RELIABILITYFIRST

Joint Review of Protection System Commissioning Webinar

Monday, January 24, 2022

2:00-3:30pm Eastern Standard Time

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Welcome and Logistics

- This WebEx event is not being recorded.
- Today's presentations will be posted to RF public website at rfirst.org.
- Please submit all questions through Slido instead of the WebEx chat.
- For your convenience, we will provide the workshop survey live at the end of event via Slido, so please stay on the call.

Join the conversation at

Slido.com

#Commissioning

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Agenda

Presentation	Presenter	Time (Eastern)
Welcome and Introductions	Michelle Cross, RF	2:00 – 2:05
Joint Review Recommendations and Findings	Bill Crossland, RF	2:05 – 2:30
Misoperations and Commissioning in the RF Region	Thomas Teafatiller, RF	2:30 – 2:45
Enhancing Oversight and Peer Reviews – Case Studies	Jim Kubrak, RF	2:45 – 3:05
Commissioning Inverter Based Resources	Rich Bauer, NERC	3:05 – 3:25
Closing Remarks	Michelle Cross, RF	3:25 – 3:30

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FERC/NERC
Protection System Commissioning
Joint Technical Report

Bill Crossland – Principal Engineer, Protection

RF Joint Review of Protection System Commissioning Webinar

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History of the Commissioning Debate

- For some time now, FERC has suggested there is a need for a NERC Standard on Protection System commissioning, pointing out various high-profile events as evidence
- In June 2016, FERC issued Order 824 to gain access to all the NERC Section 1600 data to allow them to perform their own analytics
- Their review of a sample of MIDAS data suggested there was a correlation between the data and inadequate commissioning testing that led to Protection System Misoperations

History of the Commissioning Debate (cont'd)

- NERC and industry have maintained that such a standard would not allow enough flexibility to test Protection Systems in the traditional methodology used by each Entity (too prescriptive) and would be extremely burdensome to track compliance
- As a compromise, NERC engaged the IEEE Protection System and Control Subcommittee (PSRC) to develop a Protection System commissioning guideline document (Working Group I25 or WG I25)

IEEE WG I25 Report

The WG I25 report is more focused on how to stand up a commissioning program rather than prescribing specific actions and testing procedures

- **Core elements of a commissioning program:**
  - Planning and sequencing
  - Print and technical review
  - Preparing installed equipment for modification
  - Equipment and device acceptance testing
  - Equipment isolation
  - Functional testing
  - In-service load checks
  - Documentation

Joint Technical Review

- As a result of the previously-mentioned MIDAS data analysis, FERC approached NERC and its Regional Entities to conduct a joint technical review that benchmarked Entity practices for commissioning Protection Systems against the recommended practices contained in WG I25 guidance
- The joint team selected eight Registered Entities from across the ERO to participate in this effort, along with one contracting firm that conducted commissioning testing

Joint Technical Review

- The team developed a set of interview questions based on the WG I25 report
- Entity responses were benchmarked against the guidance in the WG I25 report
- Responses beyond the WG I25 report recommendations were considered a “best practice”
- Responses that were inferior to the WG I25 report recommendations were considered an “area for improvement”

Review Criteria

The joint team focused on the following elements when reviewing the Protection System Commissioning (PSC) program of each participant:

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

Common Issues

The joint team determined that these common issues in PSC programs impact Misoperations:

- Lack of independent review of Protection System designs by the commissioning group prior to construction activities
- Lack of centralized overarching PSC programs that serve as a tool for the execution of PSC procedures
- Lack of feedback controls to prevent repeated problems from previous projects impacting future PSC projects

PSC Program Recommendations

Recommendations and opportunities for improvement for PSC programs. Entities should:

- Have a documented PSC program
- Include goals and objectives for its PSC program
- Review PSC program to include adequate detail for commissioning test plans
- Have separate commissioning personnel from its design and installation personnel
- Have well-documented training requirements that include classroom and on-the-job elements, as well as proficiency assessments
- Have internal controls to track and correct issues to improve its PSC program

PSC Procedure Recommendations

Recommendations and opportunities for improvement of PSC procedures:

- Use of detailed PSC checklists to identify each task and deliverable in the commissioning procedure
- Entities should ensure contracts written with external contractors require a design review by their commissioning team
- Entities should compare its acceptance testing practices with WG I25 Section 3
- Entities should maintain an isolation log
- Entities should perform both functional and in-service tests
- In-service tests provide thorough check of voltage and current circuits to verify proper magnitude and phase relationships

PSC Procedure Recommendations

Recommendations and opportunities for improvement of PSC procedures (cont'd):

- Entities should use end-to-end testing for all communication-based protection schemes
- Entities should test for all types of faults (each phase to ground, phase to phase and three phase)
- Entities should perform a final walkdown upon completion of in-service testing using a checklist to document the results
- Entities should update PSC documentation as necessary to reflect current conditions

Noted Best Practices

Some noted best practices:

- Some participants used oversight personnel to review and evaluate contractor performance
- One participant required company SME to review and sign off on commissioning test results done by contractors
- Some participants have detailed training and qualification processes to evaluate personnel to lead commissioning projects
- Some participants used peer reviews to access commissioning test results to avoid possible bias

Noted Best Practices

Some noted best practices (cont'd):

- Some participants employ back-to-back testing in a lab environment and end-to-end testing in the field to commission tie lines between Entities to confirm designs and relay settings function as intended
- One participant identified all equipment that was put in an abnormal state are identified in the engineering package for each stage of the project
- Some participants used physical tags in association with the isolation log
- One participant used three phase primary injection to verify phasing, ratio and polarity on all current circuits

Summary

- Many items in the WG I25 report are currently done by Entities, but any gaps in the process can introduce an entry point for errors
- A good starting point for Entities wanting to refine their commissioning program would be to do an honest assessment of your program against the WG I25 report
- As long as the root cause of high-profile events continues to point to inadequate commissioning, FERC will continue to push for a commissioning standard

Reference Material

- IEEE PSRC I25 WG Commissioning Testing of Protection Systems 10 May 2017
- FERC Joint Review of Protection System Commissioning Programs 2Nov2021

Questions & Answers

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Misoperations and Commissioning in the RF Region

Thomas Teafatiller – Principal Engineer, Protection

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Discussion Topics

- Overall ERO Enterprise Misoperation trends
- RF-specific Misoperation performance results
- Drivers of Misoperation challenges
- Ongoing RF initiatives to improve performance

ERO Enterprise – Misoperation Rates

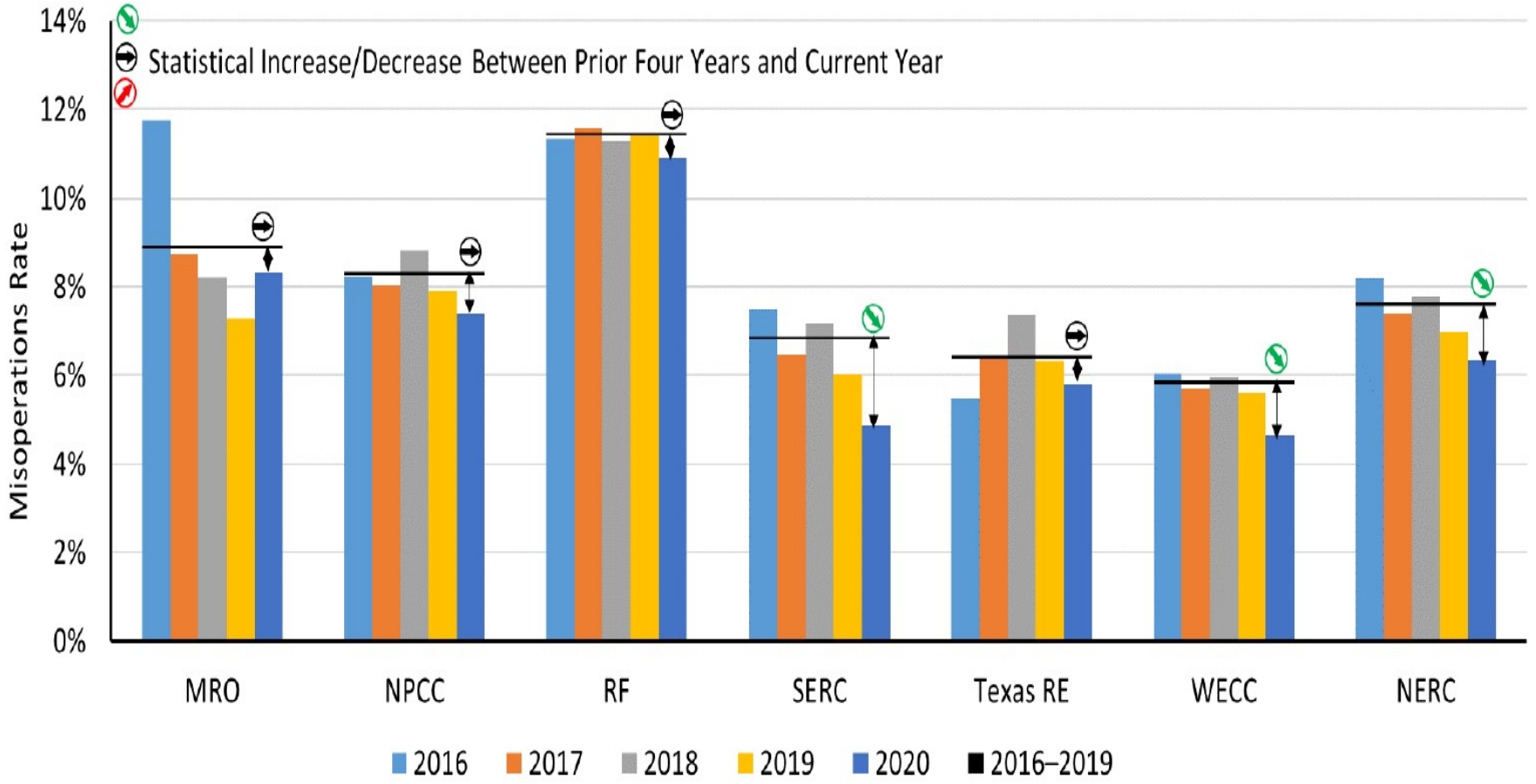
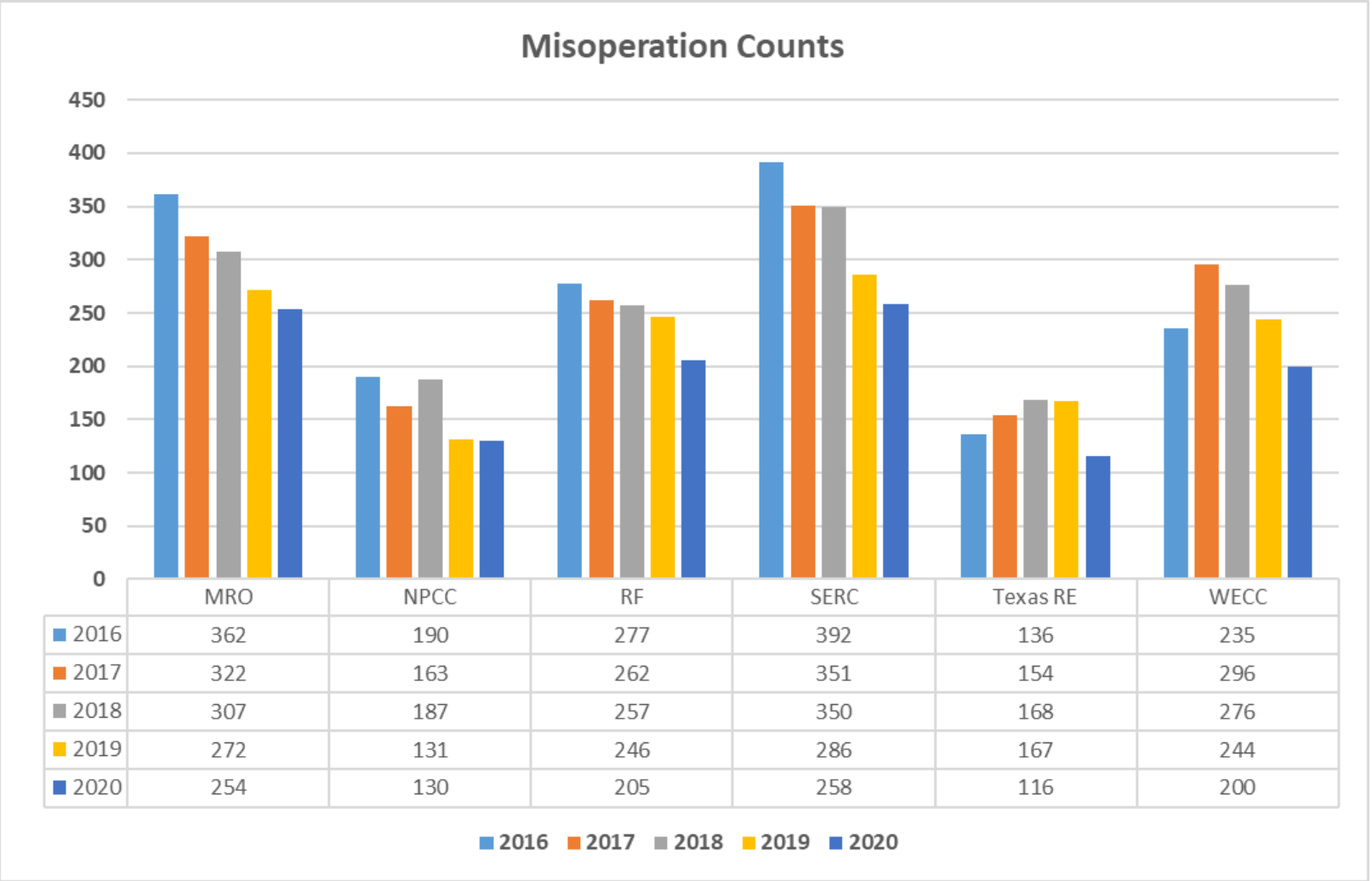


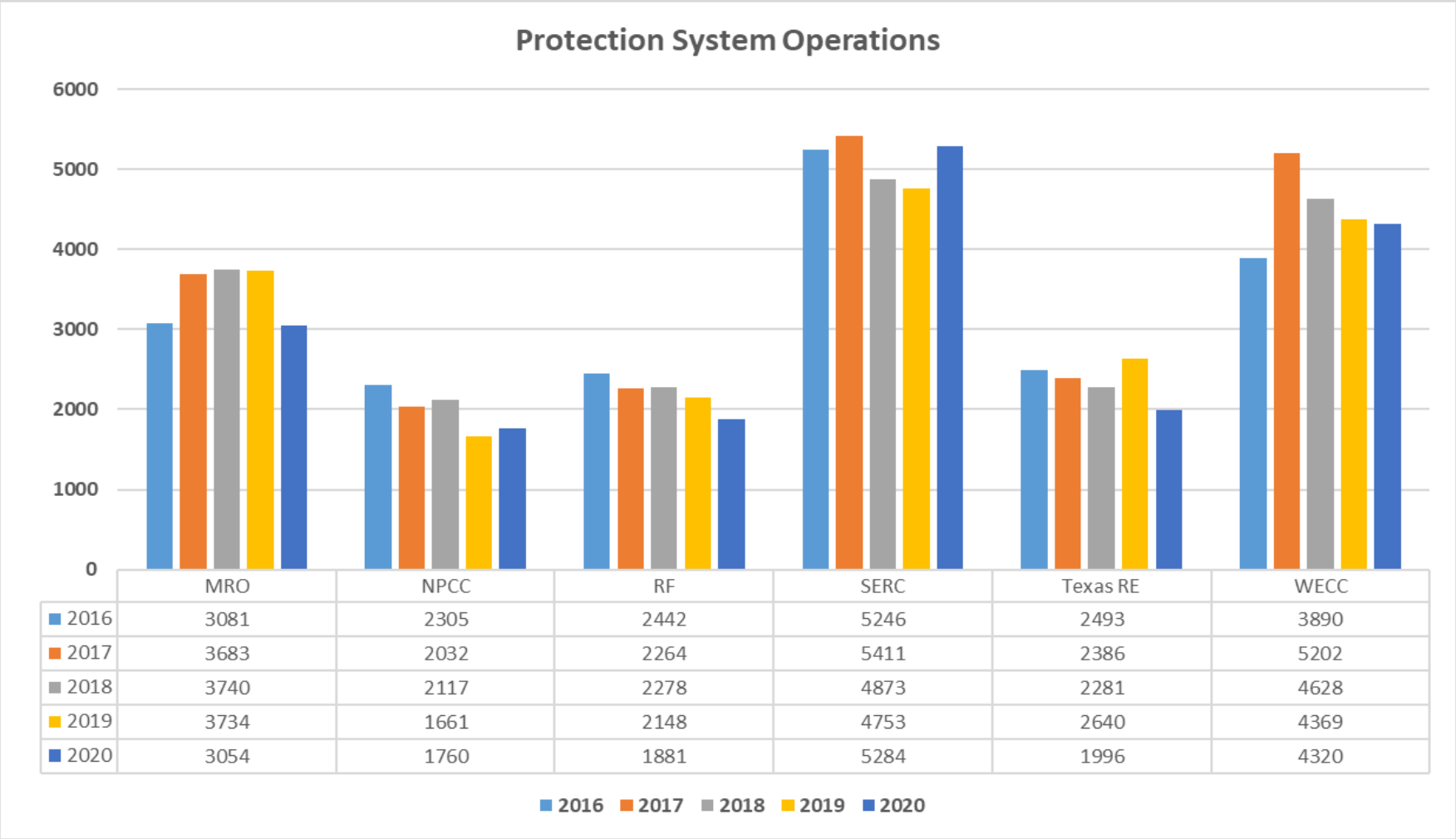
Chart sourced from the NERC 2021 State of Reliability Report
https://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/NERC_SOR_2021.pdf

ERO Enterprise – Misoperation Count



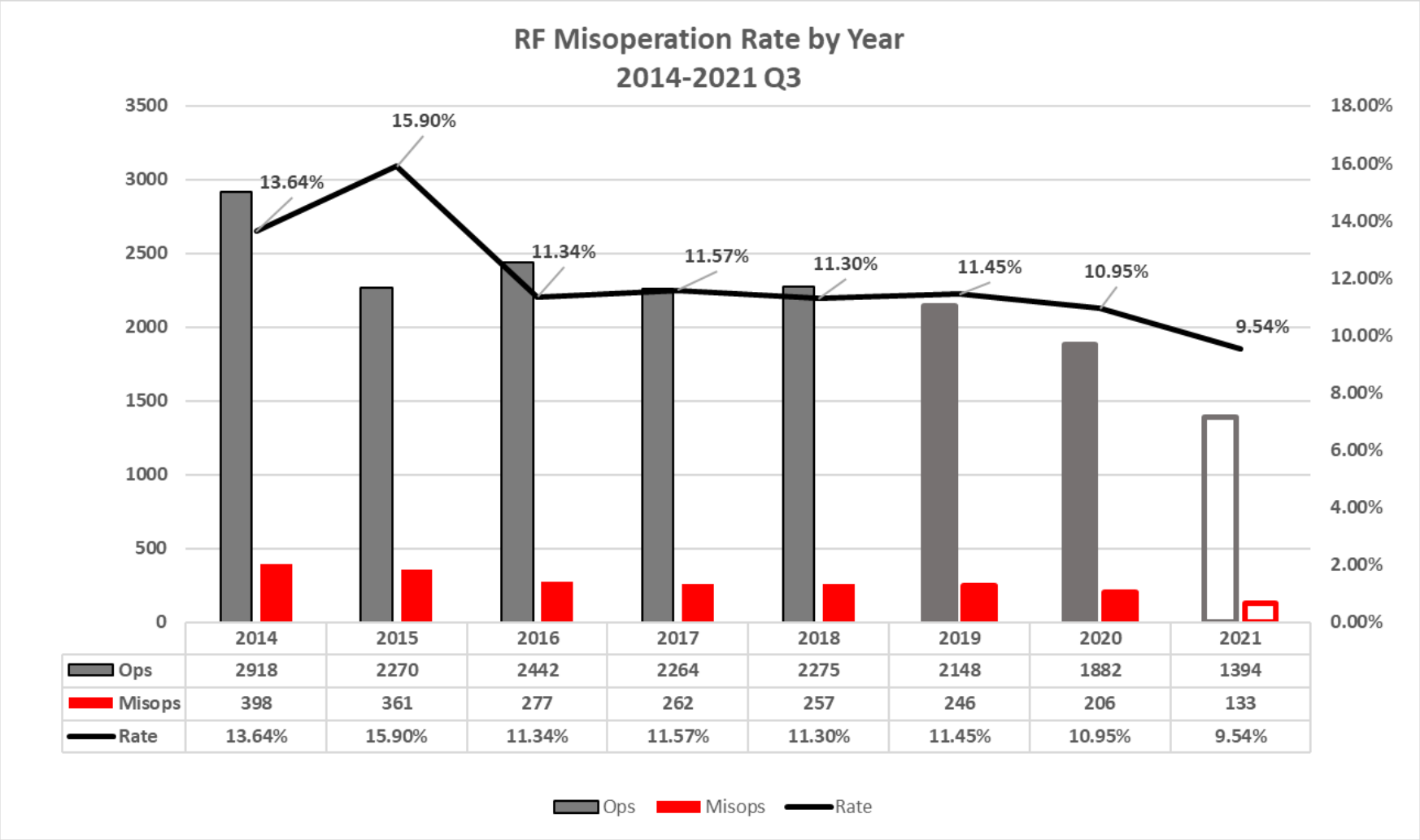
	MRO	NPCC	RF	SERC	Texas RE	WECC
2016	362	190	277	392	136	235
2017	322	163	262	351	154	296
2018	307	187	257	350	168	276
2019	272	131	246	286	167	244
2020	254	130	205	258	116	200

ERO Enterprise – Operations



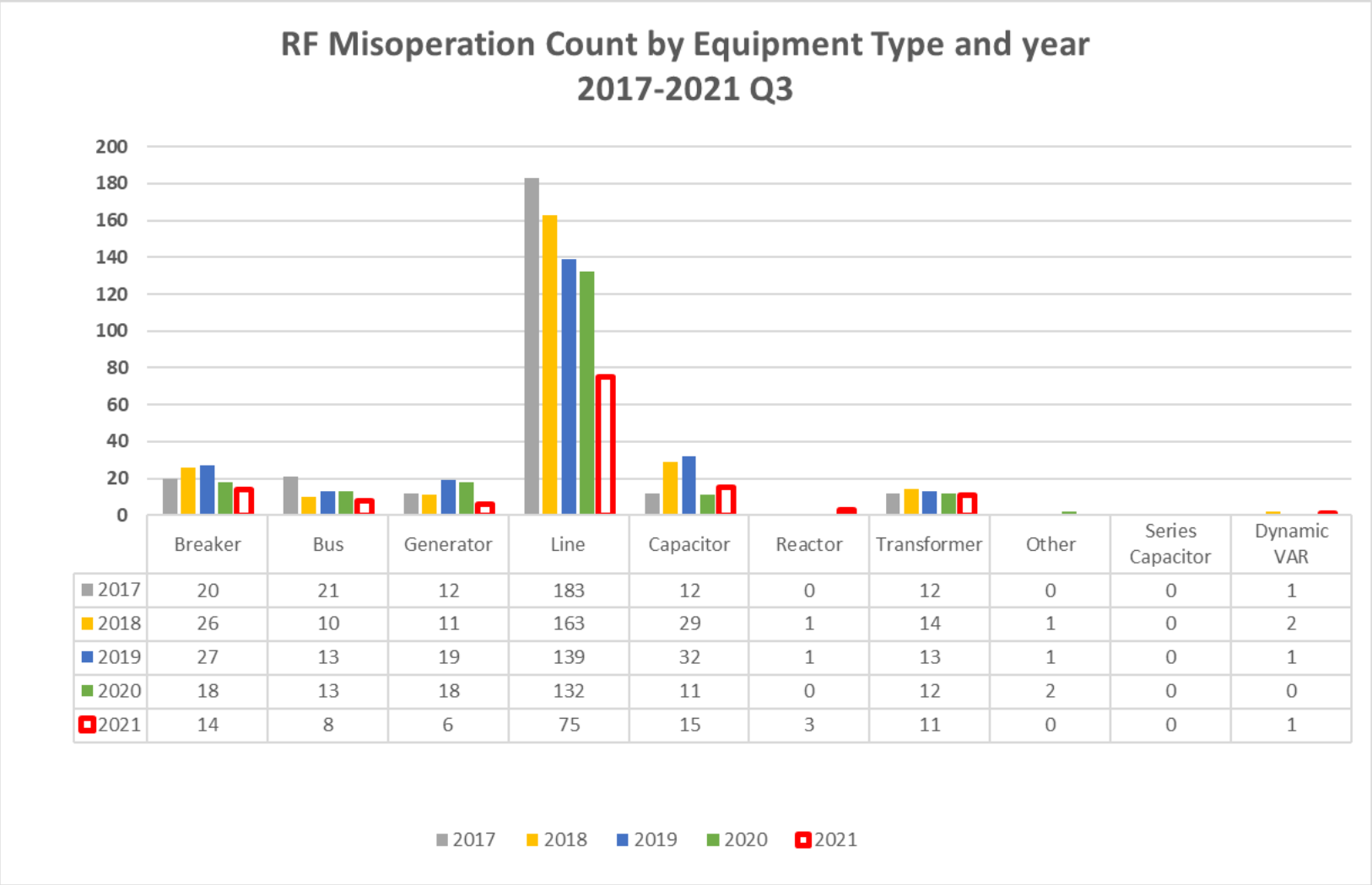
	MRO	NPCC	RF	SERC	Texas RE	WECC
2016	3081	2305	2442	5246	2493	3890
2017	3683	2032	2264	5411	2386	5202
2018	3740	2117	2278	4873	2281	4628
2019	3734	1661	2148	4753	2640	4369
2020	3054	1760	1881	5284	1996	4320

RF Misoperation Rate



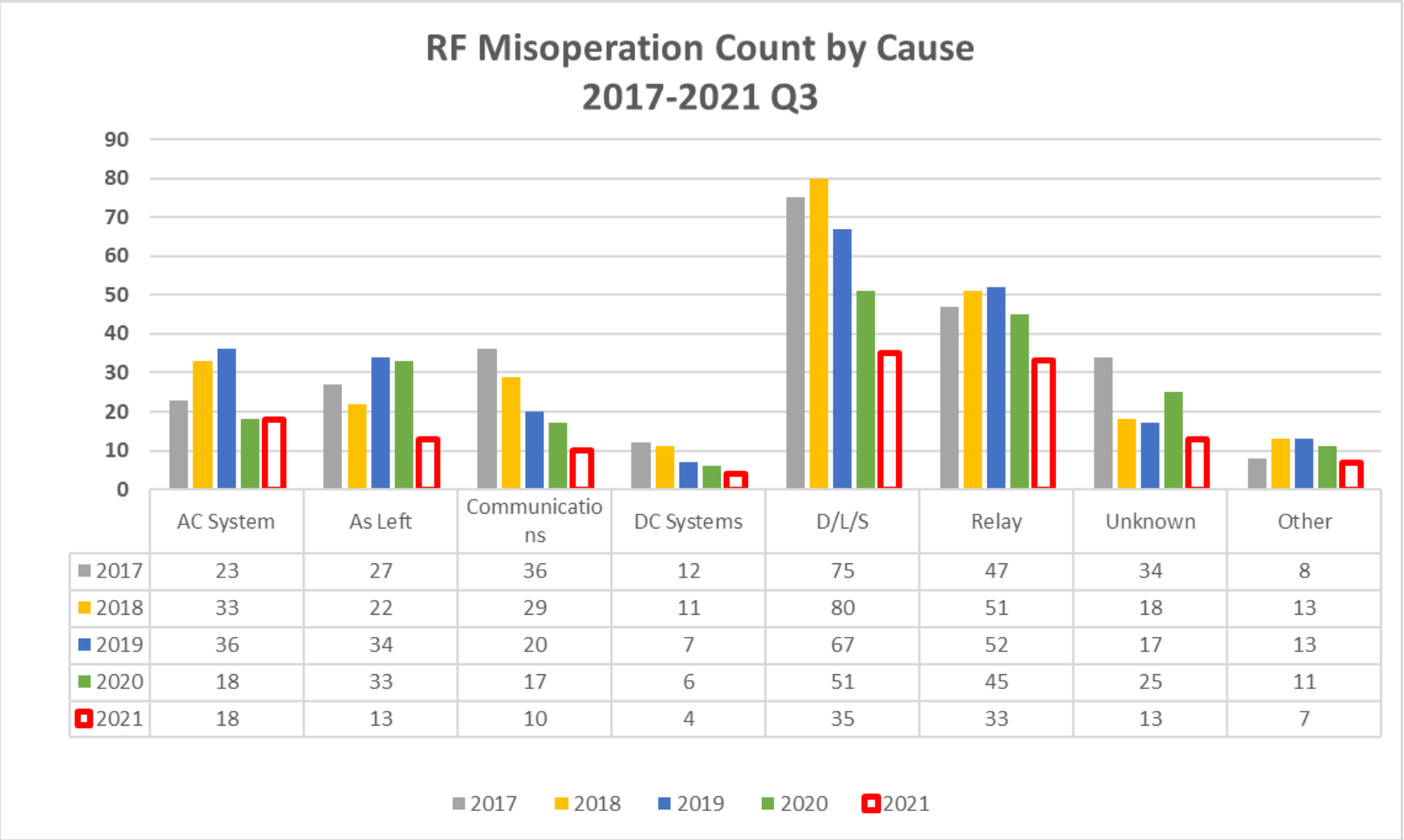
	2014	2015	2016	2017	2018	2019	2020	2021
Ops	2918	2270	2442	2264	2275	2148	1882	1394
Misops	398	361	277	262	257	246	206	133
Rate	13.64%	15.90%	11.34%	11.57%	11.30%	11.45%	10.95%	9.54%

RF Misoperation Count – Equipment Type



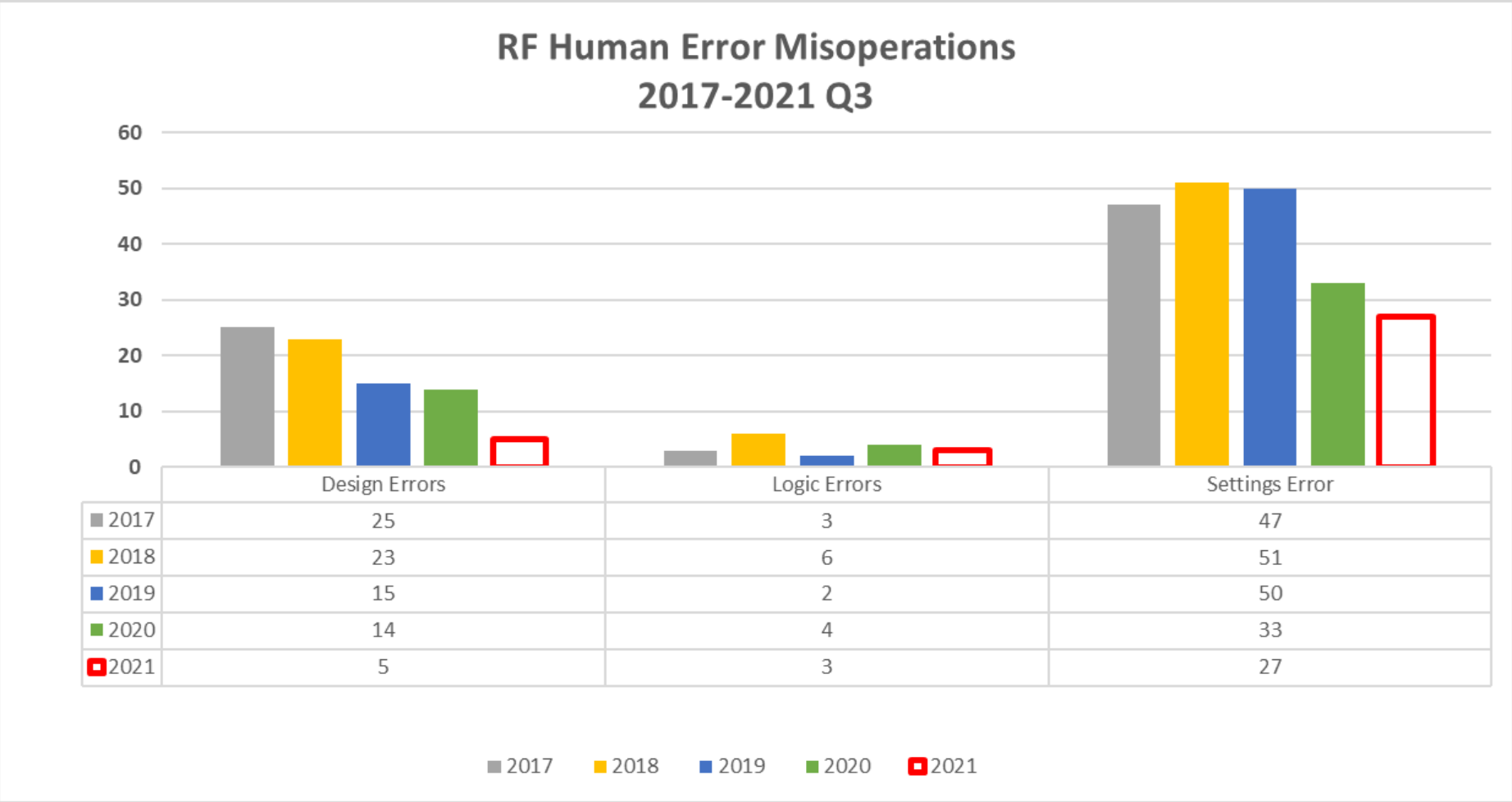
	Breaker	Bus	Generator	Line	Capacitor	Reactor	Transformer	Other	Series Capacitor	Dynamic VAR
2017	20	21	12	183	12	0	12	0	0	1
2018	26	10	11	163	29	1	14	1	0	2
2019	27	13	19	139	32	1	13	1	0	1
2020	18	13	18	132	11	0	12	2	0	0
2021	14	8	6	75	15	3	11	0	0	1

RF Misoperation Count - Cause



	AC System	As Left	Communications	DC Systems	D/L/S	Relay	Unknown	Other
2017	23	27	36	12	75	47	34	8
2018	33	22	29	11	80	51	18	13
2019	36	34	20	7	67	52	17	13
2020	18	33	17	6	51	45	25	11
2021	18	13	10	4	35	33	13	7

RF Misoperation Count – Human Performance



	Design Errors	Logic Errors	Settings Error
2017	25	3	47
2018	23	6	51
2019	15	2	50
2020	14	4	33
2021	5	3	27

Performance Improvement Initiatives

- Protection Subcommittee
- Misoperation Peer Review Team
- Protection System/Human Performance Workshops
- Substation Maintenance Community of Practice
- RF Outreach: Entity Engagement and the One-on-One outreach

RF Protection Subcommittee (PS)

Educate, review, and discuss protection system related issues and misoperations with industry subject matter experts with the goal to improve operational performance

- Consists of relay experts from companies in the RF footprint
- Meets quarterly
- Reviews system events initiated by protection system components (lessons learned)
- Discusses and provides guidance to NERC PRC Reliability Standards
- Provided annual training sessions by Schweitzer Engineering Laboratories University (SELU) on line protection topics from 2015-2019

Misoperation Peer Reviews

Review conducted to ensure accurate record keeping and understanding of protection system misoperations

- Conducted quarterly by subgroup of the PS
- Educational opportunity by allowing participants to review a wide variety of misoperations
- Unique misoperations are presented at the PS for risk awareness and performance improvement efforts

Protection/Human Performance Workshops

- **Spring 2017 Reliability Workshop focused on Misoperations**
- **Annual Protection System Workshops for Technical Personnel:**
  - Power Line Carrier Failure – 2015
  - Commissioning and Testing – 2016
  - Human Performance in Design – 2017
  - Protection System Drawings – 2018
  - Asset Management Tools, the future of Managing Protection System Data – 2019
  - Misoperation investigation inside the substation and CAP Bank Protection – 2020
  - Commissioning – 2021
- **Annual Human Performance Workshops beginning in 2018**
- **Short Circuit Modelers Workshop in June 2019 to support a biennial short circuit survey conducted by the Protection Subcommittee to validate short circuit models between entities to help reduce Misoperations on interconnections**

RF Outreach

Entity Engagement

- Internal Controls Evaluations
- Assist Visits

➢ Entity Engagement has conducted at least two in-depth Protection System Operation/Misoperation process reviews with great success

➢ RF cross-departmental team has conducted multiple one-on-one Misoperation discussions with Entities to learn their best practices and lessons learned

What Entities Can Do To Reduce Misops

- Participate and be involved with the Protection Subcommittee
- Entity Relay Protection SMEs should be a member of the Misoperation Peer Review Team
- Partner with the RF Entity Engagement Team to evaluate your company's processes and controls
- Have a second set of eyes review relay settings and commissioning testing procedures

Questions & Answers

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Enhancing Oversight and Peer Reviews – Case Studies

Jim Kubrak – Manager, Operations and Planning Monitoring

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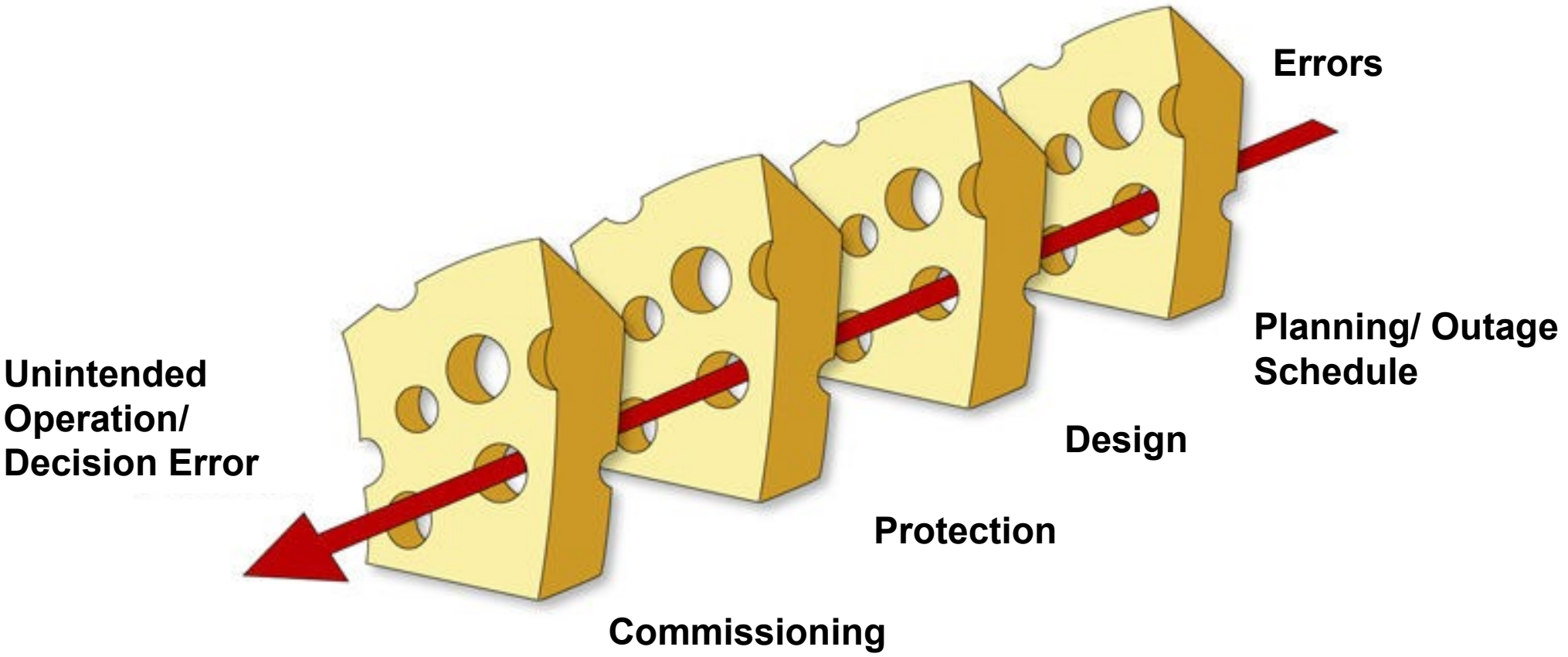
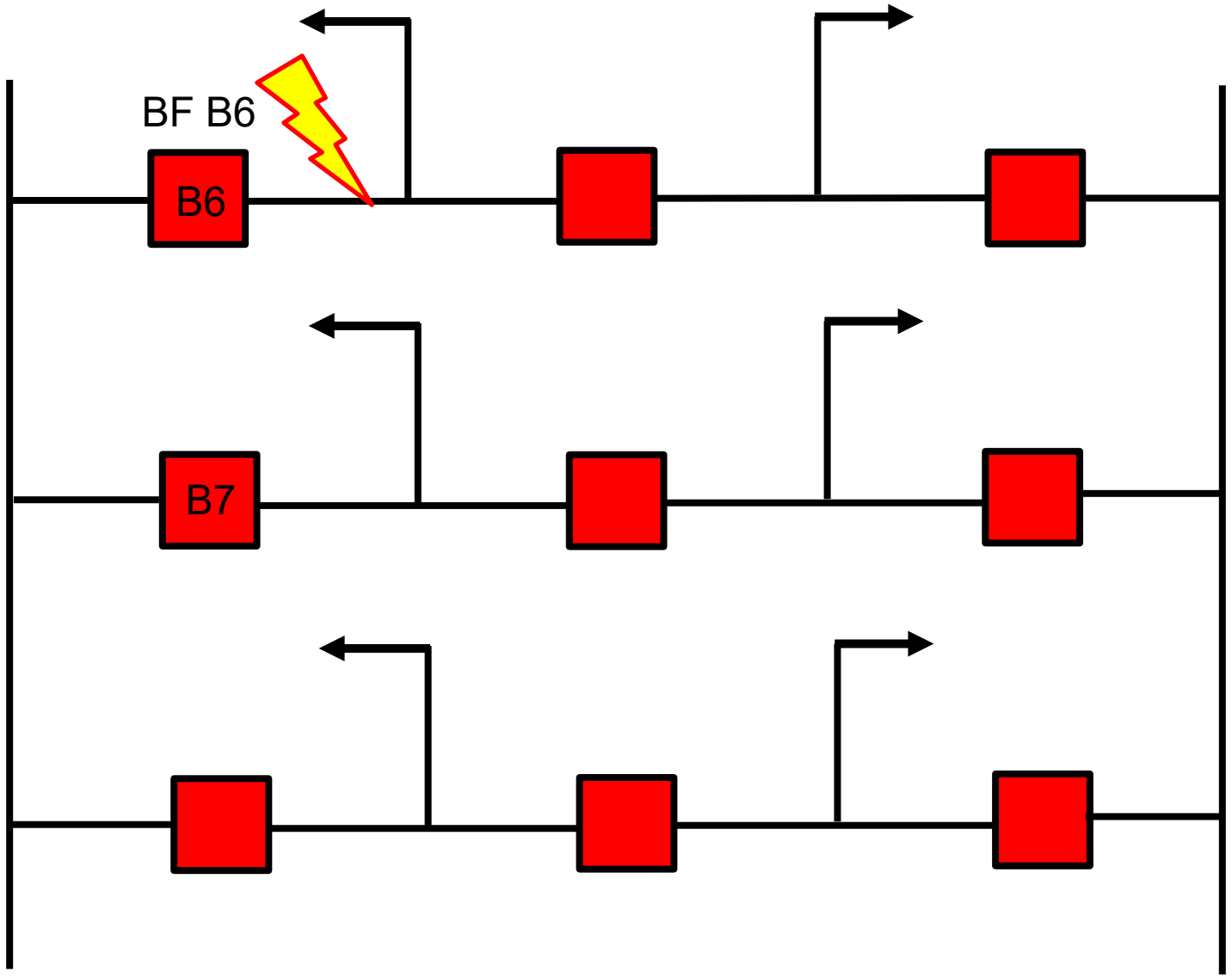
Commissioning Objective



Entities Should Perform Both Functional and In-service Tests

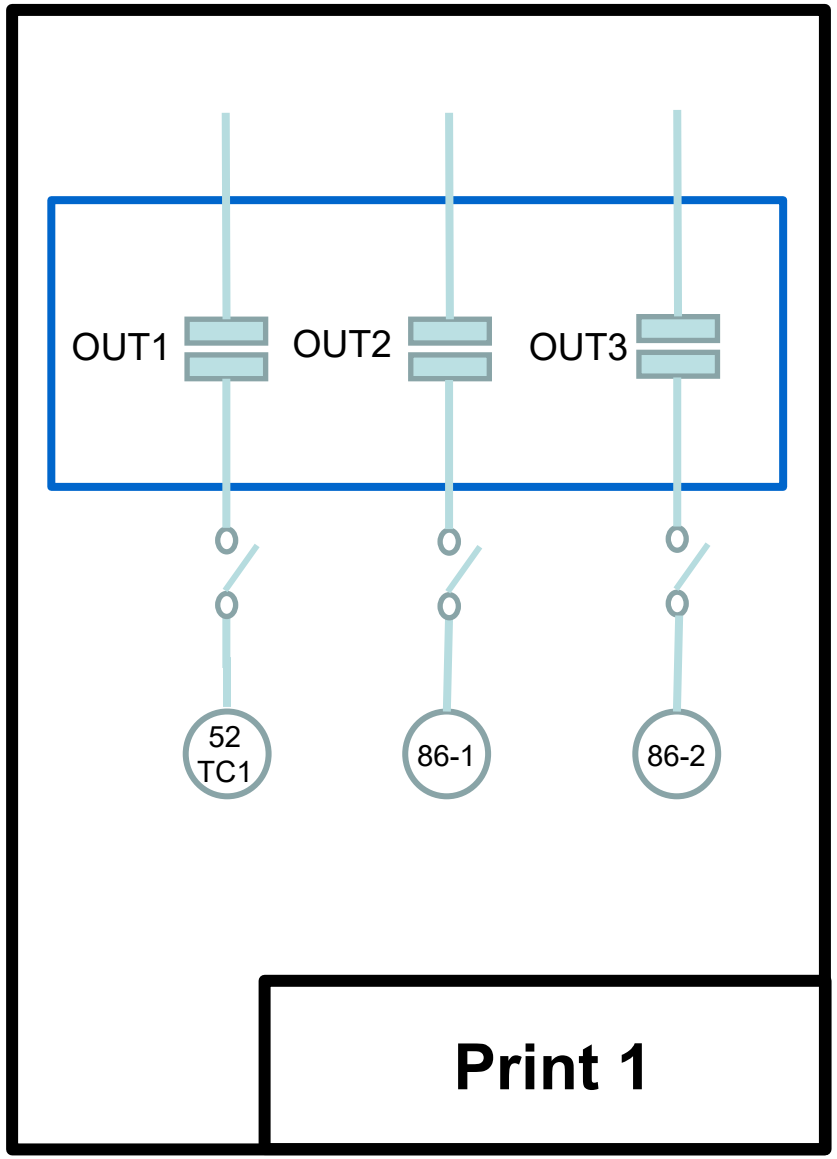


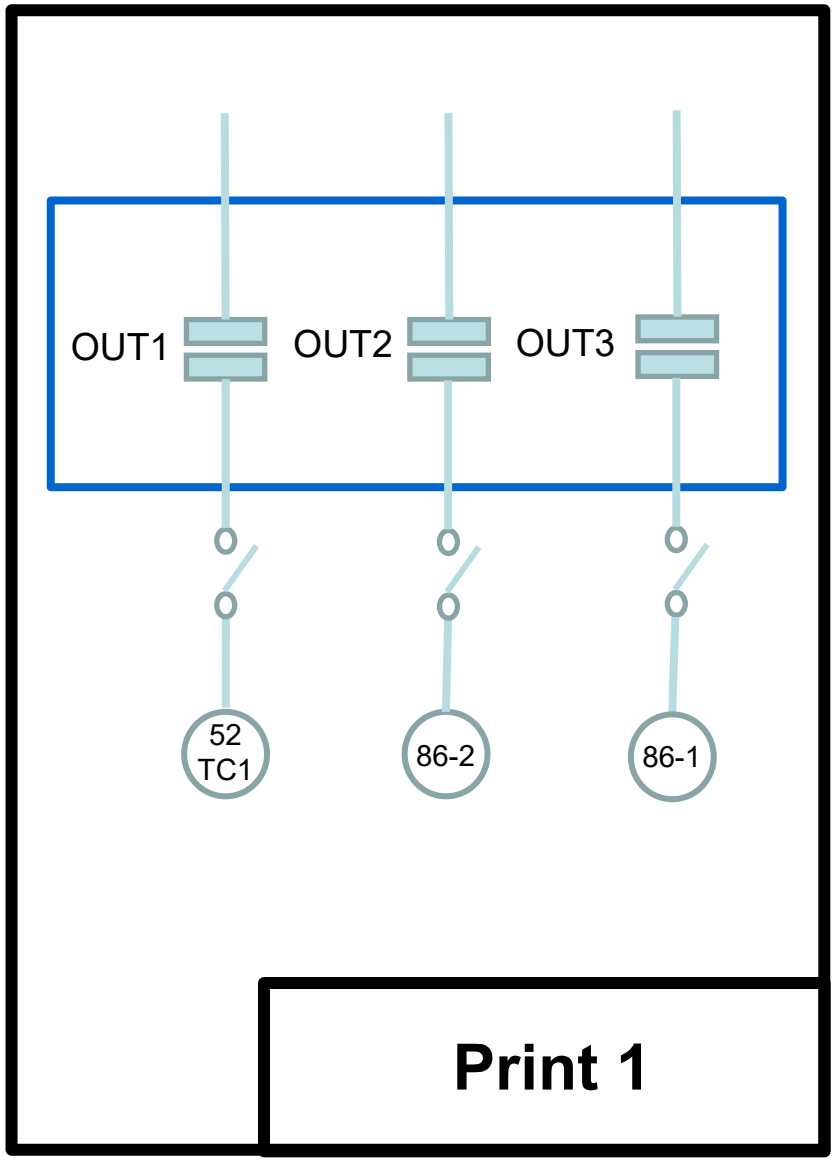
Final Walk-down

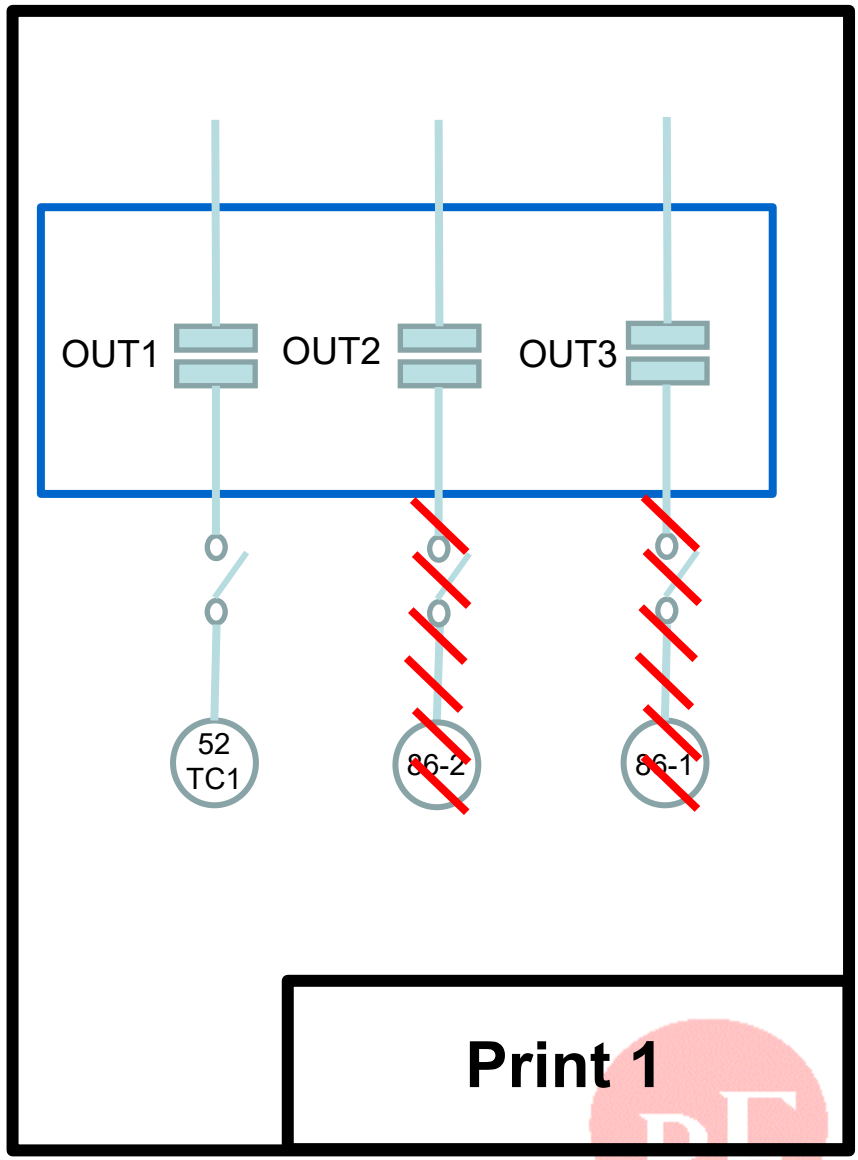
Entities should perform a final walk-down after the in-service testing is completed and use a checklist to document the visual inspection

- **Should also provide adequate "close out time"**
  - Organizing prints
  - Ensure data is received to update model, as left settings

Adequate Close Out Time Once Project is Completed





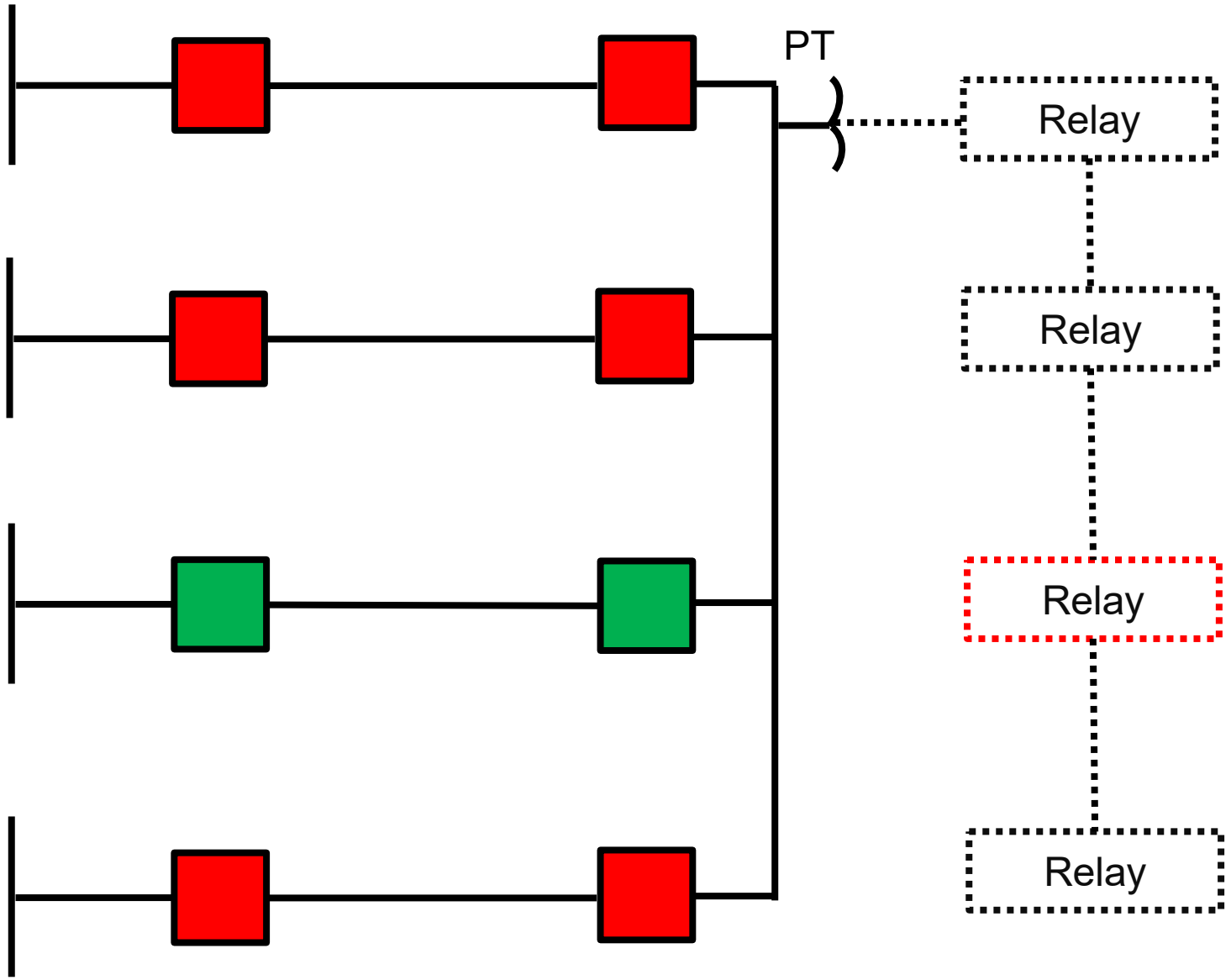


Entities Should Use Internal Controls to Find, Track & Correct Issues

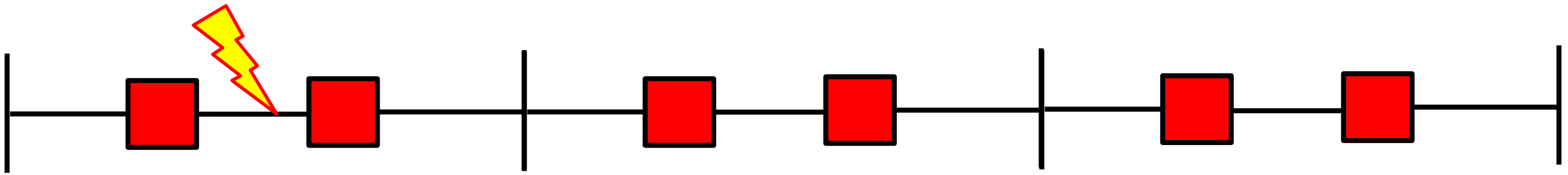
Communication platform that can provide awareness of near misses, human error, design traps, etc.

- Safety Meetings
- Utilizing Technology

Entities Should Maintain an Isolation Log



Entities Should Perform End-to-end Testing for Communication Relays



Checklist

Entities' individual technicians should use a consistent and complete PSC test checklist that identifies specific tasks and deliverables/objectives in the commissioning procedure

Take Away

Setting up the next person for success

Questions & Answers

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IBR Commission Testing

Rich Bauer
Associate Principal Engineer – Event Analysis
RF Industry Webinar – Commissioning and Misoperations
January 24, 2022

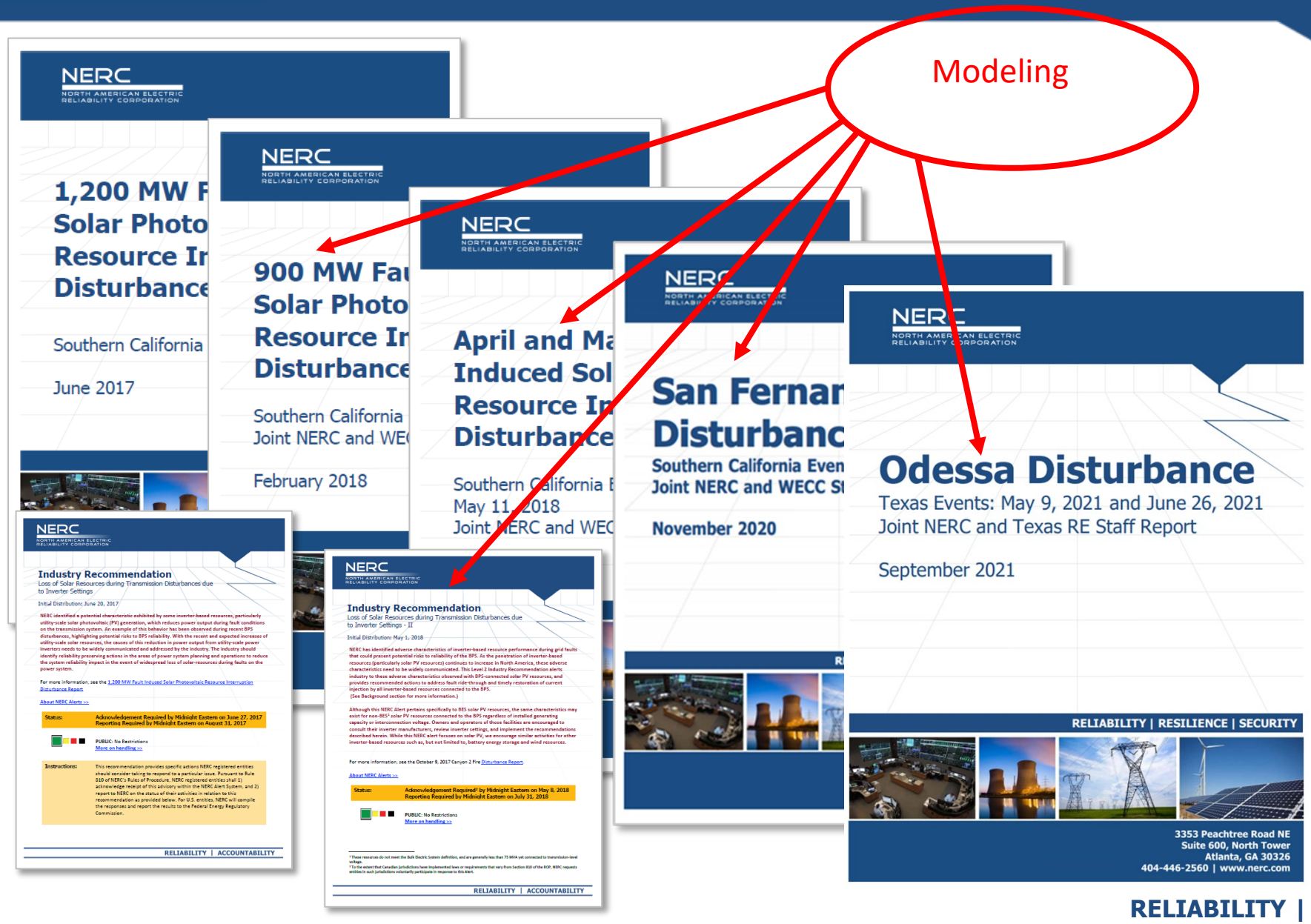
RELIABILITY | ACCOUNTABILITY




IBR Commission testing

- Commission testing of conventional protection systems
- Commission testing of IBRs is different
- Commission testing of IBRs needs to verify the dynamic model of the facility

NERC Disturbance Reports and Alerts



NERC Disturbance Reports and Alerts

Modeling

FERC Interconnection Procedure

- Interconnection Request
- Feasibility Study
- System Impact Study
- Facilities Study
- Interconnection Agreement
- Construction
- Trial Operation/Commissioning
- Commercial Operation

Interconnection Procedure

- Interconnection Request
- Feasibility Study
- System Impact Study
- Facilities Study
- Interconnection Agreement
- Construction
- Trial Operation/Commissioning
- Commercial Operation

Interconnection Request

- **3.4 Valid Interconnection Request.**
- **3.4.1 Initiating an Interconnection Request.**
- To initiate an Interconnection Request, Interconnection Customer must submit all of the following: (i) a $10,000 deposit, (ii) a completed application in the form of Appendix 1, and (iii) demonstration of Site Control or a posting of an additional deposit of $10,000…

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Interconnection Request

Attachment A to Appendix 1
Interconnection Request

LARGE GENERATING FACILITY DATA

UNIT RATINGS

kVA _____ °F _____ Voltage _____
Power Factor _____
Speed (RPM) _____ Connection (e.g. Wye) _____
Short Circuit Ratio _____ Frequency, Hertz _____
Stator Amperes at Rated kVA _____ Field Volts _____
Max Turbine MW _____ °F _____

Primary frequency response operating range for electric storage resources:
Minimum State of Charge:_____

Maximum State of Charge:_____

COMBINED TURBINE-GENERATOR-EXCITER INERTIA DATA

Inertia Constant, H = _____ kW sec/kVA
Moment-of-Inertia, WR^2 = _____ lb. $ft.^2$

REACTANCE DATA (PER UNIT-RATED KVA)

		DIRECT AXIS		QUADRATURE AXIS
Synchronous – saturated	X_{dv}	_____	X_{qv}	_____
Synchronous – unsaturated	X_{di}	_____	X_{qi}	_____
Transient – saturated	X'_{dv}	_____	X'_{qv}	_____
Transient – unsaturated	X'_{di}	_____	X'_{qi}	_____
Subtransient – saturated	X''_{dv}	_____	X''_{qv}	_____
Subtransient – unsaturated	X''_{di}	_____	X''_{qi}	_____
Negative Sequence – saturated	$X2_v$	_____		
Negative Sequence – unsaturated	$X2_i$	_____		
Zero Sequence – saturated	$X0_v$	_____		
Zero Sequence – unsaturated	$X0_i$	_____		

FIELD TIME CONSTANT DATA (SEC)

Open Circuit	T'_{do}	_____	T'_{qo}	_____
Three-Phase Short Circuit Transient	T'_{d3}	_____	T'_{q}	_____
Line to Line Short Circuit Transient	T'_{d2}	_____		
Line to Neutral Short Circuit Transient	T'_{d1}	_____		
Short Circuit Subtransient	T''_{d}	_____	T''_{q}	_____
Open Circuit Subtransient	T''_{do}	_____	T''_{qo}	_____

ARMATURE TIME CONSTANT DATA (SEC)

Three Phase Short Circuit	T_{a3}	_____
Line to Line Short Circuit	T_{a2}	_____
Line to Neutral Short Circuit	T_{a1}	_____

NOTE: If requested information is not applicable, indicate by marking "N/A."

MW CAPABILITY AND PLANT CONFIGURATION
LARGE GENERATING FACILITY DATA

ARMATURE WINDING RESISTANCE DATA (PER UNIT)

Positive	R_1	_____
Negative	R_2	_____
Zero	R_0	_____

Rotor Short Time Thermal Capacity I_2^2t = _____
Field Current at Rated kVA, Armature Voltage and PF = _____ amps
Field Current at Rated kVA and Armature Voltage, 0 PF = _____ amps
Three Phase Armature Winding Capacitance = _____ microfarad
Field Winding Resistance = _____ ohms _____ °C
Armature Winding Resistance (Per Phase) = _____ ohms _____ °C

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Interconnection Request

EXCITATION SYSTEM DATA

Identify appropriate IEEE model block diagram of excitation system and power system stabilizer (PSS) for computer representation in power system stability simulations and the corresponding excitation system and PSS constants for use in the model.

GOVERNOR SYSTEM DATA

Identify appropriate IEEE model block diagram of governor system for computer representation in power system stability simulations and the corresponding governor system constants for use in the model.

WIND GENERATORS

Number of generators to be interconnected pursuant to this Interconnection Request: _____

Elevation: _____ _____ Single Phase _____ Three Phase

Inverter manufacturer, model name, number, and version:
_____

List of adjustable setpoints for the protective equipment or software:
_____

Note: A completed General Electric Company Power Systems Load Flow (PSLF) data sheet or other compatible formats, such as IEEE and PTI power flow models, must be supplied with the Interconnection Request. If other data sheets are more appropriate to the proposed device, then they shall be provided and discussed at Scoping Meeting.

INDUCTION GENERATORS

(*) Field Volts: _____
(*) Field Amperes: _____
(*) Motoring Power (kW): _____
(*) Neutral Grounding Resistor (If Applicable): _____
(*) I_2^2t or K (Heating Time Constant): _____
(*) Rotor Resistance: _____
(*) Stator Resistance: _____
(*) Stator Reactance: _____
(*) Rotor Reactance: _____
(*) Magnetizing Reactance: _____
(*) Short Circuit Reactance: _____
(*) Exciting Current: _____
(*) Temperature Rise: _____
(*) Frame Size: _____
(*) Design Letter: _____
(*) Reactive Power Required In Vars (No Load): _____
(*) Reactive Power Required In Vars (Full Load): _____
(*) Total Rotating Inertia, H: _____Per Unit on KVA Base

Note: Please consult Transmission Provider prior to submitting the Interconnection Request to determine if the information designated by (*) is required.

Interconnection request data

- What Data do we need?
- Inverters do not respond according to physics
- Inverter characteristic/performance is determined by controls
- How are those controls configured?
- What protection is enabled?

Controls

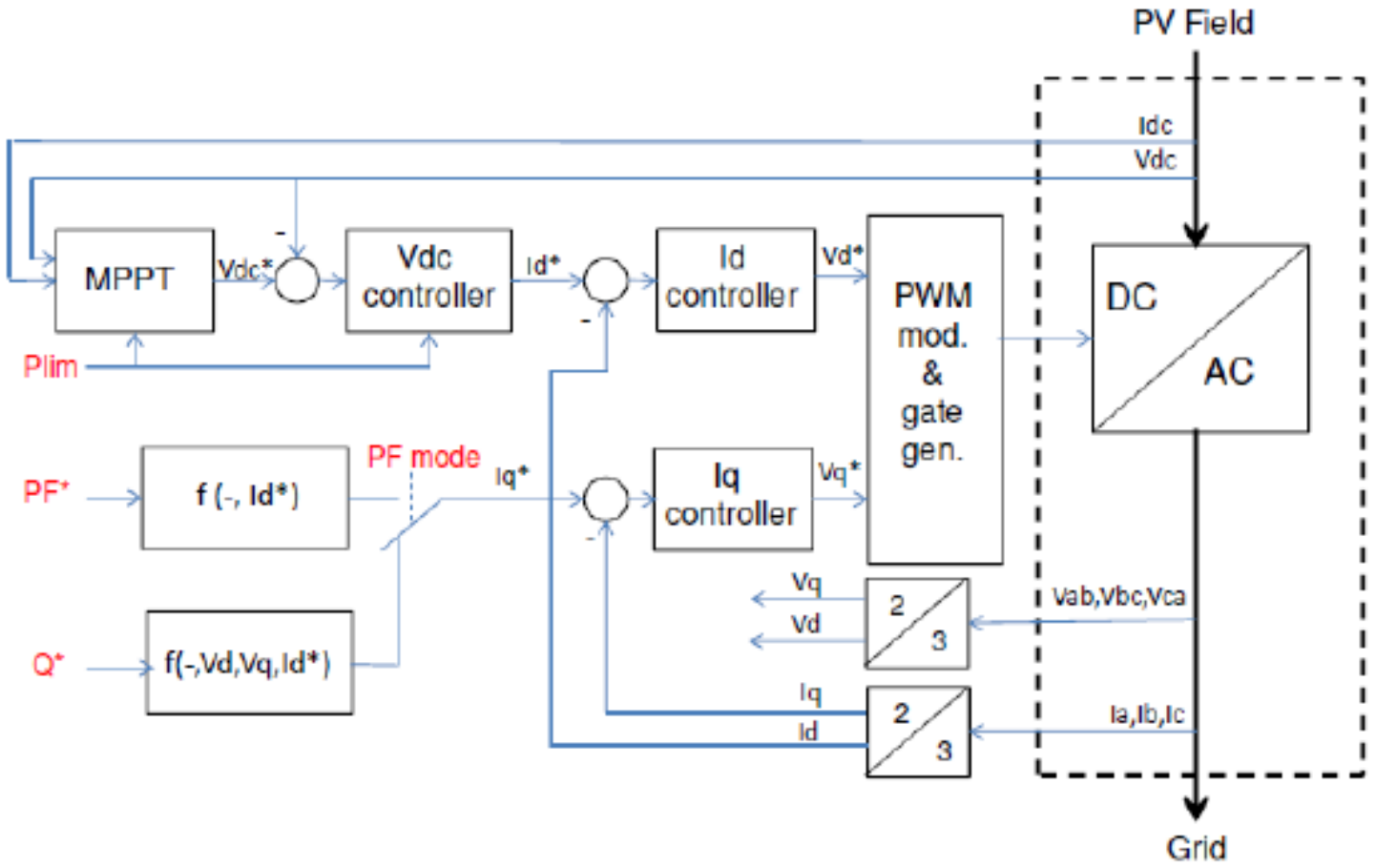


Figure 3.1. Basic Diagram of Solar Inverter Controls [Source: GE]

Controls

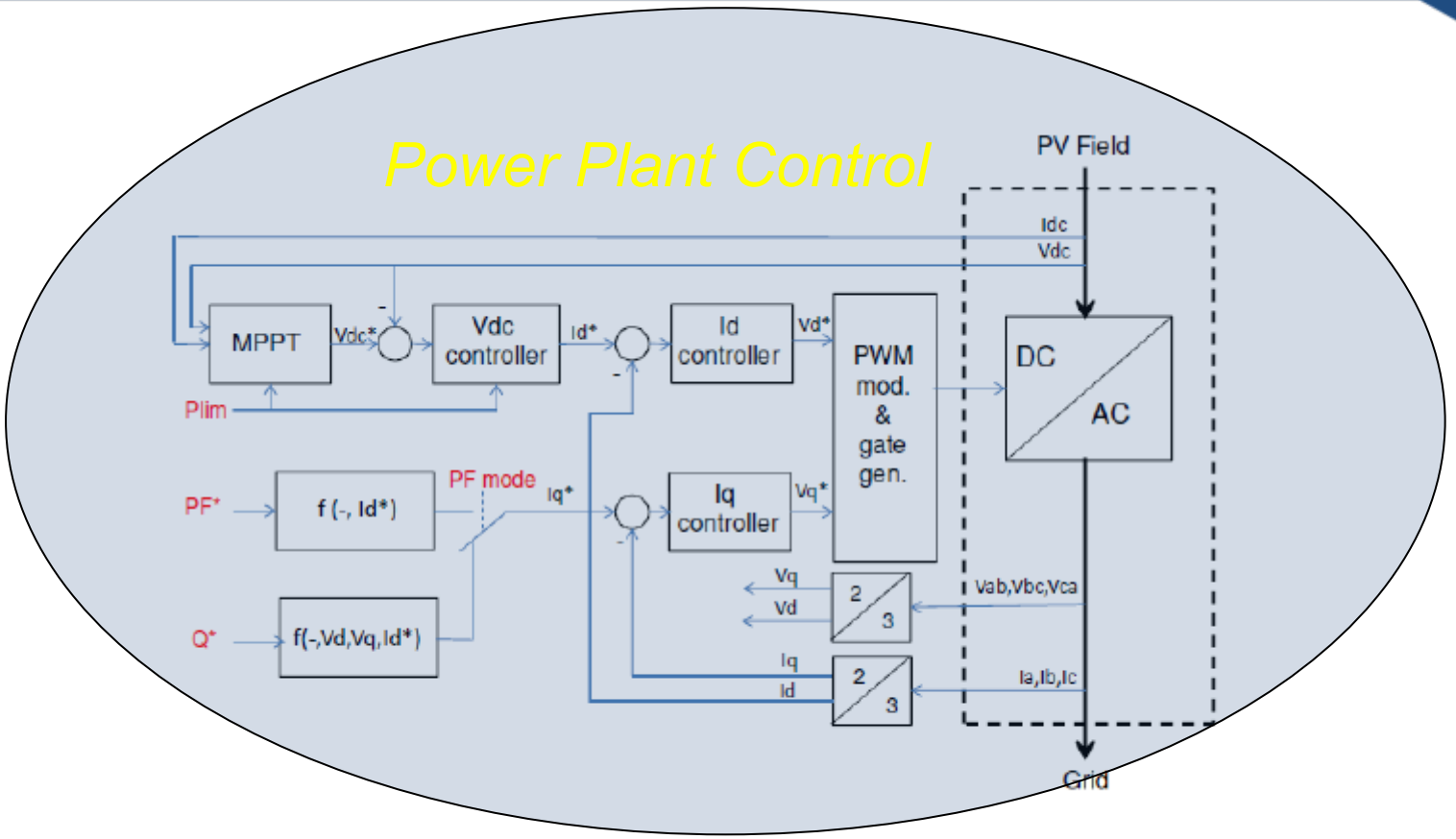


Figure 3.1. Basic Diagram of Solar Inverter Controls [Source: GE]

Model verification

- We need accurate representation of how those controls are set up
- We need accurate models

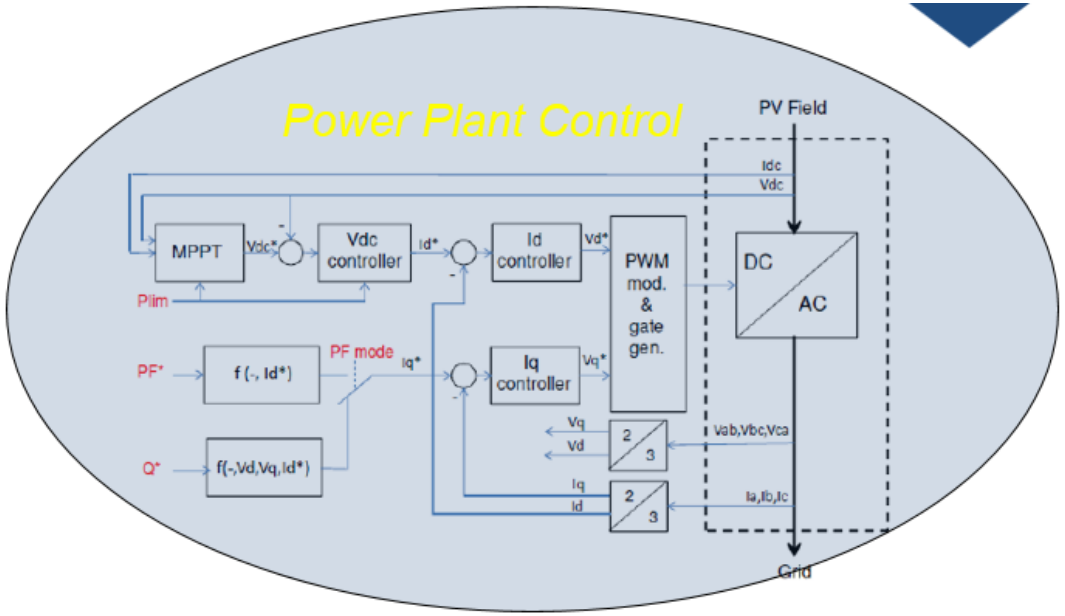


Figure 3.1. Basic Diagram of Solar Inverter Controls [Source: GE]

Interconnection Procedure

- Interconnection Request
- Feasibility Study
- System Impact Study
- Facilities Study
- Interconnection Agreement
- Construction
- Trial Operation/Commissioning
- Commercial Operation

Model verification

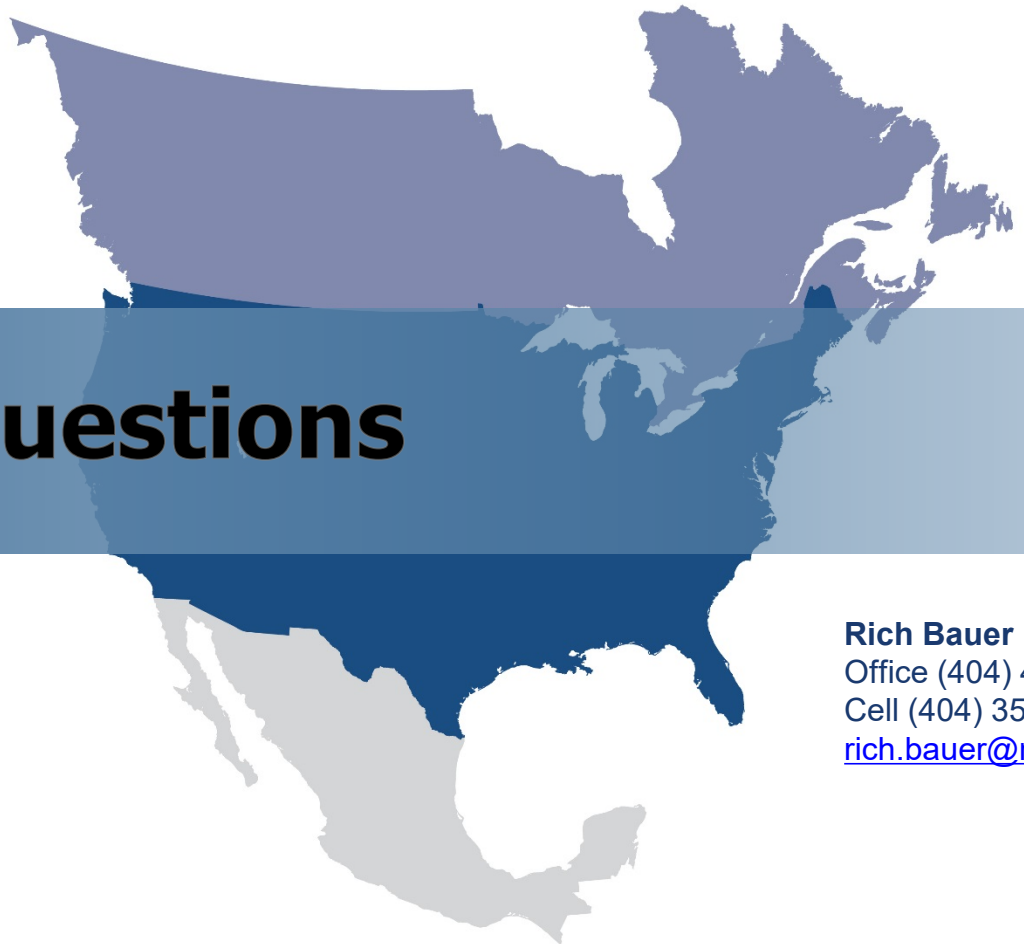
- During the commissioning of IBR facilities, tests must be performed to verify that the dynamic model represents the actual performance

What does your system look like?

Summary

	26.17% Nov Average Renewable Serving Load	**31.27%** Year to Date Average Renewable Serving Load	**94.5%** Max 5 min. Renewable Serving Load All-time	**4.359TWh** Nov Metered Renewable Generation
	11323MW Nov Max Solar Production	**13205MW** Year to Date Max Solar Production	**13205MW** All-time Max Solar Production	**42590MWh** Nov Solar Energy Curtailed
	4477MW Nov Max Wind Production	**5754MW** Year to Date Max Wind Production	**5754MW** All-time Max Wind Production	**646.5MWh** Nov Wind Energy Curtailed

14757MW/3hr Nov Max 3 Hour Net Load Ramp	**0.8676%** Percent of 5-min Intervals with Negative Prices	**152.2%** Nov Average Control Performance Standard (CPS1)	**43236.5MWh** Nov Wind and Solar Energy Curtailed



Questions

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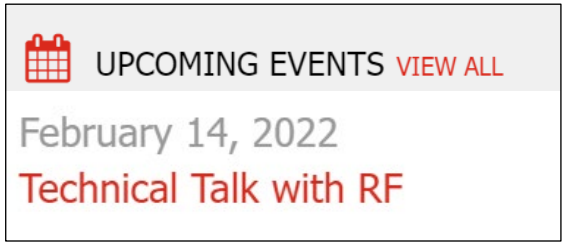
Upcoming RF Events

Mark your calendar for Monday, February 14 Technical Talk with RF

Link to WebEx at rfirst.org



February Agenda Topics:

- Align Update – Anthony Jablonski, RF Manager, Risk Analysis and Mitigation
- Physical Security Best Practices – Kevin Doss, CEO of Level 4 Security
- Physical Security Visitor Access – Tony Freeman, RF Principal Analyst

Upcoming ERO Events

TEXAS RE
Ensuring electric reliability for Texans

January 27 – Talk with Texas: Colonial Pipeline Hack
February 10 – Talk with Texas: Cybersecurity Threats

SERC Reliability Corporation

March 8 - Spring O&P Reliability Seminar - Virtual
March 9 - Spring CIP Security Seminar - Virtual

WECC

February 17 – Align Training for Self Certifications

MIDWEST RELIABILITY ORGANIZATION

January 26 – Regional Winter Assessment Overview

Closing Remarks

Thank you for attending RF's Protection System Commissioning Webinar! Your feedback is extremely important to us and allows RF to continuously improve our webinars, workshops and outreach efforts.

Please take our event survey in Slido now at **Slido.com #Commissioning**.