MIDWEST
RELIABILITY
ORGANIZATION

# Meeting Agenda

## Protective Relay Subgroup (PRS)

**August 16, 2022**

**8:00 am to 3:00 pm central**

*MRO Corporate Offices, King Conference Center*
*St. Paul, MN 55102*

## VIDEO AND AUDIO RECORDING

**Please note that Midwest Reliability Organization (MRO) may make a video and/or an audio recording of this organizational group meeting for the purposes of making this information available to board members, members, stakeholders and the general public who are unable to attend the meeting in person.**

**By attending this meeting, I grant MRO:**

1. **Permission to video and/or audio record the meeting including me; and**
2. **The right to edit, use, and publish the video and/or audio recording.**
3. **I understand that neither I nor my employer has any right to be compensated in connection with the video and/or audio recording or the granting of this consent.**

# MRO ORGANIZATIONAL GROUP GUIDING PRINCIPLES

**These MRO Organizational Group Guiding Principles complement charters. When the Principles are employed by members, they will support the overall purpose of the organizational groups.**

**Organizational Group Members should:**

1. **Make every attempt to attend all meetings in person or via webinar.**

2. **Be responsive to requests, action items, and deadlines.**

3. **Be active and involved in all organizational group meetings by reviewing all pre-meeting materials and being focused and engaged during the meeting.**

4. **Be self-motivating, focusing on outcomes during meetings and implementing work plans to benefit MRO and MRO's registered entities.**

5. **Ensure that the organizational group supports MRO strategic initiatives in current and planned tasks.**

6. **Be supportive of Highly Effective Reliability Organization (HEROTM) principles.**

7. **Be supportive of proactive initiatives that improve effectiveness and efficiency for MRO and MRO's registered entities.**

## MRO PROTECTIVE RELAY SUBGROUP Q3 MEETING AGENDA

**Agenda Item**

**1 Call to Order and Determination of Quorum**
*Greg Sessler, Protective Relay Subgroup Chair*

a. Determination of Quorum
*Reliability Analysis Administrator*

b. Robert's Rules of Order

**2 Standards of Conduct and Antitrust Guidelines**
*Jake Bernhagen, Senior Systems Protection Engineer, MRO*

**3 Chair's Remarks**
*Greg Sessler, Protective Relay Subgroup Chair*

**4 Diversity Initiative**
*Julie Peterson, Assistant Corporate Secretary and Senior Counsel, MRO*

**5 Consent Agenda**
*Greg Sessler, Protective Relay Subgroup Chair*

a. Approve May 3, 2022 PRS Meeting Minutes

**6 NERC Activities**
*Jake Bernhagen, Senior Systems Protection Engineer, MRO*

a. NERC SPCWG Update
*Mark Gutzmann, Director, System Protection & Communication Engineering, Xcel Energy*

b. NERC MIDASUG Update
*Jake Bernhagen, Senior Systems Protection Engineer, MRO*

c. TADS
*John Grimm, Principal Systems Protection Engineer, MRO*

**7 PRS Business**

a. Updates
*Jake Bernhagen, Senior Systems Protection Engineer, MRO*

b. Action Item List Review
*Greg Sessler, Protective Relay Subgroup Chair*

**Break – 10:00 a.m.**

**8 Misoperations**
*Jake Bernhagen, Senior Systems Protection Engineer, MRO*

a. Q1 2022 Results, Review and Discussion

b. Technical Presentations

i. **Harrington Substation Event**
*Kevin Jones, Consulting Engineer, System Protection Engineering, Xcel Energy*

ii. **SPS Load Shed Philosophy**
*Kevin Jones, Consulting Engineer, System Protection Engineering, Xcel Energy*

c. Project Updates

i. **Instantaneous Ground Overcurrent**
*Jake Bernhagen, Senior Systems Protection Engineer, MRO*

**9 Protection System Commissioning**
*Cody Remboldt, Montana-Dakota Utilities and PRS Member*

a. Webinar Recap

b. Lessons Learned

10 **NERC State of Reliability**
*John Grimm, Principal Systems Protection Engineer, MRO*

**Lunch 12:00 p.m.**

11 **Mitsubishi Falsifying Transformer Test Results**
*Jake Bernhagen, Senior Systems Protection Engineer, MRO*

12 **2022 Meeting Dates**
*Greg Sessler, Protective Relay Subgroup Chair*

13 **PRS Roundtable Discussion**
*Greg Sessler, Protective Relay Subgroup Chair*

14 **Other Business and Adjourn**
*Greg Sessler, Protective Relay Subgroup Chair*

# AGENDA 1

**Call to Order and Determination of Quorum**

a. Determination of Quorum

***Reliability Analysis Administrator***

| Name | Role | Company | Term |
|---|---|---|---|
| **Greg Sessler** | **Chair** | American Transmission Company | 12/31/23 |
| **David Wheeler** | **Vice Chair** | Southwestern Public Services Co. | 12/31/23 |
| Adam Daters | Member | ITC Holdings | 12/31/24 |
| Alex Bosgoed | Member | Saskatchewan Power Corporation | 12/31/22 |
| Casey Malskeit | Member | Omaha Public Power District | 12/31/22 |
| Cody Remboldt | Member | Montana-Dakota Utilities | 12/31/24 |
| David Weir | Member | Western Area Power Administration | 12/31/22 |
| Dennis Lu | Member | Manitoba Hydro | 12/31/23 |
| Derek Vonada | Member | Sunflower Electric Power Corporation | 12/31/22 |
| Derrick Schlangen | Member | Great River Energy | 12/31/23 |
| Glenn Bryson | Member | American Electric Power | 12/31/24 |
| Greg Hill | Member | Nebraska Public Power District | 12/31/22 |
| Jeff Beasley | Member | Grand River Dam Authority | 12/31/22 |
| Josh Erdmann | Member | Xcel Energy | 12/31/24 |
| Matt Boersema | Member | Western Farmers Electric | 12/31/22 |
| Ryan Einer | Member | Oklahoma Gas & Electric | 12/31/23 |
| Sarah Marshall | Member | Alliant Energy | 12/31/24 |
| Scott Paramore | Member | Kansas City Board of Public Utilities | 12/31/24 |
| Terry Fett | Member | Central Iowa Power Cooperative | 12/31/23 |

# AGENDA 1

## Call to Order and Determination of Quorum

b. Robert's Rules of Order

***Greg Sessler, Protective Relay Subgroup Chair***

**Parliamentary Procedures.** Based on Robert's Rules of Order, Newly Revised, Tenth Edition

**Establishing a Quorum.** In order to make efficient use of time at MRO organizational group meetings, once a quorum is established, the meeting will continue, however, no votes will be taken unless a quorum is present at the time any vote is taken.

**Motions.** Unless noted otherwise, all procedures require a "second" to enable discussion.

| When you want to… | Procedure | Debatable | Comments |
|---|---|---|---|
| Raise an issue for discussion | Move | Yes | The main action that begins a debate. |
| Revise a Motion currently under discussion | Amend | Yes | Takes precedence over discussion of main motion. Motions to amend an amendment are allowed, but not any further. The amendment must be germane to the main motion, and cannot reverse the intent of the main motion. |
| Reconsider a Motion already resolved | Reconsider | Yes | Allowed only by member who voted on the prevailing side of the original motion. Second by anyone. |
| End debate | Call for the Question *or* End Debate | No | If the Chair senses that the committee is ready to vote, he may say "if there are no objections, we will now vote on the Motion." Otherwise, this motion is not debatable and subject to majority approval. |
| Record each member's vote on a Motion | Request a Roll Call Vote | No | Takes precedence over main motion. No debate allowed, but the members must approve by majority. |
| Postpone discussion until later in the meeting | Lay on the Table | Yes | Takes precedence over main motion. Used only to postpone discussion until later in the meeting. |
| Postpone discussion until a future date | Postpone until | Yes | Takes precedence over main motion. Debatable only regarding the date (and time) at which to bring the Motion back for further discussion. |
| Remove the motion for any further consideration | Postpone indefinitely | Yes | Takes precedence over main motion. Debate can extend to the discussion of the main motion. If approved, it effectively "kills" the motion. Useful for disposing of a badly chosen motion that cannot be adopted or rejected without undesirable consequences. |

| | | | |
|---|---|---|---|
| Request a review of procedure | Point of order | No | Second not required. The Chair or secretary shall review the parliamentary procedure used during the discussion of the Motion. |

**Notes on Motions**

**Seconds.** A Motion must have a second to ensure that at least two members wish to discuss the issue. The "seconder" is not required to be recorded in the minutes. Neither are motions that do not receive a second.

**Announcement by the Chair.** The chair should announce the Motion before debate begins. This ensures that the wording is understood by the membership. Once the Motion is announced and seconded, the Committee "owns" the motion, and must deal with it according to parliamentary procedure.

***Voting***

| Voting Method | When Used | How Recorded in Minutes |
|---|---|---|
| | When the Chair senses that the Committee is substantially in agreement, and the Motion needed little or no debate. No actual vote is taken. | The minutes show "by unanimous consent." |
| Vote by Voice | The standard practice. | The minutes show Approved or Not Approved (or Failed). |
| Vote by Show of Hands (tally) | To record the number of votes on each side when an issue has engendered substantial debate or appears to be divisive. Also used when a Voice Vote is inconclusive. (The Chair should ask for a Vote by Show of Hands when requested by a member). | The minutes show both vote totals, and then Approved or Not Approved (or Failed). |
| Vote by Roll Call | To record each member's vote. Each member is called upon by the Secretary, and the member indicates either<br><br>"Yes," "No," or "Present" if abstaining. | The minutes will include the list of members, how each voted or abstained, and the vote totals. Those members for which a "Yes," "No," or "Present" is not shown are considered absent for the vote. |

**Notes on Voting.**

**Abstentions.** When a member abstains, he/she is not voting on the Motion, and his/her abstention is not counted in determining the results of the vote. The Chair should not ask for a tally of those who abstained.

**Determining the results.** A simple majority of the votes cast is required to approve an organizational group recommendations or decision.

**"Unanimous Approval."** Can only be determined by a Roll Call vote because the other methods do not determine whether every member attending the meeting was actually present when the vote was taken, or whether there were abstentions.

**Electronic Votes** – For an e-mail vote to pass, the requirement is a simple majority of the votes cast during the time-period of the vote as established by the Committee Chair.

**Majorities**. Per Robert's Rules, as well as MRO Policy and Procedure 3, a simple majority (one more than half) is required to pass motions

# AGENDA 2

**Standards of Conduct and Antitrust Guidelines**

*Jake Bernhagen, Senior Systems Protection Engineer, MRO*

## Standards of Conduct Reminder:

Standards of Conduct prohibit MRO staff, committee, subcommittee, and task force members from sharing non-public transmission sensitive information with anyone who is either an affiliate merchant or could be a conduit of information to an affiliate merchant.

## Antitrust Reminder:

Participants in Midwest Reliability Organization meeting activities must refrain from the following when acting in their capacity as participants in Midwest Reliability Organization activities (i.e. meetings, conference calls, and informal discussions):

- Discussions involving pricing information; and
- Discussions of a participants marketing strategies; and
- Discussions regarding how customers and geographical areas are to be divided among competitors; and
- Discussions concerning the exclusion of competitors from markets; and
- Discussions concerning boycotting or group refusals to deal with competitors, vendors, or suppliers.

# AGENDA 3

**Chair's Remarks**
*Greg Sessler, Protective Relay Subgroup Chair*

## Action
Information

## Report
Chair Sessler will lead this discussion during the meeting.

# AGENDA 4

**Diversity Initiative**

*Julie Peterson, Assistant Corporate Secretary and Senior Counsel, MRO*

## Action

Information

## Report

Julie Peterson will provide an overview during the meeting.

# MRO Organizational Groups

## Diversity Initiative

# Types of Diversity

| Inherent Diversity | Acquired Diversity |
|---|---|
| Race | Expertise (e.g., engineering, operations, security) |
| Ethnicity | Experience (e.g., executive, technical) |
| Age | Geography (e.g., US, Canada, north, south) |
| National origin | Company (e.g., no more than two members from the same company per group) |
| Sexual orientation | |
| Cultural identity | |
| Assigned sex | |
| Gender identity | |

# The Value of Diverse Teams

- **More focused on facts**
  - More likely to constantly reexamine facts and remain objective
  - Can lead to improved and more accurate group thinking
- **Facts are processed more carefully**
  - Considering the perspective of an outsider can result in improved decision-making and results
- **More innovative**
  - Diversity boosts intellectual potential
  - Conformity discourages innovative thinking

SOURCE: https://hbr.org/2016/11/why-diverse-teams-are-smarter

# Be an MRO Diversity Ambassador

- **Help us reach a wider pool of applicants**
  - Share MRO LinkedIn posts with your network
  - Discuss and share the request for nominations within your organizations
- **Participation is a developmental opportunity**
- **Nominate and elect diverse candidates**

# Nominations & Elections

- Nominations period will open in September (Date TBD)
- Organizational Group Membership Recommendations made during Q4 Meetings

# Thank you!

## Questions?

Contact
**Julie Peterson**
MRO Assistant Corporate Secretary and Senior Counsel
julie.peterson@mro.net

# AGENDA 5

**Consent Agenda**

a. Approve May 3, 2022 Meeting Minutes

*Greg Sessler, Protective Relay Subgroup Chair*

## Action

Discussion

## Report

Chair Sessler will lead this discussion during the meeting.

MIDWEST RELIABILITY ORGANIZATION

380 St. Peter St, Suite 800
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# Draft Minutes of the Protective Relay Subgroup Meeting

**Webex**

*May 3, 2022, 8:02 a.m. to 11:12 a.m. Central*

*Notice for this meeting was electronically posted to the MRO website here on April 5, 2022. A final agenda, including advanced reading materials, was also posted on April 26, 2022.*

## 1. Call to Order and Determination of Quorum

Protective Relay Subgroup (PRS) Chair Greg Sessler called the meeting to order at 8:02 a.m. Sessler welcomed everyone and brief introductions were made by those on the call. Rebecca Schneider, Reliability Analysis Administrator, advised the chair that a quorum of the PRS was present. A complete list of attendees is included as Exhibit A.

## 2. Standards of Conduct and Antitrust Guidelines

Pursuant to Policy and Procedure 4, Senior Systems Protection Engineer, Jake Bernhagen highlighted MRO's Standards of Conduct, Conflict of Interest, and Antitrust Guidelines

## 3. Consent Agenda

The PRS reviewed the consent agenda, which included draft minutes from the February 22, 2022 open and closed meetings.

*Upon a motion duly made and seconded, the Protective Relay Subgroup approved the consent agenda, which included minutes from the February 22, 2022 PRS meeting as written.*

## 4. Chair's Report

Chair Sessler highlighted the desire for technical presentations at upcoming PRS meetings and encouraged subgroup members to contribute newsletter articles for Midwest Reliability Matters. He also noted that the upcoming PRS meeting in mid-August will be hybrid (in-person and virtual).

## 5. PRS Business

*Updates.*
Bernhagen invited members to reach out to MRO if they have an interesting topic to share with the region as a possible newsletter article.

*PRS Charter Review.*
The PRS reviewed the 2022 charter and no changes were recommended.

*PRS Number of Members Discussion.*
As a follow-up to a previous PRS discussion, Bernhagen provided an explanation as to why MRO did not support removing the limit on the number of PRS members at this time. He noted that the PRS could increase its membership by two members in fall 2022 during open nominations, if the group decided it was necessary or beneficial. Discussion ensued.

*Action Item List Review.*
Chair Sessler reviewed the action item list and updates were made accordingly.

**6. NERC Activities**

*Update on NERC System Protection and Control Working Group (SPCWG).*
Mark Gutzmann, MRO representative on the NERC SPCWG, provided an overview of the April 14, 2022 conference call. The February 2021 cold weather recommendation update was discussed. Two recommendations from that report were directed towards the SPCWG (recommendation 13 and 22). There was an inter-entity short circuit model update by Lynn Schroeder. There was a review of compliance implementation guidance for PRC-019 and PRC -024. There is a SAR being reviewed and discussed related to PRC-025 for hybrid plants. FERC order 881 was also discussed. Discussion ensued.

*NERC Misoperation Information Data Analysis System User Group (MIDASUG) Update.*
Bernhagen provided an update from the April 5, 2022 meeting. There was a discrepancy between the data reporting instructions and the website regarding fault type. NERC will update the Data Reporting Instructions (DRI) to reflect that fault type is not a required field. A regional entity asked about capacitor bank reporting requirements for misoperations during the April meeting. NERC reviewed changes to the MIDAS portal. Discussion ensued.

*FERC/NERC Protection System Commissioning Program Review Update.*
Senior Power Systems Engineer, Max Desruisseaux provided an update of the FERC/NERC Protection System Commissioning Program Review webinar tentatively scheduled for July 14, 2022. MRO has decided to include case studies and share best practices. NERC proposed discussing EA events tied to commission-related issues. Bernhagen will present MIDAS data tied to commissioning practices. PRS members, Sarah Marshall, Cody Remboldt and Ryan Einer are assisting with the webinar presentation. The PRS may be invited to attend a dry run of the webinar presentation. Discussion ensued.

*Transmission Availability Data System (TADS)*.
Principal Systems Protection Engineer, John Grimm provided an update regarding TADS. Due to an application update, the deadline for Q1 and Q2 reporting is August 15, 2022. The update will affect the forms, but a prolonged outage is not expected. TADS training is scheduled for October 11-12, 2022. Discussion ensued.

**7. Misoperations**

**Fourth Quarter 2021 Results and Review and Discussion.**
*MIDAS and Misoperations Q4 Update.*
Bernhagen provided an overview of fourth quarter misoperations data. There were 30 total misoperations during the quarter. MRO's 2021 misoperation rate finished above the NERC average. Total operations were significantly lower than previous years, and misoperationss are slowly trending downward. Bernhagen illustrated that the highest percentage of misoperations by cause subdivided by relay type were human error associated with microprocessor relays. He also noted that an apparent increase in overcurrent misoperations requires further investigation. Discussion ensued

**Project Updates**
*Instantaneous Ground Overcurrent*.

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Bernhagen provided an update for this ongoing project. He solicited volunteers from the PRS to review the data to determine if there is enough information to pursue a white paper. PRS members and guests, Adam Daters, Greg Sessler and Kenneth Casperson, volunteered to work on the project.

**Event Analysis Report**
Bernhagen reviewed the misoperations review process at MRO and noted that he would like to improve the review process. He discussed the process that WECC used during a recent meeting where they performed misoperations review during a relay subgroup call in a closed session. Bernhagen proposed that the PRS try reviewing misoperations during the fourth quarter meeting in breakout groups during a closed session. There was a proposal to move the November 15, 2022 meeting to the first week of December to align with the MIDAS reporting due date. Discussion ensued.

Bernhagen provided an update of the events to date. There have been eight qualified events in 2022: six category 1a events (loss of three of more BES elements) and two category 1h events (loss of EMS/SCADA).

*Review Lessons Learned.*
Bernhagen led a discussion of the six new lessons learned posted on the NERC website. Discussion ensued.

*Seek Input for T-Line Icing Lessons Learned.*
Bernhagen reported that an entity asked NERC for best practices related to high wind events. He participated on a review team working on the lessons learned. They discussed the preparations and mitigations for wild fires and high winds in the West as well as icing in the Midwest and Northeast. The review team grouped the lessons learned into three parts: 1) high winds, 2) high winds and fire, and 3) high winds and icing. Bernhagen asked the PRS members to research what their organizations do to prepare for high wind events and provide feedback or reach out to him with the appropriate contact information.

**8. Summer 2021 BES Events**

Desruisseaux provided an overview of the summer 2021 BES events and the Energy Emergency Alerts. There were a total of 17 events in 2021. Six events during summer 2021 were highlighted, all involving protection system misoperations. Discussion ensued.

**9. FERC Order 881 – Ambient Adjusted Ratings and FERC NOI – Dynamic Line Ratings**

Principal Technical Advisor, John Seidel, provided an overview of FERC Order 881 at the meeting. He noted that FERC Order 881 ties into PRC-023. He explained that FERC made the ruling on Ambient Adjusted Ratings (AARs) because transmission line ratings can directly affect wholesale electricity rates. He mentioned that NERC standard FAC-008-5 may be revised to include the new ruling. Seidel noted that Dynamic Line Ratings (DLR) are still in the notice of inquiry phase, and the ruling has not been posted. Seidel also noted that DLRs may not be required for all BES facilities. Discussion ensued.


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Outreach & Engagement
ASSURANCE
Oversight & Risk Management
RESULTS
Reliablity Performance

**10. 2022 Dates**

Chair Sessler reviewed the meeting dates for the PRS and the other councils and subgroups. A new date was proposed for the fourth quarter hybrid meeting, and there was no objection from the subgroup. The meeting will take place on December 6, 2022.

**11. PRS Roundtable Discussion**

The PRS members next participated in a roundtable discussion. The following topics were highlighted:

- PRC-004-6 – the NERC Inverter Based Resource Performance Subcommittee (IRPS) has created a draft SAR for PRC-004-6 to revise the standard to explicitly require IBR loss analysis and corrective action to identify misoperations.
- Switch-on-to-Fault (SOTF) – PRS member, Sarah Marshall surveyed the subgroup related to SOTF, which is a safety feature built into microprocessor relays designed to trip quickly when a breaker is inadvertently closed into a faulted line. Sarah was interested if any entities used SOTF on their distribution assets and, if so, how it is implemented. Alliant Energy uses SOTF protection on their distribution assets. Discussion ensued.

**12. Other Business and Adjourn**

Having no further business to discuss, the meeting was adjourned at 11:12 a.m.

**Prepared by:** Rebecca Schneider, Reliability Analysis Administrator
**Reviewed and Submitted by:** Jake Bernhagen, Senior Systems Protection Engineer

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## Exhibit A – Meeting Attendees

| Subgroup Members Present | |
|---|---|
| **Name** | **Company** |
| Greg Sessler, Chair | American Transmission Company |
| David Wheeler, Vice Chair | Southwestern Public Services Co. |
| Adam Daters | ITC Holdings |
| Alex Bosgoed | Saskatchewan Power Corporation |
| Casey Malskeit | Omaha Public Power District |
| Cody Remboldt | Montana-Dakota Utilities |
| David Weir | Western Area Power Administration |
| Dennis Lu | Manitoba Hydro |
| Derek Vonada | Sunflower Electric Power Cooperative |
| Derrick Schlangen | Great River Energy |
| Greg Hill | Nebraska Public Power District |
| Jeff Beasley | Grand River Dam Authority |
| Josh Erdmann | Xcel Energy |
| Matt Boersema | Western Farmers Electric |
| Ryan Einer | Oklahoma Gas & Electric |
| Sarah Marshall | Alliant Energy |
| Scott Paramore | Kansas City Board of Public Utilities |
| Terry Fett | Central Iowa Power Cooperative |
| **Subgroup Members Not Present** | |
| **Name** | **Title** |
| Glenn Bryson | American Electric Power |
| | |
| | |

| MRO Staff | |
|---|---|
| **Name** | **Title** |
| Jake Bernhagen | Senior Protection Systems Engineer |
| Rebecca Schneider | Reliability Analysis Administrator |
| Lisa Stellmaker | Executive Administrator |
| John Grimm | Principal Systems Protection Engineer |
| John Seidel | Principal Technical Advisor |
| Max Desruisseaux | Senior Power Systems Engineer |
| **Guests** | |
| **Name** | **Company** |
| Mark Gutzmann | Xcel Energy |
| Terry Fett | Central Iowa Power Cooperative |
| Allen Halling | Evergy |
| Terry Volkmann | Glencoe Light and Power |
| Catherine Jacobs | ITC Holdings |
| Steve Klecker | MidAmerican Energy |
| Chad Whisman | American Electric Power |
| Mark Hopkins | Evergy |
| Kenneth Casperson | ITC Holdings |

# AGENDA 6

**NERC Activities**

a. NERC SPCWG Update

*Mark Gutzmann, Director, System Protection & Communication Engineering, Xcel Energy*

## Action

Information

## Report

Mark Gutzmann will provide an oral report during the meeting.

# AGENDA 6

**NERC Activities**

b. NERC MIDASUG Update

*Jake Bernhagen, Senior Systems Protection Engineer, MRO*

## Action

Information

## Report

Jake Bernhagen will provide an oral report during the meeting.

# AGENDA 6

**NERC Activities**

c. TADS

*John Grimm, Principal Systems Protection Engineer, MRO*

## Action

Information

## Report

John Grimm will provide an oral report during the meeting.

# AGENDA 7

**PRS Business**

a. Updates

*Jake Bernhagen, Senior Systems Protection Engineer, MRO*

## Action
Information

## Report
Jake Bernhagen will provide an oral report during the meeting.

# AGENDA 7

**PRS Business**

b. Action Item List Review

*Greg Sessler, Protective Relay Subgroup Chair*

## Action

Information

## Report

Chair Sessler will lead this discussion during the meeting.

# AGENDA 8

**Misoperations**

a. Q1 2022 Results, Review and Discussion

*Jake Bernhagen, Senior Systems Protection Engineer, MRO*

## Action

Information

## Report

Jake Bernhagen will provide an oral report during the meeting.

# AGENDA 8

**Misoperations**

b. Technical Presentations

i. Harrington Substation Event

ii. SPS Load Shed Philosophy

*Kevin Jones, Consulting Engineer, System Protection Engineering, Xcel Energy*

## Action

Information

## Report

Kevin Jones will provide an overview during the meeting.

# HARRINGTON BUS #3 OUTAGE
# JANUARY 14, 2022

**Kevin W. Jones, Consulting Engineer, System Protection Engineering**

**Presented to MRO Protective Relay Subgroup (PRS)**

**August 16, 2022**

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# OUTLINE OF EVENT

1. Transmission Work Request (TWR) Work Summary
2. TWR Work Execution
3. Unexpected Outcome
4. Event Root Cause Analysis
5. Lessons Learned
6. Conclusions

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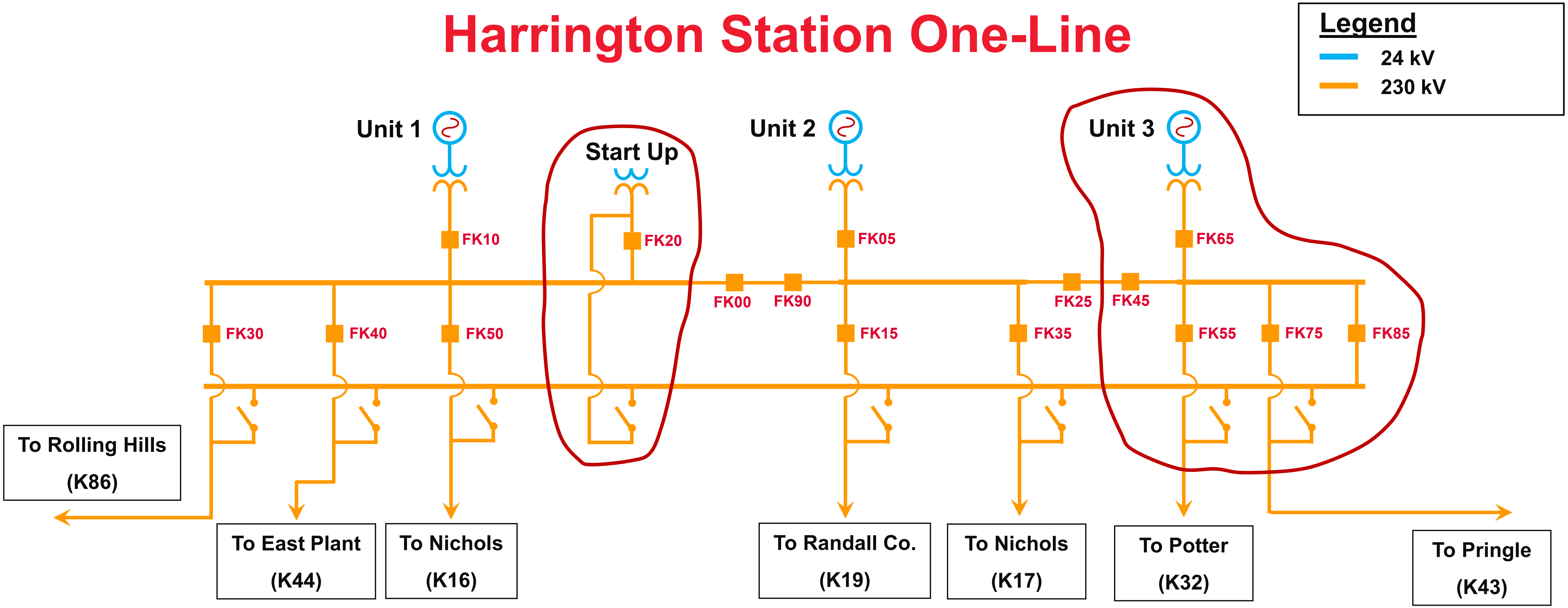
# Harrington Station One-Line

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# Transmission Work Request (TWR) Work Summary

- ❑ Put transfer breaker FK85 in FK20 (start-up transformer) position
- ❑ Preliminary work requires changing FK85 primary and secondary relay CT ratios from 400:1 to 240:1 to allow distance elements to see to low-side of start-up transformer
- ❑ Once CT ratios have been changed, transfer switch to bypass FK20 can be closed

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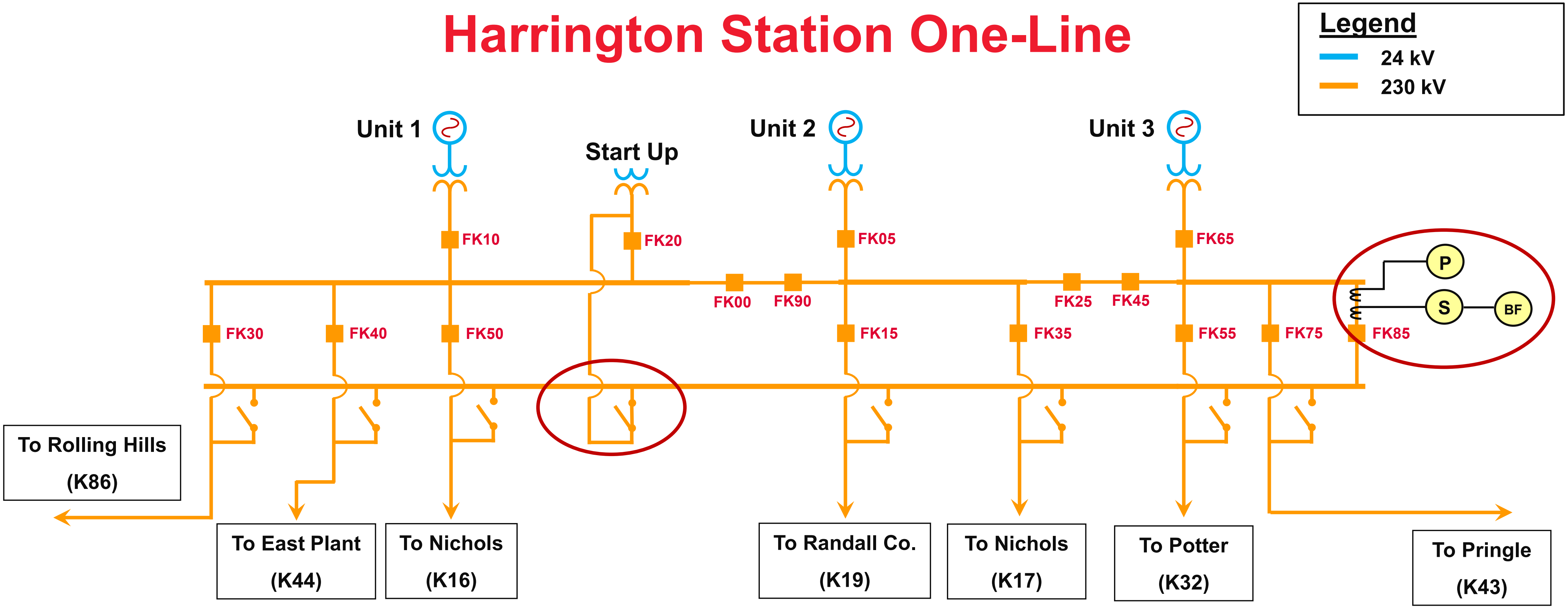
# Harrington Station One-Line

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# TWR Work Execution

- Previous TWR's to change CT ratios were successfully executed as follows:
  - Leave primary and secondary line relays and breaker failure relay in service
  - Go to transfer breaker FK85 to make CT ratio changes
  - Short secondary relay CT's then short primary relay CT's
  - Make CT ratio changes on secondary relay
  - Make CT ratio changes on primary relay
  - Unshort secondary relay CT's
  - Unshort primary relay CT's

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# Unexpected Outcome

- Steps were followed in sequence as had been done successfully in the past:
  - Short secondary relay phase “A” CT – **Success**
  - Short secondary relay phase “B” CT – **Success**
  - Short secondary relay phase “C” CT – **Success**

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# Unexpected Outcome

- ❑ Steps were followed in sequence as had been done successfully in the past:
  - ➢ Short primary relay phase "A" CT – **Success**
  - ➢ Short primary relay phase "B" CT – **Success**

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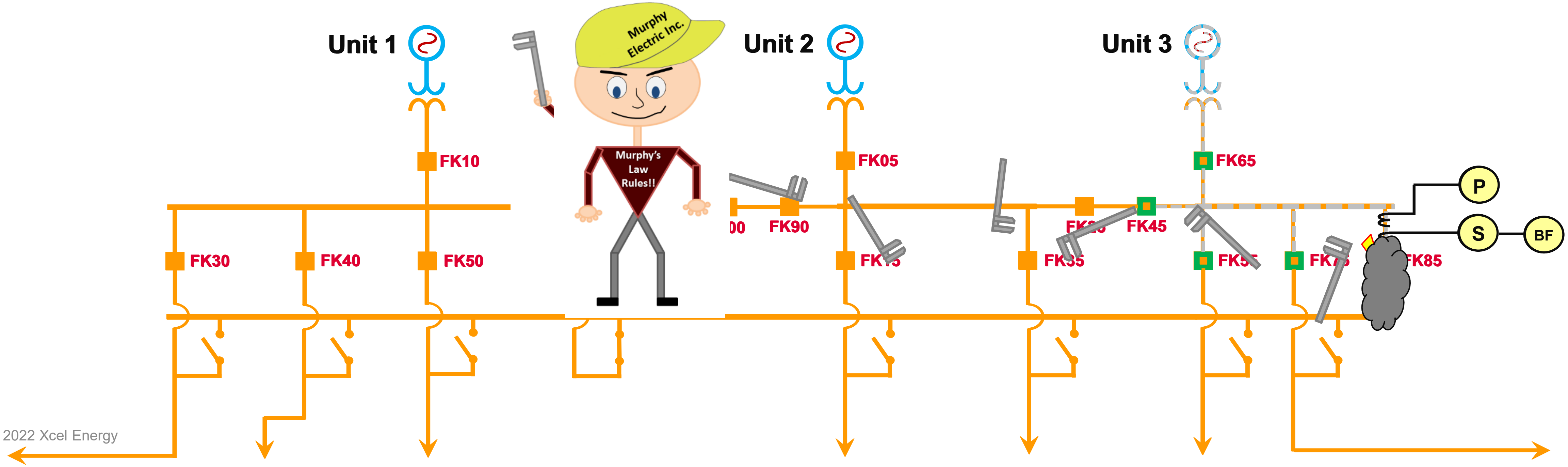
# Unexpected Outcome

- ❑ Steps were followed in sequence as had been done successfully in the past:
  - ➢ Short primary relay phase “A” CT – **Success**
  - ➢ Short primary relay phase “B” CT – **Success**
  - ➢ Shorting primary relay phase “C” CT – **?????**

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# Root Cause Analysis – What Happened???

- ❑ Relay Technician checked for relay targets in the control house and found a trip on the primary relay (SEL-421) and a trip on the breaker failure relay (SEL-501)
- ❑ Relay event records were downloaded and sent to System Protection Engineering for analysis

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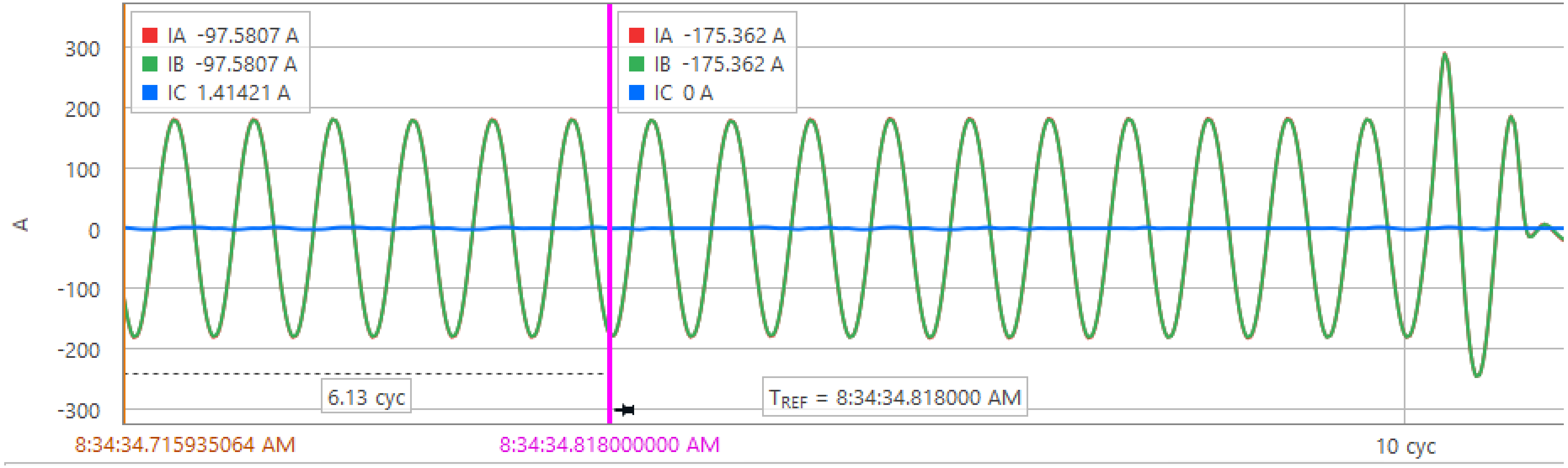
# Root Cause Analysis – Primary Transfer Breaker Relay




- ❑ “A” and “B” phase show primary current and both are exactly in phase
- ❑ “C” phase current is zero

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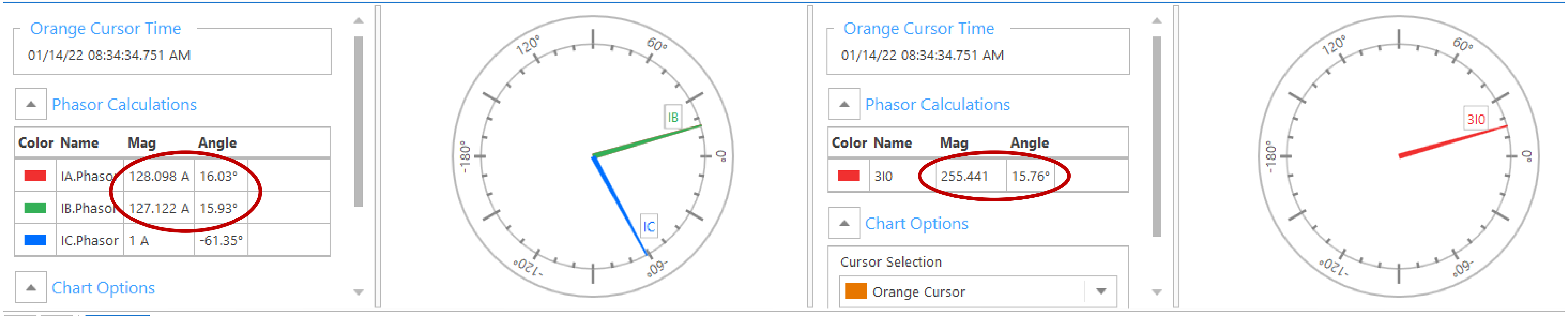
# Root Cause Analysis – Primary Transfer Breaker Relay




- ❑ "A" and "B" phase RMS phasors added together yield 3I0 of 255 amps, primary

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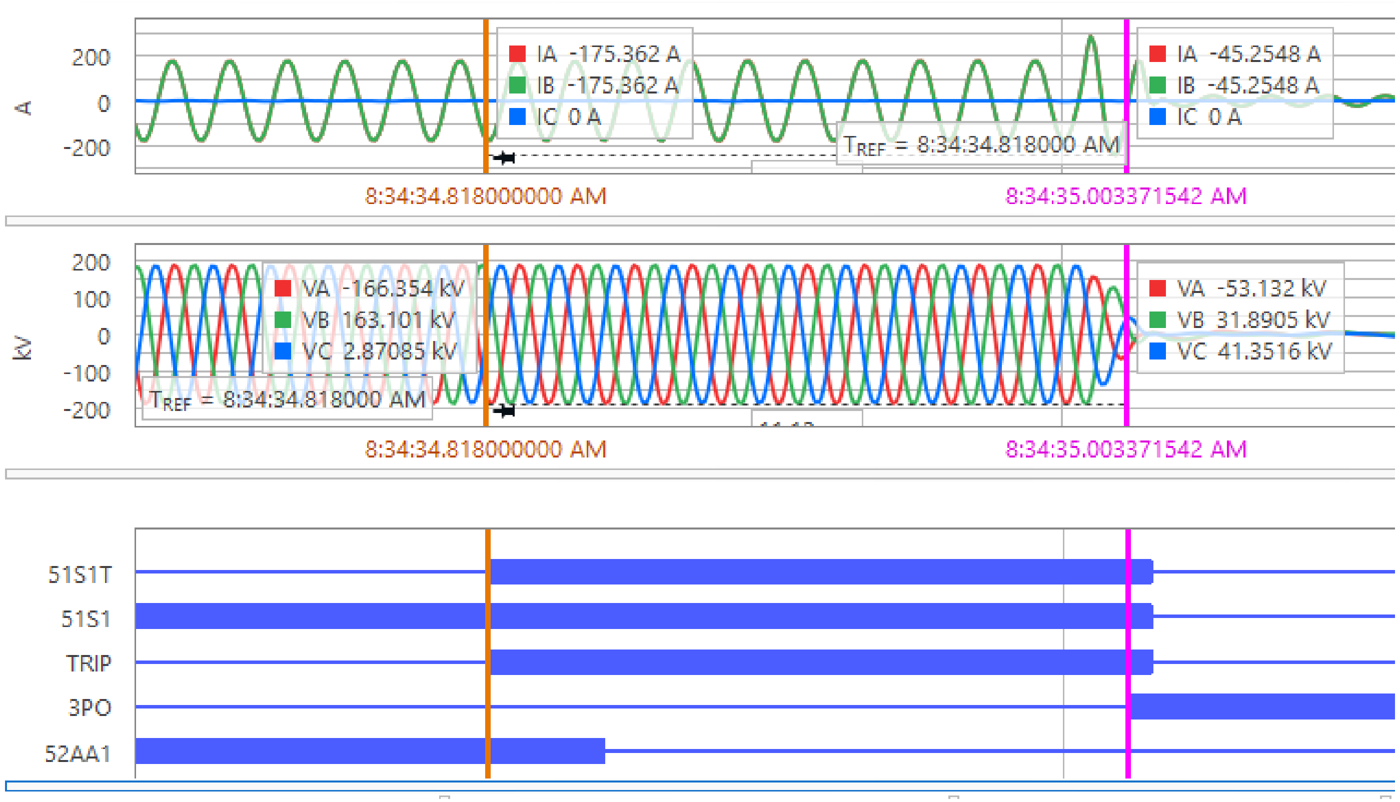
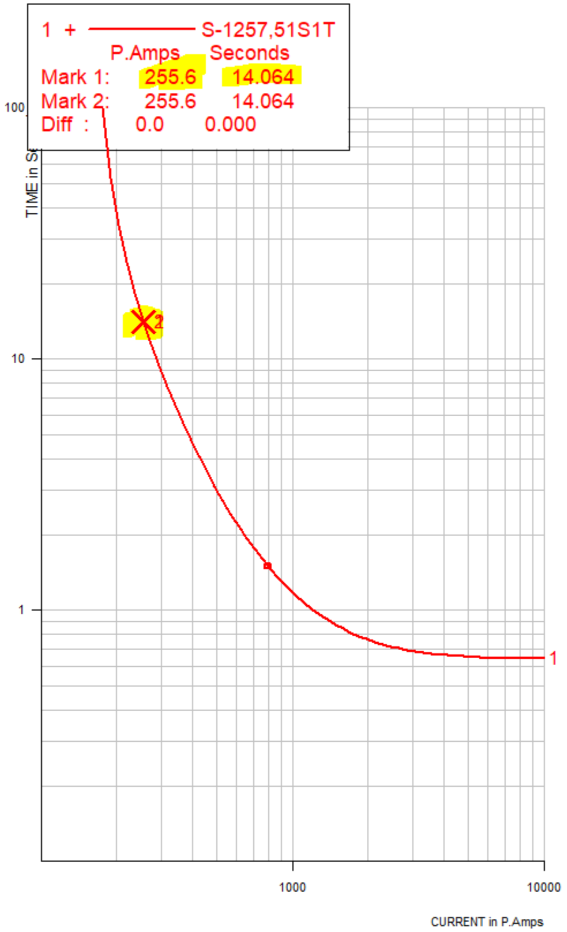
# Root Cause Analysis – Primary Transfer Breaker Relay




- ❑ Ground TOC 51S1 pickup is 160 amps, primary
- ❑ With 255 amps 3I0, 51S1T trip would occur in about 14 seconds after “B” phase was shorted

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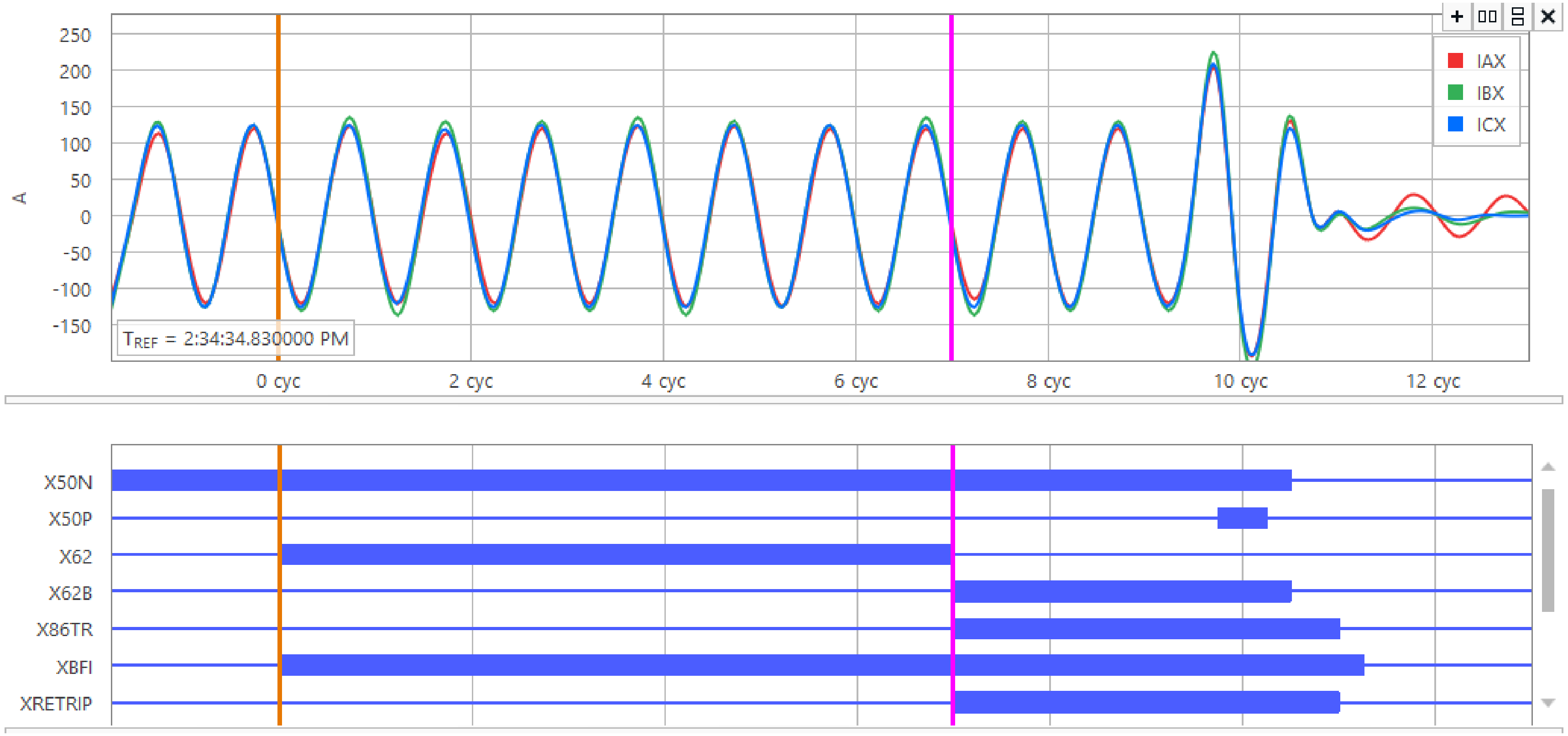
# Root Cause Analysis – Breaker Failure Relay




- ❑ All three phase currents are in-phase and at the same magnitude, similar to the SEL-421 relay

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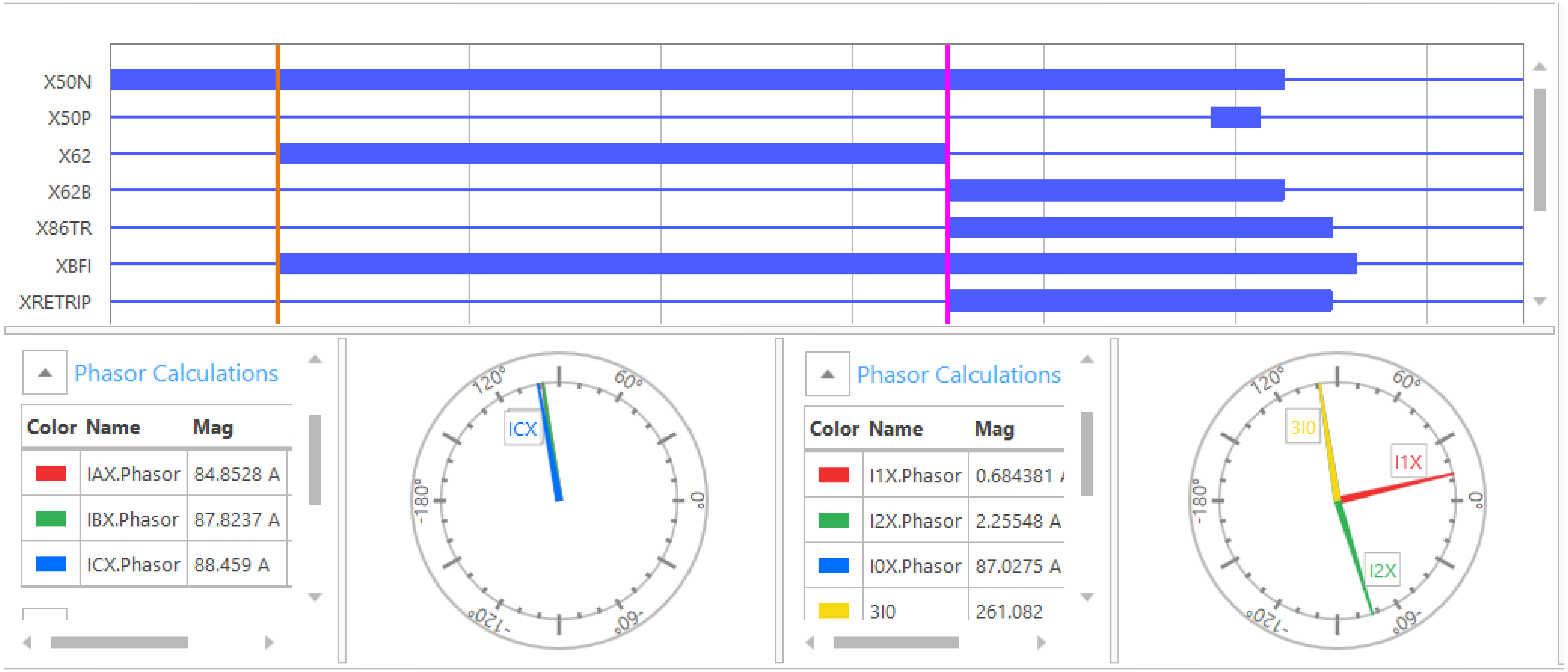
# Root Cause Analysis – Breaker Failure Relay




- ❑ 3I0 current is above the 200 amp primary pick-up threshold for the duration of the event

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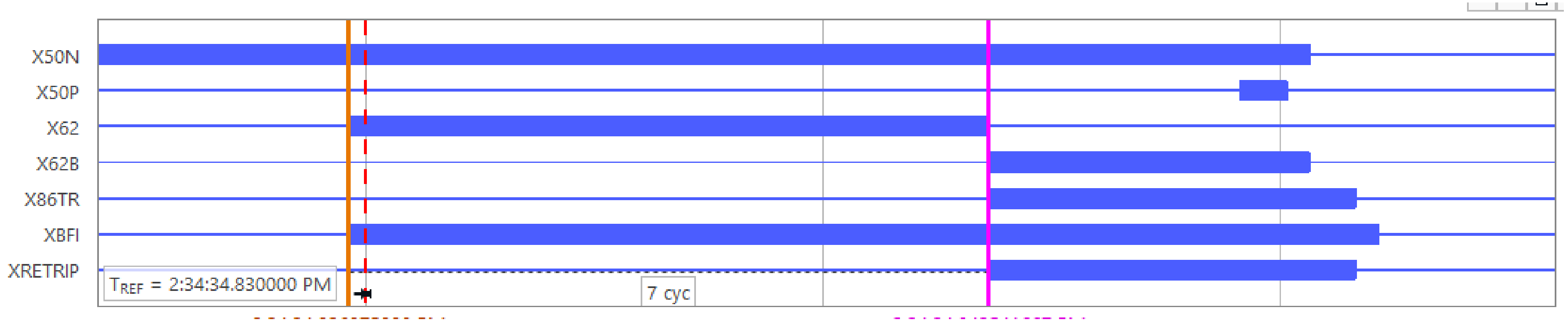
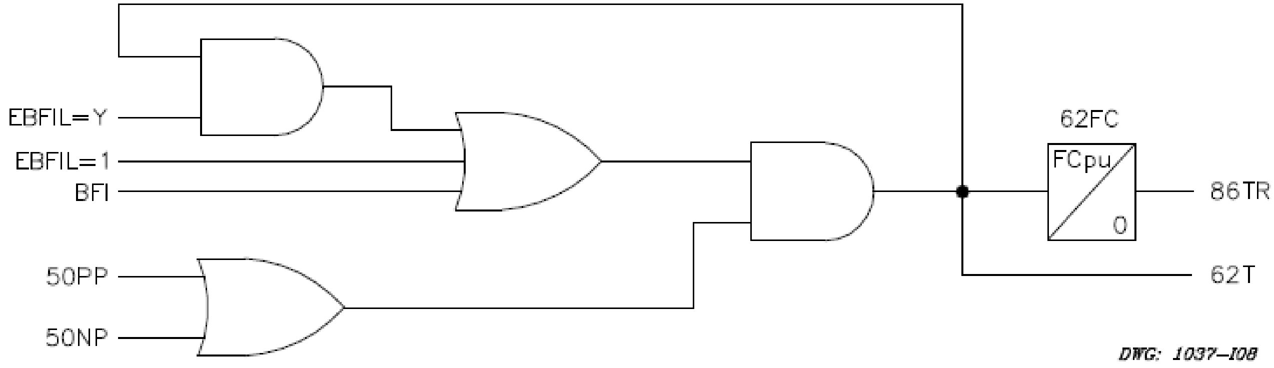
# Root Cause Analysis – Breaker Failure Relay




- ❑ BFI asserts when the SEL-421 trip output closes
- ❑ 50N is picked up due to residual current being above the 200 amp primary set-point
- ❑ Breaker failure trip occurs after 7-cycle timer expires

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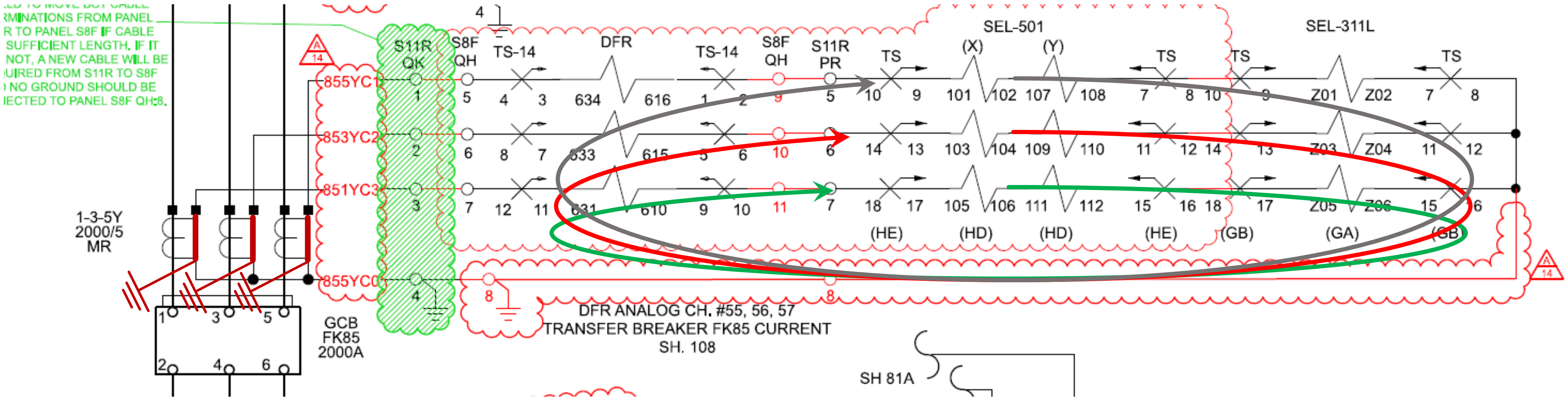
# Root Cause Analysis – Why Did the Trips Occur???



- ❑ The secondary relay CT circuit was shorted first with no issues
- ❑ When the shorts were applied, two grounds were present on each phase separated by about 500 feet, allowing stray AC ground grid currents to circulate in the SEL-311L and SEL-501 BF relays

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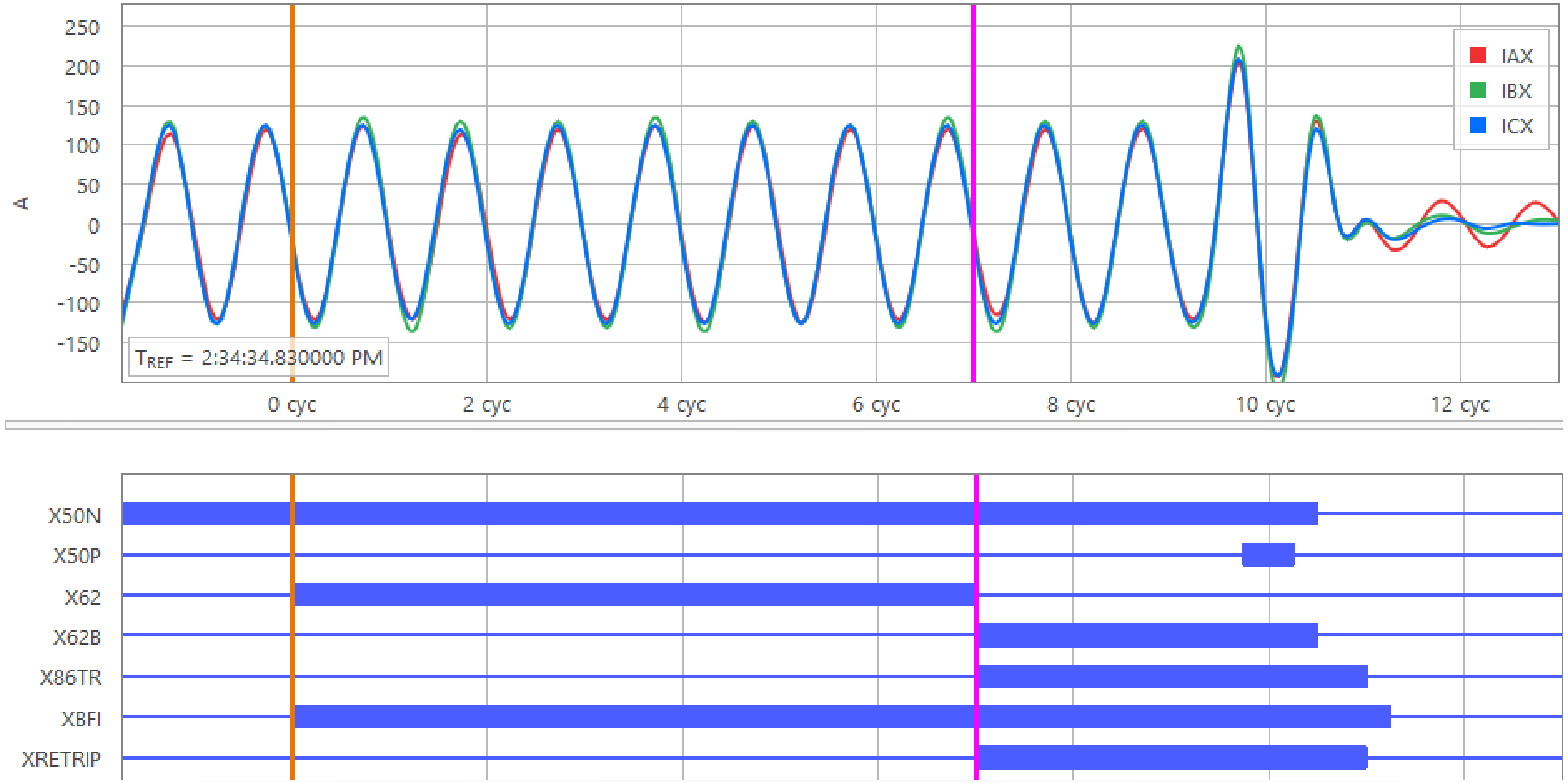
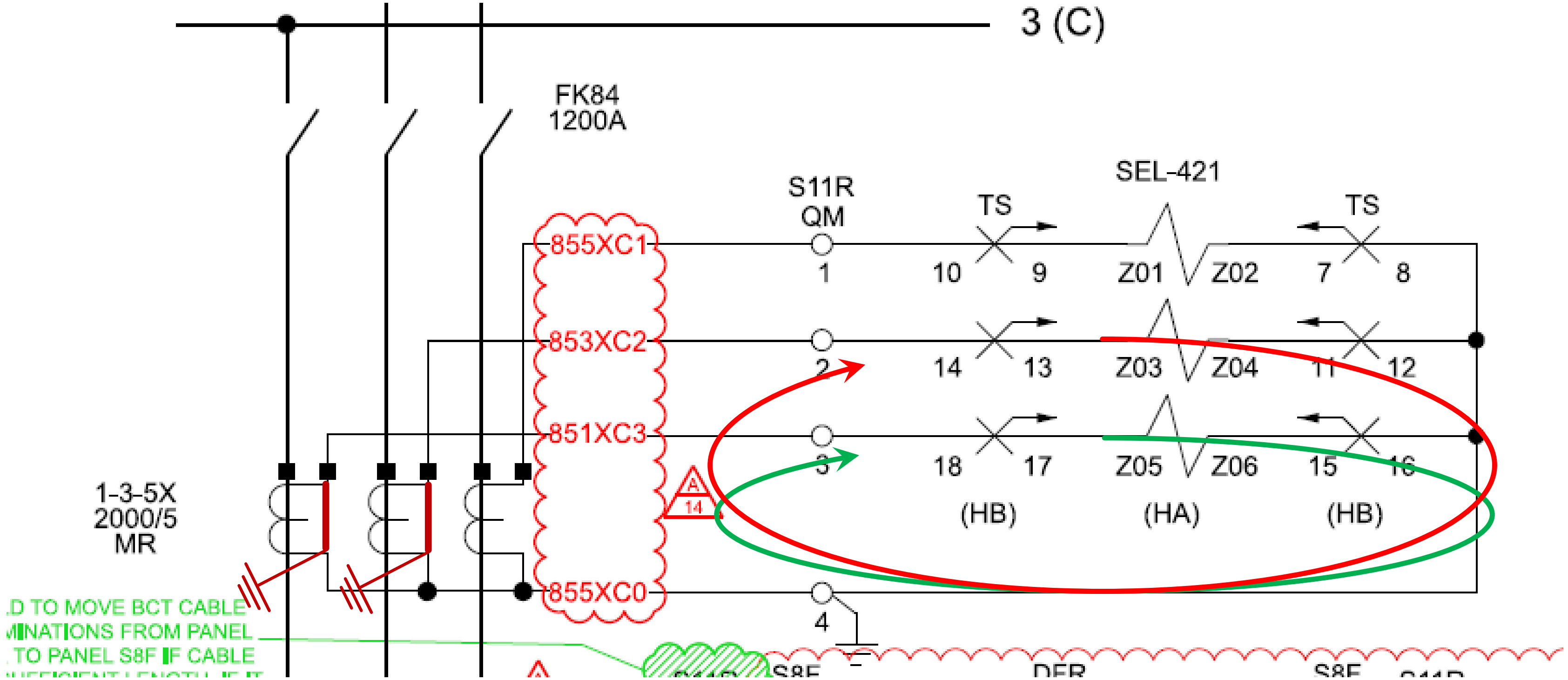
# Root Cause Analysis – Why Did the Trips Occur???




- ❑ About 0.22 amps secondary stray AC current was induced in all three phases of the SEL-501 BF relay, translating to about 88 amps primary per phase
- ❑ With all three phases being in phase, a residual current of 260 amps primary asserted the 50N element

# Root Cause Analysis – Why Did the Trips Occur???




- About 0.32 amps secondary stray AC current was induced in each shorted SEL-421 relay phase, translating to about 128 amps primary
- The first short of phase “A” was 80% of the ground TOC pickup; the second short of phase “B” was 160% of ground TOC pickup

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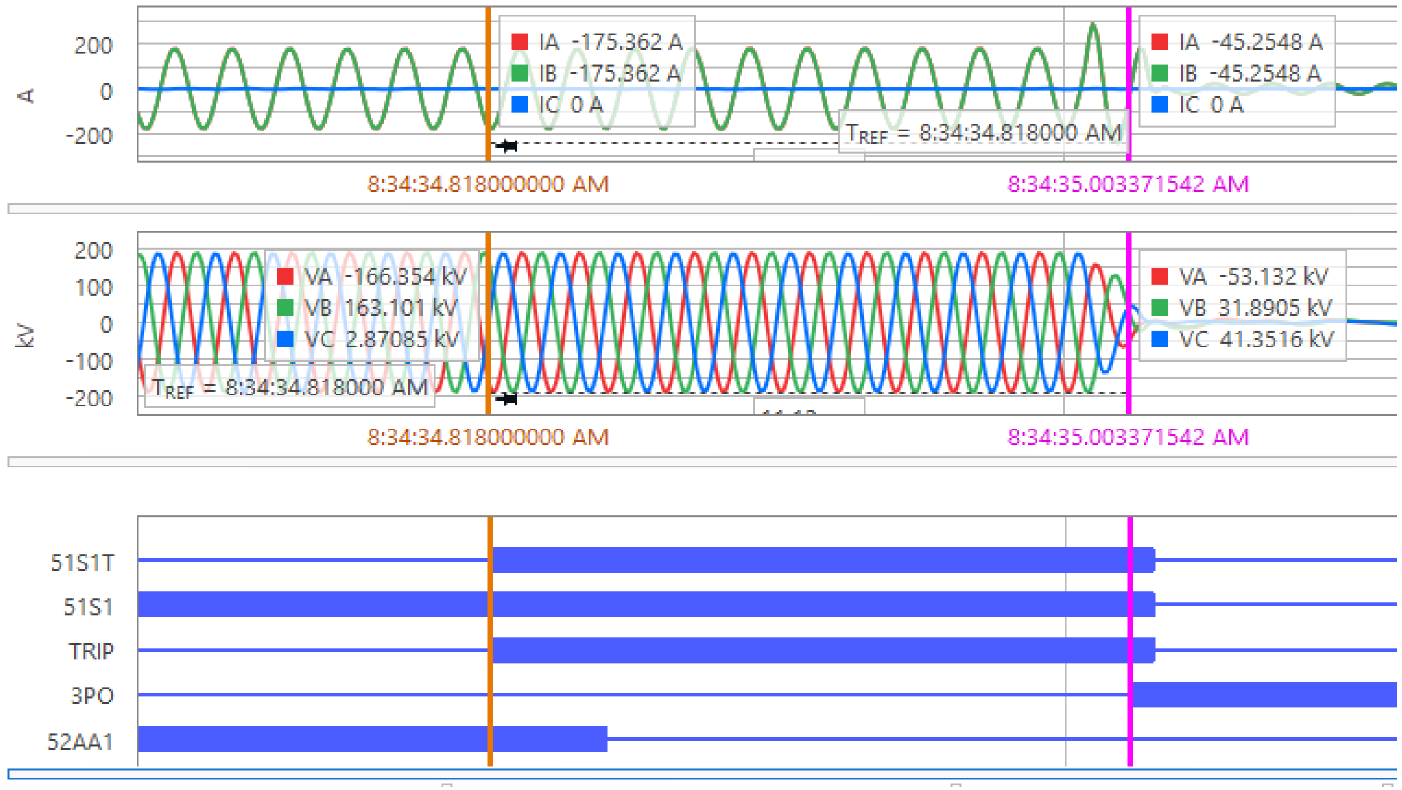
# Root Cause Analysis – Why Did the Trips Occur???




- ❑ Once the second SEL-421 CT was shorted, ground TOC tripping and breaker failure tripping was inevitable and unavoidable

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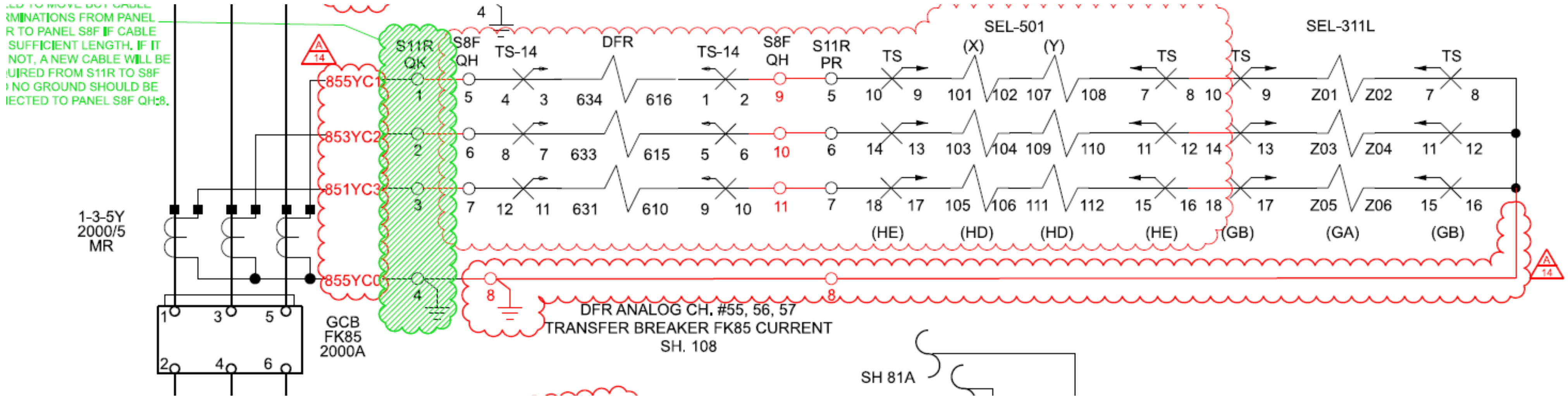
# Lessons Learned




- ❑ Work on one CT circuit at a time!!!
- ❑ Disable relay trips and short relay currents at relay test switch for each relay in CT circuit being worked
- ❑ Short CT’s, change ratio, unshort CT’s
- ❑ Ensure no relay targets on disabled relay(s), then enable relay trips and currents

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# Conclusions

- ❑ ANY work on CT circuits should be done with extreme care and thoughtful planning
- ❑ The most efficient way to perform work does not guarantee the most efficient outcome
- ❑ Job tasks should not be done the same way they were done in the past without thinking through all the steps and pondering negative possibilities

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# NEW SPS UFLS PROGRAM

Kevin W. Jones, Consulting Engineer, System Protection Engineering

Presented to MRO Protective Relay Subgroup (PRS)

August 16, 2022

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# OUTLINE OF PRESENTATION

1. Need to rethink existing UFLS program
2. Existing program details and performance
3. New program details and performance
4. Next steps to implement new program
5. Conclusions

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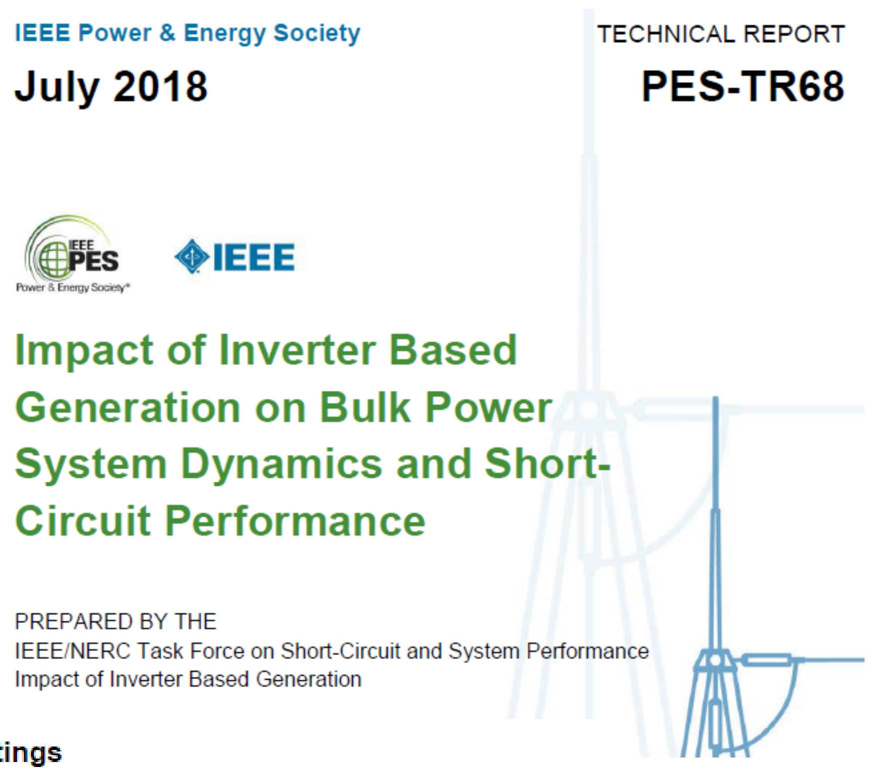
# Need to Rethink Existing UFLS Program

- High penetrations of renewable resources are depleting system inertia
- Lower system inertia results in higher Rate-of-Change-of-Frequency (RoCoF)



IEEE Power & Energy Society

TECHNICAL REPORT

July 2018

PES-TR68

Impact of Inverter Based Generation on Bulk Power System Dynamics and Short-Circuit Performance

PREPARED BY THE
IEEE/NERC Task Force on Short-Circuit and System Performance
Impact of Inverter Based Generation

**3.2.9 UFLS Frequency Time Delay Settings**

Under Frequency Load Shed (UFLS) is necessary to keep load and generation in an electrical island balanced and as close to the nominal system frequency (60 Hz for North America) as possible after the loss of significant amounts of generation or after the loss of significant power imports following a system separation event. The rapid influx of IBR has both offset and replaced conventional fossil generation resources. Because of this, lower levels of system inertia are available at any given time, which results in more rapid frequency decay following a loss of generation or power imports.

K. Jones, P. Pourbeik, Et. Al., "Impact of Inverter Based Generation on Bulk Power System Dynamics and Short Circuit Performance", July, 2018. Available: Impact of Inverter Based Generation on Bulk Power System Dynamics and Short-Circuit Performance (TR68) (ieee-pes.org)

# Existing Program Details and Performance

- ❑ The planning coordinator for the Xcel Energy NM/TX region is the Southwest Power Pool (SPP)
- ❑ Per NERC standard PRC-006, SPP developed a UFLS program summarized below:

| UFLS Step | Frequency (Hz) | Minimum Accumulated Load Relief as Percentage of Forecasted Peak Load (%) | Maximum Accumulated Load Relief as Percentage of Forecasted Peak Load (%) |
|---|---|---|---|
| **1** | **59.3** | 10 | 25 |
| **2** | **59.0** | 20 | 35 |
| **3** | **58.7** | 30 | 45 |

  - Intentional time delay less than or equal to 30 cycles
  - Undervoltage inhibit less than or equal to 85% nominal voltage

- ❑ Xcel Energy NM/TX uses normal intentional time delays of 6 cycles and RoCoF supervision to prevent feeder trips on motor spin-down
- ❑ Xcel Energy NM/TX uses an undervoltage inhibit setting of 67%

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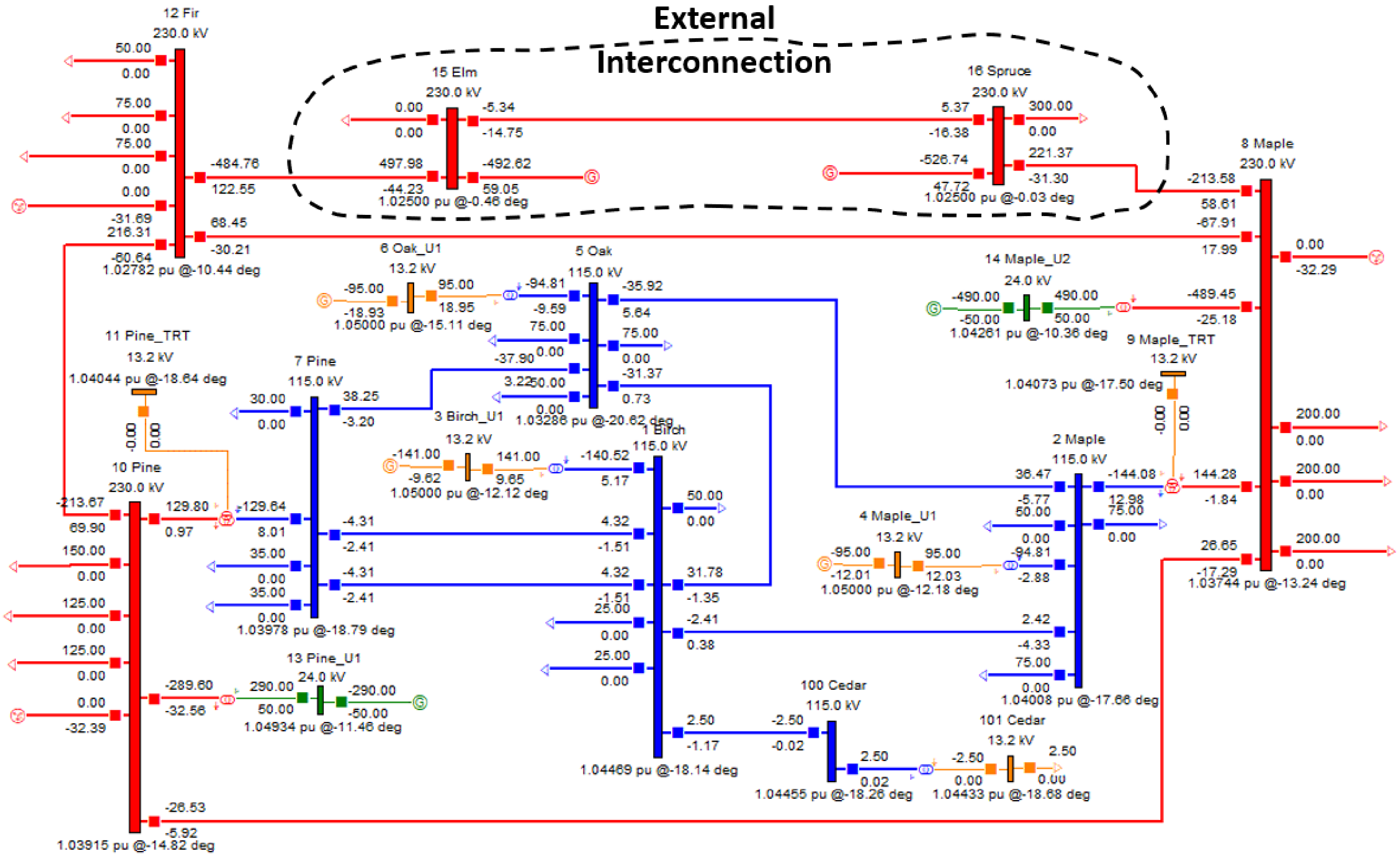
# Existing Program Details and Performance

- The existing UFLS program was tested using a generic system model in CAPE TS-Link:

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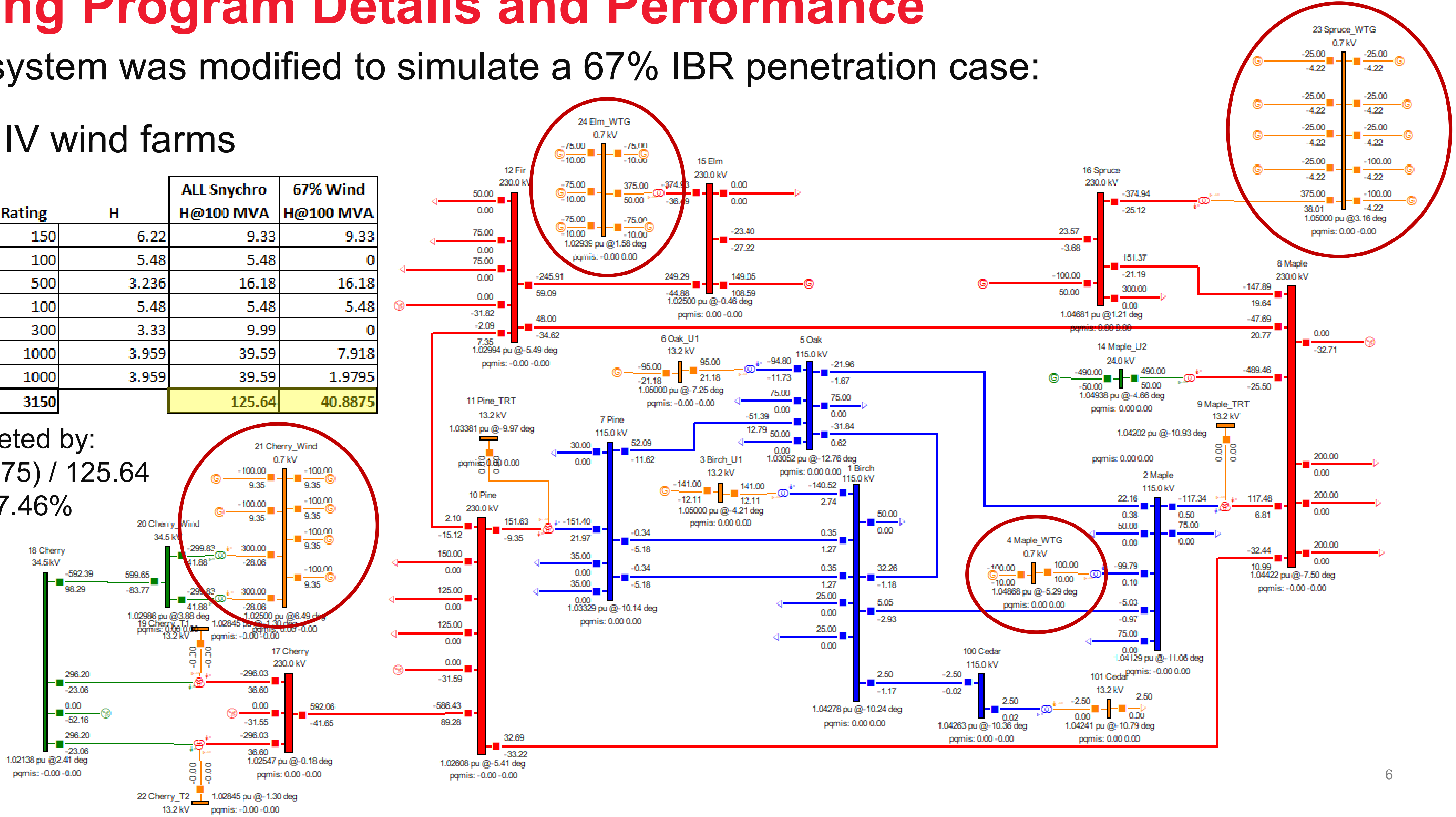
# Existing Program Details and Performance

- ❑ The system was modified to simulate a 67% IBR penetration case:
- ❑ Type IV wind farms

| Generator | MVA Rating | H | ALL Snychro H@100 MVA | 67% Wind H@100 MVA |
|---|---|---|---|---|
| Birch_U1 | 150 | 6.22 | 9.33 | 9.33 |
| Maple_U1 | 100 | 5.48 | 5.48 | 0 |
| Maple_U2 | 500 | 3.236 | 16.18 | 16.18 |
| Oak_U1 | 100 | 5.48 | 5.48 | 5.48 |
| Pine_U1 | 300 | 3.33 | 9.99 | 0 |
| Elm | 1000 | 3.959 | 39.59 | 7.918 |
| Spruce | 1000 | 3.959 | 39.59 | 1.9795 |
| TOTAL | 3150 | | 125.64 | 40.8875 |

Inertia depleted by:
(125.64 – 40.8875) / 125.64 * 100 = 67.46%

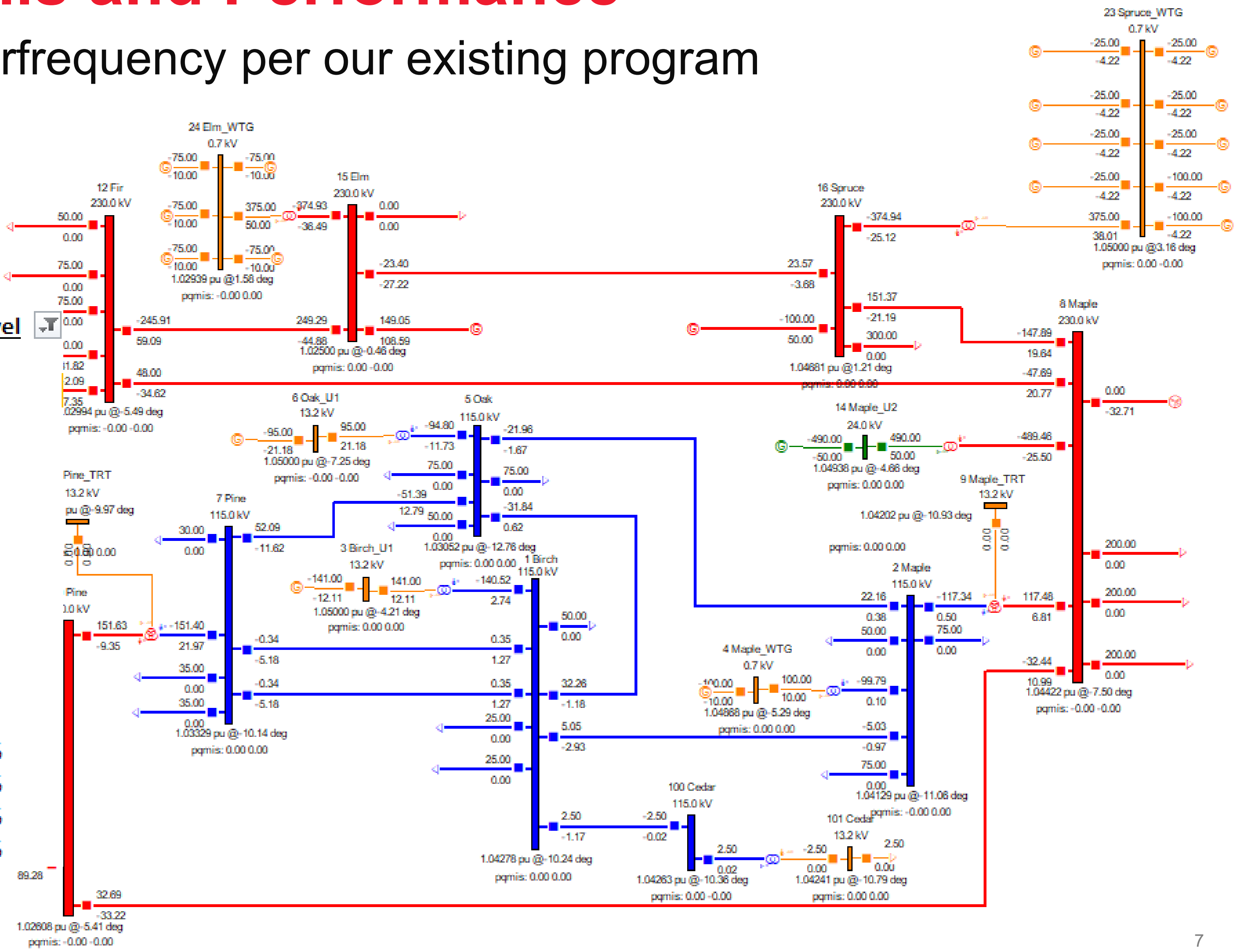


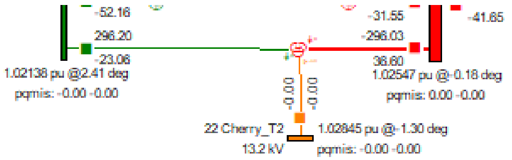
# Existing Program Details and Performance

- ❑ Loads were set to trip on underfrequency per our existing program
- ❑ 10% in each level
- ❑ 6-cycle time delay

| Substation | Load Label | Load (MW's) | UFLS Level |
|---|---|---|---|
| Birch | 1-1 | 50 | 3 |
| Fir | 12-2 | 75 | 2 |
| Fir | 12-3 | 50 | 1 |
| Maple | 2-1 | 75 | 3 |
| Maple | 2-2 | 75 | 3 |
| Maple | 2-3 | 50 | 2 |
| Oak | 5-2 | 75 | 2 |
| Pine | 10-1 | 150 | 1 |
| | | | |
| TOTAL | | 1800 | |

| | | | |
|---|---|---|---|
| Level 1 Total | 200 | MW's | 10.00% |
| Level 2 Total | 200 | MW's | 10.00% |
| Level 3 Total | 200 | MW's | 10.00% |
| Not Used Total | 1200 | MW's | 60.00% |



# Existing Program Details and Performance

- ❑ CAPE TS-Link simulations were performed to cause an underfrequency event by tripping various amounts of generation
- ❑ Generation tripped ranged from 95 MW's to 750 MW's
- ❑ Thirteen studies were simulated overall in increments of about 50 MW's
- ❑ All generator trips occurred at t = 0.5 seconds and were run out to 10 seconds
- ❑ Results were tabulated and evaluated to assess UFLS program performance under high IBR conditions

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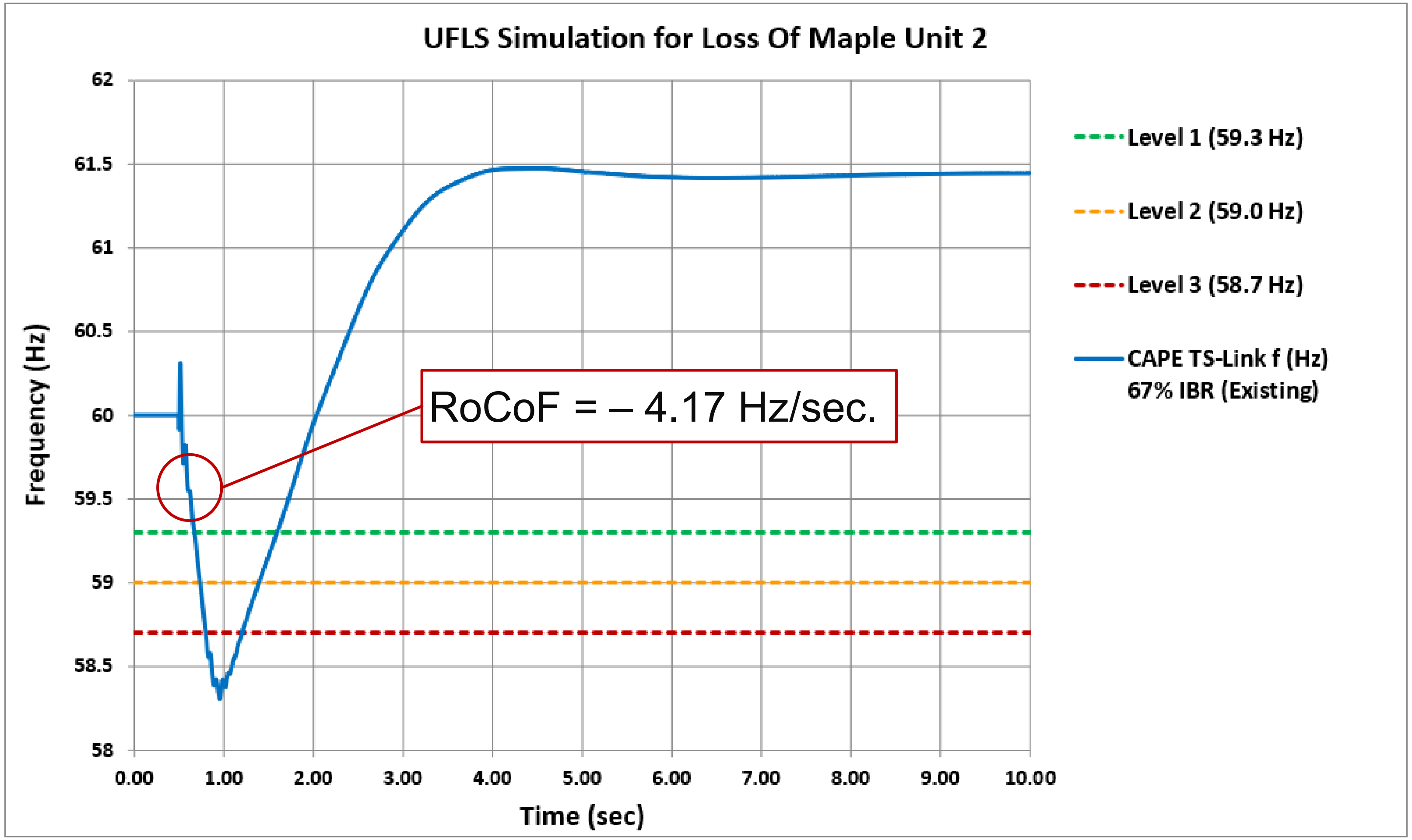
# Existing Program Details and Performance

- ❑ CAPE TS-Link example for trip of 490 MW Maple Unit 2
- ❑ All three levels of UFLS operate tripping 600 MW of load

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# Existing Program Details and Performance

- ❑ 10/13 (77%) cases studied would result in potential uncontrolled generator tripping due to over/under frequency per NERC PRC-024 Standard

- ❑ 5/13 (38%) cases studied would lead to uncontrolled, instantaneous tripping of generation, leading to a blackout

**Eastern Interconnection**

| High Frequency Duration | |
|---|---|
| **Frequency (Hz)** | **Time (Sec)** |
| ≥61.8 | Instantaneous trip |
| ≥60.5 | $10^{(90.935-1.45713*f)}$ |
| <60.5 | Continuous operation |

| Low Frequency Duration | |
|---|---|
| **Frequency (Hz)** | **Time (sec)** |
| ≤57.8 | Instantaneous trip |
| ≤59.5 | $10^{(1.7373*f-100.116)}$ |
| > 59.5 | Continuous operation |

| | | Existing UFLS | | | | |
|---|---|---|---|---|---|---|
| Generation Tripped (MW's) | RoCoF (Hz/Sec.) | Total Load Shed (MW's) | Excess Amount of Load Shed (MW's) | Frequency Nadir (Hz) | Overshoot Freq. (Hz) | Final Freq. (Hz) |
| 95 | -0.54 | 200 | 105 | 59.23 | 61.23 | 60.92 |
| 140 | -1.01 | 200 | 60 | 59.14 | 60.84 | 60.60 |
| 190 | -1.24 | 200 | 10 | 59.10 | 60.21 | 60.13 |
| 235 | -1.71 | 400 | 165 | 58.96 | 62.15 | 61.54 |
| 330 | -2.53 | 400 | 70 | 58.71 | 61.74 | 61.18 |
| 375 | -2.23 | 400 | 25 | 58.79 | 60.33 | 60.23 |
| 435 | -3.35 | 600 | 165 | 58.46 | 64.04 | 62.52 |
| 490 | -4.17 | 600 | 110 | 58.31 | 61.47 | 61.44 |
| 540 | -4.54 | 600 | 60 | 58.17 | 60.86 | 60.85 |
| 600 | -3.58 | 600 | 0 | 58.30 | 60.04 | 59.99 |
| 640 | -5.44 | 600 | -40 | 57.79 | N/A | 57.79 |
| 700 | -4.05 | 600 | -100 | 56.95 | N/A | 56.95 |
| 750 | -4.27 | 600 | -150 | 54.93 | N/A | 54.93 |
| | | TOTAL | 770 | | | |
| | | Ave. Difference | 77.00 | | | |

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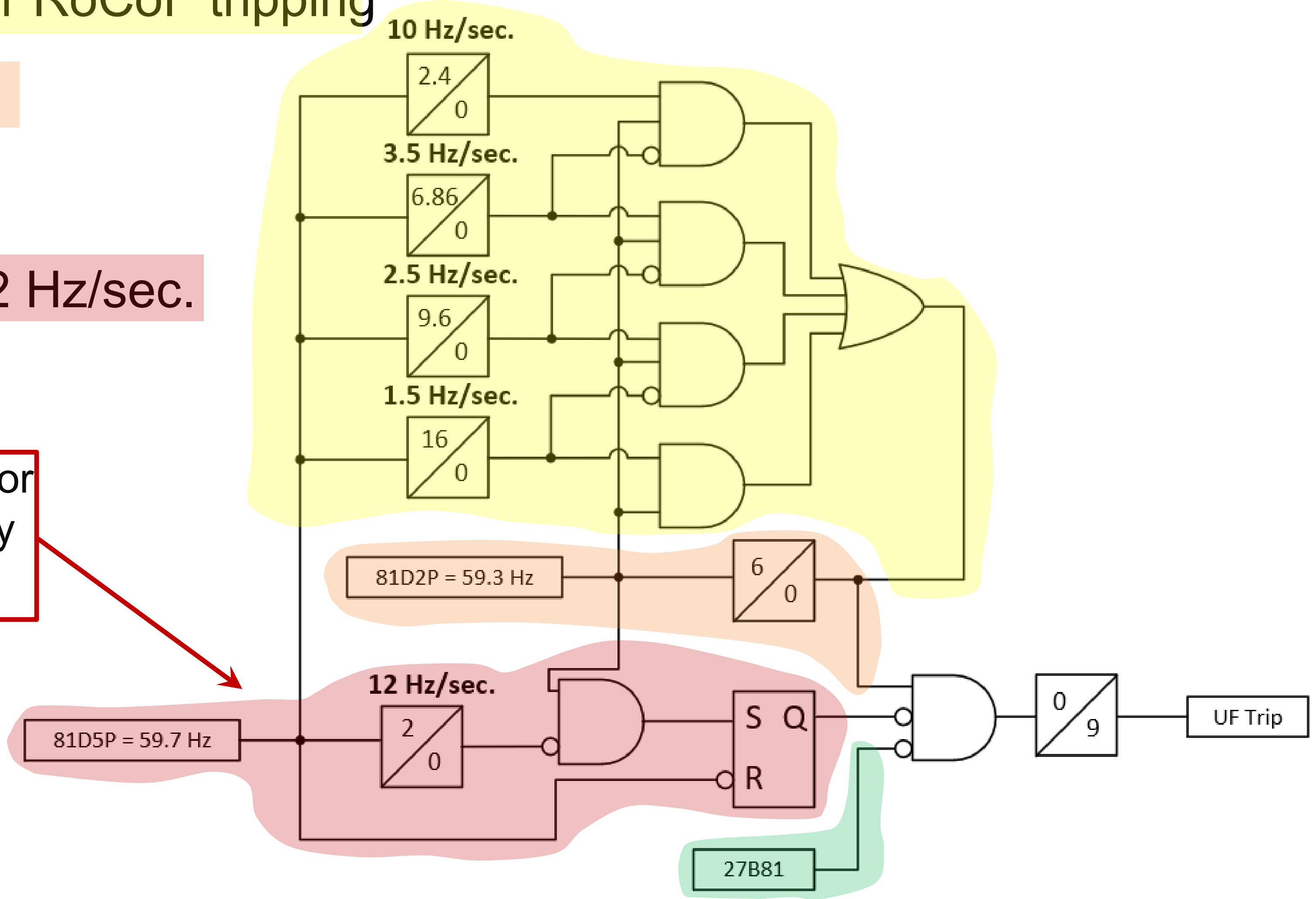
# NEW Program Details and Performance

- Trip ***AT*** the UF set point ***IF*** the RoCoF is greater than zero and less than 10 Hz/sec.
- NO intentional time delay for RoCoF tripping
- Maintain normal UF tripping
- Maintain UV inhibit at 67%
- Block tripping if RoCoF > 12 Hz/sec.

Block tripping for motor spin-down caused by loss of source




The Need for Faster UFLS

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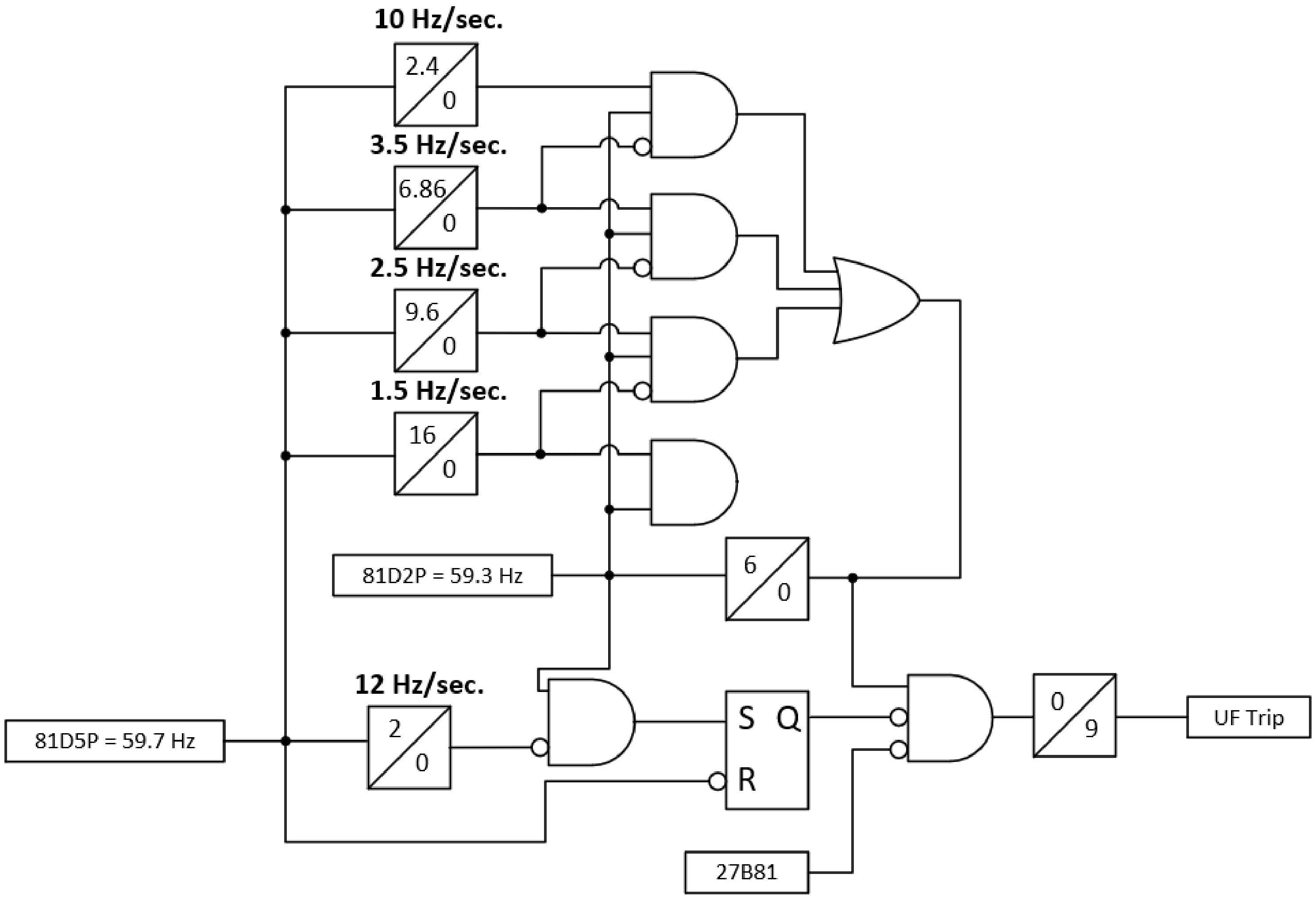
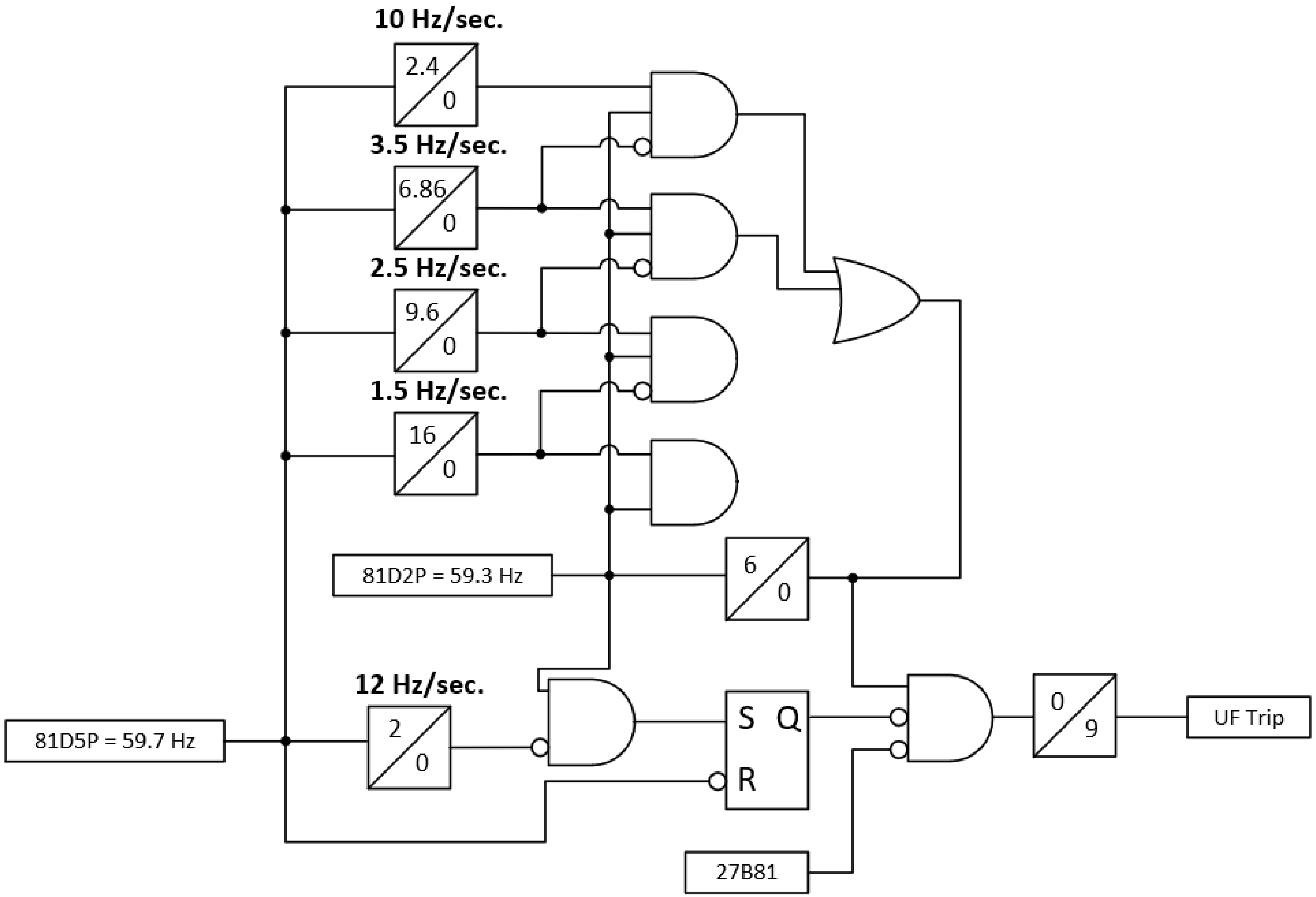
# NEW Program Details and Performance

- Some locations will only trip for RoCoF between 1.5 – 10 Hz/sec.



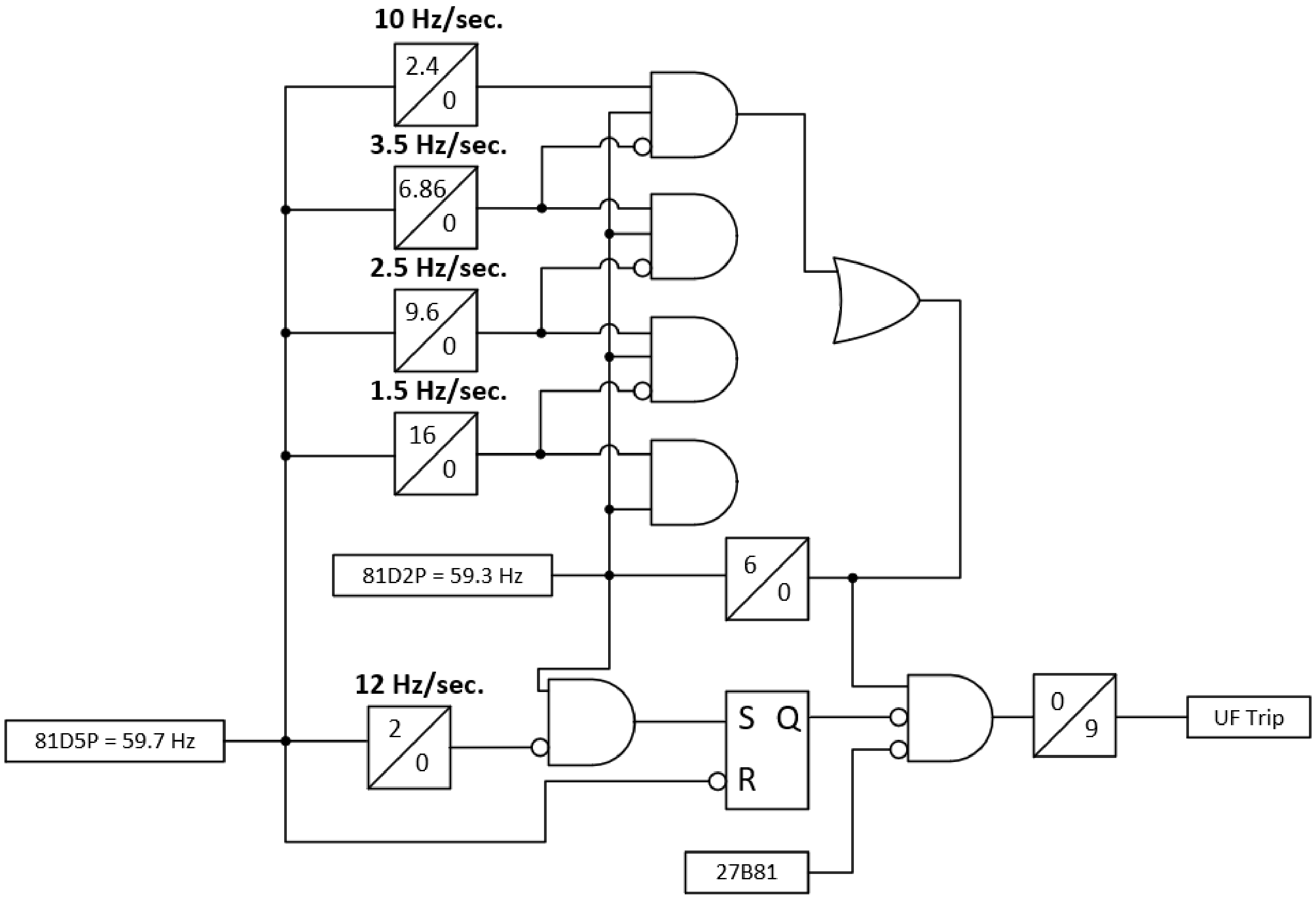
# NEW Program Details and Performance

- ❑ Some locations will only trip for RoCoF between 2.5 – 10 Hz/sec.



# NEW Program Details and Performance

- ❑ Some locations will only trip for RoCoF between 3.5 – 10 Hz/sec.

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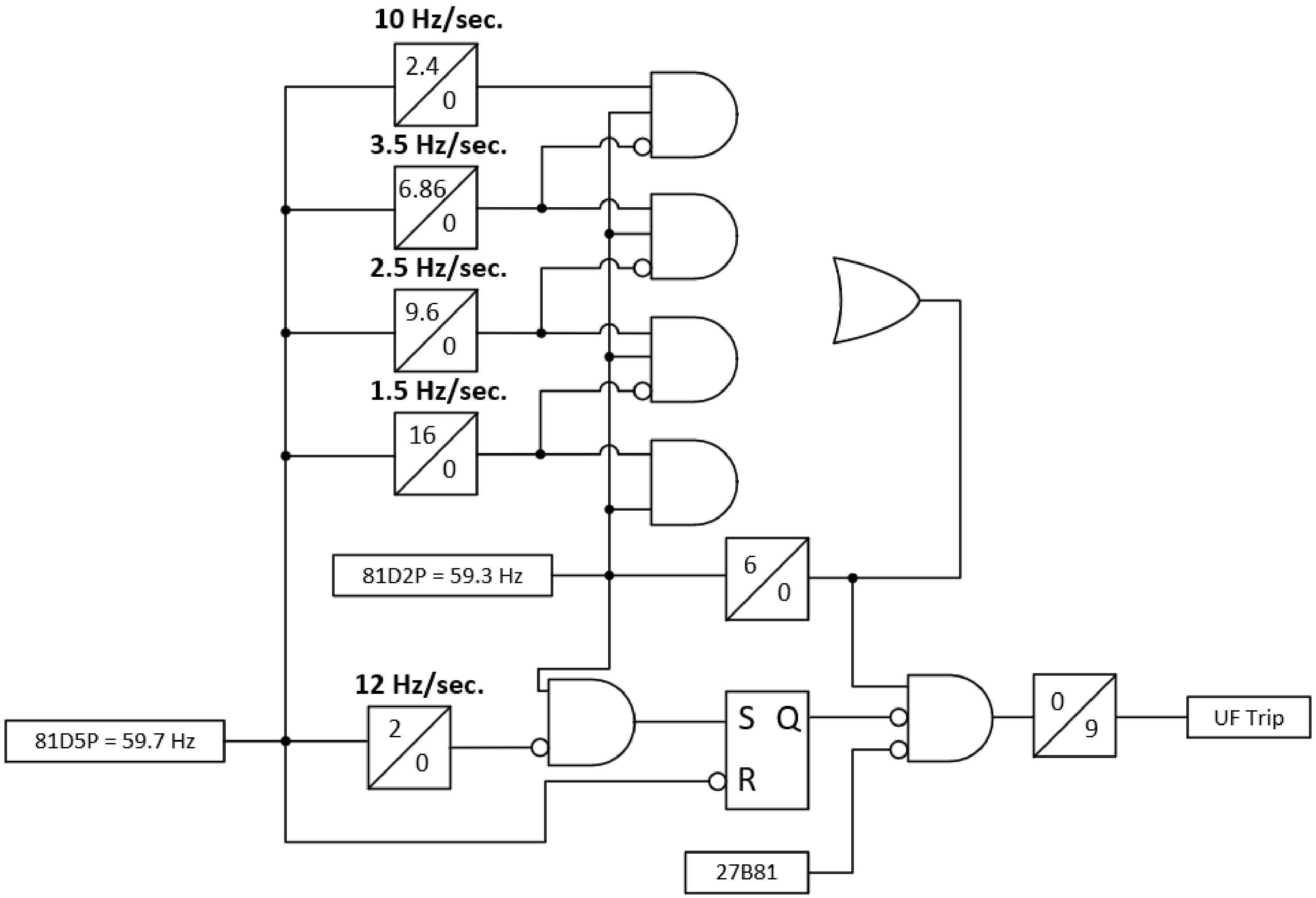
# NEW Program Details and Performance

- ❑ Some locations will only trip per conventional UF tripping

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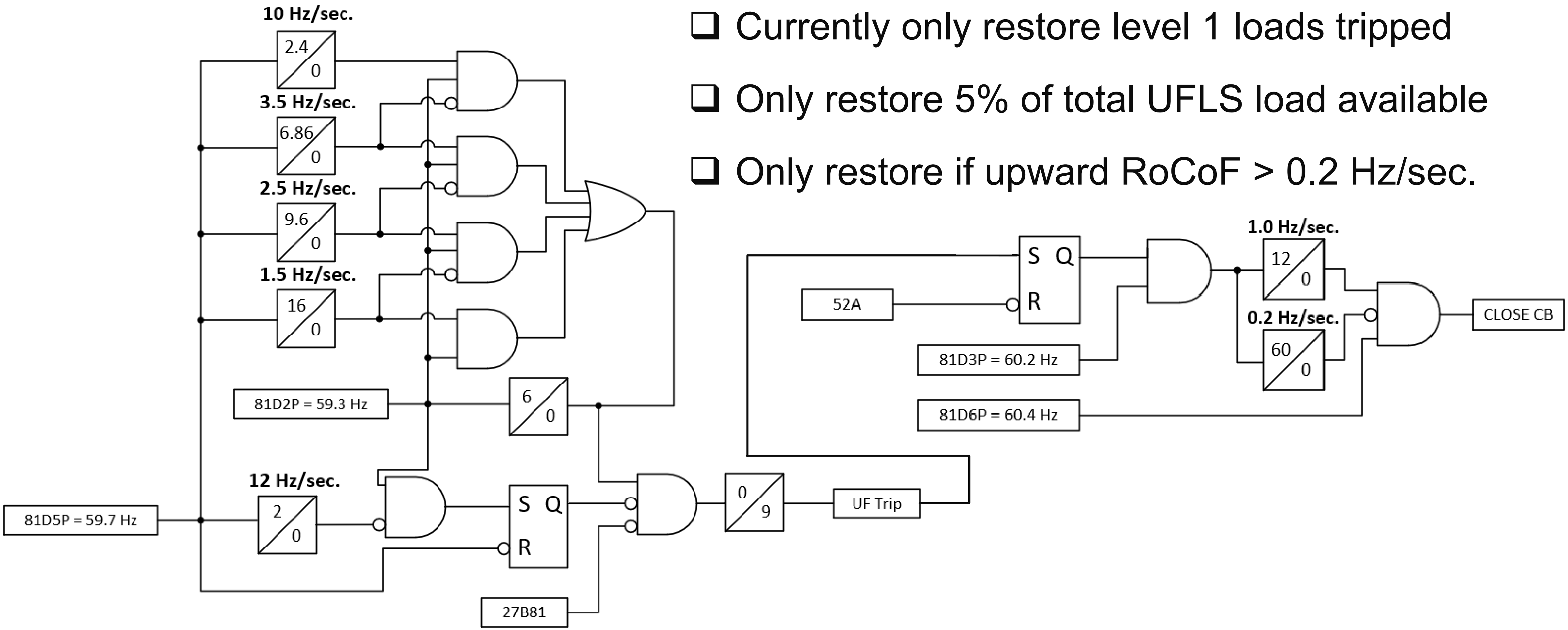
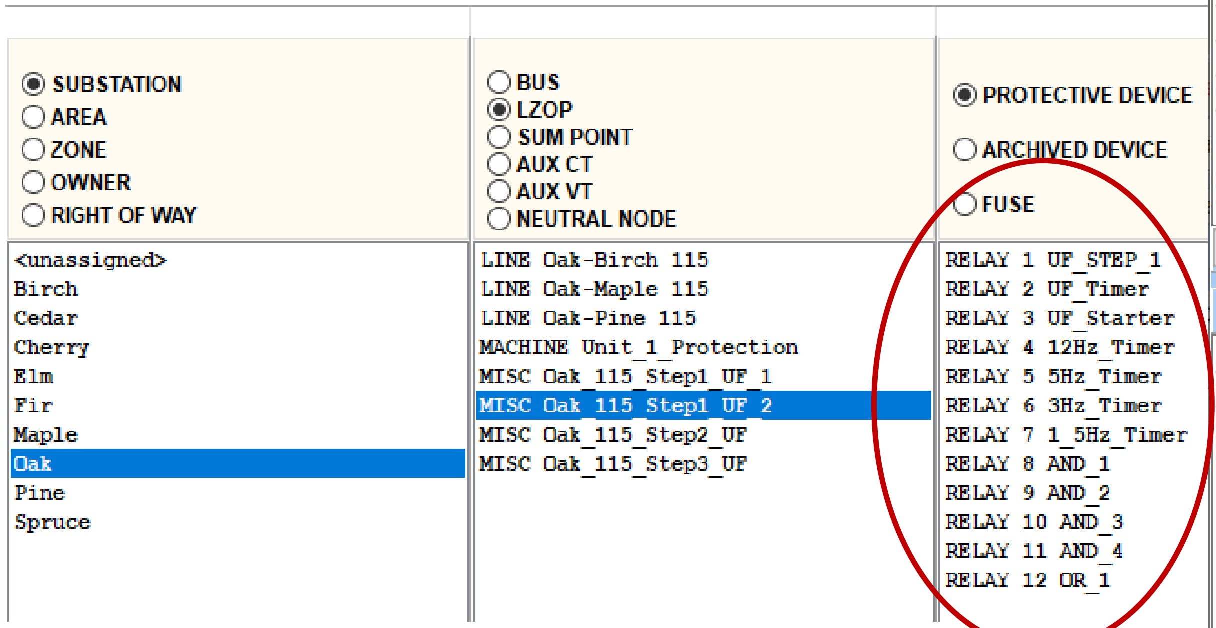
# NEW Program Details and Performance

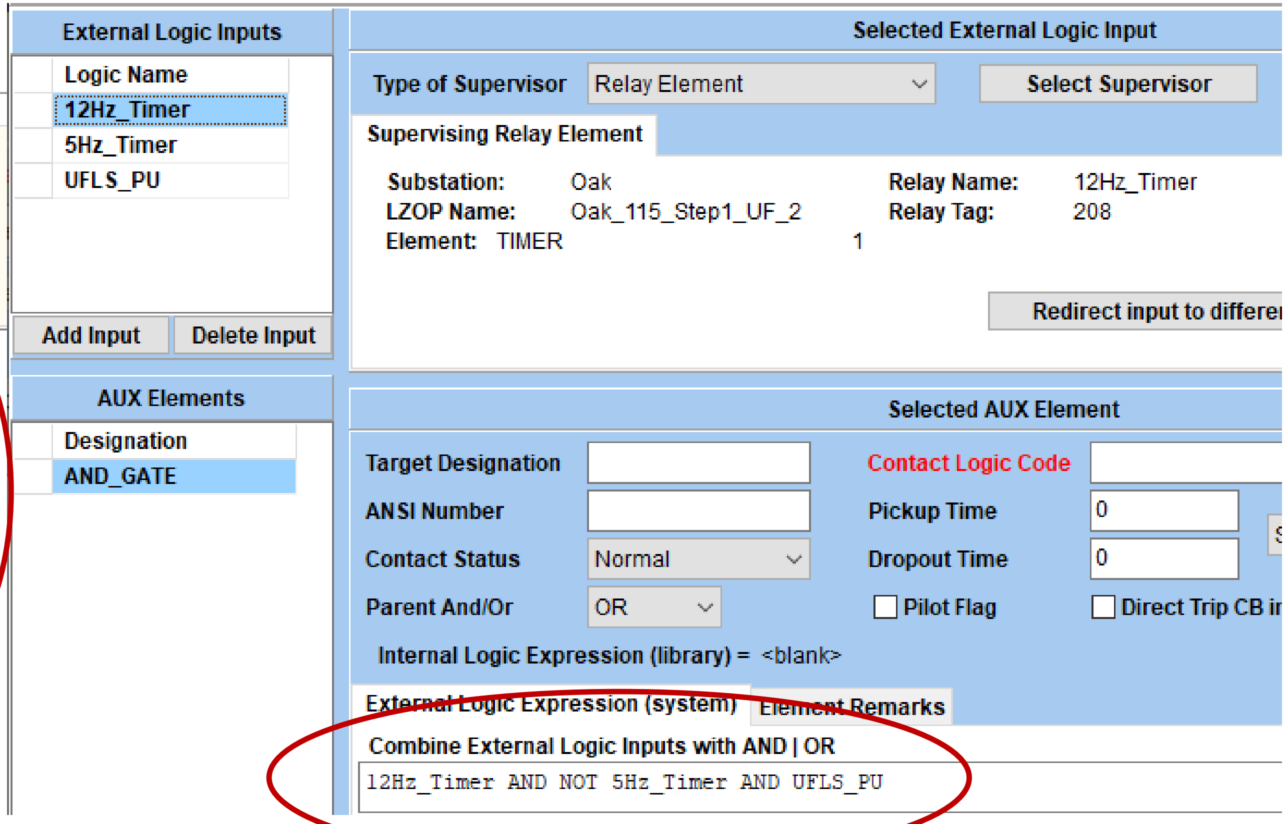
- ❑ Some locations will have auto load restoration
- ❑ Currently only restore level 1 loads tripped
- ❑ Only restore 5% of total UFLS load available
- ❑ Only restore if upward RoCoF > 0.2 Hz/sec.

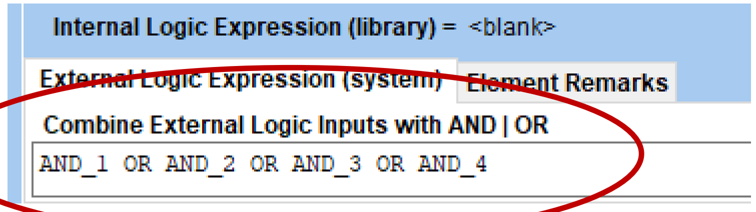


# NEW Program Details and Performance

- CAPE allows building custom logic, which was done for every logic element of this RoCoF UFLS scheme



# NEW Program Details and Performance

- ❑ Trip more load in level 1, up to 25%, but minimum of 10%
- ❑ Trip 10% in level 2 and level 3

| Substation | Load Label | Load (MW's) | UFLS Level | AND_1 RoCoF 3.5-10 Hz? | AND_2 RoCoF 2.5-3.5 Hz? | AND_3 RoCoF 1.5-2.5 Hz? | AND_4 RoCoF 0-1.5 Hz? | Time Delay | Load Restore |
|---|---|---|---|---|---|---|---|---|---|
| Birch | 1-1 | 50 | 3 | Y | Y | Y | Y | 6 | N |
| Birch | 1-2 | 25 | 1 | Y | Y | Y | Y | 6 | 1 |
| Birch | 1-3 | 25 | 1 | Y | Y | Y | N | 12 | 1 |
| Fir | 12-2 | 75 | 2 | N | N | N | N | 6 | N |
| Fir | 12-3 | 50 | 1 | Y | Y | Y | N | 30 | N |
| Maple | 2-1 | 75 | 3 | N | N | N | N | 20 | N |
| Maple | 2-2 | 75 | 3 | N | N | N | N | 20 | N |
| Maple | 2-3 | 50 | 2 | N | N | N | N | 30 | N |
| Oak | 5-1 | 75 | 1 | Y | Y | Y | Y | 6 | N |
| Oak | 5-2 | 75 | 2 | N | N | N | N | 15 | N |
| Oak | 5-3 | 50 | 1 | Y | N | N | N | 599940 | N |
| Pine | 7-1 | 35 | 1 | Y | Y | N | N | 599940 | N |
| Pine | 7-2 | 35 | 1 | Y | Y | N | N | 599940 | N |
| Pine | 7-3 | 30 | 1 | Y | Y | Y | N | 20 | N |
| Pine | 10-1 | 150 | 1 | Y | N | N | N | 599940 | N |
| | | | | | | | | | |
| **TOTAL** | | **1800** | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| **Level 1 Total** | 475 | **MW's** | 23.75% | **%** | | | | | |
| **Level 2 Total** | 200 | **MW's** | 10.00% | **%** | | | | | |
| **Level 3 Total** | 200 | **MW's** | 10.00% | **%** | | | | | |

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# NEW Program Details and Performance

- ❑ Trip 205 MW's (10.25%) of level 1 load when RoCoF is less than 1.5 Hz/sec.

| Substation | Load Label | Load (MW's) | UFLS Level | AND_1 RoCoF 3.5-10 Hz? | AND_2 RoCoF 2.5-3.5 Hz? | AND_3 RoCoF 1.5-2.5 Hz? | AND_4 RoCoF 0-1.5 Hz? | Time Delay | Load Restore |
|---|---|---|---|---|---|---|---|---|---|
| Birch | 1-1 | 50 | 3 | Y | Y | Y | Y | 6 | N |
| Birch | 1-2 | 25 | 1 | Y | Y | Y | Y | 6 | 1 |
| Birch | 1-3 | 25 | 1 | Y | Y | Y | N | 12 | 1 |
| Fir | 12-2 | 75 | 2 | N | N | N | N | 6 | N |
| Fir | 12-3 | 50 | 1 | Y | Y | Y | N | 30 | N |
| Maple | 2-1 | 75 | 3 | N | N | N | N | 20 | N |
| Maple | 2-2 | 75 | 3 | N | N | N | N | 20 | N |
| Maple | 2-3 | 50 | 2 | N | N | N | N | 30 | N |
| Oak | 5-1 | 75 | 1 | Y | Y | Y | Y | 6 | N |
| Oak | 5-2 | 75 | 2 | N | N | N | N | 15 | N |
| Oak | 5-3 | 50 | 1 | Y | N | N | N | 599940 | N |
| Pine | 7-1 | 35 | 1 | Y | Y | N | N | 599940 | N |
| Pine | 7-2 | 35 | 1 | Y | Y | N | N | 599940 | N |
| Pine | 7-3 | 30 | 1 | Y | Y | Y | N | 20 | N |
| Pine | 10-1 | 150 | 1 | Y | N | N | N | 599940 | N |
| | | | | | | | | | |
| **TOTAL** | | **1800** | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| **Level 1 Total** | 475 | **MW's** | 23.75% | **%** | | | | | |
| **Level 2 Total** | 200 | **MW's** | 10.00% | **%** | | | | | |
| **Level 3 Total** | 200 | **MW's** | 10.00% | **%** | | | | | |

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# NEW Program Details and Performance

- Trip 205 MW's (10.25%) of level 1 load when RoCoF is between 1.5 Hz/sec. and 2.5 Hz/sec.

| Substation | Load Label | Load (MW's) | UFLS Level | AND_1 RoCoF 3.5-10 Hz? | AND_2 RoCoF 2.5-3.5 Hz? | AND_3 RoCoF 1.5-2.5 Hz? | AND_4 RoCoF 0-1.5 Hz? | Time Delay | Load Restore |
|---|---|---|---|---|---|---|---|---|---|
| Birch | 1-1 | 50 | 3 | Y | Y | Y | Y | 6 | N |
| Birch | 1-2 | 25 | 1 | Y | Y | Y | Y | 6 | 1 |
| Birch | 1-3 | 25 | 1 | Y | Y | Y | N | 12 | 1 |
| Fir | 12-2 | 75 | 2 | N | N | N | N | 6 | N |
| Fir | 12-3 | 50 | 1 | Y | Y | Y | N | 30 | N |
| Maple | 2-1 | 75 | 3 | N | N | N | N | 20 | N |
| Maple | 2-2 | 75 | 3 | N | N | N | N | 20 | N |
| Maple | 2-3 | 50 | 2 | N | N | N | N | 30 | N |
| Oak | 5-1 | 75 | 1 | Y | Y | Y | Y | 6 | N |
| Oak | 5-2 | 75 | 2 | N | N | N | N | 15 | N |
| Oak | 5-3 | 50 | 1 | Y | N | N | N | 599940 | N |
| Pine | 7-1 | 35 | 1 | Y | Y | N | N | 599940 | N |
| Pine | 7-2 | 35 | 1 | Y | Y | N | N | 599940 | N |
| Pine | 7-3 | 30 | 1 | Y | Y | Y | N | 20 | N |
| Pine | 10-1 | 150 | 1 | Y | N | N | N | 599940 | N |
| | | | | | | | | | |
| **TOTAL** | | **1800** | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| **Level 1 Total** | 475 | **MW's** | 23.75% | **%** | | | | | |
| **Level 2 Total** | 200 | **MW's** | 10.00% | **%** | | | | | |
| **Level 3 Total** | 200 | **MW's** | 10.00% | **%** | | | | | |

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# NEW Program Details and Performance

- ❑ Trip 275 MW's (13.75%) of level 1 load when RoCoF is between 2.5 Hz/sec. and 3.5 Hz/sec.

| | | | | AND_1 | AND_2 | AND_3 | AND_4 | | Load |
|---|---|---|---|---|---|---|---|---|---|
| Substation | Load Label | Load (MW's) | UFLS Level | RoCoF 3.5-10 Hz? | RoCoF 2.5-3.5 Hz? | RoCoF 1.5-2.5 Hz? | RoCoF 0-1.5 Hz? | Time Delay | Restore |
| Birch | 1-1 | 50 | 3 | Y | Y | Y | Y | 6 | N |
| Birch | 1-2 | 25 | 1 | Y | Y | Y | Y | 6 | 1 |
| Birch | 1-3 | 25 | 1 | Y | Y | Y | N | 12 | 1 |
| Fir | 12-2 | 75 | 2 | N | N | N | N | 6 | N |
| Fir | 12-3 | 50 | 1 | Y | Y | Y | N | 30 | N |
| Maple | 2-1 | 75 | 3 | N | N | N | N | 20 | N |
| Maple | 2-2 | 75 | 3 | N | N | N | N | 20 | N |
| Maple | 2-3 | 50 | 2 | N | N | N | N | 30 | N |
| Oak | 5-1 | 75 | 1 | Y | Y | Y | Y | 6 | N |
| Oak | 5-2 | 75 | 2 | N | N | N | N | 15 | N |
| Oak | 5-3 | 50 | 1 | Y | N | N | N | 599940 | N |
| Pine | 7-1 | 35 | 1 | Y | Y | N | N | 599940 | N |
| Pine | 7-2 | 35 | 1 | Y | Y | N | N | 599940 | N |
| Pine | 7-3 | 30 | 1 | Y | Y | Y | N | 20 | N |
| Pine | 10-1 | 150 | 1 | Y | N | N | N | 599940 | N |
| | | | | | | | | | |
| **TOTAL** | | **1800** | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| **Level 1 Total** | 475 | **MW's** | 23.75% | **%** | | | | | |
| **Level 2 Total** | 200 | **MW's** | 10.00% | **%** | | | | | |
| **Level 3 Total** | 200 | **MW's** | 10.00% | **%** | | | | | |

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# NEW Program Details and Performance

- Trip 475 MW's (23.75%) of level 1 load when RoCoF is between 3.5 Hz/sec. and 10 Hz/sec.

| | | | | AND_1 | AND_2 | AND_3 | AND_4 | | Load |
|---|---|---|---|---|---|---|---|---|---|
| Substation | Load Label | Load (MW's) | UFLS Level | RoCoF 3.5-10 Hz? | RoCoF 2.5-3.5 Hz? | RoCoF 1.5-2.5 Hz? | RoCoF 0-1.5 Hz? | Time Delay | Restore |
| Birch | 1-1 | 50 | 3 | Y | Y | Y | Y | 6 | N |
| Birch | 1-2 | 25 | 1 | Y | Y | Y | Y | 6 | 1 |
| Birch | 1-3 | 25 | 1 | Y | Y | Y | N | 12 | 1 |
| Fir | 12-2 | 75 | 2 | N | N | N | N | 6 | N |
| Fir | 12-3 | 50 | 1 | Y | Y | Y | N | 30 | N |
| Maple | 2-1 | 75 | 3 | N | N | N | N | 20 | N |
| Maple | 2-2 | 75 | 3 | N | N | N | N | 20 | N |
| Maple | 2-3 | 50 | 2 | N | N | N | N | 30 | N |
| Oak | 5-1 | 75 | 1 | Y | Y | Y | Y | 6 | N |
| Oak | 5-2 | 75 | 2 | N | N | N | N | 15 | N |
| Oak | 5-3 | 50 | 1 | Y | N | N | N | 599940 | N |
| Pine | 7-1 | 35 | 1 | Y | Y | N | N | 599940 | N |
| Pine | 7-2 | 35 | 1 | Y | Y | N | N | 599940 | N |
| Pine | 7-3 | 30 | 1 | Y | Y | Y | N | 20 | N |
| Pine | 10-1 | 150 | 1 | Y | N | N | N | 599940 | N |
| | | | | | | | | | |
| **TOTAL** | | **1800** | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| **Level 1 Total** | 475 | **MW's** | 23.75% | **%** | | | | | |
| **Level 2 Total** | 200 | **MW's** | 10.00% | **%** | | | | | |
| **Level 3 Total** | 200 | **MW's** | 10.00% | **%** | | | | | |

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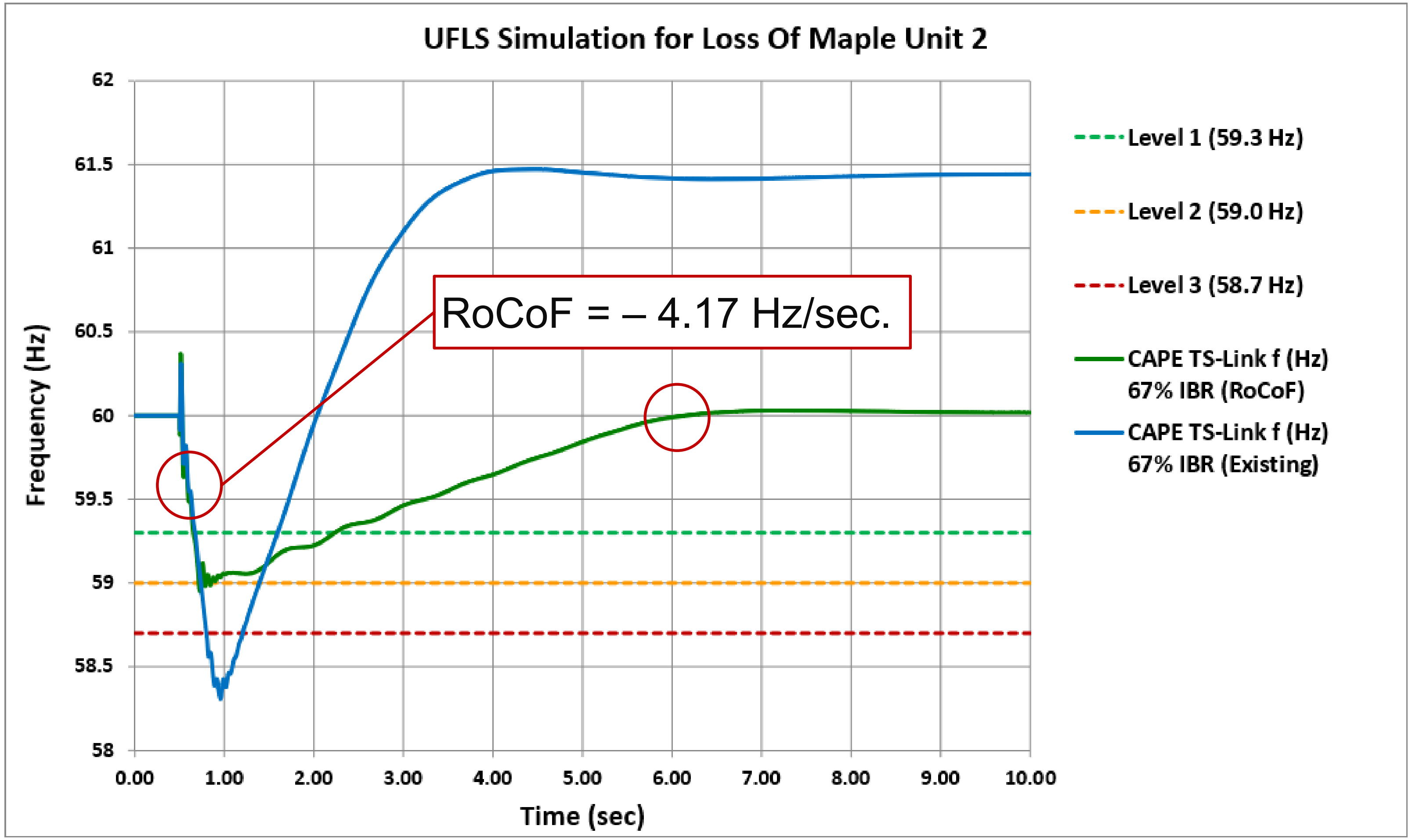
# NEW Program Details and Performance

- ❑ CAPE TS-Link example for trip of 490 MW Maple Unit 2
- ❑ ONLY level 1 UFLS operates tripping 475 MW of load

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# NEW Program Details and Performance

- ❑ Only 1/13 (8%) cases studied would result in potential uncontrolled generator tripping due to over/under frequency per NERC PRC-024 Standard

- ❑ NONE of the cases studied would lead to uncontrolled, instantaneous tripping of generation, leading to a blackout

**Eastern Interconnection**

| High Frequency Duration | |
|---|---|
| **Frequency (Hz)** | **Time (Sec)** |
| ≥61.8 | Instantaneous trip |
| ≥60.5 | $10^{(90.935-1.45713*f)}$ |
| <60.5 | Continuous operation |

| Low Frequency Duration | |
|---|---|
| **Frequency (Hz)** | **Time (sec)** |
| ≤57.8 | Instantaneous trip |
| ≤59.5 | $10^{(1.7373*f-100.116)}$ |
| > 59.5 | Continuous operation |

| | | RoCoF UFLS | | | | |
|---|---|---|---|---|---|---|
| Generation Tripped (MW's) | RoCoF (Hz/Sec.) | Total Load Shed (MW's) * | Excess Amount of Load Shed (MW's) | Frequency Nadir (Hz) | Overshoot Freq. (Hz) | Final Freq. (Hz) |
| 95 | -0.54 | 100 | 5 | 59.27 | 60.17 | 60.10 |
| 140 | -1.01 | 155 | 15 | 59.20 | 60.48 | 60.17 |
| 190 | -1.24 | 205 | 15 | 59.06 | 60.23 | 60.14 |
| 235 | -1.71 | 205 | -30 | 59.09 | N/A | 59.72 |
| 330 | -2.53 | 345 | 15 | 58.94 | 60.67 | 60.20 |
| 375 | -2.23 | 405 | 30 | 58.81 | 60.38 | 60.27 |
| 435 | -3.35 | 425 | -10 | 58.97 | 60.44 | 59.91 |
| 490 | -4.17 | 475 | -15 | 58.99 | 60.03 | 60.02 |
| 540 | -4.54 | 545 | 5 | 58.86 | 60.50 | 60.25 |
| 600 | -3.58 | 625 | 25 | 58.75 | 60.42 | 60.11 |
| 640 | -5.44 | 645 | 5 | 58.59 | 60.50 | 60.22 |
| 700 | -4.05 | 795 | 95 | 58.54 | 60.85 | 60.56 |
| 750 | -4.27 | 825 | 75 | 58.39 | 60.69 | 60.44 |
| | | **TOTAL** | **55** | | | |
| | | **Ave. Difference** | **16.50** | | | |

* Includes Auto Load Restoration

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# Next Steps to Implement New Program

- ❑ Continue testing 50%, 25% and 0% IBR penetration models and compare results
- ❑ Develop relay settings and test using COMTRADE file play-back in test lab
- ❑ Perform additional test system studies with synchronous condensers and battery energy storage systems (BESS) to see how much of each is necessary to give similar or better results to new UFLS program
- ❑ Cost compare new UFLS to synchronous condenser and BESS solutions to see which is more cost effective
- ❑ Write paper with three co-authors and present at conferences
- ❑ Convince Xcel Energy SPE Technical Council that this is a good program to implement
- ❑ Convince Southwest Power Pool that this solution fits their PRC-006 mold and is worthy of implementation at SPS
- ❑ Implement program in the SPS region

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# Conclusions

- Underfrequency load shed programs across the industry are outdated and need to be modernized to operate successfully with systems that have high IBR penetrations and low system inertia that leads to high RoCoF

- If UFLS programs are left as-is, blackouts will become more common

- Implementing this new RoCoF UFLS scheme will better guarantee adequate load shed and blackout avoidance

- Implementing this new RoCoF UFLS scheme can potentially save millions of dollars in avoided costs of investment in synchronous condensers to replace depleted inertia and BESS to provide MW injection during UF events

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# AGENDA 8

**Misoperations**

c. Project Updates

i. Instantaneous Ground Overcurrent

*Jake Bernhagen, Senior Systems Protection Engineer, MRO*

## Action
Information

## Report
Jake Bernhagen will provide an oral report during the meeting.

# AGENDA 9

**Protection System Commissioning**

a. Webinar Recap

*Cody Remboldt, Montana-Dakota Utilities and PRS Member*

## Action

Information

## Report

Cody Remboldt will provide an oral report during the meeting.

# AGENDA 9

**Protection System Commissioning**

b. Lessons Learned

*Cody Remboldt, Montana-Dakota Utilities and PRS Member*

## Action

Information

## Report

Cody Remboldt will provide an oral report during the meeting.

# AGENDA 10

## NERC State of Reliability

*John Grimm, Principal Systems Protection Engineer, MRO*

### Action

Information

### Report

John Grimm will provide an overview during the meeting.

# 2022 STATE OF RELIABILITY

**The State of Reliability provides analysis of past bulk power system performance to identify system trends and emerging reliability risk. It also highlights the health of the interconnected bulk power system and the effectiveness of reliability risk mitigation activities.**

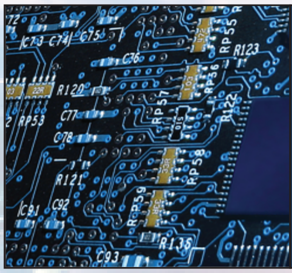
**Leading indicators show that the bulk power system continues to perform in a highly reliable and resilient manner overall with year-over-year improvement, demonstrating the success of industry actions. However, the rapidly changing risk profile requires new approaches to navigate reliability effectively. Significant events in 2021 highlight the need for aggressive action.**

**Extreme cold weather across South Central United States and Texas led to largest controlled load shedding event in North American history. Unserved energy demand underscores the need for winterization requirements in power generation and addressing resource availability issues.**

**Severe weather—such as extreme cold and heat, hurricanes, and drought-related wildfires—challenged the bulk power system, underscoring the need for more robust resilience tools to withstand extreme events.**

**Electricity and natural gas industry interdependencies have evolved from an emerging risk to a realized one, requiring reconsideration of the regulatory framework and coordination between the two sectors.**

**Multiple solar loss events in Texas and California in 2021 demonstrated that unaddressed inverter issues increase reliability risk, particularly in those large assessment areas that have become dependent upon renewable resources to meet peak loads. New Reliability Standards under development will mitigate inverter risk.**



**The cyber security threat landscape continues to degrade as demonstrated by geopolitical events, new vulnerabilities, changing technologies, and increasingly bold adversaries. Continued vigilance and effective industry/government information sharing are essential.**

**Reliability | Resilience | Security**

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

NERC

NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

# 2022 State of Reliability

## July 2022

**An Assessment of 2021 Bulk Power System Performance**

### Transmission Availability Data System (TADS)

TADS inventory and outage data are used to study the initiating cause codes and sustained cause codes of transmission outages. Metrics are developed that analyze outage frequency, duration, causes, and many other factors related to transmission outages. This analysis can shed light on prominent and underlying causes that affect the overall performance of the BPS.

Transmission
100 kV and greater

### Generation Availability Data System (GADS)

GADS contains information that can be used to compute generation-related reliability measures, such as the weighted-equivalent forced outage rate, which is a metric for measuring the probability that a unit will not be available to deliver its full capacity at any given time due to forced outages and derates. NERC's GADS maintains operating histories on more than 5,000 generating units in the North America.

Conventional Generators
20 MW and larger
Wind Plants
75 MW and greater

### Misoperation Info Data Analysis System (MIDAS)

MIDAS collects protection system relay operations and misoperations. Metrics are developed to assess protection system performance. Trends are evaluated and can be used to identify remediation techniques to reduce the rate of occurrence and the severity of misoperations. Misoperations exacerbate event impacts on the BPS. The data collection is granular and allows NERC to identify specific trends associated with certain geographies, technologies, human performance, and management.

Transmission Owners,
Generator Owners,
Distribution Providers

### The Event Analysis Management System (TEAMS)

TEAMS is used to track and process records originating from the EOP-004 reporting, OE-417 reporting, Event Analysis Process and the ERO Cause Code Assignment Process. Relevant reports are recorded, uploaded, and tied together into a single event. The data in TEAMS is used to support event cause coding, general system performance analysis, and key performance indicators for the bulk power system.

Balancing Authorities,
Reliability Coordinators,
Transmission
Owner/Operators,
Generation
Owner/Operators

**Figure AR.1: Information Systems Administered and Maintained by the ERO**

## Considerations

- The data in this report represents the performance for the January–December 2021 operating year unless otherwise noted.
- Analysis in this report is based on data from 2017–2021 that was available at the time of this report and provides a basis to evaluate 2021 performance relative to performance over the last five years. Any updates to data that occur after the report is published will be reflected in a subsequent report.
- This report is a review of industry-wide trends and not a review of the performance of individual entities. Accordingly, information presented in this report is always aggregated at the Interconnection level or the Regional Entity level in order to maintain the anonymity of individual reporting organizations.
- The background on approaches, method, statistical tests, and procedures are available by request.
- When analysis is presented by Interconnection, the Québec Interconnection (QI) is combined with the Eastern Interconnection (EI) for confidentiality unless specific analysis for the QI is shown.

# Executive Summary

This *2022 State of Reliability* report is NERC's review of BES reliability during 2021. It is prepared to inform regulators, policymakers, and industry leaders of major reliability risks and performance trends, actions that are being taken to address them, and the effectiveness of past actions.

There were unprecedented challenges to BES reliability in 2021. Despite these challenges, grid operators were able to maintain reliability with one notable exception: The extreme and sustained cold weather in February 2021,[2] especially in the Texas and South Central parts of the United States, led grid operators in the impacted areas to order the largest controlled load shed event in U.S. history.[3] The event was also the third largest in the quantity of outaged megawatts of load—following the August 2003 Northeast and the August 1996 Western Interconnection (WI) blackouts.[4] While these emergency operating measures were necessary in order to prevent more prolonged blackouts, firm load shed and weather-related unplanned outages imposed enormous hardships on millions of electricity customers. At least 210 deaths resulted from the outages and cold weather in Texas.[5] In November 2021, the Federal Energy Regulatory Commission (FERC), NERC, and the affected Regional Entities issued a report that thoroughly analyzed the event. The analysis confirmed that industry had not sufficiently implemented voluntary recommendations from similar events that were first identified in 2011.[6] Based on these related findings, this *2022 State of Reliability* report considers the 28 recommendations from the *FERC, NERC and Regional Entity Staff Report,*[7] including several mandatory cold weather preparedness Reliability Standards.

In March 2021, the NERC Board acted to expedite completion of revisions to Reliability Standards EOP-011-2, IRO-010-2, and TOP-003-5 under Project 2019-06 Cold Weather. The NERC Board adopted the three revised standards in June; FERC subsequently approved all three in August, and they become effective on April 1, 2023. EOP-011-2 includes new cold weather preparedness planning requirements for Generator Owners and Generation Operators. IRO-010-2 and TOP-003-5 establish new cold weather generating unit operating limitation data specifications as well as collection and reporting requirements for Reliability Coordinators, Balancing Authorities (BA), Generator Owners, Generation Operators, Transmission Operators, Transmission Owners, and Distribution Providers.

In addition to the aforementioned development of cold weather winterization standards, the ERO Enterprise has ramped up mitigating activities, including implementation of a fuel assurance guideline that addresses extreme weather scenarios in long-term reliability assessments and the development of additional standards for energy resource adequacy. Among other things, the February 2021 cold weather event and other past related severe weather events confirm that interdependencies between the electricity and natural gas industries are a major new reliability risk that must be explicitly managed.

Throughout 2021, the North American electricity industry continued to weather cyber and physical attacks of varying degrees of sophistication and severity. Although the reliability of the BES was maintained, nation-state adversaries and organized cyber criminals have demonstrated that they have the ability and willingness to disrupt critical infrastructure. Notably, cyber-attacks routinely targeted the digital supply chain. In addition, reports of suspicious cyber incidents (including vulnerability exposure, phishing, malware, denial of service, and other cyber-related reports) increased significantly. While 2021 saw a moderate increase in the overall number of physical security incidents, the most serious types of incidents declined.

---

[2] February 2021 was the 19th coldest out of the 127 year record: https://www.ncei.noaa.gov/news/national-climate-202102

[3] Federal Energy Regulatory Commission (2021, November) *FERC, NERC and Regional Entity Staff Report: The February 2021 Cold Weather Outages in Texas and the South Central United States* p.9, fn. 6: https://www.ferc.gov/media/february-2021-cold-weather-outages-texas-and-south-central-united-states-ferc-nerc-and

[4] Id.

[5] Id. at 9.

[6] Id. at 17, fn 26.

[7] Id. at 240–41.

Going forward, industry must continue to integrate cyber and physical security considerations with conventional power system planning, operations, design, and restoration practices. The E-ISAC is contributing to these efforts with a two-pronged approach: active response to specific events and specialized trend analysis to suit the operational and information technology environments of member and partner organizations.

In 2021, as in past years, there were several widespread solar photovoltaic (PV) loss events: two in Texas[8] and four in California.[9] While reliability was maintained, the fact that these events continue to take place highlights the importance and urgency of expanding and accelerating ERO Enterprise and industry efforts to address them. It is imperative that the industry reliably integrate the rapidly growing fleet of inverter-based resources (IBRs), including solar PV and energy storage.

To address systemic issues with IBRs, NERC continues to urge industry's adoption of the recommended practices set forth in NERC guidelines even as NERC begins the process of developing mandatory Reliability Standards based on those guidelines (See **Key Findings and Actions in Progress** section). Recommended practices include a renewed focus on establishing and improving interconnection requirements, improved interconnection and reliability studies that mitigate systemic modeling errors, and development of a comprehensive inverter ride-through standard.

The impact of wide-area and long-duration extreme weather events, like the February 2021 South Central U.S. cold weather event and the August 2020 Western U.S. wide-area heat event, have underscored the need to consider extreme scenarios in resource adequacy and energy sufficiency planning. Diminished levels of flexible generation (i.e., fuel-assured, weatherized, and dispatchable resources) are occurring in many areas as the resource mix evolves, increasing the risk of energy shortfalls. No longer is the peak demand period the only clear risk period; instead, risks can emerge when weather-dependent generation is impacted by abnormal atmospheric conditions or when extreme conditions disrupt fuel supplies. Accordingly, the ERO's methods for analyzing and tracking the effects of these events are evolving. Although margins in 2021 were all assessed as adequate for traditional reliability criteria, the NERC analysis used for seasonal reliability assessments in 2021 accounted for more extreme conditions and warned of potential seasonal shortfalls in 8 of the 20 assessment areas, accounting for nearly half of the geographic area that comprises the North American BPS.

In addition, the events of the past year have led the ERO Enterprise to begin reassessing how best to measure the overall reliability performance objectives for the industry as reflected in the definition of "Adequate Level of Reliability (ALR)."[10] As far back as 2015, the Performance Analysis Subcommittee highlighted the need for metrics to evaluate the resilience of the BPS to the changing resource mix, and industry's efforts have advanced that work forward. This report introduces methods for evaluating restoration events as a first step toward developing formal resilience metrics.

The year 2021 saw improvement in both the year-over-year and the five-year average in automatic outages, both for transmission and transformers as initiated by failed substation equipment and human performance. Transmission outage severity (TOS), transmission events resulting in loss of load, and the ERO Enterprise-wide planning reserve margin also improved. The frequency response remained stable or improved across all Interconnections, and the number of energy emergency alert (EEA) Level 3s improved in the QI and WI.

As a result of the February 2021 cold weather event, the EEA Level 3 metric for the Texas Interconnection (TI) and EI is now being monitored. Other reliability indicators being monitored are automatic transmission and transformer outages due to ac circuit unavailability and failed protection systems, the generation weighted-equivalent forced outage rate (WEFOR), and the disturbance control standard.

[8] https://www.nerc.com/pa/rrm/ea/Pages/May-June-2021-Odessa-Disturbance.aspx
[9] https://www.nerc.com/pa/rrm/ea/Pages/CAISO-2021-Disturbance-Report.aspx
[10] Informational Filing on Definition: *Adequate Level of Reliability for the Bulk Electric System*, May 10, 2013.

## Key Findings and Actions in Progress

Based on data and information collected for this assessment of BES reliability performance in 2021, NERC identified six key findings and is taking actions to address them. The impact of extreme weather upon BES reliability is a consistent theme underlying four of the key findings.

### Key Finding 1

**The February cold weather event demonstrated that a significant portion of the generation fleet in the impacted areas was unable to supply electrical energy during extreme cold weather.**

In February, BES operators were confronted with unplanned and uncontrolled generator outages that required reliance on an extraordinary amount of necessary emergency actions to avoid instability, uncontrolled separation, cascading, or voltage collapse. As a result of February's cold weather event, the amount of unserved energy due to operator-initiated load shedding reported through the EEA process was the highest amount since the ERO Enterprise began reporting this metric and almost one-hundred times higher than the prior year (1,015 GWh in 2021 vs. 13 GWh in 2020). Refer to the **Energy Emergency Alerts** section of Chapter 3 for more information on this topic.

#### *Actions in Progress*

The ERO Enterprise is quickly implementing the recommendations in the *FERC, NERC and Regional Entity Staff Report: The February 2021 Cold Weather Outages in Texas and the South Central United States*.[11] Once implemented, these corrective actions will provide BES planners and operators with additional tools to avoid a recurrence of BES reliability threats arising from extreme cold weather events and address energy availability standards development for long-term planning and operational planning/operations time frames.

### Key Finding 2

**Electricity and natural gas interdependencies are no longer emerging risks but require immediate attention, including implementation of mitigating approaches.**

Over the past several years, the electricity and natural gas industries' interdependencies have been identified as emerging risks to BES reliability. It is now evident that these risks are no longer emerging; they are certain and expected to increase. Natural-gas-fired generators are now necessary balancing resources for reliable integration of the growing fleet of variable renewable energy resources and can be expected to remain so until new storage technologies are fully developed and deployed at scale to provide balancing. At the same time, reliable electric power supply is often required to ensure uninterrupted delivery of natural gas to these balancing resources, particularly in areas where penetration levels of renewable generation resources are highest. Refer to the **Planning Reserve Margin** of Chapter 3 and the **Critical Infrastructure Interdependencies** of Chapter 4 for more information.

#### *Actions in Progress*

NERC's forward-looking Reliability Assessment Program continues to emphasize the risk of increased reliance on natural gas generation. The ERO Enterprise is actively encouraging registered entities to conduct studies to model plausible and extreme natural gas disruptions set forth in NERC's March 2020 reliability guideline, *Fuel Assurance and Fuel-Related Reliability Risks Analysis for the Bulk Power System*.[12] Furthermore, the ERO Enterprise and industry are prioritizing two standards authorization requests that are currently being drafted to require registered entities to conduct studies for both planning and operations to ensure energy resource adequacy.

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[11] Federal Energy Regulatory Commission (2021, November) *FERC, NERC and Regional Entity Staff Report: The February 2021 Cold Weather Outages in Texas and the South Central United States*: https://www.ferc.gov/media/february-2021-cold-weather-outages-texas-and-south-central-united-states-ferc-nerc-and

[12] https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Fuel_Assurance_and_Fuel-Related_Reliability_Risk_Analysis_for_the_Bulk_Power_System.pdf

## Key Finding 3

**As climate change increases extreme weather event intensity and frequency,[13] severe weather again challenged the BPS putting grid resilience (the ability to withstand and recover from extreme events) into focus.**

NERC began analyzing the largest transmission events caused by severe weather in 2020 and introduced new quantitative measures to assess the severity of these events and the ensuing restoration processes. Resilience and restoration analysis in **Chapter 2** provides additional insights into BES performance during and after extreme weather events. The ERO Enterprise continues to examine outage and restoration processes for large weather-related transmission events to develop resilience statistics that measure and track the BES's ability to withstand, adapt, protect against, and recover from the impacts of extreme weather events.

### *Actions in Progress*

The ERO Enterprise is expanding and further refining resilience and restoration analysis by examining generation and load loss as well as improving linkage between equipment outages and weather. The resulting analysis can help target certain risk areas, benchmark the performance the system impacted by varying weather events, and serve as key data for industry investment and mitigation.

## Key Finding 4

**Geopolitical events, new vulnerabilities, new and changing technologies, and increasingly bold cyber criminals and hacktivists presented serious challenges to the reliability of the BES.**

The North American electricity industry weathered a series of attacks on the digital supply chain. In addition, reports of suspicious cyber incidents (including vulnerabilities, phishing, malware, denial of service, and other cyber-related reports) increased significantly. Vulnerabilities and risks to reliability are serious and unavoidable in an internet-enabled environment. The **Cyber and Physical Security** section of Chapter 4 provides more information on this topic.

### *Actions in Progress*

Industry is developing security-informed institutional practices that leverage security frameworks and activities to protect and secure the operational and organizational environment in order to mitigate and prepare for the security risks that threaten reliability. Supply chain requirements and guidance are being drafted by NERC and the technical committees to reduce vulnerabilities and better protect industry systems and infrastructure.

## Key Finding 5

**Large assessment areas have become dependent upon renewable resources to meet peak loads, but multiple loss of solar events in Texas and California in 2021 confirm that unaddressed inverter issues increased reliability risk.**

Multiple loss of solar events in Texas and CAISO as detailed in the *Odessa Disturbance Report*[14] and the *2021 CAISO Solar PV Disturbance Report*[15] highlight that there are continued BES reliability risks associated with inadequately interconnected IBRs. At the same time, assessment data from several areas revealed that peak demand could not be met without renewable generation.[16] Failing to address remaining solar PV inverter issues increased reliability risk. More information on this topic can be found in the **Resource Adequacy** section in Chapter 3.

### *Actions in Progress*

The ERO Enterprise and industry are implementing the recommendations set forth in the *Odessa Disturbance Report* and the *2021 CAISO Solar PV Disturbance Report* with high priority and a focused strategy. High priority items include incorporating Electromagnetic Transient Modeling into the NERC Reliability Standards and developing a comprehensive ride-through requirement that focuses specifically on generator protections and controls.

[13] https://www.nationalacademies.org/based-on-science/climate-change-global-warming-is-contributing-to-extreme-weather-events
[14] https://www.nerc.com/pa/rrm/ea/Pages/May-June-2021-Odessa-Disturbance.aspx
[15] https://www.nerc.com/pa/rrm/ea/Pages/CAISO-2021-Disturbance-Report.aspx
[16] *NERC 2021 Long-Term Reliability Assessment*

## Key Finding 6

**Additional data types are needed to enable more complete analysis of adequate level of reliability performance objectives.**

Two of the five ALR performance objectives do not have performance measures in place because data to support them is not collected. Data to measure performance of IBRs, voltage performance, energy resource adequacy, and load loss and restoration are needed to improve analysis and trending of BES reliability performance. While the BES restoration and resiliency analyses have begun, quantifying and trending the efficiency with which resources and load are restored during these events require new analyses that depend on additional data. **Chapter 5** provides more information on this topic.

***Actions in Progress***

NERC is identifying appropriate approaches for measuring ALR performance objectives where gaps have been identified.

# Chapter 1: The North American BPS—By the Numbers

**Figure 1.1** highlights a few key numbers and facts about the North American BPS. How NERC defines BPS reliability is outlined on the next page.

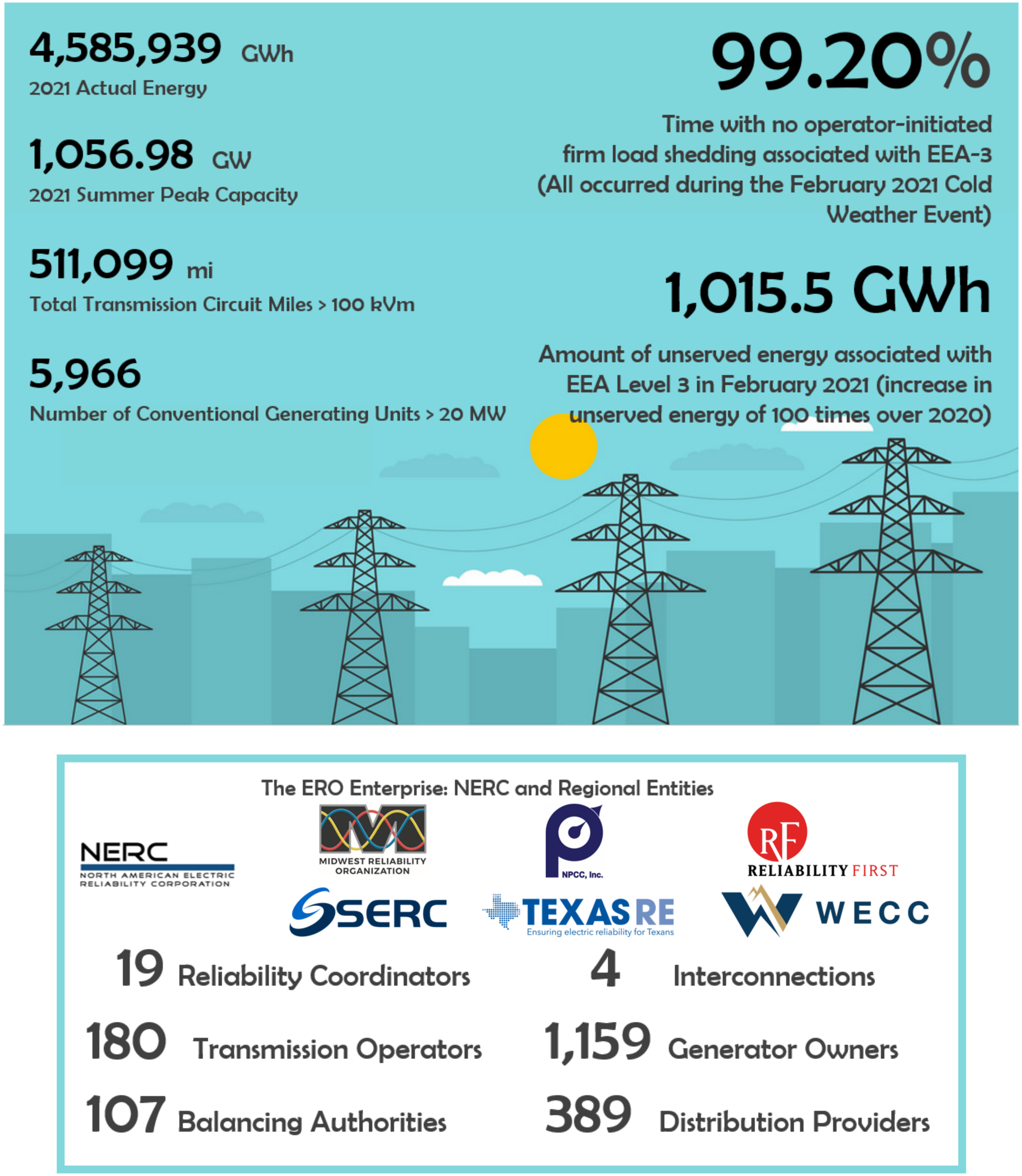


**Figure 1.1: 2021 BPS Inventory, Performance Statistics, and Key Functional Organizations**

# 2021 Key Occurrences

Extreme weather, recurring systemic issues with solar IBRs, and cyber security threats contributed to a number of events that impacted adversely upon BES reliability and produced a dramatic increase year-to-year in the amount of unserved energy in 2021. In February 2021, for example, resource unavailability that resulted from a lack of cold weather preparedness and natural gas supply interruptions contributed to an historic loss of firm load in Texas and the South Central United States. Extreme weather events in 2021 also included the June Northwest heat dome, Hurricane Ida, and tornadoes that ran a destructive and deadly path through eight South Central and Midwestern states in early December. 2021 also saw recurrences of systemic issues with solar IBRs' inability to ride through momentary events on the transmission system, resulting in hundreds of MWs of supply from smaller, individual solar generation facilities coming off-line at the same time. Through all of this, BES planners and operators continued to manage risks from the Covid-19 pandemic, cyber security threats, and supply chain issues.

## 2021 Extreme Weather Events

As emphasized in NERC's comments for the Climate Change, Extreme Weather, and Electric System Reliability Technical Conference15 and in the *FERC, NERC and Regional Entity Staff Report: The February 2021 Cold Weather Outages in Texas and the South Central United States*, 16 extreme events are having greater impacts on BPS reliability, and these impacts are largely attributable to the effect of extreme weather on the rapidly transforming grid. NERC's most recent planning assessments have warned of the potential for the loss of large amounts of generating resources due to severe weather in winter and summer as well as the potential need for grid operators to employ operating mitigations or EEAs to meet energy demand. In what can only be described as extraordinary, 2021 saw the manifestation of each of these risks. This subsection covers the **February Cold Weather Event**, **Northwest Heat Dome**, **Texas and California Loss of Solar Events**, **Western U.S. and Canadian Wildfires**, **Hurricane Ida**, and **Thunderstorms and Tornadoes.**

### *February Cold Weather Event*

As shown in **Figure 1.2**, the February 2021 winter weather event was the fourth cold-weather-related event in the last 10 years to jeopardize BES reliability.

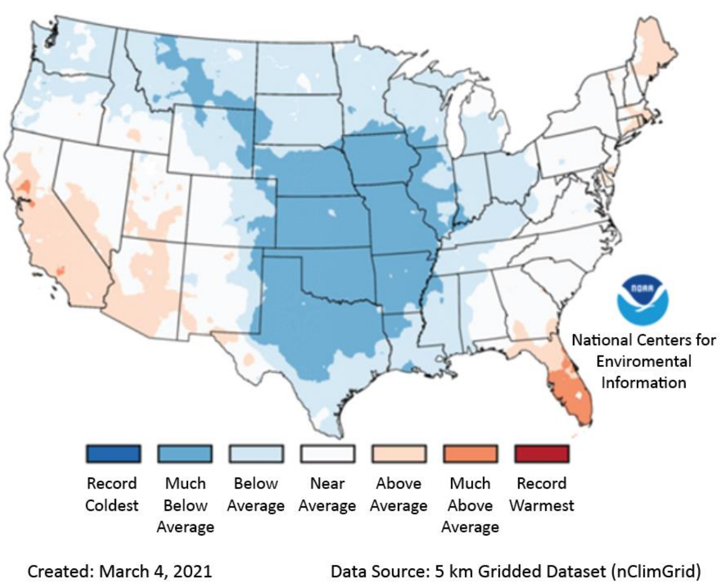


**Figure 1.2: Average February Temperatures across North America—February 2021**

Between February 8 and 20, extreme cold temperatures and freezing precipitation led 1,045 individual BES generating units with a combined 192,818 MW of nameplate capacity in Texas and the South Central United States to experience 4,124 outages, derates, or failures to start. Unplanned generation outages escalated over the duration of the February 2021 winter weather event and accumulated to over four times the amount that had occurred during the previous largest cold weather event in 2011 (65,622 MW vs. 14,702 MW). Between 7:00 a.m. Central, February 15 and 1:00 p.m. Central, February 17, ERCOT alone averaged 34,000 MW of unavailable generation, nearly half of ERCOT's all-time winter peak electricity load of 69,871 MW. As the coldest weather took hold during the week of February 14 and electricity demand increased, ERCOT, Southwest Power Pool (SPP), and MISO simultaneously faced emergency conditions.[17] In response to these emergency conditions and to avoid more damaging cascading outages and system-wide blackouts, ERCOT system operators issued firm load shed orders that totaled 20,000 MW at the worst point. In the EI, SPP, and MISO system operators also shed a combined total of 3,418 MW of firm load on February 15 and 16. The combined 23,418 MW of manual firm load shed was the largest controlled firm load shed event in U.S. history.[18]

In Texas, temperatures were below freezing for over six days. More than 4.5 million people in Texas were without power during the period, some for as long as four days. As documented in the comprehensive November 2021 *FERC, NERC and Regional Entity Staff Report* analyzing the event, at least 210 deaths were directly or indirectly connected to the February 2021 cold weather outages along with an estimated loss to just the Texas economy of between $80 and $130 billion.

The *FERC, NERC and Regional Entity Staff Report* identifies a confluence of two causes, which are part of a recurring pattern observed over the last decade, that led to sharp increases in generation unavailability and ultimately loss of firm load:

- Generating units that were unprepared for cold weather failed in large numbers.
- In the wake of massive cold weather-induced natural gas production declines and declines in natural gas processing to a lesser extent, the natural gas fuel supply struggled to meet both residential heating load and generating unit demand for natural gas.

Additionally, the generation fleet's increasing reliance on natural gas worsened the impacts of reductions in natural gas fuel supply.

The report identifies 28 recommendations, including revisions to mandatory Reliability Standards. These recommendations address generation cold weather reliability, natural gas infrastructure cold weather reliability and joint preparedness with BES winter peak operations, grid emergency operations preparedness, and grid seasonal cold weather preparedness. The ERO Enterprise is currently implementing many of these recommendations.

### *Northwest Heat Dome*

The heat wave that enveloped the Pacific Northwest from late June through early July 2021 delivered unprecedented temperatures to the normally cool region—108°F (42°C) in Seattle, 116°F (47°C) in Portland—and claimed over 1,000 lives, mostly in British Columbia.[19] As shown in **Figure 1.3**, some of the most populated areas of the Pacific Northwest recorded the highest average mean temperatures on record. These unprecedented temperatures resulted in utilities across the region setting new all-time summer peak demand records. During the Heat Dome, several substation distribution transformers reached internal hotspot levels causing outages in some areas. In combination with the Bootleg Fire, the event resulted in Reliability Coordinators issuing three EEA Level 3s due to transmission impacts that produced energy-constrained load pockets.

[17] https://www.ncei.noaa.gov/access/monitoring/us-maps/1/202102

[18] FERC, NERC, and Regional Entity Staff Report

[19] Neal, E., Huang, C. S. Y., & Nakamura, N. (2022). The 2021 Pacific Northwest heat wave and associated blocking: Meteorology and the role of an upstream cyclone as a diabatic source of wave activity. Geophysical Research Letters, 49, e2021GL097699: https://doi.org/10.1029/2021GL097699

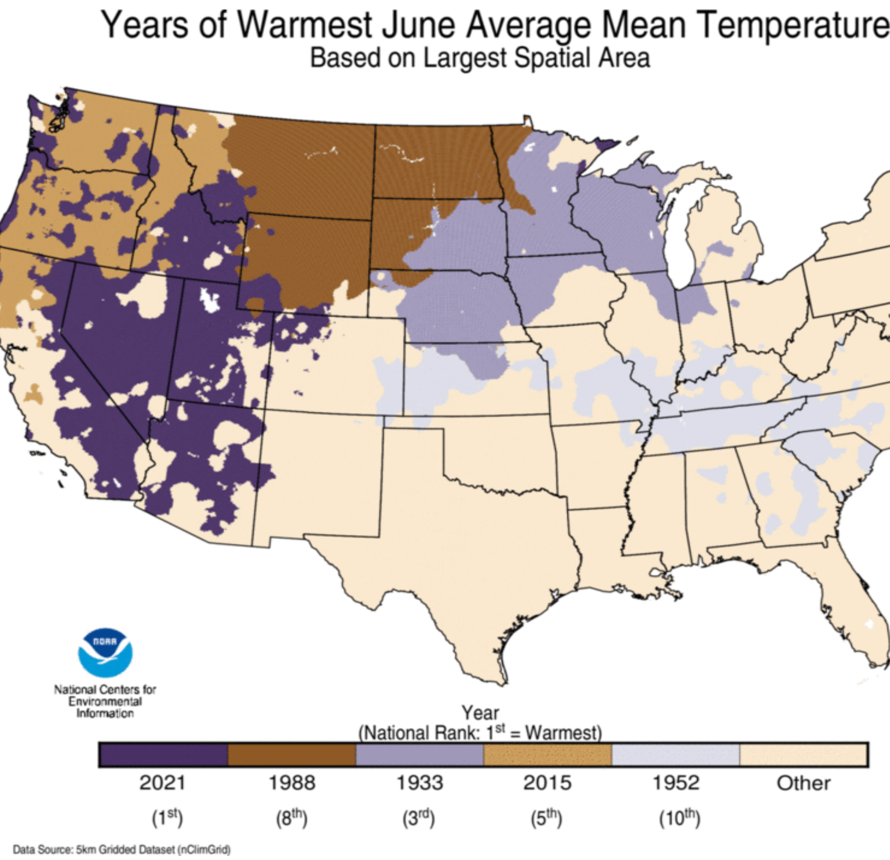


**Figure 1.3: Average June Temperatures across the United States—June 2021**[20]

### *Texas and California Loss of Solar Events*

Grid disturbances on the BPS continue to result in unreliable operation of BPS-connected solar PV resources, particularly an inability to "ride through" these disturbances. On May 9 and June 26, 2021, widespread reductions of solar PV resource power output occurred in the TI, the first events of this type that have occurred outside California. The May 9 "Odessa Disturbance," the subject of the September 2021 *Joint NERC Texas RE Staff Report*,[21] involved over 1,100 MW of reduced output from solar PV facilities up to 200 miles away from the location of the initiating event and a single-line-to-ground fault that occurred on a generator step-up transformer near Odessa, Texas. Like the California events that preceded them, the May and June events in Texas were mainly attributed to abnormal performance of the inverter controls, plant controls, and protections within the facility. Four additional widespread solar PV loss events occurred in California between June and August of 2021, caused primarily by the legacy facilities that had been interconnected with minimal performance requirements. The April 2022 *Joint NERC and WECC Staff Report - Multiple Solar PV Disturbances in CAISO Disturbances between June and August 2021*[22] provides detailed analyses of these four California disturbances. Across these events, widespread loss of solar PV resources was also coupled with the loss of synchronous generation, unintended interactions with remedial action schemes, and some tripping of distributed energy resources (DERs).

The Texas and California events continue to highlight the criticality of ensuring a reliable resource mix that is able to support the BPS by providing essential reliability services, including during contingency events. The previously mentioned disturbance reports highlights three notable areas for improvement moving forward:

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[20] NOAA National Centers for Environmental Information, State of the Climate: Monthly National Climate Report for June 2021, published online July 2021, retrieved on May 19, 2022: https://www.ncei.noaa.gov/access/monitoring/monthly-report/national/202106/supplemental/page-7.
[21] September 2021 Joint NERC Texas RE Staff Report
[22] https://www.nerc.com/pa/rrm/ea/Documents/NERC_2021_California_Solar_PV_Disturbances_Report.pdf

- Industry adoption of NERC guidelines focused on establishing and improving interconnection requirements to ensure reliable operation of IBRs with performance validation to confirm resources are providing essential reliability services that meet those requirements as well as improving modeling and study practices to mitigate systemic modeling errors and challenges that the industry faces.
- Significant updates to the NERC Reliability Standards to address systemic performance issues, particularly in the areas of inverter-specific performance-based resources, the establishment of a performance validation standard, developing a comprehensive ride-through standard, and significantly enhancing modeling and study standards to ensure accurate and verified/validated models are used when making reliability decisions.
- Modernization of the generator interconnection process and FERC generator interconnection procedures and agreements to ensure that adequate steps are taken so that the reliability of newly interconnection IBRs and overall reliability of the BPS are considered when rapidly interconnecting more IBRs.

To understand the operational performance of IBRs, a Section 1600 Data Request for the collection of GADS data for solar PV facilities and an expansion of wind reporting is underway in 2022.

## *Western U.S. and Canadian Wildfires*

While most wildfire impacts on the electricity system are at the distribution level, wildfires also pose a risk to the reliable operation of the BPS. These risks arise through damage to transmission infrastructure and through pre-emptive public safety power shutoffs.

At least one wildfire in the third quarter of 2021 had a significant effect on the BES: the Bootleg Fire resulted in a BPS event that began on July 6 when three 500 kV lines tripped over a seven-minute period. The BPS impacts lasted just over five hours when the second of the three lines was returned to service. While no firm load was shed, one entity did use their demand response program to lower their load by 1,748 MW prior to escalating to an EEA-3. Two other EEA-3s were declared when entities fell short of their reserve requirements.

In 2021, the number and size of wildfires in the WI were slightly below the 2020 totals, but wildfires remained a threat. Almost 26,000 fires consumed 8.1 million acres in 2021, year-over-year reductions of 3% and 14%, respectively. Most states suffered fewer acres lost to wildfires than in the year before, but Idaho, Montana, and New Mexico were exceptions. The number of acres burned in Alberta and British Columbia were 15 and 57 times greater, respectively, than that of the year before; this highlights the extreme variability of state- and province-level statistics from one year to the next rather than a trend.

Wildfires correlate with drought and persist in the Western United States, particularly in Oregon, California, Nevada, Utah, New Mexico, and Montana. The fraction of the entire area facing severe to exceptional drought conditions was slightly greater in March 2022 than it was in March 2021. To better understand the relationship between wildfires and transmission outages, WECC has launched a Geographic Information System-based research project by using detailed information about fires and transmission outages. While the results of this inquiry will not be public for some time, preliminary results have not revealed any obvious trends.

## *Hurricane Ida*

According to the National Oceanographic and Atmospheric Administration, 2021 was the third most active year on record in terms of named storms, marking the sixth consecutive above-normal Atlantic hurricane season and the first time on record that two consecutive hurricane seasons exhausted the list of 21 storm names.

One of the most damaging storms of 2021 was Hurricane Ida, which made landfall in Louisiana on August 29, 2021, on the 16 year anniversary of Hurricane Katrina. Hurricane Ida was a deadly and destructive Category 4 hurricane that became the second most damaging hurricane on record to strike the state of Louisiana (only behind Hurricane Katrina). As the hurricane cut across Southeastern Louisiana, it maintained hurricane strength, primarily affecting entities in Louisiana and Mississippi. Hurricane force winds were predominately isolated to Louisiana, resulting in 210 transmission lines out of service and approximately 1.2 million customers out of power in SERC, including the greater New Orleans area. Over 30,000 workers from 41 states worked to restore power throughout the affected areas. **Figure 1.4** shows Hurricane Ida's path, **Table 1.1** and **Table 1.2** summarize its BES impacts.

Map plotting the track and intensity of the storm, according to the Saffir-Simpson Scale

| Table 1.1: Transmission Line Outages by Voltage Class[23] | |
|---|---|
| 500 kV | 5 |
| 230 kV | 93 |
| 138 kV | 10 |
| 115 kV | 70 |
| 69 kV | 33 |
| Total | 211 |

| Table 1.2: Initial Customer Outages by State Where Hurricane Ida Made Landfall | |
|---|---|
| Louisiana | 1,041 k |
| Mississippi | 123 k |
| Alabama | 20 k |
| Total: | > 1.2 Million |

**Figure 1.4: Path of Hurricane Ida[24]**

### *Thunderstorms and Tornadoes*

A major storm system formed the afternoon of December 10, 2021, with long-lived thunderstorms (see **Figure 1.5**) that consolidated into a line that reached from Arkansas into Missouri, Tennessee, Kentucky, and Illinois. Eight states reported tornadoes during this time, including two long-tracked EF-4 tornadoes. The longest tornado track associated with this event was nearly 166 miles across Kentucky and a small portion of Tennessee. There were over 800 total miles of tornado path length associated with this storm system with wind speeds of 190 mph at peak intensity. At its height, the storm damage caused outages that affected more than 270,000 customers in SERC.

The December 2021 tornado event resulted in extensive transmission system damage, including the outages of 67 transmission lines or line segments. One tornado followed the path of the right-of-way along a 500 kV transmission corridor, resulting in extensive damage to a large number of transmission structures, including foundation damage. The miles of damage to the 500 kV circuit complicated restoration efforts.

[23] A resilience analysis in **Chapter 2**, which is based on TADS data, shows 225 outages on the transmission system that were caused by Hurricane Ida. This count, in contrast with **Table 1.2,** includes both momentary and sustained outages that occurred on BES elements reportable in TADS and reported in all areas affected by Ida.

[24] File:Ida 2021 track.png - Wikimedia Commons

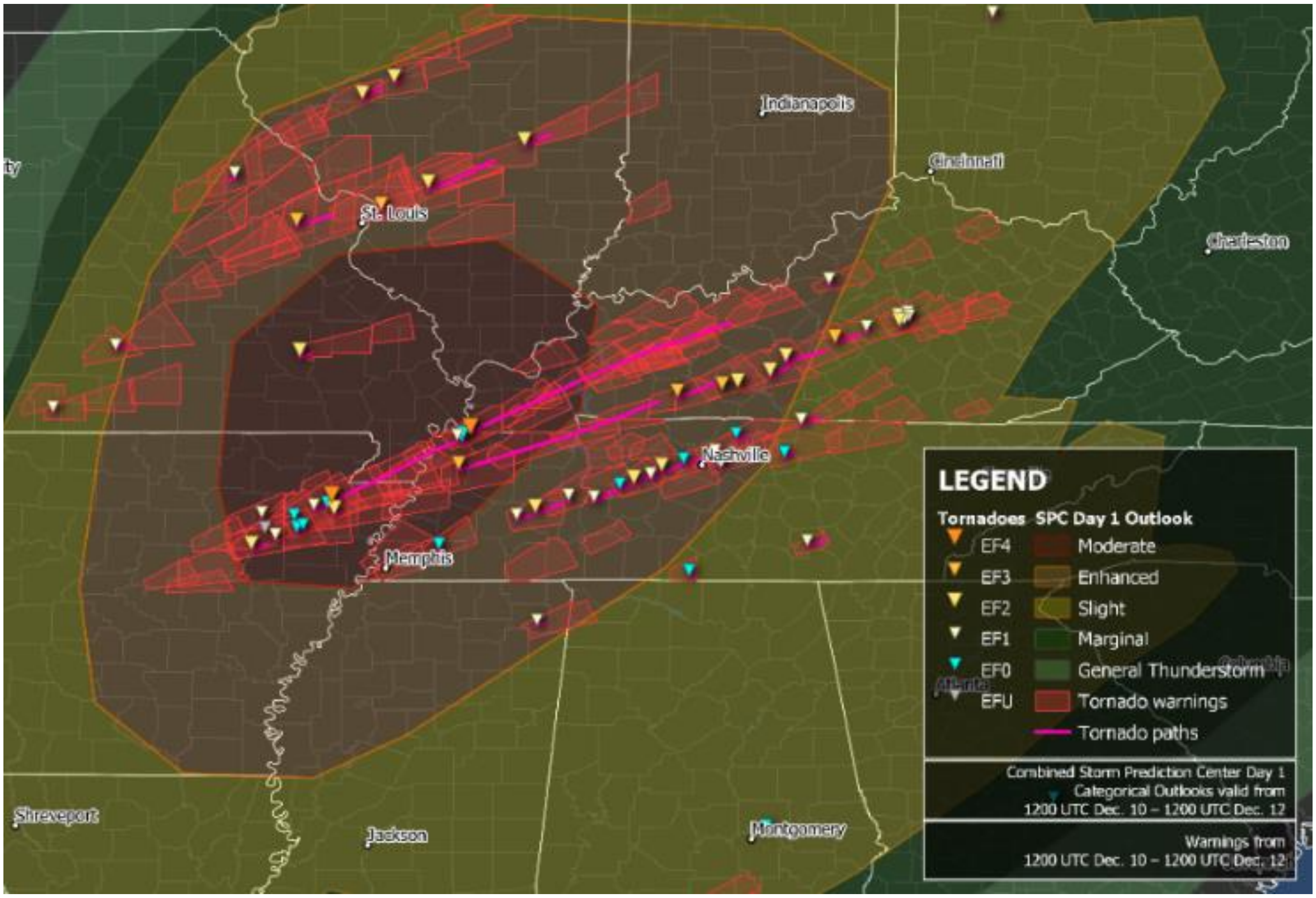



**Figure 1.5: Widespread December 2021 Tornadoes[25]**

25 https://en.wikipedia.org/wiki/Tornado_outbreak_of_December_10%E2%80%9311,_2021#/media/File:December_10%E2%80%9311,_2021_tornado_outbreak_warnings_and_reports.png

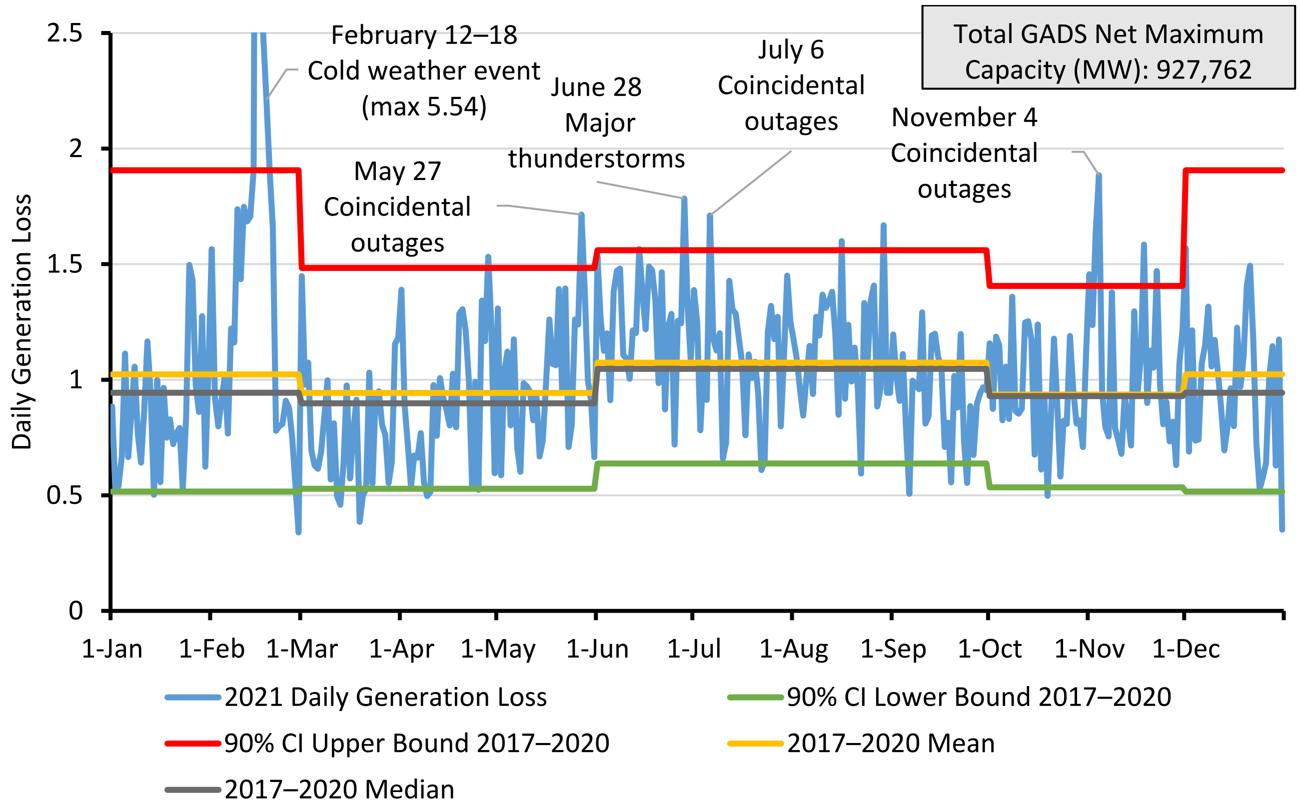



**Figure 2.5: 2021 Generation Impacted during Extreme Days—North America**

### *Top Causes of Outages on Extreme Days*

The top causes reported for outages that occurred on extreme days are shown below in rank order for North America as a whole and each Interconnection. Weather (Excluding Lightning), Fire, and Failed Protection System Equipment were the top three causes for transmission systems (**Table 2.4**).

**Table 2.4: Top Transmission Outage Causes on Extreme Days**

| Area | Cause #1 | Cause #2 | Cause #3 | Cause #4 | Cause #5 |
|---|---|---|---|---|---|
| **North America** | Weather (Excluding Lightning) | Failed Protection System Equipment | Failed AC Substation Equipment | Failed AC Circuit Equipment | Unknown |
| **Eastern–Québec Interconnections** | Weather (Excluding Lightning) | Failed Protection System Equipment | Failed AC Circuit Equipment | Failed AC Substation Equipment | Lightning |
| **Texas Interconnection** | Weather (Excluding Lightning) | Failed AC Circuit Equipment | Lightning | Unknown | Failed AC Substation Equipment |
| **Western Interconnection** | Weather (Excluding Lightning) | Fire | Unknown | Power System Conditions | Failed AC Circuit Equipment |

The primary causes of generation outages reported on extreme days were equipment-related to Fuel/Ignition/Combustion Systems and Economic reasons, both of which are attributable to cold weather events (**Table 2.5**).

| Table 2.5: Top Generation Outage Causes on Extreme Days | | | | | |
|---|---|---|---|---|---|
| **Area** | **Cause #1** | **Cause #2** | **Cause #3** | **Cause #4** | **Cause #5** |
| **North America** | Fuel, Ignition, and Combustion Systems | Economic | Catastrophe | Electrical | Boiler Tube Leaks |
| **Eastern–Québec Interconnections** | Economic | Fuel, Ignition, and Combustion Systems | Boiler Tube Leaks | Electrical | Catastrophe |
| **Texas Interconnection** | Catastrophe | Fuel, Ignition, and Combustion Systems | Economic | Auxiliary Systems | Boiler Control Systems |
| **Western Interconnection** | Electrical | Controls | Boiler Tube Leaks | Auxiliary Systems | Miscellaneous (Natural Gas Turbine) |

# Bulk Electric System Resilience against Extreme Weather

In the 2021 SOR,[30] NERC introduced a new analysis of 2020 large transmission events caused by extreme weather that quantified some aspects of restoration and recovery activities. Restoration and recovery actions can mitigate those conditions identified as posing the highest risk to the BES on extreme event days. This analysis was based on outage and restoration processes for transmission elements, not on disruption and restoration of customer load. Restoration of the transmission system to serve customer load is always the priority, and restoration of load generally takes place long before all transmission elements are returned to service.

This year's SOR focuses on the 2021 large transmission weather-related events and extends the resilience analysis to assess Hurricane Ida as a major transmission and generation event. Additionally, **Appendix B** includes detailed analyses and statistics for large transmission events caused by extreme weather, such as hurricanes and tornadoes. These statistics enable the measurement and tracking of the transmission system ability to withstand, adapt, protect against, and recover during and after extreme weather events. Changes in the transmission system resilience statistics from 2016–2020 to 2017–2021 for each extreme weather type are identified by the analysis.

## Weather-Related Transmission Outage Events

### *TADS Outage Grouping and 2021 Large Weather Events*

An algorithm group's automatic outages reported in TADS are based on Interconnection and associated start and end times.[31] The resulting transmission outage events are determined to be weather-related if at least one outage in the event is initiated or sustained by one of the following TADS cause codes: Weather (excluding lighting), Lightning, Fire, or Environmental. The procedure produces groupings of outages that are further reviewed and compared with the weather information from external sources to confirm or refine the events. This combination of automatic and manual procedures results in a set of transmission events that can cross boundaries of different utilities and Regional Entities as well as allows for the capture of significant events caused by extreme weather, such as hurricanes.

The outage grouping procedure produced eight large transmission events (events with the event size of 20 or more outages) that occurred in the year 2021. **Table 2.6** lists these events in chronological order and shows the severe weather type for each event with statistics that quantify the impact of the event on the system. All of the large

[30] Report (nerc.com)

[31] S. Ekisheva, R. Rieder, J. Norris, M. Lauby, and I. Dobson, "Impact of extreme weather on North American transmission system outages," 2021 IEEE Power & Energy Society General Meeting.

transmission events identified as part of the restoration analysis have also been identified as extreme in the TOS extreme weather analysis, indicating consistency between the methodologies.

In 2021, the largest number of outages in a single event occurred in the EI with Hurricane Ida, which started on August 29 (225 transmission outages reported); this is shown in red in **Table 2.6**. Note that the February cold weather event, which was the largest event on the generation system, also resulted in a large transmission event in the TI. The definitions of element-days lost and the MVA-days lost are provided in **Appendix B.**

**Table 2.6: 2021 Large Transmission Weather-Related Events**

| Event Start | Event Outage Count | Inter-connection | Extreme/Severe Weather Event | MVA Affected | Miles Affected | Duration (Days) | Element-Days Lost | MVA-Days lost |
|---|---|---|---|---|---|---|---|---|
| January 13 | 144 | Western | Strong winter storms, high winds, landslides | 41,592 | 5,439 | 13 | 146 | 32,592 |
| January 26 | 21 | Eastern | Storm system with high winds, snow, sleet, and ice | 10,835 | 354 | 3 | 8 | 3,923 |
| February 15 | 28 | Texas | February 2021 Cold Weather | 16,695 | 902 | 1.4 | 12 | 4,115 |
| April 10 | 25 | Eastern | Tornadoes | 7,970 | 508 | 11 | 39 | 35,118 |
| May 4 | 24 | Eastern | Tornadoes and thunderstorms | 9,666 | 624 | 4 | 21 | 7,035 |
| August 29 | 225 | Eastern | Hurricane Ida | 101,058 | 2,876 | 124 | 1,300 | 641,506 |
| December 11 | 53 | Eastern | Tornadoes and thunderstorms | 17,653 | 1,691 | 21 | 230 | 114,393 |
| December 15 | 87 | Eastern | Strong storms with high winds | 36,529 | 2,849 | 16 | 123 | 63,693 |

### *Outage, Restore, and Performance Curves*

**Table 2.6** illustrates the variability in event sizes and event duration. However, these statistics do not completely explain what happened during the events; the outage, restore, and performance curves of the events provide more details on how the events unfolded.[32] As shown in **Figure 2.6** to describe transmission outages during an event, these curves track the number of elements out or the MVA impact on the vertical axis vs. time on the horizontal axis. Similarly, to describe generation outages during the event, these curves track generation out on the vertical axis vs. time on the horizontal axis.

[32] S. Ekisheva, I. Dobson, R. Rieder, and J. Norris, “Assessing transmission resilience during extreme weather with outage and restore processes,” 2022 17th International Conference on Probabilistic Methods Applied to Power Systems

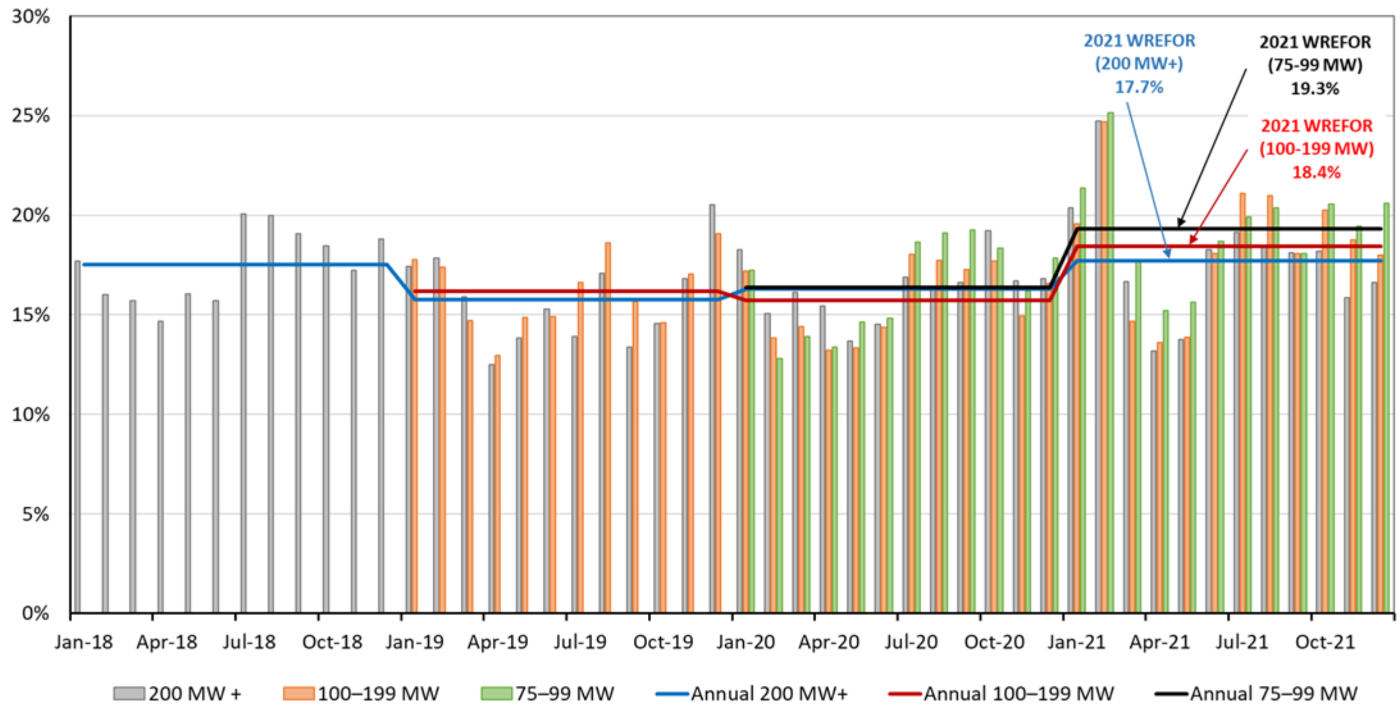



**Figure 4.7: Monthly Capacity WREFOR and Annual Average Wind Plant Reporting Group**

# Transmission Performance and Unavailability

When evaluating transmission reliability, an important concept is that transmission line outages have different impacts on BPS reliability. Some impacts can be very severe, such as those that affect other transmission lines and load loss. Additionally, some outages are longer than others, leaving the transmission system at risk for extended periods of time. Reliability indicators for the transmission system are measured by using qualified event analysis reporting not related to weather and outages reported to TADS.

The number of qualified events that include transmission outages that resulted in firm load loss not related to weather is provided in the following subsection.

## Transmission-Related Events Resulting in Loss of Load

### *2021 Performance and Trends*

In 2021, four distinct non-weather-related transmission events resulted in loss of firm load meeting the Event Analysis Process (EAP) reporting criteria (see **Figure 4.8**). Analysis indicates no discernable trend in the number of annual events. The median firm load loss over the past five years was 131 MW, which is a significant decrease from 2016–2020's 183 MW. In 2021, the median was 74.7 MW, and this represents a decrease in both the number of events and median load loss in 2021 with 2021's median load loss remaining below the five-year median value.

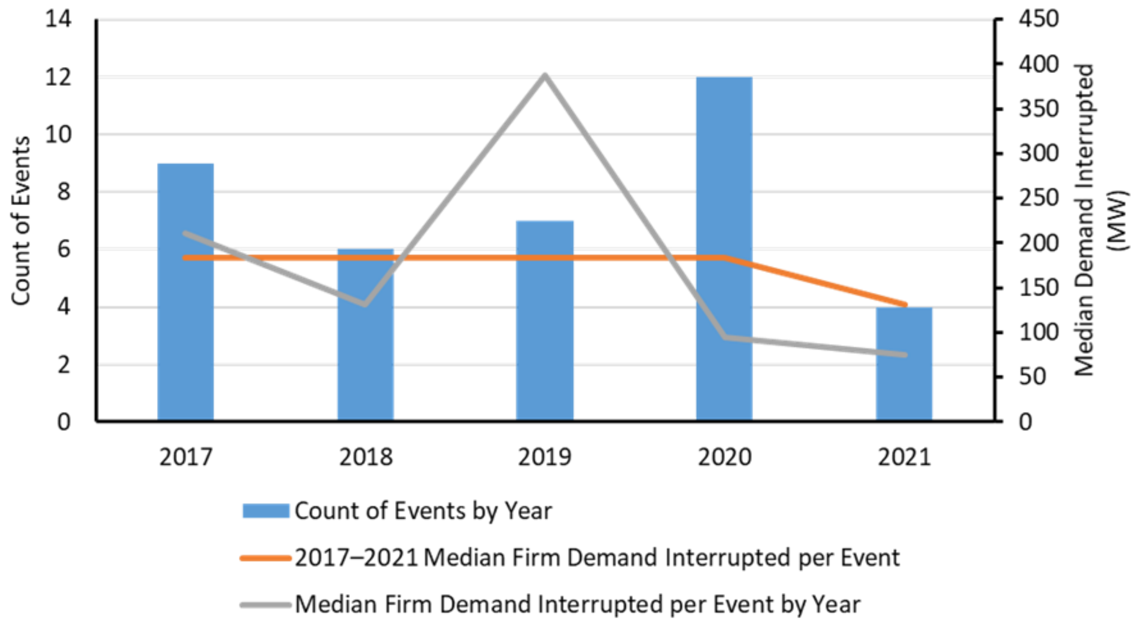



**Figure 4.8: Transmission-Related Events Resulting in Loss of Firm Load and Median Amount of Firm Load Loss Excluding Weather-Related Events**

## TADS Reliability Indicators

A TADS event is an unplanned transmission incident that results in the automatic outage (sustained or momentary) of one or more elements. TADS event information was analyzed for the following indicators in this section:

- Transmission Outage Severity
- Automatic AC Transmission Outages
- Automatic AC Transformer Outages
- Transmission Element Unavailability

## Transmission Outage Severity

### *2021 Performance and Trends*

The impact of a TADS event on BPS reliability is called the TOS of the event, which is defined by the number of outages in the event and by the type and voltage class of transmission elements involved in the event. TADS events are categorized by initiating cause codes (ICCs). These ICCs facilitate the study of cause-effect relationships between each event's ICC and event severity.

By examining the average TOS, duration, and frequency of occurrence for events with different ICCs (see Figure 4.9), it is possible to determine which ICCs contribute most to reliability performance for the time period considered. The average TOS for an ICC's events is displayed on the Y-axis. A higher TOS for an ICC indicates more outages or higher voltage elements were involved in an event. The average duration for a given ICC's events is displayed on the X-axis; events with a longer duration generally pose a greater risk to the BPS. The number of ICC occurrences is represented by the bubble size; larger bubbles indicate an ICC occurs more often. Change in size or position of a bubble with the same number (identifying ICC) may indicate improved or declined performance. Lastly, the bubble colors indicate a statistical significance of a difference in the average TOS of this group and the events from other groups.

There was a statistically significant reduction in the average event TOS and duration from 2016–2020 to 2017–2021 (past five-year period to the current five-year period) that indicates an improvement in the TOS and duration sub-metrics.

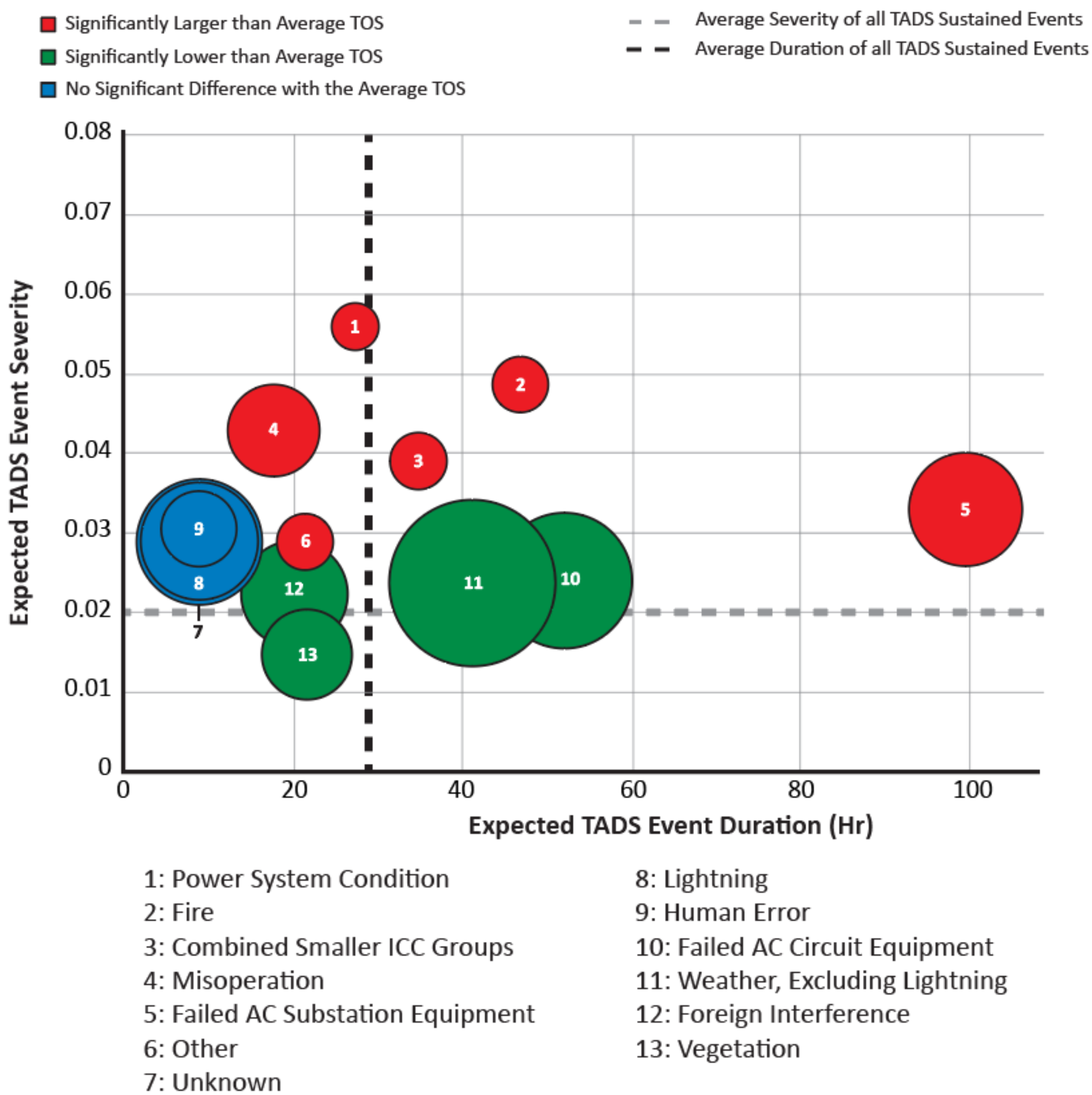



**Figure 4.9: TOS vs. Expected TADS Event Duration**

An analysis of the total TOS by year indicates a statistically significantly improving trend for the last five years (see Figure 4.10); this is a positive indication that transmission outages are leading to less severe reliability impacts.

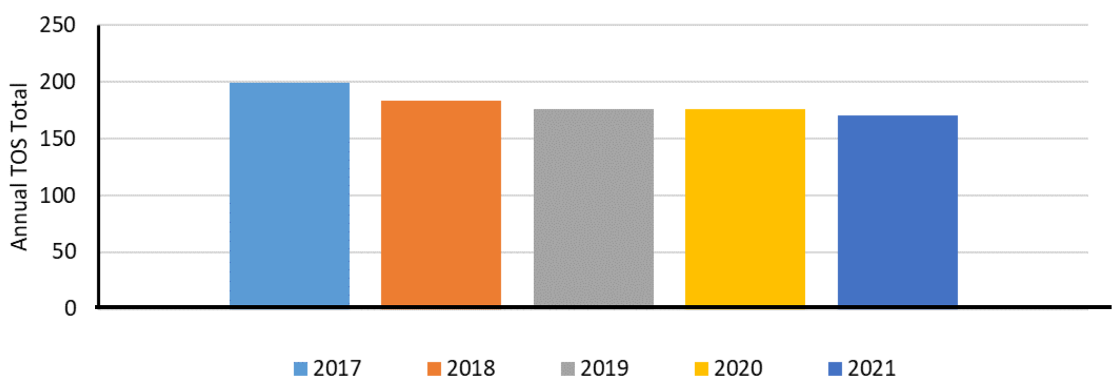



**Figure 4.10: TOS of TADS Sustained Events of 100 kV+ AC Circuits and Transformers by Year Automatic AC Transmission Outages**

### *2021 Performance and Trends*

The average number of outages per circuit due to Failed AC Substation Equipment has continued to improve consistently over the last four years, showing a statistically significant decrease in 2021 compared to 2017–2020 (See Figure 4.11). The number of sustained outages due to Failed AC Circuit Equipment per 100 miles saw a slight increase, bringing it above the five-year average; however, it remains Stable overall (See Figure 4.12).

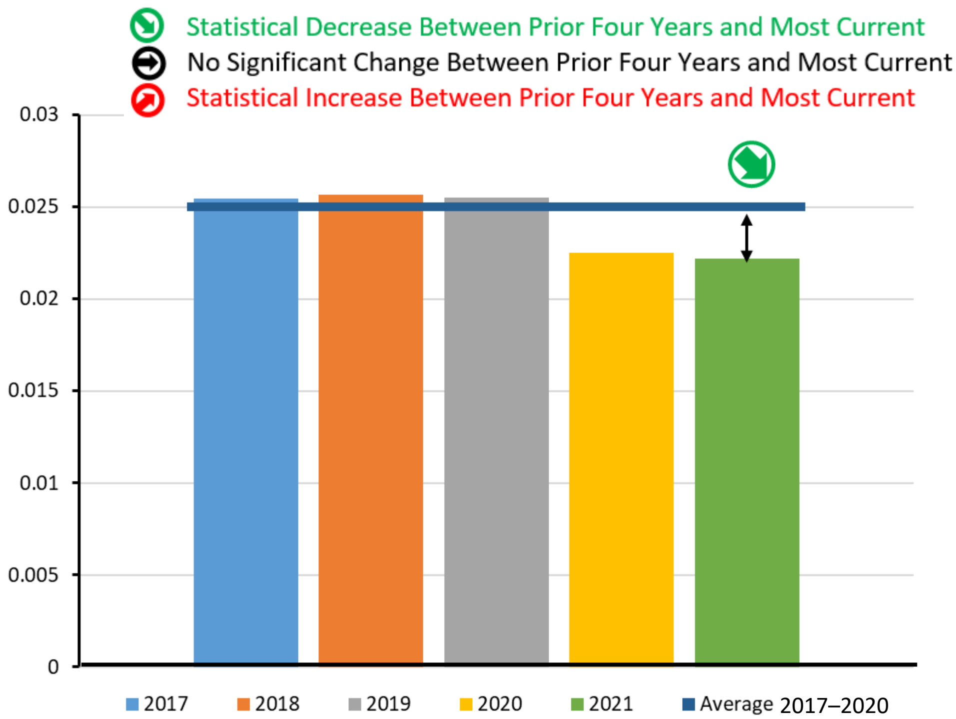



**Figure 4.11: Number of Outages per AC Circuit due to Failed AC Substation Equipment**

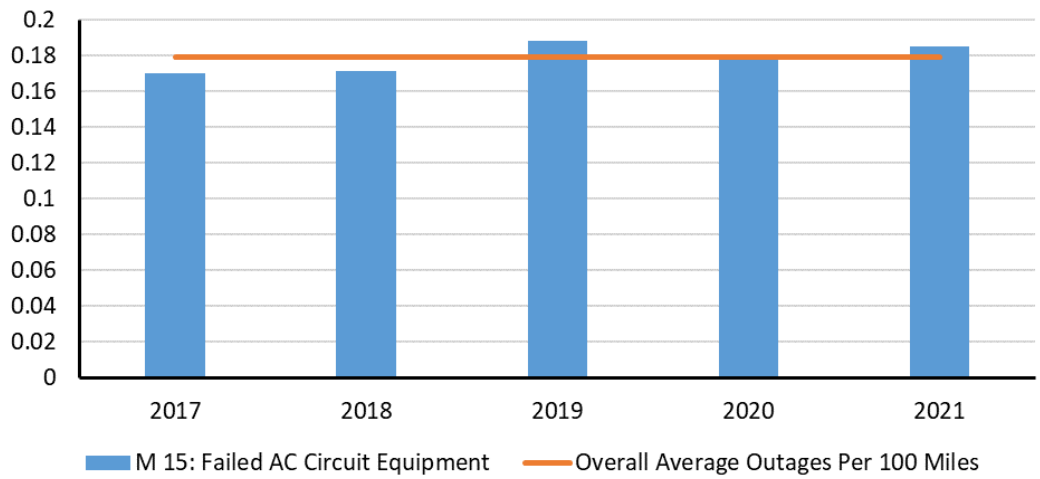



**Figure 4.12: Number of Outages per Hundred Miles due to Failed AC Circuit Equipment**

## Automatic AC Transformer Outages

### *2021 Performance and Trends*

From 2017 through 2021, the trend of automatic ac transformer outages caused by Failed AC Substation Equipment is showing a statistically significant decrease in the number of outages per element.

See **Figure 4.13** for the number of outages per transformer due to various initiating causes.

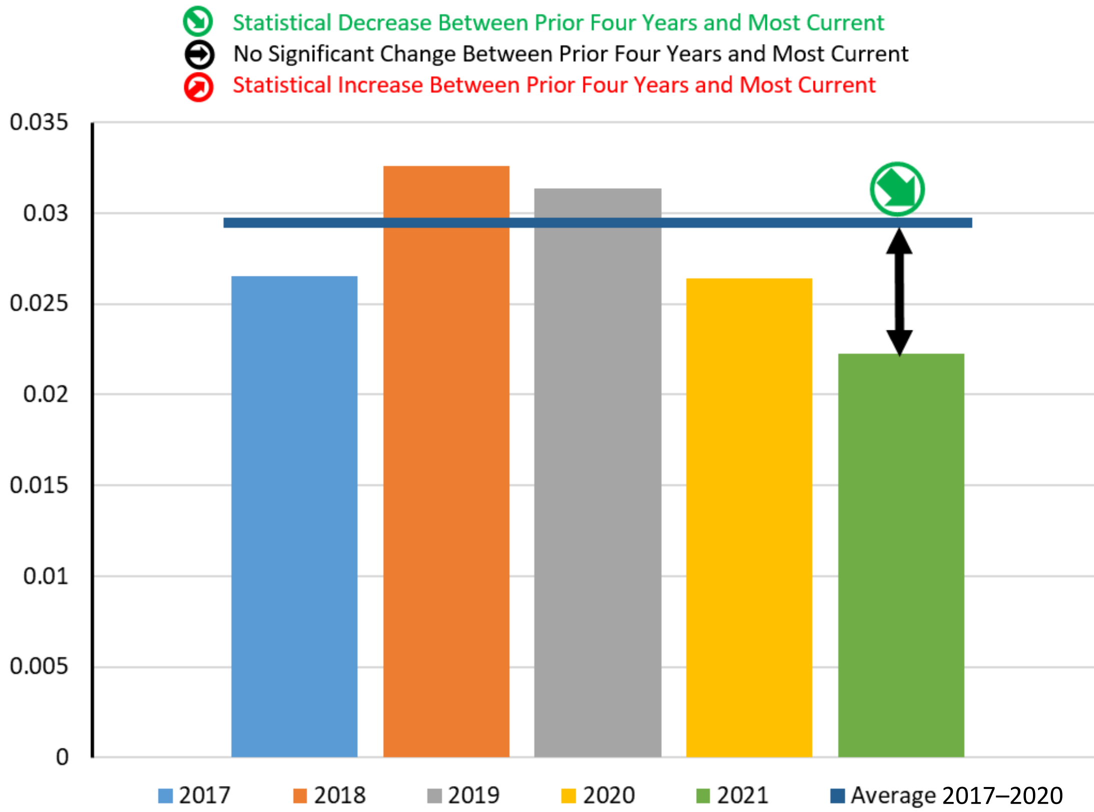



**Figure 4.13: Number of Outages per Transformer Due to Failed AC Substation Equipment**

## Transmission Element Unavailability

### *2021 Performance and Trends*

In 2021, ac circuits over 200 kV across North America had an unavailability rate of 0.275%, meaning that there is a 0.275% chance that a transmission circuit is unavailable due to sustained automatic and operational outages at any given time. Transformers had an unavailability rate of 0.20% in 2021. **Figure 4.14** shows 2021 was the second highest year for ac circuit unavailability of the five-year analysis period behind 2020. **Figure 4.15** shows 2021 was the second lowest year for transformer unavailability behind 2020.

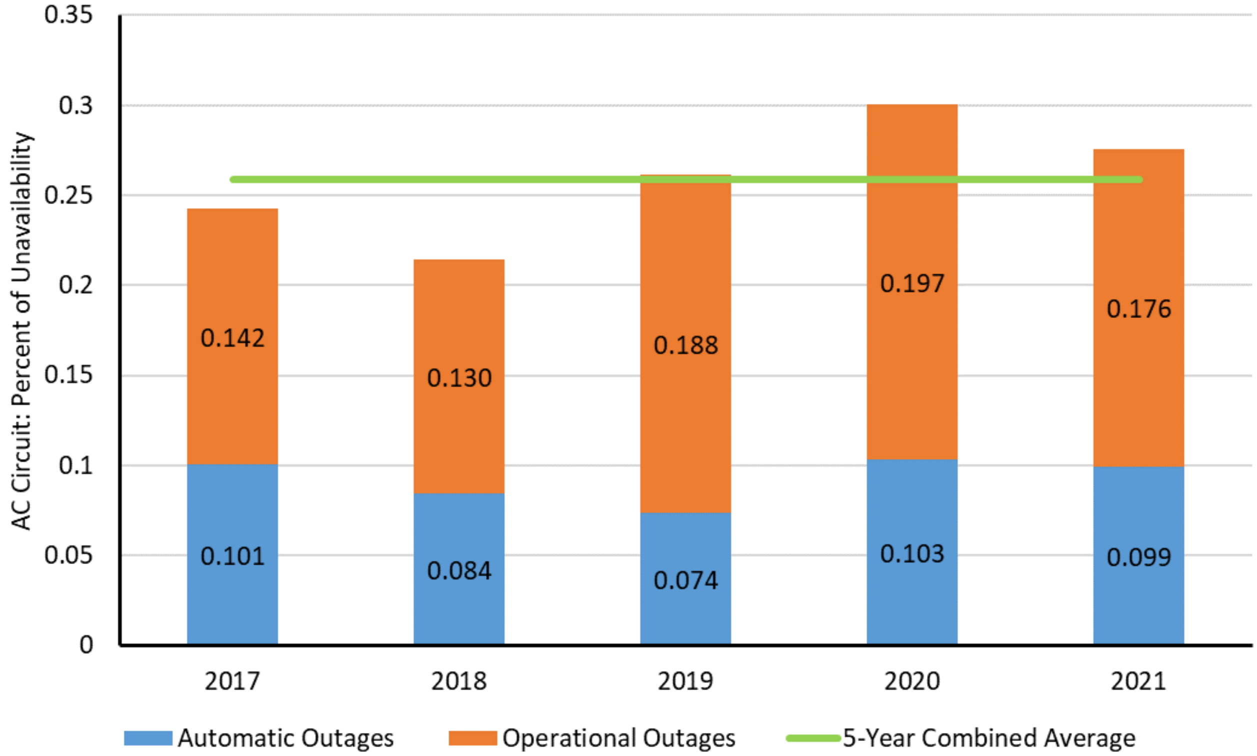



**Figure 4.14: AC Circuit Unavailability**

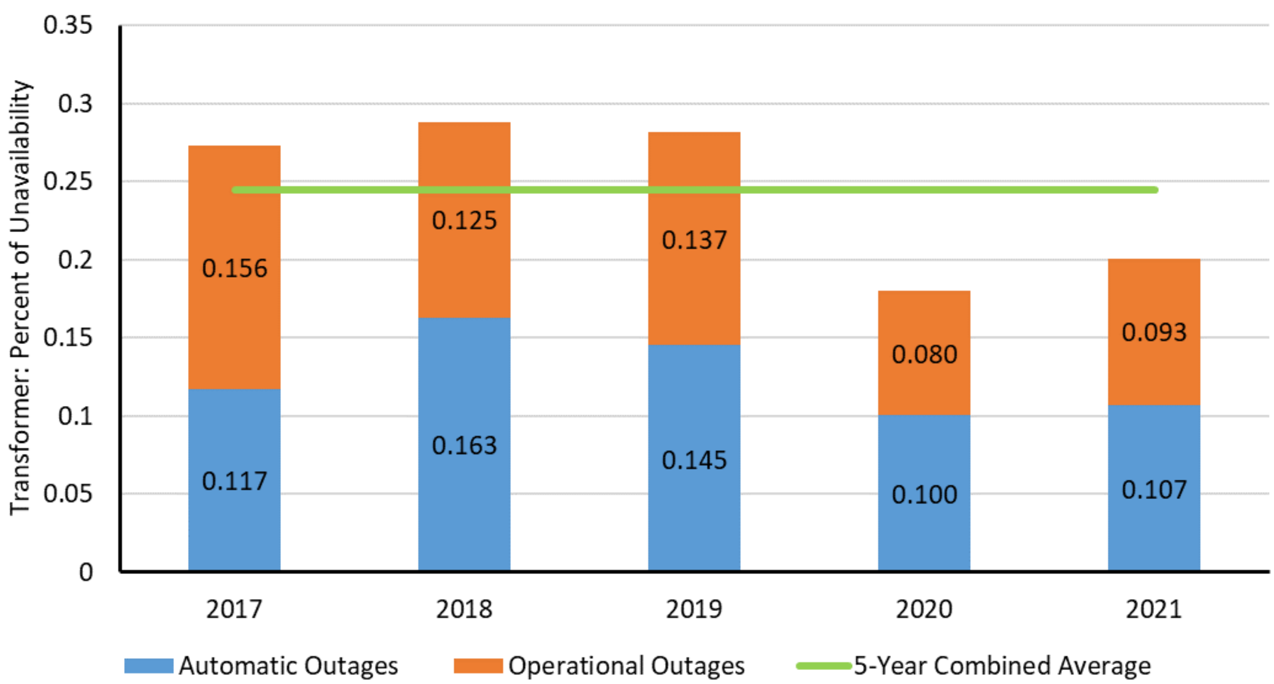



**Figure 4.15: Transformer Unavailability**

### *Assessment*

Software and communications failure are major contributors to the loss of EMS. The complete loss of monitoring or control capability has been the most prevalent event failure since 2020, but the loss of SE/RTCA is the most prevalent one over the evaluation period from 2017–2021. Both loss of SE/RTCA events and loss of ICCP events have been declining since 2018 due to the EOP-004-4 impact on partial loss of EMS functions reporting and the industry effort to enhance EMS reliability and resilience.

While failure of a decision-support tool has not directly led to the loss of generation, transmission lines, or customer load, EMS failures may hinder the decision-making capabilities of the system operators during normal operations or more importantly during a disturbance. The ERO has analyzed data and identified that short-term outages of tools and monitoring systems are not uncommon and that the industry is committed to reducing the frequency and duration of these types of events.

# Increasing Complexity of Protection and Control Systems

## Protection and Control Systems

As the system of interconnected power generation, transmission, and distribution assets has evolved, so too has the numbers and types of automated tools and systems that use digital information and microprocessor-driven devices to manage the electricity grid. This technologically diverse environment allows an operator to manage specified controls from virtually anywhere and at a cost far lower than what would have been possible otherwise. When designed and implemented properly, automated tools can enhance the reliable and secure use of new technologies and concepts that become available. On the other hand, maintaining, prudently replacing, and upgrading BPS control system assets can lead to protection and control system misoperations. Misoperations can initiate more frequent and/or more widespread outages. Resource mix changes that involve growth in inverter-based generation sources can also impact wide-area protection and increase the need to coordinate protection with the distribution system.

By evaluating the annual misoperation rates across North America and separately for each Regional Entity over the last five years and comparing the average of the first four years with the most recent year (see **Figure 4.22**), a statistically significant decreasing trend can be observed in the misoperation rates for RF and Texas-RE. No statistically significant trend is observed for MRO, SERC, WECC, or the overall MIDAS data reported to NERC.

A statistically significant increase in the misoperation rate for NPCC occurred in 2021. Looking at the components of the misoperation rate in **Table 4.4** indicates that this increase is driven primarily by a sharp decrease in the number of protection system operations and a slight increase in the count of misoperations. Historically, substantial changes in the misoperations rate have occurred when large changes in the protection system operations counts occur. The increase in the number of misoperations for NPCC was due to an increase in misoperations that occurred during non-fault conditions. This category of misoperation made up 65% of NPCC's misoperations reported in 2021, compared with 57% of NPCC's misoperations over the prior four years. This finding suggests that additional information is needed to further analyze the impact of misoperations.

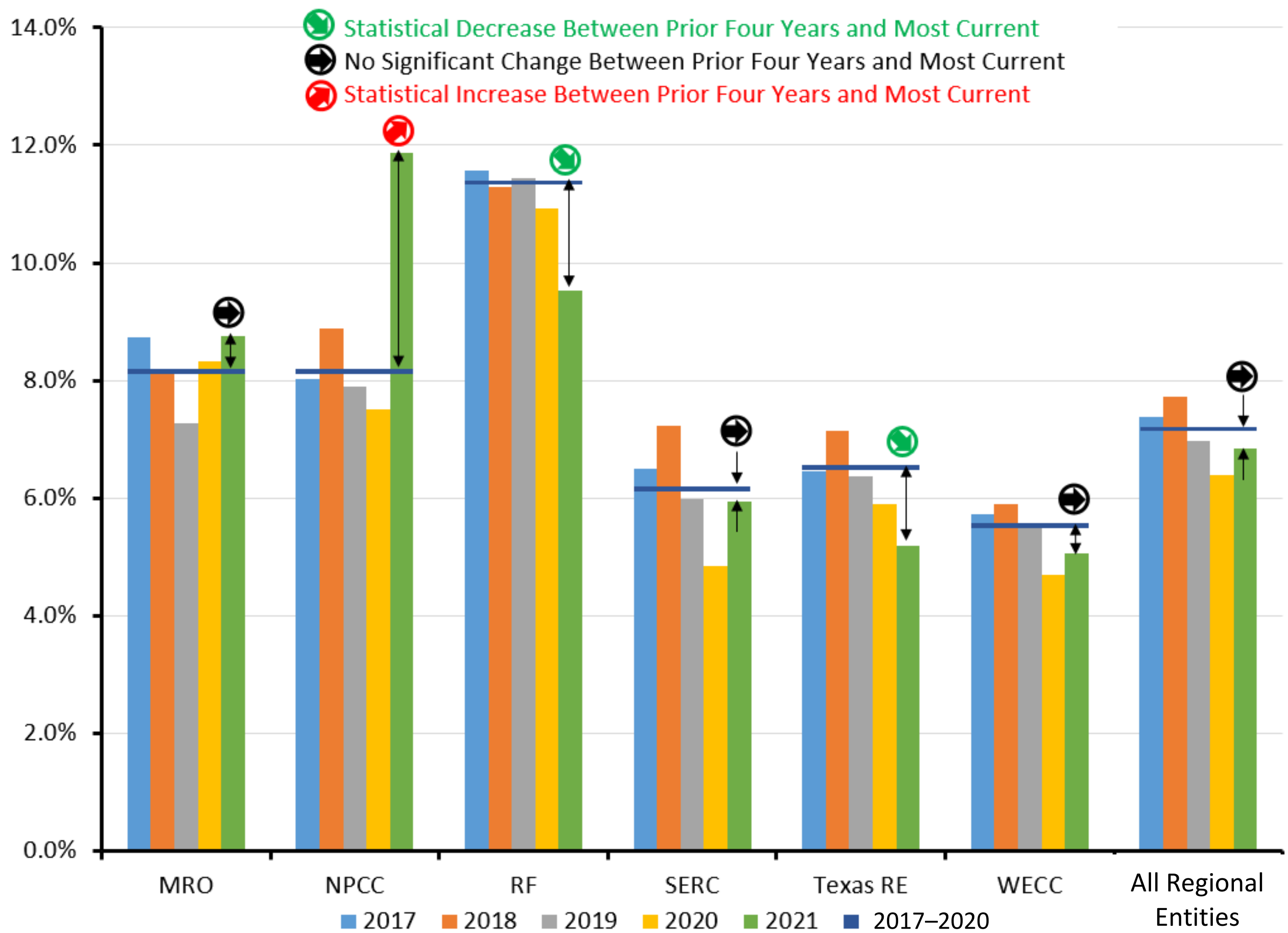


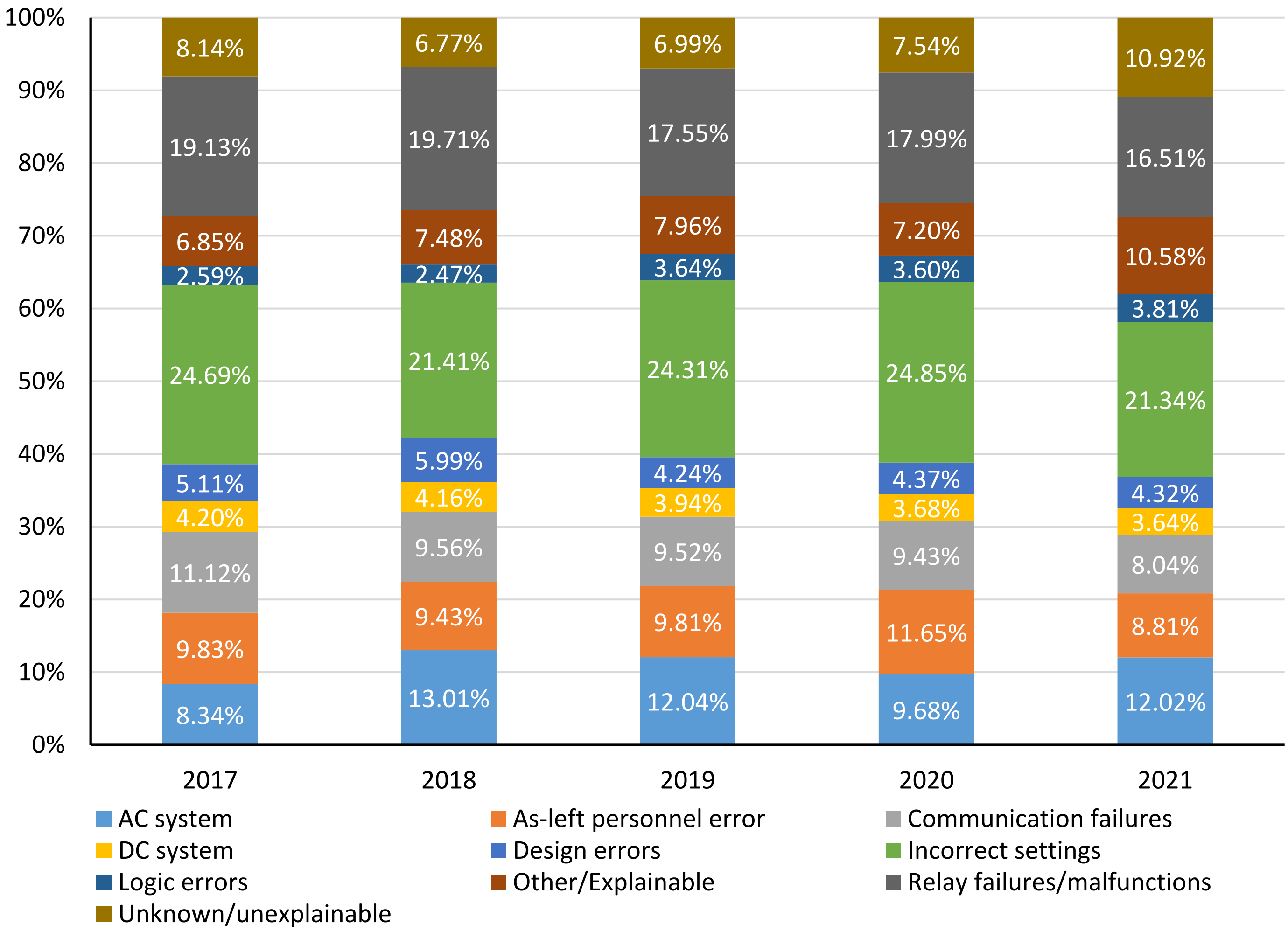

**Figure 4.22: Changes and Trends in the Annual Misoperations Rate by Regional Entity**

**Table 4.4: Five-Year Protection System Operations and Misoperations Counts 2017 through 2021**

| Area | Protection System Operations | | | | | Misoperations | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2020 | 2021 | 2017 | 2018 | 2019 | 2020 | 2021 |
| All Regional Entities | 20,971 | 19,905 | 19,305 | 18,279 | 17,239 | 1,550 | 1,539 | 1,345 | 1,167 | 1,180 |
| MRO | 3,678 | 3,740 | 3,734 | 3,054 | 2,617 | 321 | 306 | 272 | 254 | 229 |
| NPCC | 2,031 | 2,117 | 1,661 | 1,760 | 1,365 | 163 | 188 | 131 | 132 | 162 |
| RF | 2,264 | 2,275 | 2,149 | 1,875 | 1,658 | 262 | 257 | 246 | 205 | 158 |
| SERC | 5,411 | 4,873 | 4,753 | 5,267 | 4,616 | 352 | 352 | 284 | 255 | 274 |
| Texas RE | 2,385 | 2,279 | 2,639 | 2,000 | 2,599 | 154 | 163 | 168 | 118 | 135 |
| WECC | 5,202 | 4,621 | 4,369 | 4,323 | 4,384 | 298 | 273 | 244 | 203 | 222 |

## Leading Causes of Misoperations

The top causes of misoperations over the past five years have consistently been Incorrect Settings and Relay Failures/Malfunctions (see **Figure 4.23**), and the relative frequency of these two causes has been slowly decreasing. 2021 also saw the first increase in the number of misoperations coded as Unknown/Unexplainable in the past five years, up to 129 from 88 in 2020.




| Year | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|
| Misoperation Count | 1,550 | 1,539 | 1,345 | 1,167 | 1,180 |

**Figure 4.23: Misoperations by Cause Code (2017–2021)**

## Protection System Failures Leading to Transmission Outages

AC circuits and transformers both saw a slight increase in the number of outages per element in 2021, but neither was statistically significant (see **Figure 4.24**).

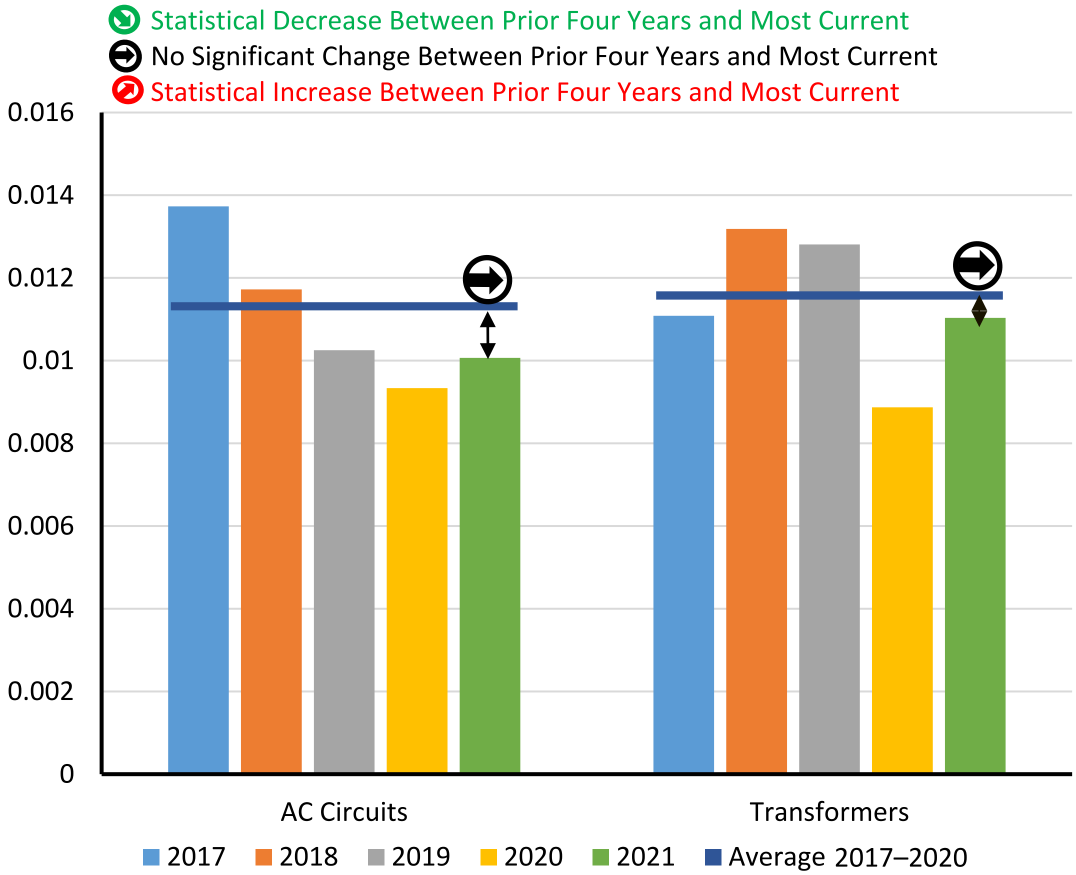



**Figure 4.24: Failed Protection System Equipment**

### Event-Related Misoperations

An analysis of qualified events reported through the ERO EAP found that there were 75 transmission-related system disturbances in 2017. Of those 75 events, a total of 47 events (63%) had associated misoperations. Since 2017, the ERO and industry stakeholders have continued efforts to reduce protection system misoperations through initiatives that included formation and participation in various task forces, workshops, and conducting more granular root cause analysis. In 2021, there were 69 transmission-related qualified events. Of those 69 events, 31 events (45%) involved misoperations (see **Figure 4.25**). The efforts made by the ERO and industry have resulted in a declining trend in the number of events with misoperations over the last five years.

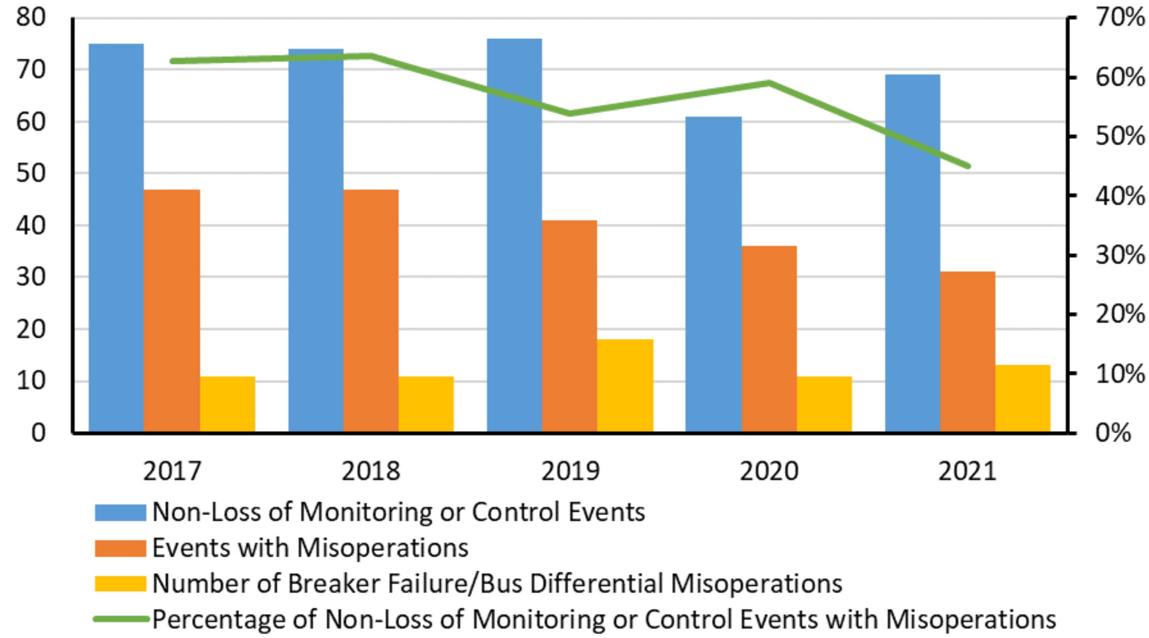



**Figure 4.25: Events with Misoperations**

### *Actions in Progress*

- NERC, Regional Entities, and stakeholders continue to conduct industry webinars on protection systems and document success stories on how Generator Owners and Transmission Owners are achieving high levels of protection system performance.
- The Misoperation Information Data Analysis System (MIDAS) User Group (MIDASUG) continues to collect and analyze protection system misoperations data and information through MIDAS and provide training to ensure consistency of operations and misoperations reporting.

# Human Performance

## Transmission Outages Related to Human Performance

NERC TADS collects transmission outage data with a variety of causes that include Human Error. The definition of Human Error as a cause of transmission outage is defined in the *TADS Data Reporting Instructions*.[57] The effective use of human performance will help mitigate the active and latent errors that negatively affect reliability. Weaknesses in human performance hamper an organization's ability to identify and address precursor conditions that degrade effective mitigation and behavior management.

Statistical significance testing was done that compared 2021 to the average outage rate of the prior four years. For ac circuits, all forced outages caused by Human Error have seen a statistically significant decrease in frequency (see **Figure 4.26**). For transformers, operational outages caused by Human Error have seen a statistically significant decrease; however, automatic and all forced outages caused by Human Error have seen no statistically significant change in frequency (see **Figure 4.27**).

[57] Human Error: relative human factor performance that include any incorrect action traceable to employees and/or contractors to companies operating, maintaining, and/or assisting the Transmission Owner.

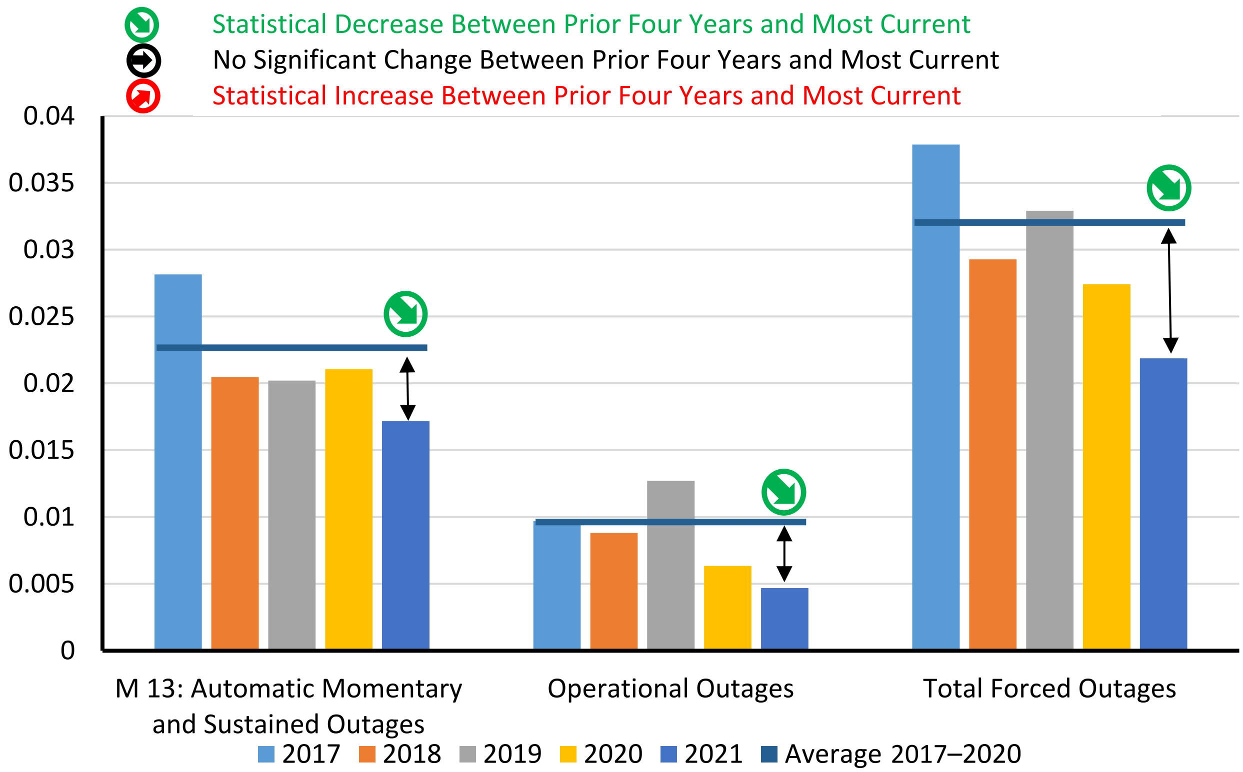



**Figure 4.26: AC Circuit Outages Initiated by Human Error**

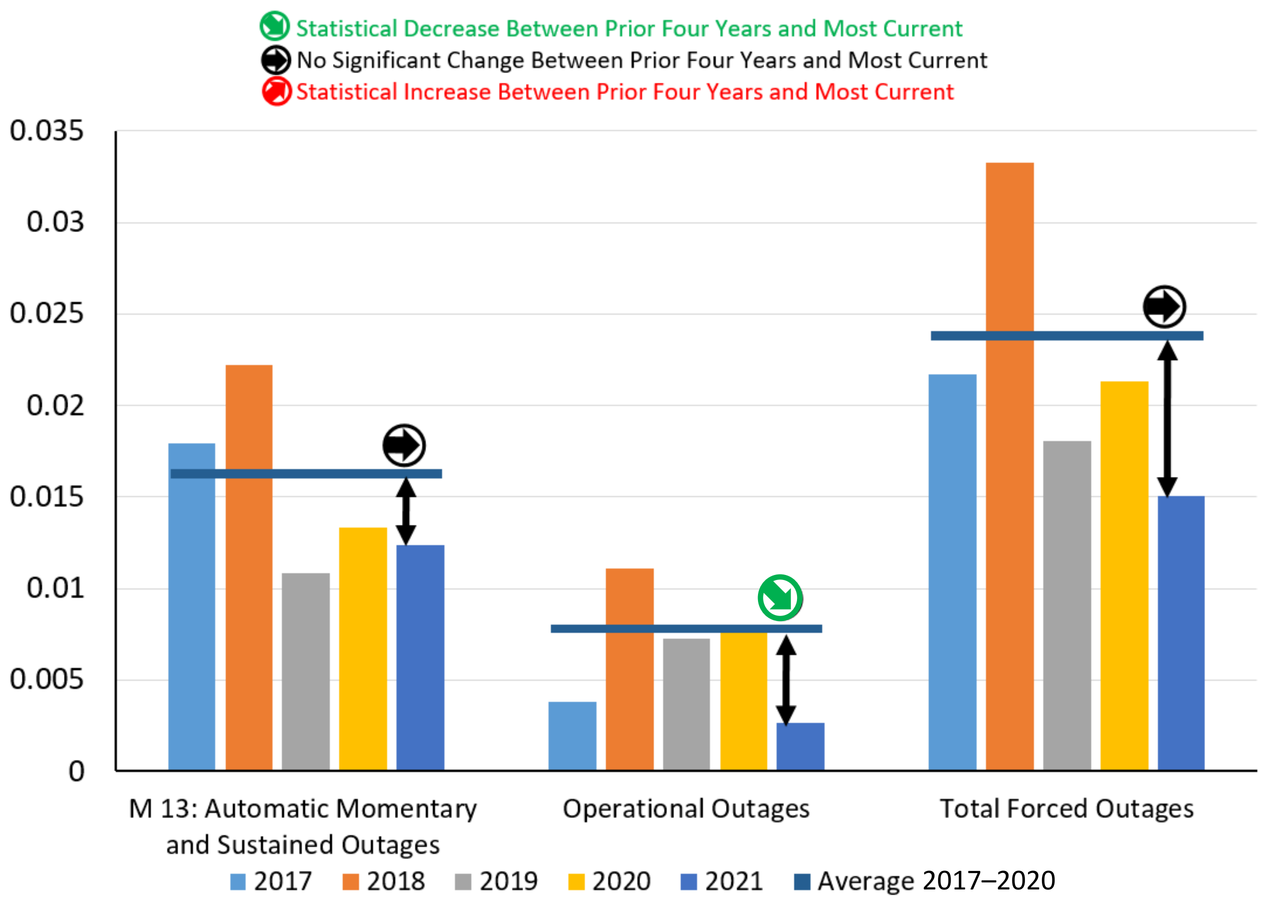



**Figure 4.27: Transformer Outages Initiated by Human Error**

## Human Performance and Generation Outages

NERC GADS collects generation outage data associated with a variety of causes that include Human Error. Over the past five years, forced outages attributed to Human Error have averaged around 1% of all forced generator outage events, and no fuel type showed a notable increase in 2021.

### *Trends of Events Involving Human/Organization Performance as a Root Cause*

In the ERO EAP, the cause sets of individual human performance and management/organization identify events or conditions that are directly traceable to individual or management actions or organization methods (or lack thereof) that caused or contributed to the reported event. In 2021, human/organization performance was identified as the root cause for 46% of processed events (see **Figure 4.28**). This is higher than for the previous years but may not fully project the final percentage as more than half of the 2021 events have not yet had a final root cause assigned to them. For the same period, the top five detailed root causes, listed in priority order, below are members of the management or organization performance categories:

1. Corrective action responses to a known or repetitive problem were untimely
2. Design output scope less than adequate
3. Management policy guidance or expectations are not well-defined, understood, and/or enforced
4. Job scoping did not identify special circumstances and/or conditions
5. System interactions not considered or identified

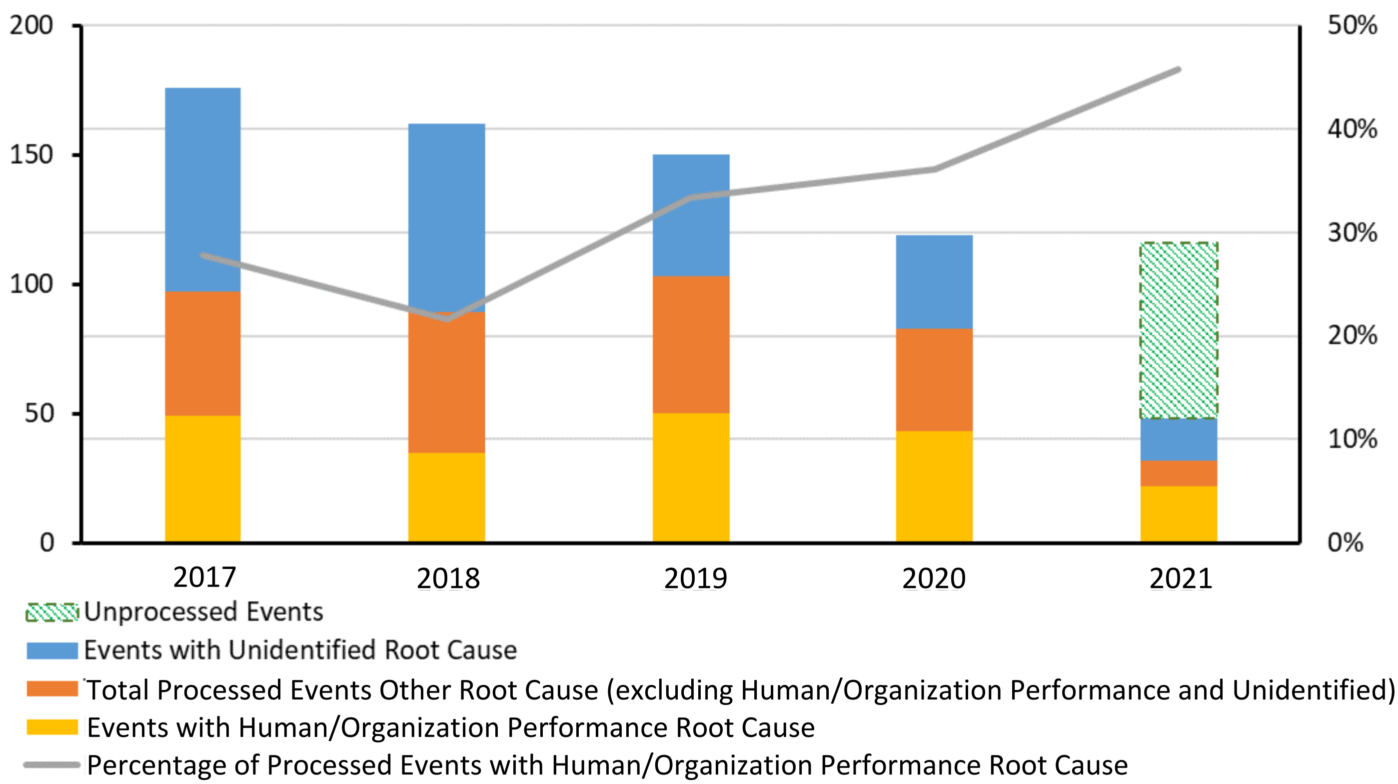



**Figure 4.28: Human/Organization Performance Root Cause by Year**

Events processed during 2021 saw three of the same top five root causes identified in 2020. Two causes—“Inadequate work package preparation” and “risks/consequences associated with change not adequately reviewed/assessed”—were replaced with “corrective action responses to a known or repetitive problem was untimely,” and the “design output scope was less than adequate.”

The top five detailed root causes coupled with the apparent underlying increase suggests that an opportunity exists for industry to improve BPS reliability through increased focus in the area of management and organization performance and engineering design. Possible contributing and root causes in the area of management and organization performance include subcategories where methods, actions, and/or practices are less than adequate, such as management methods, resource management, work organization and planning, supervisory methods, and change management. Possible contributing and root causes in the area of engineering and design include ensuring that the engineering group has a robust peer review process to identify procedural errors and all the considerations a design needs to be accountable to contain.

## Human Error and Protection System Misoperations

Protection system misoperations remain an important indicator of the reliability of the BPS; Human Error is one of the potential causes for misoperations to occur. Figure 4.29 shows the number of misoperations due to Human Error by Regional Entity for the past five years. There are two different causes of Human Error misoperations reported in MIDAS: As-left Personnel Errors and Incorrect Settings/Logic/Design Errors. Together, these account for roughly 40% of misoperations over the last five years, described in more detail as follows:

- **As-left Personnel Errors:** These misoperations are due to the as-left condition of the composite protection system following maintenance or construction procedures. These include test switches left open, wiring errors not associated with incorrect drawings, carrier grounds left in place, settings placed in the wrong relay, or settings left in the relay that do not match engineering intended and approved settings. This includes personnel activation of an incorrect settings group.
- **Incorrect Settings/Logic/Design Errors:** These are misoperations due to errors in the following:
  - **Incorrect Settings:** These are errors in issued settings associated with electromechanical or solid-state relays, the protection element settings in microprocessor-based relays, and setting errors caused by inaccurate modeling. It excludes logic errors discussed in the Logic Error cause code.
  - **Logic:** This includes errors in issued logic settings and errors associated with programming microprocessor relay inputs, outputs, custom user logic, or protection function mapping to communication or physical output points.
  - **Design:** This involves incorrect physical design. Examples include incorrect configuration on ac or dc schematics or wiring drawings or incorrectly applied protective equipment.

Figure 4.29 indicates the number of misoperations varying among Regional Entities. The five-year trends generally show a stable or downward trend in misoperations with causes attributed to Human Error.

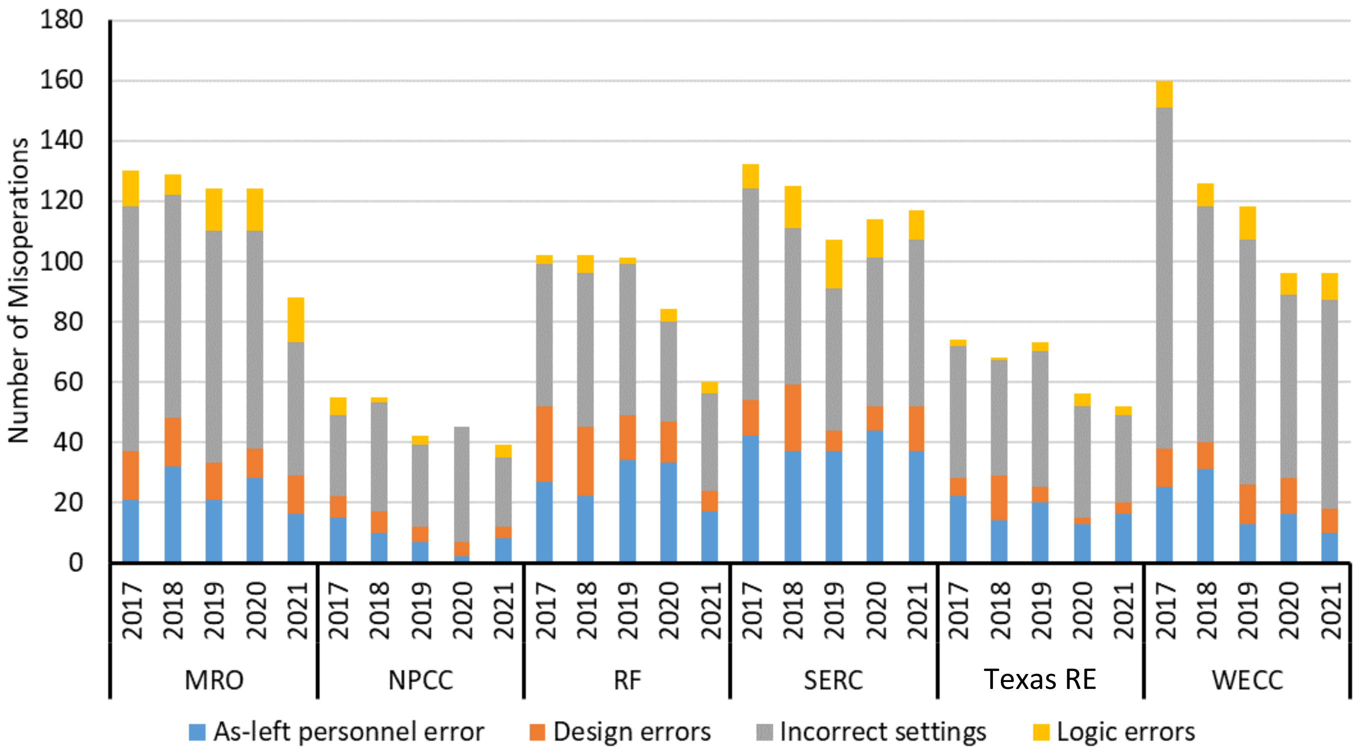



**Figure 4.29: Protection System Misoperations Due to Human Error by Regional Entity**[58]

## *Actions and Mitigations in Progress*

- The ERO has identified work force capability and Human Error as possible threats to the reliability of the BPS. These broad topics are categorized for analysis by the ERO under management, organization, and individual contributions. The data suggests a need for focus on both individual actions and organizational processes/procedures pertaining to protective systems.
- The ERO Enterprise provides educational opportunities annually to help industry understand and focus on reducing Human Error through human performance concepts, methods, techniques, and procedures.
- The Regional Entities have been working with local industry working groups to review and aid in addressing reported misoperations and other human performance issues.
- The ERO Event Analysis Program continues.
- Regional-Entity-specific activities related to human performance continue to occur.

[58] Protection System Operation data collection for WECC began in Q2 2016.

# AGENDA 11

**Mitsubishi Falsifying Transformer Test Results**
*Jake Bernhagen, Senior Systems Protection Engineer, MRO*

## Action
Information

## Report
Jake Bernhagen will provide an overview during the meeting.

# AGENDA 12

**2022 Meeting Dates**

***Greg Sessler, Protective Relay Subgroup Chair***

## Action

Information

## Report

Chair Sessler will provide an overview during the meeting.

| | Q1 2022 | Q2 2022 | Q3 2022 | Q4 2022 |
|---|---|---|---|---|
| RAC | 4/6* | 5/19 | 8/17 | 11/16 |
| PRS | 2/22 | 5/3 | 8/16 | 12/6 |
| SAC | 2/16 | 6/22* | 10/4-10/5 | 11/9 |
| SACTF | 2/9 | 6/15 | 10/6 | 11/2 |
| CMEPAC | 2/15 | 6/7 | 9/21* | 11/10 |
| OGOC | 4/6 | 6/22 | 9/21 | 11/30 |
| BOD | 4/7 | 6/23 | 9/22 | 12/1 |

*Joint with OGOC

| MRO CONFERENCE DATES 2022 | |
|---|---|
| Q1 | RAM/CIP Conference: March 23, 2022 *virtual |
| Q2 | Reliability Conference: May 17-18, 2022 networking reception and conference Kansas City |
| Q3 | CMEP: July 25-26, 2022 networking reception and conference |
| Q4 | Security Conference: October 4-5, 2022 SAC training and conference |

# AGENDA 13

**PRS Roundtable Discussion**
*Greg Sessler, Protective Relay Subgroup Chair*

## Action
Discussion

## Report
Chair Sessler will lead this discussion during the meeting.

# AGENDA 14

**Other Business and Adjourn**
*Greg Sessler, Protective Relay Subgroup Chair*

## Action
Discussion

## Report
Chair Sessler will lead this discussion during the meeting.