Introduction to PowerWorld Simulator: Interface and Common Tools

I10: Introduction to Contingency Analysis

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Contingency Analysis

- Power systems are operated so that overloads do not occur either in real-time or under any statistically likely contingency.
  - This is often called maintaining system “security”
- Simulator is equipped with tools for analyzing contingencies in an automatic fashion
- Contingencies can consist of several actions or elements
  - Simple Example: outage of a single transmission line
  - Complex: outage of a several lines, a number of generators, and the closure of a normally open transmission line

Contingency elements allowed in PowerWorld Simulator

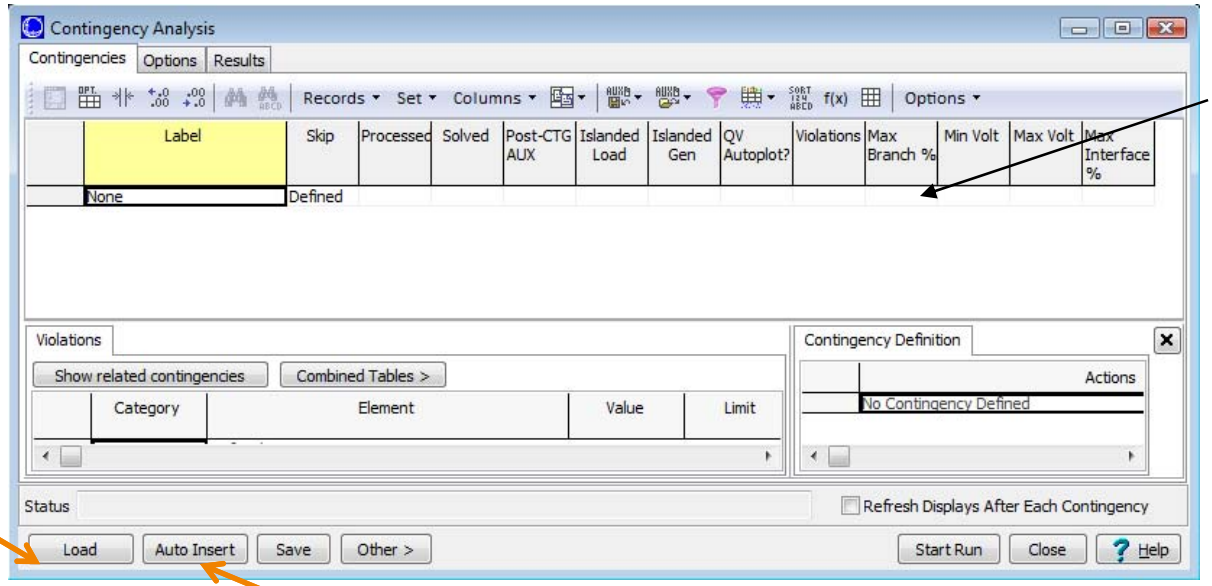
- Contingency Elements allowed in Simulator
  - Opening/Closing of transmission lines and transformers
  - Loss or Recovery of a generator, load, or switched shunt
  - Movement of generation, load, injection group, or switched shunt MWs or Mvars.
  - Changing or Setting of generation, load, injection group, or switched shunt MWs or Mvars

  specification of make-up power also allowed
  - Changing or Setting of generator or switched shunt voltage setpoint
  - Opening of all lines connected to a bus
  - Opening/Closing of all lines or transformers in an interface
  - Open/Close, Set/Change injection group values
  - 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
  - Solve Power Flow

Note: "Conditional" Elements which only occur if a particular condition is met are also allowed. These are covered in another section.

Contingency Analysis Tool in Simulator

- Contingency Analysis tools can be accessed by selecting **Tools** ribbon tab → **Contingency Analysis** in Run Mode.
- Initially, no contingencies are defined for a case.



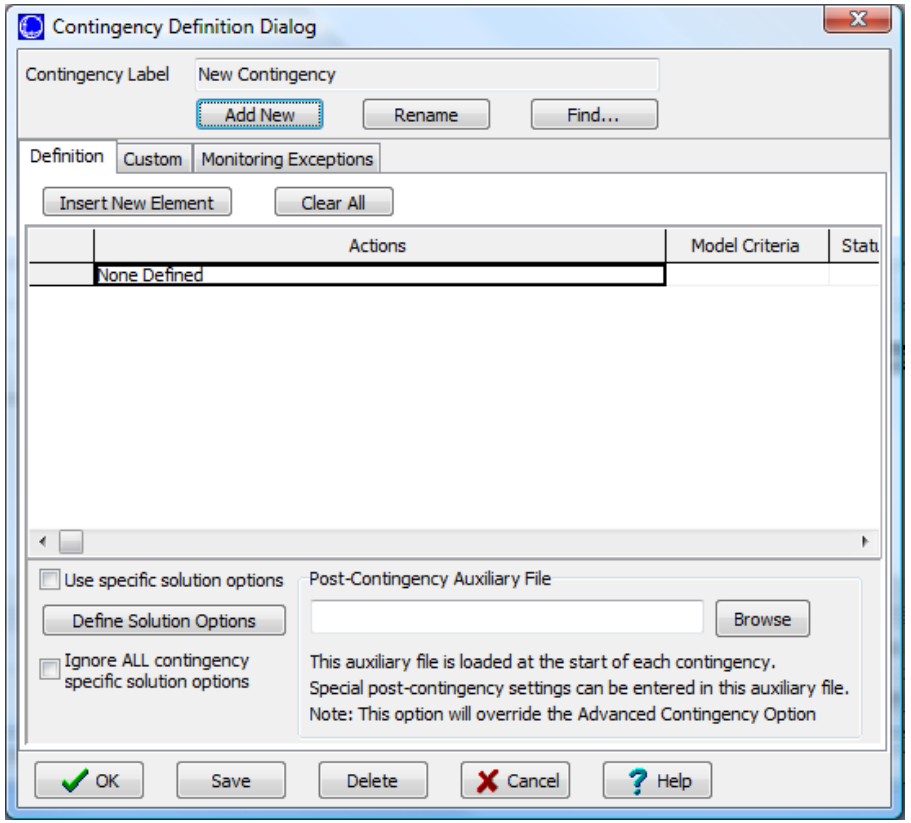
Right-click and choose Insert to add a contingency

Select to load from a file

Select to allow Simulator to define

Inserting a Contingency Definition

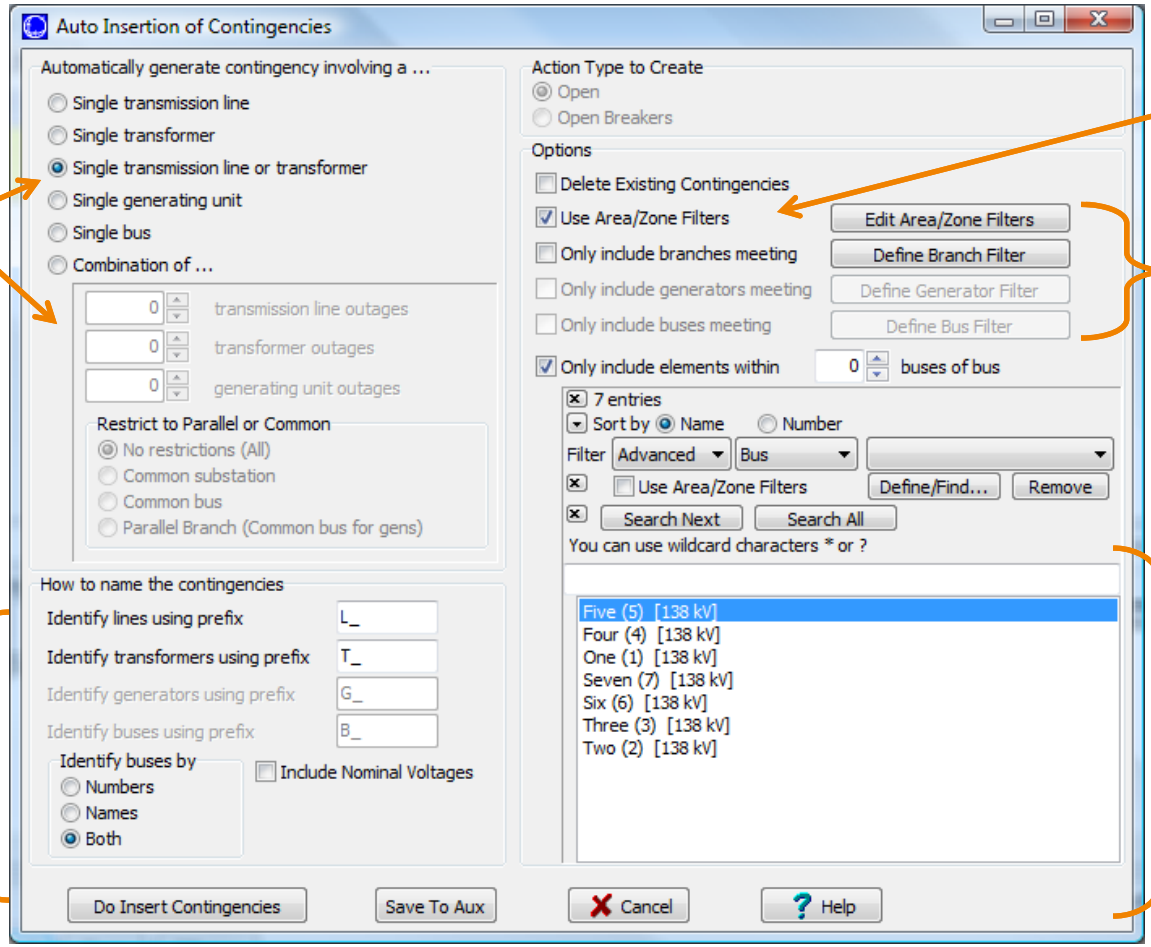
- To insert a contingency
  - On the Case Information Toolbar, choose **Records > Insert**
  - Right-click to bring up the local menu and choose **Insert**
- This opens the dialog to the right.



Auto Insertion of Contingencies

- To automatically insert a set of contingencies. This is available from
  - On the Case Information Toolbar, choose **Records > Auto Insert Contingencies…**
  - Right-click to bring up the local menu and choose **Insert Special > Auto Insert Contingencies**
  - Click on the Auto Insert Button at the bottom of the **Contingency Analysis** dialog
- The Auto Insert dialog is shown on the following slide.

Auto-Insertion of Contingencies Dialog



Choose types to include

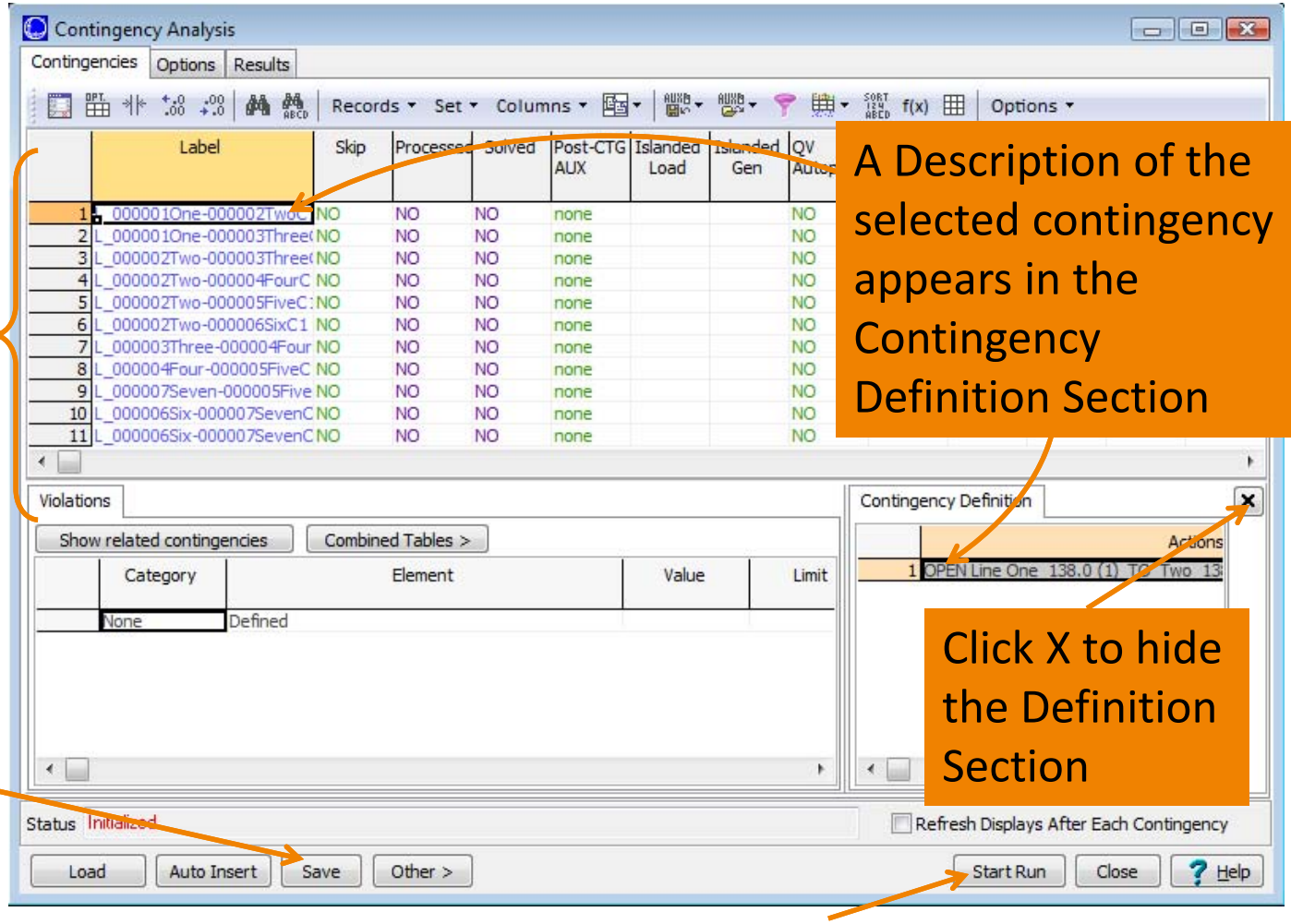
Select to include only elements in chosen areas

Apply Advanced Filters for branches, generators, or buses

Include only elements that are near a particular bus

Specify how to create automatic names for the new contingencies

Contingency Analysis Dialog with Contingencies Defined



List of contingencies now defined

A Description of the selected contingency appears in the Contingency Definition Section

Click X to hide the Definition Section

Click to save the contingencies to file

Click to process the contingencies

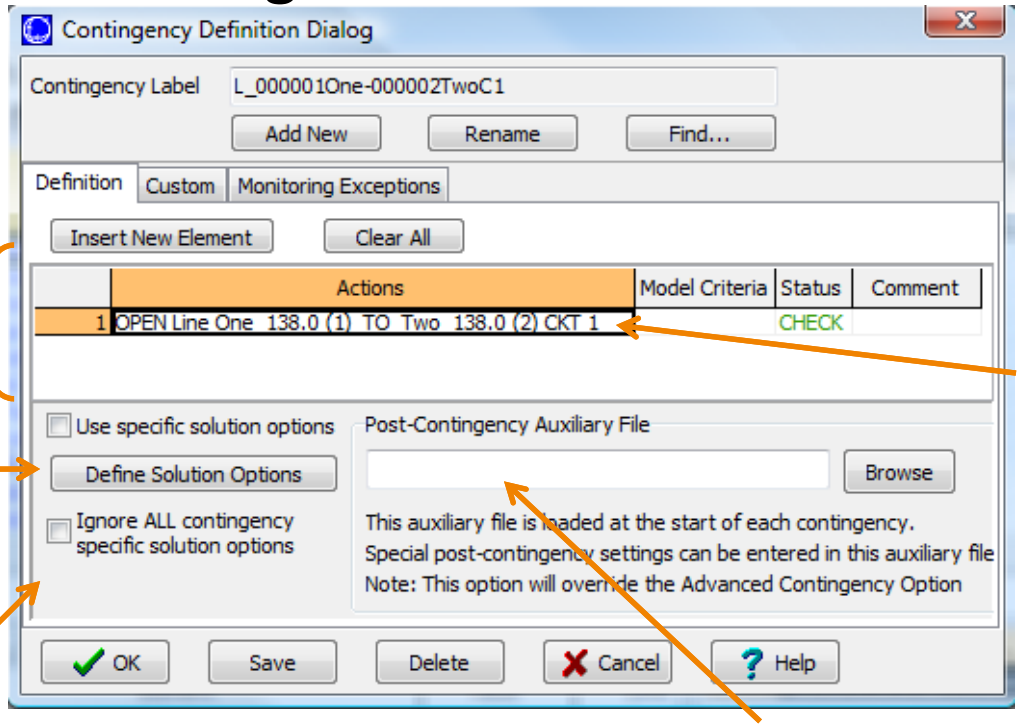
Contingency Definition Dialog

- To open the Contingency Definition Dialog, right-click on one of the contingencies and choose **Show Dialog**.

List of contingency elements

Specify power flow solution options for this contingency

Apply only general power flow solution options

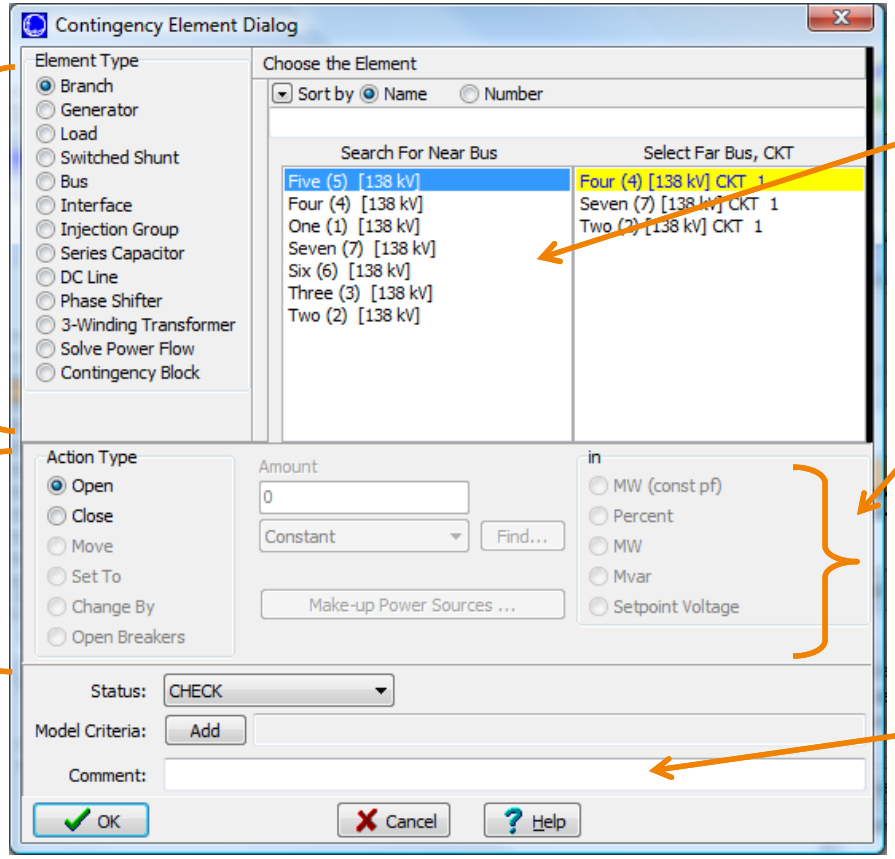


Right-click and choose Insert to add a new Element (or click Insert New Element)

Specify aux file containing actions to perform after the contingency. If this is specified, the post-CTG aux file for all contingencies specified on the Advanced Modeling tab is not applied.

Contingency Element Dialog

- To open, right-click on the Contingency Definition Dialog and choose **Insert** or **Show Dialog**



Choose element type

Choose action type

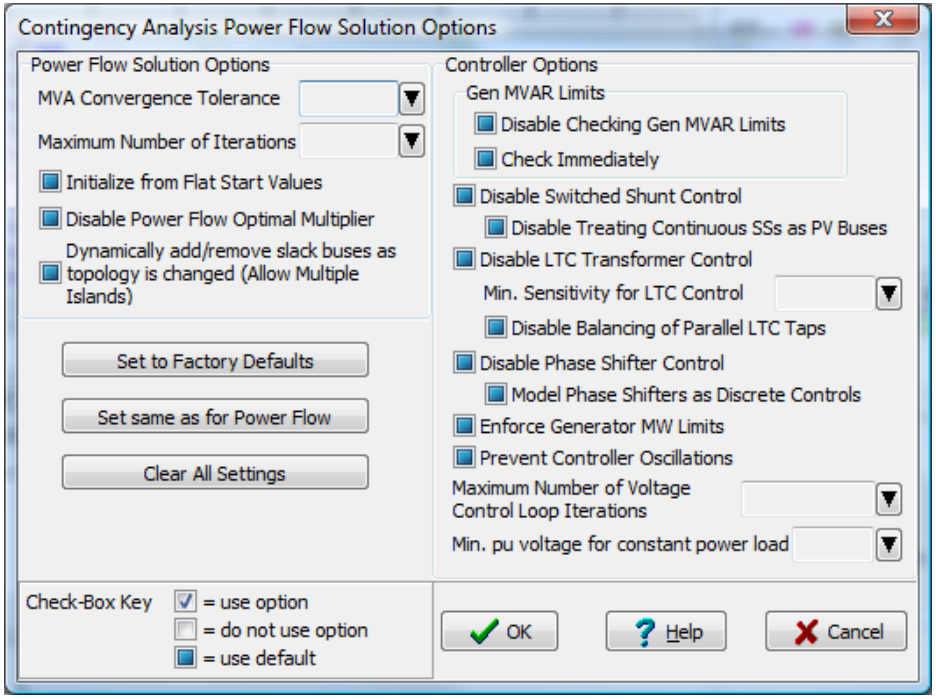
Choose the Element

Choose the action parameters, options based on Action Type and Element Type

Add a comment which will be saved with Auxiliary Files

Contingency Analysis
Power Flow Solution Options

- To Open this dialog, click on **Define Solution Options** on the Contingency Definition Dialog
- This dialog allows you to specify custom solution options for solving the post-contingency power flow



What is the Reference State?

- Contingency analysis always stores a Reference State or pre-contingency state
- Immediately before solving a contingency (whether one at a time or using the automatic processing), this reference state is always loaded into memory
  - Done so that all contingencies start from a common reference
- When using the automatic processing of a list of contingencies, the system is set back to the reference state at the end of the processing

Defining the Reference State

- Initially, the reference state is defined as the power system state that exists at the moment that the Contingency Analysis dialog is opened for the first time
- To change the reference at a later time, you may choose the **Set As Reference** option from the **Other >** button
- Reference state can be reset each time that the Contingency Analysis dialog is opened
  - A dialog will appear asking you what to do each time you reopen the Contingency Analysis dialog

What is stored in the Reference State?

Bus State
- In or out of service
- Voltage magnitude
- Voltage angle
- Boolean stating whether any load exists at the bus (this is used because some of the contingency actions such as *MOVE GEN* will create a fictitious load if there is no generation at the destination bus to merge with.)
- MW Marginal Cost

Switched Shunt State
- In or out of service
- Nom Value MW, MVAR
- Control Mode (FIXED/DISCRETE/CONTINUOUS)
- All the setpoint values
- Description of blocks
- Low/high range for voltage control

Limit Group State
The original ratings sets for normal operation (Line, interfaces – A, B, etc..)

Power Flow Solution Options

Load State
- In or out of service
- Constant power MW and MVAR components of load
- Constant current MW and MVAR load, assuming one per unit voltage
- Constant impedance MW and MVAR load, assuming one per unit voltage
- MW Scale
- Mvar Scale
- AGC status
- Min/Max Load MW

Line State
- In or out of service
- Bypassed or not
- Transformer control settings
- Tap ratio
- Phase shift
- High/Low desired setpoints
- Series Reactance X (Only for Series Caps because they can change)

DC Line State

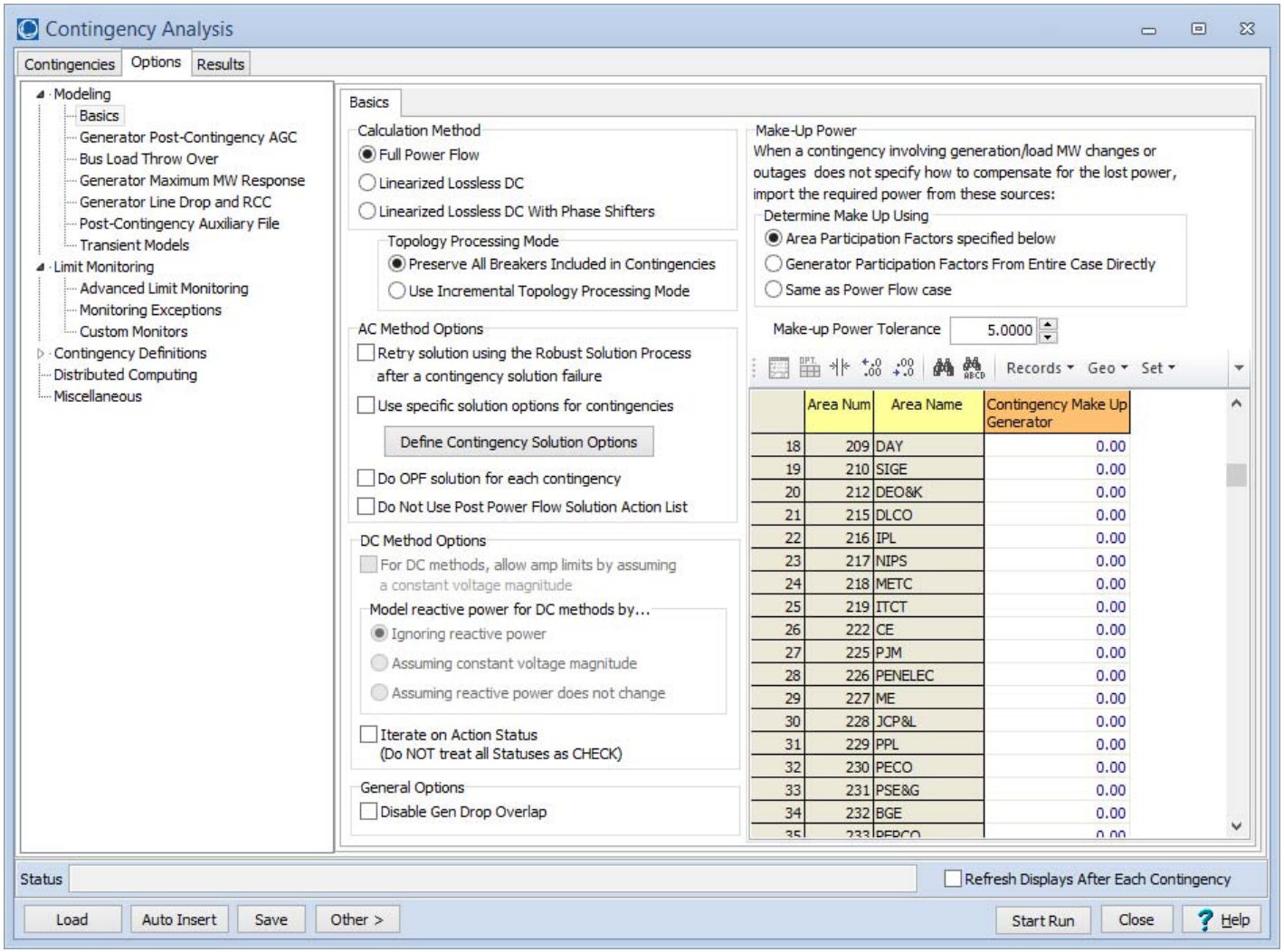
Multi-Terminal DC Line State

Gen State
- In or out of service
- MW output
- MVAR output
- Max/Min MW Output
- Participation Factor
- Max/Min Mvar output
- Voltage Setpoint
- AGC status (YES/NO)
- AVR status (YES/NO)
- Capability Curve
- Whether to use Capability Curve
- Line Drop Compensation Impedance
- Line Drop Compensation Status (YES/NO/POSTCTG)
- Regulated Bus

Area State and Super Area
- Unspecified MW Transactions
- MW Scale
- Mvar Scale
- AGC Status
- Use Area Part Factors (for Super Area)

MW Transaction
- MW Value
- Enabled Status

Options Tab: Modeling



Options Tab: Modeling, Basics

- Calculation Method
  - Full Power Flow
  - Linearized Lossless DC
    - similar to the *DC Power Flow*, but linear sensitivities are used to approximate the effect of outages and insertions, around present operating point
  - Linearized Lossless DC with Phase Shifters
    - Assumes constant MW flow across phase-shifting transformers
- For Linearized DC methods, allow amp limits by assuming a constant voltage magnitude
  - The net effect is that line operating at higher than 1.0 per unit voltage can carry more power
  - Treat Line as Equivalent Amps option must also be selected with Limit Monitoring Settings
- Iterate on Action Status and Disable Gen Drop Overlap
  - discussed in Advanced Contingency Analysis

Options Tab: Modeling, Basics

- Model reactive power for DC methods by…
  - Specify how you want to treat reactive power when using one of the DC methods.
    - Ignore reactive power
      - MVA flow = MW flow
    - Assume constant voltage magnitude
      - Look up Mvar flow from operating circle to calculate MVA flow
    - Assume reactive power does not change
      - Use Mvar flow from base case to calculate MVA flow

Options Tab: Modeling, Basics

- Retry Solution using the Robust Solution Process after a contingency failure
  - Attempts to solve the power flow in a series of steps that involves turning on controls one type of control at a time
- Use specific solution options for contingencies
  - Click “Define Contingency Solution Options” to adjust these
- Do OPF solution for each contingency
  - Uses OPF with current OPF settings in place of single-solution power flow
  - Can help identify mitigation actions
- Do Not Use Post Power Flow Solution Action List
  - Globally defined list set with the power flow solution options and performed after every ac power flow solution
  - Actions may interfere with contingency results if they alleviate loadings caused by contingencies, thus masking the impact of a contingency

Options Tab: Modeling, Basics – Make-up Power

- Describe which areas make up for a change in the MW generation or load in the system.
- Normally done using some sort of "participation" from the areas or generation in the case
  - Typically, power systems control schemes like AGC (or Economic Dispatch), do not respond quickly enough to remove an overload after a contingency. AGC acts on the 15 minute to 1 hour time frame (not tens of seconds)

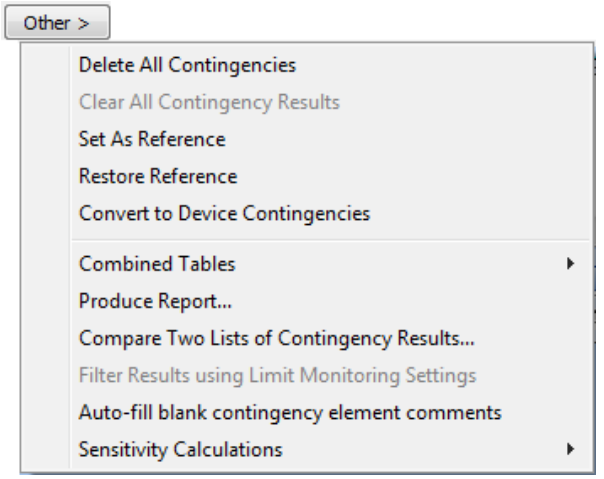
Options Tab: Modeling, Basics – Make-up Power

- Area Participation Factors specified below
  - Each area is weighted according to the factors specified. The total weight for the area is then "spread" across all the area generation according to generator participation factors.
  - The power flow is then solved using Island-Based AGC
- Generator Participation Factors from the Entire Case Directly
  - Generators are weighted by their participation factors
  - The power flow is then solved using Island-Based AGC
- Same as the Power Flow case
  - Just uses the settings for the normal power flow area interchange

Options Tab: Modeling, Basics

- Define Contingency Solution Options
  - Allows you to specify different power flow solution options for solving the post-contingency power flow.
  - This gives 3 levels of power flow solution options
    1. Contingency Specific Options (Contingency Definition Dialog)
    2. Contingency Analysis Tool (Contingency Analysis Options Tab)
    3. General Power Flow Options
  - When Simulator executes a particular contingency, it will look at options in the precedent defined by the order above.
    - For a specific contingency, levels 1 and 2 can be ignored by using option to **Ignore ALL contingency specific solution options**.
  - First it looks to contingency-specific. If an option is marked *use default*, it will look at the Contingency Analysis Tool Options, etc…

Other > Button Remaining Actions



- Delete All Contingencies
  - Deletes all the presently defined contingencies
- Clear All Contingency Results
  - Clears all the results of the presently defined contingencies, but leaves the definitions
- Set As Reference
  - Sets the present power system state to the reference state for Contingency Analysis
- Restore Reference
  - Restores the system to the reference state
- Auto-fill Blank Contingency Element Comments – covered later
- Sensitivity Calculations – covered in a later section
  - Calculate OTDFs using existing PTDFs
  - Filter out violations using OTDFs

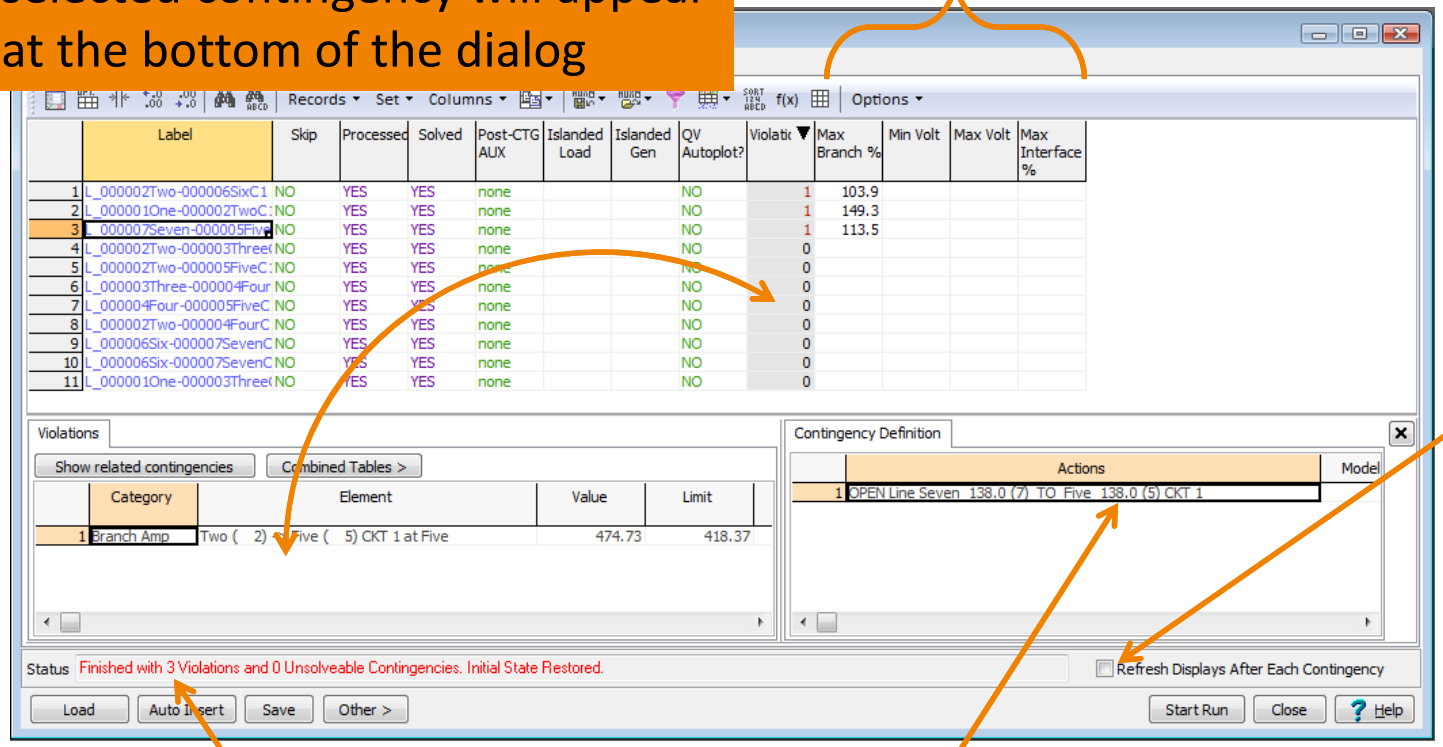
Running Contingency Analysis

- Run every contingency in the list
  - On the Case Information Toolbar, click **Records > Run Contingency Analysis** (also on right-click local menu)
  - Press **Start Run** on Contingencies tab
- On Case Info Toolbar, under **Records >** there are several other options
  - Solve Selected Contingency
    - Note: the system will remain in the post-contingency state after solving the contingency
    - Then when you go to solve another contingency, the reference case will be reinstated prior to solving
  - Solve and Set as Reference
    - Same as Solve Selected, but after completing solution, then the post-contingency state will be saved as a new reference case

Viewing Contingency Results: Contingencies Tab

A list of violations for the selected contingency will appear at the bottom of the dialog

Worst Violation of a various type for each contingency



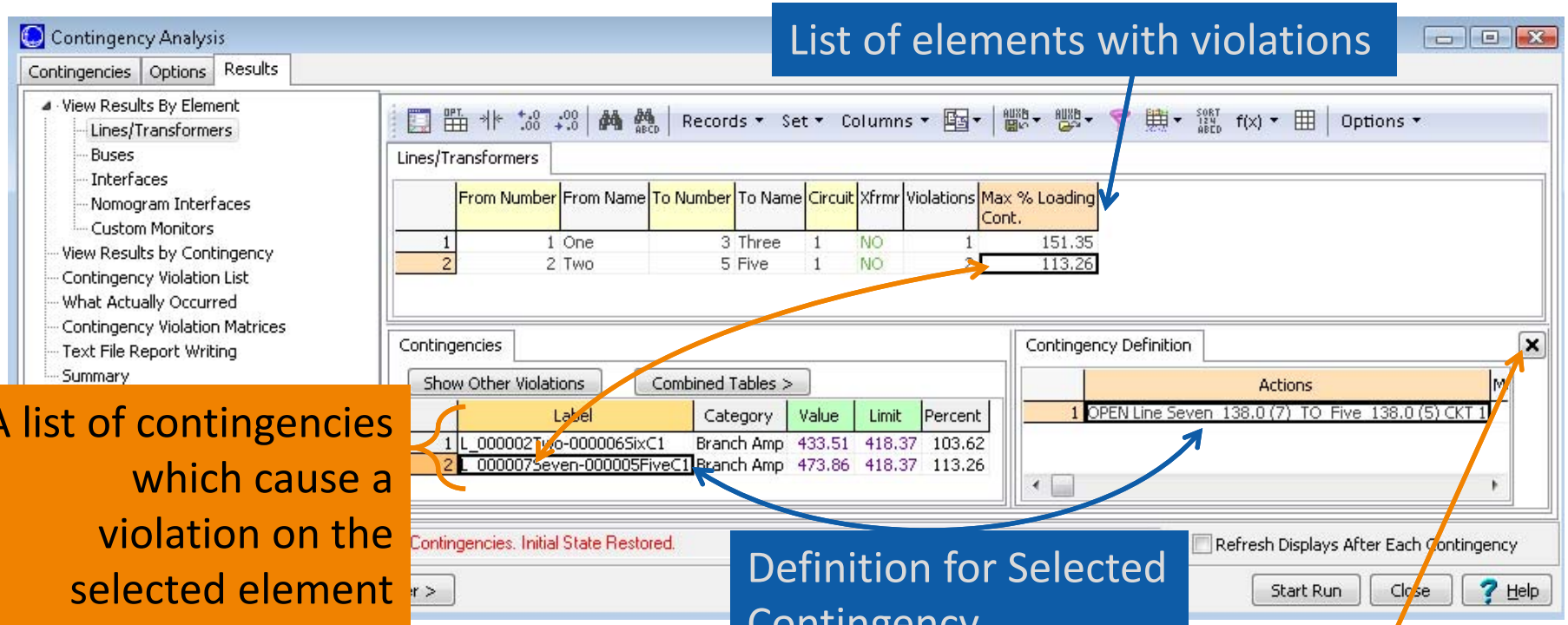
While processing contingencies, the dialog will update continuously if this is checked. This can slow down your analysis a small amount, so uncheck to stop updating.

Total Violations for all processed contingencies

Contingency Definition

View Results by Element: Lines/Transformers Tab

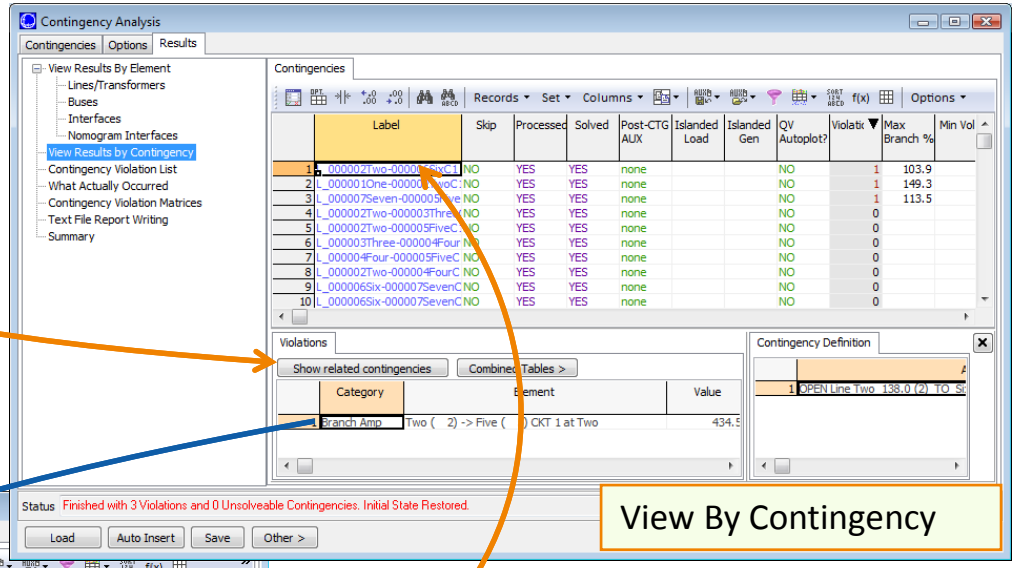
Branches, Buses, Interfaces, Nomogram Interfaces each have a page

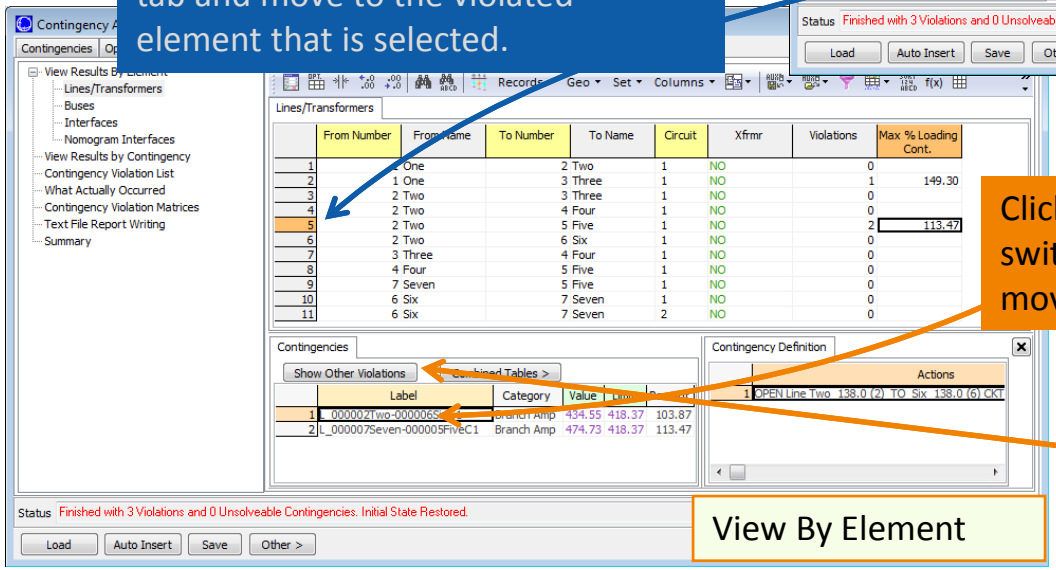


Navigating the Contingency Results

Click Show related contingencies to see other contingencies that cause the same element violation

Click button, and the dialog will switch to the Lines, Buses, Interfaces tab and move to the violated element that is selected.



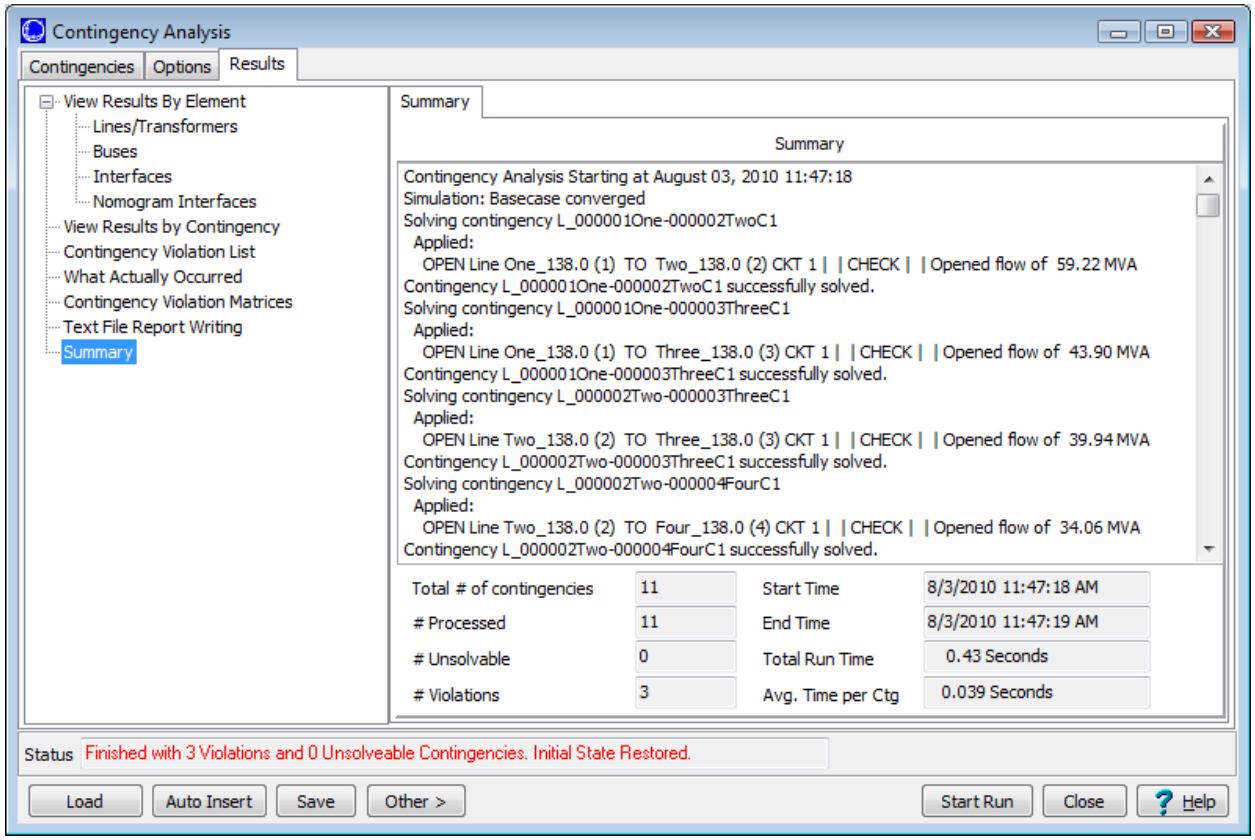


Click button, and the dialog will switch to the Contingencies tab and move to contingency that is selected

Click Show Other Violations to see other violations caused by the same contingency

Summary Tab

- Provides a summary of the status of the present contingency analysis run
- Also, Pause and Abort buttons available while contingency is running



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