NORTHERN EXPORT AND CEDARS IMPORT STABILITY LIMITS ANALYSIS (NX-19)

A report by the
New York Independent System Operator

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Executive Summary

This study was conducted to define two new NYISO administered interfaces that would replace local stability limits imposed by NYPA (New York Power Authority) for major equipment outages. The study proposes an interface definition that would capture the power flows heading out of Zone D on all lines except for the MSU1. A second interface, called Cedars Import, is required to account for the effects of importing power from Hydro Quebec via Cedars.

The stability transfer limit study was conducted in accordance with the stability criteria indicated in NPCC Regional Reliability Reference Directory # 1 Design and Operation of the Bulk Power System and the NYSRC Reliability Rules for Planning and Operating the New York State Power System, Section C.1-R3. The stability transfer limits were determined using the methodology cited in the NYISO Transmission Expansion and Interconnection Manual Attachment H, NYISO Transmission Planning Guideline Section 2.1. The limits recommended in this report are all based on stable system response prior to observed system instability.

The stability transfer cases were developed using the 2018 NYISO Operations summer dynamics package and nineteen (19) contingencies were applied to each dynamics case to evaluate system stability. For the system configurations where the Moses plant generation rejection scheme is available, limits are provided with and without the arming of the generation rejection remedial action scheme (RAS) at the Moses plant. Generator machine angles and bus voltages were monitored to assess system dynamic response.

It is recommended that the Northern Export stability transfer limits be implemented as reported in Tables 1A- 4A. These limits are anticipated to have minimal impact on NYISO operations.

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Summary of Proposed Limits

The proposed limit revisions and the magnitude of the changes are presented in the following tables:

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MSU1 O/S, 7040 O/S, HVDC O/S, L33/L34@ 0 MW ,PV-20 @ 100 MW	NX Limit	Cedars Limit
One 765 KV Path out of service		
MSU1&7040&HVDC O/S	1250	100
MSU1&7040&HVDC & R8105 O/S	1050	100
MSU1&7040&HVDC & PV-20 O/S	850	100
One 765 KV Path & One 230 kV circuit on one 230 kV path out of service		
MSU1&7040&HVDC & (L33 or L34) O/S	1100	100
MSU1&7040&HVDC & R8105 & (L33 or L34) O/S	1100	100
MSU1&7040&HVDC & PV-20 & (L33 or L34) O/S	850	100
MSU1&7040&HVDC & (MAP1 or MAP2) O/S	850	100
MSU1&7040&HVDC & R8105 & (MAP1 or MAP2) O/S	750	100
MSU1&7040&HVDC & PV-20 & (MAP1 or MAP2) O/S	600	100
One 765 KV Path & One 230 kV circuit on each 230 kV path out of service		
MSU1&7040&HVDC & (L33 or L34) & (MAP1 or MAP2) O/S	850	100
MSU1&7040&HVDC & R8105 & (L33 or L34) & (MAP1 or MAP2) O/S	800	100
MSU1&7040&HVDC & PV-20 & (L33 or L34) & (MAP1 or MAP2) O/S	600	100
One 765 KV Path & One entire 230 kV path out of service with 7 unit rejection		
MSU1&7040&HVDC & L33 & L34 O/S w/ 6 unit rej.	600	10
MSU1&7040&HVDC & R8105 & L33 & L34 O/S w/ 6 unit rej.	500	10
MSU1&7040&HVDC & PV-20 & L33 & L34 O/S w/ 6 unit rej.	400	10
MSU1&7040&HVDC & MAP1 & MAP2 O/S w/ 6 unit rej.	500	10
MSU1&7040&HVDC & R8105 & MAP1 & MAP2 O/S w/ 6 unit rej.	300	10
MSU1&7040&HVDC & PV-20 & MAP1 & MAP2 w/ 6 unit rej.	200	10
One 765 KV Path & One entire 230 kV path with another 230 kV circuit O/S with 7 unit rejection		
MSU1&7040&HVDC & L33 & L34 & (MAP1 or MAP2) O/S w/ 6 unit rej.	350	10
MSU1&7040&HVDC & MAP1 & MAP2 & (L33 or L34) O/S w/ 6 unit rej.	450	10
MSU1&7040&HVDC & L33 & L34 & (MAP1 or MAP2) & PV-20 O/S w/ 6 unit rej.	200	10
MSU1&7040&HVDC & MAP1 & MAP2 & (L33 or L34) & R8105 O/S w/ 6 unit rej.	300	10
One 765 KV Path & One entire 230 kV path out of service		
MSU1&7040&HVDC & L33 & L34 O/S	450	10
MSU1&7040&HVDC & R8105 & L33 & L34 O/S	250	10
MSU1&7040&HVDC & PV-20 & L33 & L34 O/S	150	10
MSU1&7040&HVDC & MAP1 & MAP2 O/S	400	10
MSU1&7040&HVDC & R8105 & MAP1 & MAP2 O/S	200	10

MSU1&7040&HVDC & PV-20 & MAP1 & MAP2 O/S	100	10
One 765 KV Path & One entire 230 kV path w/ another 230 kV circuit O/S		
MSU1&7040&HVDC & L33 & L34 & (MAP1 or MAP2) O/S	100	10
MSU1&7040&HVDC & MAP1 & MAP2 & (L33 or L34) O/S	350	10
MSU1&7040&HVDC & L33 & L34 & (MAP1 or MAP2) & PV-20 O/S(Generation Rejection Recommended)	0	10
MSU1&7040&HVDC & MAP1 & MAP2 & (L33 or L34) & R8105 O/S	150	10

Table 2A: Northern Export Stability Limits for L33 & L34 O/S		
MSU1 I/S, 7040 I/S, HVDC I/S, 7040 I/S,PV-20 @ 100 MW	NX Limit	Cedars Limit
One 230 kV Path out of service		
L33&L34 O/S	1000	10
L33&L34 & R8105 O/S	750	10
L33&L34 & PV-20 O/S	650	10
One 230 kV Path & One 230 kV circuit path out of service		
L33&L34 & (MAP1 or MAP2) O/S	750	150
L33&L34 & R8105 & (MAP1 or MAP2) O/S	650	100
L33&L34 & PV-20 & (MAP1 or MAP2) O/S	450	100
One 230 kV Path & One 230 kV circuit on each 230 kV remaining path out of service		
L33&L34 & (MAP1 or MAP2) & (MMS1 or MMS2) O/S	450	10
L33&L34 & R8105 & (MAP1 or MAP2) & (MMS1 or MMS2) O/S	300	10
L33&L34 & PV-20 & (MAP1 or MAP2) & (MMS1 or MMS2) O/S	250	10
Two 230 kV paths out of service		
L33&L34 & MAP1 & MAP2 O/S	250	10
L33&L34 & MAP1 & MAP2 & R8105 O/S	150	10
L33&L34 & MAP1 & MAP2 & PV-20	0	10

Table 3A: Northern Export Stability Limits for MAP1 & MAP2 O/S		
MSU1 I/S, 7040 I/S, HVDC I/S,L33/L34 @ 0 MW, PV-20 @ 100 MW	NX Limit	Cedars Limit
One Path out of service		
MAP1&MAP2 O/S	1250	150
MAP1&MAP2 & R8105 O/S	1200	100
MAP1&MAP2 & PV-20 O/S	900	150
One Path & One 230 kV circuit path out of service		
MAP1&MAP2 & (L33 or L34) O/S	900	150
MAP1&MAP2 & R8105 & (L33 or L34) O/S	1050	100
MAP1&MAP2 & PV-20 & (L33 or L34) O/S	750	100
One Path & One 230 kV circuit on each 230 kV remaining path out of service		
MAP1&MAP2 & (L33 or L34) & (MMS1 or MMS2) O/S	850	150
MAP1&MAP2 & R8105 & (L33 or L34) & (MMS1 or MMS2) O/S	850	100
MAP1&MAP2 & PV20 & (L33 or L34) & (MMS1 or MMS2) O/S	750	100

Table 4A: Northern Export Stability Limits for MMS1 & MMS2 O/S		
MSU1 I/S, 7040 I/S, HVDC O/S, L33/L34@ 0 MW ,PV-20 @ 100 MW	NX Limit	Cedars Limit
One Path out of service		
MMS1&MMS2 O/S	850	100
MMS1&MMS2 & R8105 O/S	650	100
MMS1&MMS2 & PV-20 O/S	550	100
One Path & One 230 kV circuit path out of service		
MMS1&MMS2 & (L33 or L34) O/S	850	100
MMS1&MMS2 & R8105 & (L33 or L34) O/S	650	100
MMS1&MMS2 & PV-20 & (L33 or L34) O/S	550	100
MMS1&MMS2 & (MAP1 or MAP2) O/S	700	100
MMS1&MMS2 & R8105 & (MAP1 or MAP2) O/S	650	100
MMS1&MMS2 & PV20 & (MAP1 or MAP2) O/S	550	100
One Path & One 230 kV circuit on each 230 kV remaining path out of service		
MMS1&MMS2 & (L33 or L34) & (MAP1 or MAP2) O/S	800	100
MMS1&MMS2 & R8105 & (L33 or L34) & (MAP1 or MAP2) O/S	700	100
MMS1&MMS2 & PV-20 & (L33 or L34) & (MAP1 or MAP2) O/S	400	100

Introduction

This study was conducted to define two new NYISO administered interfaces that would replace local stability limits imposed by NYPA for major equipment outages. The study evaluated the MSU1-7040-HVDC out-of-service condition as well as significant North Country (Zone D) line outage scenarios listed in Section 8.1.

Northern Export limits were determined employing resources under NYISO control, i.e. generation located in the North Country. The Cedars Import limits, i.e. limits on the permissible transfers through the North Country from external sources were determined at the highest Northern Export limit transfer for the applicable network configuration.

This study proposes the definition of the Northern Export and Cedars import interfaces and the associated stability transfer limits for all cases listed as per Tables 1A-4A.

System Operating Limit (SOL) Methodology

The NYSRC Reliability Rules for Planning and Operating the New York State Power System provide the documented methodology employed to develop System Operating Limits (SOLs) within the NYISO Reliability Coordinator Area. NYSRC Reliability Rules require compliance with all North American Electric Reliability Corporation (NERC) Standards and Northeast Power Coordinating Council (NPCC) Standards and Criteria. Rule C.1 addresses the contingencies to be evaluated and the performance requirements to be applied. Rule C.1 also references the "Guideline for Stability Analysis and Determination of Stability-Based Transfer Limits" found in the NYISO "Transmission Expansion and Interconnection Manual" Attachment H.

Interface Summary

Northern Export Interface:

The Northern Export limit is defined as the maximum transfer permissible across the Northern Export interface sourced from generation within the North Country. This limit is determined with zero imports modeled from external areas. Table5A compares the difference between the new proposed Northern Export interface and the current Moses South interface. Figure 1 gives a graphical representation of the same.

Mathematically, the Northern Export definition is as follows:

Northern Export= (Moses South Flows + MMS1 + MMS2 + L33P + L34P + PV20) – MSU1 flows.

Northern Export			**Moses South**		
Name	Line ID	Voltage (kV)	Name	Line ID	Voltage (kV)
			*Massena-Marcy	MSU1	765
*Moses-Adirondack	MA1	230	*Moses-Adirondack	MA1	230
*Moses-Adirondack	MA2	230	*Moses-Adirondack	MA2	230
*Dennison-Norfolk	4	115	*Dennison-Norfolk	4	115
*Dennison-Sandstone	5	115	*Dennison-Sandstone	5	115
*Alcoa-N. Ogdensburg	13	115	*Alcoa-N. Ogdensburg	13	115
Parishville-Colton*	3	115	Parishville-Colton*	3	115
*Moses- St. Lawrence	L33P	230			
*Moses- St. Lawrence	L34P	230			
*Plattsburgh-Sand Bar	PV-20	115			
*Moses-Massena	MMS1	230			
*Moses-Massena	MMS2	230			

*Indicates line metering location

Table 5A: Comparison between the proposed Northern Export interface definition and the current Moses South interface definition

Cedars Import Interface:

The Cedars import limit is defined as the maximum transfer permissible without degrading the Northern Export Limit transfers. Table 5B lists the tie lines that would comprise of the Cedars Import interface. Figure 1 gives a graphical representation of the same.

Cedars Import		
Name	Line ID	Voltage (kV)
Rosemont- Dennison*	1	115
Rosemont- Dennison*	2	115

Table 5B: Definition of proposed Cedars Import interface

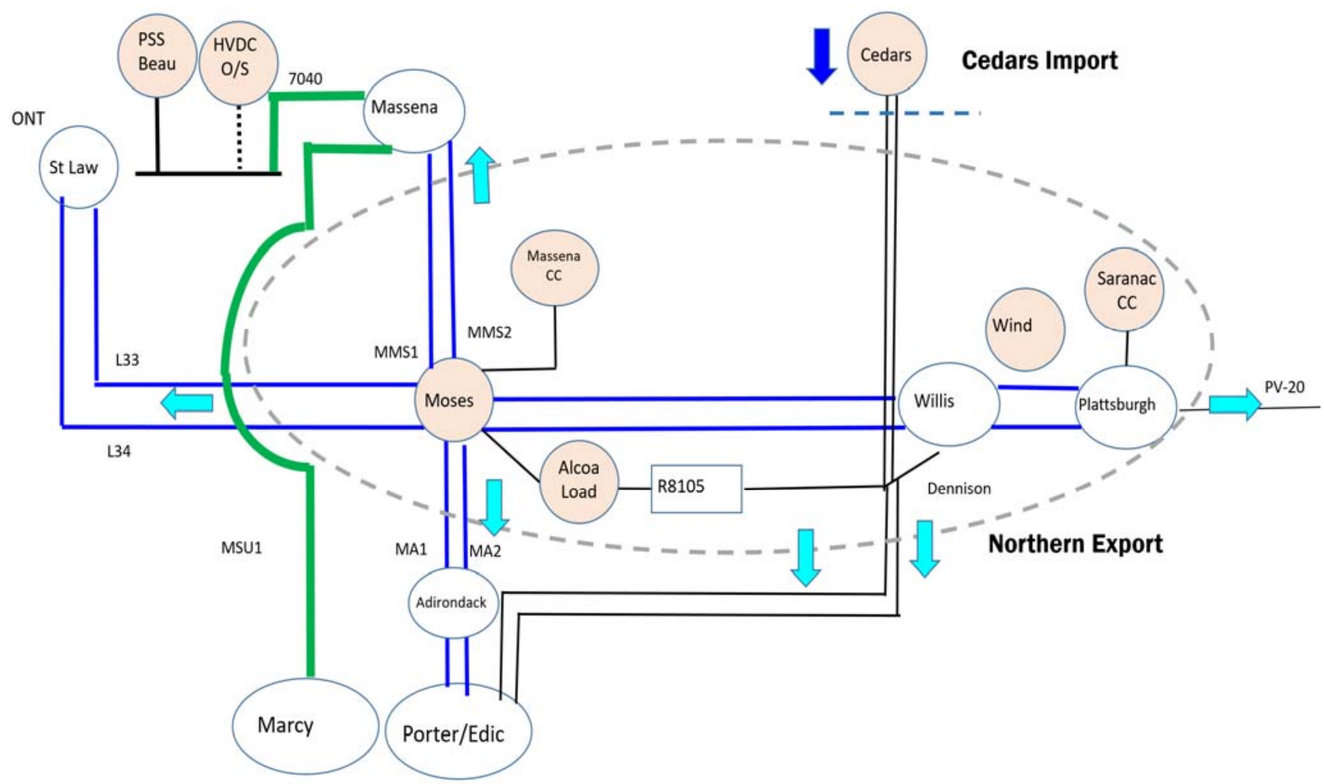

Figure 1. Northern Export Interface Definition

System Representation and Transfer Case Development

The analysis was based on the 2018 NYISO Operations dynamics base case. This case was developed from the 2018 MMWG dynamics base case with the NYISO representation updated to the representation of the NYISO 2018 Summer Operating Study.

The Moses-St. Lawrence PARs (Phase Angle Regulators) connecting the NYCA with IESO were set to control 0 MW flow. The PV20 PAR connecting NYCA with ISO-NE was set to control 100 MW flowing from NY to VT, which is the typical operating condition.

Northern Export power transfers were developed using generation shifts from North Country (Zone D) to Central NY (Zone C). Cedars Import power transfers were developed using generation shifts between North Country (Zone D) and Cedars to Central NY (Zone C).

The sensitivity of Northern Export limits was examined under variations of Central East flow and Marcy South Series Compensation (MSSC) configuration.

Generation output of the Moses units and North Country wind generation were set to their maximum possible output depending on the transfer levels across Northern Export. Outputs of the Moses units and North Country wind farms were adjusted for changes in Northern Export transfer levels. In most cases, the Saranac combined cycle generation was modeled to be offline. In cases with higher transfer levels (>1300 MW) across Northern Export, the Saranac combined cycles units were modeled in-service.

In contingencies where Moses generation rejection is available, scenarios were tested with and without the Moses generation rejection scheme armed.

The Northern Export stability limits are defined as the highest tested transfer levels reduced by a 100 MW safety margin. Similarly, the Cedars Import stability limits are defined as the highest tested transfer levels reduced by margins of 50 MW, 25 MW and 15 MW for scenarios having the tested transfer levels as 200 MW, 125 MW and 25 MW respectively.

Tested Contingencies

Nineteen (19) contingencies were tested for each developed Northern Export transfer case scenario. Table 6 provides the identification and description of these contingencies.

Table 6.
Contingencies Applied for Evaluating Northern Export Stability Transfer Limits

#	ID	Description
1	MS01	3PH-NC@MARCY 765/MASSENA-MARCY MSU-1 W/REJ
2	MS02	3PH-NC@MOSES 230kV/MOSES-ADIR W/NO REJ.
3	MS03MOD	LLG@MOSES 230kV ON MOSES-ADIRONDACK 1&2
4	MS04	3PH-NC@MOSES 230/MASSENA-MOSES 765/230 MMS-1
5	MS05	3PH-NC@MASSENA 765/MASSENA-MOSES 765/230 MMS-1
6	MS06	SLG-STK@MOSES/MASSENA-MOSES MMS-2 W/NO REJ
7	MS07	SLG-STK@MASSENA765/MASSENA-MOSES 765/230 MMS-1
8	MS08MOD	SLG-STK@MOSES /MOSES-ADIRONDACK 230 W/NO REJ
9	MS09	3PH-NC@MASSENA 765/MASSENA-MARCY MSU-1 W/REJ
10	MS10MOD	SLG-STK@MOSES /MOSES-WILLIS 230
11	MS13	LLG@MOSES /MOSES-MASSENA 230
12	MS150	LLG@MOSES 230/MOSES-ST.LAWRENCE L33/34P
13	CE03	SLG/STK@EDIC345kV EDIC-N.SCOT #14/BKUP CLR@FITZ 345
14	CE07AR	LLG @MARCY/EDIC ON MARCY-COOPER & EDIC-FRASER DBL CKT
15	CE15	SLG/STK@MARCY345/VOLNEY-MARCY VU-19/STK@MARCY 345
16	CE23	LLG@FRASER ON MARCY-COOPERS/EDIC-FRASER D/C
17	CE23AR	LLG@FRASER ON MARCY-COOPERS/EDIC-FRASER D/C w/ AR
18	CE99	SLG/STK@SCRIBA345/SCRIBA-VOLNEY 21/FITZ-SCRIBA #10
19*	MS150(3Ph)	3PH@MOSES230 – L/O MOSES-ST.LAWRENCE L33/34P DCT W/NO REJ

The standard contingency MS150 is a line to line to ground fault modeled on the L33/L34 circuits with an appropriate fault impedance. For the scenario where one of the L33/L34 circuits is out-of-service, MS150 is adjusted to employ a three phase fault on the single remaining circuit.

The fault impedances for the traditional Moses South contingencies were developed for an all-lines-in-service configuration where the major fault current contributions would come from Moses generation, the 230kV L33/L34 ties to IESO, the 765kV ties to the rest of the NYISO system via Massena and the 230kV ties to the NYISO system via Adirondack. Fault impedances calculated for an all lines in-service condition are extremely conservative when applied in a system configuration where the sources of fault current are significantly reduced. Modified fault impedances, reflecting the MSU1 outage condition, were developed by NYPA for MS03, MS08, MS10 and MS150 contingencies for configurations where MSU1 is modeled out of service. The typical Moses South fault impedances were employed when MSU1 was in service.

Monitored Elements

In order to assess system stability response for the Northern Export transfer scenarios, generator angles and system voltages were monitored and analyzed. The recommended limits in this report are all based on stable system response at the highest tested transfer level, prior to observed instability.

Discussion

Background:

Northern Export limits are required to be established for North Country element outages. With regard to Northern Export, there are four major corridors linking the NYISO generation pocket north of Moses to the rest of the Eastern interconnection as shown in Figure 2 below. The base outage conditions evaluated were independent outages of MSU1, MMS1/2, MAP1/2 and L33/L34. Each of these corridors are susceptible to loss through a NYSRC criteria contingency. In the event of a corridor being out-of- service due to maintenance or forced outage, the contingency loss of a second corridor could, depending on the transfer level, result in instability within the North Country.

Cedars import limits are required to be established for North Country element outages. Units sourcing Cedars Imports are more electrically radial from the Eastern interconnection than the generating resources within Zone D. Under the system condition with all lines in service, Cedars Imports are not a stability concern since Zone D is solidly tied to the Eastern Interconnection. As maintenance and/or forced outages reduce the strength with which Zone D is tied into the Eastern Interconnection, the Cedars Import sources become susceptible to classical instability effects of a generation source interconnected to a large system through a radial high impedance path.

Outages which will trigger Northern Export Limits include:

- MSU1 out-of-service
- MMS1 & MMS2 out-of-service
- L33 & L34 out-of-service
- MAP1 & MAP2 out-of-service

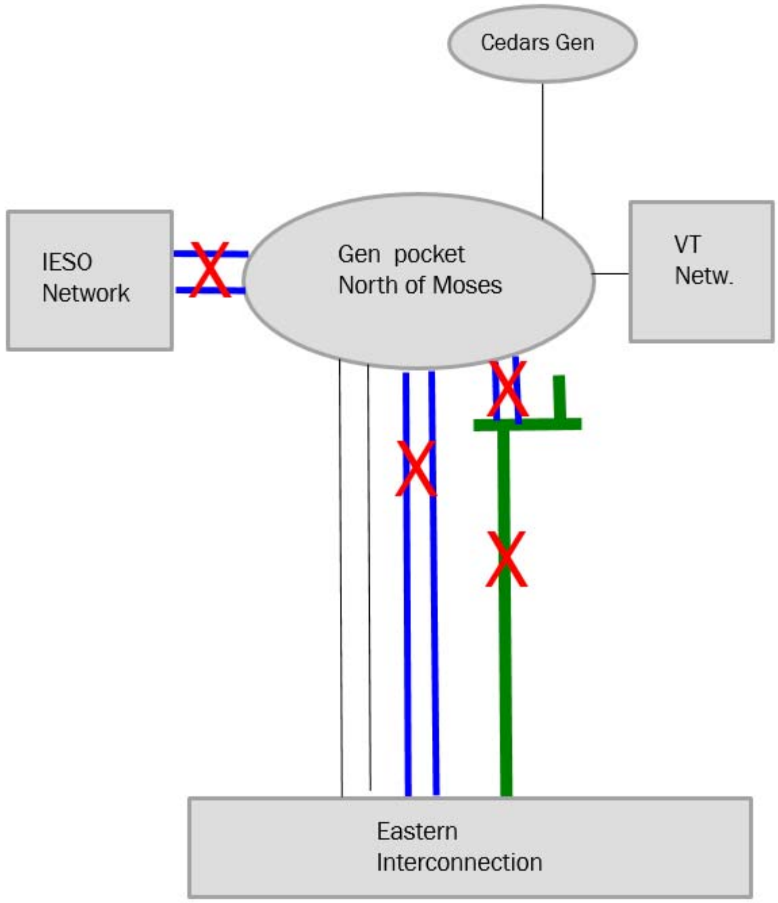

Figure 2. Northern Export and Cedars Import Transmission Elements connecting North Country with the rest of eastern interconnection

Northern Export Limits range from 0 MW to 1250 MW and the Cedars Import Limits range from 10 MW to 150 MW for the outage conditions evaluated.

Angle and Voltage Monitoring

Machine angles and system voltages were employed in this analysis as the key indicators of system stability. The discussions that follow include representative plots of generation unit angle response for illustration purposes. Similar plots are included in the Appendices for all the simulations conducted.

The representative plots for the dynamic response of Moses machine angle for all the evaluated contingencies at the limiting transfer level are shown below.

The generator angle of the Beauharnois generators connected to NYISO via Cedars was also used as an indicator of system stability for imports into NYISO from these units.

Appendix A – D contains all the plots of dynamic response of all the Northern Export stability transfer cases, cited in Tables 1B – 4B.

Most Limiting Contingencies

Following is the list of contingencies that were the most limiting:

- MS01(3PH-NC@MARCY 765 – L/O MASSENA-MARCY MSU-1 W/REJ)
- MS03(LLG@MOSES230 – L/O MOSES-ADIRONDACK 1&2)
- MS06(SLG-STK@MOSES230 – L/O MASSENA-MOSES 230#MMS-2 W/NO REJ)
- MS08(SLG-STK@MOSES230 – L/O MOSES-ADIRONDACK 230 W/NO REJ)
- MS09(3PH-NC@MASSENA765 – L/O MASSENA-MARCY MSU-1 W/REJ)
- MS150(LLG@MOSES230 – L/O MOSES-ST.LAWRENCE L33/34P DCT W/NO REJ)

A comparative display of Moses machine angle responses to all the tested contingencies of the MSU-1 out of service condition is shown in Figure 3. For cases with MSU1 O/S and MMS1/MMS2 O/S, the contingencies MS03, MS08 and MS150 were the three most limiting contingencies. Similarly, for cases with L33/L34 O/S and MAP1/MAP2 O/S the three most limiting contingencies were MS01, MS06 and MS09.

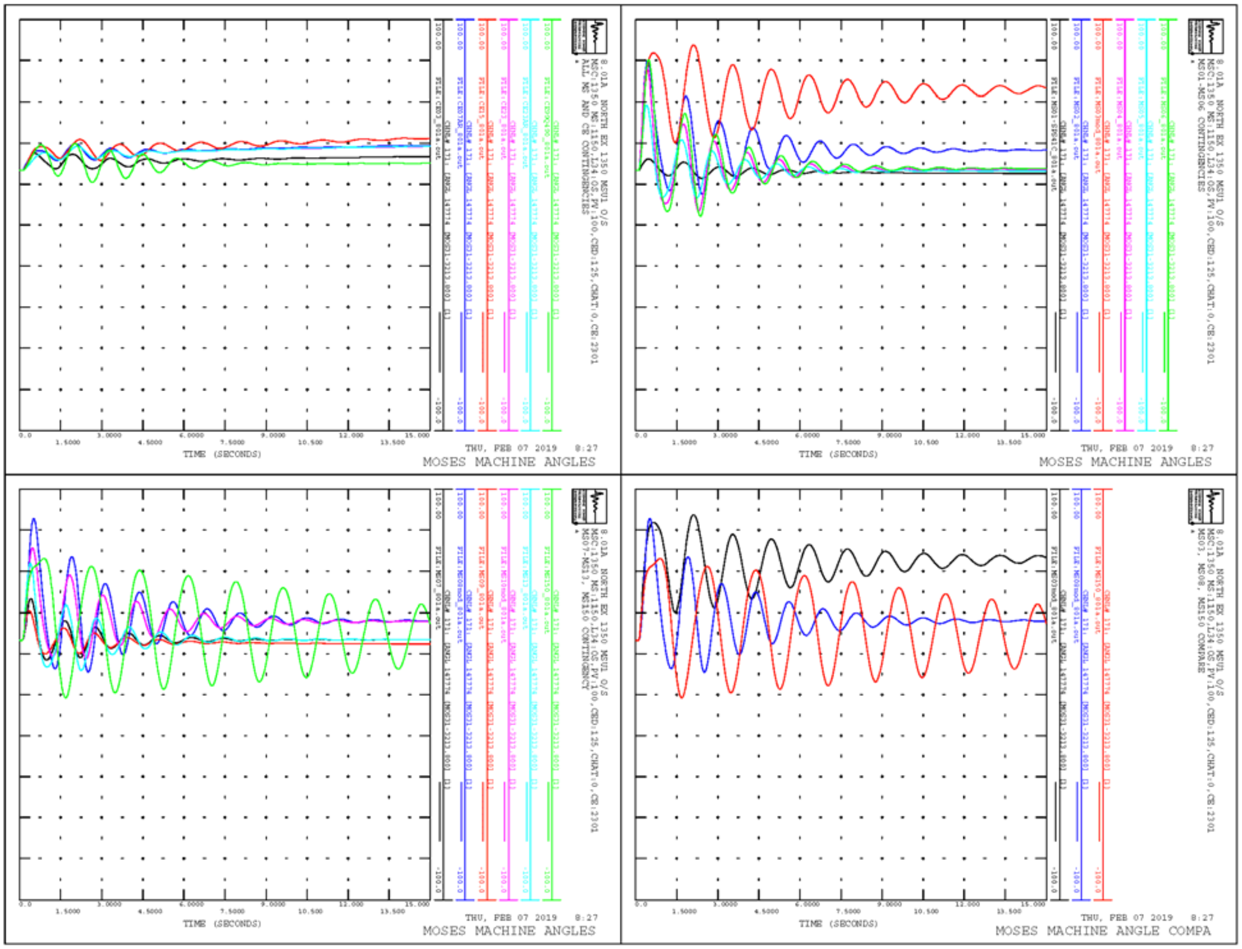

Figure 3. Comparative plots for Moses unit angle dynamic response plots for MSU1, 7040, HVDC out-of-service scenario for all Moses and select Central East contingencies

In Figure 3, the plots show the Moses machine angle when subjected to all Northern Export contingencies. The bottom right plot is a comparison of the three most limiting contingencies. On comparing the response to all the contingencies simulated it is observed that the MS150 (bottom left green) contingency is the most limiting.

Generation Rejection at Moses Plant

Northern Export limits were developed without generation rejection at the Moses plant as a base line assumption; however, Northern Export Limits were also developed for the contingencies where generation rejection may potentially be armed at the Moses plant.

Not all Northern Export contingencies result in the operation of Moses plant breakers for which generation rejection can be made available. Under specific system conditions (triggered by the status change of breakers at the Moses plant), rejection of Moses generation may be armed to operate for contingencies that are compatible (MS03, MS08, MS150) with generation rejection. Not all Northern Export contingencies can trigger the automatic rejection of Moses generation. Moses generation rejection cannot be armed for loss of MSU1 or MMS circuits as they are not initiating incidents that would trigger generation rejection. For scenarios with generation rejection armed, limits were developed based on 342 MW of Moses generation being rejected. The Moses generation rejection scheme was implemented as per NYPA operating procedures.

Impact of Central East Transfer Levels and MSSC on Northern Export Transfer Levels:

Outage of the MSU1 line and MSSC (Marcy South Series Compensation) being in service imposes a derate on the Central East transfer levels. A sensitivity analysis was done with higher transfer levels across Central East for cases where MSU1 is in-service and the MSSC was bypassed. Similarly, a sensitivity analysis was also performed for cases with MSU1 out of service and the MSSC bypassed. It was determined that the Central East transfer levels had no impact on the Northern Export tested transfer levels and the system stability across the North Country would not be impacted.

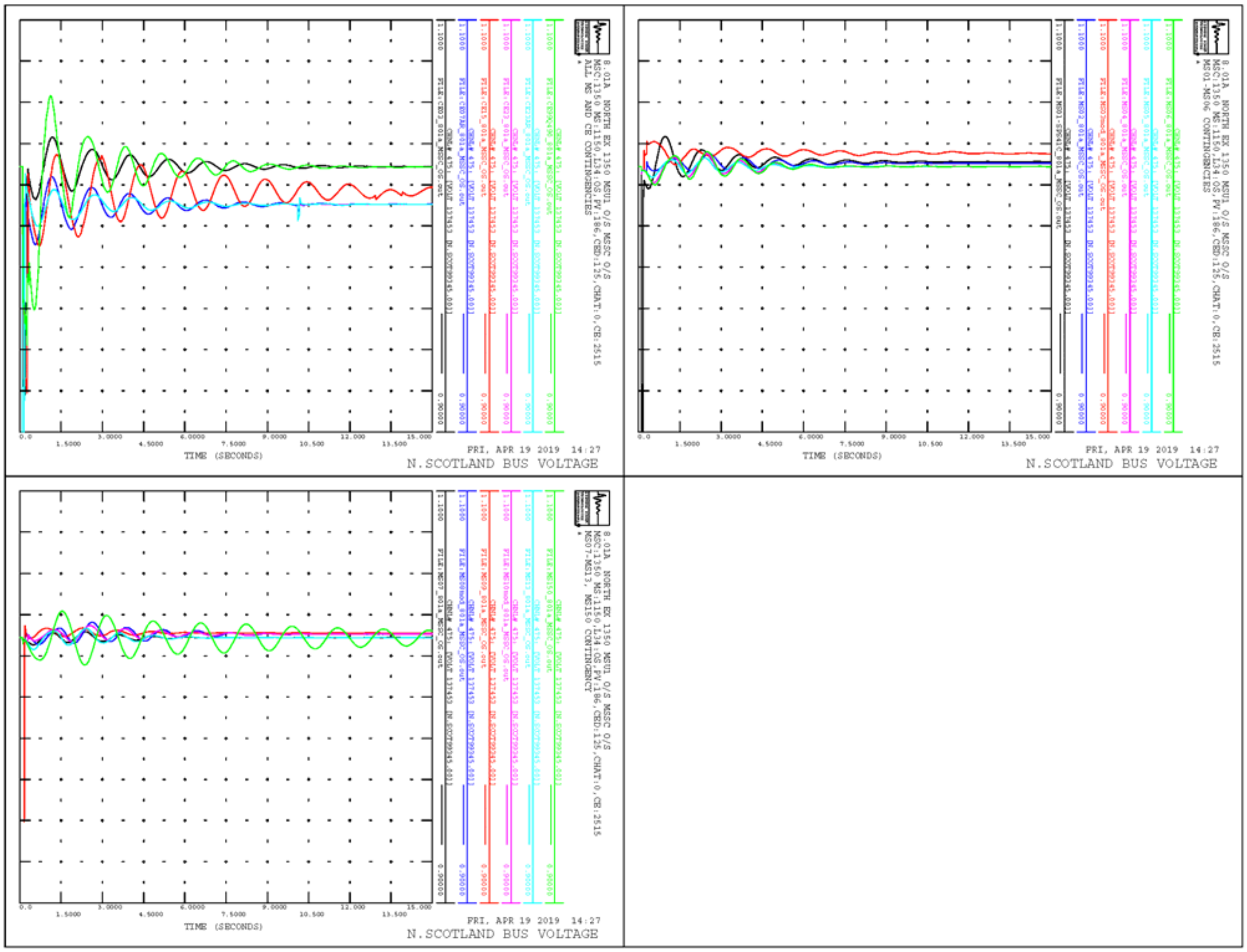

Figure 4. Comparative plots for Moses South and Central East contingencies when MSU1 Out-of-service and MSSC is bypassed

MSU1 out-of-service, MSSC bypassed

In Figure 4, for a given tested transfer level across Northern Export (1350 MW) with MSU1 out-of-service, bypassing the MSSC eliminated the 235 MW Central East de-rate and the transfer levels increased from 2255 MW to 2490 MW. When subjected to all the Northern Export contingencies, the post contingency system response was stable for all contingencies. With the higher transfer level across Central East, the most limiting Central East contingency was CE15 (top left red plot) but less limiting than MS150 (bottom left green plot). As a result, the effect of bypassing the MSSC had no impact on the Northern Export stability when MSU1 is out-of-service. The voltage at the New Scotland 99 Bus was used to gauge the system dynamic response. Comparing the responses of CE15 and MS150 contingency, MS150 is more limiting as the amplitude of the oscillations is larger than that of CE15.

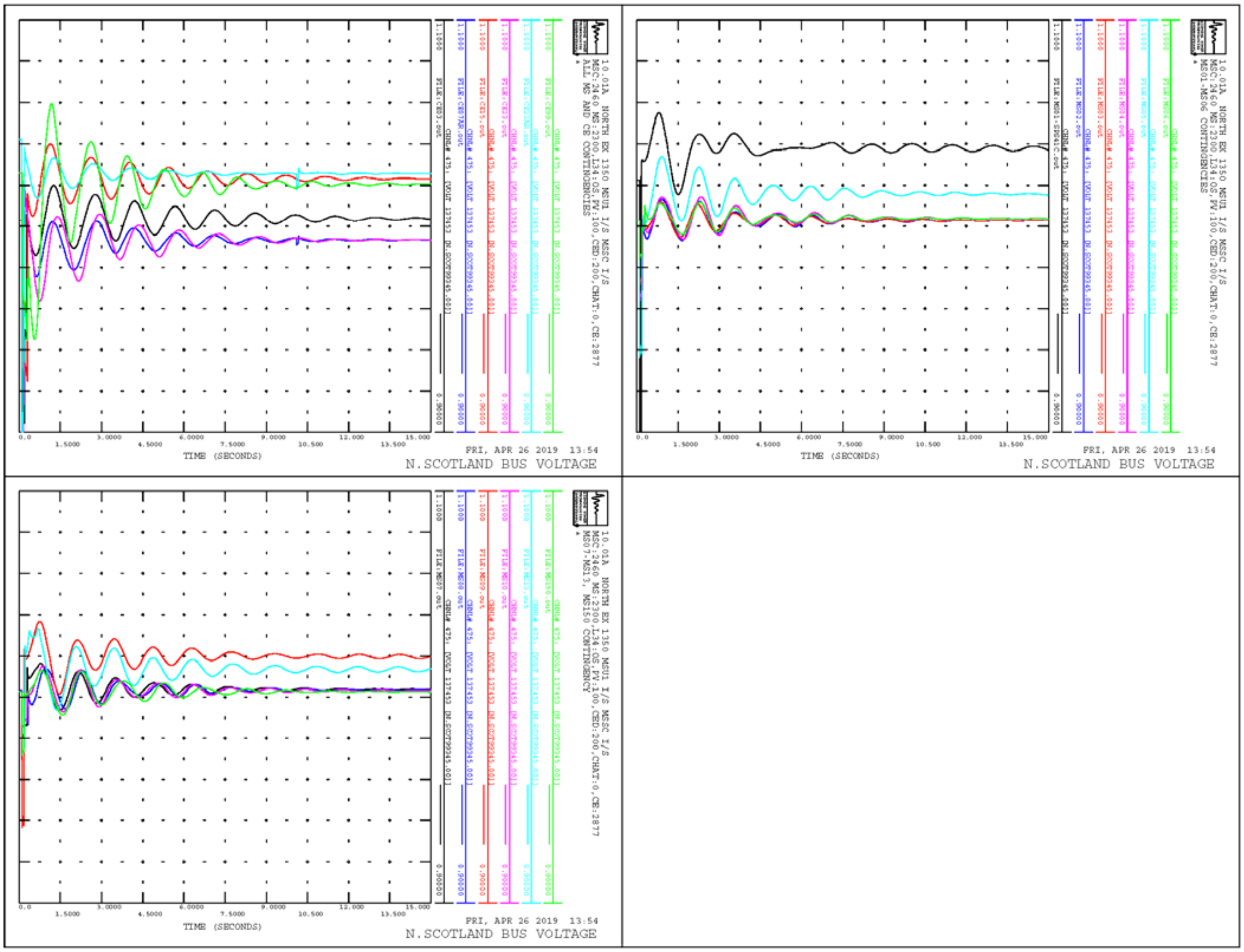

Figure 5. Comparative plots for Moses South and Central East contingencies when MSU1 and MSSC is In-Service

MSU1 in-service, MSSC in-service

In Figure 5, for a given tested transfer level across Northern Export (1350 MW) with MSU1 in-service and the MSSC I/S, the MSU1 outage de-rate is not imposed and Central East transfer levels increased from 2255 MW to 2850 MW. When subjected to all the Northern Export contingencies, the post contingency system response was stable for all contingencies. With the higher transfer level across Central East, the most limiting Central East contingency was CE15 (top left red plot) but less limiting than MS01 (top right black plot). As a result, the effect of higher transfer levels due to MSU1 being in service had no impact on the Northern Export stability. The voltage at the New Scotland 99 Bus was used to gauge the system dynamic response.

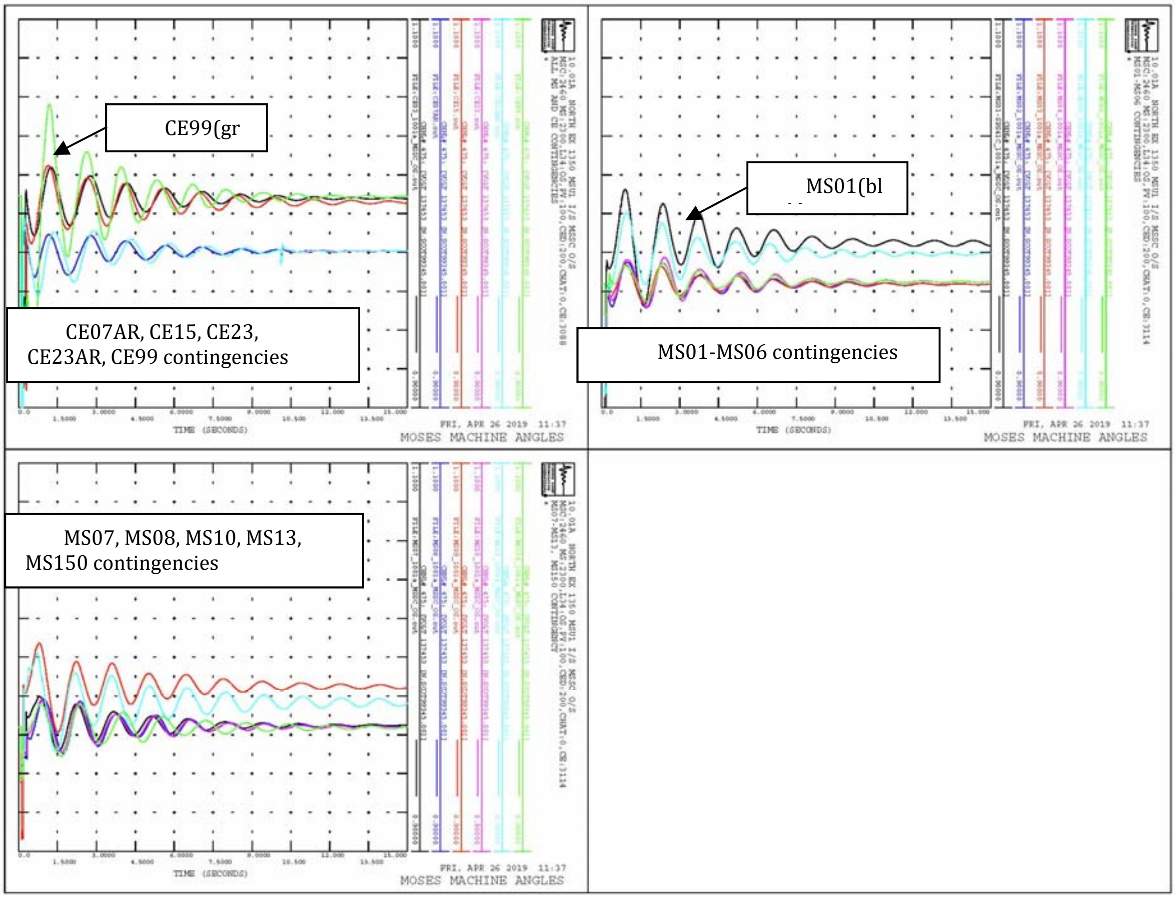

Figure 6. Comparative plots for Moses South and Central East contingencies when MSU1 In-Service and MSSC bypassed

MSU1 in-service, MSSC bypassed

In Figure 6., for a given tested transfer level across Northern Export (1350 MW) with MSU1 I/S, and the MSSC bypassed, the MSU1 outage derate and the MSSC in service penalty are not imposed and Central East transfer levels increased from 2255 MW to 3085 MW. When subjected to all the Northern Export contingencies, the post contingency system response was stable for all contingencies. With the higher transfer level across Central East, the most limiting Central East contingency was CE99 (top left green plot) but less limiting than MS01(top right black plot). As a result, the effect of higher transfer levels due to MSU1 being in service and MSSC being bypassed had no impact on the Northern Export stability. The voltage at the New Scotland 99 Bus was used to gauge the system dynamic response.

ISO-NE stability criterion for Vermont voltage oscillations:

ISO-NE stability criteria states that there must be 50% damping exhibited in the last 4 oscillations. However, this criterion can be relaxed if the oscillations are not varying by more than ±1% after 30 seconds. A sensitivity analysis was conducted on the voltage at the Sandbar 115kV bus in Vermont and the post contingency response of the system was found to be well damped and adhering to the stability criteria. Figure 7 illustrates this observation.

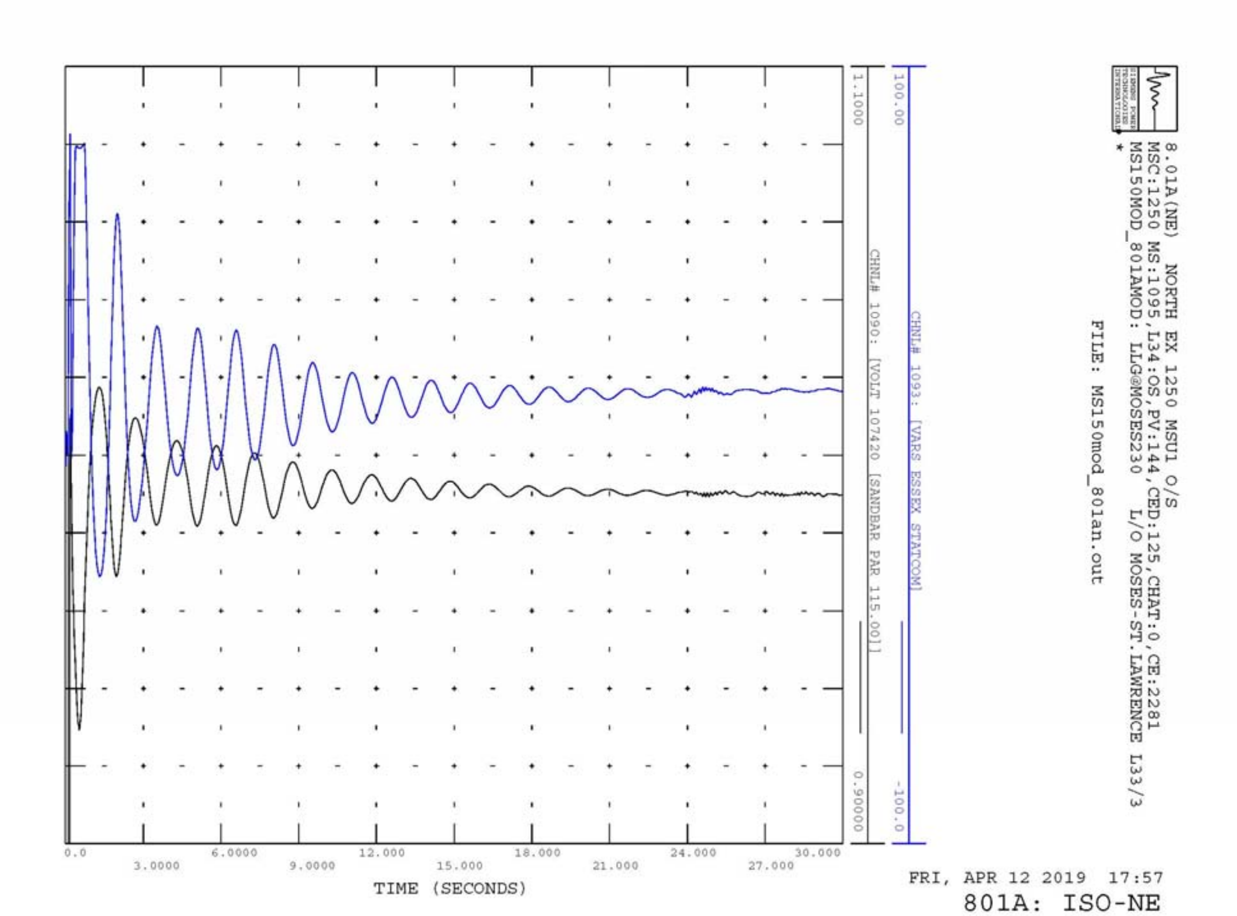

Figure 7. Impact of MS150mod contingency on the voltage at Sandbar 115kV bus and VAR output of Essex STATCOM

Recommendations

Based on the results of this study, it is recommended that the Northern Export stability limits be implemented as per Table 1A-4A. Tables 1B to 4B can be referred to for more detailed explanation of Northern Export Limits implementation.

Table 1B: Basis of the Northern Export Stability Limits for MSU1 & 7040 & HVDC O/S										
MSU1 O/S, 7040 O/S, HVDC O/S, L33/L34@ 0 MW ,PV-20 @ 100 MW	NX Limit	Cedars Limit	LF#	NX Test	LF#	NX Cedars Test		Limiting Cont.	Equiv. Moses South	Moses South Closed
One 765 KV Path out of service										
MSU1&7040&HVDC O/S	1250	100	8.01a	1350	8.01b	125		MS150	1150	1350
MSU1&7040&HVDC & R8105 O/S	1050	100	8.02a	1150	8.02b	125		MS03	1050	1250
MSU1&7040&HVDC & PV-20 O/S	850	100	8.03a	950	8.03b	125		MS150	950	950
One 765 KV Path & One 230 kV circuit on one 230 kV path out of service										
MSU1&7040&HVDC & (L33 or L34) O/S	1100	100	8.04a	1200	8.04b	125		MS08/MS150	1061	1300
MSU1&7040&HVDC & R8105 & (L33 or L34) O/S	1100	100	8.05a	1200	8.05b	125		MS03	1050	1200
MSU1&7040&HVDC & PV-20 & (L33 or L34) O/S	850	100	8.06a	950	8.06b	125		MS03	950	950
MSU1&7040&HVDC & (MAP1 or MAP2) O/S	850	100	8.07a	950	8.07b	125		MS150	775	950
MSU1&7040&HVDC & R8105 & (MAP1 or MAP2) O/S	750	100	8.08a	850	8.08b	125		MS150	680	850
MSU1&7040&HVDC & PV-20 & (MAP1 or MAP2) O/S	600	100	8.09a	700	8.09b	125		MS150	700	700
One 765 KV Path & One 230 kV circuit on each 230 kV path out of service										
MSU1&7040&HVDC & (L33 or L34) & (MAP1 or MAP2) O/S	850	100	8.10a	950	8.10b	125		MS150	775	950
MSU1&7040&HVDC & R8105 & (L33 or L34) & (MAP1 or MAP2) O/S	800	100	8.11a	850	8.11b	125		MS150	740	900

MSU1&7040&HVDC & PV-20 & (L33 or L34) & (MAP1 or MAP2) O/S	600	100	8.12a	700	8.12b	125		MS150	700	700
One 765 KV Path & One entire 230 kV path out of service with 7 unit rejection										
MSU1&7040&HVDC & L33 & L34 O/S w/ 6 unit rej.	600	10	8.13.a	700	8.13.b	25	First Second Limiting	MS36mod MS86mod	593	700
MSU1&7040&HVDC & R8105 & L33 & L34 O/S w/ 6 unit rej.	500	10	8.14a	600	8.14b	25	First Second Limiting	MS36mod MS86mod	491	600
MSU1&7040&HVDC & PV-20 & L33 & L34 O/S w/ 6 unit rej.	400	10	8.15a	500	8.15b	25	First Second Limiting	MS36mod MS86mod	505	505
MSU1&7040&HVDC & MAP1 & MAP2 O/S w/ 6 unit rej.	500	10	8.16a	600	8.16b	25	First Second Limiting	MS156mod MS86mod	313	604
MSU1&7040&HVDC & R8105 & MAP1 & MAP2 O/S w/ 6 unit rej.	300	10	8.17a	400	8.17b	25	First Second Limiting	MS156mod MS86mod	172	405
MSU1&7040&HVDC & PV-20 & MAP1 & MAP2 w/ 6 unit rej.	200	10	8.18a	300	8.18b	25	First Second Limiting	MS156mod MS86mod	300	300
One 765 KV Path & One entire 230 kV path with another 230 kV circuit O/S with 7 unit rejection										
MSU1&7040&HVDC & L33 & L34 & (MAP1 or MAP2) O/S w/ 6 unit rej.	350	10	8.19a	450	8.19b	25	First Second Limiting	MS86mod MS36mod	350	450
MSU1&7040&HVDC & MAP1 & MAP2 & (L33 or L34) O/S w/ 6 unit rej.	450	10	8.20a	500	8.20b	25	First Second Limiting	MS156mod MS86mod	284	509
MSU1&7040&HVDC & L33 & L34 & (MAP1 or MAP2) &	0	0	8.29a	100*	8.29b	25*		MS86mod	2	102

R8105 O/S w/ 6 unit rej.(No stable transfer limit possible)(Abnormal Operating Condition)										
MSU1&7040&HVDC & L33 & L34 & (MAP1 or MAP2) & PV-20 O/S w/ 6 unit rej.	200	10	8.30a	300	8.30b	25	First	MS86mod		
							Second Limiting	MS36mod	300	300
MSU1&7040&HVDC & MAP1 & MAP2 & (L33 or L34) & R8105 O/S w/ 6 unit rej.	300	10	8.31a	400	8.31b	25	First	MS156mod	164	400
							Second Limiting	MS86mod		
One 765 KV Path & One entire 230 kV path out of service										
MSU1&7040&HVDC & L33 & L34 O/S	450	10	8.21.a	575	8.21.b	25		MS03mod	464	575
MSU1&7040&HVDC & R8105 & L33 & L34 O/S	250	10	8.22a	375	8.22b	25		MS03mod	268	375
MSU1&7040&HVDC & PV-20 & L33 & L34 O/S	150	10	8.23a	275	8.23b	25		MS03mod	275	275
MSU1&7040&HVDC & MAP1 & MAP2 O/S	400	10	8.24a	500	8.24b	25		MS150mod	308	575
MSU1&7040&HVDC & R8105 & MAP1 & MAP2 O/S	200	10	8.25a	300	8.25b	25		MS150mod	135	300
MSU1&7040&HVDC & PV-20 & MAP1 & MAP2 O/S	100	10	8.26a	200	8.26b	25		MS150mod	200	200
One 765 KV Path & One entire 230 kV path w/ another 230 kV circuit O/S										
MSU1&7040&HVDC & L33 & L34 & (MAP1 or MAP2) O/S	100	10	8.27a	205	8.27b	25		MS08mod	98	205
MSU1&7040&HVDC & MAP1 & MAP2 & (L33 or L34) O/S	350	10	8.28a	475	8.28b	25		MS150(3Ph)	288	475
MSU1&7040&HVDC & L33 & L34 & (MAP1 or MAP2) &	0	10	8.30ab	9	8.30ab	25		MS08mod	9	9

PV-20 O/S(Generation Rejection Recommended)										
MSU1&7040&HVDC & MAP1 & MAP2 & (L33 or L34) & R8105 O/S	150	10	8.31ab	261	8.31b	25		MS150mod	120	261

Table 2B: Basis of the Northern Export Stability Limits for L33 & L34 O/S									
MSU1 I/S, 7040 I/S, HVDC I/S, 7040 I/S,PV-20 @ 100 MW	NX Limit	Cedars Limit	LF#	NX Test	LF#	NX Cedars Test	Limiting Cont.	Equiv. Moses South	Moses South Closed
One 230 kV Path out of service									
L33&L34 O/S	1000	10	9.01a	1100	9.01b	25	MS01	2460	2600
L33&L34 & R8105 O/S	750	10	9.02a	850	9.02b	25	MS01	2290	2400
L33&L34 & PV-20 O/S	650	10	9.03a	780	9.03b	25	MS01	2275	2275
One 230 kV Path & One 230 kV circuit path out of service									
L33&L34 & (MAP1 or MAP2) O/S	750	150	9.04a	863	9.04b	200	MS01	1794	1901
L33&L34 & R8105 & (MAP1 or MAP2) O/S	650	100	9.05a	772	9.05b	125	MS01	1700	1807
L33&L34 & PV-20 & (MAP1 or MAP2) O/S	450	100	9.06a	566	9.06b	125	MS01	1601	1601
One 230 kV Path & One 230 kV circuit on each 230 kV remaining path out of service									
L33&L34 & (MAP1 or MAP2) & (MMS1 or MMS2) O/S	450	10	9.07a	563	9.07b	25	MS06	1494	1600
L33&L34 & R8105 & (MAP1 or MAP2) & (MMS1 or MMS2) O/S	300	10	9.08a	422	9.08b	25	MS06	1356	1458
L33&L34 & PV-20 & (MAP1 or MAP2) & (MMS1 or MMS2) O/S	250	10	9.09a	363	9.09b	25	MS06	1396	1396
Two 230 kV paths out of service									
L33&L34 & MAP1 & MAP2 O/S	250	10	9.10a	364	9.10b	25	MS01	1294	1400
L33&L34 & MAP1 & MAP2 & R8105 O/S	150	10	9.11a	254	9.11b	25	MS01	1194	1300
L33&L34 & MAP1 & MAP2 & PV-20	0	10	9.12a	115	9.12b	25	MS01	1200	1200

Table 3B: Basis of the Northern Export Stability Limits for MAP1 & MAP2 O/S

MSU1 I/S, 7040 I/S, HVDC I/S, 7040 I/S,PV-20 @ 100 MW	NX Limit	Cedars Import Limit	LF#	NX Test	LF#	NX Cedars Test	Limiting Cont.	Equiv. Moses South	Moses South Closed
One Path out of service									
MAP1&MAP2 O/S	1250	150	10.01a	1350	10.01b	200	MS01	2300	2460
MAP1&MAP2 & R8105 O/S	1200	100	10.02a	1330	10.02b	125	MS01	2275	2440
MAP1&MAP2 & PV-20 O/S	900	150	10.03a	1000	10.03b	200	MS01	2120	2100
One Path & One 230 kV circuit path out of service									
MAP1&MAP2 & (L33 or L34) O/S	900	150	10.04a	1000	10.04b	200	MS01	2002	2108
MAP1&MAP2 & R8105 & (L33 or L34) O/S	1050	100	10.05a	1150	10.05b	125	MS01	2120	2260
MAP1&MAP2 & PV-20 & (L33 or L34) O/S	750	100	10.06a	850	10.06b	125	MS01	2000	1950
One Path & One 230 kV circuit on each 230 kV remaining path out of service									
MAP1&MAP2 & (L33 or L34) & (MMS1 or MMS2) O/S	850	150	10.07a	950	10.07b	200	MS06	1950	2050
MAP1&MAP2 & R8105 & (L33 or L34) & (MMS1 or MMS2) O/S	850	100	10.08a	950	10.08b	125	MS06	1950	2050
MAP1&MAP2 & PV20 & (L33 or L34) & (MMS1 or MMS2) O/S	750	100	10.09a	850	10.09b	125	MS06	1950	1950

Table 4B: Basis of the Northern Export Stability Limits for MMS1 & MMS2 O/S

MSU1 I/S, 7040 I/S, HVDC O/S, L33/L34@ 0 MW ,PV-20 @ 100 MW	NX Limit	Cedars Limit	LF#	NX Test	LF#	NX Cedars Test	Limiting Cont.	Equiv. Moses South	Moses South Closed
One Path out of service									
MMS1&MMS2 O/S	850	100	11.01a	975	11.01b	125	MS03	1914	2011
MMS1&MMS2 & R8105 O/S	650	100	11.02a	775	11.02b	125	MS03	1710	1812
MMS1&MMS2 & PV-20 O/S	550	100	11.03a	675	11.03b	125	MS03	1717	1711
One Path & One 230 kV circuit path out of service									
MMS1&MMS2 & (L33 or L34) O/S	850	100	11.04a	975	11.04b	125	MS03	1897	2011
MMS1&MMS2 & R8105 & (L33 or L34) O/S	650	100	11.05a	775	11.05b	125	MS03	1703	1811
MMS1&MMS2 & PV-20 & (L33 or L34) O/S	550	100	11.06a	675	11.06b	125	MS03	1714	1711
MMS1&MMS2 & (MAP1 or MAP2) O/S	700	100	11.07a	800	11.07b	125	MS150	1681	1836
MMS1&MMS2 & R8105 & (MAP1 or MAP2) O/S	650	100	11.08a	775	11.08b	125	MS150	1656	1811
MMS1&MMS2 & PV20 & (MAP1 or MAP2) O/S	550	100	11.09a	675	11.09b	125	MS150	1714	1711
One Path & One 230 kV circuit on each 230 kV remaining path out of service									
MMS1&MMS2 & (L33 or L34) & (MAP1 or MAP2) O/S	800	100	11.10a	900	11.10b	125	MS150	1735	1935
MMS1&MMS2 & R8105 & (L33 or L34) & (MAP1 or MAP2) O/S	700	100	11.11a	800	11.11b	125	MS150	1670	1836
MMS1&MMS2 & PV-20 & (L33 or L34) & (MAP1 or MAP2) O/S	400	100	11.12a	500	11.12b	125	MS150	1535	1535