RAS

(Remedial Action Schemes)
33rd Annual Hands On Relay School
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Davis Erwin P.E.

Principal Protection Engineer

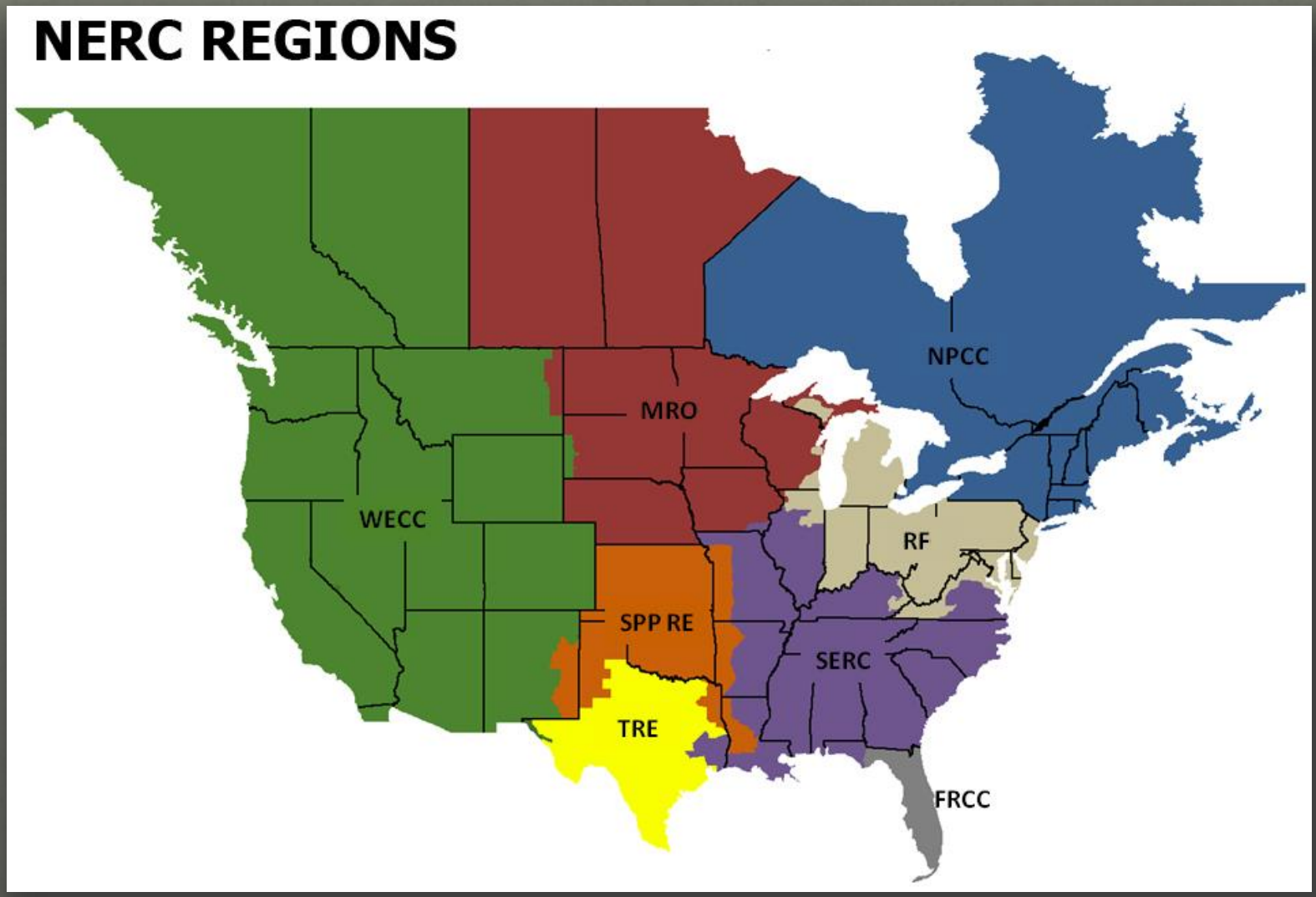
Pacific Gas and Electric Company

dpe4@pge.com

Overview

- Past and present state of "Special Schemes" -
- Definition of SIPS, SPS, RAS, etc.
  - NERC Glossary of Terms changes for "Special Protection System" and "Remedial Action Scheme"
- RAS Classifications
- Future NERC PRC standard changes for RAS/SPS
- Redundancy (Single Component Failure)
- Remedial Action Scheme Examples and Testing
- Telecom Considerations

NERC Regions



Regional Scheme Distribution

Table 1: Overview of SPS by Region		
Region	**Total Number**	**Percentage**
FRCC	20	4.3%
MRO	36	7.8%
NPCC	117	25.3%
RFC	47	10.2%
SERC	20	4.3%
SPP	6	1.3%
TRE	24	5.2%
WECC	192	41.6%
Total	**462**	100%

Source: System Analysis and Modeling Subcommittee (SAMS) and System Protection and Control Subcommittee (SPCS) – NERC Report 2013

Terminology for Unique Schemes

- SIPS (IEEE)
  - System Integrity Protection System
- SPS (NERC)
  - Special Protection System
- RAS (NERC)
  - Remedial Action Scheme

IEEE Definition for Special Schemes

- Per IEEE: System Integrity Protection System(SIPS): *"The SIPS encompasses special protection system (SPS), remedial action schemes (RAS), as well as other system integrity schemes, such as underfrequency (UF), undervoltage (UV), out-of-step (OOS), etc."*
  - **Per NERC*: SIPS is not an appropriate term for use in the NERC Reliability Standards, as its definition is overly inclusive. Example: UF and UV have dedicated standards and OOS schemes have traditionally been considered as Protection Systems**

*Source: System Analysis and Modeling Subcommittee (SAMS) and System Protection and Control Subcommittee (SPCS) – NERC Report 2013

NERC Definition of "Protection System"

- The Glossary of Terms Used in NERC Reliability Standards defines a **Protection System** as:
  - 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 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.

NERC Definition of "SPS"
"Special Protection System"

- An automatic protection system designed to detect abnormal or predetermined system conditions, and take corrective actions other than and/or in addition to the isolation of faulted components to maintain system reliability. Such action may include changes in demand, generation (MW and Mvar), or system configuration to maintain system stability, acceptable voltage, or power flows.

  An SPS does not include (a) underfrequency or undervoltage load shedding or (b) fault conditions that must be isolated or (c) out-of-step relaying (not designed as an integral part of an SPS). Also called Remedial Action Scheme.

NERC Definition of "RAS" "Remedial Action Scheme "

- Remedial Action Scheme: *See "Special Protection System"*

  Note: SPS and RAS definitions are interchangeable (Cross Referenced in NERC Glossary of Terms)

  Note: "SIPS" is not Synonymous with "RAS" and "SPS". SIPS is more broadly defined.

NERC "SPS" and "RAS" Changes

- NERC: Existing definition of SPS lacks clarity and specificity and results in inconsistent identification of SPS/RAS and the application of RAS standards across all regions (such as redundancy). SPS definition is overly inclusive (Actions are too broad)
  - NERC Standard Drafting Team (SDT) was formed April 2014 (Project 2010-05.2 Phase 2 of Protection Systems). Objective: Revise Definitions for improved Continent Wide Consistency
- Project 2010-05.2 – Special Protection Systems - (STD Results):
  - Retain the term Remedial Action Scheme (RAS)
  - Ultimately retire the term Special Protection System (SPS)
  - Drafted a new Definition of RAS

NERC Standard Drafting Team

Member	Entity
Gene Henneberg (Chair)	NV Energy / Berkshire Hathaway Energy
Bobby Jones (Vice Chair)	Southern Company
Amos Ang	Southern California Edison
Alan Engelmann	ComEd / Exelon
Davis Erwin	Pacific Gas and Electric
Sharma Kolluri	Entergy
Charles-Eric Langlois	Hydro-Quebec TransEnergie
Robert J. O'Keefe	American Electric Power
Hari Singh	Xcel Energy

Standard Drafting Team Results: NERC "SPS" and "RAS" Changes

- Use a Single Term
  - A single term will promote consistency across all regions
  - What Single Term?
- Use "RAS" – Retire "SPS"
  - "RAS" is a more descriptive term for the installation
  - "RAS" is in use within all regions (and within existing standards "SPS or RAS")
  - Eliminates the confusion associated with the defined terms "Special Protection System" and "Protection System"
    - Protection System components are often used to build RAS

New NERC Definition of "RAS" Remedial Action Scheme

A scheme designed to detect predetermined System conditions and automatically take corrective actions that may include, but are not limited to, adjusting or tripping generation (MW and Mvar), tripping load, or reconfiguring a System(s). RAS accomplish objectives such as:

- Meet requirements identified in the NERC Reliability Standards;
- Maintain Bulk Electric System (BES) stability;
- Maintain acceptable BES voltages;
- Maintain acceptable BES power flows;
- Limit the impact of Cascading or extreme events.

NERC Definition of "RAS" Remedial Action Scheme (continued)

- The following do not individually constitute a RAS:
  a. Protection Systems installed for the purpose of detecting Faults on BES Elements and isolating the faulted Elements
  b. Schemes for automatic underfrequency load shedding (UFLS) and automatic undervoltage load shedding (UVLS) comprised of only distributed relays
  c. Out-of-step tripping and power swing blocking
  d. Automatic Reclosing schemes
  e. Schemes applied on an Element for non-Fault conditions, such as, but not limited to, generator loss-of-field, transformer top-oil temperature, overvoltage, or overload to protect the Element against damage by removing it from service

NERC Definition of "RAS" Remedial Action Scheme (continued)

- The following do not individually constitute a RAS (Continued):
  f. Controllers that switch or regulate one or more of the following: series or shunt reactive devices, flexible alternating current transmission system (FACTS) devices, phase-shifting transformers, variable-frequency transformers, or tap-changing transformers; and, that are located at and monitor quantities solely at the same station as the Element being switched or regulated
  g. FACTS controllers that remotely switch static shunt reactive devices located at other stations to regulate the output of a single FACTS device
  h. Schemes or controllers that remotely switch shunt reactors and shunt capacitors for voltage regulation that would otherwise be manually switched
  i. Schemes that automatically de-energize a line for a non-Fault operation when one end of the line is open

NERC Definition of "RAS" Remedial Action Scheme (continued)

- The following do not individually constitute a RAS (Continued):
  j. Schemes that provide anti-islanding protection (e.g., protect load from effects of being isolated with generation that may not be capable of maintaining acceptable frequency and voltage)
  k. Automatic sequences that proceed when manually initiated solely by a System Operator
  l. Modulation of HVdc or FACTS via supplementary controls, such as angle damping or frequency damping applied to damp local or inter-area oscillations
  m. Sub-synchronous resonance (SSR) protection schemes that directly detect sub-synchronous quantities (e.g., currents or torsional oscillations)
  n. Generator controls such as, but not limited to, automatic generation control (AGC), generation excitation [e.g. automatic voltage regulation (AVR) and power system stabilizers (PSS)], fast valving, and speed governing

Future Definition of "RAS" and "SPS"

- New RAS Definition
  - NERC BOT Approved Date: 11/13/2014
  - FERC Approved Date: 11/19/2015
  - Effective: 4/1/2017
    - **Implementation Plan**
- Proposed Definition SPS: See "Remedial Action Scheme"
  - Passed Industry Ballot January 2016

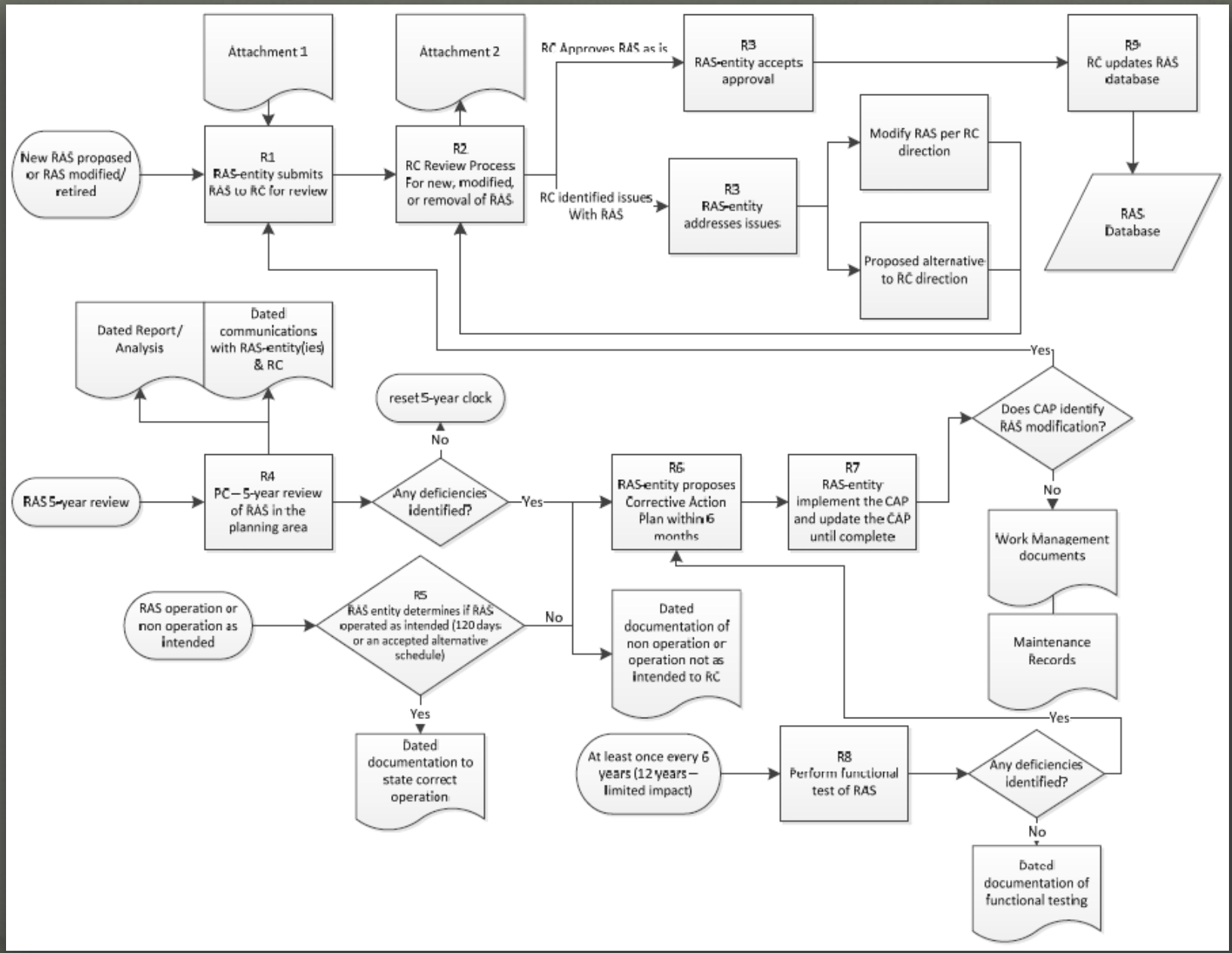
NERC SDT Continued Work

- Project 2010-05.3 Phase 3 of Protection Systems: Remedial Action Schemes (RAS)
- PRC-012-2 (On-Going work. Industry Ballot concludes March 18th 2016)
  - **Standard(s) affected**
    - PRC-012-1
    - PRC-013-1
    - PRC-014-1
    - PRC-015-1
    - PRC-016-1

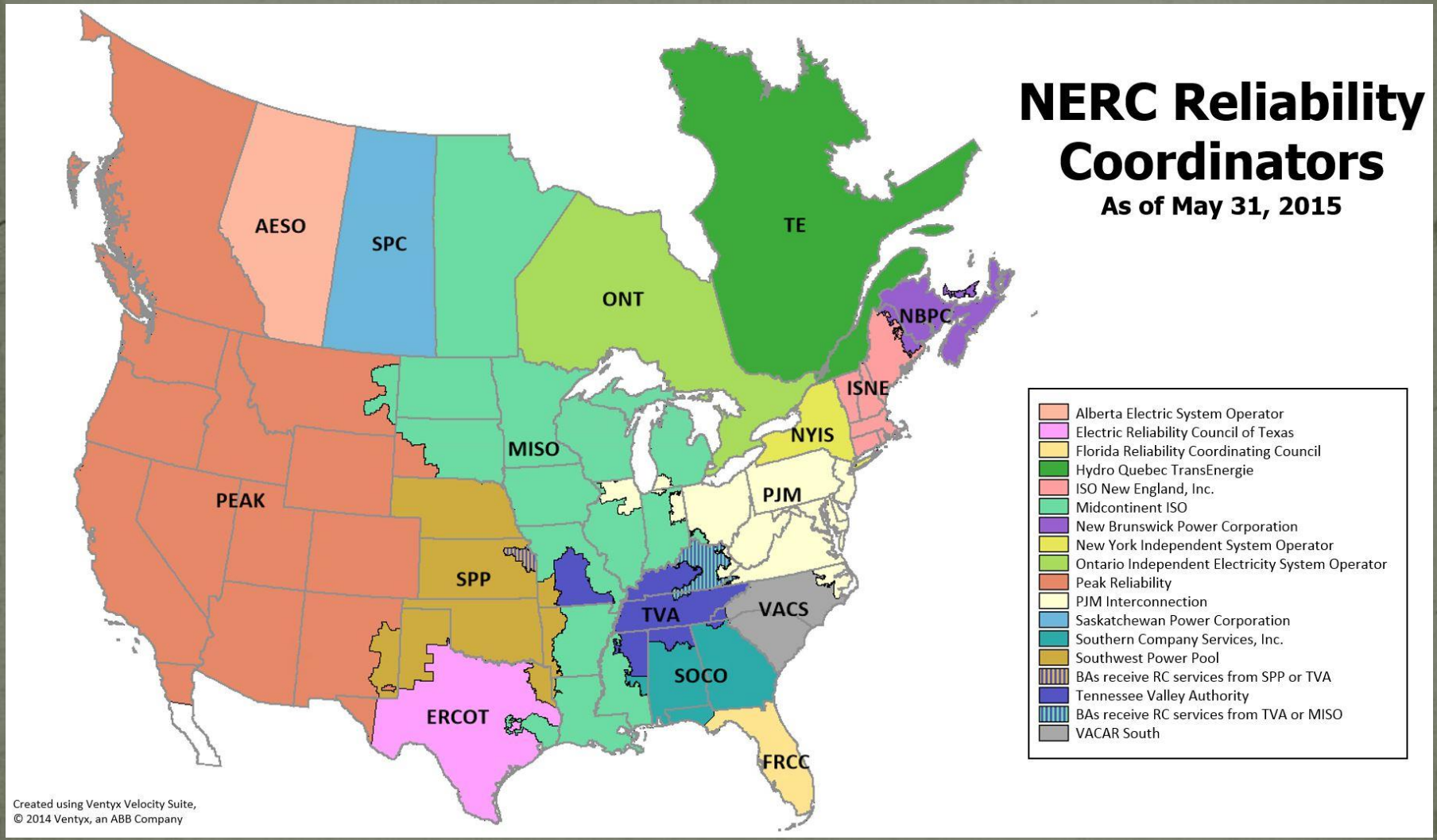
NERC Compliance Standards for RAS (SPS are -0 Versions)

Standard Number	Title	Enforcement Date	Notes
PRC-012-1	Remedial Action Scheme Review Procedure	4/1/2017	
PRC-013-1	Remedial Action Scheme Database	4/1/2017	
PRC-014-1	Remedial Action Scheme Assessment	4/1/2017	
PRC-015-1	Remedial Action Scheme Data and Documentation	4/1/2017	Entities with newly classified "Remedial Action Scheme" (RAS) resulting from the application of the revised definition must be fully compliant with all Reliability Standards applicable RAS 24 months from the Effective Date of the revised definition of RAS. This additional time applies only to existing schemes that must transition to RAS due to the revised definition.
PRC-016-1	Remedial Action Scheme Misoperations	4/1/2017	
PRC-017-1	Remedial Action Scheme Maintenance and Testing	4/1/2017	

NERC SDT Continued Work (PRC-012-2)



NERC SDT Continued Work (PRC-012-2)



RAS Classifications (Existing Only)

- Classifications differentiate the reliability risk associated with RAS and provides a means to establish more or less stringent requirements consistent with the reliability risk.*
- Approximate Equivalency of Classifications*
  - NPCC Type I = WECC WAPS = TRE Type 1
  - NPCC Type III = WECC LAPS = TRE Type 2
  - NPCC Type II = WECC Safety Net

*Source: System Analysis and Modeling Subcommittee (SAMS) and System Protection and Control Subcommittee (SPCS) – NERC Report 2013

WECC RAS Categories Existing (LAPS, WAPS, SN)

- **Local Area Protection Scheme (LAPS):** A Remedial Action Scheme (RAS) whose failure to operate would NOT result in any of the following:
  - Violations of TPL-(001 thru 004)- WECC-1-CR– System Performance Criteria,
  - Maximum load loss ≥ 300 MW,
  - Maximum generation loss ≥ 1000 MW.
- **Wide Area Protection Scheme (WAPS):** A Remedial Action Scheme (RAS) whose failure to operate WOULD result in any of the following:
  - Violations of TPL-(001 thru 004)-WECC-1-CR – System Performance Criteria,
  - Maximum load loss ≥ 300 MW,
  - Maximum generation loss ≥ 1000 MW.
- **Safety Net:** A type of Remedial Action Scheme designed to remediate TPL-004-0 (System Performance Following Extreme Events Resulting in the Loss of Two or More Bulk Electric System Elements (Category D)), or other extreme events.

RAS Future Classifications (PRC-012-2 Proposal)

- Limited Impact
  - A limited impact RAS cannot, by inadvertent operation or failure to operate, cause or contribute to BES Cascading, uncontrolled separation, angular instability, voltage instability, voltage collapse, or unacceptably damped oscillations.*
- Limited impact RAS are not subject to the RAS single component malfunction and failure tests. (Adds complexity to the design with minimal benefit to BES reliability.)
- RAS can be designated by the reviewing RC(s) as limited impact.*

*Source: NERC PRC-012-2 Draft 3 (Project 2010-05.3 Phase 3 of Protection Systems: Remedial Action Schemes (RAS))

Single Component Failure Considerations (Redundancy)

- Dependability
  - Assurance the scheme will operate when intended
  - Maintenance Considerations
- Redundant Schemes
  - WECC: WAPS and LAPS
  - NPCC: Type I
- Redundancy Not Required
  - WECC: SN
  - NPCC: Type III
- Duplication (System A and System B)
- Over-arming
- Security – Voting Scheme
  - Assurance the scheme will not operate when not intended

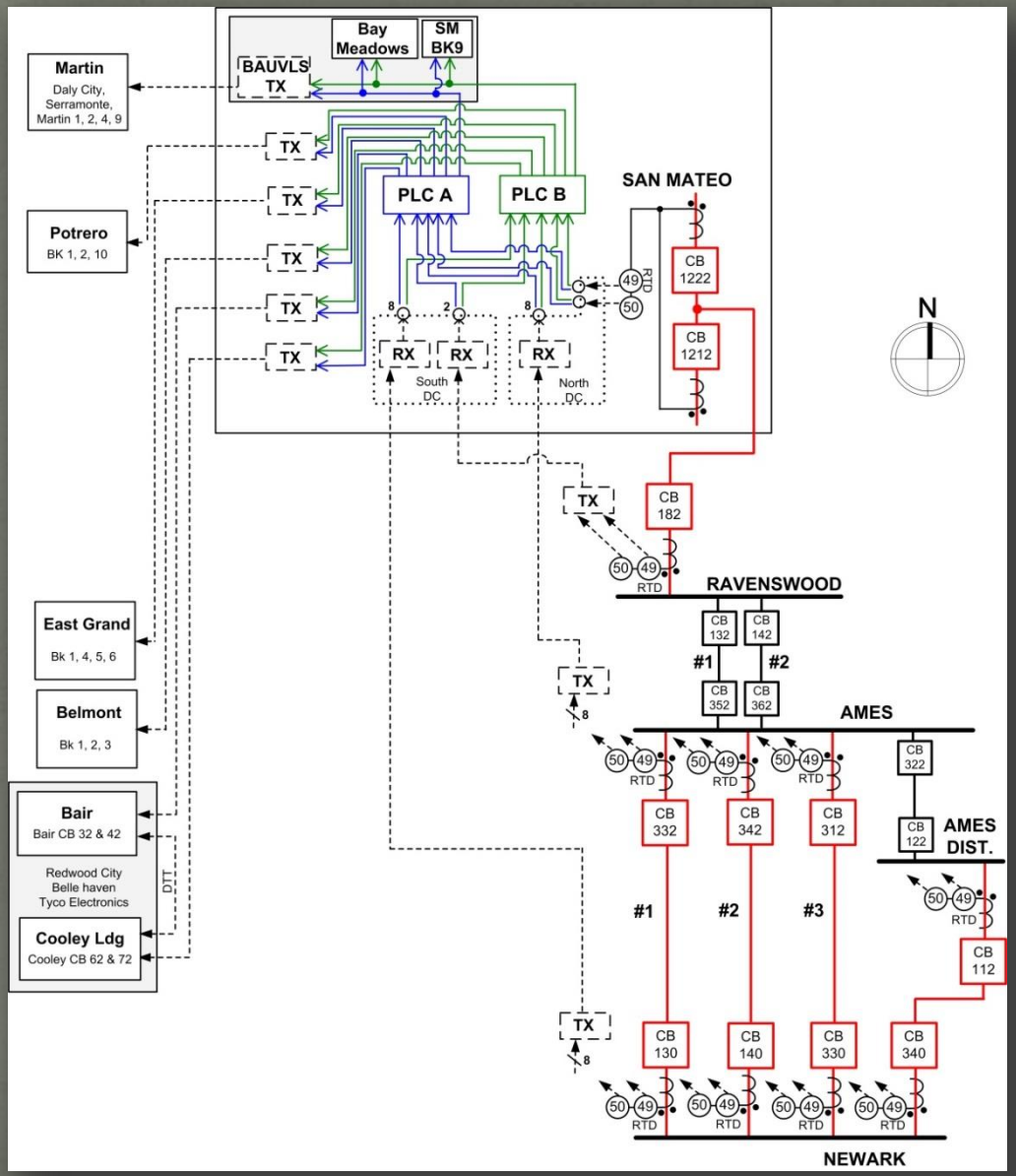
Single Component Failure Considerations (Redundancy)

- Instrumentation Sources
  - CT
  - PT (CCVT) – Secondary's
- Devices
  - Protection System Devices (Relays)
  - Non-Protection System Devices (Computers and PLC's)
  - Aux Devices
- Communication Channels (and Equipment)
- DC Control Circuitry (Up to Breaker Panel)
- Breaker Trip Coil
- Single Battery (Where battery Open and Low Voltage is not monitored)

Examples of Redundancy

Over-Arming

Single Piece of equipment and multiple load group tripping stations



Only PLC has customary "Duplication"

Duplication

Thermal Overload Detection. One at each end of each line

Why a RAS is Needed

- Meet Performance Criteria specified in TPL Standards (Planning). Routine Validation or New Project Evaluation (TPL-001-4 Table 1)
  - Single Line Outage
  - Credible Double Line Outages
  - Stability, Cascading, Overload, Voltage,
  - Etc.
- Increase Path Ratings without infrastructure investment
  - Significant cost savings
  - Faster Implementation
- For reasons beyond NERC criteria (To establish a higher than minimum level of reliability)

Why a RAS is Needed

- Abnormal conditions that require automatic mitigation to maintain system integrity/performance for the following reasons:
  - Speed required for mitigation actions.
    - Throughput Time: Time measured from the Detection of Contingency to the operation of the mitigation actions.
  - Complex & numerous combinations of contingencies make it difficult for a human to process.
  - Contingencies (could be numerous) are pre-defined by studies and are easy for a machine to process.

General RAS Components/Functions

- Identify System Problem (Studied or experienced)
  - Stability, Overload, etc.
- Contingency Detection
  - What triggers the RAS
  - Examples: Line Outage (breaker Seal and UC), Overload (Current or Thermal)
- Arming
  - Scheme Interlocking
  - Examples: Current, Power Flow, etc
- Actions
  - Mitigation – Relief of System Problem
  - Examples: Gen or Load Trip, Gen Run-back, Series Capacitor Bypass, Shunt Capacitor Insertion, Series Reactor Insertion

Types of RAS

- Event Based (Predetermined by Studies)
  - Line Outage at a Measured Path Flow
- Response Based
  - Direct Detect: Such as Thermal Overload
- Combination of both

RAS are unique and customized assemblages of protection and control equipment that vary in complexity and impact on the reliability of the BES.*

*Source: NERC PRC-012-2 Draft 3 (Project 2010-05.3 Phase 3 of Protection Systems: Remedial Action Schemes (RAS))

Types of RAS

- Angular Stability (Fastest) - Cycles
- Voltage Stability (Fast) – Tens of Cycles to Minute
- Overload (Much Slower) – Seconds to Minutes
  - For Security purposes: Protection Engineers tend to Implement schemes to take advantage of the Time Allocation given by the Transmission Planners (Throughput Time Budget)

Stability

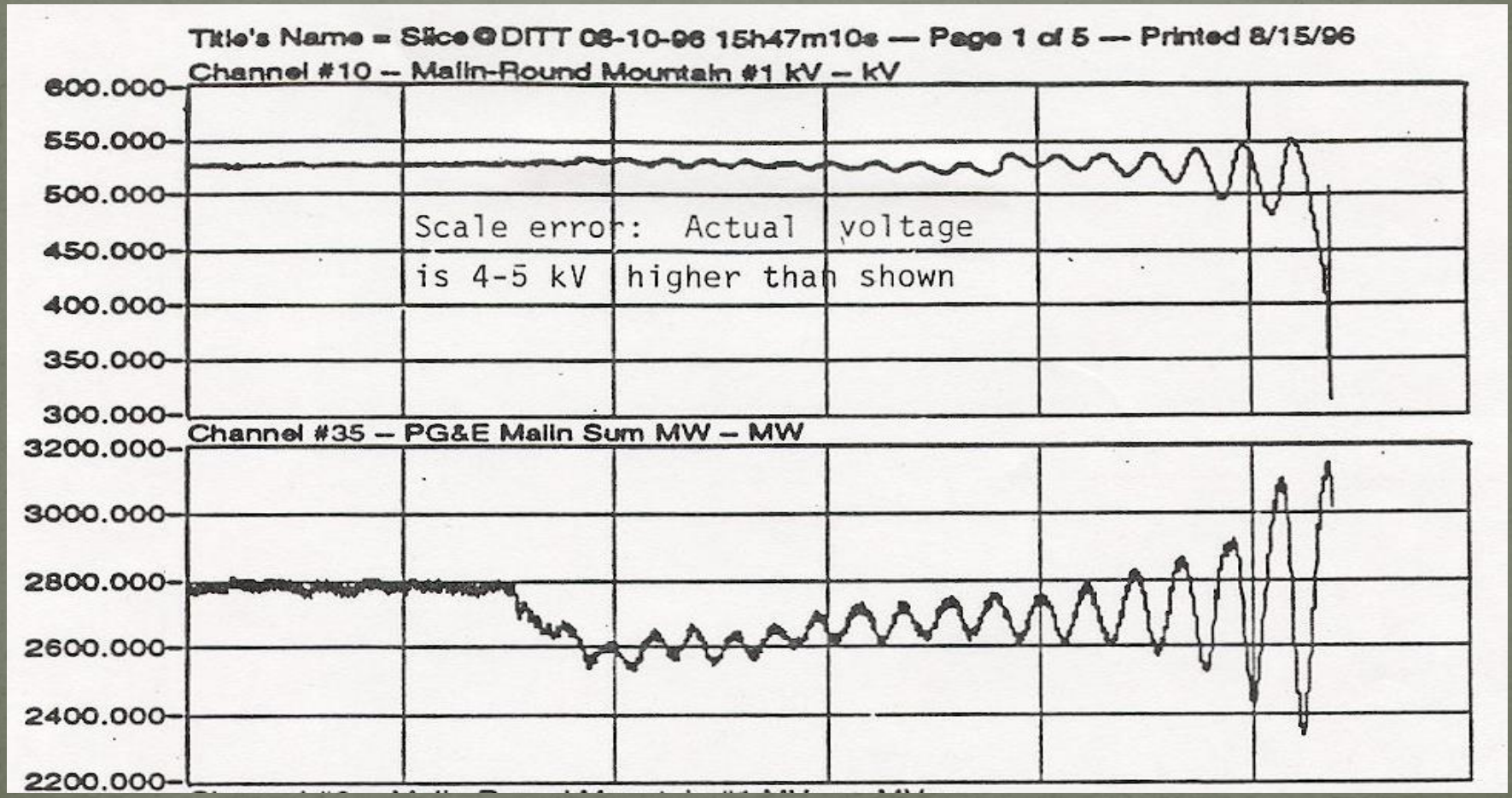
- Angular Stability (Example - Diablo SPS, 500kV PACI-RAS)
  - AKA – Transient Stability
  - Synchronization of Generation with Load
  - Major Cutplanes or "Paths" (possibility of Out of Step – Angular Stability)
    - COI, SRMt, SLB, NMdw, P26
- Voltage Stability (Example – Metcalf SPS)
  - AKA – Post Transient Stability
  - Voltage Decline and Collapse - Lack of reactive support (VAR Margin)
- Risk:
  - Blackout
  - Rotating machines (generators/motors) normally running synchronously together may fall out of synch with one another following a system disturbance.
  - Damage to rotating machines can occur

Stability

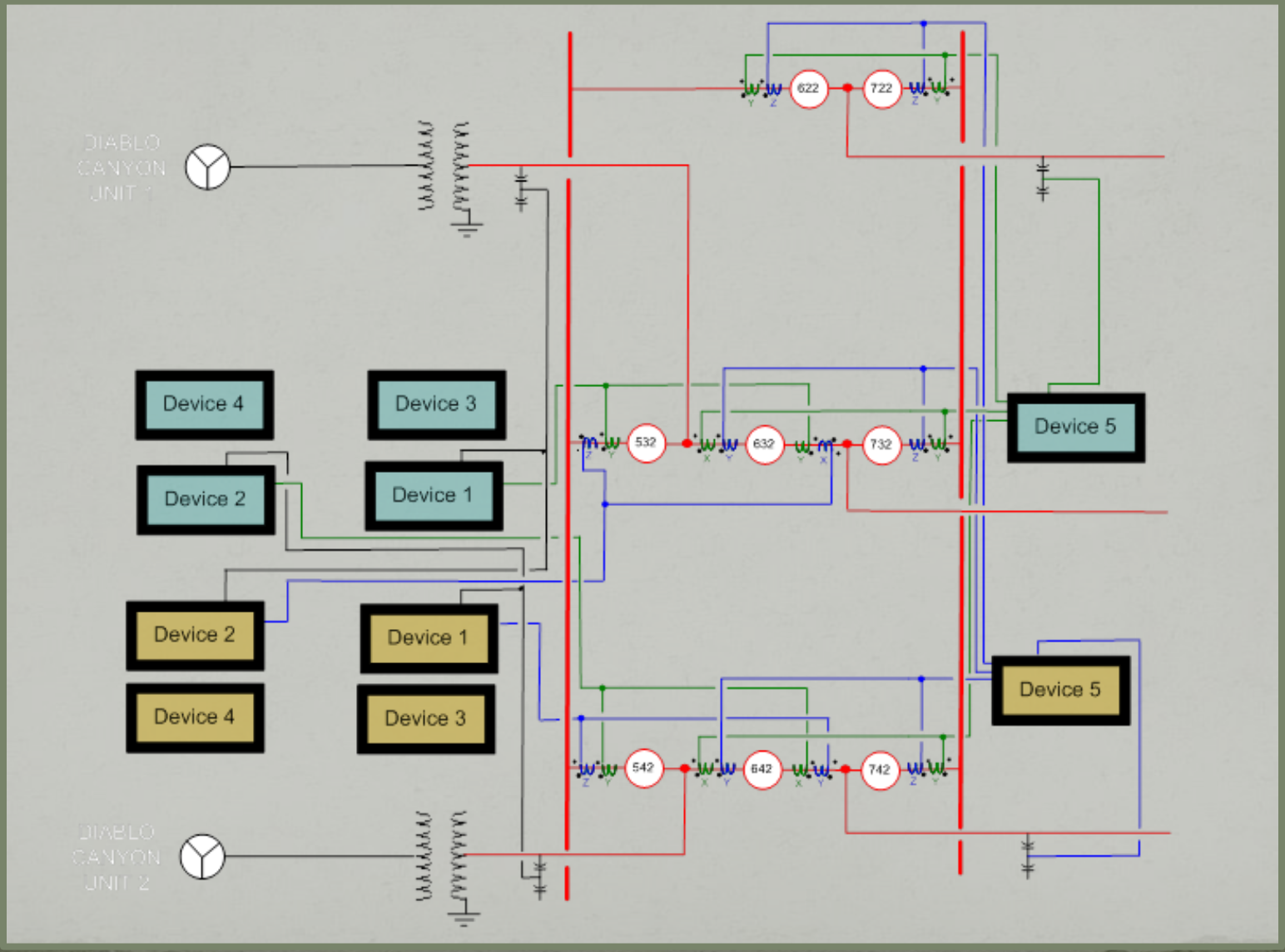
- Methods of Detection:
  - Generally Stability Studies are performed beforehand.
  - Results of studies identify events and contingencies that will result in system stability problems.
  - Contingencies are then monitored for by combination of currents/voltages/CB status.
  - Example: If a contingency is a double 500kV line outage, the currents on the line and breaker status at the terminals of the lines may be monitored to detect the line outages. (or Trip coil monitor if additional speed is necessary.
  - Newer methods may be developed for real time stability evaluation.

Examples of Transient Stability

Stability (NERC Glossary of Terms): The ability of an electric system to maintain a state of equilibrium during normal and abnormal conditions or disturbances.



Stability Scheme Example

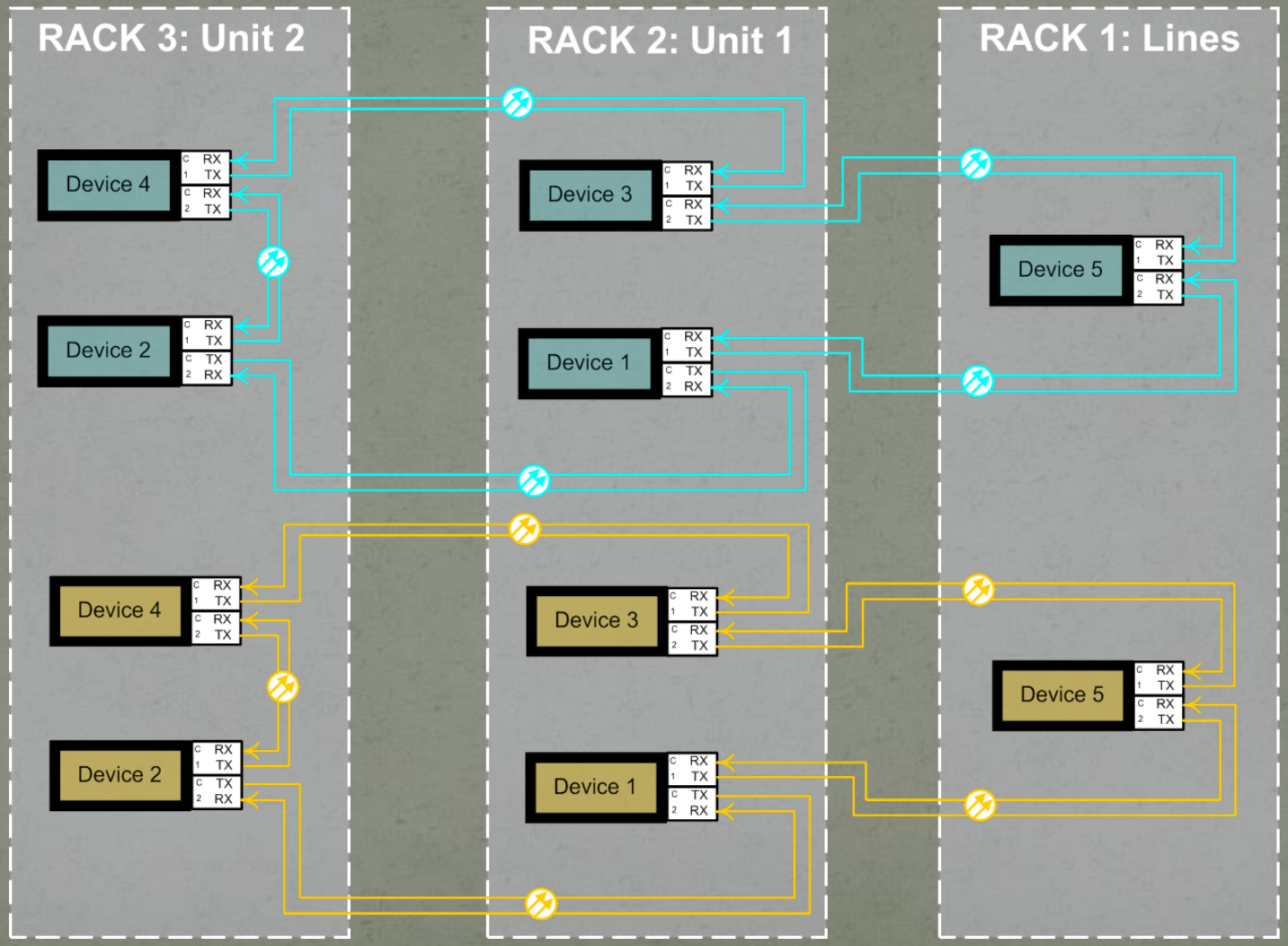


Stability Scheme Throughput Time

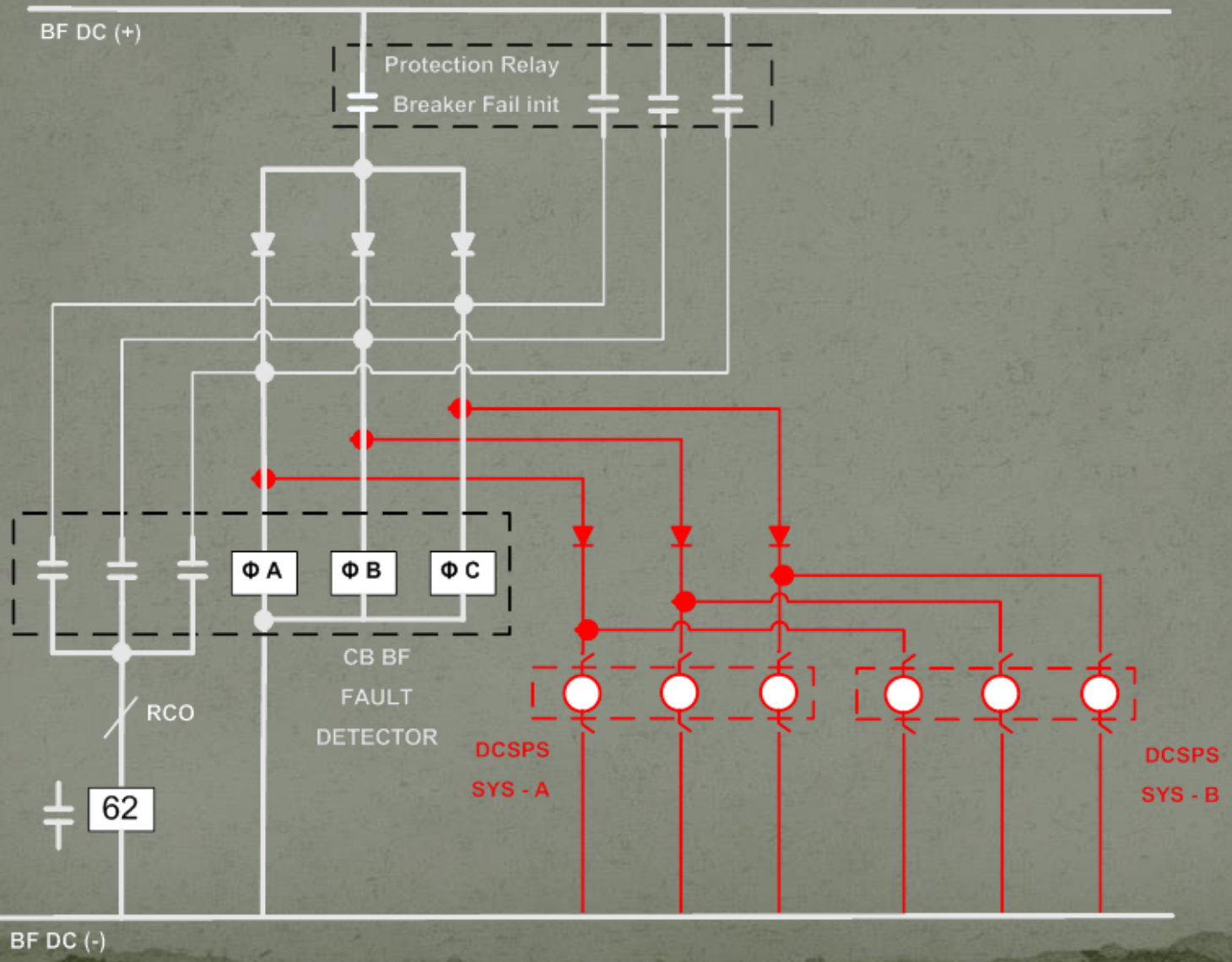
Event Detection & Transient suppression	20	msec
Data Communication	12-16	msec
Logic Execution	2	msec
Trip Decision Transmission	12-16	msec
System Coordination time	12-16	msec
Contact Output Time	4	msec
Total Delay:	**62-74**	**msec**

Field Testing Validates Timing Expectations

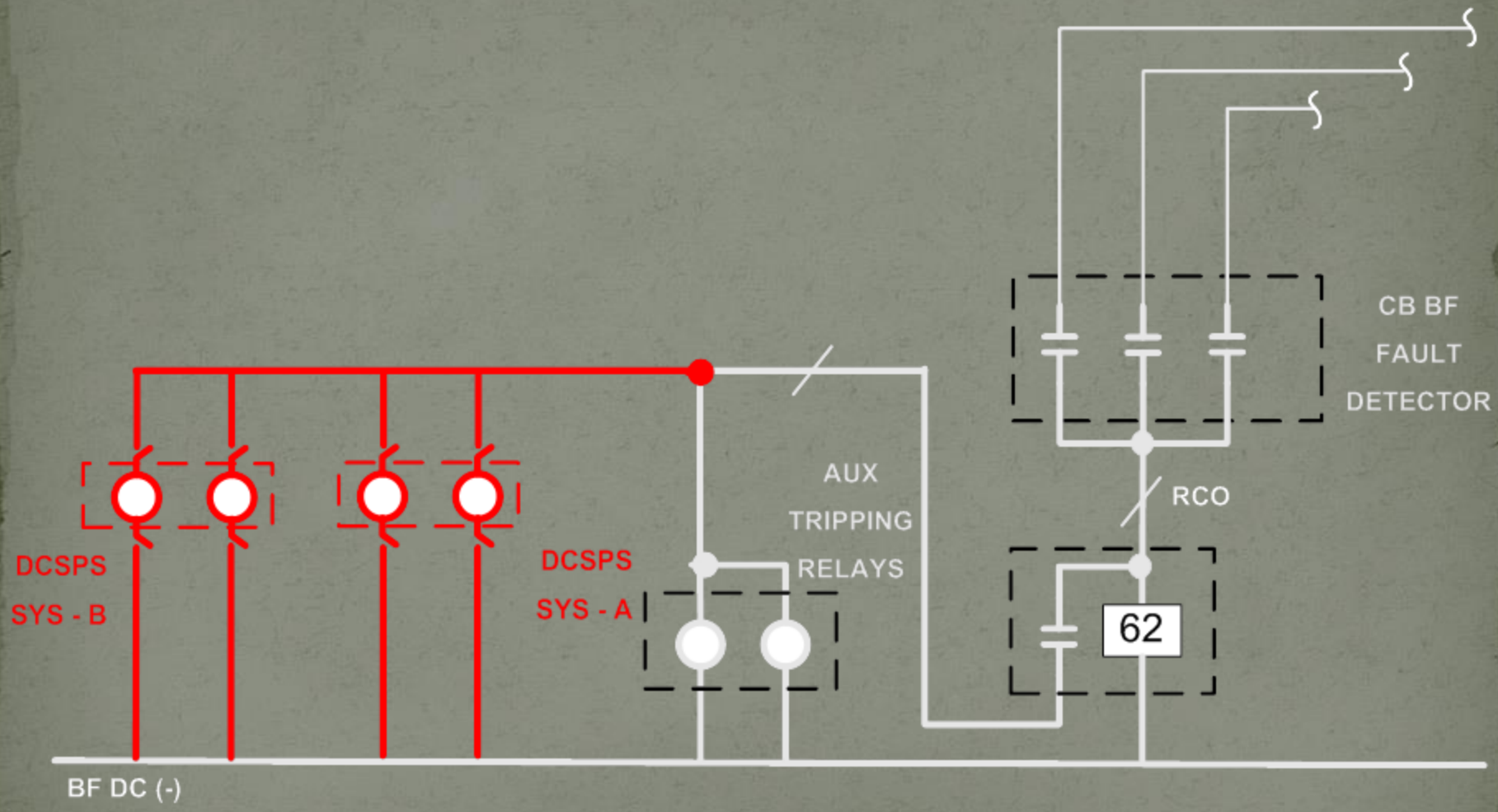
Stability Scheme Example



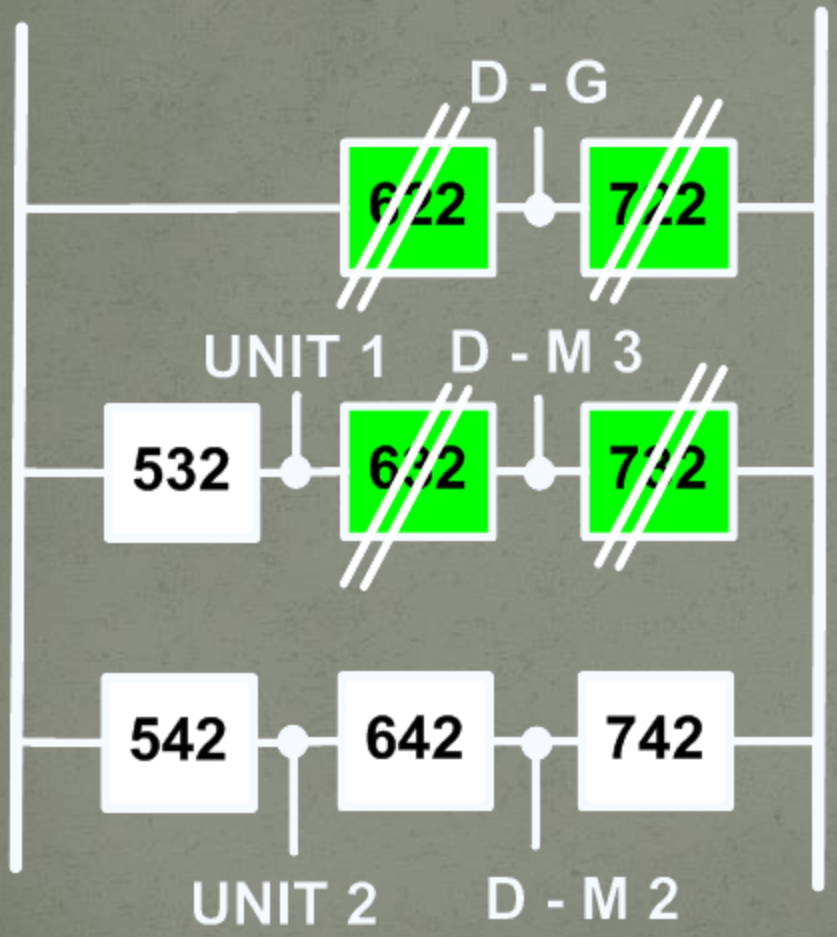
Line Outage Detection (Speed)



Stuck Breaker (BF) Detection



Outage Detection Logic Derivation



642 742 \ 532 542	00	01	11	10
00	N	N	N	N
01	N	N	N	N
11	N	N	U1	N
10	N	N	U1	N

0: Open 1: Closed
N: No Scheme Action
U1: Unit Tripped

Outage Detection Logic Derivation

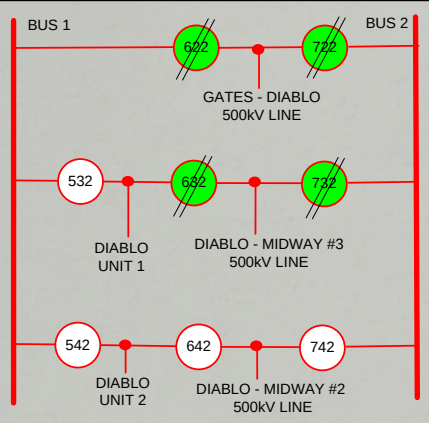
DCSPS Event - 1*x* and 2*x*: Unit Trip Selection as a function of BUS CONFIGURATION

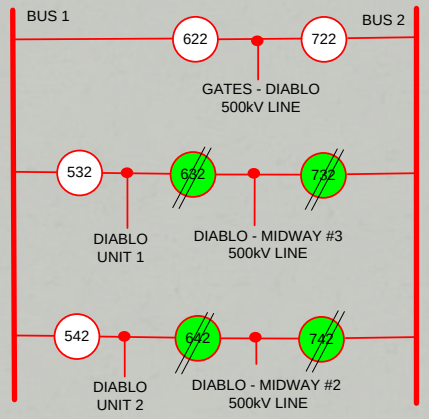
DCSPS EVE-2A
DIABLO - GATES LINE TRIP or OUTAGE
DIABLO - MIDWAY #3 LINE TRIP or OUTAGE
DCSPS EVE-1A
DIABLO - GATES LINE OUTAGE
DIABLO - MIDWAY #3 LINE TRIP
DCSPS EVE-1D
DIABLO - GATES LINE TRIP
DIABLO - MIDWAY #3 LINE OUTAGE

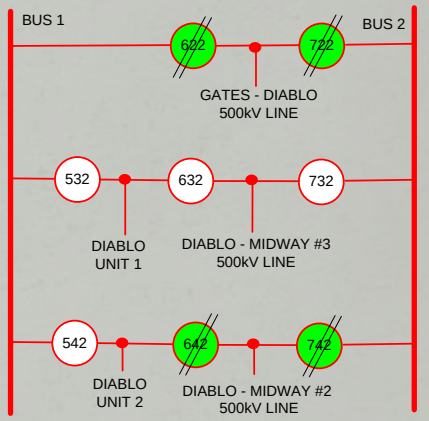
DCSPS EVE-2B
DIABLO - MIDWAY #3 LINE TRIP or OUTAGE
DIABLO - MIDWAY #2 LINE TRIP or OUTAGE
DCSPS EVE-1C
DIABLO - MIDWAY #3 LINE OUTAGE
DIABLO - MIDWAY #2 LINE TRIP
DCSPS EVE-1F
DIABLO - MIDWAY #3 LINE TRIP
DIABLO - MIDWAY #2 LINE OUTAGE

DCSPS EVE-2C
DIABLO - MIDWAY #2 LINE TRIP or OUTAGE
DIABLO - GATES LINE TRIP or OUTAGE
DCSPS EVE-1B
DIABLO - GATES LINE OUTAGE
DIABLO - MIDWAY #2 LINE TRIP
DCSPS EVE-1E
DIABLO - GATES LINE TRIP
DIABLO - MIDWAY #2 LINE OUTAGE

BUS CONFIGURATION AS A FUNCTION OF THE EVENT







UNIT TRIP DECISION AS A FUNCTION OF REMAINING 500kV BREAKER CONFIGURATION

642 742 \ 532 542	00	01	11	10
00	N	N	N	N
01	N	N	N	N
11	N	N	U1	N
10	N	N	U1	N

622 722 \ 532 542	00	01	11	10
00	N	N	N	N
01	N	N	N	N
11	N	N	E	N
10	N	N	E	N

632 732 \ 532 542	00	01	11	10
00	N	N	N	N
01	N	N	N	N
11	N	N	U2	N
10	N	N	U2	N

Scheme Testing

- Design Validation & Commissioning
  - System test – all conditions, all states, all transitions
- Periodic (w/ system out of service)
  - Breaker status information integrity
  - Trip circuit integrity (output contact and associated wiring)
  - BFI detection integrity
  - Aux relay integrity
- Scheme Health
  - System A / System B Consistency Alarm
    - Status & Decisions
  - Communication Alarms
  - Relay Alarms
    - Critical – disable respective system
    - Operation alarm

Scheme Testing (Arming Levels)

INJECT AC QUANTITIES INTO DE-ENERGIZED UNIT DCSPS RELAYS

	Vsec	120				
			U1 MW	U2 MW		
	SETTINGS		1140		Current Injection	
EV1	L1	1808		668	1.86	742.2222
EV2	L2	1790		650	1.81	722.2222
EV3 BF	L3	1723		583	1.62	
	Uvs	0.57				
	Uvm	0.8				
	Vdlos	1.039	311.7 kV		124.68	

Scheme Testing

EVE	Scenario	ARM LEVELS	G→MW2	Test	MW2→G	Test
2	TRIP → TRIP Within 10 sec	MW<L3	No Trip		No Trip	
		L3<MW<L2	No Trip		No Trip	
		L2<MW	U2 TRIP		U2 TRIP	
	TRIP → LLO Within 10 sec	L3<MW<L2	No Trip		No Trip	
		L2<MW	U2 TRIP		U2 TRIP	
	TRIP → ROD Within 10 Sec	L3<MW<L2	No Trip		No Trip	
		L2<MW	U2 TRIP		U2 TRIP	

EVE	Scenario	ARM LEVELS	G→MW3	Test	MW3→G	Test	MW2→MW3	Test	MW3→MW2	Test	UNIT SEL SW
2	TRIP → TRIP Within 10 sec	MW<L3	No Trip		No Trip		No Trip		No Trip		
		L3<MW<L2	No Trip		No Trip		No Trip		No Trip		
		L2<MW	U1 TRIP		U1 TRIP		U1 TRIP		U1 TRIP		Unit 1 Selected
							U2 TRIP		U2 TRIP		Unit 2 Selected
	TRIP → LLO Within 10 sec	L3<MW<L2	No Trip		No Trip		No Trip		No Trip		
		L2<MW	U1 TRIP		U1 TRIP		U1 TRIP		U1 TRIP		Unit 1 Selected
							U2 TRIP		U2 TRIP		Unit 2 Selected
	TRIP → ROD Within 10 Sec	L3<MW<L2	No Trip		No Trip		No Trip		No Trip		
		L2<MW	U1 TRIP		U1 TRIP		U1 TRIP		U1 TRIP		Unit 1 Selected
							U2 TRIP		U2 TRIP		Unit 2 Selected

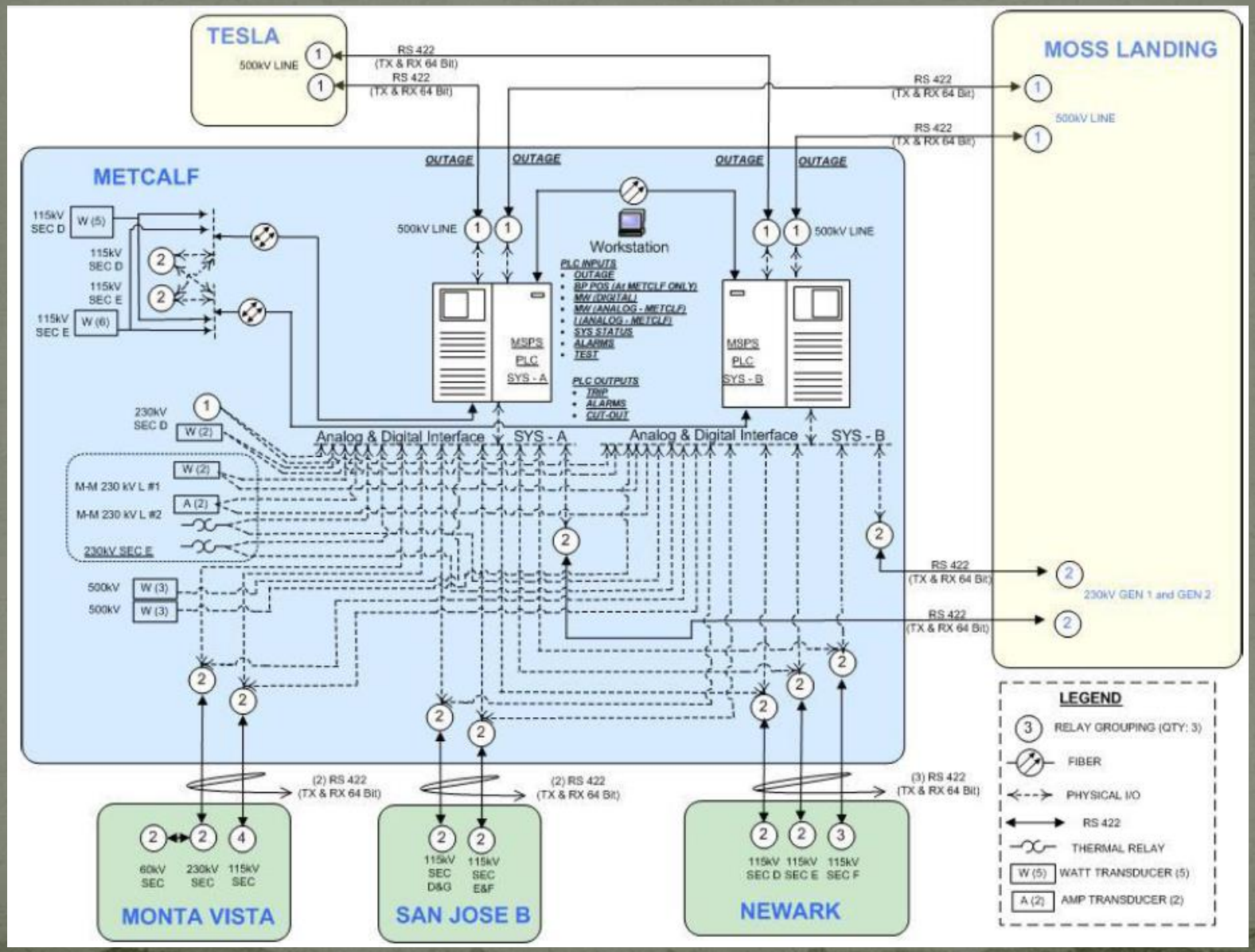
Overload

- Operating Power System equipment above its rated capacity.
- Risk
  - Thermally overloaded lines will develop excessive sag. The conductors' sag in turn will increase the risks of faults from contact with nearby objects. Depends on amount and duration of overload.
  - Causes equipment degradation and accelerated loss of life or failure.
- Typical Cause:
  - Removal of faulted elements re-directs power flows through other BES elements.
    - Example 1: Two banks in parallel. Removal of one bank forces remaining bank to carry all of the load.
    - Example 2: Loss of a line will redirect flows to other lines or a parallel path

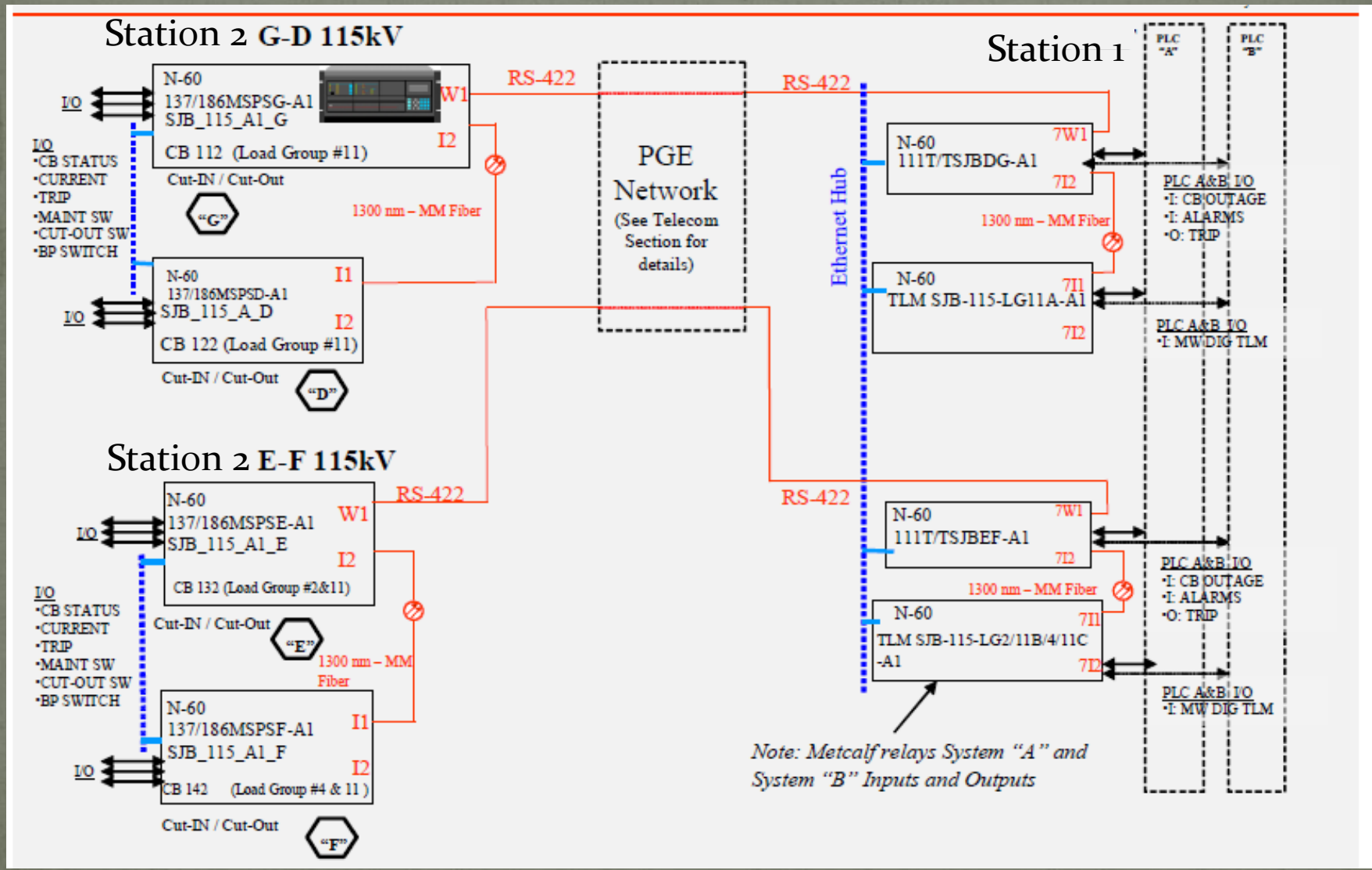
Overload

- Methods of Detection:
  - Overcurrent
    - Non-Directional
    - Directional
  - Thermal relay using a mathematical model.
  - Thermal relay using a mathematical model with additional Overcurrent supervision.
  - Sag monitoring
  - Tripping or loss of a line or path
  - Combination of above.

Voltage Stability and Overload



Segmented Testing (2 segments)



Segmented Testing
Overlap point when Testing Components

Segmented Testing
System A and System B Testing

Date(s): PLANNED: JANUARY 2015

Project (need for Test): PRC-017
Station and Bus Section Station A
Circuit #: N/A

Measure (not needed for this test)

System A Time: **N/A msec** round trip delay

System B Time: **N/A msec** round trip delay

Test Selection

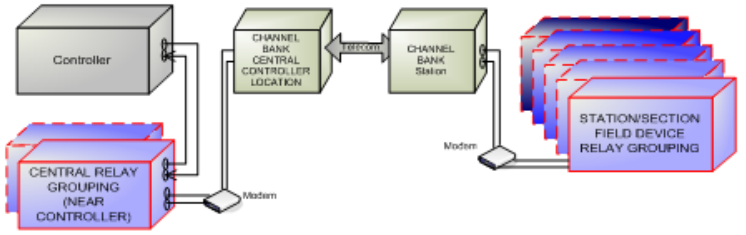
- ○ Commission Testing
- ◉ PRC-017

Testers

Name

Central Location (Relay Group)

Name: ()	Station 1
#1 Device # DD8	Device 1
#2 Device # DD7	Device 2
#3 Device #	N/A
#4 Device #	N/A
#5 Device #	N/A
#6 Device #	N/A



Station

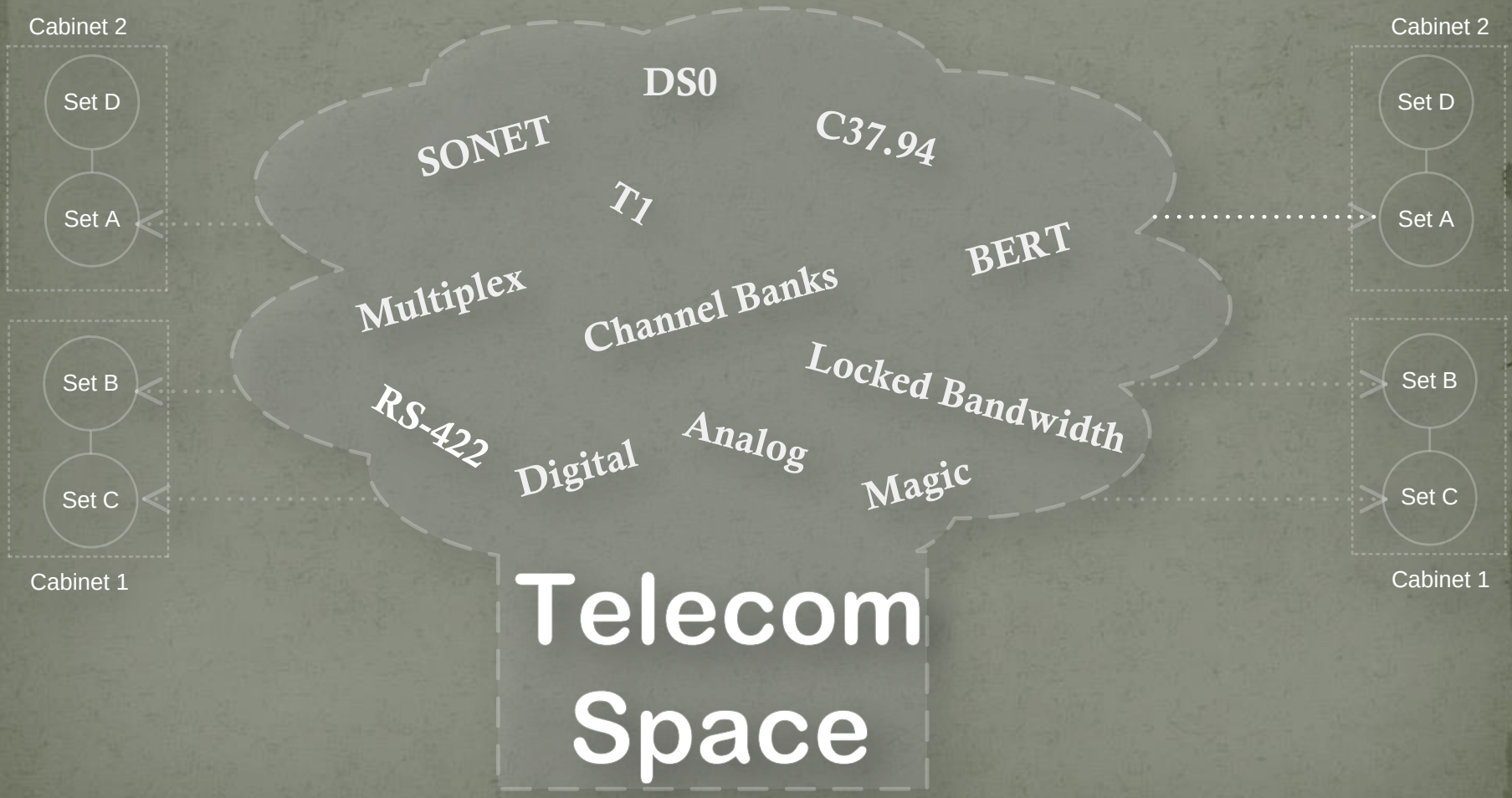
Station/Section Nam	Station 2
#1 Device # DD1	Device 1
#2 Device # DD2	Device 2
#3 Device #	N/A
#4 Device #	N/A
#5 Device #	N/A
#6 Device #	N/A

Step	METCALF Date Complete	METCALF Tester	Station/Section Date Complete	Station/Section Tester	Description

Test documentation Example (Bi-Directional Data)

PRC-005, PRC-017, PRC-012-2 R8 (Future)

Protection Engineer Perspective on Telecommunication Infrastructure



Expectations on Telecommunication Infrastructure

- Alarms should be logged by endpoint devices

WECC: Communication System Performance Guide for Electric Protection Systems

WECC TelWG

(WG under Technical Operations Subcommittee)

Table 2 – Protection Function Performance Recommendations - Availability and Delay

Level	Protection Application	Performance Recommendation for each Function [1]		
		Protection System	Communications Component	Relaying Component
1	A BES transmission line or RAS; typically for 300 kV and above, HVDC, and those facilities defined as "critical" by the utility. Requires two redundant, fully-diverse, independent communications channels.	Min Availability 99.93% For combination of dual, diverse systems	Min Availability 99.95% For combination of dual, diverse systems	Min Availability 99.98% For combination of dual, diverse systems
		Max End-to-End Delay 25.0 msec	Max End-to-End Delay 16.7 msec [2][4]	Max End-to-End Delay 8.3 msec
2	A BES transmission line or RAS; typically between 200 kV and 300 kV. Redundancy may be used to meet recommended availability.	Min Availability 99.88%	Min Availability 99.90%	Min Availability 99.98%
		Max End-to-End Delay 33.3 msec	Max End-to-End Delay 16.7 msec [2][4]	Max End-to-End Delay 16.7 msec
3	A BES transmission line or RAS; typically below 200 kV. Redundancy is typically not required to meet recommended availability.	Min Availability 99.48%	Min Availability 99.50%	Min Availability 99.98%
		Max End-to-End Delay 67 msec	Max End-to-End Delay 33.3 msec [2][4]	Max End-to-End Delay 33.3 msec

[2] For RAS, communication delays are based on the system studies and the overall requirements of the system.

Protection Engineer Expectations on Telecommunication Infrastructure

- Digital circuit Bit Error Rate (BER)
  - Determine BER setting and verify relays alarm for “channel failure” at that BER test value
  - Verify that Channel Banks alarm when appropriate
  - Verify device sequence of events accurately captures accounting of channel down time
  - Verify channel fail alarms will be available to operators.
- Variable Channel Delays
  - Establish maximum channel delay value
  - Locked Bandwidth?
  - If not locked: SONET switching - 50 msec hits (digital circuits)
- Channel bank failures
  - Disable channel bank cards and document response of relays. (Verify relay communication channel failure)
  - Verify Alarm can be received and documented by Telecom maintenance organization and Operators

Channel Availability Calculations

	A	G	H	J
1	1	8/29/2015 14:53:11.625	EVENTS CLEARED	02 0:48:48.375
2				
7	102	8/30/2015 10:25:16.724	Ames-Nw1 RFL Off (CI5)	
10	105	8/30/2015 10:25:35.483	Ames-Nw1 RFL On (CI5)	99.98933%
11				
12				
13	168	8/30/2015 10:36:15.333	Ames-Nw2 RFL Off (CI9)	
16	171	8/30/2015 10:36:36.382	Ames-Nw2 RFL On (CI9)	99.98802%
17				
18				
20	137	8/30/2015 10:28:23.674	Ames-Nw3 RFL Off (CI15)	
22	139	8/30/2015 10:28:43.459	Ames-Nw3 RFL On (CI15)	99.98874%
23				
24	165	8/30/2015 10:31:36.100	Bair RFL Off (CI51)	
25	167	8/30/2015 10:31:55.264	Bair RFL On (CI51)	99.98909%
26				
27	186	8/30/2015 12:33:34.741	Martn RFL Off (CI60)	
30	189	8/30/2015 12:33:53.481	Martn RFL On (CI60)	99.98934%
31				
32				
93	319	8/31/2015 10:19:39.878	Nw-Ames1 RFL Off (CI25)	
94	322	8/31/2015 10:19:55.510	Nw-Ames1 RFL On (CI25)	
95				99.96597%
96				
157	318	8/31/2015 10:19:39.660	Nw-Ames2 RFL Off (CI30)	
158	325	8/31/2015 10:19:56.840	Nw-Ames2 RFL On (CI30)	
159				99.96507%

Thank you…

Questions ?