Q. Please provide the minimum Effective Short Circuit Capacity ("ESCC") at Soldiers Pond at which the LIL will be expected to deliver:

- Maximum power
- 50% of maximum power
- Minimum power

In the response state whether the appropriate ESCC will always be available for the required operating conditions.

A. The Short Circuit Level (SCL) is a measure of electrical current that can be delivered into a solid three phase fault at a specific point in an ac transmission network. As such, the SCL is a good indicator of ac system strength. Table 1 outlines the SCLs that have been calculated for determining equipment and performance ratings of the HVdc scheme.

Table 1: Soldiers Pond Short Circuit Levels (3Φ MVA)

System Configuration	SCL Results Purpose	SCL (3Φ MVA)
Maximum Foreseeable	Equipment Rating	4208
Maximum	Performance	4208
Minimum	Performance	3462
Extreme Minimum	Equipment Rating	2849

Typically when considering the location of an HVdc infeed, the Short Circuit Ratio (SCR) is calculated to determine the strength of the ac network as a ratio of the SCL and the power rating of the HVdc scheme. CIGRE TB-68[1] defines three categories of ac/dc systems; a high SCR, low SCR and very low SCR. A strong ac network connection with a high SCR is considered having an SCR >3, whereas systems with

[1]CIGRE Technical Brochure 68 - Guide for Planning DC Links Terminating at ac Systems Locations Having Low Short- Circuit Capacities – Part I: AC/DC Interaction Phenomena, June 1992

low SCR are those with SCR between 2 and 3. Very low or weak ac/dc system interconnections have an SCR <2.0. The SCR gives an indication of the impact the transmitted power will have on the converter bus voltage. As the SCR is used in the early design phase of an HVdc system and does not take into account the impact of the shunt harmonic filter banks, the Effective Short Circuit Ratio (ESCR) is typically used in detailed design following filter design.

The SCR is defined as:

$$SCR = SCL/P_{dc}$$

Table 2 outlines the SCR for each SCL defined in Table 1 using a P_{dc} of 900 MW.

Table 2: Soldiers Pond Short Circuit Ratio

System Configuration	SCL Results Purpose	SCL (3Φ MVA)	SCR
Maximum Foreseeable	Equipment Rating	4208	4.68
Maximum	HVdc Performance	4208	4.68
Minimum	HVdc Performance	3462	3.85
Extreme Minimum	Equipment Rating	2849	3.17

In addition to the SCR, the Effective Short Circuit Ratio (ESCR) is used to determine the impact of the shunt harmonic filter banks installed at the local converter bus and subsequent interactions between the dc and ac systems. As the voltage at the converter ac bus changes, the reactive power provided by the filter banks change by the square of the voltage change. The ESCR is calculated by subtracting the MVAR rating of the harmonic filters online at nominal voltage for a particular power order on the HVdc. The Effective Short Circuit Ratio (ESCR) is defined as:

$$ESCR = (SCL-Q_f)/P_{dc}$$

The LIL HVdc scheme has been designed to meet performance specifications (rated power) down to the *"Minimum Fault Level"* which has been determined as 3462 3Φ MVA at the Soldiers Pond (SOP) 230 kVac bus. For the purposes of the HVdc contract (CD0501), the control system will be tested for reduced short circuit levels down to an ESCR of 2.5[2] at the inverter.

The minimum three phase fault level at SOP was calculated using the following assumptions:

- All NLH thermal generation (diesel and combustion turbine) offline;
- NLH hydro units at minimum dispatch;
- All customer hydro generation online;
- All NUGs in service;
- Two SOP synchronous condensers (SC) in service;
- Holyrood G3 in service as SC, G1 and G2 are out of service;
- Holyrood CT in service as SC;
- Stephenville G1 in service as SC;
- Hardwoods G1 in service as SC;
- Granite Canal G1 in service;
- Upper Salmon G1 in service;
- Bay d'Espoir G3 and G7 online;
- Cat Arm G2 out of service;
- Hinds Lake G1 out of service; and
- Maritime Link offline.

[2] Supply and Install Converters and Transition Compounds – Performance Requirements, Section 7.3, bullet k, doc# ILK-SN-CD-8000-EL-DC-0001-01

General Electric (GE) Grid[3] has determined that the ac harmonic filter design at SOP shall involve the switching of five 230 kV 75 MVAR shunt filter banks to absorb harmonics generated by the converter station switching dynamics and provide reactive power support for the converter and connected ac system. A spare filter bank will be installed at the Soldiers Pond Converter Station (SOPCS), for a total of six filters to allow operation of the LIL with one filter bank out of service.

The SOPCS will have a total of three 75 MVAR 3/12/23 triple tuned filters considered as "Type A" and three 75 MVAR 11/24/36 triple tuned filters considered as "Type B". Table 3 outlines the proposed filter switching strategy for the SOPCS under nominal dc voltage operation in balanced bipole configuration. It should be noted that all power orders are referenced at the rectifier dc terminals (MFACS).

Table 3: Filter Switching Strategy - Nominal DC Voltage – Normal Bipole Operation

Number of AC Filter Banks Online (75 MVAR)	LIL Power Order (MW) @ MFACS	
	Switch-In	Switch-Out
2	Scheme De-Block	Scheme De-Block
3	324	279
4	549	504
5	765	720

Given the switching points as defined in Table 3, the Effective Short Circuit Ratio (ESCR) is calculated in Table 4 and Table 5.

[3] Formerly Alstom Grid.

Table 4: SOP ESCR for Bipole Operation – Filter Switch-In – Minimum SCL

HVdc Power Order (MW)	Harmonic Filters Online	ESCR
0	2	N/A
90	2	36.80
314	2	10.55
315	3	10.28
584	3	5.54
585	4	5.41
764	4	4.14
765	5	4.04
900	5	3.43

Table 5: SOP ESCR for Bipole Operation – Filter Switch-Out – Minimum SCL

HVdc Power Order (MW)	Harmonic Filters Online	ESCR
900	5	3.43
721	5	4.28
720	4	4.39
505	4	6.26
504	3	6.42
280	3	11.56
279	2	11.87
90	2	36.80
0	0	N/A

The Effective Short Circuit Ratio (ESCR) for all key operating points from HVdc scheme de-block to rated power are well above 3 which indicates a strong ac/dc interconnection with the Island Interconnected System.

If the same calculations are completed for the *"extreme minimum"* SCL of 2849 3Φ MVA using the switching points in Table 3, we have the resultant ESCRs shown in Table 6 and Table 7.

The extreme minimum 3Φ SCL at SOP was calculated using the following assumptions:

- All NLH thermal generation (diesel and combustion turbine) off;
- NLH hydro units at minimum dispatch;
- All customer hydro generation on;
- All NUGs in service;
- One Soldiers Pond synchronous condenser in service;
- Holyrood G3 in service, G1 and G2 are out of service;
- Holyrood CT in service;
- Hardwoods G1 in service;
- Granite Canal G1 in service;
- Upper Salmon G1 in service;
- Bay d'Espoir G3 and G7 online;
- Cat Arm G2 out of service;
- Hinds Lake G1 out of service; and
- Maritime Link offline.

Table 6: SOP ESCR for Bipole Operation – Filter Switch-In – Extreme Minimum SCL

HVdc Power Order (MW)	Harmonic Filters Online	ESCR
0	2	N/A
90	2	29.99
314	2	8.60
315	3	8.33
584	3	4.49
585	4	4.36
764	4	3.34
765	5	3.23
825	5	3.00
900	5	2.75

Table 7: SOP ESCR for Bipole Operation – Filter Switch-Out – Extreme Minimum SCL

HVdc Power Order (MW)	Harmonic Filters Online	ESCR
900	5	2.75
825	5	3.00
721	5	3.43
720	4	3.54
505	4	5.05
504	3	5.21
280	3	9.37
279	2	9.67
90	2	29.99
0	0	N/A

The Effective Short Circuit Ratio (ESCR) for key operating points from 825 MW to scheme blocking are (above) 3, indicating a strong ac/dc interconnection with the Island Interconnected System. However, it should be noted that operating the LIL at a power order exceeding 825 MW will result in an ESCR less than 3. Operation at SCLs and ESCRs below the minimum fault level (HVdc performance) may result in the reduction of maximum dc power transmission over the HVdc link. The

equipment, however, will be rated for the electrical stresses at SCLs down to the extreme minimum fault level.