REPORT

Power to Ontario.
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System Impact Assessment Report (Addendum)

CONNECTION ASSESSMENT & APPROVAL PROCESS

Issue 1.0

Final Addendum
Project: Cornwall Interconnection
Applicant: Canadian Niagara Power Inc.

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SYSTEM IMPACT ASSESSMENT REPORT
For
Cornwall Interconnection

System Impact Assessment Report

115 kV Interconnection between Cornwall and Hydro One

Acknowledgement

The IESO wishes to acknowledge the assistance of Hydro One in completing this assessment.

its best efforts to advise you of any such changes, it is the responsibility of the connection applicant to ensure that it is using the most recent version of this report.

HYDRO ONE

Special Notes and Limitations of Study Results

The results reported in this study are based on the information available to Hydro One, at the time of the study, suitable for a preliminary assessment of a new generation or load connection proposal.

The short circuit and thermal loading levels have been computed based on the information available at the time of the study. These levels may be higher or lower if the connection information changes as a result of, but not limited to, subsequent design modifications or when more accurate test measurement data is available.

This study does not assess the short circuit or thermal loading impact of the proposed connection on facilities owned by other load and generation (including OPGI) customers.

In this study, short circuit adequacy is assessed only for Hydro One breakers and does not include other Hydro One facilities. The short circuit results are only for the purpose of assessing the capabilities of existing Hydro One breakers and identifying upgrades required to incorporate the proposed connection. These results should not be used in the design and engineering of new facilities for the proposed connection. The necessary data will be provided by Hydro One and discussed with the connection proponent upon request.

The ampacity ratings of Hydro One facilities are established based on assumptions used in Hydro One for power system planning studies. The actual ampacity ratings during operations may be determined in real-time and are based on actual system conditions, including ambient temperature, wind speed and facility loading, and may be higher or lower than those stated in this study.

The additional facilities or upgrades which are required to incorporate the proposed connection have been identified to the extent permitted by a preliminary assessment under the current IESO Connection Assessment and Approval process. Additional facility studies may be necessary to confirm constructability and the time required for construction. Further studies at more advanced stages of the project development may identify additional facilities that need to be provided or that require upgrading.

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SIA Findings

Summary

Canadian Niagara Power Inc. is proposing to establish a parallel operation of the IESO–controlled grid, Cornwall Electric, New York and Cedars systems. Canadian Niagara Power intends to accomplish this with phase shifter(s) between St. Lawrence and Rosemount that will limit the flow to 100 MW. Canadian Niagara Power is currently evaluating among three possible interconnection configurations: (1) single phase shifter in series with L5C interconnection, (2) single phase shifter in series with upgraded L5C interconnection and (3) double phase shifter interconnection.

This addendum examines the impact of the Ontario-Hydro Quebec HVdc interconnection on the Cornwall-Ontario interconnection. The Ontario-Hydro Quebec HVdc is presently under construction and planned to come in service at the beginning of 2009.

The IESO has completed all necessary studies based on the preliminary information provided by the proponent. The IESO will proceed with a Post System Impact Assessment at the discretion of the proponent once more project details become available.

Conclusions

The following conclusions are in addition to the conclusions made in the original SIA:

1. Under coincident high imports and high Ontario generation, Cornwall may not be able to import to Ontario due to existing loading concerns on the St. Lawrence x Hinchbrooke 230 kV corridor. Pre-contingency overloads are currently being addressed through various means.

2. Under non-coincident high imports and high Ontario generation, the St.Lawrence x Hinchbrooke 230 kV corridor may be overloaded post-contingency for the loss of L24A+L22H, L24A, L20H+L22H or L21H+L22H. Imports from Cornwall will further aggravate existing overloads. Existing overloads are currently being addressed by various means.

3. The angle range for the phase shifter(s) should be at least ±45º rather than ±40 º identified in the original SIA.

4. The loss of L33P+L34P will result in greater post-contingency loading on the Cornwall interconnection than the loss of the HVdc tie.

5. Under a single phase shifter in series with L5C interconnection, the loss of the HVdc interconnection will result in L5C becoming overloaded. As such, pre-contingency flow on L5C will have to be limited as follows, assuming a typical phase shifter impedance value:

Condition on HVdc lines	L5C Operating Range (MW)
High Import	$-100 < L5C_{flow} < 68.3$
High Export	$-59.2 < L5C_{flow} < 100$

6. The Cornwall-interconnection will be able to realize its full operating range with a L5C upgrade, or double phase shifter interconnection configuration.

IESO's Requirements

The following tentative requirements for connection are in addition to those made in the original SIA. These requirements may be modified should a Post System Impact Assessment be initiated.

1. The phase shifting transformer(s) must provide an operating range of ± 45º. This replaces the original requirement for an operating range of ± 40º.

2. Any overloads due to the Cornwall interconnection would need to be addressed and eliminated.

   A possible solution to eliminate overloads due to the interconnection would be to have a Special Protection Scheme that would reject the Cornwall interconnection for the loss of any St. Lawrence 230 kV circuits. In order to comply with IESO criteria, this special protection scheme will have to be fully redundant and with separate communication paths. The scheme will need to meet the 'Special Protection System Criteria', as detailed in the NPCC Document A-11. Any SPS will require concurrence from New York. Studies by NYISO will be required as well as an agreement from both Ontario and New York.

System Impact Assessment Report

1. Project Description

Canadian Niagara Power Inc. is proposing to establish a parallel operation of the IESO–controlled grid, Cornwall Electric, New York and Cedars systems. Canadian Niagara Power intends to accomplish this with phase shifter(s) between St. Lawrence and Rosemount that will limit the flow to 100 MW.

This purpose of this addendum is to examine the impact of the HVdc interconnection on the Cornwall-Ontario interconnection. The Ontario-Hydro Quebec HVdc is presently under construction and planned to come in service at the beginning of 2009. The connection consists of a double-circuit 230 kV line connecting the Ottawa Hawthorne Transformer Station and the Outaouais substation in Quebec. The maximum transfer capability to the IESO via this line is 1250 MW.

– End of Section –

2. System Description

A single-line diagram of the Cornwall interconnection and the Ontario-Hydro Quebec HVdc interconnection is shown in **Figure 1**. The three Cornwall interconnection configurations that were analyzed in the original SIA are shown in **Figures 2**, **3** and **4**.

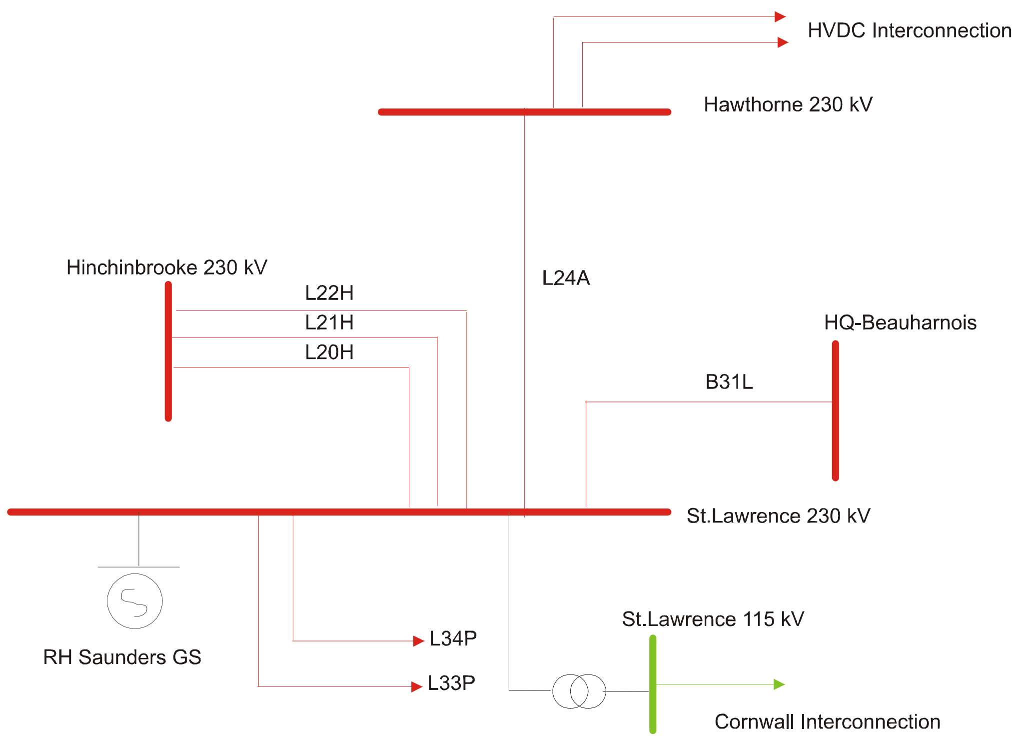

FIGURE 1: SINGLE LINE DIAGRAM OF CORNWALL AND HVdc INTERCONNECTIONS

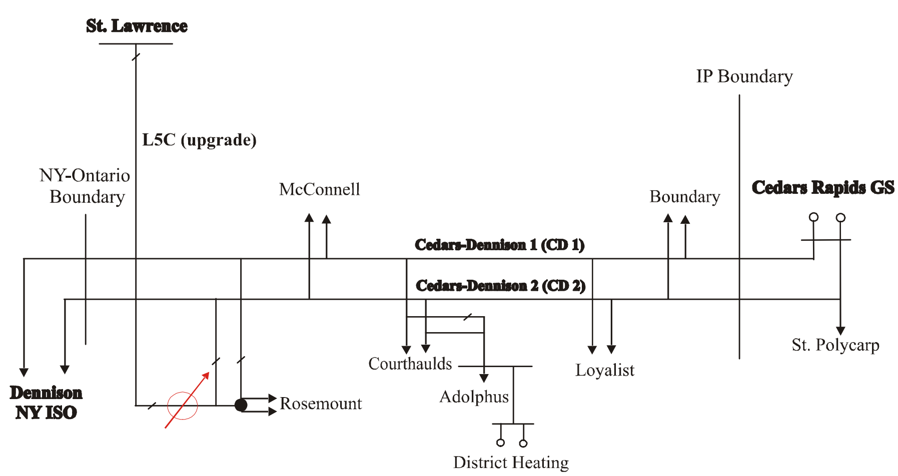

FIGURE 2: INTERCONNECTION WITH SINGLE PHASE SHIFTER

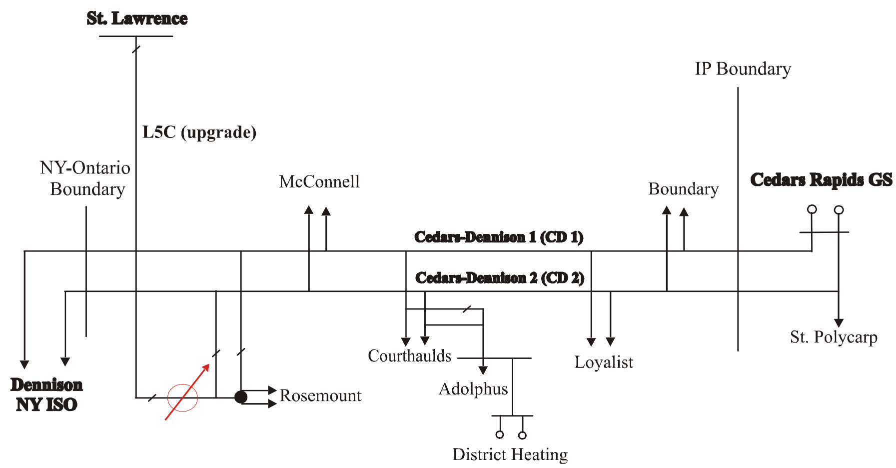

FIGURE 3: INTERCONNECTION WITH SINGLE PHASE SHIFTER AND L5C UPGRADE

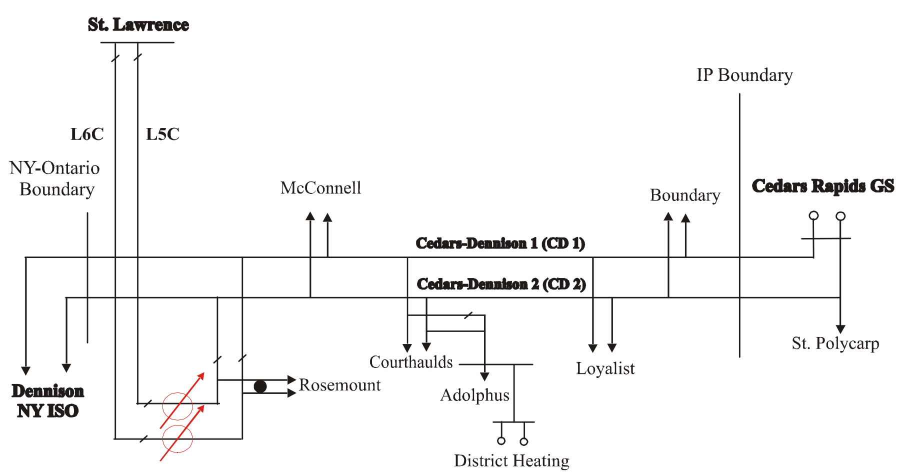

FIGURE 4: INTERCONNECTION WITH TWO CIRCUITS AND TWO PHASE SHIFTERS

3. System Impact Studies

The original SIA indicated that the operation of the Cornwall-Ontario interconnection may be limited by thermal concerns. As such, this addendum is limited to a thermal and phase shifter angle analysis.

3.1 Study Scenarios

Figure 5 shows generation duration curve representing the average hourly Saunders output for 2006. The generation duration curve shows the percentage of time at which the generator was greater than a certain value. It can be seen that about 43% of the time, Saunders is at an output of 800 MW or greater. **Figure 6** shows a historical hourly average plot of the flow on B31L at Beauharnois for 2006. Positive flow represents flow into Ontario.

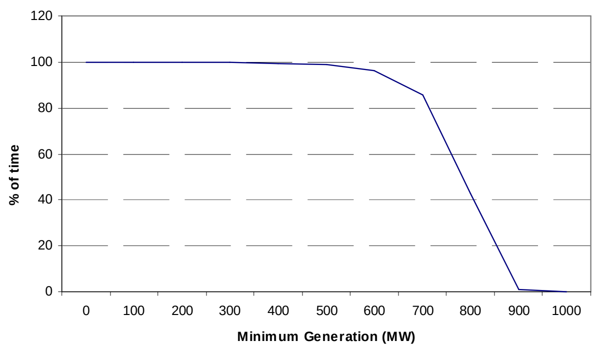

FIGURE 5: SAUNDERS GENERATION CURVE

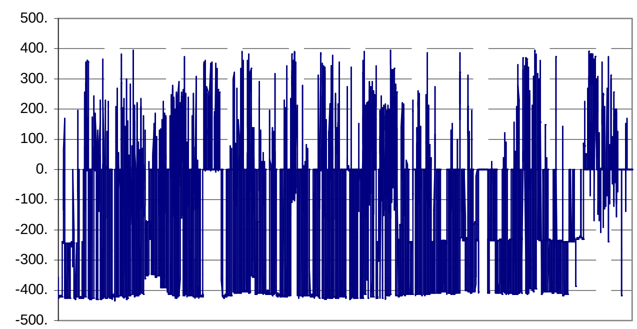

FIGURE 6: MW FLOW IN B31L @ BEAUHARNOIS

Based on the data from **Figures 5 and 6,** three scenarios, as shown in **Table 1**, were developed to understand the effect of the Ontario-Hydro Quebec HVdc interconnection on the Cornwall-Ontario interconnection:

Table 1: Study Scenarios

	HQ Beauharnois on B31L (MW)	Saunders (MW)	NY via St. Lawrence[1] (MW)	HVdc[1] (MW)
$S_{import1}$	0	800	400	1250
$S_{import2}$	400	800	400	1250
S_{export}	0	800	-400	-1250

Note: (1) positive value represents flow into Ontario

3.2 Thermal Analysis

3.2.1 St.Lawrence x Hinchinbrooke Corridor: Pre-Contingency Conditions

As identified in the “Ontario to Quebec 1250 MW HV dc Interconnection” Post-System Impact Assessment report (CAA ID 2000-001), under coincident high imports and high Ontario generation, the circuits along the St. Lawrence x Hinchinbrooke 230 kV corridor may be near overloading or overloaded during pre-contingency conditions. An additional 100 MW import from Cornwall will further aggravate the loading on these circuits. The pre-contingency loading on the St.Lawrence 230 kV circuits are shown in **Table 2**.

As shown in the values for scenario, $S_{import2}$, overloading conditions may result with an additional 100 MW import from Cornwall. Therefore, under coincident high imports and high Ontario generation, and depending on market dispatch conditions, Cornwall may not be able to import from Ontario due to thermal concerns.

Table 2: Pre-Contingency Loading on St. Lawrence 230 kV Circuits

Pre-Contingency Loading on St.Lawrence 230 kV Circuits						
Ckt	From	To	Cont. Rating (A)[1]	% of Continuous		
				$S_{import1}$	$S_{import2}$	S_{export}
L24A	RAISNJ24 220	HAWTHORN 220	1762.0	63.3	88.2	36.3
	ST LAWRE 220	RAISNJ24 220	1784.0	62.5	87.1	35.9
L20H	CROSBJ20 220	HINCHBRK 220	774.0	71.0	94.2	23.2
	ST LAWRE 220	EASTNJ20 220	774.0	85.3	108.8	11.2
	EASTNJ20 220	BROCKV20 220	904.0	12.2	12.4	10.4
	EASTNJ20 220	CROSBJ20 220	774.0	75.6	98.9	18.7
	CROSBJ20 220	CROSB T3 220	1401.0	3.1	3.2	2.8
L21H	CROSBJ21 220	HINCHBRK 220	874.0	61.5	82.1	21.7
	ST LAWRE 220	EAS YJ21 220	774.0	87.3	110.8	8.5
	EAS YJ21 220	SMITHL21 220	1206.0	9.5	9.9	8.3
	EAS YJ21 220	CROSBJ21 220	774.0	72.6	95.8	21.6
	CROSBJ21 220	CROSBY21 220	1401.0	2.0	2.0	1.8
L22H	EASTNJ22 220	BROCKV22 220	912.0	10.3	10.3	9.0
	RAISNR22 220	EAS YJ22 220	1017.0	62.9	79.4	5.5
	EAS YJ22 220	SMITHL22 220	1206.0	8.4	8.7	7.7
	EAS YJ22 220	EASTNJ22 220	1017.0	52.8	69.1	13.8
	EASTNJ22 220	HINCHBRK 220	1017.0	47.9	64.1	18.5
	ST LAWRE 220	RAISNR22 220	1176.0	54.4	68.7	3.2

Note: (1) Ratings at 35ºC ambient temperature and 5 km/h wind speed conditions.

Scenarios $S_{import1}$ and S_{export} are within continuous ratings pre-contingency. While the Saunders contribution for $S_{import1}$ is 800 MW (similar to $S_{import2}$) the loading on the St.Lawrence 230 kV circuits is less due to 0 MW contribution from B31L. The rest of the HVdc analysis was performed for scenarios $S_{import1}$ and S_{export}.

3.2.2 St.Lawrence x Hinchinbrooke Corridor: Post-Contingency Conditions

A post-contingency thermal analysis was performed for various contingencies on the St. Lawrence 230 kV interface as well as for the loss of the HVdc tie.

Table 3 summarizes the post-contingency loading, post-ULTC action, for contingencies which were found to result in overloads under a $S_{import1}$ scenario with the Cornwall interconnection in-service.

Table 3: Post-Contingency Loading on St. Lawrence 230 kV Circuits (Cornwall Interconnection I/S)

Post-Contingency Loading on St. Lawrence 230 kV Circuits (Cornwall Interconnection I/S)							
Ckt	From	To	15 min LTR[1]	% of 15 min LTR			
				L24A+L22H	L24A	L20H+L22H	L21H+L22H
L24A	RAISNJ24 220	HAWTHORN 220	2200	0.0	0.0	72.9	73.5
	ST LAWRE 220	RAISNJ24 220	2339	0.0	0.0	68.6	69.1
L20H	CROSBJ20 220	HINCHBRK 220	925	110.3	86.0	0.0	95.9
	ST LAWRE 220	EASTNJ20 220	925	128.6	97.7	0.0	113.5
	EASTNJ20 220	BROCKV20 220	1046	15.9	9.9	0.0	15.9
	EASTNJ20 220	CROSBJ20 220	925	114.0	89.7	0.0	99.6
	CROSBJ20 220	CROSB T3 220	1680	2.6	2.6	0.0	2.6
L21H	CROSBJ21 220	HINCHBRK 220	1046	94.4	75.0	81.3	0.0
	ST LAWRE 220	EAS YJ21 220	925	132.1	99.3	116.7	0.0
	EAS YJ21 220	SMITHL21 220	1416	15.7	8.0	15.2	0.0
	EAS YJ21 220	CROSBJ21 220	925	109.3	87.4	94.5	0.0
	CROSBJ21 220	CROSBY21 220	1680	1.6	1.6	1.6	0.0
L22H	EASTNJ22 220	BROCKV22 220	1055	0.0	8.2	0.0	0.0
	RAISNR22 220	EAS YJ22 220	1175	0.0	73.5	0.0	0.0
	EAS YJ22 220	SMITHL22 220	1416	0.0	7.0	0.0	0.0
	EAS YJ22 220	EASTNJ22 220	1175	0.0	65.0	0.0	0.0
	EASTNJ22 220	HINCHBRK 220	1175	0.0	60.8	0.0	0.0
	ST LAWRE 220	RAISNR22 220	1416	0.0	60.9	0.0	0.0

Note: (1) Ratings under 35ºC ambient temperature, 5 km/h wind speed and 75% pre-load conditions.

Table 4 summarizes the post-contingency loading with the Cornwall-Ontario interconnection out of service. As shown, overloads would still be present without the Cornwall-Ontario interconnection in service. It can also be seen that for the loss of L24A, L21H is not overloaded when the Cornwall interconnection is out of service, whereas when the Cornwall interconnection is in-service, L21H is loaded to 99% of its 15 minute rating under 2009 conditions.

Table 4: Post-Contingency Loading on St. Lawrence 230 kV Circuits (Cornwall Interconnection O/S)

Post-Contingency Loading on St.Lawrence 230 kV Circuits (Cornwall Interconnection O/S)							
Ckt	From	To	15 min LTR[1]	% of 15 min LTR			
				L24A+L22H	L24A	L20H+L22H	L21H+L22H
L24A	RAISNJ24 220	HAWTHORN 220	2200	0.0	0.0	66.3	66.8
	ST LAWRE 220	RAISNJ24 220	2339	0.0	0.0	62.3	62.9
L20H	CROSBJ20 220	HINCHBRK 220	925	100.9	78.5	0.0	88.4
	ST LAWRE 220	EASTNJ20 220	925	118.8	90.1	0.0	105.7
	EASTNJ20 220	BROCKV20 220	1046	15.7	10.2	0.0	15.5
	EASTNJ20 220	CROSBJ20 220	925	104.7	82.3	0.0	92.1
	CROSBJ20 220	CROSB T3 220	1680	2.6	2.6	0.0	2.6
L21H	CROSBJ21 220	HINCHBRK 220	1046	86.3	68.3	74.8	0.0
	ST LAWRE 220	EAS YJ21 220	925	122.2	91.8	108.9	0.0
	EAS YJ21 220	SMITHL21 220	1416	15.2	7.9	14.9	0.0
	EAS YJ21 220	CROSBJ21 220	925	100.1	79.9	87.1	0.0
	CROSBJ21 220	CROSBY21 220	1680	1.6	1.6	1.6	0.0
L22H	EASTNJ22 220	BROCKV22 220	1055	0.0	8.6	0.0	0.0
	RAISNR22 220	EAS YJ22 220	1175	0.0	68.0	0.0	0.0
	EAS YJ22 220	SMITHL22 220	1416	0.0	7.0	0.0	0.0
	EAS YJ22 220	EASTNJ22 220	1175	0.0	59.5	0.0	0.0
	EASTNJ22 220	HINCHBRK 220	1175	0.0	55.4	0.0	0.0
	ST LAWRE 220	RAISNR22 220	1416	0.0	56.4	0.0	0.0

Note: (1) Ratings under 35ºC ambient temperature, 5 km/h wind speed and 75% pre-load conditions.

The existing overloads are currently being addressed by various means. An additional 100 MW of imports from the Cornwall will further aggravate the existing overloads. It is required that any overloads due to the Cornwall interconnection would need to be addressed and eliminated. A possible solution to partially relieve the St. Lawrence circuit overloads would be to have a special protection scheme installed to arm the Cornwall interconnection to cross trip for the following contingencies listed in **Table 5**:

Table 5: Contingency Scope for Cornwall Interconnection Protection Scheme

Contingency Scope for Cornwall Interconnection Protection Scheme							
L20H	L21H	L22H	L20H+L21H	L21H+L22H	L20H+L22H	L24A	L24A+L22H

At most a cross-trip scheme would only relieve the overloading on the St. Lawrence 230 kV x Hinchinbrooke 230 kV corridor by the Cornwall interconnection's contribution; the corridor would likely still be overloaded post-interconnection rejection.

In order to comply with the IESO's criteria, this special protection scheme will have to be fully redundant and with separate communication paths. The scheme would need to be capable of meeting the 'Special Protection System Criteria,' as detailed in the NPCC Document A-11.

It should be noted that this scheme would require concurrence from New York. Studies by NYISO would be required as well as an agreement from both Ontario and New York.

Note: post-contingency thermal problems on the St. Lawrence 230 kV interface are not expected for the high export S_{export} study scenario.

3.2.3 Loss of HVdc

The following tables represent the change in active power on the Ontario-Cornwall interconnection for the loss of the HVdc and the loss of L33P+L34P for the various configurations.

Note: For the "Double Phase Shifter Interconnection" configuration, L6C and L5C were loaded to a pre-contingency loading of 50 MW each. The analysis assumes a typical phase shifter impedance (X=0.1 pu).

(1) Single phase shifter in series with L5C

As shown in **Table 6**, approximately 2.54% and 3.26% of the HVdc pre-contingency flow will appear on L5C for the loss of the HQ interconnection under high imports and high exports respectively.

Table 6: Loss of HVdc versus L33P+L34P for Single Phase Shifter in Series with L5C Configuration

	Pre-Contingency Flow on L5C (MW)	Post-Contingency Flow on L5C (MW)		L5C Flow Δ (MW)	
		Loss of HVdc	Loss of L33P+L34P	Loss of HVdc	Loss of L33P+L34P
$S_{import1}$	99.9	131.6	215.2	31.7	115.3
S_{export}	-100.2	-141.0	-226.1	40.8	125.9

Note: where positive flow is into the St. Lawrence 115 kV bus

Under a single phase shifter in series with L5C, the loss of the HVdc interconnection will result in L5C becoming overloaded. As a solution, under high HVdc import and export levels, the pre-contingency flow on L5C will have to be limited as follows:

Table 7: L5C Operating Range to Respect loss of HVdc Interconnection for Single Phase Shifter in Series with L5C Configuration

Condition on HVdc lines	L5C Operating Range (MW)
High Import	$-100 < L5C_{flow} < 68.3$
High Export	$-59.2 < L5C_{flow} < 100$

(2) Single phase shifter in series with L5C upgrade

As shown in **Table 8**, under a "single phase shifter in series with L5C upgrade configuration" the loss of L33P+L34P has a greater thermal impact than the loss of the HVdc. Therefore, the pre-contingency flow on Cornwall-Ontario interconnection would not need to be limited for the loss of the HVdc as the L5C upgrade would be capable of handling the loss of L33P+L34P.

Table 8: Loss of HVdc versus L33P+L34P for Single Phase Shifter in Series with L5C Upgrade Configuration

	Pre-Contingency Flow on L5C (MW)	Post-Contingency Flow on L5C (MW)		L5C Flow Δ (MW)	
		Loss of HVdc	Loss of L33P+L34P	Loss of HVdc	Loss of L33P+L34P
$S_{import1}$	100.0	131.9	216.2	31.9	116.2
S_{export}	-100.0	-141.0	-226.2	41.0	126.2

Note: where positive flow is into the St. Lawrence 115 kV bus

(3) Two Phase Shifter Two Line Interconnection

As shown in **Table 9**, under a "two phase shifter two line interconnection" the loss of L33P+L34P has a greater thermal impact than the loss of the HVdc. Therefore, the pre-contingency flow on Cornwall-Ontario interconnection would not need to be limited for the loss of the HVdc as the two line interconnection would be capable of handling the loss of L33P+L34P.

Table 9: Loss of HVdc versus L33P+L34P for Two Phase Shifter Two Line Interconnection Configuration

		Pre-Contingency Flow (MW)	Post-Contingency Flow (MW)		Flow Δ (MW)	
			Loss of HVdc	Loss of L33P+L34P	Loss of HVdc	Loss of L33P+L34P
$S_{import1}$	L5C	50.0	74.2	129.2	24.2	79.2
	L6C	50.0	74.3	129.3	24.2	79.3
S_{export}	L5C	-51.0	-79.9	-132.0	28.9	81.0
	L6C	-51.0	-79.9	-131.9	28.9	80.9

Note: where positive flow is into the St. Lawrence 115 kV bus

3.3 Phase Shifter Angle Adequacy

The flow on Cornwall was varied between ± 100 MW for the $S_{import1}$ and S_{export} scenarios under the three phase shifter configurations to determine whether the requirements on the phase shifter operating angle would need to be changed. The original SIA indicated a phase shifter angle range requirement of at least ± 40º.

(1) Single phase shifter in series with L5C

Table 10: Angle Variations for Single Phase Shifter in series with L5C

Scenario	L5C Phase Shifter Conditions	
	Flow on L5C	Angle
$S_{import1}$	+100 MW	29.1º
	-100 MW	-8.6 º
S_{export}	+100 MW	44.7 º
	-100 MW	6.9 º

Note: (1) positive value represents flow into Ontario

(2) Single phase shifter in series with L5C Upgrade

Table 11: Angle Variations for Single Phase Shifter in series with L5C Upgrade

Scenario	L5C Phase Shifter Conditions	
	Flow on L5C	Angle
$S_{import1}$	+100 MW	29.1 º
	-100 MW	-8.6 º
S_{export}	+100 MW	44.6 º
	-100 MW	7.0 º

Note: (1) positive value represents flow into Ontario

(3) Two Phase Shifter Two Line Interconnection

Table 12: Angle Variations for Two Line Interconnection

	L5C Phase Shifter Conditions		L6C Phase Shifter Conditions	
	Flow on L5C	Angle	Flow on L6C	Angle
$S_{import1}$	0 MW	20.4º	+100 MW	29.2 º
	+100 MW	29.2 º	0 MW	20.4 º
	0 MW	-0.5 º	-100 MW	-7.9 º
	-100 MW	-7.9 º	0 MW	-0.5 º
S_{export}	0 MW	34.3 º	+100 MW	44.8 º
	+100 MW	44.8 º	0 MW	34.3 º
	0 MW	14.6 º	-100 MW	7.2 º
	-100 MW	7.2 º	0 MW	14.6 º

As shown in the phase shifter adequacy analysis for configurations (1), (2) and (3), a phase angle range of ± 40º may not be enough to handle an import from Cornwall to Ontario during high Ontario export with the HVdc. It is recommended that the angle range for the single phase shifter(s) be at least ±45º.