APPENDIX B - METHODOLOGY FOR DEVELOPING LOAD POWER FACTOR STANDARDS

References:

ISO New England Operating Procedure No. 12 - Voltage and Reactive Control, Appendix B - Voltage and Reactive Schedules (OP-12B)

ISO New England Operating Procedure No. 19 - Transmission Operations (OP-19)

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I.OVERVIEW

The methodology set forth in this Appendix shall be used to establish minimum and maximum load power factor (LPF) standards for each of the eleven (11) study areas as defined in OP-17, Appendix A. The New England load levels used for the LPF standards may be modified by the Voltage Task Force (VTF) from time-to-time, as system changes dictate. As of 2021, the 2020 LPF standards were composed of five (5) points:

Maximum standard is composed of three (3) points:

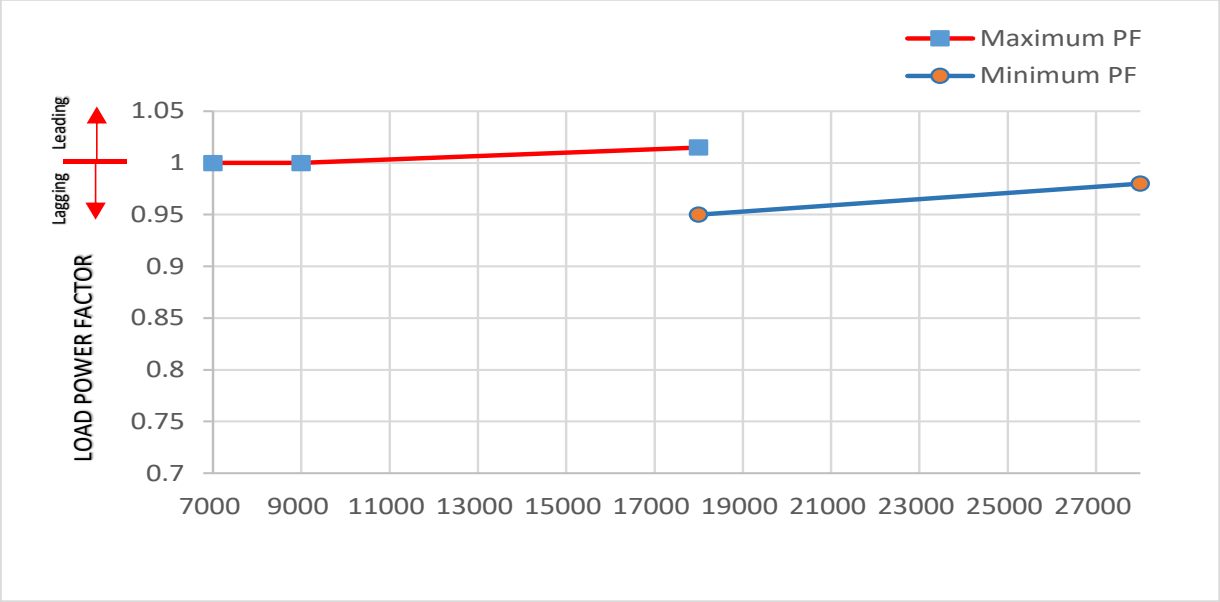
- 7,000 MW light load
- 9,000 MW light load
- 18,000 MW intermediate load biased for high voltage

Minimum standard is composed of two (2) points:

- 18,000 MW intermediate load biased for low voltage
- 28,000 MW heavy load

One curve connects the minimum LPF standard points and a second curve connects the maximum LPF standard points. The two (2) curves represent the upper and lower boundaries of LPFs that establish the standard for the area. The following figure shows an example of minimum and maximum LPFs for an area, as a function of load level.

Figure 1.1: Example of LPF Standards for a Given Study Area



II.TESTING CRITERIA

A general criterion is used to determine the minimum and maximum LPFs at each load level, for all areas.

1. **Minimum/Maximum Voltage**

    a. When the study area LPF is at its maximum, a significant number of transmission busses (69 kV and above) within the study area cannot exceed the high voltage design criteria of the Transmission Owners (TOs) in the area.

    b. When the study area LPF is at its minimum, a significant number of transmission busses (69 kV and above) within the study area cannot drop below the low voltage design criteria of the TOs in the study area.

    c. A “significant number of transmission busses” is to be determined by the VTF, on a case-by-case basis.

Post-contingency analysis must be performed for the Minimum/Maximum Voltage test during all lines-in system conditions.

Additionally, for the maximum LPF standard at light load levels, post Contingency Analysis (CA) must be performed for the most limiting facility out system condition.

For all load levels, the VTF will determine, based upon a review of results, the appropriate LPF standard to apply.

2. **Limiting Criterion for Minimum and Maximum LPF: -**

   The LPF standards should not create an overreliance on distribution-installed reactive devices to maintain acceptable transmission system voltage performance.

   To prevent LPF over-correction:

   - The maximum LPF standard must **not** fall below unity (i.e., lagging LPF limit is **not** allowed)*; and
   - The minimum LPF standard must **not** fall above unity (i.e., leading LPF limit is **not** allowed)

   The maximum LPF standard is determined by system performance at light to intermediate load levels based upon post-contingency high voltage performance. If the maximum voltage criterion indicates that a lagging (below unity) maximum LPF standard is needed, this result will be deemed unacceptable. Other transmission solutions (e.g., transmission reactors) should be investigated.

   The minimum LPF standard is determined by system performance at intermediate to peak load levels based upon post-contingency low voltage performance. If the minimum voltage criterion indicates that a leading (above unity) minimum LPF standard is needed, this result will be deemed unacceptable. Other transmission solutions (e.g., transmission capacitors) should be investigated.

See Figures 2.1 and 2.2 below for examples of acceptable and unacceptable LPF standards.

Figure 2.1 notes an example of acceptable LPF standards, in part, because neither curve crosses unity LPF.

Figure 2.2 documents an example of unacceptable LPF curves for both the minimum and maximum LPF standards. Both curves cross the unity LPF line. These results indicate a reliance on distribution-installed reactive devices to maintain acceptable transmission system voltage performance (i.e., capacitors to support low voltage concerns and reactors to support high voltage concerns).

*Boston LPF area is the one area that is exempted from the maximum standard limiting criterion. This is due to the abundance of cables in Boston, which necessitated planning for a lagging LPF.

Figure 2.1

Example of acceptable LPF standards

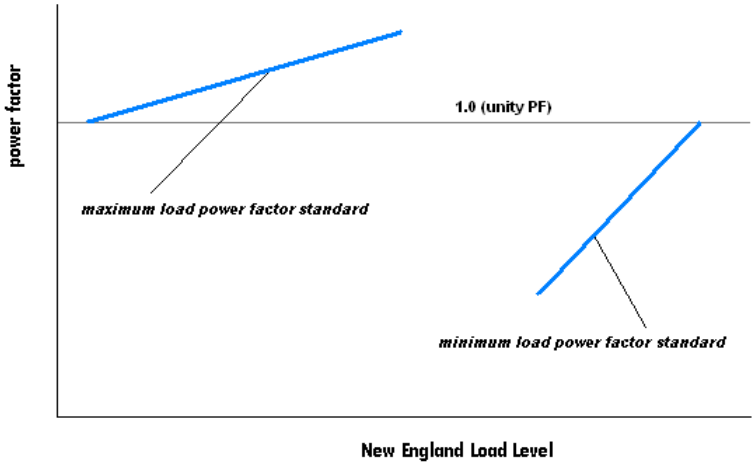
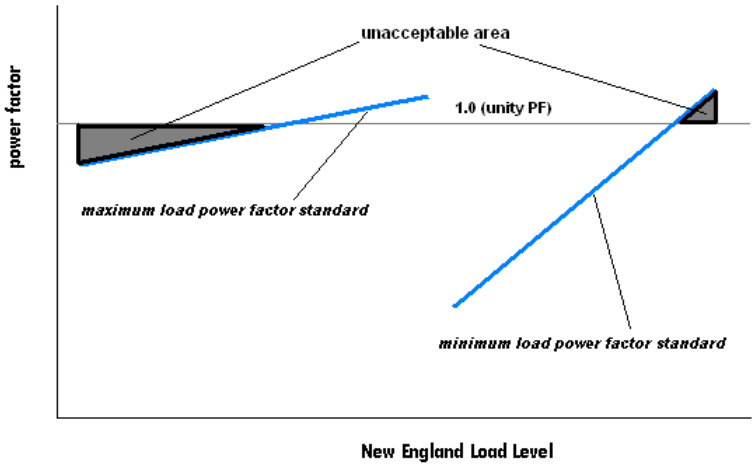


Figure 2.2

Example of unacceptable LPF standards



III.LPF DEVELOPMENT

1. New England Load Levels to be Modeled

a. Heavy Net Load (28,000 MW)

b. Intermediate Net Load (18,000 MW)

c. Light Net Load (7,000 MW)

NOTE

New England load will be calculated as follows:

New England area Load +

New England area Losses –

New England area Station Service Load.

Pump Storage units will **not** be included in the calculation of New England load level for the purposes of these load power factor studies.

2. LPF Area Definition

Each LPF area shall be modeled according to the definition in, Operating Procedure No. 17 – Load Power Factor and System Assessment Appendix A – Area Definitions (OP-17A). Should new transmission projects introduce a change along the existing LPF area boundaries, OP-17A shall be promptly updated to reflect the area definitions used in the current study.

3. Load Data

a. MW loads at each bus are to be initialized using ISO projections for the appropriate net load level. MW load values contained in New England Library LPF cases are typically suitable. These will reflect appropriately applied PV and energy efficiency impacts for the studied conditions.

b. MW loads at each bus are to be scaled to the appropriate net load level (i.e. 28,000 MW, 18,000 MW or 7,000 MW).

c. Loads are independent of voltage [constant Power/Reactive (PQ) representation].

4. Generator Data and Dispatch

a. For each load level, Generators are to be dispatched economically in the base cases, assuming all New England Generators are available and respecting reserve requirements.

5. Capacitors/Reactors

All sub-transmission/distribution capacitors and reactors (below 69 kV) are to be considered as part of the study area load.

6. Tie-Lines

a. Inter-Reliability Coordinator Area/Balancing Authority Area (RCA/BAA) Interface transfers should be tested up to transfer limits where appropriate.

b. HVDC Tie-Lines should be treated like Generators/Demand, and dispatched accordingly.

7. Solution Parameters for Contingency Testing

a. Automatic load tap changing is allowed on all tests.

b. Phase Angle Regulators (PARs) are allowed to regulate flow.

c. The system swing bus is located outside of New England with **no** regulation of RCA/BAA interchange flows.

8. LPF Measurement

The LPF must be measured at the transmission level (i.e., at the high side of the transmission step down transformers), typically the 115 kV or 69 kV bus.

IV.CONTINGENCIES TO BE TESTED

The VTF will determine the list of contingencies to be tested for each area's LPF standard study. All normal contingencies, as defined in ISO New England Operating Procedure No. 19 - Transmission Operations (OP-19), may be selected for the LPF study. The OP-19 contingencies consist of individual transmission facilities (i.e., transmission lines, transformers, generators), as well as contingencies that result in the loss of multiple transmission facilities (i.e., Breaker Failure and Double Circuit Tower Contingencies) that have unacceptable inter-RCA/BAA impact.

If a contingency would knowingly trigger a Remedial Action Scheme (RAS) or Automatic Control Scheme (ACS), then the RAS and ACS actions are to be modeled in a contingency definition.

V.TESTING PROCEDURE

LPFs for these tests are developed from the guidelines described in Section III of this document ("LPF Development"). Testing focuses on only one study area, at one load level, at a time. To develop a minimum LPF standard for a given load level, the loadflow case is biased toward low voltage conditions. To develop a maximum LPF standard for a given load level, the loadflow case is biased toward high voltage conditions.

As the LPF is varied in an attempt to find the LPF standard, a uniform LPF must be applied (i.e., the same LPF must be applied to each bus in the study area).

A. MINIMUM LPF - The minimum LPF for each load level is determined as follows.

1. Low Voltage Bias - Starting from an economic dispatch, generation should be biased toward low voltage conditions:

a. **Import Study Areas** - In study areas where less economical generation exists in comparison with the load (i.e. "Import Study Areas"), the base cases should be biased for low voltage as follows:

1) Shut off the Generator with largest net VAr producing capability (unless such Generator is required to run for reliability reasons), within subject area.

2) Adjust New England Transmission Interface transfers so as to depress transmission voltages within study area. Interface transfers that tend to depress study area voltages are to be dispatched up to or near existing limits, depending on the practicality of dispatch and operations at each load level. This could involve dispatching up to existing import limits for Import Interfaces (e.g., Boston Import), and/or dispatching up to existing limits for through-flow Interfaces (e.g., North-South). The preference when changing interface transfers is to fully shut off generators as opposed to partially lowering output. This minimizes the availability of available MVAR sources.

b. **Export Study Areas** - In study areas where more economical generation exists in comparison with the load (i.e., "Export Study Areas"), the base cases should be biased for low voltage as follows:

1) Adjust New England Transmission Interface transfers so as to depress transmission voltages within study area. This usually involves dispatching to existing export limits for the study area.

Interface transfers that tend to depress study area voltages are to be dispatched up to or near existing limits, depending on the practicality of dispatch and operations at each load level.

2. **Reactive Dispatch** - For each load level, VAr support from all area generation and transmission VAr sources is to be maximized:

   a. Turn on all Transmission VAr sources (e.g., Capacitor banks, STATCOMs, etc.) in the area (subject to minimum/maximum voltage schedule at all busses, as well as other constraints, e.g., Phase II filter requirements, dynamic reserve requirement for STATCOMs, etc.).

   b. Shut off all Transmission VAr absorption facilities (e.g., Reactors, etc.) in the study area (subject to minimum/maximum voltage schedule at all busses, as well as other constraints, e.g., Phase II filter requirements, dynamic reserve requirement for STATCOMs, etc.).

   c. Set voltage schedules of all study area Generators to the normal schedule.

   The general approach, when determining the minimum LPF standard, is to use as much generation and transmission VAr support in the area as possible.

3. **Voltage Criteria Testing** - For each load level, the minimum LPF standard based on voltage criteria is to be determined as follows:

   a. Determine the contingency that results in the lowest transmission voltages in the study area

   b. Adjust the study area LPF until a significant number of transmission busses (69 kV and above) do **not** drop below the design criteria of TOs in the study area. This LPF constitutes the minimum LPF for the study area based on voltage criteria.

B. MAXIMUM LPF - The maximum LPF for each load level is determined as follows.

1. **High Voltage Bias** - Starting from an economic dispatch, generation should be biased toward high voltage conditions as follows (for either export or import study areas):

   a. Shut off the Generator with largest net VAr absorbing capability (unless such Generator is required to run for reliability reasons), within the study area.

   b. Adjust the New England Transmission Interface transfers so as to inflate transmission voltages within subject area. This entails a dispatch that minimizes I^2X losses in the subject area.

2. **Reactive Dispatch** - For each load level, VAr absorption capability from all area generation and transmission VAr facilities is to be maximized:

   a. Shut off all transmission VAr sources (e.g., capacitors, etc.) in area (subject to minimum/maximum voltage schedule at all busses, as well as other constraints (e.g., Phase II filter requirements, dynamic reserve requirement for STATCOMs, etc.).

   b. Turn on all transmission VAr absorption facilities (e.g., reactors, STATCOMs, etc.) in the area [subject to minimum/maximum voltage schedules at all

busses, as well as other constraints (e.g., Phase II filter requirements, dynamic reserve requirements for STATCOMs, etc.)].

c. Set the voltage schedules of all study area Generators to the normal schedule.

The general approach, when determining the maximum LPF standard, is to use as much generation and transmission VAr absorption capability in the study area as possible.

3. Voltage Criteria Testing - For each load level, the maximum LPF based on voltage criteria is to be determined as follows:

a. Determine contingency that results in the highest transmission voltages in the study area.

b. Adjust the study area LPF until a significant number of transmission busses (69 kV and above) do **not** exceed the design criteria of TOs in the study area. This LPF constitutes the maximum LPF for the study area based on voltage criteria.

VI.STUDY SUMMARY

A study summary shall be written to document all analysis conducted to determine the LPF standard. The study summary is specific to a LPF study area, load level, and a maximum or minimum standard. For example, there would be one study summary for SEMA 7GW maximum point, and another study summary for SEMA 18GW minimum point. The study summary shall include the following:

- The new LPF standard
- List of contingencies evaluated. Indication of the worst contingency.
- For the maximum standard, light load study, list the facility out conditions studied.
- Location of violating bus(es)
- Base Case Summaries for all load levels studied:

    1) MW and MVAr output of all major Generators in the studied LPF. Specify which Generator was deemed the largest MVAR source and therefore set offline for the study.

    2) Interface flows (MW) for all transmission interfaces relevant to the studied LPF area.

    3) The New England RCA/BAA load (MW)

    4) HVDC Transfer Levels (MW)

OP-17, Appendix B Revision History

Document History (This Document History documents action taken on the equivalent NEPOOL Procedure prior to the RTO Operations Date as well as revisions made to the ISO New England Procedure subsequent to the RTO Operations Date.)

Rev. No.	Date	Reason
Rev 1	03/07/03	
Rev 2	02/01/05	Updated to conform to RTO terminology
Rev 3	06/02/05	Revised data resulting from Voltage Task Force review
Rev 4	09/07/06	Update for changes resulting from VTF meetings
Rev 5	10/01/06	Revised for ASM Phase 2
Rev 6	11/18/10	Biennial review by procedure owner; Editorial changes including font change, format changes, clarification of directed actions, added References Section, added Table of Contents, added disclaimer on page 1 and added uncontrolled to all pages, defined acronyms for applicable terms, Update for change of using 80% of ICU instead of 2/3 of ICU
Rev 7	05/08/14	Biennial review by procedure owner; Minor editorial and format and required administrative changes consistent with current practices and management expectations; Changed the number of areas to 11 in the introduction section to match OP17A; Made the following three major changes in the “Criteria Testing” section: 1) added language requiring additional facility out testing for light and shoulder load levels; 2) modified language to indicate 0 VAR criteria even if more limiting might not be the appropriate criterion to set the standard; and 3) clarifying the language in the “Limiting Criterion for Min/Max Power Factor” and added figures for illustration; Deleted references stating “the most limiting criteria will set the Area LPF standard” in the “Testing Procedure” section; Made the following two changes in the report section: 1) added a requirement to submit power flow area diagrams as a part of the Area LPF Study report; and 2) corrected the “Total MW Demand” and “Area LPF” values in the “Sample Report Table - Figure 1.2
Rev 8	10/29/14	In References Section, added OP-19 title and updated OP-14 title (same in the main body); Globally replace “VAR” with “VAr” in document content; In Sections I & III & Figure 1.2: removed reference to percentage of CELT identified for the three discrete load levels studied and replaced with three discrete load levels identified by the Voltage Task Force. Added a NOTE to identify how New England loads are calculated in the LPF Studies. In Section V: made minor editorial change, added a period after the second sentence in the second paragraph.; Re-numbered Figure 1.2 to be Figure 6.1(to be consistent with figure numbering in other sections);
Rev 8.1	07/06/16	Periodic review performed requiring no changes; Made administrative changes required to publish a Minor Revision;
Rev 8.2	06/14/18	Periodic review performed requiring no changes; Made administrative changes (including updating OP-14 title) required to publish a Minor Revision;
Rev 8.3	04/24/20	Periodic review performed requiring no changes; Made administrative changes required to publish a Minor Revision

Rev. No.	Date	Reason
Rev 9	10/01/20	Global edits to coordinate with OP-17 rev.7 LPF business process changes; Globally eliminated zero VAr Interchange from testing criteria
Rev 10	09/08/22	Update to current practices.
Rev 10.1	09/04/24	Periodic review performed by Procedure Owner requiring no changes; Made administrative changes required to publish a Minor Revision.