

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



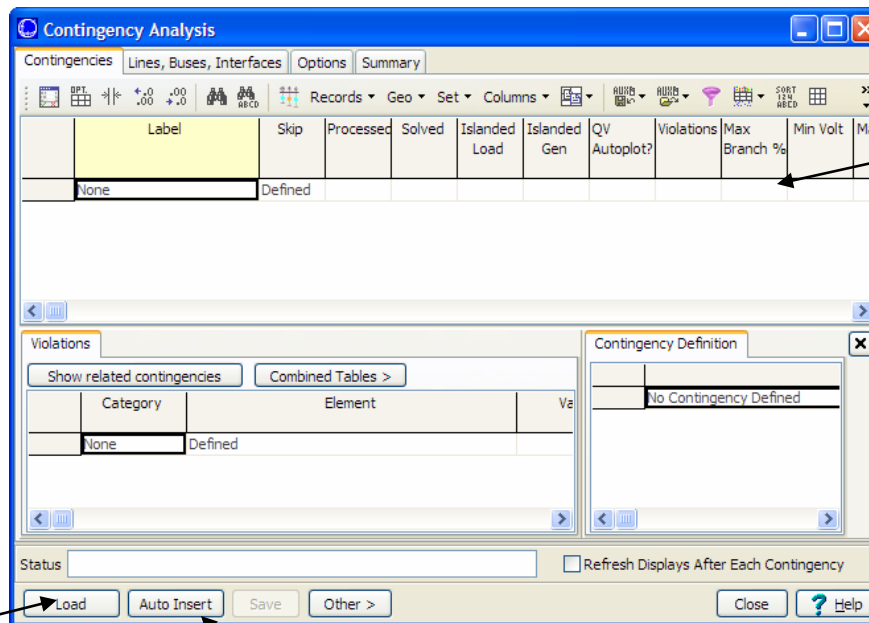
- Contingency Elements allowed in Simulator
 - Opening/Closing of transmission lines and transformers
 - Loss or Recovery of a generator, load, or switched shunt
 - Movement of generation, load, injection group, or switched shunt MWs or Mvars.
 - Changing or Setting of generation, load, injection group,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

Note: “Conditional” Elements which only occur if a particular condition is met are also allowed. These will be covered at the end of this 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

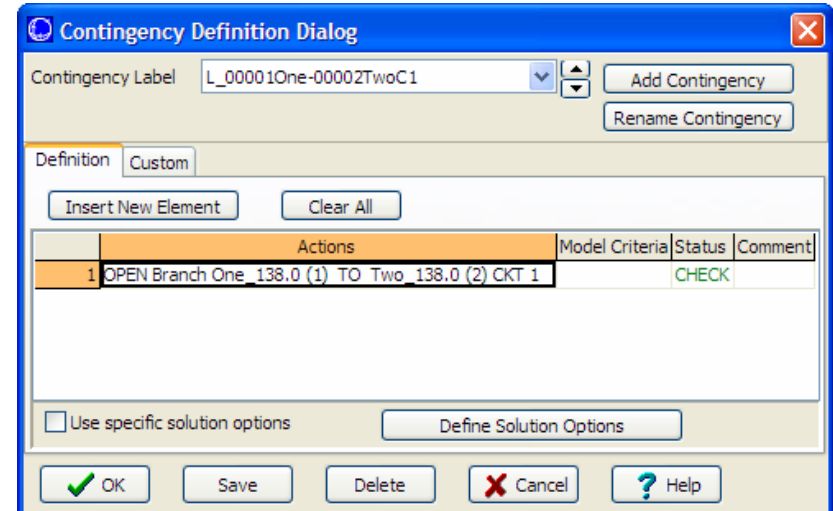
Select to load from a file

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

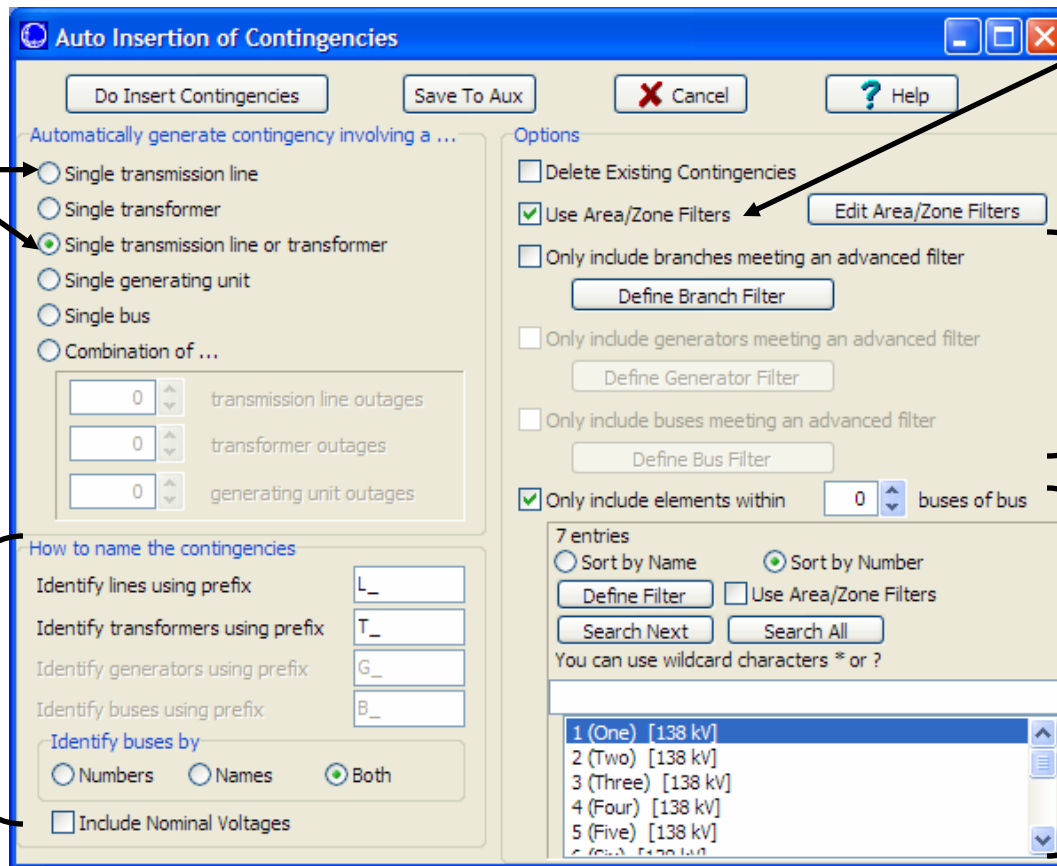


- To automatically insert a set of contingencies. This is available from
 - On the Case Information Toolbar, choose **Records > Auto Insert Contingencies...**
 - Right-click to bring up the local menu and choose **Insert Special > Auto Insert Contingencies**
 - Click on the Auto Insert Button at the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

	Label	Skip	Processed	Solved	Islanded Load	Islanded Gen	QV Autoplot?
1	L_00001One-00002TwoC1	NO	NO	NO			NO
2	L_00001One-00003ThreeC1	NO	NO	NO			NO
3	L_00002Two-00003ThreeC1	NO	NO	NO			NO
4	L_00002Two-00004FourC1	NO	NO	NO			NO
5	L_00002Two-00005FiveC1	NO	NO	NO			NO
6	L_00002Two-00006SixC1	NO	NO	NO			NO
7	L_00003Three-00004FourC1	NO	NO	NO			NO
8	L_00004Four-00005FiveC1	NO	NO	NO			NO
9	L_00007Seven-00005FiveC1	NO	NO	NO			NO
10	L_00006Six-00007SevenC1	NO	NO	NO			NO
11	L_00006Six-00007SevenC2	NO	NO	NO			NO

Actions
1 OPEN Branch 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

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

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

Click to specify power flow solution options for this contingency

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. 'Load' is selected. Other options include Branch, Generator, Switched Shunt, Bus, Interface, Injection Group, Series Capacitor, DC Line, Phase Shifter, 3-Winding Transformer, and Solve Power Flow.
- Choose the Element:** A section with radio buttons for 'Sort by Name' and 'Sort by Number' (selected). It includes a 'Define Filter' button and a 'Use Area/Zone Filters' checkbox. A list of elements is shown, with '2 (Two) [138 kV]' selected.
- Action Type:** A section with radio buttons for 'Open', 'Close', 'Move', 'Set To' (selected), and 'Change By'.
- Amount:** A text box containing '0', a 'Constant' dropdown menu, and a 'Find...' button.
- in:** A section with radio buttons for 'MW (const pf)' (selected), 'Percent', 'MW', 'Mvar', and 'Setpoint Voltage'.
- Model Criteria:** A section with an 'Add' button and a text box.
- Comment:** A text box for entering a comment.

Annotations with arrows point to specific parts of the dialog:

- 'Choose element type' points to the 'Element Type' list.
- 'Choose the Element' points to the list of elements.
- 'Choose the action parameters' points to the 'Action Type', '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

Contingency Analysis Power Flow Solution Options

Power Flow Solution Options

MVA Convergence Tolerance ▼

Maximum Number of Iterations ▼

Initialize from Flat Start Values

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

Disable Switched Shunt Control

Disable Treating Continuous SSs as PV Buses

Disable LTC Transformer Control

Min. Sensitivity for LTC Control ▼

Disable Balancing of Parallel LTC Taps

Disable Phase Shifter Control

Model Phase Shifters as Discrete Controls

Enforce Generator MW Limits

Prevent Controller Oscillations

Maximum Number of Voltage Control Loop Iterations ▼

Min. pu voltage for constant power 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 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 MVAR
- Control Mode
(FIXED/DISCRETE/CONTINUOUS)
- Nom Value MW
- 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..)

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
- whether transformer was on control
- 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 Power Flow Solution Options

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)

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



- Calculation Method
 - Full Power Flow
 - Linearized Lossless DC
 - similar to the *DC Power Flow*, but this is linearized around present operating point
 - Linearized Lossless DC with Phase Shifters
- Limit Monitoring Settings
 - Click this button to open the Limit Monitoring Settings dialog
- 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



Options Tab: Modeling



- 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
- 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 – Make-up Power



- Describe which areas make up for a change in the MW generation or load in the system.
- Normally done use 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 – 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



- 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.
 - 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 whatever the present power system state is as 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
 - Click **Start** on Summary 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



Total Violations for the contingency Worst Violation of a various type for each contingency

The screenshot shows the 'Contingency Analysis' dialog box with the 'Contingencies' tab selected. The main table lists contingencies with columns for Label, Skip, Processed, Solved, Violations, Max Branch %, Min Volt, Max Volt, and Max Interface %. A pink callout box points to the bottom of the dialog, stating: 'A list of violations under the selected contingency will appear at the bottom of the dialog'. A red arrow points from this box to the 'Violations' section below. The 'Violations' section has a 'Show related contingencies' dropdown set to 'Combined Results >' and a table with columns: Category, Element, Value, Limit, Percent, Area Name, and Nom kV. The status bar at the bottom indicates 'Finished with 606 Violations and 5 Unsolvable Contingencies'. A checkbox labeled 'Refresh Displays After Each Contingency' is checked. A callout box points to this checkbox with the text: 'This updating can slow down your analysis a small amount, so uncheck to stop refreshing'. Other callouts include: 'Click O to show the Definition Section' pointing to a small circle icon on the right side of the dialog, and 'Total Violations for the contingency' and 'Worst Violation of a various type for each contingency' pointing to the 'Violations' and 'Max Branch %' columns respectively.

Label	Skip	Processed	Solved	Violatio	Max Branch %	Min Volt	Max Volt	Max Interface %
11 L_01855ALLIANCE-01859EAGLEMTC1	NO	YES	YES	4	120.2			
				4	121.9			
				4	117.3			
				4	119.4			
				4	119.5			
				4	119.2			
				4	119.2			
				4	127.4			
19 L_03313501EAS-4230000W3433C2	NO	YES	YES	3	119.3			
20 L_40600FRONTR-45972KUYDAL5275	NO	YES	YES	3	119.5			
21 L_03390JEWETTS-45500T_H_W_5C1	NO	YES	YES	3	119.6			
22 L_02428WATMILLE-02435WATMLLDBC1	NO	YES	YES	3	119.4			
23 L_03391JEWETT-46500TUMBAL5C1	NO	YES	YES	3	119.6			

Category	Element	Value	Limit	Percent	Area Name	Nom kV
1	Branch MVA DFW SW (2009) -> LIGNORTH (1922) CKT 1 at LIGNORTH	255.25	214.00	119.28	DFW-DFW	138.0
2	Branch MVA EULESS (2016) -> DFW SW (2009) CKT 1 at DFW SW	229.11	214.00	107.06	DFW-DFW	138.0
3	Branch MVA PETERS 8 (46220) -> PETERS 9 (46230) CKT A1 at PETERS 8	20.55	20.00	102.75	Houston-South	138.0

Click O to show the Definition Section

This updating can slow down your analysis a small amount, so uncheck to stop refreshing

While processing the list of contingencies, the dialog will update itself continuously if this checkbox is checked.

Viewing Contingency Results: Lines, Buses, Interfaces Tab



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

List of elements which could be monitored

The screenshot shows the 'Contingency Analysis' window with the 'Lines, Buses, Interfaces' tab selected. The main table lists contingencies with columns for From Number, From Name, To Number, To Name, Circuit, Xfrmr, Violatio, and Max % Loading Cont. A red arrow points from the 'Violatio' column of the first row to the 'Contingency Definition' panel.

	From Number	From Name	To Number	To Name	Circuit	Xfrmr	Violatio	Max % Loading Cont.
1	38732	HOIST 33	38733	HOIST123	1	Yes	8	100.00
2	13	PEACHBTM	24	LIMERICK	1	No	0	
3	29227	20BOONE	29519	205 PAI				
4	13	PEACHBTM	31	CONE G				
5	13	PEACHBTM	32	KEYS G				
6	13	PEACHBTM	33	KEYS G				
7	19540	20COEE V	19542	20COEE				
8	13	PEACHBTM	35	PCHBTM				

The 'Contingency Definition' panel shows the definition for the selected contingency: '1 OPEN Branch 5MARSHAL (18007) TO X/O for'. A green arrow points from the 'Contingency Definition' panel to the 'Definition for Selected Contingency' text box.

The 'Actions' panel shows the definition: '1 OPEN Branch 5MARSHAL (18007) TO X/O for'. A yellow box highlights the text 'X/O for' with the note 'showing or not showing the definition'.

The status bar at the bottom indicates: 'Paused on Contingency L_14REID5161-14HOPC05161C1'. Buttons for 'Load', 'Auto Insert', 'Save', 'Other >', 'Abort', 'Continue', 'Close', and 'Help' are visible.

A list of contingencies which cause a violation on the selected contingency will appear at the bottom of the dialog

Definition for Selected Contingency

showing or not showing 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

Contingency Analysis

Contingencies | Lines, Buses, Interfaces | Options | Summary

Label	Skip	Processed	Solved	Violatio	Max Branch %	Min Volt	Max Volt
L_02397WLEVP1-02398WLEVEEC1	NO	YES	YES	4	118.7		
L_02389IVVR-02406NORWDC1	NO	YES	YES	3	121.2		
L_02387HACKBRY-02389IVVRC1	NO	YES	YES	3	121.2		
L_0591550TEX5-44000W_A_P_5_39	NO	YES	YES	3	118.7		
L_01853RDANOKE-01855ALLIANCE1	NO	YES	YES	2	101.6		
L_01855ALLIANCE-01859EAGLEMTCT	NO	YES	YES	2	102.5		
L_01886VEAST-01907VENUSNC1	NO	YES	YES	2	106.7		

Violations

Show related contingencies | Combined Results

Category	Element	Value	Limit	Percent	Area Name	Nom kV
Branch MVA	LIGGETT (1921) -> LIGAUTO1 (1923) CKT 1 at LIGGETT	581.41	525.00	110.74	DFW-DFW	345.0
Branch MVA	LIGSOUTH (1924) -> IV VAL V (2006) CKT 1 at LIGSOUTH	220.51	214.00	103.04	DFW-DFW	138.0
Branch MVA	NORWOODT (2410) -> NORWDTIE (2404) CKT 1 at NORWOODT	610.98	504.00	121.23	DFW-DFW	345.0

Status: Finished with 82 Violations and 5 Unsolvable Contingencies

Refresh Displays After Each Contingency

Save | Other Actions > | Start Run | Close | Help

Contingency Analysis

Contingencies | Lines, Buses, Interfaces | Options | Summary

Lines/Transformers | Buses | Interfaces

	From Number	From Name	To Number	To Name	Circuit	Xfrmr	Violatio	Max % Loading Cont.
1	46230	PETERS 9	46220	PETERS 8	A1	Yes	18	118.70
2	2410	NORWOODT	2404	NORWDTIE	1	Yes	7	121.24
3	1921	LIGGETT	1923	LIGAUTO1	1	Yes	6	120.31
4	8352	NWESLCO2	8353	WES.SW 2	1	No	5	129.73
5	1957	SAGINAW	2047	HALTOM 1	1	No	5	102.59
6	2044	WATCET	2047	HALTOM 1	1	No	5	102.05

Contingencies

Show Other Violations

Label	Category	Value	Limit	Percent
L_02361CLTNW-02387HACKBRYC1	Branch MVA	525.77	504.00	104.52
L_02387HACKBRY-02389IVVRC1	Branch MVA	610.98	504.00	121.23
L_02389IVVR-02406NORWDC1	Branch MVA	611.03	504.00	121.24
L_02396WLEVP2-02428WATMILLEC1	Branch MVA	598.19	504.00	118.69

Status: Finished with 82 Violations and 5 Unsolvable Contingencies

Refresh Displays After Each Contingency

Load | Auto Insert | Save | Other Actions > | Start Run | Close | Help

Summary Tab



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

Contingency Analysis

Contingencies | Lines, Buses, Interfaces | Options | Summary

Summary

Contingency L_14WILSO7345-14REID7345C1 successfully solved.
Solving contingency L_14WILSO7345-14COLE7345C1
Applied:
OPEN Branch 14WILSO7 (27561) TO 14COLE 7 (27563) CKT 1 | | CHECK |
Contingency L_14WILSO7345-14COLE7345C1 successfully solved.
Solving contingency L_14MEADE5161-14N.HAR5161C1
Applied:
OPEN Branch 14MEADE5 (27566) TO 14N.HAR5 (27616) CKT 1 | | CHECK |
Contingency L_14MEADE5161-14N.HAR5161C1 successfully solved.
Solving contingency T_14N.HAR4138-14N.HAR5161C1
Applied:
OPEN Branch 14N.HAR4 (27615) TO 14N.HAR5 (27616) CKT 1 | | CHECK |
Contingency T_14N.HAR4138-14N.HAR5161C1 successfully solved.
Solving contingency L_14LIVIN5161-RENSHAW161C1
Applied:
OPEN Branch 14LIVIN5 (27618) TO RENSHAW (30352) CKT 1 | | CHECK |
Contingency L_14LIVIN5161-RENSHAW161C1 successfully solved.
Contingency Analysis finished at February 21, 2004 16:51:04

Total # of contingencies	29	Start Time	2/21/2004 4:50:10 PM
# Processed	29	End Time	2/21/2004 4:51:04 PM
# Unsolvable	0	Total Run Time	53.70 Seconds
# Violations	18	Avg. Time per Ctg	1.852 Seconds

Status: Finished with 18 Violations and 0 Unsolvable Contingencies. Initial State Restored. Refresh Displays After Each Contingency

Start Close ? Help