System Impact Study for
Alcan Kitimat Smelter Modernization Project

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PERFORMANCE PLANNING

Executive Summary

Alcan plans to modernize the existing Kitimat smelter in Northern BC to increase its productivity and efficiency with a planned in service date of 2010. The proposed new smelter is significantly different from the current Kitimat smelter design.

- The maximum load will be 675 MW, 45 MW more than the existing plant.
- The entire smelter is on one potline compared to the existing plant which consists of seven individual potlines.
- The new potline design has very limited load shedding capability, compared to the existing smelter which has various fast load shedding capabilities, including under frequency, under-voltage, etc.

BCTC has been requested by Alcan to conduct system impact studies to assess the system performance based on the new smelter design. The results then can be used by Alcan to optimize their plant design. The major findings are summarized below:

(1) A significant number of scenarios and contingencies could cause Alcan to become islanded.

(2) Fast KMO generation shedding and KIT load shedding of a significant amount may prevent islanding for certain scenarios and contingencies. Detailed studies are required to confirm feasibility.

(3) The available load shedding amount and speed is inadequate to maintain acceptable transient stability and dynamic performance.

(4) The island system dynamic performance will depend on the amount of generation and load imbalance, generator over frequency relay performance, smelter load characteristics, governor actions, the available amount, location, granularity and speed of under frequency load shedding, and generator var output, etc. The availability of appropriate over-frequency generation shedding and under-frequency load shedding is crucial to the success of saving the system from collapse.

(5) Without an appropriate under-frequency load shedding scheme, the Alcan system cannot contribute to meeting WECC coordinated off-nominal frequency load shedding requirements. This may result in system collapse under islanding conditions.

(6) BCTC system does not have enough capability to support the full Kitimat load for complete loss of Kemano generation. Alcan system needs to be restored as soon as possible to prevent damages to the smelter.

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1 Introduction

1.1 Alcan Modernization Project

Alcan plans to upgrade its aluminium smelter at Kitimat in northern BC which will increase its productivity and efficiency. The new smelter will consist of a single potline of 625 MW and a 50 MW auxiliary load, totalling 675 MW. The project is planned to be in service around 2010.

Electrically there are some major changes from the existing plant. The new smelter load is 675MW, up by 45 MW compared to the existing plant. Without generation capacity increase, the surplus power from Kemano generation available for transfer to BCTC will be reduced. Given the new design of a single potline, the flexibility of applying appropriate amount of load shedding in a timely manner in response to disturbances is not available in the new smelter. This will negatively impact the system performance, plant reliability and security.

1.2 Purpose of Study

This study is to assess the impact on the performance of the BCTC and Alcan transmission system due to the integration of the new Kitimat modernized smelter from a power flow and transient stability perspective. The results can be used as inputs and considerations for the ultimate optimized design of the new smelter by Alcan.

1.3 System Background

Figure 1 shows the one-line diagram of Alcan (BC) and BCTC North Coast area transmission system. Alcan (BC) System consists of an 8 generator plant at Kemano (KMO) serving the Kitimat smelter with two 287 kV transmission lines. KIT is then tied to the BCTC main system at Williston (WSN) via a KIT-MIN 287 kV line (2L103, 2.5 km), MIN-SKA 287 kV line (2L99, 59 km), several serial 500 kV lines including SKA-TKW (5L63, 143 km), TKW-GLN (5L62, 131 km) and GLN-WSN (5L61, 175 km) with a total line length about 510 km. The North coast area system is weakly connected due to long distance transmission to the main grid. While the 500kV lines are equipped with single pole reclose to improve the transmission reliability, line outages do occur. This would result in an islanding condition with Kemano and some other small local generations supplying power to the island load. Some historical outage data are shown in Appendix A.

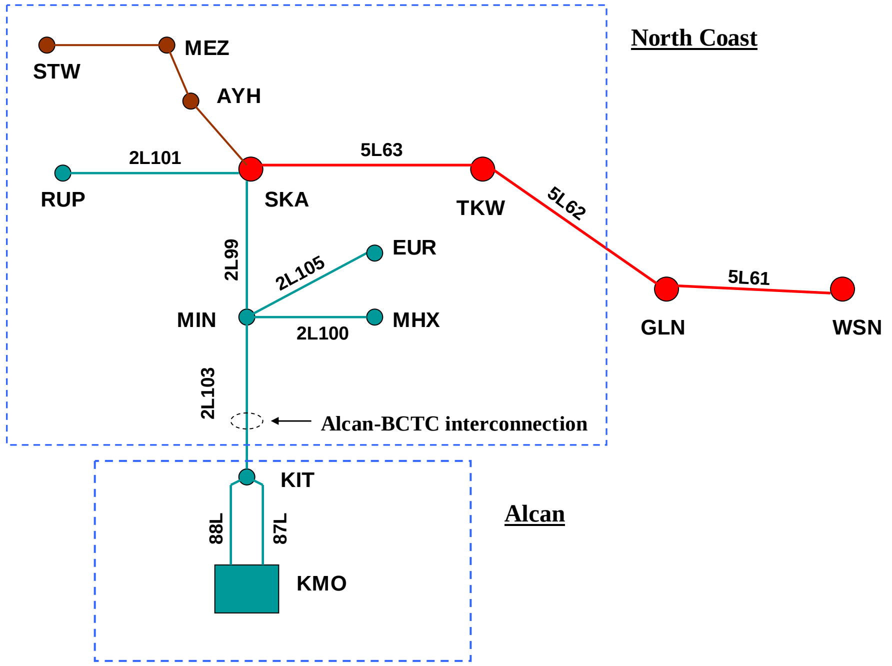

Figure 1 Alcan and Northcoast Area System One Line Diagram

2 *Study Assumptions*

The studies are conducted based on the existing equipment in place, unless otherwise specified by Alcan / ABB, such as the Kitimat new potline load and model (Section 2.1), Kitimat smelter voltage and frequency requirement (Section 2.2), and new potline load shedding capability (Section 2.3.3). 2010 base cases are used.

2.1 Kitimat New Potline Load and Model

The single potline is normally supplied with 5 converters.

2.1.1 The load measured at KIT287 bus is

- 625 + j347 MVA (without compensation),
  625 + j77 MVA (with 5 x 54 MVAR compensation), plus
- An auxiliary load of 50 +j 37.5 MVA (PF = 0.8).

2.1.2 Load Modeling

- For power flow steady state study, constant P and Q are applied.
- For transient stability study, constant current for P and constant impedance for Q are used.
- In some critical situations, different models have been tested.

2.2 Kitimat Smelter Voltage and Frequency Requirements

Alcan has indicated the following voltage and frequency requirements listed in Table 2.1 and Table 2.2.

Table 2.1 Voltage Requirement (pu. kV)

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">Steady State</th><th rowspan="2">Dynamic
(Over seconds)</th><th colspan="2">Transient</th></tr>
<tr><th>min</th><th>max</th></tr>
<tr><td>KIT 287</td><td>0.95 ~ 1.063
272 ~ 305</td><td>0.923~1.098
265 ~ 315</td><td>= 0 < 200 ms</td><td>1.2 p.u. or 344 kV for 5-10 sec</td></tr>
</table>

Table 2.2 Dynamic Frequency Requirement (Hz)

Alcan New Potline Requirements	58.5~61.5Hz

ABB has also confirmed that this limit refers to the performance specification of the pot line current control system. Short excursions outside this range are acceptable.

2.3 Load Shedding

In the existing Kitimat smelter, some potlines are available for shedding as remedial actions to mitigate the impact caused by various contingencies, such as under frequency load shedding and under voltage load shedding as indicated in Section 2.3.2 below. In the new single potline design however, load shedding capability is rather limited as described in Section 2.3.3.

2.3.1 WECC Load shedding requirements:

WECC Coordinated Off-Nominal Frequency Load Shedding and Restoration Requirements (http://www.wecc.biz/documents/library/procedures/planning/WECC_ONF_Report_July_2005.pdf)

has stated the under-frequency load shedding requirement, which is applicable throughout the WECC system. Some highlights are noted below.

2A: WECC should adopt the 59.1 Hz Plan as a minimum standard. (See Table 2.3)

2B: The system average total tripping time (relay & breaker) should be no more than 14 cycles at the indicated frequency set points.

4: Intentional tripping of tie lines due to under-frequency is permitted at the discretion of the individual system, providing that the separation frequency is no higher than 57.9 Hz with a one-second-time delay. While acknowledging the right to trip tie lines at 57.9 Hz, the preference is that intentional tripping not be implemented.

Table 2.3 WECC Coordinated Off-Nominal Frequency Load Shedding Requirement

Load Shedding Block	% of customer load dropped	pickup (Hz)	Tripping time*	Corresponding to Alcan new 675 MW Load (MW)	
				Individual	Cumulative
1	5.3	59.1	14 cycles	36	36
2	5.9	58.9	14 cycles	40	76
3	6.5	58.7	14 cycles	44	120
4	6.7	58.5	14 cycles	45	165
5	6.7	58.3	14 cycles	45	210

Tripping time* includes relay and circuit breaker times

2.3.2 Existing load shedding scheme in North Coast & Alcan

(1) BC Hydro U/F load shedding,
Load shedding begins at 59.0 Hz, with the last stage shedding at 57.7 Hz.
Maximum total load available for shedding is 221 MW.

(2) Alcan existing potlines U/F, U/V load shedding,
- Stage 1, 59.1 Hz Shed Potline 4 (100 MW)
- Stage 2, 58.0 Hz Shed Potline 5 (100 MW)
- Stage 3, 57.7 Hz Shed Potline 7, Potline 8 and Electric boiler load (Total Max 280 MW for stage 3)
- If KIT287 < 256 kV (0.892 pu) for more than 1.6 seconds, then trip all three stages of KIT load shedding
- If the power flow from MIN-KIT exceeds 254 MW and KIT voltage is below 256 kV for 0.033 seconds (2 cycles), then trip all three stages of KIT load shedding,

2.3.3 New Potline Possible Load shedding Capability

Alcan / ABB have indicated four possible means for load reduction, as summarized in Table 2.4.

- De-saturate the saturable reactors: reduction of 24.5 MW, Time needed approx. 500 ms.
- Trip one rectifier: reduction of 41 MW, Time needed approx. 2-3 s
- Trip two rectifiers: reduction of 100 MW, Time needed approx. 3 s (Not recommended)
- Lower tap changer by 7 taps: reduction of 100 MW, Total time 28 + 2.5 = 30.5 sec.

In this study, 100 MW load reduction is assumed when one rectifier is tripped with 4 rectifier units initially in service, Case 3A.

Table 2.4 Kitimat Potline Emergency Load Reduction Scheme

No.	Actions	Shed amount	time to effect
1	De-Saturate the saturable reactors (with 5 rectifier units)	24.5 MW	500 ms

2	Trip one rectifier (5 to 4)	41 MW	2-3 seconds
3	Trip two rectifiers (5 to 3)	100 MW	3 s
3A	Trip two rectifiers (4 to 3) (Assumed scenario)	100 MW	3 s
4	Lower tap changer by 7 taps (With 5 rectifier units)	100 MW	30 s

Compared with the existing Kitimat load shedding capability, the amount of load available for shedding has been reduced from 480 MW to 100 MW and the timing becomes much longer, from cycles to seconds.

2.4 Alcan-KMO O/F generation shedding scheme

Presently with KIT-MIN power flow transfer above 150 MW, KMO three units are armed for over frequency generator shedding at 61, 61.3 and 61.6 Hz respectively. This is to prevent severe over frequency when KMO/KIT/partial North Coast system is islanded after a line outage.

2.5 Alcan-BCTC Tie (2L103) Tripping Scheme

Table 2.5 shows the protections related to 2L103 that have been in use for several years.

Table 2.5 KIT-MIN (2L103) Tripping Scheme

Protections	settings	Actions
Under-frequency	57.5 Hz	Tripping 2L103
Out-of-Step Relay	• Impedance Z Crossing |0.18 pu ~ 0.16 pu| gap more than 2 cycles • V < 0.85 pu for 5 cycles	Tripping 2L103
Under-voltage	KIT287 < 256 kV (0.892 pu) for 2.0 sec	Tripping 2L103
Power Relay	KIT-MIN > 500 MW for 1.5 sec	Tripping 2L103

In addition, Alcan recently has installed two relays at KIT to detect multi-phase faults, called the “Separation Scheme”; one toward Alcan system, another toward the BCTC system. If either relay detects any multi-phase faults, the KIT to MIN line (2L103) will be tripped immediately. Furthermore if the relay looking toward KMO detects any type of fault on the KMO to KIT lines, it will trip 2L103.

2.6 Transmission Line Capacity

Table 2.6 Transmission Lines Capacity

Line Designation	Summer Rating @ 30 C	
	A	MVA at 287 kV
2L103	632	314
2L99	632	314
2L81/87, 2L82/88	1463	727

3 Summary of Results

Five categories of disturbances have been studied; disturbance in KIT smelter, disturbances on the KMO-KIT transmission lines, disturbances in the KMO generating plant, disturbances that result in islanding conditions, and other BCTC system disturbances. The contingencies in the new smelter have been identified by ABB. Other contingencies are typically used to assess the performance of existing Alcan to BCTC interconnection. Highlights of findings are summarized below.

(1) Fast KIT load reduction is required for the loss of the 2nd rectifier unit to ensure acceptable dynamic performance.

(2) KMO generation shedding is required for the loss of KIT potline.

(3) A fault on one of the KMO to KIT lines is a severe disturbance to the Alcan system. If the Alcan to BCTC tie is to be maintained, appropriate amount of fast generation shedding at KMO and load shedding at KIT would be required to produce acceptable dynamic performance. This could be a challenge and detailed studies to fine tune the requirement would be needed.

(4) If the Alcan to BCTC tie is to be tripped upon detecting such fault, the resulting islanding of large amount of generation (8 units) supplying power to the full KIT load with a single 287kV line could be problematic to address.

(5) KMO generation shedding may be required for single line to ground faults on the KMO-KIT lines. This could be used to keep the 2nd line in service for single line to ground faults with successful reclose, provided that 2L103 is not tripped due to swings.

(6) Fast load shedding to trip the entire new potline would be required after the loss of both KMO-KIT lines, if the KIT auxiliary load is to be kept connected to BCTC.

(7) A KMO bus fault and subsequent loss of four generators and tripping off one KMO-KIT line could cause collapse unless some KIT loads are quickly shed. However because of the severe swing, the out of step relay could pick up and trip open 2L103.

(8) The islanding condition caused by loss of one of the segments of the radially connected transmission network could be difficult to come to a balanced state due to lack of under frequency load shedding at KIT.

(9) A fault on 2L100 and 2L105 could cause the out of step relay to pickup resulting in tripping 2L103.

4 Major Conclusions

(1) A significant number of scenarios and contingencies could cause Alcan to become islanded.

(2) Fast KMO generation shedding and KIT load shedding of a significant amount may prevent islanding for certain scenarios and contingencies. Detailed studies are required to confirm feasibility.

(3) The available load shedding amount and speed is inadequate to maintain acceptable transient stability and dynamic performance.

(4) The islanded system dynamic performance will depend on the amount of generation and load imbalance, generator over frequency relay performance, smelter load characteristics, governor actions, the available amount, location, granularity and speed of under frequency load shedding, and generator var output, etc. The availability of appropriate over-frequency generation shedding and under-frequency load shedding are crucial to the success of saving the system from collapse.

(5) Without an appropriate under-frequency load shedding scheme, the Alcan system cannot contribute to meeting WECC coordinated off-nominal frequency load shedding requirements. This may result in system collapse under islanding conditions.

(6) BCTC system does not have enough capability to support the full Kitimat load for complete loss of Kemano generation. Alcan system needs to be restored as soon as possible to prevent damages to the smelter.

5 Study Details

The results are covered in detail in Tables 5.1 to 5.5.

5.1 Kitimat Smelter Disturbances

(Contingencies 1, 2 and 3 are specified by ABB)

(1) Loss of one rectifier unit at Kitimat (fault at KIT 287) under system normal condition (N-1 contingency).

Fault is cleared in 5 cycles. Both power flow and dynamic studies indicate acceptable system performance.

(2) KIT transformer T4 fault at KIT 287 when KIT T5 OOS (N-1-1 contingency)

The smelter load will be reduced from 625 MW to 433 MW in 40-50 seconds. Post-contingency power flow study shows that the system performance is acceptable. The dynamic performance will depend on the rate of load reduction, the faster the rate, the more likely to survive the disturbance.

(3) KIT Load Rejection

Sudden loss of whole potline load due to fault on KIT287 will result in KMO generators to becoming unstable. Applying generation shedding (e.g. 6 generators) at KMO can keep the remaining generators stable.

5.2 KMO-KIT transmission line Disturbances

(1) Loss of one KMO-KIT line

With the existing separation scheme in place, any type of fault on one of the two KMO-KIT lines will cause 2L103 to be tripped resulting in an islanding condition with KMO supplying KIT load. The island dynamic performance will depend on the amount of surplus power, the generator over frequency relay performance, the smelter load characteristics, governor actions, generator var output balance, etc.

To explore other possible options excluding tripping 2L103, generation shedding at KMO and load shedding at KIT have been applied. Results indicate that the available load shedding amount and speed is inadequate to achieve the objective of maintaining acceptable transient stability and dynamic performance.

A hypothetical case of shedding 123MW KIT load in 14 cycles (to meet WECC u/f load shedding speed requirement) assuming all KIT capacitors still in service and also shedding two KMO units in 8 cycles, shows acceptable rotor swings, however with unacceptable dynamic voltage performance. The transient voltage dip at KIT/MIN is still too low with the minimum voltage about 0.74 pu, i.e. lower than 0.85pu for 35 cycles, which does not meet the WECC disturbance performance standard (See Appendix C). In addition 2L103 might be tripped by the out-of-step relay and still result in an islanding situation. Applying faster load shedding with increased amount might resolve the low voltage issue.

Another case was examined with shedding 4 KMO units without applying load shedding. The system can be maintained stable however the transient voltage dips down to 0.65 pu, and lower than 0.85 pu for 36 cycles. Again, 2L103 might be tripped by the out-of-step relay. The islanding system will not survive as the full KIT load can not be served with 4 KMO units due to large generation deficiency.

(2) Single-Line-Ground fault with successful reclose with the 1st KMO-KIT line already OOS

With one KMO-KIT line OOS, single line to ground fault on the 2nd circuit will require shedding two KMO units in 8 cycles to maintain transient stability. However KIT/MIN transient voltages drop down to 0.78 pu, lower than 0.85 for 40 cycles which could cause 2L103 to be tripped by the out-of-step relay.

(3) Loss of both KMO-KIT lines

Loss of both KMO-KIT lines could cause collapse unless the entire new potline is quickly tripped in 8 cycles, assuming 2L103 remains and not tripped by the separation relay. The auxiliary load can remain to be served from BCTC.

5.3 KMO Disturbances

(1) Loss of one of KMO transformers

Loss of one transformer will result in tripping two KMO generators. Power flow and transient stability performance are acceptable based on fault cleared within 4 cycles.

(2) Loss of one of KMO transformers with another one already OOS

With one KMO transformer out of service, three generators could be connected to one transformer in steady state operation to maximize the plant output. Loss of this transformer will result in tripping three KMO generators. The KIT load will then be supplied with four generators and increased power flow from MIN to KIT. Study results indicate while transient stability could be maintained the post outage power flow on 2L99 could exceed thermal limits during summer.

(3) KMO bus contingency

With eight KMO generators split between the two 287 kV buses, i.e. 4 generators tied to each bus, loss of one of the two buses will result in tripping 4 generators and one of the two KMO-KIT lines.

The post contingency power flow would not be solved unless about 100 MW KIT load is shed. This could mean the requirement of fast load shedding of 100 MW at Kitimat to prevent potential voltage collapse.

KMO generators will remain stable, but the transient voltage at KIT287 may dip to 0.78pu, i.e. less than 0.85 for 20 cycles. Consequently 2L103 might be tripped by the out-of-step relay resulting in islanding condition.

5.4 Islanding Contingencies

Historical record indicates that the forced outage rates of 5L61, 5L62, 5L63 and 2L99 are high, shown in Appendix A, Table A.1. These outages will result in islanding conditions.

(1) 5L61 contingency

With 8 KMO generators on line and 190 MW flow on 5L61 from WSN toGLN, loss of 5L61 will result in a generation shortage in the North coast island. Without adequate under frequency load shedding available at KIT the islanding system frequency could drop down to 58.3 Hz, which is beyond the operating range of Kitimat smelter. This is based on BC Hydro under frequency load shedding taken place.

With 7 KMO generators on line and 245 MW on 5L61 from WSN to GLN, the under-frequency condition would be worse than the previous case. The island frequency could drop down to 57.4 Hz which could result in tripping 2L103 and thus the subsequent blackout of entire BC Hydro area loads. At this point the Alcan KMO-KIT system frequency could bounce up due to loss of load, resulting in over frequency, which then could cause tripping off some generators on over frequency, etc. until the island system comes to a balance.

(2) 2L103 contingency

With a 187 MW transfer from KIT to MIN, loss of 2L103 will result in Alcan system islanded from BCTC system with surplus generation. The Alcan island system could run up to 62.4 Hz unless some generators are shed. With the current O/F generation shedding scheme in place, two KMO units could be tripped off which could reduce the maximum frequency to 61.5 Hz. However, shedding these two units will result in generation deficiency in the Alcan island system, thus resulting in an under frequency condition.

The actual dynamic performance of an islanding condition after line outage is difficult to predict due to modeling inaccuracy and the complexity involved. Governor actions such as deflector effect, load characteristics are examples of needing improved modeling to simulate their dynamic response. Other variables such as the amount of load/generation imbalance, the island system inertia, under frequency load shedding speed, amount and location, and subsequent generator tripping by over frequency, etc. are also crucial to the actual performance. Without the benefit of fast under frequency load shedding of some KIT loads to provide the adjustment between load and generation imbalance to quickly settling down to a balanced state, the actual islanding performance could be less than desirable.

5.5 Other BCTC System Disturbances

(1) Various other contingencies in BCTC system have also been studied based on 187MW transfer from KIT to MIN. The results indicate acceptable performances both in terms of power flow and transient stability for all contingencies as shown in Table 5.5.

(2) A three phase fault on 2L100 or 2L105 at MIN could cause severe swing and low dynamic voltages similar to the present system dynamic performance. The out-of-step relay and/or the separation relay will pickup and trip 2L103, resulting in Alcan islanding condition.

Table 5.1A Kitimat Smelter Disturbance Post-Contingency Powerflows

Case No.	System Condition	Contingency and Response	Powerflow (MW,MVAR)			Voltage (pu/kV)			Comments
			KMO-KIT (87L)	KIT-MIN (2L103)	MIN-SKA (2L99)	KMO287	KIT287 or MIN287	SKA287	
1	HW, System normal	KIT T5	438+j152	184-j42	98-j73	1.07/307	1.00/287	1.02/293	
2	HW, KIT T5 OOS	KIT T4	Not solved due to heavy potline load						
2A		#2 & shed 41 MW load	Not solved due to heavy potline load						
2B		#2 & shed 100 MW load	440+j166	287-j36	201-j68	1.077/309	1.00/287	1.016/292	Rectifier V = 0.89
3	HW, System normal	Loss of whole potline Load	Not solved						
3A		#3 & Shed 6 KMO units	110+j34	168+j67	83+j37	1.024/294	1.00/287	0.98/281	

Table 5.1B Kitimat Smelter Disturbance Dynamic Performance

Case No.	System Condition	Fault Location	Response Action	KMO G1 Angle	KIT287 frequency	Voltage (pu)		Comment s
						KMO287	KIT287	
1	HW, System normal	KIT T5 287 kV side	tripped at 5 cycles	5~65		0.95~1.1	0.85~1.05	
2	HW, KIT T5 OOS	KIT T4 287 kV side	tripped at 5 cycles	5~65		0.89~1.13	0.85~1.05	
2A			#2 & @ 3 sec. shed 41 MW load	the same as above within first 3 seconds				
2B			#2 & @ 3 sec. shed 100 MW load	the same as above within first 3 seconds				
3	HW, System normal	KIT T4 287 kV side	Lost whole potline load at 5 cycles	KMO Unstable				
3A			#3 & @ 14 cyc. Shed 6 KMO units	-35~70		0.88~1.15	0.85~1.1	

Table 5.2A KMO-KIT Transmission Line Disturbance Post-Contingency Powerflows

Case No.	System Condition	Contingency and Response	Powerflow (MW,MVAR)			Voltage (pu/kV)			Comments
			KMO-KIT (87L)	KIT-MIN (2L103)	MIN-SKA (2L99)	KMO287	KIT287 or MIN287	SKA287	
1	HW, system normal	KMO-KIT (87L)	Not solved due to less VAR support at KIT						
1A		#1 & trip 2L103	Result in islanding Situation						
1B		#1 plus shed 2 units	657+j263	-34-j19	-119-j50	1.104/317	1.00/287	1.02/293	
2	HW, 87L OOS	88L SLG fault Successful Reclosed	707+j291	16-j27	-69-j59	1.11/318	1.0/287	1.02/293	Pre- and post-contingency are the same
2A		#2 & shed 1 KMO unit	607+j255	-80-j8	-165-j38	1.1/316	1.0/287	1.02/292	
2B		#2 & shed 2 KMO units	508+j227	-168+j12	-253-j16	1.09/313	0.99/285	1.01/290	(Note)
3	HW, System Normal	KMO-KIT both lines	Voltage Collapse due to heavy potline load						
3A	HW, System Normal	#3 & Shed whole potline load (Aux load is kept)	--	-50-j37.5	-135-j62	--	0.985/283	1.011/290	

Note: Powerflow can be solved with constant I or Z for P and constant Z for Q model. It cannot be solved with constant P and Q model.

Table 5.2B KMO-KIT Transmission Line Disturbance Dynamic Performance

Case No.	System Condition	Fault Location	Response Action	KMO G1 Angle	KIT287 frequency	Voltage (pu)		Comments
						KMO287	KIT287	
1	HW, system normal	87L at KIT287	Trip 87L at 6 cyc	KMO Unstable, Voltage Collapse				Note 1
1A	HW, System normal		#1 & Direct Transfer Trip (DTT) 2L103	Islanding Situation				Separation Scheme Response
1B	HW, system normal	#1 & Shed 2 units at 8 cyc		KMO Unstable, Voltage Collapse				
1C	HW, system normal	#1 & Shed 2 units at 8 cyc 25 MW load at 500 ms.		KMO Unstable, Voltage Collapse				
1D	HW, system normal	#1 & Shed 2 units at 8 cyc 100 MW load and 2 caps at 14 cyc.		KMO Unstable, Voltage Collapse				Note 2
1E	HW, system normal	#1 & Shed 2 units at 8 cyc 123 MW load no caps at 14 cyc.		-20~75		0.87~1.13	0.74~1.07	Note 3: <0.85 for 35 cyc
1F	HW, System normal	87L SLG at KMO	Auto-reclosing unsuccessful	KMO Unstable, Voltage Collapse				
2	HW, 87L OOS	88L SLG	6 cyc. Clear fault, 1.43 sec reclose successfully	KMO Unstable, Voltage Collapse				
2A		88L SLG	#2 & @ 8 cycles shed one unit	KMO Unstable, Voltage Collapse				
2B		88L SLG	#2 & @ 8 cycles shed two units	-20~45		1.01~1.15	0.78~1.05	Note 3: <0.85 for 40 cyc.
3	HW, System Normal	87L at KIT	6 cycles tripped both lines	Collapse				
3A	HW, System Normal		#3 & @ 8 cyc. Shed whole potline load (Aux load is kept)	N/A		--	0.9~1.0	

Note 1: Assuming Separation scheme is disabled

Note 2: Assuming fast load shedding within 14 cycles is available to meet WECC requirements

Note 3: If Voltage at MIN is lower than 0.85 for more than 5 cycles, out-of-step relay may pick-up and trip 2L103

Table 5.3A KMO Disturbance Post-Contingency Powerflows

Case No.	System Condition	Contingency and Response	Powerflow (MW,MVAR)			Voltage (pu/kV)			Comments
			KMO-KIT (87L)	KIT-MIN (2L103)	MIN-SKA (2L99)	KMO287	KIT287 or MIN287	SKA287	
1	HW, System Normal	KMO T4 Loss of 2 units	329+j71	-29-j21	-111-j51	1.04/298	1.00/287	1.02/293	
2	HS, KMO T3 and 1 unit OOS	KMO T4, loss of 3 more units	235+j77	-210+j37	-295+j6	1.044/300	1.00/287	1.01/290	
3	HW, System normal	KMO bus, loss of one line and 4 units	Not Solved due to heavy potline load						
3A		#3 & shed 41 MW load	Not Solved due to heavy potline load						
3B		#3 & shed 100 MW load	440+j131	-140+j34	-225+j3	1.06/305	1.00/287	1.01/289	

Table 5.3B KMO Disturbance Dynamic Performance

Case No.	System Condition	Fault Location	Response Action	KMO G1 Angle	KIT287 frequency	Voltage (pu)		Comments
						KMO287	KIT287	
1	HW, System Normal	KMO T4	Tripped at 4 cyc. Loss of 2 units	-15~45		0.97~1.1	0.93~1.06	
2	HS, KMO T3 and 1 unit OOS	KMO T4	Tripped at 4 cyc. loss of 3 more units	-47~42		0.9~1.1	0.88~1.05	
3	HW, System normal	KMO287 bus	trip one line and 4 units in 4 cyc.	-36~50		0.85~1.1	0.78~1.0	<0.85 for 20 cyc. Out-of-step relay may pick up
3A	HW, System normal		#3 & shed 41 MW load at 3 sec.	Same as above within first 3 seconds.				
3B	HW, System normal		#3 & shed 100 MW load at 3 sec.	Same as above within first 3 seconds.				

Table 5.4A Islanding Contingency Post-contingency Powerflow

Case No.	System Condition	Contingency and Response	Voltage (pu/KV)						
			KMO287	KIT287	MIN287	SKA287	SKA500	TKW500	GLN500
1	HW,System Normal WSN-GLN 190 MW	5L61 GLN	1.037/298	1.0/287	1.0/287	1.005/289	1.034/517	1.021/511	1.007/503
2	LS, System Normal KIT-MIN 187 MW	2L103 KIT	1.046/300	1.00/287	Acceptable with scaled generation				
2A	LS, 80% KIT Load, 7 units	2L103 KIT	1.017/292	1.00/287					
2B	LS, 80% KIT Load, 7 units	2L103, Shed 2 units	1.017/292	1.00/287					

Table 5.4B Islanding Contingency Dynamic Performance

Case No.	System Condition	Contingency and Response	Frequency (Hz)			Voltage (pu)			
			KMO287	KIT287	SKA287	KMO287	KIT287	MIN287	SKA287
1	HW,System Normal WSN-GLN 190 MW	5L61 GLN	< 58.3			BCH U/F load shedding already applied:			
1A	HW,KMO 1units OOS WSN-GLN 245 MW	5L61 GLN	< 57.4			0.88~1.0	0.88~1.0	0.88~1.0	0.88~1.0
1B	HW,KMO 2units OOS WSN-GLN 407 MW	5L61 GLN	< 55.0			0.88~1.0	0.88~1.0	0.88~1.0	0.88~1.0
1C	HW,KMO 1units OOS	5L61 GLN, DTT Shed 40% load	> 59.6			0.98~1.08 before 3 seconds			
2	LS, System Normal KIT-MIN 187 MW	2L103 KIT	~ 62.4 (Note)		~ 60	1.0~1.15	1.08~1.10	0.95~1.05	1.0~1.04
2A	LS, 80% KIT Load, 7 units KIT-MIN 206 MW	2L103 KIT	~ 62.8			0.98~1.15	0.95~1.12	1.0~1.03	~1.05
2B	LS, 80% KIT Load, 7 units	2L103, DTT Shed 2 units	59~61		~60		0.98~1.12	1.0~1.04	

Note, in this case the O/F generation shedding will trip two units and result in generation deficiency situation.

Table 5.5A Other BCTC System Disturbance Post-Contingency Powerflows

Case No.	System Configuration	Contingencies	KMO Generation (MW)	KMO to KIT VAR (MVAR)	KIT Load (MW)	KIT to MIN Flow (MW)	KIT to MIN var (MVAr)	KIT287 Volt (pu)
1b	New KIT smelter load	Loss of 2L100 by fault @MIN287	880	244	675	190	-2.8	1.0
2b	New KIT smelter load	Loss of 2L105 by fault @MIN287	880	238	675	190	-8.9	1.0
3b	New KIT smelter load	Loss of 2L101 by fault @SKA287	880	259	675	190	11.6	1.0
4b	New KIT smelter load	Loss of SKA T1, T5 & T6 by fault @SKA287	880	228	675	190	-18.3	1.0
5b	New KIT smelter load	Loss of SKA T2 & T4 by fault @SKA500	880	228	675	190	-18.3	1.0
6	New KIT smelter load	Loss of 5L12 & 5L13 by fault @WSN500	880	316	675	190	2.4	1.0
7	New KIT smelter load	Loss of 5L81 & 5L82 by fault @NIC500	880	240	675	190	-72	1.0
8	New KIT smelter load	SLG on 5L63 with auto-reclose	880	244	675	190	-3.2	1.0
9	New KIT smelter load	SLG on 5L62 with auto-reclose	880	244	675	190	-3.2	1.0
10	New KIT smelter load	SLG on 5L61 with auto-reclose	880	244	675	190	-3.2	1.0

Table 5.5B Other BCTC System Disturbance Dynamic Performance

Case No.	System Configuration	Contingencies	Fault Clearance Time (cycles)	KMO Generation (MW)	KIT Load (MW)	KIT to MIN Flow (MW)	KIT287 Volt (pu)	Minimum 2L103 appr Impedance (pu) @ MIN	MIN Out-of-Step Relay
1a	Current KIT smelter load	Loss of 2L100 by fault @MIN287	6	820	615	190	0.87	-0.152 (R), 0.0175 (X)	no pick up
1b	New KIT smelter load	Loss of 2L100 by fault @MIN287	6	880	675	190	0.849	-0.136 (R), 0.0144 (X)	pick up
2a	Current KIT smelter load	Loss of 2L105 by fault @MIN287	6	820	615	190	0.88	-0.158 (R), 0.0174 (X)	no pick up
2b	New KIT smelter load	Loss of 2L105 by fault @MIN287	6	880	675	190	0.86	-0.143 (R), 0.0152 (X)	no pick up
3a	Current KIT smelter load	Loss of 2L101 by fault @SKA287	6	820	615	190	0.91	-0.173 (R), 0.0212 (X)	no pick up
3b	New KIT smelter load	Loss of 2L101 by fault @SKA287	6	880	675	190	0.90	-0.165 (R), 0.0174 (X)	no pick up
4a	Current KIT smelter load	Loss of SKA T1, T5 & T6 by fault @SKA287	6	820	615	190	0.89	-0.161 (R), 0.0176 (X)	no pick up
4b	New KIT smelter load	Loss of SKA T1, T5 & T6 by fault @SKA287	6	880	675	190	0.88	-0.157 (R), 0.0163 (X)	no pick up
5a	Current KIT smelter load	Loss of SKA T2 & T4 by fault @SKA500	4	820	615	190	0.937	-0.213 (R), 0.0074 (X)	no pick up
5b	New KIT smelter load	Loss of SKA T2 & T4 by fault @SKA500	4	880	675	190	0.939	-0.22 (R), 0.0064 (X)	no pick up
6	New KIT smelter load	Loss of 5L12 & 5L13 by fault @WSN500	4	880	675	190	0.861	-0.165 (R), -0.0164 (X)	no pick up
7	New KIT smelter load	Loss of 5L81 & 5L82 by fault @NIC500	4	880	675	190	0.876	-0.174 (R), 0.0235 (X)	no pick up
8	New KIT smelter load	SLG on 5L63 with auto-reclose	4	880	675	190	0.948	-0.21 (R), -0.0056 (X)	no pick up
9	New KIT smelter load	SLG on 5L62 with auto-reclose	4	880	675	190	0.961	-0.226 (R), 0.032 (X)	no pick up
10	New KIT smelter load	SLG on 5L61 with auto-reclose	4	880	675	190	0.983	-0.236 (R), 0.034 (X)	no pick up

Appendix

A. 5L61, 5L62, 5L63 and 2L99 Forced Outage Index

Table A.1 5L61, 5L62, 5L63 and 2L99 Forced Outage Index

5L61, 5L62 5L63 and 2L99 Forced Outage Indices based on Last 10 Year's Data (ended on Dec. 31, 2005)		
Circuit	Sustained Forced Outage Frequency Per Year	Average Duration (hour)
5L61	1.00000	1.0015
5L62	0.30000	0.2356
5L63	0.30000	0.1722
2L99	1.00000	5.2127

B. Equipment parameters

(1) Each of 5 main transformers,

Rated Voltages: 287/(105~6.5)/28 kV, Taps (100.531+ 5x0.931 ~ 100.531 - 101x0.931)
X12 = 18%, X13 = 2.7%, X23 = 14.7&, MVA Base 206.7.
Winding 1: 287 kV; Winding 2: 100 kV; Winding 3: 28 kV.

(2) Each of 5 rectifier transformers,

Two transformers in one tank, one Zigzag/Delta, the other one is Zigzag/Star.

Rated Voltages: 99.6 kV/1441 V
X = 13%, MVA Base 107.

(3) Rectifier transformers,

Each of 5 filters: 54 MVAr at 28 kV

C. WECC Disturbance-Performance Standard

(http://www.wecc.biz/documents/library/procedures/CriteriaMaster.pdf)

WECC DISTURBANCE-PERFORMANCE TABLE OF ALLOWABLE EFFECTS ON OTHER SYSTEMS

NERC and WECC Categories	Outage Frequency Associated with the Performance Category (outage/year)	Transient Voltage Dip Standard	Minimum Transient Frequency Standard	Post Transient Voltage Deviation Standard (See Note 2)
A	Not Applicable	Nothing in addition to NERC		
B	≥ 0.33	Not to exceed **25%** at load buses or **30%** at nonload buses. Not to exceed **20% for more than 20 cycles** at load buses.	Not below **59.6** Hz for 6 cycles or more at a load bus.	Not to exceed **5%** at any bus.
C	0.033 ~ 0.33	Not to exceed **30%** at any bus. Not to exceed **20% for more than 40 cycles** at load buses.	Not below **59.0** Hz for 6 cycles or more at a load bus.	Not to exceed **10%** at any bus.
D	< 0.033	Nothing in addition to NERC		

D. Power Flow Diagram

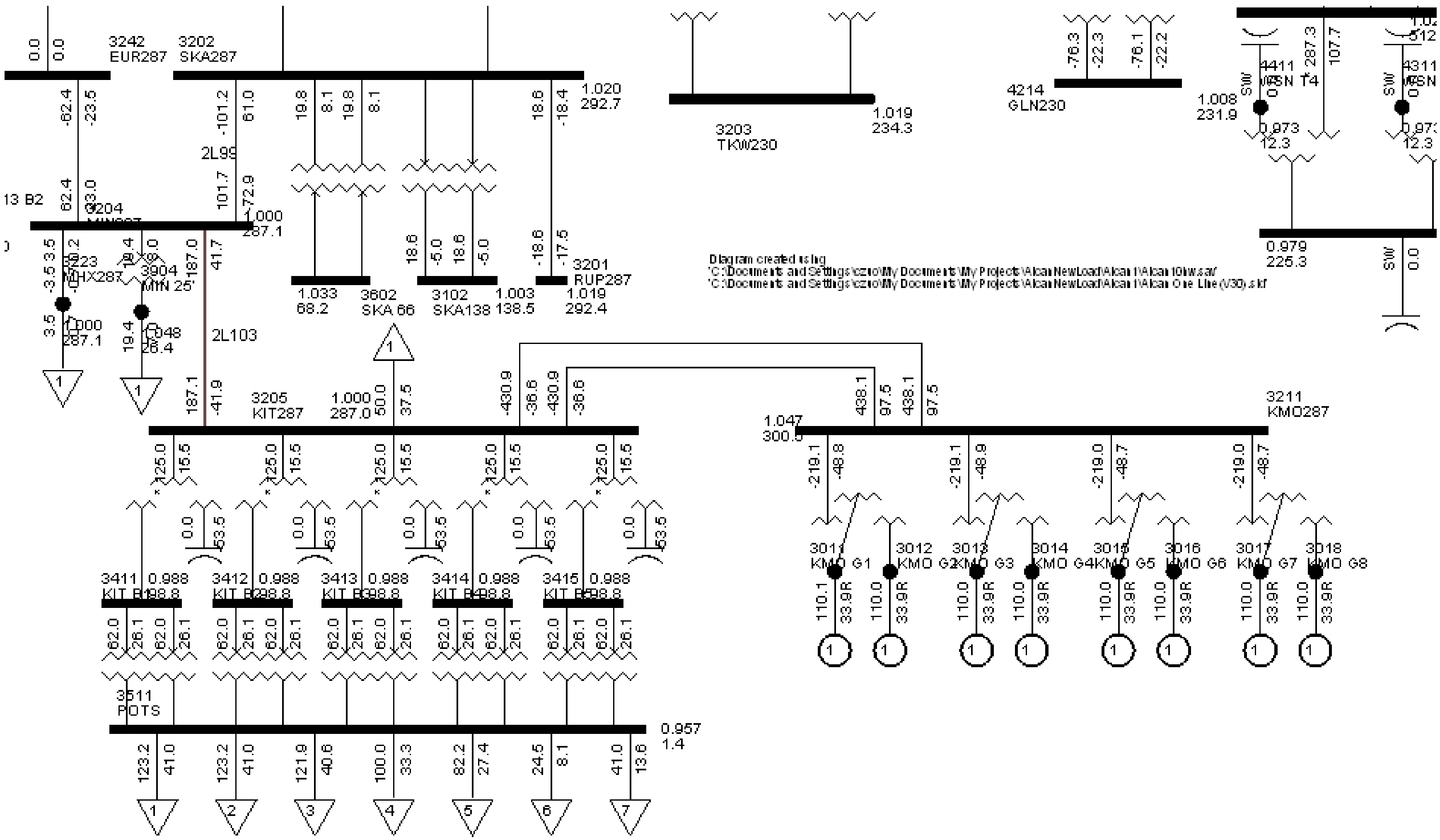

Figure D. 2010 Winter Heavy Load -- System Normal Powerflow