RAS and Contingency Modeling Workshop

May 27 – 29, 2015 in Salt Lake City

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Presenters

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- Caroline Marzinzik, M.S.E.E.
  - Senior Software Developer at PowerWorld since 2004
  - 1995 – 2004: spent 10 years running transfer capability studies and writing software to implement studies at a NERC Region: Mid-American Interconnected Network (MAIN). This has since been absorbed into MidWest ISO
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Presenters:
Experience with RAS and Relays

- For 15 years we have been working with engineers on directly modeling the logic and actions that describe RAS and Relays in software
  - Contingency Analysis Tool
  - Available Transfer Capability Add-on (ATC)
  - PV and QV Curves Tool (PVQV)
- We have a lot of experience looking at descriptions of RAS and encoding them in software
- We have a lot of experience adding new features to software to permit additional wrinkles in how RAS is defined.
- This feature set has evolved incrementally over the past 15 years doing several dozen very small projects to enhance the software feature set

Introduction

- Define RAS and Relaying
- Contingency Definitions
- Legacy Methods for Modeling RAS and Relays
- Who has *details* on RAS modeling
- Overview of this Workshop

What is RAS?

- NERC wrote a document to define this in June 2014
  - http://www.nerc.com/pa/Stand/Prjct201005_2SpclPrtctnSstmPhs2/FAQ_RAS_Definition_0604_final.pdf
  - WECC was well represented on this team

Project 2010-05.2 – Special Protection Systems SDT		
	Participant	**Entity**
Chair	Gene Henneberg	NV Energy / Berkshire Hathaway Energy
Vice Chair	Bobby Jones	Southern Company
Member	Amos Ang	Southern California Edison
	John Ciufo	Hydro One Inc.
	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
NERC Staff	Al McMeekin (Standards Developer)	NERC
	Erika Chanzes (Standards Developer)	NERC
	Phil Tatro (Technical Advisor)	NERC
	Bill Edwards (Legal Counsel)	NERC

NERC Definition: **Protection System**

- The NERC Glossary of Terms 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)
  - Control circuitry associated with protective functions through the trip coil(s) of the circuit breakers or other interrupting devices.

NERC Definition:
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, curtailing or tripping generation or other sources, curtailing or tripping load, or reconfiguring a System(s). RAS accomplish one or more of the following objectives:
  - Meet requirements identified in the NERC Reliability Standards
  - Maintain System stability
  - Maintain acceptable System voltages
  - Maintain acceptable power flows
  - Limit the impact of Cascading
  - Address other Bulk Electric System (BES) reliability concerns.
- These schemes are not Protection Systems; however, they may share components with Protection Systems.

Note: Most of this document is dedicated exceptions of what is NOT RAS

Note: Term "RAS" is used instead of "SPS" (Special Protection Scheme) to avoid confusion

My Simple Definition

- Protection System Device (typically a Relay)
  - Device monitors a small set of mostly local signals
  - Usually protects a single piece of equipment from damage
  - Actions are typically limited to opening or closing breakers
- Remedial Action Scheme (RAS)
  - Control scheme monitors a larger set of signals (potentially more than local signals)
  - Protects one or more pieces of equipment or prevents larger system-wide or region-wide collapse
  - Actions are more diverse

What is the Time-Frame?

- These definitions make no distinction about the time-frame of the Relay or RAS actions
  - If milliseconds to a few seconds
    → a Transient Stability model is necessary
  - If tens of seconds to minutes with automated response of Relay or RAS → Power Flow solution simulation only
  - Minutes of response as a person (the operator) walks over and takes off the shelf the binder entitled "What to do when stuff happens" → again Power Flow

- Majority of this workshop in focuses only on topics related to the steady state power flow solutions

What is Measured

- System Protection definition says "*Voltage and current sensing devices providing inputs to protective relays*"
  - Voltage and current are available in a Power Flow solution
  - But time-frame again may require Transient Stability
- RAS definition says "*scheme designed to detect predetermined System conditions*"
  - This may be voltage and current → Power Flow
  - But could be generator speed, frequency, etc. → Transient Stability

In software: when are RAS and Relays used?

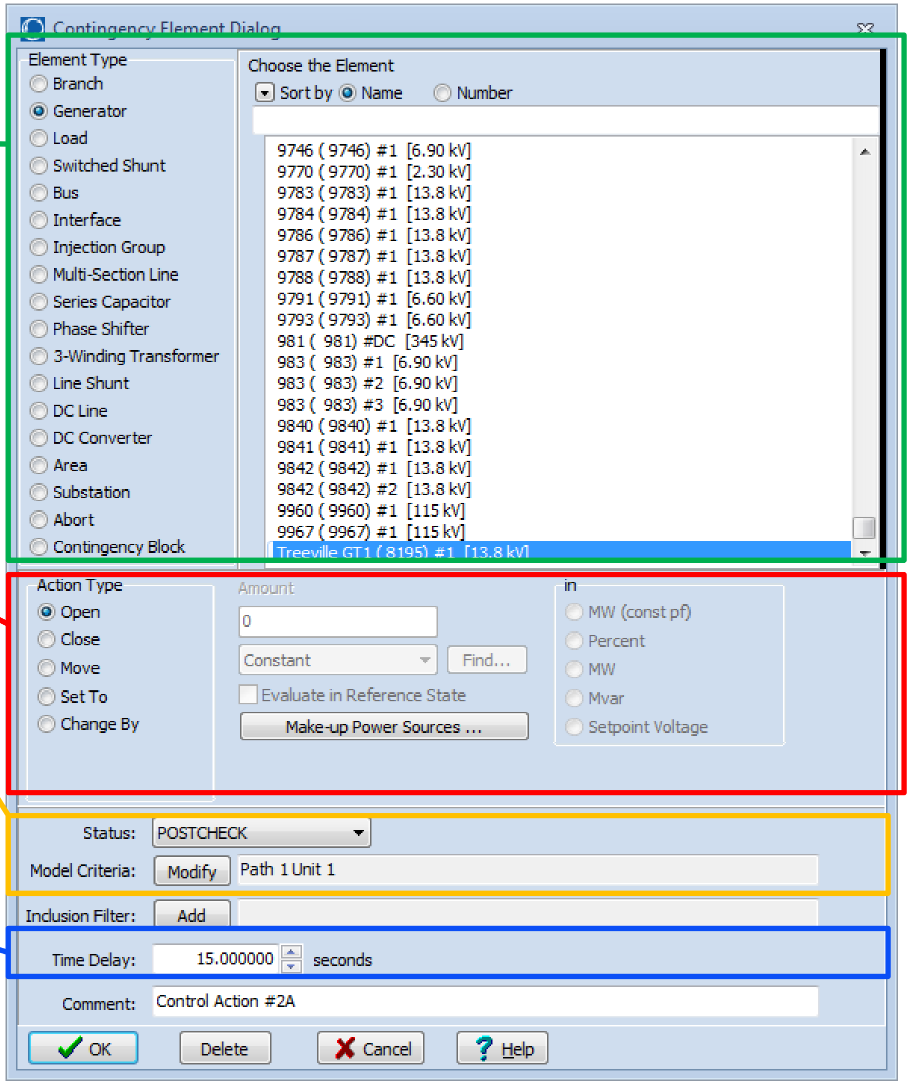
- Clearly *not* under normal operating conditions
  - When solving a base case power flow solution → RAS should not be doing anything
- Within a software tool, when are RAS and Relays going to matter?
  - **Contingency, Contingency, Contingency**
  - RAS will respond to the changes that occur during an unexpected event → **Contingency**
- For RAS and Relay models to be useful → first obtain or define a list of contingencies

Defining Contingencies

- Each **Contingency** has *Name* which is a unique string used to identify it
  - We need the name because this will also be used to identify it when looking at results
- Each **Contingency** is then made up of many **ContingencyElements**
- A **ContingencyElement** describes
  - *Object* to which an action is applied
  - *Action* that occurs
  - *Criteria, CriteriaStatus, TimeDelay* under which the action occurs (Boolean logic, where to apply, ordering)
    - These aren't needed for plain contingency definitions, but will become vital in the RAS modeling which will be discussed in examples

ContingencyElement

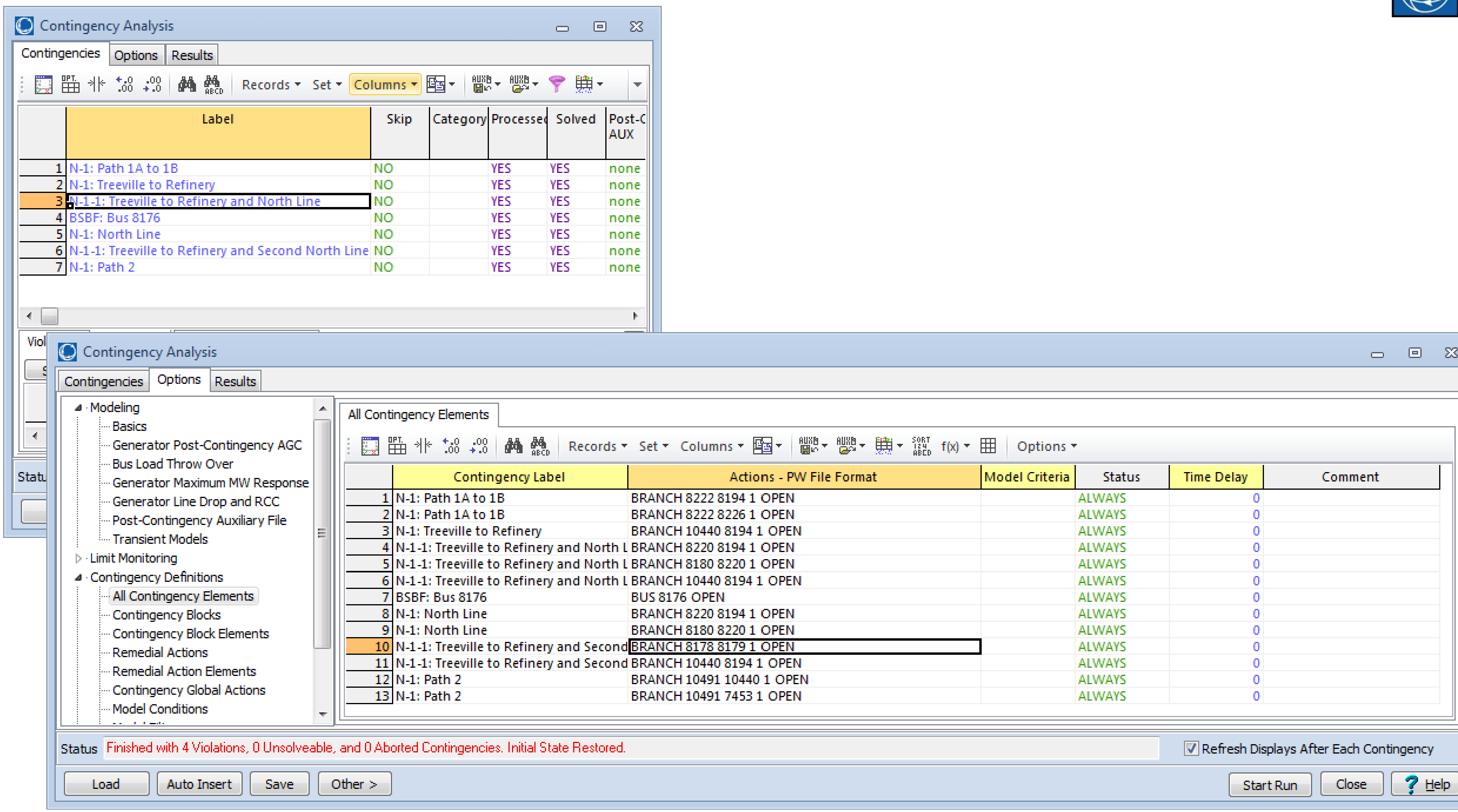
- *Object*
  - many choices of various contingency actions are available
- *Action*
  - What happens to the object
- *Criteria, CriteriaStatus*
  - Logical criteria under which actions are applied
- Time Delay
  - Use for ordering



ContingencyElement Actions

- There are many – we continue adding them as users have a need
  - Opening/Closing of transmission lines and transformers
  - Loss or Recovery of a generator, load, or switched shunt
  - Movement of generation, load, injection group, or switched shunt MWs or Mvars.
  - Changing or Setting of generation, load, injection group, or switched shunt MWs or Mvars
  - Changing or Setting of generator or switched shunt voltage setpoint
  - Opening of all lines connected to a bus
  - Opening of all lines connected to a substation
  - Opening/Closing of all lines or transformers in an interface
  - Open/Close, Set/Change injection group values
    - Many special options with this
  - Bypass/Inservice, Set impedance of series capacitors
  - Changing or Setting of phase-shifter setpoint
  - Open/Close 3-winding transformer
  - Open/Close DC lines, Set/Change DC line setpoints or resistance

Contingency Dialog



Contingency Definitions

- A lot more detail to discuss
  - We will cover in great detail on May 27 – 29 in Salt Lake City at WECC offices
- Final output for sharing with others

```
Contingency (Name, Category, Skip, Memo)
{
"L-2_Roughrider-Raven 2&3" "Double" "NO" "My Memo A"
"L-2_Roughrider-Raven 1&2" "Double" "NO" "My Memo A"
"L_Falcon-PatriotC1"       "Single" "NO" "My Memo A"
"T_Falcon-TitanC1"         "Single" "NO" "My Memo A"
}

ContingencyElement (Contingency, Object, Action, Criteria, CriteriaStatus,
                    TimeDelay, Comment)
{
"L-2_Roughrider-Raven 2&3" "BRANCH 15 54 2" "OPEN" "" "CHECK" 0 ""
"L-2_Roughrider-Raven 2&3" "BRANCH 15 54 3" "OPEN" "" "CHECK" 0 ""
"L-2_Roughrider-Raven 1&2" "BRANCH 15 54 1" "OPEN" "" "CHECK" 0 ""
"L-2_Roughrider-Raven 1&2" "BRANCH 15 54 2" "OPEN" "" "CHECK" 0 ""
"L_Falcon-PatriotC1"       "BRANCH 10 13 1" "OPEN" "" "CHECK" 0 ""
"T_Falcon-TitanC1"         "BRANCH 10 39 1" "OPEN" "" "CHECK" 0 ""
}
```

Contingency Solution: It’s more than just the actions

- “Post-Transient” Power Flow: options matter a lot
  - What happens when you change MW injection by 2000 MW (outage generators)
    - Load or Generator change Make-up Power
    - Specify input parameter with each generator
      - Participation Factor
      - Max MW response
      - Disable response
  - Generator Voltage Control for Post-Transient
    - Generator Line Drop Compensation
    - Regulate terminal bus only (ignore remote regulation)
  - Bus Load Throwover (model distribution switching)
  - Control Options
    - Switched Shunt and Transformer switching
- We’ll cover these in the next day

Limit Monitoring Options

- These matter a great deal too
- Setup with the model (case)
  - Provide options to specify various limits for Branches (A, B, C, D, E, etc.)
  - Provide options for specifying various limits for Buses (A, B, C, D)
  - Provide LimitSet for choosing which limits to use
- Advanced Limit Monitoring During Contingency
  - Monitor for a violation due to a *change* in the system (5% voltage drop for example)

- We'll cover these in the next day

What do you need to model RAS in the Power Flow

- The description of a RAS is really the same as a Contingency.
  - A list of actions that occur
    - Actions become more complex though.
      - Trip MWs from a group of generators equal to 50% of the flow on an interface (or use a 2D lookup table to determine what to trip)
  - The *Criteria* is vital here
    → these actions do ***not always*** occur
    - Must describe the Boolean logic of when these actions occur
  - The CriteriaStatus and TimeDelay
    →describe when and at what point in solution process to include

- Question
  - *How do you implement the Boolean checks of when to trigger the RAS and the ordering of actions?*
  - *How do you handle the lookup tables, expressions used in more complex actions?*

Traditional Modeling of RAS in Software Studies

- Often the more complex features are provided *manually* by you the power engineer
  - Boolean logic of when to apply
    - May know that taking a double-line outage will cause RAS to be applied
    - Thus if contingency is for double line outage just include RAS actions
  - Figure out the "RAS Arming" level from the base case
  - Solve the contingency → If a line is overloaded then open it and resolve

Other Common Shortcuts

- Run a very detailed study of RAS
  - Particular contingencies cause violations (line overloads, bus voltage violations)
  - Verify that your RAS fixes these violations
- Then, for the next 1, 2, … (10?) years assume the RAS always works to fix these problems
- Functionally this means
  - Run your list of 100s or 1,000s of contingencies
  - Manually wade through the 1,000s of violations that occur and just ignore what is handled by RAS (experience)

Another common treatment for RAS

- Power engineer writes custom code to automate all the processes from the previous 2 slides
  - Write custom code to implement RAS
  - Write custom code to remove particular violations from your output reporting

Problems with these approaches (1/2)

- Reproducibility
  - Can you replicate a manual process and get the same answer over and over?
- Validity of assumptions
  - The RAS was designed many years ago. Are you sure your RAS is still always fixing the problems for which it was designed?
- Narrow assumption of when RAS is implemented
  - You are limiting the application of RAS to specific contingencies
  - This prevents you from seeing a cascading outage caused by several RAS interacting with each other

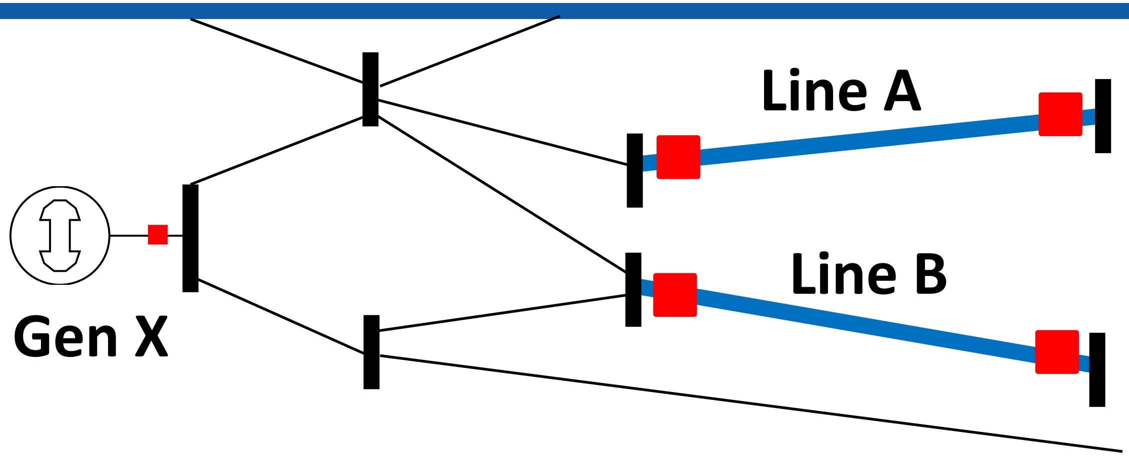
Problems with these approaches (2/2)

- Documentation and Sharing
  - How do you communicate what your RAS does to another utility or neighbor with the precision necessary to model it in software?
  - Custom code → who manages and takes support calls for that code?
- Input Data Management
  - Much of this leads to *manually* created contingency lists that are tuned for a particular operating condition
    - RAS arming, Boolean criteria
- Training – Human Resource Problem
  - Rely completely on the power engineer’s experience which takes many years to develop
    - Engineers move jobs within a company
    - Engineers switch companies
  - How do you train new engineers or communicate all these assumptions? And do it quickly!

Another Hidden Problem

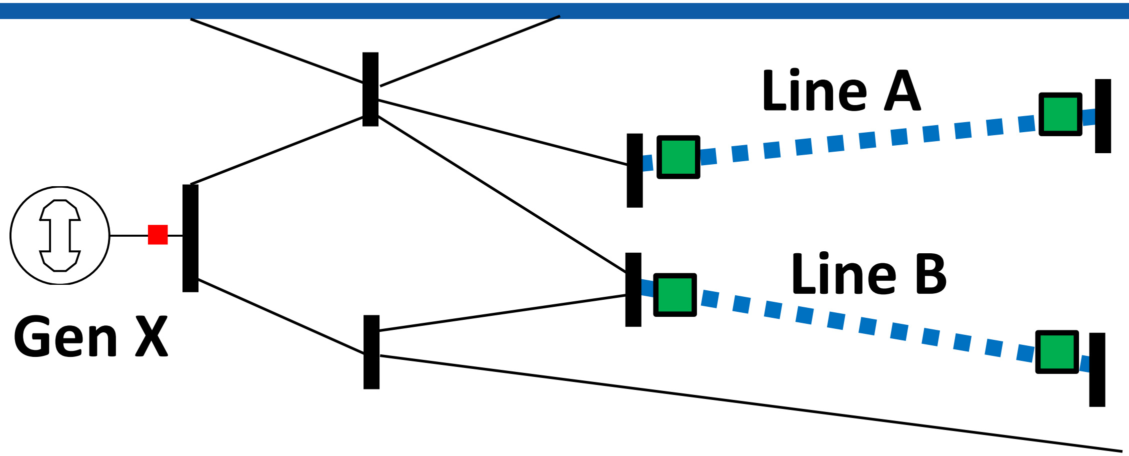
- PowerWorld's experience working with utility engineers
  - The engineers running power flow and transient stability studies have a general idea of how RAS functions
  - However, they may not manage and design the RAS itself, so they may miss details
- The implementation of ***when*** to "arm" and ***how much*** is very specific
  - The details matter!
  - Consider a very simple RAS example next

"Simple RAS"



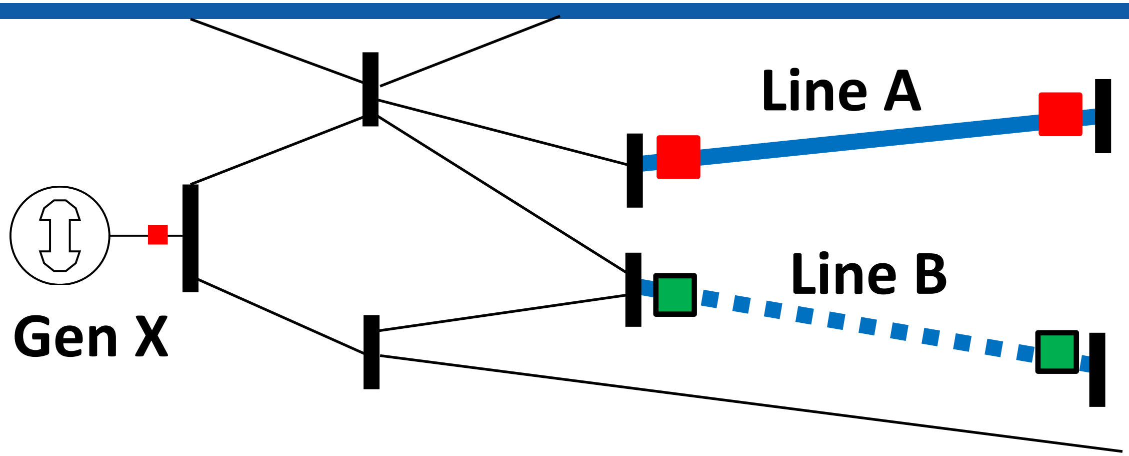
- General Description of RAS
  - If two transmission lines (**Line A** and **Line B**) are tripped → then trip a generator (**Gen X**)
- RemedialAction definition seems simple
  - *Object* = **Gen X**
  - *Action* = OPEN
  - *Criteria* = (**Line A** is OPEN) AND (**Line B** is OPEN)

Wait!
Differences in Initial Case



- What if **Line A** and **Line B** are out for maintenance this week?
  - Using our "Simple RAS" then this means that the Criteria always evaluates as TRUE!
  - Running a contingency analysis tool with this RAS defined would trip **Gen X** under every contingency
  - In this example, clearly the RAS criteria should evaluate to FALSE

Wait?
More differences in Initial Case



- What if **Line B** is out for maintenance this week?
- Using our “Simple RAS” then this means that if **Line A** is opened during the contingency then **Gen X** will be tripped
  - That *might* be correct, … but
  - It may *not* be correct for some RAS
    - For some if **Line B** is OPEN in the reference case then the RAS will *not be armed*! Tripping **Gen X** is not correct then
- The engineers running power flow/stability need to go talk with the RAS engineers to learn these details

Communication

- RAS design requires that their be redundant communication systems for RAS to prevent communication failure
- We also need the human communication between different groups of engineers to work as well
- Our experience is there are 4 groups here (though at most organizations there is some overlap)
  1. “Planning Engineers” run power flow and stability studies
  2. “Operations Engineers” run power flow and stability studies
  3. “Relay Engineers” who manage/ design the system protection
  4. “RAS Engineers” who manage and design the RAS
- Most in audience today are in Groups 1 and/or 2, but we all need to engage with folks in Group 3 and 4 to get the details of RAS and Relay modeling correct

Classroom Style

- Classroom Style Portion –
  Wednesday PM and Thursday AM
  - Presentations on how to implement the various input parts that represent RAS and Relay models
    - Contingency Actions
    - Boolean Logic
    - Lookup tables and Expressions
  - You will work along with Caroline and I while doing this portion
  - This is “Hands-On Classroom style”

Break-Out Groups

- Break-out Groups Work – Thursday Afternoon
  - You have all been assigned to 6 break-out groups on your name tags (A, B, C, D, E, F)
    - At least one engineer experienced in building RAS and Contingency definitions in each group
    - Several utility engineers who may have sample RAS
  - Goal for Thursday afternoon is for you to sit down and implement some of your RAS
  - If you don't have RAS, then dream some up or we can go through the WECC RAS catalog for ideas
- Break-Out Group Work/Presentation – Friday Morning
  - 1 hour organizing thoughts to put together a brief presentation on RAS
  - 2 hours of presenting RAS to the full group
    - Educates the group. Provides discussion of alternative ways to implement the same RAS
  - Finish by discussing potential new features needed to model RAS

Classroom Agenda for First PM: Fundamental Structures/Processes

- Case Information Displays
  - Navigating a case, Records and Fields
  - Filtering, Conditions, Device Filtering, Expressions, Searching
  - Injection Groups and Interfaces
- Auxiliary Files
  - Key Fields, Labels, ObjectID
  - Variable Names
  - Self-defining structure
- Contingency Solution Basics
  - MW Participation Factor Control (Make-up power)
  - Contingency Analysis Basics

Classroom Agenda for First AM: Contingencies and RAS

- Limit Monitoring Settings
- "Post-Transient" Power Flow: options matter a lot
  - What happens when you change MW injection by 2000 MW (outage generators)
    - Load or Generator change Make-up Power
    - Specify input parameter with each generator
      - Participation Factor, Max MW response, Disable response
  - Generator Voltage Control for Post-Transient
  - Bus Load Throwover (model distribution switching)
  - Control Options
    - Switched Shunt and Transformer switching
- Modeling of Remedial Action Schemes