Alberta-BC Export Capability

Power – Voltage Stability Analysis

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Updated on Feb 17, 2005 by Steve Heidt

	Name	Signature	Date
Prepared:	Kapil Saxena		
Approved:	Steve Heidt		

APEGGA Permit to Practice P-8200

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1.0 Background

The AESO initiated a study to examine the transfer limits on the Alberta BC intertie in late 2003. The study, titled Alberta –BC Interconnection studies, was completed in May 2004. The study results were primarily used to develop operating procedures related to BC import levels combined with single and multiple contingencies in the KEG area with Genesee #3 in service.

A second study, Transmission Study of KEG Region was undertaken during September 2004 to determine if the increased flows on the Edmonton to Calgary corridor due to Genesee #3 operation should be considered in defining transfer limits on the Alberta BC intertie. The study concluded that no changes to operating procedures were required for the period 2004 to winter 2005/06.

Previous studies performed in 2002 by the Transmission Administrator identified that Alberta to BC transfer limits were a function of both Alberta demand and southern Alberta generation. The studies completed in 2004 confirmed the results of the previous studies. The studies also indicated that southern Alberta is subject to voltage collapse for contingencies during conditions of high demand, high exports, low southern generation.

In the last quarter of 2004, the AESO performed a detailed study to determine the impact of southern generation on export capability. This document contains the details and results of the study.

2.0 Study Objective

To review and revise, where necessary, export limitations for both the winter and summer seasons. Export limitation findings will be applicable until the 240 KV backbone and associated network topology is significantly modified.

Determine the sensitivity of export capability on various generation and transmission facilities, and to develop specific export limitations for each contingency.

2.1 Sensitivity Study Objective

To determine the sensitivity of export capability on various groups of generation, such as the Calgary area, Bow, Sheerness, and Medicine Hat.

3.0 Study Scope

Performed power-voltage (PV) analysis on the AIES to determine the voltage stability load limit (VSLL) of the AIES in base conditions.

This study uses a deterministic methodology to reduce the reliance on assumptions regarding online southern generation.

The analysis was repeated for the winter 2004/05, and summer 2005 cases, taking into account the unique system characteristics of each season.

Each seasonal study was analyzed by doing PV analysis of various contingencies, repeated for 0-800 MW of export (in increments of 100 MW).

4.0 Study Assumptions

Constant MVA load models were used. This is in alignment with the WECC Paper titled “Voltage Stability Criteria, Undervoltage Load shedding Strategy, and reactive Power Reserve Monitoring Methodology” dated May 1998

Area loads were scaled using a constant power factor.

Only areas of the province that are not largely made up of industrial load were scaled during PV analysis; this is because areas with large industrial loads are generally base loaded, and do not grow in the same uniform manner as non-industrial loads. The areas scaled include: 6, 13, 20- 24, 26, 27, 29-32, 34-39, 42-47, 49, 50, 52-57, and 60.

5.0 Methodology

Selected single and double transmission contingencies were examined for Power-Voltage stability. These contingencies include the loss of major generation units in southern Alberta, as well as single line, and double circuit contingencies. Single contingencies require a 5% load margin, while double contingencies require a 2.5% load margin.

Additional contingencies were examined to determine the export capability of the province during times when a major system element was out of service. Double contingencies (over an original outage) were taken into consideration in these scenarios.

Selected sensitivities were studied together in order to determine the additive effect of various units.

6.0 Scenarios Studied

The base cases used were medium-light load cases. All capacitor banks in southern Alberta were online in the base case; this resulted in very high levels in the base cases, but allowed the system to be scaled up to a realistic load level (in reality, the caps would be switched in on a need basis, but the PV analysis tool does not allow this).

6.1 Pre-Conditions

The table below lists the power factor that each base case was set to; these values correspond to other cases used in previous studies, and represent the historical power factors determined for each season.

Table 1: Base Case Power Factors

Area	Winter	Summer
AIES	0.939	0.930
Calgary area	0.958	0.923
South	0.958	0.933

6.2 Generation Dispatch

Southern generation was adjusted in the study cased to levels that represent the lowest level that could be expected from each plant on most days. A unit would have to be on approximately 95% of all hours (in the recent year) for it to be on in the case. This analysis was based on seasonal duration curves from each plant.

Table 2: Southern Generation Levels

	Winter	Summer
Sheerness NTG	550 MW	355 MW
Battle River NTG	580 MW	582 MW
South Hydro (Irrigation)	Disconnected	36 MW*
South Wind	Disconnected	Disconnected
Med Hat (Negative number means load)	-32 MW	-32 MW

Joffre	95 MW	125 MW
Brazeau	Disconnected	Disconnected
Bow Hydro	16 MW	24 MW
Carseland	64 MW	32 MW

Old Man = 20 MW, Raymond Reservoir = 9 MW, Taylor = 4.5 MW, Chin Chute = 2.5 MW

6.3 Contingencies

The following table lists the single contingencies that were analyzed for voltage stability:

Table 3: Single Contingencies

Contingency #	Element
A4	Sheerness 1
A5	21S Cap
A6	Carseland 1
A7	Calpine 1 & 2
A8	900L
A9	911L
A10	912L
A11	916L
A12	918L
A13	924L
A14	928L
A15	929L
A16	932L
A17	937L

The following table lists the single contingencies, while one Sheerness unit was also out of service, that were analyzed for voltage stability:

Table 4: Single Contingencies with One Sheerness Unit out

Contingency #	Element
A18	900L & Sheerness1
A19	911L & Sheerness1
A20	912L & Sheerness1
A21	916L & Sheerness1
A22	918L & Sheerness1
A23	924L & Sheerness1
A24	928L & Sheerness1
A25	929L & Sheerness1
A26	932L & Sheerness1
A27	937L & Sheerness1

The following table lists the double contingencies that were analyzed for voltage stability:

Table 5: Double Contingencies

Contingency #	Elements	Notes
B1	Sheerness 1 & 2	
B2	Sheerness 1 & Langdon SVC	
B3	Carseland 1 & 2	
B4	900L & Sheerness1 & 2	See Note

Contingency #	Elements	Notes
B5	911L & Sheerness1 & 2	See Note
B6	912L & Sheerness1 & 2	See Note
B7	916L & Sheerness1 & 2	See Note
B8	918L & Sheerness1 & 2	See Note
B9	924L & Sheerness1 & 2	See Note
B10	928L & Sheerness1 & 2	See Note
B11	929L & Sheerness1 & 2	See Note
B12	932L & Sheerness1 & 2	See Note
B13	937L & Sheerness1 & 2	See Note
B14	927L & 924L	
B15	901L & 910L	
B16	901L & 912L	
B17	903L & 190L	
B18	911L & 925L	
B19	912L & 914L	
B20	914L & 910L	
B21	916L & 917L	
B22	917L & 932L	
B23	918L & 190L	
B24	922L & 906L	
B25	925L & 900L	
B26	925L & 901L	

Contingency #	Elements	Notes
B27	926L & 922L	
B28	928L & 903L	
B29	928L & 906L	
B30	928L & 916L	
B31	929L & 917L	
B32	929L & 918L	
B33	929L & 925L	
B34	929L & 932L	
B35	933L & 931L	
B36	933L & 934L	
B37	936L & 937L	
B38	937L & 901L	
B39	937L & 924L	

Note: The contingencies are similar with contingencies A18 through A27 except and additional Sheerness unit is off line. This analysis was completed in order to further determine the effects of Sheerness outages.

6.4 Cases

The summer and winter base cases were modified to have various levels of BC export; the initial case load varied from each case in order to increase/decrease export appropriately for that case. Scaling was done according to the description in section 4.

Table 6: Base Cases

Case ID	Description
S0	Summer 2005 – 0 MW Export

Case ID	Description
S1	Summer 2005 – 100 MW Export
S2	Summer 2005 – 200 MW Export
S3	Summer 2005 – 300 MW Export
S4	Summer 2005 – 400 MW Export
S5	Summer 2005 – 500 MW Export
S6	Summer 2005 – 600 MW Export
S7	Summer 2005 – 700 MW Export
S8	Summer 2005 – 800 MW Export
W0	Winter 2004/05 – 0 MW Export
W1	Winter 2004/05 – 100 MW Export
W2	Winter 2004/05 – 200 MW Export
W3	Winter 2004/05 – 300 MW Export
W4	Winter 2004/05 – 400 MW Export
W5	Winter 2004/05 – 500 MW Export
W6	Winter 2004/05 – 600 MW Export
W7	Winter 2004/05 – 700 MW Export
W8	Winter 2004/05 – 800 MW Export

7.0 Sensitivity Studies

7.1 Sensitivities

For the sensitivity studies a different generation level were used in the base case. These differences are as follow:

Table 7: Generation Differences for Sensitivities Studies

Plant	Winter	Summer
Sheerness NTG	733 MW	750 MW
Med Hat Export	0 MW	0 MW
Joffre	200 MW	200 MW

The following sensitivities were studied by setting various generation units to the output levels listed below.

Table 8: Plant and Element Sensitivities Studied

Plant / Element	Winter	Summer
Carseland	0-80 MW	0-80 MW
Calpine	0-290 MW	0-290 MW
Balzac	0-100 MW	0-100 MW
Cavalier	0-100 MW	0-100 MW
Calgary Area Generation (Combination of Units)	0-570 MW	0-570 MW
Bow Hydro	0-25 MW	0-150 MW
Med Hat Export	0-40 MW	0-40 MW
Joffre Generation	0-400 MW	0-400 MW
Sheerness Min	@ 280 MW NTG	@ 280 MW NTG
Battle River	580 – 660 MW	582 – 662 MW
South Hydro	0 MW	0-35 MW
Brazeau	0-290 MW	0-350 MW
Calgary Area MVAR	Loss of 50 MVar Cap bank	Loss of 50 MVar Cap Bank

8.0 Summary of Results

8.1 Sensitivity Results

Note that the sensitivity has slightly different results, as load correction offsets were not used, and the base case conditions were different that the final cases used for the determining Alberta to BC export Levels.

The sensitivity equations below represent the MW increase in AIES VSLL that can be achieved by dispatching a given MW level for each generator or plant. Note that some units were dispatched to nonzero levels in the base case.

Table 9: Sensitivities Results

	Increase in VSLL from Base Case	
Sensitivity	**Winter**	**Summer**
Carseland Plant	MW Gen	35 + MW Gen
Calpine Plant	75 + MW Gen	95 MW + MW Gen
Balzac Plant	80 + MW Gen	85 MW + 1.05 MW Gen
Cavalier Plant	-15 + MW Gen	MW Gen
Calgary Area Generation (Combination of Units)	Additive – 30 MW	Additive as listed above.
Bow Hydro	1.25 * MW Gen	20 MW + 1.35 * MW Gen
Med Hat Export	1.65 * MW Export	1.75 * MW Export
Joffre Generation[1]	110 MW + 0.45 * MW Gen	62.5 MW + 0.425 * MW Gen
Sheerness Min	100 MW	-25 MW for 0-200 MW, 0 MW for 300-700 MW[2]
Battle River	40 MW	40 MW
South Hydro[3]	-	MW Generation
Brazeau	50 MW + 0.275 MW Gen	35 + 0.25 * MW Gen
Calgary Area MVAR	1 MVar = 1 MW	1 MVar = 1 MW

[1] Base Case Generation Level = 200 MW

[2] This worst contingency for this switched from the loss of 936L & 937L to Sheerness 1 and 2 at 300 MW export (only because the tie would trip if 936L & 937L were to trip for ≥ 300 MW of Export).

[3] Base Generation = 35 MW in summer

Graphical results are located in appendix B.

The percentage of MW effectiveness for each generator was found by setting the generator MW output to various levels, and finding the increase in VSLL for each increase in generation MW output; most units provided a very linear MW support level relative to MW generation. Almost all of the generators and plants provided some support just from being on line; this can be attributed to the SVC-like characteristics of a generator when it is on line (in terms of MVAr response and MVAr output). The Calpine and Balzac plants provided the most significant support just from being online. Generally, the electrical connection characteristics of each generator or plant determined its effectiveness.

Initial findings suggest that the results from sensitivity studies could be considered to provide support in an additive manner, i.e. the VSLL increase resulting from two generators can be added if both generators are online. As this is an initial finding, it needs to be examined further to confirm that additive properties are applicable for all sensitivities.

The voltage stability load limits found in the summer case were lower than those found in the winter case for a given scenario; this is due to the lower power factor in the summer case. However, most of the generators and plants in the sensitivity studies actually provided a higher level of support in the summer case. This is also a result of the low power factor, because more VAr support is needed in the summer due to the lower power factor.

8.2 Overall Results

The results indicate that separate sets of ATC limits are required for the winter and summer operations.

8.3 Winter Season results

Review of the current limits indicate that the current limits need only minor adjustments for the winter season operations; the export capability limits can be increased slightly for Alberta Internal Load levels of lower than 7800 MW, and decreased slightly for levels greater than 7800 MW.

With respect to voltage stability, the results of the winter case analysis indicate that the loss of the both of the Sheerness units is most often the worst contingency. When one of the Sheerness units is out of service (i.e. planned or forced maintenance), the limiting contingency is a double contingency of the loss of the other Sheerness unit along with the loss of the Langdon SVC. This is a credible event as the as the SVC could trip due to the MVAr swings it could experience in the event of the loss of the Sheerness unit.

Finally, the loss of 936L and 937L double contingency is the most severe contingency when both Sheerness units are already out of service

8.4 Summer Season Results

Review of the current limits indicate that the summer limits require significant changes; slight export capability increases are capable for loads of less than 6800 MW, while more significant reductions in the export capability limits are needed for load levels greater than 6800 MW. The need for decreased limits can be attributed to not only the lack of based loaded southern generation, but also to the low power factor representative of summer. This power factor is significantly lower (and more realistic) than the power factor used in the past export study and results in a larger need for southern MVar support. Similar to the winter results, the limiting contingency is a double contingency of the loss of both Sheerness units.

If one of the Sheerness unit was out of service (i.e. planned or forced maintenance), the limiting contingency like is the winter conditions is the double contingency of the loss of the Sheerness unit and the Langdon SVC.

Finally, the loss of 936L and 937L double contingency is the most severe contingency when both Sheerness units are already out of service.

8.5 Summary of overall results

A comparison of the existing ATC limits with the winter and summer VSLL can be found on pages A3-A4 and A6-A7. All of the proposed ATC limits are provided on pages A2 and A5; these values were found by interpolating the voltage stability data, and fitting them to the load values that are already in the ATC tool and procedures used by the system controllers.

Thermal and steady state stability limits were also considered, and were used the limiting criteria in place of the PV analysis results if they were more constraining.

APPENDIX A

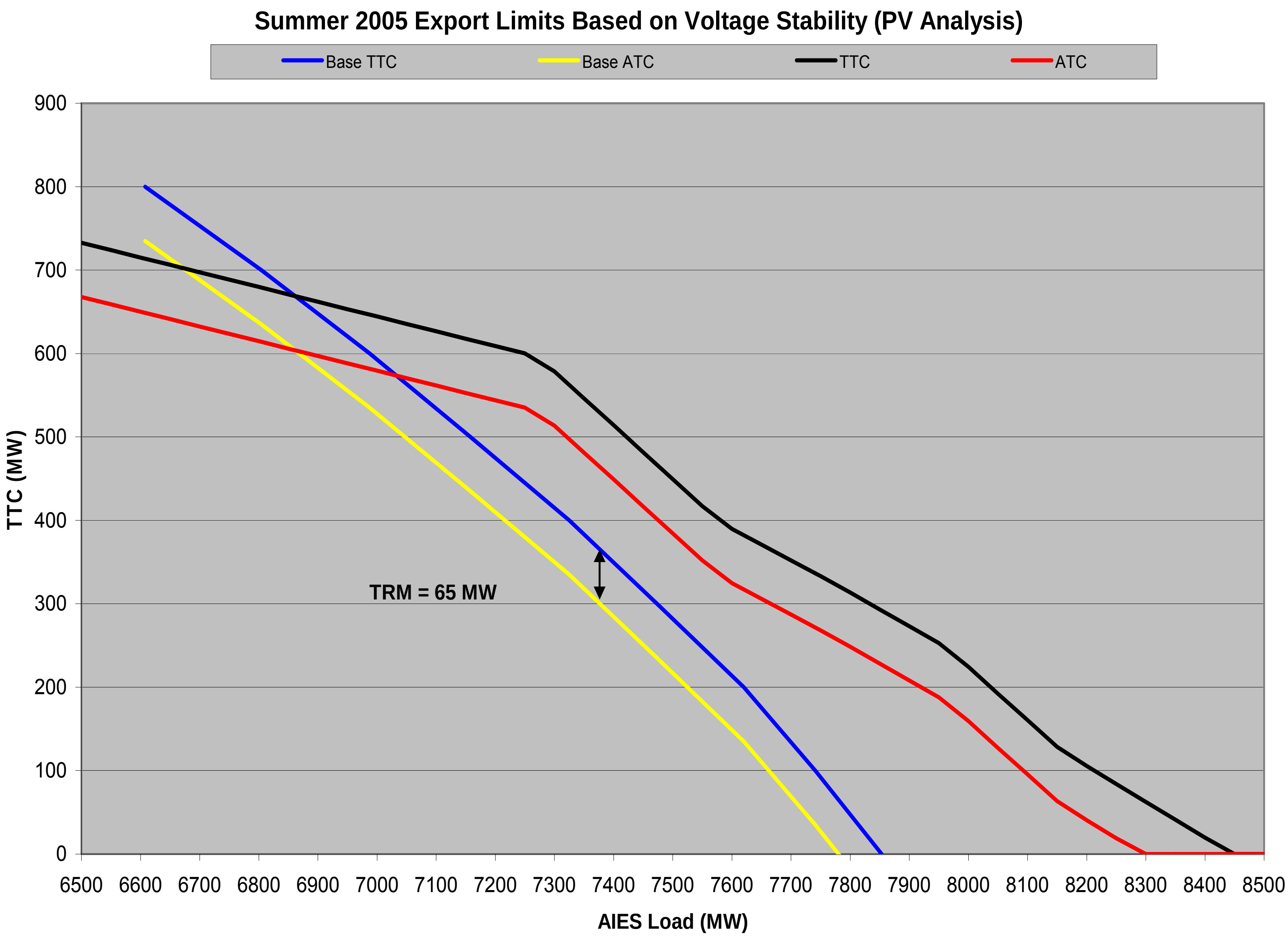
Summer - Export TTC Table

Considering facility Outages

Alberta Internal Load (MW)	**Alberta Internal Load (MW)**	System Normal	1201L Out of Service	SVC Out of Service	937L or 936L Out of Service	North South 240kV Line Out of Service	One Sheerness Unit Off Line	Two Sheerness Units Off Line	0 to 54 Calgary Area cap bank MVAr unavailable	55 to 81 Calgary Area cap bank MVAr unavailable	82 to 108 Calgary Area cap bank MVAr unavailable	Carseland Generation Off Line
8100	9999	65	65	65	65	65	65	65	65	65	65	65
7900	8099	65	65	65	65	65	65	65	65	65	65	65
7700	7899	65	115	65	65	65	65	65	65	65	65	65
7500	7699	135	115	65	115	65	65	65	90	65	65	85
7300	7499	255	115	130	240	165	130	65	215	190	175	205
7100	7299	390	115	255	365	285	255	90	340	315	305	340
6900	7099	515	115	385	465	405	385	165	465	455	425	465
6600	6899	615	115	465	465	515	510	240	590	580	555	590
6300	6599	800	115	465	465	715	690	365	795	765	740	790
0	6299	800	115	465	465	800	800	365	800	800	800	800

Summer - Export ATC Table Considering facility Outages												
Alberta Internal Load (MW)	**Alberta Internal Load (MW)**	System Normal	1201L Out of Service	SVC Out of Service	937L or 936L Out of Service	North South 240kV Line Out of Service	One Sheerness Unit Off Line	Two Sheerness Units Off Line	0 to 54 Calgary Area cap bank MVAr unavailable	55 to 81 Calgary Area cap bank MVAr unavailable	82 to 108 Calgary Area cap bank MVAr unavailable	Carseland Generation Off Line
8100	9999	0	0	0	0	0	0	0	0	0	0	0
7900	8099	0	0	0	0	0	0	0	0	0	0	0
7700	7899	0	50	0	0	0	0	0	0	0	0	0
7500	7699	70	50	0	50	0	0	0	25	0	0	20
7300	7499	190	50	65	175	100	65	0	150	125	110	140
7100	7299	325	50	190	300	220	190	25	275	250	240	275
6900	7099	450	50	320	400	340	320	100	400	390	360	400
6600	6899	550	50	400	400	450	445	175	525	515	490	525
6300	6599	735	50	400	400	650	625	300	730	700	675	725
0	6299	735	50	400	400	735	735	300	735	735	735	735

Using a TMR of 65 MW



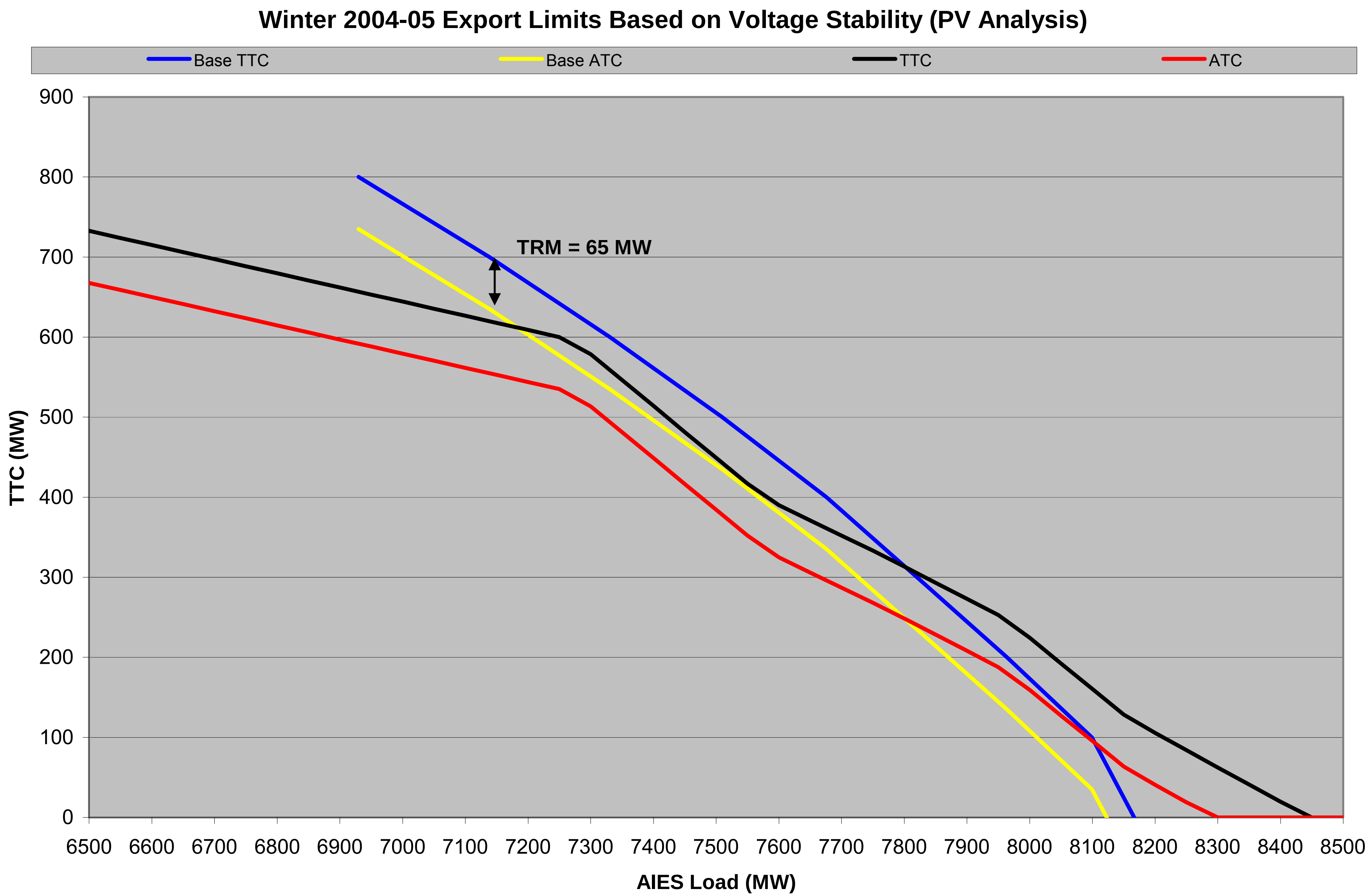
Summer 2005 Export Limits Based on Voltage Stability (PV Analysis)
Base TTC
Base ATC
TTC
ATC
TTC (MW)
900
800
700
600
500
400
300
200
100
0
TRM = 65 MW
6500
6600
6700
6800
6900
7000
7100
7200
7300
7400
7500
7600
7700
7800
7900
8000
8100
8200
8300
8400
8500
AIES Load (MW)

1.

Winter - Export TTC Table Considering facility Outages												
Alberta Internal Load (MW)	**Alberta Internal Load (MW)**	System Normal	1201L Out of Service	SVC Out of Service	937L or 936L Out of Service	North South 240kV Line Out of Service	One Sheerness Unit Off Line	Two Sheerness Units Off Line	0 to 54 Calgary Area cap bank MVAr unavailable	55 to 81 Calgary Area cap bank MVAr unavailable	82 to 108 Calgary Area cap bank MVAr unavailable	Carseland Generation Off Line
8100	9999	65	65	65	65	65	65	65	65	65	65	65
7900	8099	95	65	65	85	65	65	65	65	65	65	65
7700	7899	215	115	95	205	115	95	65	140	115	65	130
7500	7699	345	115	215	315	240	225	90	265	240	205	255
7300	7499	465	115	340	445	365	345	155	390	365	335	385
7100	7299	605	115	465	465	485	465	215	515	490	455	505
6900	7099	725	115	465	465	605	590	265	640	615	585	635
6600	6899	800	115	465	465	715	705	335	765	740	705	755
6300	6599	800	115	465	465	800	800	365	800	800	800	800
0	6299	800	115	465	465	800	800	365	800	800	800	800

Winter - Export ATC Table Considering facility Outages												
Alberta Internal Load (MW)	**Alberta Internal Load (MW)**	System Normal	1201L Out of Service	SVC Out of Service	937L or 936L Out of Service	North South 240kV Line Out of Service	One Sheerness Unit Off Line	Two Sheerness Units Off Line	0 to 54 Calgary Area cap bank MVAr unavailable	55 to 81 Calgary Area cap bank MVAr unavailable	82 to 108 Calgary Area cap bank MVAr unavailable	Carseland Generation Off Line
8100	9999	0	0	0	0	0	0	0	0	0	0	0
7900	8099	30	0	0	20	0	0	0	0	0	0	0
7700	7899	150	50	30	140	50	30	0	75	50	0	65
7500	7699	280	50	150	250	175	160	25	200	175	140	190
7300	7499	400	50	275	380	300	280	90	325	300	270	320
7100	7299	540	50	400	400	420	400	150	450	425	390	440
6900	7099	660	50	400	400	540	525	200	575	550	520	570
6600	6899	735	50	400	400	650	640	270	700	675	640	690
6300	6599	735	50	400	400	735	735	300	735	735	735	735
0	6299	735	50	400	400	735	735	300	735	735	735	735

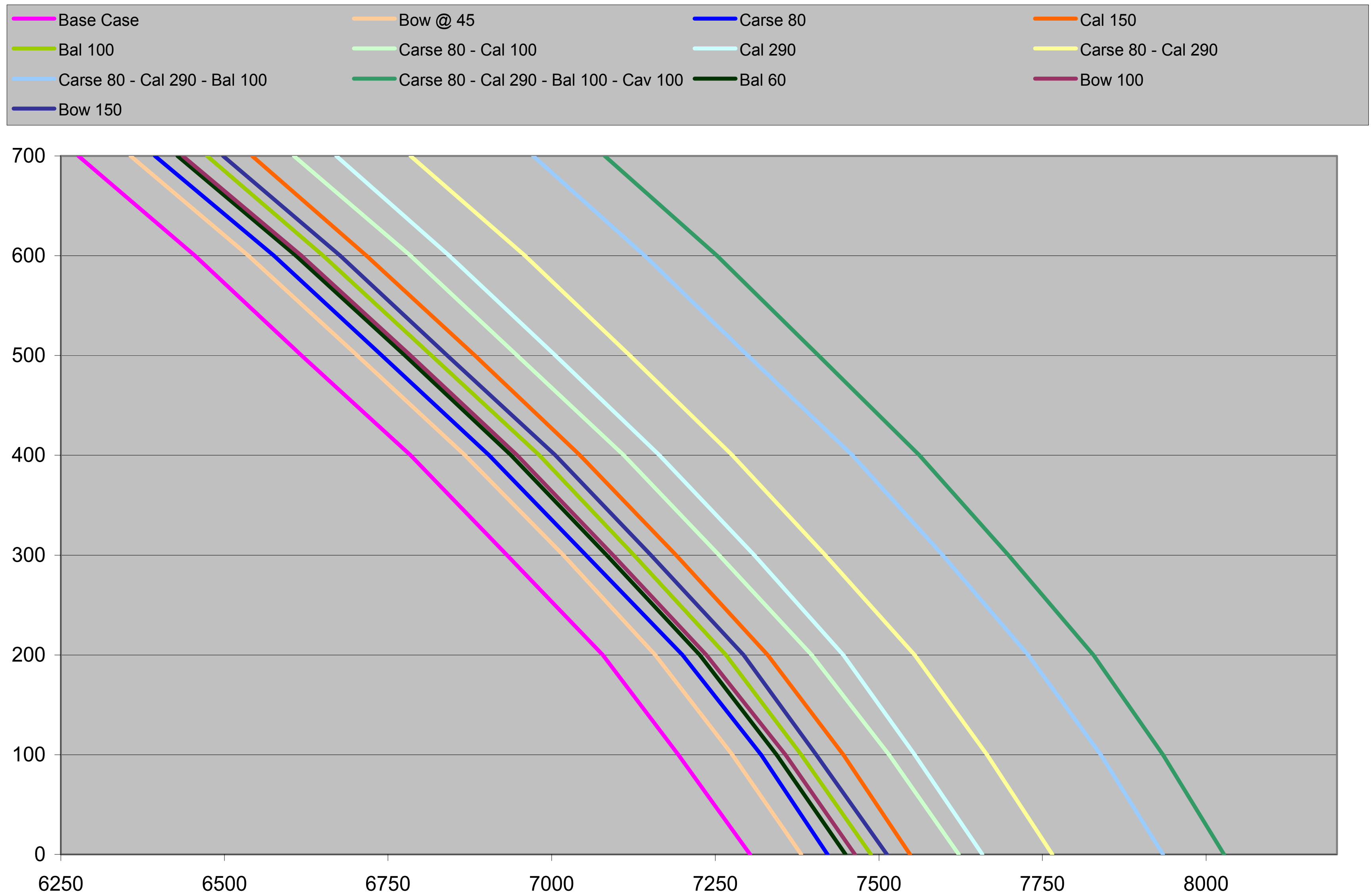
Using a TMR of 65 MW

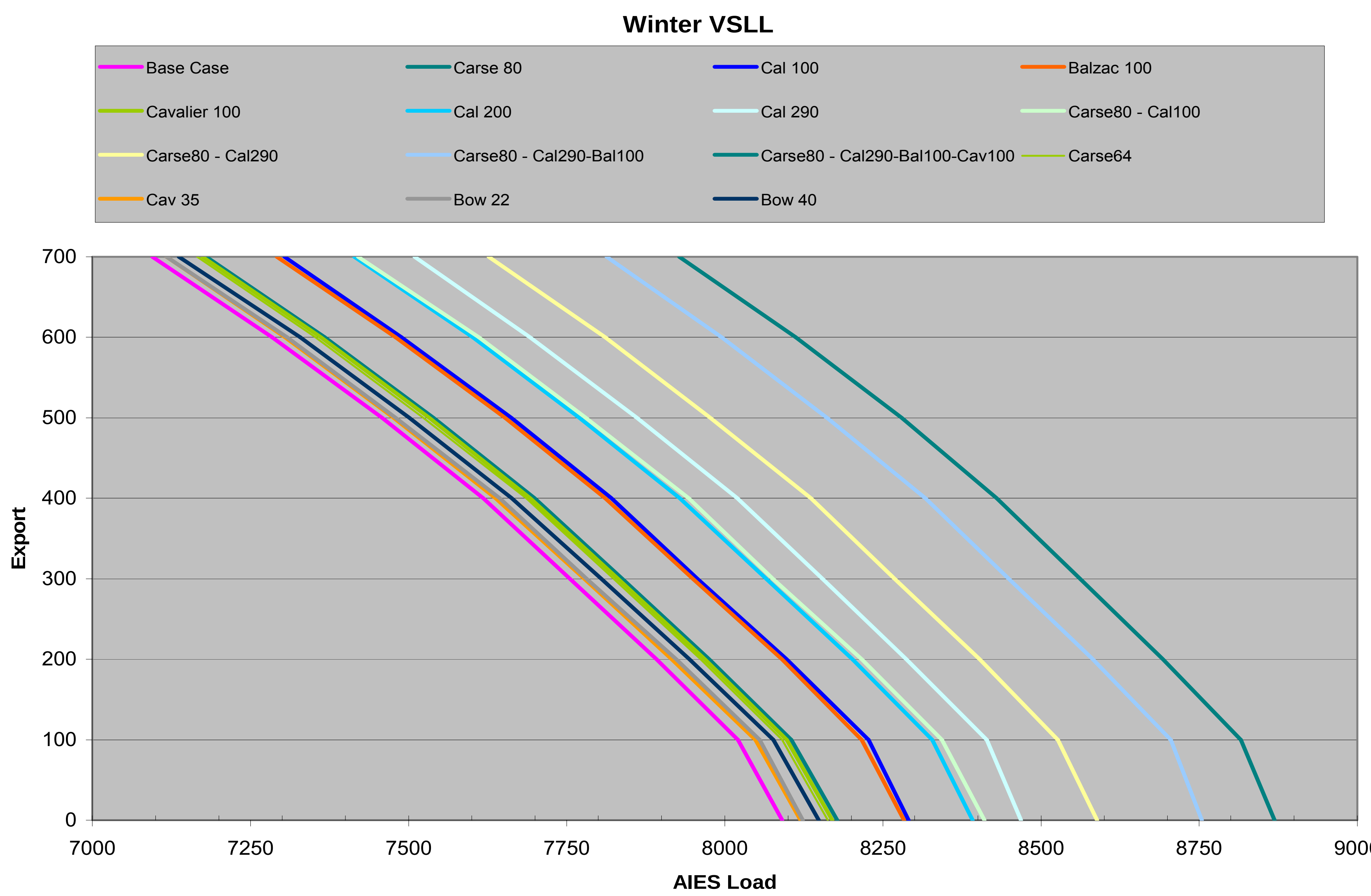

Winter 2004-05 Export Limits Based on Voltage Stability (PV Analysis)
Base TTC
Base ATC
TTC
ATC
TRM = 65 MW
TTC (MW)
900
800
700
600
500
400
300
200
100
0
6500
6600
6700
6800
6900
7000
7100
7200
7300
7400
7500
7600
7700
7800
7900
8000
8100
8200
8300
8400
8500
AIES Load (MW)

APPENDIX B

System VSLL Results

Summer VSLL


Base Case
Bow @ 45
Carse 80
Cal 150
Bal 100
Carse 80 - Cal 100
Cal 290
Carse 80 - Cal 290
Carse 80 - Cal 290 - Bal 100
Carse 80 - Cal 290 - Bal 100 - Cav 100
Bal 60
Bow 100
Bow 150
700
600
500
400
300
200
100
0
6250
6500
6750
7000
7250
7500
7750
8000


Winter VSLL
Base Case
Carse 80
Cal 100
Balzac 100
Cavalier 100
Cal 200
Cal 290
Carse80 - Cal100
Carse80 - Cal290
Carse80 - Cal290-Bal100
Carse80 - Cal290-Bal100-Cav100
Carse64
Cav 35
Bow 22
Bow 40
Export
0
100
200
300
400
500
600
700
7000
7250
7500
7750
8000
8250
8500
8750
9000
AIES Load