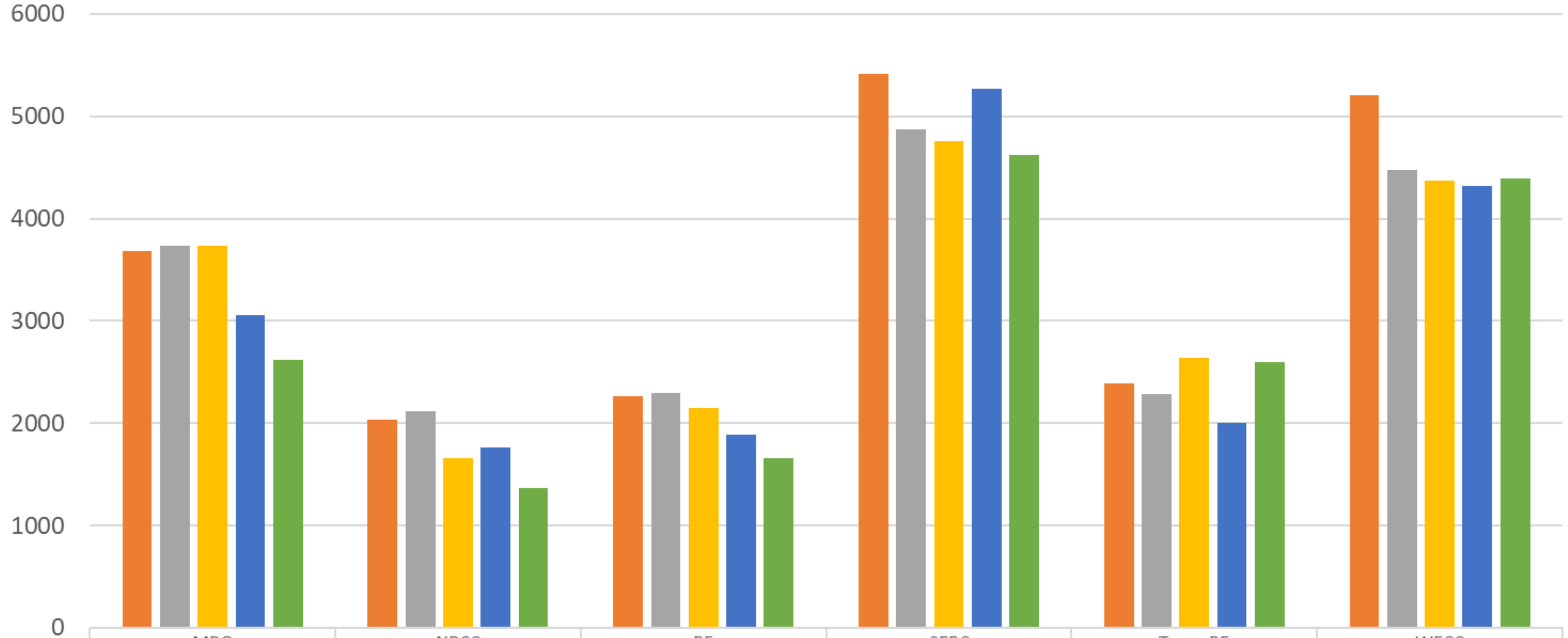
By Jake Bernhagen, P.E. – Senior Systems Protection Engineer

ERO Misoperations by Year



	MRO	NPCC	RF	SERC	Texas RE	WECC
2017	321	160	262	352	154	298
2018	306	188	257	352	163	272
2019	272	131	245	284	168	244
2020	257	132	206	256	118	203
2021	230	165	158	274	135	224

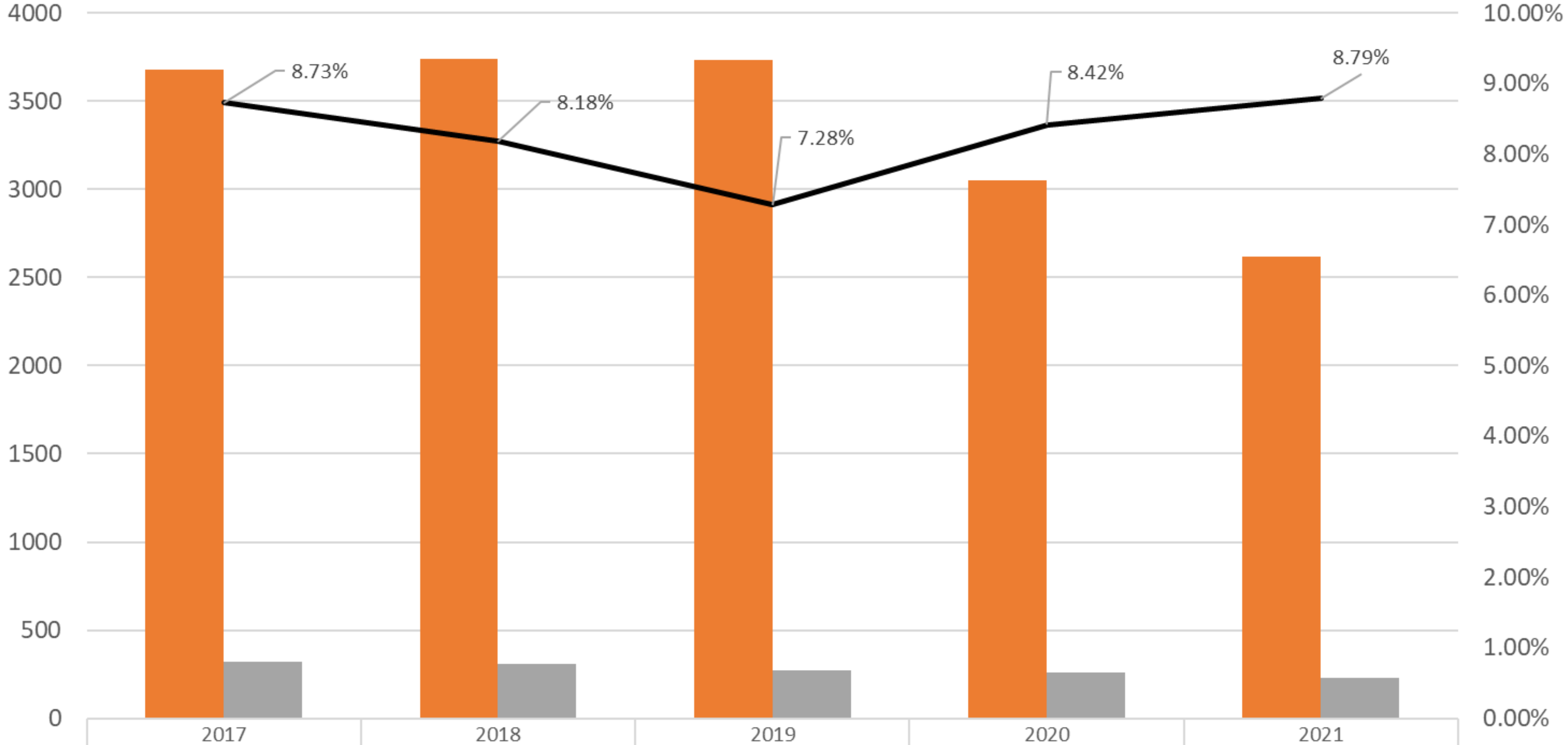
ERO Operations by Year



	MRO	NPCC	RF	SERC	Texas RE	WECC
2017	3678	2031	2264	5413	2385	5202
2018	3740	2117	2295	4873	2280	4474
2019	3734	1661	2149	4753	2640	4369
2020	3054	1760	1885	5267	2000	4323
2021	2617	1365	1660	4619	2599	4390

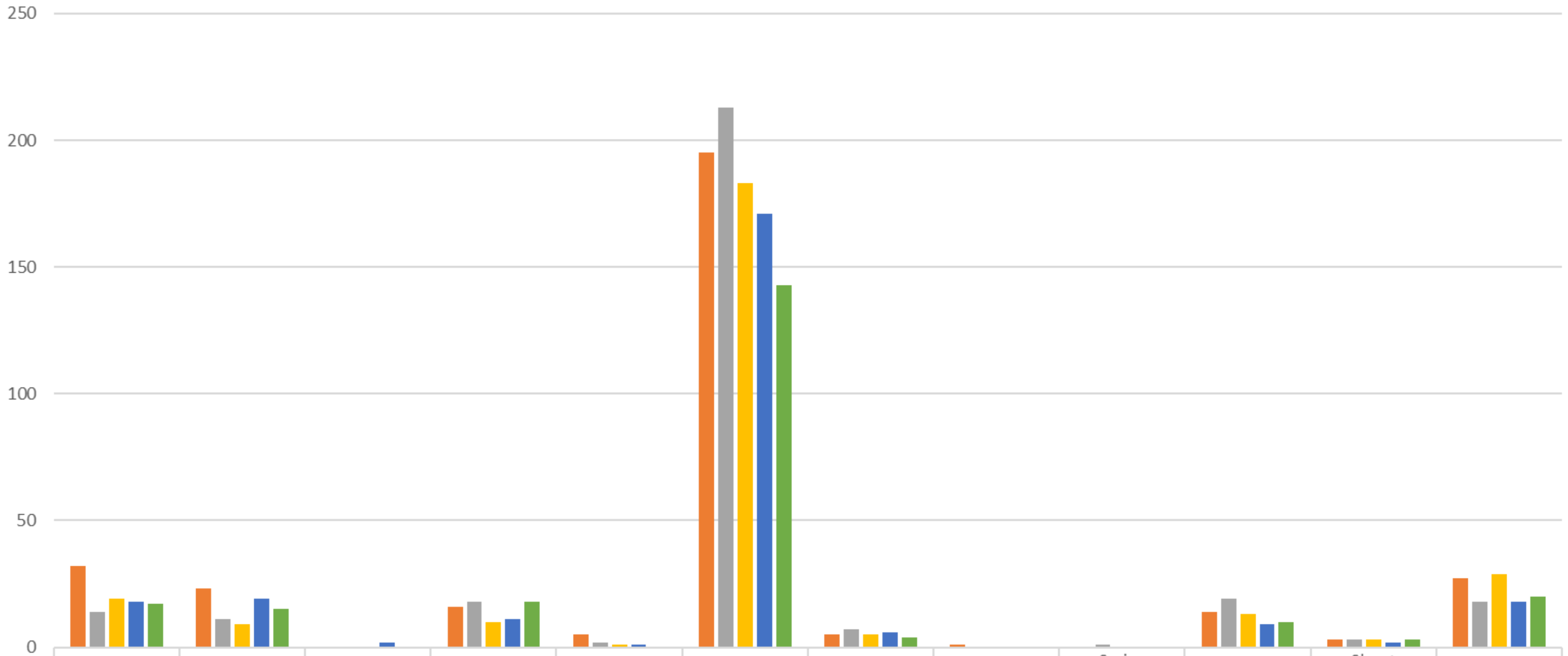
2017 2018 2019 2020 2021

MRO Misoperation Rate by Year



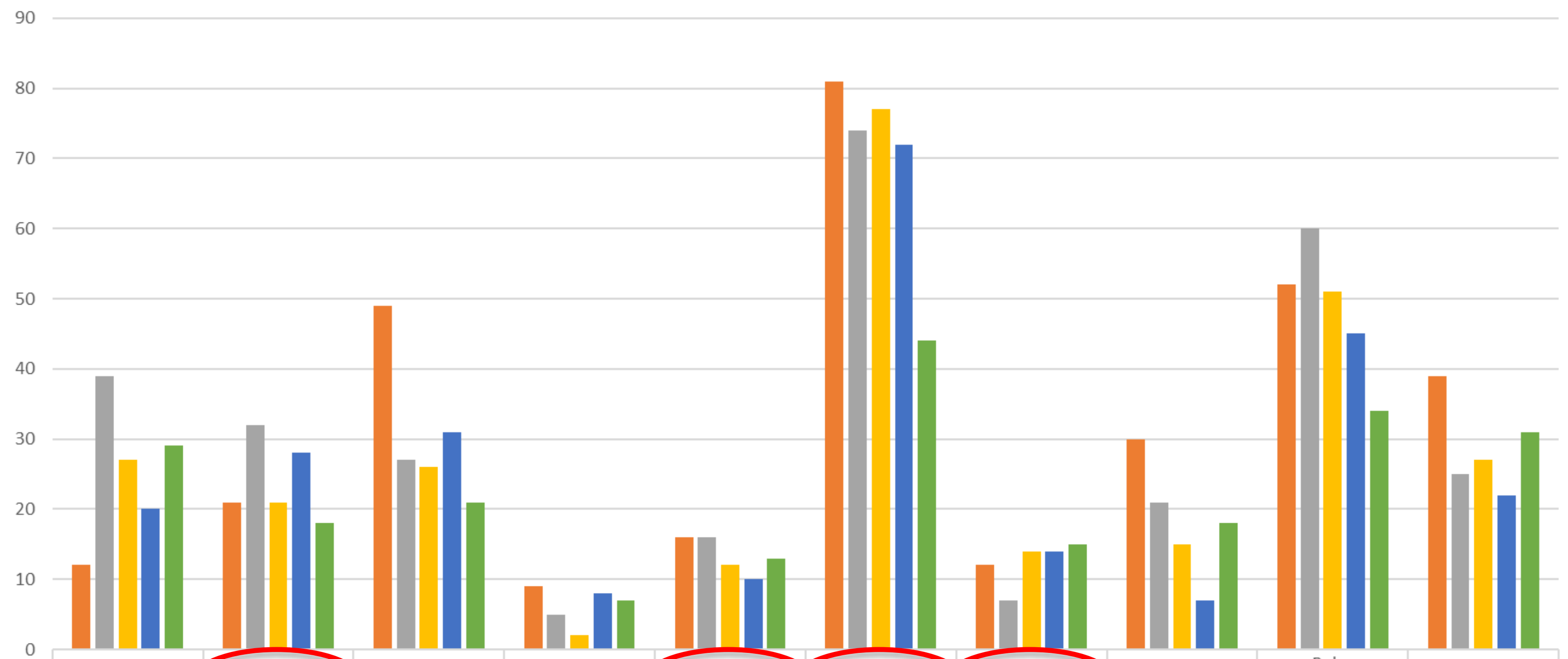
	2017	2018	2019	2020	2021
Operations	3678	3740	3734	3054	2617
Misoperations	321	306	272	257	230
Misop Rate	8.73%	8.18%	7.28%	8.42%	8.79%

MRO Misoperations by Equipment Type



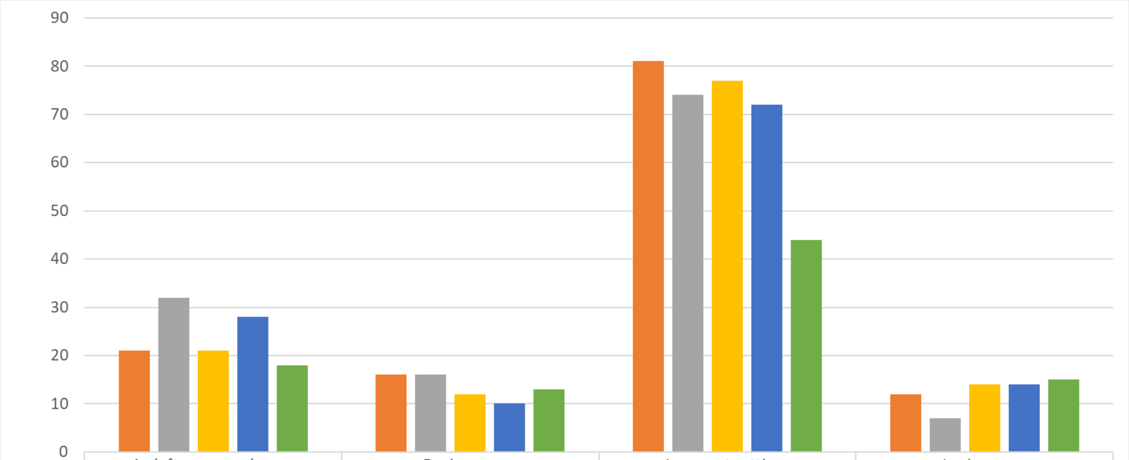
	Breaker	Bus	Dynamic Var Systems	Generator	HVdc	Line	Other	Series Capacitor	Series Reactor/Inductor	Shunt Capacitor	Shunt Reactor/Inductor	Transformer
2017	32	23	0	16	5	195	5	1	0	14	3	27
2018	14	11	0	18	2	213	7	0	1	19	3	18
2019	19	9	0	10	1	183	5	0	0	13	3	29
2020	18	19	2	11	1	171	6	0	0	9	2	18
2021	17	15	0	18	0	143	4	0	0	10	3	20

MRO Misoperations by Cause



	AC system	As-left personnel error	Communication failures	DC system	Design errors	Incorrect settings	Logic errors	Other/Explainable	Relay failures/malfunctions	Unknown/unexplainable
2017	12	21	49	9	16	81	12	30	52	39
2018	39	32	27	5	16	74	7	21	60	25
2019	27	21	26	2	12	77	14	15	51	27
2020	20	28	31	8	10	72	14	7	45	22
2021	29	18	21	7	13	44	15	18	34	31

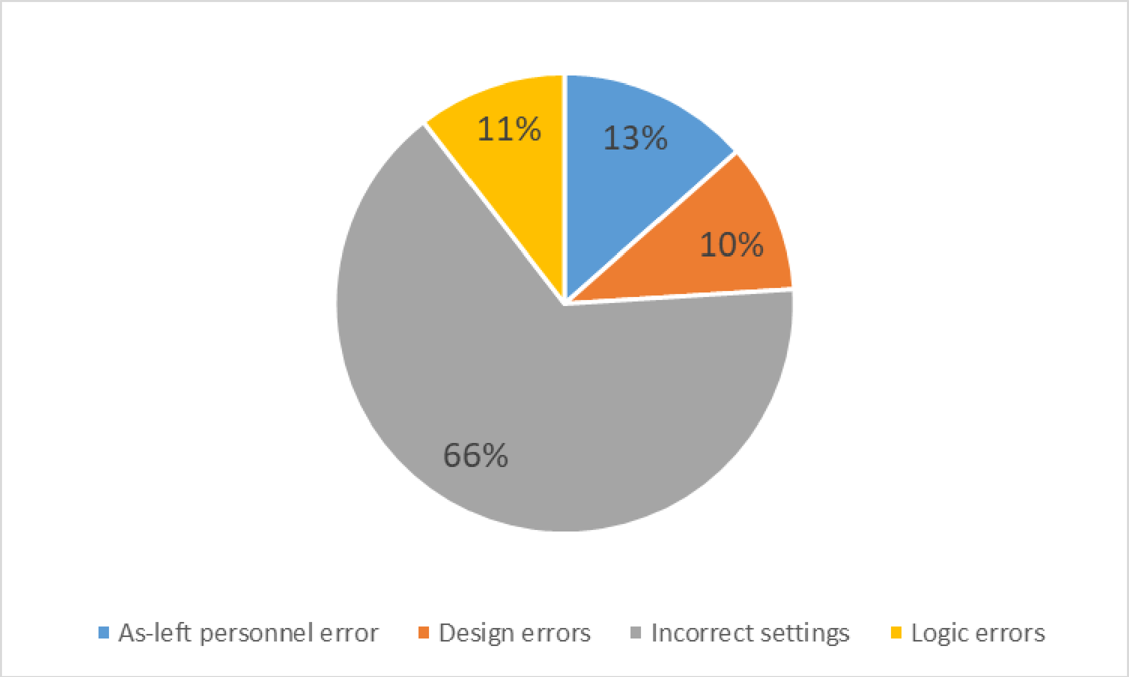
MRO Human Error Misoperations



	As-left personnel error	Design errors	Incorrect settings	Logic errors
2017	21	16	81	12
2018	32	16	74	7
2019	21	12	77	14
2020	28	10	72	14
2021	18	13	44	15

- **Between 2017 & 2021, 41.6% of MRO misoperations were Human Error related As-Left Personnel Error, Design Errors, Incorrect Settings, Logic Errors)**
- **64.7% of HE are associated with transmission line misoperations**
- **Overall, Incorrect Settings account for**
    - 24.8% of all misoperations
    - 59.7% of all HE misoperations

MRO Microprocessor Misoperations



- **Between 2017 & 2021, 85.2% of HE misoperations are associated with microprocessor relays**
- **Of those misoperations, two-thirds are associated with Incorrect Settings**

MRO Performance Improvement Initiatives

- Protective Relay Subgroup (PRS)
- White Papers
- Misoperation Peer Review Team

MRO Protective Relay Subgroup (PRS)

The purpose of the MRO Protective Relay Subgroup (MRO PRS) is to identify, review and discuss system protection and control issues relevant to the reliability of the bulk electric system and to develop and implement regional procedures for the NERC PRC standards.

- **Reports to MRO’s Reliability Advisory Council (RAC)**
- **Consists of relay subject matter experts from companies in the MRO footprint**
- **Meets quarterly**
- **Reviews NERC Lessons Learned related to protection system components**
- **Periodic presentations on events that occur in MRO’s region**
- **Periodic technical presentations by members**

MRO Protective Relay Subgroup (PRS) Membership

Member	Company	Member	Company
Greg Sessler, Chair	American Transmission Company	Derek Vonada	Sunflower Electric Power Corporation
David Wheeler, Vice Chair	Southwestern Public Services Co.	Derrick Schlangen	Great River Energy
Adam Daters	ITC Holdings	Glenn Bryson	American Electric Power
Alex Bosgoed	Saskatchewan Power Corporation	Greg Hill	Nebraska Public Power District
Casey Malskeit	Omaha Public Power District	Jeff Beasley	Grand River Dam Authority
Cody Remboldt	Montana-Dakota Utilities	Josh Erdmann	Xcel Energy
David Weir	Western Area Power Administration	Matt Boersema	Western Farmers Electric
Dennis Lu	Manitoba Hydro	Ryan Einer	Oklahoma Gas & Electric

White Papers

The MRO PRS has published two white papers:

- 2016 paper covers overcurrent relaying, Direction Comparison Blocking (DCB) schemes, & Direct Transfer Trip (DTT) schemes
- 2017 paper covers breaker failure relaying, differential relay application, & commissioning practices

Misoperation Peer Review Team

Misoperations are reviewed to ensure correct and consistent reporting

- **Conducted quarterly by a subgroup of PRS members**
- **Allows participants to review a variety of misoperations and discuss solutions, findings, best practices, etc.**
- **Unusual or severe misoperations may be presented on at PRS meetings for technical discussion**

What Entities Can do to Reduce Misoperations

- Participate in and be involved with the Protective Relay Subgroup
- Company relay subject matter experts should assist in PRS relay misoperation reviews
- Reach out to the MRO PRS for misoperation assistance & advice
- Peer review relay settings and commissioning testing procedures

Protective Relay Subgroup (PRS)

- **MRO Protective Relay Subgroup**
  - https://www.mro.net/organizational-groups/reliability-advisory-council/protective-relay-subgroup/
- **MRO Protective Relay Subgroup Q3 Meeting, Tuesday, August 16, 2022 8:00 am - 3:00 pm CDT**
  - https://www.mro.net/event/mro-protective-relay-subgroup-q3-meeting/
- **MRO Protective Relay Subgroup Misoperations Phase II Whitepaper**
  - https://www.mro.net/wp-content/uploads/document-library/Protective-Relay-Subcommittee-Misoperations-Phase-II-Whitepaper.docx.pdf

Resources

- **Joint Review of Protection System Commissioning Programs**
  - https://www.ferc.gov/sites/default/files/2021-11/Protection%20System%20Commissioning%20Program%20Review%20Project.pdf

- **IEEE PSRC, WG I-25, Commissioning Testing of Protection Systems, (2017)**
  - https://www.pes-psrc.org/kb/published/reports/WG%20I-25%20Commissioning%20_Testing%20of%20Protection%20Systems%205-10-2017.pdf

- **2022 MRO Regional Risk Assessment**
  - https://www.mro.net/wp-content/uploads/document-library/2022-MRO-RRA.pdf

MRO PRS Protection System Commissioning Webinar

For more information, please contact:

Max Desruisseaux, Senior Power Systems Engineer
Max.Desruisseaux@mro.net

Jake Bernhagen, Senior Systems Protection Engineer
Jake.Bernhagen@mro.net

John Grimm, Principal Systems Protection Engineer
John.Grimm@mro.net

Questions