

# Steady-State Power System Security Analysis with PowerWorld Simulator

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## S8: Security Analysis for a Generator Interconnection Study



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# Generator Interconnection Study

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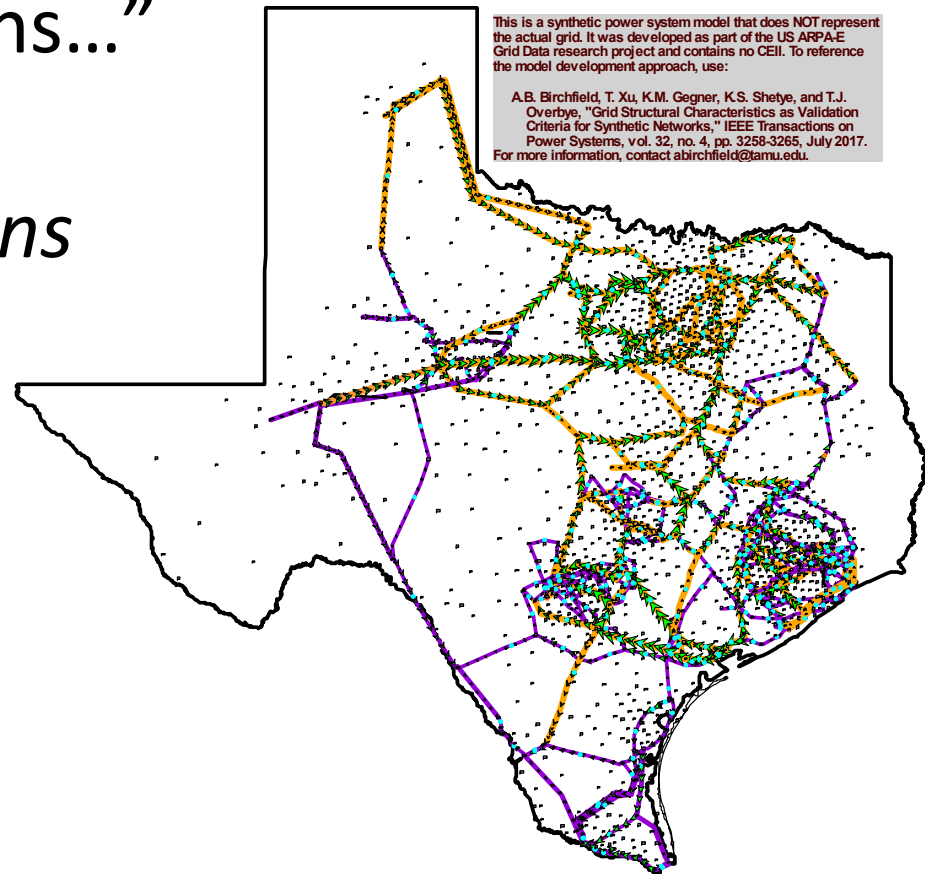


- This session encompasses several types of analysis that might be performed as part of an interconnection study for a proposed generator
  - Contingency Analysis: Comparison of Contingent Overloads with and without proposed unit
  - PTDF: Visualize incremental flows from proposed unit
  - ATC: How much 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:  $R = 0.0024$ ,  $X = 0.086$ , 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: Recent, Network, Aggregations (Areas, Balancing Authorities, Bus Pairs, Data Maintainers, Injection Groups, Interfaces, Islands, Multi-Section Lines, MW Transactions, Nomograms, Owners, Substations, Super Areas)

Injection Groups | Areas | Buses | MW Transactions

Filter: Advanced | Injection Group | Find... Remove Quick Filter

	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

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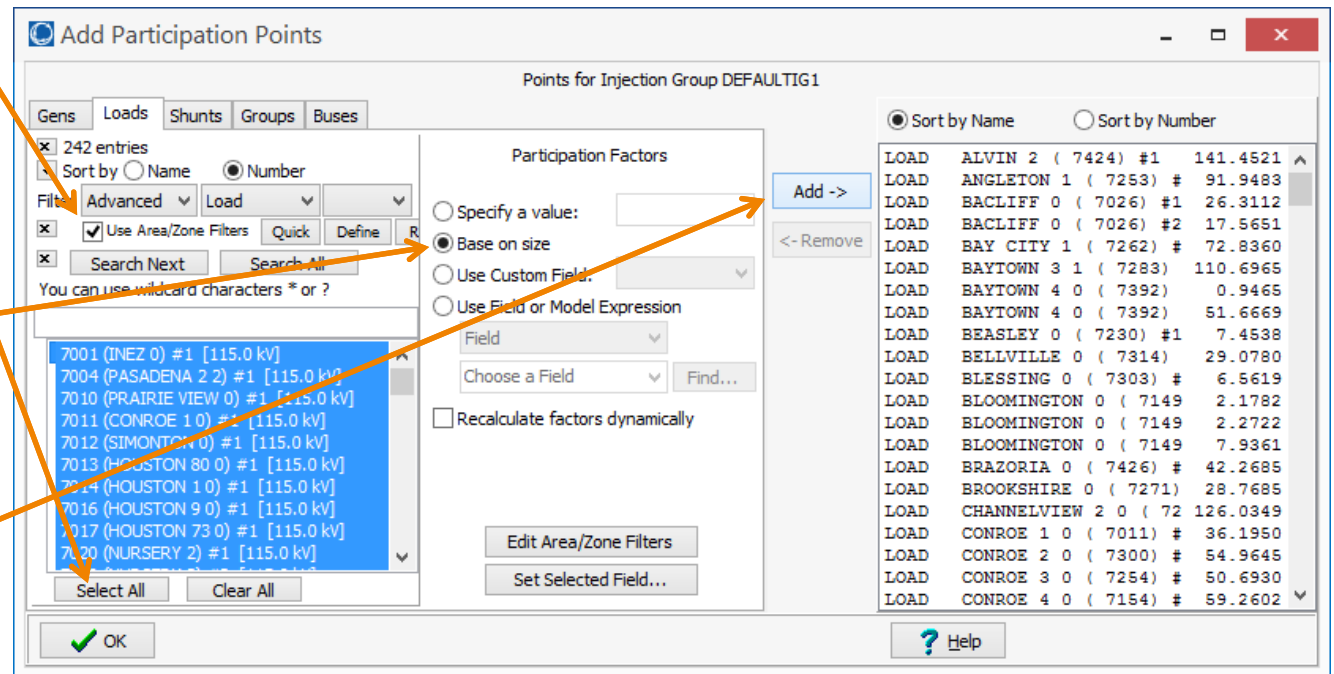


- Group “Lamesa” contains only the new generator at Bus 1
- Group “Coast Load” contains all loads in Area 7 (Coast), with participation factors set to the size of the load
- Add these groups manually or load from *aux2030InjectionGroups.aux*

# 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

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- 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**

# Limit the Areas for which contingency area defined



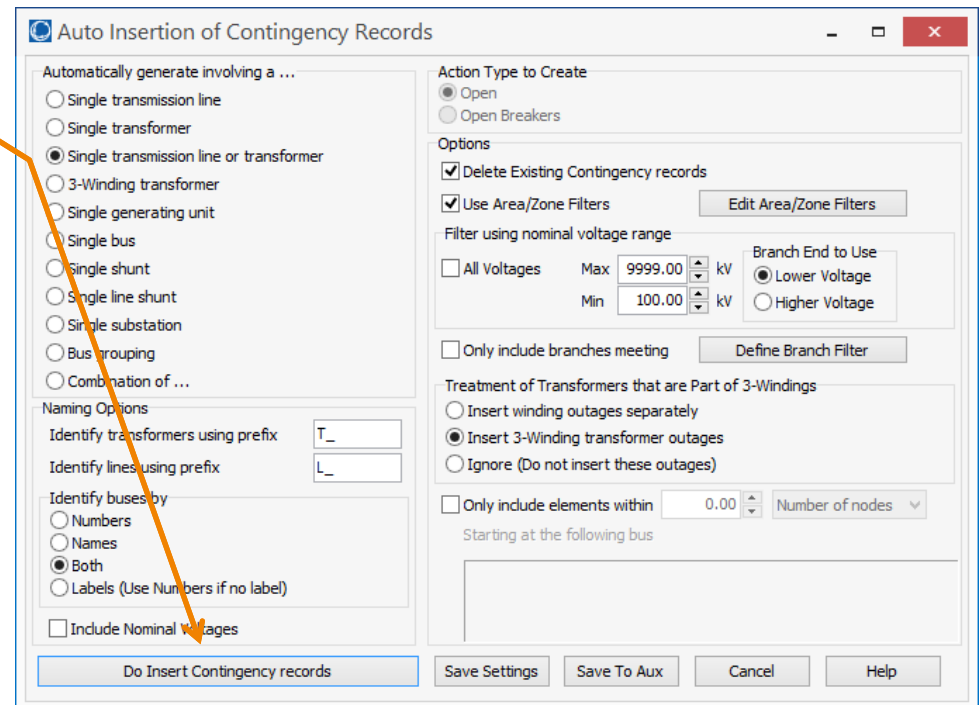
- Modify the Area/Zone Filters so that all areas are set to Shown = NO
- Then set the following 3 areas to YES
  - 1 (Far West)
  - 7 (Coast)
  - 10 (Lamesa)
- Click **Close**

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

# Insert the Contingencies



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



# 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

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  $\geq 0.05$
- Report changes in bus dV/dQ sensitivity at least 5x greater than reference state, advanced filter on buses with  $\geq 5$  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

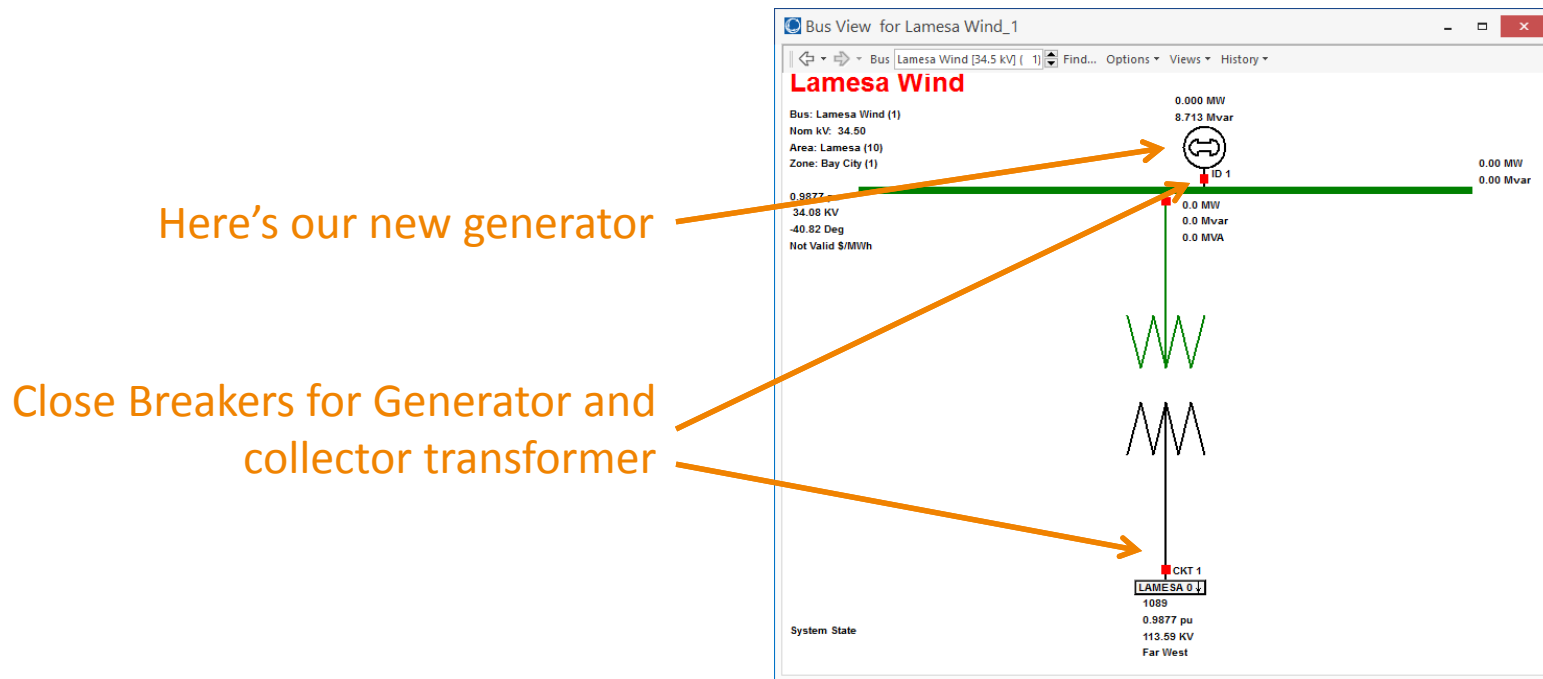
What to Store

- 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



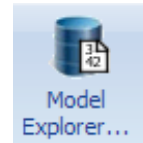
- Study the hypothetical new 200 MW generator at Lamesa
- Open Bus View Online and navigate to Bus 1



# 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	5557.98	1	Far West	Part. AGC	3009.07	1
2	5955.41	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	17844.07	6	South Central	Part. AGC	11830.68	12
7	25553.26	7	Coast	IG Slack	23699.34	18
8	1416.44	8	East	Part. AGC	3676.71	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: [dropdown]  
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 Table:

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)

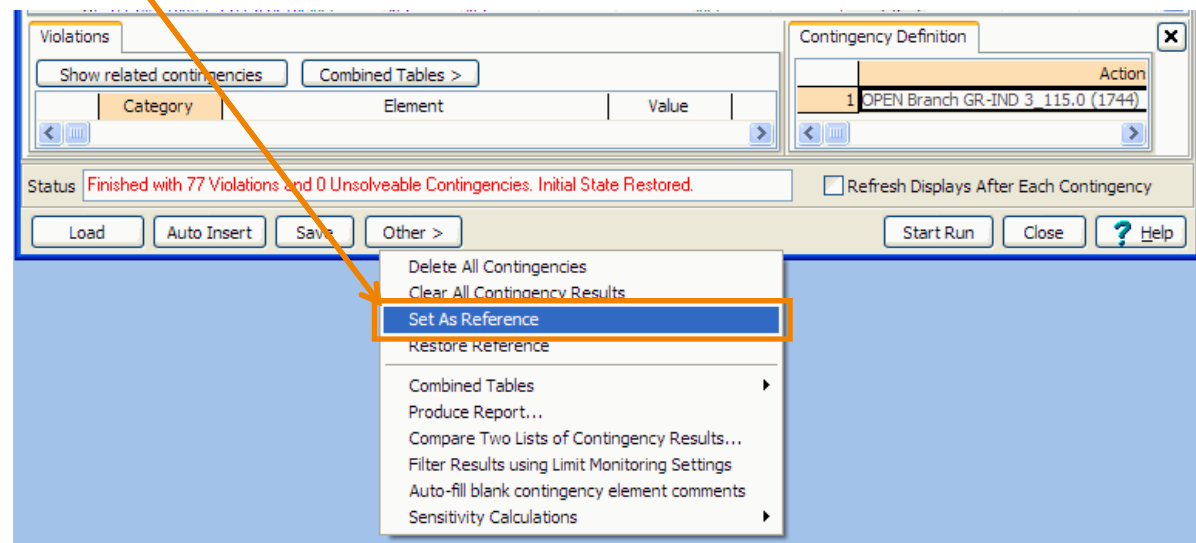
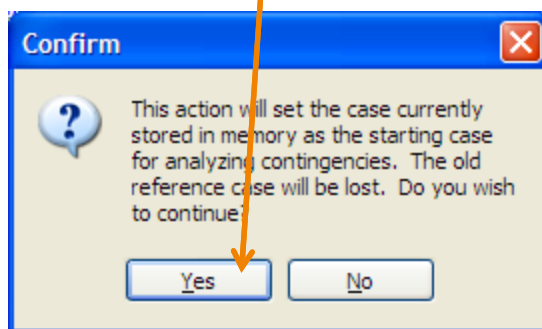
200.000 MW  
0.335 Mvar

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

- 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

# 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

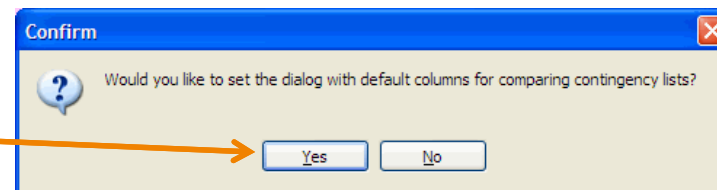
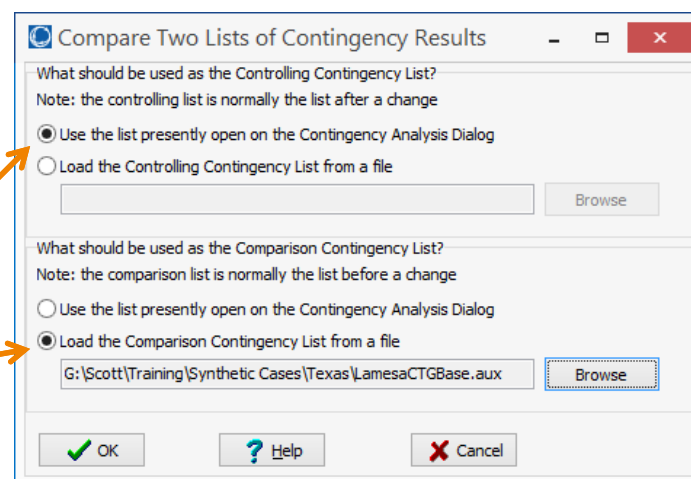
- *LamesaCTGBase.aux*

- 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



Contingency Analysis

Contingencies Options Results

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_L_001089LAMESA0-001054STANTON0C1	NO		YES	YES	YES	YES	NO	none	2	0	2	163.8		63.8	
2_L_001055ODONNELLO-001089LAMESA0C1	NO		YES	YES	YES	YES	NO	none	1	0	1	162.3		62.3	
3_L_001055ODONNELLO-001003ODONNELL10C1	NO		YES	YES	YES	YES	NO	none	1	0	1	158.3		58.3	
4_L_001054STANTONO-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	Per	Comp P
1	Branch MVA LAMESA 0 ( 1089 ) -> ODONNELL 0 ( 1055) CKT 1 at LAMESA 0	Controlling	160.51			98.00			163.78	
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.  Refresh Displays After Each Contingency

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_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	

Category	Element	Source List	Value	Comp Value	Diff Value	Limit	Comp Limit	Diff Limit	Per	Comp Percent	Diff
1	Branch MVA LAMESA 0 ( 1089) -> ODONNELL 0 ( 1055) CKT 1 at LAMESA 0	Controlling	140.70			98.00			143.57		
2	Branch MVA ODONNELL 0 ( 1055) -> O DONNELL 1 0 ( 1003) CKT 1 at ODONNELL 0	Controlling	133.83			98.00			136.56		

- LAMESA 0 – ODONNELL 0 went from no overload to 143.0%: treated as 43.0% for “Worst comparison
- ODONNELL 0 – O DONNELL 1 0 went from no overload to 136.0%: treated as 36.0% for “Worst” comparison
- Thus LAMESA 0 – ODONNELL 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

Records Geo Set Columns Options

Lines/Transformers (filtered)

	From Number	From Name	To Number	To Name	Circuit	Xfmr	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
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.  Refresh Displays After Each Contingency

Load Auto Insert Save Other > 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 in 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	Xfmr	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 Violations Combined Tables >										
	Label	Category	Source List	Value	Comp Value	Diff Value	Limit	Pert	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

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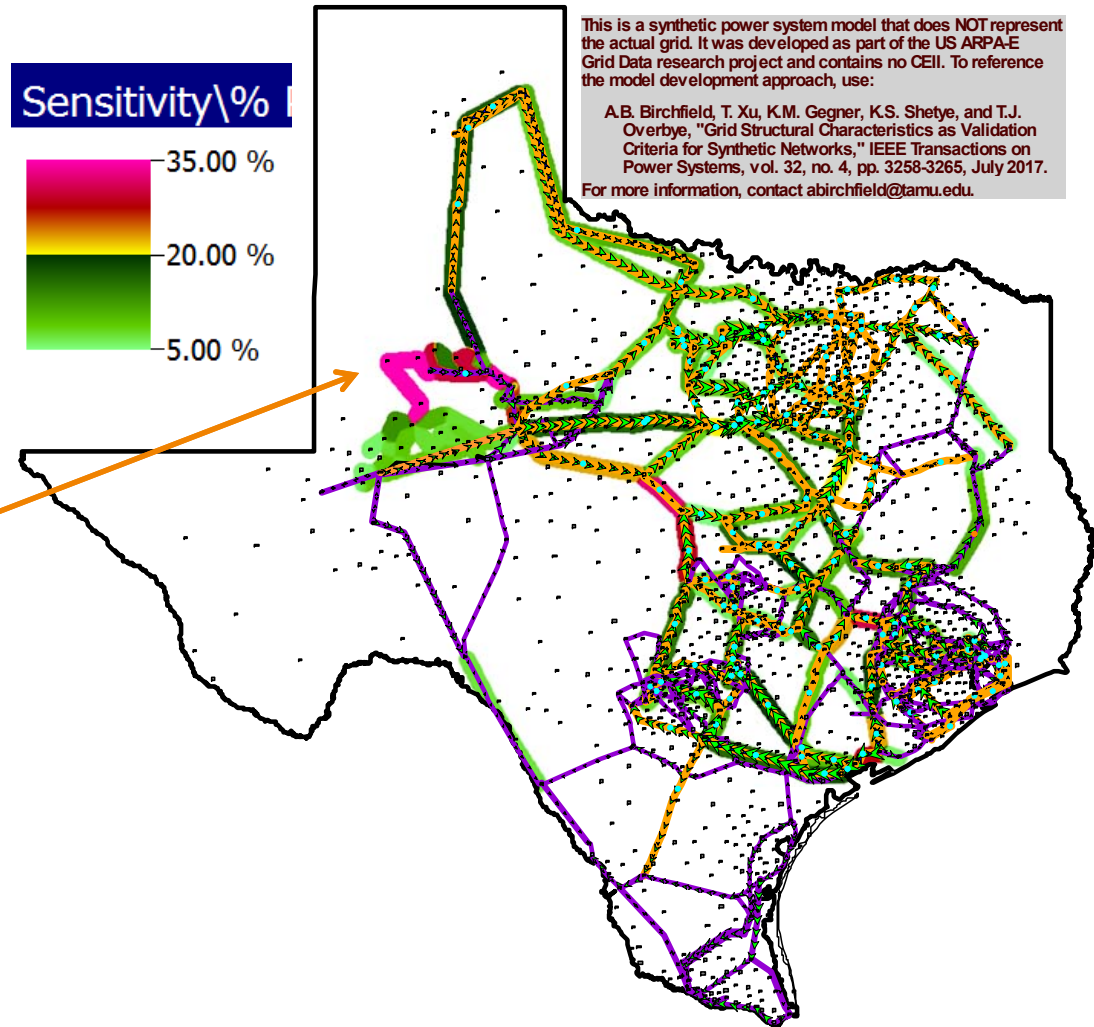


- Next, examine how incremental power from the proposed unit would flow through the system
- Shut off proposed unit by disabling transfer between area Lamesa and area Coast
- Open PTDF tool (Tools → Sensitivities → Power Transfer Distribution Factors)
- Choose Injection Group “Lamesa” as Seller, Injection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

# PTDF Visualization



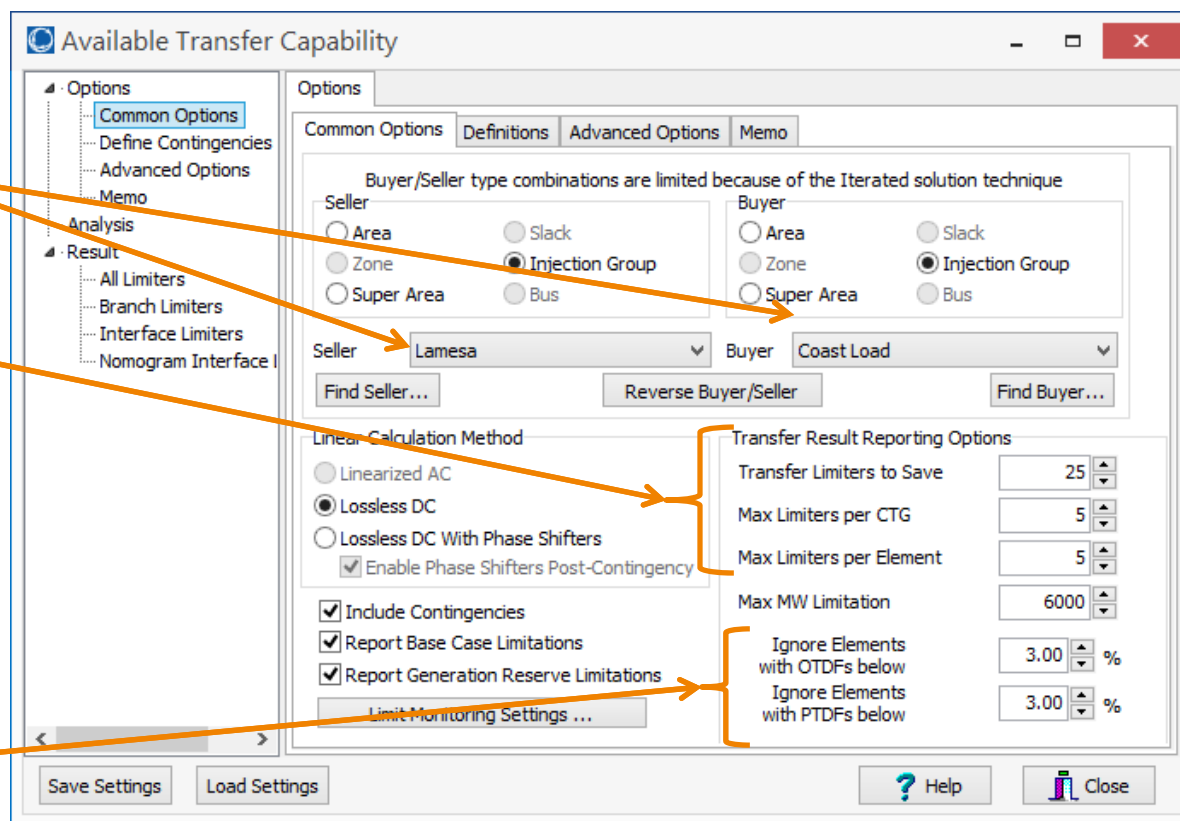
- Color contour
- 5%-35% range
- Ignore zero values, below min
- Lamesa



# Available Transfer Capability



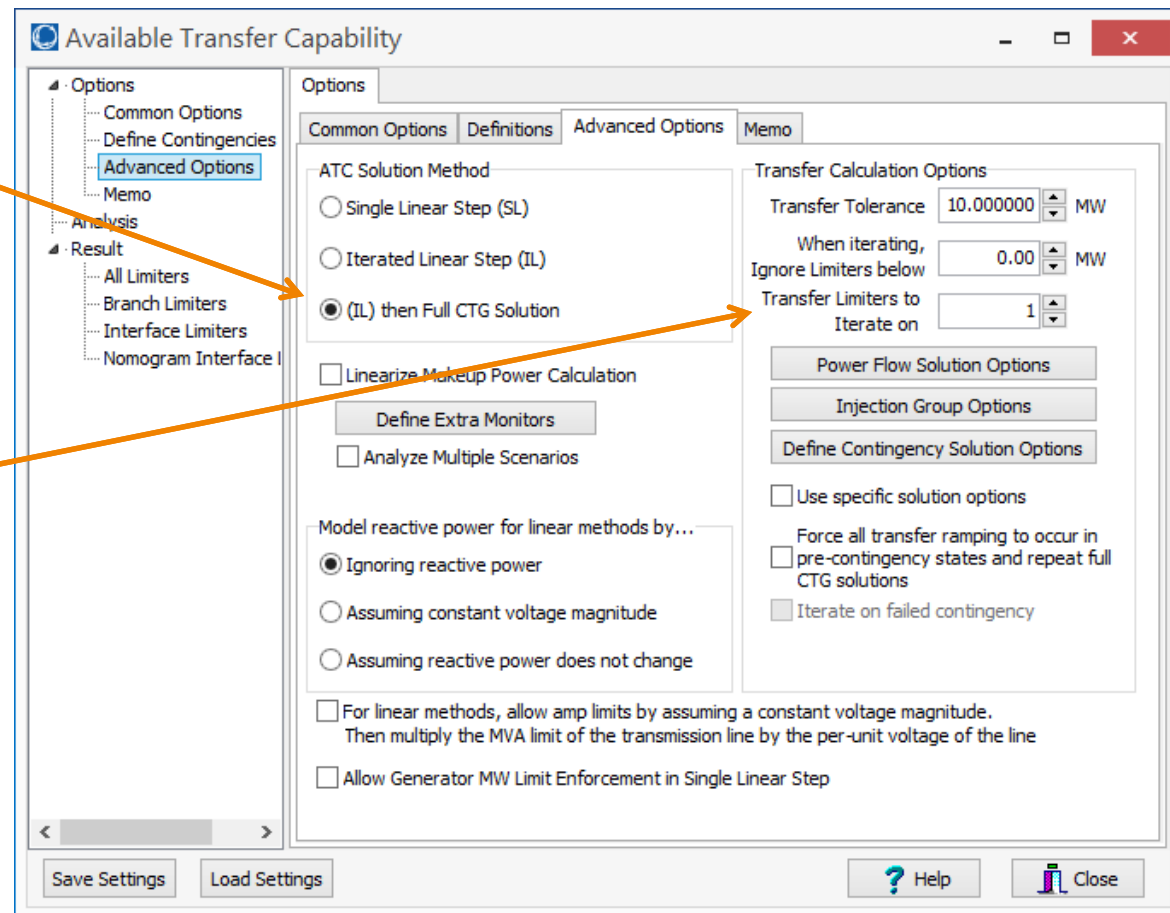
- Keep Seller and Buyer selections the same as PTDF
- Save 25 Limiters, 5 per CTG, 5 per element
- Ignore Elements with OTDF/PTDF below 3%



# Available Transfer Capability



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



# ATC Results



Overloads to remediate so proposed plant may be operated at full capacity without thermal security violations

	Trans Lim	Limiting Element	Limiting CTG	% OTDF	Pre-Trans Est	Limit Used
1	108.50	Line COAHOMA 0 (1028) TO FLUVANNA 10 (3109) CKT 1 [115.00 - 115.00] L_0010040DONNELL11-003133SNYDER20C1		53.67	245.75	250.00
2	123.08	Transformer FLUVANNA 2 1 (3097) TO FLUVANNA 2 0 (3096) CKT 1 [L_0010040DONNELL11-003133SNYDER20C1		26.83	155.73	162.00
3	123.08	Transformer FLUVANNA 2 1 (3097) TO FLUVANNA 2 0 (3096) CKT 2 [L_0010040DONNELL11-003133SNYDER20C1		26.83	155.73	162.00
4	124.48	Line LAMESA 0 (1089) TO STANTON 0 (1054) CKT 1 [115.00 - 115.00] L_0010040DONNELL11-003133SNYDER20C1		46.33	86.53	98.00
5	136.02	Line ODONNELL 0 (1055) TO LAMESA 0 (1089) CKT 1 [115.00 - 115.00] T_001079ODESSA18-001071ODESSA10C1		-61.45	-75.69	-98.00
6	138.85	Line ODONNELL 0 (1055) TO LAMESA 0 (1089) CKT 1 [115.00 - 115.00] L_001089LAMESA0-001054STANTON0C1		-100.00	-58.87	-98.00
7	139.05	Line LAMESA 0 (1089) TO STANTON 0 (1054) CKT 1 [115.00 - 115.00] L_001055ODONNELLO-001089LAMESA0C1		100.00	58.67	98.00
8	142.82	Line ODONNELL 0 (1055) TO O DONNELL 1 0 (1003) CKT 1 [115.00 - 115.00] T_001079ODESSA18-001071ODESSA10C1		61.45	71.52	98.00
9	143.03	Line ODONNELL 0 (1055) TO O DONNELL 1 0 (1003) CKT 1 [115.00 - 115.00] L_001089LAMESA0-001054STANTON0C1		100.00	54.69	98.00
10	143.03	Line LAMESA 0 (1089) TO STANTON 0 (1054) CKT 1 [115.00 - 115.00] L_001055ODONNELLO-001003ODONNELL10C1		100.00	54.69	98.00
11	151.72	Line FLUVANNA 1 0 (3109) TO FLUVANNA 2 1 (3097) CKT 1 [115.00 - 115.00] L_0010040DONNELL11-003133SNYDER20C1		53.67	312.09	340.00
12	155.67	Line ODONNELL 0 (1055) TO LAMESA 0 (1089) CKT 1 [115.00 - 115.00] L_001054STANTON0-001056LENORAH0C1		-100.00	-42.05	-98.00
13	159.84	Line ODONNELL 0 (1055) TO O DONNELL 1 0 (1003) CKT 1 [115.00 - 115.00] L_001054STANTON0-001056LENORAH0C1		100.00	37.87	98.00
14	188.39	Line LAMESA 0 (1089) TO STANTON 0 (1054) CKT 1 [115.00 - 115.00] L_001028COAHOMA0-003109FLUVANNA10C1		46.12	57.10	98.00
15	195.76	Line LAMESA 0 (1089) TO STANTON 0 (1054) CKT 1 [115.00 - 115.00] T_0010040DONNELL11-001003ODONNELL10C1		46.33	53.50	98.00
16	199.59	Line ODONNELL 0 (1055) TO LAMESA 0 (1089) CKT 1 [115.00 - 115.00] T_001023ODONNELL21-001022ODONNELL20C1		-59.97	-38.11	-98.00
17	200.00	InjectionGroup Lamesa	Base Case	0.00	0.00	0.00
18	204.61	Line ODONNELL 0 (1055) TO LAMESA 0 (1089) CKT 1 [115.00 - 115.00] L_001056LENORAH0-001027MIDLAND20C1		-61.94	-33.04	-98.00
19	206.56	Line ODONNELL 0 (1055) TO O DONNELL 1 0 (1003) CKT 1 [115.00 - 115.00] T_001023ODONNELL21-001022ODONNELL20C1		59.97	33.93	98.00
20	206.87	Line STANTON 0 (1054) TO LENORAH 0 (1056) CKT 1 [115.00 - 115.00] L_001055ODONNELLO-001089LAMESA0C1		100.00	41.85	149.00

# 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

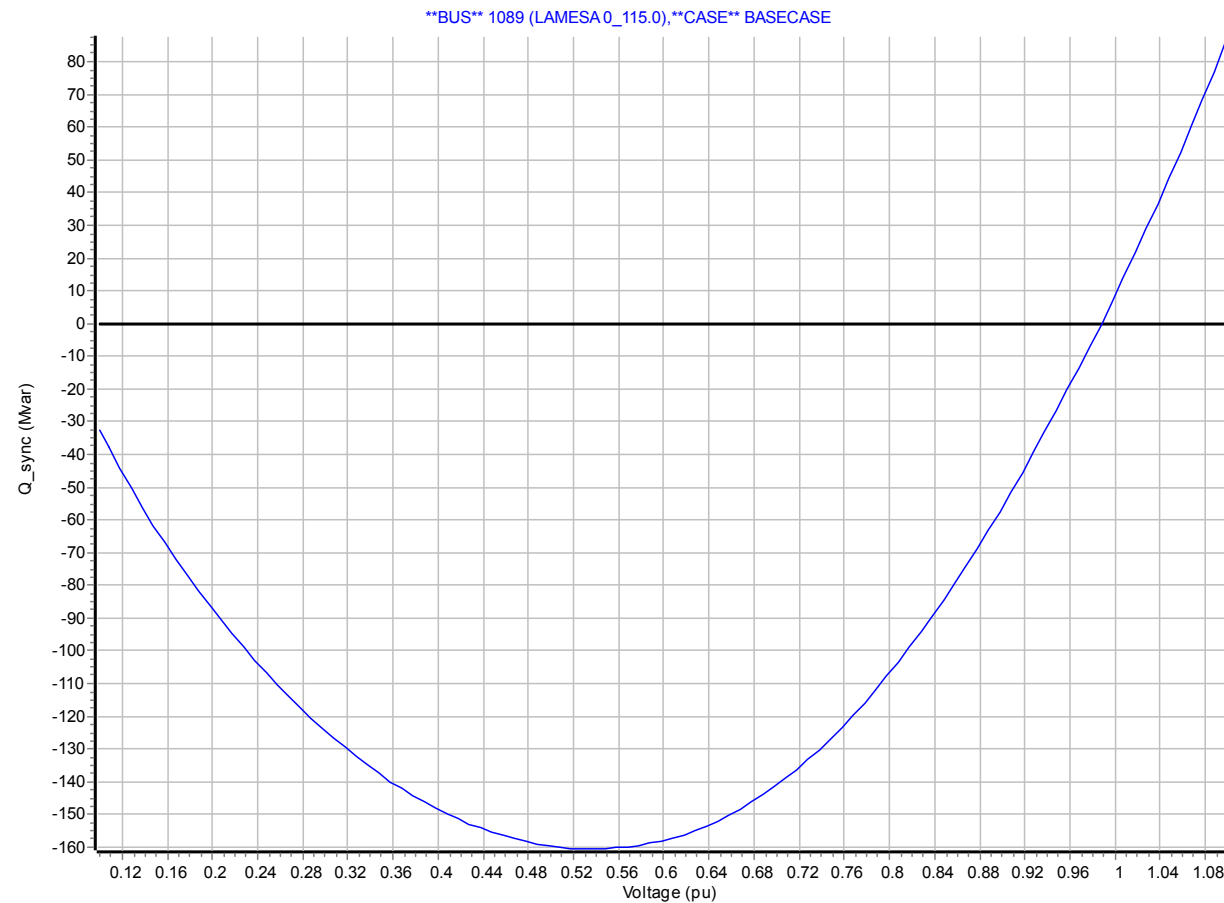


- Plot QV curves at bus 1089 (Lamesa 115 kV)
  - First, without proposed generator; then with
  - To quickly interconnect new generator
    - load *aux2000MasterInterconnectSetup.aux*
    - Close transformer between buses 1 and 1089 and generator
    - enable the transaction between area 10 and area 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 *LouisianaGeneratorQVOptionsCough.aux*

# QV Curve without Proposed Unit



- Q margin = 161 MVar

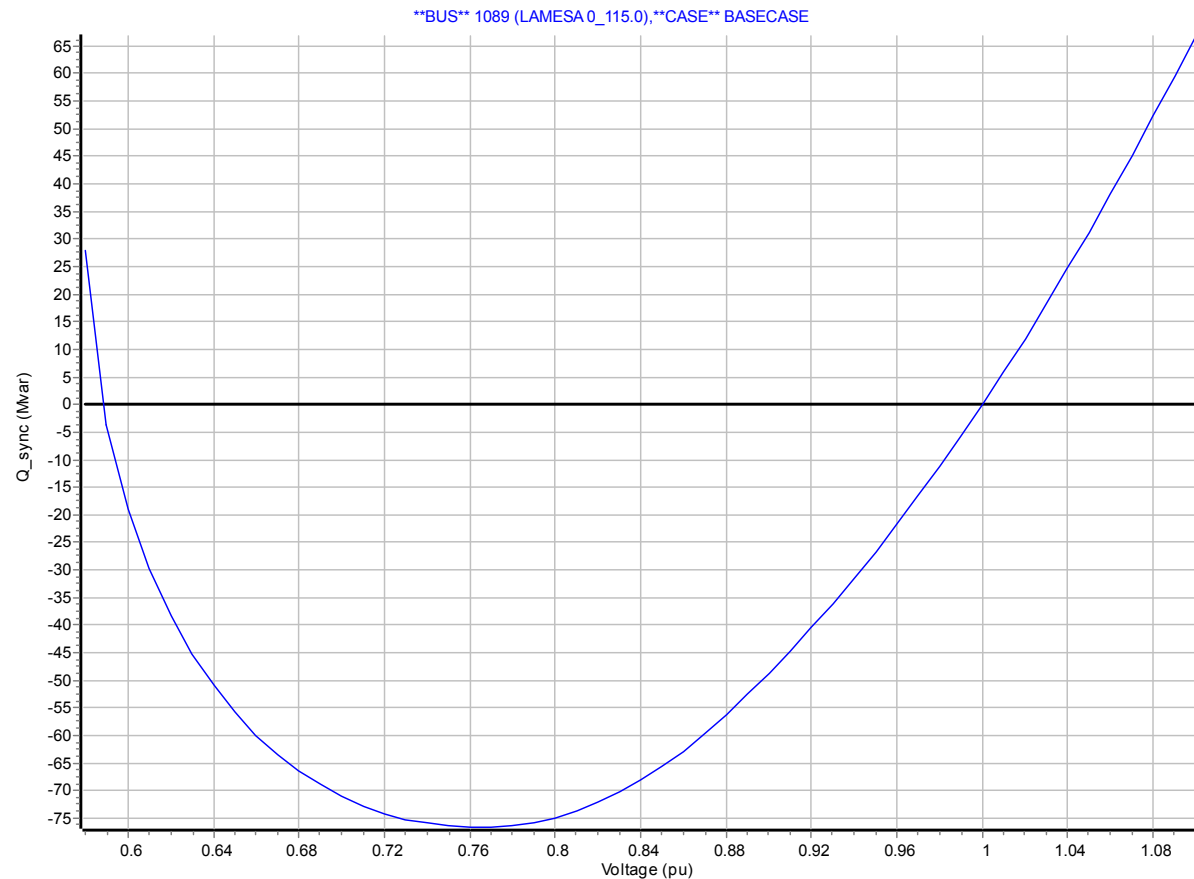


Build Date: January 25, 2018

# 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

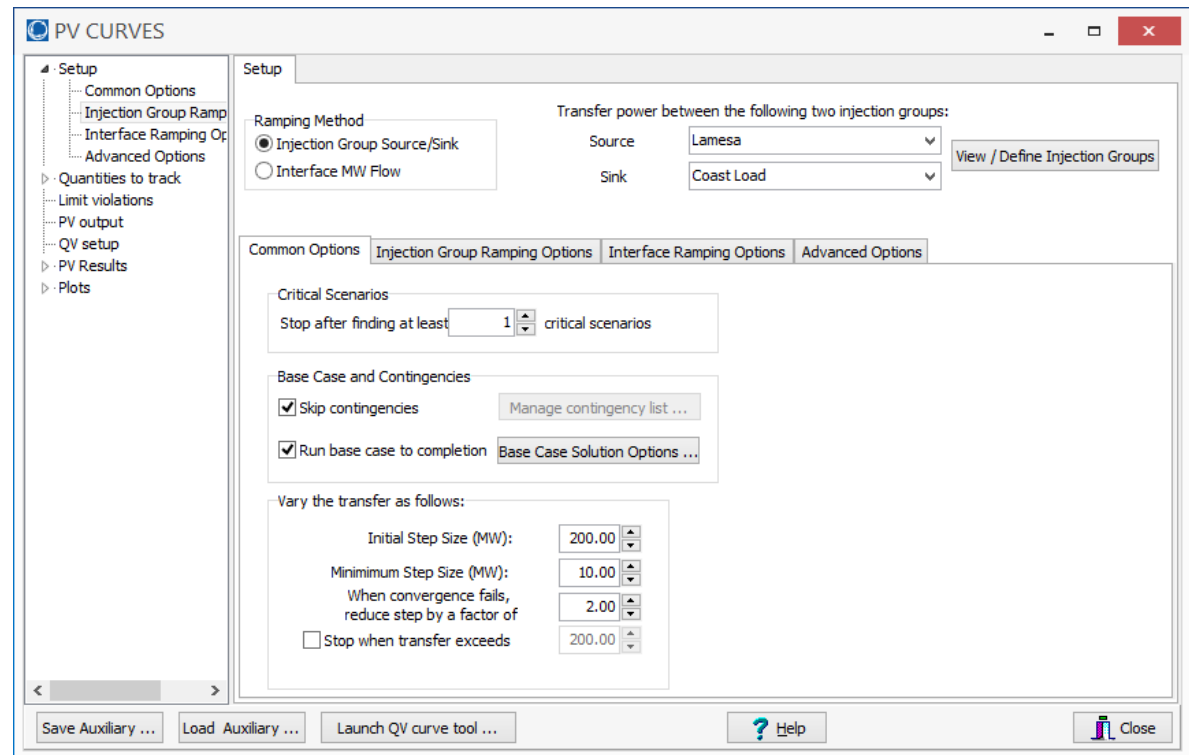


- Examine the ability to transfer power from the proposed generator to loads in area 7
- Contingency screening process
  - Run PV on base case only (Skip Contingencies)
  - Repeat base case only, but stop when transfer gets to about 80% of the level of the nose point
  - Run contingency analysis on this 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



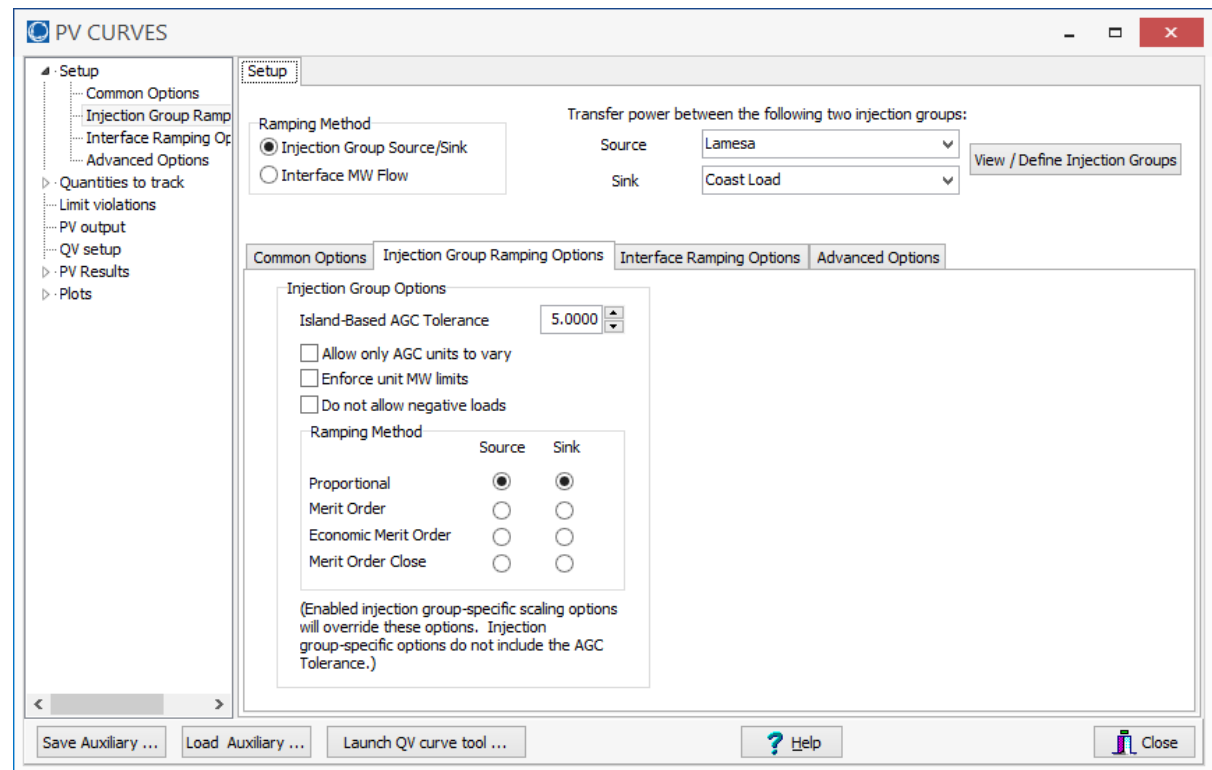
- Source as Lamesa; sink as Coast Load
- Stop after 1 critical scenario
- Skip contingencies; Run base case to completion
- 200 MW Initial Step Size, 10 MW minimum



# 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:

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

View detailed results

Other actions >>

Found 1 limiting case.

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

	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 %	M
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

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	Min N 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							

Category	Element	Value	Limit	Per	Area Name Assoc.	Nom KV Assoc.
1 Branch MVA	LAMESA 0 ( 1089) -> STANTON 0 ( 1054) CKT 1 at LAMESA 0	183.35	98.00	187.09	Far West	115.00
2 Branch MVA	STANTON 0 ( 1054) -> LENORAH 0 ( 1056) CKT 1 at LENORAH 0	172.49	149.00	115.77	Far West	115.00
3 Change Bus Low Volts	STANTON 0 (1054)	0.9166	0.9000	92.42	Far West	115.00
4 Change Bus dV/dQ	LAMESA 0 (1089)	0.07226			Far West	115.00
5 Change Bus dV/dQ	STANTON 0 (1054)	0.02194			Far West	115.00

# PV Analysis with Contingencies

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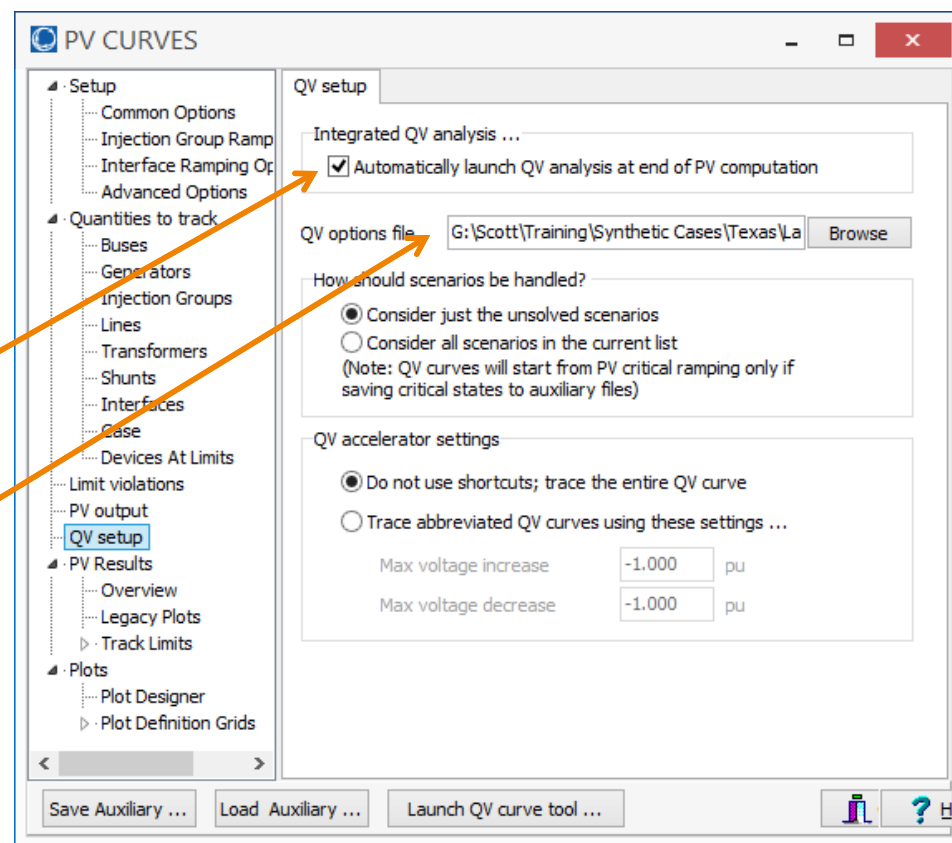


- Stop after 5 critical scenarios
- Initial Step 25 MW, Minimum Step 5 MW
- Track bus voltage at Lamesa and other vulnerable buses:
  - 1022 O DONNELL 2 0
  - 1028 COAHOMA 0
  - 1054 STANTON 0
- Track MW and Mvar Reserve at Lamesa Wind
- Settings may be loaded from *LamesaPVOptions.aux*

# Integrated QV Analysis



- Optionally select “Automatically launch QV analysis at end of PV computation” from *QV setup* tab
- Set “QV options file” to *LamesaIntegratedQVOptions.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

Source	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 >>

Present step size: [ ]

Found 6 limiting cases.

Overview Legacy Plots Track Limits

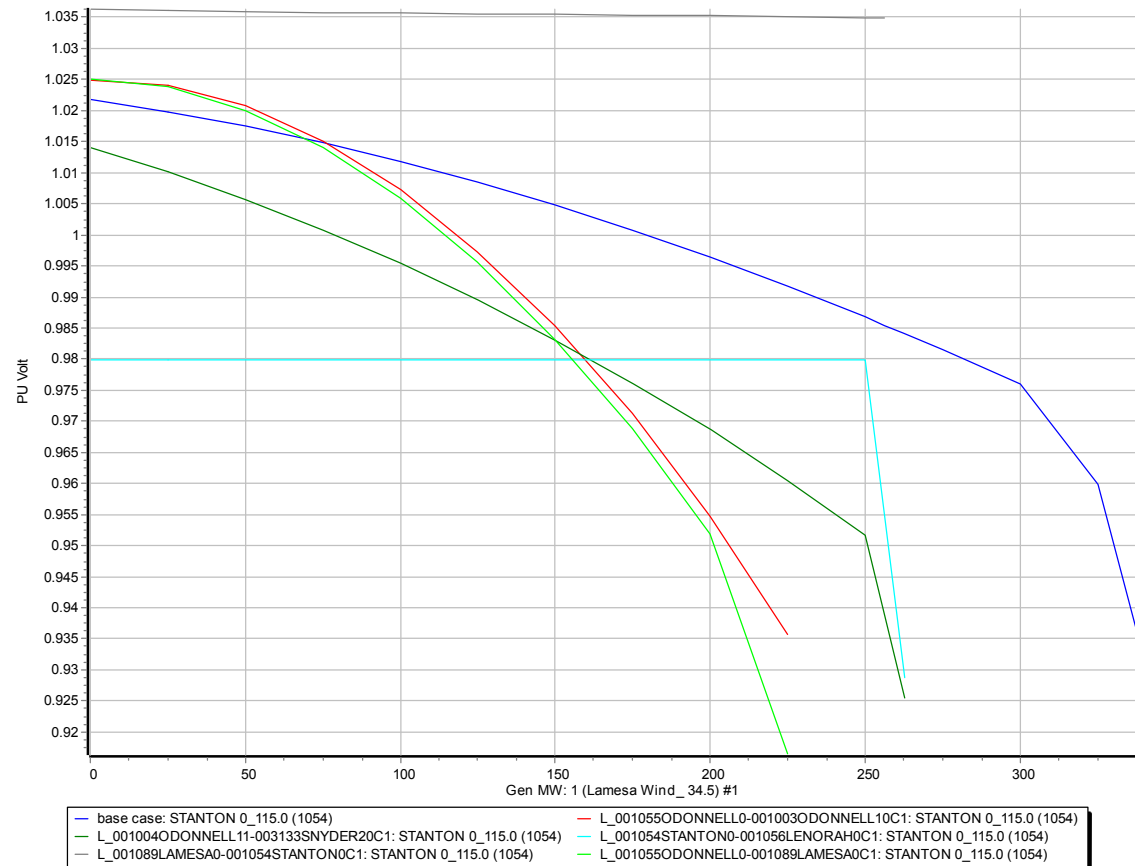
Scenario	Critical?	Critical Reason	Max Shift	Max Export	Max Import	# Viol	Worst V Viol	Worst V Bus
1 base case	YES	Reached Nose	337.50	337.50	-273.04	0		
2 L_001055ODONNELLO-001003ODONNELL10C1	YES	Reached Nose	225.00	225.11	-200.91	0		
3 L_001004ODONNELL11-003133SNYDER20C1	YES	Reached Nose	262.50	262.81	-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_001055ODONNELLO-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

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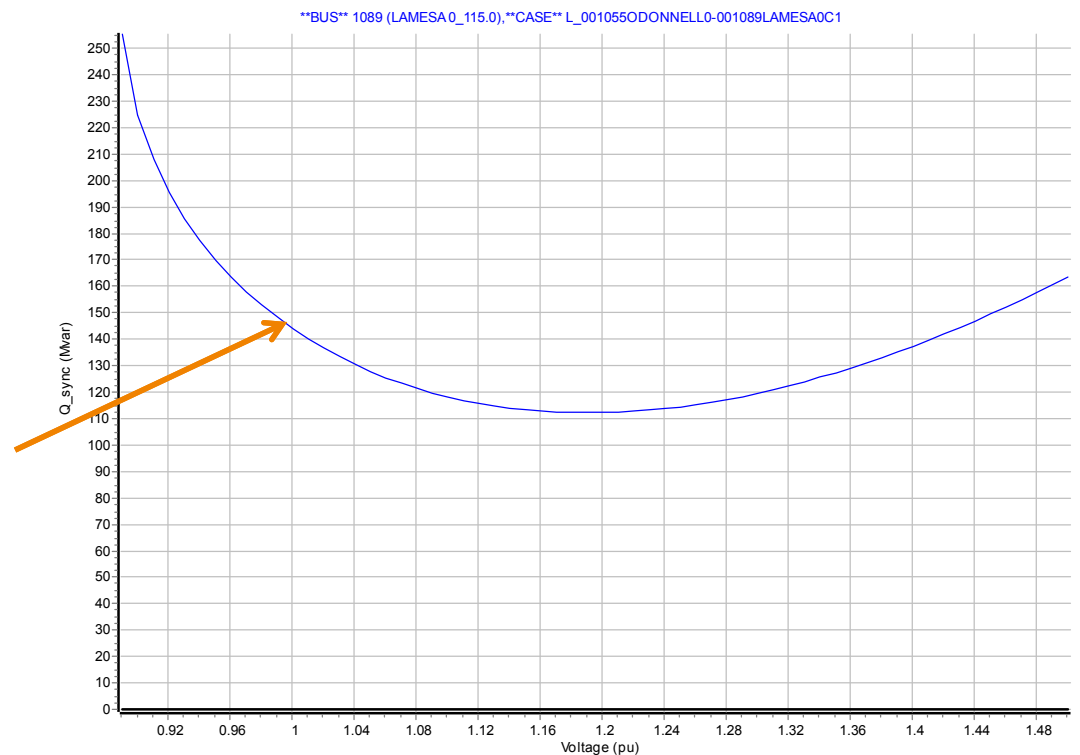


- Numerous thermal violations (ATC) caused by new interconnection at 200 MW
- Voltage margins also decrease significantly at 200 MW
- Major transmission upgrades likely needed to support this interconnection

# 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  
Bus Name: LAMESA 0  
Shunt ID: 1  
Labels: no labels

Status:  Open  Closed  
Energized:  NO (Offline)  YES (Online)

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  
 Generator Mvar  
 Wind Mvar  
 Custom Control

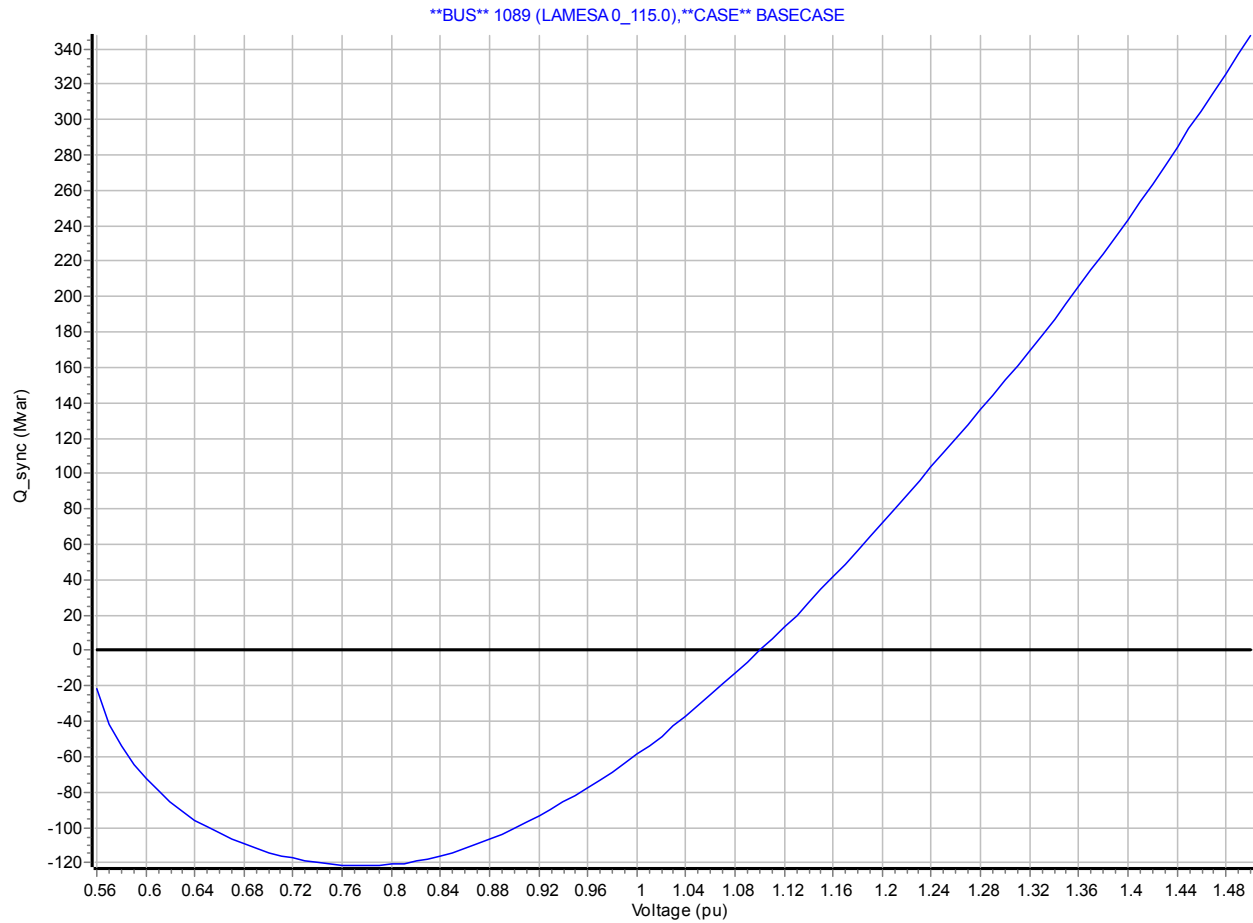
High Value: 30.000 Mvar  
Low Value: 0.000 Mvar  
Target Value: 15.000 Mvar  
Reg. Value: 49.7164 Mvar  
Reg. Bus #: 1089  
Var Regulation Sharing: 1.00  
Reg. Bus PU Voltage to Mvar Sensitivity: 0.000001

Switched Shunts Mvar Blocks:

Number of Steps	Mvars per Step
12	10.0

Buttons: 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

**PV CURVES**

**PV Results**

Run Stop  Restore Initial State on Completion of Run

Base case could not be solved

Present nominal shift: 450.000  
Present step size: [ ]

Source	Gen MW	Load SMW	Load IMW	Load ZMW
Sink	450.00	0.00	0.00	0.00
Sink	0.00	18558.16	0.00	0.00

View detailed results  
Other actions >>

Found 6 limiting cases.

Overview Legacy Plots Track Limits

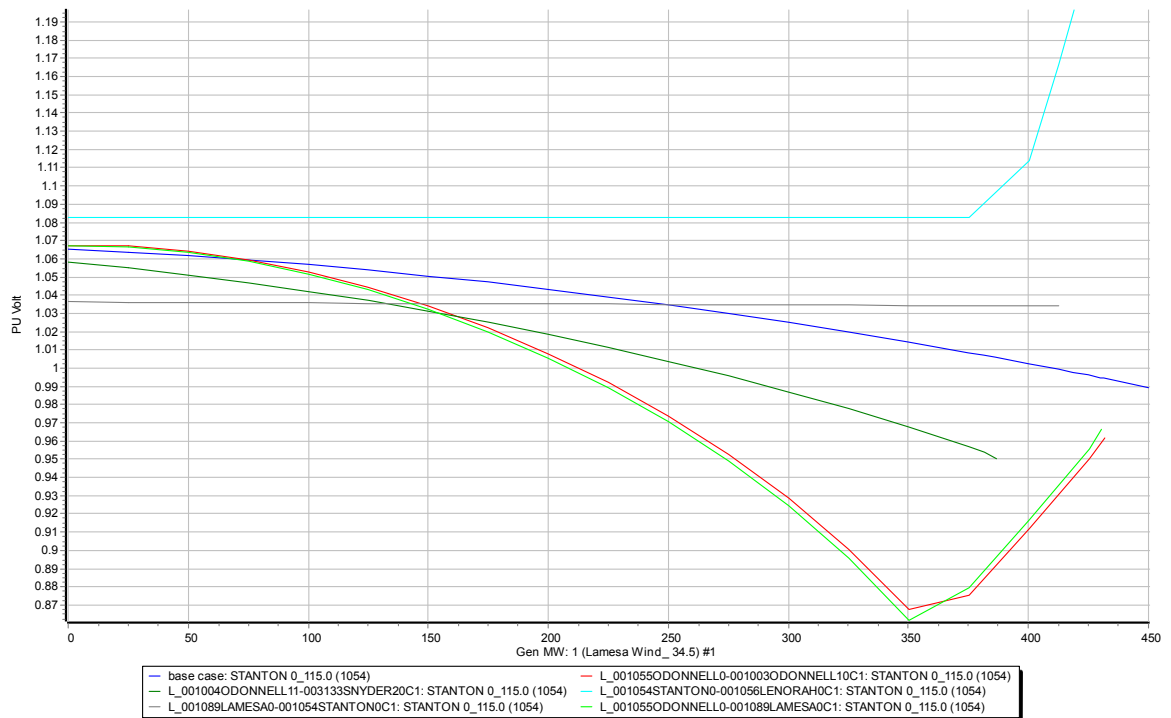
	Scenario	Critical?	Critical Reason	Max Shift	Max Export	Max Import	# Viol	Worst V Viol	W
1	base case	YES	Reached Nose	450.00	450.00	-368.54	0		
2	L_001055ODONNELLO-001003ODONNELL10C1	YES	Reached Nose	431.25	431.57	-355.46	0		
3	L_001004ODONNELL11-003133SNYDER20C1	YES	Reached Nose	386.25	386.57	-325.63	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_001055ODONNELLO-001089LAMESA0C1	YES	Reached Nose	430.00	430.32	-354.73	0		

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

# PV Analysis with Modifications



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



Build Date: January 25, 2018

# 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.

Slack Buses (show)  
GLEN ROSE 1 2

Calculate Sensitivities

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

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 LA PORTE 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

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