MIDWEST RELIABILITY ORGANIZATION

Meeting Agenda

Protective Relay Subgroup (PRS)

Wednesday, September 6, 2023
9:00 am to 3:00 pm central

MRO Corporate Offices, King Conference Center
St. Paul, MN & Webex

Classification: Public

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.**

Classification: Public

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
Ryan Einer, PRS Chair
a. Determination of Quorum and Introductions
b. Robert's Rules of Order

2 Standards of Conduct and Antitrust Guidelines
Jake Bernhagen, Manager of Reliability Performance, MRO

3 Safety Briefing
Jake Bernhagen, Manager of Reliability Performance, MRO

4 Chair's Remarks
Ryan Einer, PRS Chair

5 Consent Agenda
Ryan Einer, PRS Chair
a. Approve June 27, 2023 meeting minutes

6 NERC Activities
Jake Bernhagen, Manager of Reliability Performance, MRO
a. NERC SPCWG Update
Lynn Schroeder, System Protection Engineer, Sunflower Electric Power Corporation
b. NERC MIDASUG Update
Jake Bernhagen, Manager of Reliability Performance, MRO
c. TADS
John Grimm, Principal Systems Protection Engineer, MRO

7 PRS Business
Jake Bernhagen, Manager of Reliability Performance, MRO
a. Updates
b. Action Item List Review
Ryan Einer, PRS Chair

8 2023 Meeting Dates
Ryan Einer, PRS Chair

Break – 10:00 a.m.

9 Commissioning Lessons Learned – Montana-Dakota Utilities
Cody Remboldt, System Protection Engineer, MDU and PRS Member

10 Technical Presentations
a. PRC Impacts on Ethernet Based Protection & Control Device Maintenance and Design
Eric Udren, Executive Advisor, Quanta Technology, LLC
b. WAPA's Geomagnetic Disturbance (GMD) Project Presentation
Chris Colson, Transmission System Planning Manager, Western Area Power Administration

11 Misoperations
Jake Bernhagen, Manager of Reliability Performance, MRO
a. Q2 2023 Update, Review and Discussion
b. Review NERC Lessons Learned
c. 2023 ERO Misoperation Workshop Update

Lunch 12:00 p.m.

Classification: Public

12 PRS Roundtable Discussion
Ryan Einer, PRS Chair

13 Q2 2023 Misoperations Review
Jake Bernhagen, Manager of Relliability Performance, MRO

a. Breakout Sessions

14 Other Business and Adjourn
Ryan Einer, PRS Chair

Classification: Public

AGENDA

Call to Order and Determination of Quorum

a. Determination of Quorum

Ryan Einer, Protective Relay Subgroup Chair

Name	Role	Company	Term
Adam Daters	Member	ITC Holdings	12/31/24
Alex Bosgoed	Member	Saskatchewan Power Corporation	12/31/25
Casey Malskeit	Member	Omaha Public Power District	12/31/25
Cody Remboldt	Member	Montana-Dakota Utilities	12/31/24
David Weir	Member	Western Area Power Administration	12/31/25
David Wheeler	Member	Southwestern Public Services Co.	12/31/23
Dennis Lu	**Vice Chair**	Manitoba Hydro	12/31/23
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	12/31/25
Greg Sessler	Member	American Transmission Company	12/31/23
Jeff Beasley	Member	Grand River Dam Authority	12/31/25
Josh Erdman	Member	Xcel Energy	12/31/24
Lynn Schroeder	Member	Sunflower Electric Power Corporation	12/31/25
Rochelle Trefry	Member	MidAmerican Energy Company	12/31/25
Ryan Einer	**Chair**	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

Classification: Public

AGENDA

Call to Order and Determination of Quorum

b. Robert's Rules of Order

Ryan Einer, 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 "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

Standards of Conduct and Antitrust Guidelines
Jake Bernhagen, Manager of Reliability Performance, 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.

Classification: Public

AGENDA

Safety Briefing
Jake Bernhagen, Manager of Reliability Performance, MRO

Action
Information

Report
Jake Bernhagen will lead this discussion during the meeting.

Classification: Public

AGENDA

Chair's Remarks
Ryan Einer, Protective Relay Subgroup Chair

Action
Information

Report
Chair Einer will lead this discussion during the meeting.

Classification: Public

AGENDA

Consent Agenda

a. Approve June 27, 2023 meeting minutes

Ryan Einer, Protective Relay Subgroup Chair

Action

Discussion

Report

Chair Einer will lead this discussion during the meeting.

Classification: Public

MIDWEST RELIABILITY ORGANIZATION

380 St. Peter St, Suite 800
Saint Paul, MN 55102
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651-855-1760

Draft Minutes of the Protective Relay Subgroup Meeting

Hybrid: St. Paul, MN and Webex

Tuesday, June 27, 2023, 9:00 a.m. to 3:01 p.m. Central

Notice for this meeting was electronically posted to the MRO website on May 30, 2023.
A final agenda, including advanced reading materials, was also posted on June 20, 2023.

1. **Call to Order and Determination of Quorum**

   Protective Relay Subgroup (PRS) Chair Ryan Einer called the meeting to order at 9:00 a.m. Einer welcomed everyone and roundtable introductions were made. 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, MRO Manager of Reliability Performance, Jake Bernhagen highlighted MRO's Standards of Conduct, Conflict of Interest, and Antitrust Guidelines.

3. **Safety Briefing**

   Bernhagen gave a safety briefing for in-person attendees which included information regarding emergency exits, evacuation procedures, and the location of the automated external defibrillator (AED).

4. **Chair's Remarks**

   Chair Einer highlighted two items on today's agenda: the Commissioning Lessons Learned presentation by Les Wolf from Xcel Energy and the Relay Automation Demonstraton by Kasey Borboa from Minnkota Power Cooperative.

5. **Consent Agenda**

   The PRS reviewed the consent agenda, which included minutes from the March 14, 2023 meeting.

   Upon a motion duly made and seconded, the PRS approved the consent agenda in its entirety.

6. **NERC Activities**

   Update on NERC System Protection and Control Working Group (SPCWG).

   Lynn Schroeder, MRO representative on the NERC SPCWG, shared that the position paper related to FERC Order 881 was endorsed by the Reliabiity and Security Technical Committee (RSTC) at the June 21-22, 2023 meeting. The SPCWG will discuss plans to roll out the position paper to industry at their next meeting on August 10, 2023. Schroeder noted that the SPCWG is still working on the Technical Reference related to maintenance for ethernet based protection and control (P&C). Project 2019-04 Modifications for PRC-005-6 is now open for formal comment. Discussion ensued.

   NERC Misoperation Information Data Analysis System User Group (MIDASUG) Update.

   Bernhagen was unable to attend the last MIDASUG meeting on May 2, 2023, but notes from the meeting were provided. Jack Norris from NERC disussed the MIDAS section of the NERC 2023 State

of Reliability (SOR). Generally, ERO-wide there is a downward trend in the number of misoperations. The impact score was rolled out and applied to the last five years of misoperations data. There was discussion about Section 1600 revisions for MIDAS submittals, possibly removing some fields. Bernhagen noted that the PRS would begin utilizing the misoperations impact score during the misoperations review next quarter. There was discussion around misoperations training.

Transmission Availability Data System (TADS).

John Grimm, MRO Principal Systems Protection Engineer, provided an update on TADS. There may be an update to the TADS data reporting instructions (DRI). Grimm noted that changes need to be made to the process when inventory is updated for shared facilities.

7. PRS Business

Updates.

There were no notable business updates since the last quarterly meeting.

Action Item List Review.

Chair Einer reviewed the action item list and updates were made accordingly. An action item was added for Bernhagen to reach out to Eric Udren regarding a potential technical presentation at the third quarter PRS meeting. The topic is maintenance for ethernet based P&C.

8. 2023 Meeting Dates

Chair Einer reviewed the proposed 2023 meeting dates for the PRS and the other councils and subgroups. Einer noted the upcoming MRO CMEP Conference in St. Paul, MN on July 25-26, 2023 and the MRO Security Conference on September 26-27, 2023 in Oklahoma City, OK.

9. Commissioning Lessons Learned – Xcel Energy

Les Wolf, Manager, Substation Commissioning Engineering, Xcel Energy, gave a presentation on misoperations – commissioning lessons learned. Several recent misoperations were reviewed, including the event description, cause of the misoperation, and notes on how the misoperation could have been prevented. A summary of Xcel Energy's best practices was also shared. Discussion ensued.

10. Relay Automation Demonstration

Kasey Borboa, Engineering Manager, Minnkota Power Cooperative, performed a live demonstration of relay automation software (Siemens CROSSBOW) currently being utilized by his organization. Some uses of the software include event retrieval, password management and CIP compliance. Discussion ensued.

11. Misoperations

2023 Update, Review and Discussion

Bernhagen provided a summary of the 2022 misoperations data. "Incorrect settings" was the largest contributing factor for misoperations by cause in 2022. Bernhagen solicited feedback from the entities regarding what type of misoperations data they would find beneficial. Bernhagen will develop misoperation summary sheets by entity for the third quarter meeting. A member suggested revisiting

the Protection System Misoperation White Papers prepared by the Protective Relay Subcommittee in 2016 – 2017. Discussion ensued.

Bernhagen reviewed NERC's 2023 State of Reliabiity (SOR) and highlighted areas of interest for the group. He also shared misoperations information and tools located on the WECC website.

2023 ERO Misoperation Workshop Update

Bernhagen shared a draft agenda of the NERC ERO Misoperation Workshop scheduled for October 25-26, 2023 in Atlanta, GA.

12. PRS Roundtable Discussion

Chair Einer invited member participants to share other relevant industry observations. Topics discussed included, out-of-step protection for generators, system protection modeling of directional overcurrent elements during loss of potential (LOP) conditions, and transformer gage malfunctions.

13. Q1 2023 Misoperations Review

Breakout Sessions

The PRS members reviewed the first quarter 2023 misoperations in breakout sessions both in-person and via Webex. Discussion ensued.

14. Other Business and Adjourn

Having no further business to discuss, the meeting was adjourned at 3:01 p.m.

Prepared by: Rebecca Schneider, Reliability Analysis Administrator
Reviewed and Submitted by: Jake Bernhagen, Manager of Reliability Performance

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Exhibit A – Meeting Attendees

Subgroup Members Present	
Name	**Company**
Ryan Einer, Chair	Oklahoma Gas & Electric
Dennis Lu, Vice Chair	Manitoba Hydro
Alex Bosgoed	Saskatchewan Power Corporation
Casey Malskeit	Omaha Public Power District
Cody Remboldt	Montana-Dakota Utilities
David Weir	Western Area Power Administration
Derrick Schlangen	Great River Energy
Glenn Bryson	American Electric Power
Greg Hill	Nebraska Public Power District
Greg Sessler	American Transmission Company
Jeff Beasley	Grand River Dam Authority
Josh Erdman	Xcel Energy
Lynn Schroeder	Sunflower Electric Power Corporation
Sarah Marshall	Alliant Energy
Scott Paramore	Kansas City Board of Public Utilities
MRO Staff Present	
Name	**Title**
Jake Bernhagen	Manager of Reliability Performance
Rebecca Schneider	Reliability Analysis Administrator
Shawn Keller	Outreach Coordinator
John Grimm	Principal Systems Protection Engineer
Max Desruisseaux	Senior Power Systems Engineer
Mark Tiemeier	Principal Technical Advisor

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Other Attendees	
Name	**Company**
Les Wolf	Xcel Energy
Matthew Wyatt	Liberty Utilities
Catherine Jacobs	MidAmerican Energy Company
David Oswald	Liberty Utilities
Dylan Underwood	Southwestern Power Administration
Kasey Borboa	Minnkota Power Cooperative
Kevin Thompson	ITC
Shannon Bellinghausen	Xcel Energy
Tyler Porter	Great River Energy
Terry Volkmann	Glencoe Light and Power

AGENDA

NERC Activities

a. NERC SPCWG Update

Lynn Schroeder, Sunflower Electric Power Corporation and PRS Member

Action

Information

Report

Lynn Schroeder will provide an oral report during the meeting.

Classification: Public

AGENDA

NERC Activities

b. NERC MIDASUG Update

Jake Bernhagen, Manager of Reliability Performance, MRO

Action

Information

Report

Jake Bernhagen will provide an oral report during the meeting.

Classification: Public

AGENDA

NERC Activities

c. Transmission Availability Data System (TADS)

John Grimm, Principal Systems Protection Engineer, MRO

Action

Information

Report

John Grimm will provide an oral report during the meeting.

Classification: Public

AGENDA

PRS Business

a. Updates

Jake Bernhagen, Manager of Reliability Performance, MRO

Action

Information

Report

Jake Bernhagen will provide an oral report during the meeting.

Classification: Public

AGENDA

PRS Business

b. Action Item List Review

Ryan Einer, Protective Relay Subgroup Chair

Action

Discussion

Report

Chair Einer will lead this discussion during the meeting.

Classification: Public

AGENDA

2023 Meeting Dates

Ryan Einer, Protective Relay Subgroup Chair

Action

Information

Report

Chair Einer will provide an overview during the meeting.

	Q1 2023	Q2 2023	Q3 2023	Q4 2023
RAC	3/1	5/18	8/10	11/9
SAC	2/22	5/24	8/8	10/12
CMEPAC	2/21	5/31	8/9	10/19
PRS	3/14	6/27	9/6	12/6
OGOC	4/12	6/14	9/13	12/13
BOD	4/13	6/15	9/14	12/14

MRO CONFERENCE DATES 2023	
Q1	**RAM Conference: March 21-22, 2023 networking reception and conference (hybrid)**
Q2	**Reliability Conference: May 16-17, 2023 networking reception and conference (hybrid)**
Q3	**CMEP Conference: July 25-26, 2023 networking reception and conference (hybrid)**
Q4	**Security Conference: September 26-27, 2023 networking reception, training and conference (hybrid); Oklahoma City, OK**

Classification: Public

AGENDA

Commissioning Lessons Learned – Montana-Dakota Utilities

Cody Remboldt, System Protection Engineer, MDU and PRS Member

Action

Information

Report

Cody Remboldt will provide an oral report during the meeting.

Classification: Public

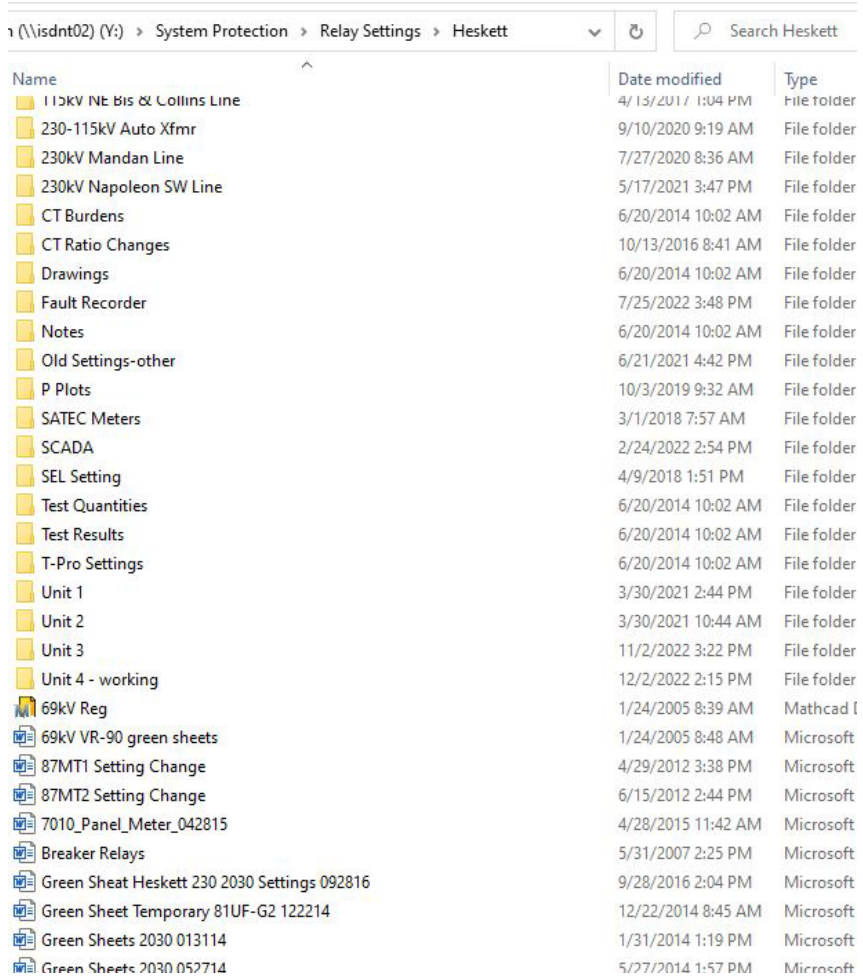
Life of a Relay Setting

Cody Remboldt, System Protection Engineer, Montana-Dakota Utilities

Creation → In Review → Issued → As Left → Setting Management

Out with the Old Process…

- Sorted by Date
- Managed in Windows Explorer
- No Status Tracking
- Can be Messy and Unorganized



In with the New Process…

AcSELerator® QuickSet - [Device Manager]

File Edit View Communications Tools Windows Help Language

Connection Explorer

- Mobile Cap. Bank 3 Trans. Sub (Monango)
- Mobile Cap. Bank 4 Trans. Sub (Sandstone)
- Mobridge Dist. Sub
- Napoleon SW
- New England Trans. Sub
- Phasor Data Concentrators
- Plentywood Trans. Sub
- Poplar Trans. Sub
- Ray Trans Sub
- Rosebud
- Sheridan SW Trans. Sub
  - SEL-3530
    - 272360 230kV PCB 3316 50_62BF_25
    - 272361 41.6kV PCB 3302 50_62BF_25
    - 272362 41.6kV PCB 3312 50_62BF_25
    - 272363 41.6kV PCB 3322 50_62BF_25
    - 272364 41.6kV PCB 3332 50_62BF_25
    - 272365 41.6kV PCB 3342 50_62BF_25
    - 272366 41.6kV PCB 3352 50_62BF_25
    - 272367 41.6kV PCB 3362 50_62BF_25
    - 272368 230kV Sheridan Line 21A
    - 272370 41.6kV Highview Line 21A
    - 272370 41.6kV Highview Line 21B
    - 272372 41.6kV Dayton Line 21A
    - 272373 41.6kV Dayton Line 21B
    - 272376 41.6kV Big Horn Line 21A
    - 272377 41.6kV Big Horn Line 21B
    - 272380 41.6kV Sheridan Solar Line 21A
    - 272381 41.6kV Sheridan Solar Line 21B
    - 272382 230_41.6kV XFMR 87T1
    - 272385 41.6kV Bus 87B1
    - 272386 ANNUN1
    - 272387 ANNUN2
    - 272388 ANNUN3

Device: /MDU/Sheridan SW Trans. Sub/SEL-3530/272380 41.6kV Sheridan Solar Line 21A

Welcome - Getting Started | 272372 41.6kV Dayton Line 21A | 272380 41.6kV Sheridan Solar Line 21A

Device | Connection | Custom Attributes | Documents | Applications | Settings | TEAM

Export Send View Compare Compare to Device

New Edit Import Read Clear

Workspace

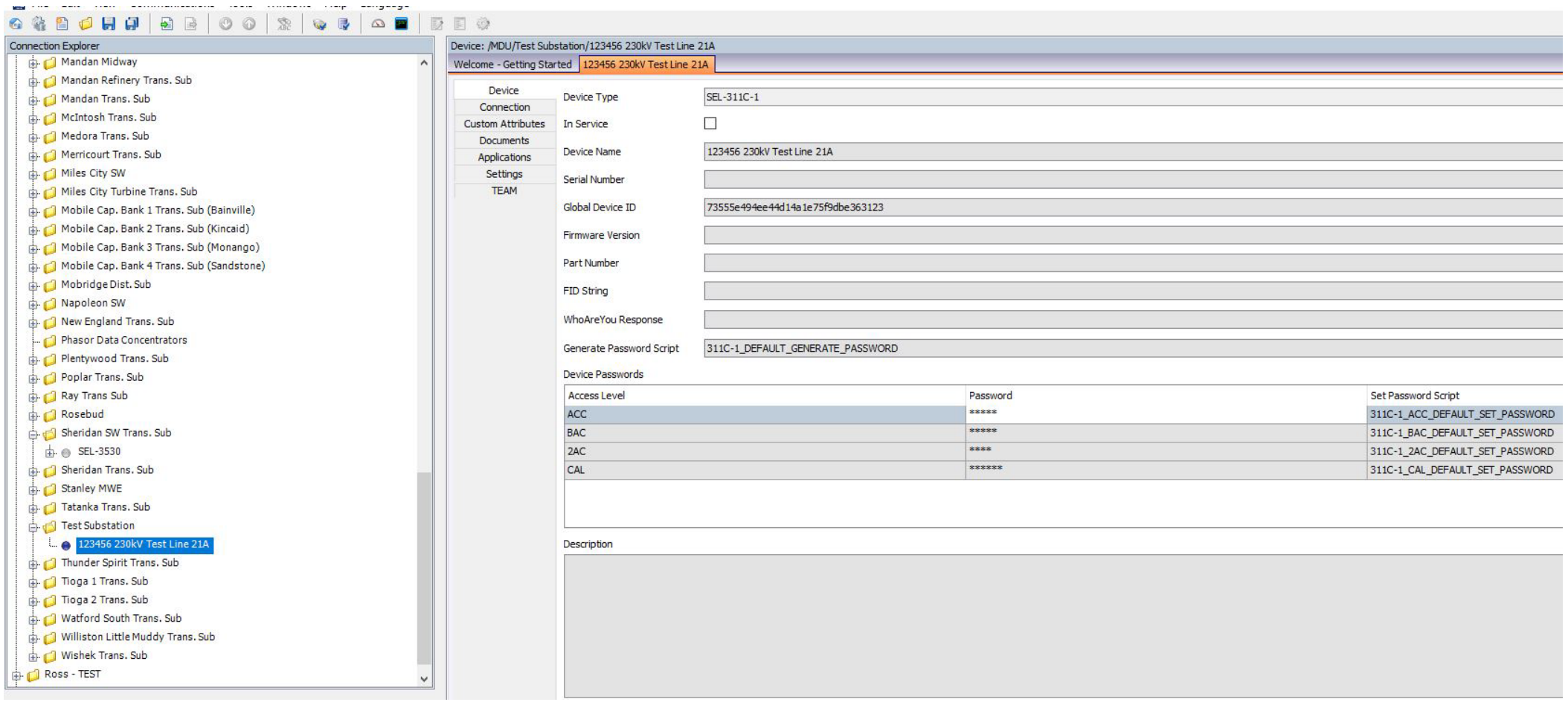
Settings Type	Created	Created By	Saved	Saved By	Comment

Create Version Copy to Workspace

Version History

State	Version	Settings Type	Saved	Saved By	Comment
Issued	0.2	SEL-311C-1 104	12/28/2022 11:03:55 AM	Brian Fettig (brian.fettig)	Reviewed and approved.
In Review	0.1	SEL-311C-1 104	12/28/2022 10:44:39 AM	Cody Remboldt (cody.remboldt)	New settings for Sheridan SW.

Creating New Settings



Creating New Settings

SEL-311C – Distance Relay Test Date _____.

SETTING AND TEST REPORT

Main Setting Group 1

Station TEST TRANS SUB Date 1/23/2022 – CAR . Version _____.

Circuit 230kV TEST LINE Device # 21A .

PCBs 1234 Purchase Order #191058-OP Dated 03/15/22 .

Panel 12AA Drawings _____.

Catalog Number Schweitzer SEL-311C 0311C11HP3E5462 .

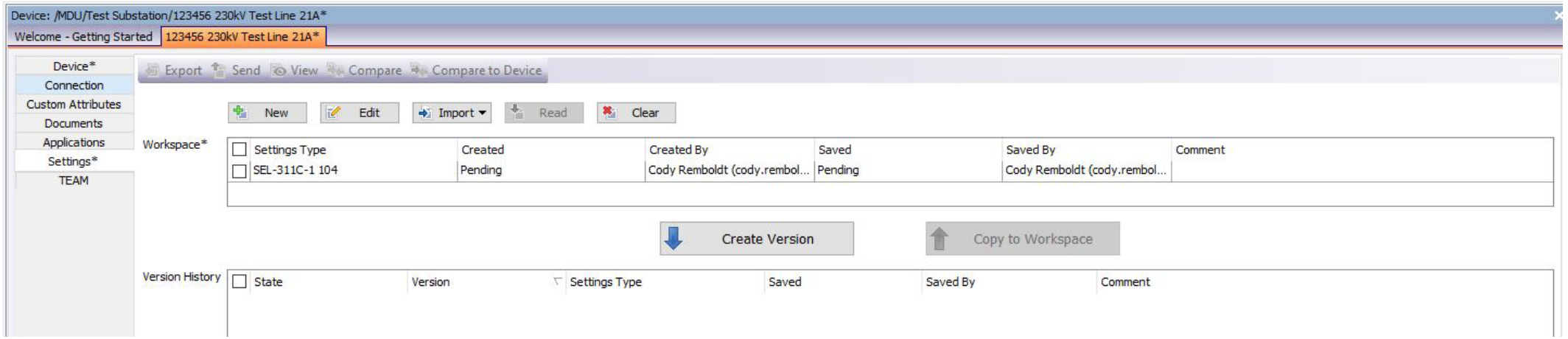
Creating New Settings

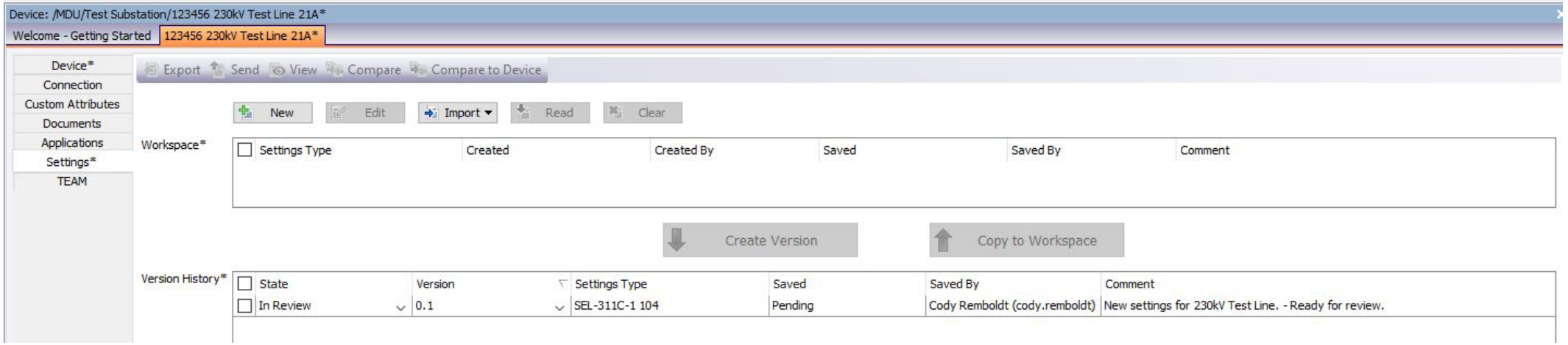
New settings are created in the Relay Setting Database workspace.

Relay documentation is stored in Documents section in Relay Setting Database.

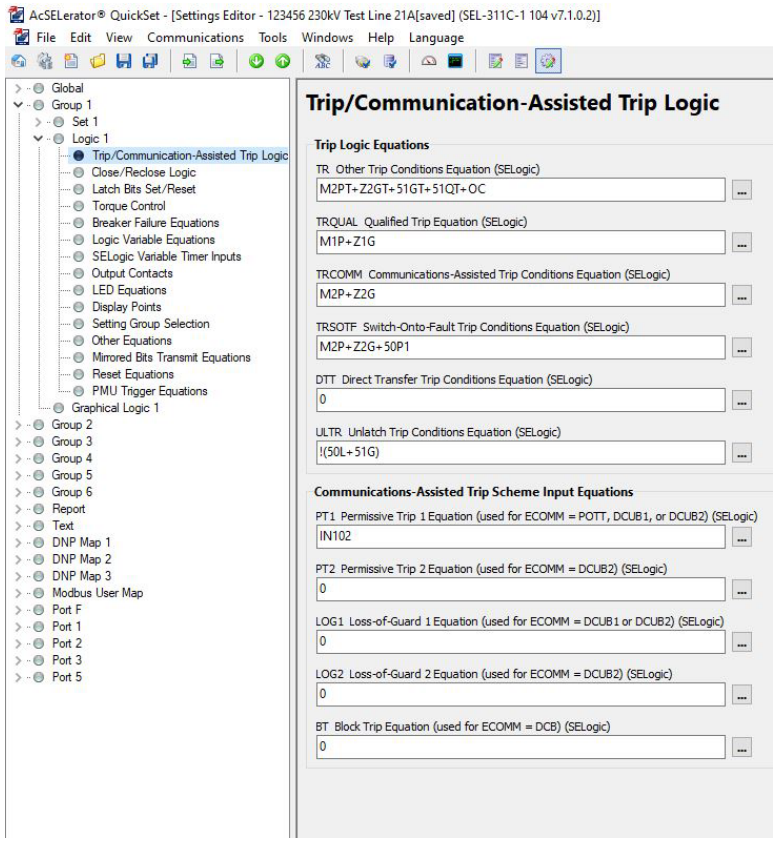
Version field left blank until settings are through review.

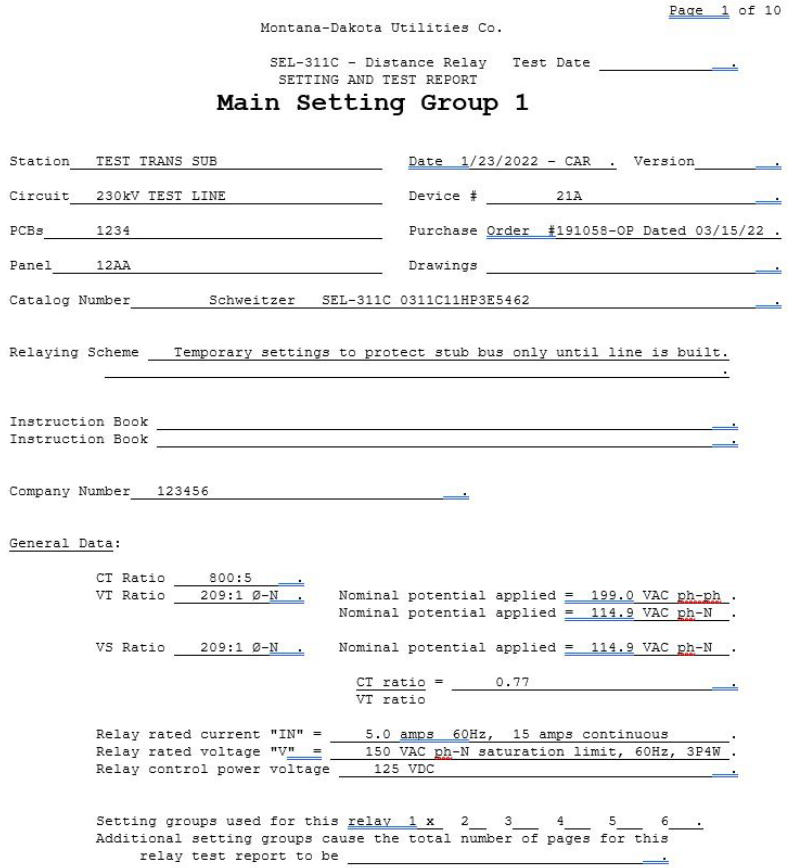
Moving to “In Review”





In Review





Page 1 of 10

Montana-Dakota Utilities Co.

SEL-311C - Distance Relay Test Date _____.
SETTING AND TEST REPORT

Main Setting Group 1

Station TEST TRANS SUB Date 1/23/2022 - CAR . Version _____.

Circuit 230kV TEST LINE Device # 21A .

PCBs 1234 Purchase Order #191058-OP Dated 03/15/22 .

Panel 12AA Drawings _____.

Catalog Number Schweitzer SEL-311C 0311C11HP3E5462 .

Relaying Scheme Temporary settings to protect stub bus only until line is built.

Instruction Book _____.
Instruction Book _____.

Company Number 123456 .

General Data:

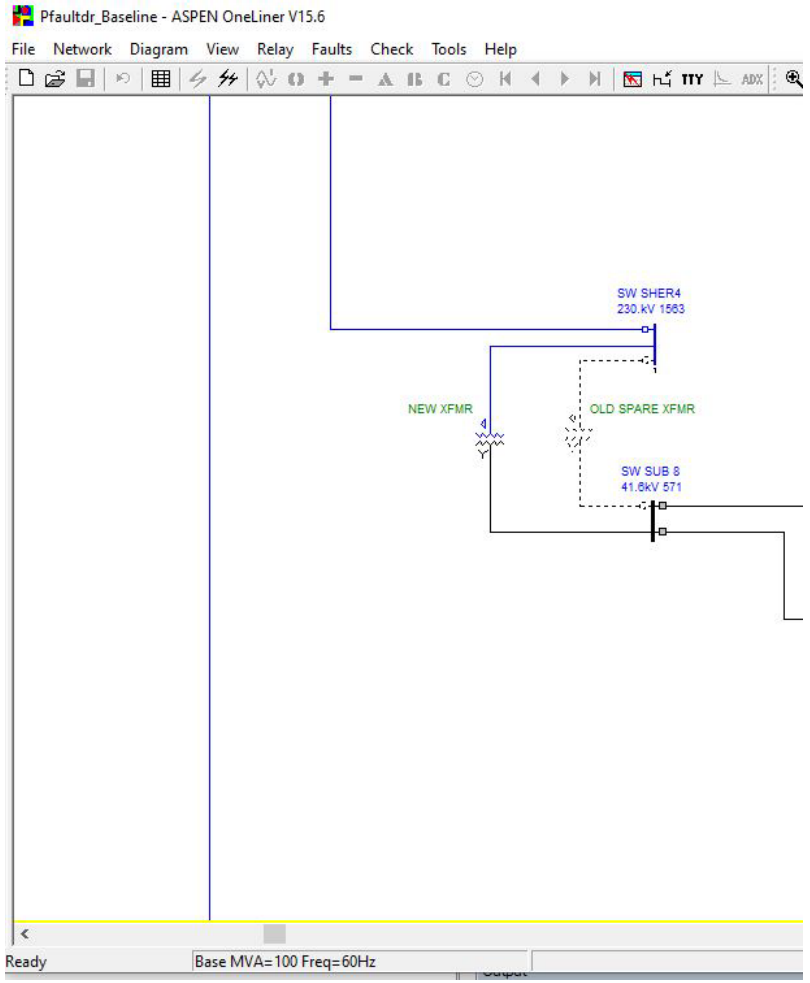
CT Ratio 800:5 .
VT Ratio 209:1 Ø-N . Nominal potential applied = 199.0 VAC ph-ph .
Nominal potential applied = 114.9 VAC ph-N .

VS Ratio 209:1 Ø-N . Nominal potential applied = 114.9 VAC ph-N .

CT ratio = 0.77 .
VT ratio

Relay rated current "IN" = 5.0 amps 60Hz, 15 amps continuous .
Relay rated voltage "V" = 150 VAC ph-N saturation limit, 60Hz, 3P4W .
Relay control power voltage 125 VDC .

Setting groups used for this relay 1 x 2 3 4 5 6 .
Additional setting groups cause the total number of pages for this relay test report to be _____.



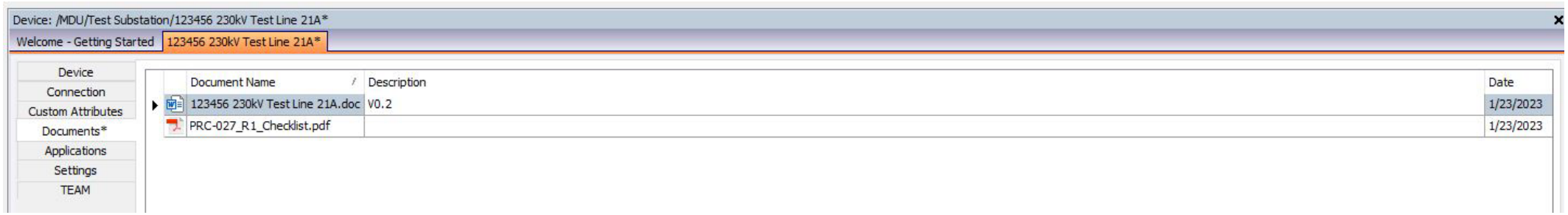
In Review

Main Setting Group 1

Station TEST TRANS SUB Date 1/23/2022 - CAR . Version 0.2 .

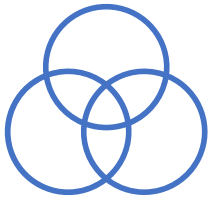
Circuit 230kV TEST LINE Device # 21A .

PCRs 1234 Purchase Order #191058-OP Dated 03/15/22 .



In Review Settings

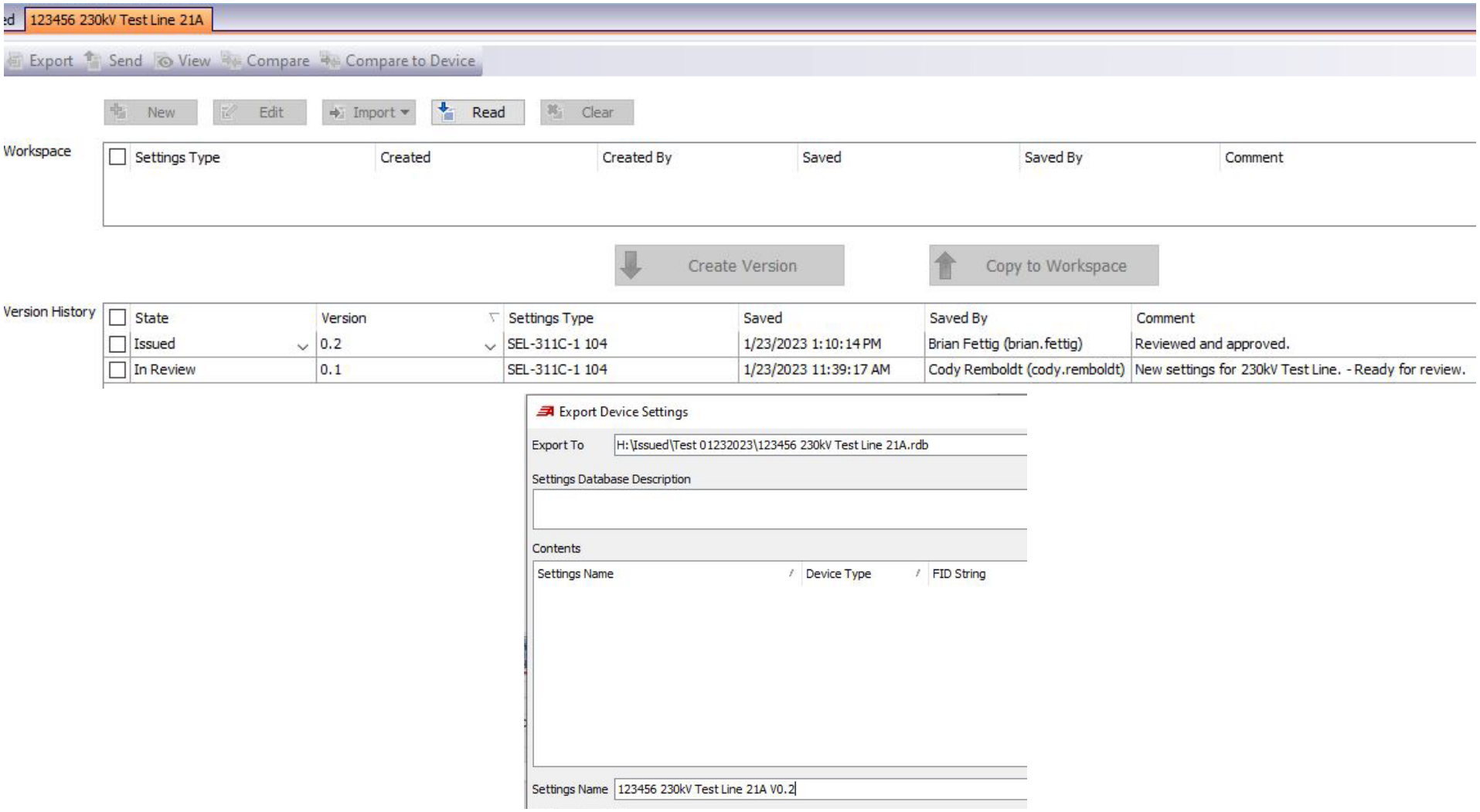
Settings reviewed by Manager/Peer.



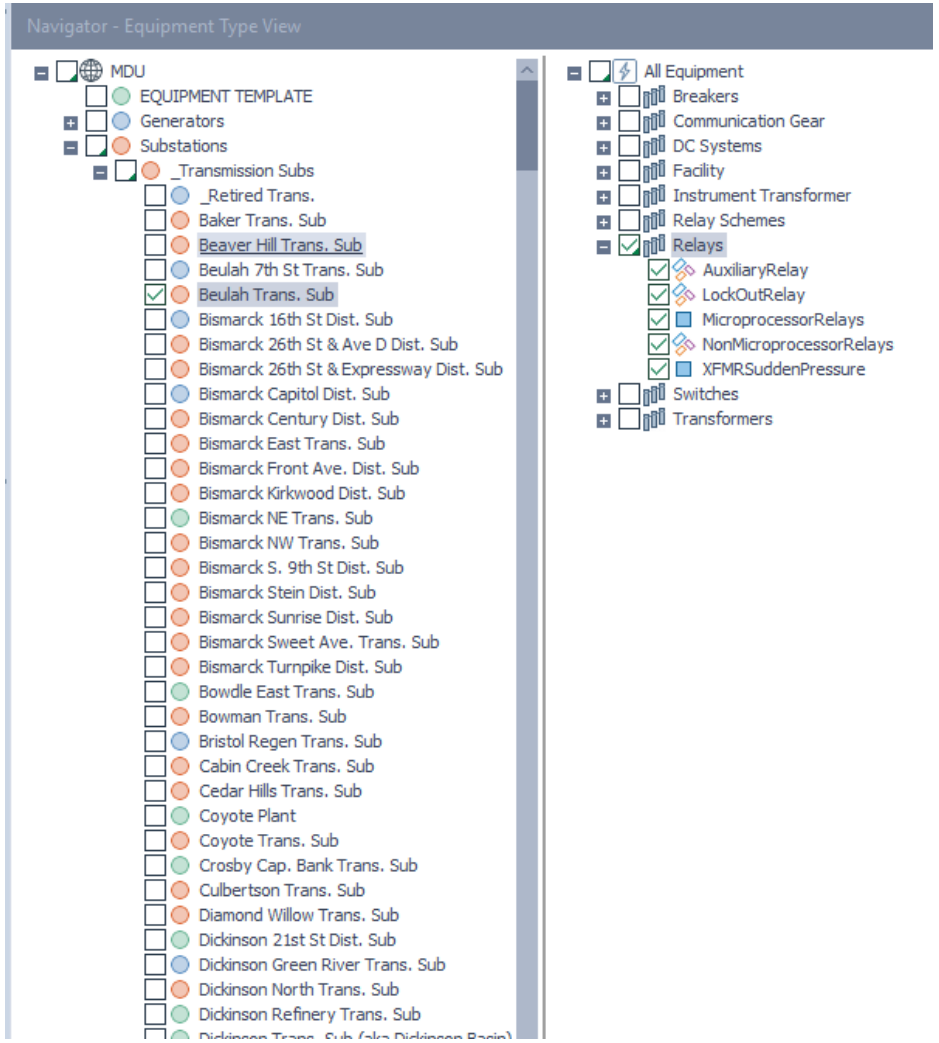
Settings compared against Model and Setting Sheet.

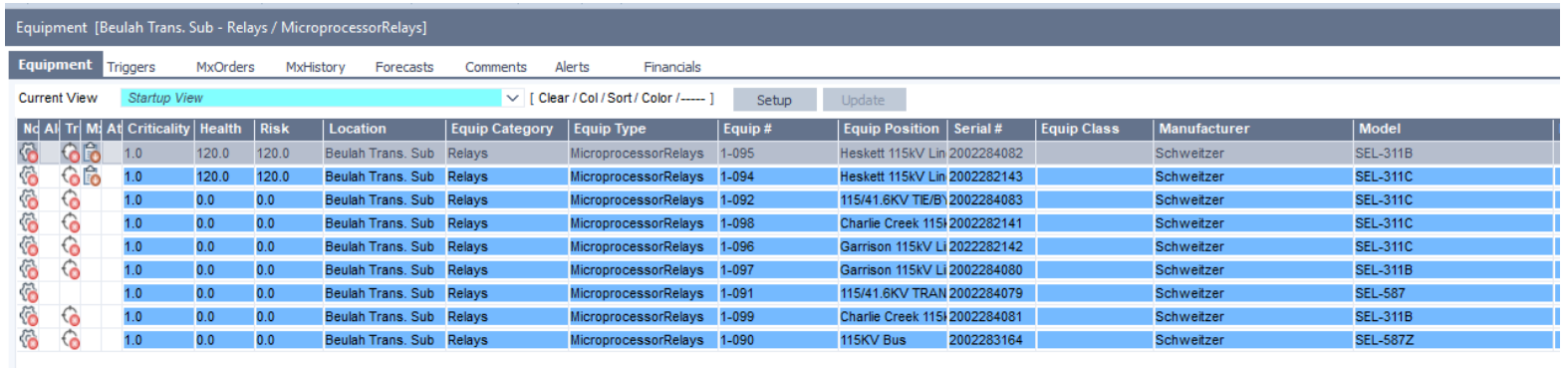
Version field filled in.

Moving Settings to "Issued"



Issued


Navigator - Equipment Type View
MDU
EQUIPMENT TEMPLATE
Generators
Substations
_Transmission Subs
_Retired Trans.
Baker Trans. Sub
Beaver Hill Trans. Sub
Beulah 7th St Trans. Sub
Beulah Trans. Sub
Bismarck 16th St Dist. Sub
Bismarck 26th St & Ave D Dist. Sub
Bismarck 26th St & Expressway Dist. Sub
Bismarck Capitol Dist. Sub
Bismarck Century Dist. Sub
Bismarck East Trans. Sub
Bismarck Front Ave. Dist. Sub
Bismarck Kirkwood Dist. Sub
Bismarck NE Trans. Sub
Bismarck NW Trans. Sub
Bismarck S. 9th St Dist. Sub
Bismarck Stein Dist. Sub
Bismarck Sunrise Dist. Sub
Bismarck Sweet Ave. Trans. Sub
Bismarck Turnpike Dist. Sub
Bowdle East Trans. Sub
Bowman Trans. Sub
Bristol Regen Trans. Sub
Cabin Creek Trans. Sub
Cedar Hills Trans. Sub
Coyote Plant
Coyote Trans. Sub
Crosby Cap. Bank Trans. Sub
Culbertson Trans. Sub
Diamond Willow Trans. Sub
Dickinson 21st St Dist. Sub
Dickinson Green River Trans. Sub
Dickinson North Trans. Sub
Dickinson Refinery Trans. Sub
All Equipment
Breakers
Communication Gear
DC Systems
Facility
Instrument Transformer
Relay Schemes
Relays
AuxiliaryRelay
LockOutRelay
MicroprocessorRelays
NonMicroprocessorRelays
XFMRSuddenPressure
Switches
Transformers


Equipment [Beulah Trans. Sub - Relays / MicroprocessorRelays]
Equipment Triggers MxOrders MxHistory Forecasts Comments Alerts Financials
Current View Startup View [Clear / Col / Sort / Color /-----] Setup Update
Criticality Health Risk Location Equip Category Equip Type Equip # Equip Position Serial # Equip Class Manufacturer Model
1.0 120.0 120.0 Beulah Trans. Sub Relays MicroprocessorRelays 1-095 Heskett 115kV Lin 2002284082 Schweitzer SEL-311B
1.0 120.0 120.0 Beulah Trans. Sub Relays MicroprocessorRelays 1-094 Heskett 115kV Lin 2002282143 Schweitzer SEL-311C
1.0 0.0 0.0 Beulah Trans. Sub Relays MicroprocessorRelays 1-092 115/41.6KV TIE/B 2002284083 Schweitzer SEL-311C
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1.0 0.0 0.0 Beulah Trans. Sub Relays MicroprocessorRelays 1-091 115/41.6KV TRAN 2002284079 Schweitzer SEL-587
1.0 0.0 0.0 Beulah Trans. Sub Relays MicroprocessorRelays 1-099 Charlie Creek 115 2002284081 Schweitzer SEL-311B
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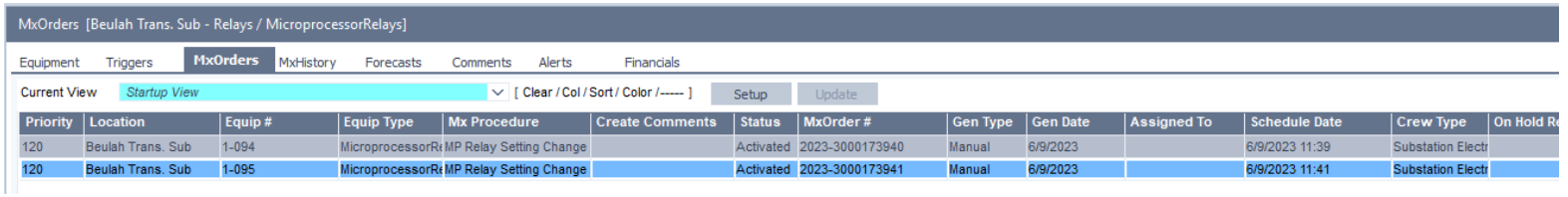
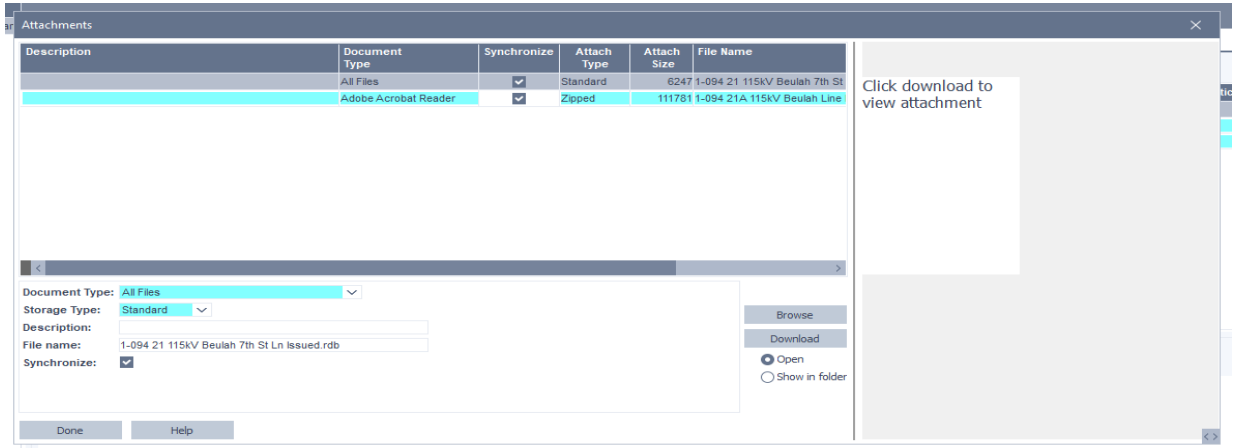
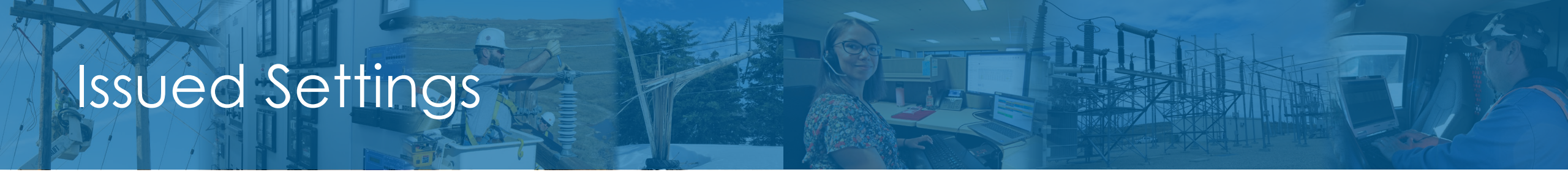

MxOrders [Beulah Trans. Sub - Relays / MicroprocessorRelays]
Equipment Triggers MxOrders MxHistory Forecasts Comments Alerts Financials
Current View Startup View [Clear / Col / Sort / Color /-----] Setup Update
Priority Location Equip # Equip Type Mx Procedure Create Comments Status MxOrder # Gen Type Gen Date Assigned To Schedule Date Crew Type
120 Beulah Trans. Sub 1-094 MicroprocessorRe MP Relay Setting Change Activated 2023-3000173940 Manual 6/9/2023 6/9/2023 11:39 Substation Electr
120 Beulah Trans. Sub 1-095 MicroprocessorRe MP Relay Setting Change Activated 2023-3000173941 Manual 6/9/2023 6/9/2023 11:41 Substation Electr


Attachments
Description Document Type Synchronize Attach Type Attach Size File Name
All Files Standard 6247 1-094 21 115kV Beulah 7th St
Adobe Acrobat Reader Zipped 111781 1-094 21A 115kV Beulah Line
Click download to view attachment
Document Type: All Files
Storage Type: Standard
Description:
File name: 1-094 21 115kV Beulah 7th St Ln Issued.rdb
Synchronize:
Browse
Download
Open
Show in folder
Done
Help



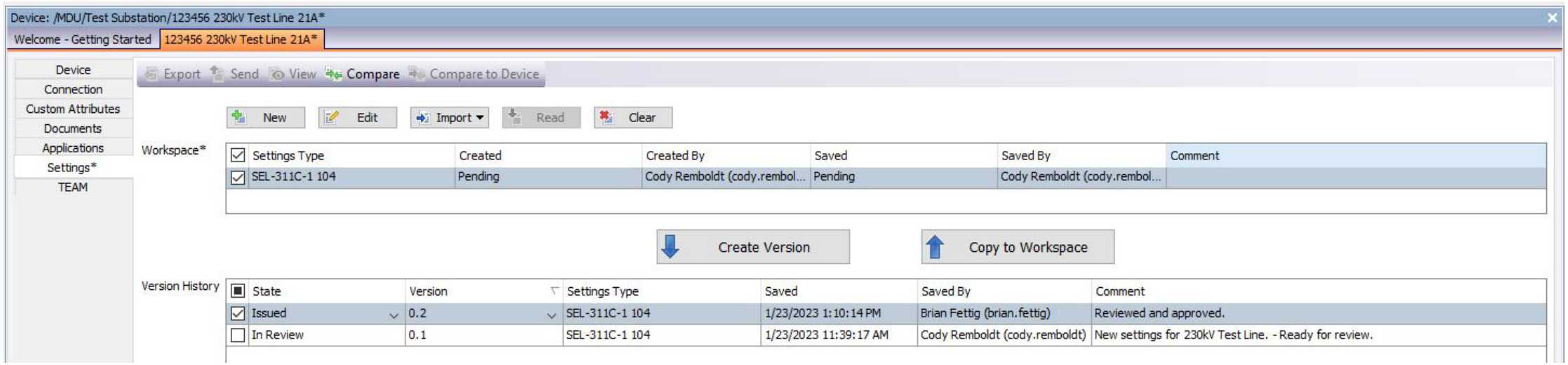
Issued Settings

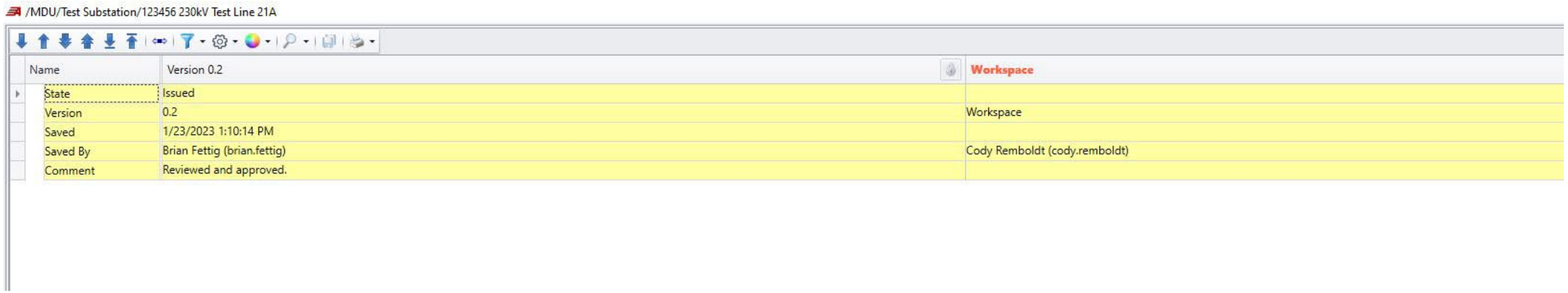
Settings/Documentation exported from Relay Setting Database.

New WO created in Asset Database.

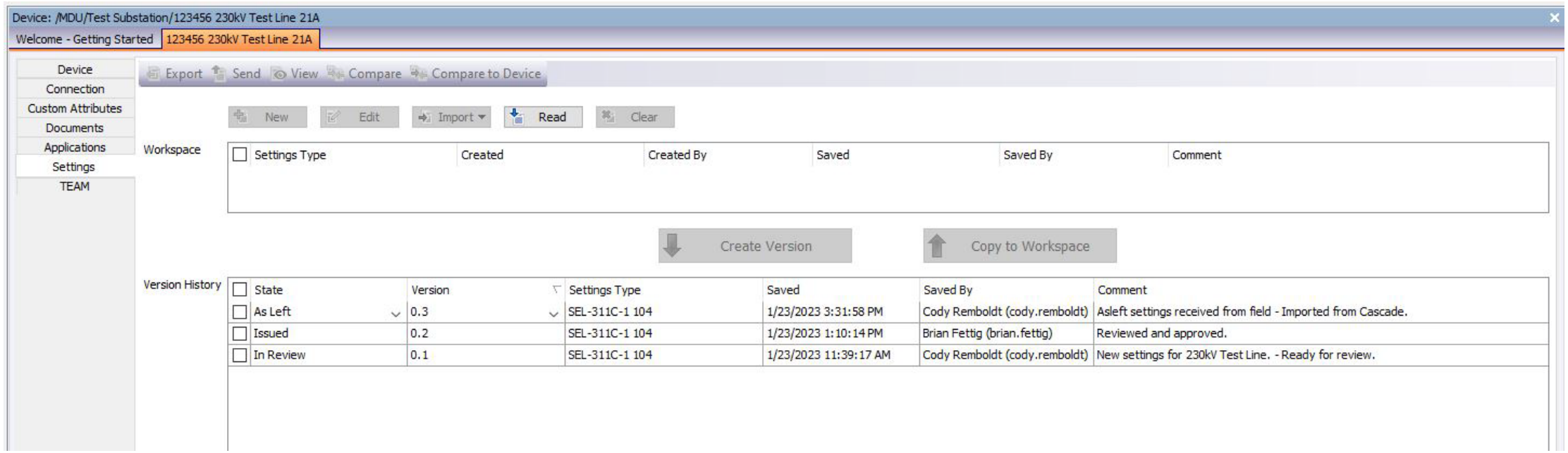
Settings/Documentation uploaded to Asset Database.

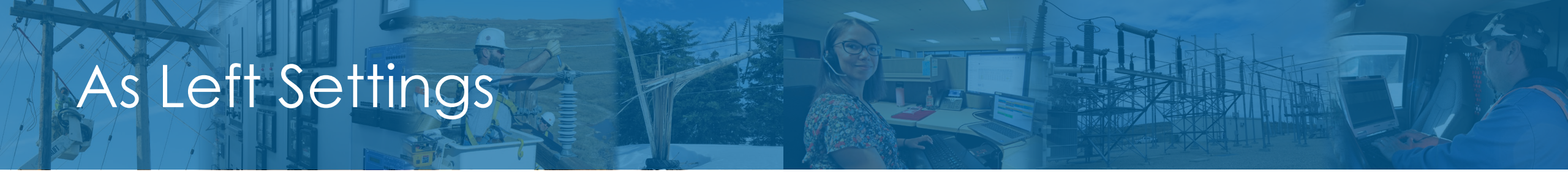
Importing “As Left” Settings





As Left Settings





As Left Settings

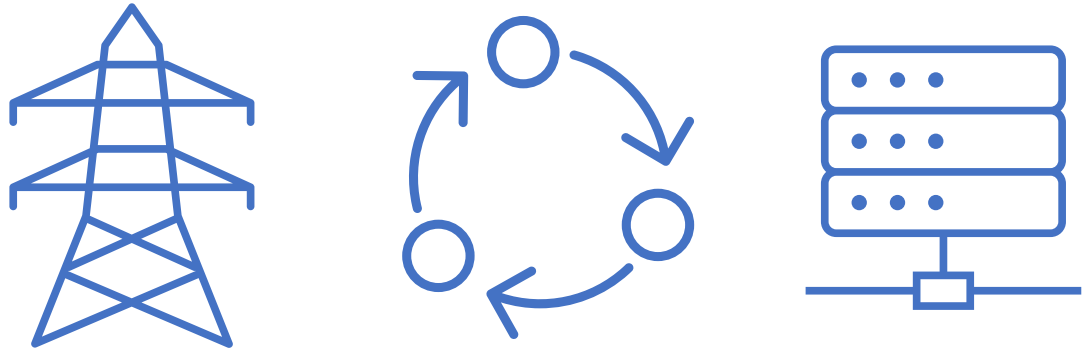
As Left Settings downloaded from Asset Database.

As Left settings imported to Relay Setting Database.

Compare As Lefts received to Issued settings.

Upload Compare file to Asset Database and close WO if no issues found.

Setting Management



- Adoption of setting versions, instead of dates, will lessen confusion and strengthen confidence that the setting sheet and settings match.
- Tracking setting progress with Asset Database and Relay Setting Database will ensure that the settings on file are the settings on the relay.
- Review of testing data, along with compare files, will catch potential issues before problems arise.

Thank You! Questions?

AGENDA

Technical Presentations

a. PRC Impacts on Ethernet Based Protection & Control Device Maintenance and Design
Eric Udren, Executive Advisor, Quanta Technology, LLC

Action
Information

Report
Eric Udren will provide an oral report during the meeting.

Classification: Public

IEC 61850 Substation P&C Architecture and NERC Standards for Definition of Protection System

Eric A. Udren, Member NERC SPCWG
Quanta Technology LLC

MRO Protective Relay Subgroup Q3 Meeting

September 9, 2023

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SPCWG project - Ethernet-based Protection and Control Technical Reference

Project team: Eric Udren (SME - Quanta Technology LLC), Lynn Schroeder (SPCWG Chair; Sunflower Coop), Davis Erwin (PG&E), Jeff Iler (AEP), George Wegh (Eversource), Michael Thompson (SME – SEL); Brian Kasmarzik (monitoring as Chair of PRC-005 SDT)

Theme: Which NERC standards are impacted or have clarity issues when the P&C system is based on:

1. Ethernet network or data communications paths among relays or protective computing elements, carrying data or control signals used in fault protection.
2. Switchyard data acquisition or I/O (merging units (MUs, or remote I/O units, RIOs) with fiber communications in place of switchyard or panel dedicated wires.
3. Wide-area system protection functions using inter-site communications, such as PMU-based backup fault or swing protection.

Looking forward with caution – what is present now or soon:

1. P&C performed on interconnected computing platforms supporting flexible combinations or allocations of protection functions. This includes 'centralized' (CPC) or distributed unified protection systems (unified grid control platform, UGCP) coming to the industry over time.
2. Electronic instrument transformers or binary state sensors with analog, binary, or data message outputs.
3. Power apparatus with computer-based control interfaces with communications messaging for fault protection.

Potentially impacted NERC standards & definitions

1. NERC Glossary Definition of *Protection System (Protective relays, associated communication systems, voltage and current sensing devices, station dc supply, and control circuitry)* – In SDT balloting right now.
2. PRC-004-6 - Protection System Misoperation Identification and Correction.
3. PRC-005-6 – Protection System Maintenance (*including Condition-Based Maintenance PSMP*).
4. TPL-001-4/5 - Transmission System Planning Performance Requirements (*has prot sys component definitions*)
5. PRC-012-2 – RASs (design & review, testing, op/misop reporting & actions, databases, review)
6. FAC-008 – Facility Ratings (*e.g., as applied to MUs, EITs*)

- How are each of these impacted?
- What interpretations are required? Are changes needed?
- How does the industry deal with these systems going forward with respect to NERC reliability standards?

Conclusions are to be *functional* and not focused on a specific technologies, designs, or protocols.

Tech Reference development is in progress for late 2023 draft – we can explore and review issues freely – nothing here is a conclusion.

Recent P&C design technologies calling for interpretation

- IEC 61850 communications replace single-function wires with Ethernet packet messaging services over optical fibers – *thousands of functional connections for many uses on one fiber.*
  - *GOOSE service* – high-speed tripping, control, and status reporting messages exchanged among relays, and between relays and MUs, for protection.
  - *Routable GOOSE or R-GOOSE services*– wide-area or WAN GOOSE with automated routing configuration and authentication security – will be used for wide-area protection & control, like RAS, CPC, UGCP.
  - *Sampled Values (SV) service* – streaming packages of point-on-wave sampled data and status points – e.g., from switchyard MUs to networked relays sharing measurements in the control house.
  - *Routable Sampled Values or R-SV service* - wide-area or WAN SV with automated routing configuration and authentication security – will be used for synchronized measurement or synchrophasor streaming, plus wide-area protection & control like RAS, CPC, UGCP.
- Tech reference will consider other protocols including proprietary choices used for protection.
  - Examples – Mirrored Bits® or Direct I/O®; DNP3, Modbus, proprietary messaging *if used for protection or RAS*.
  - Some non-protection protocols may be used to achieve *compliance* – e.g., SCADA monitoring and alarming via trip coil circuit monitor; heartbeat monitoring per PRC-005-2/6/7 CBM PSMP.

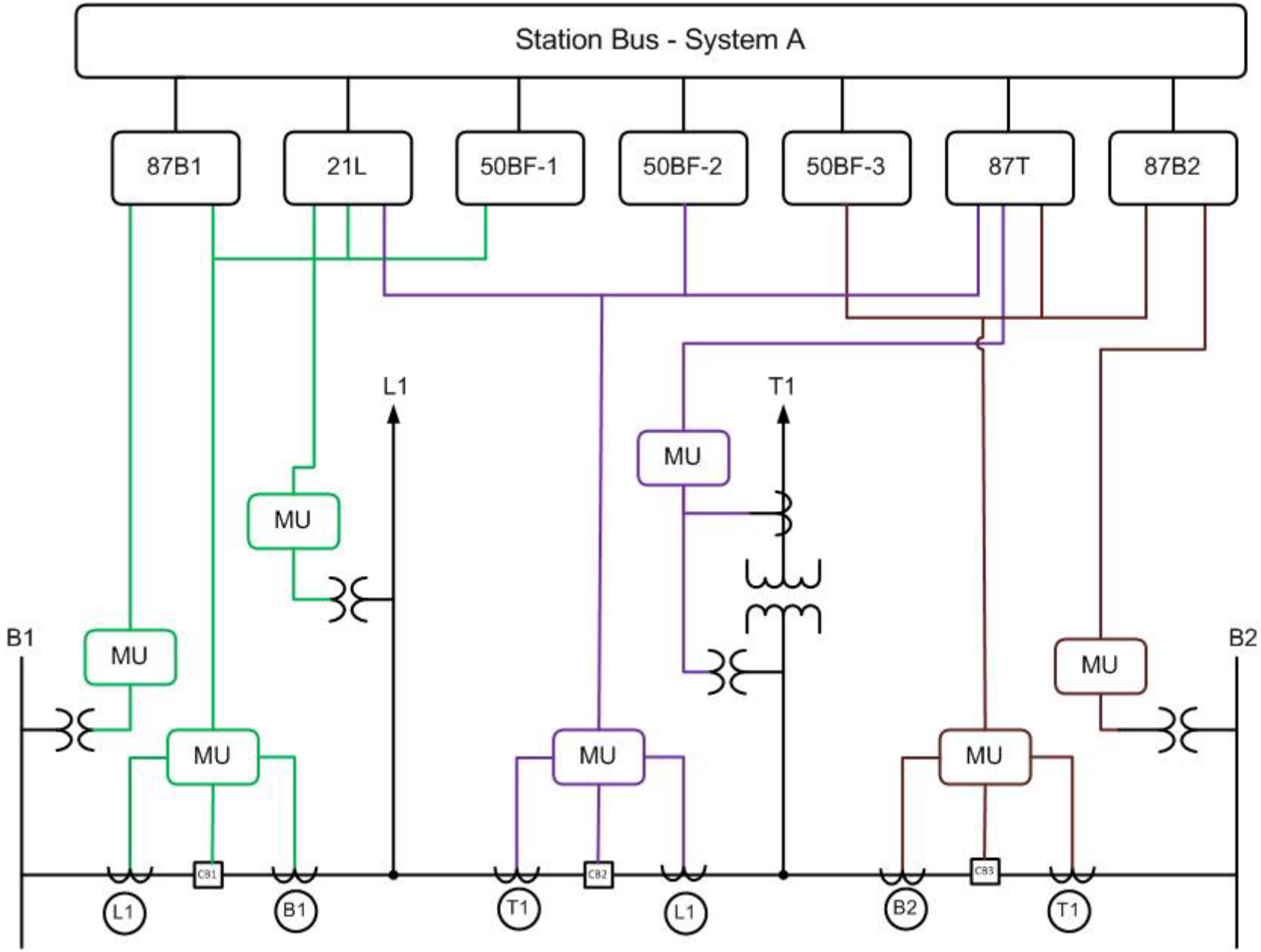
IEC 61850 background - drivers and absorption

- IEC 61850 comprises:
  - List of standard communications services – GOOSE, SV, client-server and configuration exchanges like automatically configured DNP3, time synchronization, more…
  - Standardized data exchange interfaces for each function ('logical nodes') – PDIS, PIOC, XCBR, etc.
  - Substation Configuration Language (SCL) project or P&C system engineering process based on automation tools to save time and money – interconnect the functions for the substation topology and forget about mapping points.
- Products available from relay vendors for two decades.
  - Largely used by international relay vendors in turnkey projects until last decade.
  - Technical details remain to work through during industry adoption process.
- Many NA utilities are now trying 61850 P&C or are developing standards around it.
- *Organizational education and adaptation are needed for success* – this is not simply the next generation of P&C products to adapt to the design and maintenance standards we have.
  - Impacts engineering process, documentation, maintenance programs and procedures, skills, configuration management systems, asset management.

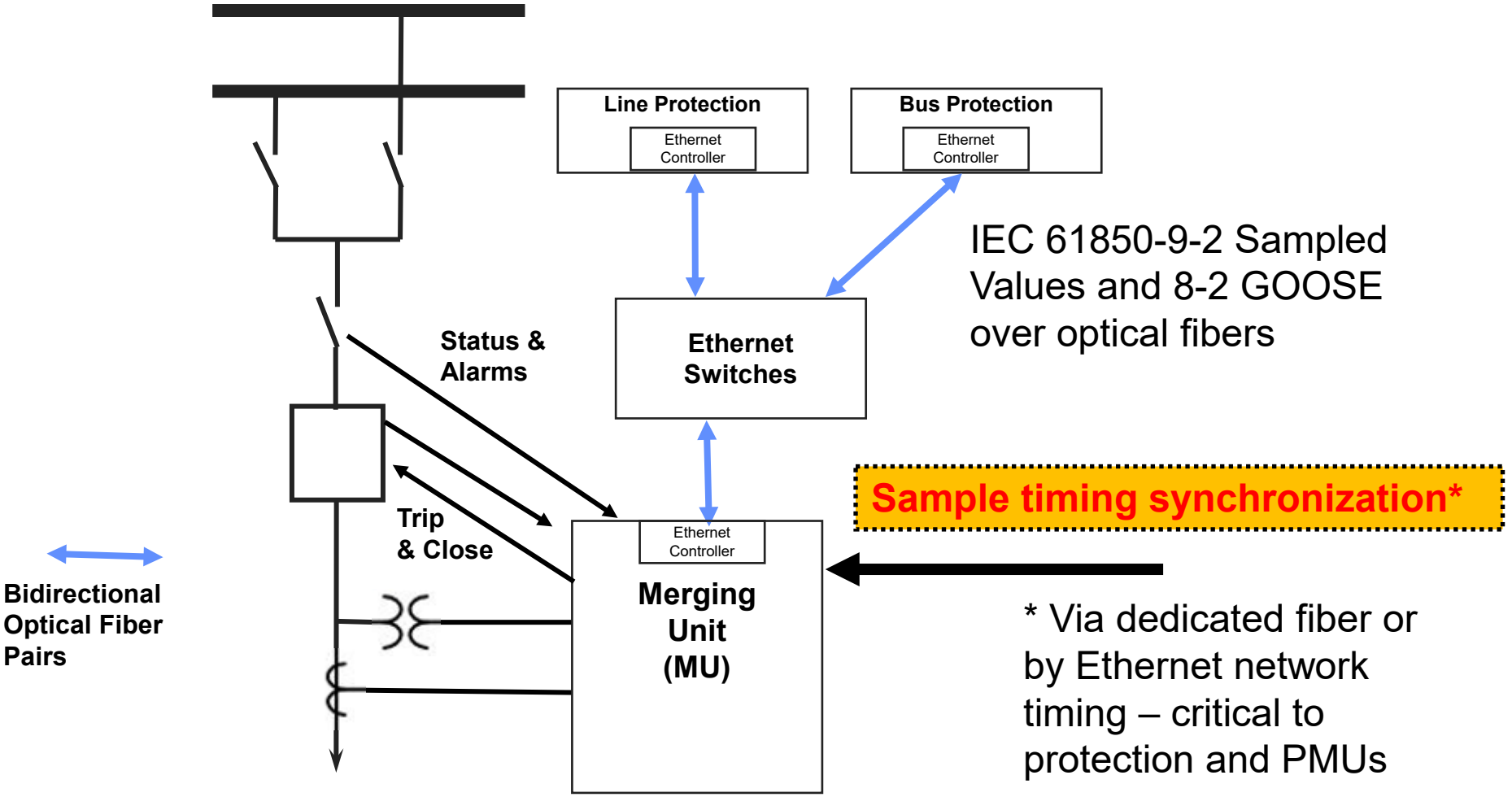
IEC 61850 drivers and absorption

- Ethernet networking components from the IT world combine with substation-grade processing to utilize the world's supply chain of latest electronic systems.
  - P&C teams learn fundamental Ethernet network engineering and IT-OT principles.
  - Make friends and collaborate with your utility IT/Telecoms team.
- Vendors are focusing on expanding relay product lines based on IEC 61850.
- Most wiring eliminated – replaced by *configured* Ethernet messaging (i.e., settings)
  - Among relays, IEDs, functions in control building.
  - Between field sensing and control units (merging units or MUs) and P&C system.
- High-level 61850-6 substation configuration language (SCL) automated system engineering process & tools save major time & money once user process is running.
- Secure wide-area communications and management can & must be built in.
  - Tacked-on boundary security solutions will be tough to manage.
- 61850 logical node (LN) modeling serves future generic-platform and digital-twin models of grid protection, monitoring, control, management (more later).

Typical IEC 61850 substation P&C system with process bus



Merging unit in switchyard

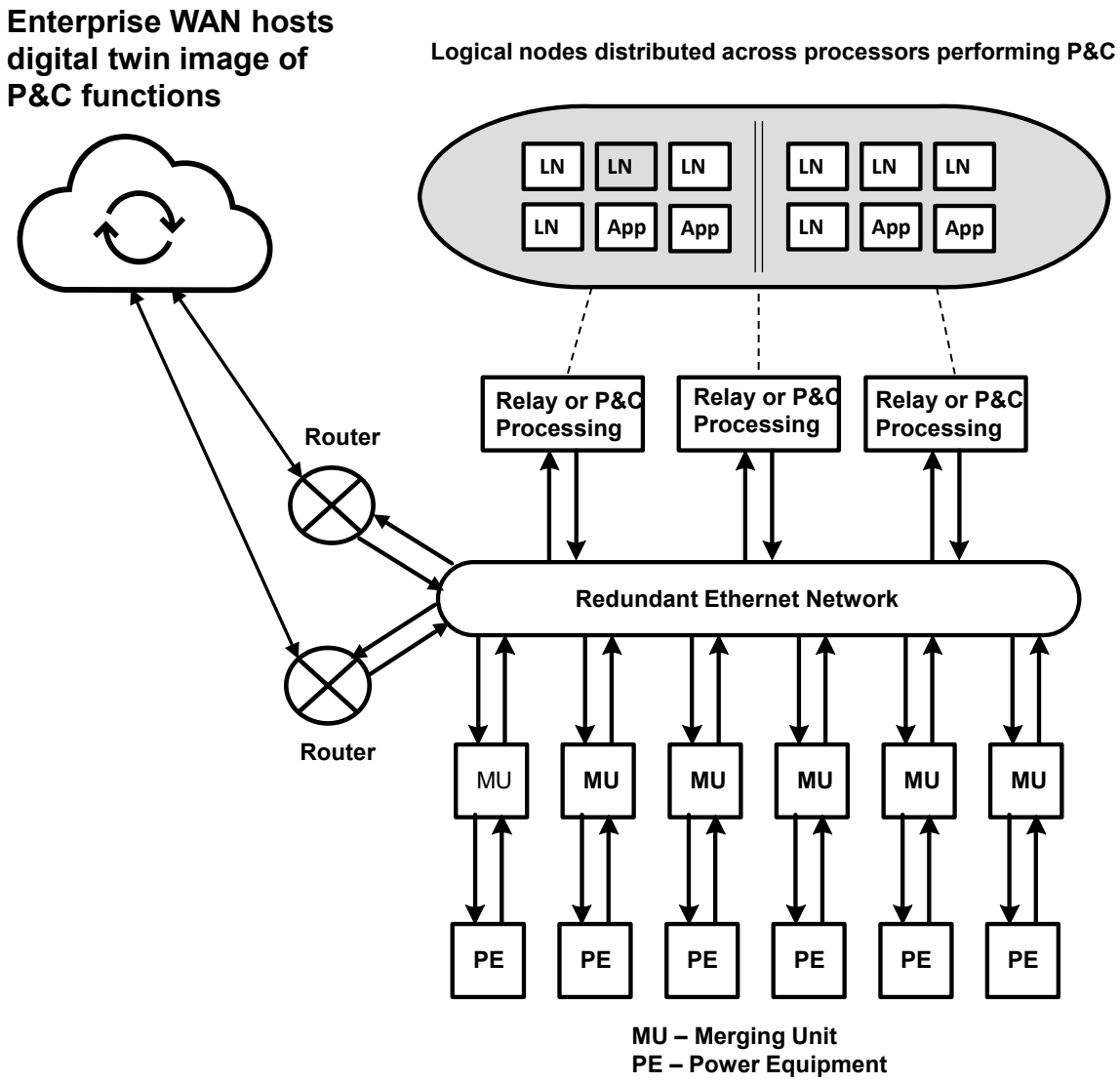


IEC 61850-9-2 Sampled Values and 8-2 GOOSE over optical fibers

Sample timing synchronization*

* Via dedicated fiber or by Ethernet network timing – critical to protection and PMUs

Evolutionary substation architecture with IEC 61850 services

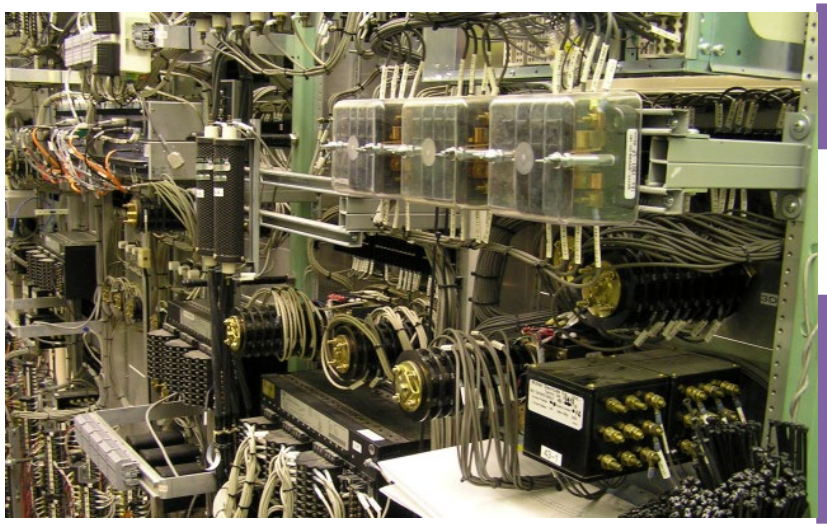


IEC 61850 services:

- MMS client-server – a DNP3-like exchange protocol with automated configuration capability
- GOOSE and Routable GOOSE (R-GOOSE) – millisecond-speed point-to multipoint message stream for tripping, control, status, more
- Sampled values (SV) and R-SV – millisecond-speed point-to multipoint stream for analog point-on-wave data and status
- Precision time synchronization messaging for substation and wide area functions
- *Side discussion – role of GPS and precision time distribution in protection*.

Wiring reduction – Ethernet & fibers

IEC 61850 and Ethernet P&C eliminate almost all wiring for protection, control, automation, and data gathering.



Conventional
point to point wiring

Ethernet on optical fibers

Standardized object models, point descriptions

Integrated P&C system using fiber optic network cables

The wiring is gone, but what happened to the complex functionality?

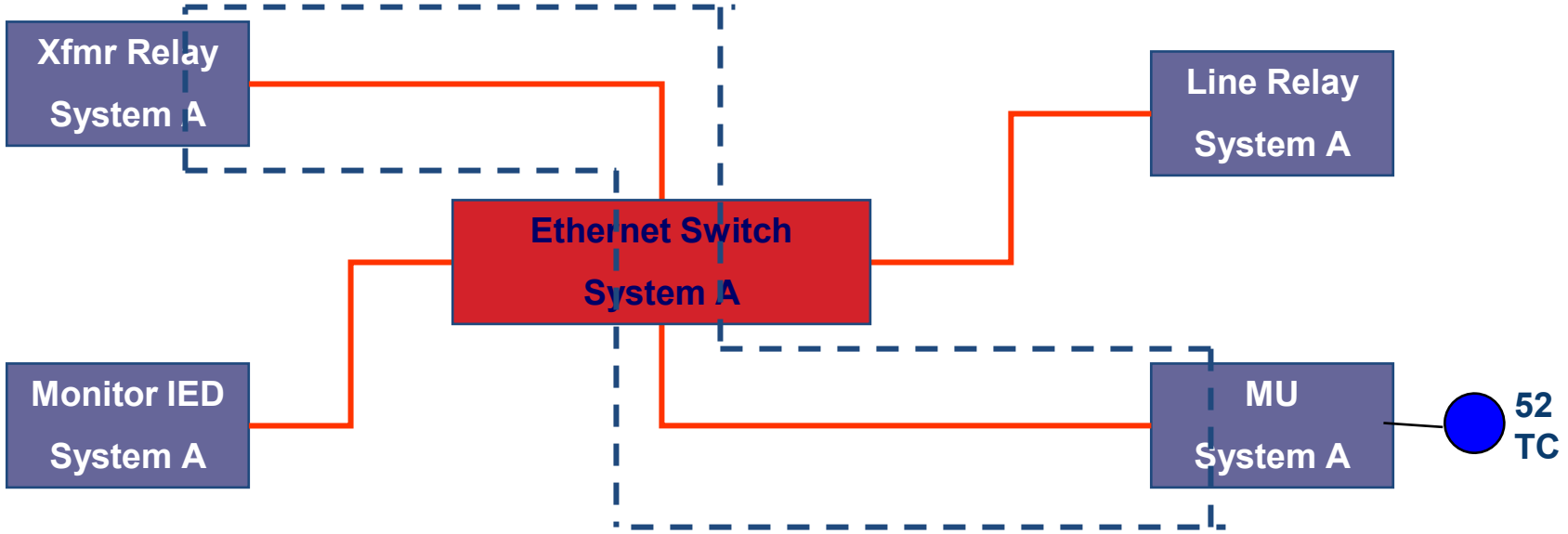
It is embedded in settings or configuration throughout the system

- Where are the test switches and maintenance check points?
- How does utility update firmware or settings in this interactive array?

Continuous end-to-end monitoring serves PRC-005-2/6/7 CBM - 1

End-to-end check of IEC 61850 tripping or protection-critical communications:

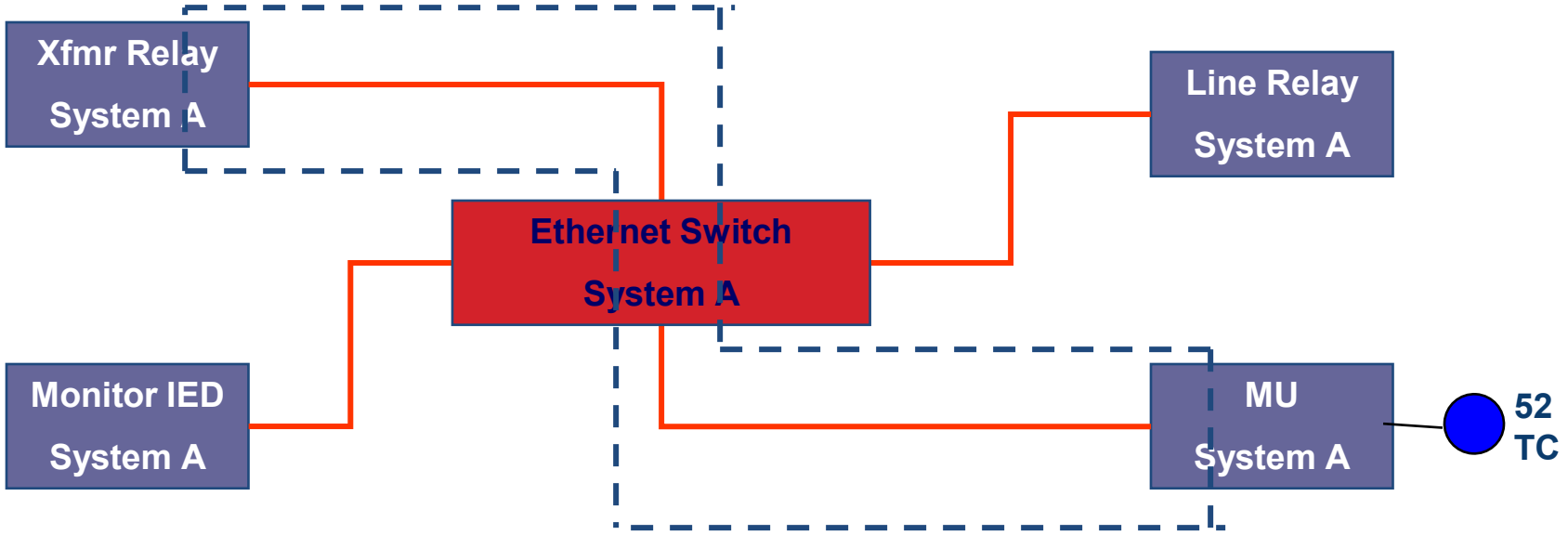
- All processors are monitoring themselves continuously.
- *Example*: transformer relay publishes a GOOSE message including a specific breaker trip bit.
- Normal-state message (*do not trip*) is generated *every second* by DSP in transformer relay.
- Passed to the communications processor in transformer relay
- GOOSE message passes through relay Ethernet controller to fiber, then to Ethernet switch.



Continuous end-to-end monitoring serves PRC-005-2/6/7 CBM - 2

- Ethernet switch passes GOOSE message to subscriber MU incoming control Ethernet port.
- Communications processor of MU passes *no-action* message to MU processor every second.
- MU processor alarms if *no-action* subscribed GOOSE isn't received every second.
- MU sends alarm back to substation relays or concentrator via GOOSE or MMS with the same type of heartbeat (subscriber to alarm message will raise a different alarm if this path is lost).
- We always know that when we finally send a *trip-action* bit, it will be received and acted on.

Not all wires can check themselves continuously like this. This monitoring alarms for configuration/setting errors as well as optical path, processor interface, or switch failures.



NERC PRC Topic 1 – mapping Protection System definition to IEC 61850

Protective relays which respond to electrical quantities, Communications systems necessary for correct operation of protective functions, Voltage and current sensing devices providing inputs to protective relays, Station dc supply associated with protective functions (including station batteries, battery chargers, and non-battery-based dc supply), and Control circuitry associated with protective functions through the trip coil(s) of the circuit breakers or other interrupting devices.

For IEC 61850 protection systems – Some discussions and proposals among Tech Reference team members:

- In-substation communications network paths are already regarded as 'control circuitry' in Technical Reference for PRC-005-2.
- Treat merging unit as a protective relay; or same for system of merging unit and relays or processing with which it communicates.
- Add clarity regarding system timing functions like GPS and PTP messaging when they are critical to protection performance
- PRC-005 drafting team is adding clarity for protection functions embedded in other devices, like generic processing boxes.
- What if any adaptation is needed to ensure that a mission-critical OT network in an IEC 61850 P&C system is not subject to IT disruption that could impact protection functions?
- How can we assure auditor understanding of a compliant design and program? Do we need *functional* language in definitions?
- Is there any action required to help ensure proper design of redundant configurations? Are there *functional* rules to be stated? How does this relate to TPL-001-5?
- Can a PSRC White Paper clarify requirements to help users, or to guide audit processes? Compliance guidance document?

News – latest PRC-005-7 definition proposal fails ballot

- Protective relays, or components of control systems, which respond to measured electrical quantities and provide protective functions;
- Communications systems necessary for correct operation of protective functions;
- Voltage and current sensing devices providing inputs necessary for the correct operation of protective functions;
- Station dc supply associated with protective functions (including station batteries, battery chargers, and non-battery-based dc supply);
- Control circuitry associated with protective functions through the trip coil(s) of the circuit breakers or other interrupting devices.

SDT rationale:

"…functions that are implemented to initiate or prevent the automatic isolation of Facilities to protect power system Elements, to maintain Stability, or in response to detected faults.

Functions **not** applicable to the definition include those which do not initiate or prevent automatic isolation (such as limiters or functions which only provide indication) or devices which do not respond to the aforementioned scenarios, such as those detecting malfunctions of an excitation system, or automatic switching of capacitor banks for the purpose of voltage-control). Protective functions focus on the action being performed and not the equipment itself, which allows for exclusion of components or functionality within the relay or control system that are not performing a protective function."

NERC PRC Topic 2 – Practical auditable CBM programs

- Documentation of how condition is monitored in a P&C system replaces extensive TBM work and records
  - No hidden failures – failures reported when they happen, not when found years later in a test or when a misoperation exposes it.
- Design standardization helps – document once to support all standard installations
- Some records of alarms and failure mitigation could help demonstrate that CBM program is effective
- Do we need guidance on audit-acceptable documentation for a CBM PSMP based on IEC 61850?

Component Attributes	Interval	Maintenance Activities
Unmonitored protective relay	6 years	Verify that settings are **as specified** *Non-microprocessor relays:* Test; and calibrate if needed *Microprocessor relays:* Test protection I/O Verify ac measurements.
Monitored microprocessor relay with alarming for failures	12 years	Verify settings are as specified. Test operation of protection I/O. Verify ac measurements.
Monitored microprocessor protective relay as above plus Auto comparison check of ac measurements Alarming for change of settings Some monitoring of protection I/O	12 years	Test operation of protection I/O that isn't monitored. *Remote SCADA trip test = never touch the relay until it alarms*

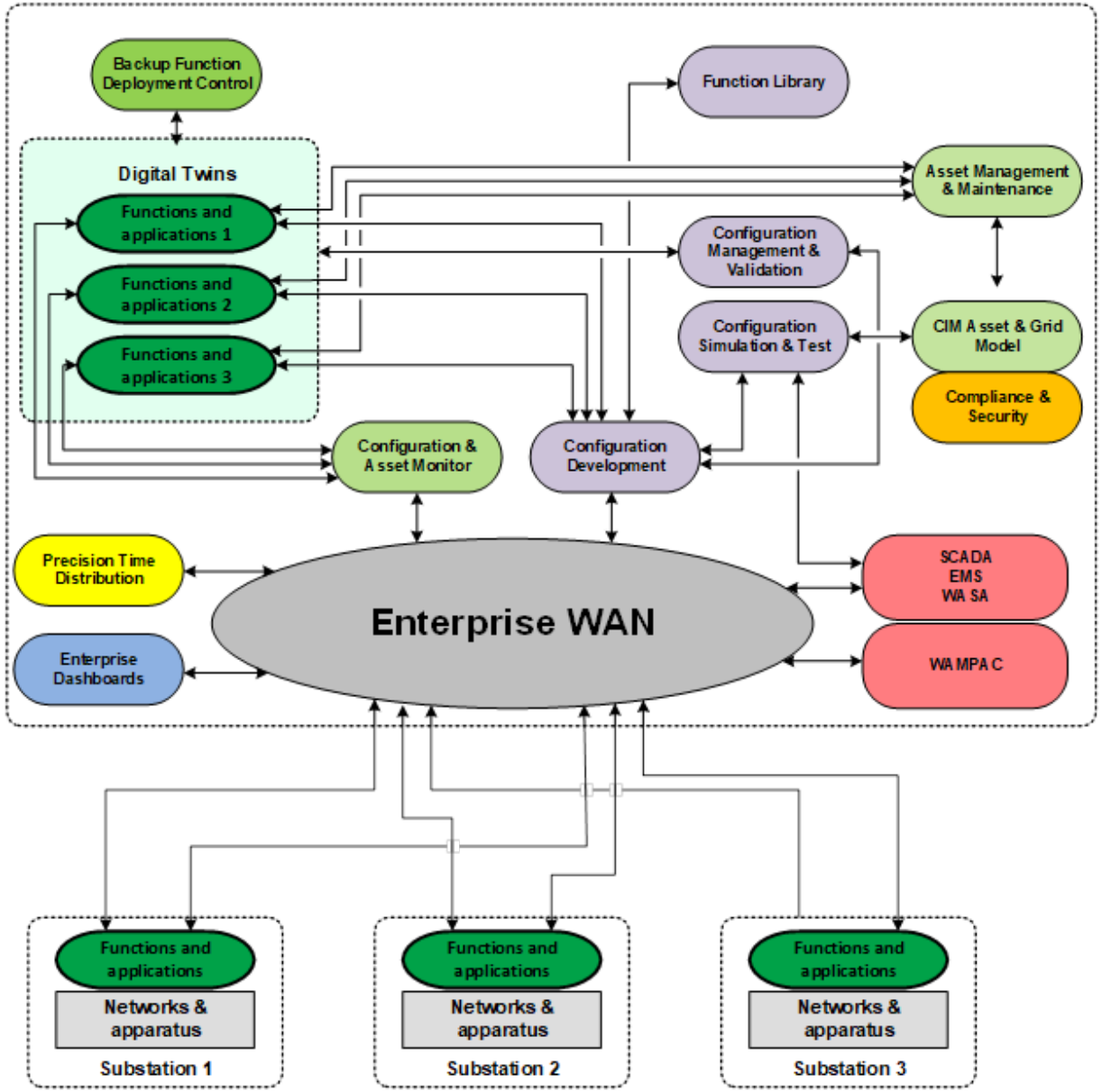
Recent P&C design technologies calling for interpretation 2

Unified Grid Control platform (UGCP) *includes 'Centralized Protection & Control' (CPC).*

- Distributed array of redundant standardized data sensing, processing, and storage resources interconnected with redundant high-reliability cybersecure data communications.
- Inherits IEC 61850 digital substation elements.
- Redundant processing platforms and networks.
- Floating protection apps with Logical Node (LNs) standard interfaces and virtual processing compartments..
- Centrally managed configuration & modeling.

Includes substation and wide-area protection and RAS functions and connected dynamic elements.

Paper and presentation at Texas A&M Relay Conference 2023; coming to WPRC October 2023.



Conclusions

- SPCWG Technical Reference team is working to advise NERC and the industry in 2023 on impact of emerging P&C technologies on standards, definitions, and compliance.
- Focus on Ethernet IEC 61850 substations – but what else is coming?
- We look for designs and issues that are coming to substations and wide-area protection systems – with caution about scope.

***First goal* – explain technical issues and interpretation topics to industry stakeholders.**

***Second goal* – give interpretation advice wherever that is resolves clarity or enforcement issues.**

***Third goal* – recommend changes to standards and definitions if that is the only path to clarity.**

Questions & Discussion

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Current outline of Tech Reference on following slides.

Outline - Ethernet-based Protection and Control Technical Reference Document

V0.5 – August 23, 2023

1. Introduction – Statement of the purpose of the report and recommendations

2. Review of protection technologies in sequence, and key standard-related elements. R*eference designs* to support these explanations.

    a. Ethernet network or data communications path among relays or protective computing elements, carrying data or control signals used in fault protection.

        i. Features of redundancy and architecture that impact reliability.

    b. P&C systems with the above features may have protection functions based on IEC 61850 services on Ethernet such as GOOSE or Routable GOOSE (R-GOOSE) and Sampled Value (SV) or Routable SV (R-SV) messaging; but other protocols and services capable of control or data transfer for relaying by communications messaging are included, including proprietary methods.

    c. Switchyard data acquisition and binary I/O - merging units (MUs) or remote I/O (RIO) units.

        i. Data communications multiplexed on optical fibers in place of switchyard or interconnecting dedicated wires.

        ii. Switchyard protection system elements & enclosures.

        iii. Binary inputs and contact outputs.

    d. Wide-area system protection functions using inter-site communications of messaging services, such as PMU-based backup fault or swing protection.

        i. DOE development and a paper with the concept – only needs to be explained on the top level for this tech reference.

    e. P&C performed on interconnected or centralized standard computing platforms supporting flexible selections, combinations, or allocations of protection functions in operating system containers.

        i. This includes ‘centralized’ (CPC) or distributed unified protection systems coming to the industry - separate technical paper on Unified Grid Control Platform.

        ii. Present straw man is that this will have the same issues as a combo of IEC 61850 substations, teleprotection, and wide-area protection schemes.

        iii. Functions are mixed on platforms; need continuous monitoring.

    f. Electronic instrument transformers or state sensors with analog, binary, or data message outputs.

    g. Power apparatus with computer based control interfaces which are activated by communications messaging exchanges with protection functions.

    h. *Not in scope* - non-protection control communications, such as DNP3 or IEC 61850 non-protection control communications, even if these operate over the same data communications paths. These messages are present on the same data paths or networks; and they can be leveraged for PRC-005 CBM maintenance purposes. For example, a SCADA trip from a control center or HMI through a relay to a merging unit trip contact can demonstrate that that the protection trip path is functioning down through the trip coil.

3. Review of NERC reliability standards that need mapping, clarification, or expansion – for each of the following, what may be impacted? What change if any might be needed?
    a. PRC-004-6
    b. PRC-005-6/7 – a whole section below
    c. TPL-001-4/5
    d. PRC-012-2
    e. FAC-008 and merging unit interfaces
4. Relationship to NERC CIP standards and security methods or requirements for communications paths outside of PSP, such as teleprotection paths using What are the elements of a Protection System built from subject technologies?
    a. Goal is to evaluate the adequacy of the existing protection system definition and suggest options to address gaps or lack of clarity
    b. Current NERC Protection System definition
    c. For each protection system element, describe elements from each listed technology – conceptual table or mapping
    d. Discuss variations in the *definition* across NERC standards needing clarification – status of PRC-005-6/7 definitions, TPL-005 definition aberrations, RAS elements...any others?
    e. Ethernet routable protocols? This is out of scope – just point out CIP/security issue and compliance need.
5. PRC-005-6/7 CBM program impacts
    a. Report section explaining CBM approach of PRC-005-6 and practical application.
    b. Criticality of CBM for protection systems based on technologies in (2); challenges of applying TBM to these.
    c. Recommended direction of CBM programs
        i. Criticality of configuration and setting management.
        ii. Network components like switches and routers may be protection system components requiring monitoring and configuration management. Where in definitions and standards is this assured?
    d. Avoid technical prescription and stay functional.
    e. Help to guide future implementations of CBM.
6. Recommendations
    a. Recommendations for Protection System definition
        i. Changes or not to Protection System definition
        ii. Mapping or clarifications to Protection System elements where PS definition change is not required.
    b. Identified issues with NERC PRC or other standards listed above.
        i. Recommended revisions if any to above-cited standards.
7. Conclusion - Conclusions should be functional and not focused on a specific technology or protocol.
    a. Best practices

TPL-001-5.1 Definition of Protection System in Table 1 Footnote 13

13. For purposes of this standard, non-redundant components of a Protection System to consider are as follows:

a. A single protective relay which responds to electrical quantities, without an alternative (which may or may not respond to electrical quantities) that provides comparable Normal Clearing times;

b. A single communications system associated with protective functions, necessary for correct operation of a communication-aided protection scheme required for Normal Clearing (an exception is a single communications system that is both monitored and reported at a Control Center);

c. A single station dc supply associated with protective functions required for Normal Clearing (an exception is a single station dc supply that is both monitored and reported at a Control Center for both low voltage and open circuit);

d. A single control circuitry (including auxiliary relays and lockout relays) associated with protective functions, from the dc supply through and including the trip coil(s) of the circuit breakers or other interrupting devices, required for Normal Clearing (the trip coil may be excluded if it is both monitored and reported at a Control Center).

AGENDA

Technical Presentations

b. WAPA's Geomagnetic Disturbance (GMD) Project Presentation

Chris Colson, Transmission System Planning Manager, Western Area Power Administration

Action

Information

Report

Chris Colson will provide an oral report during the meeting.

Classification: Public

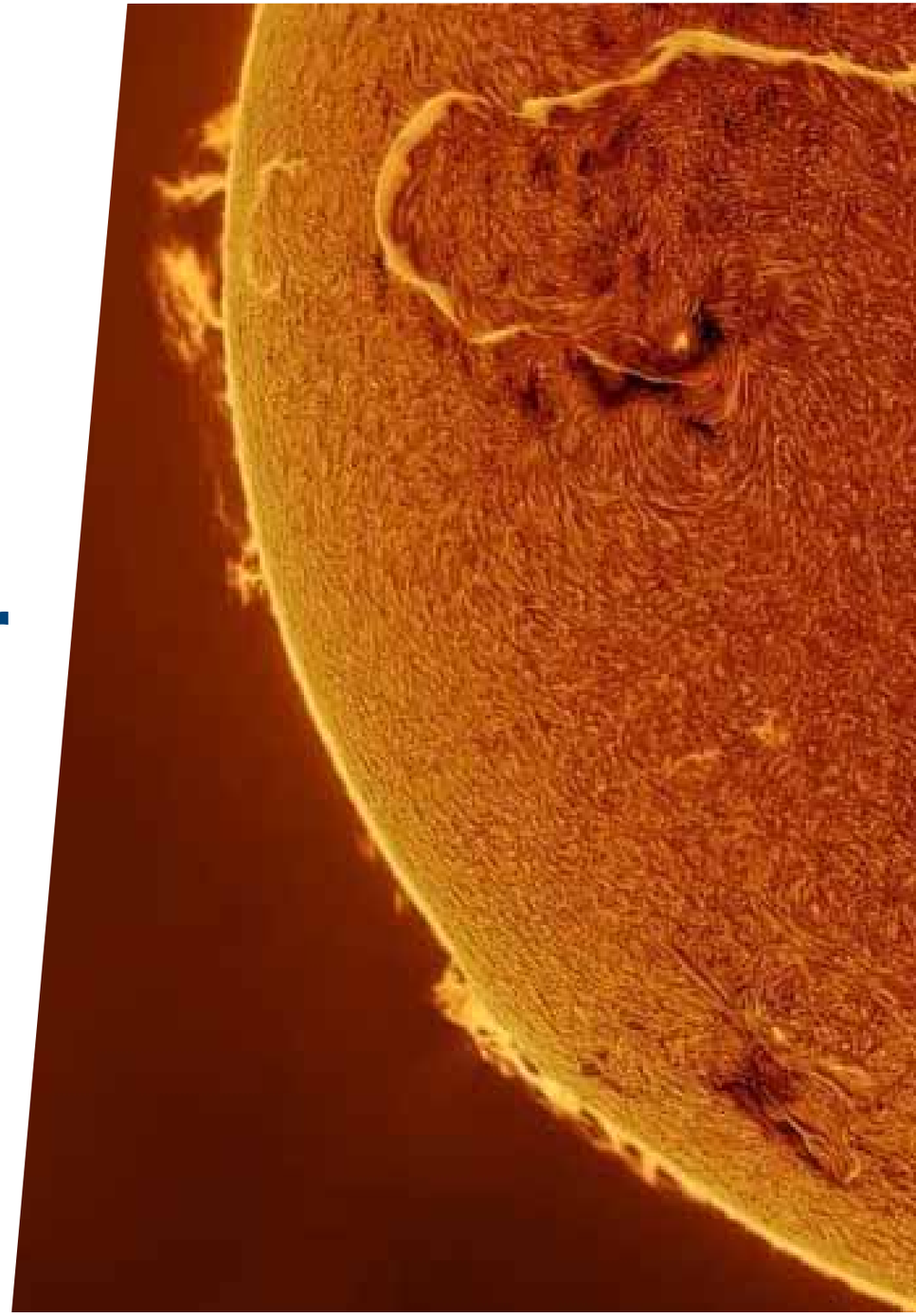
Western Area Power Administration

Aware & Prepared for Space Weather

Presented to MRO PRS

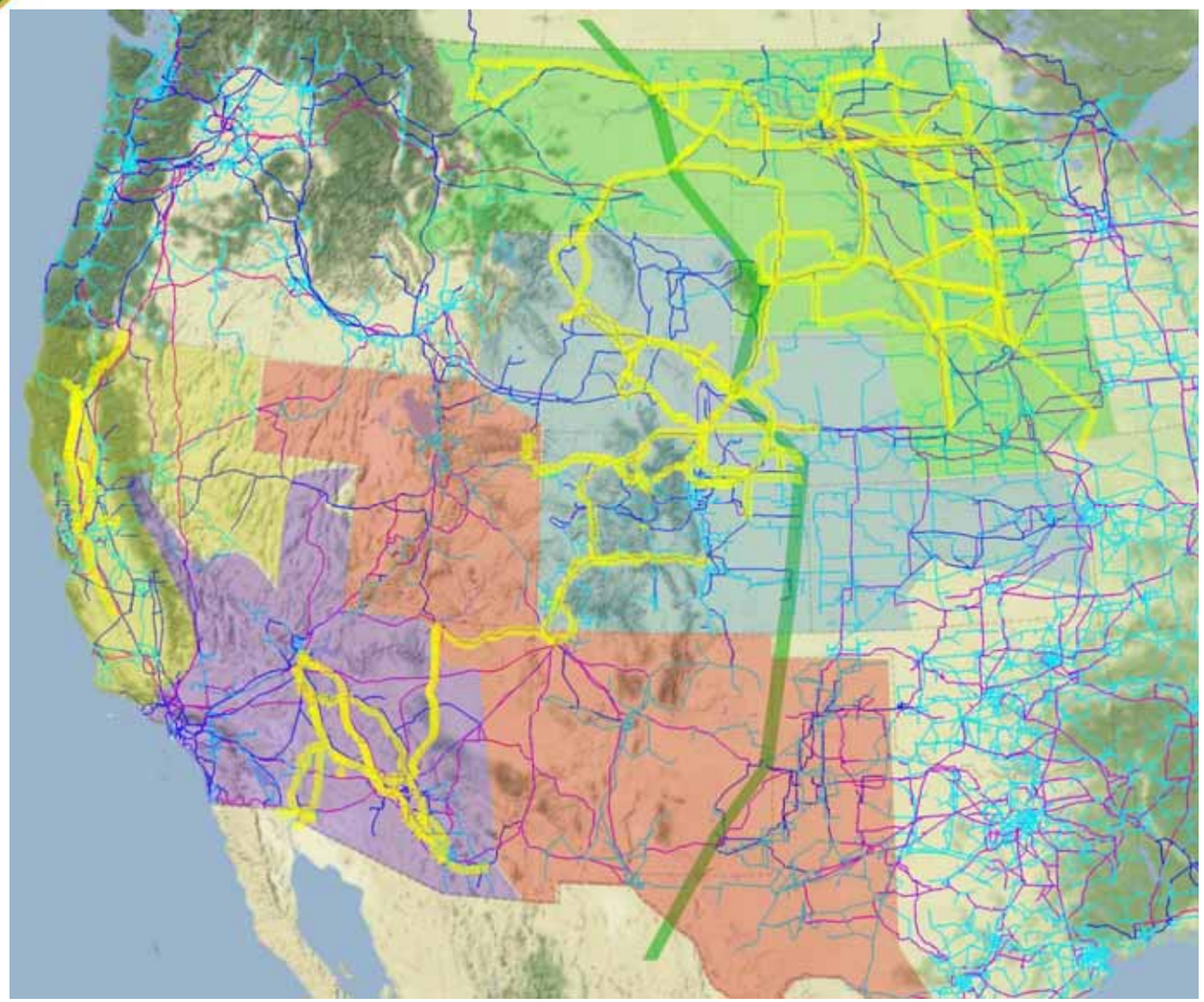
Chris Colson

06 Sept 2023



Who am I representing?

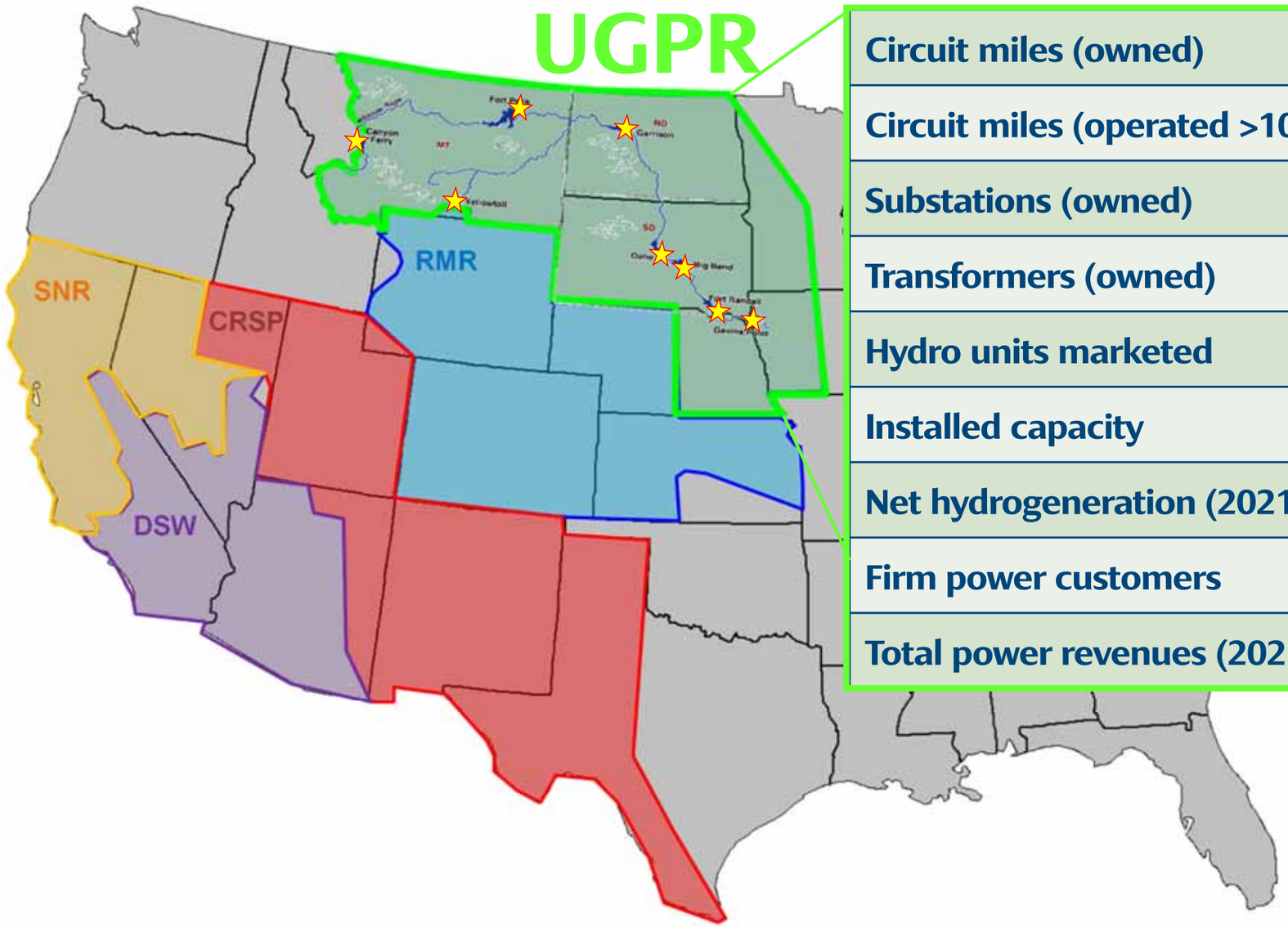
One of four Power Marketing Administration (PMA) of U.S. Dept of Energy.



Western Area Power Administration

- Four WAPA regions.
- Own & maintain 17,000 miles across 15 states.
- Markets over 10 GW of clean, dependable hydropower across a reliable transmission network to over 40 million Americans.

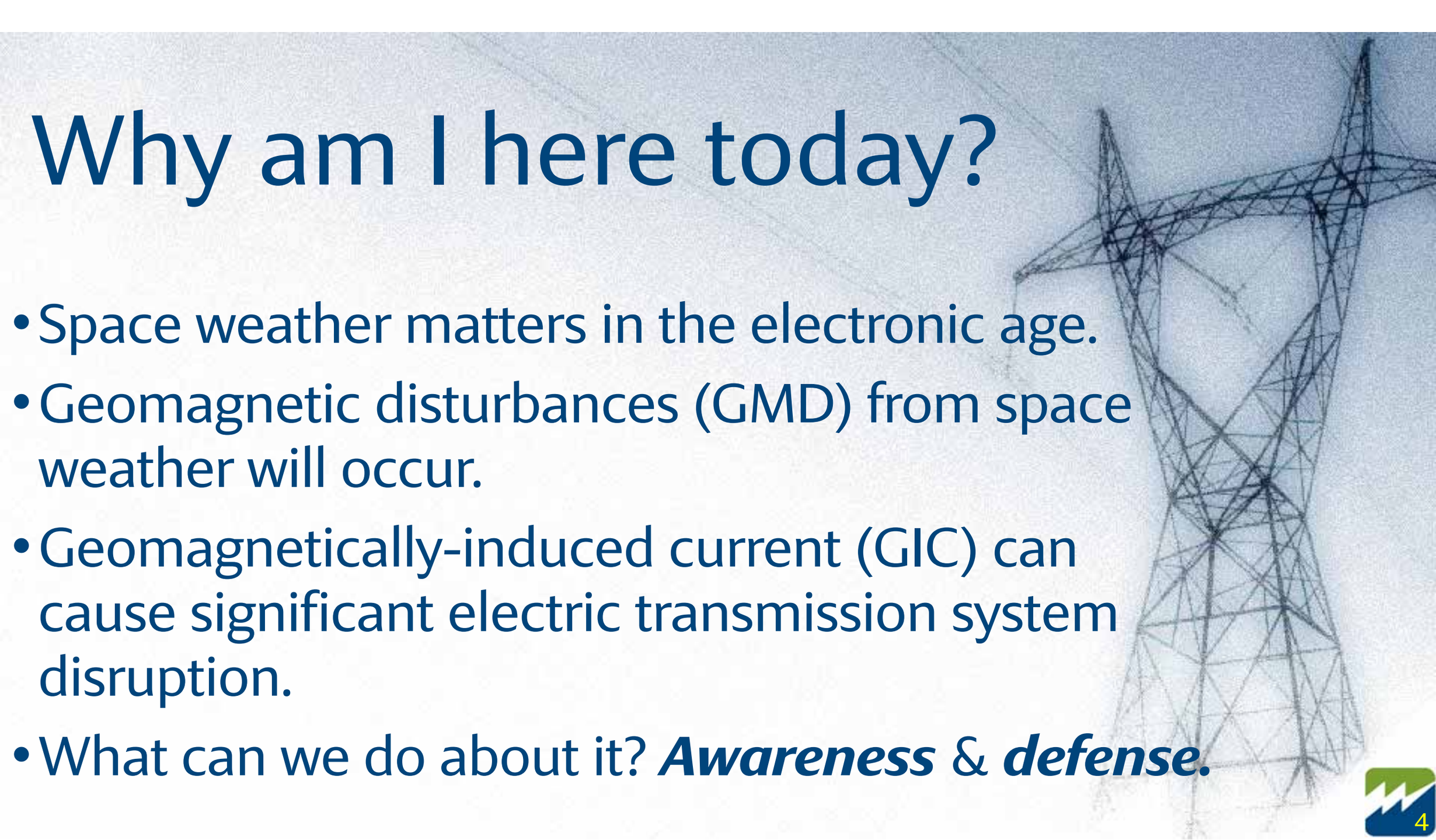
WAPA Regional Footprints



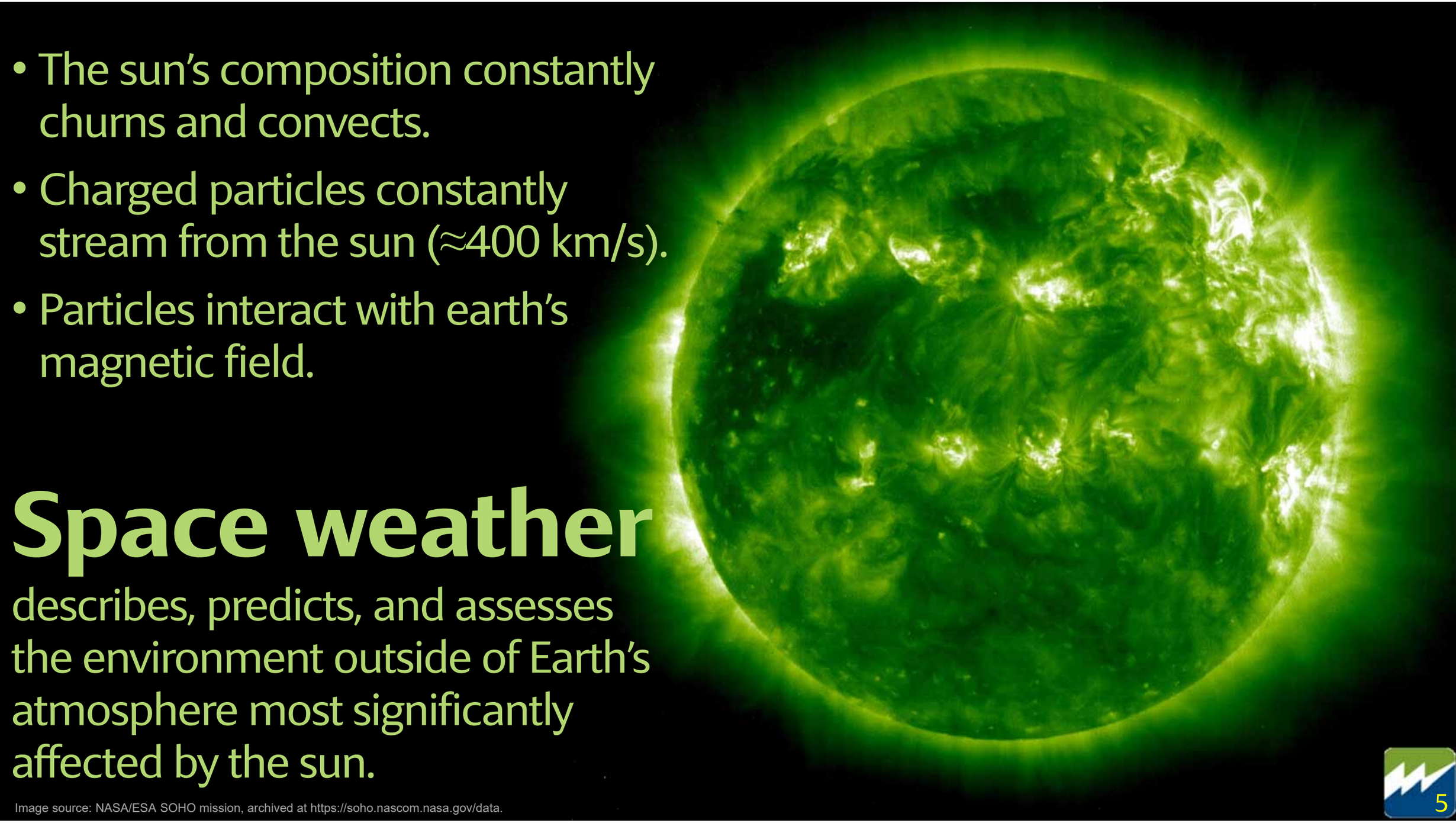
Circuit miles (owned)	7,829
Circuit miles (operated >100kV)	13,281
Substations (owned)	130
Transformers (owned)	120
Hydro units marketed	41
Installed capacity	2,698 MW
Net hydrogeneration (2021)	9,332 GWh
Firm power customers	349
Total power revenues (2021)	$273 M

Why am I here today?

- Space weather matters in the electronic age.
- Geomagnetic disturbances (GMD) from space weather will occur.
- Geomagnetically-induced current (GIC) can cause significant electric transmission system disruption.
- What can we do about it? ***Awareness*** & ***defense.***



- The sun's composition constantly churns and convects.
- Charged particles constantly stream from the sun (≈400 km/s).
- Particles interact with earth's magnetic field.



Space weather

describes, predicts, and assesses the environment outside of Earth's atmosphere most significantly affected by the sun.

Image source: NASA/ESA SOHO mission, archived at https://soho.nascom.nasa.gov/data.

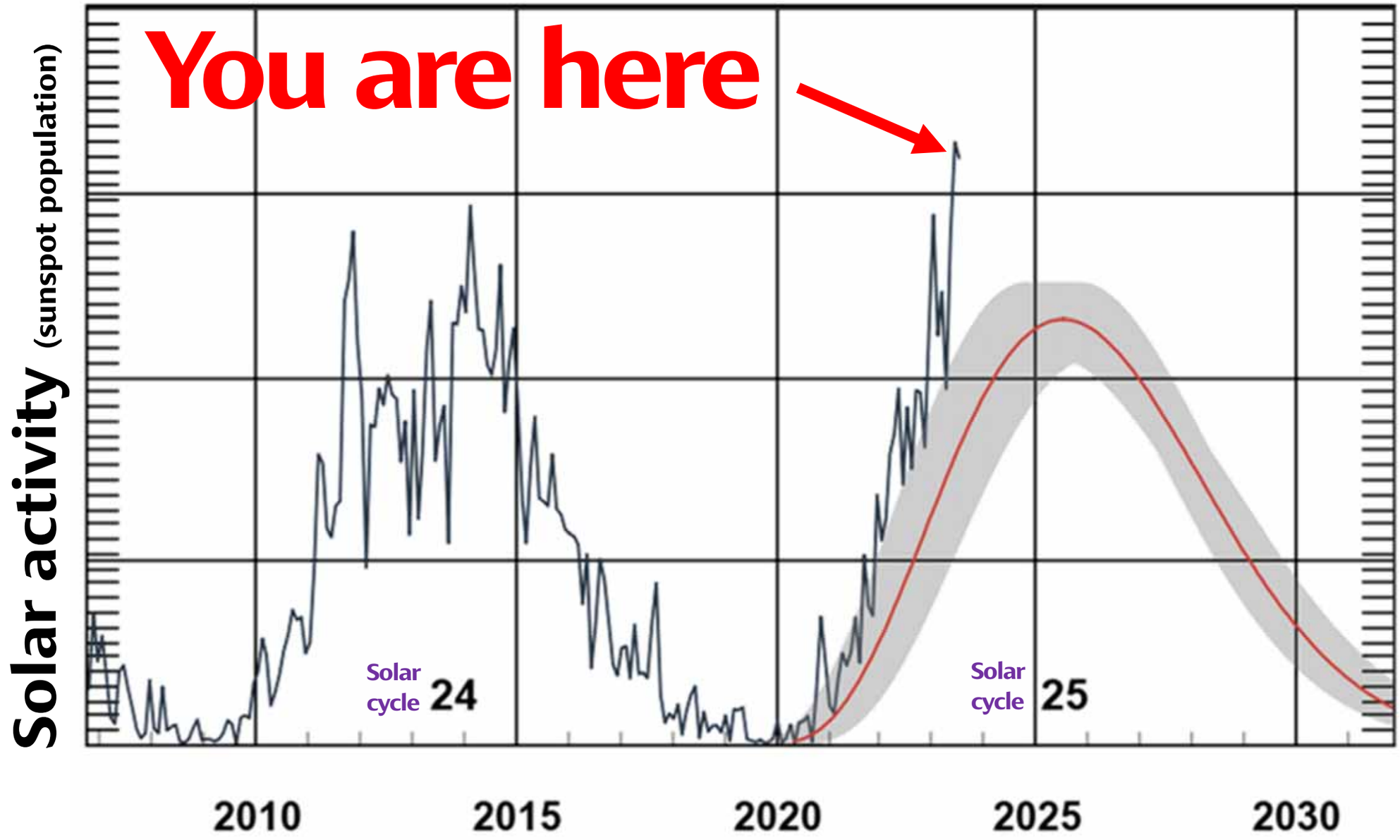
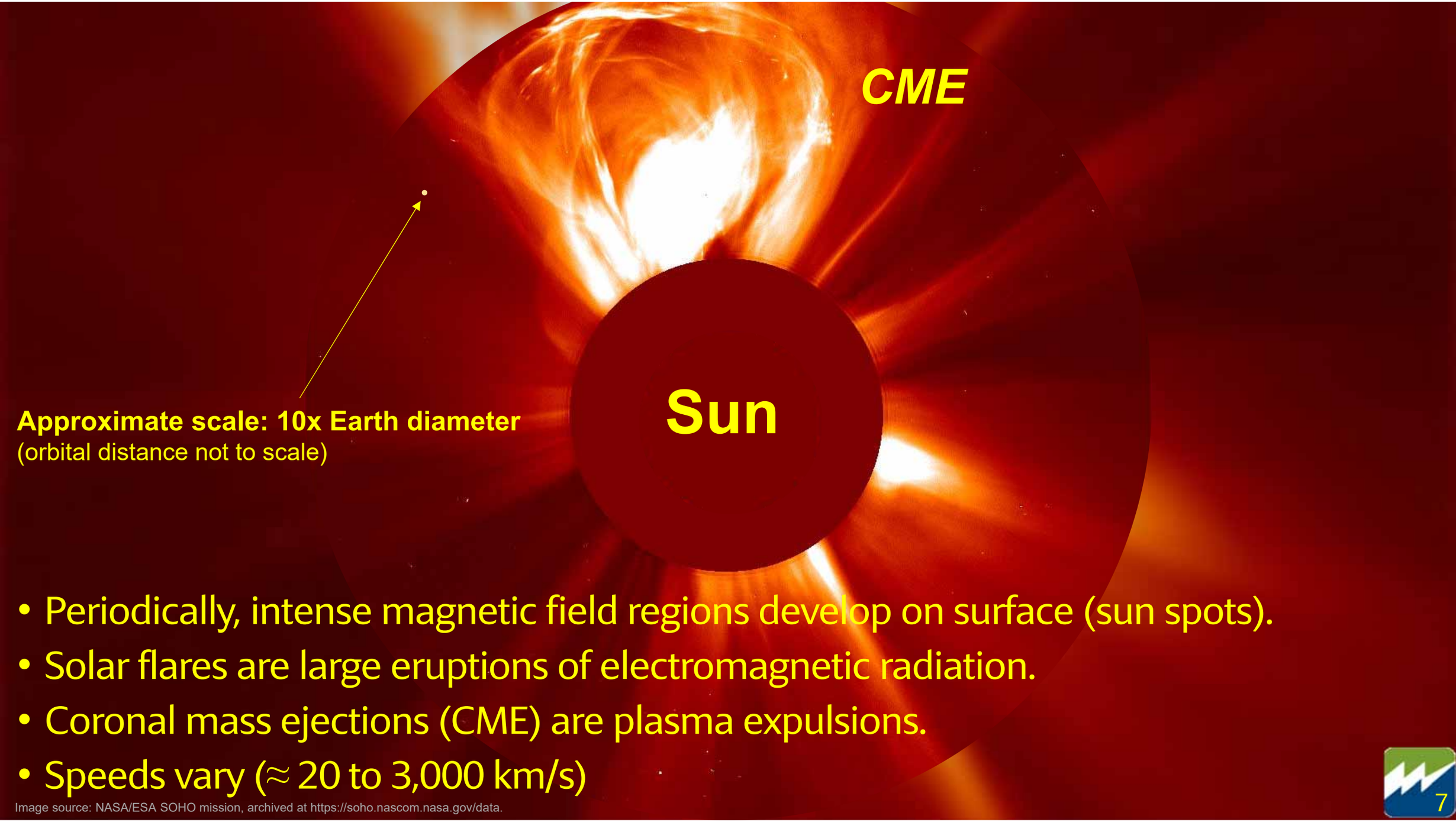
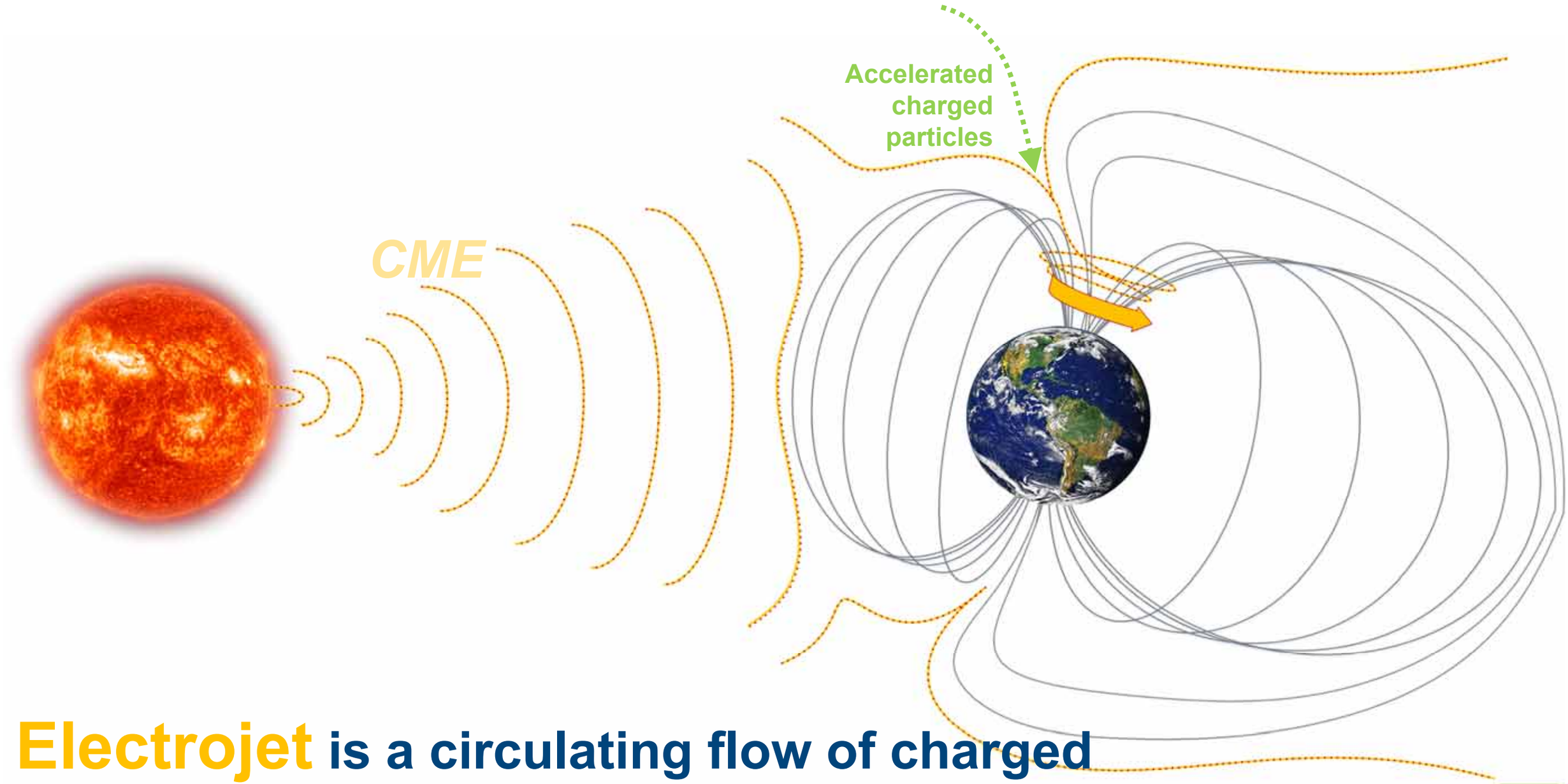


Image source: Space Weather Prediction Center, retrieved from https://www.swpc.noaa.gov/products/solar-cycle-progression.

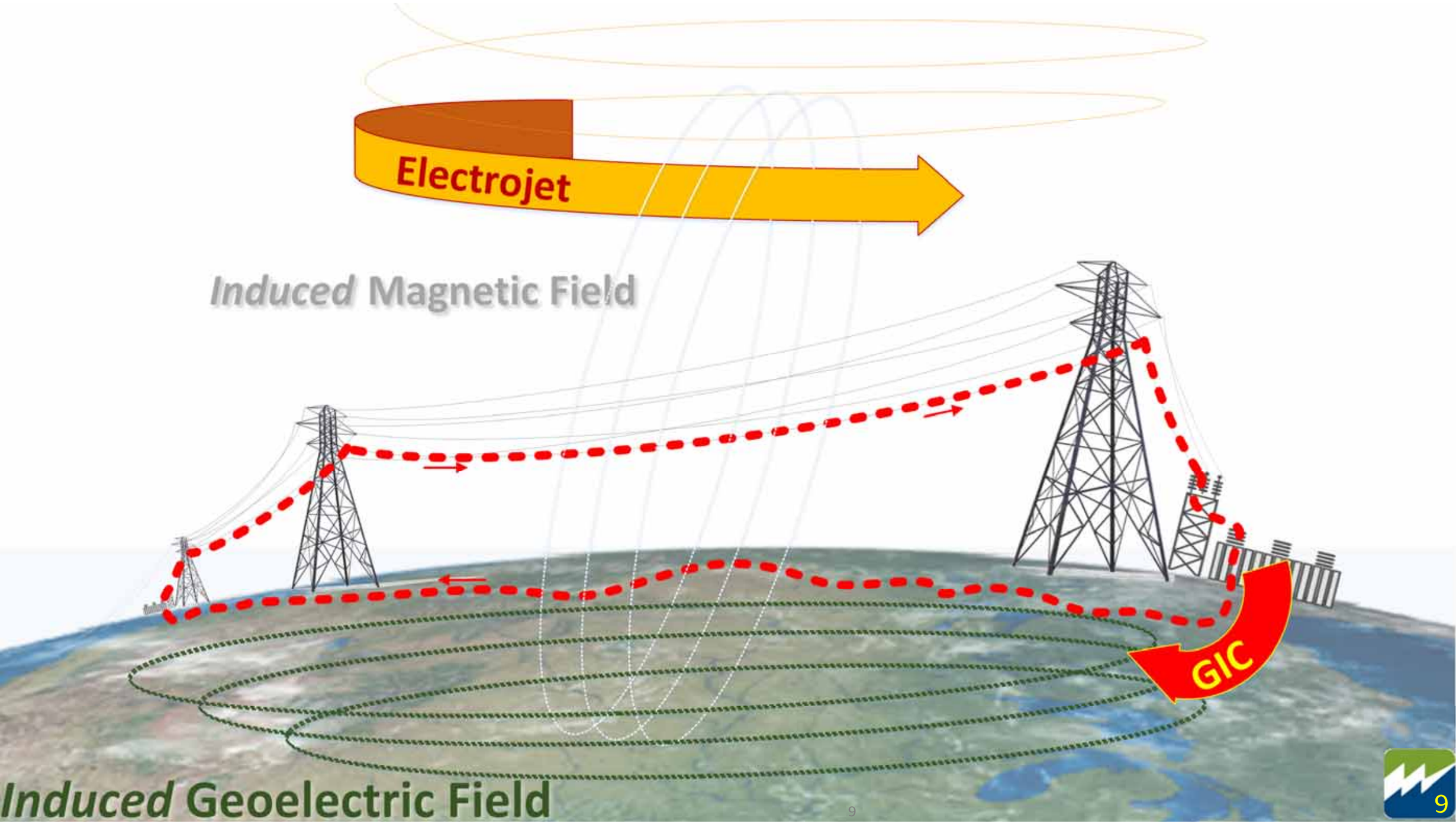


- Periodically, intense magnetic field regions develop on surface (sun spots).
- Solar flares are large eruptions of electromagnetic radiation.
- Coronal mass ejections (CME) are plasma expulsions.
- Speeds vary (≈ 20 to 3,000 km/s)

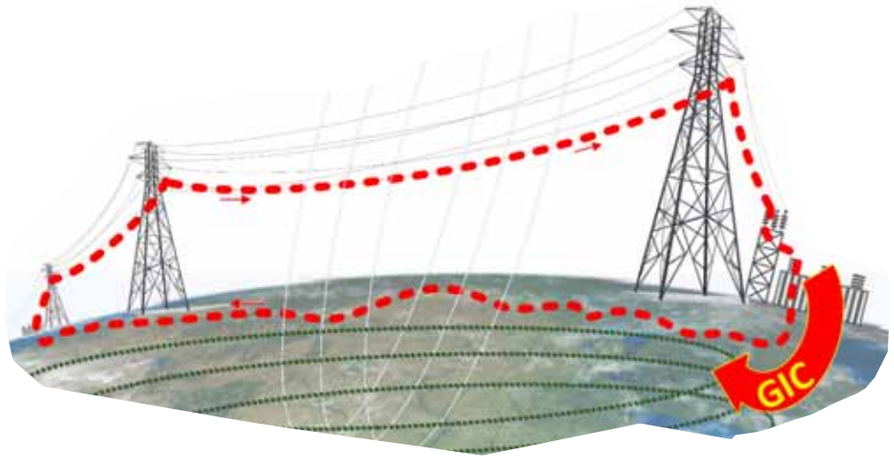
Image source: NASA/ESA SOHO mission, archived at https://soho.nascom.nasa.gov/data.



Electrojet is a circulating flow of charged particles in the ionosphere (aka *current*)


Electrojet
Induced Magnetic Field
GIC
Induced Geoelectric Field

Potential Transmission System Impacts of GMD



GIC flows in lines

Transformer half-cycle saturation

Harmonic currents

Capacitor bank tripping

Increased Reactive Power Consumption

Reactive power losses

Protection misoperation

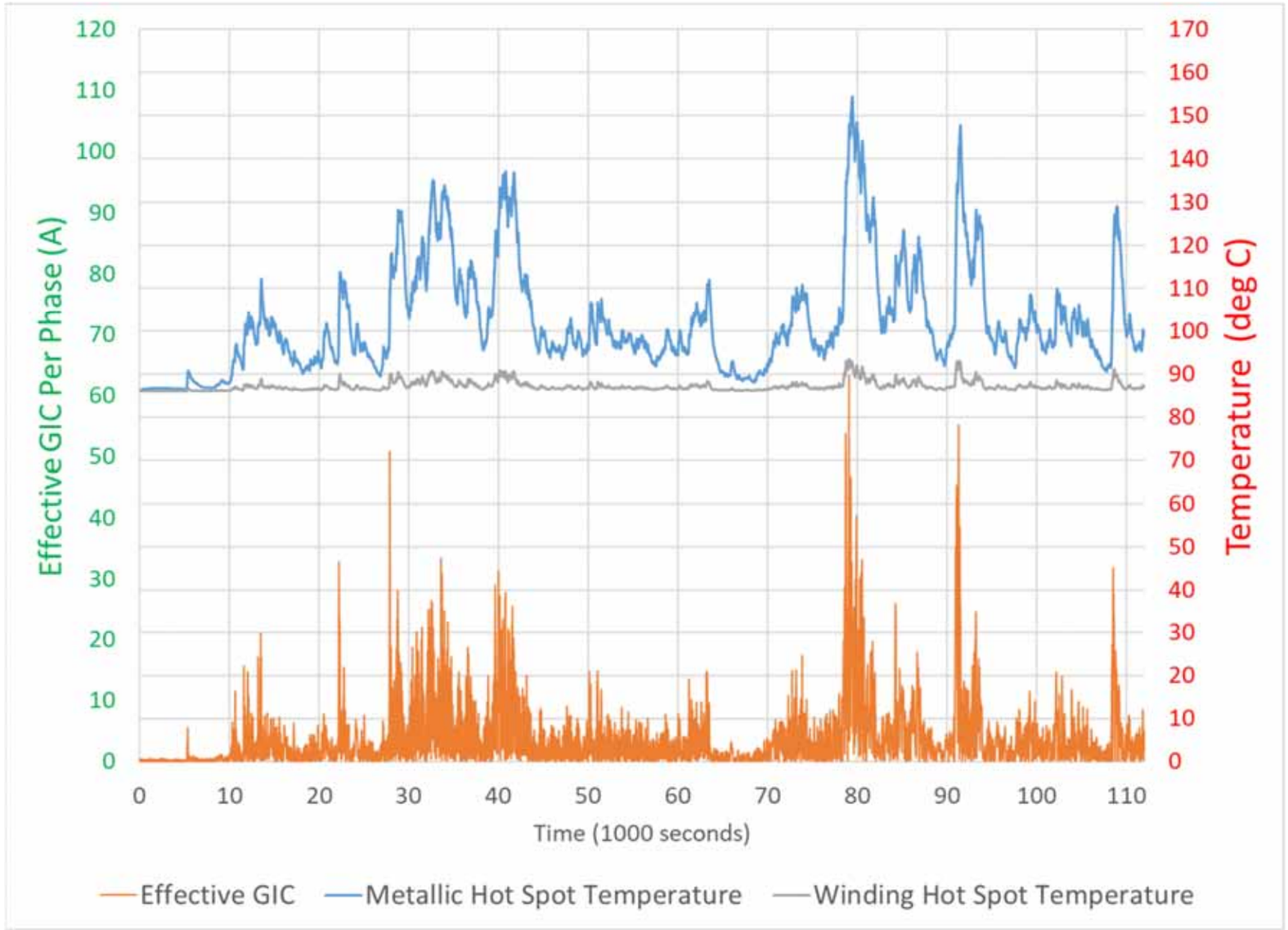
Voltage instability and collapse

Transformer heating

Flowchart source: “Geomagnetic disturbances,” IEEE PES Tech Council Task Force on Geomagnetic Disturbances”, *IEEE Power & Energy Magazine*, July/August 2013.

Transformer Heating

- Increased transformer saturation leads to more core heating.
- Temperature rise exhibits a proportionally-lagging response to GIC.

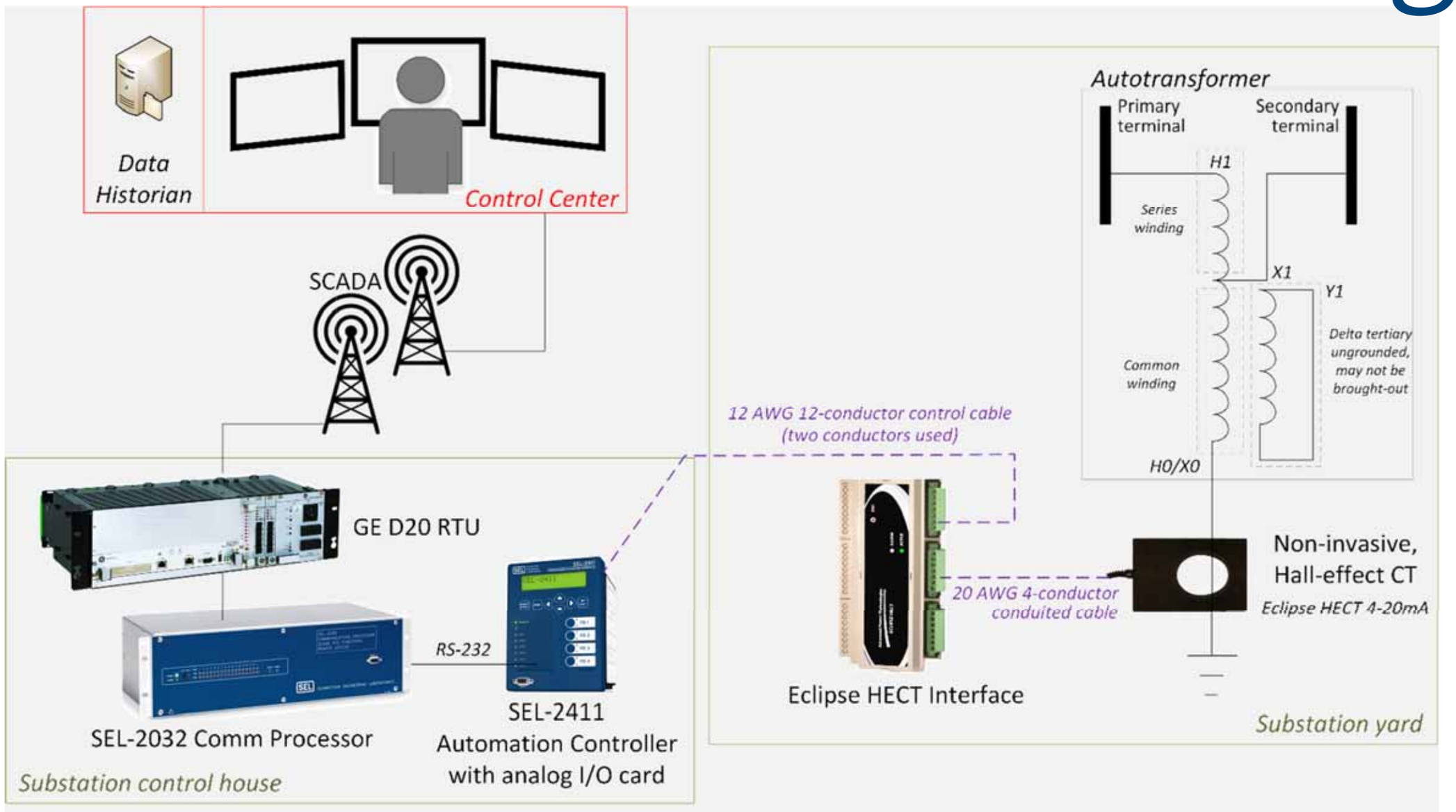


Example of transformer thermal modeling during two-day duration of 1-in-100-year solar storm

What can we do about it?

Image source: NASA Solar Dynamics Observatory, retrieved from https://sdo.gsfc.nasa.gov//data

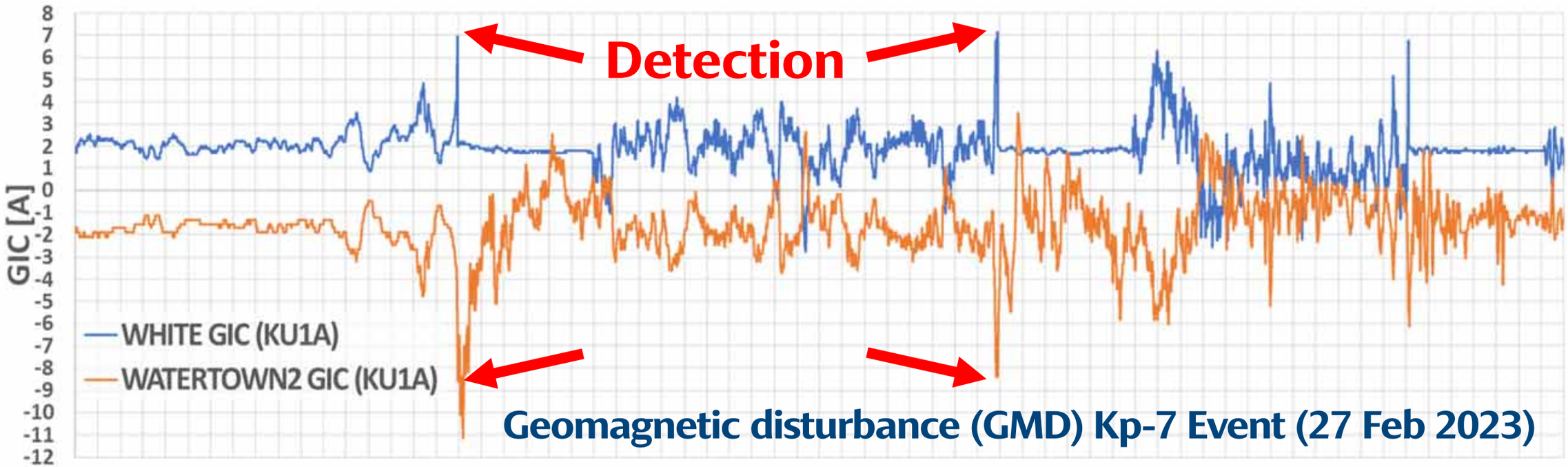
Space Weather Monitoring



Space Weather Monitoring

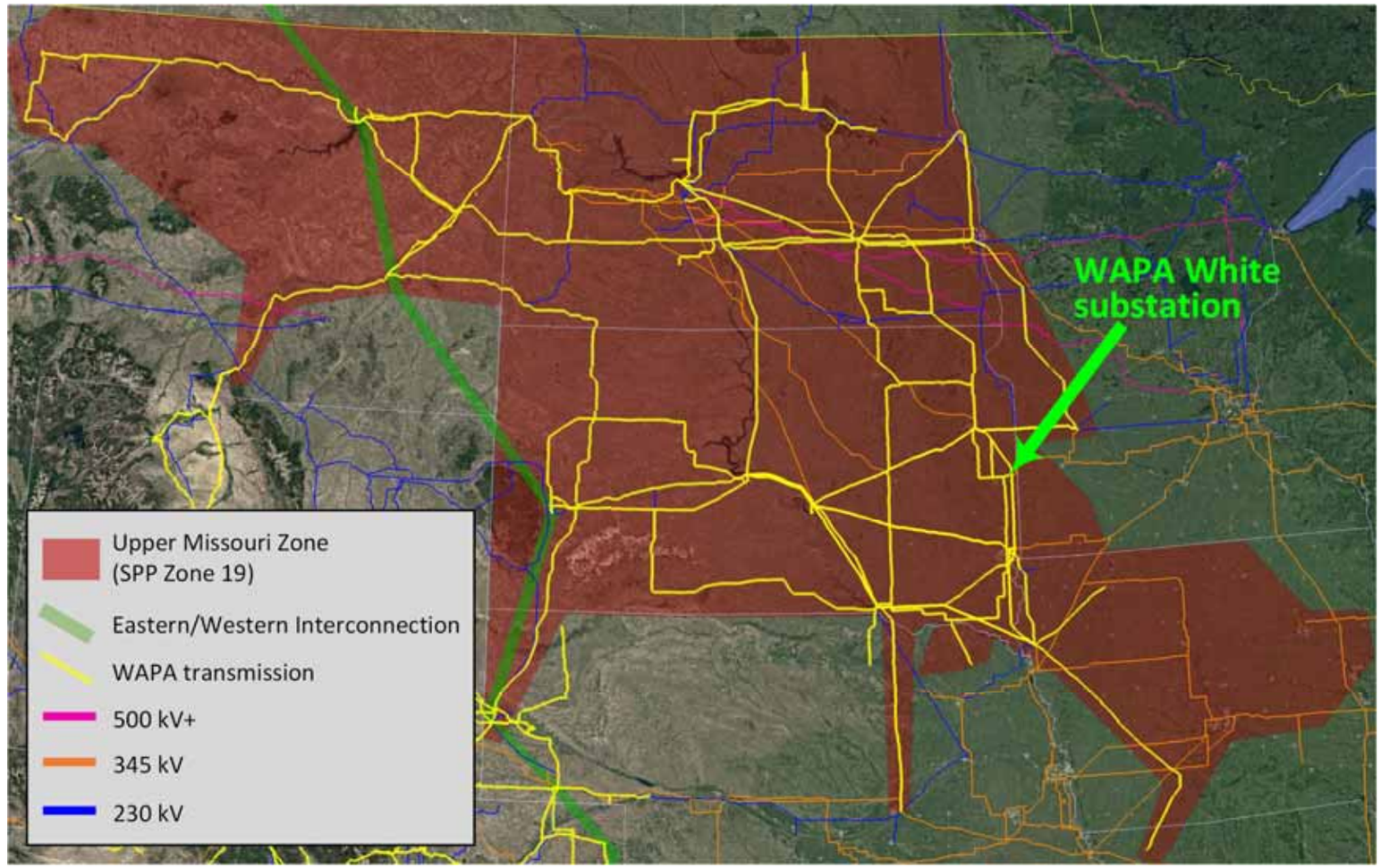
Space Weather Awareness

- GMD situational awareness with direct feed into SCADA.
- UGPR Operations aware of transmission impacts before national alerts
  - WTO notified SPP RC of on-going GMD event **seventy minutes** prior to the SWPC GMD Alert.



Space Weather Defense

- Pilot project funding from the DOE Office of Cybersecurity, Energy Security, and Emergency Response (CESER).
- Deployed neutral blocking device (NBD).
- Operates automatically to insert a capacitance into autotransformer neutral ground path.



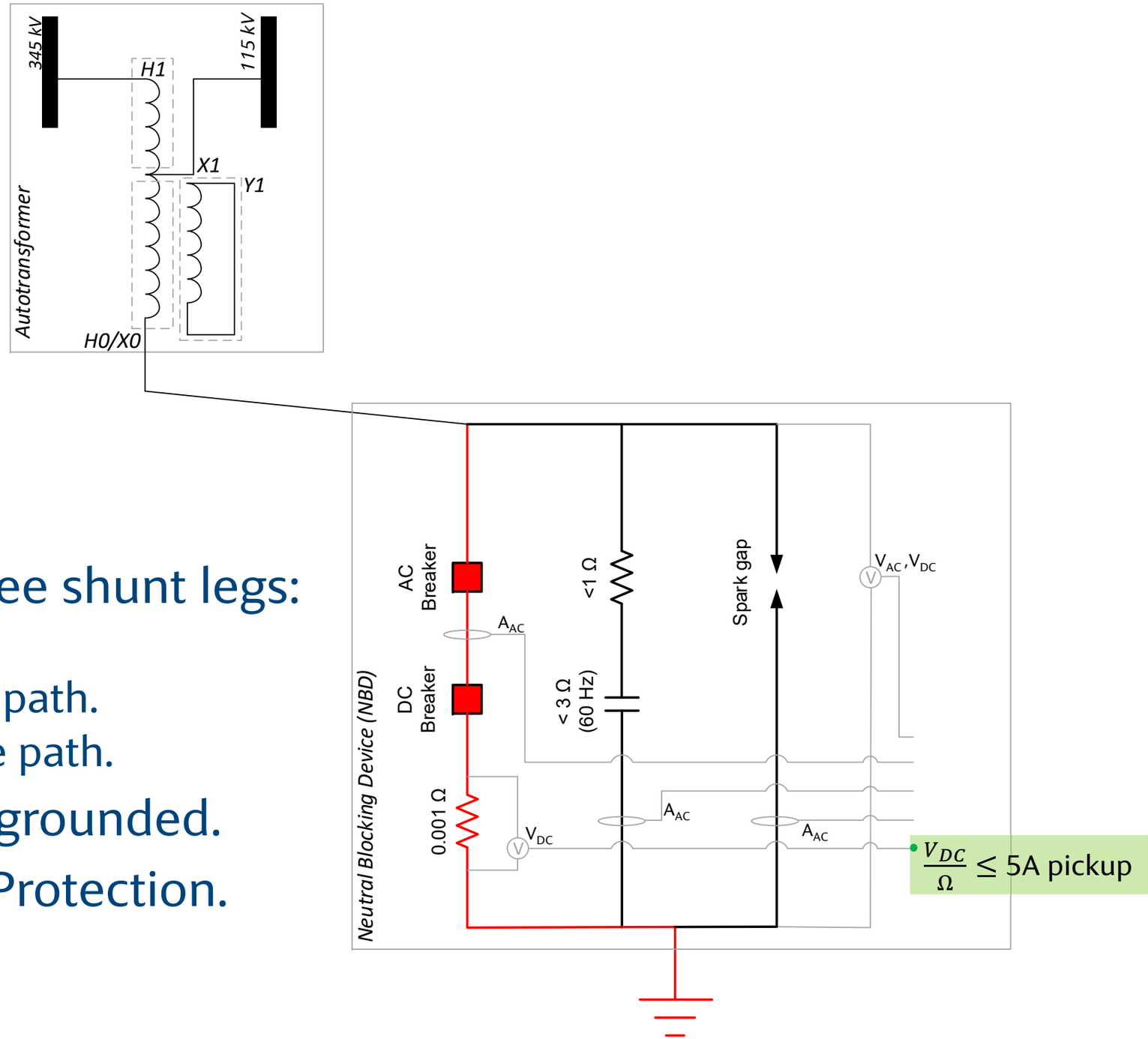
- Stops quasi-DC GIC flow through the transformer.
- Can also manually preposition NBD if a severe solar storm is predicted.

Space Weather Defense

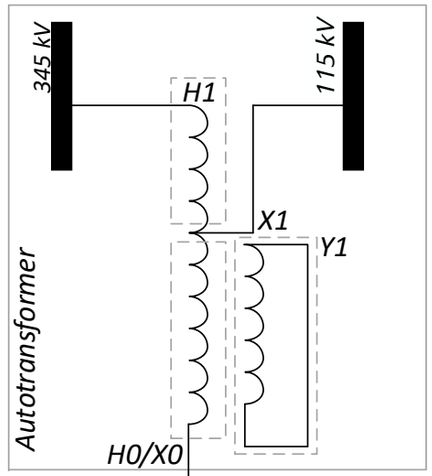
- Manufactured by: empPRIMUS™

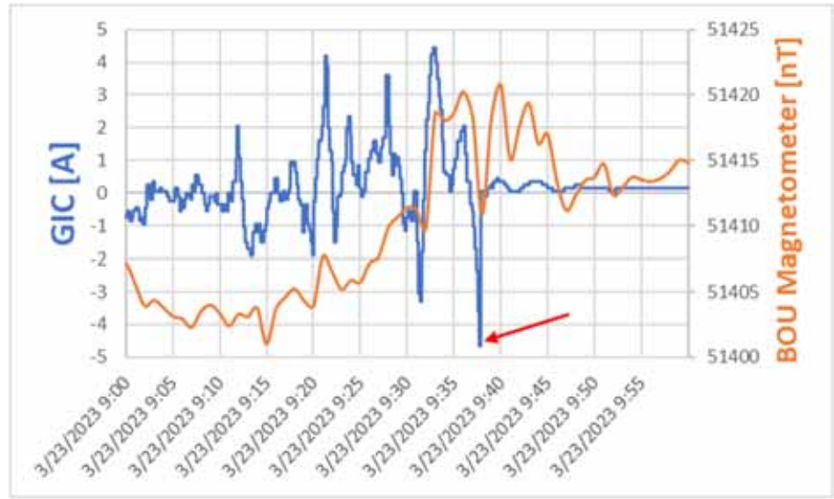
NBD Normal Mode

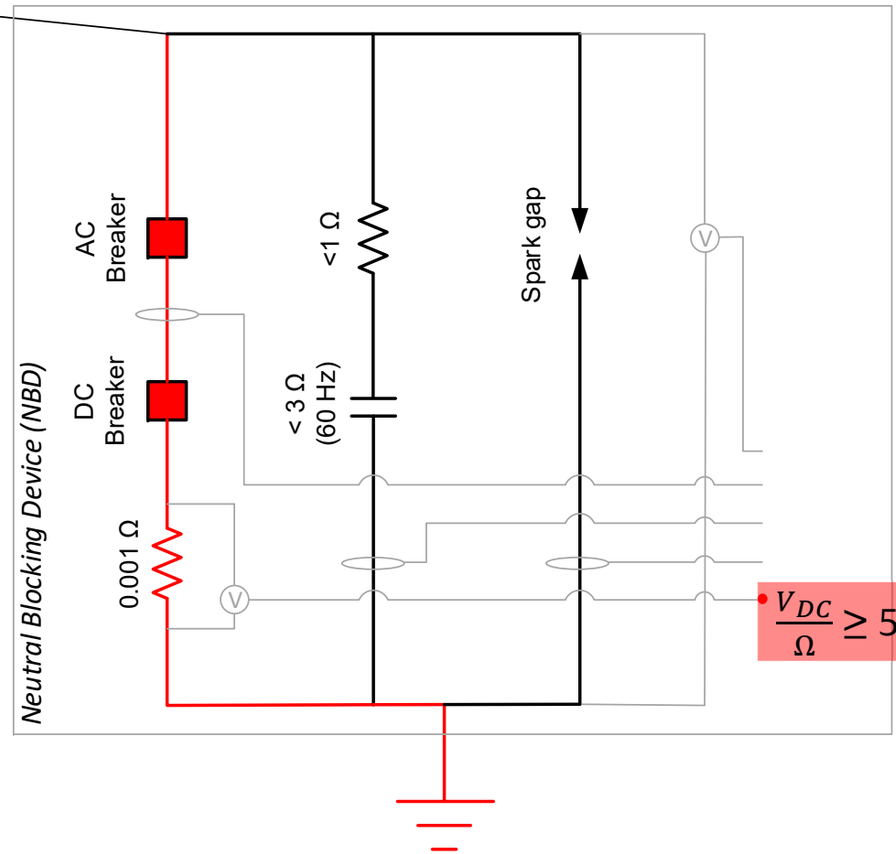
- NBD comprised of three shunt legs:
  - Solid ground path.
  - Capacitance blocking path.
  - Spark gap overvoltage path.
- Normal mode = solid grounded.
- No impact to System Protection.



GIC above Pickup



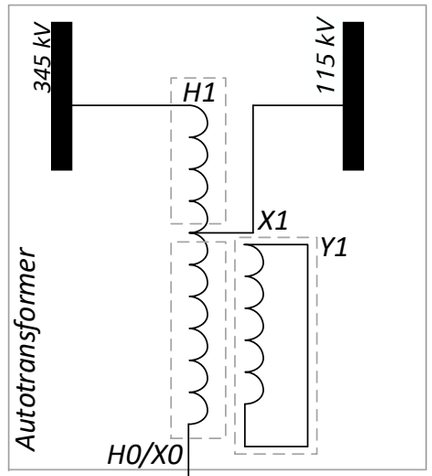


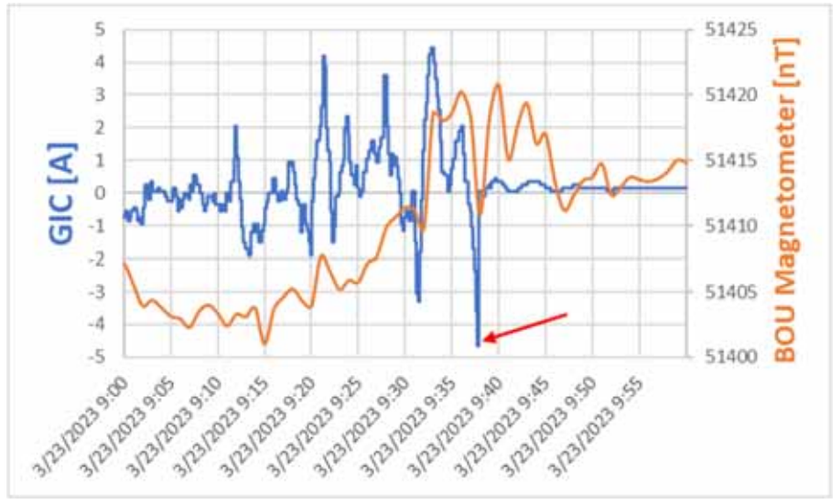


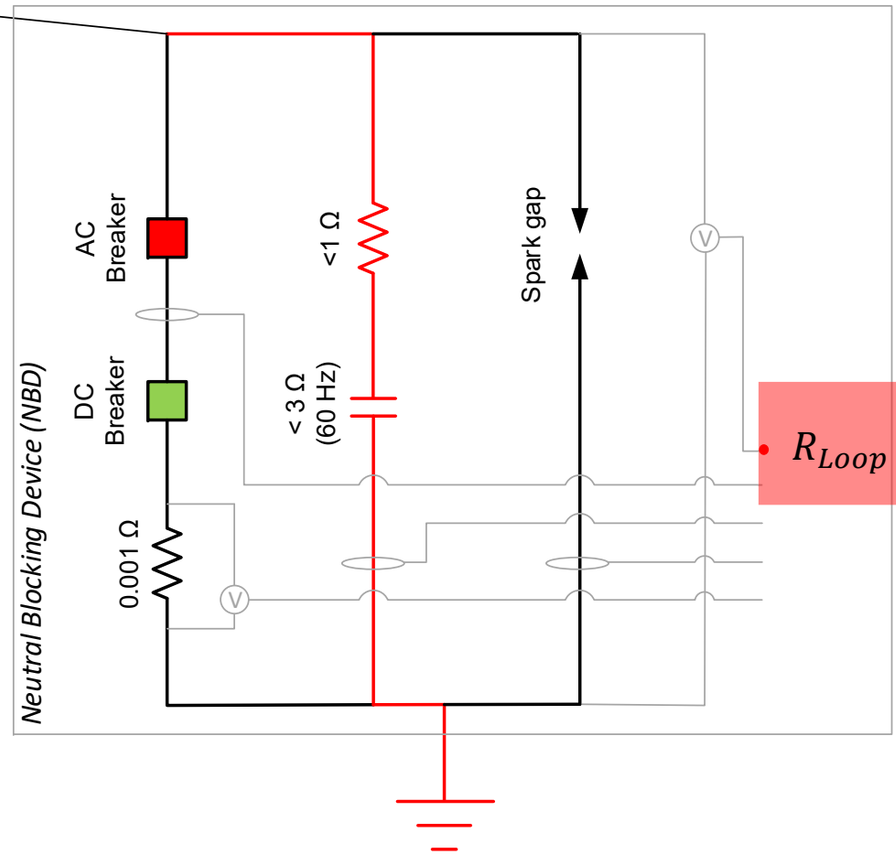
- GIC exceeds 5A setpoint.
- Setpoint is user-defined.

GIC above Pickup

- DC breaker opens first.
- DC arc suppression rated.
- Saves AC breaker for AC applications.
- May calculate GIC loop resistance.

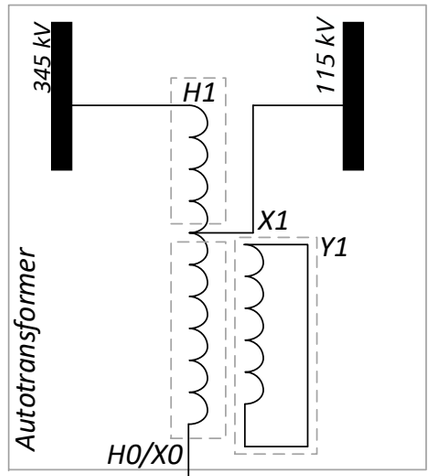


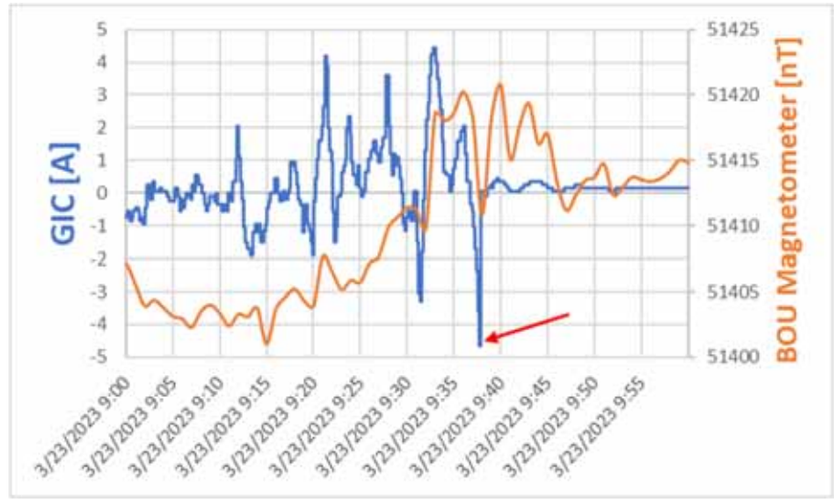


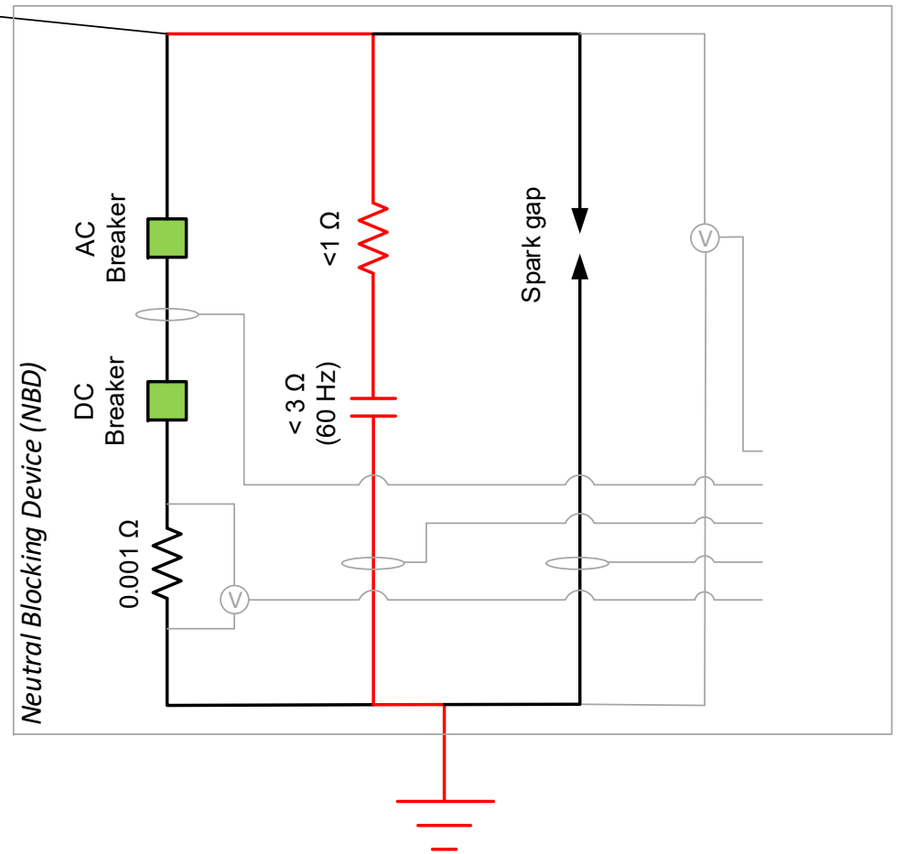


GIC above Pickup

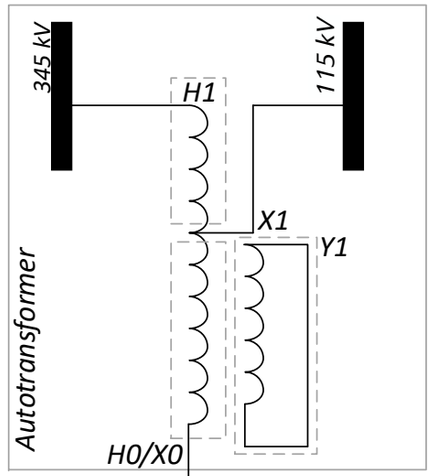
- Current already zeroed.
- AC breaker opens on DC breaker aux contact.

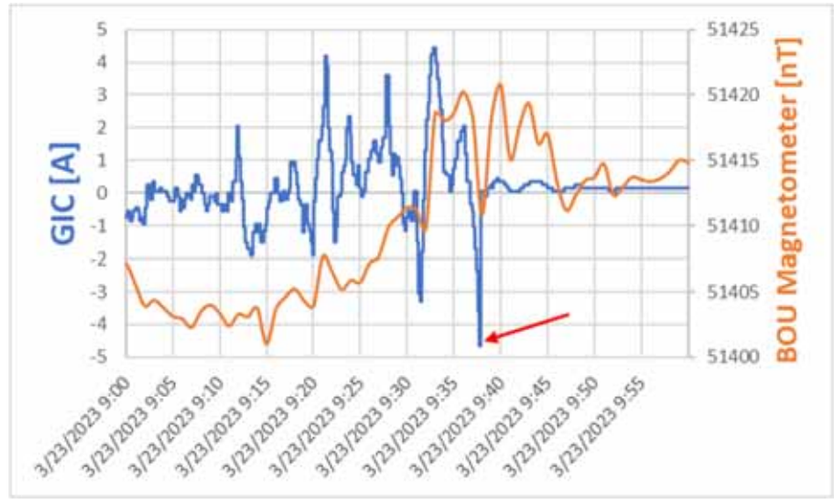


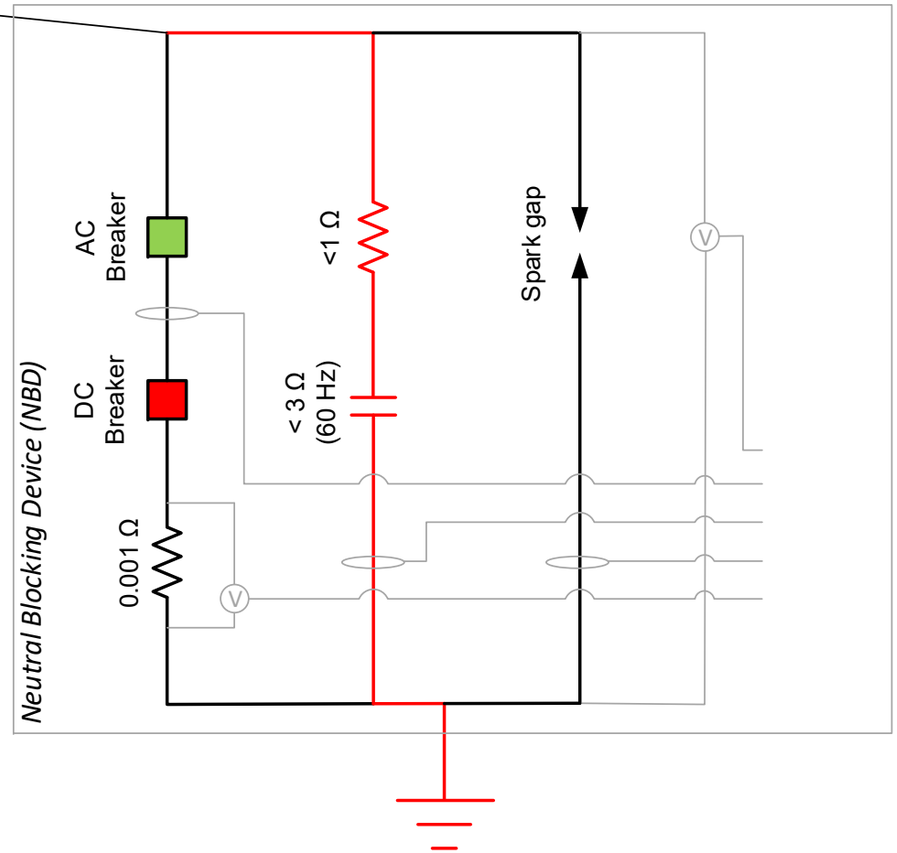




GIC above Pickup



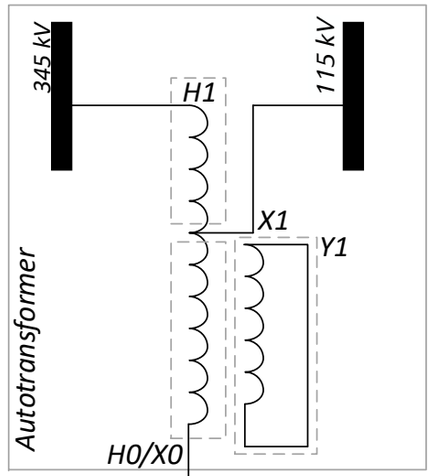


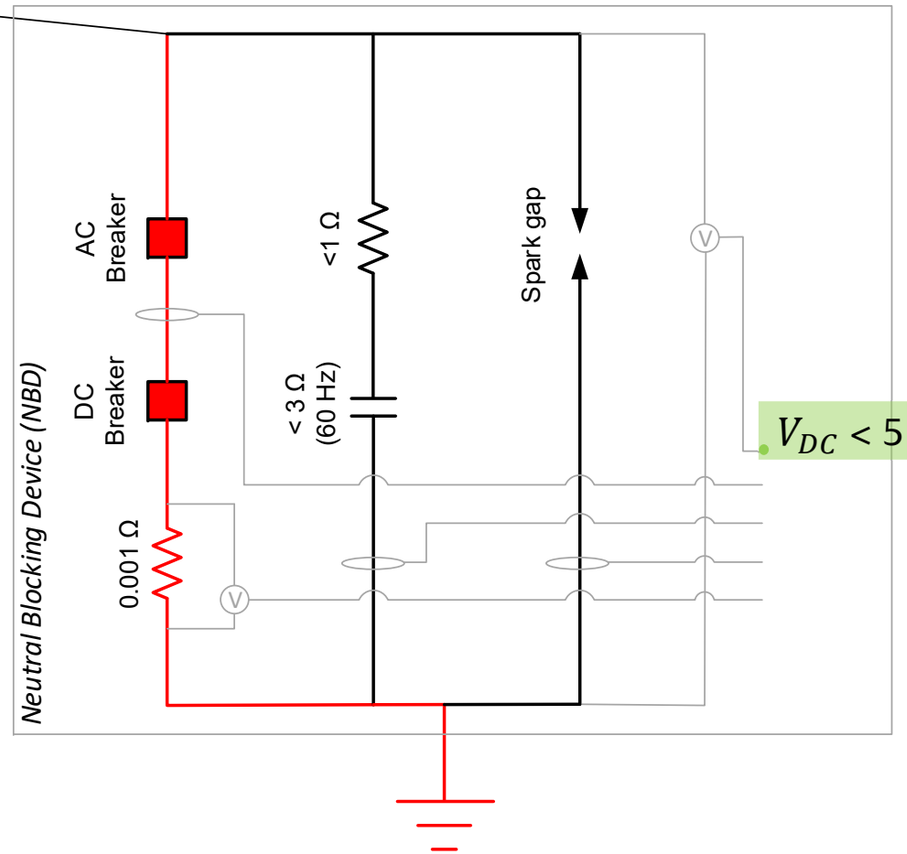


- DC breaker reshuts.
- No closing arc.
- Quasi-DC GIC blocked.
- AC remains grounded.

Return to Normal

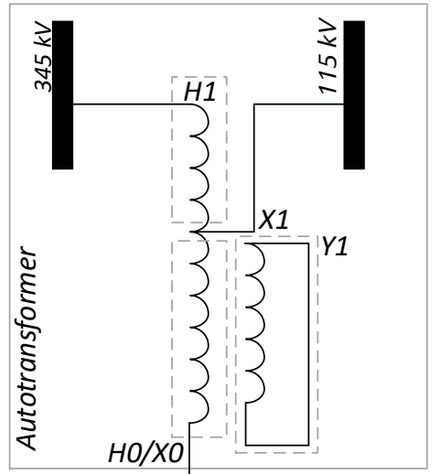
- Monitor V_{DC} remains low.
- AC breaker reshuts.



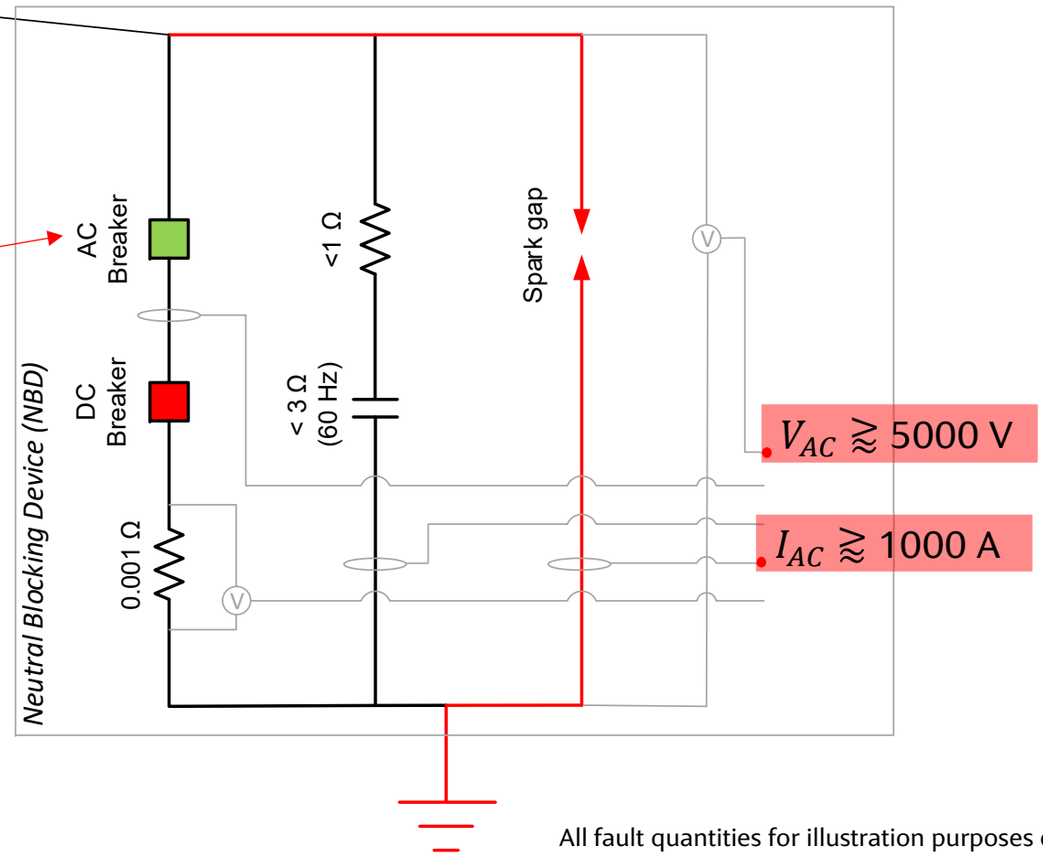


V_{DC} < 5 V for 60 mins

Blocking mode + ground fault

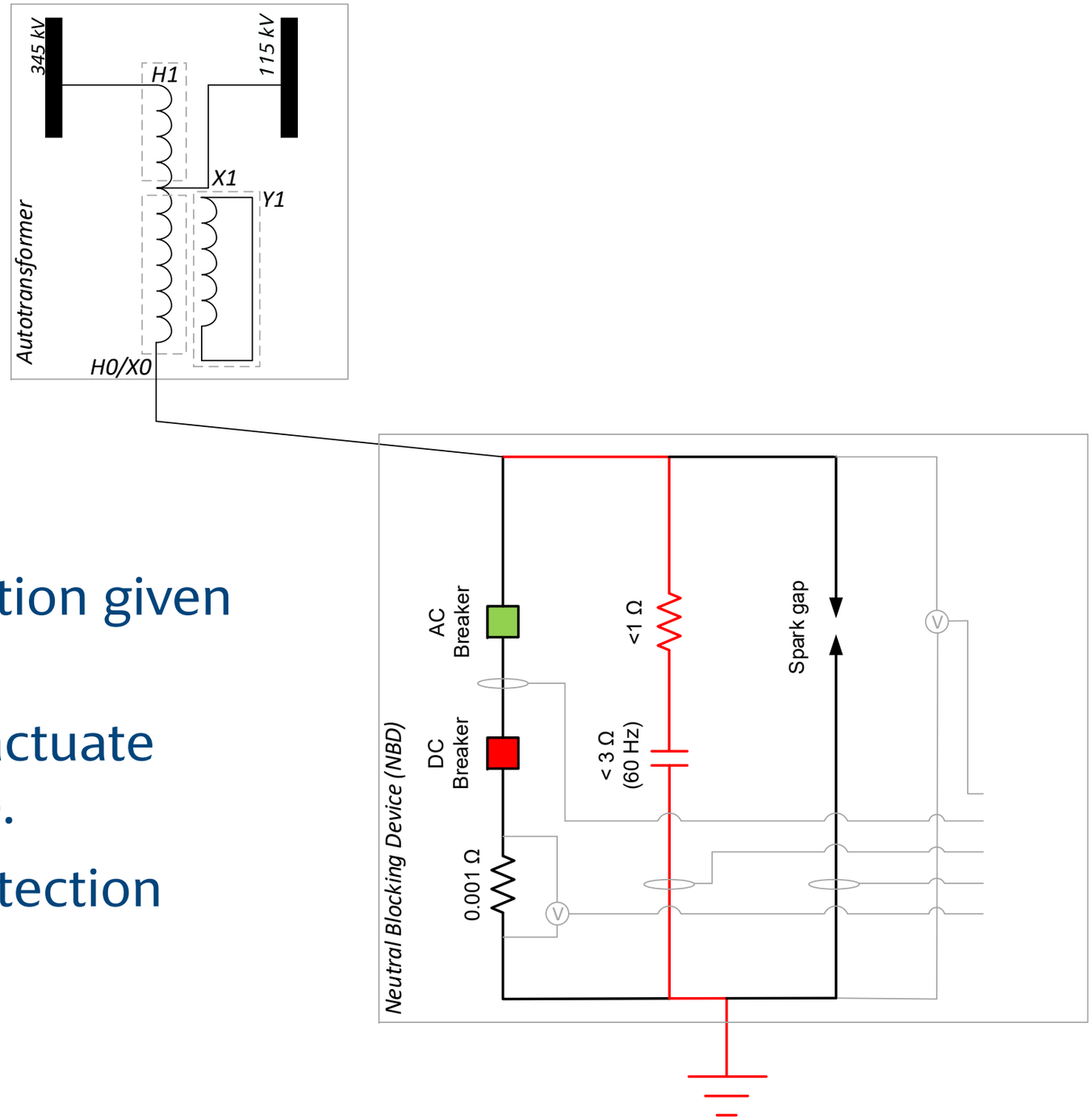


- Overvoltage protection through spark gap.
- AC fault current on any CT.
- AC breaker reshuts.
- Reestablishes solid grounded path for any subsequent fault events.
- While blocking, also reshuts on AC neutral imbalance, TOV exceed, loss of blocking path.



All fault quantities for illustration purposes only.

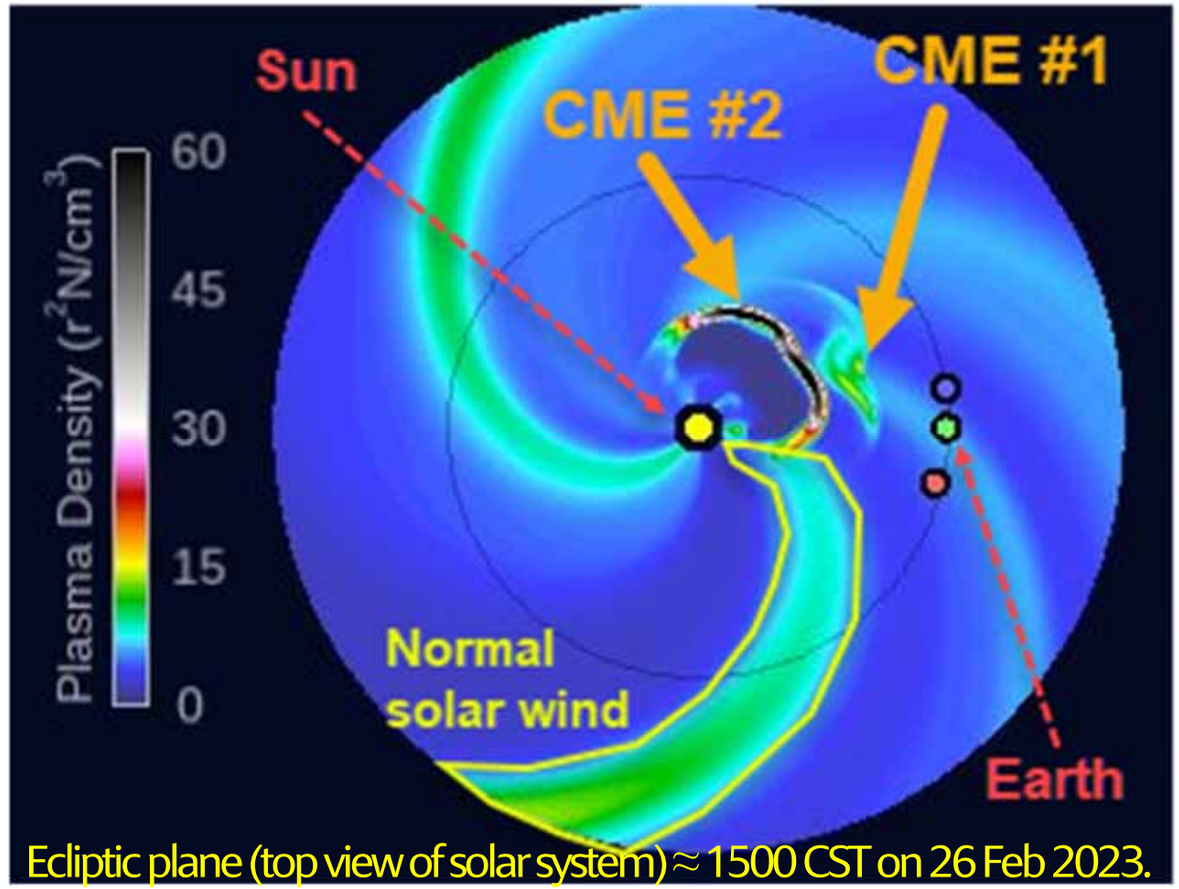
Operator Override



- Preparatory action given GMD forecast.
- Operator can actuate blocking mode.
- Same fault protection in-effect.

Recent Experience

- At about 1430 CST on 24 Feb 2023, a region of the sun (#3229 @ N25W39) that had been active for weeks with roiling sunspots produced an M3.7/2b flare categorized as R1 (Minor).
- A partial-halo CME burst in the vicinity and was detected by the Large Angle & Spectrometric COronagraph (LASCO) instrument operating on the NASA/ESA Solar and Heliospheric Observatory (SOHO) satellite.



Ecliptic plane (top view of solar system) ≈ 1500 CST on 26 Feb 2023.

- SOHO orbits at the First Lagrangian Point (L1) where the Earth and solar gravity cancel out (about 900k miles from Earth; 4x distance Moon to Earth).
- Later, at about 1344 CST on 25 Feb 2023, another flare (larger M6) and larger + faster-moving CME were detected from the same region.

Image sources: NASA WSA-ENLIL simulations, retrieved from SWPC.

Recent Experience (continued)

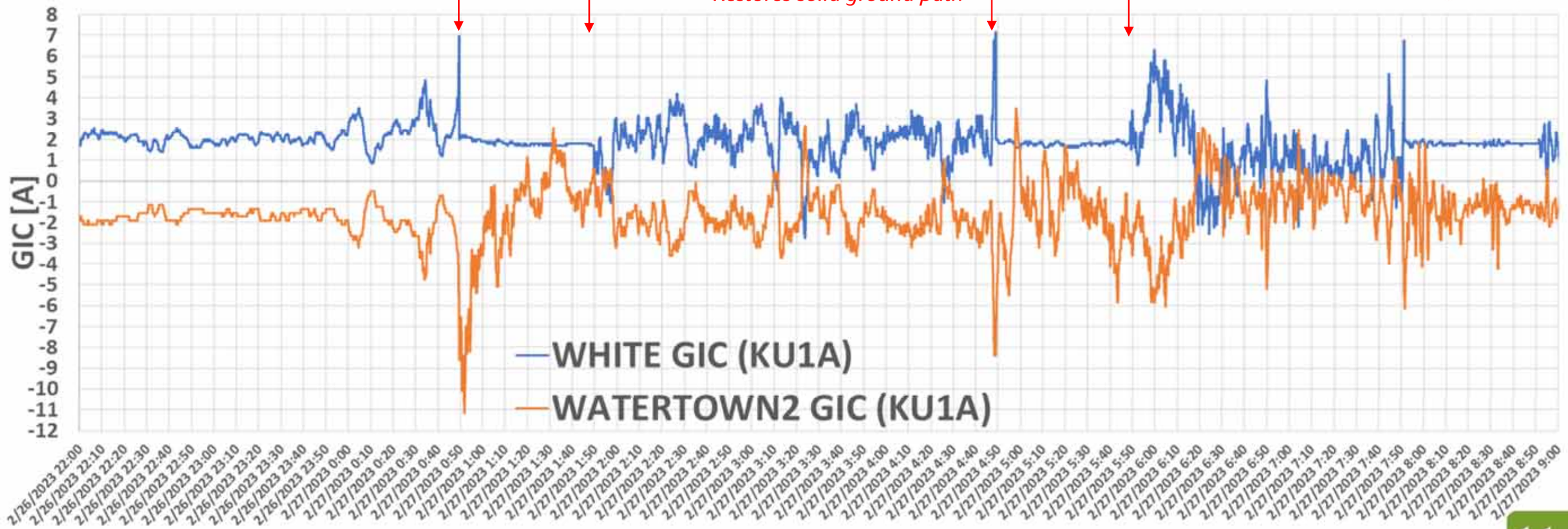
2023/02/27 00:49:24.570 * WHT NBD DC BREAKER TRIPPED
2023/02/27 00:49:24.616 * WHT NBD AC BREAKER TRIPPED
2023/02/27 00:49:25.275 * WHT NBD DC BREAKER CLOSED

Normal NBD trip sequence
(Inserts capacitive ground path)

2023/02/27 04:48:39.869 * WHT NBD DC BREAKER TRIPPED
2023/02/27 04:48:39.915 * WHT NBD AC BREAKER TRIPPED
2023/02/27 04:48:40.575 * WHT NBD DC BREAKER CLOSED

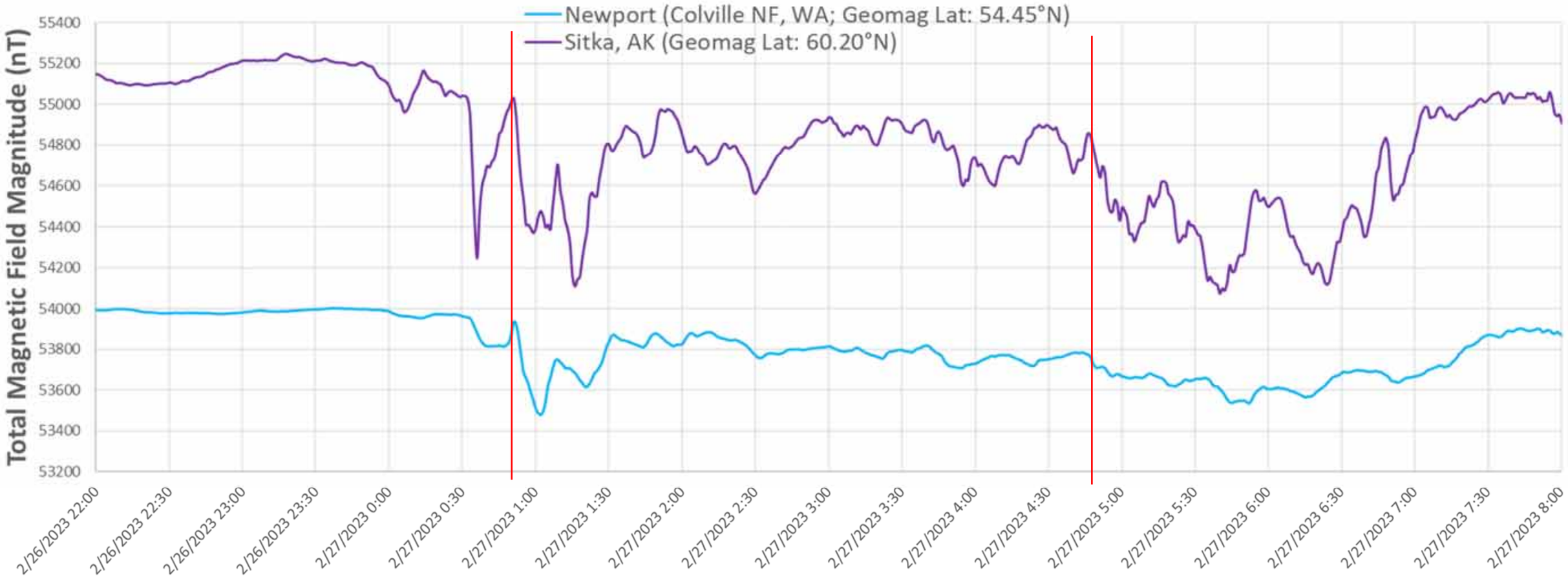
2023/02/27 01:49:25.007 * WHT NBD AC BREAKER CLOSED
Restores solid ground path

2023/02/27 05:48:40.408 * WHT NBD AC BREAKER CLOSED
Restores solid ground path



Note: eDNA Historian times are one hour behind SCADA log times (synchronized for this plot)

Recent Experience (continued)



- Closest USGS magnetometer (Boulder, CO) off-line at time.
- Shows next closest federal observatory data.
- Some discernable correlation with developed GIC in SD.

Parting Remarks

- Threat from space weather is real.
- *In situ* GIC monitoring gives direct measure of GMD impact to transmission.
- NBD can protect vulnerable equipment.
- Must perform detailed analysis to determine how blocking redirects GIC.
- Both monitoring & NBD offer opportunities for improved EOP-010-1 awareness and defensive operations.

Deficiente consilium agitat cadere.

Questions?

Image source: Randy Diede, WAPA-UGPR.

Chris Colson

colson@wapa.gov

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AGENDA

Misoperations

a. Q1 2023 Update, Review and Discussion

Jake Bernhagen, Manager of Reliability Performance, MRO

Action

Information

Report

Jake Bernhagen will provide an oral report during the meeting.

Classification: Public

AGENDA

Misoperations

b. Review NERC Lessons Learned

Jake Bernhagen, Manager of Reliability Performance, MRO

Action

Discussion

Report

Jake Bernhagen will lead this discussion during the meeting.

Classification: Public

AGENDA

Misoperations

c. 2023 ERO Misoperation Workshop Update

Jake Bernhagen, Manager of Reliability Performance, MRO

Action

Discussion

Report

Jake Bernhagen will lead this discussion during the meeting.

Classification: Public

AGENDA

PRS Roundtable Discussion
Ryan Einer, Protective Relay Subgroup Chair

Action
Discussion

Report
Chair Einer will lead this discussion during the meeting.

Classification: Public

AGENDA

Q2 2023 Misoperations Review

a. Breakout Sessions

Jake Bernhagen, Manager of Reliability Performance, MRO

Action

Discussion

Report

Jake Bernhagen will lead this discussion during the meeting.

Classification: Public

AGENDA

Other Business and Adjourn

Ryan Einer, Protective Relay Subgroup Chair

Action

Discussion

Report

Chair Einer will lead this discussion during the meeting.

Classification: Public