

# Introduction to PowerWorld Simulator: Interface and Common Tools

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## I10: Introduction to Contingency Analysis



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# Contingency Analysis

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- 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



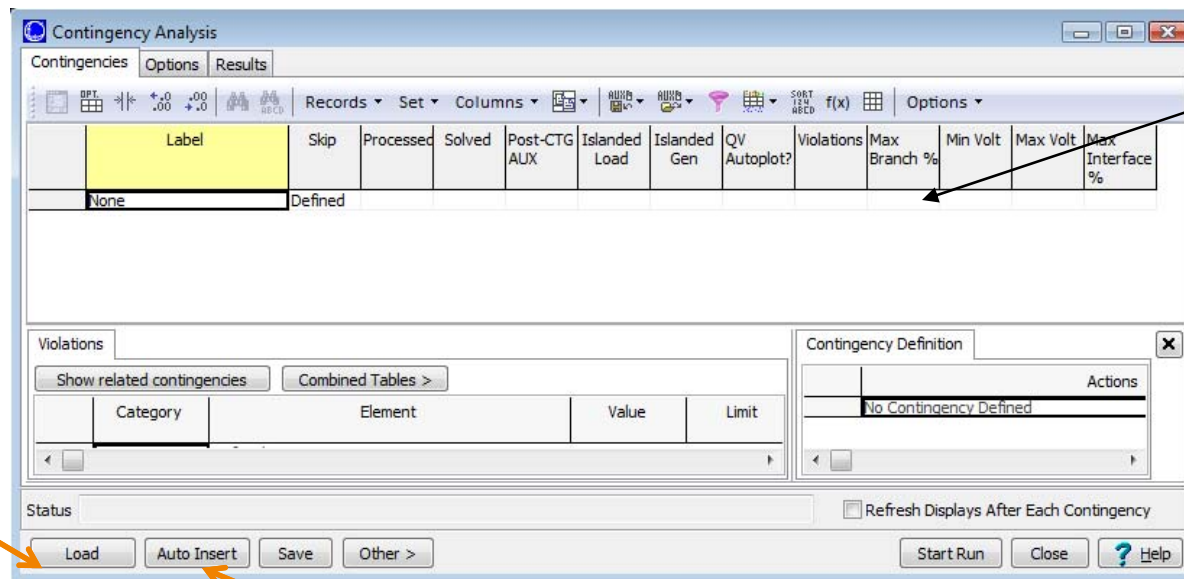
- Contingency Elements allowed in Simulator
    - Opening/Closing of transmission lines and transformers
    - Loss or Recovery of a generator, load, or switched shunt
    - Movement of generation, load, injection group, or switched shunt MWs or Mvars.
    - Changing or Setting of generation, load, injection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

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.



Select to load from a file

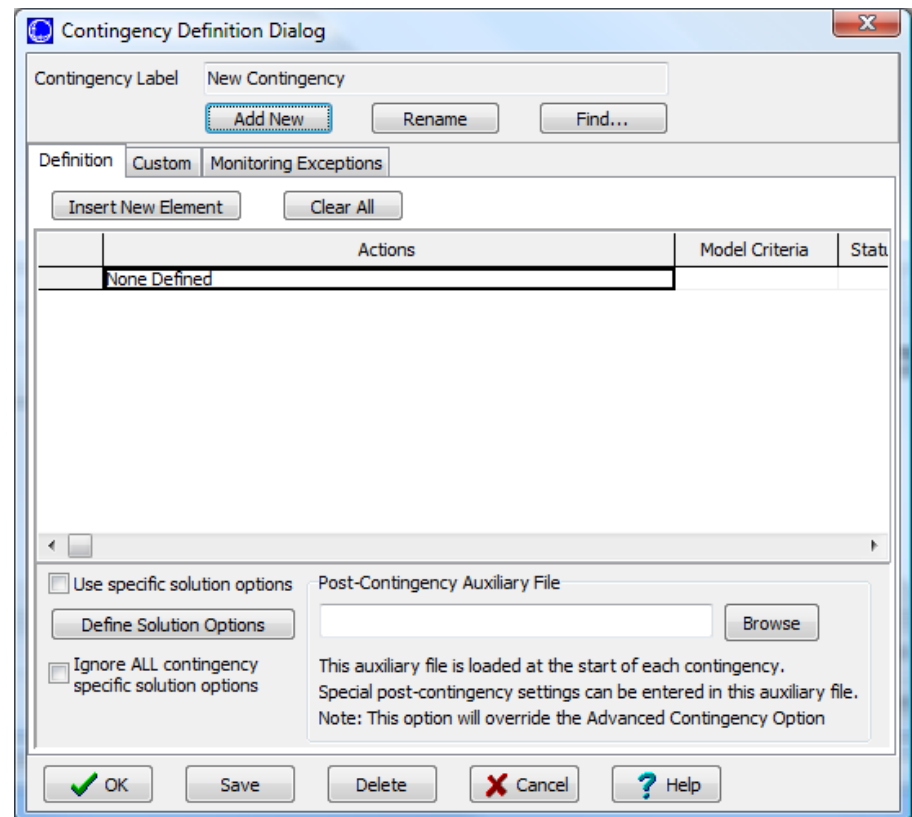
Right-click and choose Insert to add a contingency

Select to allow Simulator to define  
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# 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

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- 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



The screenshot shows the 'Auto Insertion of Contingencies' dialog box. It is divided into several sections:

- Automatically generate contingency involving a ...**: Radio buttons for 'Single transmission line', 'Single transformer', 'Single transmission line or transformer' (selected), 'Single generating unit', 'Single bus', and 'Combination of ...'. Below are spinners for 'transmission line outages', 'transformer outages', and 'generating unit outages'. A sub-section 'Restrict to Parallel or Common' has radio buttons for 'No restrictions (All)' (selected), 'Common substation', 'Common bus', and 'Parallel Branch (Common bus for gens)'.
- Action Type to Create**: Radio buttons for 'Open' (selected) and 'Open Breakers'.
- Options**: Checkboxes for 'Delete Existing Contingencies', 'Use Area/Zone Filters' (checked), 'Only include branches meeting', 'Only include generators meeting', 'Only include buses meeting', and 'Only include elements within' (checked) with a spinner for 'buses of bus'.
- How to name the contingencies**: Text boxes for prefixes 'L\_', 'T\_', 'G\_', and 'B\_'. A section 'Identify buses by' has radio buttons for 'Numbers', 'Names', and 'Both' (selected). A checkbox 'Include Nominal Voltages' is also present.
- Advanced Filters**: A list of 7 entries with 'Sort by' set to 'Name'. The filter is set to 'Advanced' and 'Bus'. A list of elements is shown: 'Five (5) [138 kV]', 'Four (4) [138 kV]', 'One (1) [138 kV]', 'Seven (7) [138 kV]', 'Six (6) [138 kV]', 'Three (3) [138 kV]', and 'Two (2) [138 kV]'. Buttons for 'Define/Find...', 'Remove', 'Search Next', and 'Search All' are present.

Annotations with orange arrows and brackets point to various parts of the dialog:

- 'Choose types to include' points to the 'Automatically generate contingency...' section.
- 'Select to include only elements in chosen areas' points to the 'Use Area/Zone Filters' checkbox.
- 'Apply Advanced Filters for branches, generators, or buses' points to the 'Only include branches meeting', 'Only include generators meeting', and 'Only include buses meeting' checkboxes.
- 'Include only elements that are near a particular bus' points to the 'Only include elements within' checkbox and the 'buses of bus' spinner.
- 'Specify how to create automatic names for the new contingencies' points to the 'How to name the contingencies' section.

Specify how to create automatic names for the new contingencies

# Contingency Analysis Dialog with Contingencies Defined



List of contingencies now defined

	Label	Skip	Processed	Solved	Post-CTG AUX	Islanded Load	Islanded Gen	QV Auto
1	L_000001One-000002TwoC	NO	NO	NO	none			NO
2	L_000001One-000003ThreeC	NO	NO	NO	none			NO
3	L_000002Two-000003ThreeC	NO	NO	NO	none			NO
4	L_000002Two-000004FourC	NO	NO	NO	none			NO
5	L_000002Two-000005FiveC	NO	NO	NO	none			NO
6	L_000002Two-000006SixC1	NO	NO	NO	none			NO
7	L_000003Three-000004FourC	NO	NO	NO	none			NO
8	L_000004Four-000005FiveC	NO	NO	NO	none			NO
9	L_000007Seven-000005FiveC	NO	NO	NO	none			NO
10	L_000006Six-000007SevenC	NO	NO	NO	none			NO
11	L_000006Six-000007SevenC	NO	NO	NO	none			NO

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

Click to save the contingencies to file

Click X to hide the Definition Section

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.

	Actions	Model Criteria	Status	Comment
1	OPEN Line One 138.0 (1) TO Two 138.0 (2) CKT 1		CHECK	

# Contingency Element Dialog



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

The screenshot shows the 'Contingency Element Dialog' window. It is divided into several sections:

- Element Type:** A list of radio buttons for selecting the element type. 'Branch' is selected.
- Choose the Element:** A table with two columns: 'Search For Near Bus' and 'Select Far Bus, CKT'. The 'Near Bus' column lists buses like 'Five (5) [138 kV]', 'Four (4) [138 kV]', etc. The 'Far Bus' column lists circuit breakers like 'Four (4) [138 kV] CKT 1', 'Seven (7) [138 kV] CKT 1', etc. An arrow points to the 'Five (5) [138 kV]' row.
- Action Type:** A list of radio buttons for selecting the action type. 'Open' is selected.
- Amount:** A text box containing '0' and a dropdown menu set to 'Constant'. A 'Find...' button is next to it.
- in:** A list of radio buttons for selecting the unit or parameter. 'MW (const pf)' is selected.
- Status:** A dropdown menu set to 'CHECK'.
- Model Criteria:** An 'Add' button and a text box.
- Comment:** A text box for entering a comment.

Annotations with orange arrows and brackets point to these sections:

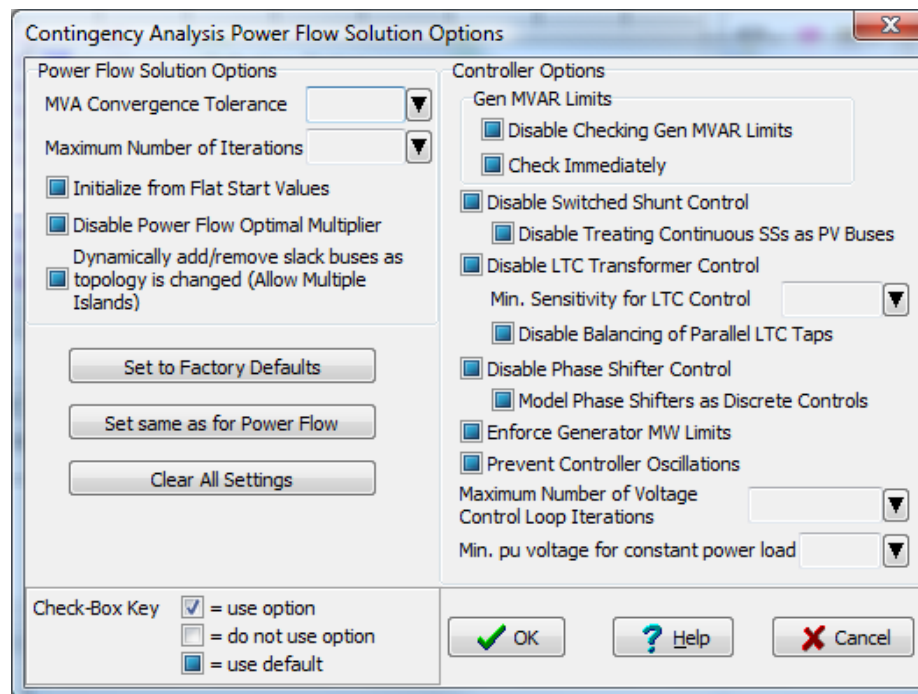
- 'Choose element type' points to the 'Element Type' list.
- 'Choose action type' points to the 'Action Type' list.
- 'Choose the Element' points to the 'Choose the Element' table.
- 'Choose the action parameters, options based on Action Type and Element Type' points to the 'Amount' and 'in' sections.
- 'Add a comment which will be saved with Auxiliary Files' points to the 'Comment' text box.

# 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?

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- 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

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- 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



Contingency Analysis

Contingencies Options Results

Modeling

- Basics
- Generator Post-Contingency AGC
- Bus Load Throw Over
- Generator Maximum MW Response
- Generator Line Drop and RCC
- Post-Contingency Auxiliary File
- Transient Models
- Limit Monitoring
  - Advanced Limit Monitoring
  - Monitoring Exceptions
  - Custom Monitors
- Contingency Definitions
  - Distributed Computing
  - Miscellaneous

Basics

Calculation Method

- Full Power Flow
- Linearized Lossless DC
- Linearized Lossless DC With Phase Shifters

Topology Processing Mode

- Preserve All Breakers Included in Contingencies
- Use Incremental Topology Processing Mode

AC Method Options

- Retry solution using the Robust Solution Process after a contingency solution failure
- Use specific solution options for contingencies

Define Contingency Solution Options

- Do OPF solution for each contingency
- Do Not Use Post Power Flow Solution Action List

DC Method Options

- For DC methods, allow amp limits by assuming a constant voltage magnitude

Model reactive power for DC methods by...

- Ignoring reactive power
- Assuming constant voltage magnitude
- Assuming reactive power does not change

- Iterate on Action Status (Do NOT treat all Statuses as CHECK)

General Options

- Disable Gen Drop Overlap

Make-Up Power

When a contingency involving generation/load MW changes or outages does not specify how to compensate for the lost power, import the required power from these sources:

Determine Make Up Using

- Area Participation Factors specified below
- Generator Participation Factors From Entire Case Directly
- Same as Power Flow case

Make-up Power Tolerance 5.0000

Area Num	Area Name	Contingency Make Up Generator
18	209 DAY	0.00
19	210 SIGE	0.00
20	212 DEO&K	0.00
21	215 DLCO	0.00
22	216 IPL	0.00
23	217 NIPS	0.00
24	218 METC	0.00
25	219 ITCT	0.00
26	222 CE	0.00
27	225 PJM	0.00
28	226 PENELEC	0.00
29	227 ME	0.00
30	228 JCP&L	0.00
31	229 PPL	0.00
32	230 PECO	0.00
33	231 PSE&G	0.00
34	232 BGE	0.00
35	233 BPCO	0.00

Status

Refresh Displays After Each Contingency

Load Auto Insert Save Other > Start Run Close ? Help

# 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

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- 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

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- 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



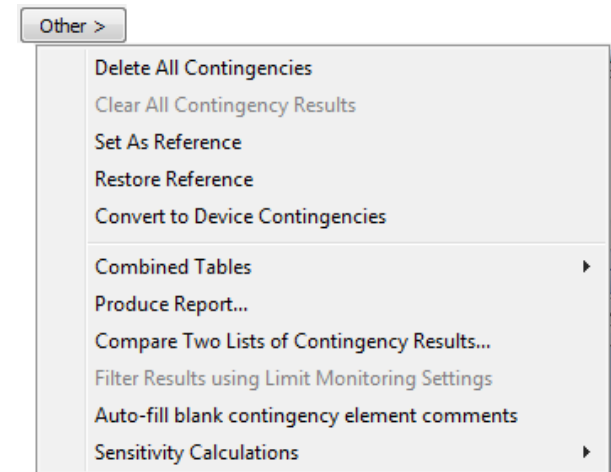
- Define Contingency Solution Options
  - Allows you to specify different power flow solution options for solving the post-contingency power flow.
  - This gives 3 levels of power flow solution options
    1. Contingency Specific Options (Contingency Definition Dialog)
    2. Contingency Analysis Tool (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

Label	Skip	Processed	Solved	Post-CTG AUX	Islanded Load	Islanded Gen	QV Autoplot?	Violatix	Max Branch %	Min Volt	Max Volt	Max Interface %
1 L_000002Two-000006SixC1	NO	YES	YES	none			NO	1	103.9			
2 L_000001One-000002TwoC	NO	YES	YES	none			NO	1	149.3			
3 L_000007Seven-000005Five	NO	YES	YES	none			NO	1	113.5			
4 L_000002Two-000003Three	NO	YES	YES	none			NO	0	0			
5 L_000002Two-000005FiveC	NO	YES	YES	none			NO	0	0			
6 L_000003Three-000004Four	NO	YES	YES	none			NO	0	0			
7 L_000004Four-000005FiveC	NO	YES	YES	none			NO	0	0			
8 L_000002Two-000004FourC	NO	YES	YES	none			NO	0	0			
9 L_000006Six-000007SevenC	NO	YES	YES	none			NO	0	0			
10 L_000006Six-000007SevenC	NO	YES	YES	none			NO	0	0			
11 L_000001One-000003Three	NO	YES	YES	none			NO	0	0			

Violations

Category	Element	Value	Limit
1 Branch Amp	Two ( 2 ) Five ( 5 ) CKT 1 at Five	474.73	418.37

Contingency Definition

Actions	Model
1 OPEN Line Seven 138.0 (7) TO Five 138.0 (5) CKT 1	

Status Finished with 3 Violations and 0 Unsolvable Contingencies. Initial State Restored.

Buttons: Load, Auto Insert, Save, Other >, Refresh Displays After Each Contingency, Start Run, Close, Help

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

**List of elements with violations**

	From Number	From Name	To Number	To Name	Circuit	Xfrmr	Violations	Max % Loading Cont.
1	1	One	3	Three	1	NO	1	151.35
2	2	Two	5	Five	1	NO	1	113.26

**A list of contingencies which cause a violation on the selected element appears at the bottom of the dialog**

	Label	Category	Value	Limit	Percent
1	L_000002Two-000006SixC1	Branch Amp	433.51	418.37	103.62
2	L_000007Seven-000005FiveC1	Branch Amp	473.86	418.37	113.26

**Definition for Selected Contingency**

Actions	
1	OPEN Line Seven 138.0 (7) TO Five 138.0 (5) CKT 1

**X/O for showing or hiding the definition**



# 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

Label	Skip	Processed	Solved	Post-CTG AUX	Islanded Load	Islanded Gen	QV Autoplot?	Violatn	Max Branch %	Min Vol
1_000002Two-00005FiveC1	NO	YES	YES	none			NO	1	103.9	
2_000001One-00005FiveC1	NO	YES	YES	none			NO	1	149.3	
3_000007Seven-000005FiveC1	NO	YES	YES	none			NO	1	113.5	
4_000002Two-000003ThreeC1	NO	YES	YES	none			NO	0	0	
5_000002Two-000005FiveC1	NO	YES	YES	none			NO	0	0	
6_000003Three-000004FourC1	NO	YES	YES	none			NO	0	0	
7_000004Four-000005FiveC1	NO	YES	YES	none			NO	0	0	
8_000002Two-000004FourC1	NO	YES	YES	none			NO	0	0	
9_000006Six-000007SevenC1	NO	YES	YES	none			NO	0	0	
10_000006Six-000007SevenC1	NO	YES	YES	none			NO	0	0	

View By Contingency

From Number	From Name	To Number	To Name	Circuit	Xfmr	Violations	Max % Loading Cont.
1	One	Two	Two	1	NO	0	
2	One	Three	Three	1	NO	1	149.30
3	Two	Three	Three	1	NO	0	
4	Two	Four	Four	1	NO	0	
5	Two	Five	Five	1	NO	2	113.47
6	Two	Six	Six	1	NO	0	
7	Three	Four	Four	1	NO	0	
8	Four	Five	Five	1	NO	0	
9	Seven	Five	Five	1	NO	0	
10	Six	Seven	Seven	1	NO	0	
11	Six	Seven	Seven	2	NO	0	

View By Element

# Summary Tab



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

The screenshot shows the 'Contingency Analysis' software window with the 'Summary' tab selected. The interface includes a tree view on the left, a main text area for the summary, and a status bar at the bottom.

**Summary**

Contingency Analysis Starting at August 03, 2010 11:47:18  
Simulation: Basecase converged  
Solving contingency L\_000001One-000002TwoC1  
Applied:  
OPEN Line One\_138.0 (1) TO Two\_138.0 (2) CKT 1 | CHECK | | Opened flow of 59.22 MVA  
Contingency L\_000001One-000002TwoC1 successfully solved.  
Solving contingency L\_000001One-000003ThreeC1  
Applied:  
OPEN Line One\_138.0 (1) TO Three\_138.0 (3) CKT 1 | CHECK | | Opened flow of 43.90 MVA  
Contingency L\_000001One-000003ThreeC1 successfully solved.  
Solving contingency L\_000002Two-000003ThreeC1  
Applied:  
OPEN Line Two\_138.0 (2) TO Three\_138.0 (3) CKT 1 | CHECK | | Opened flow of 39.94 MVA  
Contingency L\_000002Two-000003ThreeC1 successfully solved.  
Solving contingency L\_000002Two-000004FourC1  
Applied:  
OPEN Line Two\_138.0 (2) TO Four\_138.0 (4) CKT 1 | CHECK | | Opened flow of 34.06 MVA  
Contingency L\_000002Two-000004FourC1 successfully solved.

Total # of contingencies	11	Start Time	8/3/2010 11:47:18 AM
# Processed	11	End Time	8/3/2010 11:47:19 AM
# Unsolvable	0	Total Run Time	0.43 Seconds
# Violations	3	Avg. Time per Ctg	0.039 Seconds

Status: Finished with 3 Violations and 0 Unsolvable Contingencies. Initial State Restored.

Buttons: Load, Auto Insert, Save, Other >, Start Run, Close, Help

Blank Page