

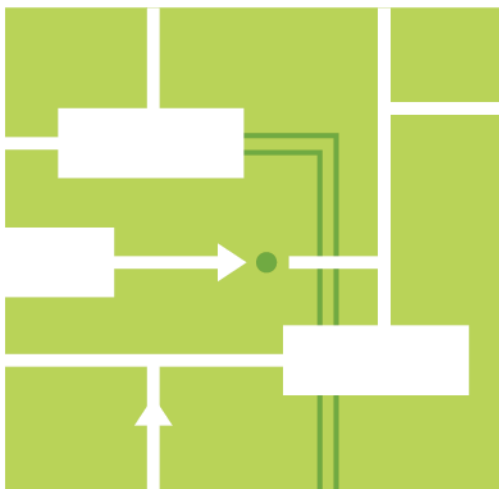
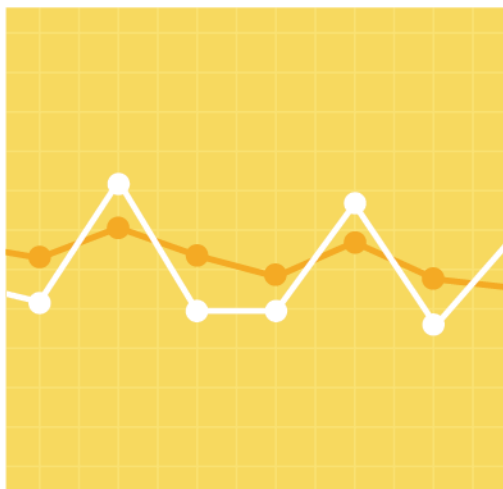
Transmission Planning Technical Guide

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System Planning

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NOTE: Additional updates continuing to review the content of the guide in further detail to match current processes and procedures will follow.

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Disclaimer

The provisions in this document are intended to be consistent with ISO New England's Tariff. If, however, the provisions in this planning document conflict with the Tariff in any way, the Tariff takes precedence as the ISO is bound to operate in accordance with the ISO New England Tariff.

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Section 1

Introduction

This Transmission Planning Technical Guide (the Guide) describes the current standards, criteria and assumptions used in various system planning studies in New England. An accompanying Transmission Planning Process Guide¹ provides additional detail on the existing regional system planning process as described in Attachment K of Section II of the ISO New England Transmission, Markets and Services Tariff (ISO Tariff).² This Technical Guide is not intended to address every assumption of system planning studies but to provide additional detail on certain assumptions not fully described in the ISO Planning Procedures.

The guide has been organized into four main sections. Section 1 describes its purpose, the source of the standards, criteria and assumptions used in system planning studies, and a description of the various types of studies that are conducted. Section 2 describes the modeling assumptions that are followed to create the network and system condition representations used in system planning studies. Section 3 describes the reliability criteria and standards that establish the bounds of acceptable system performance. They are applied to each analysis to determine if any violations exist. Section 4 defines the methodologies used to conduct various system planning studies.

Capitalized terms in this guide are defined in Section I of the ISO Tariff, in Section 1.3 of this guide, and Section 5.1, Appendices of this guide. Additional documents and white papers describing topics in further detail throughout this guide are listed in Section 5.

1.1 Purpose

The purpose of this guide is to clearly articulate the current assumptions used in planning studies of the transmission system consisting of New England Pool Transmission Facilities (PTF). Pursuant to Attachment K of the ISO New England Open Access Transmission Tariff (OATT),³ ISO New England Inc. (the ISO) is responsible for the planning of the PTF portion of New England's transmission system. Pool Transmission Facilities are the transmission facilities owned by Participating Transmission Owners (PTO), over which the ISO exercises Operating Authority in accordance with the terms set forth in the Transmission Operating Agreement,⁴ rated at 69 kV and above, except for lines and associated facilities that contribute little or no parallel capability to the PTF. The scope of PTF facilities is defined in Section II.49 of the OATT.

The PTOs are responsible for planning of the non-PTF and coordinating such planning efforts with the ISO. The PTOs establish the assumptions for planning of the non-PTF which does not impact the PTF. Section 6 of Attachment K to the OATT describes the responsibilities for planning the PTF and non-PTF transmission systems.

The planning assumptions in this guide also apply to studies of the impacts of system changes on the PTF transmission system, the Highgate Transmission System, Other Transmission Facilities, and

¹ <https://www.iso-ne.com/system-planning/transmission-planning/transmission-planning-guides>

² <https://www.iso-ne.com/participate/rules-procedures/tariff>

³ <https://www.iso-ne.com/participate/rules-procedures/tariff/oatt>

⁴ <https://www.iso-ne.com/participate/governing-agreements/transmission-operating-agreements>

Merchant Transmission Facilities. This includes studies of the impacts of Elective Transmission Upgrades and generator interconnections, regardless of the point of interconnection.

1.2 Applicable Reliability Standards

ISO New England establishes reliability criteria and procedures for the six-state New England region on the basis of authority granted to the ISO by the Federal Energy Regulatory Commission (FERC). Because New England is part of a much larger interconnected power system, the region also is subject to reliability standards established for the northeast and the entire United States by the Northeast Power Coordinating Council (NPCC) and the North American Electric Reliability Corporation (NERC), respectively.

The standards, criteria, and assumptions used in planning studies are guided by a series of reliability standards and criteria:

- North American Electric Reliability Corporation reliability standards for Transmission Planning (TPLs) which apply to North America. These standards can be found on the NERC website.⁵
- Northeast Power Coordinating Council, *Design and Operation of the Bulk Power Systems*, (Directory #1) and *NPCC Classification of Bulk Power System Elements*, (Document A-10) which describe criteria applicable to Ontario, Québec, Canadian Maritimes, New York and New England. These documents can be found on the NPCC website.⁶
- ISO New England Planning and Operating Procedures which apply to the New England transmission system, which excludes the northern section of Maine that is not directly interconnected to the rest of the United States transmission system but is interconnected to the New Brunswick system. These procedures can be found on the ISO website.⁷

NERC, NPCC, and the ISO describe the purpose of their reliability standards and criteria as:

- NERC describes the intent of the TPL standards as providing for system simulations and associated assessments that are needed periodically to ensure that reliable systems are developed that meet specified performance requirements with sufficient lead time, and that continue to be modified or upgraded as necessary to meet present and future system needs.
- NPCC describes the intent of its Directory #1 criteria as providing a “design-based approach” to ensure the Bulk Power System (BPS) is designed and operated to a level of reliability such that the loss of a major portion of the system, or unintentional separation of a major portion of the system, will not result from any design contingencies.
- ISO New England, in its Planning Procedure No. 3 (PP 3), *Reliability Standards for the New England Area Pool Transmission Facilities*, describes that the purpose of the New England Reliability Standards is to assure the reliability and efficiency of the New England PTF through coordination of system planning, design, and operation.

⁵ <http://www.nerc.net/standardsreports/standardssummary.aspx>

⁶ <https://www.npcc.org/Standards/default.aspx>

⁷ <https://www.iso-ne.com/participate/rules-procedures/planning-procedures> and <https://www.iso-ne.com/participate/rules-procedures/operating-procedures>

The ISO planning standards and criteria, which are explained in this guide, are based on the NERC, NPCC, and ISO specific standards and criteria, and are set out for application in the region in the ISO Planning and Operation procedures. As the NERC registered Planning Authority, the ISO has the responsibility to establish procedures and assumptions that satisfy the intent of the NERC and NPCC standards.

1.3 Types of System Planning Studies

There are a number of different types of planning studies conducted in New England which assess or reflect the capability of the transmission system, including Market Efficiency upgrade studies, operational studies and reliability studies. The focus of this guide is on reliability studies.

The major types of studies addressed in this guide are:

- **Proposed Plan Application (PPA) Study** – Study done to determine if any addition or change to the New England transmission system has a significant adverse effect on stability, reliability, or operating characteristics of the PTF or non-PTF transmission system (See Section I.3.9 of the OATT).
Note: This does not need to be an independent study but can be a submission or supplementation of another study such as a System Impact Study or transmission Solutions Study, as long as appropriate system conditions were included in that study.
- **System Impact Study (SIS)** – Study done to determine the system upgrades required to interconnect a new or modified generating facility (See Schedule 22, Section 7 and Schedule 23, Section 3.4 of the OATT), to determine the system upgrades required to interconnect an Elective Transmission Upgrade (See Schedule 25, Section 7 of the OATT), or to determine the system upgrades required to provide transmission service pursuant to the OATT. A Feasibility Study is often the first step in the interconnection study process and may be done as part of the System Impact Study or separately.
- **Transmission Needs Assessment** – Study done to assess the adequacy of the New England PTF (See Attachment K, Section 4.1 of the OATT).
- **Transmission Solutions Study** – Study done to develop regulated solutions to issues identified in a transmission Needs Assessment of the New England PTF (See Attachment K, Section 4.2[b] of the OATT).
- **Public Policy Transmission Study** – Study done to develop a rough estimate of the cost and benefits of high-level concepts that could meet transmission needs driven by Public Policy Requirements. Later sections of this document do not include specific assumptions for a Public Policy Transmission Study since the scope of the required studies is dependent upon specific and unique Public Policy Requirements (See Attachment K, Section 4A.3 of the OATT).
- **NPCC Area Transmission Review** – Study to assess reliability of the New England BPS (See NPCC Directory #1, Appendix B).
- **Bulk Power System (BPS) Testing** – Study done to determine if Elements should be classified as part of the Bulk Power System (See NPCC Document A-10).
- **Transfer Limit Study** – Study done to determine the range of megawatts (MW) that can be transferred across an interface under a variety of system conditions (See NERC Standard FAC-013).
- **Interregional Study** – Study involving two or more adjacent regions, for example New York ISO and ISO New England (See Section 6.3 of the OATT).
- **Overlapping Impact Study** – Optional study that an Interconnection Customer may select as part of its interconnection studies. This study provides information on the potential upgrades required for the generation project to qualify as a capacity resource in the Forward Capacity Market (FCM) (See Schedule 22, Section 6.2 or 7.3 and Schedule 25, Section 6.2 or 7.3 of the OATT).
- **FCM New Resource Qualification Network Capacity Interconnection Standard Analyses** – Study of the transmission system done to determine a list of potential Element or interface loading problems caused by a resource seeking to obtain a new or increased Capacity Supply Obligation (CSO). This study is

done if an SIS for a generator interconnection is not complete (See ISO New England Planning Procedure No. 10 [PP 10], Section 5.6).

- **FCM New Resource Qualification Overlapping Impact Analyses** – Study of the transmission system done to determine the deliverability of a resource seeking to obtain a new or increased CSO (See PP 10, Section 5.8).
- **FCM Study for Annual Reconfiguration Auctions and Annual CSO Bilaterals** – Study of the transmission system done to determine the reliability impact of a resource seeking to obtain a new or increased CSO (See PP 10, Sections 7 and 8).
- **FCM Delist Analyses** – Study of the transmission system done to determine the reliability impacts of delists (See PP 10, Section 7).
- **Transmission Security Analyses** – Deterministic study done as part of the determination of the capacity requirements of import constrained load zones (See PP 10, Section 6).
- **Non-Commercial Capacity Deferral Notifications** – Study done to determine the reliability impacts of non-commercial capacity deferral notifications (See PP 10, Section 11).

Section 2

Modeling Assumptions

This Section describes the various modeling assumptions that are assembled to create the steady state, short circuit, and transient stability network representations used in system planning analyses.

2.1 Base Case Topology

Base case topology refers to how system Elements are represented and linked together for the year(s) to be studied. System Elements modeled in base cases include, but are not limited to transmission lines, transformers, series and shunt Elements in New England, generators on the New England transmission and distribution systems, merchant transmission facilities in New England, and similar topology for adjacent systems.

There are a number of Tariff and practical considerations that determine the topology used for various types of planning studies. For example, transmission Needs Assessments and Solutions Studies need to include the facilities that have a commitment to be available (e.g., an obligation in the Forward Capacity Market, a reliability upgrade with an approved PPA, or a merchant facility with an approved PPA and an associated binding contract) and need to exclude projects that are not committed to be available. For generation System Impact Studies, the studies need to include all active generators in the FERC section of the ISO interconnection queue that have earlier (higher priority) queue positions.

The starting point for the development of a base case is the ISO's Model on Demand database which includes a model of the external system from the Multiregional Modeling Working Group (MMWG). This Model on Demand data base is used to create the ISO's portion of the MMWG base case. However, the Model on Demand data base is updated periodically to include updates to existing Elements' modeling parameters and inclusion of newly approved projects. Table 2-1 summarizes the topology used in planning studies.

Table 2-1
Base Case Topology

Type of Study	Transmission in New England	Generation in New England	Merchant Facilities	Transmission outside New England	Generation outside New England
PPA Study of Transmission Project (Steady State and Stability)	In-Service, Under Construction, and Planned (1)	In-Service, Under Construction or has an approved PPA (1)(7)	In-Service, Under Construction or has an approved PPA	Models from recent MMWG base case	Models from recent MMWG base case
System Impact Study (Steady State and Stability)	In-Service, Under Construction, and Planned (1)	In-Service, Under Construction, or has an approved PPA or is included in FERC section of the ISO queue (1)(7)	In-Service, Under Construction or has an approved PPA	Models from recent MMWG base case	Models from recent MMWG base case

Type of Study	Transmission in New England	Generation in New England	Merchant Facilities	Transmission outside New England	Generation outside New England
Transmission Needs Assessment (Steady State)	In-Service, Under Construction, Planned, and Proposed (6)	Has a CSO or a binding contract (4)(8)(9)	In-Service, Under Construction, or has an approved PPA; and delivers an import with a CSO or a binding contract (4); and has a certain in-service date (ISD)	Models from recent MMWG base case	Models from recent MMWG base case
Transmission Solutions Study (Steady State and Stability)	In-Service, Under Construction, Planned, and Proposed (6)	Has a CSO or a binding contract (4)(8)(9)	In-Service, Under Construction, or has an approved PPA: and delivers an import with a CSO or a binding contract (4); and has a certain ISD	Models from recent MMWG base case	Models from recent MMWG base case
Area Review Analyses (Steady State and Stability)	In-Service, Under Construction, and Planned	In-Service, Under Construction, or has an approved PPA (9)	In-Service, Under Construction, or has an approved PPA	Models from recent MMWG base case	Models from recent MMWG base case
BPS Testing Analyses (Steady State and Stability)	In-Service, Under Construction, and Planned	In-Service, Under Construction, or has an approved PPA (9)	In-Service, Under Construction, or has an approved PPA	Models from recent MMWG base case	Models from recent MMWG base case
Transfer Limit Studies (Steady State and Stability)	In-Service, Under Construction, and Planned	In-Service, Under Construction or has an approved PPA (9)	In-Service, Under Construction or has an approved PPA	Models from recent MMWG base case	Models from recent MMWG base case
Interregional Studies	In-Service, Under Construction, and Planned (2)	In-Service, Under Construction or has an approved PPA (9)	In-Service, Under Construction or has an approved PPA	Models from recent MMWG base case	Models from recent MMWG base case
FCM New Resource Qualification Overlapping Impact Analyses (3)(5)	In-Service, or Under Construction, Planned, or Proposed with an ISD certified by the PTO	Existing resources and resources that have a CSO	In-Service, Under Construction, Planned, or Proposed with an ISD certified by the Owner	Models from recent MMWG base case	Models from recent MMWG base case and generators which represent flows to/from external areas
FCM New Resource Qualification Network Resource Interconnection Standard Analyses (5)	In-Service or Under Construction, Planned, or Proposed with an ISD certified by the PTO	Existing resources and resources that have a CSO	In-Service, Under Construction, Planned, or Proposed with an ISD certified by the Owner	Models from recent MMWG base case	Models from recent MMWG base case and generators which represent flows to/from external areas

Type of Study	Transmission in New England	Generation in New England	Merchant Facilities	Transmission outside New England	Generation outside New England
FCM Study for Annual Reconfiguration Auctions and Annual CSO Bilaterals (5)	In-Service or Under Construction, Planned, or Proposed with an ISD certified by the PTO	Existing resources and resources that have a CSO	In-Service, Under Construction, Planned, or Proposed with an ISD certified by the Owner	Models from recent MMWG base case	Models from recent MMWG base case and generators which represent flows to/from external areas
FCM Delist Analyses (5)	In-Service or Under Construction, Planned, or Proposed with an ISD certified by the PTO	Existing resources and resources that have a CSO (4)	In-Service, Under Construction, Planned, or Proposed with an ISD certified by the Owner	Models from recent MMWG base case	Models from recent MMWG base case and generators which represent flows to/from external areas
Transmission Security Analyses (5)	In-Service or Under Construction, Planned, or Proposed with an ISD certified by the PTO	Existing resources and resources that have a CSO	In-Service, Under Construction, Planned, or Proposed with an ISD certified by the Owner	N/A	N/A
Non-Commercial Capacity Deferral Notifications (5)	In-Service or Under Construction, Planned, or Proposed with an ISD certified by the PTO	Existing resources and resources that have a CSO (4)	In-Service, Under Construction, Planned, or Proposed with an ISD certified by the Owner	Models from recent MMWG base case	Models from recent MMWG base case and generators which represent flows to/from external areas

- (1) Projects with a nearly completed PPA Study and that have an impact on this study are also considered in the base case. This includes transmission projects and generation interconnections to the PTF or non-PTF transmission system. Also generators without CSOs in the FCM are included in PPA Studies.
- (2) Some interregional studies may include facilities that do not have approved PPAs.
- (3) Base cases for preliminary, non-binding overlapping impact analysis done as part of a generation Feasibility Study or generation System Impact Study are developed with input from the Interconnection Customer.
- (4) Attachment K, Section 4.2, describes that resources that are bound by a state-sponsored RFP or financially binding contract are represented in base cases.
- (5) These studies are described in ISO New England Planning Procedure No. 10 (PP 10), *Planning Procedure to Support the Forward Capacity Market*.
- (6) Sensitivity analysis may also be done to confirm the proposed projects in the study area continue to be needed.
- (7) Generators that have submitted a Non-Price Retirement Request are modeled out of service at the start of the Capacity Commitment Period (CCP) associated with their Non-Price Retirement Request and in subsequent years. Generators that have submitted a Retirement De-List Bid (RDL) are modeled out of service as of the start of the CCP associated with the Forward Capacity Auction (FCA) for which the retirement has been confirmed (such as having cleared in the FCA or having a final price above the FCA starting price) and in subsequent years.

- (8) In transmission Needs Assessments and Solutions Studies, additional generators are often considered unavailable. Generators that have a rejected Permanent De-list bid are considered unavailable (See Attachment K, Section 4.1.c). Also, generators that have an accepted static or dynamic de-list bid for the full resource in the two most recent FCM auctions are considered unavailable. In addition, the ISO may consider generators unavailable because of circumstances such as denial of license extensions or being physically unable to operate.
- (9) Generators that have submitted a Non-Price Retirement Request are modeled out of service at the start of the CCP associated with their Non-Price Retirement Request and in subsequent years. Generators that have submitted a RDL are modeled out of service as of the start of the CCP associated with the FCA for which they have submitted a Retirement De-List Bid and in subsequent years. Generators that have demand bids that cleared in a substitution auction are modeled out of service as of the start of the CCP associated with the substitution auction for which they cleared and in subsequent years.

The base cases used for short circuit analysis originate from the Year N+5 Case that is created as part of the OP-16 Appendix K⁸ process.

2.1.1 Modeling Existing and Proposed Generation

Generating facilities 5 MW and greater are listed in the Forecast Report of Capacity, Energy, Loads, and Transmission (the CELT Report) and are explicitly modeled in planning study base cases. The current exception to this is generators 5 MW and greater that are “behind-the-meter” and do not individually participate in the ISO New England energy market. Some of these generators are netted to load. However, as these generators could have an impact on system performance, future efforts will be made to model these resources in greater detail. The ISO is collecting load flow, stability and short circuit models for generators 5 MW and greater that are new or being modified. Additional models such as PSCAD models are collected as necessary. For example, a PSCAD model is often required for solar and wind generation connecting to the transmission system.

Generators less than 5 MW are modeled explicitly, either as individual units, the equivalent of multiple units, or netted to load. Generators connected to the distribution system are generally modeled at a low voltage bus connected to the transmission system through a load serving transformer.

2.1.2 Base Cases for PPA Studies and System Impact Studies

Similar topology is used in base cases for PPA Studies for transmission projects and System Impact Studies. Both types of studies include projects in the Planned status in their base cases. However, projects with a nearly completed PPA Study and that have an impact on a study area are also considered in the base case.

Schedule 22, Section 2.3, of the OATT states that base cases for generation interconnection Feasibility and System Impact Studies shall include all generation projects and transmission projects, including merchant transmission projects, that are proposed for the New England Transmission System for which a transmission expansion plan has been submitted and approved by the ISO. This provision has been interpreted that a project is approved when it is approved under Section I.3.9 of the Tariff.

⁸ OP-16 Appendix K, https://www.iso-ne.com/static-assets/documents/2015/11/op16k_rto_final.pdf.

Schedule 22, Sections 6.2 and 7.3, of the OATT further state that on the date the Interconnection Study is commenced, the base cases for generation interconnection studies shall also include generators that have a pending earlier-queued Interconnection Request to interconnect to the New England Transmission System or are directly interconnected to the New England Transmission System.

2.1.3 Coordinating Ongoing Studies

At any point in time there are numerous active studies of the New England transmission system. The New England planning process requires study teams to communicate with other study teams to ascertain if the different teams have identified issues which may be addressed, in whole or in part, by a common solution, or if changes to the transmission system are being proposed that might impact their study. It is appropriate for a transmission Needs Assessment, a transmission Solutions Study or a Generator Interconnection Study to consider relevant projects that have nearly completed their PPA analyses.

For example, a study of New Hampshire might consider a 345 kV line from New Hampshire to Boston that is a preferred solution in a Solutions Study of the Boston area, or, when issues in both areas are considered, may suggest a benefit of modifying a solution that has already progressed to the Proposed or the Planned stage.

2.1.4 Base Case Sensitivities

Often in transmission planning studies, there is uncertainty surrounding the inclusion of a resource, a transmission facility, or a large new load in the base case for a study. These uncertainties are handled by doing sensitivity analysis to determine the impact the inclusion or exclusion of a particular resource, transmission project or load has on the study results.

For Needs Assessments and Solution Studies, sensitivity studies may be done to determine the impact of changes that are somewhat likely to occur within the planning horizon and may influence the magnitude of the need or the choice of the solution. Typically, stakeholder input is solicited at Planning Advisory Committee (PAC) meetings in determining the manner in which sensitivity results are factored into studies. Examples are resources that may retire or be added, and transmission projects that may be added, modified, or delayed. Sensitivity analysis usually analyzes a limited number of conditions for a limited number of contingencies.

2.1.5 Modeling Projects with Different In-Service Dates

In some situations it is necessary to do a study where the year of study is earlier than the in-service dates of all the projects that need to be considered in the base case. In such situations it is necessary to also include a year of study that is after the in-service dates of all relevant projects.

As an example, consider two generation projects in the ISO's queue. The first project has queue position 1000 and a Commercial Operation Date of 2018. The second project has queue position 1001 and a Commercial Operation Date of 2015. Schedule 22, Sections 6.2 and 7.3, of the OATT require that the study of the project with queue position 1001 to include the project with queue position 1000. To accomplish this, the study of the project with queue position 1001 would be done with a 2015 base case without the project with queue position 1000 and also with a 2018 base case that includes the project with queue position 1000 and any transmission upgrades associated with queue position 1000.

2.2 System Load

The following section describes the make-up of the load data in the cases provided by the ISO. Appendix J – Load Modeling Guide for ISO New England Network Model provides additional detail on how the load data is developed for the base case.

ISO New England Planning Procedure No. 5-3 (PP 5-3): *Guidelines for Conducting and Evaluating Proposed Plan Application Analyses* states:

“Disturbances are typically studied at peak load levels in steady state analysis since peak load levels usually promote more pronounced thermal and voltage responses within the New England Control Area than at other load levels. However, other load levels may be of interest in a particular analysis and, as appropriate, additional studies are conducted.”

2.2.1 System Load Levels

The following load levels are used in planning studies:

- Peak Load
- Intermediate Load
- Light Load
- Minimum Load

The New England system experiences its peak load in the Summer. When assessing peak load conditions, up to 100% of the projected 90/10 Summer Peak Load for the New England Control Area is modeled. The Intermediate Load, Light Load, and Minimum Load levels were derived from actual measured load, which is total generation plus net flows on external tie lines. These load levels include transmission losses and manufacturing loads. The loads in the base cases provided by the ISO are adjusted to account for these factors. Since actual measured load includes the impacts of distributed resources and distributed generation, no adjustments to the ISO bases cases are needed to address these impacts. The Intermediate Load, Light Load, and Minimum Load will be reviewed periodically and may be adjusted in the future based on actual load levels.

2.2.1.1 Summer Peak Load Level

The Summer Peak Load level represents conditions that can be expected during the highest load levels of the summer season. The Summer Peak Load is classified by the probability of occurrence such as 90/10 or 50/50. The 90/10 Summer Peak Load represents a load level that has a 10% probability of being exceeded due to variations in weather, the 50/50 represents a load level that has a 50% probability of being exceeded.

Summer Peak Load values are obtained from the CELT Report. The exception is for planning studies that go beyond the last year of the CELT Report. For those studies, the percentage of load growth between the last two years of the CELT forecast is used to grow the load to the appropriate year of study. For example, the 2017 CELT report forecasts load until the Summer of 2026. For a study that will model the Summer of 2027, the growth rate between 2025 and 2026 is obtained and multiplied to the 2026 load to derive a 2027 value. See the following equation for details on how to calculate any future year load level beyond the end of the CELT forecast.

$$\text{Year (X + n) Load Level} = \left(\frac{\text{Year X Load Level}}{\text{Year (X - 1) Load Level}} \right)^n \times \text{Year X Load Level}$$

Where X represents the last year of the CELT forecast and n represents the number of years after the last year of the CELT forecast.

The CELT forecast includes losses of about 8% of the total gross load, which is comprised of 2.5% for transmission and large transformer losses, and 5.5% for distribution losses. Thus the amount of customer load served is typically slightly less than the gross forecast. The peak load level is additionally adjusted for modeling of demand resources and behind-the-meter solar PV as discussed in Sections 2.3.11 and 2.3.10 respectively. The target load level for Summer Peak Load is achieved by building a case with a recent CELT forecast and the study year being evaluated.

2.2.1.2 Intermediate (Shoulder) Load Level

The Intermediate Load level, also called the shoulder load level, represents both loads in off peak hours during the Summer and loads during peak hours in the Spring and Fall. The Intermediate Load level was developed by reviewing actual system loads for the three years (2011-2013) and approximating a value system loads were at or below 90% of the time (7,884 hours). The load level analysis used 500 MW increments and the current value was rounded down to account for the anticipated impact of continuing energy efficiency programs. The target load level for non-manufacturing load for Intermediate Load is 17,680 MW. The manufacturing loads are modeled in addition to the non-manufacturing loads (See Section 2.2.3 for more details on non-CELT loads).

2.2.1.3 Light Load Level

The Light Load level was developed by reviewing actual system loads for the last ten years and approximating a value system loads were at or below for 2,000 hours. The load level analysis used 500 MW increments and the current value was rounded down to account for the anticipated impact of continuing energy efficiency programs. The target load level for non-manufacturing load for Light Load is 12,180 MW. The manufacturing loads are modeled in addition to the non-manufacturing loads (See Section 2.2.3 for more details on non-CELT loads).

2.2.1.4 Minimum Load Level

In a similar fashion, the Minimum Load level was developed by reviewing actual minimum system loads, excluding data associated with significant outages such as after a hurricane. The target load level for non-manufacturing load for Minimum Load is 7,680 MW. The manufacturing loads are modeled in addition to the non-manufacturing loads (See Section 2.2.3 for more details on non-CELT loads).

2.2.2 Load Levels Tested

Steady state testing is done at the Summer Peak Load level because equipment ratings are lower in the Summer and loads are generally higher. For the creation of probabilistic base case assumptions, as described in Section 4.1.1, a seasonal cumulative load probability distribution is assembled by averaging the forecasted cumulative load probability distribution for the 17 weeks of the Summer season defined in Section 3.1.3. The underlying data used to arrive at the Summer weekly load probability distributions is identical to the data used to derive the forecasted Summer Peak Load MW values available in the annual CELT report. Probabilistic base cases used in transmission Needs Assessments and Solutions Studies will use the 90/10 Summer Peak Load described in Section 2.2.1.1.

Testing at the Intermediate Load level is typically done to test for the effects running the pumped storage facilities in pumping mode overnight during a heat wave, or high penetration of renewables during the Spring and Fall seasons. Testing at the Minimum Load level is done to test for potential high voltages when line reactive losses may be low and fewer generators are dispatched resulting in lower availability of reactive resources.

Stability testing is always done at the Light Load level to simulate stressed conditions due to lower inertia resulting from fewer generators being dispatched and reduced damping resulting from reduced load. Except where experience has shown it is not necessary, stability testing is also done at peak loads to bound potential operating conditions and test for low voltages.

The load levels generally used in different planning studies are shown in Table 2-2. This list should be used as a guide for typical load levels studied but it is ultimately up to the transmission planner performing the study to determine what is needed for each specific study.

Table 2-2
Typical Load Levels Tested in Planning Studies

Type of Study	Steady State	Stability	Summer	Intermediate	Light	Minimum	Notes
PPA Study of Transmission Project	X		Yes	1	No	2	
		X	Yes	No	Yes	No	
System Impact Study	X		Yes	Yes	3	2	
		X	Yes	No	Yes	No	
Transmission Needs Assessment	X		Yes	1	No	Yes	
		X	Yes	No	Yes	No	
Transmission Solutions Study	X		Yes	1	No	Yes	
		X	Yes	No	Yes	No	
Area Review Analyses	X		Yes	No	No	No	
		X	Yes	No	Yes	No	
BPS Testing Analyses	X		Yes	No	No	No	
		X	Yes	No	Yes	No	
Transfer Limit Studies	X		Yes	4	No	No	
		X	Yes	No	Yes	No	
Interregional Studies	X	X	Yes	No	No	No	
FCM New Resource Qualification Overlapping Impact Analyses	X		Yes	No	No	No	5
FCM New Resource Qualification Network Resource Interconnection Standard Analyses	X		Yes	No	No	No	5
FCM Study for Annual Reconfiguration Auctions and Annual CSO Bilaterals	X		Yes	No	No	No	5,6
FCM Delist Analyses	X		Yes	No	No	No	5
Transmission Security Analyses	X		Yes	No	No	No	5
Non-Commercial Capacity Deferral Notifications	X		Yes	No	No	No	5

- (1) It may be appropriate to explicitly analyze Intermediate Load levels to assess the consequences of generator and transmission maintenance.
- (2) Testing at a Minimum Load level is done for projects that add a significant amount of charging current to the system, or where there is significant generation or other facilities such as conventional HVDC that do not provide voltage regulation.
- (3) Testing at Light Load is done when generation may be limited due to Light Load export limits.

- (4) Critical outages and limiting facilities may sometimes change at load levels other than peak, thereby occasionally requiring transfer limit analysis at Intermediate Load levels.
- (5) These studies are described in PP 10.
- (6) Sensitivity analyses at load levels lower than peak are considered when such lower load levels might result in high voltage conditions, system instability or other unreliable conditions per PP 10.

2.2.3 Non-CELT Loads

The CELT Report is the primary source of assumptions for use in electric planning and reliability studies for the ISO New England Reliability Coordinator area. The CELT includes generators at their net output and customers with behind-the-meter generation at their net load or generation. In many planning studies, this generation is modeled at its gross output. When this is done, it is necessary to add generating station service loads and certain manufacturing loads, predominately mill load in Maine, to the CELT load forecast.

There is about 1,100 MW of this is station service load, however the amount of station service represented will be dependent on the generation that is in service. Station service should be turned off if the generation it is associated with is out of service, with the exception of station service to nuclear plants. Due to the trend of retiring manufacturing load, the amount of manufacturing load that is modeled will be documented in study documents where it is relevant.

Also specific large new loads, such as data centers and large green house facilities, are not generally included in the CELT load forecast, and may be included in the study depending on the degree of certainty that the large new load will come to fruition.

2.2.4 Load Power Factor

The power factor of the load is important in planning studies because it impacts the current flow in each transmission Element. For example, a 100 MW load causes about 500 amps to flow in a 115 kV line if it is at unity power factor and about 560 amps to flow if it is at 0.90 power factor. The larger current flow resulting from a lower power factor causes increased real power and reactive power losses and causes poorer transmission voltages. This may result in the need for replacing transmission Elements to increase their ratings, in the need for additional shunt devices such as capacitors or reactors to control voltages, or in a decreased ability to transfer power from one area to another.

Each Transmission Owner (TO) in New England uses a process that is specific and appropriate to their particular service area to determine the load power factor to be assumed for loads in its service territory. Table 2-3 summarizes the methods used by TOs within the New England Control Area to set the load power factor values to be used in modeling their systems at the 90/10 Summer Peak Load level.

Table 2-3
Load Power Factor Assumptions

Transmission Owner	Base Modeling Assumption
Avangrid (Maine)	Historical metered PF values (Long-term studies use 0.955 lagging)
Avangrid (SWCT)	0.995 lagging PF at Distribution Bus
Emera Maine	Uses Historical Power Factor (PF) values
Eversource (Boston)	Individual Station 3 Year Average PF at Distribution Bus
Eversource (Cape Cod)	0.985 lagging PF at Distribution Bus
Eversource (CT, NH, WMA)	0.990 lagging PF at Distribution Bus
Municipal Utilities	Uses Historical PF values
National Grid	1.00 PF at Distribution Bus
VELCO	Historical PF at Distribution Bus provided by Distribution Companies

The power factor assumptions are also used in Intermediate Load and Light Load cases. The power factor at the Minimum Load level is set at 0.998 leading at the distribution bus for all scaling load in New England with the exception of:

1. Downtown Boston load served by Eversource is set to a power factor of 0.978 lagging at the distribution bus.
2. Suburban Boston load served by Eversource is set to a power factor of 1.00 at the distribution bus.

The non-scaling load includes mill loads in Maine, Massachusetts Bay Transportation Authority (MBTA) loads in Boston, railroad loads in Connecticut, and other similar loads.

ISO New England Operating Procedure No. 17 (OP 17), *Load Power Factor Correction*, discusses load power factor in more detail and describes the annual survey done to measure compliance with acceptable load power factors.

2.2.5 Load Models

2.2.5.1 Steady State

In steady state studies, loads are modeled as constant MVA loads, comprised of active (real) P and reactive (imaginary) Q loads. The distributions of Transmission Owners' loads are based on historical and projected data at individual buses, modeling equivalent loads that represent line or transformer flows. These loads may be modeled at distribution, sub-transmission, or transmission voltages.

2.2.5.2 Transient Stability

Loads (including generator station service) are assumed to be uniformly modeled as constant impedances throughout New England and New York. The constant impedances are calculated using the P and Q values of the load. This representation is based on extensive simulation testing using various load models to derive the appropriate model from an angular stability point of view, as

described in the 1981 New England Power Pool (NEPOOL) report, *Effect of Various Load Models on System Transient Response*.

For under frequency load shedding analysis, other load models are sometimes used, such as either a polynomial combination of constant impedance, constant current and constant load; or a complex load model, including modeling of motors. The alternate modeling is based on the end use composition of the load. Voltage stability analysis is sometimes done using a complex load model, including modeling of motors.

2.3 System Resources

2.3.1 Generator Maximum Power Rating Types

Within New England, a number of different real power (MW) ratings for generators connected to the grid are published. Examples of the different generator ratings are summarized in Table 2-4. The detailed definitions of these ratings are included in Appendix A – Terms and Definitions. Capacity Network Resource Capability (CNRC) and Network Resource Capability (NRC) values for New England generators are published each year in the CELT Report.⁹ Qualified Capacity (QC) values are calculated based on recently demonstrated capability for each generator. The Capacity Supply Obligation value and QC values are published for each Forward Capacity Auction in the informational results filings to FERC.¹⁰

Table 2-4
Generator Real Power Ratings

Generator Maximum Value Type	Description
Capacity Network Resource Capability – Summer (CNRC Sum) (Maximum output at or above 90° F)	CNRC Summer is the maximum amount of capacity that a generator has interconnection rights to provide in Summer. It is measured as the net output at the Point of Interconnection and cannot exceed the generator's maximum output at or above 90° F.
Capacity Network Resource Capability – Winter (CNRC Win) (Maximum output at or above 20° F)	CNRC Winter is the maximum amount of capacity that a generator has interconnection rights to provide in Winter. It is measured as the net output at the Point of Interconnection and cannot exceed the generator's maximum output at or above 20° F.
Capacity Supply Obligation (CSO)	A requirement of a resource to supply capacity. This requirement can vary over time based on the resource's participation in the Forward Capacity Market.
Network Resource Capability – Summer (NRC Sum) (Maximum output at or above 50° F)	NRC Summer is the maximum amount of electrical output that a generator has interconnection rights to provide in Summer. It is measured as the net output at the Point of Interconnection and cannot exceed the generator's maximum output at or above 50° F.
Network Resource Capability – Winter (NRC Win) (Maximum output at or above 0° F)	NRC Winter is the maximum amount of electrical output that a generator has interconnection rights to provide in Winter. It is measured as the net output at the Point of Interconnection and cannot exceed the generator's maximum output at or above 0° F.

⁹ <http://www.iso-ne.com/trans/celt/index.html>

¹⁰ <http://www.iso-ne.com/regulatory/ferc/filings/index.html>

Generator Maximum Value Type	Description
Qualified Capacity (QC)	QC is the amount of capacity a resource may provide in the Summer or Winter in a Capacity Commitment Period, as determined in the Forward Capacity Market qualification processes.

2.3.2 Generator Models

In New England planning studies, except for the FCM studies, generators connected to the transmission system are generally modeled as a generator with its gross output, its station service load, and its generator step-up transformer (GSU). In FCM studies, except for Network Capacity Interconnection Standard studies, generation is generally modeled net of station service load at the low voltage side of the GSU and station service load is set to zero. This is done because the CSO, QC, and CNRC values are net values. One exception is made in FCM-related studies for nuclear resources, where the generator is modeled at its gross output, in order to capture the need to maintain supply to the generator's station service load if the generator is out of service.

Another exception is generating facilities composed of multiple smaller generators such as wind farms, solar PV, and small hydro units. These facilities are often modeled as a single equivalent generator on the low voltage side of the transformer that interconnects the facility with the transmission system.

The ratings and impedances for an existing GSU are documented on the NX-9 form for that transformer. The existing generator's station service load is documented on the NX-12 form for that generator. Similar data is available from the Interconnection Requests for proposed generators. The generator's gross output is calculated by adding its appropriate net output to its station service load associated with that net output. GSU losses are generally ignored in calculating the gross output of a generator. This data is used by the ISO to help create the base cases for planning studies.

In New England planning studies, generators connected to the distribution system are generally modeled as connected to a low voltage bus that is connected to a transformer that steps up to transmission voltage or netted to distribution load. Multiple generators connected to the same low voltage bus may be modeled individually or as an equivalent generator.

2.3.3 Maximum Real Power Ratings

Different types of studies are conducted to achieve different transmission planning objectives. Therefore, it is necessary to consider the different range of anticipated generator capabilities which are appropriate to the objectives of study and the specific conditions which are being examined.

The following table lists the maximum generation levels generally used in different planning studies. Generators, when dispatched, are usually dispatched up to their maximum output in a study. Generators such as wind (Section 2.3.7), hydro (Sections 2.3.8 and 2.3.9), and solar PV (Section 2.3.10) may have a de-rated output below their maximum power rating based on reasons as described in later sections of this guide.

Table 2-5
Generator Maximum Power Ratings in Planning Studies

Type of Study	Steady State	Stability	Conventional Generation	Fast Start Generation	Hydro (1) Generation	Wind Generation	Solar (2) Generation
PPA Study of Transmission Project	X	X	NRC Sum NRC Win	NRC Sum NRC Win	NRC Sum NRC Win	NRC Sum NRC Win	NRC Sum NRC Win
System Impact Study	X	X	NRC Sum NRC Win	NRC Sum NRC Win	NRC Sum NRC Win	NRC Sum NRC Win	NRC Sum NRC Win
Transmission Needs Assessment	X		QC Sum	QC Sum	Historical Level	5% of nameplate for on-shore wind (3)	QC Sum
Transmission Solutions Study	X		QC Sum	QC Sum	Historical Level	5% of nameplate for on-shore wind (3)	QC Sum
Transmission Solutions Study		X	NRC Win	NRC Win	NRC Win	NRC Win	NRC Win
Area Review Analyses	X	X	NRC Sum NRC Win	NRC Sum NRC Win	NRC Sum NRC Win	NRC Sum NRC Win	NRC Sum NRC Win
BPS Testing Analyses	X	X	NRC Sum NRC Win	NRC Sum NRC Win	NRC Sum NRC Win	NRC Sum NRC Win	NRC Sum NRC Win
Transfer Limit Studies	X	X	NRC Sum NRC Win	NRC Sum NRC Win	NRC Sum NRC Win	NRC Sum NRC Win	NRC Sum NRC Win
Interregional Studies	X	X	NRC Sum	NRC Sum	NRC Sum	NRC Sum	NRC Sum
FCM New Resource Qualification Overlapping Impact Analyses	X		CNRC Sum	CNRC Sum	CNRC Sum	CNRC Sum	CNRC Sum
FCM New Resource Qualification Network Resource Interconnection Standard Analyses	X		NRC Sum	NRC Sum	NRC Sum	NRC Sum	NRC Sum
FCM Study for Annual Reconfiguration Auctions and Annual CSO Bilaterals	X		Lower of QC Sum or CSO	Lower of QC Sum or CSO	Lower of QC Sum or CSO	Lower of QC Sum or CSO	Lower of QC Sum or CSO
FCM Delist Analyses	X		QC Sum	QC Sum	QC Sum	QC Sum	QC Sum
Transmission Security Analyses	X		QC Sum	QC Sum	QC Sum	QC Sum	QC Sum
Non-Commercial Capacity Deferral Notifications	X		Lower of QC Sum or CSO	Lower of QC Sum or CSO	Lower of QC Sum or CSO	Lower of QC Sum or CSO	Lower of QC Sum or CSO

- (1) Table lists treatment on conventional hydro. The treatment of pumped storage hydro is described in Section 2.3.9.
- (2) Table lists treatment of solar generation 5 MW or greater that is in the ISO system model. See Section 2.3.10 for a complete description of treatment of solar generation.
- (3) 20% of the nameplate for off-shore wind.

Further explanations of the decision to apply a certain maximum power rating for different types of system planning studies are described in the following subsections.

2.3.3.1 Transmission Steady State Needs Assessments and Solutions Studies

The Summer Qualified Capacity value is used to represent a machine's maximum real power output (MW) for all load levels studied except for Light Load (when applicable) and Minimum Load Studies. QC is used in these studies because QC represents the recently demonstrated capability of the generation. The QC value is the maximum Capacity Supply Obligation that a resource may obtain in the Forward Capacity Market. Any requested reduction in obligation from a resource's QC is subject to a reliability review and may be rejected for reliability reasons. The Capacity Network Resource Capability acts as an approved interconnection capability cap within the Forward Capacity Market that limits how much a resource could increase its QC without an Interconnection Request. In other words, QC cannot exceed CNRC. Because QC corresponds to the recently demonstrated capability, as opposed to CNRC which is the upper limit of the capacity capability of a resource, using QC instead of CNRC does not overstate the amount of capacity that could potentially be obligated to provide capacity to the system.

For reliability analysis conducted at Light Load and Minimum Load levels, the generator's Summer NRC value (maximum MW output at or above 50° F) is used. Some generators have higher individual resource capabilities at 50° F ratings compared with 90° F. Therefore, using 50° F ratings allows a smaller number of resources to be online to serve load. The fewer the number of resources online, the less overall reactive capability on the system to mitigate high voltage concerns. This value is also consistent with the expected ratings of machines at the temperatures that are typically experienced during lighter load periods in the Summer rating period.

2.3.3.2 Other Transmission Planning Steady State Studies

The generator's Summer NRC value is used to represent a machine's maximum real power output (MW) for all load levels. For generator System Impact Studies, using this value ensures that studies match up with the level of service being provided. Studying Elective Transmission Upgrades and transmission projects with machines at these ratings also ensures equal treatment when trying to determine the adverse impact to the system due to a project.

2.3.3.3 Other Transmission Planning Transient Stability Studies

The generator's Winter NRC value is used to represent a machine's maximum real power output (MW) for all load levels in all stability studies. Using the Winter NRC values ensures that stressed dispatches (in terms of limited inertia on the system and internal generator rotor angles) are studied and addressed, therefore ensuring reliable operation of the system in real time. This operability is required because real-time power system analysis is unable to identify stability concerns or determine stability limits that may exist on the system. These limits are determined in offline operational studies performed in a manner that ensures that they are applicable over a wide range of system conditions, including various ambient temperatures and load levels.

2.3.3.4 Forward Capacity Market Studies

The generator's Summer CNRC value is used to represent a machine's maximum real power output (MW) for FCM New Resource Qualification Overlapping Impact Analyses. This output represents the level of interconnection service that a generator has obtained for providing capacity.

The generator's Summer NRC value is used to represent a machine's maximum real power output (MW) for FCM New Resource Qualification NCIS Analyses. This output represents the level of interconnection service that a generator has obtained for providing energy.

The generator's Summer QC value is used to represent a machine's maximum real power output (MW) for FCM Delist Analyses and Transmission Security Analyses. This output represents the expected output of a generator during Summer peak periods.

The lower of a generator's Summer QC value or Summer Capacity Supply Obligation is used to represent a machine's maximum real power output (MW) for FCM Study for Annual Reconfiguration Auctions and Annual CSO Bilaterals and the Non-Commercial Capacity Deferral Notifications. This output represents the expected capacity capability of a generator during Summer peak periods.

2.3.4 Reactive Power Ratings

This section is under development.

2.3.5 Generator Unavailability Probability

For the creation of probabilistic base case generation dispatches, as described in Section 4.1.1, a cumulative probability distribution for generation unavailability is created using outage rates based on historical generation availability. The outage rate of non-renewable¹¹ resources is their historical five year average Equivalent Forced Outage Rate on demand (EFORD). The outage rate of future non-renewable resources is the NERC class average EFORD value of each resource's respective unit type and size. Resources such as hydro, wind, and solar PV, are modeled in the base cases with a de-rated output, as described in Sections 2.3.8, 2.3.7, and 2.3.10 respectively. Since the output of these resources is already reduced to represent their expected output at the peak hour, they are assigned an outage rate of 0% (meaning their de-rated MW amount is considered 100% available) in the creation of the cumulative probability distribution for generation unavailability. A summary of the outage rate values used for each type of resource is shown in Table 2-6.

Table 2-6
Resources Outage Rate Values in the Probabilistic Base Case Development

Resource Type	Existing	Future	Notes
Conventional Generation	5yr Avg (if known) NERC Class Avg (if unknown)	NERC Class Avg	1
Wind	De-rated Output	De-rated Output	
Hydro Generation	De-rated Output	De-rated Output	
Solar Photovoltaic	De-rated Output	De-rated Output	
Waste (Municipal Solid and Wood)	5yr Avg (if known) NERC Class Avg (if unknown)	NERC Class Avg	1

- (1) In some instances, a resource's five-year average EFORD reflects the past occurrence of a long-term atypical outage that has a low probability of reoccurrence. In these cases, the EFORD values for these units may be replaced by their average EFORD without the atypical event. This will prevent overstating the amount of unavailable resources in a given Study Area for an event that has a low probability of reoccurrence.

¹¹ For the purposes of this Technical Guide, the term 'non-renewable' refers to generation that is not wind, hydro (run-of-river and pumped storage), and solar photovoltaic.

2.3.6 Combined Cycle Generation

For the purposes of modeling generating units in a base case and in generator contingencies, all generators of a combined cycle unit are considered to be in service at the same time or out of service together. The basis for this assumption is that many of the combustion and steam generators that make up combined cycle units cannot operate independently because they share a common shaft, they have air permit or cooling restrictions, or they do not have a separate source of steam. Other combined cycle units share a GSU or other interconnection facilities such that a fault on those facilities causes the outage of the entire facility. The ISO's operating history with combined cycle units has shown that even for units that claim to be able to operate in modes where one portion of the facility is out of service, they rarely operate in this partial mode.

2.3.7 Wind Generation

Studies of wind generation in New England reveal that the output of on-shore (land-based) wind generation can be very low during Summer peak load hours.¹² In general, when it is needed to support area transmission requirements, on-shore wind generation is modeled at 5% of nameplate and off-shore wind is modeled at 20% of nameplate for transmission Needs Assessment and Solutions Studies. If a wind farm's Qualified Capacity is lower than the above value, the Qualified Capacity will be used in transmission Needs Assessments and Solutions Studies.

The above percentages are estimates of the level of wind generation output that can be counted on during Summer peak for reliability analysis. To ensure that the interconnection rights of wind resources are preserved, wind generation is modeled at its NRC value in PPA studies.

2.3.8 Conventional Hydro Generation

There are two classifications of conventional hydro, those hydro facilities that have no control over water flow, for example no capability to store water, and those hydro facilities that can control water flow, for example those facilities with a reservoir or river bed that can store water. For the purpose of planning studies, hydro facilities, listed as "hydro (weekly cycle)" or "hydro (daily cycle-pondage)" in the CELT report, are considered to be able to control water flow. Hydro facilities listed as "hydro (daily cycle-run of river)" in the CELT report, are assumed to have no ability to control water flow and are classified as intermittent resources. Hydro facilities that can control water flow are classified as non-intermittent resources. For both classifications the output of the hydro generation is set at its historic capability that can be relied on for reliability purposes or at 10% of nameplate, which is an estimate of that historic capability, in the base cases for transmission Needs Assessments and Solutions Studies. Post contingency, conventional hydro that has the capability to control water flow and has sufficient water storage capability is dispatched up to 100% of its nameplate to relieve criteria violations in transmission Needs Assessments and Solutions Studies. Hydro facilities that have no control over water flow or limited water storage capability are dispatched at the same output pre and post contingency.

2.3.9 Pumped Storage Hydro Generation

There are three pumped storage hydro plants connected to the New England transmission system: Northfield Mountain and J. Cockwell (also known as Bear Swamp) in Massachusetts and Rocky River in Connecticut. Records indicate that these facilities historically have had limited stored energy during prolonged heat waves because limited time and resources are available to allow

¹² This was discussed at the Planning Advisory Committee meetings on September 21, 2011 and October 22, 2014.
https://www.iso-ne.com/static-assets/documents/2014/10/a7_transmission_planning_assumptions_wind_generation.pdf

these units to refill their reservoirs during off-peak periods. Additionally J. Cockwell and Northfield are often used to provide reserve capacity. Based on this, the following generation levels are generally used in transmission Needs Assessments and Solutions Studies.

Table 2-7
Pumped Storage Hydro Generation Levels

Pumped Storage Facility	MW Output
J. Cockwell (Bear Swamp)	50% of Summer QC
Northfield Mountain	50% of Summer QC
Rocky River	Treated as conventional hydro with ponding capability

In transmission Needs Assessments and Solutions Studies addressing the area that includes a pumped storage hydro facility, the facility(ies) in that area may also be dispatched at their maximum and/or minimum values to ensure that they can be utilized to serve load when they are available since they are often utilized in operations to provide reserve. In PPA studies, pumped storage-hydro plants are dispatched at their full output when necessary to show that their ability to supply load is maintained.

2.3.10 Solar Photovoltaic Generation

Solar photovoltaic (solar PV) generation will be represented in the power flow base cases that are provided by the ISO. ISO New England includes a solar PV forecast in the CELT Report. The CELT Report provides a forecast of the installed AC nameplate of solar PV at the end of each year and a table that lists the monthly growth of solar PV. Long-term planning studies will use the PV forecast for the end of the year prior to that being evaluated plus the expected growth of PV through the end of May for the year being evaluated. As an example for a study in the year 2025, all the PV as of end of 2024 plus the expected growth of PV through May 2025 will be modeled.

As a part of the solar PV forecast, the data on solar PV is divided into the following three mutually exclusive groups:

- Group 1: Solar PV as a capacity resource in the Forward Capacity Market (FCM)
 - Qualified for the FCM
 - Have Capacity Supply Obligations
 - Size and location identified and visible to the ISO
 - May be supply or demand side resources
- Group 2: Non-FCM Settlement Only Resources (SOR) and Generators (per OP 14)
 - ISO collects energy output
 - Participate only in the energy market
- Group 3: Behind-the-Meter (BTM) Solar PV
 - Reduces system load
 - ISO has an incomplete set of information on generator characteristics
 - ISO does not collect energy meter data, but can estimate it using other available data
 - ISO calculates its value based on the difference between the total solar PV forecast and those resources that are in Groups 1 and 2.

For long-term transmission planning studies including generator interconnection studies, the solar PV will be modeled in the base cases to account for all three groups. See Section 6 of Appendix J – Load Modeling Guide for ISO New England Network Model for more details on how solar PV is modeled in the base cases.

The solar PV forecast is only on a state-wide basis. However, within a state, the solar PV does not grow uniformly, with some areas in the state having larger amounts of solar PV. To account for this locational variation of solar PV, the locational data of existing solar PV that is in service as of the end of the previous year is utilized to obtain the percentage of solar PV that is in each Dispatch Zone. The New England Control Area is divided into 19 Dispatch Zones and the percentage of solar PV in each Dispatch Zone as a percentage of total solar PV in the state is available. This percentage is assumed to stay constant for future years to allocate future solar PV to the Dispatch Zones. The percentage of existing solar PV in each Dispatch Zone as of the end of each year that is used as a part of the solar PV forecast is based on Distribution Owner interconnection data.¹³

As an example, if the SEMA Dispatch Zone accounts for 20% of existing solar PV in Massachusetts, it will be assumed that 20% of any growth in solar PV as a part of the forecast will be in SEMA.

Once we have the solar PV data by Dispatch Zone, the solar PV within the Dispatch Zone falls into three categories:

- Category 1: Facilities greater than or equal to 5 MW
 - Locational data available
 - Will be modeled as aggregate generation representing the facility
- Category 2: Facilities greater than 1 MW¹⁴ and less than 5 MW
 - Locational data available through the PPA notifications¹⁵
 - Will be modeled as a single aggregate injections at specific locations (Negative loads similar to DR – See Section 2.3.11 for details)
- Category 3: Existing facilities less than or equal to 1 MW and all future forecasted solar PV for which locational information is not available
 - No locational data available
 - Category 3 = Forecast – Category 1 – Category 2
 - Will be modeled by spreading the MWs across the Dispatch Zone (Negative loads spread across the Dispatch Zone similar to how ADCR is spread)

2.3.10.1 Load Levels Modeled

For Intermediate, Light, and Minimum Load levels, the ISO uses fixed load levels for studies based on historic data, which already includes the impacts of solar PV. Hence, no solar PV in Category 2 or 3 will be explicitly modeled in Intermediate, Light, and Minimum Load cases. Solar PV under Category 1 will be modeled in all the cases. The specific output of the facility will vary dependent on the type of study.

During Winter season, peak conditions are expected after sunset, and hence no solar PV in Category 2 or 3 will be modeled for Winter Peak Load cases. The only case where solar PV under Category 2 and 3 will be explicitly modeled is for Summer Peak Load conditions.

Solar PV under Category 1 will be modeled in all the cases. The specific output of the unit will vary dependent on the study.

¹³ <https://www.iso-ne.com/system-planning/system-forecasting/distributed-generation-forecast>

¹⁴ There are instances of 1.0 MW facilities submitting PPA notifications even though they are not required to. Any facility that has notified the RC will be counted as a Category 2 facility.

¹⁵ <https://www.iso-ne.com/system-planning/transmission-planning/proposed-plan-applications>

2.3.10.2 Adjustment for Losses

For solar PV in Categories 2 and 3, an adjustment to the AC nameplate will need to be made to account for avoided losses on the distribution system. Currently, the ISO assumption for distribution losses as a percentage of load is 5.5%. Hence the negative loads will be the AC nameplate solar PV injection at the bus on the low-side of the distribution transformer plus 5.5% to account for avoided distribution losses.

2.3.10.3 Availability in Transmission Planning

Based on a review of historic solar PV outputs, the ISO has determined a 26% availability factor to be appropriate for transmission planning studies. The 26% level represents the output of solar PV during the Summer Peak Load period between 4 p.m. and 6 p.m. in the Summer. This is the time period when solar output begins to decrease due the angle of the sun and when loads are still at or near their peak levels.

The solar PV in Categories 2 and 3 will be assumed to be at 26% output for transmission Needs Assessments and Solutions Studies. For transmission PPA studies and generation System Impact Studies, the solar PV in Category 2 and 3 may be assumed to be up to 100% available.

For transmission Needs Assessments and Solutions Studies the Category 1 solar PV will be modeled at 26% of their nameplate rating (50° F rating) for Summer Peak Load studies. For all other load levels, the Category 1 solar PV facilities will be modeled based on the study specific requirements. For transmission PPA studies and generation System Impact Studies, the Category 1 solar PV will be treated consistent with the treatment of conventional generators.

2.3.10.4 Modeling in FCM Studies

Solar PV that has qualified in FCM will be treated consistent with the treatment of other intermittent generators that have qualified in FCM. Non-FCM solar PV that is participating in the ISO energy market will not be included in FCM studies because they have no obligation to generate. Behind-the-meter solar PV will be modeled at a level based on the estimated median of its net output during the defined Intermittent Reliability Hours.

2.3.10.5 Forecasting Beyond the Forecast Horizon

Occasionally, transmission planning studies have to look beyond the 10 year solar PV forecast horizon. For these cases, the growth of the solar PV forecast from Year 9 to Year 10 will be used to obtain the Year 11 forecast. This process will be repeated to obtain Year 12 forecast from Year 11 forecast and Year 10 forecast and so on. This is the same methodology that is used to scale the Summer Peak Load past the forecast horizon (See Section 2.2.1.1 for details).

2.3.10.6 Impacts on Load Power Factor

Solar PV will be represented in Summer Peak Load cases such that it does not affect the net power factor of the load. It is assumed that distribution companies will adjust their power factor correction programs to account for solar PV. At Summer Peak Load levels, solar PV generally should reduce distribution VAR losses, therefore modeling solar power such that it does not impact net load power factor should be a slightly conservative approach. If no load is present at the bus, then a 1.0 unity power factor will be assumed.

2.3.11 Demand Resources

Beginning June 1, 2018, certain resources, formerly classified as Demand Resources are allowed to participate in the ISO New England markets as energy-only resources. The change results in new terms that will be used to represent energy-only versus capacity resources. In this document the undefined term, demand resources (DR), will be used generically to generally mean demand-side resources while the proper terms will be referred to where appropriate.

Through the Forward Capacity Market, Demand Capacity Resources (DCR) can be procured to provide capacity and have future commitments similar to that of a generation resource. There are currently two categories of DCR in the FCM: passive Demand Capacity Resources (passive DCR) and Active Demand Capacity Resources (ADCR). Passive DCR consists of two types of resources: On-Peak Demand Resources and Seasonal Peak Demand Resources. ADCR consists of Demand Response Resources that reduce load based on ISO instructions under real-time system conditions. Demand Response Resources must be associated with an ADCR in order to be considered as a capacity resource in the FCM.

2.3.11.1 Energy Efficiency beyond FCM Horizon

In addition to the demand resources mentioned above that are procured through the FCM, the ISO forecasts Energy Efficiency as a part of the annual CELT forecast. This energy efficiency is a form of passive DR but is treated separately as it is forecasted beyond the FCM horizon. This demand resource is included for studies that analyze time periods beyond the FCM horizon.

2.3.11.2 Modeling Demand Resources

The modeling of demand resources in planning studies varies with the type of study and the load level being studied. Demand resources and their modeling are described fully in Appendix C – Guidelines for Treatment of Demand Resources in System Planning Analysis.

Demand resources will not be modeled explicitly in the Intermediate, Light, and Minimum Load level cases because the impact of demand resources was included in the actual measured load used to establish the fixed load levels (see Section 2.2.1).

2.3.12 Behind-the-Meter Mill Generation

Several industrial mill facilities in Maine have on-site generation that reduces their net load as experienced by the transmission system. This behind-the-meter generation is explicitly modeled in the ISO base case to account for a sudden load increase following the loss of this generation in steady state and transient stability analyses. Each industrial facility has a contractual load limit with the interconnecting transmission owner. For transmission planning studies, the entire facility is modeled such that if the largest generator is lost, the net flow into the facility would be at the contractual limit. See Section 2.2.3 for a description of the manufacturing load.

2.4 Phase Shifting Transformers

A summary of each phase shifting transformer (PST) also known as phase angle regulators (PAR) in New England is described in this section (See Appendix G – Phase Shifting Transformers Modeling Guide for ISO New England Network Model for a detailed description of each PST's operation.) Modeling of phase shifting transformers in steady state power flow studies is also addressed in Section 2.11.2.

PSTs are used by system operators in the following locations within New England to control active (real) power flows on the transmission system within operating limits.

- **Saco Valley / Y138 Phase Shifter** – It is located along the New Hampshire – Maine border, and is used to control power flow along the 115 kV Y138 line into central New Hampshire.
- **Sandbar Phase Shifter** – It is located along the Vermont – New York border, and is used to control power flow along the 115 kV PV-20 line into the northwest Vermont load pocket from northeast New York.
- **Blissville Phase Shifter** – It is located along the Vermont – New York border, and is mainly used to prevent overloads on the New York side by controlling power flow on the 115 kV K7 line.
- **Granite Phase Shifters** – They are located in Vermont and are mainly used to control power flow on the 230 kV F206 line between New Hampshire and Vermont
- **Waltham Phase Shifters** – They are located in the Boston, Massachusetts area. They are adjusted manually to regulate the amount of flow into and through Boston on the 115 kV 282-520 and 282-521 lines.
- **Baker Street Phase Shifters** – They are located in the Boston, Massachusetts area. They are adjusted manually to regulate the amount of power flow into and through Boston on the 115 kV 110-510 and 110-511 lines.
- **Northport/Norwalk Harbor Cable (NNC) Phase Shifter** – It is located at the Northport 138 kV station in New York (controlled by Long Island Power Authority outside of ISO New England's control) and is used to control the power flow on the 138 kV Norwalk Harbor – Northport 601, 602, and 603 submarine cables.

2.5 Load Tap Changing Transformers

Many transformers connected to the New England transmission system have the capability of automatic load tap changing. This allows the transformer to automatically adjust the turns' ratio of its windings to control the voltage on the regulated side of the transformer. In transmission planning studies, load tap changers are allowed to operate when determining the system voltages and power flows after a contingency.

Modeling the operation of load tap changers on transformers that connect load to the transmission system generally produces conservative results because raising the voltage on the distribution system will reduce the voltage on the transmission system. Operation of load taps changers on autotransformers raises the voltage on the lower voltage transmission system (typically 115 kV) and reduces the voltage on the higher voltage transmission system (typically 230 kV or 345 kV).

In areas of the transmission system where there are known voltage concerns that occur prior to load tap changer operation, it is necessary to do sensitivity testing to determine if voltage criteria violations occur prior to load tap changer operation. This is further discussed in the voltage criteria (See Section 3.1.2.2). Modeling of transformer load tap changers in steady state power flow studies is also addressed in Section 2.11.2.

2.6 Static Compensation Devices

2.6.1 Series Devices

2.6.1.1 Reactors

Series reactors serve many purposes on the New England transmission system. Some of these are permanently in service to limit short circuit duty, others may be switched to control flows on

specific transmission Elements. Table 2-8 lists these devices and briefly describes their purpose and operation in planning studies.

Table 2-8
Series Reactors Modeled in Planning Studies

Line	Station	State	kV	Ohms	Normal Operation	Purpose
1322	Breckwood	MA	115	5.55	Out of Service (By-passed)	Inserted to limit short circuit duty at Breckwood when 1T circuit breaker is closed
1556	Cadwell	MA	115	3.97	In Service	Limits short circuit duty at 115 kV East Springfield substation, not to be switched in planning studies
1645	Cadwell	MA	115	3.97	In Service	Limits short circuit duty at 115 kV East Springfield substation, not to be switched in planning studies
1497	East Devon	CT	115	1.32	In Service	Limits short circuit duty on 115 kV system, not to be switched in planning studies
1776	East Devon	CT	115	1.32	In Service	Limits fault duty on 115 kV systems, not to be switched in planning studies
F162	Greggs	NH	115	10.0	Out of Service (By-passed)	Controls flows on the 115 kV system, can be switched in to mitigate thermal overloads
1222	Hawthorne	CT	115	5.00	Out of Service (By-passed)	Controls flows on the 115 kV system, can be switched in to mitigate thermal overloads
1610	Mix Avenue	CT	115	7.50	In Service	Control flows on the 115 kV system and will normally be operated in service
1784	North Bloomfield	CT	115	2.65	In Service	Controls flows on the 115 kV system, can be by-passed to mitigate thermal overloads
329-530	North Cambridge	MA	115	2.75	In Service	Limit flows and short circuit duty on 115 kV cables, not to be switched in planning studies
329-531	North Cambridge	MA	115	2.75	In Service	Limit flows and short circuit duty on 115 kV cables, not to be switched in planning studies
1637	Norwalk	CT	115	5.00	Out of Service (By-passed)	Controls flows on the 115 kV system, can be switched in to mitigate thermal overloads
115-10-16	Potter	MA	115	3.00	In Service	Limit flows on 115 kV cables, not to be switched in planning studies
PV-20	Sandbar	VT	115	30.0	Out of Service (By-passed)	Sandbar Overload Mitigation Reactor – Controls flows on the 115 kV system, can be switched in to mitigate thermal overloads
1910 (Existing)	Southington	CT	115	3.97	In Service	Controls flows on the 115 kV system, can be by-passed to mitigate thermal overloads. Size will be increased as a result of GHCC study.
1910 (Future 12/2017)	Southington	CT	115	6.61	In Service	Controls flows on the 115 kV system, can be by-passed to mitigate thermal overloads.
1950 (Existing)	Southington	CT	115	3.97	In Service	Controls flows on the 115 kV system, can be by-passed to mitigate thermal overloads. Size will be increased as a result of GHCC study.
1950 (Future 12/2017)	Southington	CT	115	6.61	In Service	Controls flows on the 115 kV system, can be by-passed to mitigate thermal overloads.
211-514	Woburn	MA	115	2.75	In Service	Limit flows and short circuit duty on 115 kV cables, not to be switched in planning studies
1346 (Future 12/2018)	Southwest Hartford	CT	115	2.65	In Service	Controls flows on the 115 kV system, can be by-passed to mitigate thermal overloads
1704 (Future 12/2018)	Southwest Hartford	CT	115	3.97	In Service	Controls flows on the 115 kV system, can be by-passed to mitigate thermal overloads

Line	Station	State	kV	Ohms	Normal Operation	Purpose
Southington Bus 1 to 2 Tie (Future 6/2018)	Southington	CT	115	3%	In Service	Limit flows and short circuit duty on 115 kV, not to be switched in planning studies

2.6.1.2 Capacitors

This section is under development.

2.6.2 Shunt Devices

In transmission planning studies, switchable shunt devices are allowed to operate when determining the voltages and flows after a contingency.

In areas of the transmission system where there are known high or low voltage concerns that occur prior to operation of switchable shunt devices, it is necessary to do testing to determine if voltage criteria violations occur prior to operation of switchable shunt devices. This is further discussed in the voltage criteria Section 3.1.2.

Modeling of switchable shunt devices in power flow studies is also addressed in Section 2.11.4.

2.7 Dynamic Compensation Devices

This section is under development.

2.8 Interface Transfer Levels

Reliability studies begin with development of system models which must include definition of the initial or base conditions that are assumed to exist in the study area over the study horizon. These assumed initial conditions must be based on requirements as described within the applicable reliability standards and criteria as well as supplemental information that describe system operating conditions likely to exist.

2.8.1 Methodology to Determine Transfer Limits

In accordance with NERC standard FAC-013, *Assessment of Transfer Capability for the Near-Term Transmission Planning Horizon*, the ISO documented the methodology used to determine transfer limits. This document is included as Appendix I – Methodology Document for the Assessment of Transfer Capability.

2.8.2 System Conditions

NPCC Directory #1 (Section 3.0, R7.1) requires planning entities include modeling of conditions that “stress” the system when conducting reliability assessments:

“Credible combinations of system conditions which stress the system shall be modeled including load forecast, inter-Area and intra-Area transfers, transmission configuration, active and reactive resources, generation availability and other dispatch scenarios. All reclosing facilities shall be assumed in service unless it is known that such facilities will be rendered inoperative.”

PP 3 also states in Section 3, that studies be conducted assuming conditions that “reasonably stress” the system:

“The design shall assume power flow conditions with applicable transfers, loads, and resource conditions that reasonably stress the system.”

In each case, an assumption that considers stressed system conditions with respect to transfer levels must be included in reliability studies. The ISO has the primary responsibility for interpreting these general descriptions.

Additionally, these requirements are confirmed by PP 5-3, which sets forth the testing parameters for the required PPA approval under Section I.3.9 of the Tariff. PP 5-3 requires that “intra-Area transfers will be simulated at or near their established limits (in the direction to produce ‘worst cases’ results).” Given the reliability standard obligations as well as the requirements for the PPA approval of any transmission upgrade, reasonably stressed transfer conditions that simulate interfaces at or near their defined limits are used in determining the transmission system needs.

2.8.3 Modeling Procedures

Interfaces associated with a study area must be considered individually as well as in combination with each other when more than one interface is involved. Transfer levels for defined interfaces are tested based on the defined capability for the specific system conditions and system configurations to be studied. Internal transfers not related to the study area can be set up based upon expected system conditions up to the limit and external transfers can be up to the limit depending on the type of study. Internal transfers within or related to the study area will be set based upon the generation dispatch derived from the probabilistic methods. Each analysis type described in Section 4 will detail the methodology used to set up system transfers.

2.9 High Voltage Direct Current (HVDC) Lines

There are three existing high voltage direct current facilities on the New England transmission system, Highgate, Hydro Québec Phase II (Phase II), and the Cross Sound Cable (CSC). Table 2-9 lists the flows on these existing facilities generally and how they are used in the base cases for different planning studies. Imports on these facilities are considered Resources as discussed in ISO New England Planning Procedure No. 5-6 (PP 5-6), *Interconnection Planning Procedure for Generation and Elective Transmission Upgrades*.

Table 2-9
Modeling Existing HVDC Lines in Planning Studies

Type of Study	Highgate	Phase II	Cross Sound Cable
PPA Study of Transmission Project	0 to 225 MW towards VT border	0 to 2000 MW towards NE	-330 to 346 MW towards Long Island
System Impact Study	0 to 225 MW towards VT border	0 to 2000 MW towards NE	-330 to 346 MW towards Long Island
Transmission Needs Assessment	0 to 225 MW towards VT border	0 to 2000 MW towards NE	0 to 346 MW towards Long Island
Transmission Solutions Study	0 to 225 MW towards VT border	0 to 2000 MW towards NE	0 to 346 MW towards Long Island
Area Review Analyses	0 to 225 MW towards VT border	0 to 2000 MW towards NE	0 to 346 MW towards Long Island
BPS Testing Analyses	0 to 225 MW towards VT border	0 to 2000 MW towards NE	0 to 346 MW towards Long Island
Transfer Limit Studies	0 to 225 MW towards VT border	0 to 2000 MW towards NE	-330 to 346 MW towards Long Island

Type of Study	Highgate	Phase II	Cross Sound Cable
Interregional Studies	0 to 225 MW towards VT border	0 to 2000 MW towards NE	-330 to 346 MW towards Long Island
FCM New Resource Qualification Overlapping Impact Analyses	0 to 225 MW towards VT border	0 to 1400 MW towards NE	0 MW
FCM New Resource Qualification Network Resource Interconnection Standard Analyses	0 to 225 MW towards VT border	0 MW towards NE	0 MW
FCM Study for Annual Reconfiguration Auctions and Annual CSO Bilaterals	0 MW to cleared imports	0 MW to cleared imports	Cleared Administrative export to 0 MW
FCM Delist Analyses	0 MW to qualified existing imports	0 MW to qualified existing imports	Qualified Administrative export to 0 MW
Transmission Security Analyses	Qualified existing imports	Qualified existing imports	0 MW
Non-Commercial Capacity Deferral Notifications	0 MW to cleared imports	0 MW to cleared imports	Cleared Administrative export to 0 MW

Power flow solution settings for high voltage direct current lines in steady state studies are detailed in Section 2.11.5.

2.10 Special Protection Systems / Remedial Action Schemes

Special Protection Systems (SPS) may be employed in the design of the interconnected power system subject to the guidelines in the ISO New England Planning Procedure No. 5-5 (PP 5-5), *Special Protection Systems Application Guidelines*. Many SPS in New England are also classified as Remedial Action Schemes (RAS) according to the NERC RAS definition. All SPSs proposed for use on the New England transmission system must be reviewed by the ISO Reliability Committee and NPCC and approved by the ISO. Some SPSs may also require approval by NPCC. The requirements for the design of SPSs are defined in NPCC Directory #4, *Bulk Power System Protection Criteria* and NPCC Directory #7, *Special Protection Systems*.

The owner of the SPS must provide sufficient documentation and modeling information such that the SPS can be modeled by the ISO, and other planning entities, in steady state and transient stability analyses. The studies that support the SPS must examine, among other things:

- System impact should the SPS fail to operate when needed
- System impact when the SPS acts when not needed
- Will the SPS function properly and acceptably during facility out conditions

Once an SPS is approved, its operation should be considered in all system planning studies.

2.11 Steady State Power Flow Solution Settings

This section describes the solution settings for running power flow analysis. The settings are summarized in Table 2-10 and more background for each setting is described in the following sub-sections.

Table 2-10
Steady State Power Flow Solution Settings

Case	Area Interchange Control	Tap Adjustments	Adjust Phase Shift	Switched Shunt Adjustments	DC Tap Adjustments
Emergency (Post-Contingency)	Disabled	Stepping	Disabled	Disabled	Disabled

2.11.1 Area Interchange Control

Enabling area interchange models the normal operation of the power system in that it adjusts generation to maintain inter-area transfers at a pre-determined level. Each area defined in the power system network representation has one of its generators designated as the area-slack bus. Area interchange is implemented by setting an overall interchange with all neighboring areas and the power flow program adjusts the output of the area-slack bus generation to match that schedule.

The area-slack bus for the New England Area is generally Canal 2 in Southeast Massachusetts. For studies of the area near Canal 2, a remote generator such as Seabrook in New Hampshire or Yarmouth 4 in Maine (also referred to as Wyman 4) is typically chosen as the area-slack bus.

Annually the Multiregional Modeling Working Group (MMWG) establishes the area interchange assumptions for different seasons, load levels, and years. These assumptions are included in base cases provided by the ISO. Requesting base cases from the ISO, which represent the scenarios that will be studied, ensures that area interchanges external to New England are appropriate.

In establishing a base case (N-0 or N-1) for a particular study, the planner selects the appropriate interchanges between New England and other areas. This should be done with area interchange enabled for tie lines and loads. This ensures that area interchanges external to New England are correct and that loads shared between New England and Québec are accounted for properly. The planner should re-dispatch generation in New England to obtain the desired interchanges with areas external to New England. The area-slack bus will adjust its output for the change in losses resulting from this re-dispatch. The planner should verify that the generation at the area-slack bus is within the operating limits of that generator.

For contingency analysis, area interchange is generally disabled. This causes the system swing bus output in the power flow model to increase for any generation lost due to a contingency. Following a loss of generation, each generator in the Eastern Interconnection increases its output in proportion to its inertia. About 95% of the total inertia for the Eastern Interconnection is to the west of New England. The system swing bus in the New England base cases is Browns Ferry in TVA. Using the system swing bus to adjust for any lost generation appropriately approximates post-contingency conditions on the power system prior to system-wide governors reacting to the disturbance and readjusting output.

2.11.2 Transformer Load Tap Changer Adjustment

Transformer load tap changers (LTCs) can exist on autotransformers, load serving transformers, and transformers associated with generation (e.g. transformers associated with wind parks). LTCs allow the ratio of the transformer to be adjusted while the transformer is carrying load so that voltage on low voltage side of the transformer can be maintained at a pre-determined level.

An LTC adjusts voltage in small steps at a rate of about 3-10 seconds per step. A typical LTC may be able to adjust its ratio by plus or minus ten percent may have sixteen 0.625% steps. Also the action of an LTC is delayed to prevent operations during temporary voltage excursions. For example, a

345 kV autotransformer might delay initiating tap changing by thirty (30) seconds. A load-serving transformer, which is connected to the 115 kV system near the autotransformer, might delay changing its tap by forty-five (45) seconds to coordinate with the autotransformer. The total time for an LTC to adjust voltage can be several minutes. For example, a LTC, which has thirty-two 0.625% steps, requires five (5) seconds per step and has a thirty (30) second initial delay, would require seventy (70) seconds to adjust its ratio by five (5) percent.

To model the actual operations of the system, LTC operation is typically enabled in the power system model to allow the LTCs to adjust post-contingency for steady state analysis. This generally represents the most severe condition because contingencies typically result in lower voltages and operation of LTCs to maintain distribution voltages result in higher current flow and lower voltages on the transmission system. Similarly operation of LTCs on autotransformers typically results in lower voltage on the high voltage side of the autotransformer.

In some portions of the transmission system, the voltage immediately following a contingency may be problematic because voltage collapse may occur. When instantaneous voltage is a concern, sensitivity analysis should be done with LTCs locked (not permitted to adjust) in the power flow model due to the amount of time required for the taps to move.

2.11.3 Phase Shifting Transformer Adjustments

The modeling of each phase shifting transformers (Phase Angle Regulator or PAR) is described in detail in Appendix G – Phase Shifting Transformers Modeling Guide for ISO New England Network Model.

2.11.4 Switched Shunt Adjustments

This section is under development by the ISO/TO study coordination group and will be sent out at a later date.

2.11.5 High Voltage Direct Current (HVDC) Lines Tap Adjustments

The flows in higher voltage direct current lines are not automatically adjusted after a contingency except where an adjustment is triggered by a special protection system.

2.11.6 Series Reactive Devices

Section 2.6.1 of this guide describes the series reactive devices in the New England transmission system. The tables list those series devices that can be switched to resolve criteria violations. Those switchable devices that are out of service in the base case can be switched into service. Those switchable devices that are in service in the base case can be switched out of service. The switching can be done post-contingency, if the flow does not exceed the STE rating. When the post-contingency flow exceeds the STE rating, switching must be done pre-contingency and analysis must be done to ensure that the switching does not create other problems.

Section 3

Reliability Criteria and Guidelines

This Section describes the various reliability criteria and guidelines used in the evaluation of the New England transmission system in system planning steady state, transient stability, and short-circuit analyses.

3.1 Steady State Criteria and Guidelines

This Section details the criteria used during steady state analysis. Criteria include thermal performance of all transmission Elements, system voltage requirements, and guidelines for the interruption of load following a contingency event.

3.1.1 Thermal Criteria

System planning utilizes the thermal capacity ratings shown in Table 3-1 for New England transmission facilities, as described in ISO New England Operating Procedure No. 16 (OP 16), *Transmission System Data*, Appendix A, *Explanation of Terms and Instructions for Data Preparation of NX-9A*, (OP 16A).

Table 3-1
Steady State Thermal Ratings

Type	PSSE Rating	Summer Duration	Winter Duration
Normal	Rate A	Continuous 24-hour	Continuous 24-hour
Long Time Emergency (LTE)	Rate B	12-hour	4-hour
Short Time Emergency (STE)	Rate C	15-min	15-min

Summer equipment ratings (April 1 through October 31) and Winter equipment ratings (November 1 through March 31) are applied as defined in OP 16. The twelve-hour and four-hour durations are based on the load shape for Summer and Winter peak load days.

The transmission Element ratings used in planning studies are described in PP 5-3 and in ISO New England Planning Procedure No. 7 (PP 7), *Procedures for Determining and Implementing Transmission Facility Ratings in New England*. In general, Element loadings up to normal ratings are acceptable for "All lines in" conditions. Element loadings up to LTE ratings are acceptable for up to the durations described above. Element loadings up to the STE ratings may be used following a contingency for up to fifteen minutes. STE ratings may only be used in limited situations such as in export areas where the Element loading can be reduced below the LTE ratings within fifteen minutes by operator or automatic corrective action.

There is also a Drastic Action Limit (DAL) that is only used as a last resort during actual system operations where preplanned immediate post-contingency actions can reduce loadings below LTE within five minutes. Drastic Action Limits are not used in testing the system adequacy in planning studies or for planning the transmission system.

Element ratings are calculated per PP 7, and are submitted to the ISO per OP 16.

3.1.2 Voltage Criteria

The low voltage criteria used for transmission planning have been established to satisfy three constraints: maintaining voltages on the distribution system and experienced by the ultimate customer within required limits, maintaining the voltages experienced by transmission equipment and equipment connected to the transmission system within that equipment's rating, and avoiding voltage collapse. Generally the maximum voltages are limited by equipment, and the minimum voltages are limited by customer requirements and voltage collapse.¹⁶

The voltage criteria prior to equipment operation apply to voltages at a location that last for seconds or minutes, such as voltages that occur prior to transformer load tap changer (LTC) operation or capacitor/reactor switching. The voltage standards prior to equipment operation do not apply to transient voltage excursions such as switching surges, or voltage excursions during a fault or during disconnection of faulted equipment. See Section 3.3 for more details on transient stability voltage criteria.

The voltage standards apply to PTF facilities operated at a nominal voltage of 69 kV or above.

3.1.2.1 Pre-Contingency Voltages

The voltages at all PTF buses must be in the range of 0.95-1.05 per unit with all lines in service.

There are two exceptions to these criteria. The first is voltage limits at nuclear units, which are described in Section 3.1.2.5. The second exception is that higher voltages are permitted at buses where the Transmission Owner has determined that all equipment at those buses is rated to operate at the higher voltage. Often the limiting equipment under steady-state high voltage conditions is a circuit breaker. IEEE standard C37.06 lists the maximum voltage for 345 kV circuit breakers as 362 kV, the maximum voltage for 230 kV circuit breakers as 245 kV, the maximum voltage for 138 kV circuit breakers as 145 kV, the maximum voltage for 115 kV circuit breakers as 123 kV and the maximum voltage for 69 kV circuit breakers as 72.5 kV. Older 115 kV circuit breakers may have a different maximum voltage.

For testing N-1 contingencies, shunt reactive devices are modeled in or out of service pre-contingency, to prepare for high or low voltage caused by the contingency, as long as the pre-contingency voltage standard is satisfied. For testing of an N-1-1 contingency, shunt reactive devices are switched between the first and second contingencies to prepare for the second contingency as long as the post-contingency voltage standard is satisfied following the first contingency and prior to the second contingency.

3.1.2.2 Post-Contingency Low Voltages

Prior to Equipment Operation

The lowest post-contingency voltages at all PTF buses must be equal to or higher than 0.90 per unit prior to the automatic or manual switching of shunt or series capacitors and reactors, and operation of tap changers on transformers, autotransformers, phase-shifting transformers and shunt reactors. Dynamic compensation devices such as generator voltage regulators, STATCOMs, SVCs, DVARs, and HVDC equipment are assumed to have operated properly to provide voltage support when calculating these voltages.

¹⁶ Note: This Transmission Planning Technical Guide does not address voltage flicker or harmonics.

Also capacitor banks that switch automatically with no intentional time delay (switching time is the time for the sensing relay and the control scheme to operate, usually a few cycles up to a second) may be assumed to have operated when calculating these voltages.

No contingencies as defined in Section 3.4 are allowed to cause a voltage collapse.

After Equipment Operation

The lowest voltages at all PTF buses must be equal to or higher than 0.95 per unit after the switching of shunt or series capacitors and reactors, and operation of tap changers on transformers, autotransformers, phase-shifting transformers and shunt reactors.

There are two exceptions to these criteria. The first is voltage limits at nuclear units, which are described in Section 3.1.2.5. The other exception is that voltages as low as 0.90 per unit are allowed at a limited number of PTF buses where the associated lower voltage system has been designed to accept these lower voltages, and where the change in voltage pre-contingency to post-contingency is not greater than 0.1 per unit. The planner should consult with the Transmission Owner and the ISO to determine if the second exception applies to any buses in the study area.

3.1.2.3 Post-Contingency High Voltages

Prior to Equipment Operation

The standard for high voltages prior to corrective action is under development.

After Equipment Operation

The highest voltages at all PTF buses must be equal to or lower than 1.05 per unit.

The only exception is that higher voltages are permitted where the Transmission Owner has determined that all equipment at those buses is rated to operate at the higher voltage. The planner should consult with the Transmission Owner and the ISO to determine if the exception applies to any buses in the study area.

3.1.2.4 Line End Open Contingencies

There is no minimum voltage limit for the open end of a line if there is no load connected to the line section with the open end. If there is load connected the above standards for post-contingency low voltage apply.

The maximum voltage limit for the open end of a line is under development.

3.1.2.5 Nuclear Units

The minimum and maximum voltage limits at the following buses serving nuclear units, both for pre-contingency and for post-contingency after the switching of capacitors and operation of transformer load tap changers, are shown in Table 3-2. These limits apply whether or not the generation is dispatched in the study.

Table 3-2
Nuclear Unit Voltage Limits

Critical Bus	kV	Minimum Bus Voltage (kV)	Maximum Bus Voltage (kV)
Millstone	345	345.0	362.0
Seabrook	345	345.0	362.0

The minimum voltage requirements at buses serving nuclear units are provided in accordance with NERC Standard NUC-001, *Nuclear Plant Interface Coordination*, and documented in the appendices to the Master Local Control Center Procedure No. 1 (MLCC 1).

3.1.3 Probabilistic Threshold Guideline

The probabilistic threshold used to establish probabilistic base case dispatches, referred to in the rest of this document, as the transmission security probabilistic threshold value, was derived from an amount of risk equivalent to planning our system's resource adequacy need to a Loss of Load Expectation (LOLE) of '1 day in 10 years'. Transmission Needs Assessments and transmission Solutions Studies primarily assess system conditions during the Summer peak load season. Consistent with other market definitions; this Summer period is defined as the four (4) months of June, July, August, and September. Excluding weekends due to typically non-peak loads, the system should be designed to be secure for the peak load hours of the 85 peak days (17 weeks * 5 weekdays) that constitute the bulk of the Summer season. Assuming that the risk is equally shared by each of these 85 peak days, the LOLE criterion is roughly equivalent to a system-wide level of risk of:

$$\frac{0.1 \text{ days}}{85 \text{ peak days per year}} = 0.001176 \cong 0.0012 \text{ (1.2E-03)}$$

Given that each study area carries its own transmission security risk and the aggregate New England system additively carries the risk of all its study areas, the risk threshold for individual study areas is further reduced such that the sum of the risks carried by all of the study areas is less than or equal to the System threshold.

$$P_{\text{Study Area}} \leq P_{\text{Control Area}}$$

This is done so the combined reliability of study areas will maintain sufficient reliability for the entire control area. To accomplish this requirement, a minimum threshold was established by dividing the New England threshold by 10 (1.2E-04) and then using a linear interpolation based on relative amount of resources in the study area to the total amount of resources in New England. The study area threshold is calculated by the following equation:

$$P_{\text{Study Area}} = P_{\text{Max}} - \left\{ (P_{\text{Max}} - P_{\text{Min}}) \times \left(1 - \left[\frac{\text{Resources}_{\text{Study Area}}}{\text{Resources}_{\text{New England}}} \right] \right) \right\}$$

$$P_{\text{Study Area}} = 1.2\text{E-03} - \left\{ (1.2\text{E-03} - 1.2\text{E-04}) \times \left(1 - \left[\frac{\text{Resources}_{\text{Study Area}}}{\text{Resources}_{\text{New England}}} \right] \right) \right\}$$

Note: The amount of resources used in the calculation includes all resources that have not been de-rated. See Section 2.3.5 for details on resource outage rate values.

3.1.4 Load Interruption Guidelines

This section is under development.

Guidelines, which describe the amount of load that may be interrupted and the circumstances where load may be interrupted, were presented to the Reliability Committee (RC) on November 17, 2010.¹⁷ At the request of stakeholders, the ISO retransmitted this material to the RC on November 17, 2011 for comment and to the Planning Advisory Committee on November 21, 2011. The ISO has received comments on the guideline and is reviewing those comments.

3.2 Short Circuit Criteria

This Section details the criteria used for short circuit analysis.

In accordance with NERC TPL-001 Requirement 2.3, NPCC Directory 1 Requirement R10, and ISO PP3 Section 3, all equipment capabilities shall be adequate for all fault current levels with all transmission and generation facilities in service. This equates to all equipment having a fault current duty of less than or equal to 100% of their ratings.

3.3 Transient Stability Criteria and Guidelines

This Section details the criteria used during transient stability analysis. Criteria include post-fault unit stability, system voltage performance, system damping, and voltage sag.

3.3.1 Unit Stability Criteria

NERC and NPCC require that the New England Bulk Power System shall remain stable and damped and the NERC Standard, *Nuclear Plant Interface Coordinating Standard*, (NUC-001) shall be met.

These requirements must be met during and following the most severe of the contingencies defined “with due regard to reclosing”, and before making any manual system adjustments. The ISO’s planning defines a unit¹⁸ as maintaining stability when it meets the damping criteria described in Section 3.3.3. The ISO also uses a voltage sag guideline (See Section 3.3.4) to determine if it may be necessary to mitigate voltage sags.

For each of the contingencies below that involves a fault, system stability and damping shall be maintained when the simulation is based on fault clearing initiated by the “system A” protection group, and also shall be maintained when the simulation is based on fault clearing initiated by the “system B” protection group where such protection group is required, or where there would otherwise be a significant adverse impact outside the local area. Table 3-3 describes which protection group is tested to evaluate BPS elements.

Table 3-3
Modeling of Protection Systems in Transmission Planning

¹⁷ https://www.iso-ne.com/static-assets/documents/committees/comm_wkgrps/relbty_comm/relbty/mtrls/2010/nov172010/a13_load_interruption_guidelines.ppt

¹⁸ A unit is defined as any single unit ≥ 5 MW or any set of units totaling more than 20 MW. For example, this includes a set of individual turbines within a wind plant. The performance of generating facilities that are ≥ 5 MW and ≤ 20 MW and that are connected to the system at a voltage less than 69 kV will be evaluated in accordance with the interconnection performance requirements of those generating facilities.

NPCC Element Classification	Fastest Protection System Modeling for Normal Design Contingencies	
	In Service	Out of Service
BPS	Not Tested	Tested
Non-BPS	Tested	Not Tested

Consistent with ISO New England Operating Procedure No. 19 (OP 19), *Transmission Operations*, New England's planning procedures require generator unit stability for all Normal Design Contingencies as defined in PP 3. This criterion applies when the fastest protection scheme is unavailable at any BPS substation involved in the fault clearing. This criterion applies if the fastest protection scheme is available at any non-BPS substation involved in the fault clearing. If the fastest protection scheme is unavailable at a non-BPS substation, unit instability is permitted as long as the net source loss resulting from the Normal Design Contingency is not more than 1,200 MW, and the net source loss is confined to the local area (i.e. no generator instability or system separation can occur outside the local area).

The 1,200 MW limit derives from the NPCC Directory #1 criteria which require that a Normal Design Contingency listed in Table 3 of the document have no significant adverse impact outside the local area. The maximum loss of source for a Normal Design Contingency has been jointly agreed upon by NYISO (formerly NYPP), ISO-NE (formerly NEPEX), and PJM to be between 1,200 MW and 2,200 MW depending on system conditions within NYISO and PJM. This practice is observed pursuant to a joint, FERC-approved protocol, which is described in Attachment C Section 5.2.2.1 of the OATT. The low limit of 1,200 MW has historically been used for Design Contingencies in New England.

3.3.2 Voltage Criteria

NERC has revised its transmission planning procedures to establish the requirement for transient voltage response criteria.

This section is under development.

3.3.3 Damping Criteria

Appendix C of PP 3 contains the damping criteria used in stability studies of the New England transmission system. This guideline is duplicated below.

The purpose of the damping criterion is to assure small signal stability of the New England bulk power supply system. System damping is characterized by the damping ratio, ζ . The damping ratio provides an indication of the length of time an oscillation will take to dampen. The damping criterion specifies a minimum damping ratio of 0.03, which corresponds to a 1% settling time of one minute or less for all oscillations with a frequency of 0.4 Hz or higher. Conformance with the criterion may be demonstrated with the use of small signal eigenvalue analysis to explicitly identify the damping ratio of all questionable oscillations.

Time domain analysis may also be utilized to determine acceptable system damping. Acceptable damping with time domain analysis requires running a transient stability simulation for sufficient time (up to 30 seconds) such that only a single mode of oscillation remains. A 53% reduction in the magnitude of the oscillation must then be observed over four periods of the oscillation, measuring from the point where only a single mode of oscillation remains in the simulation.

As an alternate method, the time domain response of system state quantities such as generator rotor angle, voltage, and interface transfers can be transformed into the frequency domain where the damping ratio can be calculated.

A sufficient number of system state quantities including rotor angle, voltage, and interface transfers should be analyzed to ensure that adequate system damping is observed.

3.3.4 Voltage Sag Guideline

The minimum post-fault positive sequence voltage sag must remain above 70% of nominal voltage and must not exceed 250 milliseconds below 80% of nominal voltage within 10 seconds following a fault. These limits are supported by the typical sag tolerances shown in Figures C.5 to C.10 in IEEE Standard 1346-1998. These parameters are shown graphically in Figure 3-1. A more detailed description of the voltage sag guideline with references is in Appendix E – Dynamic Stability Simulation Voltage Sag .

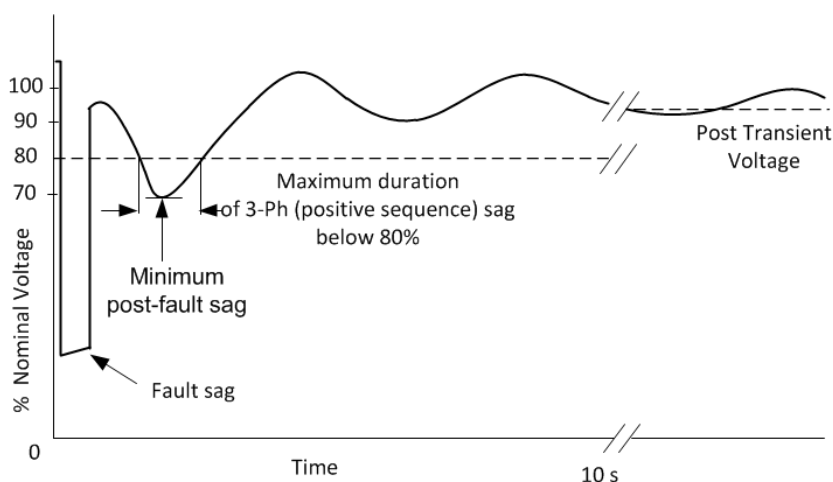


Figure 3-1: Voltage Sag Guideline

3.4 System Events (Contingencies)

The events (contingencies) that are tested in planning studies of the New England transmission system are defined in NERC, NPCC and ISO New England reliability standards and criteria. These standards and criteria form deterministic planning criteria. The application of this deterministic criteria results in a transmission system that is robust enough to operate reliably for the myriad of operating conditions that occur on the transmission system.

These standards and criteria identify certain events that must be tested and the power flow in each Element in the system must remain under the Element's emergency limits following any specified contingency. In most of New England, the LTE Rating is used as the emergency thermal limit. The STE Rating may be used as the emergency thermal limit when an area is exporting and if generation can be dispatched lower to mitigate overloads. The STE Rating may also be used as the emergency thermal limit in areas where phase-shifting transformers can be used to mitigate overloads. Voltage criteria limits are discussed in Section 3.

Planning Events used for the design of the transmission system can be classified as:

- N-1 – those Normal Contingencies (NCs) with a single initiating cause (a N-1 contingency may disconnect one or more transmission Elements)
- N-1-1 – those NCs with two separate initiating causes and where timely system adjustments are permitted between initiating causes
- Extreme events

Planning criteria allow certain adjustments to the transmission system between the two initiating causes resulting in N-1-1 contingencies as described in Section 3.4.2.

Steady state analysis focuses on the conditions that exist following the contingencies. Stability analysis focuses on the conditions during and shortly after the contingency, but before a new steady state condition has been reached.

3.4.1 N-1 Events

NERC and/or NPCC require that the following N-1 events be tested:

- A three-phase fault with Normal Fault Clearing on any:
 - Generator
 - Transmission circuit
 - Transformer
 - Bus section
 - Shunt compensating device
- Simultaneous phase-to-ground faults on:
 - Different phases of each of two adjacent transmission circuits on a multiple circuit transmission tower, with normal fault clearing.
 - NERC TPL-001, in note 11 to Table 1, allows excluding circuits that share a common structure for one mile or less
 - NPCC Directory #1 in note vii to Table 1 allows excluding circuits that share a common tower if the multiple circuit towers are used only for station entrance and exit purposes, and if they do not exceed five towers at each station
 - For exclusions of more than five towers, the ISO and the NPCC Reliability Coordinating Committee need to specifically approve each request for exclusion.
- A phase-to-ground fault, with delayed fault clearing,¹⁹ on any:
 - Generator
 - Transmission circuit
 - Transformer
 - Bus section
 - Shunt compensating device
- Opening any circuit breaker or loss of any of the following without a fault (See Section 3.4.4)
 - Generator
 - Transmission circuit
 - Transformer
 - Bus section
 - Shunt compensating device
 - Single pole of a direct current facility
- A phase-to-ground fault in a circuit breaker, with normal fault clearing. (Normal clearing time for this condition may not be high speed.)

¹⁹ Delayed fault clearing may result from a stuck breaker or a protective relay system failure.

- Simultaneous permanent loss of both poles of a direct current bipolar facility without an AC fault
- The failure of a circuit breaker to operate when initiated by an SPS following: loss of any of the following without a fault:
 - Generator
 - Transmission circuit
 - Transformer
 - Bus section
 - Shunt compensating device
- The failure of a circuit breaker to operate when initiated by an SPS following a phase to ground with normal fault clearing, on any of the following:
 - Generator
 - Transmission circuit
 - Transformer
 - Bus section
 - Shunt compensating device

3.4.2 N-1-1 Events

NERC and/or NPCC require that the N-1-1 events be tested. These are events that have two initiating events that occur close together in time. The list of first initiating events tested must include events from all of the following possible categories:

- Loss of a generator
- Loss of a series or shunt compensating device
- Loss of one pole of a direct current facility
- Loss of a transmission circuit
- Loss of a transformer

Following the first initiating event, system adjustments are made in preparation for the next initiating event. These adjustments can consist of any combination of the following:

- Increasing resources available within ten minutes following notification
- Adjustments that can be achieved in thirty minutes such as:
 - Generator runback and/or generator tripping
 - Reducing transfers on HVDC facilities
 - Adjusting phase angle regulators, transformer load tap changers, and variable reactors
 - Switching series and shunt capacitors and reactors.
 - Reducing imports from external Areas

The total amount of resources that are turned online in New England must not exceed 1,200 MW.

3.4.3 Extreme Events

Consistent with NERC and NPCC requirements, New England tests extreme events. This assessment recognizes that the New England transmission system can be subjected to events that exceed in severity the contingencies listed in Sections 3.4.1 and 3.4.2. Planning studies are conducted to determine the effect of the following extreme events on New England PTF system performance as a measure of system strength. Plans or operating procedures are developed, where appropriate, to reduce the probability of occurrence of such contingencies, or to mitigate the consequences that are indicated as a result of the simulation of such contingencies.

Extreme events are listed in NERC Standard TPL-001 Table 1 and Table 2 of NPCC Directory #1.

The following responses are considered unacceptable responses to an extreme contingency involving a three phase fault with delayed clearing due to a stuck breaker and should be mitigated:

- Transiently unstable response resulting in wide spread system collapse
- Transiently stable response with undamped or sustained power system oscillations
- A net loss of source within New England in excess of 2,200 MW resulting from any combination of the loss of synchronism of one or more generating units, generation rejection initiated by a Special Protection System, tripping of the New Brunswick-New England tie, or any other system separation. The loss of source is net of any load that is interrupted as a result of the contingency.

The following response can be considered acceptable to an extreme contingency involving a three phase fault with delayed clearing:

- A net loss of source above 1,400 MW and up to 2,200 MW,²⁰ resulting from any combination of the loss of synchronism of one or more generating units, generation rejection initiated by a Special Protection System, or any other defined system separation, if supported by studies, on the basis of acceptable likelihood of occurrence, limited exposure to the pre-contingent operating conditions required to create the scenario, or efforts to minimize the likelihood of occurrence or to mitigate against the consequence of the contingency. The loss of source is net of any load that is interrupted as a result of the contingency.

3.4.4 Line End Open Testing

One of the NERC TPL-001 Category P2 planning events is described as the ‘Opening of a line section w/o a fault.’ The requirement to evaluate a no-fault contingency (sometimes thought of as the opening of one terminal/end of a line) as a contingency event in system planning studies is described below. Additional details are provided in the white paper that is included in Appendix H – Position Paper on the Simulation of No-Fault Contingencies.

The following is a summary of the line open testing requirements:

- NERC BES facilities
 - N-1 Testing (Single Event) - Evaluate the opening of the terminal of a line, independent of the design of the termination facilities
 - N-1-1 Testing (First or Second Event) – Not required
- NPCC BPS or New England PTF facilities
 - N-1 Testing (Single Event) – Evaluate the opening of a single circuit breaker
 - N-1-1 Testing (First Event) – Not required
 - N-1-1 Testing (Second Event) – Evaluate the opening of a single circuit breaker

When evaluating the no-fault contingencies pursuant to implementation of NERC, NPCC, and ISO standards and criteria, the following will be used to establish the acceptability of post-contingency results and potential corrective actions:

²⁰ The 1,400 MW and 2,200 MW levels are documented in a NEPOOL Stability Task Force presentation to the NEPOOL Reliability Committee on September 9, 2000. This presentation is included in Appendix F – Stability Task Force Presentation to Reliability Committee – September 9, 2000, Section 5.6.

- If voltage is within acceptance criteria and power flows are within the applicable emergency rating, operator action can be assumed as a mitigating measure.
- If voltage is outside of acceptance criteria or power flows are above the applicable emergency rating, operator action cannot be assumed as a mitigating measure. Mitigating measures may include, but are not limited to, transfer trip schemes detecting an open circuit breaker(s) or open disconnect switch(es), or, Special Protection Systems designed to trigger for specific system conditions that include the no-fault opening of a transmission line.

Special consideration must be given to the design and operation of the system when evaluating this no-fault contingency. Control schemes, transfer trip schemes, and Special Protection Systems may not operate for a line end open condition if their triggers are not satisfied, or may operate inappropriately if their triggers are satisfied but only one terminal of a line is open.

Generally, in New England, the opening of one end of a two terminal line is not a concern. However, in instances of long lines, high voltages may be a concern due to the charging associated with an unloaded line.

Section 4

Analysis Methodology

This section describes the details in the methodologies applied to conduct system planning studies. It is not intended to be an exhaustive description of all aspects of every study, but rather a description of some aspects that are specific to certain studies within New England.

4.1 Transmission Needs Assessment and Solutions Studies

4.1.1 Steady State Thermal and Voltage Analysis

This section details the setup and analysis of the steady state thermal loadings and system voltages on the New England transmission system for transmission Needs Assessments and Solutions Studies.

4.1.1.1 Base Case Generation Dispatch

In the development of the base cases for transmission Needs Assessments and Solutions Studies, several standards and criteria describe the initial setup of the model prior to applying contingency outage events.

NERC Standard TPL-001²¹ Requirement R1 states:

*“The models ... shall represent **projected** System conditions.” (emphasis added)*

NPCC Reliability Reference Directory #1²² Requirement R7.1 states:

*“**Credible combinations** of system conditions which **stress the system** shall be modelled including, **load forecast**, inter-Area and intra-Area transfers, transmission configuration, active and reactive resources, **generation availability** and other dispatch scenarios. ...” (emphasis added)*

ISO Planning Procedure No. 3²³ Section 3 states:

*“The design shall assume power flow conditions with applicable transfers, loads, and resource conditions that **reasonably stress** the system.” (emphasis added)*

These standards and criteria describe the modeling of base system conditions that are ‘credible’ and ‘reasonably stressed’ before performing a contingency analysis. In general, modeling some amount of generation out in a base case addresses issues such as higher forced outage rates for generators than for transmission system elements.

To accomplish the modeling of base system conditions for peak load conditions that are ‘credible’ and ‘reasonably stressed’, base case generation dispatches are determined probabilistically, where the combined probability of the system load level and the amount of unavailable generation cannot exceed an established transmission security probabilistic threshold value. The derivation of the

²¹ <http://www.nerc.net/standardsreports/standardssummary.aspx>

²² <https://www.npcc.org/Standards/Directories/Forms/Public%20List.aspx>

²³ <https://www.iso-ne.com/participate/rules-procedures/planning-procedures/>

probabilistic transmission security threshold value is described in Section 3.1.3. The data used to create the load level and generation unavailability cumulative probabilities is described in Sections 2.2.2 and 2.3.5 respectively.

Units modeled offline in base cases fall into one of four categories:

- Unavailable – Units based on probabilistically derived outage curves that are out-of-service due to an unplanned outage and not available to system operators.
- Reserves – Units that are offline as “reserves” are discussed in Section 4.1.1.3.
- Generation behind system constraints – Units that are located in an export constrained area and may need to be offline to avoid violating system constraints. These generators cannot count towards reserves because that may not be useful for required system adjustments after the first contingency.
- Offline for load-resource balance – Units that are offline to ensure that the supply is equal to demand.

As transmission planners develop probabilistically derived base case dispatches for use in transmission Needs Assessments and Solutions Studies, the following guidelines are respected for “unavailable” units.

4.1.1.2 Generator Groups for Probabilistic Threshold Calculation

Section 3.1.3 provides information on how the maximum generation that may be assumed unavailable for a group of generators in New England is obtained. This value is called MW unavailable threshold (MWUT) for each group of generators considered.

Typically, at a minimum three groups of generators are created for each study:

- Study area generators – This group includes all the non-renewable generators in the study area that are being dispatched based on probabilistic based unavailability.
- Study area & adjacent area generators – This group includes the study area generators and any generators that are in the region surrounding the study area that may be relevant to the study area.
- Receiving end of system stress generators – This group includes all generators on the receiving end of the system stress that is established in the base cases. Additional details on this group are provided in Section 4.1.1.3

When considering generation unavailable in the study base cases, the transmission planner will identify non-renewable generators that will be considered unavailable in the study area, study area & adjacent area, and receiving end of the system stress, while honoring the MWUT for each of the groups. Planners will also consider all single generator unavailable dispatches to be acceptable.

Additionally, for larger study areas, the transmission planner may create smaller generator populations and calculate the MWUTs for these populations. Guidelines on some of the smaller populations are described below.

Unavailable Units at a Single Station / Bus

Several locations throughout New England have multiple generating units at a single station / bus. At a minimum, generator subgroups will be created for locations throughout New England that have multiple generating units at a single station / bus. These groups are created to avoid taking out an unrealistic amount of generation at a single station when creating dispatches for an entire study area.

During initial implementation of the probabilistic methodology, the curves indicated a large number of units could be expected unavailable at a single station. While mathematically this dispatch is acceptable, it did not align with historical operating experience. Preliminary investigation indicates the EFORD for units with limited run times can skew the results. To account for this concern, an upper limit of two units per single station / bus will be assumed unavailable in a single study dispatch.

Large Unit within a Study Area

When defining a study area, the size of the units within the area can vary significantly. In some cases, one or two large units can dominate a study area with many smaller units. Taking all the units in a study area together, the probability curves determine an aggregate amount of unavailable generation. When the large unit(s) is (are) in-service for a particular dispatch, the curves indicate a significant amount of the remaining small units can be unavailable. While this is acceptable according to the criteria, it did not align with historical operating experience. To account for this concern, when there is a significant discrepancy between the size of the units in a study area and a large unit is in-service for a specific dispatch, the probabilistic curves will be re-created with the remaining units in the study area to establish a more acceptable unavailability amount for the smaller units.

4.1.1.3 System Transfers

The methodology to define system interface capability is described in Appendix I – Methodology Document for the Assessment of Transfer Capability. The following sections discuss how interface transfer levels are modeled in transmission Needs Assessments and Solutions Studies for external and internal interfaces.

External Inter-Area Transfers

In November 2013, the ISO revised its practice with respect to transmission Needs Assessments and Solutions Studies. Transmission Needs Assessments no longer model power exports to other Areas (New York, New Brunswick, and Québec) when evaluating transmission system needs. As a result, reliability based needs and their related backstop transmission solutions will not be identified and developed to support power exports out of New England. The only exception to this policy change would be long-term power exports realized through the Forward Capacity Market.

For transmission Needs Assessments and Solutions Studies, the base cases will not model exports to other areas unless there is a long-term export realized through the Forward Capacity Market. For imports on inter-Area ties, they can be tested from their minimum up to their maximum amounts listed in Table 4-1.

Table 4-1
Inter-Area Import Levels Tested

Inter-Area Interface	Minimum Transfer Tested (MW)	Min Notes	Maximum Transfer Tested (MW)	Max Notes
New Brunswick – New England	0	1	700	2
New York – New England	0	3	1400	2
Phase II Imports	950	4	1400	2
Cross Sound Cable (CSC) Imports	0	1	0	2
Highgate Imports	200	5	200	2

- (1) No long-term contracts for imports on this interface
- (2) The maximum import tested on these interfaces is the capacity import capability on the interface. The details of the capacity import capability are presented yearly at a PAC meeting typically in Q1 of each year for the next year's FCA.
- (3) While there are currently 81.8 MW of long-term contracts in place over the NY to NE interface, they are due to expire on August 31, 2025, which is within the 10-year planning horizon and therefore cannot be relied upon for entire planning horizon. The 81.8 MW of long-term contracts is bounded by the proposed transfer levels of 0 and 1,400 MW.
- (4) The 950 MW value is based on a review of the Hydro Québec Interconnection Capability Credit (HQICC) in past auctions.
- (5) Highgate is modeled at its capacity import capability based on a long-term contract to import power.

Phase II has historically been treated differently than other import interfaces in New England. In the New England East-West Solution Interstate Needs Assessment, Phase II was considered as one of the two largest resources out-of-service in eastern New England in addition to Seabrook. Turning off Phase II with two largest generators in eastern New England was considered to be too stressed for the study. On this basis, setting the minimum value on Phase II to 0 MW did not seem appropriate for use in future transmission Needs Assessments. HQICCs are compensated through the FCM and therefore the HQICC MW value was considered a reasonable minimum amount that can be relied upon, similar to other capacity resources.

Depending on the proximity of the study area to the external interfaces, the external interfaces that are relevant to the study area will be modeled at both maximum and minimum levels to assess the impact of the range of possible import conditions.

Internal Area Transfers

Similar to the local generation dispatch of a study area, internal transfer stresses are established using probabilistic curves to define the expected amount of generation unavailable on the receiving end of the system stress being studied. Additional units will be unavailable to establish contingency reserves.

For transmission Needs Assessments and Solutions Studies, four stress conditions are considered. Depending on the relative location of the study area and the four major stress conditions, one or more stress conditions may be evaluated in a Needs Assessment or Solutions Study. For each stress condition, the generators on the receiving end are considered a group generators and the maximum generation unavailable is calculated using the probabilistic curves. The definitions of the four stresses are shown in Table 4-2.

Table 4-2
New England System Stresses for Internal Transfers

System Stress	Group of Generators on Receiving End
North-South	Southern New England (Generators south of North-South interface)
South-North	Northern New England (Generators north of North-South interface)
East-West	Western New England (Generators west of East-West interface)
West-East	Eastern New England (Generators east of East-West interface)

Establishment of Reserves

The term “reserves” described in this section refers to the “resources available within ten minutes following notification” as described in PP 3. A transmission Needs Assessment and Solution Study

base case will model 1,200 MW of reserves to account for generation adjustments after the first contingency. These resources are available after the first contingency to: 1) Keep load-resource balance in the base case if the first contingency involves the loss of a resource (generator/inter-Area tie); and 2) Make system adjustments in preparation for the next contingency while maintaining load-resource balance in the base case. The reserves in a base case may include hydro generation and non-renewable²⁴ generation.

Reserves in the peak load base case can be procured from the following sources:

- Weekly Cycle Hydro Units – These generators may be dispatched up to their qualified capacity from their historical de-rated output in the base case after the first contingency.
- Pumped-Storage Hydro Units – These generators may be dispatched anywhere between 0 and 50% of QC in the base case and may be dispatched to 50%²⁵ of their QC after the first contingency.
- Offline Fast Start²⁶ Units – These generators may be dispatched up to their Summer QC after the first contingency.
- Online Non-Renewable Generators – If weekly cycle hydro, pumped-storage hydro, and offline fast start units do not provide 1,200 MW of reserves, then generators capable of ramping up after the first contingency will be assigned reserves equal to their 10 minute ramp capability.

For a particular system stress selected, an attempt is made to establish reserves on the receiving end of the system stress. However, interface limits must not be violated when establishing reserves on the receiving end. If an interface limit is violated, the remaining reserves will be established on the sending end of the stress.

If the study area is on the receiving end of the system stress, additional generation may not be turned off in the study area or adjacent area to establish reserves. If the study area is part of a Load Zone, additional generation in the Load Zone containing the study area may not be turned offline to establish reserves. An exception to this rule is the available weekly cycle hydro units in the study area which may be used to establish reserves in the receiving end.

Reserves are established in the base case relying on the following types and using the priority listed in parenthesis:

- Receiving end weekly cycle hydro units (Priority 1)
- Study area weekly cycle hydro units (Priority 1)
- Receiving end pumped-storage hydro units (Priority 2)
- Receiving end offline fast start units (Priority 2)
- Receiving end online non-renewable units (Priority 3)
- Sending end units outside the study area (Priority 4)

4.1.1.4 Contingencies Tested

NERC, NPCC, and the ISO require that the New England BES, BPS, and PTF (respectively) shall maintain equipment loadings and voltages within normal limits for pre-disturbance conditions and

²⁴ The term ‘non-renewable’ generation refers to those generators that are dispatched based on probabilistic methods and not de-rated based on historical data.

²⁵ An exception to this is if the study area is in the Western MA area, then a dispatch with the pumped-storage hydro units at 100% in the base case may be studied. In this case, the pumped-storage hydro units will not provide reserves.

²⁶ For the purpose of transmission Needs Assessments and Solutions Studies, fast start units are those combustion turbines or diesel generators that can go from being offline to their full Seasonal Claimed Capability in 10 minutes.

within applicable emergency limits for the system conditions following the contingencies described in Section 3.4.

4.1.1.5 Critical Load Level Analysis

Based on stakeholder feedback at the March 15, 2018 PAC meeting, the ISO has discontinued performing critical load level (CLL) analysis as part of transmission Needs Assessments.

4.1.2 Transient Stability Analysis

This section details the setup and analysis of the transient stability the New England transmission system for transmission Needs Assessments and Solutions Studies.

4.1.2.1 Base Case Generation Dispatch

At both Peak and Light Load levels, generators are modeled at their NRC Winter value which is the highest gross (maximum) MW output at 0° F or higher. Generators are generally dispatched either “full-on” at maximum capability, or “full-off.” If transmission transfers need to be adjusted, then the following is done:

- First, generators are re-dispatched by simulating them “full-on” or “full-off”
- Second, adjust generators, if necessary, least critical to study results to obtain desired transfers (“off” or as close to “full-on” as possible).

This is done to obtain generators’ maximum stressed internal angles in order to establish a stability limit under worst-case conditions. Generator reactive dispatch must also be considered for generators being evaluated for stability performance. Pre-fault reactive output is based on the Light Load voltage schedule in ISO New England Operating Procedure No. 12 (OP 12), *Voltage and Reactive Control*.

4.1.2.2 Contingencies Tested

NERC and NPCC require that the New England BES and BPS systems shall remain stable and damped and the NERC Standard NUC-001 shall be met. The ISO’s PP 3 requires:

“Individual generating units ≥ 5 MW or any set of units totaling more than 20 MW shall not lose synchronism or trip during and following the most severe of the contingencies with due regard to reclosing, and before making any manual system adjustments.”

This applies for all N-1 and N-1-1 Contingencies as defined Table 1 and 2 of the procedure.

4.1.3 Short Circuit Analysis

This section details the setup for short circuit analysis of the New England transmission system for transmission Needs Assessments, Solutions Studies, System Impact Studies and PPA studies.

4.1.3.1 Base Case Generation Dispatch

The system condition most critical for short circuit assessment is all available generation in service²⁷ and should be modeled as such in the base case used for the study.

4.1.3.2 Short Circuit Assumptions for Transmission Circuit Breaker Duty Assessment

This section summarizes the solution parameters that shall be used for fault current and breaker duty evaluation of transmission circuit breakers when conducting a short circuit assessment. ISO New England recommends using ASPEN OneLiner Breaker Rating Module (BRM) and the relevant ISO short circuit base cases for short circuit studies.

Table 4-3 shows the system-wide solution parameters that shall be used for ISO short circuit analyses.

Table 4-3
ASPEN OneLiner Solution Parameters

ASPEN OneLiner Short Circuit Assessment Assumptions		
Fault Simulation Options		Standardized Value
Switch impedance		R = 0.00001 p.u. X = 0.0001 p.u.
Pre-fault voltage	Assumed “Flat” with V(p.u.)	Refer to Table 4-4
Ignore	Loads	Selected
	Transmission line G+jB	Selected
	Shunts with + sequence values	Selected
	Transformer line shunts	Selected
Generator Impedance		Subtransient
MOV-protected series capacitor	Iterate short circuit solutions	Selected
	Acceleration Factor	0.4
Define Fault MVA As Product of		Current & pre-fault voltage

²⁷ If an inverter based resource is modeled as a voltage-controlled current source (VCCS), the breaker duty may decrease under certain circumstances if the VCCS based resource is online. If a breaker in the vicinity of a VCCS based resource is at or above its rated capability, further assessment may be necessary to confirm the observed overduty.

Current Limited Generators		Ignore all generator current limits
Simulate voltage-controlled current sources		Selected ²⁸
X/R Options		Standardized Value
Compute ANSI x/r ratio		Selected
Assume Z2 equals Z1 for ANSI x/r calculation		Selected
X-only calculation	If X is 0 use	X=0.0001 p.u.
R-only calculation	If R is 0 use	Method 1
		Rc=0.0001 p.u.
	Typical X/R ratio (g) ²⁹	80 for generators
		60 for transformers
		80 for reactors
		10 for all others
ANSI/IEEE Breaker Checking Options ³⁰		Standardized Value
Fault Types		3LG, 2LG, 1LG, LL
For X/R Calculation	Separate X-only, R-only networks	Selected
In 1LG faults, allow up to 15% higher rating for	Symmetrical current rated	Selected
Force voltage range factor K=1 in checking	Symmetrical-current rated breakers with max design kV 121 or higher	Selected

²⁸ The option to simulate voltage-controlled current sources with an assumed flat pre fault voltage is available in ASPEN OneLiner version 14.7 and above.

²⁹ Values derived from IEEE Std C37.010-1999

³⁰ For IEC rated circuit breakers, all necessary modeling data and supporting analysis methodology should be obtained from the equipment owner or their designated entity.

Miscellaneous options	Treat all sources as "Remote" ³¹	Selected
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Table 4-4 shows the pre-fault voltage values that shall be used in short circuit studies:

Table 4-4
Pre-fault Voltage by Transmission Owner

Transmission Owner	Voltage (p.u.)
Emera Maine	1.05
Avangrid (ME)	1.05
National Grid	1.05
Eversource (Boston, Cape Cod)	1.03
Eversource (CT, WMA, NH)	1.04
Avangrid (CT)	1.04
Vermont Electric Power Company (VELCO)	1.05

For facilities that are not owned by the Transmission Owner listed in Table 4-4, the pre-fault voltage for the adjacent Transmission Owner listed in Table 4-4 will be used.

4.1.3.3 Evaluation of Generator Breakers

ASPEN OneLiner BRM evaluates IEEE symmetrical current rated breakers based on guidance found in IEEE C37.010 – IEEE Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis³² and currently does not include a function that is directly applicable to Generator Circuit Breakers rated in accordance with IEEE C37.013 – IEEE Standard for AC High-Voltage Generator Circuit Breakers Rated on a Symmetrical Current Basis³³. The determination of ac and dc decrement documented in IEEE C37.010 and used by ASPEN OneLiner BRM are not necessarily relevant for Generator Circuit breakers, given the different conditions each type of breaker is expected to be exposed to. However, ASPEN OneLiner BRM may be used to screen generator breaker duty using the methodology discussed in Sections **Error! Reference source not found.** and **Error! Reference source not found.**. If the screening demonstrates a generator breaker at or above its rated capability, considerations should be made to determine if the respective generator circuit breaker has been modeled accurately within ASPEN in conjunction with the Generator Owner.

³¹ For circuit breakers in the vicinity of a generating station, this is a conservative approach and should be used during a breaker duty assessment. If warranted, further analysis should be conducted without using this option to obtain a more accurate breaker duty for circuit breakers in the vicinity of a generating station.

³² [IEEE C37-010](#)

³³ [IEEE C37-013](#)

4.1.3.4 Contingencies Tested

4.1.4 Time-Sensitive Needs and Need-by Date Determination

4.1.4.1 Introduction

At the conclusion of a Needs Assessment, a decision must be made with regard to developing regulated transmission upgrades (solutions) to resolve the needs. The development of the solution(s) shall be accomplished by either the Solutions Study process or the Competitive Solution process. The initial determining factor of the decision for Reliability Transmission Upgrades is based on the time-sensitivity of each identified need in the Needs Assessment. Time-sensitive needs are those that occur in three years or less from the completion of the Needs Assessment report. If any of the needs identified are deemed to be time-sensitive and the requirements of Section 4.1(j) of Attachment K of the OATT have been met, then the Solutions Study process will be initiated.

Additionally, for all needs that are identified as a part of the Needs Assessment, a need-by date (NBD) is determined.

4.1.4.2 Short-circuit Needs

The time-sensitivity of the short circuit need(s) is based on the expected in-service date of the future project that causes the equipment to exceed its capabilities.

- If the equipment is found to exceed its capabilities in greater than three years from the completion of the Needs Assessment report, the need would be considered non-time-sensitive.
- If the equipment is found to exceed its capabilities within three years or less from the completion of the Needs Assessment report, the need would be considered time-sensitive.

The NBD for time-sensitive needs observed as a part of the short circuit analysis will be set to June 1st of the time-sensitive year.

The NBD for non-time-sensitive needs will be set to the expected in-service date of the future project that causes the equipment to exceed its capabilities.

4.1.4.3 Off-peak Load Level Needs

If needs are identified at off peak load levels, then the needs are deemed to be time-sensitive because these off-peak load levels are possible under current day system conditions. The NBD for steady-state needs observed at off peak load levels will be defined as the date of publishing the final Needs Assessment report³⁴.

4.1.4.4 Peak Load Level Needs

For needs observed at peak load levels, additional analysis is performed to determine time sensitivity. Typically, a Needs Assessment is conducted over a 10-year study horizon with initial study base cases created for a time period 10 years into the future. These base cases will be referred to as the study horizon base cases.

³⁴ The date of publishing of the Needs Assessment report is the date when the final Needs Assessment report is posted to the PAC website.

To determine the time-sensitive needs new base cases will be created. These cases will be called the time-sensitive base cases. The year represented in these newly created base cases is determined by the date of publishing of the Needs Assessment report³⁵ and is called the time-sensitive year.

For purposes of establishing time-sensitivity, the Summer Peak Load period is assumed to begin on June 1st of each year. Therefore, the time-sensitive year will vary depending on whether the completion date of the Needs Assessment report occurs before June 1 versus on June 1 or later. Table 4-5 provides a summary of the correct summer peak loads to be represented in the time-sensitive year.

Table 4-5
Determination of Time-Sensitive year for Peak Load Needs

Publishing Date of Final Needs Assessment Report	Time-Sensitive year
Between January 1st and May 31st of Year N	Summer Peak of Year N+2
Between June 1st and December 31st of Year N	Summer Peak of Year N+3

The steps to create time-sensitive base cases are discussed below.

- The study horizon base cases are used as a starting point.
- The load is scaled to a load that matches the peak load conditions in the identified time-sensitive year.
- The study horizon base case transmission topology is not changed³⁶.
- The dispatch of study area generators in the study horizon base cases is maintained in the time-sensitive year base cases.
 - The only exception to this practice is if there are study area generators that are assumed to be retired in the study horizon base cases but are expected to be available in the time-sensitive year. These generators are assumed online in the time-sensitive base cases. Additional dispatches may be considered in the time-sensitive year with these generators unavailable³⁷. If a generator was assumed out of service in the study horizon base cases based on having accepted dynamic or static de-list bids for the full resource in the two most recent FCM auctions, the generator will be assumed OOS in the time-sensitive year. When creating the new dispatches, the same methodology that was used to establish the dispatches in the study horizon base cases is used.

Once the time-sensitive base cases are created, steady state thermal and voltage analysis is performed on these base cases.

All needs identified in the study horizon base case that still appear as a result of the analysis using the time-sensitive base cases are considered time-sensitive needs. The NBD for time-sensitive needs observed at peak load will be set to June 1st of the time-sensitive year.

³⁶ This assumption avoids identifying a need using the time-sensitive base cases which would be solved by a previously identified project that would be placed in-service in the future beyond the time sensitive-year.

³⁷ While the generator is not assumed to have been retired in the time-sensitive year, the possibility of unavailability due to a forced outage still exists. Therefore, additional dispatches with the generator assumed to be unavailable may be considered.

All needs that were observed in the analysis using the study horizon base cases but are no longer present in the analysis using the time-sensitive base cases are considered non-time-sensitive needs. If non-time-sensitive needs are observed as a part of a Needs Assessment, a NBD will only be determined if there were no time-sensitive needs that were also identified as a part of the same Needs Assessment.

NBD for Non-Time-Sensitive Needs

If non-time-sensitive needs are identified as a part of a study, the first step is to review the variation of New England net load during the years between the time-sensitive year and the study horizon year. The following formula shows how the New England net load is calculated for a given summer peak load period.

$$NE\ Net\ Load_{year\ x} = A_{year\ x} - B_{year\ x} - C_{year\ x} - D_{year\ x}$$

Where:

- $A_{year\ x}$ - 90/10 Summer Peak Load for year x,
- $B_{year\ x}$ - Available EE forecast for year x,
- $C_{year\ x}$ - Available Active DR (de-rated) acquired via the FCM for year x, and
- $D_{year\ x}$ - Available PV (de-rated) for year x.

If the net New England loads in the study horizon year are lower than the time-sensitive year, or the increase in net New England load between the time-sensitive year and the study horizon year is negligible, then the non-time sensitive needs observed under peak load conditions are caused by a system change, such as a resource retirement, that occurs in the period between the time-sensitive year and the study horizon year. In these instances, June 1 of the first year following the date associated with the system change is used to determine the NBD. As an example, if a system change occurs in December 2025, then the NBD will be set to June 1, 2026. In these instances, additional analysis will not be performed.

In situations where net New England loads are appreciably higher in the study horizon year than the time-sensitive year, the method to approximate NBD for non-time-sensitive needs is the slope-intercept equation from two points. This method is an approximation that provides a reasonable estimate with minimum additional analysis. The NBD analysis requires the level of the loading or voltage on a transmission element³⁸ to be determined at two system load levels for the contingency or contingencies that have the largest impact on that transmission element. An NBD analysis is done for each transmission element that is overloaded or experiences a voltage violation in the study horizon base cases that is categorized as a non-time-sensitive need.

The load or voltage level in each base case is plotted³⁹ on the x-axis of a graph and percentage of the overload or per unit of the voltage violation is plotted on the y-axis. A straight line is then drawn to connect these two points. The NBD load level is the load level (x-axis value) associated with the 100 percent value for thermal overloads or the lowest acceptable per unit voltage⁴⁰ on the y-axis.

³⁸ An element is any electric device with terminals which may be connected to other electric devices. Some examples of an element are a generator, transformer, circuit breaker, bus section, or transmission line.

³⁹ While this document refers to actions such as plotting and drawing, these actions are to help the reader understand the concept. In practice, the math is performed without actually creating such plots.

⁴⁰ The voltage threshold depends on the transmission owner or the Nuclear Plant Interface Requirements (NPIRs). See section 3.1.2.5 for additional details.

The two data points adhere to the following requirements:

- The dispatch of generators critical to the study area should be the same for the two points considered
- The two points must correspond to the same contingency or contingency pair

One data point corresponds to the study horizon base case. The second data point could be any year between the time-sensitive year and the study horizon year. The use of the first year after the time-sensitive year is considered a good choice for the 2nd data point because any generation retirements in the study horizon year that were not in the time-sensitive year would generally be effective in the year after the time-sensitive year. Any study that uses a different year for the second data point will include an explanation for the choice of the second data point.

The thermal loads and voltage levels are obtained from the analysis results.

Using the two data points available, a line is drawn using the slope/intercept method⁴¹. For each monitored element, the line can be used to determine the loading or voltage of an element for different system load levels. As an example, the line for Element X1 for a thermal violation is shown in Figure 4-1 below.

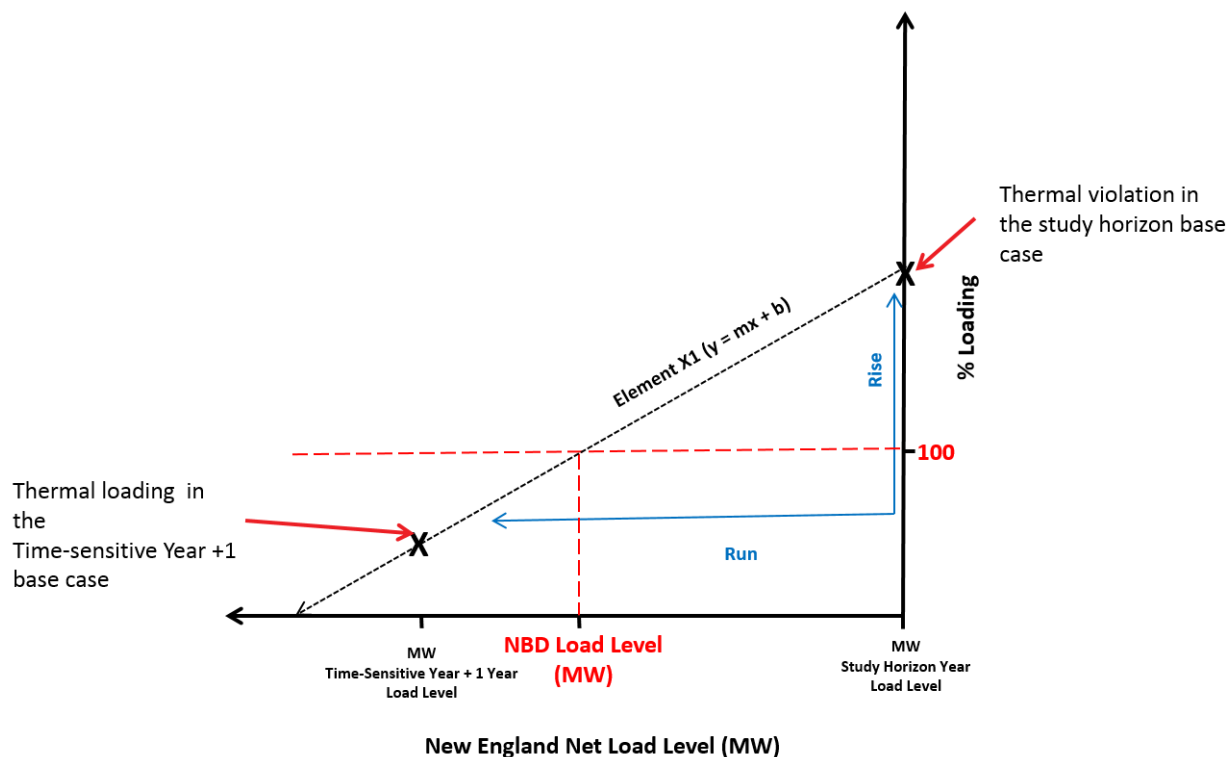


Figure 4-1: NBD Analysis for Non-Time-Sensitive Need on Element X1

⁴¹ Slope (m) = Rise divided by Run and the line equation is $y = m(x) + b$ where b is the y-intercept.

The NBD load level for thermal violations is determined from the point on the line which corresponds to the 100 percent value on the y-axis. The NBD load level for voltage violations is determined from the point on the line which corresponds to the lowest acceptable per unit voltage level on the y-axis.

For a given NBD load level, the NBD represents June 1st of the year that corresponds to the closest New England net load that is greater than or equal to the calculated NBD load level. In the example in Figure 4-2, the NBD would be June 1, 2025.

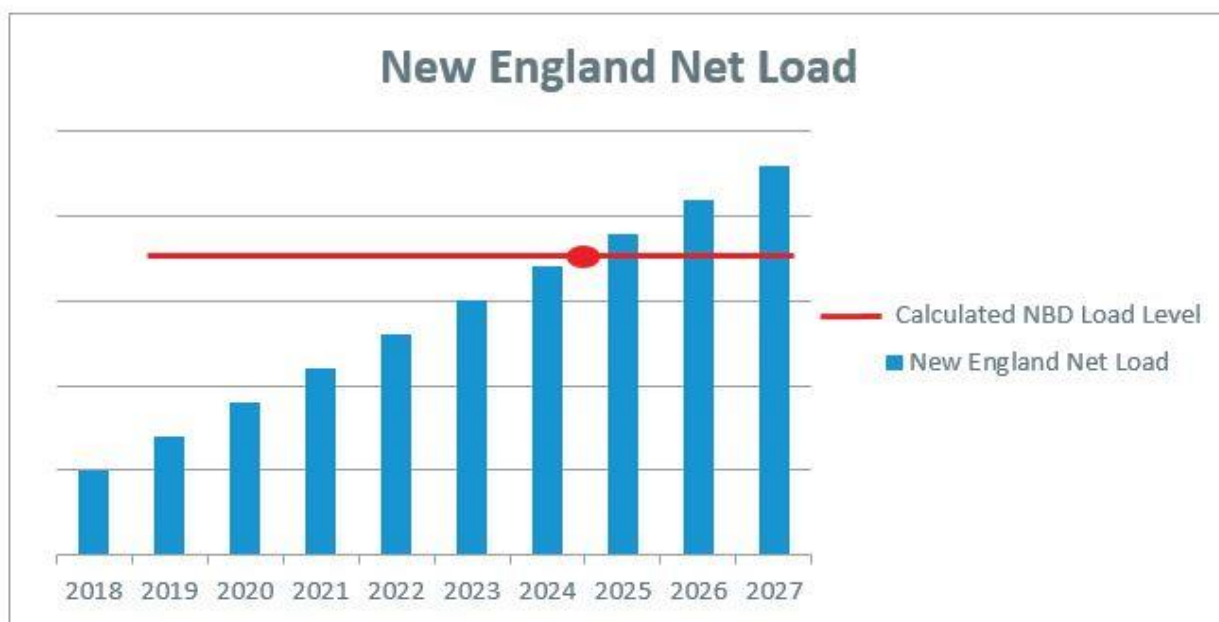


Figure 4-2: Calculating Need-By Date using NBD Load Level

4.1.4.5 Summary of Time-sensitivity and Need-By Date Determination

Table 4-6 provides a summary of the methodology used to determine the time-sensitivity of needs and the NBD associated with needs that are identified as a part of a Needs Assessment.

Table 4-6
Summary of Time-sensitivity and NBD Analysis

Load Level Studied	Time-Sensitivity of Need	Need-by Date
Short-circuit	Time-Sensitive	June 1 of the time sensitive year
	Non-Time-Sensitive	Date associated with the expected in-service date of the future project that causes the equipment to exceed its capabilities
Off-peak	Time-Sensitive (All needs at off peak load levels are time-sensitive)	Publishing Date of the final Needs Assessment Report
Peak	Time-Sensitive	June 1 of time-sensitive year
	Non-Time-Sensitive	Date obtained using linear method if study horizon year NE loads are appreciably higher than time-sensitive year NE loads June 1 of the first year following the date associated with critical system change affecting the study area for all other scenarios of load change between the time-sensitive year and the study horizon year

4.2 Proposed Plan Application Testing

This section details the setup and analysis of the New England transmission system for Proposed Plan Application testing under Section I.3.9 of the Tariff.

4.2.1 Stressed Transfer Levels

Transfer levels are also adjusted as appropriate for the load levels that are to be studied. Transfer level testing may require thermal, voltage, and/or stability testing to confirm no adverse impact on transfer limits. Interface transfer levels are tested up to their capability in order to sustain the economic efficiency of the electric system and reliable operation and transmission service obligations of the New England transmission system.

The system is designed to preserve existing range of transfer capabilities. This is a requirement defined in PP 5-3 and is a fundamental objective of the minimum interconnection standard. In order to meet this requirement, interfaces that may affect the area under study are modeled with transfer levels that cover the full range of existing capabilities. The review of interface stresses includes an evaluation of each interface internal to New England as well as interfaces between New England and adjacent Control Areas to determine the set of interfaces that may have a significant impact on the results of studies for the study area. Interfaces that are not directly connected to a study area but may have a significant effect on the study area interface are considered “coincident interfaces”. The procedures for selecting transfer levels for study area interfaces and coincident interfaces are provided below.

There may be a need to increase transfer capabilities as generation patterns shift across the system. General system trends in the direction of flow and magnitude may change dramatically over time. Some examples of conditions in which transfer capabilities requirements have changed include:

- The Connecticut area used to export across the Connecticut interface to eastern New England over many hours, but significant load growth and the outage of the nuclear units changed this to an import.
- Whether the New Brunswick Control Area is an exporter to New England or an importer from New England can vary and depends on many factors including the availability of generation in New Brunswick.
- There has been an increase of “in-merit” natural gas generation being sited adjacent to existing gas pipelines in southern New England.
- Studies associated with the New England East West Solution have in the past been focused on the need to move power from across New England from east to west. As the project progressed, the studies demonstrated a need to move power from west to east, even prior to consideration of the retirement of Salem Harbor station in 2014, Brayton Point station in 2017, or retirement of Pilgrim Nuclear station in 2019.

4.2.2 Contingencies Tested

NERC, NPCC, and the ISO require that the New England BES, BPS, and PTF (respectively) shall maintain equipment loadings and voltages within normal limits for pre-disturbance conditions and within applicable emergency limits for the system conditions following the contingencies described in Section 3.4.

4.3 Bulk Power System Testing

This section is under development.

4.3.1 **Base Case Generation Dispatch**

4.3.2 **Contingencies Tested**

Section 5

Appendices

5.1 Appendix A – Terms and Definitions

50/50 PEAK LOAD

A peak load with a 50% chance of being exceeded because of weather conditions, expected to occur in New England at a temperature of 90.4°F.

90/10 PEAK LOAD

A peak load with a 10% chance of being exceeded because of weather conditions, expected to occur in New England at a temperature of 94.2°F.

ADVERSE IMPACT

See Significant Adverse Impact.

APPLICABLE EMERGENCY LIMIT

- These Emergency limits depend on the duration of the occurrence, and are subject to New England standards.
- Emergency limits are those which can be utilized for the time required to take corrective action, but in no case less than five minutes.
- The limiting condition for voltages should recognize that voltages should not drop below that required for suitable system stability performance, meet the Nuclear Plant Interface Requirements and should not adversely affect the operation of the New England PTF System.
- The limiting condition for equipment loadings should be such that cascading outages will not occur due to operation of protective devices upon the failure of facilities.

AREA (as defined in NPCC Glossary of Terms)

An Area (when capitalized) refers to one of the following: New England, New York, Ontario, Québec or the Maritimes (New Brunswick, Nova Scotia and Prince Edward Island); or, as the situation requires, area (lower case) may mean a part of a system or more than a single system.

AREA TRANSMISSION REVIEW (see Appendix B of NPCC Directory #1)

A study to assess the reliability of the bulk power system

BULK ELECTRIC SYSTEM / BES (as defined in the NERC Glossary of Terms)

As defined by the Regional Reliability Organization, the electrical generation resources, transmission lines, interconnections with neighboring systems, and associated equipment, generally operated at voltages of 100 kV or higher. Radial transmission facilities serving only load with one transmission source are generally not included in this definition.

BULK POWER SUPPLY SYSTEM

The New England interconnected bulk power supply system is comprised of generation and transmission facilities on which faults or disturbances can have a significant effect outside of the local area.

BULK POWER SYSTEM TESTING (see NPCC Document A-10)

A study done to determine if Elements are classified as part of the Bulk Power System

BULK POWER SYSTEM / BPS (as defined in NPCC Glossary of Terms)

The interconnected electrical system within northeastern North America comprised of system elements on which faults or disturbances can have significant adverse impact outside the local Area.

CAPACITY SUPPLY OBLIGATION (as defined in Section I of the Tariff)

This is an obligation to provide capacity from a resource, or a portion thereof, to satisfy a portion of the Installed Capacity Requirement that is acquired through a Forward Capacity Auction in accordance with Section III.13.2, a reconfiguration auction in accordance with Section III.13.4, or a Capacity Supply Obligation Bilateral in accordance with Section III.13.5.1 of Market Rule 1.

CONTINGENCY (as defined in NPCC Glossary of Terms)

An event, usually involving the loss of one or more Elements, which affects the power system at least momentarily

CAPACITY NETWORK RESOURCE CAPABILITY (as defined in Schedule 22 of the OATT)

Capacity Network Resource Capability (CNR Capability) is defined in Schedule 22 of the Tariff and means (i) in the case of a Generating Facility that is a New Generating Capacity Resource pursuant to Section III.13.1 of the Tariff or an Existing Generating Capacity Resource that is increasing its capability pursuant to Section III.13.1.2.2.5 of the Tariff, the highest MW amount of the Capacity Supply Obligation obtained by the Generating Facility in accordance with Section III.13 of the Tariff, and, if applicable, as specified in a filing by the System Operator with the Commission in accordance with Section III.13.8.2 of the Tariff, or (ii) in the case of a Generating Facility that meets the criteria under Section 5.2.3 of this LGIP, the total MW amount determined pursuant to the hierarchy established in Section 5.2.3. The CNR Capability shall not exceed the maximum net MW electrical output of the Generating Facility at the Point of Interconnection at an ambient temperature at or above 90° F for Summer and at or above 20° F for Winter. Where the Generating Facility includes multiple production devices, the CNR Capability shall not exceed the aggregate maximum net MW electrical output of the Generating Facility at the Point of Interconnection at an ambient temperature at or above 90° F for Summer and at or above 20° F for Winter. The CNR Capability of a generating facility can be found in the Forecast Report of CELT Report which is produced annually by ISO New England.

DELAYED FAULT CLEARING (as defined in NERC Glossary of Terms)

Fault clearing consistent with correct operation of a breaker failure protection group and its associated breakers, or of a backup protection group with an intentional time delay.

ELEMENT (as defined in NERC Glossary of Terms)

Any electric device with terminals which may be connected to other electric devices such as a generator, transformer, circuit, circuit breaker, bus section, or transmission line. An Element may be comprised of one or more components.

FCM STUDY FOR ANNUAL RECONFIGURATION AUCTIONS AND ANNUAL BILATERALS

The FCM study as part of the annual reconfiguration auction or annual evaluation of Capacity Supply Obligations as described in Sections 13.4 and 13.5 of Market Rule 1.

FCM DELIST ANALYSES

The FCM Delist Analyses is the analysis of de-list bids, and demand bids as described in Section 7.0 of PP 10.

FCM NEW RESOURCE QUALIFICATION OVERLAPPING IMPACT ANALYSES

The FCM New Resource Qualification Overlapping Analyses is the analysis of overlapping interconnection impacts as described in Section 5.7 of PP 10. This study is similar in scope as the thermal analyses performed in a System Impact Study associated with a generator interconnection request.

FCM NEW RESOURCE QUALIFICATION NCIS ANALYSES

The FCM New Resource Qualification NCIS Analyses is the initial interconnection analysis under the Network Capability Interconnection Standard as described in Section 5.6 of PP 10. This study is similar in scope as the thermal analyses performed in a System Impact Study associated with a generator interconnection request.

NORMAL FAULT CLEARING (as defined in NPCC Glossary of Terms)

Fault clearing consistent with correct operation of the protection system and with the correct operation of all circuit breakers or other automatic switching devices intended to operate in conjunction with that protection system.

NETWORK RESOURCE CAPABILITY

Network Resource Capability (NR Capability) is defined in Schedule 22 of the Tariff and means the maximum gross and net MW electrical output of the Generating Facility at the Point of Interconnection at an ambient temperature at or above 50° F for Summer and at or above 0° F for Winter. Where the Generating Facility includes multiple energy production devices, the NR Capability shall be the aggregate maximum gross and net MW electrical output of the Generating Facility at the Point of Interconnection at an ambient temperature at or above 50° F for Summer and at or above 0° F for Winter. The NR Capability shall be equal to or greater than the CNR Capability. The NR Capability of a generating facility can be found in the Forecast Report of Capacity, Energy, Loads and Transmission (CELT Report) which is produced annually by ISO New England.

NUCLEAR PLANT INTERFACE REQUIREMENTS (as defined in the NERC Glossary of Terms)

The requirements based on Nuclear Plant Licensing Requirements (NPLRs) and Bulk Electric System requirements that have been mutually agreed to by the Nuclear Plant Generator Operator and the applicable Transmission Entities.

NUCLEAR PLANT LICENSING REQUIREMENTS (NPLRs) (as defined in the NERC Glossary of Terms)

Requirements included in the design basis of the nuclear plant and statutorily mandated for the operation of the plant, including nuclear power plant licensing requirements for:

- 1) Off-site power supply to enable safe shutdown of the plant during an electric system or plant event; and
- 2) Avoiding preventable challenges to nuclear safety as a result of an electric system disturbance, transient, or condition.

PLANNED (as defined in Attachment K of the OATT)

A transmission upgrade the ISO has approved under Section I.3.9 of the Tariff (Both a transmission Needs Assessment and a Solutions Study have been completed for planned projects).

PROPOSED (as defined in Attachment K of the OATT)

A regulated transmission solution that (1) has been proposed in response to a specific identified needs in a transmission Needs Assessment or the Regional System Plan (RSP) and (2) has been evaluated or further defined and developed in a Solutions Study, as specified in the OATT, Attachment K, Section 4.2(b) but has not received ISO approval under Section I.3.9 of the Tariff. The regulated transmission solution must include analysis sufficient to support a determination by the ISO, as communicated to the PAC, that it would likely meet the identified need included in the transmission Needs Assessment or the RSP, but has not received approval by the ISO under Section I.3.9 of the Tariff.

PROTECTION GROUP (as defined in NPCC Glossary of Terms)

A fully integrated assembly of protective relays and associated equipment that is designed to perform the specified protective functions for a power system Element, independent of other groups.

Notes:

- a) Various identified as Main Protection, Primary Protection, Breaker Failure Protection, Back-Up Protection, Alternate Protection, Secondary Protection, A Protection, B Protection, Group A, Group B, System 1 or System 2.
- b) Pilot protection is considered to be one protection group.

PROTECTION SYSTEM (as defined in NPCC Glossary of Terms)Element Basis

One or more protection groups; including all equipment such as instrument transformers, station wiring, circuit breakers and associated trip/close modules, and communication facilities; installed at all terminals of a power system Element to provide the complete protection of that Element.

Terminal Basis

One or more protection groups, as above, installed at one terminal of a power system Element, typically a transmission line.

QUALIFIED CAPACITY (as defined in Section I of the Tariff)

Qualified Capacity is the amount of capacity a resource may provide in the Summer or Winter in a Capacity Commitment Period, as determined in the Forward Capacity Market qualification processes.

RESOURCE (as defined in Section I of the Tariff)

Resource means a generating unit, a Dispatchable Asset Related Demand, an External Resource, or an External Transaction. For Capacity Commitment Periods commencing on or after June 1, 2018, it also means to include a Demand Response Resource.

SIGNIFICANT ADVERSE IMPACT (Based on Section I.3.9 of the Tariff and PP 5-3)

A change to the transmission system that increases the flow in an Element by at least two percent (2%) of the Element's rating and that causes that flow to exceed that Element's appropriate thermal rating by more than two percent (2%). The appropriate thermal rating is the normal rating with all lines in service and the long time emergency or short time emergency rating after a contingency (See Section 3.1.1).

A change to the transmission system that causes at least a one percent (1%) change in a voltage and causes a voltage level that is higher or lower than the appropriate rating by more than one percent (See Section 3.1.2).

A change to the transmission system that causes at least a one percent (1%) change in the short circuit current experienced by an Element and that causes a short circuit stress that is higher than an Element's interrupting or withstand capability (See Section 3.2).

With due regard for the maximum operating capability of the affected systems, one or more of the following conditions arising from faults or disturbances, shall be deemed as having significant adverse impact:

A fault or a disturbance that cause:

- Any loss of synchronism or tripping of a generator
- Unacceptable system dynamic response as described in PP 3
- Unacceptable equipment tripping: tripping of an un-faulted bulk power system element (element that has already been classified as Bulk Power System) under planned system configuration due to operation of a protection system in response to a stable power swing or operation of a Type I or Type II Special Protection System in response to a condition for which its operation is not required

SPECIAL PROTECTION SYSTEM / SPS (as defined in NPCC Glossary of Terms)

A protection system designed to detect abnormal system conditions, and take corrective action other than the isolation of faulted Elements. Such action may include changes in load, generation, or system configuration to maintain system stability, acceptable voltages or power flows.

However, the following are not considered SPS's:

- Automatic under frequency load shedding:
- Automatic under voltage load shedding, and
- Manual or automatic locally controlled shunt devices.

STEADY STATE (as defined in ANSI/IEEE Standard 100)

The state in which some specified characteristic of a condition such as value, rate, periodicity, or amplitude exhibits only negligible change over an arbitrary long period of time. In this guide, the term steady state refers to sixty hertz (60 Hz) currents and voltages after current and voltages deviations caused by abnormal conditions such as faults, load rejections and the like are dissipated.

SUMMER (as defined in OP 16 Appendix A)

The Summer period is April 1 to October 31.

VOLTAGE COLLAPSE

Situations which result in a progressive decrease in voltage to unacceptable low levels, levels at which power transfers become infeasible. Voltage collapse usually leads to a system blackout.

WINTER (as defined in OP 16 Appendix A)

The Winter period is November 1 to March 31.

WITH DUE REGARD TO RECLOSING (as defined in NPCC Glossary of Terms)

This phrase means that before any manual system adjustments, recognition will be given to the type of reclosing (i.e., manual or automatic) and the kind of protection.

5.2 Appendix B – Retired

This appendix was retired on November 14, 2017.

5.3 Appendix C – Guidelines for Treatment of Demand Resources in System Planning Analysis

This document referenced in Section 2.3.11.2 is listed separately on the ISO website at:

<https://www.iso-ne.com/system-planning/transmission-planning/transmission-planning-guides/>

5.4 Appendix D – Retired

This appendix on dynamic stability simulation damping criteria was retired on November 14, 2017. The contents of this appendix are now described in Section 3.3.3.

5.5 Appendix E – Dynamic Stability Simulation Voltage Sag Guideline

This document referenced in Section 3.3.4 is listed separately on the ISO website at:

<https://www.iso-ne.com/system-planning/transmission-planning/transmission-planning-guides/>

5.6 Appendix F – Stability Task Force Presentation to Reliability Committee – September 9, 2000

This document referenced in Section 3.4.3 is listed separately on the ISO website at:

<https://www.iso-ne.com/system-planning/transmission-planning/transmission-planning-guides/>

5.7 Appendix G – Phase Shifting Transformers Modeling Guide for ISO New England Network Model

This document, referenced in Sections 2.4 and 2.11.3, is listed separately on the ISO website at:

<https://www.iso-ne.com/system-planning/transmission-planning/transmission-planning-guides/>

5.8 Appendix H – Position Paper on the Simulation of No-Fault Contingencies

This document, referenced in Section 3.4.4, is listed separately on the ISO website at:

<https://www.iso-ne.com/system-planning/transmission-planning/transmission-planning-guides/>

5.9 Appendix I – Methodology Document for the Assessment of Transfer Capability

This document, referenced in Section 2.8.1, is listed separately on the ISO website at:

<https://www.iso-ne.com/system-planning/transmission-planning/transmission-planning-guides/>

5.10 Appendix J – Load Modeling Guide for ISO New England Network Model

This document, referenced in Sections 2.2 and 2.3.10, is listed separately on the ISO website at:

<https://www.iso-ne.com/system-planning/transmission-planning/transmission-planning-guides/>

Section 6

Revision History

This revision history reflects all changes after re-organization of Version 1 of the Transmission Planning Technical Guide, last updated on March 24, 2017. For revisions made to Version 1, PAC presentations, and stakeholder comments, they are posted on the ISO website.

<https://www.iso-ne.com/system-planning/transmission-planning/transmission-planning-guides#>

Rev. No.	Date	Reason
6.1	06/15/2020	<ul style="list-style-type: none"> Table 4-4 – Updated National Grid voltage
6.0	10/10/2019	<ul style="list-style-type: none"> Section 2.1 – Added language to reflect the base case used for short circuit analysis Section 3.2 – Updated language to clarify the short circuit criteria Section 4.1.3 – Updated to reflect the current process for short circuit analysis Section 4.1.4.4 – Editorial change to improve clarity
5.0	09/13/2019	<ul style="list-style-type: none"> Section 2.1 – Footnote 8 of Table 2-1 updated to clarify the treatment of units with successive accepted static or dynamic de-list bids Section 3.1.2.5 – Table 3-2 updated to reflect the removal of the Pilgrim nuclear unit voltage limits based on the retirement of the Pilgrim station Section 4.1.4 – New Section 4.1.4 to reflect the methodology for determining time-sensitive needs and the need-by date as a part of Needs Assessments
4.2	04/09/2019	<ul style="list-style-type: none"> Updated sections 2.2.1.2, 2.2.1.3, 2.2.1.4, to separate the handling of Maine paper mill load from the rest of New England load.
4.1	01/30/2019	<ul style="list-style-type: none"> Section 2.1 – Note 9 updated to reflect CASPR conforming changes.
4.0	07/03/2018	<ul style="list-style-type: none"> Section 2.2.3 – The language has been made more generic to remove specific MW values of manufacturing load and refers to study documents for the amount. Section 2.3.5 – Language about resources participating in the FCM has been removed. The language describing which resources that are to be used in each study are already documented in Table 2-1 of Section 2.1. Footnote 2 of Table 2-6 was also removed for the same reason. Section 3.1.2.5 – Table 3-2, an error was corrected in the minimum bus voltage limit for Pilgrim; it should be 343.5 kV not 345.5 kV.
3.0	05/18/2018	<ul style="list-style-type: none"> Updated guide to reflect changes to terminology associated with Price Responsive Demand (PRD) Updated to reflect current process for Needs Assessments and Solution Studies base case dispatch (Section 4.1.1.1) and system transfers (Section 4.1.1.2). Created new Section 4.2 – Proposed Plan Application Testing, to include stressed transfer language originally contained in Section 2.8. Moved power flow solutions settings from Section 4 to Section 2 to apply more generically to system studies and avoid repeating same section for each study type in Section 4.
2.0	11/14/2017	<ul style="list-style-type: none"> Re-organized original Technical Guide to group together similar topics and allow for future additions to be more logically placed within the document outline. Updated report format to latest ISO document template. Updated formatting throughout to be consistent with ISO New England Style Guide. Removed section concerning two generators out in the base case (Section 10 of Rev 1.0) of transmission Needs Assessments and replaced with base case dispatch probabilistic methods (New Sections 2.2.2, 2.3.5, 2.3.12, 3.1.3, and 4.1.1 of Rev 2.0). Retired Appendices B and D of the guide.

Rev. No.	Date	Reason
1.0	03/24/2017	• Latest version of the Technical Guide prior to re-organization in Rev 2.0.