Remedial Action Schemes; ASSETS & STANDARDS

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REMEDIAL ACTION SCHEMES; ASSETS & STANDARDS

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Northwestern Division
U.S. Army Corps of Engineers

July 16-18, 2024

U.S. ARMY

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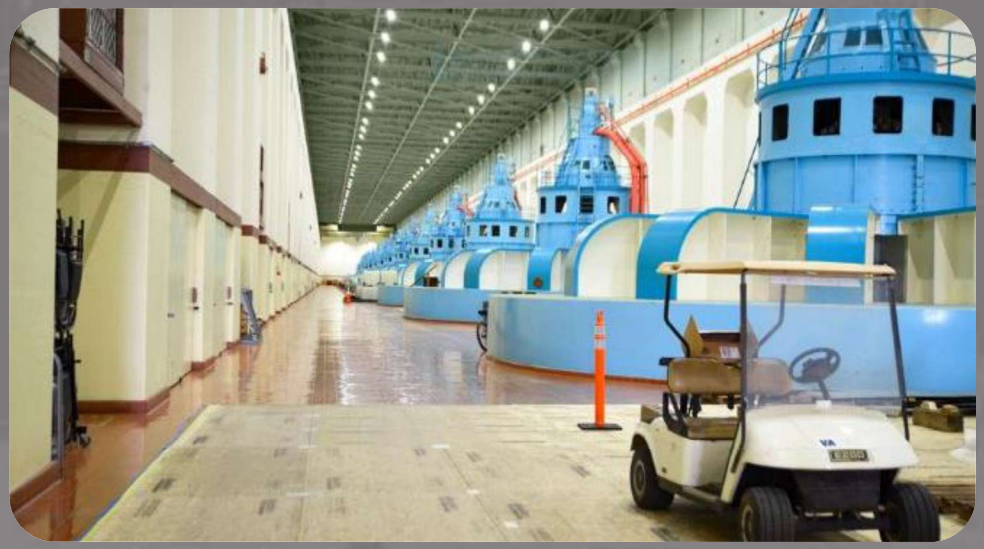
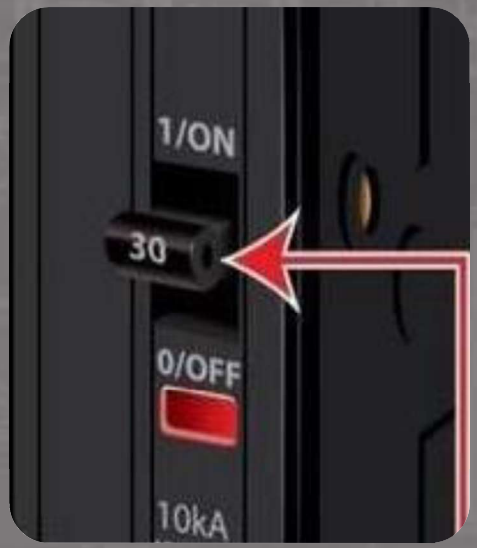




SPEAKER BACKGROUND: TATYANA

ASU - BSEE, MSE Coursework

SRP - Phoenix AZ – Senior Engineer in Transmission Planning/Operations, Apparatus, Senior Analyst in Corporate Pricing

BPA - Vancouver, WA - Electrical Engineer, Operations

PacifiCorp - Portland, OR - Supervisor, Operations

USACE, Northwestern Division, Operations/Regulatory

- HydroPower Planner, Electrical Engineer
- Asset Planning Team and Regional Acquisition NWD Chair

NORTHWESTERN DIVISION HYDROPOWER FACILITIES

Missouri River Basin

Main Stem

FORT PECK DAM, MT	1940
GARRISON DAM, ND	1953
BIG BEND DAM, SD	1963
FORT RANDALL DAM, SD	1954
GAVINS POINT DAM, SD	1958
OAHE DAM, SD	1966

Osage River, MO

HARRY S TRUMAN DAM	1978

Sac River, MO

STOCKTON DAM	1969

Columbia River Basin

Main Stem

BONNEVILLE LOCK & DAM, OR	1937
JOHN DAY LOCK & DAM, OR	1968
THE DALLES LOCK & DAM, OR	1957
MCNARY LOCK & DAM, OR	1954
CHIEF JOSEPH DAM, WA	1955

Willamette River, OR

DEXTER DAM	1955
HILLS CREEK DAM	1962
LOOKOUT POINT DAM	1953

Santiam River

GREEN PETER DAM	1967
BIG CLIFF DAM	1953
DETROIT DAM	1953
FOSTER DAM	1967

Snake River

ICE HARBOR LOCK & DAM	1962
LITTLE GOOSE LOCK & DAM	1970
LOWER GRANITE LOCK & DAM	1975
LOWER MONUMENTAL LOCK & DAM	1969

Boise River, ID

LUCKY PEAK DAM & LAKE	1955

Clearwater River, ID

DWORSHAK DAM	1973

Pend Oreille River, ID

ALBENI FALLS DAM	1955

Kootenai River, MT

LIBBY DAM	1973

Rogue River, OR

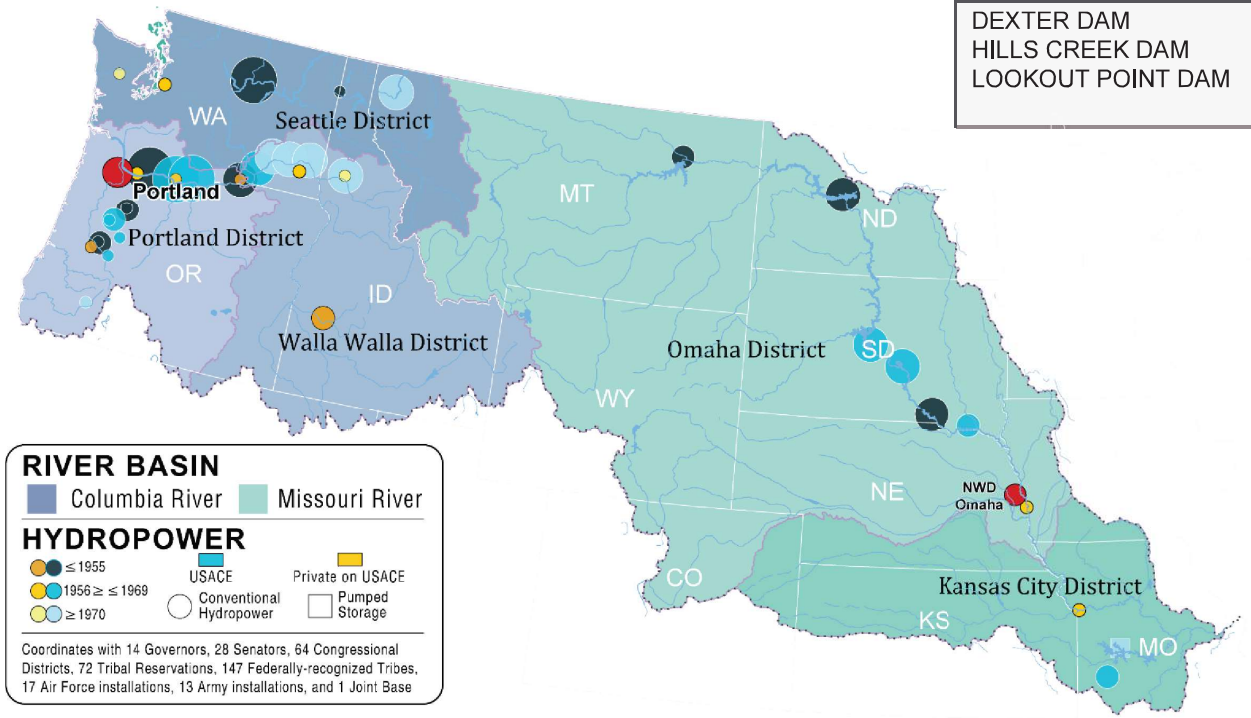
WILLIAM L. JESS DAM	1976

Fall Creek, OR

FALL CREEK DAM	1965

S. Fork McKenzie River, OR

COUGAR DAM	1963



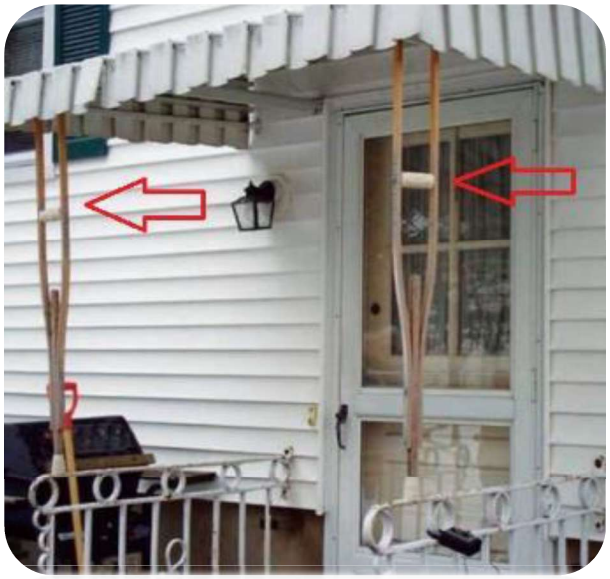
OVERVIEW

- What is a RAS?
- RAS – NERC Definition and Objectives
- What is NOT a RAS?
- NERC/WECC Standards and new PER 006-1
- 3 Part Communication and Operating Instructions
- RAS or Other Alternatives
- RAS Categories, Testing
- Logical Components of a RAS Scheme
- RAS Assets and Failure Modes
- RAS Controllers
- Common RAS Problems
- QUIZ!

WHAT IS A RAS – REMEDIAL ACTION SCHEME?

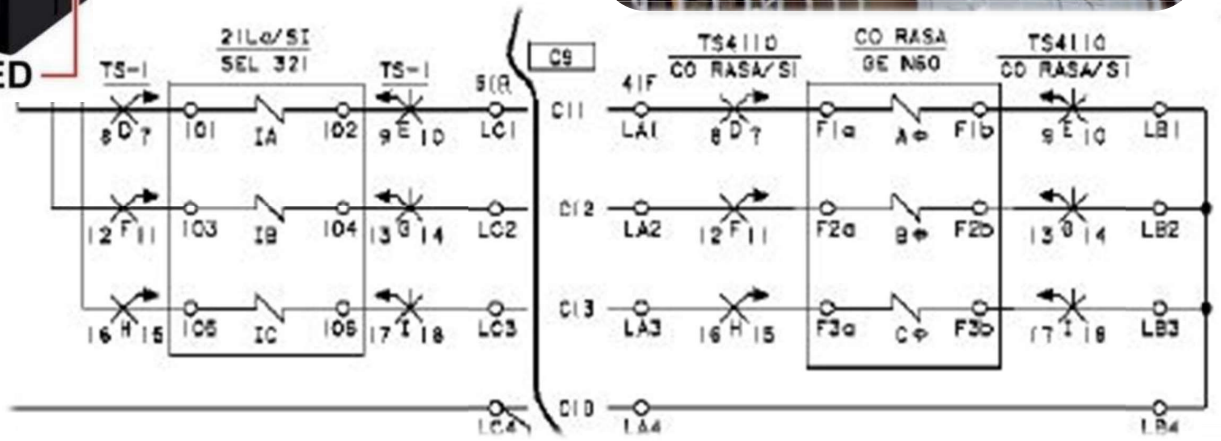
Remedial

– **Remedy** – keeps system stable in an event of a disturbance



Action

– **Action** – trip generators;
Insert capacitors, reactors,
Braking resistor



Scheme

– **Scheme** – breakers, relays, wires

RAS OBJECTIVES AND NERC DEFINITION

- Remedial Action Schemes (RASes) accomplish these OBJECTIVES:
  - **Limit** the impact of **Cascading** or **Extreme Events**
  - Maintain acceptable Bulk Electric System power flows
  - Maintain acceptable BES voltages
  - Maintain acceptable BES Stability
  - Meet NERC Reliability Standards Requirements

- NERC Definition - RAS: 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
  - Reconfiguring a System(s)

WHAT IS NOT A RAS?

- Automatic reclosing schemes; Operator initiated auto sequences
- Controller related schemes (series/shunt/FACTS devices)
- Fault Conditions isolated with standard relaying schemes
- Out of step tripping and power swing blocking
- Schemes used for non fault conditions
- Sub-synchronous resonance schemes
- Underfrequency or undervoltage load shedding
- Typical Generator Controls – AGC, AVR, PSS

RASRS Report to Operating Committee

June 25-26, 2019

Gene Henneberg

SUMMARY - MAIN NERC STANDARDS APPLICABLE TO RAS SCHEMES

- **PRC – 002-2:** Generator Owner should have adequate data to facilitate analysis of BES disturbances (SER data for breakers connected to BES buses, etc.)

- **COM – 002-4:** Generator Owner should have adequate/improve communications for the Issuance of Operating Instructions with predefined communications protocols to reduce the possibility of miscommunication that could lead to action/inaction harmful to reliability of the BES

- **PRC-004-6** Generator Owner should ensure that all Mis-operations are analyzed/mitigated; causes identified and corrected

- **PRC-005-6:** To document and implement programs for the maintenance of all Protection Systems, Automatic Reclosing, and Sudden Pressure Relaying affecting the reliability of the Bulk Electric System (BES) so that they are kept in working order; Generator owners – Protection System maintenance and testing **PLAN** if own generator, generator interconnection facility, RAS, sudden pressure, auto-reclosing that affects the reliability of the BES. Main point - You need a plan!

- **PER-006-1:** To ensure that personnel are trained on specific topics essential to reliability to perform or support Real-time operations of the Bulk Electric System

- **PRC-012-2**: Designing RAS, filing for approval with the RC, and analyzing RAS events to ensure RAS schemes don't introduce unintentional or unacceptable risks to the BES (Generator Owner)

NERC STANDARDS CONTINUED; PRC 001-1 RETIREMENT

- **PRC-015-1 –** To ensure that all Remedial Action Schemes (RAS) are properly designed, meet performance requirements, and are coordinated with other protection systems. To ensure that maintenance and testing programs are developed, and mis-operations are analyzed and corrected

- **PRC – 016-1, PRC 017-1** - To ensure that all Remedial Action Schemes (RAS) are properly designed, meet performance requirements, and are coordinated with other protection systems

- To ensure maintenance and testing programs are developed and Misoperations are analyzed/corrected

- *PRC 001 -1 Retired on 9/30/20: Generator Operator(GO) should be familiar with Purpose and Limitations of Protection System Schemes applied in its area. GO provides a list of protection schemes/RAS that can affect the BES for future PER-006-1 Audit. Generator Operator notifies TO, BA, RC of equipment failure and corrective actions during as soon as possible*
  - *Need to be able to provide evidence that could include but is not limited to, revised fault analysis study, letters of agreement on settings, notifications of changes, or other equivalent evidence that will be used to confirm that there was coordination of new protective systems or changes*

NERC STANDARDS PER – 006 -1 – QUICK OVERVIEW - 1

- **PER – 006-1** - To ensure that personnel are **trained** on specific topics essential to reliability to perform or support Real-time operations of the Bulk Electric System

- WHO?: Plant personnel who are responsible for the **Real-time control** of a generator and receive **Operating Instruction(s)** from the Generator Operator's Reliability Coordinator, Balancing Authority, Transmission Operator, or centrally located dispatch center

- You will need **recorded evidence** of your training, who, when, purpose of training, what were the training topics

- This DOES NOT apply to fuel, coal handlers, electricians, machinists, maintenance staff NERC staff guidance - supervisor who is NOT responsible for real-time control of a generator, should pass the phone to a person who is responsible for real-time control to receive the operating instruction

NERC STANDARDS PER – 006 -1 – QUICK OVERVIEW - 2

- **OPERATIONAL FUNCTIONALITY TRAINING** - how Protection Systems operate and prevent possible damage to Elements; how RAS detects pre-determined BES conditions and automatically takes corrective actions
- Purpose of protective relays and RAS
- Zones of protection
- Protection communication systems (e.g., line current differential, direct transfer trip, etc.)
- Voltage and current inputs
- Station dc supply associated with protective functions
- Resulting actions –tripping/closing of breakers; tripping of a generator step-up (GSU) transformer; or generator ramping/tripping control functions

NERC STANDARDS PER – 006 -1 – QUICK OVERVIEW - 3

- **OPERATIONAL FUNCTIONALITY TRAINING** - how Protection Systems operate and prevent possible damage to Elements; how RAS detects pre-determined BES conditions and automatically takes corrective actions

- This does not mean that a generation operator now needs to be an RC or a TO (NERC license)
- Do not need actual one lines for the training
- If you already have training modules that follow Systematic Approach to Training (NERC term) **use them**
- There is no requirement that this training be periodic, only when systems change, then new training is required. But it's obvious that the operators need training on operating instructions

Don't worry about training on auxiliary loads

OPERATING INSTRUCTIONS HYPOTHETICAL EXAMPLE

COM-002-4 OPERATING PERSONNEL COMMUNICATIONS PROTOCOLS

3 PART COMMUNICATIONS:
Part 1: Sender clearly **DELIVERS** the message
Part 2: Receiver **REPEATS** message (not necessarily verbatim)
Part 3: Sender **CONFIRMS** "correct" (or reissues message)
Time: 1445

BA or Control Center Operator/Dispatcher: This is Dispatcher Dhaliwal; I am about to issue you an operating instruction. I will be utilizing 3-part communications. I see your units at Happy MW plant are at 650 MW right now.

Plant Operator: This is USACE(USBR) Plant Operator Smith: I heard that you are about to issue an operating instruction using 3-part communication, for the Happy MW plant, please proceed.

BA or Control Center Operator/Dispatcher : This is Dispatch. I am issuing you an Operating Instruction to restrict Happy MW Powerhouse Units. Please go from total output of 650 MW to 400 MW on Powerhouse units 1 and 2 at 1500 until further notice due to a transmission outage.

Plant Operator : This is USACE (USBR) Happy MW plant operator Smith. I confirm that at 1445, I have received an Operating Instruction from Dispatch to restrict the total output of Happy MW Units 1 and 2 to 400 MW at 1500 until further notice.

BA or Control Center Operator/Dispatcher : That is correct.

COM-002-4 OPERATING PERSONNEL COMMUNICATIONS PROTOCOLS

- **NERC Guidance: Use 3-part communications whenever discussing condition of equipment in the field (open, closed, failed) or the value of an important field parameter**

- Operating Instructions are not optional unless they 1) Violate Safety 2) Violate Equipment Ratings 3) Violate Regulatory Requirements 4) Violate Statutory Requirements
- RC/BA/TO will issue instructions in clear, concise, definitive manner
- Plant operator needs to verbally confirm the operating instruction, if the operator did not understand the instruction; he/she should ask “please re-issue the operating instruction”

- **If the plant operator did not confirm the instruction correctly, the RC/BA/TO will respond “You are wrong” (this is what NERC suggests, since “incorrect” and “correct” sound alike)**

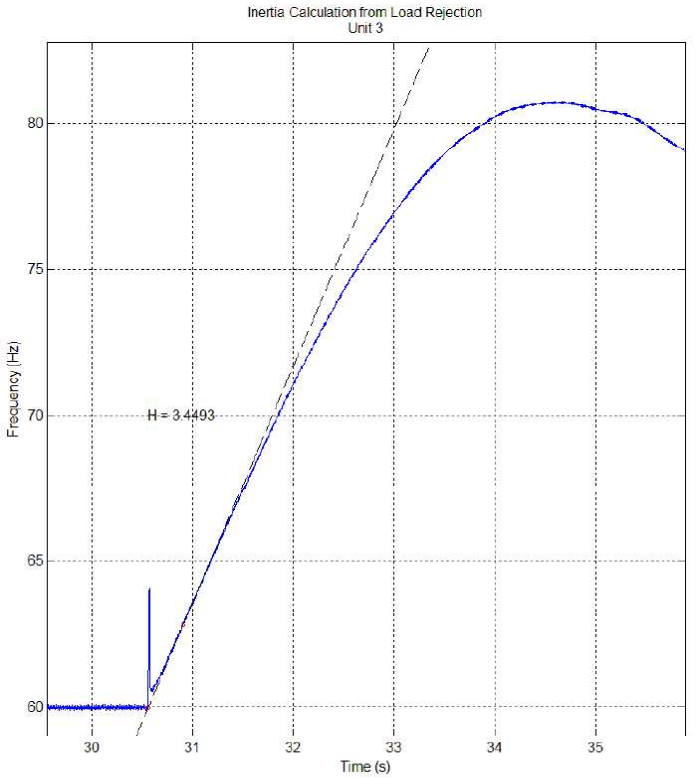
- If the plant operator is unable to perform a confirmed instruction, the operator must state: “I am unable to perform this instruction”; and then explain the reason in a timely manner

RAS OR $ OTHER ALTERNATIVES$?

- RAS helps balance load and generation after a loss of either
- A RAS scheme enables faster post disturbance restoration
- A RAS scheme helps respond to low probability events in the system
- Increases overall system reliability
- A RAS alternative can increase path capacity, no need to bundle or build more power lines
  - $1 Million spent on RAS versus $200 million spent on a new transmission line
  - Operating transfer capability on a path could quadruple with a RAS
  - A RAS alternative may allow a transmission planner (TO/BA) to maximize transmission capacity to facilitate a generation interconnection without adding additional infrastructure
- Helps meet project schedules

GENERATOR CONCERNS – IMPACTS

- RAS action causes a load rejection by tripping the generator
  - This is an overspeed event – the turbine-generator will accelerate until the governor closes the wicket gates enough to arrest the acceleration
  - This also can cause a short-duration overvoltage on the stator winding, depending on original loading and excitation performance
  - Increased breaker cycling may lead to increased maintenance cycles
  - Increased generator thermal cycling may lead to reduced lifespan (not specifically proven, but possible)
- Because RAS seeks to arrest specific system events, it may burden some plants more than others
  - Critical plants – those located at specific intertie points or on key transmission routes – will see heavier RAS arming than small or less critically located plants
  - Creates more operator action to re-synchronize the plant
  - Increased maintenance cycles if maintenance is operation-based (breakers)



- Example load rejection with 36% speed increase
- Speed may increase to 200% of rated speed

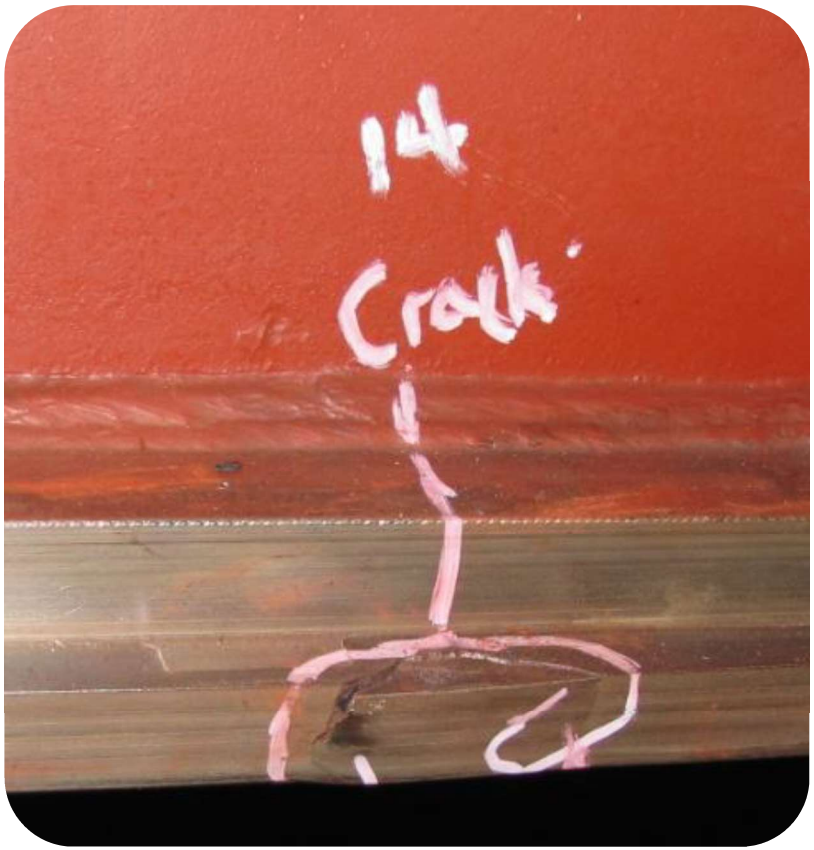
GENERATOR CONCERNS – WHEN NOT TO USE

– RAS arming should be rejected for certain generators

- Generators with known rotor stress concerns
- Generators with known gate linkage stress concerns

– A broken generator isn't useful to anyone

- Units with known stresses that are elevated by overspeed events should not be subjected to additional trip events



RAS CATEGORIES

- **Wide Area Protection Scheme (WAPS)** with a 2-year test interval, failure to operate would result in:
  - TPL-001-WECC-CRT-4 (Planning Criteria for System Performance) Violation OR
  - Load Loss >=300 MW OR
  - Generation Loss >=1000 MW

- **Limited Impact RAS** – (previously, Local Area Protection Scheme - LAPS) with 12-year test interval – Limited Impact RAS failure to operate would NOT result in the items listed above

- **Safety Net** (no requirement on test interval) – Extreme Events. No WECC requirement on periodicity of testing

PROBLEMS TO MITIGATE AND RAS DESIGN

- **Thermal** (ex. Line Overloads) – required to mitigate in minutes

- **Voltage Stability** – seconds to minutes
  - High voltage lines loaded above their SIL (Surge Impedance Loading) act like a reactor by pulling the voltage down, which creates voltage collapse risk
  - Generation drop and reactive switching are a RAS action to maximize transfer capability

- **Transient Stability** – cycles to seconds – Loss of parallel transmission lines increases system impedance, which requires a higher power angle to transmit the same amount of power. At higher angles, the system is stressed. RAS is required in 8-30 cycles to maintain a stable system

LOGICAL COMPONENTS OF A RAS SCHEME (ANALOGY)

- **P**roblem to mitigate – issue that needs to be reduced or eliminated

- **A**rming Condition – **RAS "on the lookout" to operate if present**

- **T**rigger Condition – causes the scheme to operate if armed

- **O**perate – what the scheme does to mitigate the problem
  - SWIFT ACTION

RAS – PROBLEM, ARMING, TRIGGER, OPERATE

- **PROBLEM**:
  Thermal, Voltage, Transient Stability

- **ARMING FOR = INPUTS:**
  Line Loading, Generation Output Level, Line Loss Logic

- **TRIGGER = Controller on the lookout for:**
  Line Loss, Generation Loss (Breaker Status)

- **OPERATE = OUTPUT(S):**
  Insert Reactor or Capacitor; Bypass Reactor or Capacitor; Generation Drop; Load Shed

INPUT(S) → CONTROLLER(S) → OUTPUT(S)

- EVENT BASED RAS – Fast and Accurate, but Expensive; Reliable Communication – a requirement. “0” or “1” from switchyard
  - Disconnect Status
  - Breaker Status
  - Relays
- RESPONSE BASED RAS – Lower Cost, Communication minimized, sending actual data from switchyard, slower, more error prone
  - Voltage Measurements (PTs)
  - Current Measurements (CTs)
  - Phasor Measurements (PMUs)

→

- “Dispatcher in a box”
- Makes decisions and acts on them in milliseconds
- Several locations

→

- TRIPS
  - Generators
  - Load
  - Transmission Lines,
  - Series Caps, Shunt Caps etc.
- INSERTS
  - Shunt Caps
  - Series Caps, etc.
  - Braking Resistor

RAS COMPONENTS – ASSETS, INFO AND FAILURE MODES

RAS Equipment		Info / Failure Mode(s)
	Relays/Controllers	Failed power supply, incorrect settings
	PLC	For RAS controllers or the field RAS equipment: Failed power supply, incorrect settings, loss of communication, equipment failure, triggers unnecessarily
	CTs and PTs	Only used for response-based RAS
	SERs	Used for post-event analysis. Old style pen n' ink recorders can leak; have issues
	Trip Coil	Nothing unique that's not a failure mode for any trip coil
	Monitoring and Communications Equipment	Failed power supply, incorrect settings, loss of communication, equipment failure
	Alarm	Is accidentally disconnected or disabled; Dispatcher resets and takes no action

RAS – A ROBUST SYSTEM

- Failure modes for different types of equipment were discussed on the previous slide, but these components are well-researched and proven through the nuclear, aviation, aerospace, and defense industries

- The RAS system (as a whole) does not add any unreliability in the context of tested and maintained systems

- The assets/equipment involved are tested and achieve a MTBF under test and evaluation programs - along with compliance required under the NERC/WECC standards

- Redundancy is commonly used as a means of ensuring that a single component failure within a RAS system does not prevent the interconnected transmission system from meeting the system performance requirements (PRC-012-2)

"COMMON" RAS PROBLEMS (ISSUES ~ ONCE PER YEAR)

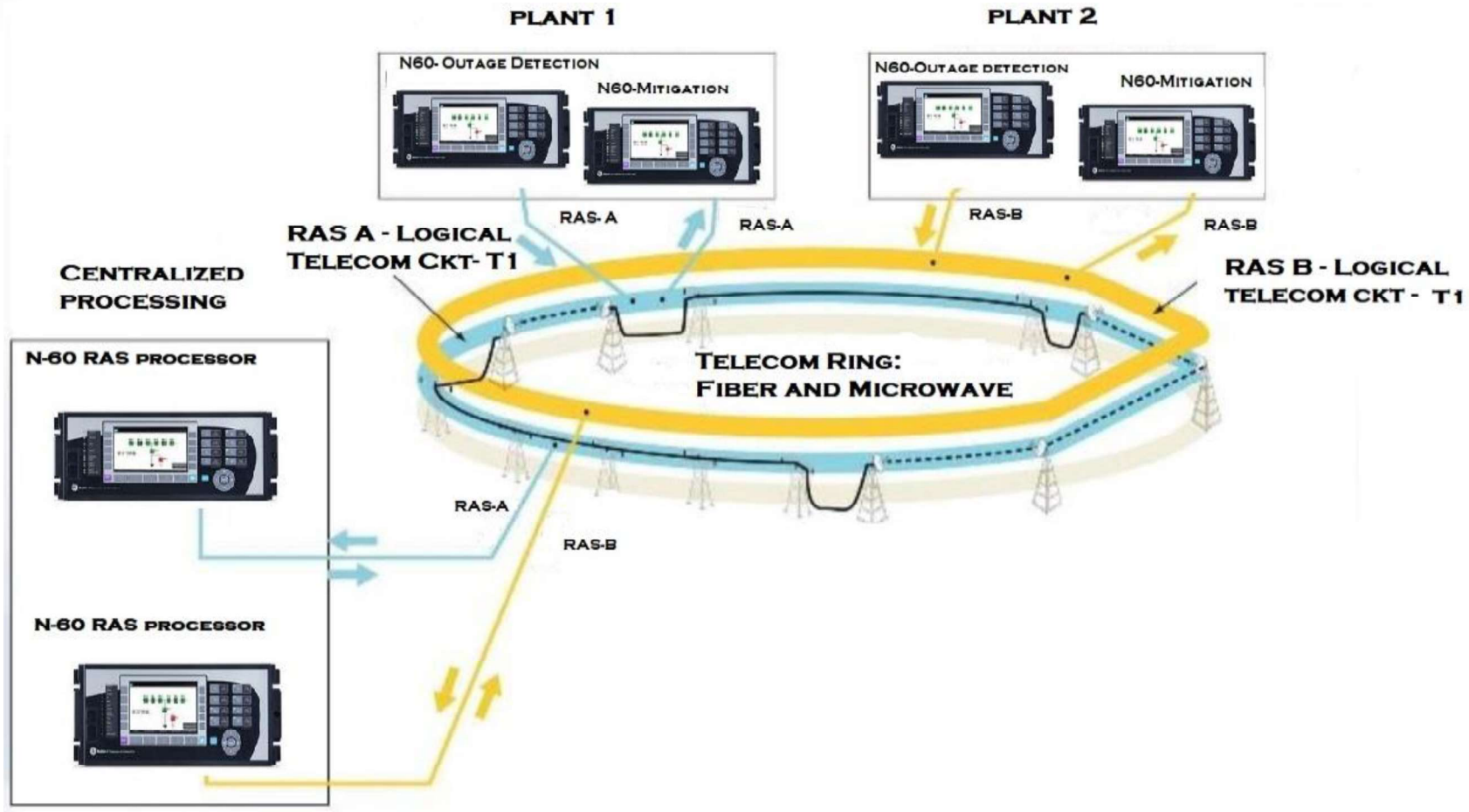
MORE LIKELY

- Bad weather causes communication failures
- Generator breaker is changed out, technician forgets to reconnect RAS trip input
- Line loss logic left cut out
- Issues with wires (damaged)
- Wrong generation unit armed to trip (dispatcher/operator error)

RARE

- Incorrect card inserted into relay
- Relay overreaching

HOW IS COMMUNICATION ACHIEVED? – A GENERIC EXAMPLE



QUIZ

A RAS solves a thermal, voltage or transient stability problem. It is armed because of line loading or generation output level exceeding a certain parameter. Identify TWO CORRECT triggers and resultant operations:

A. Breaker status from line loss logic triggers a generation drop
B. Insertion of a capacitor triggers a generation drop
C. Breaker status from generation loss triggers reactor bypass
D. Insertion of a reactor triggers a bypass of a capacitor

QUESTIONS?

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REFERENCES

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NERC's Guidance on Three-Part Communications:
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BPA RAS Presentation Hands on Relay School Dan Goodrich, 2018

NERC/WECC Standards

HYDROVISION INTERNATIONAL

CONNECTING THE GLOBAL COMMUNITY OF HYDRO VISIONARIES

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