Operating Procedures

ISO New England Operating Procedure No. 17

Load Power Factor Correction – Appendix B – Methodology for Developing Load Power Factor Limits

Effective Date: November 18, 2010
Revision No. 6

APPENDIX B -
METHODOLOGY FOR DEVELOPING LOAD POWER FACTOR LIMITS

References:

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

ISO New England Operating Procedure No.14 – Technical Requirements for Generation, Demand Resources and Asset Related Demands (OP-14), Appendix B (Generator Reactive Data)

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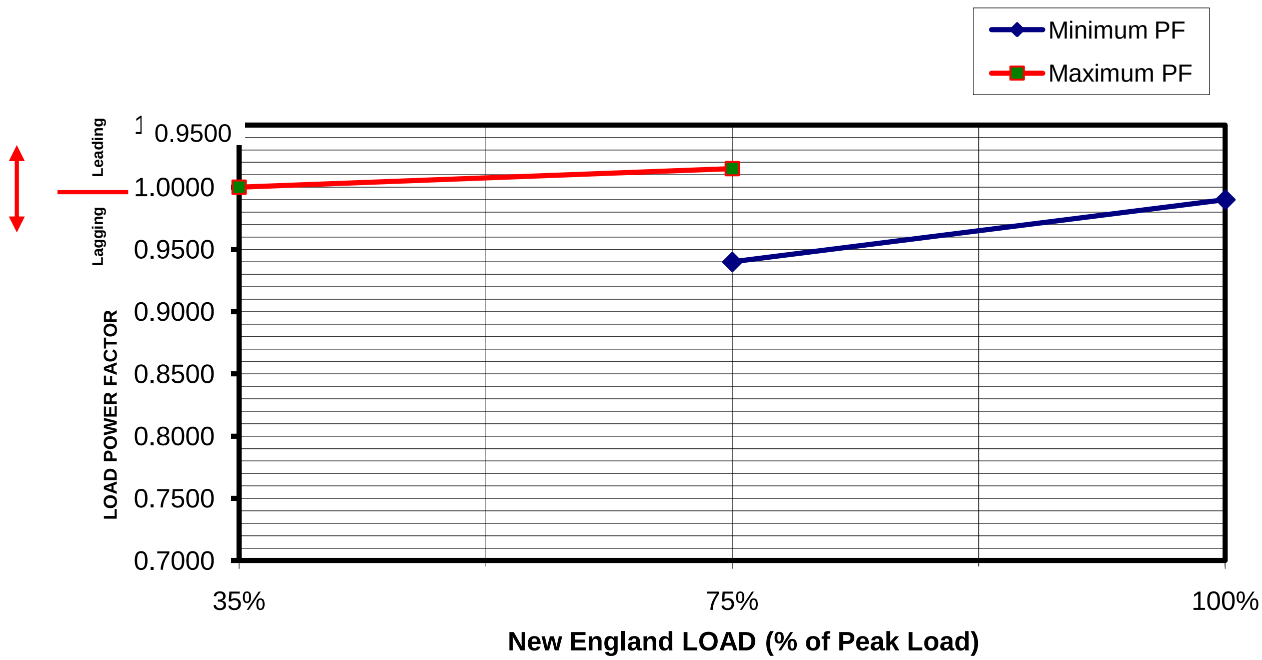
I. OVERVIEW

The methodology set forth in this Appendix shall be used to establish minimum and maximum load power factor limits for each of the 10 study areas as defined in OP-17 Appendix A. at three discrete load levels: heavy (100% of the Capacity, Energy, Loads and Transmission report (CELT) 90/10 load forecast for the study year), medium (75% of the (CELT) 50/50 load forecast for the study year), and light load (35% of the CELT 50/50 load forecast for the study year). These load levels may be modified by the Voltage Task Force (VTF) from time to time, as system changes dictate. A curve connects the two minimum points and another curve connects the two maximum points. The two curves represent the range of load power factors that establish the standard for the area. The following figure shows an example of minimum and maximum power factors for an area, as a function of load level.

Figure 1.1: Example of Load Power Factor Curve for a Given Study Area



II. TESTING CRITERIA

A general criterion is used to determine the minimum and maximum power factors at each load level, for all areas. The general criteria consist of two components; Zero (0) Voltage-Ampere Reactive (VAR) Interchange and minimum/maximum voltage.

1. **0 VAR Interchange** - When the study area load power factor is at its maximum, under conditions biased to promote excess capacitance and high voltage, no contingency can result in VARs having to be exported out of a subject area. When the study area load power factor is at its minimum, under conditions biased to promote large reactive losses and low voltage, no contingency can require that VARs be imported into the study area. Note that the 0 VAR Interchange requirement only applies during post-contingency conditions. VARs can be exchanged between study areas during pre-contingency (i.e. “all-lines-in”) conditions. 0 VAR Interchange makes each study area responsible for its own reactive needs under stressed conditions and minimizes the need to consider voltage/reactive performance of areas outside of the study area.

2. **Minimum/Maximum Voltage** - When the study area load power factor is at its maximum, a significant number of transmission busses (69 kV and above) within the study area can’t exceed the high voltage design criteria of the Transmission Owners in the area. When the study area load power factor is at its minimum, a significant number of transmission busses (69 kV and above) within the study area can’t drop below the low voltage design criteria of the Transmission Owners in the study area. A “significant number of transmission busses” is to be determined by the VTF, on a case-by-case basis.

Note that both criterion described above are to be applied at each load level. The most limiting of the two establishes the load power factor requirement for a given load level. For some load levels, the VAR interchange criterion may result in the most restrictive load power factor requirement. For other load levels, the min/max voltage criterion may result in the most restrictive load power factor requirement.

Limiting Criterion for Minimum Power Factor: Capped at Unity - The maximum allowable minimum load power factor is unity, for any load level. If the VAR Interchange or minimum/maximum Voltage criteria indicate that a leading minimum load power factor is needed, transmission solutions (e.g., transmission capacitors) should be investigated.

III. LOAD FLOW DEVELOPMENT

1. Load Levels to be Modeled

a) Summer Peak Load (100% of the CELT 90/10 load forecast for the study year)

b) Summer Intermediate Load (75% of the CELT 50/50 load forecast for the study year)

c) Spring Light Load (35% of the CELT 50/50 load forecast for the study year)

2. Load Data

a) MW loads at each bus are to be initialized using ISO projections for the appropriate load level. MW load values contained in New England Library load flow cases are typically suitable.

b) MW loads at each bus are to be scaled to the appropriate load level (i.e. 100%, 75%, or 35%) using the extreme weather 90/10 load forecast for New England for the 100% case and the normal weather 50/50 load forecast for New England for the 75% and 35% cases, as published in the most current CELT report.

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

3. 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.

b) Generator voltage schedules must not exceed limits specified in ISO New England Operating Procedure No. 12 – Voltage and Reactive Control (OP-12), Appendix B (Voltage and Reactive Survey).

c) Generator Reactive limits are equal to the VAR limits at Claimed Capability per ISO New England Operating Procedure No. 14 – Technical Requirements for Generation, Demand Resources and Asset Related Demands (OP-14), Appendix B (Generator Reactive Data) as documented on the NX-12D Forms.

d) Stations Service loads of all large Generators are to be modeled as documented on the NX-12D Forms. These loads are not to be tripped with the contingent Generator.

4. Capacitors/Reactors

All sub-transmission/distribution capacitors and reactors (below 69 kV) are to be considered as part of the study area load. Note that this requires all sub-transmission/distribution capacitors and reactors to be equivalenced with load in the load flow, unless the sub-transmission is interconnected in such a way that equivalencing is not beneficial. If a transmission capacitor or reactor is designated as “Local Area”, the Transmission Owner cannot use this capacitor or reactor to determine the load power factor requirements of the study area. This avoids taking credit for the same capacitors or reactors twice, one at the study level and one at the survey level. The “Local Area” transmission capacitors or reactors listed in OP-12 Appendix B must be turned off during all testing.

5. Tie-Lines

a) Tie-lines between OP-17 study areas must be split in half so that VAR Interchange between the study areas is metered at the electrical midpoint of each tie-line. Exceptions may be applicable in cases where contracts specify entitlements to line charging, or in cases where splitting the lines has no significant impact on VAR allocations between study areas.

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

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

6. 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.

7. Load Power Factor Measurement

The load power factor 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

All normal contingencies, as defined in OP-19, are to be tested. These 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.

All Special Protection Systems (SPSs) are to be appropriately modeled in the loadflow simulations.

V. TESTING PROCEDURE

The testing criteria (0 VAR Interchange and minimum/maximum voltage) are to be applied to each study area, at each load level, with the most restrictive load power factor becoming the study area standard.

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

A. MINIMUM LOAD POWER FACTOR - The minimum load power factor 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) With largest Generator in study area shut off, 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).

   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 maximum.

   The general approach, when determining the minimum load power factor, is to utilize as much generation and transmission VAR support in the area as possible. Note that Distribution VAR support is to be considered part of the area load.

3. **0 VAR Interchange Testing–** For each load level, the minimum load power factor based on 0 VAR Interchange is to be determined as follows:

   a. Determine the contingency (transmission line or generator) that results in the highest VAR losses within the subject area.

   b. Generators may be adjusted to simulate 10 minutes worth of post-contingent operator actions to relieve transmission overloads exceeding the Long Term Emergency (LTE) limit. Compensate for a Generator contingency by depleting the ISO New England RCA/BAA 10 minute reserve and starting up to 80% of the ISO RCA/BAA ICUs. Pick up the remainder outside the study area, but within New England. Adjust generation to the extent possible to relieve overloads.

   c. Adjust the study area load power factor until VAR Import into the study area is zero for the contingency determined above. Note: A uniform load power factor must be applied (i.e. the same load power factor must be applied to each bus in the study area).

   d. The area load power factor at which the VAR import into the study area is zero constitutes the minimum load power factor based on the 0 VAR Interchange criterion.

4. **Voltage Criteria Testing –** For each load level, the minimum load power factor 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 load power factor until a significant number of transmission busses (69 kV and above) do not drop below the design criteria of Transmission Owners in the study area. This power factor constitutes the minimum load power factor for the study area based on voltage criteria. Note: A uniform load power factor must be applied (i.e., the same load power factor must be applied to each bus in the study area).

5. **Limiting Power Factor –** For each load level, the most restrictive load power factor, based on either 0 VAR Interchange or minimum voltage, becomes the study area standard.

B. MAXIMUM LOAD POWER FACTOR - The maximum load power factor 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. With the largest Generator in study area shut off, 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 minimum.

   The general approach is to utilize as much generation and transmission VAR absorption capability in the study area as possible when determining the maximum load power factor. Note that Distribution reactors are to be considered part of the study area load.

3. **0 VAR Interchange Testing–** For each load level, the maximum load power factor based on 0 VAR Interchange is to be determined as follows:

   a. Determine contingency that results in the highest loss of VAR absorption capability within the study area.

   b. Adjust study area load power factor until VAR Export out of the study area is 0 for contingency determined above. Note: A uniform load power factor must be applied (i.e., the same load power factor must be applied to each bus in the study area).

   c. The study area load power factor at which the VAR export out of the study area is 0 constitutes the maximum load power factor based on the 0 VAR Interchange criterion.

4. **Voltage Criteria Testing –** For each load level, the maximum load power factor 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 load power factor until a significant number of transmission busses (69 kV and above) do not exceed the design criteria of Transmission Owners in the study area. This power factor constitutes the maximum load power factor for the study area based on voltage criteria. Note: A uniform load power factor must be applied (i.e. the same load power factor must be applied to each bus in the study area).

5. **Limiting Power Factor –** For each load level, the most restrictive load power factor (based on either 0 VAR Interchange or Maximum Voltage), becomes the study area standard.

VI. REPORT

A report shall be written for each study area, documenting all analysis conducted to determine the load power factor requirements. The report shall include the following:

- Interface Definition (i.e., list of branches that define the study area)
- Contingency List
- Base Case Summaries for all 4 load flows developed:
    1) MW and MVAR Output of all major Generators in the New England RCA/BAA
    2) Dispatch of all Transmission Capacitors in the study area
    3) Dispatch of all Transmission Reactors in the study area
    4) Interface flows (MW) for all relevant transmission interfaces in the New England Control Area.
    5) The New England RCA/BAA load (GW)
    6) HVDC Transfer Levels (MW)
- Figure 1.2 is a sample of the table, which itemizes the minimum and maximum power factor case results for each load level.

Figure 1.2: Sample Report Table

		(MVAR)										*(MW)*							
		Supply					*Demand*					*Supply*			*Demand*				
Loadflow Description	**Limiting Contingency**	**Line Charging**	**Area Generators:Combined MVAr Output**	**Area Xmission Capacitors: Combined MVAr Ouput**	**Tie Lines: Combined MVAr Import**	**Total MVAr Supply**	**Line Losses (I^2X)**	**Area MVAr Load**	**Area Xmission Reactors: Combined MVAr Absorbsion**	**Station Service MVAr Load**	**Total MVAr Demand**	**Area Generators:Combined MW output**	**Tie Lines: Combined MW Import**	**Total MW Supply**	**Area MW load**	**Station Service Load**	**Area MW Losses (I^2R)**	**Total MW Demand**	**Area LPF**
NE MA 100% Load LV Bias	394	338	300	1465	20	2123	1758	365	0	0	2123	2494	-307	2187	2100	0	87	87	0.985
NE MA 75% Load LV Bias	394	378	305	1197	5	1885	1221	659	0	0	1880	1976	-339	1637	1565	0	72	72	0.920
NE MA 75% Load HV Bias	Granite Ridge	241	-78	621	-38	746	693	-267	320	0	746	1416	165	1581	1565	0	16	16	0.985
NE MA 35% Load HV Bias	Salem G3	294	-41	446	11	710	228	2	480	0	710	589	267	856	852	0	4	4	1.000

OP 17 Appendix B Revision History

<u>Document History</u> (This Document History documents action taken on the equivalent NEPOOL Procedure prior to the RTO Operations Date as well 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