FOREWORD

The purpose of this document is to outline the study methods and design criteria used to assess the adequacy of the transmission, subtransmission, and substation systems.

Any questions or inquiries regarding information provided in this document should be referred to the Manager, Distribution Engineering.

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REVISION HISTORY

Revision #	Date	Description of Changes
0	04/01/2000	Initial Issue
1	12/19/2003	Revised
2	01/12/2004	Revised
3	03/13/2014	Revised & Reformatted
4	02/09/2016	Created new document number
5	11/20/2018	Updated to reference project evaluation process and modifications to sections 1.2, 1.4 (removed), 1.5 (renumbered 1.4), 3.1, 3.2, 3.7, 3.9.1, 4.3, 4.5, A-1, B-1)

6	11/14/2019	Updated section 4.4 to include reviewing NWA for loading above 80%. Added section regarding minimum daytime load analysis. Added language regarding Unitil owned DG. All references to Director, Engineering updated to Vice President, Engineering. Revised Update to Procedure (section 1.3) to Responsibilities. Removed Request for Procedure/Change Form
7	7/6/2021	Added section 4.5 detailing annual planning study requirements including details regarding DER analysis. Added additional details regarding constraint and resolution review to section 4.5.
8	9/16/2021	Added definition for System Supply Substation and update definition for System Supply Transformer. Added loss of a System Supply Substation bus to the list of contingencies that the Unitil systems should be planned and designed to operate.

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List of Appendices

1.0 Introduction

1.1 Purpose

The objective of this guide is to define study methods and design criteria used to assess the adequacy of Unitil transmission, subtransmission, and substation systems; and to provide guidance in the planning and evaluation of modifications to these systems. The purpose is to ensure appropriate and consistent planning and design practices to satisfy applicable criteria and reasonable performance expectations.

All Unitil facilities which are considered (New England Power Pool) Pool Transmission Facilities (PTF) shall be designed in accordance with the reliability standards published by ISO New England (ISO-NE), Northeast Power Coordinating Council (NPCC) and North American Electric Reliability Corporation (NERC) as well as the criteria established within this document.

All facilities which are not considered PTF but are part of Unitil's transmission, subtransmission, and substation systems shall be designed in accordance with the latest version of this document.

Detailed design of facilities may require additional guidance from industry or technical standards which are not addressed by any of the documents referenced in this guide.

Systems should be planned and designed with consideration for ease of operation. Such considerations include, but are not limited to:

- Utilization of standard components to facilitate availability of spare parts
- Minimization of post contingency switching operations
- Minimization of the use of Special Protection Systems (SPS)

All Unitil facilities shall be designed and operated in accordance with all applicable state regulatory requirements as specified in the State of New Hampshire's "Code of Administrative Rules" or the Commonwealth of Massachusetts "Code of Massachusetts Regulations".

1.2 Applicability & Scope

This document applies to the planning and design of the Unitil transmission, subtransmission, and substation systems.

This document does not apply to distribution circuits or distribution substation equipment, such as distribution substation transformers, distribution circuit terminal equipment, etc.

1.3 Responsibilities

This procedure is written and maintained by the Distribution Engineering Department to whom any questions relating to its content or application should be addressed.

1.4 Availability

Current copies of this procedure can be found on the Engineering Department Only Drive. Hard copies are not version controlled.

NOTE: Only up-to-date versions of the documents are posted on the Hampton Shared Drive. All other revisions (both electronic and hardcopy) should not be referenced.

2.0 General Information

2.1 Abbreviations and Acronyms

DER Distributed Energy Resources

2.2 Definitions

Basecase	Normal system configuration for the season of study
Contingency	An event, usually involving the loss of one or more elements, which affects the power system at least momentarily.
Contingency Configuration	A modified arrangement of the system to attain acceptable conditions following a contingency event.
Design Contingency	A pre-determined scenario for loss of an element that system adequacy is measured against.
Drastic Action Level (DAL)	Any loading of an element above its STE limit. DAL loading requires immediate relief, including the shedding of load if necessary, to avoid the likelihood of unacceptable or catastrophic damage to equipment.
Element	An overhead/underground line section or device such as a generator, transformer, or circuit breaker.
Extreme Peak Load	A load forecast equating to a 96/4 probability
Interface	A collection of transmission lines connecting two areas of the transmission system.
Large DER Facility	Any DER facility where the aggregate nameplate generation/energy storage at the point of common coupling is ≥ 500kW
Load Cycle	Refers to the varying facility loading over a 24-hour period.
Long-Time Emergency (LTE) Limit, Summer or Winter	Allowable peak loading to which equipment can operate for a single, non-repeating load cycle due to emergency circumstances, accepting the possibility of higher than normal loss of life or loss of strength.
Loss of Load	Loss of electric service to one or more customers.

Major Equipment — Any piece of equipment that would require more than $500,000 (without overheads) of capital investment to replace or upgrade.

Normal Configuration — The intended arrangement of a system when all normally in-service elements are available.

Normal Limit, Summer or Winter

Allowable peak loading to which equipment can operate during normal, continuous load cycling and prescribed seasonal conditions.

Peak Design Load — A load forecast equating to a 90/10 probability

Radial Line — A transmission or subtransmission line, or portion of a line, with only one effective supply end and no back up ties to carry or deliver power.

Short-Time Emergency (STE) Limit, Summer or Winter

One-time peak loading which can be sustained by equipment for up to 15 minutes while corrective actions are underway following a contingency, and accepting the likelihood of higher than normal loss of life or loss of strength.

Special Protection Systems — A Special Protection System (SPS) is 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. automatic under frequency load shedding is not considered an SPS.

System Supply Substation — Substations that delivers power into the electric distribution system from its external transmission supply.

System Supply Transformer — Power transformers in a System Supply Substation that stepdown voltages from transmission voltage levels (typically 115kV and above) to subtransmission and/or distribution voltage levels (typically 69kV to 34.5kV).

3.0 Planning Criteria

Unitil transmission, subtransmission, and substation systems should be planned and designed for safe, economical and reliable performance with consideration for normal and reasonably foreseeable contingency situations, load levels, and generation.

3.1 Allowable Equipment Loading

Thermal ratings for system equipment are established to obtain the maximum use of the equipment accepting some defined, limited loss of life or loss of strength. These ratings are based on Unitil's *Electrical Equipment Rating Procedures* (PR-DT-TC-06). The principal variables used to derive these ratings include specific equipment physical parameters and design, maximum allowable operating temperatures, seasonal ambient weather conditions, and representative daily load cycles.

Normal ratings describe the allowable loading to which equipment can operate for normal, continuous load cycling up to peak demands at the indicated Normal Limit. Emergency ratings allow brief operation of equipment to higher peak demand limits for emergency situations.

The following listing summarizes Unitil equipment thermal ratings:

Rating	Allowable Duration before Relief
Summer Normal Limit	Continuous
Summer Long-Time Emergency (LTE) Limit	12 hours
Summer Short-Time Emergency (STE) Limit	15 minutes
Winter Normal Limit	Continuous
Winter Long-Time Emergency (LTE) Limit	4 hours
Winter Short-Time Emergency (STE) Limit	15 minutes

Equipment loaded at or below its Normal Limit is operating within normal loading conditions. Equipment loaded above its Normal Limit is operating at emergency loading conditions, and may be experiencing higher than normal loss of life or loss of strength.

Equipment loaded above its Normal Limit and at or below its Long Time Emergency Limit is operating at a long time emergency load level. Long-time emergency loading may be sustained for a single, non-repeating load cycle where the Normal Limit is exceeded for no more than the allowable duration. Typically, the single-non-repeating load cycle portion of this criterion is met by completing necessary repairs within twenty-four hours. In situations which require longer repair times (moving a system spare transformer, repairs along the salt marsh, etc.) elements may not exceed Normal Limits for consecutive days.

Equipment loaded above its Long Time Emergency Limit and at or below its Short Time Emergency Limit is operating at a short time emergency load level. Short time emergency loading must be relieved to normal or LTE conditions within 15 minutes. Unitil systems should be planned and designed to avoid short-time emergency loading. However, it is acceptable for equipment to be loaded to short-time emergency conditions following a loss-of-element contingency, provided automatic or remote actions are in place to relieve the loading within the specified time.

Equipment loaded beyond its Short Time Emergency Limit is operating at a Drastic Action Level (DAL), and immediate relief is required including the shedding of load if necessary. If a facility operates at this level for more than five minutes, equipment may suffer unacceptable damage. Unitil systems shall not be planned for equipment to reach DAL loadings. Unitil does not publish DAL ratings higher than the STE limit since loading above the STE limit requires a drastic action response.

Reference Appendix A for a summary of the electric system planning loading threshold criteria.

3.2 Allowable System Voltages

System voltage ranges are established to obtain adequate operating voltages for system customers, maintain proper equipment performance, avoid over-excitation of transformers or under-excitation of generators, and preserve system stability. Unitil systems should be planned and designed to sustain steady state operating voltages within the following limits. Steady state operating voltages at Non-Distribution Points shall have an upper threshold of 105% of nominal (126 V on a 120 V base) and a lower threshold to allow directly connected downline regulators to boost the voltage to the programmed float voltage under basecase conditions and to 95% of the float voltage under contingency scenarios. The lower steady state voltage threshold for Non-Distribution Points that do not directly supply voltage regulators is 90% of nominal (108 V on a 120 V base). Steady state operating voltages at Regulated Distribution Points shall have an upper threshold of 104.2% of nominal (125 V on a 120 V base) and a lower threshold equal to 99% of the float voltage of the directly connected up line regulation (typically 123 V on a 120 V base) under basecase conditions and 97.5% of the regulator float voltage under contingency scenarios. Unitil systems should be planned and designed to sustain steady state operating voltages at Unregulated Distribution Points within a minimum limit of 97.5% of nominal (117 V on a 120 V base) and a maximum limit of 104.2% of nominal (125 V on a 120 V base). Additionally, Unitil systems should be planned and designed to sustain steady state operating voltages at Customer Primary Metering Points within a minimum limit of 95% of nominal (114 V on a 120 V base) and a maximum limit of 104.2% of nominal (125 V on a 120 V base).

In this context, Non-Distribution Points indicate locations that are not direct supplies for distribution loads or primary metered loads. Most transmission and subtransmission lines are Non-Distribution, as are most substation facilities where the voltage regulation is applied after the low-side bus (i.e. at the individual distribution circuit terminals).

A Regulated Distribution Points indicate locations that supply distribution loads and have directly connected up line regulation. This may be, for example, at substation low-side buses where voltage regulation is provided by load-tap-changing power transformers or regulators at the transformer output.

Correspondingly, Unregulated Distribution Points indicate locations that directly supply distribution loads without directly connected up line regulation. This may be, for example, at unregulated distribution circuits or customer taps off of subtransmission lines.

Customer Primary Metering Points are locations that directly supply primary metered loads.

It is acceptable for steady-state voltage excursions beyond these limits to occur immediately following a contingency event and while corrective actions are in progress. However, Unitil systems should be planned and designed to limit the extent and duration of such excursions. Furthermore, Unitil systems shall not be planned to accept unchecked voltage collapse.

There are no design limits on the amount of change in operating voltages from initial pre-contingency to immediate post contingency levels.

Reference Appendix B for a summary of the electric system planning voltage threshold criteria.

3.3 System Configuration

Unitil systems shall be planned and designed to meet applicable criteria utilizing specific normal and contingent configurations of system elements.

The Basecase Configuration shall describe the intended arrangement of the system when all normally in-service elements are available. Unitil systems should be planned and designed to operate within normal equipment ratings and voltage ranges when in the Basecase Configuration at all normally anticipated load levels.

The arrangement of system elements may be temporarily altered to a configuration for routine operating and maintenance purposes. An acceptable alternate configuration should also satisfy normal ratings and voltages. It is not a requirement that Unitil systems be planned or designed for every possible configuration.

A Contingency Configuration describes a modified arrangement of the system in response to planned or unplanned outage of an Element. Unitil systems should be planned and designed to be promptly arranged into prescribed Contingency Configurations when necessary to attain acceptable conditions following specific contingent emergencies, and to operate within specified equipment ratings and voltage ranges when in these configurations.

3.4 System Peak Load

Unitil systems shall be planned and designed to meet applicable criteria up to specific normal and emergency peak load levels.

3.4.1 Peak Design Load

The Peak Design Load is the benchmark load level that system adequacy is measured against. This load level is derived from a 90/10 forecast (a load level with a probability of being exceeded once every ten years). It shall be the highest anticipated coincident, active (real) power demand of all system customers, plus associated system losses, plus adjustments deemed reasonable to address forecasting uncertainties. The Peak Design Load is the actual load and losses to be supplied, and not the net sum of power flows at system boundaries after being offset by internal sources. Unitil systems should be planned and designed to operate within specified equipment ratings and voltage ranges at load levels up to the established Peak Design Load.

3.4.2 Extreme Peak Load

The Extreme Peak Load is the maximum foreseeable load level that Unitil systems should be planned and designed to operate within specified equipment ratings and voltage ranges with all elements available. This load level is derived from a 96/4 forecast (a load level with a probability of being exceeded once every twenty years).

3.5 Load Power Factor

Unitil systems should be planned and designed to operate within the ISO-NE Load Power Factor Standards published for that area at Peak Design Load levels.

3.6 System Generation & Distributed Energy Resources (DER)

For planning purposes, the output of generation interconnected to the Unitil system as well as the output or load offset by other DER projects will be evaluated based on availability and reliability during peak times. Typical historical performance for each unit may be used as the initial basis for generation dispatch assumptions. These assumptions should take into account factors for seasonal variations, demonstrated forced-outage rates, operating limits, and expected performance during system disturbances.

Unitil owned DER (PV and energy storage) facilities shall be assumed to be on-line and fully operational. Unitil owned DER shall be reviewed to confirm that the load in which they are designed to serve or off-set can be restored utilizing traditional methods (load transfers to adjacent supplies, spare equipment, mobile substation, etc.) in the event the facility becomes unavailable.

The planning and operation of generating plants outside of Unitil systems is not typically within the scope of Unitil planning requirements unless they have a direct impact on system adequacy. The impact of generation inside or within the immediate vicinity of Unitil systems should be taken into account. Unitil systems should be planned and designed to operate within normal equipment ratings and voltage ranges during the outage of any utility-owned generating plant.

The adequacy of system infrastructure to meet Unitil's end use load obligations necessitates that it be self-sufficient from generation interconnected to the Unitil system. Unitil systems are to be planned and designed to operate within specified equipment ratings and voltage ranges with at least one-half of interconnected generating facilities out of service.

3.7 Normal Conditions

Unitil systems shall be planned and designed to operate within normal equipment ratings and voltage ranges for the following conditions:

- System in Normal Configuration;
- load levels up to Peak Design Load;
- All Unitil owned DER in-service;
- outage of any one generating plant within the immediate vicinity of the Unitil system;
- largest non-Unitil owned distributed generation facility out of service and an outage of any one additional distributed generation facility within the immediate vicinity of the Unitil system.

3.8 Contingency Conditions

Unitil systems shall be planned and designed to meet applicable criteria for specific pre-determined contingency scenarios.

Design Contingencies describe the pre-determined emergency scenarios that system adequacy is measured against. Unitil systems should be planned and designed to operate within specified equipment ratings and voltage ranges following actions in response to the following Design Contingencies:

- loss of any non-Radial Line element, or
- loss of any Radial Line element with no backup tie, or
- loss of any System Supply Transformer, or
- loss of any System Supply Substation bus, or
- loss of any Unitil owned DER facility; or
- Extreme Peak Load with all elements available

3.9 Allowable Loss of Load

The objective of planning and designing the system to meet Design Contingency criteria is to utilize system elements up to their maximum allowable capabilities to carry or restore as much load as possible. It is understood and accepted that many system fault or equipment failure events, including loss-of-element Design Contingencies, may result in the temporary loss of customer load until damaged components are isolated and restoration switching is performed. However, limited loss of customer load for more extended periods of time are acceptable design compromises for specific circumstances where other alternatives are not practical or economical.

3.9.1 Loss-of-Element Contingency

To provide continuity or immediate restoration of service to all portions of system load for all reasonably foreseeable contingencies requires fixed infrastructure with spare capacity or redundancy for each element. This level of design may be inefficient and cost-prohibitive to cover the contingent loss of certain major elements. The loss of limited portions of system load for limited periods of time may be tolerated under defined circumstances as part of prudent, cost-effective alternatives to fixed infrastructure. These alternatives are traditionally either of two choices: (1) the interruption of load while repairs are being made to an element that cannot be backed up; or (2) the interruption of load while mobile or spare equipment is made available from another location, transported and placed into service where needed. The table below describes the conditions where loss of load is allowable.

Table 3.9.1-1 Allowable Loss of Load

Design Contingency	Allowable Loss of Load	Allowable Duration
Loss of a radial line element with no backup tie	≤ 30 MW	≤ 24 hours

Under these contingencies, it is understood that remaining system elements will be utilized up to their maximum allowable capabilities to carry or restore as much load as possible. Allowable Loss of Load refers to a collection of customers within the system that cannot be restored after automatic or manual actions. This load is the peak coincident demand of this collection of customers, and not the net sum of power flow that may be seen if offset by sources within the affected portions of the system. The allowable impact is limited to these affected customers, not the overall load level at any given time. If actual load at the time is not at peak conditions, it is not acceptable to extend interruptions to a wider collection of customers by summing the demands at that time up to the same numerical limit.

3.9.2 Extreme Circumstances

Widespread outages or catastrophic failures resulting from contingencies more severe than defined Design Contingencies may exceed the limits described in the previous section.

3.9.3 Regional Load Shed

Unitil systems shall be designed to maintain compliance with NERC, NPCC and ISO-NE requirements for manual and automatic load shedding capabilities.

4.0 Planning Studies

All electric system analyses/studies performed shall utilize all applicable criteria detailed in this guide. If other criteria is utilized it shall be noted in detail along with the justification for its use with published study results.

4.1 Basic Types of Studies

System planning studies based on steady-state power flow simulation shall be routinely conducted to assess conformance with the criteria and standards cited in this guide. These studies will review present and future anticipated system conditions under normal and contingency scenarios. The scale and composition of the Unitil electric system does not typically warrant routine analysis of its dynamic behavior. Transient stability analysis (and other forms of study) is conducted as needs arise.

4.2 Study Period

The lead-time required to plan, permit, license, finance, and construct transmission, subtransmission or substation upgrades is typically between one and ten years depending on the complexity of the project. As a result, system planning studies should examine conditions at various intervals covering a period of ten-years to identify potentially long-term projects.

4.3 Modeling and Assessment for Steady-State Power Flow

The modeling representation for steady-state power flow simulation should include the impedance of lines, generators, reactive sources, and any other equipment, which can affect power flow or voltage (e.g. capacitors or reactors). The representation should include voltage or angle taps, tap ranges, and control points for fixed-tap, load-tap-changing, and phase shifting transformers.

Specific issues related to the study, which need to be addressed, are discussed below.

4.3.1 Element Ratings

Thermal ratings of each load-carrying element in the system are determined to obtain the maximum use of the equipment. The thermal ratings of each modeled system element reflect the most limiting series equipment within that element (including related station equipment such as buses, circuit breakers, and switches). A circuit breaker is understood to include its associated protective relaying, current transformers, and the bus section between the breaker bushing and its current transformer(s). Models will include two rating limits for each season's case:

Summer models	Summer Normal, Summer LTE
Winter models	Winter Normal, Winter LTE

4.3.2 Modeled Load

Peak Design and Extreme Peak forecasts should be developed annually for a period of ten years. Minimum Daytime Load forecasts should be developed annually for a period of ten years.

Modeled loads for each region should be developed in sufficient detail to distribute the active and reactive coincident loads (coincident with the system's total peak load) throughout the system such that the net effect of loads and losses matches expected power flows and the overall Peak Design or Extreme Peak load for each case.

4.3.3 Load Levels

To evaluate the sensitivity to daily and seasonal load cycles, studies may require modeling several load levels. Minimum requirements call for study of peak load levels (Peak Design or Extreme Peak). Where high voltage issues or unusual reactive power flows are a concern, or the degree of consequences and exposure to risks must be quantified, lesser load levels may be studied. The basis for these loads can be either summer or winter conditions, whichever is the worst case scenario for the system.

Additionally, minimum daytime load levels shall be studied with all current (in-service) and future (approved for installation) DER facilities in-service. Depending on the purpose of the study there may be circumstances in which proposed (applications that have not been approved for installation) facilities should be included in minimum daytime load studies.

4.3.4 Balanced Load

Balanced, three-phase, 60 Hz ac loads should be assumed at each load center unless specifically identified by an area or circuit study. Balanced loads are assumed to have the following characteristics:

- The active and reactive load of any phase is within 90% to 110% of the load of the other phases
- The voltage unbalance between the phases, measured phase–to–phase, is less than 3%
- Harmonic voltage distortion is within limits recommended by the current version of IEEE Std. 519

4.3.5 Reactive Compensation

Reactive compensation should be modeled as it is designed to operate on the system. Reactive compensation on distribution feeders and circuits are assumed to be included within the modeled loads.

4.3.6 Generation Dispatch

Analysis of system sensitivity to variations in generation dispatch is necessary during a study. The intent is to test the adequacy of the Unitil system as much as can be reasonably anticipated against the end use loads which it is obligated to serve.

The basis for modeling should begin with initial assumptions of generating unit outputs at their typical seasonal levels. Cases may then be modified to reflect intended criteria and assumptions for future conditions.

4.3.7 Facility Status

Initial conditions assume all existing facilities normally connected to the system are available and operating as designed or expected.

Studies should reaffirm the necessity and in-service need date of future planned improvements or modifications and confirm that they remain the most cost-effective option available. Risks, consequences, and exposure levels should be determined in the event that projects are not completed as planned.

4.4 Annual System Planning Studies

Subtransmission system planning is conducted on an annual basis and covers a 10 year timeframe. The study process examines a ten year forecast of system conditions to identify when individual equipment loading and voltage performance concerns will occur, and propose specific system modification recommendations to meet all applicable portions of this Guide.

The electric system planning process utilizes the Peak, Extreme Peak and Minimum Daytime load forecasts developed per Unitil's *Electric System Load Forecasting Procedure* (PR-DT-DS-08).

4.4.1 Peak Load Analysis

The Unitil electric system will be evaluated annually for voltage and equipment loading violations. The system shall be evaluated under basecase and planned contingency configurations (including initial conditions, intermittent switching configurations and final configurations) utilizing Design Peak load levels. Additionally, the system shall be reviewed in its basecase configuration under Extreme Peak load levels.

The first step of creating future case peak models is the creation of a system snapshot model. The system snapshot model is a model that replicates system conditions during the previous year's system peak hour. Details of the system infrastructure shall be assembled using best available data on system impedances, transformer ratios, equipment ratings, etc. Bus loads shall be compiled for the model by aggregating substation, circuit, and large customer load information for the system peak hour. With the operating configuration, substation and capacitors set in the model to actual conditions at the time, overall scaling adjustments should be made to bus loads to reasonably match the power flow simulation results to actual recorded system flows for the peak day and hour. Once completed, this establishes a confident model representing the system as it existed during the peak hour.

Peak Design and Extreme Peak models should be created using an historical summer peak snapshot model from the previous year that is "scaled-up" to forecasted load levels. "Scaling-up" shall include the review of distribution historical and projected load levels to determine if load re-allocation is necessary. Power flow results are compared against loading and voltage criteria with identified violations being reviewed in more detail to determine/if when system upgrades are needed.

Initial evaluations shall be performed with the highest (worst case) projected forecasted load level for the year of study. Typically, this will be forecasted loads including EV load and without DER. For any identified violation loads will be reduced to determine the load level in which the constraint becomes a violation. This load level will then be compared to all forecasted loads to determine the possible years that the resolution could need to be implemented.

4.4.1.1 DER Dispatch

All Unitil owned DER (PV and energy storage) facilities shall be assumed to be on-line and fully operational. Unitil owned DER shall be reviewed to confirm that the load in which they are designed to serve or off-set can be restored utilizing traditional methods (load transfers to adjacent supplies, spare equipment, mobile substation, etc.) in the event the facility becomes unavailable.

For peak basecase modeling of the system all existing (in-service) and future (Unitil planned or approved for install) distributed generation facilities shall be modeled at their assumed (based on historic data of similar units) output during the season and time of day of study with any one generating plant and the largest non-Unitil owned distributed generation facility, as well as any one additional non-Unitil owned distributed generation facility shall be modelled out of service for the future study period with all other elements in service. This may result in evaluating the system under multiple generator dispatch cases. Remaining units may be modeled at their historical output during the season of study. This may result in additional units being reduced or off-line if that has been their typical history (e.g. hydro generation during periods of low river flow).

For contingency modeling of the systems all existing (in-service) and future (Unitil planned or approved for install) distributed generation facilities shall be modeled at their assumed (based on historic data of similar units) output during the season and time of day of study with the largest non-Unitil owned facility modelled off-line. All non-Unitil owned generation that is expected to trip offline during the fault is considered to remain offline following restoration switching. In addition, the largest single non-Unitil owned generator interconnected to the source/line used for restoration of load is considered to be offline prior to the fault occurring and following restoration switching.

DER less than 500kW is inherent in customer load information and are not typically modelled in peak load models.

4.4.2 Minimum Daytime Load Analysis

The Unitil electric system shall also be evaluated annually for voltage and equipment loading violations under minimum daytime load conditions. The system should be evaluated under basecase and planned contingency configurations (including initial conditions, intermittent switching configurations and final configurations) that involve the loss of a system supply transformer utilizing minimum daytime load levels.

The basis of minimum daytime load models shall be a minimum daytime load snapshot model that was created in a similar manner as the peak snapshot models utilizing load/generator information from the previous year's minimum daytime load hour. Future year minimum daytime load models should be created by "scaling-down" the minimum daytime load snapshot model to forecasted minimum daytime load levels. "Scaling-down" shall include the review of distribution minimum daytime load projections to determine how future DER shall be incorporated into the model. Any substation bus that is "supplying/backfeeding" the subtransmission system at the time of Minimum Daytime Load should have a generator modelled on the low-side substation bus.

All capacitor banks shall be modelled off line when performing minimum daytime load analysis.

All Large DER facilities shall be modeled at their typical historical AC output at the point of interconnection during the minimum daytime load hour. The output of all other in-service (that were not operating during the minimum daytime load hour) and approved for install DER facilities shall be modelling with their output set to the typical ratio of DER output to DER nameplate of Large DER at the historical system minimum daytime load hour.

Power flow results are compared against loading and voltage criteria with identified violations being reviewed in more detail to determine/if when system upgrades are needed.

4.4.3 Power Factor Analysis

Design Peak models with the system in its basecase configuration shall be used to review compliance with current ISO-NE reactive power requirements throughout the years of study.

Any violation shall be reviewed in more detail to determine if and when system modifications should be proposed.

4.5 Addressing System Deficiencies and Constraints

System studies should clearly identify results that fail to satisfy criteria or constrain performance. To the extent that supporting information is available, these deficiencies or constraints should be quantified in terms of severity, extent of impact, duration and periods of exposure.

Historical penetration rates of EV and DER and engineering judgement should be used to determine the necessary year (forecasted load with EV and DER, without EV nor DER, etc.) to implement resolutions to the identified constraints.

Any identified constraint requiring a system modification to be in-service within the first five years of the study period shall be developed and evaluated per section 4.6 below. For long range planning purposes constraints with resolution in-service dates in years six through ten shall have a typical, traditional alternative identified with a high level cost estimate developed.

Loading and/or voltage constraints requiring the construction of a system modification with an estimated cost of $500,000 or more without overheads that has a construction start date in the first year of the study period should include the following analysis when justifying the project.

- Review of interval real and reactive power measurement to confirm the project need. In the event permanent metering equipment with the necessary information is not installed temporary monitoring equipment should be utilized.
- The review of loading constraints should consider factors such as load cycle, clearances and conductor characteristics.

Until the year prior to the start of implementation the identified constraints and resolutions will be reviewed annually to verify the need and the proposed implementation dates as part of Unitil's annual planning and budgeting efforts.

Targeted Energy Efficiency and Load Curtailment projects should be reviewed for any piece of Major Equipment that is expected to exceed either of the following:

- Normal/Basecase Conditions - 80% of its seasonal normal rating during the first five years of the study period and 90% of its seasonal normal rating in year five of the study period.
- Planned Contingency Conditions - 100% of its seasonal normal rating during the first five years of the study period and 110% of its seasonal normal rating in year five of the study period or 80% of its seasonal LTE rating during the first five years of the study period and 90% of its seasonal LTE rating in year five of the study period.

4.6 Development and Evaluation of Alternatives

If the performance or reliability of the forecasted system does not conform to the applicable criteria, then alternative solutions shall be developed and evaluated per Unitil's *Project Evaluation Procedure* (PR-DT-DS-11). The evaluation of alternatives and recommendations for system upgrades or modifications will be summarized within system planning studies.

4.6.1 Performance

The system performance with the proposed alternatives should meet or exceed all applicable planning criteria for the duration of the ten-year planning horizon. This does not preclude incremental system upgrades or modifications that are implemented as part of a multi-phase project to meet this overall objective.

4.6.2 Capacity

All equipment should be sized based on economics, operating requirements, standard sizes, and engineering judgment. Engineering judgment should include recognition of realistic future constraints that may be avoided with minor incremental expense. As a rough guide, unless the equipment is part of a staged expansion, the capability of any new equipment or facilities should be sufficient to operate without constraining the system and without additional major modifications for at least ten years.

4.6.3 Economics

Cost estimates should be prepared for each alternative identified during the course of a study. These estimates shall be used to perform a cost/benefit analysis per Unitil's Project Evaluation Procedure (PR-DT-DS-11). Cost comparisons between alternatives shall include a net present value analysis for multi-year solutions.

4.6.4 Recommendation

Every study that identifies potential violations of design criteria shall propose recommended actions.

4.6.5 Reporting Study Results

A system planning study report should define the modeling assumptions, study procedures, system constraints and/or violations of design criteria identified, alternatives for system upgrades or modifications considered, economic comparison, and final recommendations resulting from the study.

Appendix A – Design Guideline Summary

			Allowable Element Loading		Allowable Loss of Load	
Design Condition	**Load Level**	**Generation**	**Limit[1]**	**Duration**	**Limit**	**Duration**
Normal Operation –						
all elements in service, or non-emergency configuration	≤ Peak Design Load	typical seasonal dispatch w/ largest generating plant and largest DER facility out of service as well as any one additional DER facility out of service	≤ Normal	Continuous	none	---
outage of generating plant			≤ Normal	Continuous	none	---
Contingency Operation –						
loss of non-radial line	≤ Peak Design Load	dispatch w/ largest generating plant and the largest DER facility out of service All generation that is expected to trip offline during the fault is considered to remain offline following restoration switching. In addition, the largest single generator interconnected to the source/line used for restoration of load is considered to be offline prior to the fault occurring and following restoration switching	≤ LTE	≤ 12 hours (S) ≤ 4 hours (W)	none	---
a) loss of a System Supply Transformer b) loss of a System Supply Substation bus,			≤ LTE	Per transformer rating summary	none	---
loss of radial line (no backup tie)			≤ LTE	≤ 12 hours (S) ≤ 4 hours (W)	≤ 30 MW	≤ 24 hours
Extreme Peak – all elements in service	≤ Extreme Peak Load	typical seasonal dispatch w/ largest generating plant and largest DER facility out of service	≤ LTE	≤ 12 hours (S) ≤ 4 hours (W)	none	---

(S) = Summer load cycle

(W) = Winter load cycle

[1] STE loading is acceptable following a loss-of-element contingency, provided actions are available to relieve the loading within 15 minutes.

Appendix B – Voltage Range Summary

Design Condition	Location	% Boost of Downline Regulation Directly Connected to Bus [2]	Low Limit (p.u.)	High Limit (p.u.)
Normal Operation -				
a) all elements in service, or non-emergency configuration b) outage of generating plant	Non-Distribution Point	10%	0.94	1.05
		7.5%	0.962	1.05
		5%	0.985	1.05
		n/a	0.90	1.05
	Regulated Distribution Point	n/a	1.025[3]	1.042
	Unregulated Distribution Point	n/a	0.975	1.042
	Customer Primary Metering Point	n/a	0.95	1.042
Contingency Operation -				
a) loss of non-radial line, b) loss of a System Supply Transformer c) loss of a System Supply Substation bus, d) loss of a radial line (no backup tie)	Non-Distribution Point	10%	0.91	1.05
		7.5%	0.93	1.05
		5%	0.95	1.05
		n/a	0.90	1.05
	Regulated Distribution Point	n/a	1.0	1.042
	Unregulated Distribution Point	n/a	0.975	1.042
	Customer Primary Metering Point	n/a	0.95	1.042
Extreme Peak - all elements in service	Non-Distribution Point	10%	0.91	1.05
		7.5%	0.93	1.05
		5%	0.95	1.05
		n/a	0.90	1.05
	Regulated Distribution Point	n/a	1.0	1.042
	Unregulated Distribution Point	n/a	0.975	1.042
	Customer Primary Metering Point	n/a	0.95	1.042

Non-Distribution Points are locations that do not directly supply distribution loads or primary metered loads.

Regulated Distribution Points are locations that supply distribution loads with directly connected up line regulation.

Unregulated Distribution Points are locations that directly supply distribution loads without directly connected up line regulation.

Customer Primary Metering Points are locations that directly supply primary metered loads.

[2] Assumes regulator float voltage of 1.033 p.u. (124V on 120V base)

[3] Assumes regulation float voltage of 1.033 p.u. and 1V bandwidth (123V on 120V base, lower end of band)