Line and Transformer Relay Models in PowerWorld Simulator

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Overview

- Line and Transformer Relay Models in PowerWorld Simulator Transient Stability tools
  - Distance/Impedance
  - Time Inverse Overcurrent
  - New Relay Model TIOCRS
- Treatment of Transient Stability Models in Power Flow Contingencies

Line Relay Models in PowerWorld
Transient Stability

- Nothing existed prior to Summer 2012
  - Including these in stability is something that transient stability software users were not clamoring for until the WECC MSRATF started
- August 2012
  - TLIN1 properly functioning and reporting events
- October 2012
  - Added support for Impedance/Distance Relays
- December 2012
  - Added Time-Inverse Overcurrent Relays
- March 2012
  - Added new Time-Inverse Overcurrent Relay TIOCRS to specify input parameters using standard curves (IEEE C37.112, IEC 255-4, IAC)
- Last Week
  - PowerWorld Simulator automatically utilizes transient stability relays inside the power flow contingency analysis tool

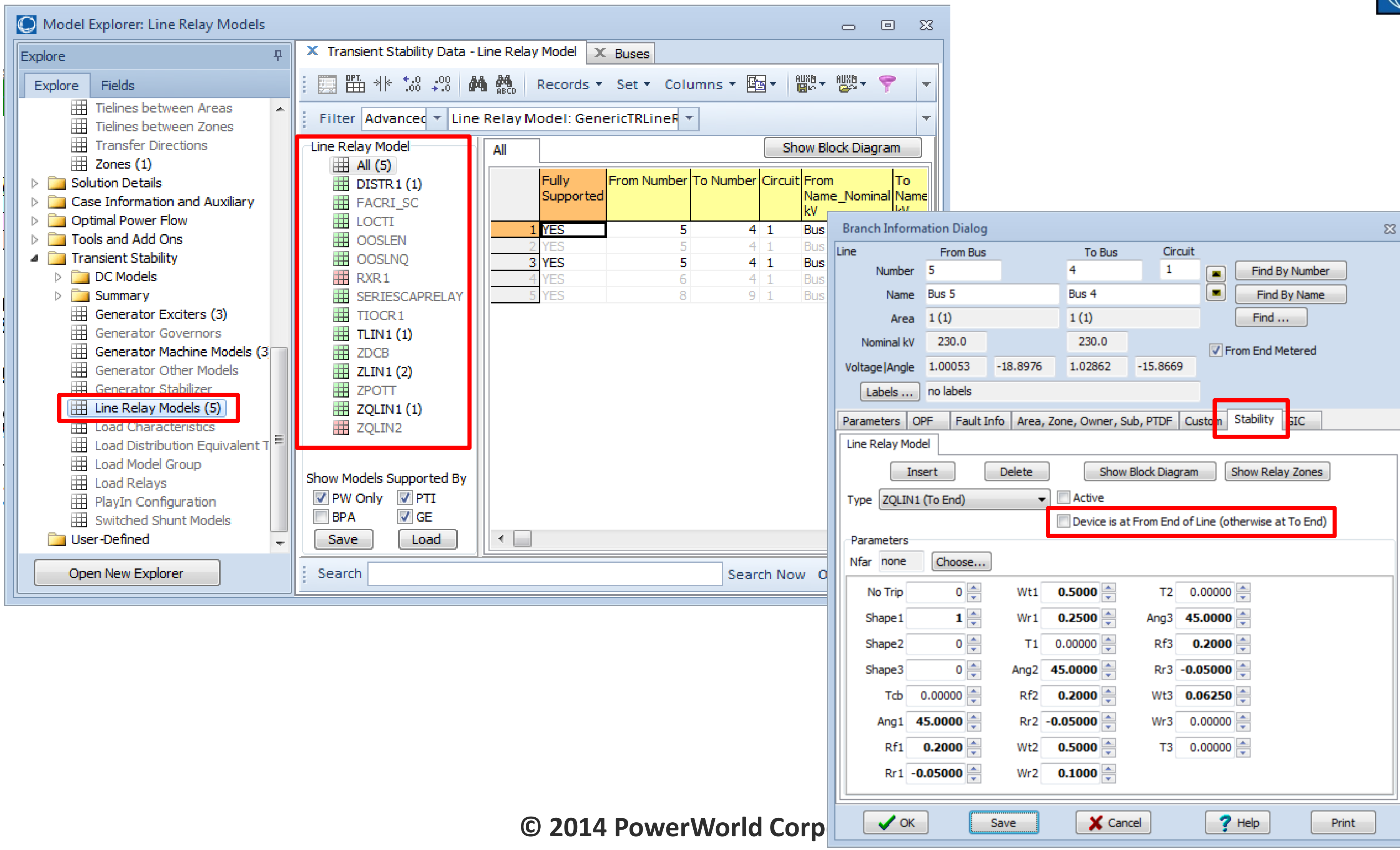
Transient Stability Relay Models

- PowerWorld Simulator Version 17 includes the following models
  - Under Voltage and Frequency Relays
    - TLIN1
  - Impedance/Distance Relays
    - DISTR1, ZLIN1, ZQLIN1, ZPOTT, ZDCB
  - Out-of-Step Impedance Relays
    - OOSLEN, OOSLNQ
  - Time Inverse Over-Current Relays
    - LOCTI, TIOCR1
    - TIOCRS (added in March 14, 2013 patch)

Transient Stability Relay Models

- Line Relay Data Structure Considerations
  - Model is assigned to specified end of a Branch. Handled by field in case information displays called **Device Location** which is *From* or *To*
  - Multiple relays can be assigned to each end of a branch
    - Distance Relay, Time-Inverse Over-Current, Voltage, etc…
    - For some types multiple relays of same type are allowed (introduced extra key field of **Device ID**)
- User Interface Considerations
  - Stability tab is available on the branch dialog
  - Line relay models listed

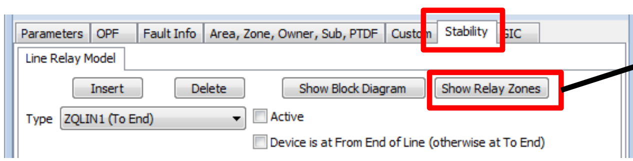
Transient Stability Relay Models User Interface

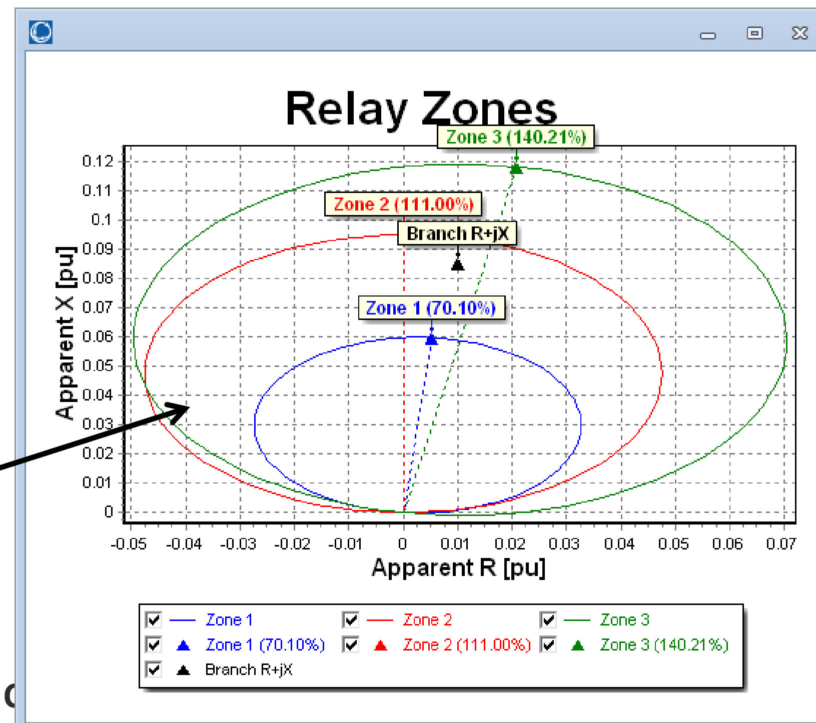


Visualization for Distance/Impedance Relays

	To Number	Circuit	From Name_Nominal kV	To Name_Nominal kV	Device Location	Device ID	From Name	To Name	Type	Device Status	Sub-Int	Zone 1 Reach %	Zone 2 Reach %	Zone 3 Reach %
1	4	1	Bus 5_230.00	Bus 4_230.00	From		Bus 5	Bus 4	ZLIN1	Active		58.42	233.68	116.84
2	4	1	Bus 5_230.00	Bus 4_230.00	To		Bus 5	Bus 4	ZQLIN1	Not active		233.68	233.68	233.68
3	4	1	Bus 5_230.00	Bus 4_230.00	From		Bus 5	Bus 4	DISTR1	Active		70.1	111	140.21
4	4	1	Bus 6_230.00	Bus 4_230.00	From		Bus 6	Bus 4	ZLIN1	Not active		106.89	0	0
5	9	1	Bus 8_230.00	Bus 9_230.00	From		Bus 8	Bus 9	TLIN1	Not active				

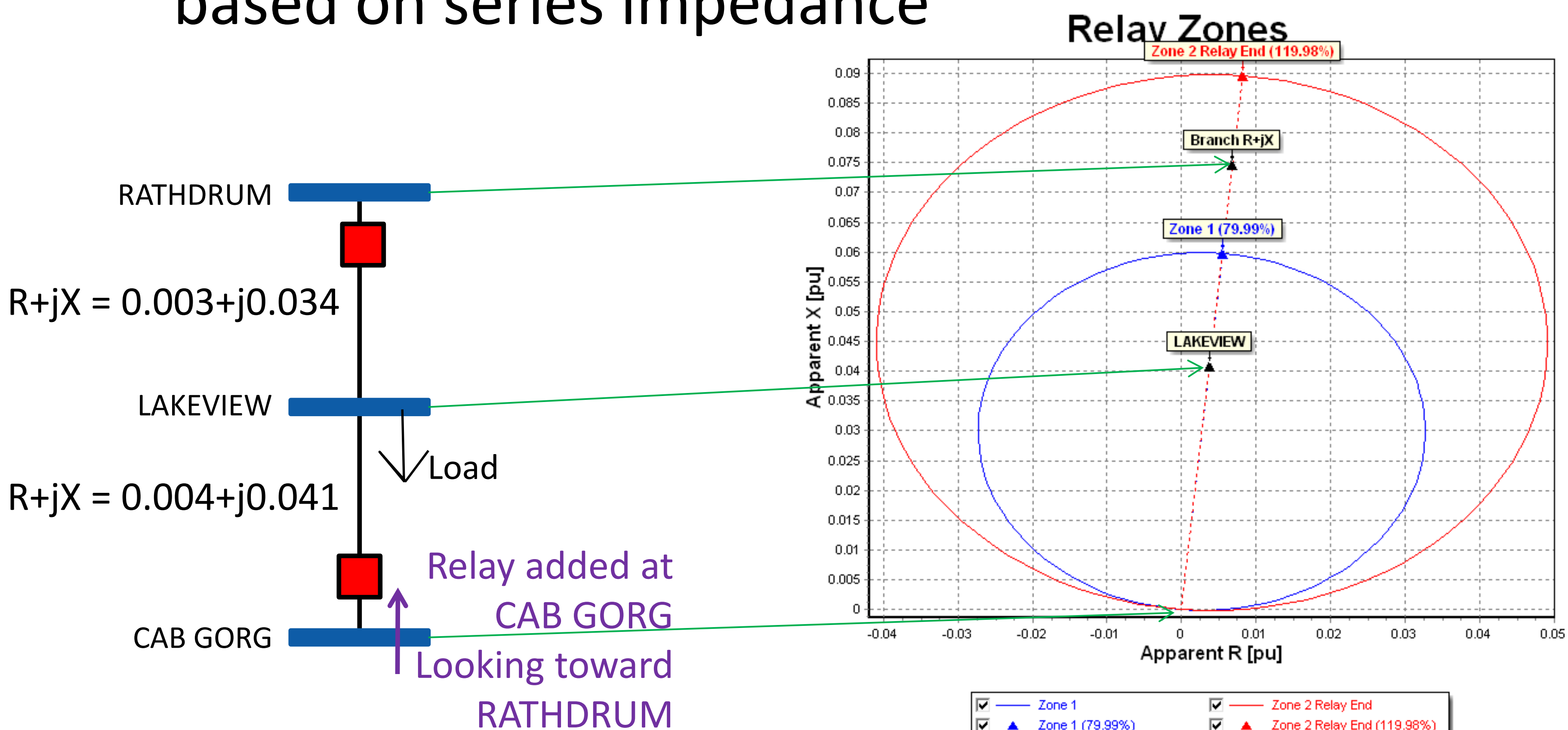
- Columns on Impedance Relays show Forward Reach %
- Click Button **Show Relay Zones** for Visualization



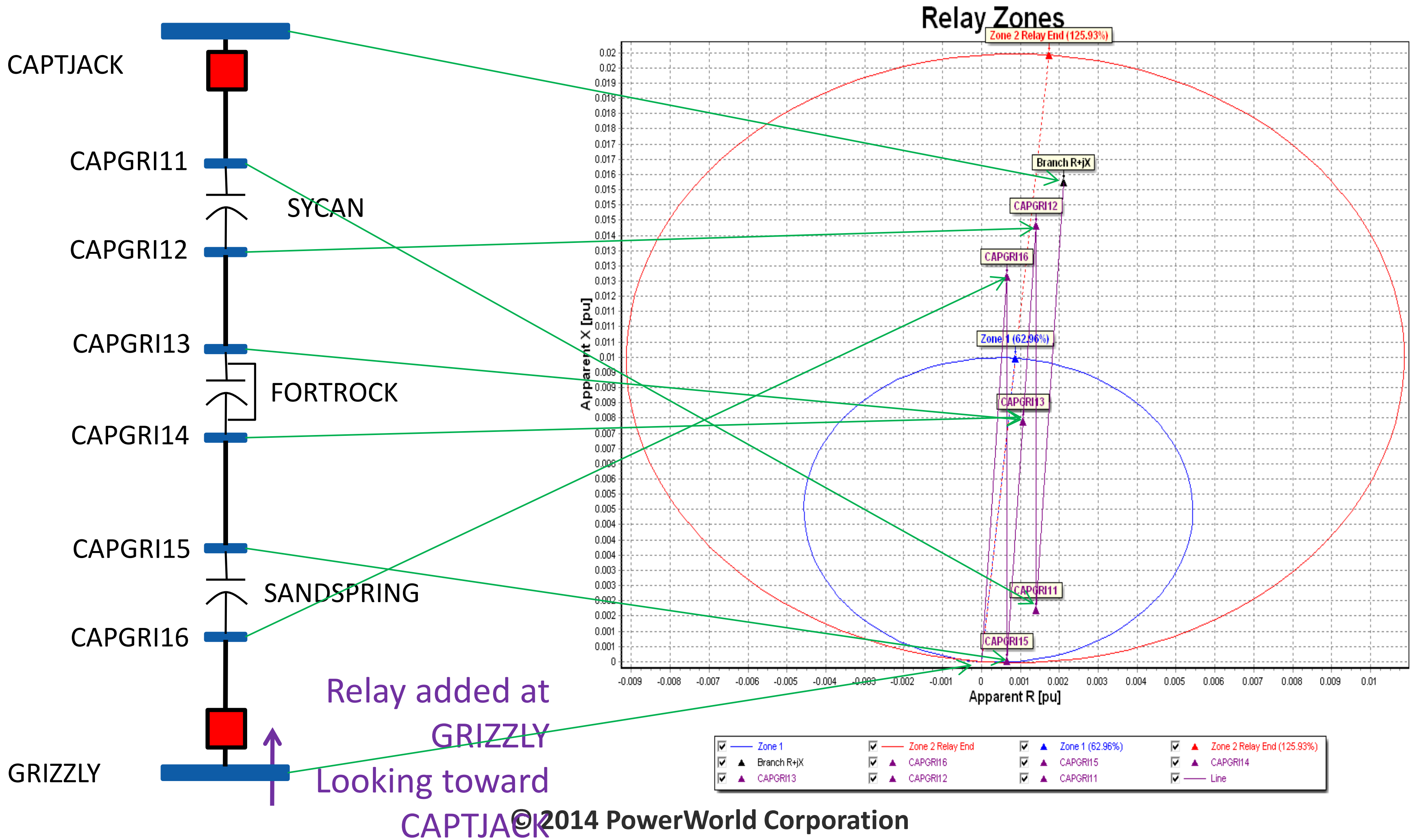


Visualization for Distance/Impedance Relays

- If relay specifies a "far end", visualization will show intermediate buses and percentage based on series impedance

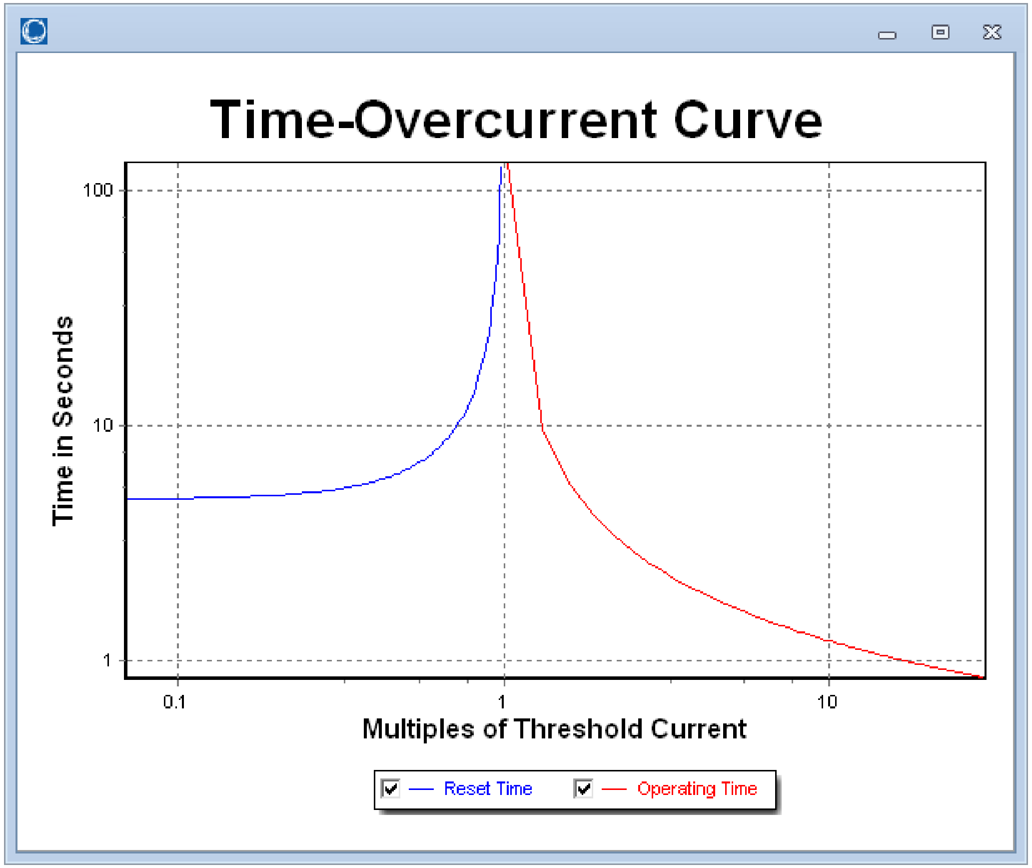


Visualization with Series Caps (CAPTJACK – GRIZZLY)



Visualization of Time-Overcurrent Curves

- For Time-Inverse Overcurrent relays, clicking button **Show Relay Zones** gives

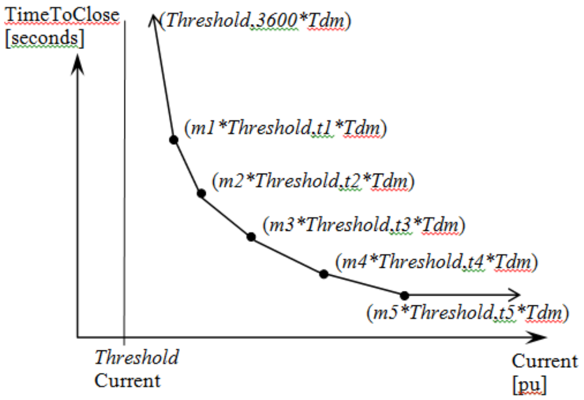


New Line/Transformer Relay Model: TIOCRS

- TIOCRS: Time Inverse Overcurrent "Standard"
  - Very similar to TIOCRS and LOCTI
- Difference – specification of the curve which describes the time-inverse overcurrent characteristic is set based on commonly used standards
  - IEEE C37.112-1996 Standard (North America)
  - IEC 255-4 or British BS142 (Europe)
  - IAC GE Curves (GE electromechanical)

Specification of Time To Close

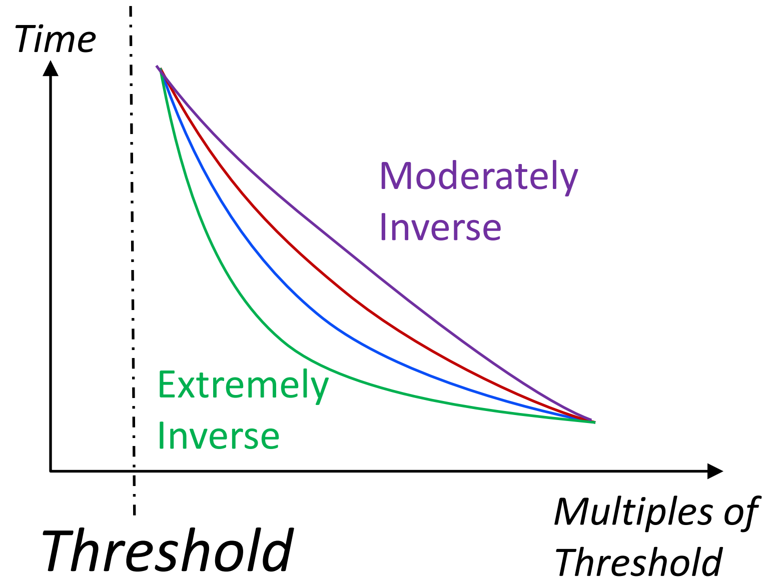
- LOCTI and TIOCR1 include specification of a piecewise linear curve to describe the Time-To-Close



- IEEE C37.112-1996 Standard
  - $TimeToClose = T_{dm}\left(B + \frac{A}{\left(\frac{Icurrent}{Threshold}\right)^{p} - 1}\right)$
- IEC 255-4 or British BS142
  - $TimeToClose = T_{dm}\left(\frac{A}{\left(\frac{Icurrent}{Threshold}\right)^{p} - 1}\right)$
- IAC GE Curves
  - $TimeToClose = T_{dm}\left(A + \frac{B}{\left(\frac{Icurrent}{Threshold} - C\right)} + \frac{D}{\left(\frac{Icurrent}{Threshold} - C\right)^{2}} + \frac{E}{\left(\frac{Icurrent}{Threshold} - C\right)^{3}}\right)$

Time Overcurrent: Standard Curve Shapes

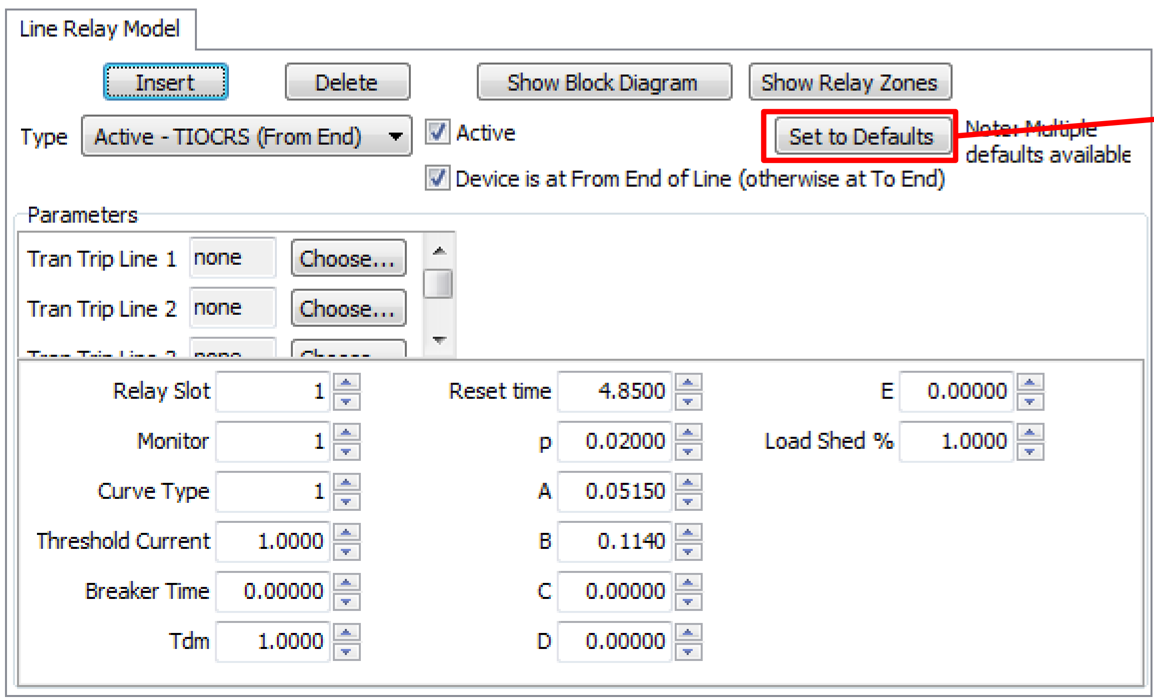
- Curve provides the "Shape"
- Relay Engineers talk about
  - Moderately Inverse
  - Inverse
  - Very Inverse
  - Extremely Inverse
  - Short-Time Inverse

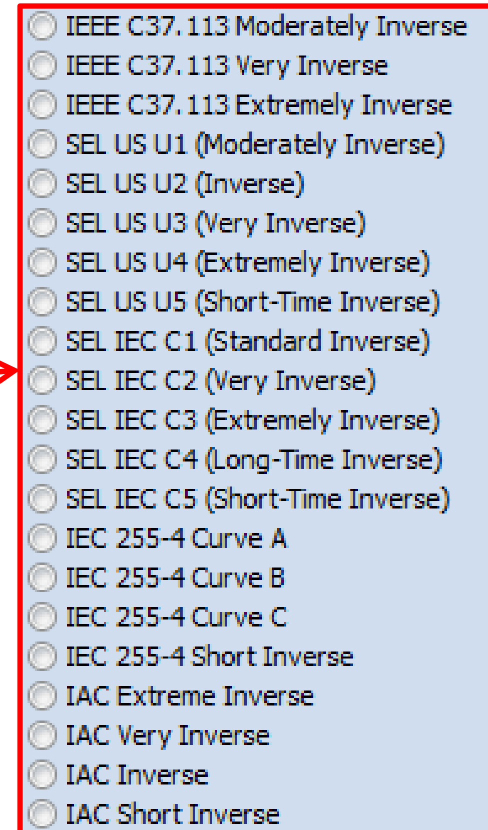


- Relays then have a Time Dial Multiplier (represented by input T_{dm}) which allows the relay engineer to tune the speed of response
  - Increase T_{dm} → curve moves up → slower
  - Decrease T_{dm} → curves moves down → faster

Standard Curves Available as Defaults

- Click on **Set To Defaults** button in PowerWorld for the TIOCRS relay and you get choices on right.





Transient Stability Relay Models

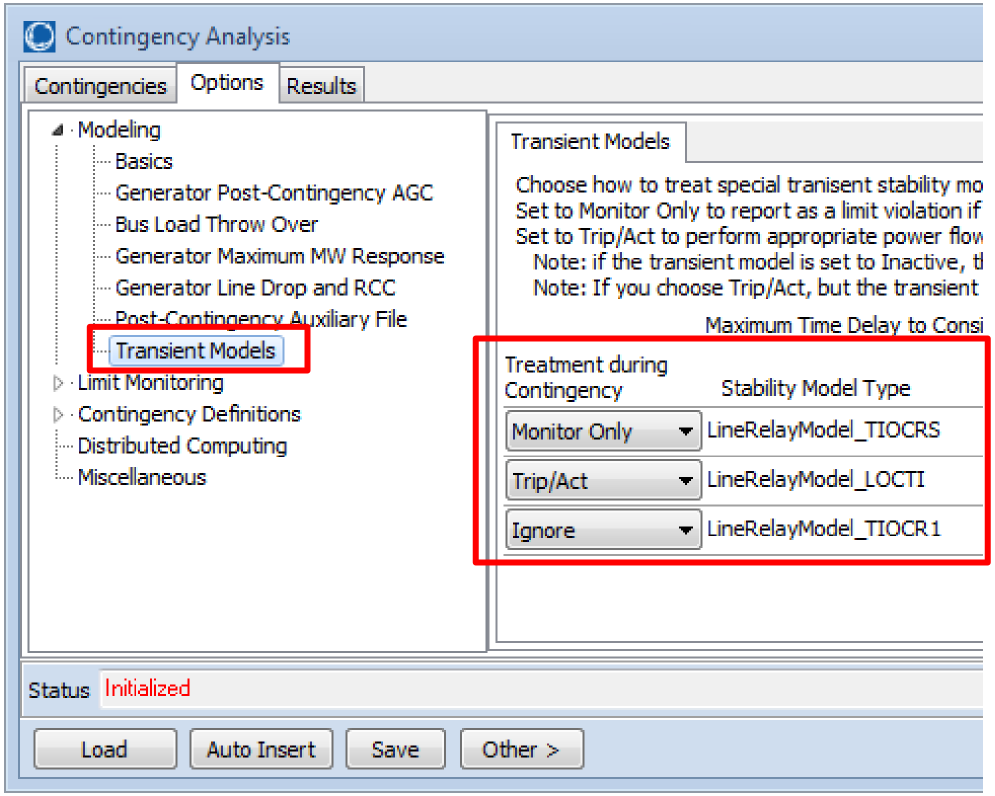
- Basics of relay modeling in transient stability is not a software hurdle
  - At this point, all the software vendors have line relay models which are appropriate for use
  - More complex relays can certainly be created, but there doesn't seem to be an immediate need
- What's hard?
  - Staff time to collect and compile the input data
- Modeling of these features in the power flow simulations is another consideration

Treatment of Transient Stability Models in Power Flow Contingencies

- Various transient relays can now be automatically handled in power flow contingency analysis
- Treatment is specified by model type
  - TIOCRS, LOCT1, and TIOCR1
  - Choices are Monitor, Trip, or Ignore
    - Default is to ignore
  - Also, if Transient Model **Status** = *Inactive* then ignore
- These have been implemented very generically inside PowerWorld Simulator
  - Future: Generator Relays, Load Relays, Load Model with embedded tripping, under voltage motor tripping
  - Other?

Options for Treatment in Power Flow Contingency Analysis

- Ignore
  - default setting
- Trip/Act
  - if conditions of model are met then actual actions will be taken (such as tripping a line for overcurrent)
  - If "monitor only" flag of stability model, then the specific model will instead just monitor
- Monitor Only
  - if conditions of model are met, then special contingency limit violations are reported
  - Similar to "Custom Monitors", but they will show up as "Transient" monitors in the contingency analysis results

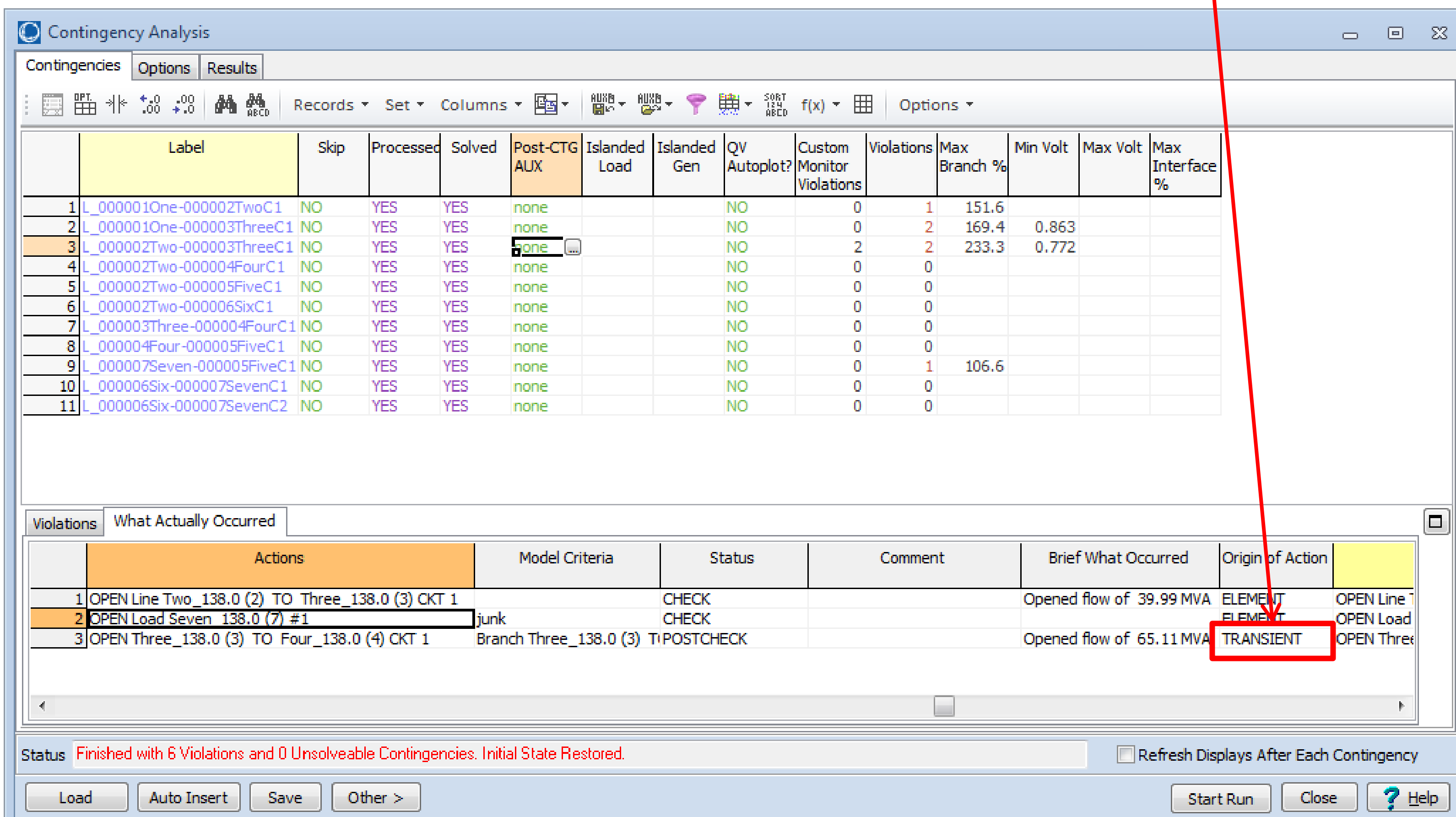


Effects on Results and Actions

- Trip/Act
  - Reported under “What Actually Occurred”
  - “Origin of Action” will indicate “Transient”
  - Available immediately
    - March 22 Patch of PowerWorld Simulator 17
- Monitoring results
  - Reported under “Violations”
  - “Category” will indicate “Transient”
  - Will be available in PowerWorld Simulator 18
    - Required modifications to PWB file format
      - Would work in 17, but when saving PWB you would lose these violations causing user confusion
    - Beta version available by request

What Actually Occurred Reporting for Transient Models

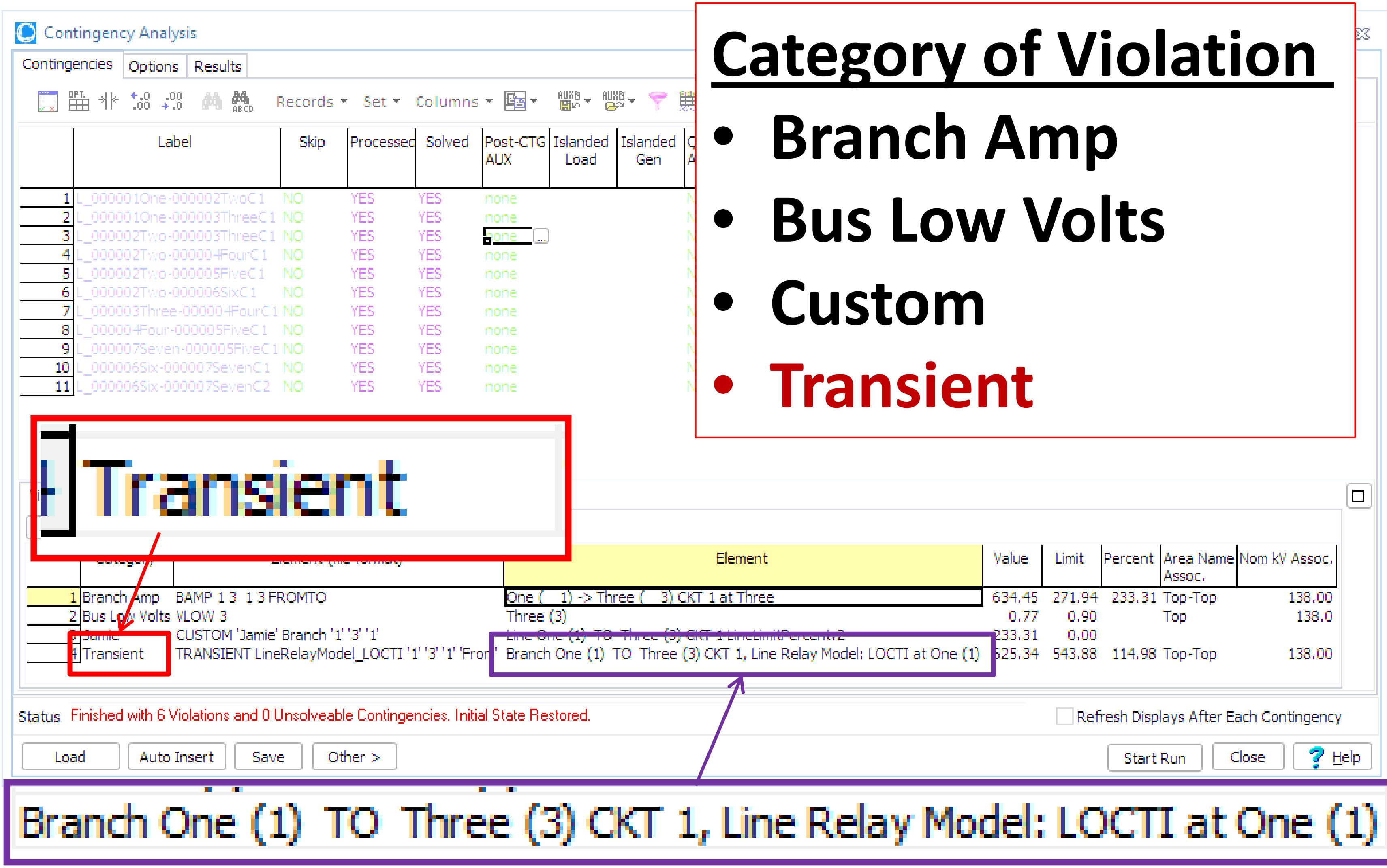
- Transient Relay Model will cause actions



Limit Violation Reporting based on Transient Models

Category of Violation

- Branch Amp
- Bus Low Volts
- Custom
- Transient



Relay Tripping Order: Time Delay Matters

- Handled at the end of POSTCHECK loop
  - Query all stability models that are enabled for Trip/Act
  - Obtain a list of models whose conditions are met
  - From this list, obtain list of models that will Trip/Act FIRST (based on time delays in transient model)
    - Models with zero time delay trip/act immediately
    - For inverse-time overcurrent relays, the "time delay" value is obtained based on the actual current
  - Apply action of models (relays trip devices)
  - Resolve power flow

How this in integrated with existing *CHECK* and *POSTCHECK* actions

- Contingency processing is as follows:
  1. Apply *ALWAYS* actions and <u>true</u> *CHECK* actions
  2. Update topology (branch, bus status)
  3. Apply <u>true</u> *TOPOLOGYCHECK* actions
  4. Solve power flow
  5. Apply <u>true</u> *POSTCHECK* and *TOPOLOGYCHECK* actions
  6. Repeat steps 2-5 until no more *POSTCHECK* and no *TOPOLOGYCHECK* actions are done
  7. Apply <u>true</u> *TRANSIENT* actions that will trip next based on the time delays in the transient model
  8. Repeat steps 2-7 until no more *TRANSIENT* actions are done

Summary

- Transient stability models of line relays
- Waiting for folks to use these features and provide feedback
- Looking for guidance on how the monitoring and action of certain transient models should be handled in the power flow
  - Relay models
  - Other models?
    - Under voltage tripping associated with certain load models