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	Distribution Planning Guide	Revision Date	11/14/2019
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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.

11/15/2019

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Date

Nov. 14. 2019

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Date

REVISION HISTORY

Date of Review:

Revision #	Date	Description of Changes
0	03/10/2014	Initial Issue
1	12/29/2014	Revised DG/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 DG 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 DG. All references to Director, Engineering updated to Vice President, Engineering. Revised Updating Guideline (section 1.3) to Responsibilities Removed Request for Procedure/Change Form

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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 and/or substations design.

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 Hampton Shared 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

DG	Distributed Generation
DER	Distributed Energy Resources

2.2 Definitions

Major Equipment	Any piece or pieces of equipment that would require more $250,000 (without overheads) of capital investment to replace or upgrade.

3.0 Distribution Planning Criteria

The follow design criteria shall be used as a guide for the planning and design of the distribution system.

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.

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.

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[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.

3.3 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 Visibility1 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.

<u>Maximum Acceptable %Voltage Fluctuation</u>

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 peak loads and to perform circuit analysis on a routine basis to ensure the overall objectives of this guideline are met.

4.1 Distribution Load Projections

The Unitil distribution system shall be planned and designed to meet applicable criteria up to projected peak load levels. Five 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 five year distribution load projections shall be compared to the distribution substation transformer and circuit position ratings and be evaluated per sections 4.3 (*Addressing System Constraints*) and 4.4 (*Development and Evaluation of Options*) below.

4.2 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.

4.2.1 DG Facilities and DER

The distribution planning process shall include the impact of interconnected DG facilities as well as the output or load offset by other DER projects.

For the purposes of this guideline, a large DG facility shall be considered to be any facility where the aggregate nameplate generation at the point of common coupling is ≥ 500kW.

DG facilities that are proposed for new installation are studied under a separate effort during the application process.

4.2.2 Peak Load Analysis

All circuits on the Unitil system will be evaluated annually for primary voltage, equipment load and protection sensitivity violations using project peak loads. 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.

4.2.2.1 DG Dispatch

When performing peak load analysis Unitil owned DG (PV and energy storage) facilities shall be assumed to be on-line and fully operational. Unitil owned DG 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 DG interconnection, the DG interconnection shall be modelled offline. Due to the uncertainty of the availability of a single DG site, the circuit must be planned in order to provide electric service to all customers that meets planning criteria with or without the DG online.

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

- Load allocation shall be performed with all DG sites disconnected from the system

- All Large DG 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 DG site status (online/offline, peak load/light load)
- Substation equipment loading constraints shall be analyzed with at least 100% of the cumulative output of all DG interconnections offline.

Small DG is inherent in peak load projections and small DG facilities shout not be or be modelled off-line in peak load models.

4.2.3 Minimum Load Analysis

Each circuit on the Unitil system that has aggregate downline DG of more than 500kW or 15% of the circuit (whichever is smaller) shall be evaluated annually under minimum load conditions for voltage and loading violations. PV facilities shall be evaluated using minimum daytime load (30% of annual peak), unless otherwise specifically known. Other DG facilities will be evaluated using circuit minimum load (25% of annual peak).

4.2.3.1 DG Dispatch

When performing minimum load circuit analysis all large and small DG interconnections shall be modeled at 100% of their AC rating at the point of interconnection.

4.2.4 Other Analysis

4.2.4.1 Customer Load Addition

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

4.2.4.2 Protection 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.

4.2.4.3 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.

4.3 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 are 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).

Non-Wires Alternative (NWA) projects should be reviewed for any piece of Major Equipment that is expected to exceed 80% of its seasonal normal rating during the five year study period and exceed 90% of its seasonal normal rating in year five of the study period during normal operating conditions.

Under planned contingency configurations NWA projects should be reviewed anytime Major Equipment is expected to exceed 90% of its seasonal normal rating during the five year study period and exceed 100% of its seasonal normal rating in year five of the study period.

4.4 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).

4.4.1 Performance

The system performance with the proposed options should meet or exceed all applicable planning criteria for the duration of the five-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.

4.4.2 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.

4.4.3 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 distribution load projections, annual distribution circuit analysis and circuit tie analysis. 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 backbone.
    - 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.
- Detailed Description of the Master Plan by area