Final Report

QP499 ETU PROJECT

QP499 Elective Transmission Upgrade Project

For ISO-NE

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RLC ENGINEERING

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Executive Summary - Redacted Version to Remove Critical Energy Infrastructure Information (CEII)

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Revision History

Rev #	Date	Revision
0	10/16/15	Original steady state draft report.
1	10/23/15	Steady State sensitivity analysis completed for revised NH loads. Stability W. Medway results included.
2	11/05/15	ISO-NE comments incorporated
3	01/15/16	TWG and SSG comments from the Scope included. Eversource Transmission Comments from rev 2 of the report incorporated
4	01/22/16	ISO Comments Incorporated
5	02/01/16	Stability Results, ISO, Eversource and TWG comments included.
6	02/26/16	SSG Comments Included
7	03/08/16	Additional SSG comments, as well initial Developer comments
8	03/11/16	Short Circuit Results included
9	04/25/16	Power Factor Analysis, SVC Leading Capability and Cost Estimates Included
10	6/21/16	Deerfield Capacitor blocks changed to 2 * 75 MVAR. ABB SSTI results included. Short circuit analysis addendum for Seabrook generator breaker included. Inter-regional analysis included.
Final	6/30/16	Minor editorial comments from the Developer, TWG and SSG.

Executive Summary

RLC Engineering, LLC (RLC) conducted a System Impact Study (the Study) in accordance with ISO-NE Open Access Transmission Tariff Schedule 25. The Study was performed on behalf of ISO New England Inc (ISO) for an Elective Transmission Upgrade (ETU) QP499. The ETU is an interconnection of a bidirectional ±320 kV, symmetrical monopole HVDC line from Des Cantons Substation in Quebec to a new substation located in Franklin, New Hampshire. This Study analyzed New England importing 1090 MW from Quebec on the HVDC line, with the point of interconnection (POI) at the 345 kV Deerfield Substation.

QP499 has a proposed in-service date of February 2019.

The Study was performed in accordance with:

- Northeast Power Coordinating Council (NPCC) Regional Reliability Reference Directory # 1 *"Design and Operation of the Bulk Power System"*
- Interconnection Procedures contained in Schedule 25 of the Tariff
- ISO New England Planning Procedure No. 3, "*Reliability Standards for the New England Area Bulk Power Supply System*"
- ISO New England Planning Procedure No. 5-3, "*Guidelines for Conducting and Evaluating Proposed Plan Application Analyses*"
- ISO New England Planning Procedures 5-6, "*Scope of Interconnection Studies for Generation and Elective Transmission Upgrades*"
- ISO New England Operating Documents
- ISO New England Transmission Planning Technical Guide
- Eversource transmission planning guideline

The purpose of the Study was to:

(i) Analyze the steady state, stability and short circuit conditions for the Project

(ii) Determine any upgrades to the transmission system that would be required to mitigate any significant adverse impacts that the Project could otherwise pose on the reliability and operating characteristics of the New England transmission system

(iii) Determine any upgrades required to mitigate any degradation to transmission transfer capability

The QP499 ETU Project requires the following construction of new facilities and system upgrades to Eversource Transmission facilities:

The interconnection customer will be responsible for the construction of the following new system facilities:

- Addition of a ±320 kV symmetrical monopole HVDC line from Des Cantons, Quebec to Franklin, New Hampshire
    - 1090 MW delivered to 345 kV Deerfield Substation; Point-of-Interconnection
    - Regulating the Franklin 345 kV bus at 1.03 pu
    - 47 miles from Des Cantons to US Border
    - 153 miles (includes ~57 miles UG) from US Border to Franklin

- The HVDC control systems will be designed and built as a Type 1 Dynamic Control System (DCS) in accordance with NPCC C-33
- One voltage source converter with a capability of 1165 MW connected to the 230 kV bus at the Des Cantons 735/230 kV Substation in Quebec, Canada
- Two 184 MVAR capacitors at the Des Cantons 230 kV bus
- One 100 MVAR capacitor at the 120 kV Monteregie bus
- Construct a 345 kV Substation in Franklin, New Hampshire
- One voltage source converter with a capability of 1102 MW connected to the 345 kV Franklin Substation
- Construct a 34 mile 345 kV ac line from Franklin Substation to Deerfield Substation
- Eliminate the single event that could cause loss of both [redacted] by a method acceptable by ISO-NE. This could be accomplished by [redacted], or another method found to be suitable.

Eversource Transmission will be responsible for the following facility upgrades:

- Loop 345 kV Line 391 in and out of Deerfield Substation and associated upgrades at the 345 kV Deerfield Substation
    - Relocate 345 kV Line 373 terminal
    - New 345 kV line terminal to interconnect QP499 to Deerfield
- Re-rate the following 345 kV lines which could be achieved by removing the existing sag limitations and re-rating the lines to operate at 140 degrees C
    - Line 373 re-rated to a minimum LTE rating of 1580 MVA
    - Line 391S rated to a minimum LTE rating of 1580 MVA
- Re-rate 115 kV Line Y151 (Power Street to Pelham) to a minimum Normal and LTE rating of 127 MVA
    - Increase the Y151 SPS summer thermal mode set point to 127 MVA from 112 MVA
    - Eversource Transmission from Power Street to the Border
    - National Grid from the Border to Pelham
- One 345 kV, continuously controllable, -160/+375 MVAR SVC at the 345 kV Deerfield substation. The SVC is required to provide continuously controllable dynamic reactive compensation throughout its full range from 160 MVAR inductive to 375 MVAR capacitive. The SVC will regulate the Deerfield 345 kV bus voltage between 1.021 pu and 1.0435 pu, and will be operated to minimize its MVAR output under all lines in conditions
- 150 MVAR of reactive compensation at the 345 kV Deerfield Substation (2 * 75 MVAR capacitors), to be controlled by the SVC at Deerfield
- 275 MVAR of reactive compensation at the 345 kV Scobie Pond Substation (2*87.5 MVAR and 2* 50 MVAR capacitors), regulating the Scobie Pond 345 kV bus voltage between 1.021 and 1.0435pu, to be controlled by NH LCC
- Addition of a series 345 kV Scobie Pond 9126 breaker
- Addition of a series 345 kV Scobie Pond 262 breaker

Steady State Analysis

Steady state voltage and thermal analyses examined system performance without the Project in order to establish a baseline for comparison. System performance was re-evaluated with the Project and required upgrades and compared with the previous baseline performance to demonstrate the impact of the Project on area transmission reliability under the guidelines of the Network Capability Interconnection Standard (NCIS).

Seven peak load dispatches, two shoulder load dispatch, and one minimum load dispatch were evaluated for the N-1 steady state analysis. The base cases were dispatched to stress the New England interfaces.

N-1 and BPS steady state testing was completed and no significant adverse impact was reported when all system upgrades were included.

N-1-1 analysis evaluated approximately seventy dispatch/outage combinations with all additional system upgrades. The D2 dispatch reported generation runback levels above 1200 MW with [redacted]. This simultaneous outage overloads the remaining [redacted]. To reduce the generation back down to 1200 MW, both of these lines must be re-rated to an LTE of at least 1580 MVA. With these additional upgrades, the runback amount does not violate NPCC's or ISO-NE's line out criteria.

Capacitor switching delta voltage analysis was completed with the proposed additional reactive support at 345 kV Deerfield and Scobie Pond Substations. The shoulder load D9 dispatch which had all New Hampshire 345 kV generation and Yarmouth 4 off-line was analyzed. Results showed that capacitors as large as 225 MVAR could be switched at Deerfield or Scobie Pond with all lines in service and not violate Eversource's 2.5 % all lines in criteria. Analysis was also completed on this dispatch with 345 kV Line 326 out of service. The full size of the Deerfield (150 MVAR) and Scobie Pond (275 MVAR) capacitors could be switched with 345 kV Line 326 out of service, and not violate Eversource's 6% criteria for line out.

Start up/shut down sequencing for the Project was analyzed and it was determined that there aren't any additional reactors required at the 345 kV Franklin Substation to eliminate potential high voltages at the 345 kV Substation.

Stability Analysis

Stability testing was performed to evaluate the impact of the Project on the transmission system. The N-1 stability testing was performed on nine light load and three peak load dispatches scenarios. This testing was performed in both pre and post-Project with upgrades configurations for a total of 24 base cases. In the stability testing the Project was dispatched against generating units north of the Northern New England Scobie stability interface.

Stability analysis evaluated the performance of approximately 70 contingencies simulating bulk power system, normal and extreme contingencies, including 12 regional Southern New England contingencies.

All N-1 stability simulations demonstrated an acceptable response.

Regional sensitivity stability testing was performed in both pre and post-Project configurations. Several simulations demonstrated system separations or unstable system responses in the pre-Project configuration. All post-Project simulations demonstrated the same system separation or the separation occurred further north or not at all. One 115 kV fault at [redacted] showed an acceptable response pre-Project and system instability post-Project, for one light load dispatch. Increasing the Deerfield SVC from 215 MVAR to 225 MVAR eliminated the system instability.

Sensitivity testing included an additional Southern New England BPS contingency in one dispatch condition. A modified D1 dispatch with Phase 2 HVDC online was created. Two contingencies were simulated to evaluate the potential control interaction between the Phase 2 HVDC converter and the Project. All simulations demonstrated an acceptable response.

Testing was performed to evaluate the system response for NY-NE transfers on two dispatches. All simulations demonstrated an acceptable response.

N-1-1 stability testing was performed to assess the Project's impact on transfers with critical transmission lines out of service.

Simulations were performed with outages on the following 345 kV transmission lines:

- 345 kV Line 326 out-of-Service – Scobie Pond to Sandy Pond
- 345 kV Line 373 out-of-Service – Deerfield to Scobie Pond
- 345 kV Line 374 out-of-Service– Surowiec to Buxton
- 345 kV Line 380 out-of-Service – Scobie Pond to Amherst
- 345 kV Line 385 out-of-Service – Buxton to Deerfield
- 345 kV Line 394 out-of-Service – Seabrook to Ward Hill
- 345 kV Line 3135 out-of-Service – Newington to Timber Swamp

In all cases the results were acceptable at tested transfers.

Short Circuit Analysis
Short circuit analysis, including assessment of the 345 kV Seabrook circuit breakers and the Seabrook generator breaker, was completed by Eversource Transmission. The full reports are found in Appendix O.

The results of these analyses showed that the Project will have a minimal impact on the maximum available short circuit current levels in the New England system. Therefore, no circuit breakers will need to be replaced.

Sub-synchronous Torsional Interaction Study
A sub-synchronous torsional interaction screening study (SSTI) was completed first for the Project and all additional upgrades, excluding the Deerfield SVC. The Study calculated the Unit Interaction Factors (UIF) between the project converter terminal at Franklin Substation and multiple units in the vicinity of the Project.

The results of this sub-synchronous torsional interaction screening study indicate that there is a potential risk of torsional interaction with a few units that were analyzed. Network conditions with three elements out-of-service indicated UIFs greater than 0.1 for six generators (affected generators). Limiting the network conditions to two elements out-of-service, or one element out-of-service and a stuck breaker condition, did not indicate any potential risk of torsional interaction from the Project for any of the generators evaluated.

After identifying the six affected generators, a detailed SSTI study was performed using the preliminary design of the HVDC and its controls to further look into the SSTI risk for these affected generators. No adverse impact was observed in that study due to SSTI between the affected generators and the Project converter terminal at Franklin. However, given that the Project is not developed yet and the detailed HVDC control systems are not available, the affected generator owners and the project proponent have agreed that the confirming SSTI study will be completed as part of the detailed design studies for the Project.

Inter-Regional Stability Testing
Testing the impact of QP499 on the inter-regional system performance was performed by two specific contingencies that include one three-phase fault at the [redacted] substation in New Hampshire and one three-phase fault at the [redacted] substation in Quebec, Canada. Both NYISO and PJM have reviewed the testing results and agreed that QP499 shows no significant adverse impact on their systems.

Cost Estimates
The combined estimates from Eversource and National Grid total $146.3 Million for the facility upgrades required for this Project.

Conclusion
The QP499 ETU Project with all proposed upgrades when interconnected to the New England transmission system will not cause a significant adverse impact on the reliability, stability and operating characteristics of the Transmission Owner's transmission facilities, the transmission facilities of another Transmission Owner, or the system of a Market Participant.

The risk of a single event that causes the loss of both [redacted] will be mitigated by a method found to be acceptable by ISO-NE. This mitigation can be accomplished by [redacted], or another method found to be suitable.

The confirming SSTI study will be completed as part of the detailed design studies for the QP499 project. The required mitigating measures and the details on implementing any such mitigating measures will be included as milestones specified within the Interconnection Agreement for QP499.