DRAFT #3

An investigation of transmission system reliability issues that could result from a potential limitation in natural gas supply to generation in the I-5 corridor

Gas-Electric Interdependencies Study Team

3rd DRAFT – December 13, 2012

Introduction

A significant amount of natural gas powered generation is located in the I-5 corridor and this generation is needed to enable the power system to reliably serve the major load areas in and around Portland and Seattle. Traditional transmission system planning studies have assumed that the natural gas supply to these plants is available when needed. This study investigates whether potential limitations in the availability of natural gas to area generation could lead to transmission reliability issues when serving I-5 corridor loads from resources outside of the area (e.g., the Columbia River system). It is important to note that there is no reason to believe that the natural gas supply system is somehow inadequate to serve its customers or that gas curtailments are expected to be any more likely in the future, this is simply an exploration of "what if" something happened to the natural gas supply system in a way that limited supply to the I-5 corridor generating stations. This study was closely coordinated with the Pacific Northwest Utilities Conference Committee (PNUCC) and the Northwest Gas Association (NWGA) which are investigating other aspects of the Interdependencies between the gas and electric systems.

Estimating the potential curtailments that could result from contingencies on the gas supply system is a difficult undertaking. As a first step, the study team decided to evaluate the impact of a total curtailment of natural gas to all the power plants in the I-5 corridor. If the electric system can perform adequately under this condition then there is not a need to perform a detailed analysis of potential curtailment scenarios on the gas supply system. A total curtailment of natural gas to power plants in the I-5 corridor would mean that the only natural gas plants left in service would be those that are capable of switching to an alternative fuel supply. About half of the 4400 MW of natural gas generation in the I-5 corridor may have the capability to switch fuels (e.g., diesel) although the actual ability of these plants to function in this mode may be limited. If the system is deemed to function adequately when supported just by these dual fuel plants, then the interaction of the gas and electricity systems may not need to be studied further; at least as it pertains to electric system reliability issues.

The study was overseen by the ColumbiaGrid Gas-Electric Interdependencies Study Team. All meetings of this study team were open to all interested parties.

Potential reliability issues based on previous studies

Initially the Study Team suspected that the primary reliability concern would be limitations in the ability of the transmission system to deliver resources from outside of the I-5 corridor (e.g., Columbia River or California generation) to replace the I-5 corridor gas fired generation. The limiting transmission paths of concern are the West of Cascades North and West of Cascades South transmission paths. These two paths deliver remote resources from east of the Cascade Mountains to west-side loads. These paths typically load most heavily during unusually cold winter weather events. Otherwise, the paths tend to be loaded well below their transfer limits. The West of Cascades North path is particularly important to serving the Puget Sound area in Washington and for transfers to British Columbia.

Beginning in 2009, ColumbiaGrid's annual system assessment raised a potential reliability concern on the West of Cascades North path. The 2010 and 2011 System Assessments again documented the possibility that a critical outage on the West of Cascades North path during the winter could jeopardize voltage stability. When remote renewable generation (wind) is increased in the system planning models to displace west-side thermal generation (combustion turbines and others), heavy loading on the path occurs. In 2010, ColumbiaGrid formed a Cross Cascades North Study Team to study West of Cascades North reliability concerns and explore potential mitigation options such as adding a new transmission line to the path. The work of that group is discussed here because the reliability concern addressed in that study could be a reliability concern associated with a limitation in natural gas supply.

The West of Cascades North Study also compared the Available Transfer Capability (ATC) benefits of various potential transmission projects in increasing the West of Cascades North path voltage stability transfer limit. The team initially identified projects with short (two to five-year) implementation times. Alternatives that involve building new lines entail a longer implementation time (more than five years) and were then studied with the assumption that the initial short-term projects were completed.

Two of the initial projects with short implementation times were found to be very effective in increasing the West of Cascades North path transfer limit. These projects are adding series capacitors on the Schultz-Raver 500 kV #3 and #4 lines and reconductoring 26 miles of the Schultz-Raver #4 line. The initial series capacitor portion of this project is being planned by BPA and is expected to be in service by 2018 so it was modeled in this study. The follow on project to further increase the size of the series capacitors on the Schultz-Raver #4 line (24 ohms) and reconductor the 2.5 inch sections of this line were not modeled in this study because they are not projected to be in-service within the 10-year study horizon.

The longer-term projects analyzed by the Cross Cascades North Study Team include major new 500 kV lines and are therefore expected to be much more complex. In addition, to fully realize the benefits of new cross Cascades line alternatives, like a second Chief Joe-Monroe 500 kV line, additional mitigation will be required outside of the West of Cascades North path, including addressing additional Portland area 115 kV line overloads and voltage stability limits in the I-5 corridor. Fortunately, the Study Team determined that a major new line would not be needed within the 10-year planning horizon. None of these long-term projects were further analyzed in this study.

Transmission Benchmark Developed

At this point in time, there is no clear guidance via the NERC Reliability Standards or WECC criteria regarding the conditions that the power system would need to endure during natural gas curtailment conditions in order to be judged to be adequate. As a result, the study team developed its own benchmark. A primary issue was whether or not the curtailment of natural gas should be considered to be a contingency in a similar way to a transmission system element contingency. Several study team members felt that the probability of a total curtailment of natural gas as modeled in this study was much lower than the probability of even the Category C (N-2) transmission outages in the NERC Reliability Standards. As a result, adding a natural gas curtailment on top of the typical transmission outages (Category B and C transmission outages) considered in planning studies would be extremely conservative. After much consideration, the Study Team decided to study only single transmission system contingencies (Category B transmission outages) in combination with the natural gas curtailment. In addition, the study team decided to use expected winter peak loads (one in two year likelihood of occurrence), rather than a more stringent criteria such as an extreme winter peak load (one in ten year likelihood of occurrence). The consensus of the study team is that this benchmark would most closely align with the Category D contingencies in the NERC Planning Standards and as a result this study should be viewed as a “risks and consequences” evaluation of an extreme event.

Transmission Planning Model

The Power Flow base case used in this study is the one used in the ColumbiaGrid 2012 System Assessment (22HW). This is the latest WECC model available and has been thoroughly reviewed and recently updated by transmission owners in the Pacific Northwest. The planning cases were revised as necessary to include the following major projects:

1. Big Eddy-Knight
2. Hemingway-Boardman
3. Adding series capacitors on the Schultz-Raver 500kV #3 and #4 lines (a sensitivity study was completed without modeling this project)
4. Puget Sound Area Transmission Expansion Plan

Projects that may well be in-service in the ten-year planning horizon but are less certain due to issues such as permitting uncertainty, financial hurdles, or sponsor commitment were not included in the study to be conservative. These projects include the following:

1. Cascade Crossing Project
2. I-5 Corridor Reinforcement Project (a sensitivity study was completed with this project in service)
3. Trojan-Horizon 230 kV
4. Reconductoring 26 miles of the Schultz-Raver #4 line
5. Central Ferry-Lower Monumental

Other important base case assumptions include:

1. The west-side Northern Intertie was set to 1500MW south-to-north to model expected firm commitments between the Northwest and British Columbia.
2. Puget Sound Area hydro Generation was set to 530 MW (see Appendix D).
3. One unit was modeled as retired at the Centralia Power Plant leaving one unit in service.

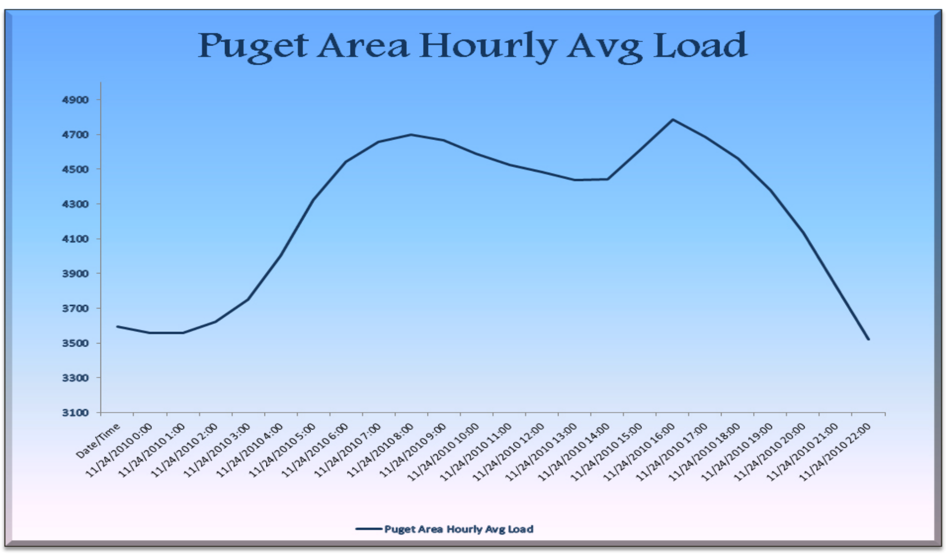
Dual Fuel Units

Studies were conducted with all natural gas-fired plants off in the I-5 corridor area with the exception of those that have dual fuel capability. A list of those units with dual fuel capability is provided in Appendix G. All of the dual fuel plants in this area use diesel fuel for back up to their natural gas supply. Although units typically have higher capacity when burning diesel, the normal maximum capacity for gas operation was used to be conservative. It should also be noted that some units may have firm contracts to gas in storage fields and that these plants may be as dependable as plants that have dual fuel capability. These plants with firm transmission to gas storage were not modeled as being in-service in the study.

The generation levels modeled in each of the cases are discussed in Appendix D, Table 1. Of particular interest is the fact that when modeling the dual fuel plants in service there was an increase in generation levels in the critical Puget Sound Area over what was modeled in the reference case.

While operating on diesel fuel, operation of these dual fuel plants can be limited by the amount of fuel that can be stored on site or delivered and by permitting restrictions based on air quality. The Study Team did not attempt to estimate the potential for these plant limitations and, for the purposes of this study, judged that they would have sufficient availability to meet the need. Provided below is a typical Peak Winter load shape for Puget Sound Energy Balancing Authority area to help gage the amount of time during the day when the dual fuel units would need to operate. [NEEDS MORE ANALYSIS HERE]

Figure 1 – Typical Winter Load Shape for the Puget Sound Energy Balancing Authority Area



Gas Generation Replacement

The effect of reduced natural gas fired generation to the performance of the electric transmission system can vary depending on the location of the replacement generation. To model worse case conditions for the Cross Cascades paths, replacement generation from eastern Washington was assumed.

Cross-Cascades Voltage Stability Limit

In each base simulation, generation was reduced in the I-5 corridor until the system reached its voltage stability limit. The west-side generation reduction sequence was essentially the same as that used by the Cross Cascades North Study Team and is based on using publicly available heat rate data. The higher heat rate units were removed from service first. Perhaps surprisingly, from a transmission system standpoint, the west-side generation pattern represented in the gas curtailment case is actually more favorable for voltage stability than the pattern used in the reference case because more west-side generation can be taken off-line before the voltage stability limit is reached. The gas curtailment case starts out with 731 MW less of west-side generation than the reference case and the voltage stability limit (including the margin required by the WECC voltage stability criteria) is reached with an additional 1440 MW of generation taken out of service (at Centralia and Chehalis). So the total I-5 corridor generation removed from service in the gas curtailment case is 2171 MW. With the reference case, only 1260 MW can be taken off-line with the assumed displacement order. Clearly, the specific location of west-side generation affects the voltage stability limit. Importantly, both cases meet the WECC voltage stability margin with capacity to spare.

Comment [JWS1]: Can this be made clearer so that someone unfamiliar with the system can understand the point?

Sensitivity Studies

The following two sensitivity studies were completed:

1) Without the Schultz Series Capacitor Addition: The WECC voltage stability margin criteria was achieved in the gas curtailment case and the reference case. In fact, an additional 1640 MW of west-side generation could be taken off-line -- while meeting the required 2.5% flow margin (570 MW) on the West of Cascades North path -- in the gas curtailment case with just the dual fuel units modeled. The limiting contingency was the N-1 Chief Joe-Monroe #1 500 kV line. The reference case could take off 638 MW of

west-side generation with the limiting contingency being the N-2 Schultz-Echo Lake & Schultz-Raver #1 500 kV lines.

2) With I-5 Corridor Reinforcement Project and PGE/BPA Pearl-Sherwood 230kV Reconfiguration Project: The thermal overloads caused by the gas off scenario for Category B contingencies were mitigated with the addition of the I-5 Corridor project and the Pearl-Sherwood 230 kV reconfiguration project, except the issues with the PacifiCorp transformers at Hood River and Troutdale remained, as well as the BPA Chemawa transformer issue.

Conclusion

The study team determined that given the benchmark adopted by the study team, the system performed acceptably from a voltage stability, steady state voltage, and thermal loading perspective with the natural gas plants that do not have dual fuel capability out of service in the I-5 corridor. The risk of such a contingency is believed to be very low and the consequences are not severe. This conclusion is dependent on the assumption that these dual-fuel plants can operate on diesel for the hours needed during the day to meet expected peak winter loads and this operation can continue for several subsequent days.

Appendix A - Path Definitions

The West of Cascades North (WOCN) path is defined in the WECC path rating catalog and listed below.

- Chief Joe – Monroe #1 500kV (BPA)
- Schultz – Echo Lake 500kV (BPA)
- Schultz – Raver #1 500kV (BPA)
- Schultz – Raver #3 500kV (BPA)
- Schultz – Raver #4 500kV (BPA)
- Chief Joe – Snohomish #3 345kV (BPA)
- Chief Joe – Snohomish #4 345kV (BPA)
- Rocky Reach – Maple Valley 345kV (BPA)
- Grand Coulee – Olympia 300kV (BPA)
- Bettas Road – Covington 230kV (BPA)
- Rocky Reach – White River 230kV (PSE)

The West of Cascades South path will be defined as listed in the WECC path rating catalog and is given below.

- Big Eddy-Ostrander 500kV (BPA)
- Ashe-Marion 500kV (BPA)
- Buckley-Marion 500kV (BPA)
- Knight-Ostrander 500kV (BPA)
- John Day-Marion 500kV (BPA)
- McNary-Ross 345kV (BPA)
- Big Eddy-McLoughlin 230kV (BPA)
- Big Eddy-Chemawa 230kV (BPA)
- Midway-N.Bonneville 230kV (BPA)
- Jones Canyon-Santiam 230kV (BPA)
- Big Eddy-Troutdale 230kV (BPA)
- Round Butte-Bethel 230kV (PGE)

Appendix B – Contingency List

The full Northwest Category B and Category C contingency definition list used for ColumbiaGrid system assessments total over 4000 individual contingencies. The full list was applied to identify potential thermal overloads. For voltage stability simulations, the list was reduced to 45 contingencies that have previously resulted in failed solutions when west side generation was displaced with wind. These contingency names are listed below.

Category B:

N-1: Raver Shunt Capacitors
N-1: Echo Lake Shunt Capacitors
L_CHIEFJO500-MONROE500C1-MS
N-1: 3TM Monroe-Echo LK-SnoK 500kV
N-1: ALLSTON500-KEELER500C
L_ECHOLAKE500-SCHULTZ500C1-MS

Category C:

BF 5072 Echo Lk-Maple Vl & Echo Lk Caps
N-2: Big Eddy-Ostrander 500kV/Big Eddy-Troutdale 230kV
N-2: CUSTER-MONROE 1&2
BF 4510 PEARL-MARION & PEARL 500/230 BK1
BF 4598 Chief Joe-Monroe #1 500kV & Chief Joe PH 6&7 (21-27)
BF 5111 MON-ECHO L-ECHO L CAPS
N-2: Pearl-Ostrander 500kV/Pearl-Marion 500kV
BF 4519 Custer-Monroe #1 500kV & Mon Caps
N-2: PAUL-SATSOP 500 & OLYMPIA-SATSOP 230
N-2: CHIEF JO-MONROE 500 & CHIEF JO-SNOHOMISH 345 #4
N-2: PAUL-STSOP, PAUL-OLY
N-2: Ashe-Marion 500kV/Buckley-Marion 500kV
N-2: MONROE-CUSTER #1 500 & CHIEF JO-SNOHOMISH #4
BF 4548 ALLSTON-PAUL-SATSOP
BF 4672 MON-C JOE 500 W/MON MSC
N-2: JOHN DAY-MARION & BUCKLEY-MARION 500
N-2: PAUL-ALLSTON 2 & ALLSTON-NAPAVINE 500
BF KEELER 230 - FAULT ANY LINE
BF 5148 COULEE-SCHULTZ-ECHO LAKE
BF 4272 INGLEDOW-CUSTER-MON

BF 5078 SCHULTZ-ECHO LAKE-MAPLE VALLEY
BF 4526 ECHO LAKE-MONROE-CUSTER
BF 5157 COULEE-SCHULTZ-RAVER
BF 4522 Monroe-Echo Lake-SnoKing 500kV & Monroe Cap Grp #3
N-2: CHIEF JO-MONROE & CHIEF JO-SICKLER 500
BF Chief Joe 1 & 2 Bus Section 230
N-2: MON-SK-EL 5 & MON-SAMM2 (198)
BF 4394 ALLSTON-KEELER-PEARL
BF OLYMPIA WEST BUS
BF 4530 RAVER-PAUL-SATSOP
BF 4322,24,94 Clear Keeler 500kV
N-2: Schultz-Echo Lake 500kV / Schultz-Raver #4 500kV
BF 5075 SCHULTZ-ECHO LAKE-ECHO LAKE CAPS
BF 4540 NAPAVINE-PAUL-SATSOP
BF 4554 OLYMPIA-PAUL-TONO
BF 5121 MAPLE VALLEY-ECHO LAKE-SCHULTZ-ECHO LAKE CAPS
N-2: CHIEF JO-MONROE 500 & CHIEF JO-SNOHOMISH 345 #3
N-2: Schultz-EchoLake & Schultz-Raver 500kV
N-2: COULEE-SCHULTZ 1&2
N-2: SCHULTZ-WAUTOMA 500 & VANTAGE-SCHULTZ 500
BF 4502 NAPAVINE-ALLSTON-KEELER

Appendix C – Westside Generation Displacement Order

Number	Name	ID
42042	WHITHRN2	2
42721	FREDERC1	1
42722	FREDERC2	2
42112	FREDONA2	2
42111	FREDONA1	1
42043	WHITHRN3	3
42115	FREDONA4	4
42114	FREDONA3	3
43019	BEAVER	1
43017	BEAVER	5
43017	BEAVER	6
43017	BEAVER	4
43017	BEAVER	3
43017	BEAVER	2
43017	BEAVER	1
42014	ENSERCHL	L
42013	ENSERCH3	3
42012	ENSERCH2	2
42011	ENSERCH1	1
42133	MRPTGEN3	3
42022	SUMAS L	L
42021	SUMAS 1	1
42032	TENASKA2	2
42033	TENASKAL	L
42031	TENASKA1	1
47734	BHP 30	30
47735	BHP 40	40
47736	BHP 5060	50
47736	BHP 5060	60
47737	BHP 70	70
47598	GRYHB S1	1
47597	GRYHB G2	1
47596	GRYHB G1	1
47676	MNTFRM S	1
47675	MNTFRM G	1
47216	RVR RD C	1
47576	FREDST S	1
47577	FREDST G	1

43907	PORTW S1	1
43905	PORTW G1	1
47590	CHEH S1	1
47588	CHEH G1	1
47589	CHEH G2	2
47740	CENTR G1	1
46439	ROSS 42	1
46439	ROSS 42	2
46441	ROSS 44	3
46441	ROSS 44	4
42124	UP BAKER	1
42124	UP BAKER	2
42121	LO BAKER	1
46429	GORGE	3
46429	GORGE	2
46429	GORGE	1
46430	GORGE 4	4
46419	DIABLO31	1
46420	DIABLO32	2
45689	JACKSN2	1
45687	JACKSN1	1

Appendix D – Puget Sound Area Generation Assumptions

Information in this appendix is intended to be used to develop the Puget Sound area generation assumptions to be used in the study which is a key study assumption. The following table shows the weighting factors that were calculated for scenarios when developing the recently completed Puget Sound Area Transmission Expansion Plan. 2007 and 2008 hourly generation and temperature data was obtained for the Northwest. For every hour of the heavy load periods (6:00 am – 10:00 pm, Monday – Friday) the generation and temperature data was compared to each of the 15 generation scenarios and 5 temperature scenarios traditionally used in operational nomogram calculations. The table shows the number of occurrences of each scenario that occurred during the two year period. Each of these values was divided by the total number of occurrence values found for any given scenario.

ATC Generation Weighting Factors for TCRM Calculator Matrix															
Percent Occurance															
BPA Op Case ATC Generation Pattern	G0	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14
SCL + Snoh Generation	**140**	**460**	**775**	**140**	**460**	**775**	**140**	**460**	**775**	**140**	**460**	**775**	**140**	**460**	**775**
PSE Generation	**100**	**100**	**100**	**260**	**260**	**260**	**525**	**525**	**525**	**1000**	**1000**	**1000**	**1200**	**1200**	**1200**
BPA Op Case ATC Temperature Pattern								Percent Chance of Flow Direction							
Summer	35	45	60	70	85			Summer	NS	77.0%	Winter	NS	45.2%		
Winter	25	35	45	60	70				SN	23.0%		SN	54.8%		
Summer NS Matrix (# of Occurances)	**G0**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**	**G8**	**G9**	**G10**	**G11**	**G12**	**G13**	**G14**
35	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0
45	0	7	0	20	22	0	99	96	35	0	0	0	0	0	0
60	8	56	3	98	362	17	394	292	4	4	9	0	0	0	0
70	0	6	0	12	146	33	186	249	2	18	20	0	0	0	0
85	0	0	0	0	0	0	7	37	0	3	9	0	0	0	0
Summer NS Matrix	**G0**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**	**G8**	**G9**	**G10**	**G11**	**G12**	**G13**	**G14**
35	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.31%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
45	0.00%	0.24%	0.00%	0.68%	0.75%	0.00%	3.37%	3.27%	1.19%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
60	0.27%	1.90%	0.10%	3.33%	12.31%	0.58%	13.40%	9.93%	0.14%	0.14%	0.31%	0.00%	0.00%	0.00%	0.00%
70	0.00%	0.20%	0.00%	0.41%	4.97%	1.12%	6.33%	8.47%	0.07%	0.61%	0.68%	0.00%	0.00%	0.00%	0.00%
85	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.24%	1.26%	0.00%	0.10%	0.31%	0.00%	0.00%	0.00%	0.00%
Summer SN Matrix (# of Occurances)	**G0**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**	**G8**	**G9**	**G10**	**G11**	**G12**	**G13**	**G14**
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	42	22	0	72	49	0	6	15	0	0	0	0	0	0	0
60	23	32	0	38	164	20	37	70	0	0	0	0	0	0	0
70	0	8	0	0	19	18	9	33	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Summer SN Matrix	**G0**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**	**G8**	**G9**	**G10**	**G11**	**G12**	**G13**	**G14**
35	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
45	1.43%	0.75%	0.00%	2.45%	1.67%	0.00%	0.20%	0.51%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
60	0.78%	1.09%	0.00%	1.29%	5.58%	0.68%	1.26%	2.38%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
70	0.00%	0.27%	0.00%	0.00%	0.65%	0.61%	0.31%	1.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
85	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Winter NS Matrix (# of Occurances)	**G0**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**	**G8**	**G9**	**G10**	**G11**	**G12**	**G13**	**G14**
25	0	0	0	0	0	0	0	1	2	0	0	3	0	0	0
35	1	21	3	3	131	12	0	84	102	0	9	10	0	0	0
45	51	116	5	62	381	29	11	198	42	0	1	0	0	0	0
60	74	66	0	42	72	3	0	20	1	0	0	0	0	0	0
70	9	43	0	8	4	0	0	2	0	0	0	0	0	0	0
Winter NS Matrix	**G0**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**	**G8**	**G9**	**G10**	**G11**	**G12**	**G13**	**G14**
25	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.06%	0.00%	0.00%	0.08%	0.00%	0.00%	0.00%
35	0.03%	0.59%	0.08%	0.08%	3.65%	0.33%	0.00%	2.34%	2.85%	0.00%	0.25%	0.28%	0.00%	0.00%	0.00%
45	1.42%	3.24%	0.14%	1.73%	10.63%	0.81%	0.31%	5.52%	1.17%	0.00%	0.03%	0.00%	0.00%	0.00%	0.00%
60	2.06%	1.84%	0.00%	1.17%	2.01%	0.08%	0.00%	0.56%	0.03%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
70	0.25%	1.20%	0.00%	0.22%	0.11%	0.00%	0.00%	0.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Winter SN Matrix (# of Occurances)	**G0**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**	**G8**	**G9**	**G10**	**G11**	**G12**	**G13**	**G14**
25	0	0	0	0	7	3	0	7	10	0	10	2	0	0	0
35	4	33	1	4	186	27	1	207	63	0	1	4	0	0	0
45	145	243	10	73	446	61	3	129	15	0	0	0	0	0	0
60	49	55	0	40	97	2	1	4	0	0	0	0	0	0	0
70	0	5	0	0	15	0	0	0	0	0	0	0	0	0	0
Winter SN Matrix	**G0**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**	**G8**	**G9**	**G10**	**G11**	**G12**	**G13**	**G14**
25	0.00%	0.00%	0.00%	0.00%	0.20%	0.08%	0.00%	0.20%	0.28%	0.00%	0.28%	0.06%	0.00%	0.00%	0.00%
35	0.11%	0.92%	0.03%	0.11%	5.19%	0.75%	0.03%	5.77%	1.76%	0.00%	0.03%	0.11%	0.00%	0.00%	0.00%
45	4.04%	6.78%	0.28%	2.04%	12.44%	1.70%	0.08%	3.60%	0.42%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
60	1.37%	1.53%	0.00%	1.12%	2.71%	0.06%	0.03%	0.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
70	0.00%	0.14%	0.00%	0.00%	0.42%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Chart 1 - Puget Sound Area Historical Generation

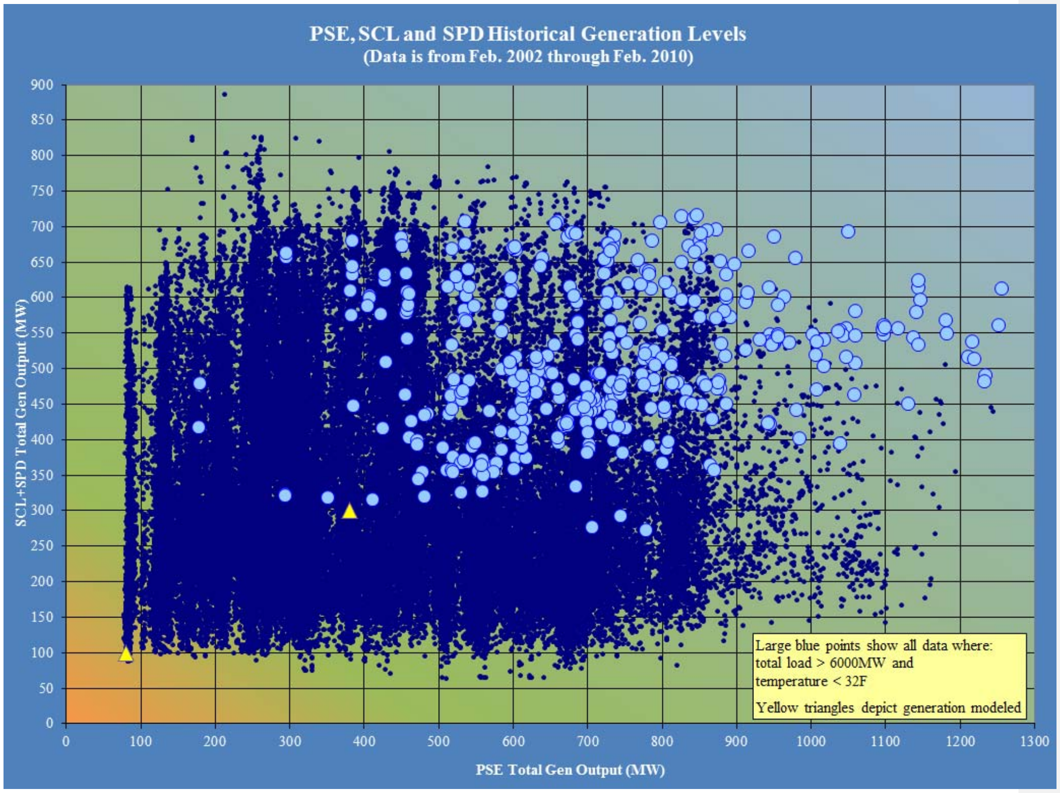


Chart 2 - Puget Sound Area Generation Duration Curve - Peak load hours

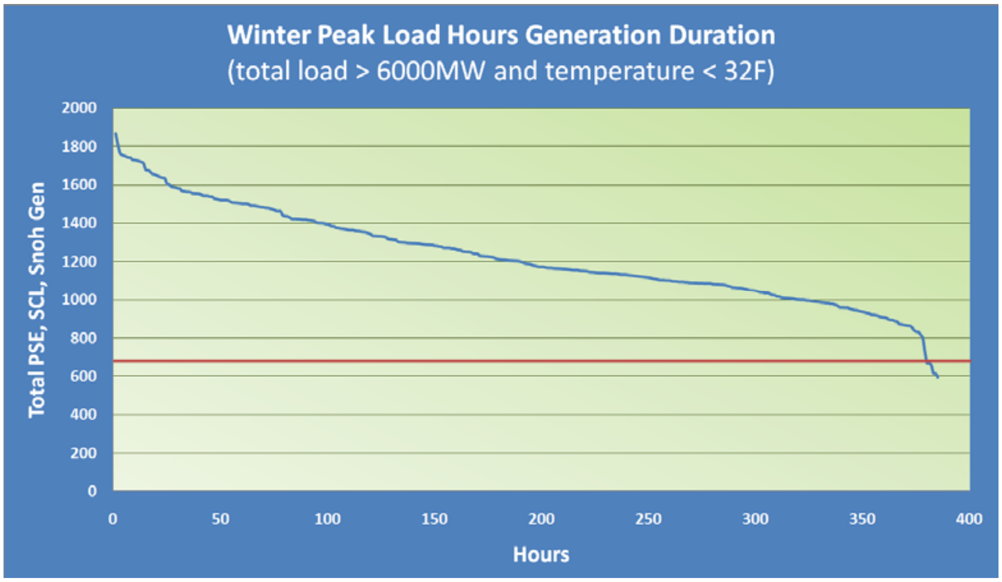


Chart 3 - Puget Sound Area Generation Duration Curve - All load hours

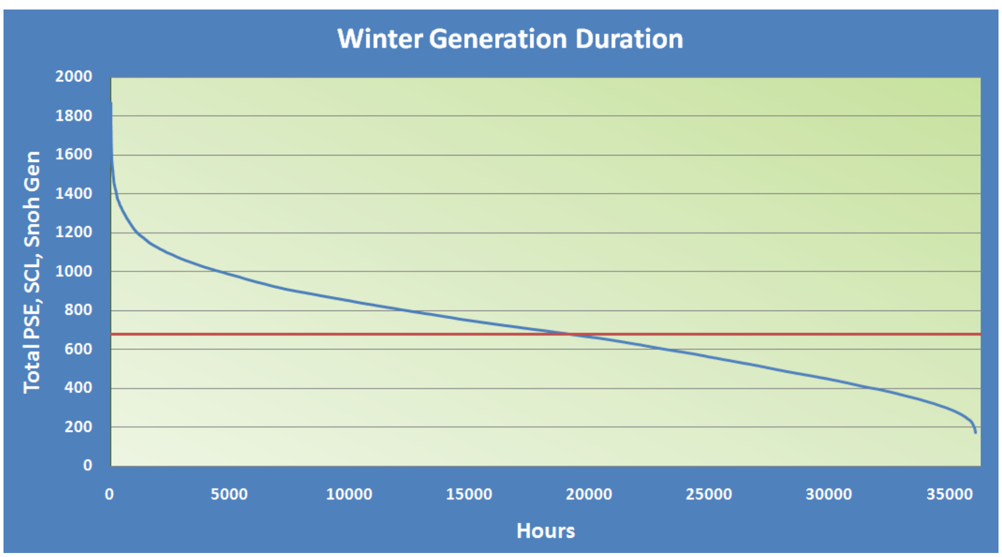


Table 1: Specific Generation Unit Modeling Assumptions

Hydro Gen Portland to BC Border

Name	Owner	Reference Case and Gas Curtailment Case Gen (MW)
Ross gen	Seattle	90
Diablo gen	Seattle	100
Gorge gen	Seattle	130
Upper Baker gen	Puget	82
Lower Baker gen	Puget	68
Cedar Falls gen	Seattle	3.23
Tolt River gen	Seattle	7.13
Snoqualmie Falls gen	Puget	30.6
Jackson gen	Snohomish	70
Electron Heights gen	Puget	11.95
Alder gen	Tacoma	42.8
Lagrande gen	Tacoma	54.5
Cushman gen	Tacoma	44.7
Mayfield gen	Tacoma	140
Mossy Rock gen	Tacoma	320
Cowlitz Falls gen	Lewis PUD	34
Glenoma gen	Energy Northwest	29
Merwin gen	Pacificorp	135
Swift gen	Pacificorp	234
Yale gen	Pacificorp	89.24

Thermal Gen Portland to BC Border

Name	Owner	Reference Case Gen (MW)	Gas Curtailment Case Gen (MW)
Beaver gen	PGE	465	465
Big Hanaford gen	Transalta	0	0
Camas Mill gen	Pacificorp	29.22	29.22
Centralia gen		712	712
Chehalis gen	Pacificorp	614	614
Enserch gen	Puget	0	160
Frederickson CCCT gen	Puget/Atlantic Capital	270	0
Frederickson gen	Puget	0	160
Fredonia gen	Puget	0	316
Grays Harbor gen	Invenergy	630	0
LongviewGen-CowlitzPUD	Cowlitz PUD	49.83	49.83

March Point gen	Puget	130	130
Mint Farm gen	Puget	235	0
Port Westward gen	PGE	399	0
River Road gen	Clark PUD	253.7	0
Sawmill gen	Puget	25	25
Sumas gen	Puget	0	0
Ferndale gen	Puget	0	270
Whitehorn gen	Puget	0	150

Appendix E – Voltage Tuning and Capacitor Switching Assumptions

Pre-contingency voltage tuning

1. Maximize the pre-contingency switched shunts at 230 kV and below on the west side. Change the 500/230 kV transformer taps to allow 230 kV switched shunt support of pre-contingency 500 kV voltage (i.e. maximize off nominal tap ratio) and adjust the 500 kV switched shunts to prevent pre-contingency over voltages.

2. Minimize the reactive generation so the dynamic reactive reserve is available post-contingency. This could involve reducing the voltage schedule at the sending end (e.g. Coulee) which will also help the Schultz series capacitors from exceeding their Vmax.

3. Maximize the SVC dynamic reactive reserve and controlled switched shunt availability to ensure maximum post contingency dynamic reactive capability.

Post Contingency

1. Shunt capacitor switching: assume reliable post contingency capacitor/reactor switching at 500 kV connected shunts.

2. Allow system design to result in a very high post contingency critical voltage (above 540 kV). Preliminary mid-term dynamics simulations with rough load model approximations suggested this could be reliably achieved.

Appendix F - Contingency Results Comparison Between Reference and Gas Off Scenarios

<u>Contingency Results Comparison Between Reference and Gas Off Scenarios</u>

The following table documents the overload comparison between the Reference Case and the Gas Off Case. The transmission contingencies beyond the Category B (N-1) are not applicable to the Gas Off case, but are provided for information with an "N/A" in the difference column and Contingency Category column identifying it as a Category C. When the column for the Reference Case shows loading above 100% for the Category C, then mitigation is needed which could alter the results of the N-1 Gas Off results (i.e. the issues could disappear). Revision of the case was not pursued, because the incremental impact of the Gas Off condition over the Reference Case for the N-1 contingencies appears to be minor.

Violation Category									**GasOff**	**Reference**		
Contingency Name	**Number From**	**Name From**	**kV**	**Number To**	**Name To**	**kV**	**Ck**	**Owner**	**Percent**	**Comp Percent**	**Diff**	**Transmission outage Contingency Category (Transmission outage only)**
BF: ROSS 230 EAST BUS, FAULT NORTH BONNEVILLE #2	45299	TROUTDAL	115	45303	TROUTPP2	230	1	PACW	121	104	**1717**	**C**
N-2: NORTH BONNEVILLE-SIFTON TAP-ROSS 1 & 2	45299	TROUTDAL	115	45303	TROUTPP2	230	1	PACW	137	121	**1616**	**C**
BF: PEARL 230 (BUS SECTIONALIZING BREAKER)	43083	CANEMAH	115	43559	SULIVAN	115	1	PGE	126	117	**99**	**C**
BF: BONNEVILLE 115	45307	TUCKER1	69	40541	HOOD RVR	115	1	PACW	126	118	**88**	**C**
L_CASCDLK115-HOODRVR115C1	45307	TUCKER1	69	40541	HOOD RVR	115	1	PACW	105	97	**8**	**B**
L_ACTON115-CASCDLK115C1	45307	TUCKER1	69	40541	HOOD RVR	115	1	PACW	104	95	**8**	**B**
L_ACTON115-BONNVILE115C1	45307	TUCKER1	69	40541	HOOD RVR	115	1	PACW	103	95	**8**	**B**
L_PEARL#230-SHERWOOD230C1	40826	PEARL W	230	90097	PEASHE11	230	1	BPA	109	102	**8**	**B**
BF: North Bonneville West 230kV flt Ross #1	40141	NBONVL E	230	40977	SIFT TP2	230	2	BPA	111	104	**77**	**C**
L_BONNVILE115-STEVNTP115C1	45307	TUCKER1	69	40541	HOOD RVR	115	1	PACW	125	117	**7**	**B**
L_NBONVLE230-NBONVLW230C1	40141	NBONVL E	230	40977	SIFT TP2	230	2	BPA	108	101	**77**	**C**
N-1: Troutdale to Gresham	45301	TROUTPP1	230	45297	TROUTDAL	69	1	PACW	102	95	**7**	**B**
N-1: MCLOUGHLIN-PEARL #-SHERWOOD	40826	PEARL W	230	90097	PEASHE11	230	1	BPA	109	102	**7**	**B**
L_PEARLE230-PEARL#230C1	40826	PEARL W	230	90097	PEASHE11	230	1	BPA	102	97	**5**	**B**
L_PEARLW230-SHERWOOD230C1-MS	40824	PEARL E	230	43773	PEARL #	230	1	PGE	109	104	**5**	**B**
L_CHEMAWA230-SALEM230C1	40213	CHEMAWA	230	40211	CHEMAWA	115	1	BPA	102	98	**3**	**B**

T_SALEM230-SALEM115C1	40213	CHEMAWA	230	40211	CHEMAWA	115	1	BPA	102	98	**3**	**B**
BF: LINNEMAN V226 (LINN & GRESH) 230KV	43763	HEMLOCK#	115	43477	ROCKWD 2	115	1	PGE	114	111	**N/A**	**C**

Planned mitigation exists for the Category B contingencies at Pearl involving L_PEARL#230-SHERWOOD230C1, N-1: MCLOUGHLIN-PEARL #-SHERWOOD, L_PEARLE230-PEARL#230C1, and L_PEARLW230-SHERWOOD230C1-MS (BPA/PGE project). The only remaining issue above 100kV is the 2% overload of the Chemawa 230/115kV transformer.

The study team reviewed the above study results and deemed the overloads noted in the Gas Off case to be minor and correctable with system adjustments that would be allowed prior to the contingency. As a result, no significant thermal overload conditions were identified in the Gas Off case.

At the team meeting on November 20, 2012, the addition of a sensitivity study to determine the incremental impact of adding the I-5 Corridor Project and the BPA/PGE Pearl-Sherwood re-termination project was requested. The Category B contingency results are shown below, which demonstrates the Pearl issues were mitigated, but the PACW transformer issues at Hood River and Troutdale remain, as well as the BPA Chemawa transformer issue.

Violation Category											
Label	Viol: Owner Names	Number From	Name From	Nom kV From	Number To	Name To	Nom kV To	Circuit	Percent	Comp Percent	Diff Percent
L_CASCDLK115-HOODRVR115C1	PacifiCorp - West	45307	TUCKER1	69	40541	HOOD RVR	115	1	104.8	96.6	8.2
L_ACTON115-BONNVILE115C1	PacifiCorp - West	45307	TUCKER1	69	40541	HOOD RVR	115	1	103.5	95.3	8.1
L_ACTON115-CASCDLK115C1	PacifiCorp - West	45307	TUCKER1	69	40541	HOOD RVR	115	1	103.6	95.5	8.1
L_BONNVILE115-STEVNTP115C1	PacifiCorp - West	45307	TUCKER1	69	40541	HOOD RVR	115	1	124.5	117.4	7.1
N-1: Troutdale to Gresham	PacifiCorp - West	45301	TROUTPP1	230	45297	TROUTDAL	69	1	101.5	95	6.5
T_SALEM230-SALEM115C1	Bonneville Power Admin	40213	CHEMAWA	230	40211	CHEMAWA	115	1	101.8	98.3	3.5
L_CHEMAWA230-SALEM230C1	Bonneville Power Admin	40213	CHEMAWA	230	40211	CHEMAWA	115	1	101.7	98.2	3.5

<u>Voltage Stability Comparison</u>

The comparison shows that the Gas Off condition has more voltage stability margin than the Reference condition. This is caused by the combination of (1) assuming generators with back up fuel are on when these same generators important the voltage stability limit calculation are actually off in the Reference condition, and (2) the criteria for system design adequacy with the Gas Off condition is N-1, compared to N-2 for the Reference condition.

Condition	Limiting Contingency	Additional Westside Gen That Can Be Off From Reference
Reference	N-2: Schultz-Raver&Schultz-EchoLake	1260 MW
Gas Off	N-1: Chief Jo-Monroe	2171 MW (note: the Gas Off condition begins with 731 MW less westside generation, so the additional westside generation that can be off from the Gas Off is 2171 – 731 = 1440 MW)

Appendix G – I-5 Corridor Dual Fuel Units

Generator	Owner	Natural Gas & Diesel	Winter capacity	Notes	Tank or pipe On site oil
Beaver	PGE	Yes	520		
Port Westward	PGE	No	415		x
Mint Farm	Puget Sound Energy	No	300		x
Encogen	Puget Sound Energy	Yes	160	2 tanks w/470,000 gallons storage each. Diesel usage must not exceed 300,000 gallons per year for testing or 10,600,00 ga/year for testing and operation. Can only be used if gas is curtailed.	tanks
Fredonia Units 1 & 2	Puget Sound Energy	Yes	208		tanks
Fredonia Units 3 & 4	Puget Sound Energy	Yes	108		tanks
Ferndale	Puget Sound Energy	Yes	270	limited to 20.4 million gallons per year	Tanks
Fredrickson New	Puget Sound Energy/ Atlantic Capital?	No	274		x
Fredrickson old	Puget Sound Energy	Yes	178	can not consume more than 6,900,000 MMBtu facility wide during any consecutive 12-month period. 139,000 Btu per gallon of distillate oil.	Tanks
March Point	MPCC	Yes	120		Pipe
Sumas Cogen	Puget Sound Energy	No	125		x
Whitehorn	Puget Sound Energy	Yes	150		tanks and pipes
River Road	Clark PUD	No	248		x
Chehalis Generating	PacifiCorp	yes	520	720 hrs/year when NG not available. May not have been used historically.	???
Grays Harbor (Satsop)	Invenergy	no	600		x
Big Hanaford	TransAlta	no	268		x

	Total Dual Fuel		2234		
	Total		4464		