

Steady-State Power System Security Analysis with PowerWorld Simulator



S8: Security Analysis for a Generator Interconnection Study



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Generator Interconnection Study

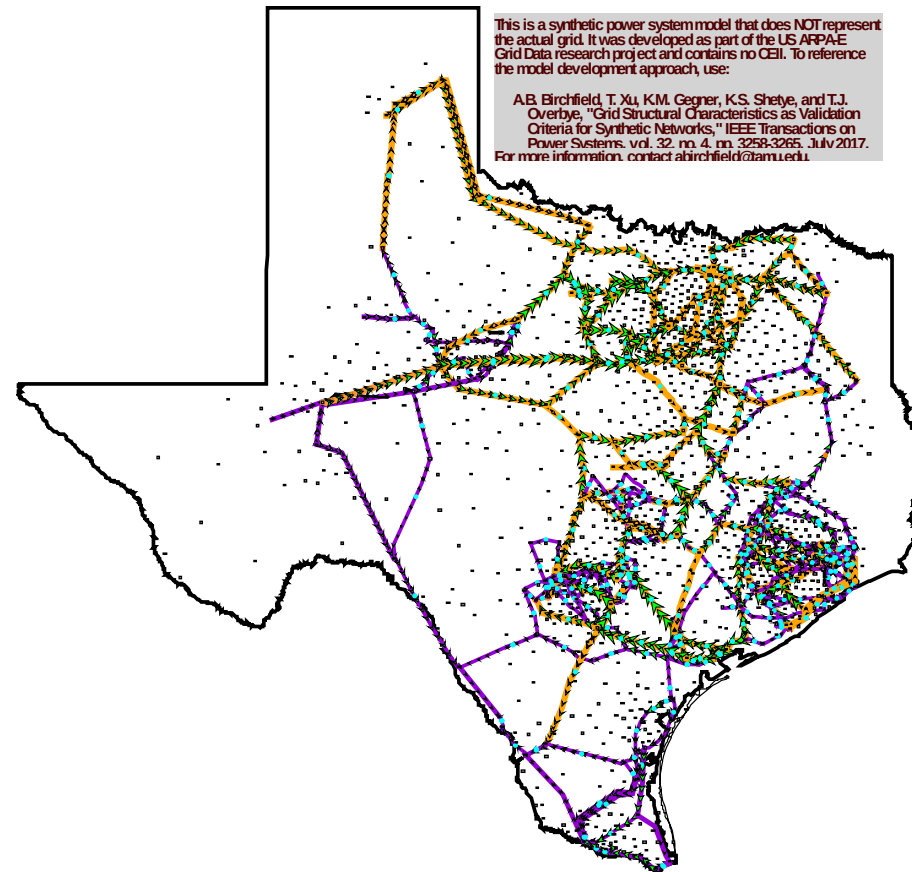


- This session encompasses several types of analysis that might be performed as part of an interconnection study for a proposed generator
 - Contingency Analysis: Comparison of Contingent Overloads with and without proposed unit
 - PTDF: Visualize incremental flows from proposed unit
 - ATC: How much power can be delivered from proposed unit before overloads occur?
 - PVQV: How much power can be delivered from proposed unit before voltage becomes unacceptable or collapses?

Using Comparison of Two Sets of Contingency Results



- Open Case *ACTIVSg2000.pwb*
- In “Simulator Options...” check box *Prevent Controller Oscillations*



Model the Proposed Generator



- Interconnect at bus 1089 in Lamesa substation
 - New Bus 1 (Lamesa Wind): 34.50 kV, located in new area 10 (Lamesa), zone 1, and substation 54 (Lamesa)
 - New transformer to connect new bus 1 to existing bus 1089: R = 00024, X = 0.086, All Limits = 0
 - New Generator at Bus 1: 200 MW Max, regulate bus 1089 to 1.0 pu volt, -50 Mvar Min, 50 Mvar Max
- Add these elements manually or load *aux2020GeneratorInterconnect.aux*

Injection Groups



- Create injection groups to serve as sources and sinks for upcoming ATC and PV Analysis

Model Explorer: Injection Groups

Explore Fields

- Recent
- Network
- Aggregations
 - Areas
 - Balancing Authorities
 - Bus Pairs
 - Data Maintainers
 - Injection Groups
 - Interfaces
 - Islands
 - Multi-Section Lines
 - MW Transactions
 - Nomograms
 - Owners
 - Substations
 - Super Areas

Open New Explorer

Injection Groups X Areas X Buses X MW Transactions

Filter Advanced Injection Group Find... Remove Quick Filter

Injection Groups Participation Points

	Name	Number of Gens	% MW Gen ParFac	Number of Loads	% MW Load ParFac	% Mvar Load ParFac	Number of Shunts	% Mvar Shunt ParFac	Total MW Injection	Total Mvar Injection
1	Coast Load	0	0.00	242	100.00	100.00	0	0.00	-18393.86	-5211.59
2	Lamesa	1	100.00	0	0.00	0.00	0	0.00	200.00	0.33

Participation Points (All) Generators Loads Switched Shunts Injection Groups Buses

	Point Type	Number	Name	ID	AutoCalc?	Initial Value	ParFac
1	GEN	1	Lamesa Wind	1	NO	SPECIFIED	10.00

Search Search Now Options

Injection Groups

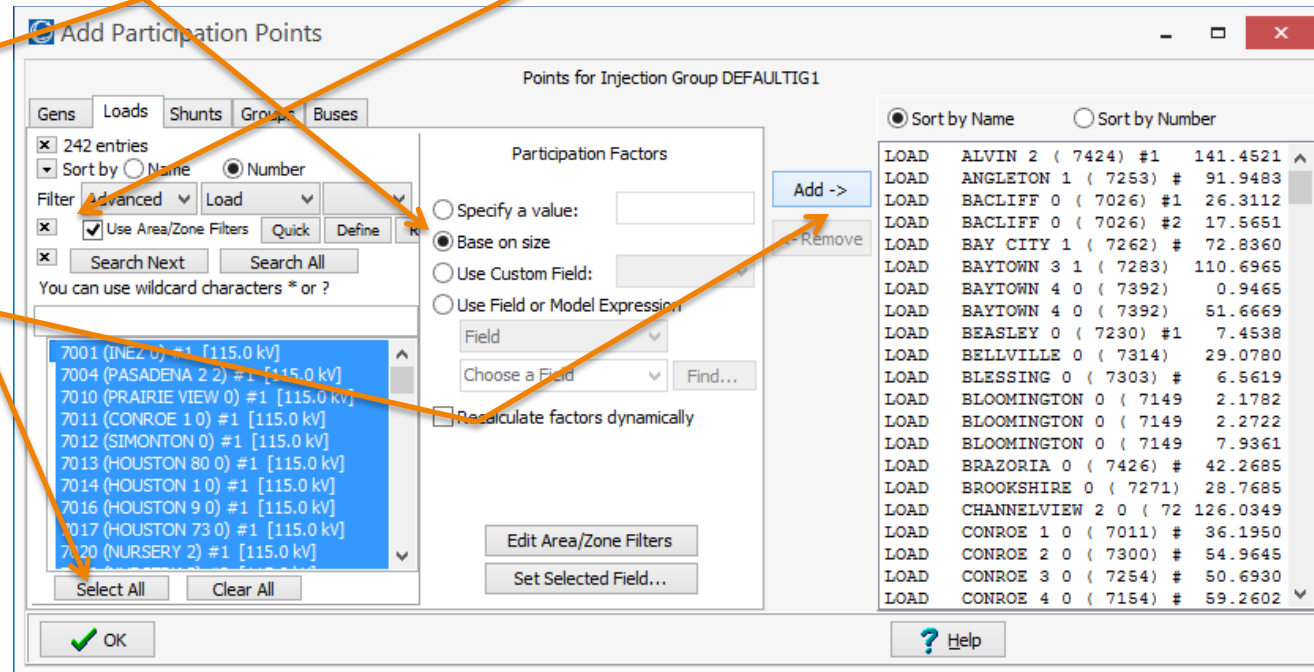


- Group “Lamesa” contains only the new generator at Bus 1
- Group “Coast Load” contains all loads in Area 7 (Coast), with participation factors set to the size of the load
- Add these groups manually or load from *aux2030InjectionGroups.aux*

Injection Group “Coast Load”



- Use Area/Zone Filters and include only Area 7
- Select All
- Base on size
- Click **Add ->**



MW Control and AGC Settings

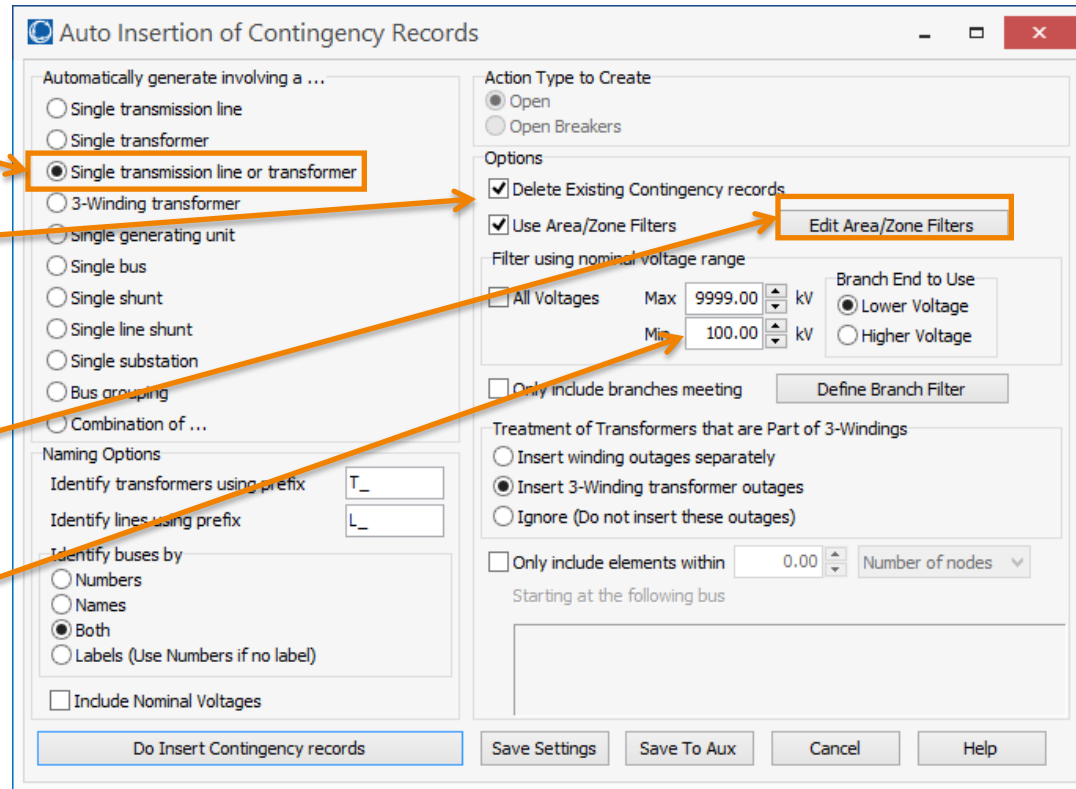


- Set Super Area “Texas” Off AGC
- Move System Slack to Bus 5262 in Area North Central (to allow control of Area 7, Coast)
- Set All Areas to Part. AGC except
 - Area 5 (North Central) to Off AGC
 - Area 7 (Coast) to IG Slack, with “Coast Load” as the injection group
- Set Unspec. MW Inter. = Int MW for all areas (to zero-out ACE)
- Perform manually or load *aux2040MWControl.aux*

Setup Contingency Analysis



- Go to **Tools Ribbon Tab** and choose **Contingency Analysis**
- Click the **Auto Insert** button at the bottom of this dialog
- Choose **Single Transmission Line or Transformer**
- Choose **Delete Existing Contingency records**
- Click **Edit Area/Zone Filters** on this dialog
- Choose **100 kV Min**



The screenshot shows the 'Auto Insertion of Contingency Records' dialog box. The 'Automatically generate involving a ...' section has 'Single transmission line or transformer' selected. The 'Action Type to Create' section has 'Open' selected. The 'Options' section has 'Delete Existing Contingency records' and 'Use Area/Zone Filters' checked. The 'Filter using nominal voltage range' section has 'All Voltages' checked, with 'Max' set to 9999.00 kV and 'Min' set to 100.00 kV. The 'Branch End to Use' section has 'Lower Voltage' selected. The 'Treatment of Transformers that are Part of 3-Windings' section has 'Insert 3-Winding transformer outages' selected. The 'Naming Options' section has 'Identify transformers using prefix' set to 'T_', 'Identify lines using prefix' set to 'L_', and 'Identify buses by' set to 'Both'. The 'Include Nominal Voltages' checkbox is unchecked. The 'Do Insert Contingency records' button is highlighted. Orange arrows point from the list items to the corresponding settings in the dialog.

Limit the Areas for which contingency area defined



- Modify the Area/Zone Filters so that all areas are set to Shown = NO
- Then set the following 3 areas to YES
 - 1 (Far West)
 - 7 (Coast)
 - 10 (Lamesa)
- Click **Close**

Area/Zone/Owner/DataMaintainer Filters

Set all Area/Zone/Owner/DataMaintainer Filters to Yes ☐ Use Data Mainta

Areas Zones Owners Data Maintainers

Records Geo Set Options

	Area Num	Area Name	Shown	# of Buses	Min Bus Num	Max Bus Num
1	1	Far West	YES	91	1001	1091
2	2	North	NO	133	2001	2133
3	3	West	NO	147	3001	4001
4	4	South	NO	196	4002	6348
5	5	North Central	NO	483	5003	5485
6	6	South Central	NO	358	5001	6360
7	7	Coast	YES	432	7001	7432
8	8	East	NO	160	8001	8160
9	10	Lamesa	YES	1	1	1

Insert the Contingencies



- Click **Do InsertContingencies**
- A prompt will ask if you want to insert 968 contingencies and delete existing contingencies
 - Choose **Yes**

The screenshot shows the 'Auto Insertion of Contingency Records' dialog box with the following settings:

- Automatically generate involving a ...**
 - ☐ Single transmission line
 - ☐ Single transformer
 - ☒ Single transmission line or transformer
 - ☐ 3-Winding transformer
 - ☐ Single generating unit
 - ☐ Single bus
 - ☐ Single shunt
 - ☐ Single line shunt
 - ☐ Single substation
 - ☐ Bus grouping
 - ☐ Combination of ...
- Naming Options**
 - Identify transformers using prefix: T_
 - Identify lines using prefix: L_
 - Identify buses by:
 - ☐ Numbers
 - ☐ Names
 - ☒ Both
 - ☐ Labels (Use Numbers if no label)
 - ☐ Include Nominal Voltages
- Action Type to Create**
 - ☒ Open
 - ☐ Open Breakers
- Options**
 - ☒ Delete Existing Contingency records
 - ☒ Use Area/Zone Filters (Edit Area/Zone Filters)
 - Filter using nominal voltage range**
 - ☐ All Voltages
 - Max: 9999.00 kV
 - Min: 100.00 kV
 - Branch End to Use**
 - ☒ Lower Voltage
 - ☐ Higher Voltage
 - ☐ Only include branches meeting (Define Branch Filter)
 - Treatment of Transformers that are Part of 3-Windings**
 - ☐ Insert winding outages separately
 - ☒ Insert 3-Winding transformer outages
 - ☐ Ignore (Do not insert these outages)
 - ☐ Only include elements within 0.00 Number of nodes
 - Starting at the following bus

Buttons at the bottom: Do Insert Contingency records, Save Settings, Save To Aux, Cancel, Help.

Setup Contingency Options



- Choose the **Options Tab**, and the **Modeling -> Basics** page
 - Set the Make-Up Power to **Generator Participation Factors from Entire Case Directly**
- Also open Limit Monitoring Settings
 - Ignore Radial Lines and Buses
 - Report Min kV = 100 for all Areas

Make-Up Power

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

Determine Make Up Using

☐ Area Participation Factors specified below

☒ Generator Participation Factors From Entire Case Directly

☐ Same as Power Flow case

Make-up Power Tolerance

☐ Prevent new island without enough controllable generation

Limit Monitoring Settings and Limit Violations

Use the Modify/Create Limit Groups to tab to modify and create limit groups to which Buses, Lines and Interfaces can be assigned. Use the Buses, Lines and Interfaces tabs to assign elements to different limit groups. The Areas and Zones tabs are provided here for your convenience.

Save Monitoring Settings

Load Monitoring Settings

Elements to Show

☒ All Elements

☐ Monitored Elements

☐ Violating Elements

Number Of Violations

Element	Number Of Violations
Low Voltage Buses	0
High Voltage Buses	0
Low-voltage Suspects	0
Lines/Transformers	0
Interfaces	0
Bus Pairs	0

Limit Group Values

Limit Group

☐ Group Disabled / Do Not Monitor

Lines & Transformers Interfaces Buses Bus Pairs

Percentage

Normal Rating Set

Contingency Rating Set

☐ Treat Line Limits as Equivalent Amps

☒ Do not monitor radial lines and buses (applied to all limit groups) (This option is not applied if using topology processing)

Advanced Limit Monitoring



- Always report as violations decrease in low bus voltage ≥ 0.05
- Report changes in bus dV/dQ sensitivity at least 5x greater than reference state, advanced filter on buses with ≥ 5 MW load in areas 1, 7, 10

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 $\geq$ 0.0500 pu

Increase in high bus voltage $\geq$ 2.0000 pu

Increase in interface flows $\geq$ 999.00 %

☒ Report changes in bus dV/dQ sensitivity

Change in dV/dQ sensitivity multiple 5.00

Monitor by Bus Filter dV/dQ check

Define Filter

☐ Report as a violation if a bus becomes disconnected

Run the Contingencies



- Go back to the Contingencies Tab
 - Click **Start Run** Button
- We now have contingency analysis result for our base case.
 - Save these to compare to later
 - Click the **Save** Button at the bottom of the dialog
 - Save as file *LamesaCTGBase.aux*
 - On Dialog that appears check
 - Save Contingency Definitions
 - Save Contingency Options
 - Save Contingency Results

Contingency Settings

There are numerous settings which affect the Contingency Analysis formatting options on how to represent them in the AUX file

What to Store

- ☒ Save Contingency Definitions
- ☒ Save Remedial Actions and Global Actions (none)
 - ☐ Save unlinked contingency actions (none)
- ☒ Save Model Filters, Model Conditions, Model Expressions, and Model Result Overrides (none)
- ☒ Save Contingency Options (also Area Makeup, Gen Line Drop, Gen AGC, Gen Max MW, Bus Load Throw, Shunt)
 - ☐ Suppress Gen and Bus Contingency Options
- ☒ Save Voltage Control Groups (none)
- ☐ Save General Power Flow Solution Options
- ☒ Save Custom Monitors (none)
- ☐ Save Limit Monitoring Settings (Area, Zone, LimitSet, Bus, Branch, and Interface)
 - ☒ Save Limit Cost Functions if they exist (none)
- ☐ Save List Display Settings
- ☒ Save Contingency Results
- ☐ Save Inactive Violations

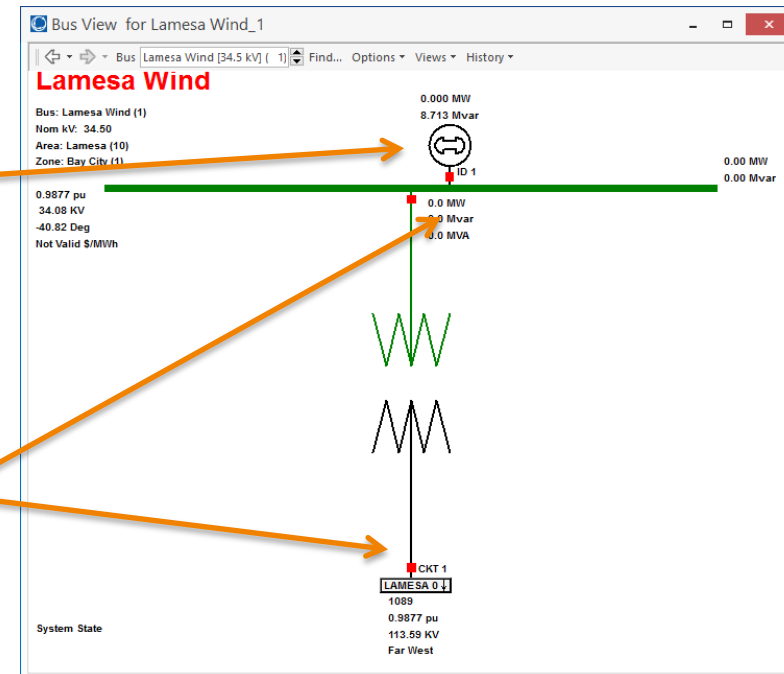
Build a Comparison Case



- Study the hypothetical new 200 MW generator at Lamesa
- Open Bus View Online and navigate to Bus 1

Here's our new generator

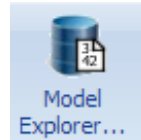
Close Breakers for Generator and collector transformer



Create a Transfer from New Generator



- Generator bus is assigned to its own area number 10 (Lamesa)
- Open the Model Explorer
 - Choose **Aggregations\Areas**
 - Choose Area 10 (Lamesa)
 - Click the **Show Dialog** button



	Gen Max MW	Area Num	Area Name	AGC Status	Gen MW	Load
1	5551.98	1	Far West	Part. AGC	3009.07	1
2	5936.41	2	North	Part. AGC	3016.69	1
3	6131.03	3	West	Part. AGC	4040.80	1
4	8748.10	4	South	Part. AGC	7094.02	6
5	17730.62	5	North Central	Off AGC	12572.08	22
6	15844.07	6	South Central	Part. AGC	11830.68	12
7	26553.26	7	Coast	IG Slack	23699.34	18
8	11416.44	8	East	Part. AGC	2676.71	3
10	200.00	10	Lamesa	Part. AGC	200.00	

200 MW Transfer to Coast



- Setup a 200 MW Export from Lamesa to Area 7 (Coast)
- Click OK
- Click **Single Solution**

Lamesa Area Information for Present

Number: 10, Name: Lamesa, Super Area: , Labels: no labels

Area MW Control Options:
☐ No Area Control
☒ Participation Factor Control
☐ Economic Dispatch Control
☐ Area Slack Bus
☐ Injection Group Area Slack
☐ Optimal Power Flow Control

Area Summary Totals:

	MW	Mvar
Load		
Generation	0.0	8.7
Fixed Bus Shunts	0.0	0.0

Interchange:

Number	Name	MW Export	Enabled	ID
1	Far West	0		
2	North	0		
3	West	0		
4	South	0		
5	North Central	0		
6	South Central	0		
7	Coast	200.0	YES	1
8	East	0		

Bus View for Lamesa Wind_1

Bus: Lamesa Wind (1)
Nom kV: 34.50
Area: Lamesa (10)
Zone: Bay City (1)

0.9899 pu
34.15 KV
-11.36 Deg
Not Valid \$/MWh

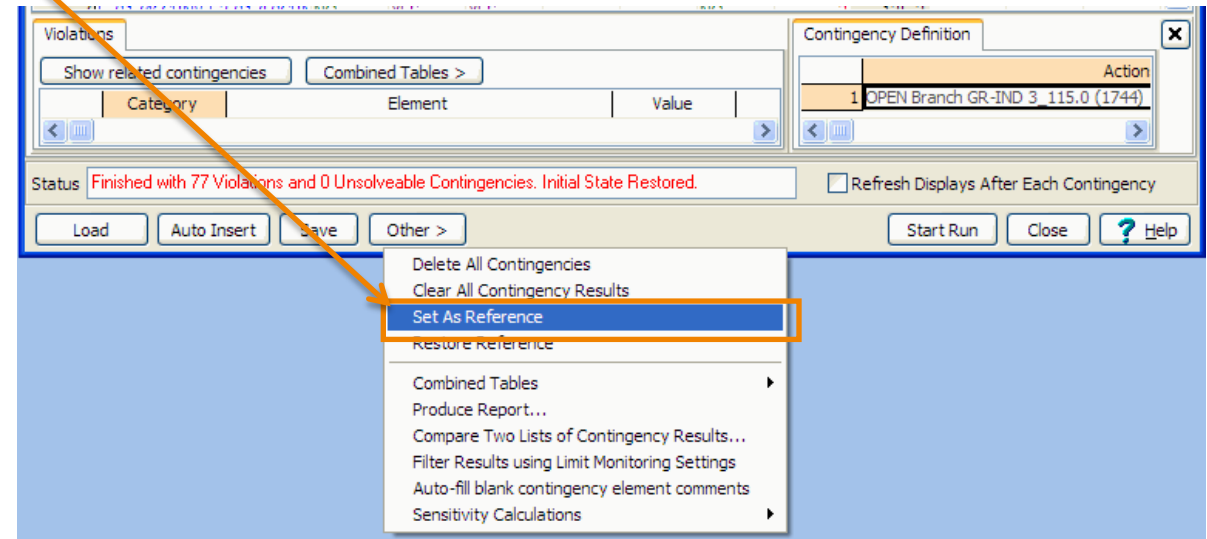
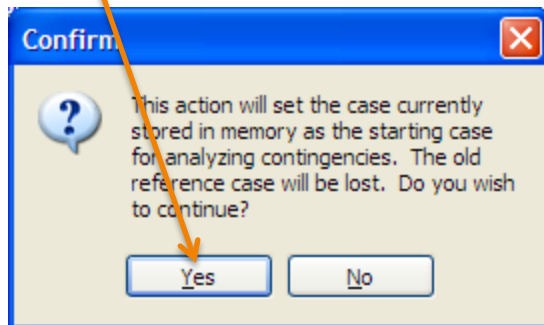
200.000 MW
0.335 Mvar

200.0 MW
0.3 Mvar
200.0 MVA

Change the Reference State



- Now Go to the Contingency Analysis Dialog again
- We have changed our system state now, but the contingency analysis tool still has the old “Reference State” stored
- We want to re-run the contingency analysis with the new 200 MW transfer included
- Choose **Other > Set As Reference**
- Click **Yes** on Dialog that appears



Run the Contingencies on the New Reference State



- Go back to the Contingencies Tab
 - Click **Start Run** Button
- We now have contingency analysis result for our reference case.
 - Save these to compare to later
 - Click the **Save** Button at the bottom of the dialog
 - Save as file
LamesaCTGTransfer.aux
 - On Dialog that appears check
 - Save Contingency Definitions
 - Save Contingency Options
 - Save Contingency Results

Contingency Settings

There are numerous settings which affect the Contingency Analysis formatting options on how to represent them in the AUX file

What to Store

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- ☒ Save Contingency Options (also Area Makeup, Gen Line Drop, Gen AGC, Gen Max MW, Bus Load Throw, Shunt)
 - ☐ Suppress Gen and Bus Contingency Options
- ☒ Save Voltage Control Groups (none)
- ☐ Save General Power Flow Solution Options
- ☒ Save Custom Monitors (none)
- ☐ Save Limit Monitoring Settings (Area, Zone, LimitSet, Bus, Branch, and Interface)
 - ☒ Save Limit Cost Functions if they exist (none)
- ☐ Save List Display Settings
- ☒ Save Contingency Results
- ☐ Save Inactive Violations

Compare the Results



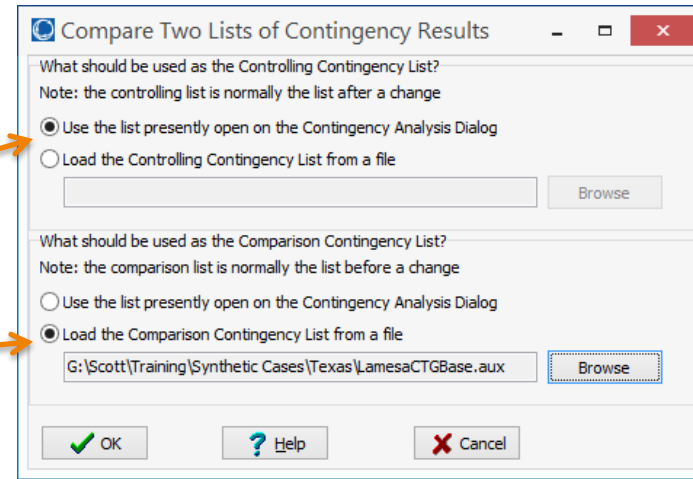
- Choose **Other > Compare Two Lists of Contingency Results...**

- Choose Controlling List

- *LamesaCTGTransfer.aux*
 - OR **Use the list presently open...**

- Choose Comparison List

- *LamesaCTGBase.aux*

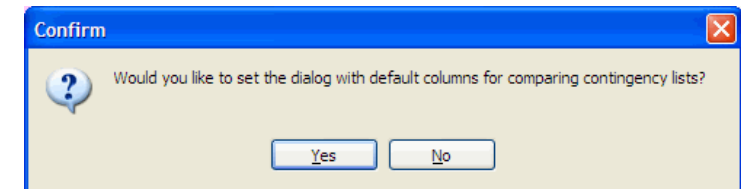


- Click **OK**

- This will import the two lists and do the comparison

- A dialog prompts for default columns for comparing contingency lists

- Choose **Yes**



Comparison of Results By Contingency



Contingencies														Options			
Records														Options			
	Label	Skip	Category	Processed	Solved	Comp Solved	Include Remedial Actions	Screen Allow	Post-CTG AUX	Violations	Comp Violations	New Violations	Max Branch %	Comp Max Branch %	Wor Bran Viola	Min	
1	001089LAMESA0-001054STANTON0C1	NO		YES	YES	YES	YES	NO	none	2	0	2	163.8		63.8		
2	L_001055ODONNELL0-001089LAMESA0C1	NO		YES	YES	YES	YES	NO	none	1	0	1	162.3		62.3		
3	L_001055ODONNELL0-001003ODONNELL10C1	NO		YES	YES	YES	YES	NO	none	1	0	1	158.3		58.3		
4	L_001054STANTON0-001056LENORAH0C1	NO		YES	YES	YES	YES	NO	none	2	0	2	148.6		48.6		
5	T_001079ODESSA18-001071ODESSA10C1	NO		YES	YES	YES	YES	NO	none	2	0	2	143.6		43.6		
6	L_001004ODONNELL11-003133SNYDER20C1	NO		YES	YES	YES	YES	NO	none	5	0	5	138.1		38.1		
7	L_001028COAHOMA0-003109FLUVANNA10C1	NO		YES	YES	YES	YES	NO	none	1	0	1	107.4		7.4		
8	T_001004ODONNELL11-001003ODONNELL10C1	NO		YES	YES	YES	YES	NO	none	1	0	1	104.9		4.9		
9	T_007036CONROE51-007035CONROE50C1	NO		YES	YES	YES	YES	NO	none	1	1	0	115.2	111.5	3.7		
10	T_007306WHARTON12-007305WHARTON11C1	NO		YES	YES	YES	YES	NO	none	1	1	0	113.9	112.0	2.0		
11	T_001023ODONNELL21-001022ODONNELL20C1	NO		YES	YES	YES	YES	NO	none	1	0	1	102.0		2.0		
12	L_007161HOUSTON52-007292HOUSTON690C2	NO		YES	YES	YES	YES	NO	none	1	1	0	113.1	111.5	1.6		
13	L_007161HOUSTON52-007292HOUSTON690C4	NO		YES	YES	YES	YES	NO	none	1	1	0	113.1	111.5	1.6		
14	L_007161HOUSTON52-007292HOUSTON690C3	NO		YES	YES	YES	YES	NO	none	1	1	0	113.1	111.5	1.6		

Violations														What Actually Occurred			
Show related contingencies														Combined Tables >			
	Category	Element				Source List	Value	Comp Value	Diff Value	Limit	Comp Limit	Diff Limit	Perc	Comp Percent	Diff Percent		
1	Branch MVA LAMESA 0 (1089) -> ODONNELL 0 (1055) CKT 1 at LAMESA 0					Controlling	160.51			98.00			163.78			1	
2	Branch MVA ODONNELL 0 (1055) -> O DONNELL 1 0 (1003) CKT 1 at ODONNELL 0					Controlling	152.45			98.00			155.57			1	

Status: Finished with 108 violations, 0 custom monitor violations, 0 unsolvable, and 0 aborted contingencies. Initial state restored.

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

Described on the next slide

Comparison by Contingency: Explanation of Columns



- Max Branch %
 - Highest Branch % overload seen on any branch during this Contingency in the *Controlling* List
- Comp Max Branch %
 - Highest Branch % overload seen on any branch during this Contingency in the *Comparison* List
- Worst Branch Violation
 - Worst Branch Violation when comparing the *Controlling* List to the *Comparison* List
 - If the overload is in both the *Controlling* and *Comparison* List
 - Highest Difference in the % Branch violation
 - If an overload is in only the *Controlling* List then
 - % Branch - 100

Comparison by Contingency: Worst Branch Violation Example



- Go to Contingency: T_001079ODESSA18-001071ODESSA10C1

Label																	
	Skip	Category	Processed	Solved	Comp Solved	Include Remedial Actions	Screen Allow	Post-CTG AUX	Violations	Comp Violations	New Violations	Max Branch %	Comp Max Branch %	Wor: Bran Viola	Mi		
5 T_001079ODESSA18-001071ODESSA10C1	NO		YES	YES	YES	YES	NO	none	2	0	2	143.6		43.6			
6 L_001004ODONNELL 11-003133SNYDER20C1	NO		YES	YES	YES	YES	NO	none	5	0	5	138.1		38.1			
7 L_001028COAHOMA0-003109FLUVANNA 10C1	NO		YES	YES	YES	YES	NO	none	1	0	1	107.4		7.4			

Violations What Actually Occurred													
Show related contingencies Combined Tables >													
	Category	Element			Source List	Value	Comp Value	Diff Value	Limit	Comp Limit	Diff Limit	Per	Comp Percent
1	Branch MVA	LAMESA 0 (1089) -> O DONNELL 0 (1055) CKT 1 at LAMESA 0			Controlling	140.70			98.00			143.57	
2	Branch MVA	ODONNELL 0 (1055) -> O DONNELL 10 (1003) CKT 1 at O DONNELL 0			Controlling	133.83			98.00			136.56	

- LAMESA 0 – O DONNELL 0 went from no overload to 143.0%: treated as 43.0% for “Worst comparison
- O DONNELL 0 – O DONNELL 10 went from no overload to 136.0%: treated as 36.0% for “Worst” comparison
- Thus LAMESA 0 – O DONNELL 0 is considered the “Worst” with a value of 43.0%
- Similar comparisons are available for bus voltages

Comparison of Results By Element



Contingency Analysis

Contingencies Options Results

View Results By Element

- Lines/Transformers
- Buses
- Interfaces
- Bus Pairs
- Nomogram Interfaces
- Custom Monitors
- View Results by Contingency
- Contingency Violation List
- Violation CTG Notes
- 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 Inceas Violati
1	7391	WILLIS 1 2	7390	WILLIS 1 1	1	YES	1	0	115.21	111.48	3.72
2	7069	EL CAMPO 1	7068	EL CAMPO 0	1	YES	1	0	113.94	111.96	1.98
3	7161	HOUSTON 5 2	7292	HOUSTON 69 0	1	YES	4	0	113.09	111.52	1.57
4	7201	CYPRESS 1 2	7200	CYPRESS 1 1	3	YES	2	0	109.77	108.24	1.53
5	7201	CYPRESS 1 2	7200	CYPRESS 1 1	1	YES	2	0	109.77	108.24	1.53
6	7201	CYPRESS 1 2	7200	CYPRESS 1 1	2	YES	2	0	109.77	108.24	1.53
7	7253	ANGLETON 1	7252	ANGLETON 0	1	YES	11	1	117.74	116.76	1.43
8	7410	KATY 2 1	7409	KATY 2 0	3	YES	2	0	111.91	110.54	1.37
9	7410	KATY 2 1	7409	KATY 2 0	1	YES	2	0	111.91	110.54	1.37
10	7410	KATY 2 1	7409	KATY 2 0	2	YES	2	0	111.91	110.54	1.37
11	7039	SUGAR LAND 3 2	7038	SUGAR LAND 3 1	2	YES	1	0	112.57	111.31	1.26

Contingencies

Show Other Violations Combined Tables >

	Label	Category	Source List	Value	Comp Value	Diff Value	Limit	Percent	Comp F
1	T-007036CONROE51-00703	Branch MVA	Both	146.54	141.81	4.73	127.20	115.21	

Status Finished with 147 violations, 0 custom monitor violations, 0 unsolvable, and 0 aborted contingencies. Initial state restored.

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

Described
on the next
slide

Comparison by Element: Explanation of Columns



- Max % Loading Cont.
 - Maximum % overload seen on this branch during any contingency in the *Controlling* List
- Max % Ld Cont Comp
 - Maximum % overload seen on this branch during any contingency in the *Comparison* List
- Worst Increase Violation
 - Worst Increase Violation when comparing the *Controlling* List to the *Comparison* List
 - If the overload is in both the *Controlling* and *Comparison* List
 - Highest Difference it the % Branch violation
 - If an overload is in only the *Controlling* List then
 - % Branch - 100

Comparison by Element: Worst Increase Violation Example



- Go to Branch: 7161 (HOUSTON 5 2) – 7292 (HOUSTON 69 0), CKT 1

Lines/Transformers (filtered)

	From Number	From Name	To Number	To Name	Circuit	Xfrmr	Violations	New Violations	Max % Loading Cont.	Max % Ld Cont Comp	Worst Increa Violati ▼
1	7391	WILLIS 1 2	7390	WILLIS 1 1	1	YES	1	0	115.21	111.48	3.72
2	7069	EL CAMPO 1	7068	EL CAMPO 0	1	YES	1	0	113.94	111.96	1.98
3	7161	HOUSTON 5 2	7292	HOUSTON 69 0	1	YES	4	0	113.09	111.52	1.57
4	7201	CYPRESS 1 2	7200	CYPRESS 1 1	3	YES	2	0	109.77	108.24	1.53
5	7201	CYPRESS 1 2	7200	CYPRESS 1 1	1	YES	2	0	109.77	108.24	1.53

Contingencies

Show Other ViolationsCombined Tables >

	Label	Category	Source List	Value	Comp Value	Diff Value	Limit	Perce ▼	Comp Percent	Diff Percent
1	L_007161HOUSTON52-007292HOUSTON690C2	Branch MVA	Both	250.05	246.57	3.48	221.10	113.09	111.52	1.57
2	L_007161HOUSTON52-007292HOUSTON690C3	Branch MVA	Both	250.05	246.57	3.48	221.10	113.09	111.52	1.57
3	L_007161HOUSTON52-007292HOUSTON690C4	Branch MVA	Both	250.05	246.57	3.48	221.10	113.09	111.52	1.57
4	L_007159HOUSTON50-007175SPRING70C1	Branch MVA	Both	228.96	226.59	2.36	221.10	103.55	102.48	1.07

- For L_007161HOUSTON52-007292HOUSTON690C2 (and other parallel outages), went from 111.5% to 113.1%: treated as 1.6% for “Worst” comparison
- For L_007159HOUSTON50-007175SPRING70C1, went from 102.5% to 103.6%: treated as 1.1% for “Worst” comparison
- Contingency L_007161HOUSTON52-007292HOUSTON690C2 is considered “Worst” with a value of 1.6%

PTDF Calculation and Visualization

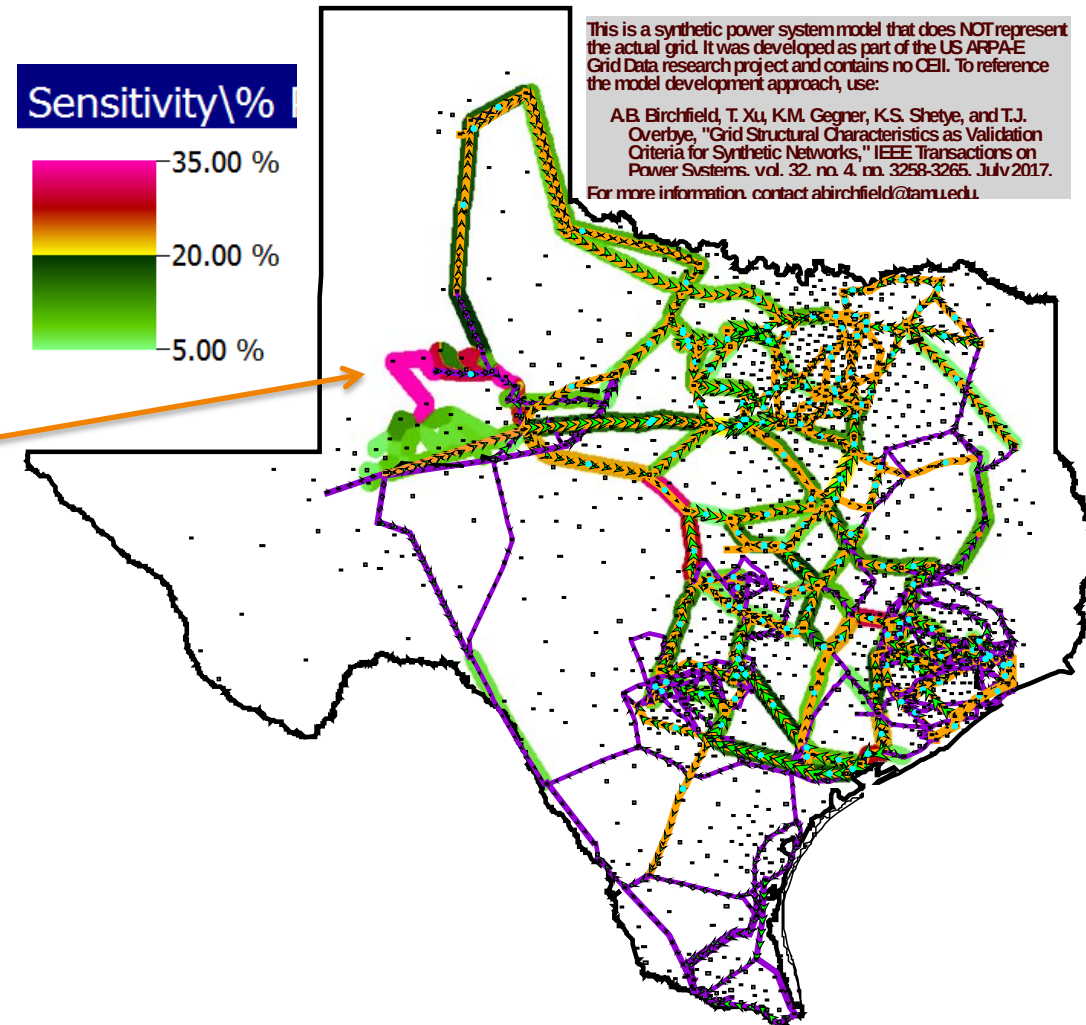


- Next, examine how incremental power from the proposed unit would flow through the system
- Shut off proposed unit by disabling transfer between area Lamesa and area Coast
- Open PTDF tool (Tools ➔ Sensitivities ➔ Power Transfer Distribution Factors)
- Choose Injection Group “Lamesa” as Seller, Injection Group “Coast Load” as Buyer

PTDF Visualization



- Color contour
- 5%-35% range
- Ignore zero values, below min
- Lamesa



Available Transfer Capability



- Keep Seller and Buyer selections the same as PTDF
- Save 25 Limiters, 5 per CTG, 5 per element
- Ignore Elements with OTDF/PTDF below 3%

The screenshot shows the 'Available Transfer Capability' dialog box with the following settings and annotations:

- Options:** Common Options (selected), Definitions, Advanced Options, Memo.
- Buyer/Seller type combinations are limited because of the Iterated solution technique:**
 - Seller:** Area, Slack, Zone, **Injection Group** (selected), Super Area, Bus.
 - Buyer:** Area, Slack, Zone, **Injection Group** (selected), Super Area, Bus.
- Seller:** Lamesa (dropdown menu).
- Buyer:** Coast Load (dropdown menu).
- Find Seller...** and **Find Buyer...** buttons.
- Reverse Buyer/Seller** button.
- Linear Calculation Method:**
 - ☐ Linearized AC
 - ☒ Lossless DC
 - ☐ Lossless DC With Phase Shifters
 - ☒ Enable Phase Shifters Post-Contingency
- Transfer Result Reporting Options:**
 - Transfer Limiters to Save:** 25
 - Max Limiters per CTG:** 5
 - Max Limiters per Element:** 5
 - Max MW Limitation:** 6000
 - Ignore Elements with OTDFs below:** 3.00 %
 - Ignore Elements with PTDFs below:** 3.00 %
- Include Contingencies:** ☒
- Report Base Case Limitations:** ☒
- Report Generation Reserve Limitations:** ☒
- Limit Monitoring Settings ...** button.
- Buttons:** Save Settings, Load Settings, ? Help, Close.

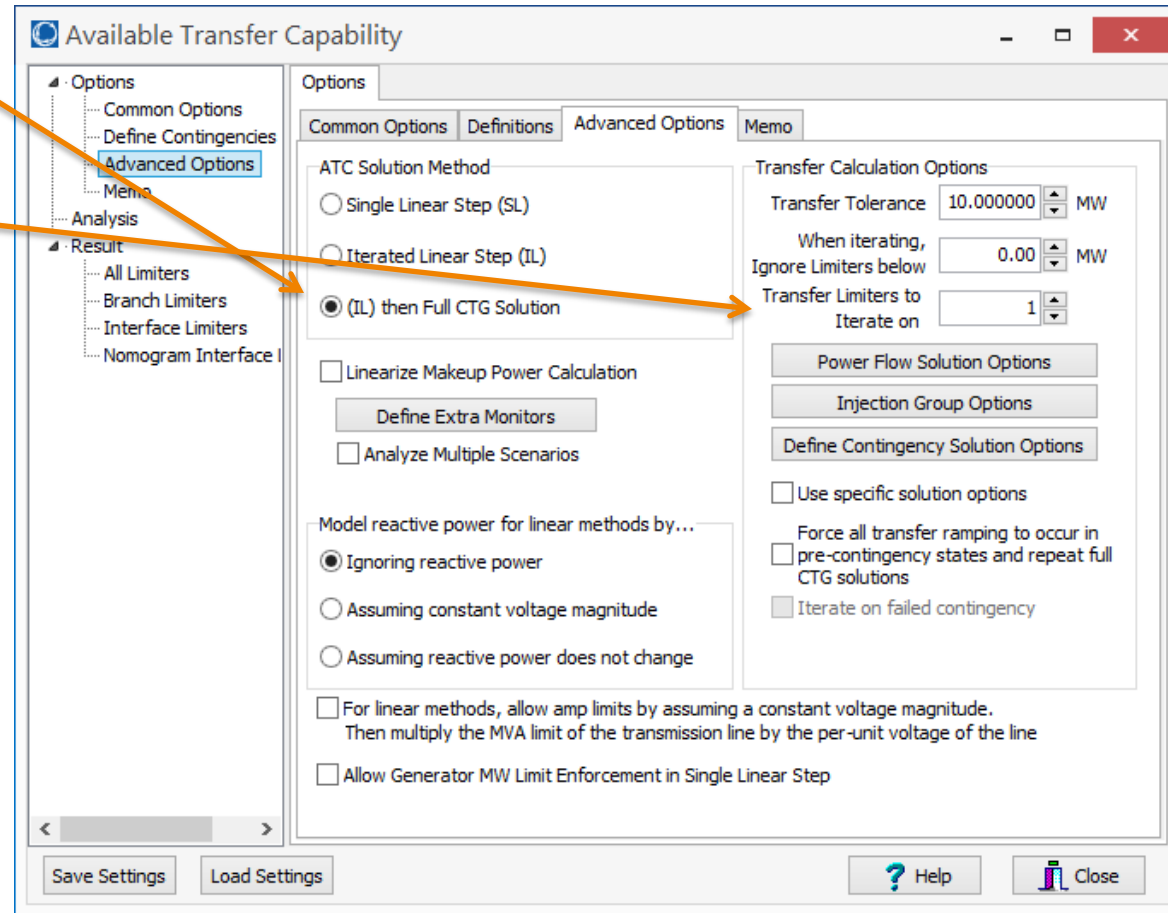
Annotations (orange arrows) point from the bullet points on the left to the corresponding settings in the dialog box:

- From 'Keep Seller and Buyer selections the same as PTDF' to the Seller and Buyer dropdown menus.
- From 'Save 25 Limiters, 5 per CTG, 5 per element' to the 'Transfer Limiters to Save', 'Max Limiters per CTG', and 'Max Limiters per Element' fields.
- From 'Ignore Elements with OTDF/PTDF below 3%' to the 'Ignore Elements with OTDFs below' and 'Ignore Elements with PTDFs below' fields.

Available Transfer Capability



- Use (IL) then Full CTG Solution method
- Iterate on 1 Transfer Limiter



ATC Automation



- The entire ATC process may be documented and automated in auxiliary files
- Re-open *ACTIVSg2000.pwb*
 - load *aux2000ATCMaster.aux*
 - results stored in *aux2090ATCResults.aux*
- Examine individual aux files (*aux20??*.aux*) for details

Voltage Analysis



- Plot QV curves at point of interconnection
 - Compare Q margin with/without new unit
- PV analysis
 - Run on base case to identify contingencies that most limit the transfer
 - Run with short list of selected contingencies
- Run QV curves on buses and contingencies that cause most voltage problems

QV Curves at Interconnection Point

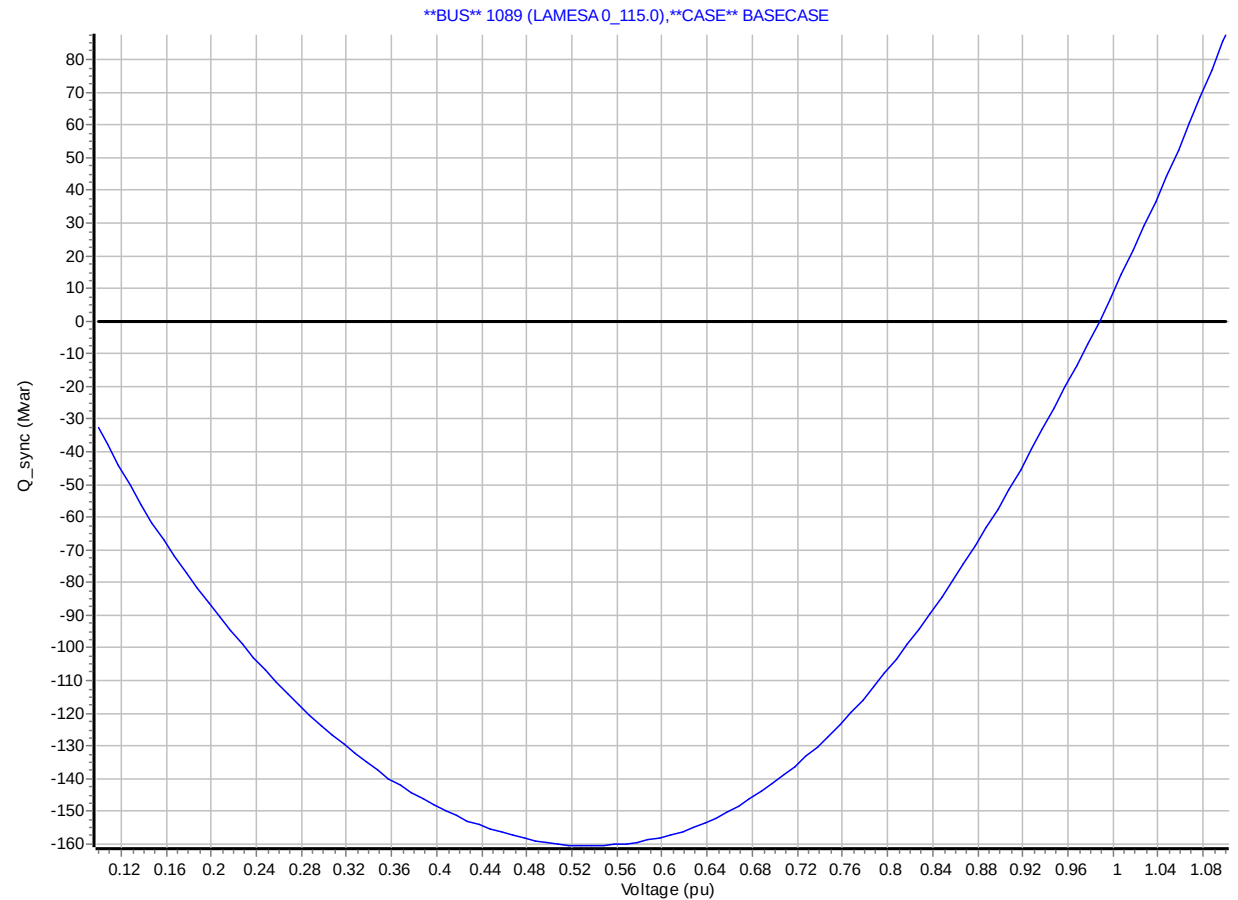


- Plot QV curves at bus 1089 (Lamesa 115 kV)
 - First, without proposed generator; then with
 - To quickly interconnect new generator
 - load *aux2000MasterInterconnectSetup.aux*
 - Close transformer between buses 1 and 1089 and generator
 - enable the transaction between area 10 and area 7
 - Solve the power flow
 - If reactive margin decreases with the new unit, then supplemental reactive support may be required
- QV Settings
 - Base case only: no contingencies
 - Disable all switched shunts, SVCs, LTCs, and phase shifters
 - Minimum pu voltage for constant power load = 0
 - May be loaded from *LamesaQVOptions.aux*

QV Curve without Proposed Unit



- Q margin = 161 MVar

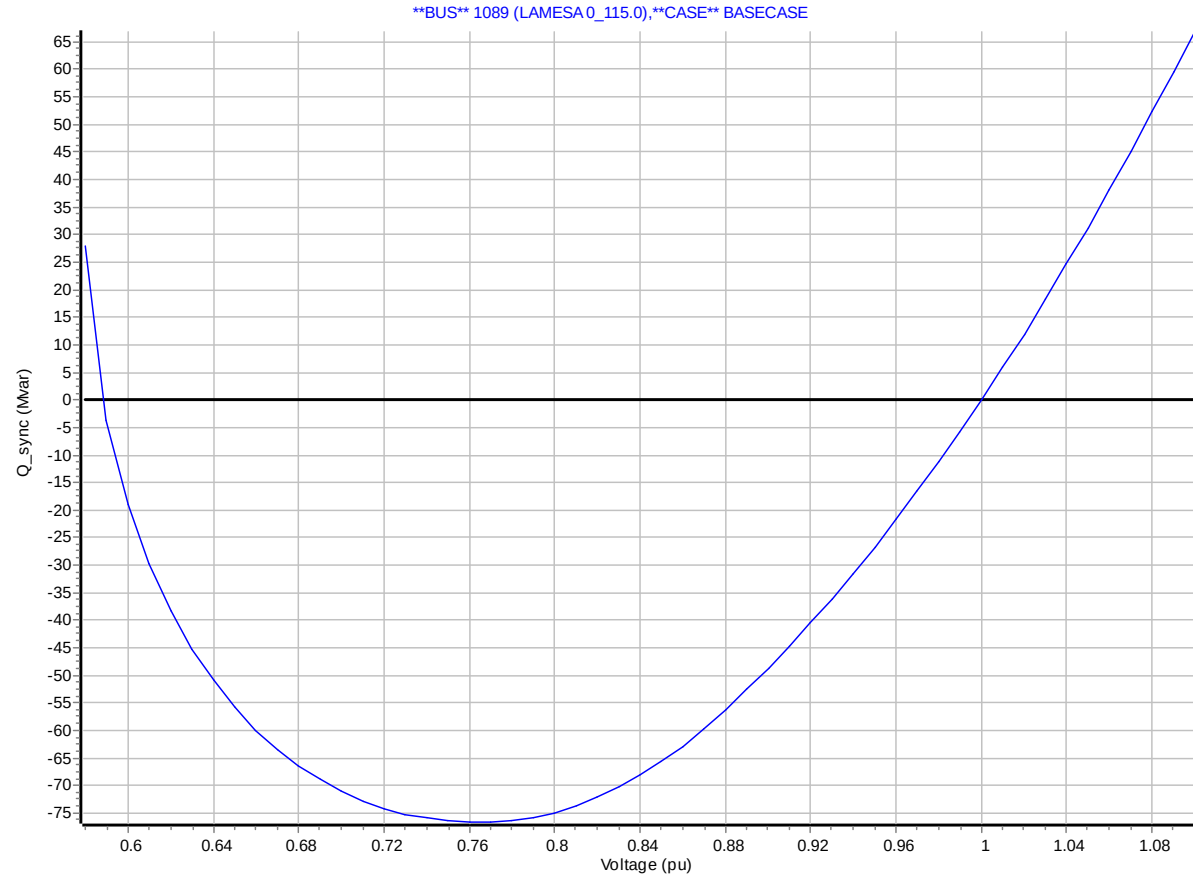


Build Date: January 25, 2018

QV Curve with Proposed Unit



- Q margin = 77 MVar, a decrease from the base case
- Additional reactive supply might be desirable



Build Date: January 25, 2018

PV Study

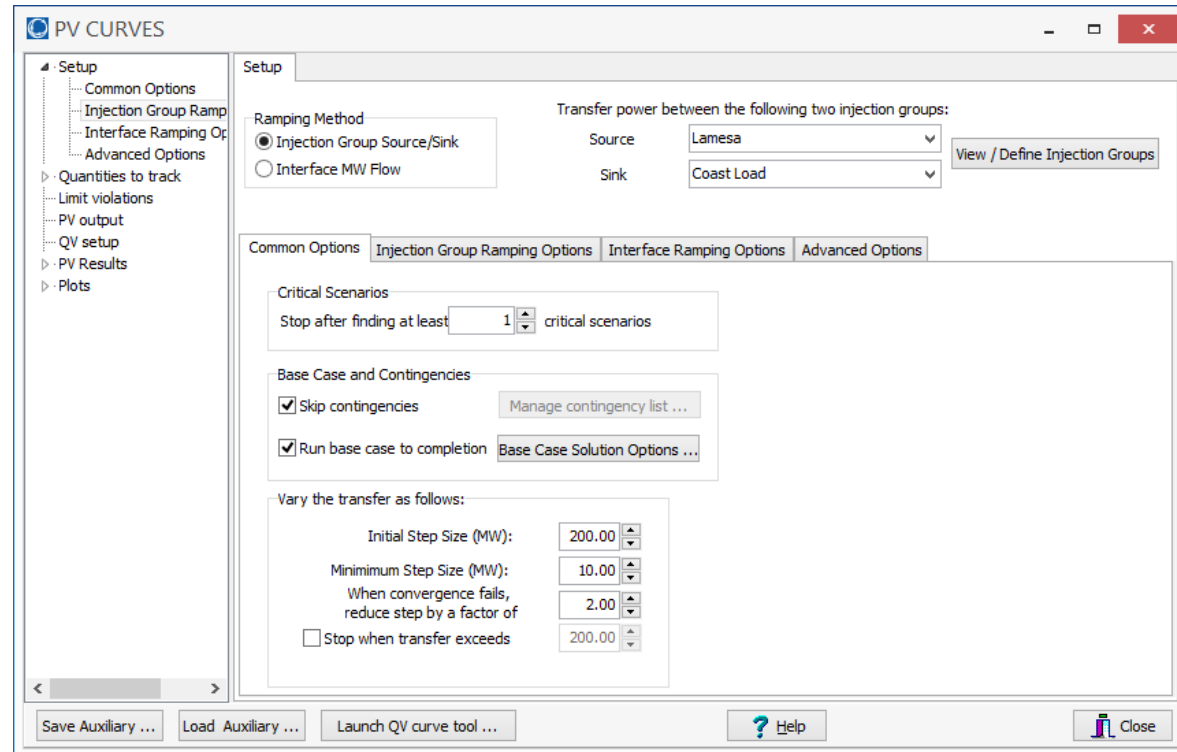


- Examine the ability to transfer power from the proposed generator to loads in area 7
- Contingency screening process
 - Run PV on base case only (Skip Contingencies)
 - Repeat base case only, but stop when transfer gets to about 80% of the level of the nose point
 - Run contingency analysis on this state
 - Run PV with only those contingencies that failed at 80% transfer (these contingencies will likely fail earlier and become the most limiting)

Base Case PV Study: Setup



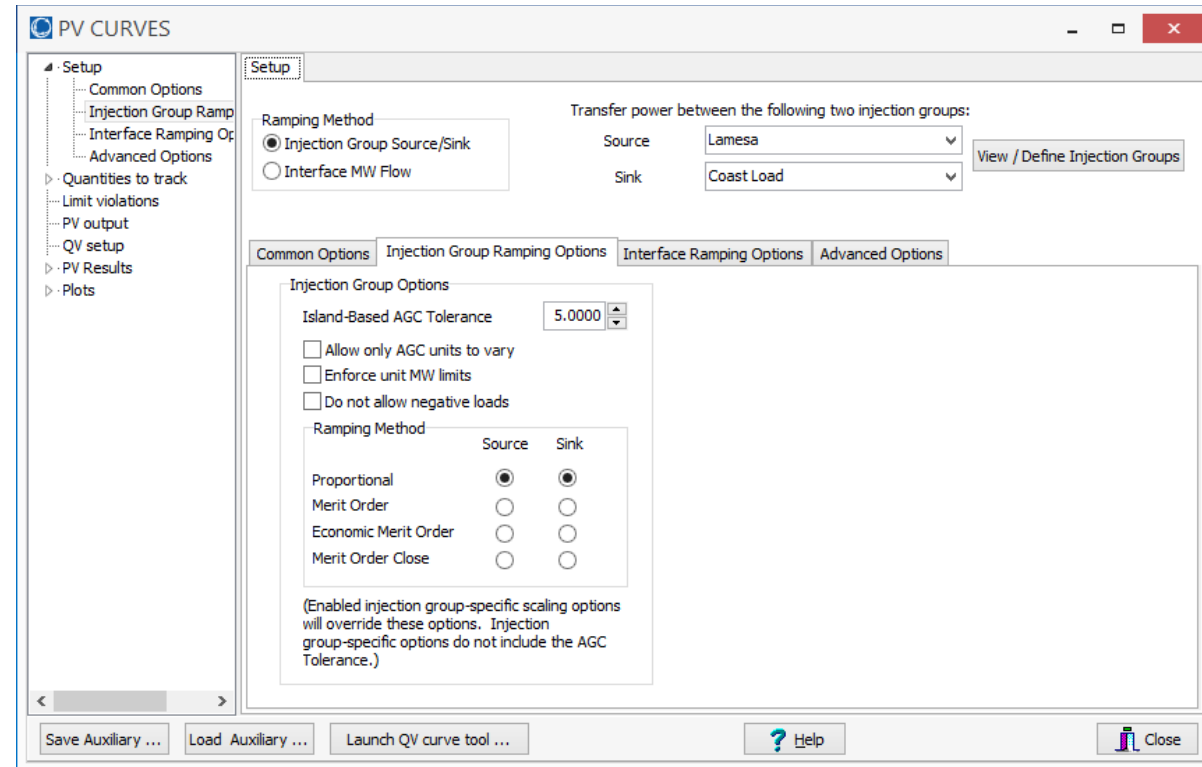
- Source as Lamesa; sink as Coast Load
- Stop after 1 critical scenario
- Skip contingencies; Run base case to completion
- 200 MW Initial Step Size, 10 MW minimum



Base Case PV Study: Setup



- Do not Enforce unit MW limits (to identify nose point if beyond 200 MW capacity)



Base Case PV Study: Setup



- Scale load Mvar with MW

PV CURVES

Setup

Ramping Method

- ☒ Injection Group Source/Sink
- ☐ Interface MW Flow

Transfer power between the following two injection groups:

Source: Lamesa

Sink: Coast Load

[View / Define Injection Groups](#)

Common Options | **Injection Group Ramping Options** | **Interface Ramping Options** | **Advanced Options**

How should reactive power load change during ramping?

- ☒ Maintain the MW/MVAR ratio at each load, but then scale MVAR by a factor of 1.0000
- ☐ As MW changes, change the MVAR at a power factor of 1.0000

(If enabled, injection group specific scaling options will override these options.)

Reverse Transfer

- ☐ Apply Reverse Transfer
- Maximum Reverse Transfer (MW > 0): 1000.00

Load Component Variation

- ☒ All changes apply to constant power (S MW, S MVAR)
- ☐ Vary in proportion to existing Z,I,P ratios
- ☐ Vary using proportions specified below:

	P (MW)		Q (MVAR)	
	Source	Sink	Source	Sink
Power (S)	1.00	1.00	1.00	1.00
Current (I)	0.00	0.00	0.00	0.00
Impedance (Z)	0.00	0.00	0.00	0.00

[Save Auxiliary ...](#) [Load Auxiliary ...](#) [Launch QV curve tool ...](#) [Help](#) [Close](#)

Run Base Case PV



- Nose occurs at 337.5 MW with no contingencies
- Click **Other actions >> Restore Initial State**

PV Results

Run Stop ☐ Restore Initial State on Completion of Run

Base case could not be solved

Present nominal shift 337.500
Present step size

Found 1 limiting case.

Source	Gen MW	Load SMW	Load IMW	Load ZMW
Sink	337.50	0.00	0.00	0.00
Sink	0.00	18460.11	0.00	0.00

View detailed results

Other actions >>

Overview Legacy Plots Track Limits

Scenario	Critical?	Critical Reason	Max Shift	Max Export	Max Import	# Viol	Worst V Viol	Worst V Bus	Max P Mism Bus #	Max P Mism Bus Name	Max MW Mism	Max Q Mism Bus #	Max Q Mism Bus Name	Max Mvar Mism
1 base case	YES	Reached Nose	337.50	337.50	-270.39	0			1	Lamesa Wind	1.7628	1	Lamesa Wind	10.2497

Contingency Analysis at 275 MW



- Enable Lamesa-Coast transaction and set to 275 MW
- Set reference to current state
- Remove Advanced Limit Monitoring options for faster processing
- 5 Unsolved contingencies
 - skip all but these and re-run PV analysis from zero
 - Optionally save these Contingency Label and Skip fields to an aux file for later use

Contingencies Options Results																
Records Set Columns Options																
	Label	Skip	Category	Processed	Sol	Include Remedial Actions	Screen Allow	Post-CTG AUX	Islanded Load	Islanded Gen	Global Actions	Transient Actions	Remedial Actions	Custom Monitor Violations	Violations	Max Branch %
1	L_001089LAMESA0-001054STANTON0C1	NO		YES	NO	YES	NO	none			0	0	0	Unsolved	Unsolved	
2	L_001054STANTON0-001056LENORAH0C1	NO		YES	NO	YES	NO	none			0	0	0	Unsolved	Unsolved	
3	L_001004ODONNELL11-003133SNYDER20C1	NO		YES	NO	YES	NO	none			0	0	0	Unsolved	Unsolved	
4	L_001055ODONNELLO-001089LAMESA0C1	NO		YES	NO	YES	NO	none			0	0	0	Unsolved	Unsolved	
5	L_001055ODONNELLO-001003ODONNELL10C1	NO		YES	NO	YES	NO	none			0	0	0	Unsolved	Unsolved	
6	L_001010PRESIDIO10-001002PRESIDIO20C1	NO		YES	YES	YES	NO	none			0	0	0	0	3	126.1
7	L_001002PRESIDIO20-001007VANHORN0C1	NO		YES	YES	YES	NO	none			0	0	0	0	3	126.2

PV Analysis with Contingencies



- Identify several bus voltages to track
 - Try various values of Lamesa-Coast transaction between 225 MW and 250 MW
 - Solve 5 contingencies, reporting as violations decreases in low bus voltage and changes in dV/dQ sensitivity

Contingencies Options Results																				
	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 Volt	Max Volt	Max Interface %	Max Bus Pair Angle	Memo	Max dV/dQ
2	NO	YES	YES	YES	NO	none			0	0	0	0	2	173.3						
3	NO	YES	YES	YES	NO	none			0	0	0	0	5	150.2						
4	NO	YES	YES	YES	NO	none			0	0	0	0	5	187.1	0.917					0.072
5	NO	YES	YES	YES	NO	none			0	0	0	0	3	183.0	0.936					

Violations What Actually Occurred							
Show related contingencies		Combined Tables >					
Category	Element			Value	Limit	Per	Area Name Assoc.
1 Branch MVA	LAMESA 0 (1089) -> STANTON 0 (1054) CKT 1 at LAMESA 0			183.35	98.00	187.09	Far West
2 Branch MVA	STANTON 0 (1054) -> LENORAH 0 (1056) CKT 1 at LENORAH 0			172.49	149.00	115.77	Far West
3 Change Bus Low Volts	STANTON 0 (1054)			0.9166	0.9000	92.42	Far West
4 Change Bus dV/dQ	LAMESA 0 (1089)			0.07226			Far West
5 Change Bus dV/dQ	STANTON 0 (1054)			0.02194			Far West

PV Analysis with Contingencies



- Stop after 5 critical scenarios
- Initial Step 25 MW, Minimum Step 5 MW
- Track bus voltage at Lamesa and other vulnerable buses:
 - 1022 O DONNELL 2 0
 - 1028 COAHOMA 0
 - 1054 STANTON 0
- Track MW and Mvar Reserve at Lamesa Wind
- Settings may be loaded from *LamesaPVOptions.aux*

PV Results



PV CURVES

Setup
Quantities to track
Limit violations
PV output
QV setup
PV Results
 Overview
 Legacy Plots
 Track Limits
Plots

PV Results

Run Stop ☐ Restore Initial State on Completion of Run

Base case could not be solved

Present nominal shift: 337.500
Present step size:

	Gen MW	Load SMW	Load IMW	Load ZMW
Source	337.50	0.00	0.00	0.00
Sink	0.00	18462.59	0.00	0.00

View detailed results
Other actions >>

Found 6 limiting cases.

Overview Legacy Plots Track Limits

Records Set Columns f(x) Options

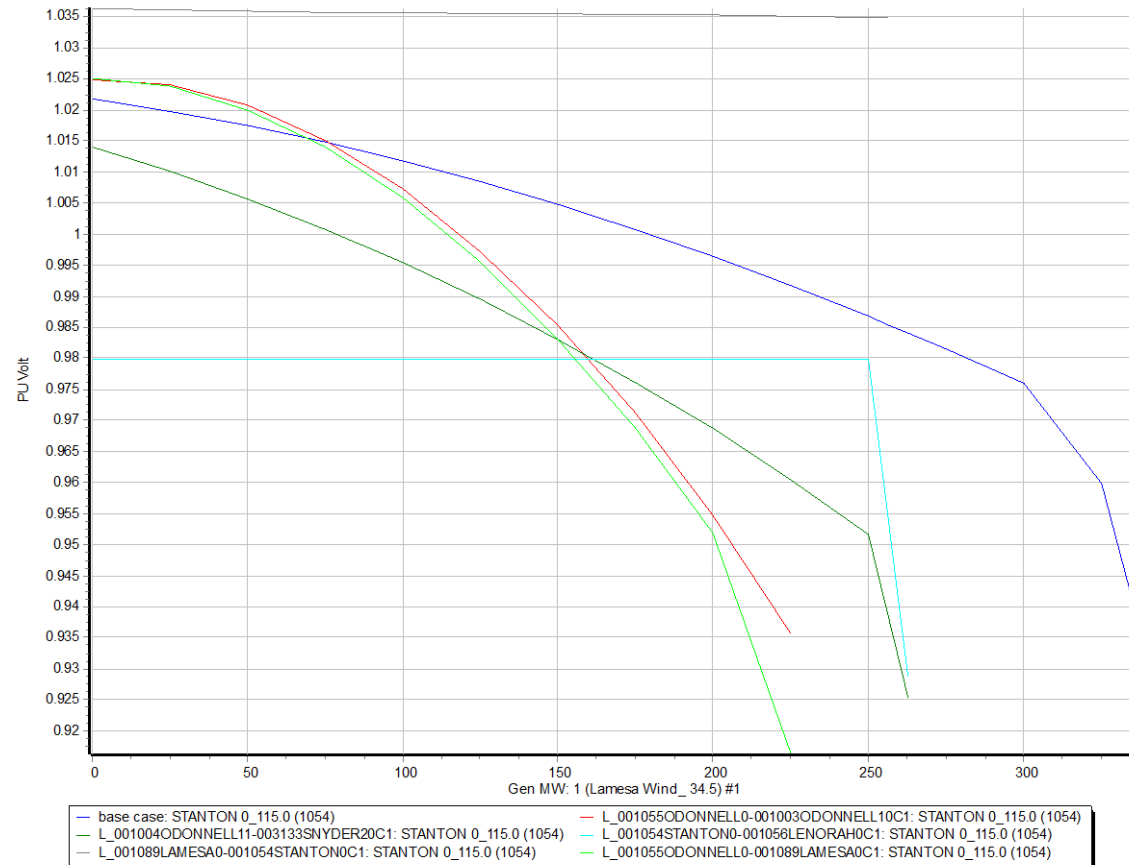
	Scenario	Critical?	Critical Reason	Max Shift	Max Export	Max Import	# Viol	Worst V Viol	Worst V Bus
1	base case	YES	Reached Nose	337.50	337.50	-273.04	0		
2	L_0010550DONNELL0-0010030DONNELL10C1	YES	Reached Nose	225.00	225.11	-200.91	0		
3	L_0010040DONNELL11-003133SNYDER20C1	YES	Reached Nose	262.50	262.81	-228.13	0		
4	L_001054STANTON0-001056LENORAH0C1	YES	Reached Nose	262.50	262.66	-228.13	0		
5	L_001089LAMESA0-001054STANTON0C1	YES	Reached Nose	256.25	256.42	-223.88	0		
6	L_0010550DONNELL0-001089LAMESA0C1	YES	Reached Nose	225.00	225.14	-200.91	0		

Save Auxiliary ... Load Auxiliary ... Launch QV curve tool ... ? Help Close

PV Plot



- Bus Voltage vs. Generator Output



Build Date: January 25, 2018

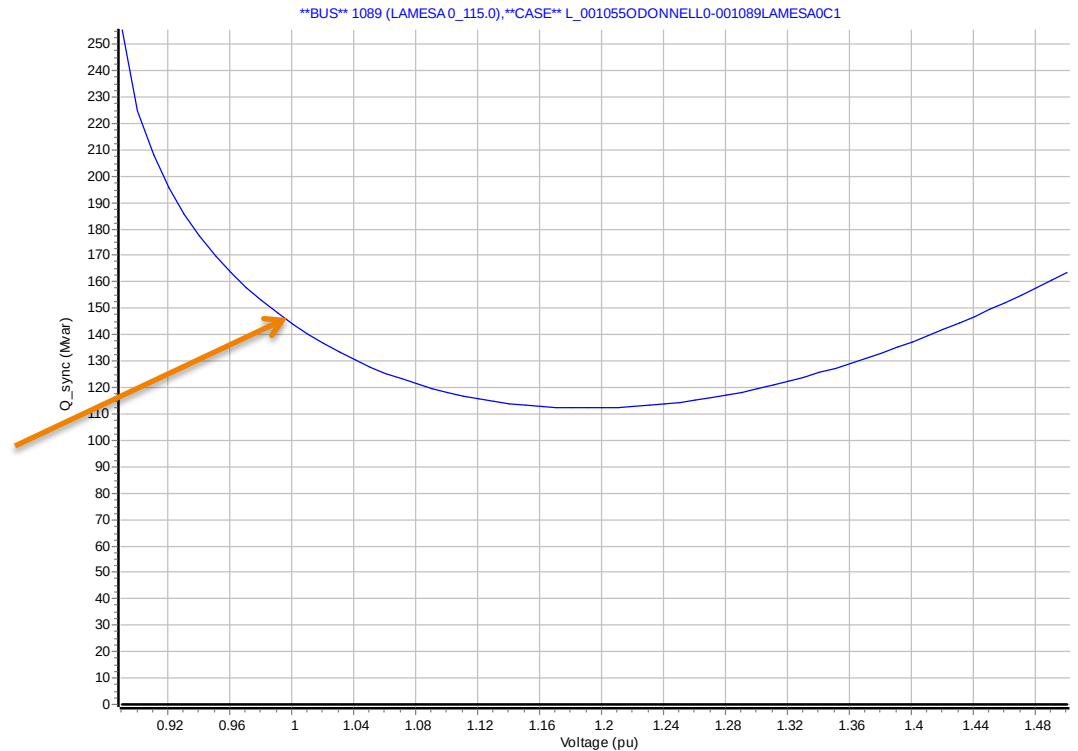
Summary



- Numerous thermal violations (ATC) caused by new interconnection at 200 MW
- Voltage margins also decrease significantly at 200 MW
- Major transmission upgrades likely needed to support this interconnection

Optional Integrated QV Analysis

- Click “Launch QV curve tool...” button to run the QV analysis at Lamesa 115 kV bus
- QV curve for outage of O Donnell – Lamesa 115 kV line at 338 MW (base case nose)
 - Negative dV/dQ at 1.0 pu voltage!
 - Cannot support this transfer without transmission upgrades



Build Date: January 25, 2018



Repeat QV at 200 MW



- Choose “Start Over” from PV Analysis
- Set Generator to regulate to 1.1 pu for better voltage support
- Add 120 Mvar Switched Shunt capacity
 - Regulate Generator Mvar between 0 and 30 Mvar
 - 12 steps at 10 Mvar per step

Switched Shunt Information for Present

Bus Number: 1089 Find By Number
Bus Name: LAMESA 0 Find By Name
Shunt ID: 1 Find ...
Labels: no labels

Status: ☐ Open ☒ Closed
Energized: ☐ NO (Offline) ☒ YES (Online)
Status Branch: Choose Branch Remove

Parameters Control Options Faults Owners, Area, Zone Custom Stability GIC

Nominal Mvar: 120.0
Actual Mvar: 145.2

Auto Control? ☒ YES ☐ NO

Control Mode:
☐ Fixed
☒ Discrete
☐ Continuous
☐ Bus Shunt (Fixed)
☐ SVC

Control Options:
☒ Area Shunt Control Enabled
☒ Case Shunt Control Enabled

Control Regulation Settings:
☐ Voltage High Value: 30.000 Mvar
☒ Generator Mvar Low Value: 0.000 Mvar
☐ Wind Mvar Target Value: 15.000 Mvar
☐ Custom Control Reg. Value: 49.7164 Mvar
Reg. Bus #: 1089
Var Regulation Sharing: 1.00
Reg. Bus PU Voltage to Mvar Sensitivity: 0.000001

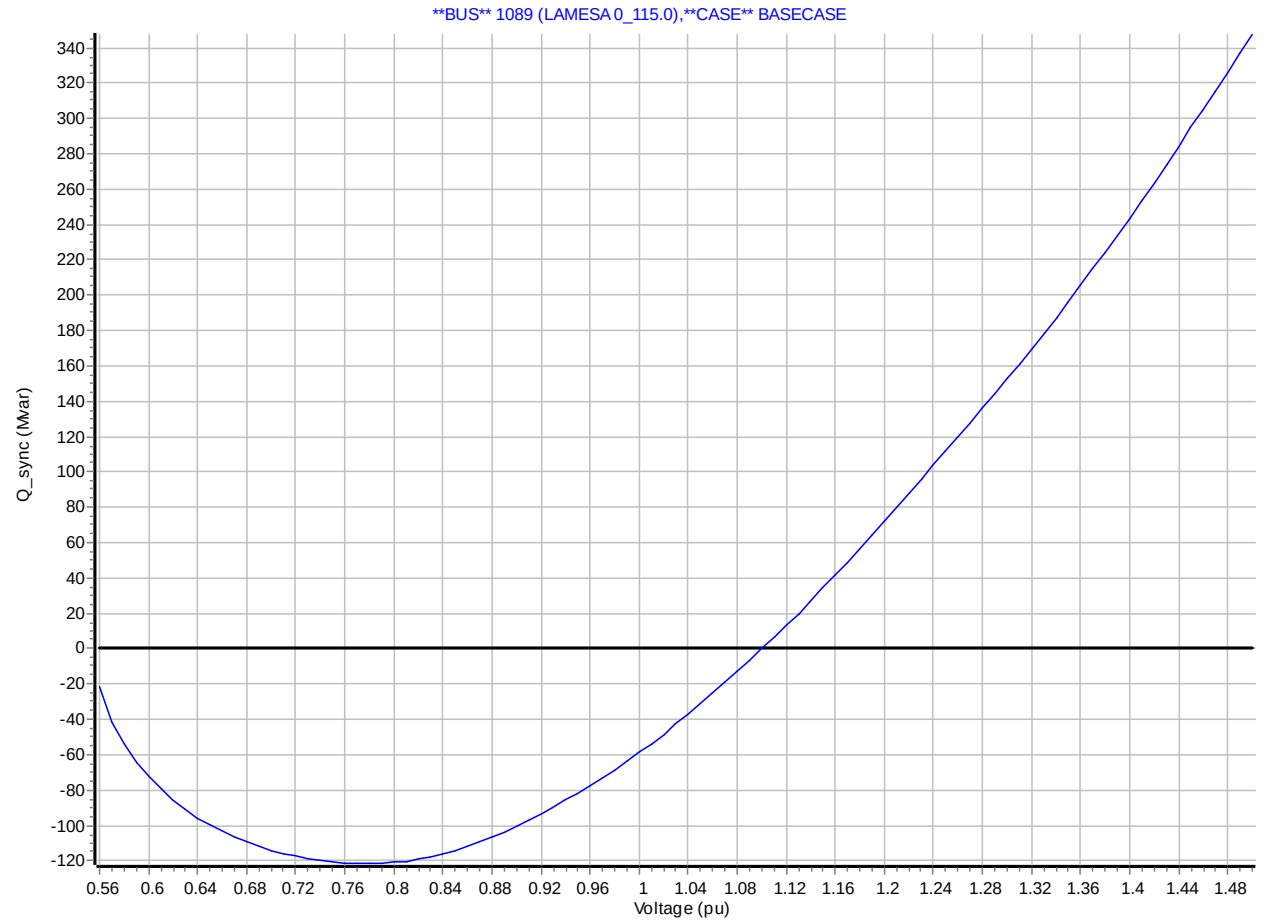
Voltage Control Group: Not in a Group Add New

Switched Shunts Mvar Blocks:
Number of Steps: 12
Mvars per Step: 10.0

OK Cancel Save Save to Aux Help Print



Slight Improvement to QV Margins



Build Date: January 25, 2018



PV Analysis with Modifications



- Transfer capacity is improved for base case and all contingencies

The screenshot displays the PV CURVES software interface. The left sidebar shows a tree view with categories like Setup, Quantities to track, Limit violations, PV output, QV setup, PV Results, and Plots. The main window is titled 'PV Results' and contains a 'Run' button, a 'Stop' button, and a checkbox for 'Restore Initial State on Completion of Run'. Below this, a red message states 'Base case could not be solved'. A table shows the 'Present nominal shift' (450.000) and 'Present step size'. A summary table lists 'Source' and 'Sink' values for Gen MW, Load SMW, Load IMW, and Load ZMW. A message indicates 'Found 6 limiting cases.' Below this, a table with tabs 'Overview', 'Legacy Plots', and 'Track Limits' shows a list of scenarios. The table has columns for Scenario, Critical?, Critical Reason, Max Shift, Max Export, Max Import, # Viol, Worst V Viol, and W. The scenarios listed are: 1 base case, 2 L_0010550DONNELL0-0010030DONNELL10C1, 3 L_0010040DONNELL11-003133SNYDER20C1, 4 L_001054STANTON0-001056LENORAH0C1, 5 L_001089LAMESA0-001054STANTON0C1, and 6 L_0010550DONNELL0-001089LAMESA0C1. All scenarios are marked as 'Critical?' and 'Reached Nose'. The bottom of the window has buttons for 'Save Auxiliary ...', 'Load Auxiliary ...', 'Launch QV curve tool ...', 'Help', and 'Close'.

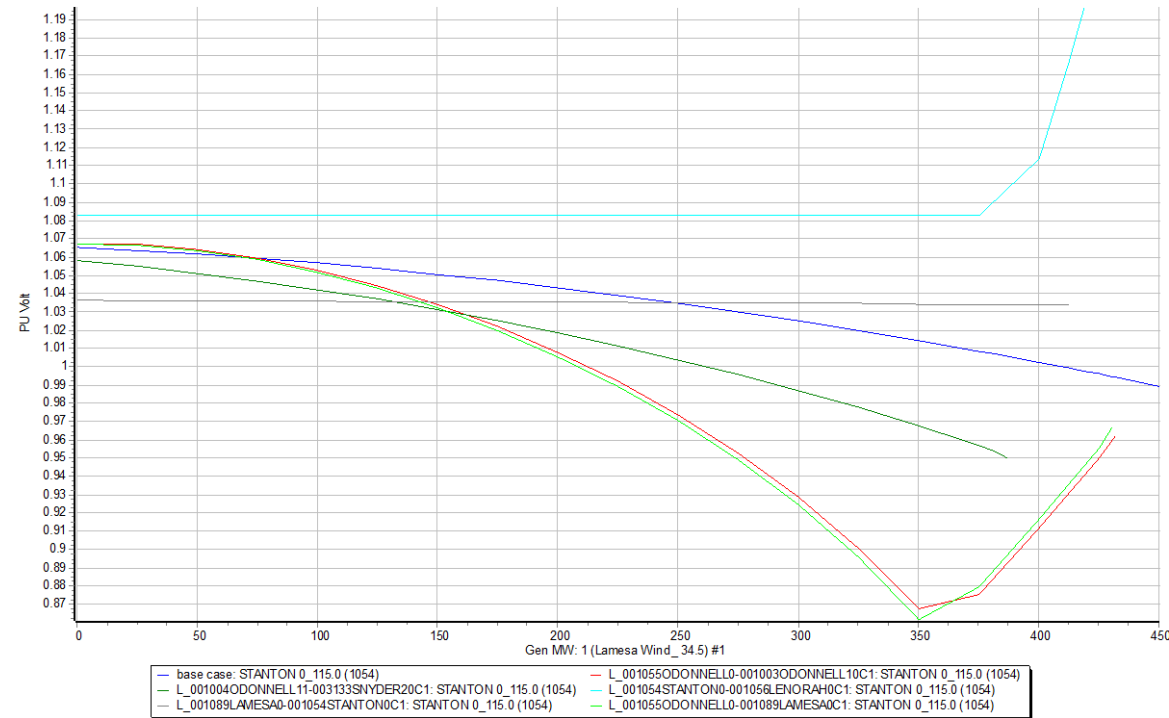
Scenario	Critical?	Critical Reason	Max Shift	Max Export	Max Import	# Viol	Worst V Viol	W
1 base case	YES	Reached Nose	450.00	450.00	-368.54	0		
2 L_0010550DONNELL0-0010030DONNELL10C1	YES	Reached Nose	431.25	431.57	-355.46	0		
3 L_0010040DONNELL11-003133SNYDER20C1	YES	Reached Nose	386.25	386.57	-325.63	0		
4 L_001054STANTON0-001056LENORAH0C1	YES	Reached Nose	418.75	418.93	-347.24	0		
5 L_001089LAMESA0-001054STANTON0C1	YES	Reached Nose	412.50	412.72	-342.86	0		
6 L_0010550DONNELL0-001089LAMESA0C1	YES	Reached Nose	430.00	430.32	-354.73	0		



PV Analysis with Modifications

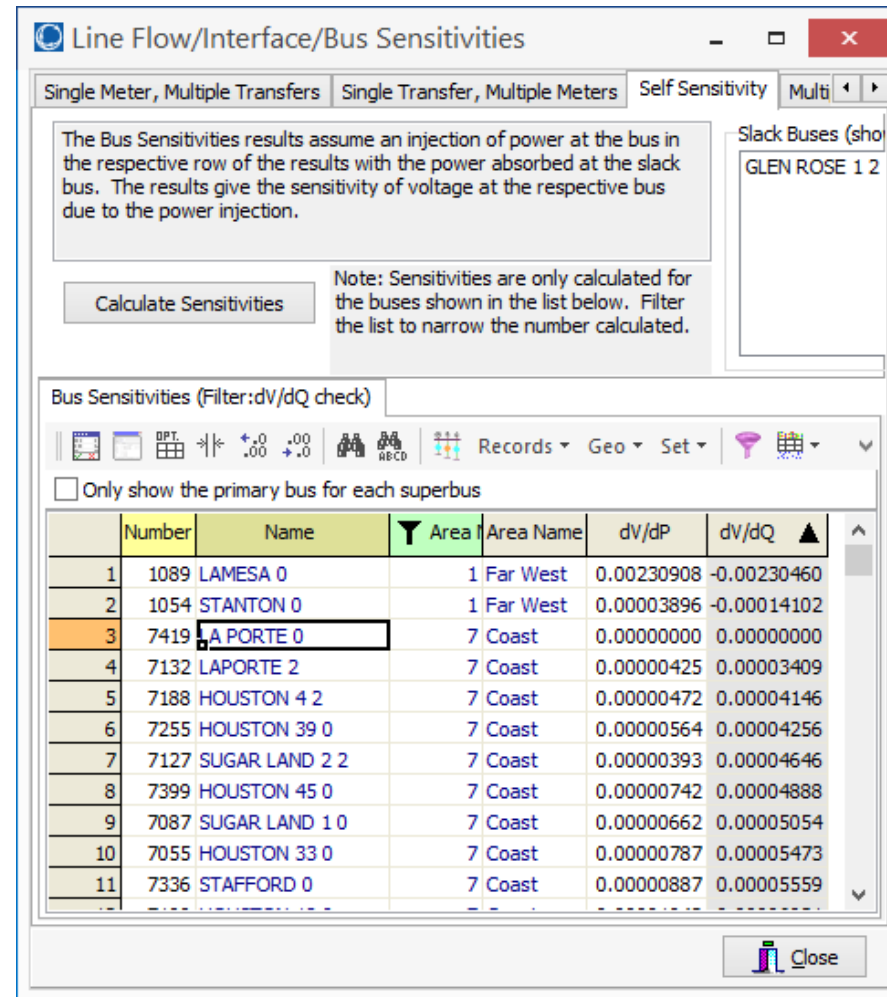


- dV/dQ appears negative near PV margin!
- Transmission upgrades still needed



dV/dQ Sensitivities

- 400 MW transfer
- O DONNELL 0 – O DONNELL 1 0, 115 kV out of service
- Negative dV/dQ at Lamesa and Stanton



The Bus Sensitivities results assume an injection of power at the bus in the respective row of the results with the power absorbed at the slack bus. The results give the sensitivity of voltage at the respective bus due to the power injection.

Note: Sensitivities are only calculated for the buses shown in the list below. Filter the list to narrow the number calculated.

Slack Buses (shown): GLEN ROSE 1 2

Calculate Sensitivities

Bus Sensitivities (Filter: dV/dQ check)

☐ Only show the primary bus for each superbus

	Number	Name	Area	Area Name	dV/dP	dV/dQ
1	1089	LAMESA 0	1	Far West	0.00230908	-0.00230460
2	1054	STANTON 0	1	Far West	0.00003896	-0.00014102
3	7419	LAPORTE 0	7	Coast	0.00000000	0.00000000
4	7132	LAPORTE 2	7	Coast	0.00000425	0.00003409
5	7188	HOUSTON 4 2	7	Coast	0.00000472	0.00004146
6	7255	HOUSTON 39 0	7	Coast	0.00000564	0.00004256
7	7127	SUGAR LAND 2 2	7	Coast	0.00000393	0.00004646
8	7399	HOUSTON 45 0	7	Coast	0.00000742	0.00004888
9	7087	SUGAR LAND 1 0	7	Coast	0.00000662	0.00005054
10	7055	HOUSTON 33 0	7	Coast	0.00000787	0.00005473
11	7336	STAFFORD 0	7	Coast	0.00000887	0.00005559

Close

Slide Intentionally Left Blank

Slide Intentionally Left Blank

Slide Intentionally Left Blank