

Steady-State Power System Security Analysis with PowerWorld Simulator



S4: Advanced Contingency Modeling



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Overview



- The basics of Contingency Analysis are covered in the Introduction to PowerWorld Simulator course
- This section will cover many advanced options that can enhance your contingency analysis studies

Outline



- Limit Monitoring
 - Advanced Limit Monitoring
 - Island Monitoring
 - Monitoring Exceptions
 - Custom Monitors
- Screening Options
- Injection Sensitivities
- Bus Load Throw Over Records
- Generator
 - Post-Contingency AGC
 - Maximum MW Response
 - Line-Drop or Reactive Current Compensation
- Switched Shunt Post CTG
- Auxiliary Files

Outline



- Transient Models
- Result Storage
- Combined Tables
- Report writing
- Comparing two sets of Contingency Results
- Conditional Contingency Actions
 - Model Conditions, Model Filters, Model Expressions
 - Modeling **Remedial Actions** (RAS) or Special Protection Schemes (SPS)
 - CHECK, POSTCHECK, TOPOLOGYCHECK, and SOLUTIONFAIL Contingency Elements
 - Persistent Actions
 - Time Delay
- Appendix: Techniques for Designing Remedial Actions

Options, Limit Monitoring: Advanced Limit Monitoring

ACTIVSg25k.pwb



- **Auto Insert** single branch contingencies for area Connecticut (23) at 200kV and higher in case *ACTIVSg25k.pwb*
- Use *Linearized Lossless DC Calculation Method*
- Click **Start Run**

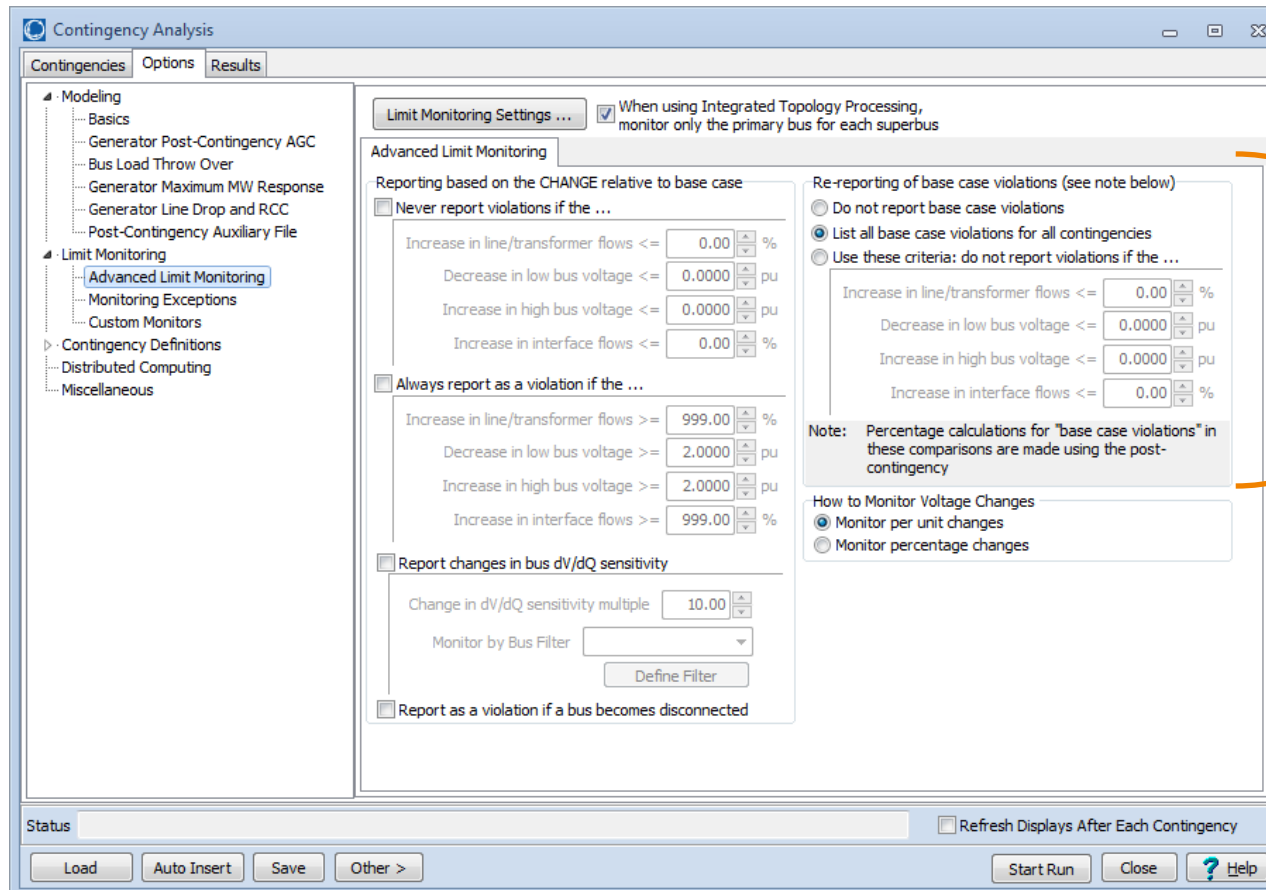
Contingency Analysis																			
		Options																	
		Results																	
		Records																	
		Columns																	
		Options																	
	Label	Skip	Category	Processed	Solved	Include Remedial Actions	Screen Allow	Post-CTG AUX	Islanded Load	Islanded Gen	Global Actions	Transient Actions	Remedial Actions	Custom Monitor Violations	Violations	Max Branch %	Min		
1	L_023013BRISTOL72-023012BRISTOL71C1	NO		YES	YES	YES	NO	none			0	0	0	0	11	108.1			
2	L_023012BRISTOL71-023015BRISTOL74C1	NO		YES	YES	YES	NO	none	69.90		0	0	0	0	10	108.6			
3	L_023485HARTFORD88-023012BRISTOL71C1	NO		YES	YES	YES	NO	none			0	0	0	0	11	108.1			
4	T_023014BRISTOL73-023013BRISTOL72C1	NO		YES	YES	YES	NO	none			0	0	0	0	10	108.7			
5	T_023014BRISTOL73-023013BRISTOL72C2	NO		YES	YES	YES	NO	none			0	0	0	0	10	108.7			
6	T_023014BRISTOL73-023013BRISTOL72C3	NO		YES	YES	YES	NO	none			0	0	0	0	10	108.7			
7	L_023013BRISTOL72-023025FARMINGTON31C1	NO		YES	YES	YES	NO	none			0	0	0	0	10	108.7			
8	L_023013BRISTOL72-023390TORRINGTON13C1	NO		YES	YES	YES	NO	none			0	0	0	0	10	108.8			
9	L_023013BRISTOL72-023391TORRINGTON21C1	NO		YES	YES	YES	NO	none			0	0	0	0	10	108.7			
10	T_023026FARMINGTON32-023025FARMINGTON31C1	NO		YES	YES	YES	NO	none			0	0	0	0	10	108.5			
11	L_023025FARMINGTON31-023027FARMINGTON33C1	NO		YES	YES	YES	NO	none	40.65		0	0	0	0	10	108.7			
12	L_023082HARTFORD11-023025FARMINGTON31C1	NO		YES	YES	YES	NO	none			0	0	0	0	10	108.7			
13	L_023724MIDDLETOWN610-023025FARMINGTON31C1	NO		YES	YES	YES	NO	none			0	0	0	0	10	108.9			
14	L_023037MANCHESTER121-023052VERNONROCKVILLE11C1	NO		YES	YES	YES	NO	none			0	0	0	0	9	108.9			
15	L_023037MANCHESTER121-023483HARTFORD84C1	NO		YES	YES	YES	NO	none			0	0	0	0	10	108.9			
16	T_023053VERNONROCKVILLE12-023052VERNONROCKVILLE11C1	NO		YES	YES	YES	NO	none			0	0	0	0	11	108.9			
17	L_023052VERNONROCKVILLE11-023054VERNONROCKVILLE13C1	NO		YES	YES	YES	NO	none	55.50		0	0	0	0	10	108.8			

Many overloads that are really base case violations

Options, Limit Monitoring: Advanced Limit Monitoring



- Re-reporting of base case violations



Tells Simulator how to treat power system elements that are operating outside their limits in the reference power system

Filtering Results



- Choose option *Use these criteria: do not report violations if the...* and set *Increase in line/transformer flows* $\leq 2\%$
- Other > Filter Results using Limit Monitoring Settings
 - Only violations that meet the present limit monitoring settings remain visible
 - Violations on elements removed from the monitored set will be hidden, but not deleted
 - Restoring the original Limit Monitoring Settings and choosing this action again will bring back hidden violations
 - If new elements are added to the monitored set, violations would not have occurred on the original list and the contingency analysis must be re-run to report them

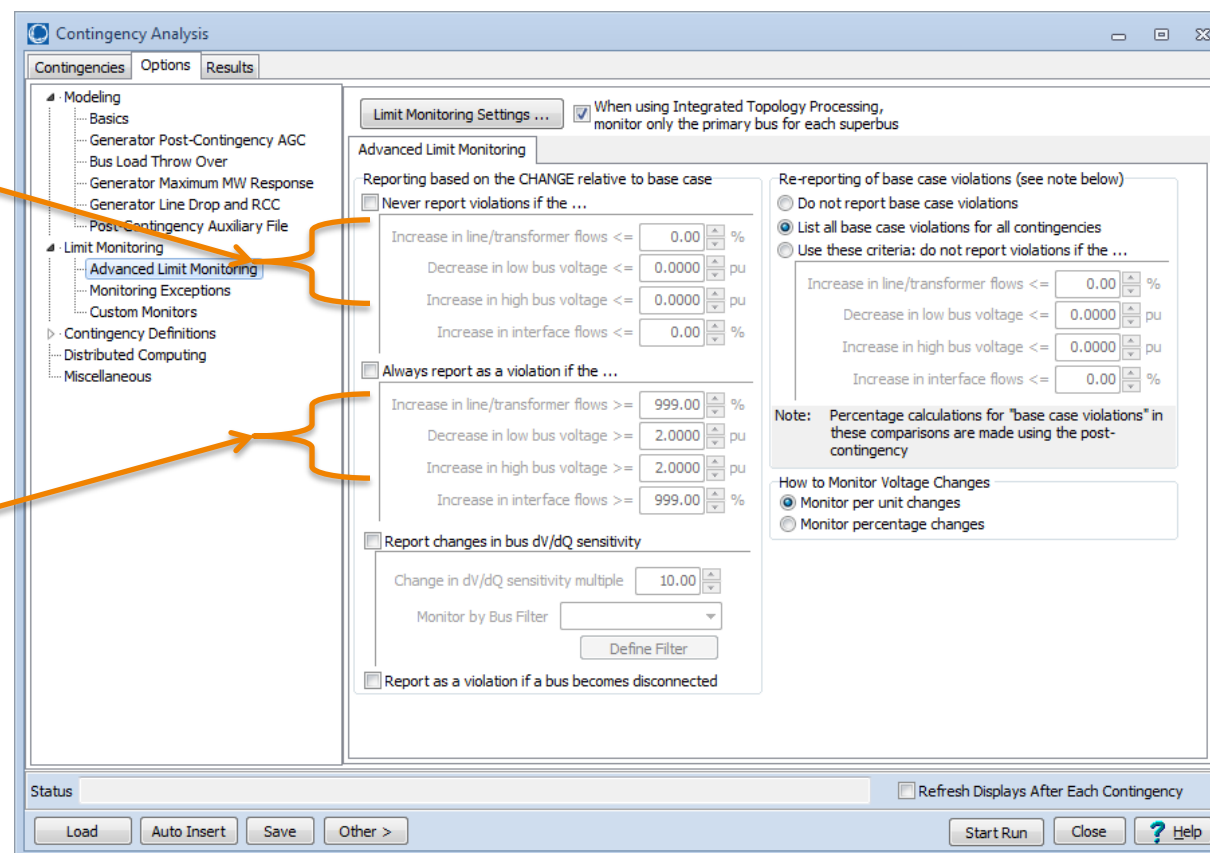
Options, Limit Monitoring: Advanced Limit Monitoring



- Reporting based on the CHANGE relative to base case

Options to NEVER report violations do not have a specified change from the reference case

Options to ALWAYS report violations that change by more than a specified change from the reference case



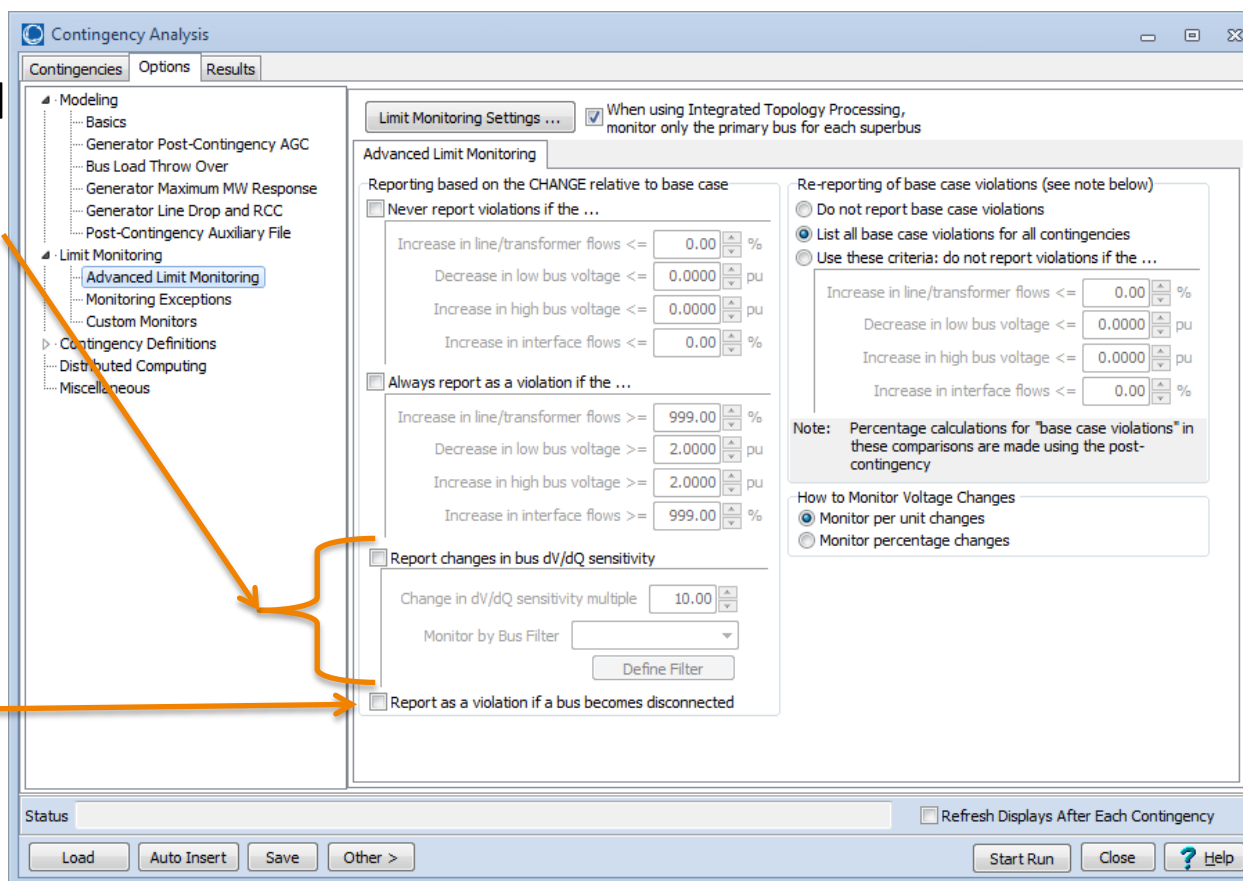
Options, Limit Monitoring: Advanced Limit Monitoring



- Advanced violation reporting

Report changes in sensitivity of voltage to Mvar injection at specified buses if change is greater than specified multiple of base case value or if the sensitivity is negative

Report disconnected buses as violations



Options, Limit Monitoring: Advanced Limit Monitoring



- Limit group Settings

Selected options can also be specified with Limit Monitoring Settings on a Limit Group basis. When active, Limit Group options will override those specified with the contingency options.

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

Limit Monitoring

- Advanced Limit Monitoring
- Monitoring Exceptions
- Custom Monitors

Contingency Definitions

- Distributed Computing
- Miscellaneous

Limit Monitoring Settings ...

When using Integrated Topology Processing, monitor only the primary bus for each superbus

Advanced Limit Monitoring

Reporting based on the CHANGE relative to base case

- ☒ Never report violations if the ...
 - Increase in line/transformer flows $\leq$ 0.00 %
 - Decrease in low bus voltage $\leq$ 0.0000 pu
 - Increase in high bus voltage $\leq$ 0.0000 pu
 - Increase in interface flows $\leq$ 0.00 %
- ☒ Always report as a violation if the ...
 - Increase in line/transformer flows $\geq$ 999.00 %
 - Decrease in low bus voltage $\geq$ 2.0000 pu
 - Increase in high bus voltage $\geq$ 2.0000 pu
 - Increase in interface flows $\geq$ 999.00 %

Re-reporting of base case violations (see note below)

- ☐ Do not report base case violations
- ☒ List all base case violations for all contingencies
- ☐ Use these criteria: do not report violations if the ...
 - Increase in line/transformer flows $\leq$ 0.00 %
 - Decrease in low bus voltage $\leq$ 0.0000 pu
 - Increase in high bus voltage $\leq$ 0.0000 pu
 - Increase in interface flows $\leq$ 0.00 %

Note: Percentage calculations for "base case violations" in these comparisons are made using the post-contingency

How to Monitor Voltage Changes

- ☒ Monitor per unit changes
- ☐ Monitor percentage changes

Note: Be VERY careful using the "Always report" options because they may result in a very large number of reported violations

Note: Be VERY careful using the "dV/dQ sensitivity" option because this may dramatically increase the processing time. Create a bus filter to monitor only those buses that are critical.

Report changes in bus dV/dQ sensitivity

Change in dV/dQ sensitivity multiple 10.00

Monitor by Bus Filter

Define Filter

☐ Report as a violation if a bus becomes disconnected

Status

Refresh Displays After Each Contingency

Load Auto Insert Save Other > Start Run Close ? Help

Island Monitoring



- Check box to report violations for islands that either do not solve or do not have enough generation MW reserves
- Set thresholds for minimum Load MW and minimum number of Super Buses (for full topology models; defaults to buses for bus-branch models)

Limit Monitoring Settings ... ☒ When using Integrated Topology Processing, monitor only the primary bus for each superbus

Island Monitoring

☒ Report Violations for Islands

Contingency Violations will reported for islands that are unsolved or islands that do not have enough MW Reserves. Also, a violation will be reported for any newly created island which solves. All of these violations will be restricted to islands meeting the following criteria

Minimum Load MW to report an island violation 10.00

Minimum number of super buses to report an island violation 5

☐ Refresh Displays After Each Contingency

Other > Start Run Close Help

Island Monitoring



- Example: insert contingency for line 23489 23494 1
- Solve with Full Power Flow Calculation Method
- Reserve Limit violation

Violations What Actually Occurred

Show related contingencies Combined Tables >

	Category	Element	Value	Limit	Percent	Area Name Assoc.	Nom kV Assoc.
1	Branch MVA	NEWARK 4 2 (13184) -> NEWARK	93.27	92.10	101.27	New Jersey	161.0
2	Branch MVA	LYNCHBURG 4 5 (15918) -> LYNCH	101.83	100.80	101.02	Virginia	69.00
3	Branch MVA	WASHINGTON 26 2 (21055) -> WA	120.71	120.70	100.01	Maryland	230.0
4	Branch MVA	DISTRICT HEIGHTS 1 1 (21262) -> I	259.34	252.00	102.91	Maryland	230.0
5	Branch MVA	CHELMSFORD 1 (57060) -> CHELM	190.06	176.40	107.75	Eastern Massachusetts	230.0
6	Branch MVA	UPPER DARBY 2 2 (61588) -> NEW	178.20	174.00	102.41	Eastern Pennsylvania	115.0
7	Branch MVA	UPPER DARBY 2 1 (61587) -> UPPE	207.71	207.10	100.29	Eastern Pennsylvania	230.0
8	Branch MVA	BROOKLYN 47 1 (69351) -> BROOK	1527.87	1361.80	112.20	NYC	765.0
9	Island Reserve Limits	NEW MILFORD 3 1 (23489)	5.788			Connecticut	100.0

Options, Limit Monitoring: Monitoring Exceptions



- Create exceptions to **Limit Monitoring** settings for specific pairs of contingencies and monitored elements
 - Include (monitor the element during the contingency)
 - Exclude (ignore the element during the contingency)
 - Default (use Limit Monitoring Settings)

Example: Exclude Seymour-Wolcott 100 kV during outage of Bethel-Danbury 230 kV if we know it can be alleviated (instead of explicit RAS/SPS modeling)

Define Monitoring Exceptions

Contingency Label: L_023406BETHEL37-023415DANBURY24C1 [Change...]

Monitor Type: ☐ Bus ☒ Line ☐ Interface

Sort by: ☐ Name ☒ Number

Filter: Advanced Branch [v]

☒ Use Area/Zone Filters Quick Define Remove

☒ Search Next Search All

You can use wildcard characters * or ?

Monitor Status: ☐ Include ☒ Exclude ☐ Default

Search For Near Bus	Select Far Bus, CKT
23268 (PORTLAND 6 2) [100.0 kV]	23271 (SEYMOUR 1 1) [100.0 kV] CKT 1
23269 (PORTLAND 6 4) [100.0 kV]	23278 (SOUTHBURY 1 2) [100.0 kV] CKT 1
23270 (SANDY HOOK 1 1) [100.0 kV]	23370 (WOLCOTT 1 1) [100.0 kV] CKT 1
23271 (SEYMOUR 1 1) [100.0 kV]	
23272 (SEYMOUR 1 2) [100.0 kV]	
23273 (SHELTON 1 1) [100.0 kV]	
23274 (SHELTON 2 1) [230.0 kV]	
23275 (SHELTON 2 2) [100.0 kV]	
23276 (SHELTON 2 3) [230.0 kV]	
23277 (SOUTHBURY 1 1) [230.0 kV]	
23278 (SOUTHBURY 1 2) [100.0 kV]	

OK Help Cancel

Options, Limit Monitoring: Custom Monitors



- Allow monitoring of any quantity during contingency analysis
- Must use *Full Power Flow Calculation Method*
- Can be applied to all of an **Element Type** or just a specific Element
- Can filter elements in reference state or post-contingent state
- Can filter based on changes from reference state

Custom Monitor

Custom Monitor Name: Seymour-Wolcott 100kV

☒ Enabled Rename

Categories:

Choose Object:
☐ All objects of Element Type
☒ Specific object

Element Type: Branch

32230 entries
Sort by: ☒ Name ☐ Number
Filter: Advanced Branch
☒ Use PreFilters Quick Define Remove
Search Next Search All
You can use wildcard characters * or ?

SEWICKLEY 2 (43117) TO SEWICKLEY 1 (43116) CKT 1
SEYMOUR 1 1 (23271) TO SEYMOUR 1 2 (23272) CKT 1
SEYMOUR 1 2 (23272) TO SOUTHBURY 1 2 (23278) CKT 1
SEYMOUR 1 2 (23272) TO WOLCOTT 1 1 (23370) CKT 1
SEYMOUR 2 1 (55370) TO CHEROKEE 1 (33226) CKT 1
SEYMOUR 2 1 (55370) TO SEVIERVILLE 1 2 (55364) CKT 1

Choose a Field: Find... MW/MW (maximum)

Choose a Pre Filter: Add

Choose a Post Filter: Add

☐ Report violations if the increase in field value > 0.00
☐ Report violations if the decrease in field value > 0.00

Meaning of Change Values:
☒ Change from Initial Value
☐ % Change from Initial Value

Start Tripping Filter: Add

Use a Time Delay of 3600.00 seconds

Action to Take:
☒ Log Violation Only
☐ Trip (Open) Device
☐ Abort Simulation

OK Help Cancel

Options, Limit Monitoring: Custom Monitors

- Example: Monitor MW flow on Seymour-Wolcott 100 kV line (23272 23370 1)

The screenshot displays the 'Contingency Analysis' software window. The 'Options' tab is active, showing a list of custom monitors. The first monitor is named 'Seymour-Wolcott 100kV Branch' with object type 'Branch' and object name '23272 23370 1'. It monitors 'LineMaxMW' with a minimum value of 9.44 and a maximum value of 114.29.

Below the custom monitors, the 'Contingencies' section shows a table of results. The table has columns for Label, Element, Value, Reference Value, and Change Value. The first row shows a violation for 'L_023406BETHEL37-023415DANBURY24C1' with a value of 114.29, a reference value of 77.09, and a change value of 37.20.

Label	Element	Value	Reference Value	Change Value
1 L_023406BETHEL37-023415DANBURY24C1	Line SEYMOUR 1 2 (23272)	114.29	77.09	37.20
2 L_023423FAIRFIELD23-023734BRIDGEPORT1111C1	Line SEYMOUR 1 2 (23272)	96.91	77.09	19.82
3 L_023406BETHEL37-023281SOUTHBURY15C1	Line SEYMOUR 1 2 (23272)	96.56	77.09	19.47
4 L_023277SOUTHBURY11-023281SOUTHBURY15C1	Line SEYMOUR 1 2 (23272)	96.56	77.09	19.47
5 T_023726BRIDGEPORT112-023725BRIDGEPORT1111C1	Line SEYMOUR 1 2 (23272)	95.76	77.09	18.67
6 L_023276SHELTON23-023770MILFORD139C1	Line SEYMOUR 1 2 (23272)	92.68	77.09	15.58
7 T_023695EASTHAVEN32-023694EASTHAVEN31C1	Line SEYMOUR 1 2 (23272)	91.10	77.09	14.01
8 L_023726BRIDGEPORT112-023734BRIDGEPORT1111C1	Line SEYMOUR 1 2 (23272)	89.98	77.09	12.89
9 L_023412DANBURY21-042104NEWBURGH412C1	Line SEYMOUR 1 2 (23272)	89.97	77.09	12.88
10 T_023413DANBURY22-023412DANBURY21C1	Line SEYMOUR 1 2 (23272)	89.94	77.09	12.85
11 L_023276SHELTON23-023340TRUMBULL21C1	Line SEYMOUR 1 2 (23272)	87.61	77.09	10.52

The status bar at the bottom indicates: 'Finished with 106 violations, 245 custom monitor violations, 3 unsolveable, and 0 aborted contingencies. Initial state restored.'



Screening Options



- Use with the *Full Power Flow* **Calculation Method** to automatically pre-screen contingencies with linear methods
- Full AC power flow is used only on those contingencies that meet the criteria
- Can save processing time with large contingency lists

Limit Monitoring



- Areas: Set “Report Limits” = NO in all areas except Connecticut (23)
- Areas: Set “Report Min kV” = 100 in all areas
- Do not monitor radial lines and buses
- Lines: Set “Monitor” = NO for lines with base case violations
- Limit Group “Default”: set Branch tolerance to 100% for Contingency Screening

Limit Group Dialog

Limit Group Name: Default

☐ Disabled

Lines/Interfaces | Buses/Summary | Contingency Options | Contingency Screening

Tolerances in % of Limit		Tolerances in Per Unit Voltage		Voltage Multiplier
Branch	100.000	Low Bus Voltage	0.01000	Low Bus Voltage: 1.000
Interface	90.000	High Bus Voltage	0.01000	
BusPair	90.000	Change Bus Voltage	0.01000	

Screening Options



- First, set **Calculation Method** (Options → Modeling → Basics) to *Full Power Flow*
- Set **Use Screening** to *Screen Only*
- Uncheck *Include Voltage*

DC and Screening Options

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)

Full AC Power Flow Screening Options

Use Screening

☐ No

☐ Yes

☒ Screen Only

☐ Include Voltage

Maximum number to select

Branches

Interfaces

Buses

BusPairs

Screening Method

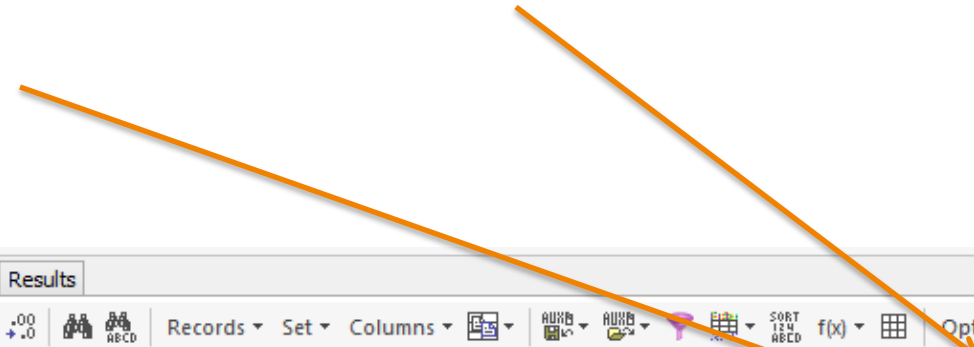
☒ Linearized Lossless DC

☐ Linearized Lossless DC With Phase Shifters

Contingency Screening



- On Contingencies tab
 - Set “Screen Allow” = YES for all contingencies
 - Show columns for “Calculation Method” and “Rank for Branches”
- Click **Start Run**



Contingencies											
Options Results											
Records Set Columns f(x) Options											
	Label	Skip	Category	Processed	Solved	Include Remedial Actions	Screen Allow	Screen Rank Branch	Calculation Method	Post-CTG AUX	Is Lo
1	L_023470WATERFORD21-023476WATERFORD28C1	NO		YES	YES	YES	YES	3702.4	ScreenDC	none	
2	L_023476WATERFORD28-023506UNCASVILLE28C1	NO		YES	YES	YES	YES	3678.0	ScreenDC	none	
3	L_071071WESTERLY1-023506UNCASVILLE28C1	NO		YES	YES	YES	YES	2890.8	ScreenDC	none	
4	T_023726BRIDGEPORT112-023725BRIDGEPORT111C1	NO		YES	YES	YES	YES	423.1	ScreenDC	none	
5	L_023726BRIDGEPORT112-023734BRIDGEPORT111C1	NO		YES	YES	YES	YES	313.6	ScreenDC	none	
6	L_023421FAIRFIELD21-023423FAIRFIELD23C1	NO		YES	YES	YES	YES	270.2	ScreenDC	none	
7	L_023314WESTHAVEN11-023316WESTHAVEN13C1	NO		YES	YES	YES	YES	136.2	ScreenDC	none	
8	L_023146STORRSMANSFIELD21-023148STORRSMANSFI	NO		YES	YES	YES	YES	133.2	ScreenDC	none	
9	L_023485HARTFORD88-065319AGAWAM35C1	NO		YES	YES	YES	YES	118.4	ScreenDC	none	
10	L_023423FAIRFIELD23-023734BRIDGEPORT111C1	NO		YES	YES	YES	YES	89.8	ScreenDC	none	

Contingency Screening



- Screen Rank Branch gives the total MW overload, summed across all branches, for each contingency
- Contingencies for which no branches are loaded past the Limit Group *Contingency Screening Tolerance* have “Screen Rank Branch” = 0
- On Screening Options:
 - Set **Use Screening** to *Yes*
 - **Maximum number to select:** set Branches to 10
- Click **Start Run** again

Contingency Screening



- Only the 10 “worst” contingencies (by Screen Rank metric) are solved with **Full AC Power Flow**
- **Full AC Power Flow** is only used on contingencies with Rank > 0
- If **Maximum Number to Select** >= number of contingencies, **Full AC Power Flow** will be used on all contingencies with Rank of the same type > 0

Contingencies Options Results																			
Records Set Columns																			
	Skip	Category	Processed	Solved	Include Remedial Actions	Screen Allow	Screen Rank	Calculation Method	Post-CTG AUX	Islanded Load	Islanded Gen	Global Actions	Transient Actions	Remedial Actions	Custom Monitor Violations	Violations	Max Branch %	Min	
1	NO		YES	NO	YES	YES	3702.4	AC	none			0	0	0	Unsolved	Unsolved			
2	NO		YES	NO	YES	YES	3678.0	AC	none			0	0	0	Unsolved	Unsolved			
3	NO		YES	NO	YES	YES	2890.8	AC	none			0	0	0	Unsolved	Unsolved			
4	NO		YES	YES	YES	YES	423.1	AC	none			0	0	0	0	3	211.7		
5	NO		YES	YES	YES	YES	313.6	AC	none			0	0	0	0	3	176.9		
6	NO		YES	YES	YES	YES	270.2	AC	none			0	0	0	0	8	157.4		
7	NO		YES	YES	YES	YES	136.2	AC	none			0	0	0	0	3	169.6		
8	NO		YES	YES	YES	YES	133.2	AC	none			0	0	0	0	5	144.1		
9	NO		YES	YES	YES	YES	118.4	AC	none			0	0	0	0	4	115.2		
10	NO		YES	YES	YES	YES	89.8	AC	none			0	0	0	0	6	126.9		
11	NO		YES	YES	YES	YES	75.2	ScreenDC	none			0	0	0	0	2	126.1		
12	NO		YES	YES	YES	YES	74.4	ScreenDC	none			0	0	0	0	3	112.1		
13	NO		YES	YES	YES	YES	73.5	ScreenDC	none			0	0	0	0	3	112.0		
14	NO		YES	YES	YES	YES	71.7	ScreenDC	none			0	0	0	0	2	125.8		
15	NO		YES	YES	YES	YES	58.3	ScreenDC	none			0	0	0	0	1	115.6		

Injection Sensitivities



- Automatically calculate Injection Sensitivities for a specified set of generators and/or loads for each contingency-violation pair
 - Helpful in identifying effective RAS actions
 - Injection Sensitivity is a Shift Factor with Island Slack Bus as the sink
- Set **Use Screening** back to *No* and **Calculation Method** back to *Linearized Lossless DC*
- On Options → Modeling → Injection Sensitivities, set **Eligible Generators** to *Area/Zone/Owner Filter*
- Click **Start Run**

Injection Sensitivities



- Results → Violations → Violation CTG Injection Sensitivities
- Filtered on **Bethel – Danbury 230 kV** outage and **Waterbury – Wolcott 100 kV** line
- Shows generators with highest sensitivity and those with greatest impact in relieving loading, if they increase/decrease output within Min/Max MW range

Injector	Name	Element	MW Inj Sensitivity	MW Effect Inc	MW Effect Dec	MW Range Inc	MW Range Dec
Gen '23474' '1'	L_023406BETHEL37-023415DANBURY24C1	WATERBURY 13 3 (23512) -> WOLCOTT 1 1 (23370) CKT 1 at WATERBURY 13 3	0.01	0.00	-8.95	0.00	-662.44
Gen '23473' '1'	L_023406BETHEL37-023415DANBURY24C1	WATERBURY 13 3 (23512) -> WOLCOTT 1 1 (23370) CKT 1 at WATERBURY 13 3	0.01	0.00	-7.76	0.00	-573.99
3 Gen '23686' '1'	L_023406BETHEL37-023415DANBURY24C1	WATERBURY 13 3 (23512) -> WOLCOTT 1 1 (23370) CKT 1 at WATERBURY 13 3	-0.17	0.00	4.71	0.00	-27.24
4 Gen '23719' '1'	L_023406BETHEL37-023415DANBURY24C1	WATERBURY 13 3 (23512) -> WOLCOTT 1 1 (23370) CKT 1 at WATERBURY 13 3	0.02	0.00	-3.59	0.00	-204.61
5 Gen '23619' '1'	L_023406BETHEL37-023415DANBURY24C1	WATERBURY 13 3 (23512) -> WOLCOTT 1 1 (23370) CKT 1 at WATERBURY 13 3	0.01	0.00	-3.20	0.00	-247.39
6 Gen '23521' '1'	L_023406BETHEL37-023415DANBURY24C1	WATERBURY 13 3 (23512) -> WOLCOTT 1 1 (23370) CKT 1 at WATERBURY 13 3	0.01	0.00	-2.92	0.00	-201.48

These generators are used in the upcoming RAS example; they are effective in relieving the overload

Options, Modeling:

Generator Post-Contingency AGC

- Choose to allow or prevent post-contingency AGC response
 - **NO** : means just leave AGC same as in reference case
 - **YES** : means to set the AGC to NO when solving the contingency
 - **RESPOND** : means to set AGC to YES when solving contingency
- Specify post-contingency participation factor
- Participation factor of *same* means to use the participation factor defined with the generator record

Contingency Analysis

ContingenciesOptionsResults

Modeling

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

Generator Post-Contingency AGC (ignore Area/Zone/Owner filter)

RecordsGeoSetColumns

Auto

RecordsGeoSetColumns

Auto

	Number of Bus	Name of Bus	Nom kv of Bus	ID	AGC	Part. Factor	Post-CTG Prevent AGC Response	Post-CTG Part. Factor
1	30	CONE G1	22.00 H	YES	5.45	NO	same	
2	30	CONE G1	22.00 L	YES	4.95	NO	same	
3	31	CONE G2	22.00 H	YES	5.45	NO	same	
4	31	CONE G2	22.00 L	YES	4.95	NO	same	
5	32	KEYS G1	22.00 H	YES	4.81	NO	same	
6	32	KEYS G1	22.00 L	YES	4.64	NO	same	
7	33	KEYS G2	22.00 H	YES	4.81	NO	same	
8	33	KEYS G2	22.00 L	YES	4.64	NO	same	
9	34	PCHBTM 2	22.00 1	YES	12.80	NO	same	
10	35	PCHBTM 3	22.00 1	YES	12.80	NO	same	

Status Initialized

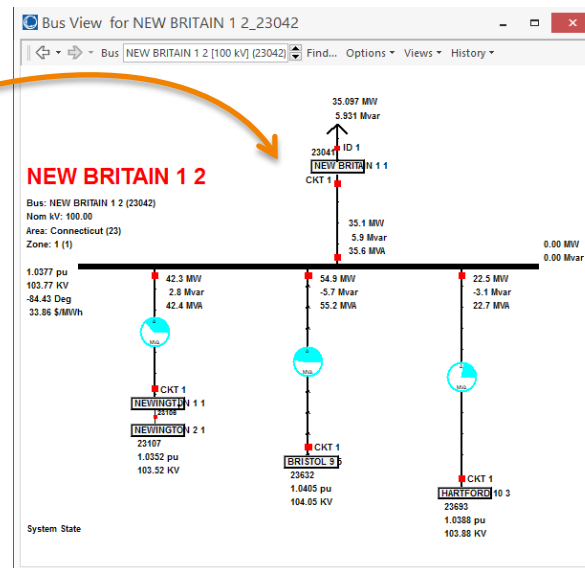
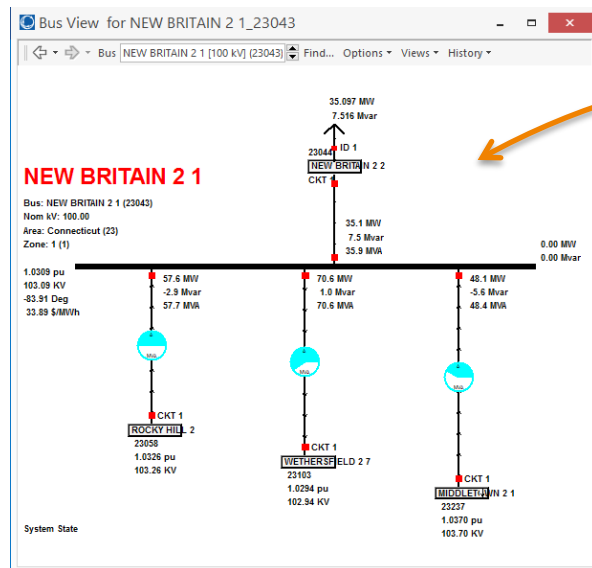
☐ Refresh Displays After Each Contingency

LoadAuto InsertSaveOther >

Start RunCloseHelp

Options, Modeling: Bus Throwover Records

- Represent global actions that transfer any load at a Bus X to another bus if Bus X becomes disconnected as a result of the contingency
- Used to model automatic distribution system switching
- Example: loads at New Britain (23044 and 23041) might switch buses
- Enter Bus Number “0” to remove the record



Bus Load Throw Over (Ignore Area/Zone/Owner filter)

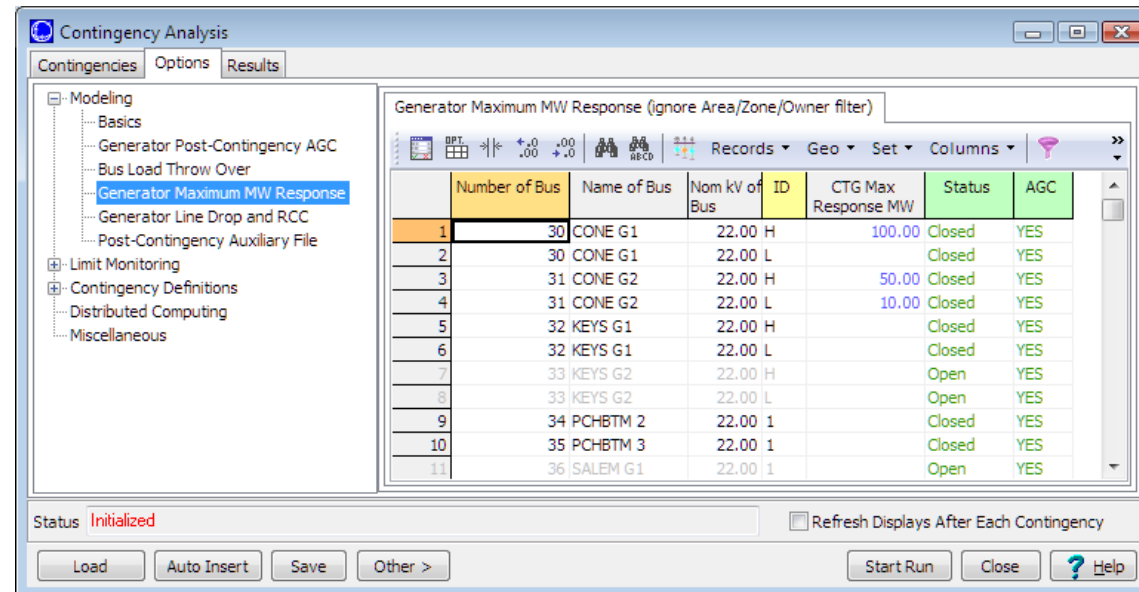
Number	Name	Nom kv	Load Throwover Bus Number	Load Throwover Bus Name_kv	Load Throwover Bus
5968	23041 NEW BRITAIN 1 1	100.00	23044	NEW BRITAIN	Bus '23044'
5969	23042 NEW BRITAIN 1 2	100.00			
5970	23043 NEW BRITAIN 2 1	100.00			
5971	23044 NEW BRITAIN 2 2	100.00	23041	NEW BRITAIN	Bus '23041'
5972	23045 NEW BRITAIN 3 1	100.00			
5973	23046 NEW BRITAIN 3 2	100.00	23047	NEW BRITAIN	Bus '23047'
5974	23047 NEW BRITAIN 4 1	100.00	23048	NEW BRITAIN	Bus '23048'
5975	23048 NEW BRITAIN 5 1	100.00	23046	NEW BRITAIN	Bus '23046'
5976	23049 NEW HARTFORD 1 1	100.00			
5977	23050 NEW HARTFORD 1 2	100.00			
5978	23051 PLAINVILLE 2 1	100.00			



Options, Modeling:

Generator Maximum MW Response

- You can enter the maximum response allowed by a generator during the contingency solution
- Values are specified in MW
- Blank values mean the response is only limited by generation limits



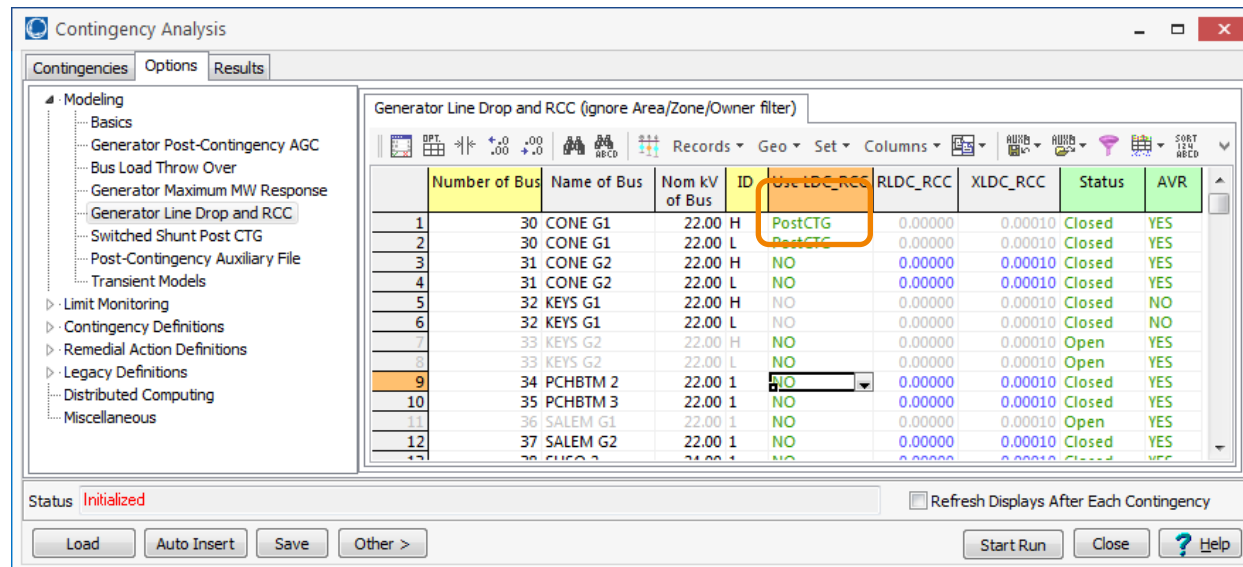
The screenshot shows the 'Contingency Analysis' software window with the 'Options' tab selected. The 'Generator Maximum MW Response (ignore Area/Zone/Owner filter)' table is displayed. The table has columns for Number of Bus, Name of Bus, Nom kV of Bus, ID, CTG Max Response MW, Status, and AGC. The status column uses color coding: green for 'Closed' and yellow for 'Open'.

	Number of Bus	Name of Bus	Nom kV of Bus	ID	CTG Max Response MW	Status	AGC
1	30	CONE G1	22.00 H		100.00	Closed	YES
2	30	CONE G1	22.00 L			Closed	YES
3	31	CONE G2	22.00 H		50.00	Closed	YES
4	31	CONE G2	22.00 L		10.00	Closed	YES
5	32	KEYS G1	22.00 H			Closed	YES
6	32	KEYS G1	22.00 L			Closed	YES
7	33	KEYS G2	22.00 H			Open	YES
8	33	KEYS G2	22.00 L			Open	YES
9	34	PCHBTM 2	22.00 1			Closed	YES
10	35	PCHBTM 3	22.00 1			Closed	YES
11	36	SALEM G1	22.00 1			Open	YES



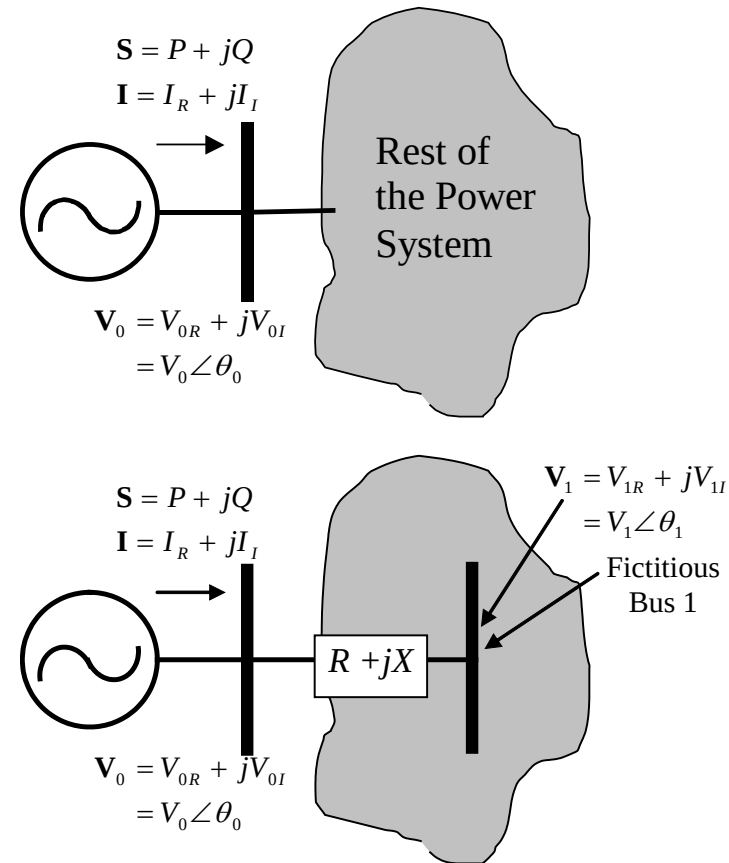
Options, Modeling: Generator Line Drop and RCC

- Allows you to specify a different type of generator voltage control during the post-contingency power flow
 - Line Drop Compensation (LDC)
 - Reactive Current Compensation (RCC)
 - Specify **Use LDC_RCC** as *PostCTG*
 - Enter an impedance value for XLDC_RCC and RLDC_RCC
 - If $X < 0$ this is called RCC,
 - If $X > 0$ this is called LDC



What does LDC_RCC Voltage Control do?

- Without LDC
 - Generator is connected to terminal and controls a bus voltage (may be terminal or remote bus)
- Generator using LDC
 - Generator controls the voltage at a “fictitious bus” some impedance away from the generator
 - This models the real-time control done at some generators
 - If RLDC_RCC and XLDC_RCC are both less than the ZBR Threshold (default 0.0002) the generator will regulate its own terminal
- Can be used always (Use LDC_RCC=YES) or only during Contingencies (Use LDC_RCC=PostCTG)
 - During contingencies, the voltage setpoint for the fictitious bus is set equal to the pre-contingency value at the fictitious bus



If $X < 0$: Called Reactive Current Compensation (RCC)

Switched Shunt Post CTG

- Several switched shunt parameters can be changed during the contingency solution

Contingency Analysis

Contingencies Options Results

Modeling

- Basics
- DC and Screening Options
- Generator Post-Contingency AGC
- Bus Load Throw Over
- Generator Maximum MW Response
- Generator Line Drop and RCC
- Switched Shunt Post CTG
- Auxiliary Files
- Transient Models
- Result Storage
- Limit Monitoring
- Contingency Definitions
- Remedial Action Definitions
- Legacy Definitions

Switched Shunt Post CTG (filtered)

	Number of Bus	Name of Bus	Nom kV of Bus	Control Mode	CTG Control Mode	CTG Reg Use	CTG Volt High	CTG Volt Low	Reg Volt	Volt High	Volt Low	CTG Mvar Use	CTG Max Mvar	CTG Min Mvar	Nominal Mvar	Max Mvar	Min Mvar
1	23012	BRISTOL 7 1	765.00	Discrete	Default	NO			1.0468	1.0575	1.0200	NO			331.50	560.5000	0.0000
2	23052	VERNON ROCKVILLE 1 1	230.00	Discrete	Default	NO			1.0350	1.0475	1.0200	NO			24.00	100.0000	0.0000
3	23096	WETHERSFIELD 1 1	100.00	Discrete	Default	NO			1.0342	1.0455	1.0200	NO			45.00	90.0000	0.0000
4	23151	ASHFORD 1	100.00	Discrete	Default	YES	1.0485	1.0000	1.0346	1.0485	1.0200	YES	44.0000	0.0000	38.50	77.0000	0.0000
5	23185	STERLING 2 1	100.00	Discrete	Default	NO			1.0418	1.0525	1.0200	NO			25.00	48.0000	0.0000
6	23196	BEACON FALLS 1	100.00	Discrete	Default	NO			1.0352	1.0465	1.0200	NO			41.00	60.0000	0.0000
7	23222	MADISON 3 1	230.00	Discrete	Default	NO			1.0438	1.0545	1.0200	NO			26.00	46.0000	0.0000
8	23249	NEWTOWN 1 1	100.00	Discrete	Default	NO			1.0363	1.0485	1.0200	NO			36.00	59.0000	0.0000
9	23260	OLD SAYBROOK 1	100.00	Discrete	Default	NO			1.0356	1.0475	1.0200	NO			46.00	94.5000	0.0000
10	23314	WEST HAVEN 1 1	230.00	Discrete	Default	NO			1.0415	1.0525	1.0200	NO			28.00	134.0000	0.0000

Option to change the switched shunt control mode during the contingency. *Default* uses the reference state setting.

Options to change the switched shunt regulated voltage range during the contingency solution. **CTG Reg Use** must be set to *YES*.

Options to change the switched shunt Mvar range during the contingency solution. **CTG Mvar Use** must be set to *YES*.

Options, Modeling: Auxiliary Files



- Post-Contingency Auxiliary File
 - Loaded *at the start* of each contingency
 - Special post-contingency settings can be included in this file; examples
 - AVR settings at generators
 - Special Reactive Capability Curves for the post-contingency power flow solution
 - You **MUST** only change values that are stored as part of the Reference State in Simulator
- Post-Contingency Solution Auxiliary File
 - Loaded *after* each contingency is solved
 - Could be used for special result storage (e.g. *SaveData* Script action)



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/SVC)
- 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.)
- Bus rating sets for contingency operation

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)
- Line limits

DC Line State

Multi-Terminal DC Line State

VSC 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)
- Area Slack (for Area)

MW Transaction

- MW Value
- Enabled Status

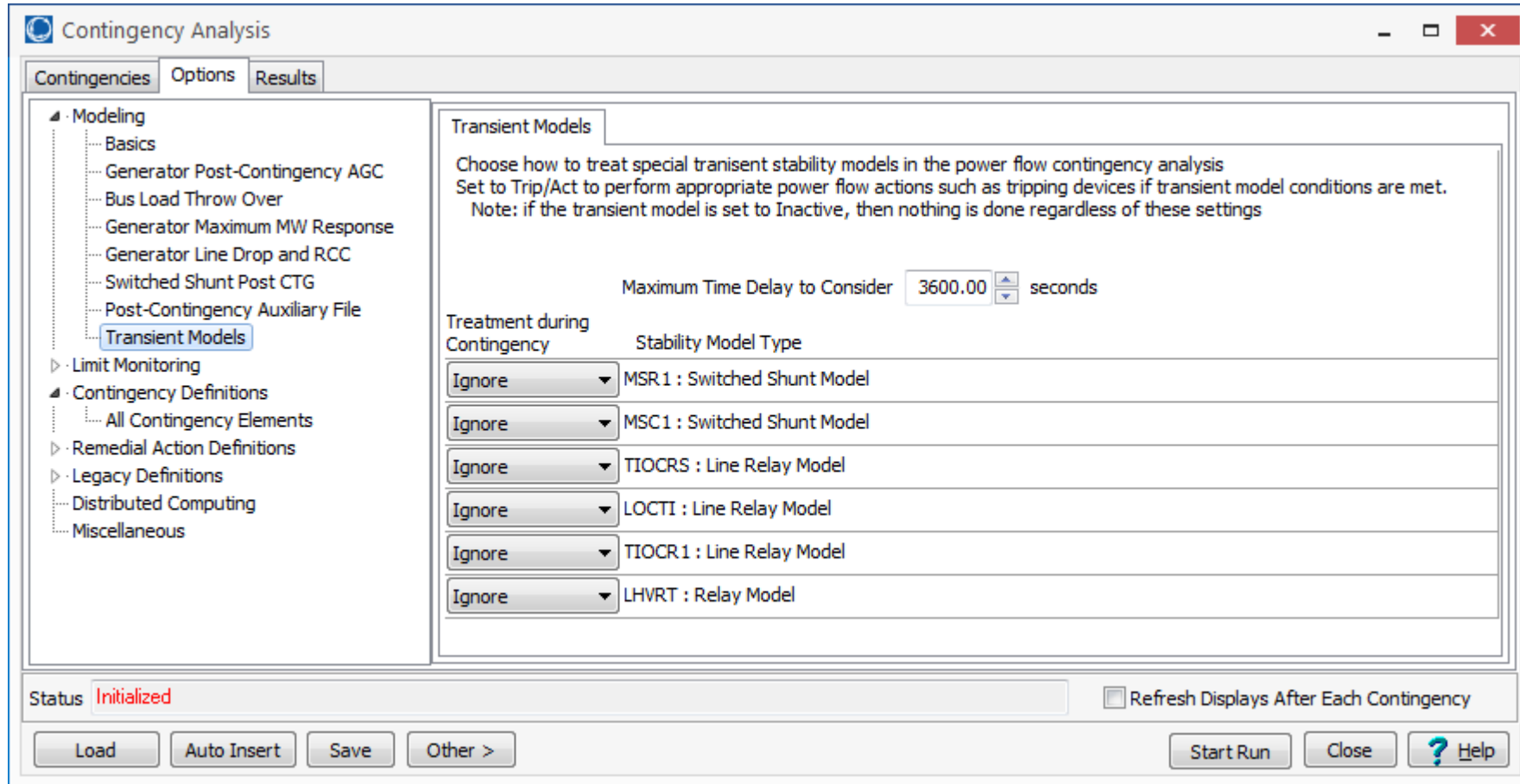


Transient Models



- Allows certain switched shunt, line relay, and relay models to respond in Contingency Analysis if their transient model conditions are met
- Treatment during Contingency
 - Ignore
 - Trip/Act: if model's conditions are met, its action will be taken and reported in "What Actually Occurred"
 - Monitor Only: if model's conditions are met, limit violations are reported in results with Category *Transient*
- Maximum Time Delay to Consider: only models with pick up time less than this value will be used
- Transient models are handled as part of the TOPOLOGYCHECK and POSTCHECK solution steps

Transient Models





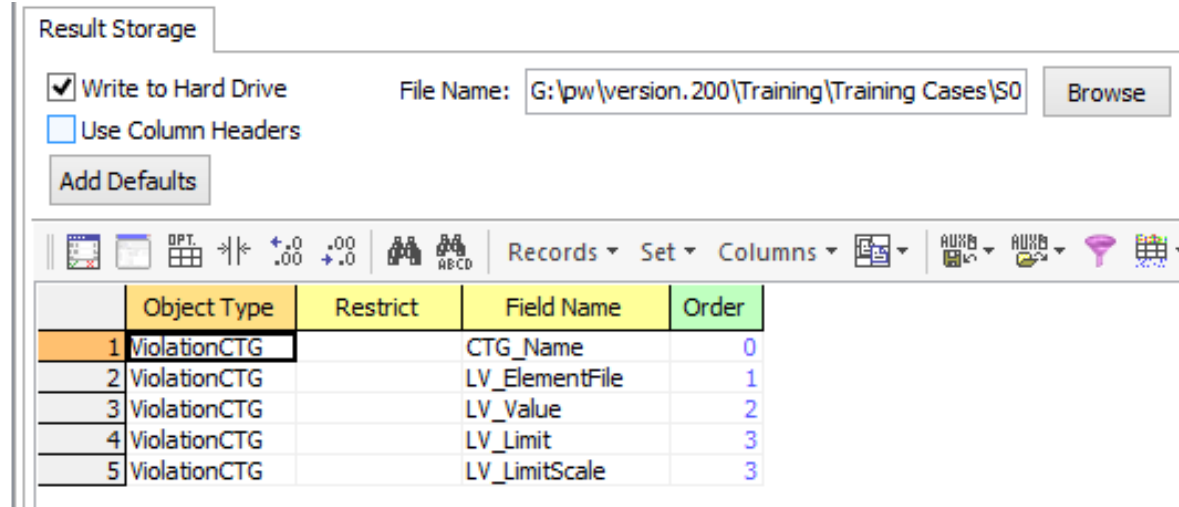
Transient Models



- Several transient stability models can be included in steady state contingency analysis
- Options to specify how models are treated during steady state contingency analysis
 - Ignore
 - Nothing happens with this model during steady state contingency analysis
 - Trip/Act
 - If conditions are met, actual actions will be taken (such as tripping a line for overcurrent)
 - Some models have a Monitor flag. If this flag is set to monitor only, an individual model will not act regardless of contingency setting.
 - Monitor Only
 - If conditions are met, special contingency violations are reported

Result Storage

- Can store contingency results to hard drive (aux or csv file)
- Useful for large contingency sets that may otherwise exceed RAM capacity
- Use Default options or add specific object types and fields



Result Storage

☒ Write to Hard Drive File Name: G:\pw\version.200\Training\Training Cases\S0 Browse

☐ Use Column Headers

Add Defaults

	Object Type	Restrict	Field Name	Order
1	ViolationCTG		CTG_Name	0
2	ViolationCTG		LV_ElementFile	1
3	ViolationCTG		LV_Value	2
4	ViolationCTG		LV_Limit	3
5	ViolationCTG		LV_LimitScale	3



Combined Tables



- Flat-file tables which could be used by external programs for parsing contingency inputs and results
 - *Contingency Violation List
 - **Contingency Element Definitions
 - *Contingency Violation Matrices
 - *What Occurred (list of applied and skipped actions)
- *Also available under Results → Violations
- **Also available under Options → Contingency Definitions → All Contingency Elements

Combined Tables >

Contingency Violation List



- Similar format to Contingency Violation Table, but allows selection of fields, advanced filters, etc. like Case Info Displays
- View within Simulator or export to Excel

All Contingency Violations

	Label	Element	Category	Value	Limit	Percent	CTG Specified Limit	Limit Scale
1	T_023068ENFIELD32-023067ENFIELD31C1	WINDSOR LOCKS 1 1 (23080) -> LONGMEADOW 1 (23002) CKT 1 at WINDSOR LOCKS 1 1	Branch MVA	113.50	101.10	112.27	NO	101.10
2	L_023067ENFIELD31-023069ENFIELD33C1	WINDSOR LOCKS 1 1 (23080) -> LONGMEADOW 1 (23002) CKT 1 at WINDSOR LOCKS 1 1	Branch MVA	113.73	101.10	112.49	NO	101.10
3	L_023090EASTHARTFORD11-023093EASTHARTFORD15C1	MANCHESTER 10 1 (23034) -> HARTFORD 5 1 (23115) CKT 1 at MANCHESTER 10 1	Branch MVA	102.96	96.80	106.36	NO	96.80
4	L_023090EASTHARTFORD11-023093EASTHARTFORD15C1	HARTFORD 8 3 (23482) -> MANCHESTER 10 1 (23034) CKT 1 at HARTFORD 8 3	Branch MVA	143.61	108.40	132.49	NO	108.40
5	L_071071WESTERLY1-023506UNCASVILLE28C1	COVENTRY 3 2 (23130) -> MANCHESTER 11 1 (23036) CKT 1 at COVENTRY 3 2	Branch MVA	164.75	87.10	189.15	NO	87.10
6	L_023485HARTFORD88-065319AGAWAM35C1	VERNON ROCKVILLE 1 1 (23052) -> MANCHESTER 12 1 (23037) CKT 1 at VERNON ROCKVILLE	Branch MVA	435.78	388.40	112.20	NO	388.40
7	L_071071WESTERLY1-023506UNCASVILLE28C1	VERNON ROCKVILLE 1 1 (23052) -> MANCHESTER 12 1 (23037) CKT 1 at VERNON ROCKVILLE	Branch MVA	502.28	388.40	129.32	NO	388.40
8	L_071071WESTERLY1-023506UNCASVILLE28C1	MANCHESTER 12 1 (23037) -> HARTFORD 8 4 (23483) CKT 1 at MANCHESTER 12 1	Branch MVA	421.03	366.20	114.97	NO	366.20
9	L_071071WESTERLY1-023506UNCASVILLE28C1	COLCHESTER 3 5 (23209) -> VERNON ROCKVILLE 1 1 (23052) CKT 1 at COLCHESTER 3 5	Branch MVA	1056.38	425.30	248.38	NO	425.30
10	T_023053VERNONROCKVILLE12-023052VERNONROCKVILLE	WINDSOR LOCKS 3 2 (23663) -> WINDSOR 2 4 (23077) CKT 1 at WINDSOR LOCKS 3 2	Branch MVA	140.53	129.10	108.86	NO	129.10
11	L_023109HARTFORD41-023114HARTFORD47C1	EAST HARTFORD 1 2 (23091) -> HARTFORD 3 1 (23087) CKT 1 at EAST HARTFORD 1 2	Branch MVA	150.72	124.20	121.35	NO	124.20
12	L_023114HARTFORD47-023483HARTFORD84C1	EAST HARTFORD 1 2 (23091) -> HARTFORD 3 1 (23087) CKT 1 at EAST HARTFORD 1 2	Branch MVA	150.75	124.20	121.38	NO	124.20
13	L_023114HARTFORD47-023483HARTFORD84C1	HARTFORD 3 1 (23087) -> WEST HARTFORD 3 1 (23118) CKT 1 at HARTFORD 3 1	Branch MVA	104.51	104.50	100.01	NO	104.50

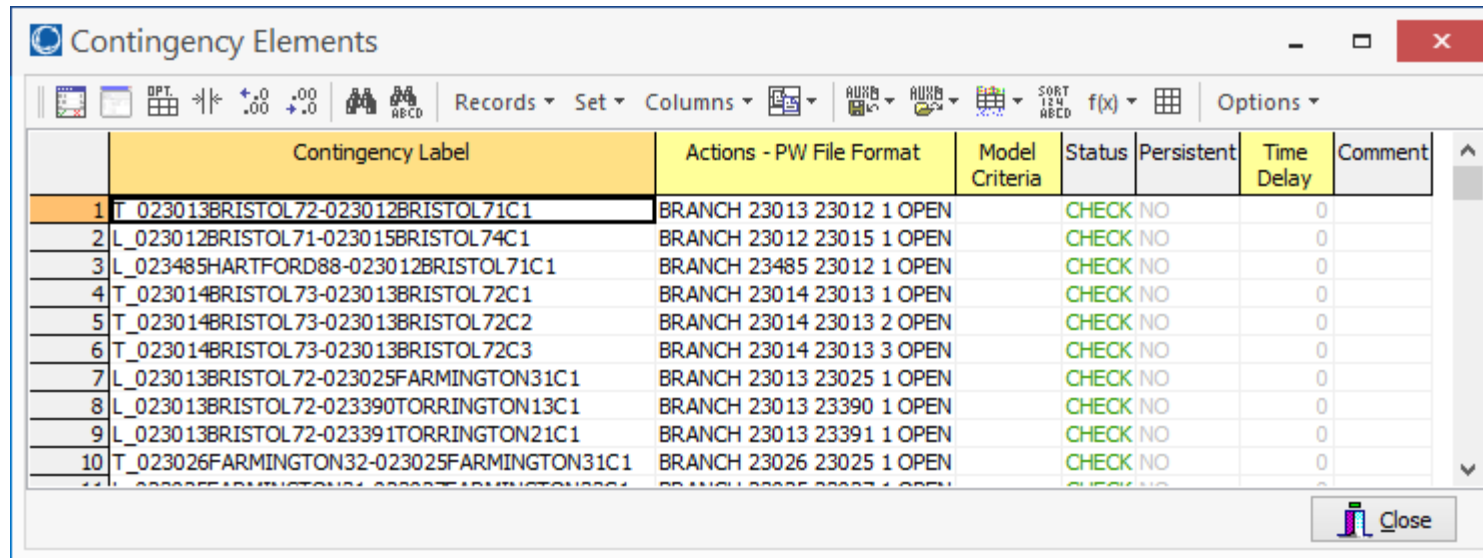
Close

Combined Tables >

Contingency Element Definitions



- Similar format to Contingency Definition Table, but allows selection of fields, advanced filters, etc. like Case Info Displays
- View within Simulator or export to Excel

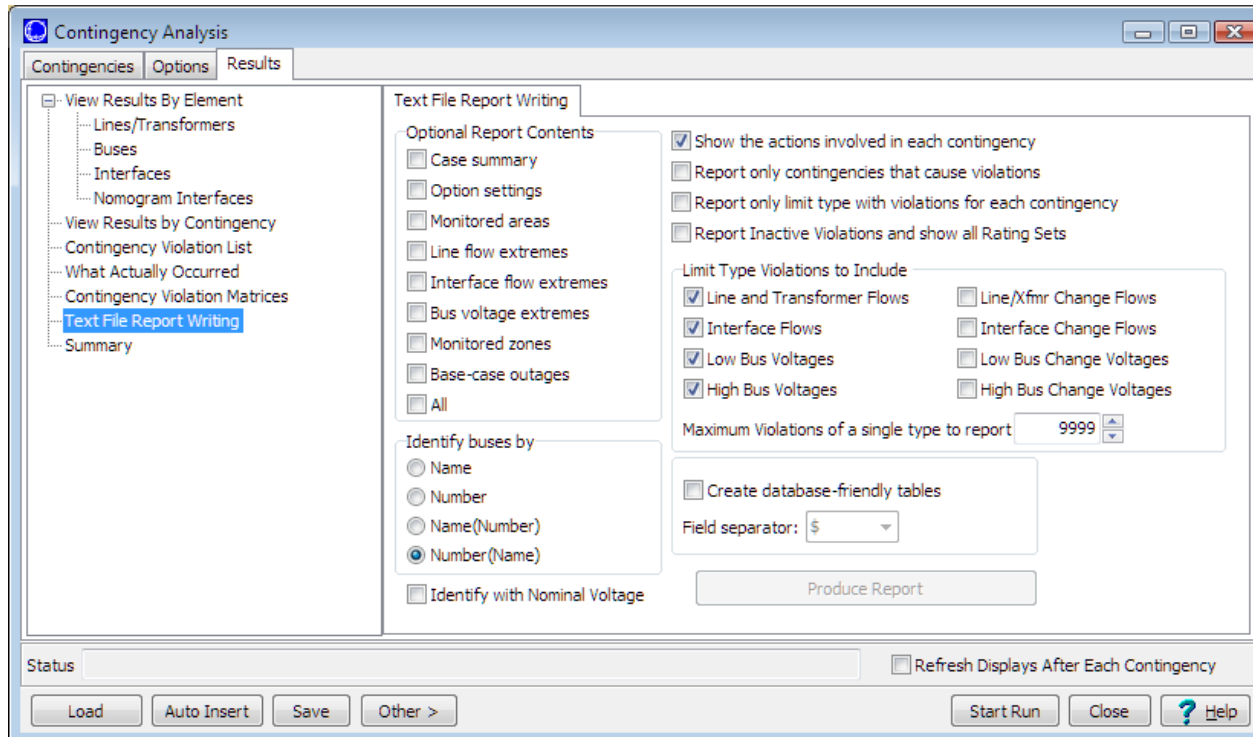


The screenshot shows a software window titled "Contingency Elements". It features a toolbar with various icons for editing and viewing data. Below the toolbar is a table with the following columns: Contingency Label, Actions - PW File Format, Model Criteria, Status, Persistent, Time Delay, and Comment. The table contains 10 rows of data, each representing a different contingency element. The first row is highlighted in orange.

	Contingency Label	Actions - PW File Format	Model Criteria	Status	Persistent	Time Delay	Comment
1	T_023013BRISTOL72-023012BRISTOL71C1	BRANCH 23013 23012 1 OPEN		CHECK	NO	0	
2	L_023012BRISTOL71-023015BRISTOL74C1	BRANCH 23012 23015 1 OPEN		CHECK	NO	0	
3	L_023485HARTFORD88-023012BRISTOL71C1	BRANCH 23485 23012 1 OPEN		CHECK	NO	0	
4	T_023014BRISTOL73-023013BRISTOL72C1	BRANCH 23014 23013 1 OPEN		CHECK	NO	0	
5	T_023014BRISTOL73-023013BRISTOL72C2	BRANCH 23014 23013 2 OPEN		CHECK	NO	0	
6	T_023014BRISTOL73-023013BRISTOL72C3	BRANCH 23014 23013 3 OPEN		CHECK	NO	0	
7	L_023013BRISTOL72-023025FARMINGTON31C1	BRANCH 23013 23025 1 OPEN		CHECK	NO	0	
8	L_023013BRISTOL72-023390TORRINGTON13C1	BRANCH 23013 23390 1 OPEN		CHECK	NO	0	
9	L_023013BRISTOL72-023391TORRINGTON21C1	BRANCH 23013 23391 1 OPEN		CHECK	NO	0	
10	T_023026FARMINGTON32-023025FARMINGTON31C1	BRANCH 23026 23025 1 OPEN		CHECK	NO	0	

Other > Produce Report...

- Will produce a fixed contingency analysis report
- Can only select what data is put into this report
- Cannot customize the format in any manner



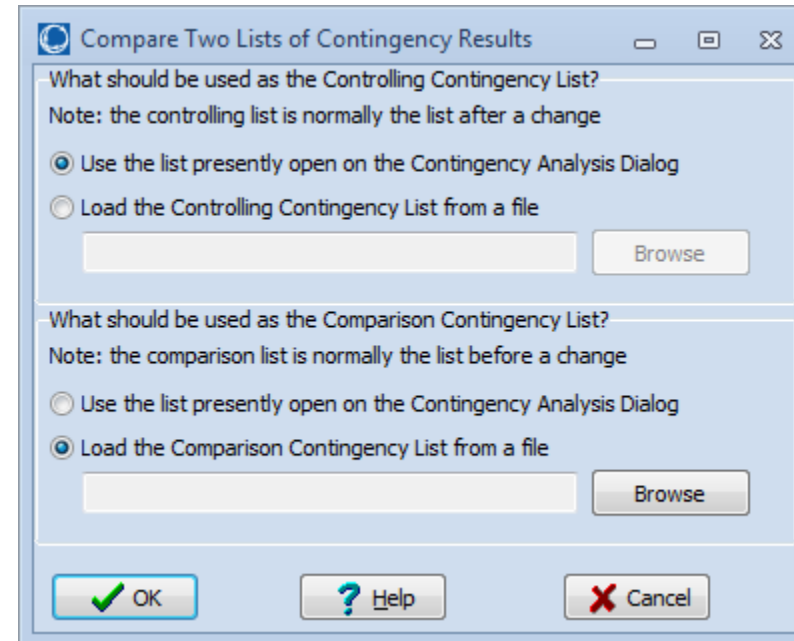
Options for the report writing tool are specified under Results
→ Text File Report Writing

Other > Compare Two Lists of Contingency Results



- Must specify two lists of contingencies
 - Controlling List
 - The list that controls what is displayed on the dialog
 - Comparison List
 - List that the Controlling Contingencies will be compared to
 - Comparisons between contingencies with same NAME

This is covered in more detail in Section S8



Example Results of a Contingency Comparison

- Contingencies Tab

Number of Violations which occur in the Controlling case, but not in Comparison

Highest Violation in the Controlling Case

Highest Violation in the Comparison Case

Show the largest increase in a violation from the comparison to the controlling list

Shows the highest violation that occurs in the controlling list, but not comparison

Maximum of [Worst Increase Violation] and [Worst New Violation - 100%]

	Label	Skip	Category	Processed	Solved	Comp Solved	Post-CTG AUX	Violations	Comp Violations	New Violations	Max Branch %	Comp Max Branch %	Worst Branch Increase Violation	Worst Branch New Violation	Worst Branch Violation
1	L_00003BRIGHTON-00004CNASTONEC1	NO		YES	YES	YES	none	15	2	13	141.7	113.4	28.350	119.4	28.3
2	L_00004CNASTONE-00026HUNTERTNC1	NO		YES	YES	YES	none	6	2	4	142.3	113.9	28.465	119.0	28.5
3	L_00001ALBURTIS-00009JUNIATAC1	NO		YES	YES	YES	none	3	2	1	100.4		100.4	0.4	
4	T_00001ALBURTIS-03051ALBURTISC1	NO		YES	YES	YES	none	0	0	0					
5	L_00002BRANCHBG-00006DEANSC1	NO		YES	YES	YES	none	6	3	3	128.3	102.7	25.670	105.6	25.7
6	L_00002BRANCHBG-00007ELROYC1	NO		YES	YES	YES	none	2	2	0					
7	T_00002BRANCHBG-04962BRANCHBGC2	NO		YES	YES	YES	none	1	1	0					

	Category	Element	Value	Comp Value	Diff Value	Limit	Comp Limit	Diff Limit	Percent	Comp Percent	Diff Percent	Are A
1	Branch MVA	CNASTONE (-4) -> CONASTON (5963) CKT 1 at CNASTONE	989.65			872.80			113.39			113.39 PJMS
2	Branch MVA	CNASTONE (-4) -> CONASTON (5963) CKT 2 at CNASTONE	989.65			872.80			113.39			113.39 PJMS
3	Branch MVA	ROXBURY (221) -> ROXBURY (233) CKT 1 at ROXBURY	160.15	160.15	0.00	123.20	154.00	-30.80	129.99	103.99	26.00	PENE
4	Branch MVA	ROXBURY (233) -> 01GREENE (20188) CKT 1 at 01GREENE	161.03	161.03	0.00	113.60	142.00	-28.40	141.75	113.40	28.35	PENE

Status: Finished with 141 Violations, 1 Unsolvable, and 0 Aborted Contingencies. Initial State Restored.

Violations For this contingency. The columns show the controlling and comparison list values.

Blank entries mean that the comparison list did not have this violation

Example Results of a Contingency Comparison

- Results tab

Number of Violations which occur in the Controlling case, but not in Comparison

Highest Violation in the Controlling Case

Highest Violation in the Comparison Case

Show the largest increase in a violation from the comparison to the controlling list

Shows the highest violation that occurs in the controlling list, but not comparison

Maximum of [Worst Increase Violation] and [Worst New Violation - 100%]

Contingency Analysis

Contingencies Options Results

View Results By Element

- Lines/Transformers
- Buses
- Interfaces
- Nomogram Interfaces
- Custom Monitors

View Results by Contingency

- Contingency Violation List
- What Actually Occurred
- Contingency Violation Matrices
- Text File Report Writing
- Summary

Lines/Transformers (filtered)

	From Number	From Name	To Number	To Name	Circuit	Xfmr	Violations	New Violations	Max % Loading Cont.	Max % Ld Cont Comp	Worst Increased Violation	Worst New Violation	Worst Violation
1	233	ROXBURY	20188	01GREENE	1	NO	15	13	141.75	113.40	28.35	115.08	28.35
2	1221	HUNTRSTN	1152	HUNTRSTN	2	YES	8	7	142.32	113.86	28.46	117.19	28.46
3	2534	GRYSTN Q	2550	WHIPPANY	1	NO	3	3	106.51			106.51	6.51
4	3054	BRUNNER	3086	W.HMPFLD	1	NO	2	2	123.17			123.17	23.17
5	25	W CHAPEL	5955	W.CHAPEL	1	YES	2	2	105.23			105.23	5.23

Contingencies

Show Other Violations Combined Tables >

	Label	Category	Value	Comp Value	Diff Value	Limit	Percent	Comp Percent	Diff Percent
1	L_00003BRIGHTON-00004C	Branch MVA	161.03	161.03	0.00	113.60	141.75	113.40	28.35
2	L_00004CNASTONE-00026H	Branch MVA	130.73			113.60	115.08		115.08

Status Finished with 141 Violations, 1 Unsolveable, and 0 Aborted Contingencies. Initial State Restored.

Refresh Displays After Each Contingency

Load Auto Insert Save Other > Start Run Close ? Help

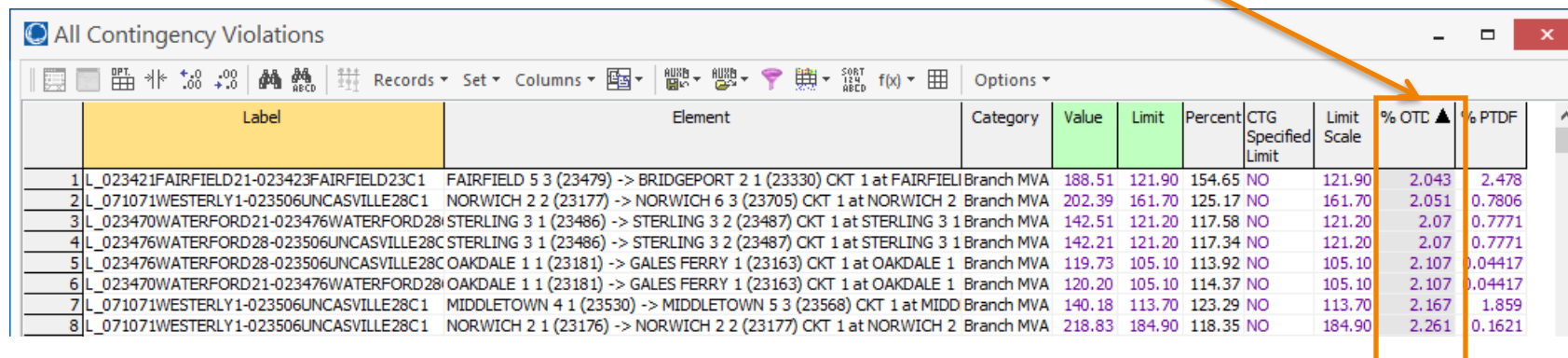




Other > Sensitivity Calculations



- Calculate OTDFs using existing PTDFs
 - This will use the PTDFs that are presently calculated in the PTDF Tool to calculate OTDFs for each violation found in the contingency tool
 - See section I11:Linear Analysis for more about PTDFs
- Filter out violations using OTDFs: specify a minimum value to hide violations with lower OTDF (e.g. 2%)



	Label	Element	Category	Value	Limit	Percent	CTG Specified Limit	Limit Scale	% OTD ▲	% PTDF
1	L_023421FAIRFIELD21-023423FAIRFIELD23C1	FAIRFIELD 5 3 (23479) -> BRIDGEPORT 2 1 (23330) CKT 1 at FAIRFIELD Branch MVA		188.51	121.90	154.65	NO	121.90	2.043	2.478
2	L_071071WESTERLY1-023506UNCASVILLE28C1	NORWICH 2 2 (23177) -> NORWICH 6 3 (23705) CKT 1 at NORWICH 2 Branch MVA		202.39	161.70	125.17	NO	161.70	2.051	0.7806
3	L_023470WATERFORD21-023476WATERFORD28C1	STERLING 3 1 (23486) -> STERLING 3 2 (23487) CKT 1 at STERLING 3 1 Branch MVA		142.51	121.20	117.58	NO	121.20	2.07	0.7771
4	L_023476WATERFORD28-023506UNCASVILLE28C1	STERLING 3 1 (23486) -> STERLING 3 2 (23487) CKT 1 at STERLING 3 1 Branch MVA		142.21	121.20	117.34	NO	121.20	2.07	0.7771
5	L_023476WATERFORD28-023506UNCASVILLE28C1	OAKDALE 1 1 (23181) -> GALES FERRY 1 (23163) CKT 1 at OAKDALE 1 Branch MVA		119.73	105.10	113.92	NO	105.10	2.107	0.04417
6	L_023470WATERFORD21-023476WATERFORD28C1	OAKDALE 1 1 (23181) -> GALES FERRY 1 (23163) CKT 1 at OAKDALE 1 Branch MVA		120.20	105.10	114.37	NO	105.10	2.107	0.04417
7	L_071071WESTERLY1-023506UNCASVILLE28C1	MIDDLETOWN 4 1 (23530) -> MIDDLETOWN 5 3 (23568) CKT 1 at MIDD Branch MVA		140.18	113.70	123.29	NO	113.70	2.167	1.859
8	L_071071WESTERLY1-023506UNCASVILLE28C1	NORWICH 2 1 (23176) -> NORWICH 2 2 (23177) CKT 1 at NORWICH 2 Branch MVA		218.83	184.90	118.35	NO	184.90	2.261	0.1621

Conditional Contingency Actions using Model Criteria



- The contingency elements discussed thus far define a list of actions that ALWAYS occur
- You can also specify actions that occur only if the system meets a Model Criteria
 - Model Criteria
 - **Model Conditions**
 - **Model Filters**
 - When a contingency is applied, these actions only occur if the Model Criteria is true
- Conditional actions are useful for realistic modeling of RAS or SPS that are armed or activated only under specific system conditions

Options, Contingency Definitions: Remedial Actions



- Provide a way to specify groups of actions which may occur under ANY contingency.
 - “Armed” only if **Arming Criteria** are met
 - Actions would normally be taken only if certain conditions (**Model Criteria**) are met
 - Example: Line X is taken out of service if it gets overloaded.
 - Actions are grouped by **Remedial Action**
 - Each **Remedial Action** has a unique label (name)
 - Each **Remedial Action** may be individually enabled or disabled and individually armed

Model Conditions and Model Filters



- A **Model Condition** or **Model Filter** may be used as *Model Criteria* for a **Contingency Action**, **Remedial Action**, or **Global Action**
 - The associated action may be executed only if the *Model Criteria* is met
- **Model Conditions**
 - The combination of a specific system element and an advanced filter
 - Each **Model Condition** references only one element; the **Model Condition** is true if the element meets the filter
 - Can compare an element's parameter to a constant, another parameter of that element, or to the value of a **Model Expression**
 - Example: Bus 4 p.u. voltage < 0.95
- **Model Filters**
 - Logical comparison of one or more **Model Conditions** or **Model Filters**
 - Example: true if several **Model Conditions** are all true

Options, Contingency Definitions: Model Conditions



- Click on **Model Conditions** page
- Right-click on the case info display and choose **Insert**
- Example: Add a condition for MW flow > 50 on Waterbury-Wolcott 100 kV line

“Evaluate in Contingency Reference State” for conditions that arm RAS prior to contingency

Choose the type of element (Branch)

Define the criteria: MW > 50

Give the Model Condition a name and save

Choose the specific element (23512 23370 1)

Works the same as the Advanced Filter Dialog

Model Conditions



- Can also use **Model Conditions** for lines statuses
- These conditions can force **Remedial Actions** to occur only during certain contingencies
- Example: check if Bethel-Danbury 230 kV line is OPEN in a post-contingent state

“Evaluate in Contingency Reference State” unchecked to examine post-contingent states

Give the Model Condition a name and save

Define the criteria (Line Status = OPEN)

Choose the specific element (23406 23415 1)

Model Conditions



- For Line Status, we may also need to check if it was different in the Reference State (i.e. Did the line open during the contingency?)
- Example: check if Bethel-Danbury 230 kV line was CLOSED

Check this condition in
the Reference State
(Base Case)

Define the criteria (Line Status =
CLOSED)

Define Model Conditions

Model Condition Name: Bethel-Danbury 230 kV CLOSED reference

☒ Evaluate in Contingency Reference State
☐ Disable if True in Contingency Reference State

Element Type: Branch

64460 entries
Sort by: Name (selected), Number
Filter: Advanced, Branch
Use Area/Zone Filters: ☐
Quick Define Remove
Search Next Search All
You can use wildcard characters * or ?

23406
23404 (BETHEL 3 4) FROM 23403 (BETHEL 3 3) CKT 1 [1,000 kV] - [18,00 kV]
23405 (BETHEL 3 5) FROM 23401 (BETHEL 3 1) CKT 1 [230.0 kV] - [230.0 kV]
23406 (BETHEL 3 7) TO 23281 (SOUTHBURY 1 5) CKT 1 [230.0 kV] - [230.0 kV]
23406 (BETHEL 3 7) TO 23415 (DANBURY 2 4) CKT 1 [230.0 kV] - [230.0 kV]
23406 (BETHEL 3 7) FROM 23401 (BETHEL 3 1) CKT 1 [230.0 kV] - [230.0 kV]
23407 (BETHEL 3 9) FROM 23401 (BETHEL 3 1) CKT 1 [230.0 kV] - [230.0 kV]

Meets the filter below Set Filter Same As

Select Filter Type: Branch

☒ Enabled (normally checked)
Logical Comparison: AND (selected), OR, Not AND, Not OR, XOR, One TRUE

Condition 1
Find... Status equal to Closed
☐ Use Another Filter ☐ Evaluate Field in Contingency Ref. State
Add >> Delete ...

☐ Enable Field to Field Comparisons

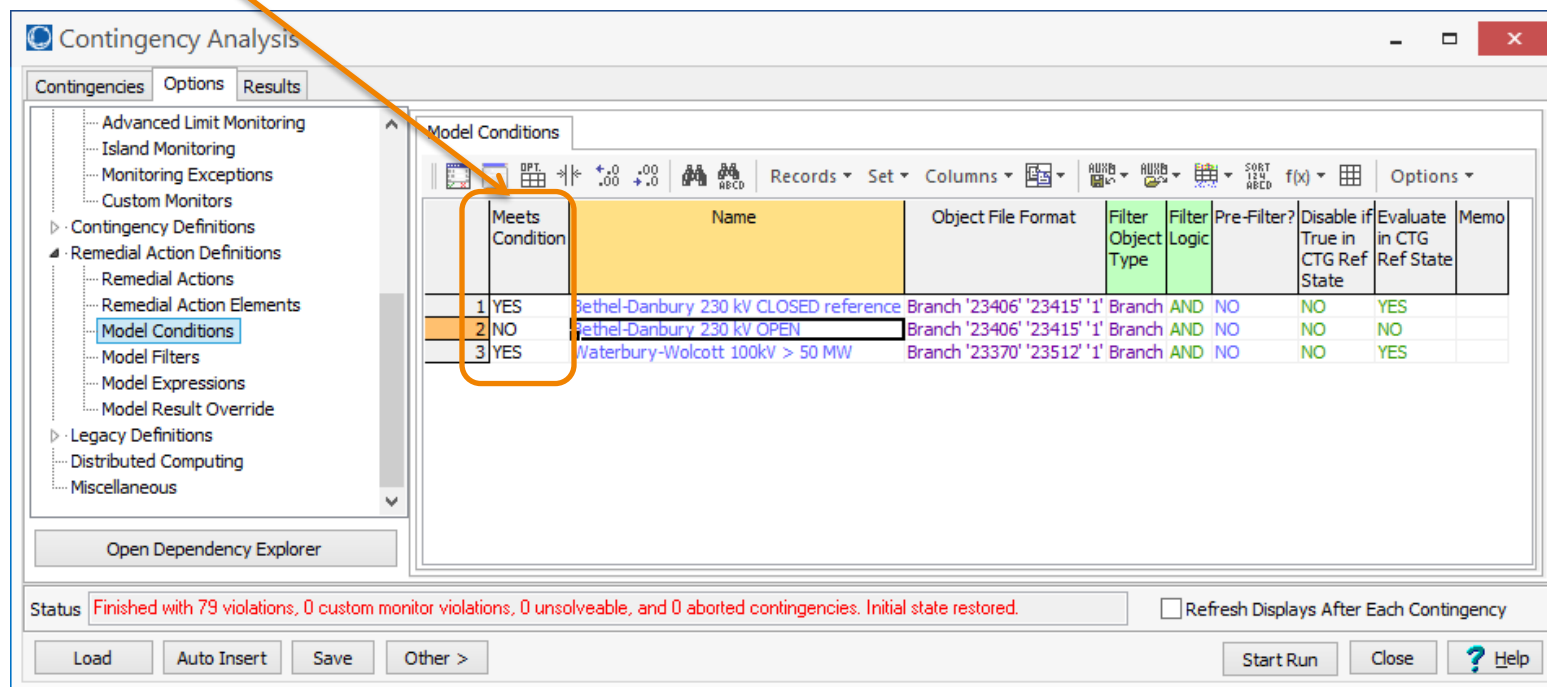
OK Help Cancel

Model Conditions



- List of created Model Conditions

Meets Condition - YES or NO



Contingency Analysis

Contingencies Options Results

Model Conditions

	Meets Condition	Name	Object File Format	Filter Object Type	Filter Logic	Pre-Filter?	Disable if True in CTG Ref State	Evaluate in CTG Ref State	Memo
1	YES	Bethel-Danbury 230 kV CLOSED reference	Branch '23406' '23415' '1'	Branch	AND	NO	NO	YES	
2	NO	Bethel-Danbury 230 kV OPEN	Branch '23406' '23415' '1'	Branch	AND	NO	NO	NO	
3	YES	Waterbury-Wolcott 100kV > 50 MW	Branch '23370' '23512' '1'	Branch	AND	NO	NO	YES	

Status: Finished with 79 violations, 0 custom monitor violations, 0 unsolveable, and 0 aborted contingencies. Initial state restored.

Load Auto Insert Save Other > Start Run Close Help

Options, Contingency Definitions: Model Filters



- Click on **Model Filters** page
- Right-click on the case info display and choose **Insert**
- Example: check the reference state and contingency status of the Bethel-Danbury 230 kV line by “ANDing” the 2 previously created **Model Conditions**

The screenshot shows the 'Filter Conditions' dialog box. It has a title bar with a close button. Inside, there's a 'Filter Name' field containing 'loss of Bethel-Danbury 230kV'. Below this are buttons for 'Save', 'Save As', 'Rename', 'Delete', and 'View Filter Logic'. A checkbox 'Disable if True in Contingency Reference State' is present. The 'Logical Comparison' section has radio buttons for 'AND' (selected), 'OR', 'Not AND', 'Not OR', 'XOR', and 'One True'. Below this are two 'Model Condition' entries. Each has a 'Find...' button, a dropdown menu, and radio buttons for 'Condition' (selected) and 'Filter'. The first condition is 'Bethel-Danbury 230 kV CLOSED reference' and the second is 'Bethel-Danbury 230 kV OPEN'. Both have a 'Time Delay' field set to '0.000000'. At the bottom are buttons for 'Add >>', 'Delete ...', 'Modify Model Conditions', 'OK', 'Help', and 'Cancel'. Annotations with orange arrows point to various parts: 'Name the Model Filter' points to the 'Filter Name' field; 'Logical comparison "AND"' points to the 'AND' radio button; 'Similar to the Advanced Filter Dialog' points to the 'Model Condition' section; 'Click to Open Model Condition dialog' points to the 'Find...' button of the first condition; and 'Model Filters may contain Model Conditions or other Model Filters' points to the 'Filter' radio button of the second condition.

Filter Conditions

Filter Name: loss of Bethel-Danbury 230kV

Save Save As Rename Delete View Filter Logic

☐ Disable if True in Contingency Reference State

Logical Comparison

☒ AND ☐ OR ☐ Not AND ☐ Not OR ☐ XOR ☐ One True

Model Condition 1

Find... Bethel-Danbury 230 kV CLOSED reference

☒ Condition ☐ Filter ☐ Not Time Delay 0.000000

Model Condition 2

Find... Bethel-Danbury 230 kV OPEN

☒ Condition ☐ Filter ☐ Not Time Delay 0.000000

Add >> Delete ... Modify Model Conditions OK Help Cancel

Name the Model Filter

Logical comparison "AND"

Similar to the Advanced Filter Dialog

Click to Open Model Condition dialog

Model Filters may contain Model Conditions or other Model Filters

Remedial Action Example



- Disable *Contingency Monitoring Exceptions* if created earlier (set **Monitor Exception Status** to *Default*)
- Run simple N-1 contingency analysis on all lines and transformers in area Connecticut at 200 kV and higher
 - *Linearized Lossless DC Calculation Method*
 - **Make-Up Power** using *Generator Participation Factors From Entire Case Directly*
 - Do not report base case violations
 - Monitor area Connecticut (23) at 100 kV and above
 - Do not monitor radial lines and buses
 - Use “A” limits for Normal and Contingency
 - Settings in *S04_AdvancedContingency\ S04AdvancedCTG01.aux*

Contingency Results



- Many contingencies with overloads
- In this example, we'll apply Remedial Actions for loss of Bethel-Danbury 230 kV (L_023406BETHEL37-023415DANBURY24C1) – 100th in list
- Overloads
 - Waterbury-Wolcott 100 kV
 - Wolcott-Seymour 100 kV

Contingency Analysis

Start Run

Abort

Load

Auto Insert

Save

Other >

Help

Status

Contingency L_023406BETHEL37-023415DANBURY24C1 converged.

☐ Refresh Displays After Each Contingency

Contingencies

Options

Results

Filter

Advanced

LimitViol

Find...

Remove

Quick Filter

	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 V
99	L_023401BETHEL31-023407BETHEL39C1	NO		YES	YES	YES	NO	none			0	0	0	0	0		
100	L_023406BETHEL37-023415DANBURY24C1	NO		YES	YES	YES	NO	none			0	0	0	0	2	119.9	
101	T_023413DANBURY22-023412DANBURY21C1	NO		YES	YES	YES	NO	none			0	0	0	0	0		
102	L_023412DANBURY21-042104NEWBURGH412C1	NO		YES	YES	YES	NO	none			0	0	0	0	0		
103	T_023414DANBURY23-023413DANBURY22C1	NO		VFC	VFC	VFC	NO	none			0	0	0	0	0		

Violations

What Occurred

Show related contingencies

Combined Tables >

	Category	Element	Value	Limit	Percent	Area Nam
1	Branch MVA	WOLCOTT 1 1 (23370) -> SEYMOUR 1 2 (23272) CKT 1 at WOLCOTT 1 1	114.90	95.80	119.93	Connecticut
2	Branch MVA	WATERBURY 13 3 (23512) -> WOLCOTT 1 1 (23370) CKT 1 at WATERBURY 13 3	135.89	121.40	111.94	Connecticut

Search

Search Now

Options

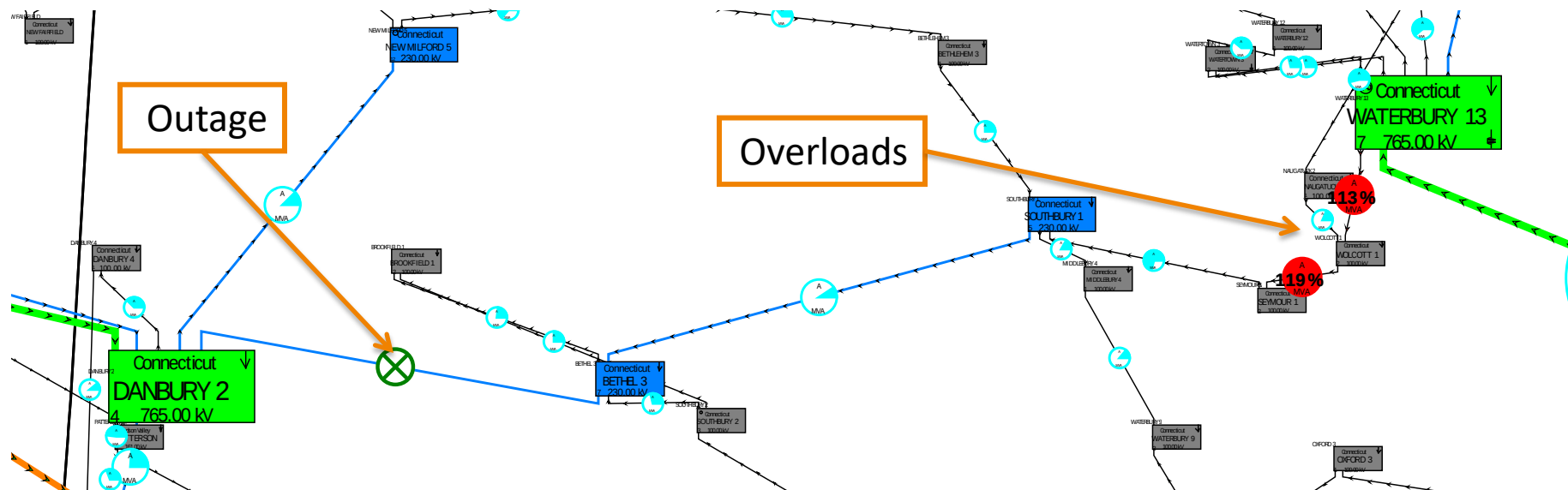
Definition

	Actions
1	OPEN Line BETHEL 3 7 230.0 (23406) TO DANBURY

Bethel-Danbury 230 kV Contingency



- Change *Calculation Method* to **Full Power Flow**
- Optionally skip all contingencies except L_023406BETHEL37-023415DANBURY24C1
- Right Click L_023406BETHEL37-023415DANBURY24C1 → Contingency records → Solve Selected Contingency



Remedial Actions



- Load definitions from *S04_AdvancedContingency\S04AdvancedCTG02.aux*
- Multiple layers of actions with different Arming Criteria depending on pre-contingent loading of Waterbury-Wolcott 100 kV
 - If exceeds 50 MW, drop 500 MW at Waterford
 - If exceeds 100 MW, drop 1000 MW at Waterford
 - If exceeds 100 MW and still overloaded after other actions, shed load at Seymour in 10% increments until overloading relieved

Remedial Actions



Remedial Action name

Optionally Skip
this Remedial
Action

Arming Criteria
(Model Condition
or Model Filter)

Status (more
details later)

The screenshot shows the 'Contingency Analysis' software interface. The 'Remedial Actions' tab is active, displaying a table of actions. The table has columns for Name, Skip, Arming Criteria, Arming Status, and Armed. Three actions are listed: 'Drop Waterford 500 MW', 'Drop Waterford 1000 MW', and 'Load Shed Seymour'. The 'Drop Waterford 500 MW' action is highlighted. Below the table, the 'Definition' window is open, showing the details for the selected action. It includes a table with columns for Actions, Model Criteria, Status, and Inclusion Filter. The first row shows the action 'CHANGE INJECTION GROUP Waterford Gens BY -500 MW' with the model criteria 'Loss of Bethel-Dani TOPOLO'.

Name	Skip	Arming Criteria	Arming Status	Armed
1 Drop Waterford 500 MW	YES	Waterbury-Wolcott CHECK	YES	YES
2 Drop Waterford 1000 MW	YES	Waterbury-Wolcott CHECK	YES	YES
3 Load Shed Seymour	YES	Waterbury-Wolcott CHECK	YES	YES

Actions	Model Criteria	Status	Inclusion Filter
1 CHANGE INJECTION GROUP Waterford Gens BY -500 MW	Loss of Bethel-Dani TOPOLO		

Action(s) included
in this Remedial
Action

Assigning Arming/Model Criteria to a Remedial Action or Element



- Double-Click in the **Arming Criteria** or **Model Criteria** cell, OR
- Click the “...” icon on the right side of the cell
- In this example, we’ll use **Arming Criteria** for **Remedial Actions** and **Model Criteria** for individual elements of **Remedial Actions**
- **Model Criteria** may also be assigned to individual **Contingency Elements** (or **Contingency Actions**)

Remedial Action

☐ Ignore Remedial Action Elements if Model Criteria is True in Contingency Reference State

Records Set Columns

	Label	Skip	Arming Criteria	Arming Status	Armed
1	Drop Waterford 500 MW	NO	...	CHECK	YES
2	Drop Waterford 1000 MW	YES	Waterbury-Wolcott	CHECK	YES
3	Load Shed Seymour	YES	Waterbury-Wolcott	CHECK	YES

Definition

	Actions	Model Criteria
1	CHANGE INJECTION GROUP Waterford Gens BY -500 MW in merit order and max	Loss of Bethel-Danbury 230kV

Remedial Action: Drop Waterford 500 MW



- Change its *Skip* field to NO
- **Arming Criteria** is the **Model Condition** “Waterbury-Wolcott 100kV > 50 MW”
- Show Dialog for the Remedial Action

Remedial Action Elements

Remedial Action: Drop Waterford 500 MW

Buttons: Add New, Rename, Find...

Definition: Custom

Buttons: Insert New Element, Clear All

	Actions	Model Criteria	Status	Inclusion Filter	Persistent	Time Delay	Arming Criteria	Arming Status	Armed
1	CHANGE INJECTION GROUP Waterford Gens BY -500 MW	loss of Bethel-Danbury 230kV TOPOLOGYCHECK			NO	0		CHECK	YES

Arming Status: CHECK

Arming Criteria: Modify Waterbury-Wolcott 100kV > 50 MW

Buttons: OK, Save, Delete, Cancel, Help

Remedial Action:

Drop Waterford 500 MW

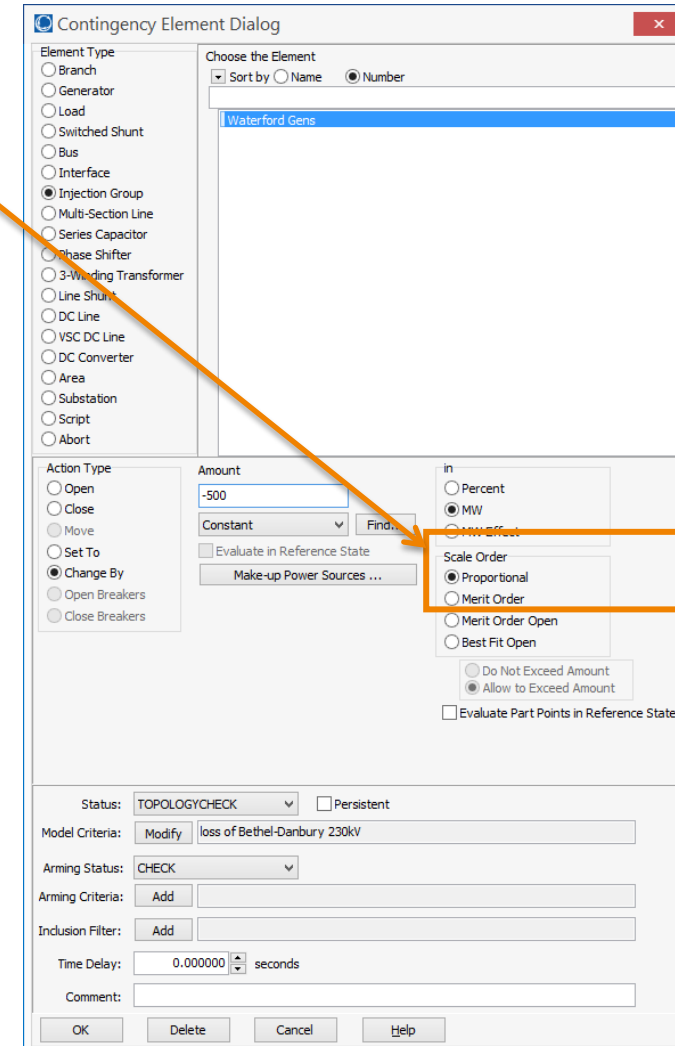


- RAS contains a single action
- CHANGE INJECTION GROUP Waterford Gens BY -500 MW
- **Model Criteria** for the action is the **Model Filter** “loss of Bethel-Danbury 230kV” with Status TOPOLOGYCHECK (evaluated after topology has changed due to contingency, but prior to solving power flow)

Remedial Action: Drop Waterford 500 MW



- **Scale Order**
 - Proportional: adjustment according to relative participation factor
 - Merit Order: highest participation factor units moved first, until limit
 - Merit Order Open: highest participation factor units are dropped (opened) first
- Leave as “Proportional” initially
- Close dialogs and solve contingency
“L_023406BETHEL37-023415DANBURY24C1”



Contingency Difference Case at Waterford



500 MW reduction from Waterford injection group, with twice as much from the unit with Participation Factor = 2

WATERFORD 2 1

Bus: WATERFORD 2 1 (23470)
Nom kV: 765.00
Area: Connecticut (23)
Zone: 1 (1)

0.0007 pu
0.51 KV
-5.83 Deg
0.00 \$/MWh

-0.538 Mvar
ID 1

446.5 MW
42.9 Mvar
-440.5 MVA

CKT 1

WATERFORD 2 8

23476

UNCASVILLE 2 8

23506

0.0005 pu

0.40 KV

-166.667 MW
0.000 Mvar
23474 ID 1
WATERFORD 2 5
CKT 1 0.0000 tap
166.5 MW
-15.0 Mvar
-152.3 MVA

-333.333 MW
0.000 Mvar
23473 ID 1
WATERFORD 2 4
CKT 1 0.0000 tap
333.0 MW
-27.1 Mvar
-300.1 MVA

0.00 MW
0.00 Mvar

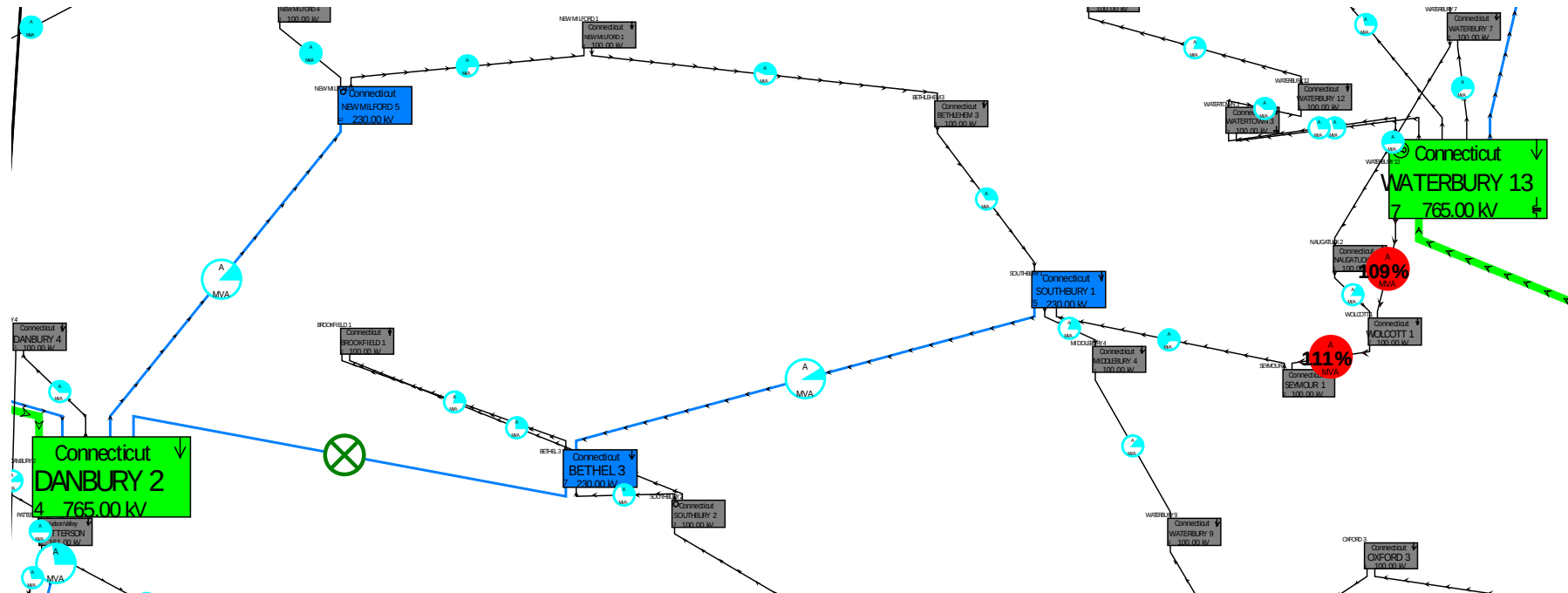
52.9 MW
-1.3 Mvar
-51.1 MVA
0.0000 tap
CKT 1
WATERFORD 2 2
23471
0.0007 pu
0.16 KV

System State

Contingency Loading with RAS



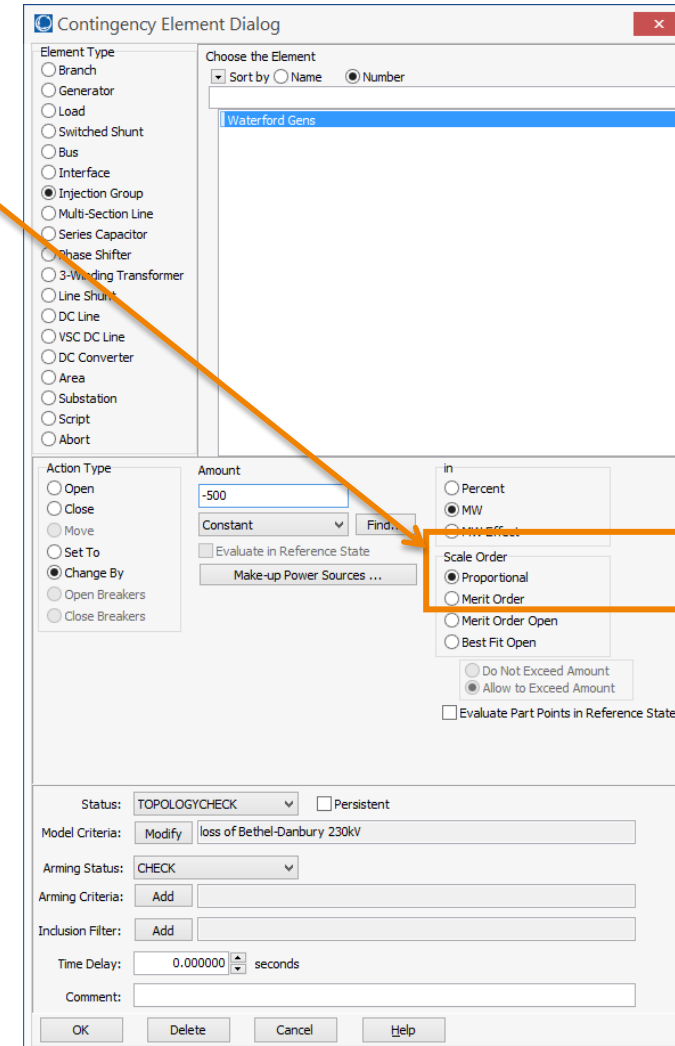
- Gen drop RAS has reduced loading, but limit violations persist



Remedial Action: Drop Waterford 500 MW



- Change **Scale Order** to “Merit Order Open” and choose “Allow to Exceed Amount”
- Close dialogs and solve contingency “L_023406BETHEL37-023415DANBURY24C1”



Merit Order Open



Unit with larger Participation Factor is opened to get at least 500 MW reduction. Exceeding 500 MW is allowed.

WATERFORD 2 1

Bus: WATERFORD 2 1 (23470)
Nom kV: 765.00
Area: Connecticut (23)
Zone: 1 (1)

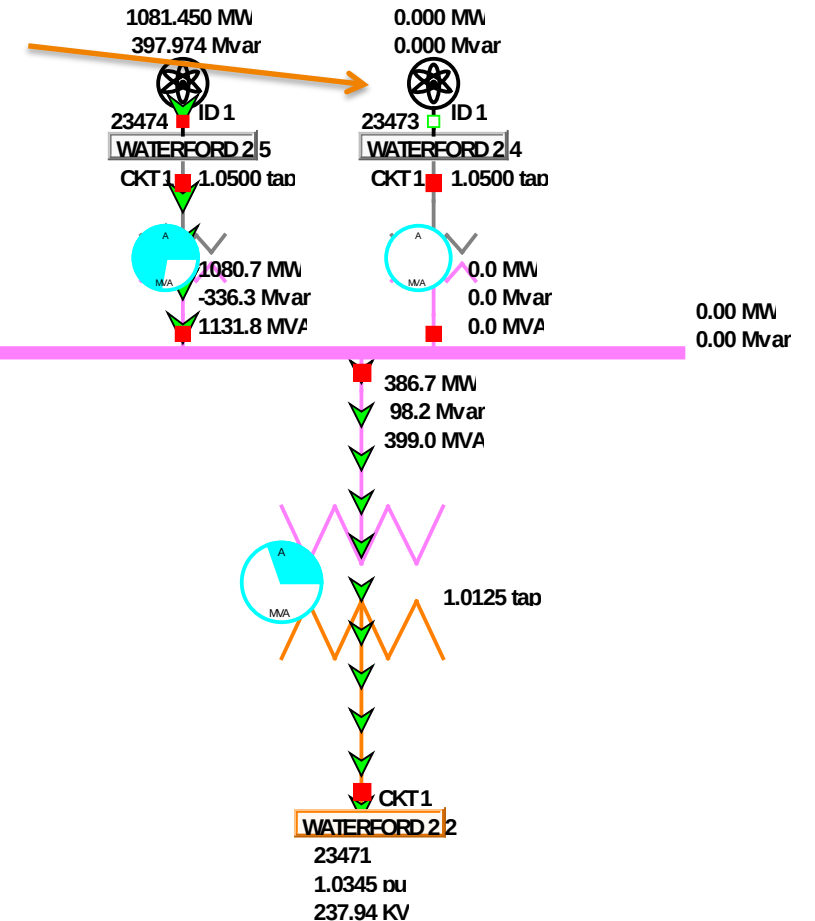
1.0298 pu
787.77 KV
-81.83 Deg
32.61 \$/MWh

System State

-409.323 Mvar
ID 1

694.0 MW
-171.3 Mvar
714.8 MVA

CKT 1
WATERFORD 2 8
23476
UNCASVILLE 2 8
23506
1.0317 pu
789.24 KV



Remedial Action: Drop Waterford 1000 MW



- Enable Remedial Action “Drop Waterford 1000 MW” (set Skip = NO)
- This reduces output at Waterford by an additional 500 MW (Merit Order) with a higher arming threshold
- Close dialogs and re-solve contingency (Note that it solves now without violations.)

Remedial Action

☐ Ignore Remedial Action Elements if Model Criteria is True in Contingency Reference State

<

Remedial Action: Load Shed Seymour



- Suppose there was not enough capability to remove overloading with generation drop
- Disable RAS “Drop Waterford 1000 MW” and Enable RAS “Load Shed Seymour”
- Action involves a 10% reduction in load
 - POSTCHECK status: criteria evaluated after contingency power flow solution
 - Persistent: action will be taken until criteria is no longer met

Contingency Solution: What Occurred



- 500 MW gen drop at Waterford
- Load at Seymour dropped 30% to relieve overload (Persistent Action repeated 3 times)

Violations	What Occurred				
	Actions	Model Criteria	Status	Brief What Occurred	Origin of Action
1	OPEN Line BETHEL 3 7_230.0 (23406) TO DANBURY 2 4_230.0 (23415) CKT 1		CHECK	Opened flow of 126.43 MVA	ELEMENT
2	CHANGE INJECTION GROUP Waterford Gens BY -500 MW in merit order by opening at loss of Bethel-Danbury 230kV		TOPOLOGYCHECK	Changed from 2162.90 to 1081.45 MW. 0.00 MW gen overlap.	REMEDIAL
3	CHANGE LOAD AT BUS SEYMOUR 1 1_100.0 (23271) BY -10 % of present MW (cnst pf)	Waterbury-Wolcott 100kV OVERLOAD	POSTCHECK	Bus changed from 38.04MW and 10.52Mvar by -3.80MW and -1.05Mvar	REMEDIAL
4	CHANGE LOAD AT BUS SEYMOUR 1 1_100.0 (23271) BY -10 % of present MW (cnst pf)	Waterbury-Wolcott 100kV OVERLOAD	POSTCHECK	Bus changed from 34.24MW and 9.47Mvar by -3.80MW and -1.05Mvar	REMEDIAL
5	CHANGE LOAD AT BUS SEYMOUR 1 1_100.0 (23271) BY -10 % of present MW (cnst pf)	Waterbury-Wolcott 100kV OVERLOAD	POSTCHECK	Bus changed from 30.43MW and 8.42Mvar by -3.80MW and -1.05Mvar	REMEDIAL

Remedial Actions for Generation Drop

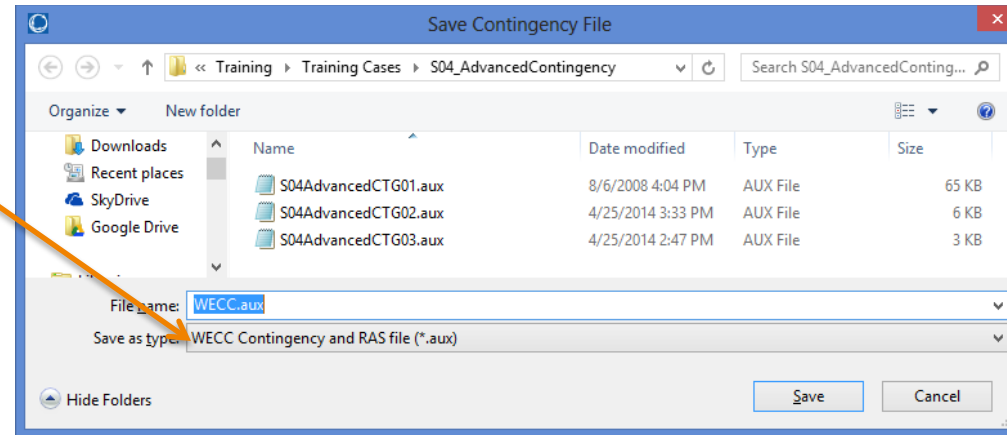


- Generators may be assigned to more than one injection group and **Remedial Actions** may drop generation in multiple injection groups
- Simulator by default provides a systematic accounting of generator changes so that generation drop for each injection group matches that specified by each Remedial Action
- To disable this accounting, check **Options** → **Modeling Basics** → **Disable Gen Drop Overlap**
- More details are provided in the Help Topic *Contingency Element Type: Injection Group*

Remedial Action Aux File Format



- Contingencies and Remedial Actions may be saved in WECC standard format from the **Save** button
- Choose type *WECC Contingency and RAS file (*.aux)*



- More details are at

http://www.powerworld.com/files/PowerWorld_RASFileFormat.pdf

Message Log

Order of Actions



- Apply contingency
- RAS is armed and TOPOLOGYCHECK condition is met for 500 MW Gen Drop
- Solve power flow

```
****
**** Solving contingency L_023406BETHEL37-023415DANBURY24C1 ****
****
APPLYING: OPEN Line BETHEL 3 7_230.0 (23406) TO DANBURY 2 4_230.0 (23415) CKT 1
****
****
**** Applying TOPOLOGYCHECK for Contingency L_023406BETHEL37-023415DANBURY24C1 ****
****
APPLYING: CHANGE INJECTION GROUP Waterford Gens BY -500 MW in merit order by opening and may exceed specified amount
****
AGC in island changed gen 1 at bus 19233 by 8.98 MW to 134.1
```

- Apply POSTCHECK actions
- Load shed is applied because Waterbury-Wolcott 100kV is overloaded
- Solve power flow

```
****
**** Applying POSTCHECK Iteration #1 for Contingency L_023406BETHEL37-023415DANBURY24C1 ****
****
APPLYING: CHANGE LOAD AT BUS SEYMOUR 1 1_100.0 (23271) BY -10 % of present MW (cnst pf)
****
```

- Apply POSTCHECK actions again (3x total) until Waterbury-Wolcott 100kV is relieved
- Solve power flow

```
**** Applying POSTCHECK Iteration #2 for Contingency L_023406BETHEL37-023415DANBURY24C1 ****
****
APPLYING: CHANGE LOAD AT BUS SEYMOUR 1 1_100.0 (23271) BY -10 % of present MW (cnst pf)
****
Number: 0 Max P: 3.804 at bus 23271 Max Q: 1.052 at bus 23271
Number: 1 Max P: 0.002 at bus 23271 Max Q: 0.007 at bus 23271
Finished voltage control loop iteration: 1
****
**** Applying POSTCHECK Iteration #3 for Contingency L_023406BETHEL37-023415DANBURY24C1 ****
****
APPLYING: CHANGE LOAD AT BUS SEYMOUR 1 1_100.0 (23271) BY -10 % of present MW (cnst pf)
****
```

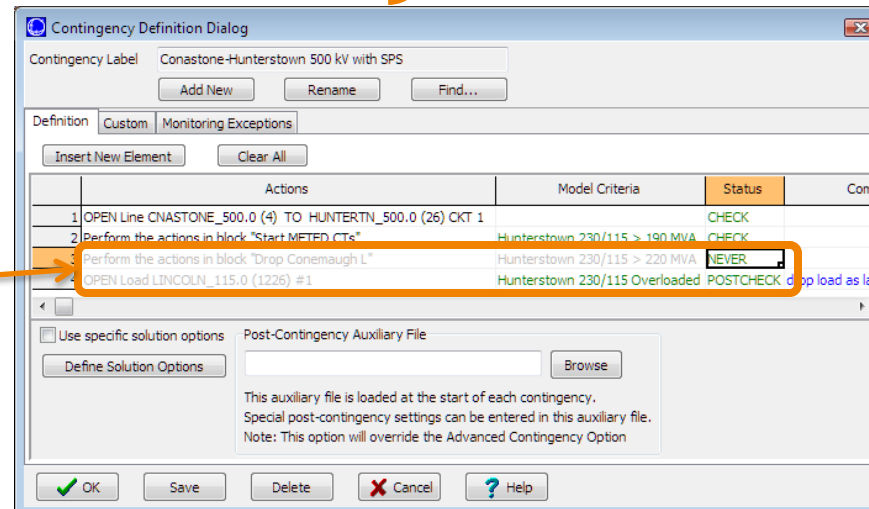
Contingency Element Status



- Along with assigning a **Model Criteria** to a Contingency Element or an **Arming Criteria** to a Remedial Action, you can also assign a **Status**
 - CHECK – action will be done only if the **Model/Arming Criteria** is true. (If there is no criteria, it will also be done.)
 - ALWAYS – action will always be done regardless of the **Model/Arming Criteria**
 - NEVER – action will never be done regardless of the **Model/Arming Criteria**
 - POSTCHECK – described on the next few pages
 - TOPOLOGYCHECK – described on the next few pages
 - SOLUTIONFAIL – described on the next few pages

Contingency Elements only

Appear “inactive”
because of **Model
Criteria and Status**



POSTCHECK Element Status



- POSTCHECK allows you to make an action conditional on the post-contingent system
 - Example: If Branch X is overloaded, then Open it.
- When POSTCHECK actions exist, the processing of the contingency will loop through applying POSTCHECK actions and solving the power flow until all actions have been implemented
- Criteria for POSTCHECK actions during linear calculation methods
 - Default is to treat these as CHECK actions
 - An iterated linear method can evaluate these after other actions have been “implemented”. This will make the linear process slower but better reflects conditional actions. (**Options → Modeling Basics → Iterate on Action Status**)

TOPOLOGYCHECK Element Status



- TOPOLOGYCHECK allows you to make an action conditional on the *post-contingent* system *before* the power flow is solved
 - Important when the outage of a line results in an unsolvable power flow solution
 - TOPOLOGYCHECK actions should only be used with conditions related to bus/branch statuses
 - Example: If Branch X is open, drop generation
- Criteria for TOPOLOGYCHECK actions during linear calculation methods
 - Default is to treat these as CHECK actions
 - An iterated linear method can evaluate these after other actions have been “implemented”. This will make the linear process slower but better reflects conditional actions. (**Options → Modeling Basics → Iterate on Action Status**)

SOLUTIONFAIL Element Status



- Action is conditional on the power flow not solving
- Model Criteria may also be specified but is not required
- If failed power flow is encountered, system state is restored to what existed before the failed solution
 - Any SOLUTIONFAIL action whose Model Criteria is met, or none is defined, will be applied
 - Another power flow solution will be attempted
- SOLUTIONFAIL actions are ignored during linear calculation methods

Time Delay



- Time to wait in seconds before an action is applied
- Serves as a relative ordering for implementation of actions during steady state analysis
- Actions with smallest delay (down to a microsecond) will be applied first during TOPOLOGYCHECK, POSTCHECK, and SOLUTIONFAIL solution steps
- Ignored during CHECK solution step
- Default all time delays to 0 to ignore

Time Delay



Contingency Definition Dialog

Contingency Label: Open 1 to 3

Definition: Custom

Actions	Model Criteria	Status	Time Delay	Comment
1 OPEN Line One 138.0 (1) TO Three 138.0 (3) CKT 1		CHECK	0	

Categories:

☐ Use specific solution options

☐ Ignore ALL contingency specific solution options

Post-Contingency Auxiliary File:

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

OK Save Delete Cancel Help

Contingency Element Dialog

Element Type: ☒ Branch

Choose the Element: ☒ Sort by Name ☐ Number

Search For Near Bus: 1 (One) [138 kV], 2 (Two) [138 kV], 3 (Three) [138 kV], 4 (Four) [138 kV], 5 (Five) [138 kV], 6 (Six) [138 kV], 7 (Seven) [138 kV]

Select Far Bus, CKT: 2 (Two) [138 kV] CKT 1, 3 (Three) [138 kV] CKT 1

Action Type: ☒ Open, ☐ Close, ☐ Move, ☐ Set To, ☐ Change By, ☐ Open Breakers, ☐ Close Breakers

Amount: 0, Constant, Evaluate in Reference State, Make-up Power Sources ...

Status: CHECK

Model Criteria: Add

Time Delay: 0.000000 seconds

Comment:

OK Delete Cancel Help

Set optional Time Delay

Time Delay with Model Filters

- Model Filters are comprised of ModelFilterConditions that can be either Model Filters or Model Conditions
- Time Delay can be associated with ModelFilterCondition

The screenshot shows a 'Filter Conditions' dialog box. At the top, there's a 'Filter Name' dropdown set to 'A Model Filter', with buttons for 'Save', 'Save As', 'Rename', 'Delete', and 'View Filter Logic'. Below this is a 'Logical Comparison' section with radio buttons for 'AND' (selected), 'OR', 'Not AND', 'Not OR', 'XOR', and 'One True'. The main area contains two 'Model Condition' entries. Each entry has a checkbox, a 'Find...' button, a text field with a dropdown, and a 'Time Delay' field. The first condition is 'Branch 1 to 3 Overloaded' with a 'Time Delay' of '0.000000'. The second condition is 'Branch 2 to 5 Overloaded' with a 'Time Delay' of '0.000000'. At the bottom, there are buttons for 'Add >>', 'Delete ...', 'Modify Model Conditions', 'OK', 'Help', and 'Cancel'. An orange bracket on the right side of the dialog points to the 'Time Delay' fields.

Time Delay with
ModelFilterCondition

Calculated Time Delay

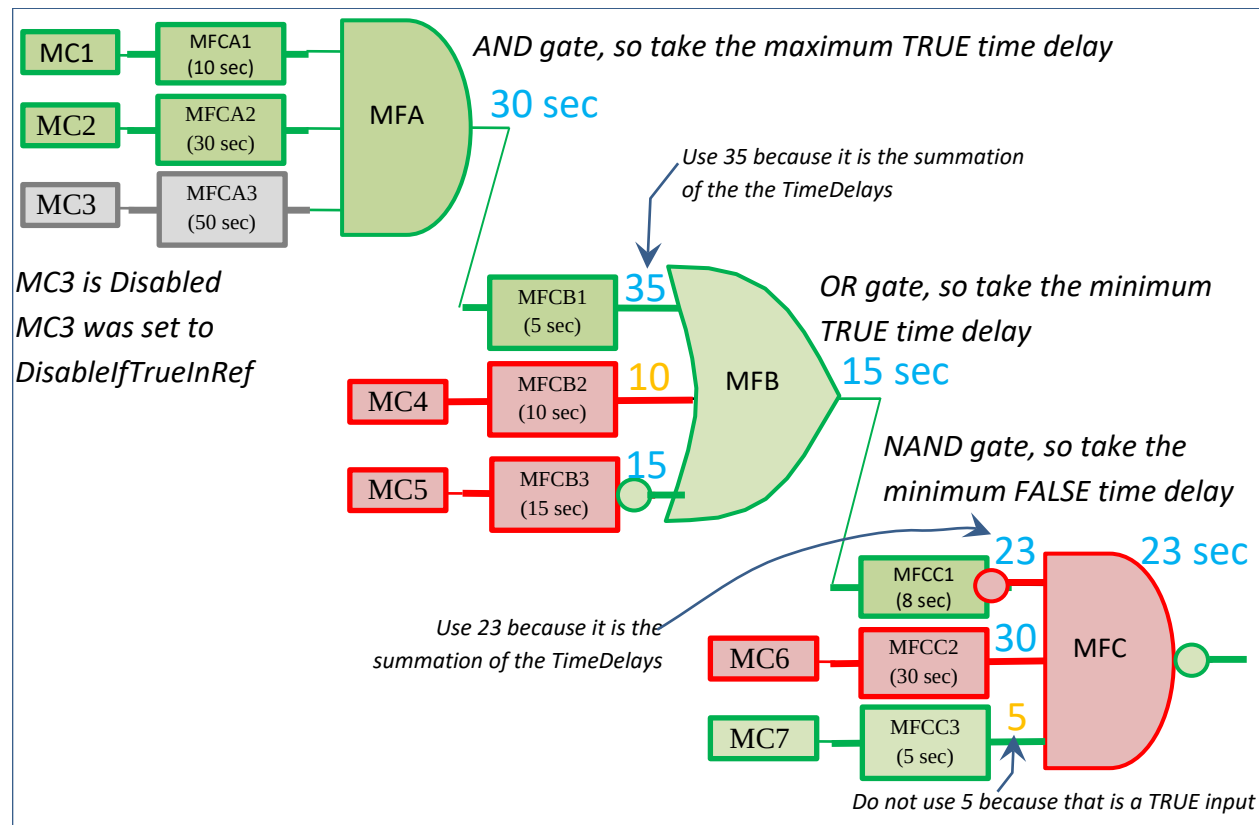
Model Filter



- Depends on logic of the filter (OR, AND, NOR, NAND, XOR, or OneTRUE)
- Depends on time delays of the ModelFilterConditions
- Input ModelFilterCondition determines time delay based on the type of the criteria object
 - ModelFilter
 - Summation of the calculated time delay of the ModelFilter and the time delay with the ModelFilterCondition
 - ModelCondition
 - Time delay with the ModelFilterCondition

Time Delay with Model Filters

The following shows the resulting evaluations of the ModelFilterConditions and Model Filters and resulting Calculated Time Delays:





What Time Delay Is Used?



- Determined by Model Criteria of Contingency Element
 - Model Condition
 - Time delay specified with the contingency element is used directly
 - Model Filter
 - Time delay specified with the contingency element added to the calculated time delay from the model filter

Persistent Contingency Elements



- Normally after any contingency action is applied it will not be applied again
- Marking an action as **Persistent** will allow the action to be applied as long as its Model Criteria is met
 - Only allowed for TOPOLOGYCHECK, POSTCHECK, and SOLUTIONFAIL actions
 - SOLUTIONFAIL actions will only remain persistent up until a solution is successfully achieved

Persistent Contingency Elements



Contingency Definition Dialog

Contingency Label: L_00004CNASTONE-00026HUNTERTNC1

Buttons: Add New, Rename, Find...

Definition: Custom, Monitoring Exceptions

Buttons: Insert New Element, Clear All

	Actions	Model Criteria	Status	Persistent	Time Delay
1	OPEN Line CNASTONE 500.0 (4) TO HUNTERTN 500.0 (26) CKT 1		CHECK	NO	0

Categories: [Empty]

☐ Use specific solution options

Post-Contingency Auxiliary File: [Empty] Browse

☐ Ignore ALL contingency specific solution options

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.

Buttons: OK, Save, Delete, Cancel, Help

Contingency Element Dialog

Element Type: ☐ Branch, ☐ Generator, ☒ Load, ☐ Switched Shunt, ☐ Bus, ☐ Interface, ☐ Injection Group, ☐ Multi-Section Line, ☐ Series Capacitor, ☐ Phase Shifter, ☐ 3-Winding Transformer, ☐ Line Shunt, ☐ DC Line, ☐ DC Converter, ☐ Area, ☐ Substation, ☐ Abort, ☐ Solve Power Flow, ☐ Contingency Block

Specific Element Type: ☒ Bus, ☐ Specific Device

Choose the Element: Sort by ☐ Name ☒ Number

2

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]

Action Type: ☐ Open, ☐ Close, ☐ Move, ☒ Set To, ☐ Change By, ☐ Open Breakers, ☐ Close Breakers

Amount: 80, Constant, Find...

☐ Evaluate in Reference State

Make-up Power Sources ...

in: ☐ MW (const pf), ☒ Percent, ☐ MW, ☐ Mvar, ☐ Setpoint Voltage

Status: POSTCHECK, ☒ Persistent

Model Criteria: Add

Time Delay: 0.000000 seconds

Comment: [Empty]

Buttons: OK, Cancel, Help

Set action to be
Persistent

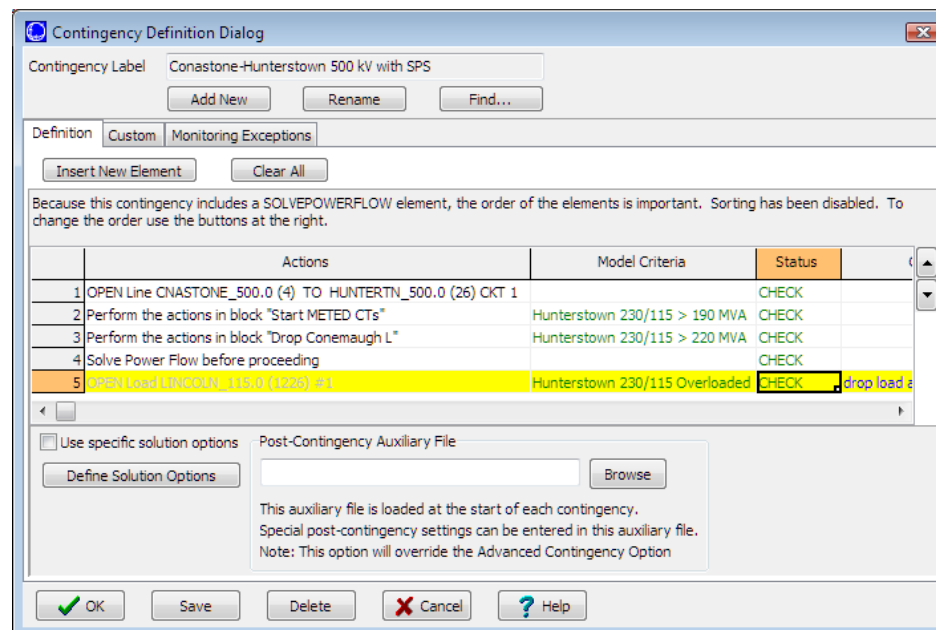
Processing Order of Contingency



1. Apply ALWAYS actions and true CHECK actions
2. Update topology (branch, bus status)
3. Apply true TOPOLOGYCHECK actions
 1. TRANSIENT actions will also be evaluated
 2. TRANSIENT or TOPOLOGYCHECK actions with smallest Time Delay will be applied
4. Store reference state for use if solution failure occurs and SOLUTIONFAIL actions exist
5. Solve power flow
 1. If the power flow solution fails and any SOLUTIONFAIL actions are available, reference state in step 4 is restored and any SOLUTIONFAIL actions with the smallest Time Delay are then applied
 2. If any SOLUTIONFAIL actions are applied, the process will go back to step 4 and repeat (this loop will abort after 100 solution failures)
 3. If there is still a solution failure, abort the contingency process and report failure
6. Apply true POSTCHECK actions and true TOPOLOGYCHECK actions
 1. TRANSIENT actions will also be evaluated
 2. TRANSIENT, POSTCHECK, or TOPOLOGYCHECK actions with smallest Time Delay will be applied
7. If any POSTCHECK, TOPOLOGYCHECK, or TRANSIENT actions are implemented then repeat steps 2-6 (this loop will abort after 100 iterations)

Special Contingency Element: Solve Power Flow

- This changes the way the contingency is solved
 - Sorting of actions no longer allowed because the order in which they are defined is important
 - You can now specify this order of actions
 - The contingency is now implemented in parts with intermediate power flow solutions executed
- POSTCHECK actions will always be processed together after all other actions are completed





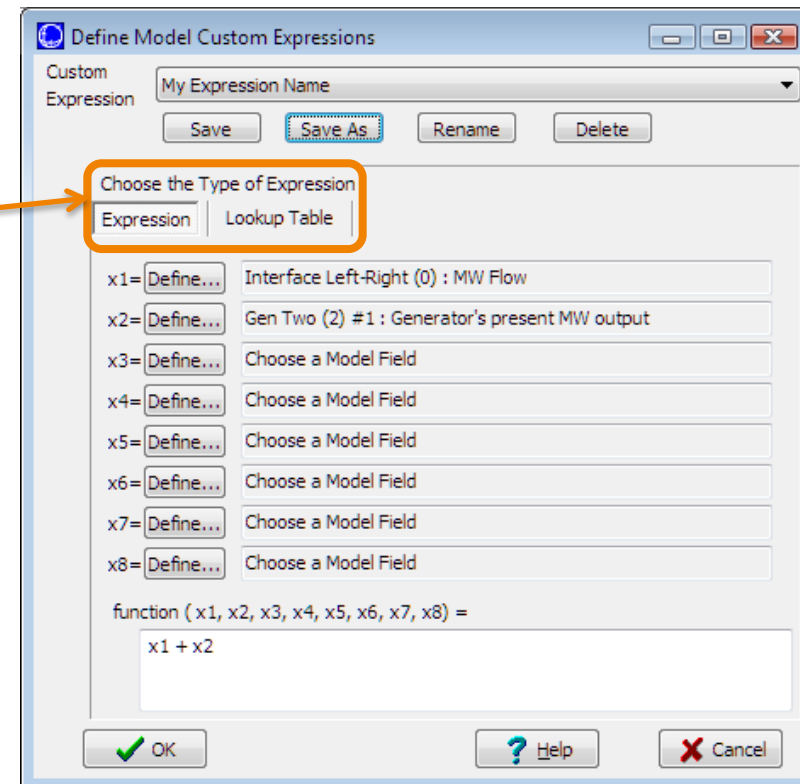
Model Expressions



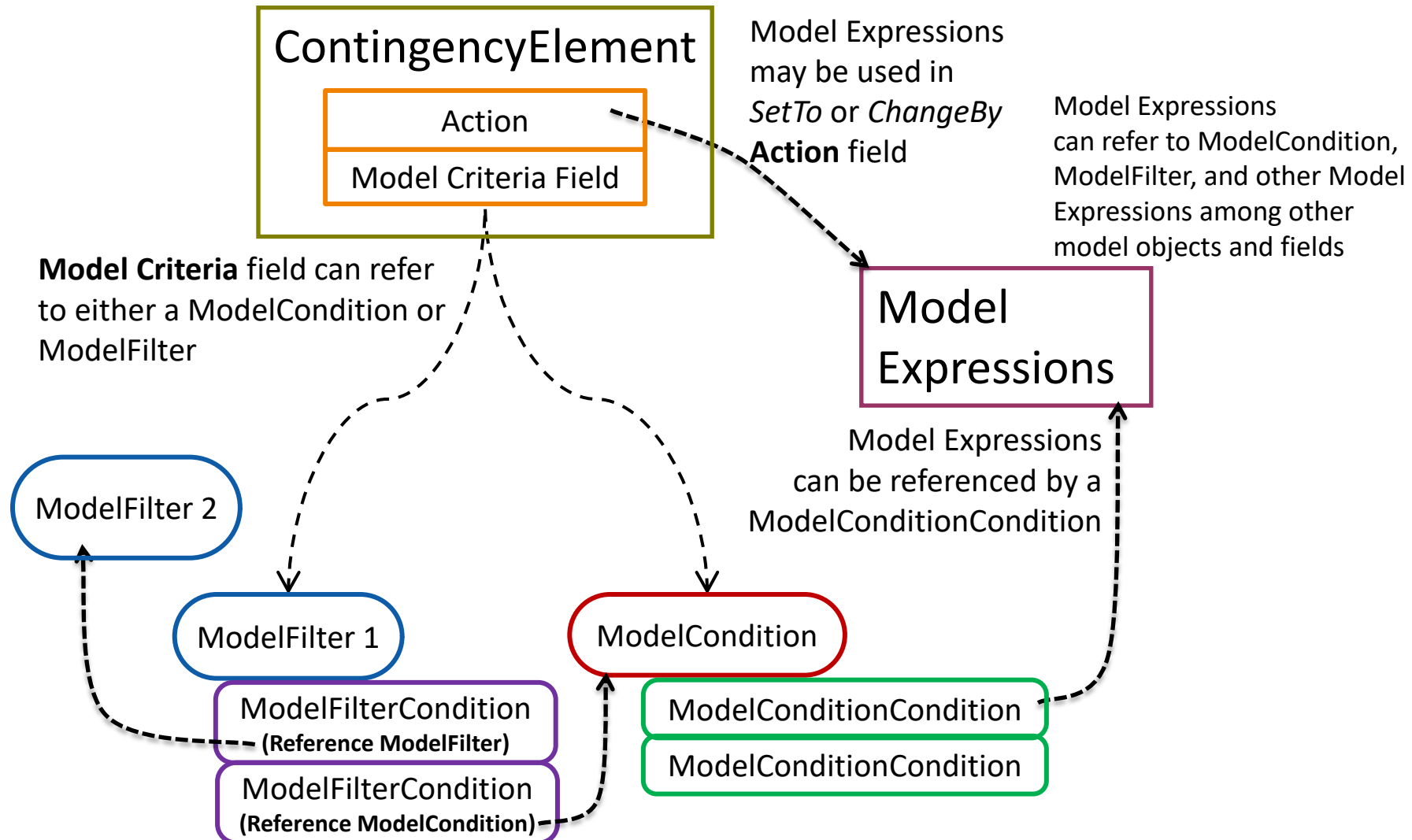
- Mathematic expression evaluated from one or more system parameters
- Similar in construction to Custom Expressions, discussed earlier, but there may be a function across many objects
- Example: (MW output of Gen A) + (MVA Flow on Line B)

Options, Contingency Definitions: Model Expressions

- Click on Model Expressions page
 - Also available in the Model Explorer under **Case Information and Auxiliary\Model Expressions**
- Right-click on the case info display and choose **Insert**
- Similar to Expressions (in another section), except they can reference more than one object and object type
- Types
 - **Expressions:** mathematical expressions involving one or more model fields
 - **Lookup Tables:** return a value based on the values of one or two model fields
- May be used inside...
 - Some kinds of contingency elements
 - Set Gen MW to *Model Expression*
 - Advanced Filters
 - Model Conditions



Relationship between Contingencies, Model Condition, Filters, Expressions



Appendix: Techniques for Designing Remedial Actions

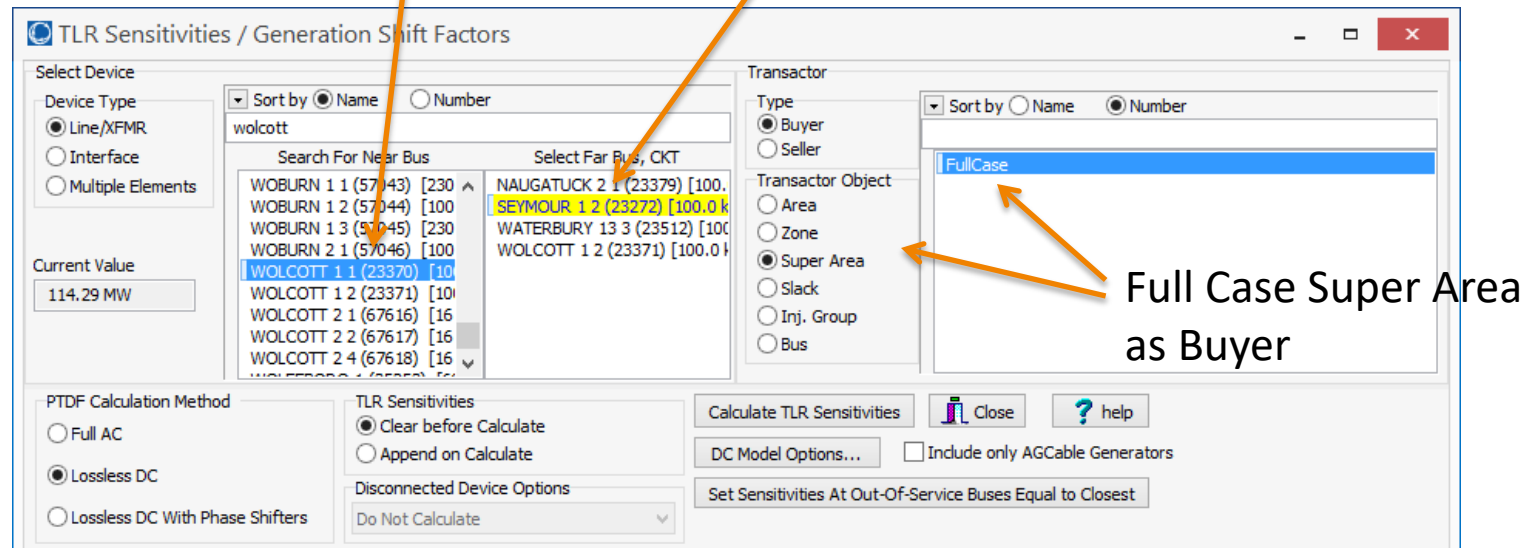


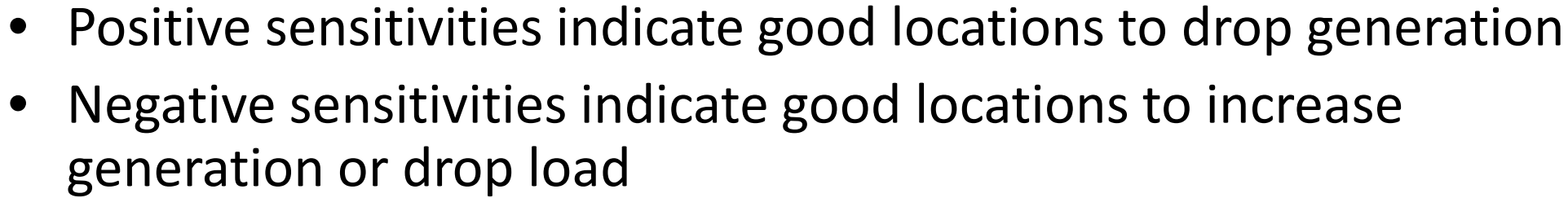
- Sensitivity analysis tools may be used to identify candidates for Remedial Actions
 - Shift Factor analysis: single or multiple element
 - Contingency Injection Sensitivities (described previously)
 - Line Outage/Closure Distribution Factors
 - Line Loading Replicator
 - OPF with minimum control change
- Tip: Make use of Contingency Analysis tool
 - Apply individual contingencies and examine system state
 - Run sensitivity analysis and apply RAS/SPS actions
 - Restore the reference state from Contingency Analysis as needed

Examine Contingency: Bethel-Danbury 230 kV

- Disable RAS, solve contingency L_023406BETHEL37-023415DANBURY24C1
- Check the TLR on the most overloaded branch (Line/XFMR Device Type)

Reference the line in the direction of overloading flow
(23370 as near bus, 23272 as far bus)





Custom Expressions to Estimate total TLR MW from dropping Gen or Load

91



Line Loading Replicator



- Apply the Line Loading Replicator while contingency is solved to obtain a list of possible RAS actions for this outage
- Line Loading Replicator
 - Considers the members of a specified injection as eligible controls
 - Proposes a re-dispatch of those controls based on merit order (where merit is determined by the sensitivity to flow on the specified line)

Line Loading Replicator: Create Injection Group

- Add All Gens

Injection Groups

Name: RAS Eligible

Gens: 4834

Loads: 0

Shunts: 0

% MW Gen Part: 100.00

% MW Load Part: 0.00

% MVR Load Part: 0.00

% MVR Shunt Part: 0.00

Participation Points: Custom

Insert Points (or right-click to insert or delete points)

Point Type	Number	Name	ID	AutoCalc?	Initial Value	ParFac
1 GEN	11487	ABBEVILLE 2 1	1	NO	MAX GEN MW	2.90
2 GEN	57871	ACTON 2 2	1	NO	MAX GEN MW	2.00
3 GEN	57871	ACTON 2 2	2	NO	MAX GEN MW	1.60
4 GEN	57872	ACTON 2 3	1	NO	MAX GEN MW	1.50
5 GEN	57873	ACTON 2 4	1	NO	MAX GEN MW	1.00
6 GEN	43760	ADRIAN 2	1	NO	MAX GEN MW	6.80
7 GEN	43760	ADRIAN 2	2	NO	MAX GEN MW	6.80
8 GEN	65244	AGAWAM 2 2	1	NO	MAX GEN MW	9.40
9 GEN	65318	AGAWAM 3 4	1	NO	MAX GEN MW	289.00
10 GEN	53921	AKRON 20 1	1	NO	MAX GEN MW	2.00
11 GEN	53921	AKRON 20 1	2	NO	MAX GEN MW	2.00
12 GEN	53949	AKRON 21 1	1	NO	MAX GEN MW	0.600
13 GEN	53949	AKRON 21 1	2	NO	MAX GEN MW	0.600
14 GEN	53949	AKRON 21 1	3	NO	MAX GEN MW	0.600
15 GEN	41991	AKRON 21 1	1	NO	MAX GEN MW	1.1R

Help Cancel

Notes: Injection Group definition may be loaded from *S04_AdvancedContingency\S04AdvancedCTG02.aux*.



Line Loading Replicator



Choose most overloaded line
(Wolcott – Seymour
23370-23272 ckt 1);
estimate desired MW flow
based on MVA limit = 95.8

Try dropping units with most
positive distribution factors
or those with most negative
Injection Change MW

Line Loading Replicator

Select Device

Device Type: ☒ Line/XFMR ☐ Interface

Sort by: ☒ Name ☐ Number

Present Flow (MW): 114.290

Desired Flow (MW): 90.000

Search For Near Bus: wolcott

Select Far Bus, CKT: NAUGATUCK 2 1 (23370), SEYMOUR 1 2 (23272), WATERBURY 13 3 (23370), WOLCOTT 1 2 (23370)

Available Injection Groups

Sort by: ☒ Name ☐ Number

RAS Eligible: Waterford Gens

☐ Only Include AGCable Generation and Load

Calculation Method

☒ Lossless DC ☐ Lossless DC with Phase Shifters

Max and Min Load Limits for Injection Changes

☒ Use Max and Min Load Values ☐ Use Multiplier on Present Value

Set Max and Min Load Values

Min Multiplier: 1.000

Max Multiplier: 1.000

Injection Changes

Element Type	Bus Number	Bus Name	ID	Distribution Factor	Injection Change MW	Present Injection MW	New Injection MW
1 Gen	23719	MIDDLETOWN 6 4	1	0.026	-204.610	0.000	-204.610
2 Gen	23720	MIDDLETOWN 6 5	1	0.026	-158.307	0.000	-158.307
3 Gen	23721	MIDDLETOWN 6 6	1	0.026	-143.714	0.000	-143.714
4 Gen	23513	WATERBURY 13 4	1	0.031	-79.442	96.000	16.558
5 Gen	23481	HARTFORD 8 2	3	0.027	-37.602	41.800	4.198
6 Gen	23692	HARTFORD 10 2	2	0.028	-33.006	39.100	6.094
7 Gen	23569	MIDDLETOWN 5 4	1	0.026	-29.333	196.600	167.267
8 Gen	23480	HARTFORD 8 1	1	0.026	-25.290	41.800	16.510

Total Injection Increase/Decrease (MW): 888.896

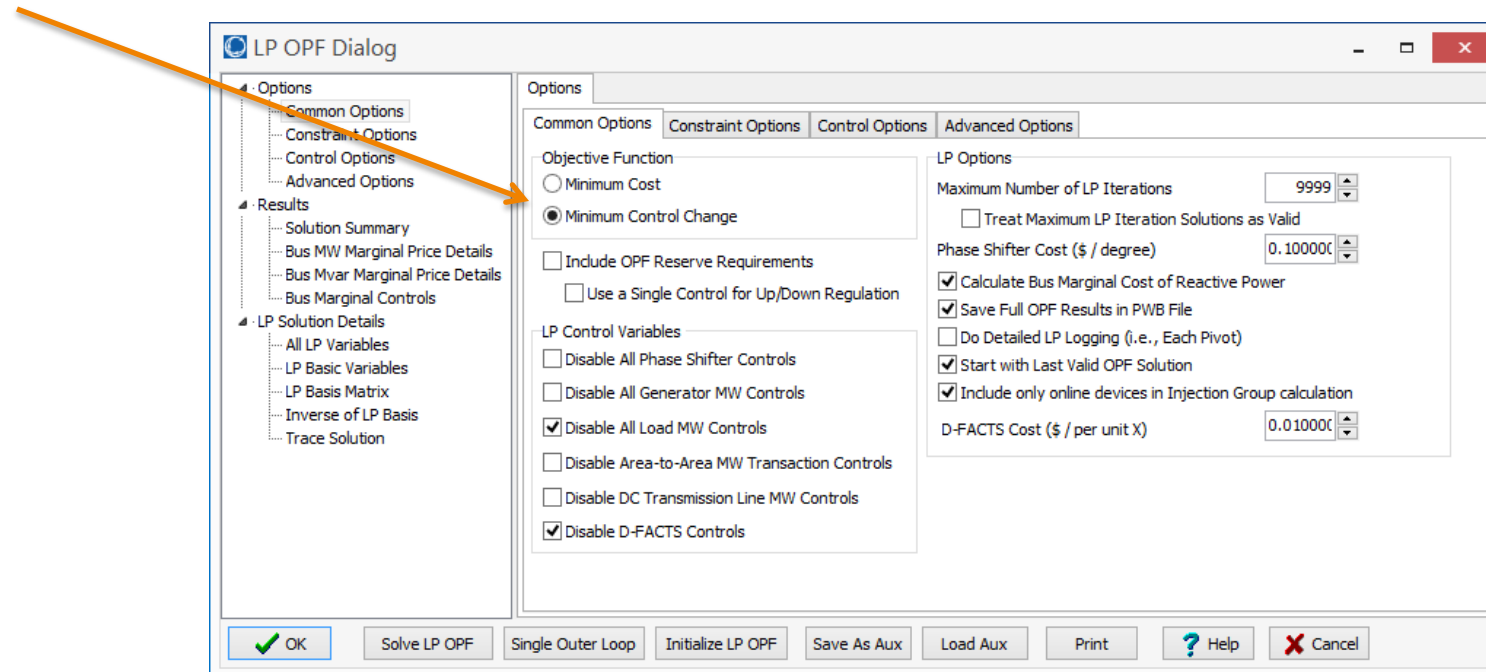
Flow Achieved (MW): 90.000



OPF with Minimum Control Change



- Solve Contingency and Disable Island Based AGC from Simulator Options
- Run OPF with Super Area FullCase on OPF control, using Minimum Control Change objective function





OPF with Minimum Control Change



- LP Solution Details:

Middletown
Units

LP OPF Dialog

Options

- Common Options
- Constraint Options
- Control Options
- Advanced Options

Results

- Solution Summary
- Bus MW Marginal Price Details
- Bus Mvar Marginal Price Details
- Bus Marginal Controls

LP Solution Details

- All LP Variables
- LP Basic Variables
- LP Basis Matrix
- Inverse of LP Basis
- Trace Solution

LP Solution Details

	ID	Org. Value	Value	Delta Value	BasicVar	NonBasicVar	Cost(t
1	Gen 23572 #1 MW Control	196.600	47.292	-149.308	0	962	
2	Gen 23721 #1 MW Control	231.000	87.286	-143.714	0	904	
3	Gen 23719 #1 MW Control	231.000	87.879	-143.121	3	0	
4	Gen 23569 #1 MW Control	196.600	58.641	-137.959	0	1041	
5	Gen 23513 #1 MW Control	96.000	16.558	-79.442	0	1010	
6	Gen 23481 #3 MW Control	41.800	4.198	-37.602	0	989	
7	Gen 23692 #2 MW Control	39.100	6.094	-33.006	0	1094	
8	Gen 23480 #1 MW Control	41.800	16.510	-25.290	0	3053	
9	Gen 23550 #1 MW Control	45.000	20.031	-24.969	0	1034	
10	Gen 23692 #1 MW Control	39.100	15.326	-23.774	0	1563	
11	Gen 23550 #2 MW Control	45.000	21.499	-23.501	0	1035	
12	Gen 23531 #2 MW Control	25.800	5.056	-20.744	0	1024	
13	Gen 23530 #1 MW Control	60.500	43.096	-17.404	1	0	
14	Gen 23773 #1 MW Control	21.800	6.248	-15.552	0	1126	
15	Gen 23689 #1 MW Control	21.800	7.166	-14.634	0	1092	
16	Gen 23549 #1 MW Control	16.300	4.253	-12.047	0	1033	
17	Gen 23778 #2 MW Control	5.200	1.128	-4.072	0	1129	
18	Gen 65313 #1 MW Control	4.800	1.482	-3.318	0	3355	

OK Solve LP OPF Single Outer Loop Initialize LP OPF Save As Aux Load Aux Print ? Help X Cancel



Possible Implications of Unenforceable Constraints



- Generators that were reduced to Min MW may possibly provide more relief if disconnected (0 MW)
 - Consider designating some units as OPF Fast Start controls
- More or different controls may be needed
 - neighboring control areas
 - load shedding



OPF with Minimum Control Change



- Care is needed to select an appropriate set of AGCable generators and loads
 - May want to disable AGC for nukes and coal units
 - May want to disable units with low WTLR with respect to overload; otherwise large number of units could participate, which may alleviate overload but be difficult and time-consuming to implement
- If dropping or starting units with non-zero minimum MW is feasible, make them fast-start units
- Watch out for bad data in generator records, such as minimum MW

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