

Assessing the Voltage Adequacy of a Power System

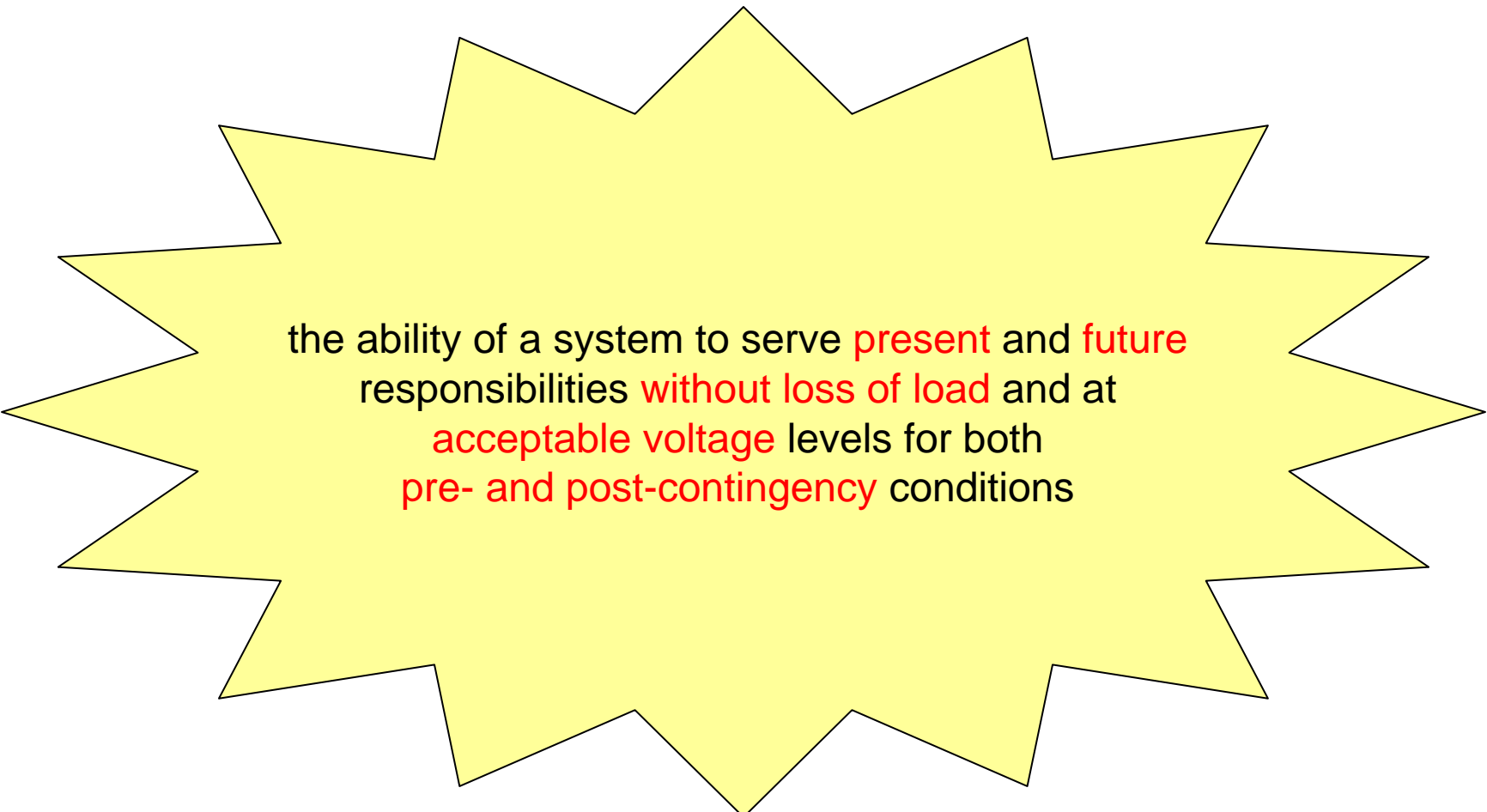
A Case Study

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Scenario

- Fictitious 37-bus, 3-area system
- Proposal:
 - retire 2 aging units in a heavy-load area
- Task
 - determine the impact of retiring the units on the voltage adequacy of the system

Voltage Adequacy

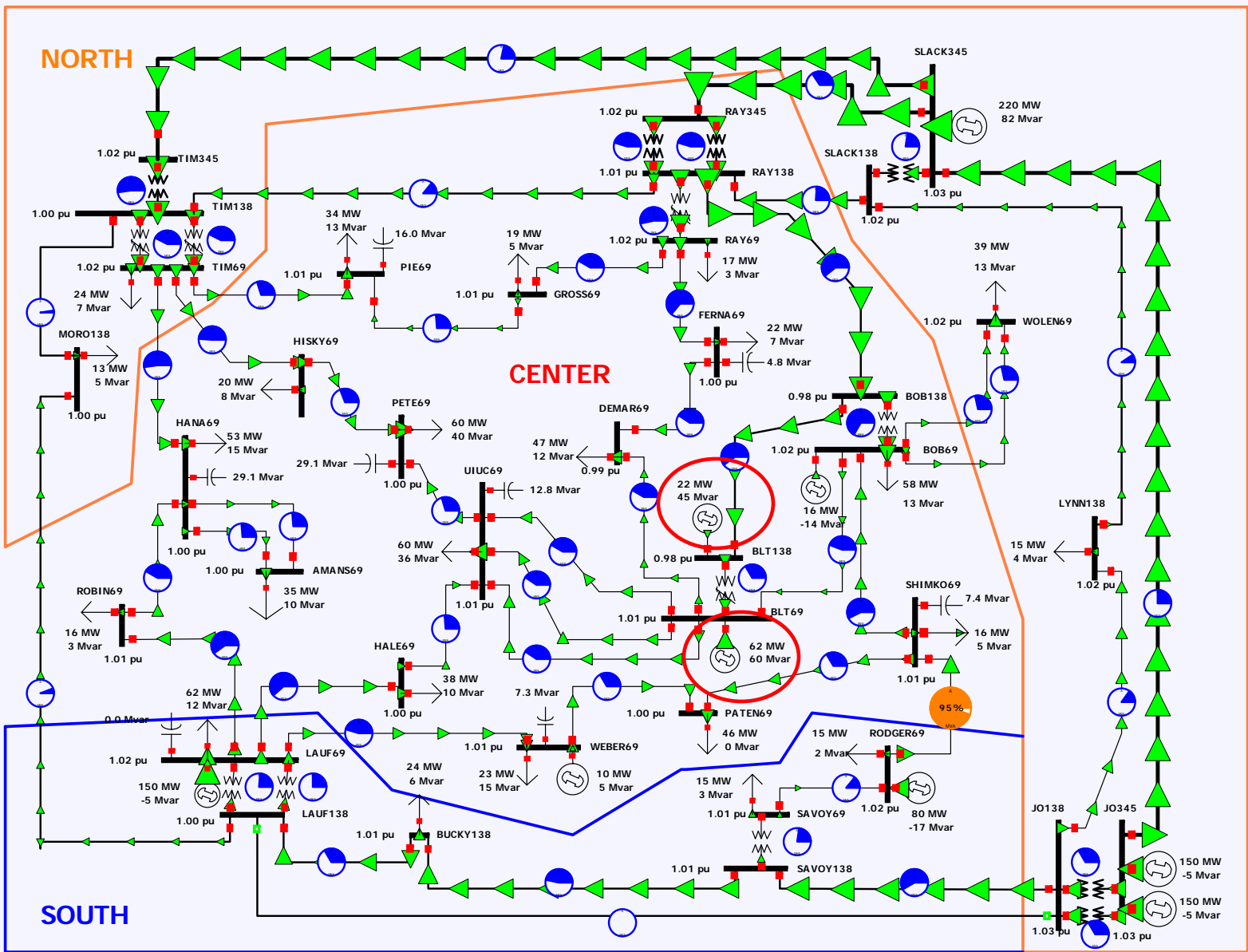


the ability of a system to serve **present** and **future** responsibilities **without loss of load** and at **acceptable voltage** levels for both **pre- and post-contingency** conditions

The Approach

- What is the impact on the pre-contingency state of the system?
 - Contours and difference flows
 - Identifies buses of potential interest
- What is the impact on n-1 reliability?
 - Contingency analysis tool
 - Identifies troublesome contingencies and buses
- What is the impact on future security?
 - PV Curve Tool
 - Identifies new restrictions on import capability

The System



Circled units to be retired

The System

Case Summary for Current Case

Number of Devices in Case		Case Totals (for in-service devices only)	
		MW	Mvar
Buses	37	Load	843.6
Generators	9	Generation	860.3
Loads	26	Shunts	0.6
Switched Shunts	8	Losses	16.16
Lines/Transformers	57	Generator Spinning Reserves	
2 Term. DC Lines	0	Positive [MW]	909.75
N-Term. DC Lines	0	Negative [MW]	739.25
Control Areas	3	Slack Buses:	
Zones	3	SLACK345 (31); in Area North (3)	
Islands	1	Case pathname: C:\PW\GloverAndSarma\DesignCase6_ThreeAreas_AllCenterGensOn_	
Interfaces	0		
Injection Groups	4		

Area Records

	Area Num	Area Name	AGC Status	Gen MW	Load MW	Tot Sched MW
1	1	Center	Part. AGC	110.08	638.64	-540.64
2	2	South	Part. AGC	230.00	115.40	113.01
3	3	North	Part. AGC	520.17	89.58	427.63

Impact on Base Case

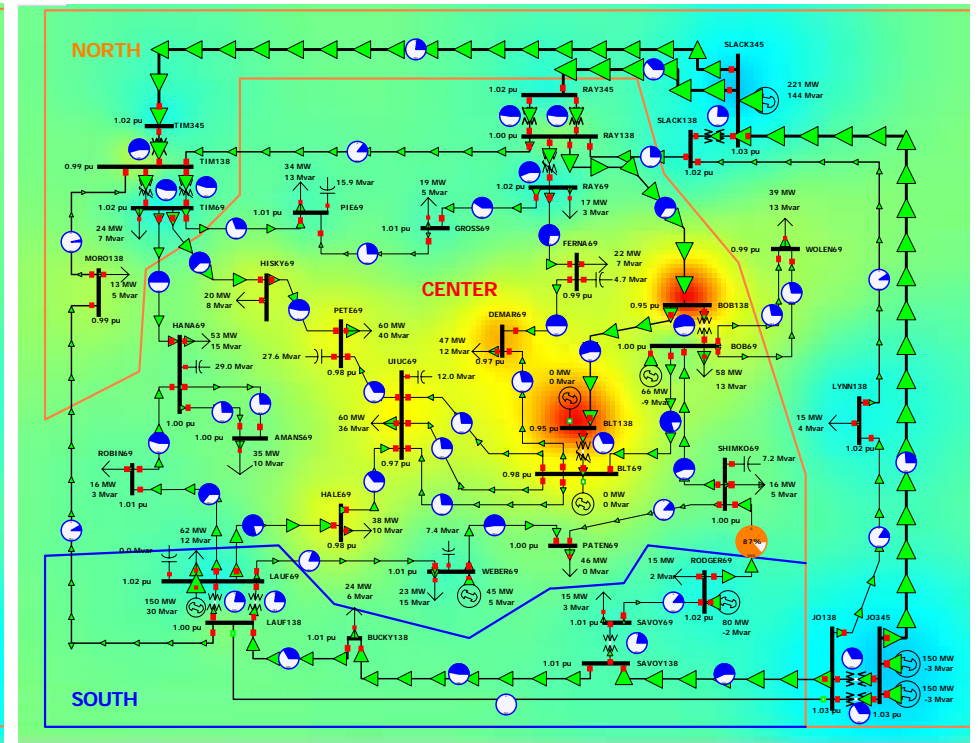
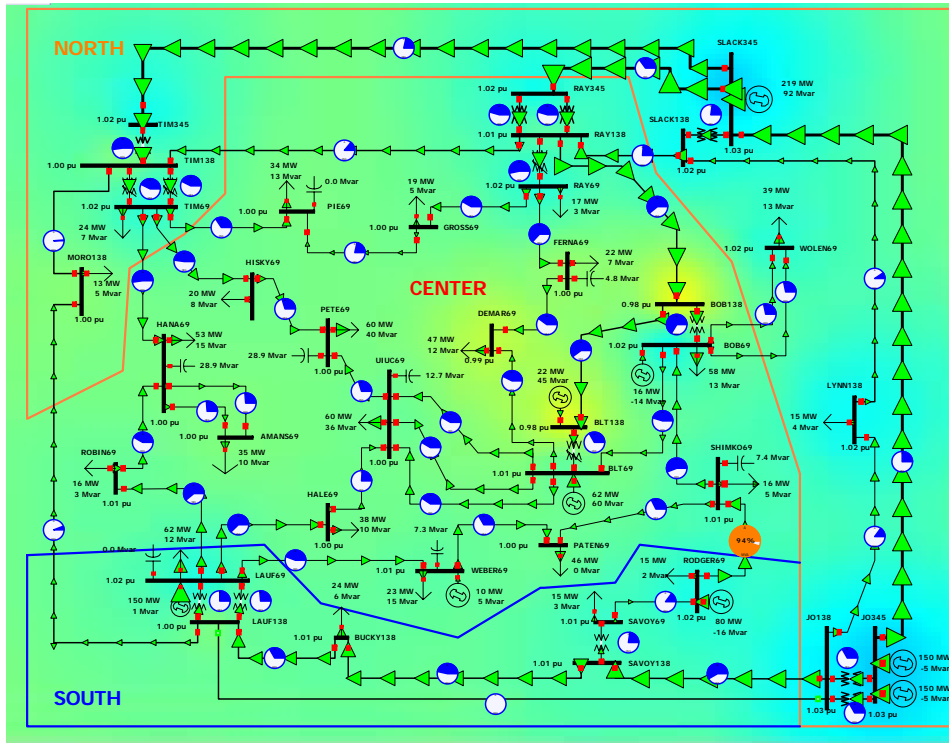
- Use difference flows to identify buses affected the most
- Use contouring to visualize the location and severity of the impact

Impact on Base Case

These buses suffered the greatest voltage decrease:

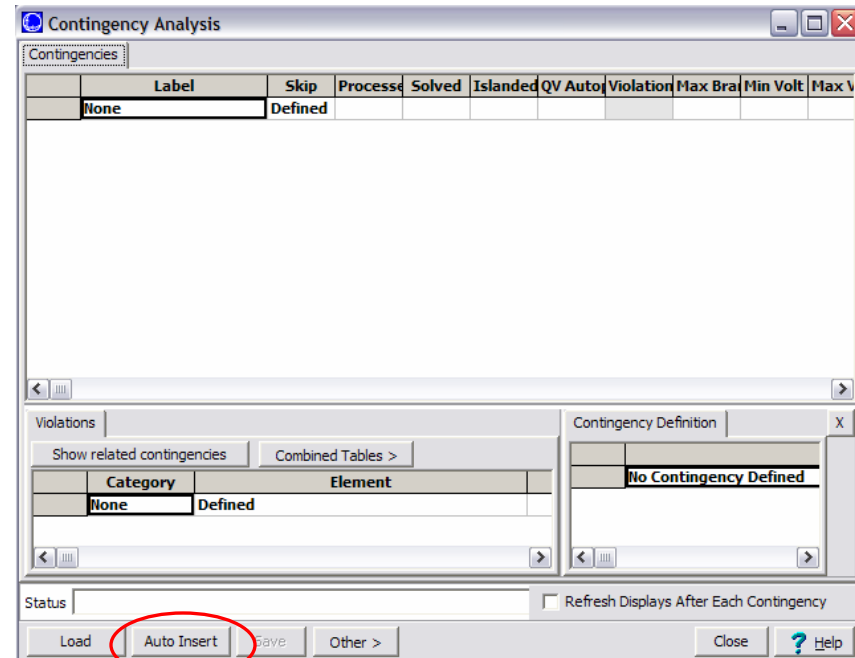
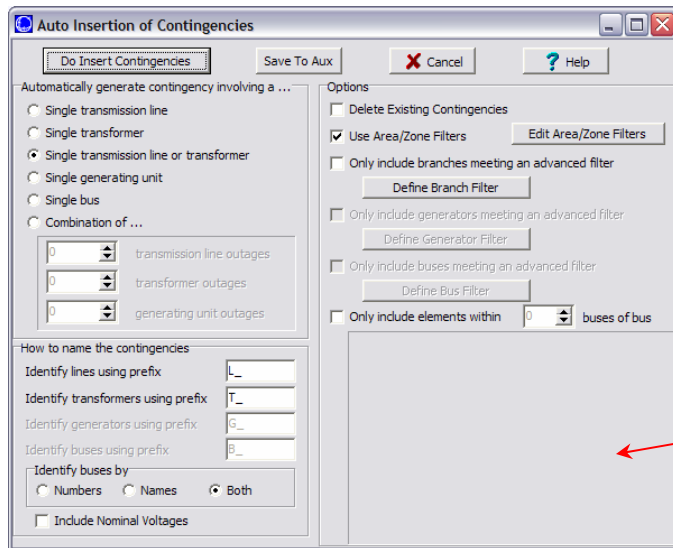
Number	Name	Del V
54	BLT69	-0.0338
53	BLT138	-0.0331
15	UIUC69	-0.0327
47	BOB138	-0.0292
16	PETE69	-0.0262
24	HALE69	-0.0249
21	WOLEN69	-0.0247
48	BOB69	-0.0246
55	DEMAR69	-0.0238
27	HISKY69	-0.0226
13	FERNA69	-0.0139
40	TIM138	-0.0138
39	RAY138	-0.0123
20	SHIMKO69	-0.0108
3	MORO138	-0.0096

Impact on Base Case



Impact on n-1 Reliability

Use contingency analysis tool to gauge condition of system for single branch and generator outages



Impact on n-1 Reliability

Violations: BLT in service

Contingency Name	Violated Element	Value	Limit
L_00010RAY69-00013FERNA69C1	FERNA69 (13)	0.93	0.95
L_00010RAY69-00013FERNA69C1	DEMAR69 (55)	0.94	0.95
L_00012TIM69-00018HANA69C1	HANA69 (18)	0.95	0.95
L_00012TIM69-00018HANA69C1	AMANS69 (37)	0.95	0.95
L_00039RAY138-00047BOB138C1	BOB138 (47)	0.95	0.95

Violations: BLT out of service

L_00039RAY138-00047BOB138C1	BOB138 (47)	0.90	0.95
L_00039RAY138-00047BOB138C1	BLT138 (53)	0.90	0.95
L_00010RAY69-00013FERNA69C1	FERNA69 (13)	0.90	0.95
L_00010RAY69-00013FERNA69C1	DEMAR69 (55)	0.91	0.95
T_00010RAY69-00039RAY138C1	FERNA69 (13)	0.93	0.95
T_00010RAY69-00039RAY138C1	DEMAR69 (55)	0.93	0.95
L_00012TIM69-00018HANA69C1	AMANS69 (37)	0.93	0.95
L_00013FERNA69-00055DEMAR69C1	DEMAR69 (55)	0.93	0.95
L_00031SLACK345-00038RAY345C1	BOB138 (47)	0.93	0.95
L_00031SLACK345-00038RAY345C1	BLT138 (53)	0.93	0.95
T_00054BLT69-00053BLT138C1	BLT138 (53)	0.93	0.95
L_00039RAY138-00047BOB138C1	UIUC69 (15)	0.94	0.95
L_00039RAY138-00047BOB138C1	BLT69 (54)	0.94	0.95
T_00010RAY69-00039RAY138C1	RAY69 (10)	0.94	0.95
L_00012TIM69-00018HANA69C1	HANA69 (18)	0.94	0.95
L_00012TIM69-00027HISKY69C1	PETE69 (16)	0.94	0.95
L_00012TIM69-00027HISKY69C1	HISKY69 (27)	0.94	0.95
L_00012TIM69-00027HISKY69C1	BOB138 (47)	0.94	0.95
L_00012TIM69-00027HISKY69C1	BLT138 (53)	0.94	0.95
L_00001TIM345-00031SLACK345C1	TIM345 (1)	0.94	0.95
L_00001TIM345-00031SLACK345C1	TIM138 (40)	0.94	0.95
L_00001TIM345-00031SLACK345C1	BOB138 (47)	0.94	0.95
L_00001TIM345-00031SLACK345C1	BLT138 (53)	0.94	0.95
L_00046PETE69-00027HISKY69C1	BLT138 (53)	0.94	0.95
T_00001TIM345-00040TIM138C1	TIM138 (40)	0.94	0.95
T_00001TIM345-00040TIM138C1	BOB138 (47)	0.94	0.95
T_00001TIM345-00040TIM138C1	BLT138 (53)	0.94	0.95
T_00054BLT69-00053BLT138C1	BOB138 (47)	0.94	0.95
L_00047BOB138-00053BLT138C1	BOB138 (47)	0.94	0.95
L_00039RAY138-00047BOB138C1	DEMAR69 (55)	0.95	0.95
T_00010RAY69-00039RAY138C1	BOB138 (47)	0.95	0.95
T_00010RAY69-00039RAY138C1	BLT138 (53)	0.95	0.95
L_00010RAY69-00013FERNA69C1	BOB138 (47)	0.95	0.95
L_00010RAY69-00013FERNA69C1	BLT138 (53)	0.95	0.95
L_00012TIM69-00018HANA69C1	BOB138 (47)	0.95	0.95
L_00013FERNA69-00055DEMAR69C1	BOB138 (47)	0.95	0.95
L_00013FERNA69-00055DEMAR69C1	BLT138 (53)	0.95	0.95
G_00044LAUF69U1	BOB138 (47)	0.95	0.95
G_00044LAUF69U1	BLT138 (53)	0.95	0.95
L_00031SLACK345-00038RAY345C1	RAY345 (38)	0.95	0.95
L_00031SLACK345-00038RAY345C1	RAY138 (39)	0.95	0.95
L_00030BUCKY138-00032SAVOY138C1	BOB138 (47)	0.95	0.95
L_00030BUCKY138-00032SAVOY138C1	BLT138 (53)	0.95	0.95
L_00016PETE69-00027HISKY69C1	BOB138 (47)	0.95	0.95
L_00030BUCKY138-00041LAUF138C1	BOB138 (47)	0.95	0.95
L_00030BUCKY138-00041LAUF138C1	BLT138 (53)	0.95	0.95
L_00031SLACK345-00028JO345C1	BOB138 (47)	0.95	0.95
L_00031SLACK345-00028JO345C1	BLT138 (53)	0.95	0.95
L_00024HALE69-00044LAUF69C1	BOB138 (47)	0.95	0.95
L_00024HALE69-00044LAUF69C1	BLT138 (53)	0.95	0.95
L_00021WOLEN69-00048BOB69C1	BOB138 (47)	0.95	0.95
L_00021WOLEN69-00048BOB69C1	BLT138 (53)	0.95	0.95
L_00020SHIMKO69-00048BOB69C1	BOB138 (47)	0.95	0.95
L_00020SHIMKO69-00048BOB69C1	BLT138 (53)	0.95	0.95
L_00003MORO138-00040TIM138C1	BOB138 (47)	0.95	0.95
L_00003MORO138-00040TIM138C1	BLT138 (53)	0.95	0.95
T_00039RAY138-00038RAY345C2	BOB138 (47)	0.95	0.95
T_00039RAY138-00038RAY345C2	BLT138 (53)	0.95	0.95
L_00017PIE69-00019GROSS69C1	BOB138 (47)	0.95	0.95
L_00017PIE69-00019GROSS69C1	BLT138 (53)	0.95	0.95
G_00050RODGER69U1	BOB138 (47)	0.95	0.95
G_00050RODGER69U1	BLT138 (53)	0.95	0.95
L_00039RAY138-00040TIM138C1	BOB138 (47)	0.95	0.95
L_00039RAY138-00040TIM138C1	BLT138 (53)	0.95	0.95
L_00018HANA69-00037AMANS69C1	BOB138 (47)	0.95	0.95

L_00039RAY138-00047BOB138C1	BOB138 (47)	0.90	0.95
L_00039RAY138-00047BOB138C1	BLT138 (53)	0.90	0.95
L_00010RAY69-00013FERNA69C1	FERNA69 (13)	0.90	0.95
L_00010RAY69-00013FERNA69C1	DEMAR69 (55)	0.91	0.95
T_00010RAY69-00039RAY138C1	FERNA69 (13)	0.93	0.95
T_00010RAY69-00039RAY138C1	DEMAR69 (55)	0.93	0.95
L_00012TIM69-00018HANA69C1	AMANS69 (37)	0.93	0.95
L_00013FERNA69-00055DEMAR69C1	DEMAR69 (55)	0.93	0.95
L_00031SLACK345-00038RAY345C1	BOB138 (47)	0.93	0.95
L_00031SLACK345-00038RAY345C1	BLT138 (53)	0.93	0.95
T_00054BLT69-00053BLT138C1	BLT138 (53)	0.93	0.95
L_00039RAY138-00047BOB138C1	UIUC69 (15)	0.94	0.95
L_00039RAY138-00047BOB138C1	BLT69 (54)	0.94	0.95
T_00010RAY69-00039RAY138C1	RAY69 (10)	0.94	0.95
L_00012TIM69-00018HANA69C1	HANA69 (18)	0.94	0.95
L_00012TIM69-00027HISKY69C1	PETE69 (16)	0.94	0.95
L_00012TIM69-00027HISKY69C1	HISKY69 (27)	0.94	0.95
L_00012TIM69-00027HISKY69C1	BOB138 (47)	0.94	0.95
L_00012TIM69-00027HISKY69C1	BLT138 (53)	0.94	0.95
L_00001TIM345-00031SLACK345C1	TIM345 (1)	0.94	0.95
L_00001TIM345-00031SLACK345C1	TIM138 (40)	0.94	0.95
L_00001TIM345-00031SLACK345C1	BOB138 (47)	0.94	0.95
L_00001TIM345-00031SLACK345C1	BLT138 (53)	0.94	0.95
L_00016PETE69-00027HISKY69C1	BLT138 (53)	0.94	0.95
T_00001TIM345-00040TIM138C1	TIM138 (40)	0.94	0.95

Impact on Future Conditions

- PV Curve tool can model gradual changes
 - load growth
 - generation shifts
- Typically study transfers across several interfaces
- Monitor bus voltages as transfers grow

PV Curve Study Requirements

- Transfer directions
- Contingencies
- Quantities to monitor
- For this case study
 - Transfer
 - North & South Gens to increasing Central Load
 - Contingencies
 - Those that caused violations at base load
 - Monitored buses
 - Those whose voltage were violated at base load for base and contingency topologies

The PV Curve Tool

PV CURVES - Test

Setup | Quantities to track | Limit violations | PV output | QV setup | PV Results

Transfer power between the following two groups:

Source: ExternalGens Areas ... View / Define Groups

Sink: CenterLoads Areas ...

Vary the transfer as follows:

Initial Step Size (MW): 20 Allow only AGC units to vary

Minimum Step Size (MW): 1 Enforce unit MW limits

When convergence fails, reduce step by a factor of: 2 Do not allow negative loads

Stop when transfer exceeds: 0

How should reactive power load change as real power load is ramped?

Keep the ratio between real and reactive power at each load constant - OR -

As MW changes, change MVR at a power factor of: 100

Skip contingencies Run base case to completion

Manage contingency list ... Pre-contingency solution options ...

Save options ... Load options ... Launch QV curve tool ... Close

PV CURVES - Test

Setup | Quantities to track | Limit violations | PV output | QV setup | PV Results

	Number	Name	Nom kV	Voltage?
1	37	AMANS69	69.00	YES
2	53	BLT138	138.00	YES
3	13	FERNA69	69.00	YES
4	39	RAY138	138.00	YES
5	10	RAY69	69.00	YES
6	1	TIM345	345.00	YES
7	15	UIUC69	69.00	YES
8	55	DEMAR69	69.00	YES
9	40	TIM138	138.00	YES
10	47	BOB138	138.00	YES
11	16	PETE69	69.00	YES

PV CURVES - Test

Setup | Quantities to track | Limit violations | PV output | QV setup | PV Results

Save results to file

c:\temp\pvresults.txt Browse View

State Archiving

Do not save system states

Save only the base case for each critical contingency

Save all states

Where should they be stored? C:\PW\UsersGroupMeeting Browse

Specify a prefix to use in naming the state archives:

contingencies | Lines, Buses, Interfaces | Options | Summary

	Label	Skip
1	L_00039RAY138-00047BOB138C1	NO
2	T_00010RAY69-00039RAY138C1	NO
3	L_00010RAY69-00013FERNA69C1	NO
4	L_00012TIM69-00018HANA69C1	NO
5	L_00012TIM69-00027HISKY69C1	NO
6	L_00013FERNA69-00055DEMAR69C1	NO
7	G_00044LAUF69U1	NO
8	L_00031SLACK345-00038RAY345C1	NO
9	L_00001TIM345-00031SLACK345C1	NO
10	L_00030BUCKY138-00032SAVOY138C1	NO
11	L_00016PETE69-00027HISKY69C1	NO
12	L_00030BUCKY138-00041LAUF138C1	NO
13	L_00031SLACK345-00028JO345C1	NO
14	T_00001TIM345-00040TIM138C1	NO
15	L_00024HALE69-00044LAUF69C1	NO
16	L_00021WOLEN69-00048BOB69C1	YES
17	L_00020SHIMKO69-00048BOB69C1	YES

PV Results

BLT In Service

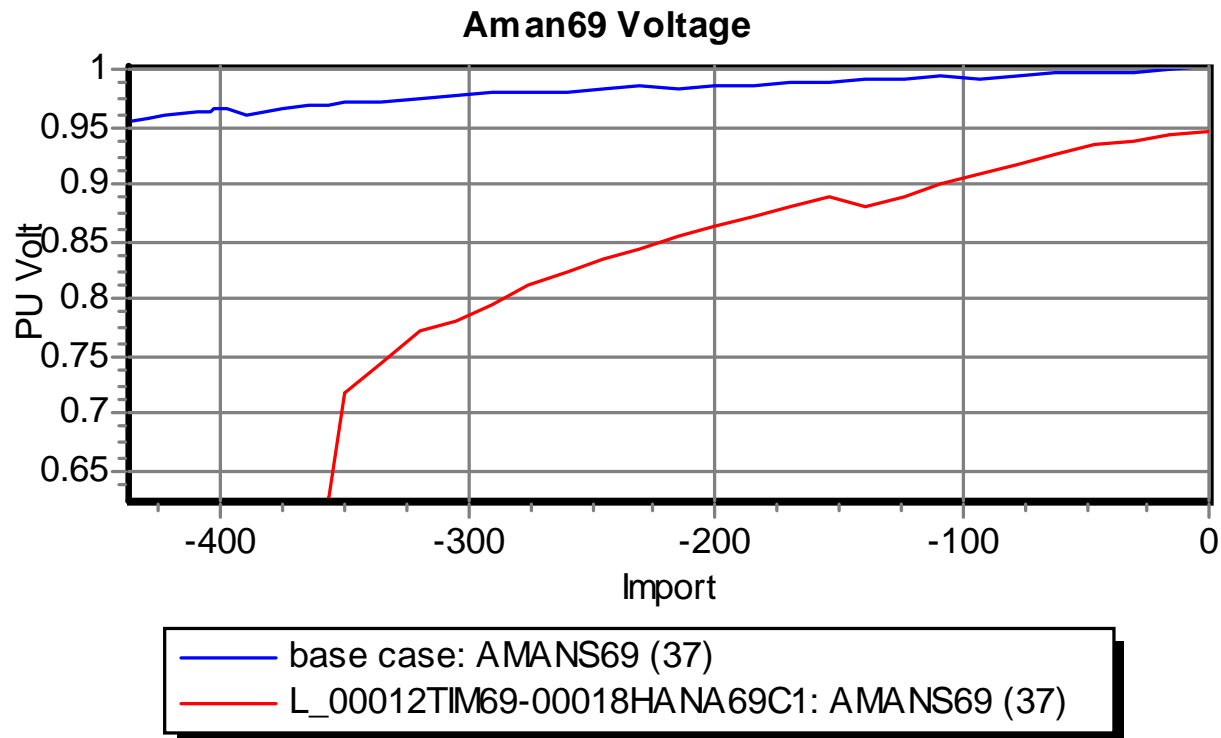
PV Scenario	Critical?	Critical Reason	Max Shift	Max Export	Max Import	# Viol	Worst V V
L_00039RAY138-00047BOB138C1	YES	Reached Nose	576	524.68	-427.81	29	0.71
L_00031SLACK345-00038RAY345C1	YES	Reached Nose	538.75	486.49	-401.3	32	0.7
L_00012TIM69-00018HANA69C1	YES	Reached Nose	475	421.22	-356.5	20	0.62

BLT Out of Service

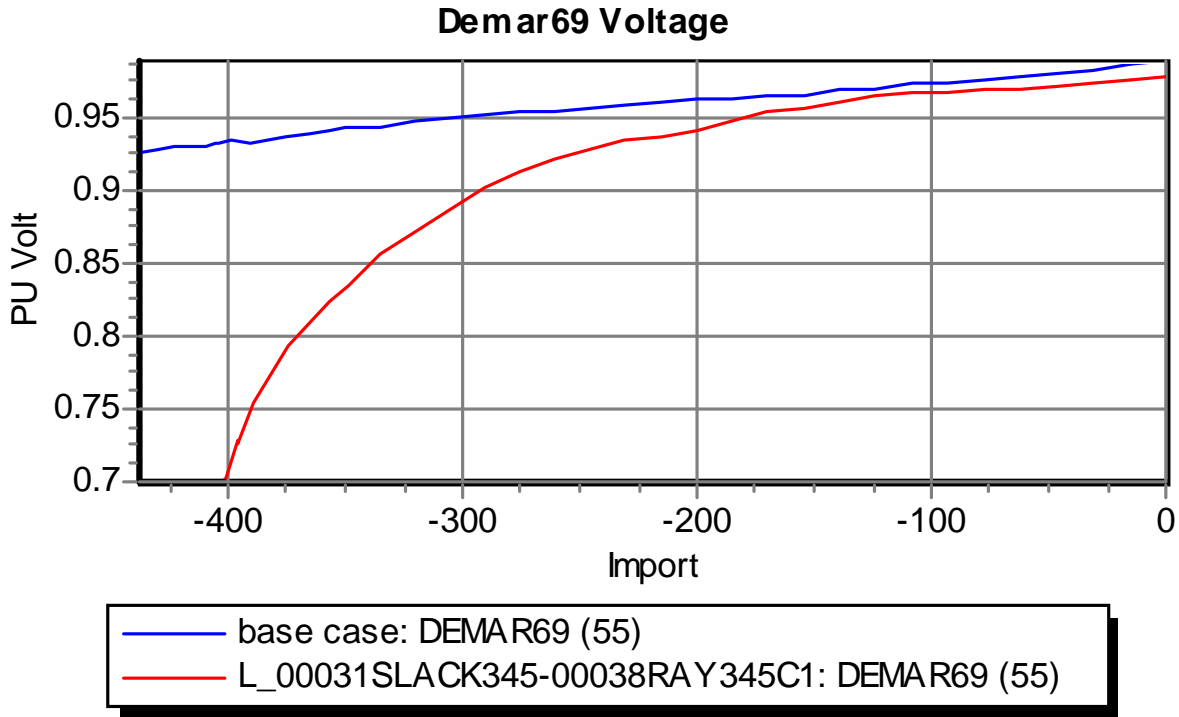
PV Scenario	Critical?	Critical Reason	Max Shift	Max Export	Max Import	# Viol	Worst V V
L_00039RAY138-00047BOB138C1	YES	Reached Nose	403.5	387.21	-298.63	29	0.64
L_00031SLACK345-00038RAY345C1	YES	Reached Nose	377.25	348.54	-278.59	32	0.69
L_00012TIM69-00018HANA69C1	YES	Reached Nose	437.25	385.66	-324.56	22	0.63

Outage reduces import capability by almost 80 MW!

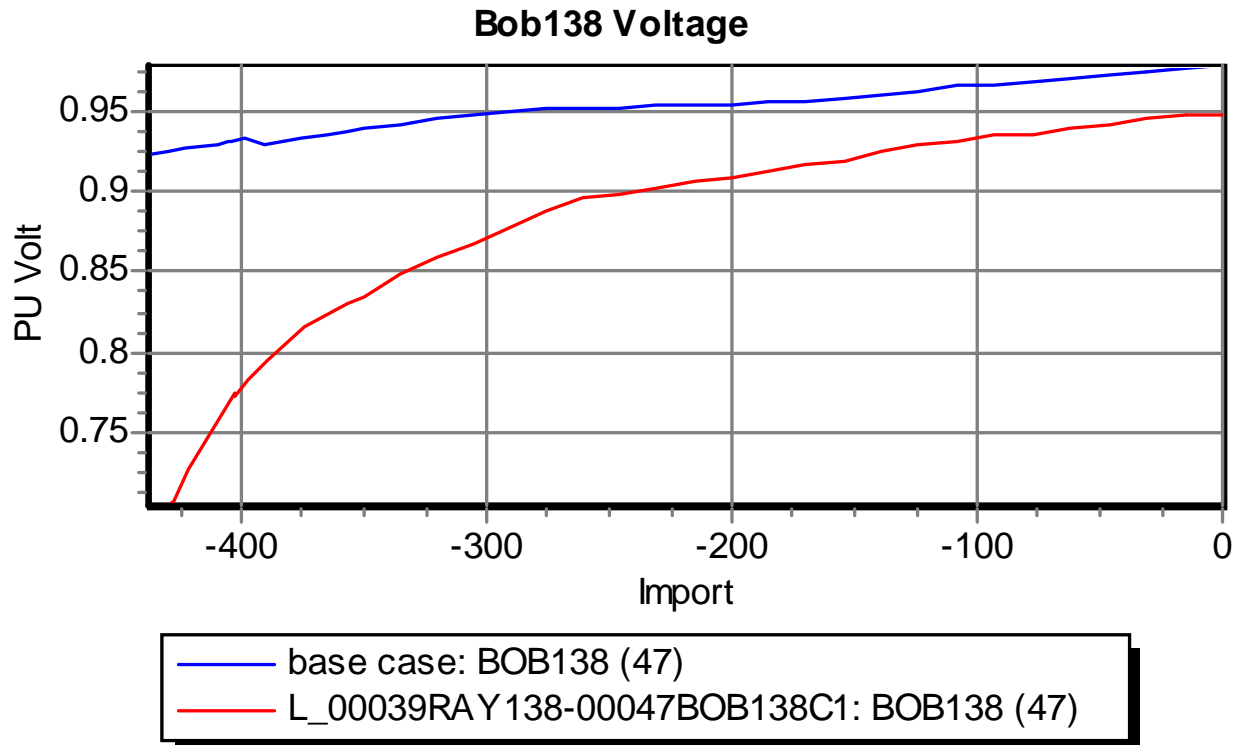
BLT Units In-Service



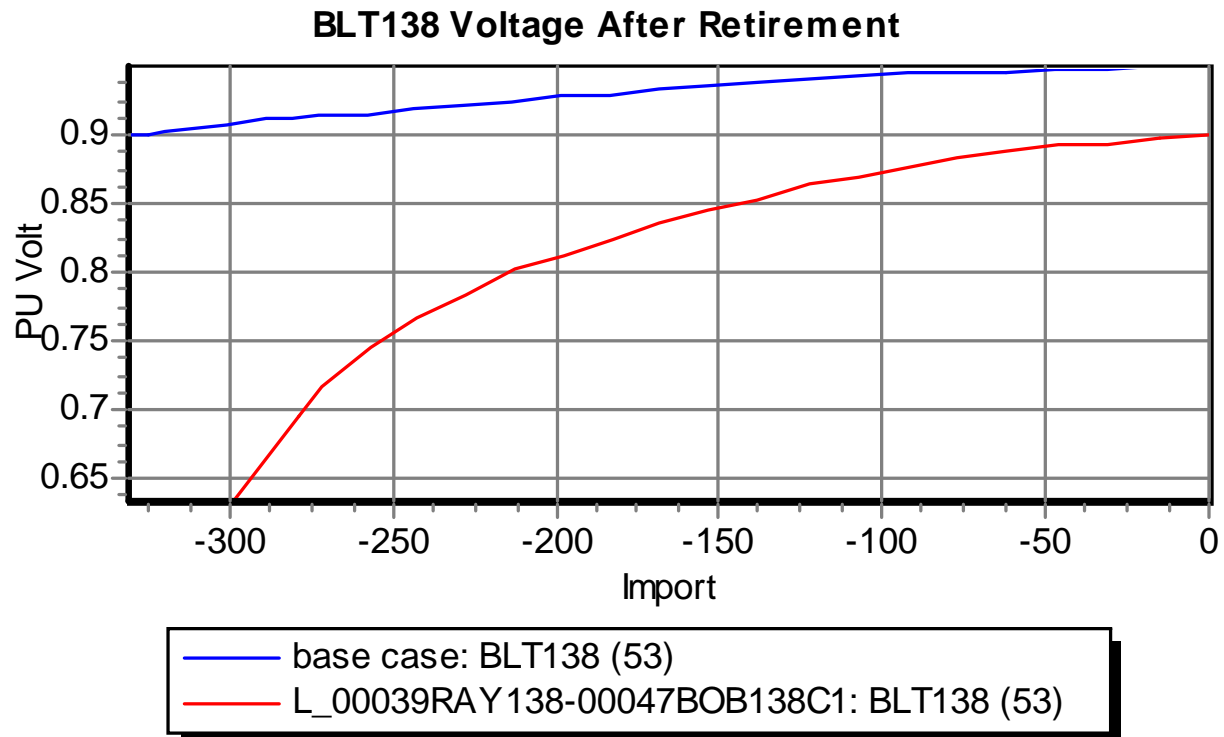
BLT Units In-Service



BLT Units In-Service

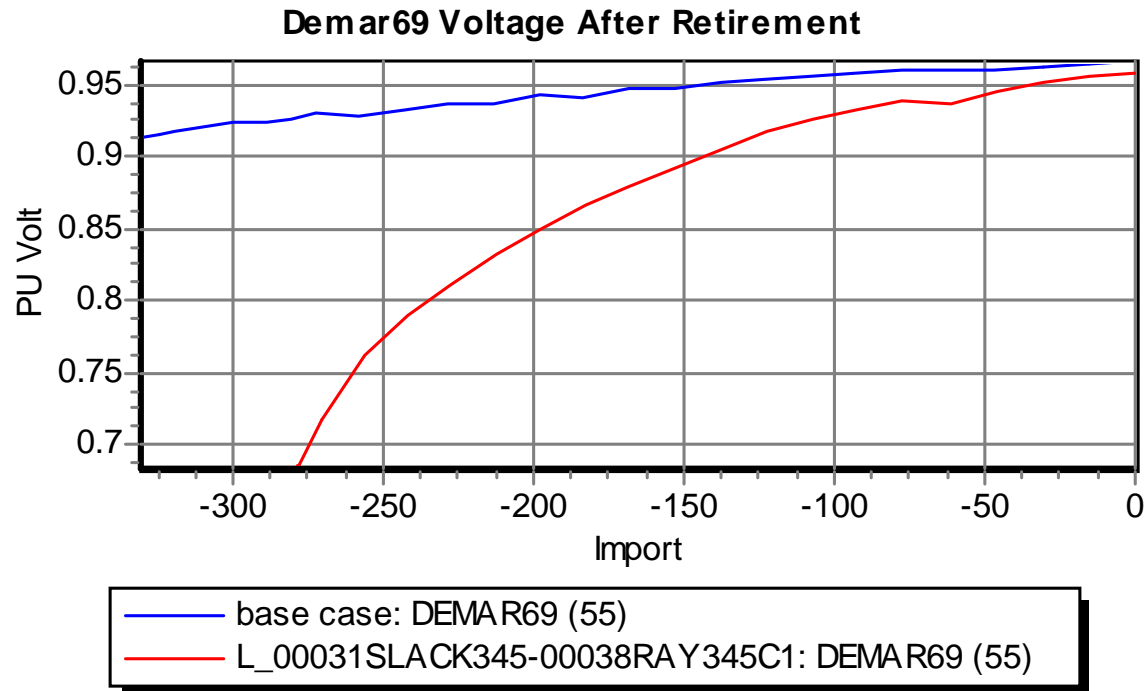


BLT Units Out-of-Service

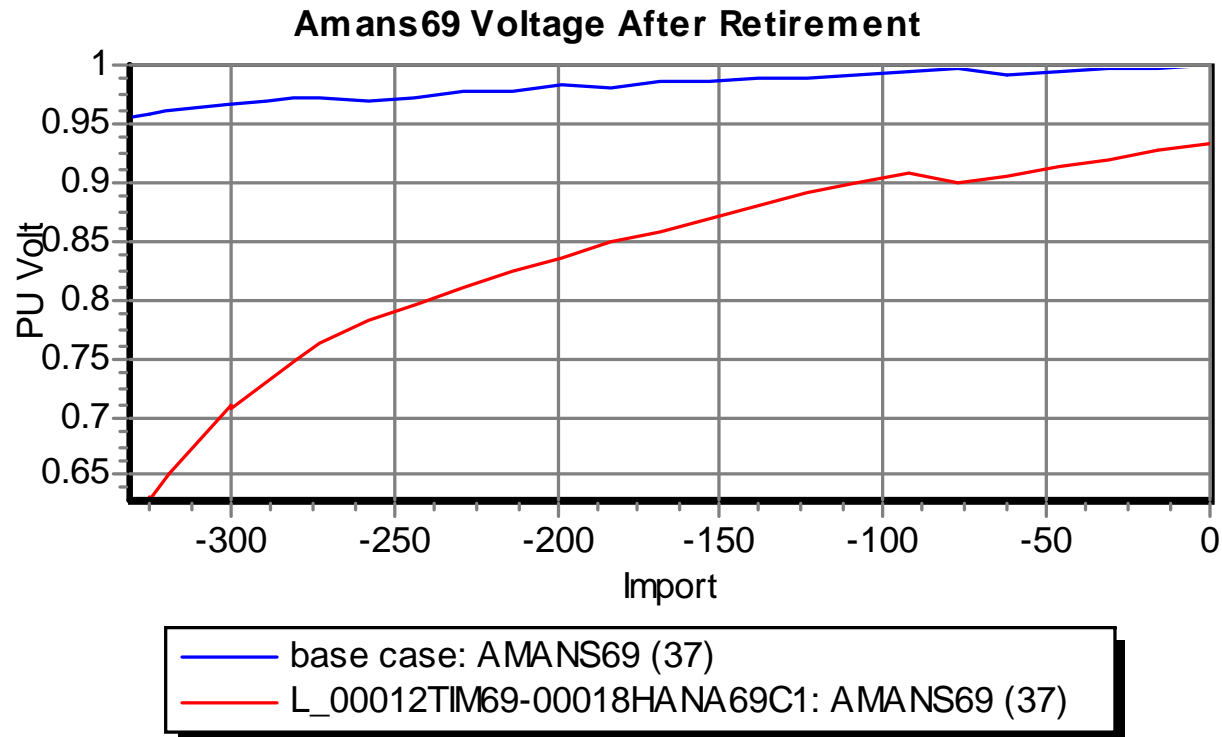


PWSIM V10.0 OPF, ATC, PVQV; Build May 21, 2004

BLT Units Out-of-Service



BLT Units Out-of-Service



PWSIM V10.0 OPF, ATC, PVQV; Build May 21, 2004

Conclusion

- Difference flows, contouring, contingency analysis and the PV tool work together
- Provide an *estimate* of the ability of the system to meet
 - current demands
 - n-1 criteria standards
 - future growth
- Next step:
 - how to fortify the system