

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



- 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
- Open/Close, Set/Change injection group values
- Opening of all lines connected to a bus
- Opening/Closing of all lines or transformers in an interface

specification of make-up power also allowed

- 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
- Open/Close DC converter, Set/Change DC converter setpoints
- Change Area AGC Type
- Open all branches and tie lines or Set/Change MWs of all online generators in a substation
- Run a SCRIPT action
- Abort or 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.

Select to load from a file

Select to allow Simulator to define

Name	Skip	Category	Processed	Solved	Include Remedial Actions	Screen Allow	Post-CTG AUX	Islanded Load	Islanded Gen	Global Actions	Transient Actions	Remedial Actions	Custom Monitor Violation	Violation	Max Branch %	Min Volt	Max Volt	Max Interface %	Max Bus Pair Angle
None		Defined																	

Violations What Occurred

Category	Element	Value	Limit	Percent	Area Name Assoc.	Nom kV Assoc.
None	Defined					

Definition

Actions
No Contingency Defined

Right-click and choose Insert to add a contingency

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

The image shows a screenshot of the 'Contingency Definition Dialog' window. The window has a title bar with a close button. Below the title bar, there is a 'Contingency Label' field containing 'New Contingency' and three buttons: 'Add New', 'Rename', and 'Find...'. Below this, there are two tabs: 'Definition' and 'Monitoring Exceptions'. Under the 'Definition' tab, there are two buttons: 'Insert New Element' and 'Clear All'. Below these buttons is a table with the following structure:

Actions	Model Criteria	Status	P
None Defined			

Below the table, there is a 'Categories' field. Below that, there are several checkboxes and a 'Post-Contingency Auxiliary File' section. The checkboxes are: 'Use specific solution options' (checked), 'Ignore ALL contingency specific solution options' (unchecked), 'Include Remedial Actions' (checked), 'Normal Rating No Action' (unchecked), 'Allow Screening' (unchecked), and 'Skip' (unchecked). The 'Post-Contingency Auxiliary File' section has a 'Browse' button and a text box. Below the text box, there is a note: 'This auxiliary file is loaded at the start of each contingency. Special post-contingency settings can be entered in this auxiliary file. Note: This option will override the Advanced Contingency Option'. At the bottom of the dialog, there are five buttons: 'OK', 'Save', 'Delete', 'Cancel', and 'Help'.

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



The screenshot shows the 'Auto Insertion of Contingency Records' dialog box. It is divided into several sections: 'Automatically generate involving a ...' with radio buttons for object types; 'Naming Options' with text boxes for prefixes and radio buttons for bus identification; 'Action Type to Create' with radio buttons for 'Open' and 'Open Breakers'; 'Options' with checkboxes for 'Delete Existing Contingency records' and 'Use Area/Zone Filters'; 'Filter using nominal voltage range' with 'All Voltages' checked and voltage range inputs; 'Branch End to Use' with radio buttons for 'Higher Voltage' and 'Lower Voltage'; 'Treatment of Transformers that are Part of 3-Windings' with radio buttons for 'Insert winding outages separately', 'Insert 3-Winding transformer outages', and 'Ignore'; and 'Only include elements within' with a numerical input and a dropdown for 'Number of nodes'. At the bottom are buttons for 'Do Insert Contingency records', 'Save Settings', 'Save To Aux', and 'Cancel'. Orange arrows point from text annotations to these specific UI elements.

Choose Object Type

Or create multiple element CTGs

Select to include only elements in chosen areas

Apply Voltage or Advanced Filters to Objects

Include only elements that are near a particular bus

Options for creating unique names for the new contingencies

Create the contingencies and close the dialog

Contingency Analysis Dialog with Contingencies Defined



Click to process the contingencies

Click to save the contingencies to aux file

List of CTGs now defined

The screenshot shows the 'Contingency Analysis' dialog box. At the top, there are buttons for 'Start Run', 'Abort', 'Load', 'Auto Insert', 'Save', and 'Other >'. The status is 'Initialized'. Below the buttons is a table of contingencies. The table has columns: Name, Skip, Category, Processed, Solved, Include Remedial Actions, Screen Allow, Post-CTG AUX, and Islanded Load. The first row is selected, and its details are shown in the 'Definition' section at the bottom right. The 'Definition' section has a table with columns 'Actions' and 'Model Cr'. The first row in the 'Definition' table is '1 OPEN Line One 138.0 (1) TO Two 138.0 (2) CKT 1'. There is an 'X' button in the top right corner of the 'Definition' section.

Name	Skip	Category	Processed	Solved	Include Remedial Actions	Screen Allow	Post-CTG AUX	Islanded Load
L_000001One-000002TwoC1	NO		NO	NO	YES	NO	none	
L_000001One-000003ThreeC1	NO		NO	NO	YES	NO	none	
L_000002Two-000003ThreeC1	NO		NO	NO	YES	NO	none	
L_000002Two-000004FourC1	NO		NO	NO	YES	NO	none	
L_000002Two-000005FiveC1	NO		NO	NO	YES	NO	none	
L_000002Two-000006SixC1	NO		NO	NO	YES	NO	none	
L_000003Three-000004FourC1	NO		NO	NO	YES	NO	none	
L_000004Four-000005FiveC1	NO		NO	NO	YES	NO	none	
L_000007Seven-000005FiveC1	NO		NO	NO	YES	NO	none	
L_000006Six-000007SevenC1	NO		NO	NO	YES	NO	none	
L_000006Six-000007SevenC2	NO		NO	NO	YES	NO	none	

Actions	Model Cr
1 OPEN Line One 138.0 (1) TO Two 138.0 (2) CKT 1	

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

Click X to hide the Definition Section

Contingency Definition Dialog



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

List of contingency element(s)

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/settings to apply 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 Element and choose **Insert** or **Show Dialog**

Choose element type

Choose the Element

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

Choose action type

Add a comment which will be saved with Auxiliary Files

Element ID	Element Name	Element Description
1	(One)	[138.0 kV]
2	(Two)	[138.0 kV]
3	(Three)	[138.0 kV]
4	(Four)	[138.0 kV]
5	(Five)	[138.0 kV]
6	(Six)	[138.0 kV]
7	(Seven)	[138.0 kV]
2	(Two)	[138.0 kV] CKT 1
3	(Three)	[138.0 kV] CKT 1

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

Contingency Analysis Power Flow Solution Options

Power Flow Solution Options

MVA Convergence Tolerance

Maximum Number of Iterations

Disable Power Flow Optimal Multiplier

Dynamically add/remove slack buses as topology is changed (Allow Multiple Islands)

Set to Factory Defaults

Set same as for Power Flow

Clear All Settings

Controller Options

Gen MVAR Limits

Disable Checking Gen MVAR Limits

Check Immediately

Check Back Off Immediately

Disable Switched Shunt Control

Disable Treating Continuous SSS as PV Buses

Disable SVC Control

Disable LTC Transformer Control

Min. Sensitivity for LTC Control

Disable Balancing of Parallel LTC Taps

Disable DC Line Transformer Tap Control

Disable Phase Shifter Control

Model Phase Shifters as Discrete Controls

Disable D-FACTS Control

Enforce Generator MW Limits

Prevent Controller Oscillations

Maximum Number of Voltage Control Loop Iterations

Min. pu voltage for constant power load

Min. pu voltage for constant current load

Check-Box Key = use option
 = do not use option
 = use default

OK Help Cancel

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 is run 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)

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)

DC Line State

Multi-Terminal DC Line State

MW Transaction

- MW Value
- Enabled Status

Options Tab: Modeling → Basics



The screenshot displays the 'Contingency Analysis' software interface. The 'Options' tab is selected, and the 'Basics' sub-tab is active. The interface includes a top toolbar with buttons for 'Start Run', 'Abort', 'Load', 'Auto Insert', 'Save', and 'Other >'. The status is 'Initialized'. A checkbox for 'Refresh Displays After Each Contingency' is present. The left sidebar shows a tree view under 'Modeling' with 'Basics' selected. The main area contains several sections of options:

- 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 (with a 'Define Contingency Solution Options' button), Do OPF solution for each contingency, Do Not Use Post Power Flow Solution Action List
- 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
 - Prevent new island without enough controllable generation

At the bottom right, there is a table with columns 'Area Num', 'Area Name', and 'Contingency Make Up Generator'. The table contains three rows of data:


Area Num	Area Name	Contingency Make Up Generator
1	1 Top	0.00
2	2 Left	0.00
3	3 Right	0.00

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
- Topology Processing Mode
 - For use with ITP add-on (discussed in another section)



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
- Disable Gen Drop Overlap
 - Affects injection group contingency elements that drop generation by merit order (discussed in another section)

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
 - NOTE: Default Part. Factor = 0 for all areas (has the effect of sending make up power to the island slack)
- 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
 - Uses the same Area/Superarea/Island MW interchange settings as the normal power flow

Options Tab:

Modeling → Basics: Make-up Power



- 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...

Options Tab:

Modeling → DC and Screening Options

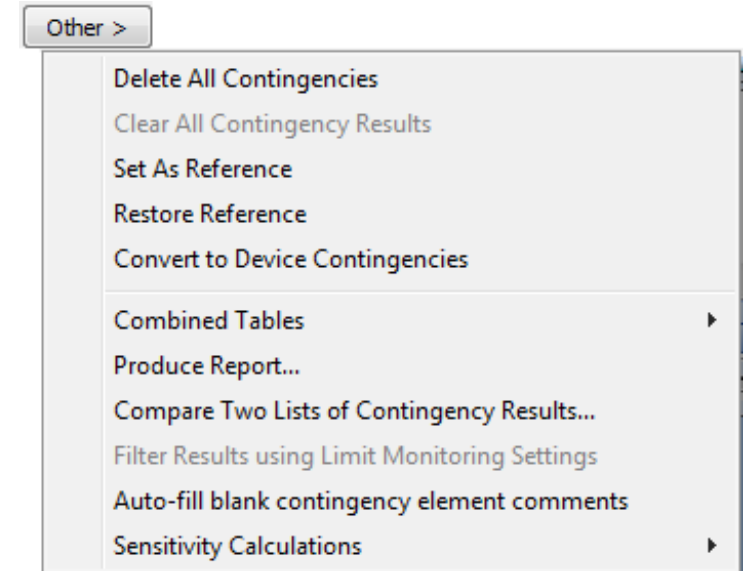


- For Linearized DC methods, allow amp limits by assuming a constant voltage magnitude
 - The net effect is that line operating at higher than 1.0 per unit voltage can carry more power
 - Treat Line as Equivalent Amps option must also be selected with Limit Monitoring Settings
- Model reactive power 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
- Screening Options (discussed in another section)

Other > Button



- 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
 - Apply Selected Contingency
 - Applies the contingency actions, but does not solve the power flow

Viewing Contingency Results

Contingencies Tab



Worst Violation of a various type for each contingency

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

The screenshot shows a software dialog box for contingency analysis. At the top, there is a table with columns: 'Stand Gen', 'QV Autoplot?', 'Violatir', 'Max Branch %', 'Min Volt', 'Max Volt', and 'Max Interface %'. Below this is a 'Violations' section with a table containing columns: 'Category', 'Element', 'Value', and 'Limit'. The 'Violations' table has one row: '1 Branch Amp', 'Two (2) -> Five (5) CKT 1 at Five', '474.73', and '418.37'. To the right is a 'Contingency Definition' section with an 'Actions' table containing one row: '1 OPEN Line Seven 138.0 (7) TO Five 138.0 (5) CKT 1'. At the bottom, there is a status bar that reads 'Status Finished with 3 Violations and 0 Unsolvable Contingencies. Initial State Restored.' and a checkbox labeled 'Refresh Displays After Each Contingency' which is unchecked. Buttons for 'Load', 'Auto Insert', 'Save', 'Other >', 'Start Run', 'Close', and 'Help' are also visible.

Total Violations for all processed contingencies

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.

Contingency Definition

Results → View Results by Element Lines/Transformers Tab



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

The screenshot shows the 'Contingency Analysis' software interface. On the left, a tree view shows 'View Results By Element' with 'Lines/Transformers' selected. The main window displays a table of violations for 'Lines/Transformers' with columns: From Number, From Name, To Number, To Name, Circuit, Xfrmr, Violations, and Max % Loading Cont. Below this is a 'Contingencies' table with columns: Label, Category, Value, Limit, and Percent. A 'Contingency Definition' dialog is open, showing an 'Actions' table with a single entry: '1 OPEN Line Seven 138.0 (7) TO Five 138.0 (5) CKT 1'. The dialog has an 'X' button in the top right corner.

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	

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

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

List of elements with violations

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

Definition for Selected Contingency

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.

View By Contingency

Label	Skip	Processed	Solved	Post-CTG AUX	Islanded Load	Islanded Gen	QV Autoplot?	Violations	Max Branch %	Min Vol
1_L_000002Two-000005FiveC1	NO	YES	YES	none			NO	1	103.9	
2_L_000001One-000007SevenC1	NO	YES	YES	none			NO	1	149.3	
3_L_000007Seven-000009NineC1	NO	YES	YES	none			NO	1	113.5	
4_L_000002Two-000003ThreeC1	NO	YES	YES	none			NO	0		
5_L_000002Two-000005FiveC1	NO	YES	YES	none			NO	0		
6_L_000003Three-000004FourC1	NO	YES	YES	none			NO	0		
7_L_000004Four-000005FiveC1	NO	YES	YES	none			NO	0		
8_L_000002Two-000004FourC1	NO	YES	YES	none			NO	0		
9_L_000006Six-000007SevenC1	NO	YES	YES	none			NO	0		
10_L_000006Six-000007SevenC1	NO	YES	YES	none			NO	0		

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

View By Element

Label	Category	Value	Units
1_L_000002Two-000005FiveC1	Branch Amp	434.55	418.37
2_L_000007Seven-000005FiveC1	Branch Amp	474.73	418.37

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
- **Pause** and **Abort** buttons are available when a contingency is solving

The screenshot shows the 'Contingency Analysis' software window with the 'Results' tab selected. The 'Summary' sub-tab is active, displaying the following text:

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

Slide Intentionally Left Blank