Attachment G – System Restoration Strategies

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I. 345 kV System Restoration Event Worksheet User Guide

The purpose of this worksheet is to provide the user a means to evaluate the transient over-voltage as well as the steady-state voltage effect of energizing 345 kV elements. While the worksheet can be used for energizing all 345 kV lines, the primary application is for 345 kV elements **not** identified in ISO New England Master/Local Control Center Procedure No. 18 – New England System Restoration Plan (M/LCC 18), Attachment A System Restoration Flowchart (M/LCC18A). Even though the stated 345 kV elements in M/LCC18A have been subject to Electromagnetic Transients Program (EMTP) and steady-state evaluations, it is recommended to use the worksheet to determine the cumulative effect on reactive margins while energizing 345 kV transmission elements since Real-Time system conditions may significantly differ from study assumptions.

Attachment G columns can be broken into four main sections:

- Task description - what line is being energized and when
- Resource information - Columns 1 and 2
- Energization information - Columns 3 through 5
- Decision to energize - Columns 6 and 7

ISO New England Master/Local Control Center Procedure No. 18 – New England System Restoration Plan (M/LCC18) Attachment G - System Restoration Strategies (M/LCC18G), this document, provides for the decision to energize to be determined as a result of comparing reactive Resources to energization information. This is an arithmetic analysis only; it is strongly recommended that System Operators confer with their respective engineering support group prior to energizing alternate paths, that are **not** identified in M/LCC18A, during system restoration.

Energization of a 345 kV element that is performed outside of the studied paths should be evaluated, by ISO and the applicable LCC(s) System Operator/s, using M/LCC18G.

The worksheet is filled out sequentially and values are cumulative; only columns that are applicable will contain information.

NOTE

As a result of electromagnetic transient studies using the EMTP analysis software, a "thumb-rule" of 150 MVA of dynamic reactive Resources (i.e., spinning generation or synchronous condensers) has been determined to provide sufficient transient dynamic reactive capability to maintain acceptable transient over-voltage during 345 kV element energizations that are **not** specified in M/LCC18 A. However, since a Generator MVA rating value is typically found on the Generator nameplate data sheet and is **not** readily available to System Operators during a system restoration event, a Generator MW rating value will be used in lieu of MVA rating value. Typically a Generator is rated in terms of maximum MVA output at a specific voltage and power factor (usually 0.85 to 0.9 lagging). For example, a 150 MVA rated Generator with a 0.9 lagging power factor will have a 135 MW rating (150 MVA * 0.9). Therefore using 150 MW of on-line Generator capability will, generally, exceed the 150 MVA of on-line capability and will result in a more acceptable transient over-voltage performance.

The term electrically close (or "near") is used when dealing with an island with multiple Resources that are not at the same electrical interconnection point. When there are multiple Resources available within an island for consideration in energizing a 345 kV line, the electrically closest Resources in the island should be used when determining if the 150 MW requirement is met.

Starting a synchronous condenser can cause a short, large voltage depression and the engineering support group should be consulted prior to energization.

For the purposes of these calculations, synchronous condenser MW equals the synchronous condenser MVA rating.

A. Column 1 is to determine that sufficient transient dynamic reactive capability exists to maintain acceptable transient over-voltages during the 345 kV element energization. The user must enter "Y" if the total MW capability of all on-line Resources is more than 150 MW or enter "N" if the total MW capability of all on-line Resources is less than 150 MW. If "N" then energization is **not** permitted using this worksheet and either:

   1) More Resource capacity should be brought on-line or;

   2) Detailed engineering studies should be performed to determine whether energization can occur.

B. Columns 2 through 6 require the user to enter the appropriate information and perform the indicated mathematical function.

   1) Column 2 identifies the available Resource Lead MVAR absorbing capability that is "near" the 345 kV energization. This value translates as the total MVAR absorbing capability. The term "near" is used to indicate that the electrical proximity of the available Resource to the point of energization is critical and should be considered prior to the 345 kV element energization. System

Operators are advised to work with engineering staff to determine whether the available Resources are electrically close to (or "near") the 345 kV energization. One variable to determine if a Resource is "near" the 345 kV element under consideration is the Resource's ability to control voltage at the point of energization.

2) Column 3 identifies the expected charging of the 345 kV element being evaluated. The charging value at NOMINAL voltage can be obtained from ISO New England Master/Local Control Center Procedure No. 18 – New England System Restoration Plan (M/LCC18) Attachment C Charging of 345 kV Circuits in New England (M/LCC18C).

3) Column 4 identifies Reactor MVAR, if any, that will be energized simultaneously with the transmission element being evaluated. If **no** reactors will be energized with the element, this value will remain zero (0).

4) Column 5 is the Net MVAR charging from the 345 kV transmission element being energized. This value is the difference of Columns 3 and 4. The value in this column will be entered on the right side of the comparison equation in Column 6 as the "Net MVAR Charging".

C. Column 6 is used to determine that sufficient leading capability exists to absorb all the MVAR Charging from the element to be energized and maintain acceptable steady state voltages.

1) Column 6 is the difference between the available Resource Lead MVAR capability (column 2) and Net MVAR Charging (column 5).

NOTE

Energizing 345 kV cables should **not** be attempted until later stages of system restoration. Rules of Thumb will not be used for cable energizations. Cable energizations will be completed through engineering evaluation.

D. Column 7 requires that the answers in column 6 are greater than zero in order for the decision to energize to be "Y". System Operators should consider taking both of the following actions prior to energizing 345 kV lines:

1) Maintain Resource* voltages at nominal/minimal levels, and

2) Create leading reactive reserve on Resources***** by using loads and available reactors to absorb reactive power.

***** Resources referred to above are those Resources considered in order to satisfy the inertia requirement (minimum 150 MW of generation capability) for energizing 345 kV elements.

II. Restoration Strategy Rules of Thumb

A. Generation Restoration

1.Frequency Control

a. Monitor appropriate frequency for the island being controlled

b. Maintain steady-state frequency 59.9-61.0 Hz

2.Generation Loading

a. When possible, maintain minimum loading on each Generator to prevent loss of any Generator, creating significant frequency excursion

b. Increasing island inertia is beneficial to stable operation. Energizing additional transmission elements, load, and generation will increase the island size and generation MW reserve in the island. These actions improve the likelihood an island will ride-through a frequency excursion caused by a system disturbance.

3.Load Shed

a. 6-10% of load shed in area produces ~1 Hz rise in frequency

4.Regulation

a. Flat Frequency- New England is isolated or larger of interconnected areas (automatically changes AGC Bias to lower value)

b. Tie-Line Bias- New England is smaller of interconnected areas

c. Use multiple slower-moving Generators vs faster-moving to prevent frequency hunting

B. Load Restoration

1. Load Pick Up

a. Until operational experience shows otherwise, loads based on normal operating values for time, date and season should be restored in block sizes that do **not** exceed 5% of total synchronized generating capability

b. When any Generator operating with the governor in isochronous (isolated, island) mode is operating in an island which also contains significant generation with the governors operating in droop (parallel, manual) mode:

i. Monitor the isochronous unit loading as new load is energized and as cold load decreases.

- Ensure no overload of the isochronous unit occurs before transferring some of its load to a droop unit with available capacity.
- Ensure cold load reduction does not threaten to trip the isochronous

unit on reverse power.

2. Frequency Control

   a. Increase frequency to 60.3-61.2 Hz prior to load pick-up

3. Cold Load

   a. Cold load remains at 150-500% of normal load for up to 30 minutes

C. Transmission Restoration

1. Voltage Control

   a. If operationally allowed, maintain steady-state voltage +/- 5% of nominal (ideally low in the voltage range)

> NOTE
>
> Cables will not be energized using Rules of Thumb. Cable energizations will be evaluated by support engineering prior to energization.

2. Charging

   a. 345 kV Overhead- 0.88 MVAR/Mile

   b. 230 kV Overhead- 0.28 MVAR/Mile

   c. 115 kV Overhead- 0.07 MVAR/Mile

3. Minimum Source (Overhead)

   a. Resources electrically close to 345 kV energization (generally 150 MW, use energization worksheet)

   b. 115 kV/230 kV ensure on-line Resources have sufficient dynamic reactive reserve (AVRs in Automatic)

D. Island Interconnections

1. Parameters to Check Prior to Interconnection

   a. Determine the largest single contingency loss

   b. Assess if Operating Reserves are adequate to cover the loss

   c. Determine the amount of spinning reserve

   d. Assess if a load shedding plan will be used for reserve

   e. Determine if any transmission facilities overload if reserves are activated

   f. Determine if either of the largest contingencies in the two islands occurs after the combined island is formed, that the interconnection circuit(s) will be able to accommodate the resultant power flows within their rating(s)

2. Synchronization Parameters

   a. Interconnect at substation with synchroscope

   b. If possible, at substation close to Resource to control phase angle and voltage

   c. Voltage difference <3%

   d. Frequency difference <0.05 Hz (<1 synchroscope rotation in 18 seconds)

   e. If possible, synchronize with a breaker equipped with sync-check relay functionality.

3. Resource Contingencies

   a. Increase in tie-line flow = {(the MW size of the Resource contingency) times (the MW size of the system on the non-contingent side of the tie-line)} divided by {the MW size of the combined synchronized system}

$$\text{Increase in tie-line flow} = \frac{\text{Contingent Resource}^{MW} \text{ X non-Contingent side Load}^{MW}}{\text{Total Synchronized Load}^{MW}}$$

II. Attachment G - 345 kV Restoration Event Worksheet

345 kV Area:		**Resource Information**		**Energization Information**			**Energization Decision**	
		1	**2**	**3**	**4**	**5**	**6**	**7**
Time	Description / Task	>150 MW of Resources Near 345 kV Energize? (**Y**/**N**) If **N** do not proceed to step 2	Available Resource(s) Lead MVAR Capability Near 345 kV Energize (**2**)	Charging MVAR From 345 kV Energize (**3**)	Reactor MVAR Energize With Transmission Element (**4**)	Net MVAR Charging From 345 kV Energize (**3**-**4**) = (**5**)	Remaining MVAR Capability after 345 kV Energize (**2**-**5**) = (**6**)	Energize Decision (**Y**/**N**)

M/LCC 18 Attachment G Revision History

Document History

Rev. No.	Date	Reason
Rev 0	03/01/13	Original document
Rev 1	01/09/14	Annual review by Document Owner, clarified Rules of Thumb and refined definition of "electrically close (near)" and "fast/slow governor response". This revision is a NOT the result of a BES change that necessitates a change to the implementation of the Restoration Plan and does NOT result in changes to roles or tasks performed by identified entities in the Plan.
Rev 2	01/06/15	Annual review by procedure owner. Moved the restoration event worksheet to follow the instructions per SRWG recommendation. This revision is NOT the result of a BES change and does NOT necessitate a change to the implementation of the Restoration Plan and does NOT result in changes to roles or tasks performed by identified entities in the Plan.
Rev 2.1	10/23/15	Annual review by procedure owner requiring no changes: This revision is not a result of a BES change that necessitates a change to the implementation of the Restoration Plan and does not result in changes to roles or tasks performed by identified entities in the Plan.
Rev 2.2	02/29/16	This minor revision incorporates the administrative changes required publish a version to correct a typo discovered in the headers of pages 8 and 9;
Rev 3	10/17/16	Annual review by Procedure Owner; Added required corporate document identity to all page footers; Section II. Transmission Restoration, modified Transmission Line charging values in steps 2.A, 2.C, and 2.D to agree with main body document;
Rev 3.1	09/19/17	Annual review by procedure owner requiring no changes; this minor revision incorporates the administrative changes required to publish including updated the document owner. This revision is not a result of a BES change that necessitates a change to the implementation of the Restoration Plan and does not result in changes to roles or tasks performed by identified entities in the Plan.
Rev 3.2	07/31/18	Periodic review performed requiring no changes; Made administrative changes required to publish a Minor Revision including updating the document owner; This revision is not the result of a BES change and does not necessitate a change to the implementation of the Restoration Plan and does not result in changes to roles or tasks performed by identified entities in the Plan.
Rev 3.3	03/27/19	Annual review by procedure owner requiring no changes; this minor revision incorporates the administrative changes required to publish including updated the document owner;; This Revision does not change the roles or specific tasks of one or more entities identified in the restoration plan. This Revision is not the result of any permanent BES modification that changes the ability of ISO or the LCCs to implement the restoration plan.
Rev 3.4	03/10/20	Annual review by procedure owner requiring no changes; Made administrative changes required to publish the Minor Revision; This revision is **not** the result of any permanent planned or unplanned BES modification; This revision does **not** change the ability, through roles or specific tasks of one or more entities identified in the Plan, to implement the approved Plan; This revision does **not** impact the ability of ISO-NE to monitor and direct restoration efforts
Rev 4	09/18/20	Deleted cable charging Rules-of-Thumb and provided new instructions; This revision is the result of a permanent planned or unplanned BES modification. This revision does **not** change the ability, through roles or specific tasks of one or more entities identified in the Plan, to implement the approved Plan. This revision does **not** impact the ability of ISO-NE to monitor and direct restoration efforts.

Rev 4.1	03/09/21	Annual review by procedure owner requiring no changes; This revision is **not** the result of a permanent planned or unplanned BES modification. This revision does **not** change the ability, through roles or specific tasks of one or more entities identified in the Plan, to implement the approved Plan. This revision does **not** impact the ability of ISO-NE to monitor and direct restoration efforts
Rev 5	03/03/22	Annual review by procedure owner; Section II.2.B: Added new instructions in Generator Restoration Rules-of-Thumb Re-titled main document; changed document owner. Edits for conforming nomenclature. This revision is **not** the result of any permanent planned or unplanned BES modification. This revision does **not** change the ability, through roles or specific tasks, of one or more entities identified in the Plan, to implement the approved Plan. This revision does **not** impact the ability of ISO-NE to monitor and direct system restoration efforts.
Rev 6	03/01/23	Annual review by procedure owner; Section II.1.B: Removed existing and added new instructions in Load Restoration Rules-of-Thumb Section II Table on page 9: Revised table column headers This revision is **not** the result of any permanent planned or unplanned BES modification. This revision does **not** change the ability, through roles or specific tasks, of one or more entities identified in the Plan, to implement the approved Plan. This revision does **not** impact the ability of ISO-NE to monitor and direct system restoration efforts.
Rev 7	02/28/24	Annual review by procedure owner. Consistency edits; Section II.D.2.e: Revision to soften language regarding use of circuit breakers equipped with sync-check relay functionality; This revision is **not** the result of any permanent planned or unplanned BES modification; This revision does **not** change the ability, through roles or specific tasks, of one or more entities identified in the Plan, to implement the approved Plan; This revision does **not** impact the ability of ISO-NE to monitor and direct system restoration efforts.