FOREWORD

The purpose of this document is to outline the distribution planning process and design criteria.

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

1/28/2022

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Date

Jan. 21, 2022

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REVISION HISTORY

Revision #	Date	Description of Changes
0	03/10/2014	Initial Issue
1	12/29/2014	Revised DER /DER Planning Guidelines (Sec 3.2)
2	12/10/2015	Revisions to Sections 3.3, 3.4 & 3.5
3	2/9/2016	Created new document number
4	8/22/2017	Removed procedure for projecting loads of circuits with DER from Sec 3.2
5	09/17/2018	Revisions to entire document and title change

6	11/14/2019	Updated substation transformer loading criteria and protective device loading criteria in section 3.1. Modified section 4.3 to include reviewing NWA for loading above 80%. Added paragraph regarding Unitil owned DER. All references to Director, Engineering updated to Vice President, Engineering. Revised Updating Guideline (section 1.3) to Responsibilities Removed Request for Procedure/Change Form
7	7/8/2021	Updated DER dispatch for substation load evaluation for sites with two or more large facilities (Section 4.3.1.1). Added details regarding DER and VVO analysis to section 4 and various changes to other sections due to the changes in section 4. Added additional details regarding constraint and resolution review to section 4.3.
8	1/20/22	Updated section 4.3.2.1 based on Windmil capabilities. Miscellaneous typo corrections.

Table of Contents

1.0 Introduction

1.1 Purpose

The intent of this guideline is to define study methods and design criteria used to assess the adequacy of Unitil's distribution circuits and distribution substation equipment. The purpose is to ensure appropriate and consistent planning and design practices to satisfy applicable criteria and reasonable performance expectations.

1.2 Applicability & Scope

This document applies to the planning of distribution circuits and distribution substation equipment (distribution substation transformers, distribution circuit terminal equipment, etc.) operating at nominal primary voltages of 34.5Y/19.92kV or less. This guideline does not apply to the design and planning of subtransmission systems, substations and/or equipment operating at secondary voltage levels (typically 600V or less).

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 Engineering Department Only 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
EV	Electric Vehicles
VVO	Volt-VAr Optimization

2.2 Definitions

Major Equipment	Any piece or pieces of equipment that would require more $500,000 (without overheads) of capital investment to replace or upgrade.
Large DER Facility	Any DER facility where the aggregate nameplate generation/energy storage at the point of common coupling is ≥ 500kW

3.0 Distribution Planning Criteria

The following design criteria shall be used as a guide for the planning and design of the distribution system. This criteria should be used for all distribution system analyses/studies performed. If other criteria is utilized it shall be noted in detail along with the justification for its use with published study results.

3.1 Loading of Distribution Equipment

Distribution systems shall be designed using the following constraints and equipment loading limitations under peak load operating conditions:

- Loading on distribution circuit conductors and other elements not otherwise specified below should not exceed their seasonal Normal rating.
- Loading on substation transformers should not exceed the following:
  - Normal Configuration:
    - In service transformer – seasonal normal limit
  - Normal Configuration after switching load to adjacent transformers – the lower of the following:
    - System Spare Transformer – seasonal normal limit
    - Mobile substation (including ancillary equipment such as protective devices, regulators, switches, etc.) – seasonal normal limit
  - Abnormal Configuration
    - In service transformer – seasonal normal limit
- Loading on distribution stepdown transformers should not exceed 120% of their nameplate rating.
- Loading on regulators during summer months should not exceed 120% of the nameplate rating for the set regulation range. Winter loading is limited 145% of nameplate[1].
- Loading on breakers, switches, CTs and isolating devices should not exceed their nameplate rating.
- Protective devices (fuse, relays, etc.) should not exceed the follow:
  - Fuses – continuous current rating or 74%[2] of minimum melt, whichever is lower.
  - Relay Protection Settings - 74%[3] of phase pick-up or 100% of the load encroachment limit, whichever is lower in normal configurations and 88%[4] of phase pick-up or 100% of the load encroachment limit in contingency scenarios.

[1] ANSI/IEEE C57.95-1984 is used as a guide for determining the maximum allowable loading of regulators for normal loss of life. Higher loading may be allowed on a short term contingency basis (LTE) or as indicated on the nameplate when the regulation range is temporarily limited (load bonus). In no case shall loading exceed the maximum load amps indicated on the nameplate

[2] 110% of 67% of minimum melt.

[3] 110% of 67% of pick-up.

[4] 110% of 80% of pick-up.

3.2 Current Unbalance

All distribution circuits and distribution substation transformers shall be reviewed for phase balance on an annual basis. In general, the goal for phase balancing is 10%. Circuits or transformers with an average phase imbalance greater than 20% are considered severe and shall be reviewed to determine if remediation is required.

3.3 Steady State Distribution Voltages and Regulation

The following outlines the required ranges for steady state RMS nominal system voltages. In all cases where system voltages are found to be outside of these limits, a detailed engineering analysis should be performed in order to determine corrective measures.

3.3.1 Low Voltage Services

Electric distribution systems should be designed and constructed such that low voltage services (600 V and below) supplied to customers operate within the following range under steady state conditions, as measured at the point of delivery:

Nominal Voltage	120/240 V	208Y/120 V	480Y/277 V
(A) Upper limit (105%)	126 / 252 V	218 / 126 V	504 / 291 V
(A) Lower limit (95%)	114 / 228 V	197 / 114 V	456 / 263 V

Practical design considerations or unusual operating circumstances may occasionally result in service voltages below the (A) lower limit conditions shown above. When these situations arise, the following extended lower limit may be tolerated:

Nominal Voltage	120/240 V	208Y/120 V	480Y/277 V
(B) Lower limit (91.7%)	110 / 220 V	191 / 110 V	440 / 254 V

Although such (B) lower limit conditions are occasionally part of practical utility design and operation, they shall be limited in extent, frequency, and duration.

(A) - corresponds to ANSI C84.1 Range A Service Voltage
(B) - corresponds to ANSI C84.1 Range B Service Voltage

Steady state service voltages operating below the (B) lower limit are unacceptable under normal conditions. Normal conditions include common system activity such as ordinary variations in loads and supply, voltage regulator or load tap changer actions, routine system maintenance configurations, and emergency configurations after equipment failures or system faults have been removed.

Abnormal conditions beyond Unitil's immediate control (including area voltage reduction actions, and during active system faults) may result in infrequent and limited periods when steady state voltages above the (A) upper limit or below the (B) lower limit occur. When voltages occur outside these limits, prompt corrective action shall be taken.

3.3.2 Primary Voltage Services

Electric distribution systems should be designed and constructed such that primary voltage services operate within the following range under steady state conditions, as measured at the point of delivery:

Nominal Voltage	4160Y/2400 V	13800Y/7970 V	34500Y/19920 V
(A) Upper limit (105%)	4370 / 2520 V	14490 / 8370 V	36230 / 20920 V
(B) Lower limit (95%)	3950 / 2280 V	13110 / 7570 V	32780 / 18930 V

(A) - corresponds to ANSI C84.1 Range A Utilization and Service Voltage
(B) - corresponds to ANSI C84.1 Range B Service Voltage
Variations outside these limits shall be brief and infrequent.

3.3.3 Primary System Voltage Regulation

In order to meet the service voltage objectives described above, primary distribution systems should be designed and constructed to the following operating ranges for steady state conditions:

Steady state primary voltages operating below 125 V (on 120 V base, or 104%) and above 117 V (on 120 V base, or roughly 97.5%) shall be considered adequate to support all service voltage objectives. A combined voltage drop of 2.5% (3 V on 120 V base) through the service transformer and the secondary and service conductors to the point of delivery will result in satisfactory service voltage. Primary system improvements will not be necessary to remedy low service voltages if the primary system operates within this range.

Steady state primary voltages operating below 115 V (on 120 V base, or roughly 96%) are unacceptable under normal conditions. Steady state primary voltages operating as low as 115 V (on 120 V base, or roughly 96%) are tolerable if they do not result in extensive, frequent, or long lasting service voltage concerns. Primary system improvements may be necessary to resolve lengthy, recurring, widespread low service voltages.

3.3.4 Voltage Unbalance

Electric distribution systems should be designed and operated to limit the maximum voltage unbalance to any three phase customer to no more than 3% as measured at the point of delivery under no load conditions.

Voltage unbalance of a three phase system is expressed as a percentage of deviation from the average voltages.

$$\text{Voltage Unbalance} = (100) \times \frac{\text{(max deviation from average voltage)}}{\text{(average voltage)}}$$

3.4 Transient Voltage Fluctuations (Flicker)

One of the most common sources of voltage flicker on the primary distribution system is switched customer load such as starting of large motors. The following shall be used as a general guideline for acceptable levels of voltage flicker. When the calculated voltage fluctuation exceeds these limits, remedial actions must be taken to reduce flicker to within acceptable levels in order to mitigate nuisance lamp flicker or other potential adverse effects experienced by the customer or other Unitil customers.

3.4.1 Voltage Flicker Criteria

The table below prescribes the acceptable voltage fluctuation due to the starting of a single motor. Unitil's ideal philosophy is to maintain flicker at a level below the Border Line of Visibility[1] but will accept levels above this limit but below the Border Line of Irritation as long as the resultant system conditions do not adversely affect other customers.

Maximum Acceptable %Voltage Fluctuation

Typical Motor Load Type/Description	Frequency of Motor Starts	Max % Fluctuation At Customer XFMR	Max % Fluctuation on Primary System
Fire Pumps	1 Start per Month	5%	4%
Pumps, air conditioning equipment, compressors, elevators, etc.	Multiple starts per hour	3%	2%

Note: the table above does not address all types of switched loads such as arc furnaces, welding equipment, etc. This type of equipment may cause multiple fluctuations per minute or even second. Prior to connecting customer load fluctuating at these rates, a detailed engineering evaluation should be performed to determine the effects to the distribution system.

In cases where voltage flicker exceeds the prescribed limitations above, remedial actions must be taken. As a first step, the customer's service transformer may be increased one standard size than is required to serve the steady state load. If the resulting condition still violates this guideline, the customer should employ some type of soft-starting method. In extreme cases where one or both of these measures still result in unacceptable conditions, a detailed engineering analysis should be performed to develop options for the most economical solution such as reconductoring, voltage conversion, static VAR compensation, etc.

4.0 Planning of the Distribution Study

The goal of distribution planning is to forecast projected loads and to perform analyses on a routine basis to ensure the overall objectives of this guideline are met.

4.1 Distribution Peak Load Projections

The Unitil distribution system shall be planned and designed to meet applicable criteria up to projected peak load levels. Ten year summer and winter peak load projections shall be created for each distribution circuit and substation transformer per Unitil's *Distribution Load Projection Guideline* (GL-DT-DS-09).

[1] IEEE Std 241-193 (Gray Book)

The ten year distribution load projections shall be compared to the distribution substation transformer and circuit position ratings as well as the minimum mainline conductor rating from the substation to the end of the circuit position's zone of protection and be evaluated per sections 4.4 (*Addressing System Constraints*) and 4.5 (*Development and Evaluation of Options*) below.

4.2 Minimum Daytime Load Forecasts

Ten year DER forecasts shall be created for each distribution circuit and substation transformer per Unitil's *Distributed Energy Resources Projection Guideline* (GL-DT-DS-12).

The ten year minimum daytime load forecasts shall be compared to the distribution substation transformer and circuit position ratings as well as the minimum mainline conductor rating from the substation to the end of the circuit position's zone of protection and be evaluated per sections 4.4 (*Addressing System Constraints*) and 4.5 (*Development and Evaluation of Options*) below.

4.2.1 DER N-1 Transformer Analysis

Minimum daytime load analysis should include the review of transformer loading with the highest loaded circuit off line to identify future reverse power or transformer loading violations in the reverse direction.

4.3 Distribution Circuit Analysis

Distribution circuit analysis shall be performed per Unitil's *Distribution Circuit Analysis Procedures* (PR-DT-DS-03) on an annual basis and as needed to review customer additions and other ad hawk needs.

Circuit analysis is performed on every circuit on the system each year. Detailed analysis is performed on a three year rotating cycle, where each circuit is analyzed in detail at least once every three years and more often if required. All other circuits not scheduled for detailed analysis in a given year are reviewed to confirm previous study results.

Detailed circuit analysis starts with each circuit being exported from Unitil's GIS. The circuits are then imported into circuit analysis software and loads are applied across the circuit using historical customer billing data. The circuit is reviewed for voltage, loading and protection sensitivity constraints.

A circuit review starts with a previous year's circuit model and has updated load projections applied. The circuit is reviewed for voltage and loading constraints to confirm previous results.

4.3.1 Peak Load Analysis

All circuits on the Unitil system will be evaluated annually for primary voltage and equipment loading violations under forecasted peak load conditions. Circuits that are summer peaking are evaluated using summer projected loads and summer ratings. Circuits that are winter peaking will be evaluated under summer peak and winter peak conditions.

Load allocation for peak load models should be performed using customer monthly billing information that includes the N-1 year peak day, where N is the year in which the detailed analysis of the circuit was last performed.

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.

4.3.1.1 DER Dispatch

When performing peak load analysis 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.

Additionally, any circuit with only one large DER interconnection, the DER interconnection shall be modelled offline. Due to the uncertainty of the availability of a single DER site, the circuit must be planned in order to provide electric service to all customers that meets planning criteria with or without the DER online.

When performing circuit analysis of any circuit with 2 or more large DER sites, the following parameters and generation output scenarios shall be studied:

- Load allocation shall be performed with all DER sites disconnected from the system
- All Large DER facilities shall be modeled at their typical historical AC output at the point of interconnection during the circuit peak hour.
- Voltage analysis shall be performed with all combinations of possible DER site status (online/offline)
- Substation equipment loading constraints shall be analyzed with at least 50% of the cumulative output of all DER interconnections offline. DER output shall not be scaled to meet this requirement. Rather each site shall be considered either online or offline

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

4.3.1.2 Large DER Outage Analysis

All circuits and substation transformers on the Unitil system with large scale DER shall be reviewed to identify loading and voltage constraints post the restoration of circuit/substation outages. It is not unusual for DER facilities to remain off-line for two hours or more post restoration.

This review shall be performed under forecasted peak load conditions with all large scale DER (including Unitil owned facilities) offline. Seasonal emergency equipment ratings shall be used for this analysis.

4.3.2 Minimum Daytime Load Analysis

Each circuit on the Unitil system that has an aggregate DER capacity of more than 500kW or 15% of the circuit load (whichever is smaller) shall be evaluated annually under minimum daytime load conditions for voltage and loading violations. This analysis shall be performed using forecasted minimum daytime load levels.

This analysis shall be performed using minimum daytime load levels. In the event actual minimum daytime load data for a particular circuit is not available the minimum daytime load shall be assumed to be 30% of the circuit's peak load over the previous three years.

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

4.3.2.1 DER Dispatch

When performing minimum daytime load analysis all in-service and approved for installation DER facilities shall be modelled.

All large and small DER interconnections shall be modeled at 100% of their AC rating at the point of interconnection.

In the event modelling all DER interconnections at 100% of their AC rating identifies violation(s) of planning criteria, additional analysis shall be performed. This analysis should include the modelling of large DER facilities at their typical historical AC output at the point of interconnection during the minimum daytime load hour. The output of all other DER facilities shall be set per the typical ratio of DER output to DER nameplate of Large DER at the historical system minimum daytime load hour.

4.3.3 VVO Analysis

As part of the three year detailed analysis all circuits and substations on the Unitil system in which VVO is implemented or proposed shall be evaluated to confirm operation of VVO and determine if any changes are required in the next five years to maintain the effectiveness of VVO as defined in Unitil's Grid Modernization plans and efforts. Additionally, this analysis shall be performed anytime a modification (load transfer, large customer addition, large DER addition, etc.) to a VVO enable/planned substation/circuit is proposed.

Peak case models will be used to analyze the system and confirm regulator and capacitor bank placement. Voltage regulator placement will be reviewed by modifying acceptable voltage thresholds in the circuit model from a maximum voltage of 125V and a minimum voltage of 117V to a maximum voltage of 122V and a minimum voltage of 118V on the primary system. This range was selected to provide some margin for modelling assumptions. Regulator location will be verified/modified to maintain voltages within the new range. Traditional circuit analysis will be utilized to determine the optimal capacitor bank locations.

Once peak models are developed with new regulator and capacitor bank locations minimum daytime load cases should utilized to ensure there are no high voltage concerns.

The peak load and minimum daytime load cases shall also be used to verify the locations of end-of-line and mid-line sensing equipment that are utilized to monitor, operate and verify VVO.

Additionally the following load cases should be evaluated to verify that the anticipated load reduction at each load level is within 90% of the original design. These cases shall be created utilizing the minimum daytime load models and “scaling” DER output per the typical ratio of DER output to DER nameplate of Large DER at the system load level of interest and reallocating load.

- 80% of Peak
- 70% of Peak
- 60% of Peak
- 50% of Peak

4.3.4 Other Analysis

4.3.4.1 Protection Device Sensitivity Review

Protection sensitivity analysis shall be performed on each circuit once every three years as part of its detailed analysis. Additionally, sensitivity analysis should be performed on any circuit using a newly exported model or previous year model anytime there is a significant modification to circuit topology.

Peak load models shall be used to review protective device sensitivity.

4.3.4.2 Customer Load Addition

Peak load models shall be used to evaluate new customer additions to confirm the distribution circuit can accommodate the added load.

4.3.4.3 Protection Device Coordination Review

Peak load models shall be used to review protective device coordination. These reviews will be performed at the request of the manager of Distribution Engineering or as needed due to load additions, reliability improvements, etc.

4.3.4.4 Circuit Tie Analysis

Analysis shall be performed on all mainline distribution circuit ties on a regular basis. Circuit ties shall be evaluated using projected summer peak loads for the first year of the study period. Circuit ties shall be assessed for loading, voltage and protection sensitivity violations.

It is understood that marginal low voltage and protection coordination concerns may exist while circuits are tied. For the purposes of this review all elements may be operated up to their long term emergency ratings while circuits are tied.

4.4 Addressing System Constraints

Distribution planning should clearly identify results that fail to satisfy criteria. All identified constraints should be reviewed in additional detail and verified against available field measurements to determine the severity of the concern.

System modification options shall be evaluated when any of the following planning thresholds is reached:

- Loading of substation transformers, stepdown transformers, protective devices and other distribution circuit elements are anticipated to reach 90% of their respective limits outlined within this guideline.
- Current imbalance at the distribution circuit supply point is recorded to be greater than 20%.
- Steady state primary voltage levels cannot be maintained within the limits outlined within this guideline.
- Steady state primary voltage imbalance is anticipated to exceed the limits outlined within this guideline.
- Protective device sensitivity does not meet the requirements set forth in Unitil's *Distribution Protection Guideline* (Guideline #GL-DT-TC-09).

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 4.5 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 primary conductor and substation power transformer 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 the 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.

4.5 Development and Evaluation of Options

If the performance of the system does not or is not projected to conform to applicable criteria then alternative solutions shall be developed and evaluated per Unitil's *Project Evaluation Procedure* (PR-DT-DS-11).

4.5.1 Performance

The system performance with the proposed options 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.

4.5.2 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.

4.5.3 Recommendation

Every identified violation of design criteria should have a proposed recommended action.

5.0 Distribution Planning Studies

Distribution planning study reports shall be created to document the results of the annual distribution planning process. The studies should detail modelling assumptions, analysis procedures, identified constraints, options for system upgrades or modifications considered and final recommendations.

In additional to reporting on the results of distribution load projections and circuit analysis distribution planning studies should contain the following:

5.1 Master Plan

A long range master plan should be included in the distribution planning studies. The purpose of this plan is to provide strategic direction for the development of the electric distribution system as a whole. It is not intended to be a cost-benefit justification for major system investments, but is meant to guide design decisions for various individual projects to work towards comprehensive system objectives.

The master plan should consist of the following:

- Master Plan Map
  - Existing and future mainline backbones.
  - Existing and future sectionalizing devices to work towards achieving the requirements detailed in Unitil's *Reliability Construction Guidelines* (GL-DT-DS-11).
  - Vision (including device locations) for the implementation of distribution automation and "self-healing" of existing and future mainline backbones.
  - Existing and future VVO equipment to work towards achieving Unitil's Grid Modernization Plans.
- Detailed Description of the Master Plan by area.