British Columbia Transmission
CORPORATION™

Alcan Kitimat Smelter Modernization Project
Remedial Action Scheme (RAS)
Functional Requirements

REPORT NO. SPA 2008-62

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SYSTEM PLANNING AND PERFORMANCE ASSESSMENT

Executive Summary

Alcan plans to update its Kitimat operation with a modernization project for service in 2010. The effect of this project has been studied and covered in an earlier BCTC report, *System Impact Study for Alcan Kitimat Smelter Modernization Project*. The study has found that the proposed significant load increase and the single potline arrangement will seriously increase the stress on system and degrade the area power system performance and reliability. Some first contingency disturbances in the area could result in Alcan islanding and voltage collapse.

In light of the above results, Alcan has subsequently requested BCTC to conduct further studies to develop potential means to mitigate the impact of these disturbances.

This study has identified the following remedial actions to respond to various contingencies in the area:

(1) Shed appropriate number of Kemano (KMO) generators.

(2) Reduce Kitimat potline load by de-saturating the saturable reactors and lowering the tap changer.

(3) Trip open 2L103.

(4) Shed the potline to preserve the Kitimat (KIT) auxiliary load in order to minimize overall impact and facilitate speedy restoration.

Actions 1 to 3 can somewhat help to preserve the Alcan system under certain conditions. Action 4 is to prevent Alcan system from total collapse under certain conditions such as the following:

(1) With all circuits in service, a multi phase fault on one of the KMO to Kitmat 287kV lines and subsequent trip out of the line.

(2) With all circuits in service, loss of a KMO bus and subsequent trip out of one of the KMO to KIT 287kV lines.

(3) With one of the KMO to KIT lines already out of service, a disturbance in the area such as a multiphase fault on a Minette line, 2L100 or a single line to ground fault on the 2nd KMO to KIT line with successful auto reclose.

(4) Loss of both KMO to KIT 287kV lines, either sequentially or simultaneously.

While shedding the potline is listed here as a possible solution, it is the lesser of two worst outcomes.

Table 3.1 provides the list of contingencies requiring the above RAS actions. Not all actions are required for all contingencies.

RAS arming rules and operation instructions are required to be developed in subsequent operation planning studies.

While the RAS identified in this report can help to alleviate the impact of the various disturbances, the level of improvement is rather limited. Other options such as major system reinforcement and/or potline design change should be considered.

The above Table 3.1 RAS actions do not address the reduction of under frequency load shedding due to the new single KIT potline arrangement.

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1 Introduction

The report *System Impact Study for Alcan Kitimat Smelter Modernization Project*, conducted in 2007 and posted on the BCTC website, has identified that the new Kitimat modernization project could result in poor performance for the disturbances in the North Coast area, such as:

(1) KMO units unstable,

(2) North Coast islanding with poor frequency response,

(3) Low transient and dynamic voltages in the KIT and MIN area, resulting in 2L103 trip out and Alcan system islanding,

(4) 2L99 and 2L103 overload,

(5) Alcan system collapse

The report has also concluded that having the ability to shed some KIT smelter load quickly is necessary to minimize the impact of the contingency and prevent the system from collapse.

In light of the above findings, Alcan requested BCTC to conduct a study to develop the Remedial Action Schemes (RAS), which will mitigate the impact caused by various contingencies in the area as defined by the Study Scope in Appendix A with one exception. The impact caused by the reduction of loads available for under frequency load shedding due to the single potline design (Issue 8) is not included in this analysis and will be addressed separately.

Accordingly, this report has documented the study results and RAS functional requirements for the new smelter.

2 Study Conditions and Assumptions

2.1 Alcan and BCTC North Coast System Configuration

Figure 2.1 and Figure 2.2 show the Alcan Kitimat New Smelter Power System Configuration and the Alcan and North Coast Area System One Line Diagram respectively.

As indicated in Figure 2.1, the two KIT 287 kV buses are normally connected as follows.

KIT 287 kV east bus

- All of the five rectifier units
- One KMO transmission line (L81/87)
- One auxiliary load transformer

KIT 287 kV west bus

- The tie line (2L103) to BCTC
- One KMO transmission line (L82/88)
- One auxiliary load transformer

There is a bus tie with a CB connecting the two buses.

2.2 Alcan and BCTC North Coast Area Load

The new Kitimat smelter has five rectifier units with the total load indicated in Table 2.1. The total loads seen from 287 kV bus have been updated recently by Alcan.

Compared with the data provided by Alcan for the previous system impact study, there are some changes to both the potline and auxiliary loads. The potline real power load is reduced from 625 MW to 617 MW and the auxiliary load power factor is increased to 0.95 from 0.8, thus effectively reducing the reactive load from 37.5 Mvar to 16 MVAr.

Table 2.2 lists the BCTC North Coast Area seasonal loads for the year 2009 and 2010, excluding Alcan load.

Table 2.1 Alcan Kitimat Load
(MW + j MVAR)

	5 rectifier units			4 rectifier units		
	potline	Aux.	Total	potline	Aux.	Total
In impact Study	625 + j78	50 + j38	675 + j116	628 + j182	50 + j38	678 + j220
Current	**617 + j78**	**50 + j16**	**667 + j94**	**619 + j152**	**50 + j16**	**669 + j168**
Difference	8 + j0	0 + j22	8 + j22	9 + j30	0 + j22	9 + j52

Table 2.2 BC Hydro North Coast Area Load
(Excluding Alcan load, MW)

	Heavy Winter	Heavy Summer	Light Summer
2009	377	321	110
2010	383	326	111

2.3 Kitimat New Smelter

The voltage and frequency performance requirements specified for the new smelter potline operation as provided by Alcan for the previous system impact study have remained the same and are shown in Table 2.3 and Table 2.4.

Table 2.3 Voltage Requirement (pu. kV)

Bus	Steady State	Dynamic (Over seconds)	Transient	
			min	max
KIT 287	0.95 ~ 1.063 pu 272 ~ 305 kV	0.923~1.098 pu 265 ~ 315 kV	= 0 < 200 ms	1.2 pu or 344 kV for 5-10 sec

Table 2.4 Dynamic Frequency Requirements (Hz)

Alcan New smelter Potline	58.5~61.5Hz

ABB, the smelter supplier has confirmed that the above constraints are still valid. ABB has also indicated that small excursions outside the above range are acceptable.

Four possible means to reduce the new smelter load as RAS actions are considered in this RAS study, shown in Table 2.5. This is the same as in the previous impact study.

- De-saturate the saturable reactors: a reduction of 24.5 MW, time required to take into effect approx. 500 ms.
- Trip one rectifier: a reduction of 41 MW, time required to take into effect approx. 2-3 s
- Trip two rectifiers: a reduction of 100 MW, time required to take into effect approx. 3 s (Not recommended)
- Lower tap position by 7 taps: a reduction of 100 MW, total time required to take into effect 28 + 2.5 = 30.5 sec.

Table 2.5 Kitimat Potline Emergency Load Reduction Scheme

Case No.	Actions	Amount of load reduction (MW)	Time to effect
1	De-Saturate the saturable reactors (with 5 rectifier units)	24.5	500 ms
2	Trip one rectifier (5 to 4)	41	2-3 seconds
3	Trip two rectifiers (5 to 3) [1]	100	3 s
3A	Trip two rectifiers (4 to 3) (Assumed scenario[2])	100	3 s
4	Lower tap position by 7 taps (With 5 rectifier units)	100	30 s

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[1] When only three rectifier units remain, the smelter load control will reduce potline load down to 433 MW within 40-50 seconds to keep the remaining rectifier units within the thermal limits.

[2] A 100 MW load reduction is assumed when one rectifier is tripped with 4 rectifier units initially in service.

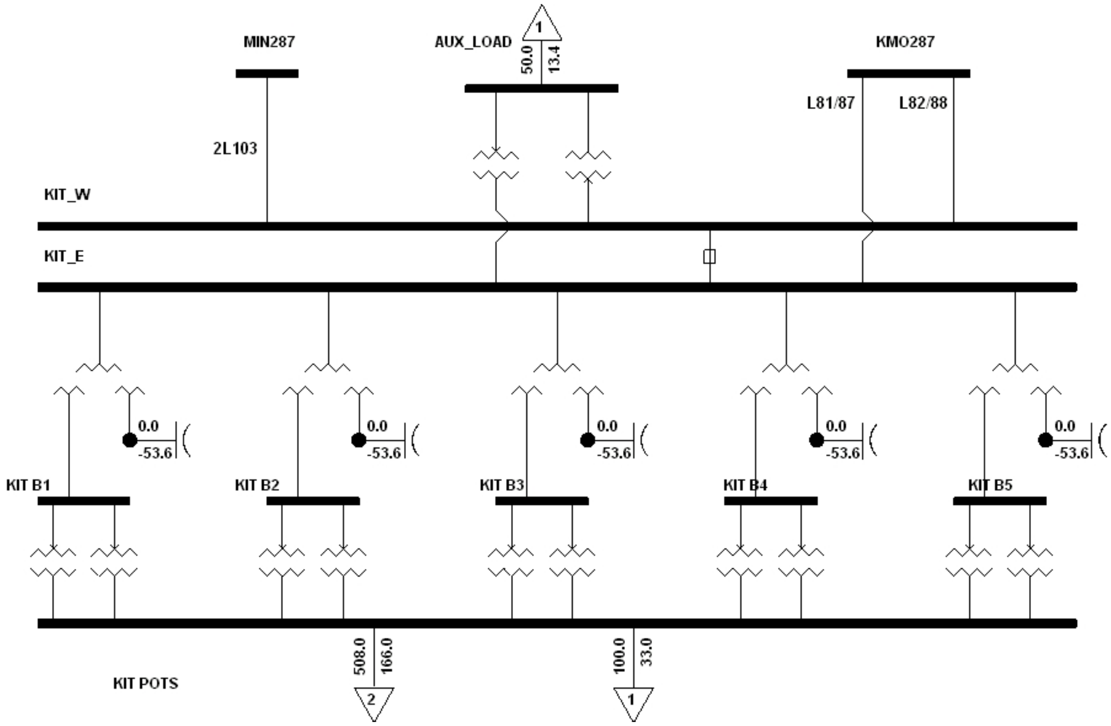


Figure 2.1 Kitimat New Smelter Power System Configuration

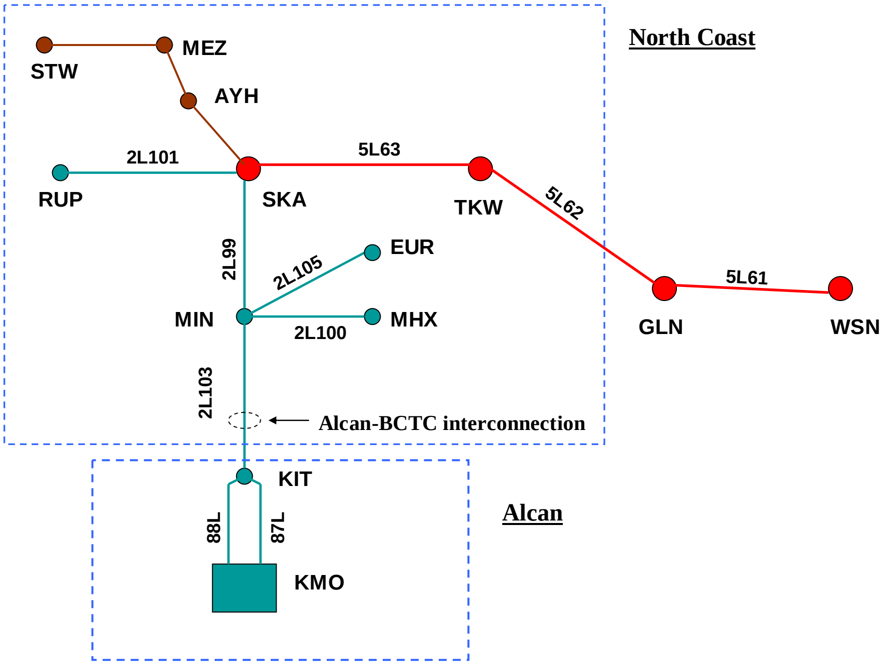


Figure 2.2 Alcan and North Coast Area System One Line Diagram

2.4 Tie line (2L103) Tripping Scheme

Table 2.6 shows the protections related to 2L103 that have been in use for several years.

Table 2.6 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 in 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 looking 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.

The "Under-frequency", "Out-of-Step Relay", and "Under-voltage" of the above 2L103 tripping schemes are still applied in this RAS study. The "Power Relay" and "Separation Scheme" are assumed replaced with the features identified by this RAS studies.

2.5 Transmission Line Ratings

Table 2.7 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

2.6 Alcan-KMO O/F generation shedding scheme

Presently three KMO units are armed with over frequency shedding with settings at 61.0, 61.3 and 61.6 Hz respectively when the transfer on KIT-MIN flow exceeds150 MW. This will prevent severe over frequency when the Alcan/BCTC system is islanded by the loss of a line between KIT and BCTC.

In this RAS scope study, the above facility is assumed a secondary function and will be superseded by the primary protection of direct generation shedding at KMO.

3 RAS Functional Requirement

Various power flow and transient stability studies have been conducted to assess the effect of RAS actions to mitigate the impact caused by various contingencies at KMO, KIT and the transmission system. The results and analysis are summarized in Section 5 and appendices. The conclusion is summarized in Table 3.1 below.

Four RAS actions are required for the identified contingencies:

(1) Shed appropriate number of Kemano (KMO) generators.

(2) Reduce Kitimat potline load by de-saturating the saturable reactors and lowering the transformer tap position.

(3) Trip open 2L103.

(4) Shed the potline to preserve the Kitimat (KIT) auxiliary load in order to minimize overall impact and facilitate speedy restoration.

Actions 1 to 3 can somewhat help to preserve the Alcan system under certain conditions. Action 4 is to prevent Alcan system from total collapse under certain conditions such as the following:

(1) With all circuits in service, a multi phase fault on one of the KMO to Kitimat 287kV lines and subsequent trip out of the line.

(2) With all circuits in service, loss of a KMO bus and subsequent trip out of one of the KMO to KIT 287kV lines.

(3) With one of the KMO to KIT lines already out of service, a disturbance in the area such as a multiphase fault on a Minette line, 2L100 or a single line to ground fault on the 2nd KMO to KIT line with successful auto reclose.

(4) Loss of both KMO to KIT 287kV lines, either sequentially or simultaneously.

While shedding the potline is listed here as a possible solution, it is the lesser of two worst outcomes, either shedding the potline or facing a total collapse of the Alcan system.

The rationale for requiring those RAS actions is described in Sections 3.1 ~ 3.4. The logic that leads to the functional requirement for various scenarios is displayed in the “TREE” diagrams, Figures 3.1 to 3.4.

Results indicate that fast load reduction improves the system response and chances of surviving the disturbance. Hence, de-saturating the saturable reactors is applied whenever load reduction is required. However due to its limited MW reduction, it may not be effective for the subject disturbance. Load reduction by changing the converter transformer tap could reduce significant amount of load, however may be too slow to be effective during a fast voltage collapse. In this study, we have assumed that the tap changing speed will meet the load reduction dynamic performance requirement.

Table 3.1 RAS Functional Requirement

Contingency		Shedding KMO Generation	Shedding KIT Potline	Reducing Potline Load [Note 1]	Tripping 2L103	Reference
KIT Smelter Disturbance						
1.	KIT Load Rejection	**Y**				Table C-1, #1,
2.	KIT East Bus	**Y**		**Y**[Note 2]		Table C-1, #2
3.	KIT West Bus	**Y**		**Y**		Table C-1, #3
4.	KIT transformer	**Y**				Table C-1, #4
KMO Plant Disturbance						
5.	KMO transformer			**Y**		Table C-2, #1
6.	KMO Bus[Note 3]	**Y**	**Y**			Table C-2, #2
BCTC Lines Disturbance						
7.	2L100 or 2L105[Note 4]	**Y**	**Y**[Note 5]			Table C-3, #1 & #2
8.	5L61			**Y**	**Y**[Note 6]	Section 3.3
9.	5L62	**Y**		**Y**	**Y**[Note 6]	
10.	5L63	**Y**		**Y**	**Y**[Note 6]	
11.	2L99	**Y**		**Y**	**Y**[Note 6]	
12.	2L101	**Y**	**Y**[Note 5]			Table C-3, #4
13.	SKA T1 or T2	**Y**	**Y**[Note 5]			Table C-3, #5
14.	2L103	**Y**		**Y**		Table C-3, #3
KMO-KIT Line Disturbance						
15.	L81/87 or L82/88 (other than SLG)	**Y**	**Y**			Table C-4, #1~3
16.	L81/87 or L82/88 SLG	**Y**	**Y**[Note 5]	**Y**		Table C-4, #4 & #5
17.	L81/87 and L82/88		**Y**			Table C-4, #5

Note

1. *Potline load reduction includes both de-saturating the saturable reactors and lowering the tap changer. De-saturating the reactor provides relatively faster load reduction than lowering the tap changer. This will increase the probability of preventing the voltage collapse or severe thermal violation.*
2. *Normally KIT east bus is connected to potline and not connected to the tie line (2L103). But if it is connected to 2L103 in some situations, potline load reduction is required.*
3. *This function is required for either KMO buses*
4. *After generation shedding is applied, 2L103 may still be tripped depending on the fault severity and other conditions.*
5. *Shedding KIT potline load is required for N-1-1 situation, i.e. a contingency happens when one KMO-KIT line is already OOS*

6. *Tie tripping may be required if one of KMO-KIT lines is already OOS to reduce load.*

3.1 KIT Smelter Disturbance

(1) KIT potline load rejection will result in surplus power transfer to BCTC. Shedding KMO to reduce the line loading will improve dynamic performance and maintain 2L103 in service.

(2) KIT east bus fault will result in the tripping of KIT potline and some auxiliary load, i.e. similar to Case (1). The proposed RAS strategy is the same as in (1).

(3) The KIT west bus contingency will result in the loss of 2L103 and one KMO-KIT line, leaving Alcan system separated from BCTC system with only one KMO-KIT line in service. To save the Alcan island system from collapsing, an adequate amount of KMO generation shedding and fast potline load reduction are required. However, lowering the transformer taps may not be fast enough to prevent from voltage collapse; fast load shedding or system reinforcement is required.

Since the KIT east bus and west bus may switch their connections, the same RAS functional requirements are required for both bus contingencies.

(4) Loss of a second KIT main transformer (N-1-1) would result in the potline load reduction to 433 MW, which could cause 2L103 to overload (KIT to MIN). Shedding KMO surplus generation is required to reduce the transfer on 2L103 below its thermal limit. However, 2L103 may be tripped out by the out-of-step relay at KIT due to low dynamic voltages. In either case with 2L103 tripped out or not, system performance is acceptable.

3.2 KMO Plant Disturbance

(1) Loss of a 2nd KMO transformer (N-1-1) may cause 2L99 to overload (SKA to MIN) due to the make up power flow from BCTC to KIT. KIT load reduction is required to resolve the overloading problem.

(2) KMO bus fault will result in significant loss of KMO generations and trip out of one KMO to KIT line, which may cause low dynamic voltages at KIT and MIN resulting in tripping 2L103. This could cause the Alcan island system voltage collapse. To prevent such problem, shedding the potline and some KMO generations quickly could keep the 2L103 tie intact, thus preserving the Alcan auxiliary load.

3.3 BCTC Line Disturbance – 2L100, 2L105, 2L101, 2L103, 2L99, 5L63, 5L62, 5L61, & SKA T1 or T2

(1) Under system normal condition with high flow on 2L103 to MIN, fault on 2L100 or 2L105 could cause low dynamic voltage at KIT and MIN. Shedding KMO generation to reduce the flow will improve dynamic voltage performance, thus preventing 2L103 from tripping. If the fault is severe, low dynamic voltage may still occur and cause 2L103 to trip resulting in an island. But the island frequency and performance would still be acceptable to Alcan due to close balance between generation and load while both KMO-KIT circuits are in service. Similar problem is expected for fault on 2L101, SKA T1 or T2.

(2) When one of the KMO-KIT lines is out of service, shedding KMO generation may not be sufficient due to relatively large power flow through high impedance to KIT, thus resulting in low dynamic voltages at KIT and subsequent tripping of 2L103 and Alcan islanding. The single KMO-KIT line could not sustain the system voltage and would result in voltage collapse. To prevent such problem, shedding the potline and some KMO generations quickly could keep the 2L103 tie intact, thus preserving the Alcan auxiliary load. Similar problem is observed for fault on 2L101, SKA T1 or T2.

(3) Loss of 2L103 will result in Alcan islanded. With both KMO-KIT circuits in service, some KMO generation can be shed to minimize over frequency. However with one of the KMO-KIT line already out of service, loss of the 2L103 tie may result in voltage collapse, unless fast and adequate load reduction at KIT can be implemented.

(4) Loss of 2L99, 5L63, 5L62 or 5L61 could result in islanding with generation and load imbalance and possibly voltage collapse depending on the pre-outage condition. The chances of surviving the disturbance would be low if there is only one KMO-KIT line in service. The following RAS actions are required to mitigate the impact:

- Shed KMO surplus generation during high Alcan to BCTC transfers (except for 5L61 contingency)
- Reduce potline load as quickly as possible
- Shed some BC Hydro load by tripping 2L103 when required (e.g. with one of KMO-KIT line already out of service)

3.4 KMO-KIT Line Disturbance

(1) A 3-phase fault on one of the KMO-KIT lines and the subsequent loss of the line will cause Alcan KMO generators to become unstable. Shedding KMO generators is not enough due to low dynamic voltage at KIT and MIN。 This will cause 2L103 to trip, resulting in Alcan islanding and voltage collapse. To prevent such problem, shedding the potline and some KMO generations quickly could keep the 2L103 tie intact, thus preserving the Alcan auxiliary load.

(2) Under system normal condition, a single line to ground fault on one of the KMO-KIT lines with successful auto reclose could cause low dynamic voltage at KIT and MIN, resulting in tripping 2L103. Shedding appropriate amount of KMO Generation is required to prevent the low dynamic voltage and keep 2L103 in service.

If the auto reclose is unsuccessful, KIT load needs to be reduced to obtain acceptable post contingency power flows and voltages.

(3) With one of the KMO-KIT line already out of service, a SLG fault on the 2nd circuit with successful auto reclose and KMO generation shedding would still result in low dynamic voltages at KIT and MIN, thus resulting in tripping 2L103 and Alcan islanded. Due to high flow on the single KMO-KIT line, the island voltage would collapse. To prevent such problem, shedding the potline and some KMO generations quickly could keep the 2L103 tie intact, thus preserving the Alcan auxiliary load.

(4) Loss of both KMO-KIT lines would result in voltage collapse unless the KIT potline load is shed quickly. The KIT auxiliary load can be served by BCTC with acceptable voltage performance.

3.5 System Disturbance Analysis Tree Diagrams

The impact of contingencies and the effectiveness of RAS actions for the various scenarios studied are summarized in a “TREE” diagram to facilitate the analysis. Figures 3.1 to 3.4 have covered most of the conditions.

Figure 3.1: Kitimat Smelter Disturbance

Case #1: Kitimat potline load rejection (Issue #2)

System Normal (2L103 KIT to MIN 196MW)

Contingency: KIT potline load rejection

↓

Excess KMO generation

RAS: shed 6 KMO units

↓

2 KMO units remaining on line
2L103 remaining connected
System OK

Case #2: Kitimat east bus 3 phase fault (Issue #11)

System Normal (2L103 KIT to MIN 196MW)

Contingency: KIT east bus 3 phase fault

↓

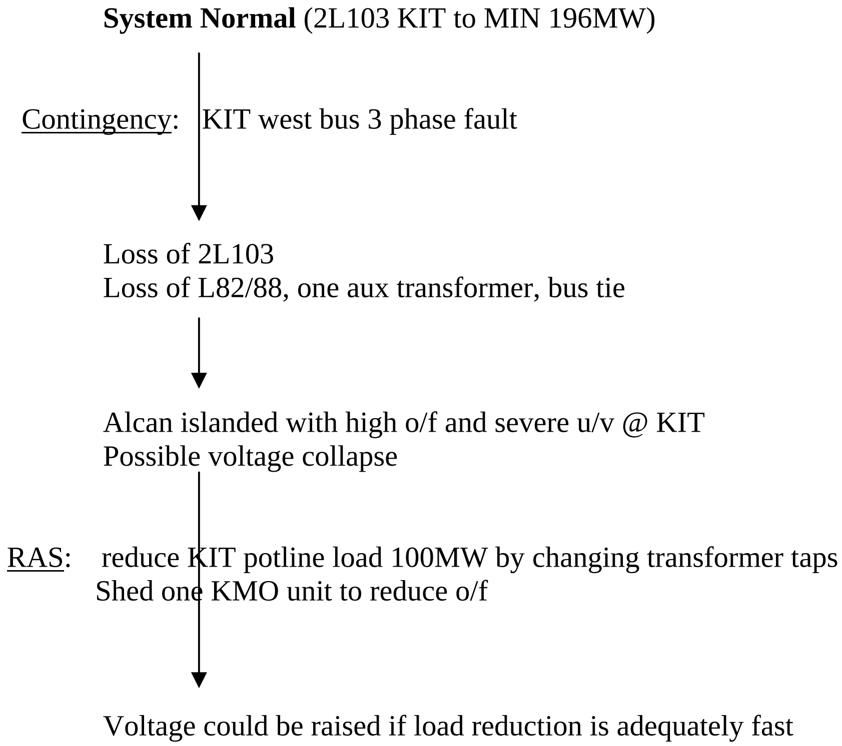
Loss of potline transformers
Loss of L81/87, one aux transformer, bus tie

RAS: shed 6 KMO units

↓

2 KMO units remaining on line
2L103 remaining connected
System OK

Case #3: Kitimat west bus 3 phase fault (Issue #11)



System Normal (2L103 KIT to MIN 196MW)

Contingency: KIT west bus 3 phase fault

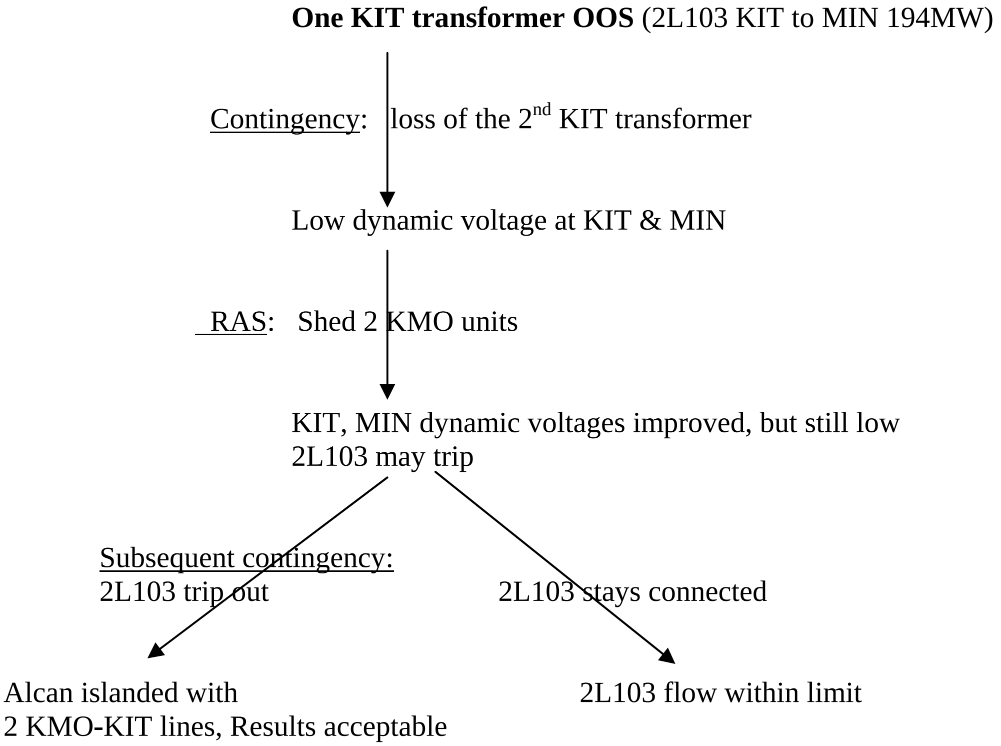
Loss of 2L103
Loss of L82/88, one aux transformer, bus tie

Alcan islanded with high o/f and severe u/v @ KIT
Possible voltage collapse

RAS: reduce KIT potline load 100MW by changing transformer taps
Shed one KMO unit to reduce o/f

Voltage could be raised if load reduction is adequately fast

Case #4: Loss of the 2nd Kitimat transformer (Issue #1)



One KIT transformer OOS (2L103 KIT to MIN 194MW)

Contingency: loss of the 2nd KIT transformer

Low dynamic voltage at KIT & MIN

RAS: Shed 2 KMO units

KIT, MIN dynamic voltages improved, but still low
2L103 may trip

Subsequent contingency:
2L103 trip out

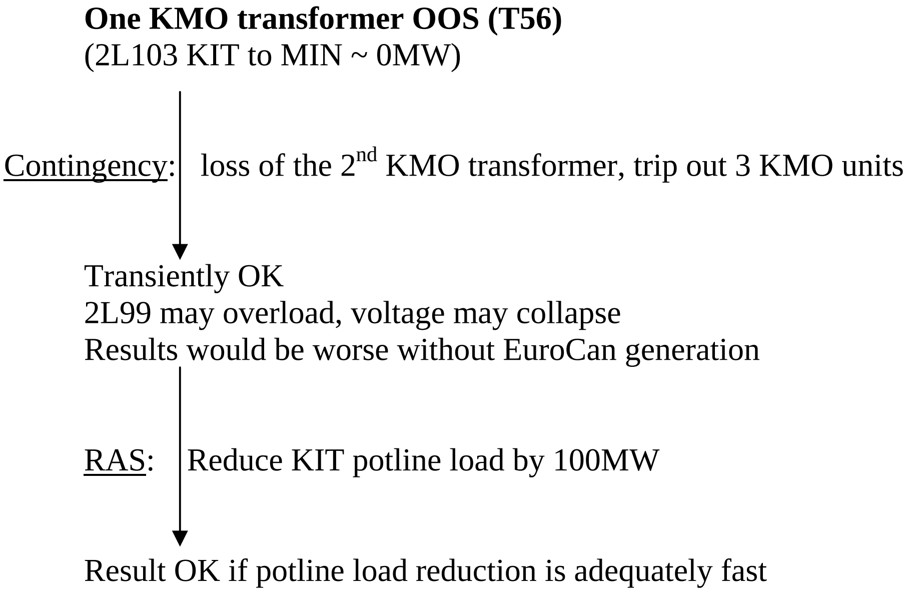
2L103 stays connected

Alcan islanded with
2 KMO-KIT lines, Results acceptable

2L103 flow within limit

Figure 3.2: KMO Plant Disturbances

Case #1: Loss of the 2nd KMO generator transformer (Issue #6)



One KMO transformer OOS (T56)
(2L103 KIT to MIN ~ 0MW)

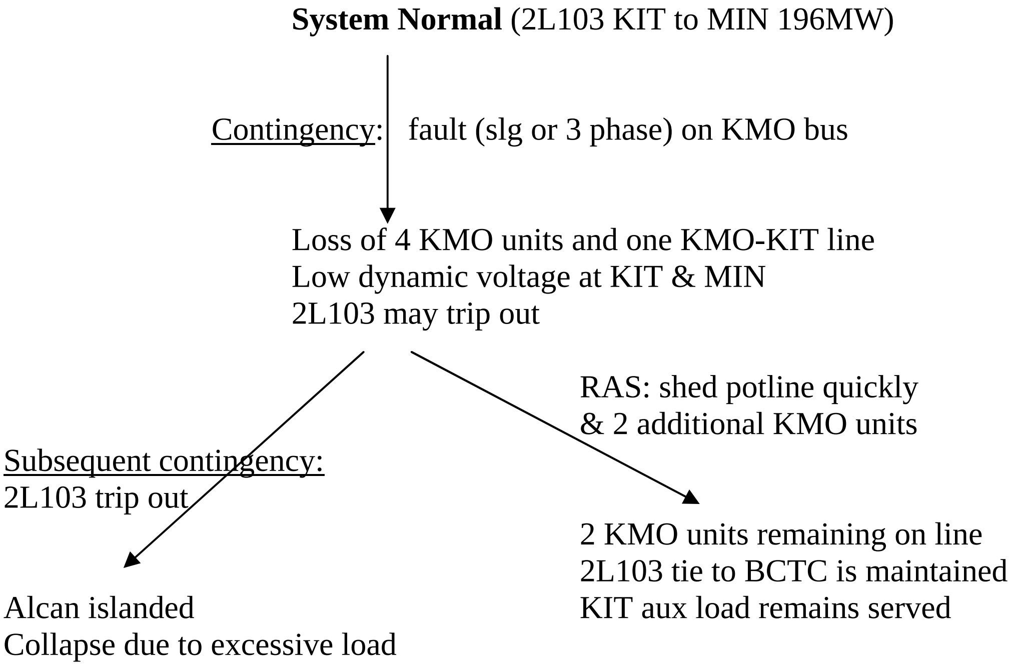
Contingency: loss of the 2nd KMO transformer, trip out 3 KMO units

Transiently OK
2L99 may overload, voltage may collapse
Results would be worse without EuroCan generation

RAS: Reduce KIT potline load by 100MW

Result OK if potline load reduction is adequately fast

Case #2: Loss of one KMO bus due to fault (SLG or multiphase) (Issue #7)



System Normal (2L103 KIT to MIN 196MW)

Contingency: fault (slg or 3 phase) on KMO bus

Loss of 4 KMO units and one KMO-KIT line
Low dynamic voltage at KIT & MIN
2L103 may trip out

Subsequent contingency:
2L103 trip out

Alcan islanded
Collapse due to excessive load

RAS: shed potline quickly
& 2 additional KMO units

2 KMO units remaining on line
2L103 tie to BCTC is maintained
KIT aux load remains served

Figure 3.3: BCTC Disturbances – 2L100, 2105 & 2L103

Case #1: 3 phase fault on 2L100 @ MIN (Issue #10)

System Normal (2L103 KIT to MIN ~ 196MW)

Contingency: 3 phase fault on 2L100 @ MIN

Low dynamic voltage at KIT & MIN, 2L103 may trip out

RAS: shed 2 KMO units

KIT, MIN dynamic voltages improve, but still low, 2L103 still may trip out

Subsequent Contingency: 2L103 trips out

ALCAN islanded with adequate generation, slight o/f

Case #2: 3 phase fault on 2L100 @ MIN (Issue #10)

One KMO-KIT line OOS (2L103 KIT to MIN ~ 109MW)

Contingency: 3 phase fault on 2L100 @ MIN

Low dynamic voltage at KIT & MIN, 2L103 may trip out

RAS: shed one KMO unit

KIT, MIN dynamic voltages improve, but still low, 2L103 still may trip out

Subsequent Contingency:
2L103 trips out

Alcan islanded
Voltage collapse

RAS: shed potline & 6 KMO units

2L103 will remain connected
KIT aux load remains served

Case #3: 3 phase fault on 2L103 @ MIN & 2L103 trips open (Issue #9)

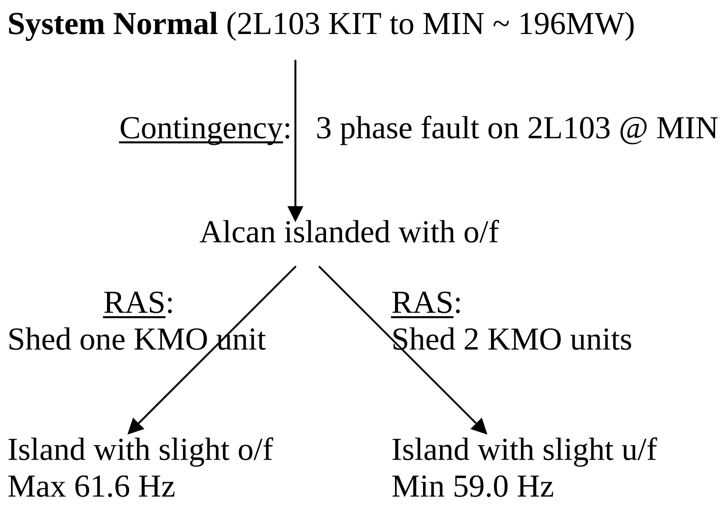
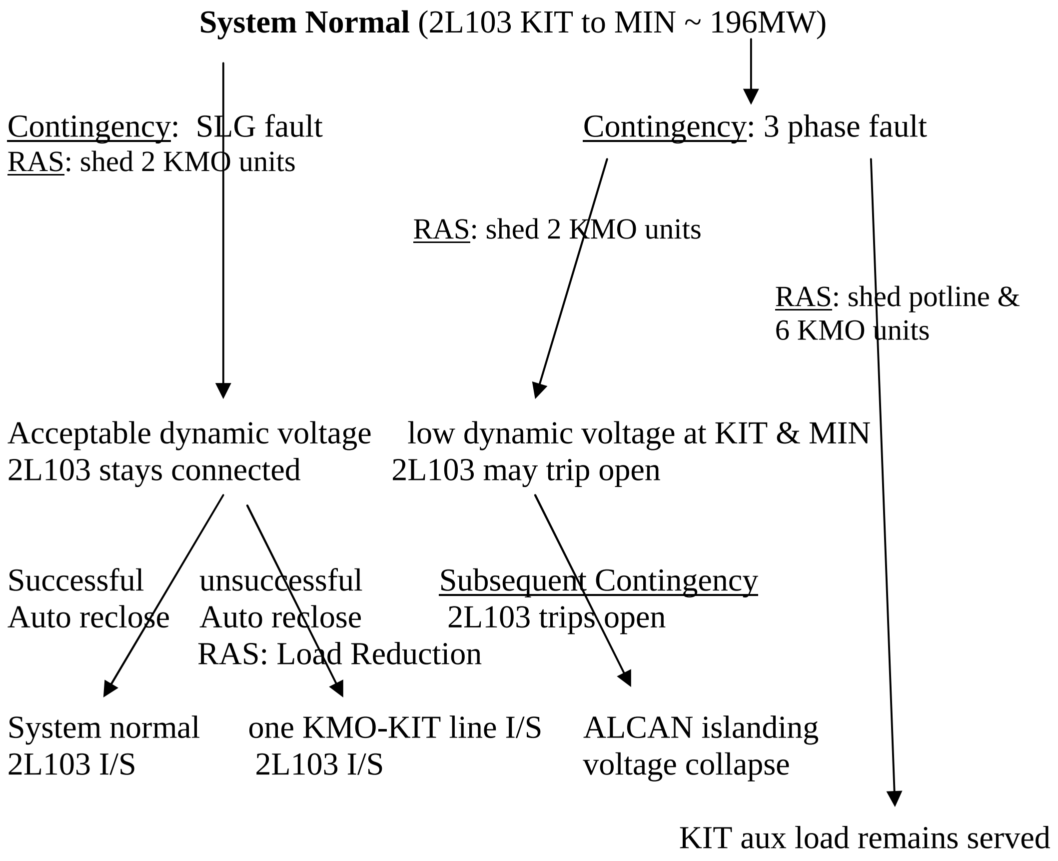
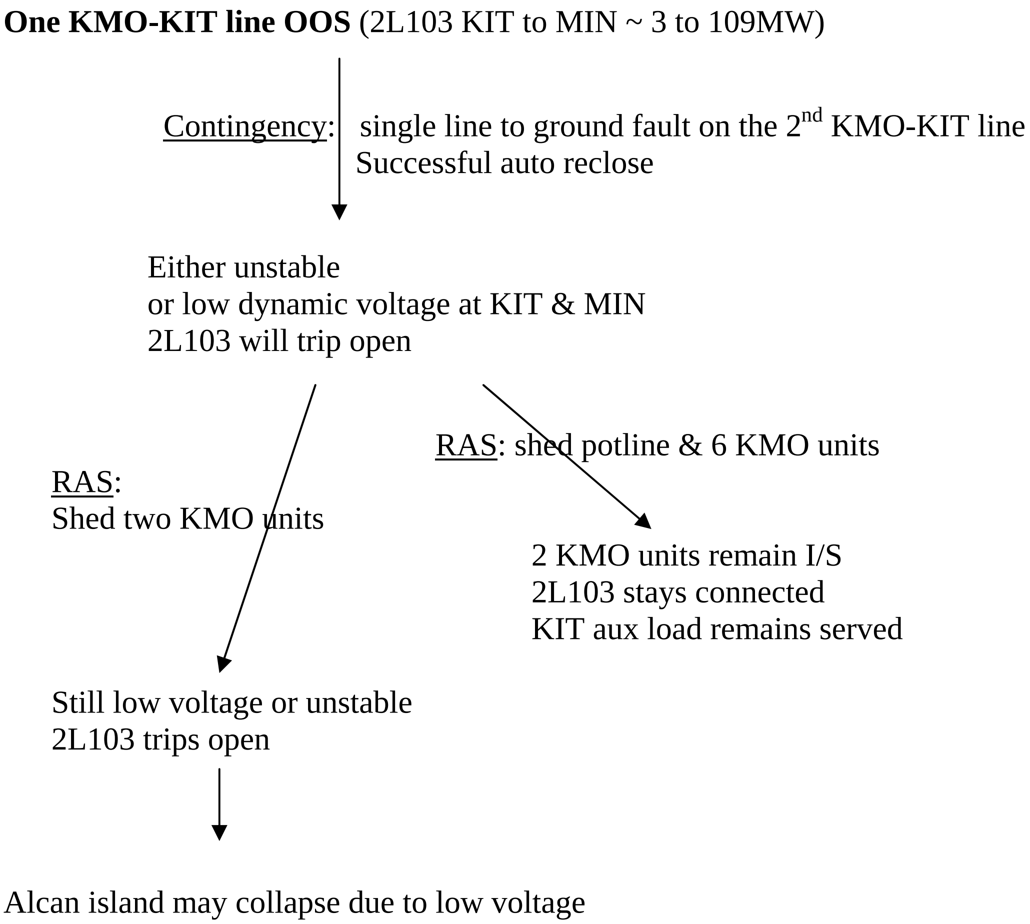


Figure 3.4: KMO-KIT line

Case #1, 2, 3, & 4: Fault on one of the KMO-KIT lines (Issue #3)



Case #5: Single line to ground fault on the 2nd KMO-KIT line with the first one OOS
(Issue #4)



One KMO-KIT line OOS (2L103 KIT to MIN ~ 3 to 109MW)

Contingency: single line to ground fault on the 2nd KMO-KIT line
Successful auto reclose

Either unstable
or low dynamic voltage at KIT & MIN
2L103 will trip open

RAS:
Shed two KMO units

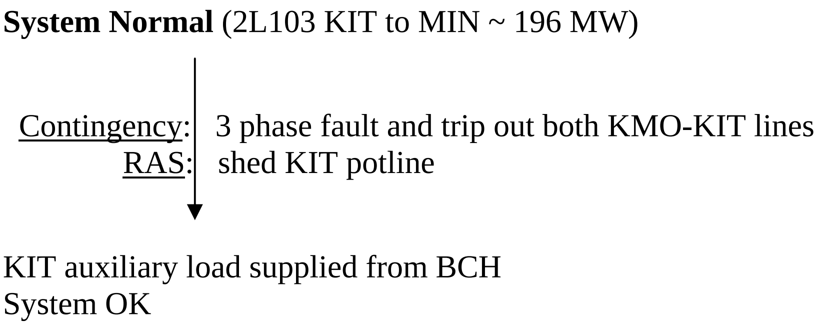
Still low voltage or unstable
2L103 trips open

Alcan island may collapse due to low voltage

RAS: shed potline & 6 KMO units

2 KMO units remain I/S
2L103 stays connected
KIT aux load remains served

Case #6: Loss of both KMO-KIT lines (Issue #5)



System Normal (2L103 KIT to MIN ~ 196 MW)

Contingency: 3 phase fault and trip out both KMO-KIT lines
RAS: shed KIT potline

KIT auxiliary load supplied from BCH
System OK

4 Conclusions

(1) Table 3.1 lists the RAS actions for various contingencies. The RAS actions include shedding KMO units, quickly reducing KIT potline load, shedding the KIT potline and tripping 2L103.

(2) The above Table 3.1 RAS actions do not address the reduction of under frequency load shedding due to the new single KIT potline arrangement. A separate study will address the issue.

(3) Shedding KIT potline is applied as a necessary action under certain scenarios to prevent total collapse of the Alcan system and to preserve the KIT auxiliary load for a speedy recovery of the KIT potline. This approach has been confirmed by Alcan as the preferred one to respond to those contingencies that could lead to Alcan islanded with a single KMO-KIT line and potential fast voltage collapse.

(4) While the RAS will somewhat mitigate the impact of various contingencies the overall Alcan system performance is degraded due to the significant KIT load increase and the reduced flexibility and capability of fast load shedding.

(5) If the RAS project proceeds, further work will be required to implement the RAS, including detailed project definition, implementation and operation planning studies.

5 List of Appendices

This section lists the study scope, switching information, and power flow and stability study results for detailed reference.

- Appendix A lists the study scope. This study is based on but not limited to this scope. Some additional scenarios are added for completeness.
- Appendix B lists the equipment switching time and sequence information for dynamic simulation.
- Appendix C lists the detailed power flow and dynamic simulation results, as shown in Tables C-1 to C-4.

Appendix

A. Study Scope

19 March 08

Kitimat Modernization Study

Impact Assessment & Mitigation Measures

Issue	Contingency & Impact	BCTC Studies & Mitigation Measures
1	**Contingency**: 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. *(Refer to #4, 4A in Table C-1)*	***Actions: BCTC*** a. Alcan to provide the var loading under N-1 pre-outage condition. ***(Alcan has provided the reduced var loading after manual adjustment for N-1 pre-outage condition. Note 1)*** b. BCTC to conduct studies and assess the effect of reduced var loading for the subject contingency. c. Without the dynamic model of rate of load reduction available, BCTC can not assess the Alcan system dynamic performance. Alcan to provide the model if available.
2	**Contingency**: KIT Load Rejection (due to potline protective relaying or manual emergency trip) Sudden loss of entire 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. *(Refer to #1 in Table C-1)*	***Actions: BCTC*** a. Alcan will confirm its preference to trip the tie rather than maintaining one or two KMO units on line ***(Alcan has decided to adopt the approach of applying generation shedding in an effort to maintain the MIT to MIN tie. A minimum of 2 KMO units will be kept as requested by Alcan. Note 2)*** b. BCTC will review and determine if the Alcan proposed approach is acceptable from a BCTC perspective

3	**Contingency**: 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. *(Refer to* #1,2, 3 and 4 in Table C-4*)*	***Actions: BCTC*** ***a.*** Alcan will investigate the feasibility of differentiating between single line to ground faults on these two lines vs. multi phase faults. If feasible, it may be preferable to apply KMO generation shedding in response to the SLG fault rather than tripping the KIT-MIN tie since the faulted phase could be successfully reclosed. Alcan needs to advise BCTC if this option is to be pursued. (***Alcan has confirmed their protection capable of differentiating between slg fault and multiphase faults. Alcan will adopt the approach of applying generation shedding for slg faults to keep the BCTC tie.***) b. If the SLG fault is not successfully cleared and reclosed, then trip KIT-MIN tie line. Would this be adequately fast to maintain the KMO-KIT line connection intact? This needs to be studied by BCTC. Alcan will need to review the results and confirm the preferred approach, i.e. applying SPR or tripping 2L103 in response to SLG fault. ***(BCTC to study the impact of unsuccessful reclose on slg faults.)*** c. If Alcan decides to differentiate between SLG vs multiphase faults and apply KMO gen shedding in response to SLG fault, BCTC will investigate and develop the RAS functional requirement. ***(BCTC to study and develop the RAS functional requirement.)***
4	**Contingency**: Single-Line-Ground fault with successful reclose while 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	***Actions: BCTC*** a. Alcan needs to decide which one of the following two options to adopt: A. Apply KMO gen shedding and wait for successful reclose. If it should fail, then trip KIT smelter load ASAP and maintain

	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. *(Refer to #5 in Table C-4)*	the auxiliary load. B. Trip KIT-MIN line to become islanded. Wait for the SLG fault to clear and reclose successfully. ***(Alcan has adopted Option A.)*** b. BCTC will conduct study to assess technical feasibility of Option A only. Option B may or may not work depending on Alcan condition. ***(BCTC will study Option A only.)*** c. BCTC will incorporate Alcan decision in the overall RAS functional requirement
5	**Contingency**: 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. *(Refer to #6 in Table C-4)*	***Actions: BCTC*** a. Alcan needs to decide the preferred options: A. Do not differentiate the types of faults on each circuit and trip KIT-MIN line immediately. Alcan system will be islanded and may or may not survive depending on the remaining KMO generation, the KMO-KIT transmission lines condition and KIT load conditions. B. Do not differentiate the types of faults on each circuit. Trip KMO-KIT lines and the KIT smelter load immediately and leave the auxiliary load intact to be served from MIN. C. Differentiate the types of faults on each circuit a) Separate SLG faults on each circuit: apply KMO gen shedding for each SLG fault. (Note that PSSE has limited functionality and can not assess system performance of different phases under unbalanced conditions. PSSE can only provide approximate solution, i.e. disregarding the unbalanced conditions.) b) For all other faults, Trip KMO-KIT lines and smelter load immediately and leave the auxiliary load intact to be served from MIN.

		(Alcan has adopted Option B. This will keep auxiliaries energized and help in fast restoration of Kemano.) b. Depending on Alcan's decision, BCTC may need to conduct studies to confirm technical feasibility and functional requirement of Option B or C. ***(Alcan has adopted Option B.)*** c. BCTC will incorporate the requirement in RAS functional scope.
6	**Contingency**: 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. *(Refer to #1, 1A in Table C-2)*	***Actions: BCTC*** a. BCTC will update the study using 8 KMO units on line with two transformers having connected with three KMO units each. Loss of one transformer will result in KIT load supplied with 5 KMO units. ***(Alcan has confirmed adopting this study requirement.)*** b. Alcan suggests to lower down the transformers tap to reduce KIT load upon detecting 2L99 O/L. BCTC will assess the severity of overload and confirm if load reduction by lowering the transformer tap position is acceptable. If so, BCTC will develop the corresponding RAS requirement.
7	**Contingency**: 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.	***Actions: Alcan*** At the meeting, Alcan indicated the preference to trip KIT to MIN line and immediately separate from the system in response to such contingency. Please confirm. ***(Alcan has confirmed adopting this approach. Note 3)***

	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. *(Refer to #2 in Table C-2)*	
8	**Contingency**: 5L61 contingency With 8 KMO generators on line and 190 MW flow on 5L61 from WSN to GLN, 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. *(See other report)*	***Actions: Alcan, BCH, & BCTC*** The existing KIT U/F load shedding is planned to be removed in the new KIT smelter design which result in having less load available for u/f load shedding in the North Coast area and BC as a whole. Alcan and BCH will need to work out the replacement for the U/F load shedding requirement from both North Coast and entire BC perspectives in order to: 1. arrest frequency decay, and 2. meet WECC u/f load shedding obligation when there is a generation deficiency in the subject area. ***BCTC will study the technical feasibility of using additional BCH loads as replacement to KIT u/f load shedding reduction for arresting frequency decay and meeting the WECC u/f load shedding requirement. (Note 2)***
9	**Contingency**: 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	***Actions: BCTC*** a. Alcan will implement KMO generation shedding for the loss of 2L103

	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. *(Refer to #3 in Table C-3)*	***(Confirmed by Alcan. Note 3)*** b. BCTC to develop RAS functional requirement
10	**Contingency**: 2L100 or 2L105 contingency 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. *(Refer to #1,#2 in Table C-3)*	***Actions: BCTC*** a. Alcan to confirm continuing with this approach. ***(Alcan has confirmed requesting BCTC to investigate a different approach of initiating KMO shedding as a mitigation measure in response to a three-phase fault on 2L100 or 2L105. Note 2)*** b. A possible option is to apply appropriate amount of KMO generation shedding in response to the disturbance to reduce the dynamic swings. If Alcan is interested in this approach, BCTC will investigate the effectiveness of this option. ***(BCTC will investigate this option.)***
11	**Contingency**: KIT bus fault Loss of east KIT bus or the west KIT bus will result in different impact to Alcan and the BCTC system due to KIT bus configuration. *(Refer to #2,#3 in Table C-1)*	***Action: BCTC*** a. BCTC to assss the impact of east bus fault and RAS functional requirement. b. BCTC to assess the impact of west bus fault and RAS functional requirement.

B. Equipment switching time and sequence information

1. For KIT bus fault

Fault on the East bus (loss of all rectifier load)

0 cycle	fault initiation
4 cycles	fault cleared by bus differential protection
6 cycles	generation shedding at KMO (2 units left in production)

Fault on the West bus (loss of the interconnection)

0 cycle	fault initiation
4 cycles	fault cleared by bus differential protection; CB 440 trips opening line 2L103

2. Load rejection

Load rejection due to bus differential protection is described above. Following is the sequence for load rejection due to potline protective relaying or manual emergency trip:

0 cycle	trip initiation (automatic or manual)
3 cycles	simultaneous opening of all rectifier transformer CBs
5.5 cycles	generation shedding at KMO (2 units left in production)

3. Loss of one KMO-KIT line

Following is the timing and sequence for a SLG fault near KIT with successful auto reclose:

0 cycle	fault initiation
3.5 cycles	fault cleared at KIT
5 cycles	fault cleared at KEM (permissive trip)
6 cycles	generation shed at KMO
35 cycles	auto reclose at KMO
36 cycles	auto reclose at KIT

Following is the timing and sequence for a SLG fault near KIT with an unsuccessful auto reclose attempt:

0 cycle	fault initiation
3.5 cycles	fault cleared at KIT
5 cycles	fault cleared at KMO (permissive trip)
6 cycles	generation shed at KMO
35 cycles	auto reclose onto fault at KMO
39 cycles	trip 3Ø and lock open at KMO
39.5 cycles	trip 3Ø and lock open at KIT (direct transfer trip)

4. Loss of both KMO-KIT lines

We feel the only credible event that would result in the loss of both transmission lines would be simultaneous multi-phase faults on both lines.

Fault location near KMO:

0 cycle	multi-phase fault initiation on both lines
4 cycles	faults cleared at KMO
4.5 cycles	faults cleared at KIT (permissive trip)
8 cycles	load shed at KIT

Following are various timings that can be used to calculate other scenarios:

Normal 3Ø auto reclose times:

L81 (KMO)	5 sec.
L82 (KMO)	10 sec.
L87 (KIT)	7.5 sec.
L88 (KIT)	12.5 sec.

Single pole auto reclose (both ends):

Dead time	500 mS

Second zone timer for distance protection:
36 cycles

Kemano circuit breakers:

Measured contact opening time	42 mS
Assumed arcing time	10-15 mS
Fault clearing time rounded off to	3.5 cycles
Closing time	3.5 cycles (estimated)

Kitimat circuit breakers:

Contact opening time	33 mS
Assumed arcing time	10-15 mS
Fault clearing time rounded off to	3 cycles
Closing time	3.5 cycles (estimated)

Relay times (21-1, 86B, 87 and 94):
0.5 cycle maximum (estimated)

Permissive tripping and direct transfer trip time:
14 mS, rounded off to 1 cycle.

5. Tap down transformer Changers to reduce potline load

- ABB has confirmed lowering 7 taps will reduce the load by 100 MW. There is a 4 second delay between tap changes. This is the maximum load reduction Alcan wants to consider for "normal" contingencies.
- There is another way to achieve greater load reduction, but it could only be considered in an extreme emergency, such as the prolonged loss of a substantial amount of generation. It involves operation at normal current, but at greatly reduced voltage, achieved by reducing the anode-cathode distance. Load can be lowered to around 28% of nominal. The energy only maintains the pots' temperature, and no aluminum is produced.

C. Power flow and Dynamic Simulation Results

The following tables (Tables C-1 ~ C-4) list the detailed information of power flow and dynamic simulation results. Some annotations are explained below.

- JLC stands for Joint Load Control at KMO. In voltage control mode, it regulates Kitimat287 bus voltage between 275 ~ 295 kV, or 0.958 ~ 1.028 pu.
- (P,Q) means potline load model is constant P and constant Q;
- (I,Z) means constant current for P and constant impedance for Q;
- (Z,Z) means constant impedance for both P and Q;
- RHS stands for Regional Heavy Summer load case, in which non-coincidental load is used and is heavier than the area coincidental load.

The correspondences between the issue number in Study Scope (Appendix A) and the case number in study results of Tables C-1 to C-4 are listed below:

Issue number in Study Scope (Appendix A)	Case number in Study Results of Tables C-1 ~ C-4
#1	#4, 4A in Table C-1
#2	#1 in Table C-1
#3	#1,2, 2A, 3 in Table C-4
#4	#4 in Table C-4
#5	#5 in Table C-4
#6	#1, 1A in Table C-2
#7	#2 in Table C-2
#8	To be covered by a separate report
#9	#1 and all others in Table C-4
#10	#1,2 in Table C-3
#11	#2,3 in Table C-1

Table C-1 Study Results for KIT Smelter Disturbance

Case No.	System Conditions	Power flow study								Dynamic performance			
		Power flow (MW+jMVAr)					Bus voltage (kV / pu.)			Rotor Angle (deg.)		Bus Volt. (pu.)	
		KMO Gen	(L81+L82) KMO[3]	(L87+L88)KIT	2L103KIT	2L99MIN	KMO287	KIT/MIN	SKA287	KMO G1	Eur G	KMO287	KIT287/MIN287
1	**System normal, 2010 light summer load; Disturbance -- KIT Pot-Line Load Rejection (issue #2 in study scope)**												
1.1	pre-fault	8x(110+j36)	876+j209	-(864+j80)	196-j14	194-j20	301/1.05	287/1.00	287/1.0				
1.2	Load rejected, 2 KMO units remain	2x(110+j24)	219+j31	-(218+j74)	168+j58	166+j43	310/1.08	305/1.06	299/1.04	34~54	78~120		1.0~1.09
1.3	Case 1.2 with JLC voltage control	2x(110-j8)	219-j36	-(218-j1)	168-j17	166-j24	287/1.00	287/1.0	287/1.00				
	Conclusion	Shedding 6 KMO units to keep 2 units on line could mitigate the impact and keep 2L103 remaining connected											
2	**System normal, 2010 light summer load; Disturbance -- KIT287 East Bus 3ϕ Fault (potline connected bus) (issue #11 in study scope)**												
2.1	pre-fault	8x(110+j36)	876+j209	-(864+j80)	196-j14	194-j20	301/1.05	287/1.00	287/1.0				
2.2	Loss of pot-line transformers, L81/87, one Aux. transformer, bus-tie; 2 KMO units remain												
2.2a	without JLC voltage control	2x(110+j33)	219+j48	-(218+j53)	168+j34	165+j19	308/1.07	299/1.04	295/1.03	24~76	78~110		1.0~1.08
2.2b	with JLC voltage control	2x(110+j10)	219+j1	-(217.4+j2)	167-j17	165-j24	289/1.01	287/1.00	287/1.00				
	Conclusion	Shedding 6 KMO units to keep 2 units on line could mitigate the impact and keep 2L103 remaining connected											
3	**System normal, 2010 light summer load; Disturbance -- KIT287 West Bus 3ϕ Fault (tie line connected bus) (issue #11 in Study scope)**												
3.1	pre-fault	8x(110+j36)	876+j209	-(864+j80)	196-j14	194-j20	301/1.05	287/1.00	287/1.0				
3.2	Loss of 2L103, L82/88, one Aux. transformer and bus-tie; power flow not converged with potline (P,Q) load model												
3.2a	(I,Z) potline model, scale down generations												
	without JLC control	8x(82+j42)	650+j294	-(635+j102)	0		306/1.06	273/0.95		63.2 (frequency)		down to 237 kV or 0.83 pu for 10 sec.	
	with JLC control	8x(86+j50)	683+j285	-(667+j97)	0		**318/1.11**	287/1.00					
3.3	case 3.2a, shed 1 KMO unit, with (I,Z) potline load model												
	without JLC control	7x(93+j50)	646+j295	-(631+j103)			304/1.06	**271/0.94**		62.5 (frequency)		down to 237 kV or 0.83 pu for 10 sec.	
	with JLC control	power flow not converged											

To be continued on next page

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[3] xxxAA means Power on xxx line flows from AA substation.

Table C-1 KIT Smelter Disturbance (Cont.1)

Case No.	System Conditions	Power flow								Dynamic Simulation			
		MW, MVAr					kV / pu.			Rotor Angle (deg.)		Bus Volt. (pu.)	
		KMO Gen	L81+L82KMO	L87+L88KIT	2L103KIT	2L99MIN	KMO287	KIT/MIN	SKA287	KMO G1	Eur G	KMO287	KIT/MIN
3.4	Load reduction by 100 MW and shed one KMO unit [Note 1]												
		7x(82+j25)	575+j139	-(564+j14)			303/1.05	287/1.00		62.3 (frequency)		raised up to 0.89	
3.5	Case 3.2, shed 2 KMO units with (I,Z) potline load model, no power flow solution												
	conclusion	**KIT west bus fault results in Alcan islanding with one KMO-KIT line in operation, Alcan system voltage could collapse. Since surviving the contingency is of the most concern, fast load reduction is required. Changing the tap can reduce the load by 100 MW in 30 sec. This may not be fast enough to prevent the voltage collapse.**											
4	**2010 light summer, KIT T5 OOS; Disturbance -- loss of 2nd KIT Transformer (issue #1 in scope)**												
4.1	Pre-fault	8x(110+j45)	876+j286	-(863+j154)	194-j14	192-j20	306/1.07	287/1.00	287/1.00				
4.2	KIT T4 kick-out, without KMO JLC voltage control, power flow not converged with mismatch of 59+j5 @potline 1440V load bus												
	(with JLC voltage control still not converged)												
4.2a	With (I,Z) potline load model, power flow not converged with mismatch of 36 - j0.4@potline 1440V load bus									21~92	48~130		0.79~1.04
4.2b	(Z,Z) load model	8x(110+j53)	876+j341	-(862+j188)	296-j37	293-j37	297/1.04	275/0.96	277/0.96				
4.3	- Case 4.2 - potline load [note 2] reduced to 433MW - with JLC voltage control	8x(110+j43)	876+j177	-(864+j62)	**372+j29**	370+j22	305/1.06	287/1.00	282/0.98				
4.4	Case 4.3 with Shedding KMO 1 unit	7x(110+j24)	767+j102	-(756+j13)	268-j0	266-j7	295/1.03	287/1.00	285/0.99				
4.5	Case 4.2 with shedding KMO 1 unit with potline (I,Z) load model				159-j82	156-j81	289/1.01	**269/0.94**		11~85	37~125		0.816~1.04
4.6	Case 4.2 with shedding KMO 2 units with potline (I,Z) load model				46-j81	44-j80	290/1.01	**272/0.95**		3~80	26~123		0.821~1.04
4.7	Case 4.2 with shedding KMO 2 units, after 2L103 tripped, with potline (P,Q) load model												
		6x(113+j35.6)	675+j153	-(667+j94)	N/A		299/1.04	287/1.00		61.3 Hz at 10 sec.			>0.95
	Conclusion	- 2L103 might be overloaded; KMO gen shedding or reduction of Alcan export is required - Voltage dip at KIT might trigger 2L103 out-of-step relay to pick up. Gen shedding can reduce this probability - If 2L103 is tripped, with or without KMO gen shedding, the voltage performance is acceptable, Alcan O/F is expected. - Shedding KMO generation with the amount of 2L103 pre-outage transfer and based on reducing KIT potline load to 433 would be the approach to mitigate the impact											

Note: 1. Changing the transformer tap position can reduce potline load by 100 MW in 30 seconds.
2. Changing the transformer tap position can to reduce potline load by 433 MW with 50 seconds to solve the problem of overloading the remaining rectifier units.

Table C-1 KIT Smelter Disturbance (Cont.2)

4A	**2010 light summer, 0 MW transfer on 2L103, KIT T5 OOS; Disturbance -- loss of 2nd KIT Transformer**												
4A.1	Pre-fault	8x(85+j32)	678+j207	-(670+j146)	1-j22	-(2+j28)	302/1.05	287/1.00	289/1.01				
4A.2	KIT T4 kick-out with (I,Z) load model	8x(85+j43)	678+j297	-(669+j228)	36-j35	34-j38)	305/1.06	285/0.99	287/1.00	7~58	48~109		0.91~1.01
	Conclusion	The power flow captures the snapshot before the potline load is tapped down. The out-of-step relay of 2L103 may not pick up after the loss of the 2nd KIT transformer with light transfer on 2L103. In order to prevent 2L103 from tripping, low 2L103 transfer is preferred											

Table C-2 Study Results for KMO Plant Disturbance

Case No.	System Conditions	Power flow								Dynamic Simulation			
		MW, MVAr					kV / pu.			Rotor Angle (deg)		Bus Volt. (pu.)	
		KMO Gen	L81+L82KMO	L87+L88KIT	2L103KIT	2L99MIN	KMO287	KIT/MIN	SKA287	KMO G1	Eur G	KMO287	KIT/MIN
1	**2010 Heavy Summer (regional) case, KMO T56 OOS, 8 units online; Disturbance -- loss of the 2nd KMO transformer T34, trip out 3 KMO units (issue #6 in scope)**												
1.1	Pre-fault	8x(85+j33)	673+j191	-(665+j132)	-3+j38	-89+j8	301/1.05	287/1.00	286/1.00				
1.2	T34 Contingency would result in loss of 3 units												
1.2a	without JLC control	With (P,Q) load model, power flow not converged. With (I,Z) load model, power flow is solved and acceptable.											
1.2b	with JLC control	5x(85+j26)	421+j88	-(417+j94)	-251-j1	**-338-j33**	295/1.03	287/1.03	295/1.03	-10~38	20~72		0.99
1.3	Case 1.2b with EuroCan outage	5x(85+j30)	421+j107	-(417+j112)	-252+j17	**-362-j22**	296/1.03	287/1.00	2957/1.03				
	Conclusion	**Dynamic voltages are OK, require potline load reduction at KIT to mitigate 2L99 overload**											
1A	**RHS case, EuroCan OOS, KMO T56 OOS, 8 units online; Disturbance -- loss of the 2nd KMO transformer T34, trip out 3 KMO units**												
1A.1	Pre-fault,T56 OOS	8x(85+j34)	673+j204	-(665+j144)	-3+j50	-113+j12	301/1.05	287/1.00	286/1.00				
1A.2	T34 Contingency without or with JLC voltage control, power flow not converged with mismatch @potline 1440V bus									-37~1	N/A		0.97~1.03
1A.3	KIT load reduction by 100 MW	5x(85+j4)	421-j20	-(418-j16)	-146-j26	-256-j65	288/1.00	287/1.00	297/1.03				
	Conclusion	1. **Without EuroCan generation in service, system voltage could collapse. Potline load reduction is required to keep voltage stability.** 2. **The unsolved power flow indicates potential voltage collapse problems. Fast load shedding is preferred.**											
2	**System normal, 2010 Heavy Winter, Disturbance -- 3ϕ or single phase ground fault @ KMO bus, lose 4 gens and one KMO-KIT line (issue #7 in scope)**												
2.1	pre-fault	8x(110+j27)	876+j142	-(864+j13)	196-j81	139-j106	296/1.03	287/1.0	296/1.03				1.00
2.2	3ϕ bus fault	4x(110+j48)	438+j154	-(431+j85)	-239-j20	**-296-j41**	304/1.06	284/0.99	292/1.02	-10~75	8~100		0.82
2.3	3ϕ bus fault, shed KIT potline load and two more KMO units to save KIT Aux load												
		2x(110+j33)	219+j48	-(218+j53)	168+j34	165+j19	308/1.07	299/1.04	295/1.03	0~45	50~76		0.97
2.4	Single phase Ground bus fault			same as 2.2						-22~30	-9~54		0.85
2.5	Bus fault, 2L103 tripped		No power flow solution with any potline load model							51.5 Hz (freq)			0.58
	Conclusion	**Case 2.2 and 2.4 indicate 2L103 could be tripped. The islanded Alcan system would collapse due to lack of generation and excessive load. In order to preserve the KIT auxiliary load, Alcan prefers to trip the potline.**											

Table C-3 BCTC Transmission Line Disturbance

Case No.	System Conditions	Power flow								Dynamic Simulation			
		MW, MVAr					kV / pu.			Rotor Angle (deg.)		Bus Volt. (pu.)	
		KMO Gen	L81+L82KMO	L87+L88KIT	2L103KIT	2L99MIN	KMO287	KIT/MIN	SKA287	KMO G1	Eur G	KMO287	KIT/MIN
1	**System normal, 2010 light summer; Disturbance -- 2L100 3ϕ fault @MIN (issue #10 in scope)**												
1.1	pre-fault	8x(110+j36)	876+j209	-864-j80	196-j14	194-j20	301/1.05	287/1.00	287/1.00	50	78		
1.2	2L100 3-ϕ fault @MIN									10~97	45~135		0.80~1.07
1.3	shed KMO 1 unit				89-j23		298/1.04	287/1.00	288/1.01	6~92	33~133		0.82~1.07
1.4	shed KMO 2 units				-19-j21		297/1.03	287/1.00	289/1.01	1~87	23~130		0.84~1.07
	Conclusion	1. Gen shedding is required to improve dynamic performance 2. 2L103 may still be tripped with KMO gen shedding applied											
2	**L88OOS, 2010 light summer with one KMO-KIT line in service; Disturbance -- 2L100 3ϕ fault @MIN (issue #10 in scope)**												
2.1	pre-fault	8x(110+j27)	Power flow not converged (system is too weak)										
2.2	reduced Gen.	8x(100+j50)	797+j332	-776-j72	109-j22	107-j28	320/1.12	287/1.00	288/1.00				
2.3	2L100 3-ϕ fault @MIN		almost the same as 2.2				320/1.12	287/1.00		15~90	48~126		0.80~1.07
2.4	Shed KMO 1 unit	7x(100+j46)			13-j22		316/1.10	287/1.00	289/1.01	3~82	34~124		0.84~1.07
	Conclusion	1. Pre-contingency power flow should be reduced when only one KMO-KIT line in service 2. Gen shedding scheme is required to improve dynamic performance 3. 2L103 may still be tripped with gen shedding applied 4. Shedding potline load to keep the auxiliary load is the approach											
3	**2010 light summer, system normal; Disturbance -- 2L103 3-ϕ fault at KIT, fault cleared in 6 cyc (issue #9 in scope)**												
3.1	pre-fault	8x(110+j36)	876+j209	-864-j80	196-j14	194-j20	301/1.05	287/1.00	287/1.00				
3.2	2L103 fault., Shed 1 KMO unit	7x(96.8+j30)	675+j153	-667-j94	N/A		298.5/1.04	287/1.00	N/A	61.6 (freq)		0.94	0.98
3.3	2L103 fault., Shed 2 KMO unit	6x(113+j36)	675+j153	-667-j94	N/A		298.5/1.04	287/1.00	N/A	59.0 (freq)		0.96	0.99
	comments	1. In islanding situation, with both KMO-KIT lines in service, dynamic voltage deviation is acceptable 2. Require shedding adequate KMO generation to prevent high frequency											

Table C-3 BCTC Transmission Line Disturbance (cont.)

Case No.	System Conditions	Power flow								Dynamic Simulation			
		MW, MVAr					kV / pu.			Rotor Angle (deg.)		Bus Volt. (pu.)	
		KMO Gen	L81+L82KMO	L87+L88KIT	2L103KIT	2L99MIN	KMO287	KIT/MIN	SKA287	KMO G1	Eur G	KMO287	KIT/MIN
4	**2010 heavy winter, L88 OOS; Disturbance -- 2L101 3-ϕ fault at SKA, fault cleared in 6 cycles**												
4.1	pre-fault	8x(110+j51)	876+j331	-852-j14	184-j80	128-j105	317/1.11	287/1.00	296/1.03				
4.2	2L101 fault., No gen shedding	8x(110+j53)	876+j346	-852-j29	184-j65	128-j90	319/1.11	287/1.00	294/1.03	-8~62	13~82	1.009	0.78
4.3	2L101 fault., shed 1 KMO unit	7x(110+j48)	767+j268	-748-j29	81-j65	24-j90	313/1.09	287/1.00	295/1.03	-23~48	3~78	1.006	0.84
4.4	2L101 fault., shed 21 KMO units	6x(110+j45)	657+j211	-643-j40	-24-j54	-81-j87	310/1.08	287/1.00	295/1.03	-35~45	-8~76	0.994	0.86
5	**2010 heavy winter, L88 OOS; Disturbance – SKA T1 3-ϕ fault at SKA, fault cleared in 6 cycles**												
5.1	pre-fault	8x(110+j51)	876+j331	-852-j14	184-j80	128-j105	317/1.11	287/1.00	296/1.03				
5.2	SKA T1 fault., No gen shedding	8x(110+j52)	876+j340	-852-j24	184-j71	128-j96	319/1.11	287/1.00	295/1.03	21~79	50~112	1.05	0.76
5.2a	SKA T1 fault., No gen shedding	Powerflow blown up with SKA Auto VAR control. It is OK with shedding one KMO unit [Note]											
5.3	SKA T1 fault shed 1 KMO unit	7x(110+j51)	767+j293	-748-j54	80-j40	24-j64	317/1.10	287/1.00	293/1.02	8~74	43~111	1.036	0.83
5.4	SKA T1 fault shed 2 KMO unit	6x(110+j49)	657+j239	-643-j68	-24-j26	-81-j51	313/1.09	287/1.00	292/1.02	-3~70	32~109	1.025	0.85
	Conclusion	1. When one KMO-KIT line in operation, 2L101 or SKA T1 contingency may cause 2L103 tripped by the out-of-step relay. KMO gen shedding is required; 2. After the gen-shedding at KMO, the voltage dip at KIT is on the border line, therefore tripping the potline is also required.											

Note: In this situation, if Auto VAR switches in the reactor at SKA, the powerflow is blown up. The gen shedding is much faster than the auto VAR control, therefore it is acceptable.

Table C-4 KMO-KIT Transmission Line Disturbance

Case No.	System Conditions	Power flow								Dynamic Simulation			
		MW, MVAr					kV / pu.			Rotor Angle		Min. Bus Volt.	
		KMO Gen	L81+L82KMO	L87+L88KIT	2L103KIT	2L99MIN	KMO287	KIT/MIN	SKA287	KMO G1	EurG	KMO287	KIT/MIN
1	**System normal, 2010 light summer; Disturbance -- L81 3ϕ fault at KMO, fault cleared at KMO in 4 cyc, at KIT in 5 cyc, shed KMO units in 6 cyc (issue #3 in scope)**												
1.1	pre-fault	8x(110+j36)	876+j209	-864-j80	196-j14	194-j20	301/1.05	287/1.00	287/1.00				
1.2	L81 3ϕ fault, trip the line, no gen shedding, power flow not converged									Unstable			
1.3	Case 1.2 with shedding 1 unit	Power flow not converged with VAR mismatch 16 MVAR											
1.4	Case 1.2 with shedding 2 units	Without JLC control, power flow not converged with VAR mismatch 1.0 MVAR								0~100	20~110		**0.65~1.03**
1.4a	with JLC control	6x(110+j51)	657+j248	-643-j74	-24-j20	-27-j27	**314/1.10**	287/1.00	289/1.01				
1.5	Shed 3 units	5x(110+j51)			-132-j6		312/1.09	287/1.00	289/1.01	-4~85	23~107		0.74~1.03
1.6	Case 1.4 with 100 MW load reduction	6x(110+j36)	657+j159	-643+j12	79-j23	77-j30	303/1.06	287/1.00	289/1.01				
	Conclusion	Gen shedding is not effective enough to keep 2L103 from tripped, depending on other conditions. With 2 KMO units shedding and load reduction, the power flow is acceptable.											
2	**system normal, 2010 heavy winter, 0 MW transfer on 2L103; Disturbance -- L81 3ϕ fault at mid-location, no gen shedding**												
2.1	pre-fault	8x(85+j16)	678+j80	-670-j21	2.7-j73	-54-j98	294/1.02	287/1.00	297/1.03				
2.2	no gen shedding	8x(85+j31)	678+j207	-663-j22	-(4.6+j72)	-61-j97	309/1.08	287/1.00	297/1.03	-10~31	4~55		0.86~1.00
3	**Case #1 with 2L103 be tripped**												
3.1	pre-fault	8x(110+j36)	876+j209	-864-j80	196-j14	194-j20	301/1.05	287/1.00	287/1.00				
3.2	L81 3ϕ fault, shed 2 KMO units, 2L103 tripped			Power flow is not converged with load model (P,Q) or (I,Z)						61.3 Hz (freq)		>0.95	>0.88
	(Z,Z) potline model	6x(104+j53)	624+j262	-610-j87	N/A		303/1.05	273/0.95					
	Comments	In islanding situation, with only one KMO-KIT line in service, the power flow does not converge with (P,Q) and (I,Z) load model. This indicate the voltage would collapse.											
	conclusion from 1,2,3	For 3-ϕ fault, • 2L103 may or may not stay in depending on the fault location and pre-contingency power flow • Shedding KMO generation may not save 2L103 from tripped • If 2L103 tripped, with only one KMO-KIT line in service, the voltage in islanded Alcan system may collapse • For this circumstance, Alcan prefers to trip the potline and preserve the auxiliary load											

Table C-4 KMO-KIT Transmission Lines Disturbance (Cont.)

Case No.	System Conditions	Power flow								Dynamic Simulation			
		MW, MVAr					kV / pu.			Rotor Angle		Min. Bus Volt.	
		KMO Gen	L81+L82KMO	L87+L88KIT	2L103KIT	2L99MIN	KMO287	KIT/MIN	SKA287	KMO G1	EurG	KMO287	KIT/MIN
4	**2010 light summer, L81 SLG@KMO, auto reclosing failed**												
4.1	pre-fault												
4.2	L81 SLG fault with no gen shedding		Power flow not converged							50~95	49~96		**0.76**~0.95
4.3	L81 SLG fault with one gen shedding		Power flow not converged with 16 MVAR mismatch							50~70	55~93		0.91~0.95
4.4	L81 SLG fault with two gen shedding and 100 MW potline load reduction		657+j159	-643+j12	79-j23	77-j30	303/1.06	287/1.00	289/1.01	38~65	54~91		0.95~0.97
	comment	For SLG fault, with 2 KMO units shedding and 100 MW potline load reduction, the power flow is acceptable.											
5	**2010 light summer, L82/88 OOS; Disturbance -- SLG on L81/87 @KMO, Auto reclosing successful (issue #4 in scope)**												
5.1	pre-fault	8x(100+j50)	797+j336	-776-j72	109-j22	107-j28	**321/1.12**	287/1.00	288/1.00				
5.1.1	shed KMO 2 units	6x(100+j45)			-83-j14		313/1.09	287/1.00	289/1.01	unstable			
5.1.2	shed 6 KMO units and the potline load		219+j48	-(218+j53)	168+j34	194-j20	308/1.07	299/1.04	295/1.03	29~65	76~126		1.00~1.10
5.2	pre-fault	7x(100+j46)	697+j267	-681-j71	14-j22	12-j29	**315/1.10**	287/1.00	289/1.01				
5.2.1	shed KMO 1 unit	6x(100+j45)	598+j219	-586-j80	-82-j14	-85-j20	312/1.09	287/1.00	289/1.01	unstable			
5.2.2	shed KMO 2 units	5x(100+j46)	498+j191	-489-j99	-179+j5	-181-j2	311/1.08	287/1.00	289/1.01	-50~122	-40~134	**0.48**	
5.3	pre-fault	8x(86+j38)	686+j260	-670-j72	3-j22	1-j28	**315/1.10**	287/1.00	289/1.01				
5.3.1	shed KMO 1 unit	7x(86+j37)	600+j220	-588-j80	-79-j14	-82-j21	312/1.09	287/1.00	289/1.01	unstable			
5.3.2	shed KMO 2 units	6x(86+j38)	514+j194	-505-j95	-163+j1	-165-j6	311/1.08	287/1.00	289/1.01	-35~106	-13~106	**0.62**	
5.4	pre-fault	7x(105+j50)	732+j288	-714-j71	47-j23	45-j30	**317/1.10**	287/1.00	289/1.01				
5.4.1	Trip 2L103	With (I,Z) load model, power flow not converged; With (Z,Z) model, result is acceptable								unstable			
	Conclusion	Pre-outage high voltage indicates the system is too weak to keep adequate KIT voltage. Post-contingency results of cases 5.1, 5.2 and 5.3 indicate the chance of keeping 2L103 in service is very low. After 2L103 is tripped, the islanding system is unlikely to survive, as indicated in case 5.4.1. Therefore shedding potline load and corresponding KMO generation is the preferred approach by Alcan, as the result indicated in case 5.1.2.											
6	**2010 heavy winter, KMO-KIT lines double contingency (issue #5 in scope)**												
6.1	pre-fault	8x(110+j27)	876+j142	864+j13	196-j81	139-j106	296/1.03	287/1.0	296/1.03				
6.2	KMO-KIT double contingency, shed potline load			--	-50-j16	-107-j48	--	303/1.056	308/1.07		25~116		0.99~1.07